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THE THESSALONIKI KLIPPE: A NAPPE OF VERTISKOS ORIGIN EMPLACED UPON THE MESOZOIC FLYSCHES OF THE VARDAR BASIN

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ABSTRACT

The eastern part of the Vardar suture zone, to the West of the Serbo - Macedonian metamorphic massif, is a complex imbricated belt which comprises high grade metamorphic rocks, Mesozoic sedimentary and volcanic rocks and ophiolites. This belt has been submitted to unevenly distributed shearing and mylonitisation under greenschist metamorphic conditions; high grade metamorphics which were submitted to a severe retrometamorphic shearing were locally mistaken for schists of sedimentary origin. A renewed field analysis shows that high grade metamorphic rocks and direved retrometamorphic schists and mylonites constitute a large synform made of allochtonous rocks which derives from the Vertiskos part of the Serbo - Macedonian massif and were emplaced upon the Mesozoic Melissochiori - Svoula flysch of the Vardar zone. The proposed age of emplacement is Cretaceous. This tectonic klippe includes the Thessaloniki - Metamorphosis metaophiolites, associated on both flanks with gneisses, marbles and amphibolites, which consiquently differ in their structural position from the Guevgueli and Kassandra ophiolites of the Vardar zone, as they differ in their petrographic type. This leads to abandon the term "Innermost Hellenic Ophiolitic Belt" previously put forward while assuming a common origin for these various ophiolites.

INTRODUCTION

The Vardar zone is the main suture zone of the Mediterranean Tethys Ocean and runs NNW - SSE from Beograd to the Aegean sea; greek geologists also call Axios zone - from the greek name of the Vardar river - its southern part on the greek territory where it separates the Pelagonian massif to the West from the Vertiskos massif to the East. The Vertiskos has been defined as the western and upper part of the Serbo - Macedonian massif in turn is followed eastward by the wider Rhodope massif. These massives are made of high grade (dominantly amphibolite facies) metamorphic rocks. In the Vardar - Axios zone, ophiolites and amphibolite facies metamorphic rocks appear to occupy various structural positions. To the West of the Axios river, they constitute metamorphic nappes and ophiolitic nappes which were emplaced westward upon the Paikon window (Godfriaux & Ricou, 1991; Ricou & Godfriaux, 1991); to the East, their position is less clear as most of them crop out as small and discontinuous bodies below the neogene and quarternary cover; (Mercier, 1968) after mapping the area north of Thessaloniki, proposed a structural interpretatioin as high - dip, west - verging, imbrications, an

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interpretation also retained by Kockel et al. (1971) and Kockel et al. (1977) who extended the survey South and East of Thessaloniki to the whole Khalkidiki peninsula. Subsequent workers (Papastavrou & Chatdzidimitriadis, 1981; Gauthier, 1984; Vergely, 1984; Kelepertsis et al., 1985; Bebien et al., 1986; Mussalam & Jung, 1986; Patras et al. 1986; Davis et al., 1989; De Wet et al., 1986, Kogoulis et al., 1990, Stais & Ferriere, 1991, Asvesta, 1992; Dimitriadis & Asvesta, 1993, Stais, 1993) followed this interpritation which lead to restore the palinspastic positions of the various tectonic units in the same order as their present - day outcrops. However, Mercier (1968) had already discussed the possible existence of a tectonic window and underlined that these imbrications can, at least locally, be superimposed on a former nappe system. Establishing the geometry of the system is a compulsory step for understanding the structure of the imbricated belt and is somehow rendered difficult due to the tectonic shearing under greenschists facies conditions; indeed, there is a significant amount of schists which derive from gneiss, amphibolites and ophiolites through retromorphic shearing and mylonitisation and should not be mistaken for schists of sedimentary origin.

The present article is based under a renewed field analysis and the corresponding map which include the larger ophiolitic body in the eastern part of the Vardar - Axios zone, the Thessaloniki - Metamorphosis body, as well as the neighbouring high - grade metamorphic rocks and the neighbouring rocks which were submitted the greenschist metamorphism only. Our field work has been focused on the recognition of the various types and their geometric relationship and we payed a special attention to the identification of those which derive from high grade metamorphic rocks through retrometamorphism and associated mylonitisation. An early work by Ricou (1965) has shown that these ophiolites are tectonically superposed at their southwestern flank upon a gneiss - marble - amphibolite unit which rests in turn, through a two - kilometer thick layer of mylonites, upon the Mesozoic sediments and granitic basement of the Vassilika unit. At the northeastern flank, an early work by Monod (1964) and the extended analysis by Kockel et al. (1971; 1977) led to define an Aspro Vrissi - Hortiatis tectonic unit which borders the ophiolites along a high angle fault zone. The name "Aspro Vrissi - Hortiatis" covers a large array of rock types, including gneiss, marbles and amphibolites together with flysch and Triassic limestones, peridotites, gabbros, diorites, dolerites, as well as various types of schists and mylonites.

The map we obtained (fig. 1) and the corresponding cross sections (fig. 2) show that the Thessaloniki - Metamorphosis ophiolites occupy the axial part of the acute synform, being bordered on both flanks by high grade metamorphic rocks such as gneisses, micaschists, amphibolites and marbles, then by sedimentary rocks which suffered only the greenschist metamorphism. The boundary amongst metamorphic rocks between those which were submitted to greenschists conditions only and those which were also submitted to earlier high grade conditions marks the basal contact of the Thessaloniki klippe which derives most probably from the Vertiskos massif furher East. Geometrical relationship near the Hortiatis village shows that the basal contact was established before the greenschist metamorphism and the associated foliation which affected jointly the allochtonous and autochtonous rocks.

DESCRIPTION

a) <u>General features</u>

The synform trends NW - SE, in strike with the greenschist foliation

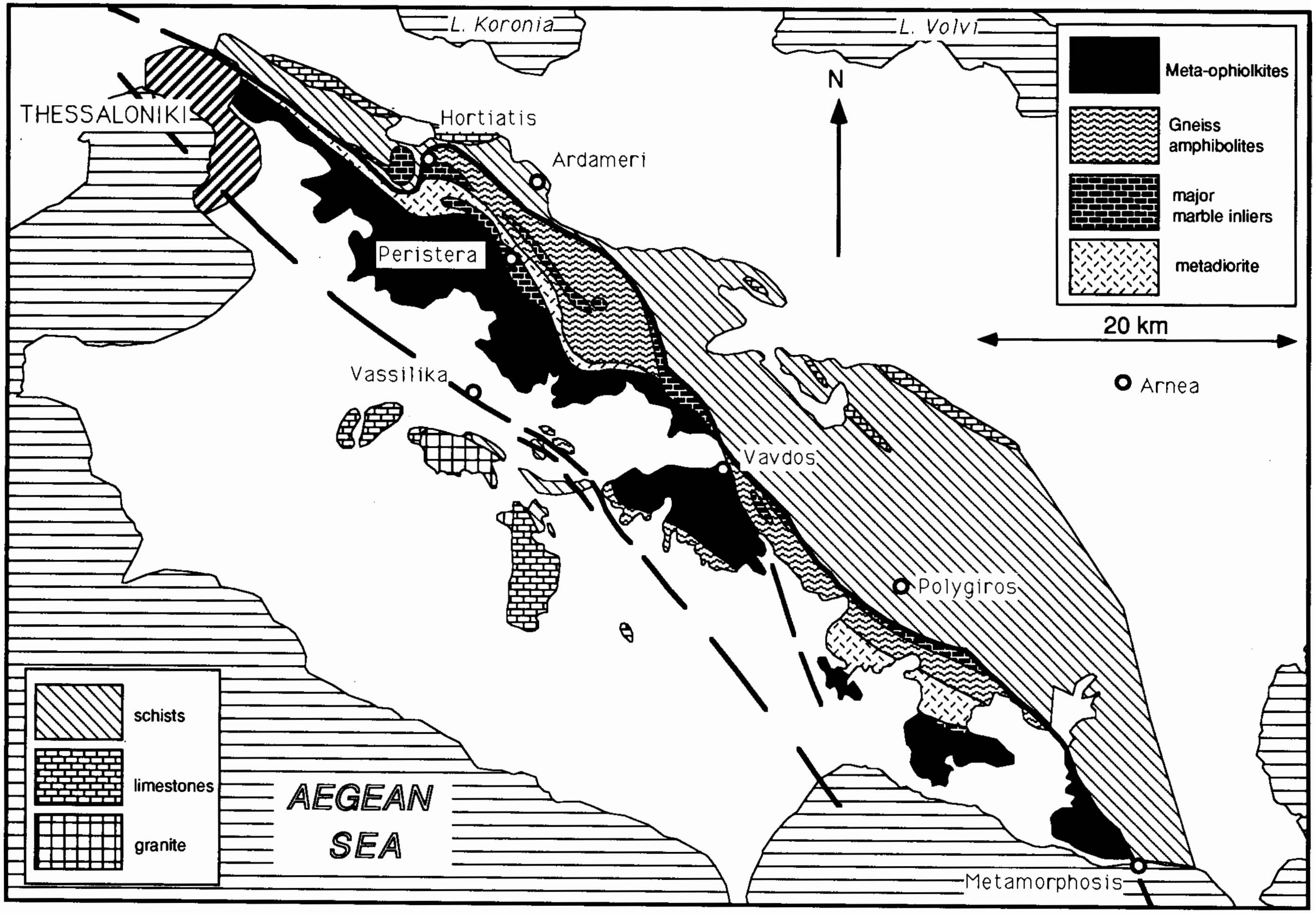

Fig. 1: Geological map of the Thessaloniki klippe and surrounding area

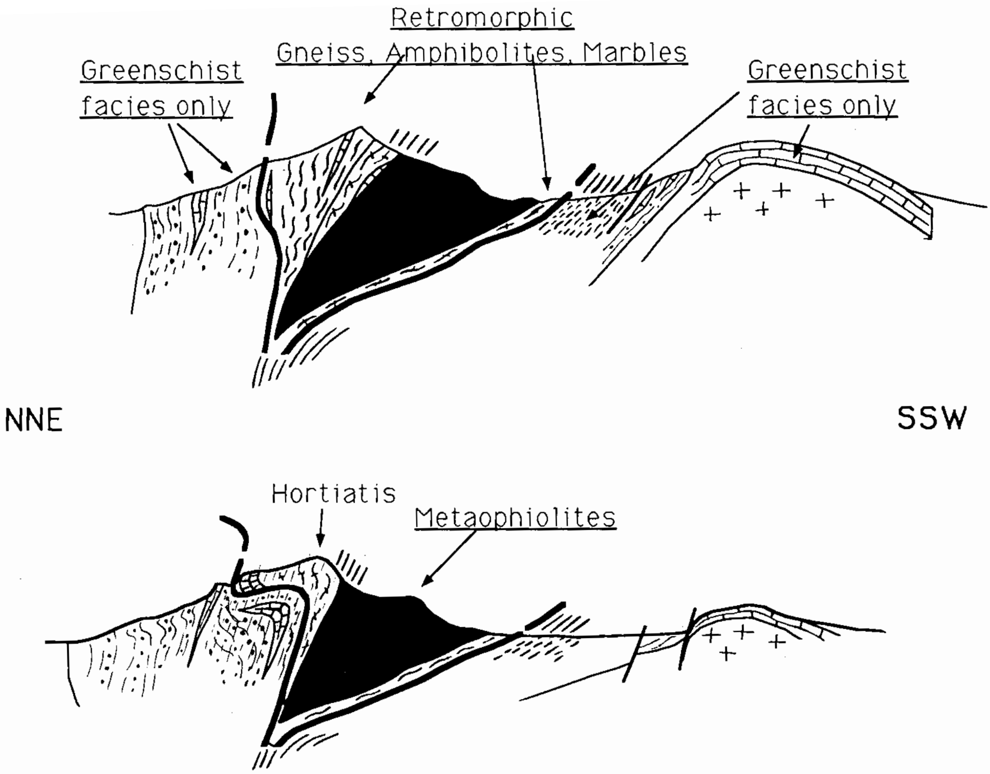

Fig. 2: above: composite cross - section, East of Vassilika; below: cross - section at the Hortiatis summit.

whose dip varies from almost vertical in the northern flank to 45° toward the NE in the southern flank. The intensity of the tectonic shearing associated with the greenschist metamorphism is unevenly distributed, being maximal in kilometer - thick mylonitic bands which are located at the basal contact of the southern flank and at the norhern boundary of the ophiolites. With a local exception near the Hortiatis village, the limits between rock types fall in accordance with the general foliation. Cartographic dextral offset along AND135 - 150 trending transverse zones (fig. 1), together whith the associated deflection of the foliation and with shear criteria indicating dextral strike - slip, are considered as ductile Riedel secondary fault zones with respect to the general strike; we thus consider that the elongated shape of the klippe and its preservation at the core of an acute synform are linked to its location along a superimposed dextral strike - slip ductile fault zone.

b) The southern flank and the axial aphiolites

At the southern flank, the basal parts (1, 2, 3) constitute the Vassilika tectonic unit. The whole section shows from base to top (Ricou, 1965):

1) The Monopigadon granite - granodiorite in association with former sedimentary rocks now forming marbles and skarns. A K - Ar biotite age of ca. 180 Ma age was obtained by Ferrara, pers. comm. in Ricou (1965); a K - Ar

biotite age of ca.149 Ma was obtained by Kreuzer, pers. comm. in Musallam and al. (1986), similar to the Late Jurassic age retained for the ophiolitic - granitic association in Guevgeli (Spray et al., 1984).

2) the Katsika limestone which rests upon the granite through a granite - bearing conglomerate; its basal part yielded a Late Jurassic association of fossils (Pseudocyclamina sp. Nerinella sp, Fibula sp, Exelissa sp.).

3) an alternance of schists and limestones; an additional section shows occurences or radiolarites in the schists. Formations 1, 2 and 3 are slightly affected by the greenschist metamorphism.

4) a kilometer - thick unit of epidote mylonites (quartz, albite, epidote, chlorite) which probably derive from a volcano - sedimentary formation.

5) a kilometer - thick unit of basic mylonites, locally grading into phyllonites, which show relict crystals of amphibolite and pyroxene within a matrix of chlorite and zoisite. Lenses of serpentinite and gabbro are included: these mylonites derive from an ophiolitic body.

6) a kilometer - thick imbricated zone which show kyanite - biotite garnet gneisses, garnet - titanite amphibolites and marbles. All these underwent retrometamorphism under the greenschist conditions and the associated deformation is unevenly distributed.

7) the Thessaloniki - Metamorphosis ophiolitic body represented by peridotites and gabbros. They have submitted to amphibolite metamorphism then to greenschist metamorphism. The greenschist overprint and the associated shearing increases upward: at the top, the gabbros crop aout as meter - size lenses and pass gradually to a matrix of albite - chlorite - epidote schists and mylonites which include millimeter - size relicts minerals of pyroxene, amphibolite and feldspar.

Prior to the greenschist facies overprint, the Thessaloniki - Metamorphosis ophiolites have been submitted to an amphibolite type metamorphism as shown by the petrographic analysis of the gabbros (Ricou, 1965; Gauthier, 1984). Such analysis alone do not allow to depart two hypothesis: - either this metamorphic event represents an ocean - floor metamorphism which affected the ophiolites prior to their tectonic association with the underlying gneisses, marbles and amphibolites; - or this event represents a regional metamorphism which affected jointly the ophiolites, gneisses, marbles and amphibolites after or during their tectonic association. The second hypothesis is more likely as it accounts for the occurence of microline - tourmaline or garnet - tourmaline pegmatitic veins as cutting across the meta - ophiolites (Kockel et al., 1977; Gauthier, 1984), a situation which is easily explained when considering the meta - ophiolites as part of a high grade metamorphic system comprising rocks of both oceanic and continental origin.

8) The upper mylonites. The mylonitic matrix described above between gabbro lenses grades upward into quartz - chlorite - epidote phllonites. The observed step by step transitions as described by Ricou (1965) are indicative of the gabbroid origin of these mylonites and phyllonites in opposition to their previous interpretation as metasediments (Monod, 1964). Northeastward, these upper mylonites include more and more elements of another origin: lenses of diorites and of muscovite - garnet micaschists, and quartz - albite - chlorite schists which include biotite and garnet as relict minerals indicative of their origin as gneisses or micaschists. This second type of protoliths already belong to the northern flank of h ophiolites. Beautiful outcrops of these 3 kilometer - thick mylonites, also called the Thessaloniki schists, are shown along the ring road of Thessaloniki where they derive mostly from gabbros and diorites.

c) <u>The northern flank</u>

For the presentation of a type section across the northern flank, we refer to the section described between Peristera and Ardameri by Monod (1964). This author distinguished from the SW the the NE: the Thessaloniki schists, the marbles and albitic gneisses of Peristera, unnamed black schists, the Alonaki marbles, the garnet - bearing chloritoschists of Vlakou Pigadi, a doleritic body which suffered only greenschist metamorphism and the Ardameri black schists. He attributes the metamorphism to the greenschist faciies only, but this point requires a reappraisal as high grade metamorphic rocks have later been described in two locations: Kockel et al. (1971; 1977) recognised retrometamorphic gneisses associated with the garnet - bearing schists in the northern parts of the section and Gauthier (1986) indicated kyanite - biotite - garnet gneisses as well as diopside - grossular marbles in the southern parts. Our field word led to recognise that most of, if not all, the rocks which crop out between these two locations are retrometamorphic high grade rocks. We introduce below our comments on the various rock types shown along this cross - section from the SW to the NE:

8) the Thessaloniki schists are the mylonites and phyllonites described above.

9) the Peristera marbles are intercalated with amphibolites which are locally well preserved but frequently affected by the subsequent greenschist metamorphism. Diopside and grossular within marbles are probably a testimony of contact metamorphism under the influence of the intrusive dioritic body (10).

10) the gray albitic rocks are representative of a metadiorite whose intrusive character is demonstrated by the presence of decimetric inliers of basic character and which includes also hectometric size lenses of marbles. This body, or a set of such metadioritic bodies, crops out along the whole length of the northern flank (fig. 1) and particularly forms the Hortiatis summit. Such a chlorite - epidote - sericite - albite gneiss yeld a K - Ar sericite age of 113 ± 4 Ma (Zapountzis, 1969).

11) the soft - wheathering outcrops which are shown further Noertheast on this section have a reduced lateral extension; they include lenses of kyanite - biotite - garnet gneiss (Gauthier, 1984) and of amphibolites in a matrix of mylonites and phyllonites. We do not absolutely exclude that some black schists here are of sedimentary origin instead of being phyllonites of retromorphic origin (see below d).

12) the Alonaki muscovite marbles are part of a high grade metamorphic systerm as shown by their association with biotite gneisses on both flanks. To the north, black siliceous rocks appear as subcrops in the fields (see below d).

13) the Vlakou Pigadi garnet - bearing chloritoschists derive from amphibolites as indicated by the occurence from place to place of sufficiently well preserved garnet amphibolites and remnants of pegmatitic veins; such a retrometamorphic origin from high grade rocks explains the ubiquist presense of garnets within a chloride - albite matrix. From poor outcrops it appears that this formation intefingers with the retrometamorphic gneisses, already shown on the geological map of Kockel and Mollat (1971 - 1977), which are mainly developed to the East of this type section.

14) the Ardameri black schists with chloritoid and interbedded layers of brown calcareous sandstones suffered only greenschist metamorphism. The same remark applies to the green dolerites which are found in the southern part of this formation.

d) <u>The contact between high grade and low grade metamorphic rocks</u>

At the southwestern flank, the contact is hidden along most of its length below plio-quaternary deposits but we can observe clearly enough that high grade metamorphics rest upon the low grade rocks in accordance with the greenschist foliation, diping 45° to the northeast. At the north-eastern flank, the contact appears also in accordance with the almost vertical greenschist foliation, with a significant exception near the Hortiatis village where it turns to a horizontal dip. Earlier workers (Monod, 1964; Kockel et al., 1971; Kockel et al., 1977) draw there a transverse fault but a cautious analysis shows that the contorted shape of the contact is due to folding. Indeed, the Ardameri black schists can be followed at the South of the village as a horizontal band in the meadows below the cliff - forming metadiorites and the associated marbles and gneisses of the Hortiatis mountain. To the North and South, both the schists and the overlying rocks bend to a sub - vertical position along the N 120 - 140 regional trend. Three comments may be done:

i) the greenschist foliation is not affected by the fold and keeps its 80° dip to the NNE across the whole structure; this observation demonstrates that the contact was established prior to the greenschist metamorphism and associated foliation.

ii) the contact truncates the above - lying, allochtonous, rock units while it parallels the Ardameri schists.

iii) below the meadows , an horizontal lense of marbles (quarry) underlies the Ardameri schists. When followed along strike, it appears further west to be intercalated between a yellow - weathering flysch and the overlying Ardameri black schists and brown sandstones. This position suggests an olistostromic emplacement of the marble lense in a flysch basin; Kauffmann et al. (1976) and Kockel & Mollat (1977) already put forward the olistostromic character of the Melissochori - Svoula flysch.

For the above comments we reach the conclusion that most probably the Thessaloniki klippe was emplaced over the flysch basin as a huge olistolith or a gravity - driven nappe following the emplacement of the marble lense. We leave open the question wether screens of the matrix can be found within the main allochtonous mass in the form of the black schists mentionned above (11) and of the black siliceous rocks (12) that we have not seen to be clearly related to the neighbouring high grade metamorphic rocks.

CONCLUSION

Field analysis shows that the Thessaloniki - Metamorphosis meta - ophiolites and the associated gneisses, amphibolites and marbles occupy the core of a synform and constitute an allochtonous body, the Thessaloniki klippe, with respect to the surrounding rocks which were affected by greenschist metamorphism only. The klippe has been emplaced over the Melissochori - Svoula flysch basin, most probably as a huge olistolith or gravity - driven nappe. Later, folding of the basal contact and synmetamorphic shearing under greenschists conditions affected jointly the allochtonous and autochtonous rocks, resulting into the present - day synform. This synforms appears to be established along a dextral strike - slip fault zone responsible for the impressive mylonitic zones which run along strike on both flanks of the meta - ophiolites and for the Readel - type dextral offsets of the structure.

The age of the flysch is not definitely established. Kaufmann et al. (1976) proposed a Jurassic age, considering that Late Triassic limestones are reworked as olistoliths and that the flysch is unconofmably covered by the polygenic Doubkon conglomerates, attributed to the Late Jurassic by J. Mercier (1968). At the Doubkon type locality, a summit along the border with former Yougoslavia, the conglomerates are attributed the Eocene on the geologic map of Yougoslavia (1970) and our visit did not convinced us that the Jurassic fossils indicate the age of sedimentation of the conglomerates. The younger limit to the age of the Melissochori - Svoula flysch is thus given by the age of its greenschist foliation; this age is established by Vergely as coeval with the intrusion of the Sithonia granite, i.e. about 40 Ma (Vergely, 1984) or 50 Ma (De Wet et al., 1989); it is anyhow older than the Late Eocene transgressive limestone of Toumba Chorigi (Mercier, 1968). The same younger limit applies to the age of emplacement of the Thessaloniki klippe as it was submitted, together with the flysch, to the Eocene foliation.

The origin of the Thessaloniki klippe should be searched for in the Vertiskos metamorphic massif further East. We propose to locate the corresponding root zone at the Pirgadikia - Sochos "Schupeenzone" described by Kockel et al. (1971 - 1977), considering that elements of the klippe such as the kyanite gneisses, the meta - ophiolites and amphibolites have equivalents in kyanite gneiss described in the Schuppenzone (Papadopoulos & Kilias, 1985) and in the meta - ophiolites and amphibolites which are largely developed in the Vertiskos group, including the Volvi meta - ophiolites which crop out immediately East of the proposed root zone. Consequently, the age of shearing in the Schuppenzone, established at about 90 Ma from white micas (Papadopoulos & Kilias, 1985) should correspond to the departure of the klippe. Such evidences for Cretaceous metamorphism and deformation in this area (De Wet et al., 1989) can be compared with the age of ca.113 Ma obtained in the retromorphic metadiorites of the Thessaloniki klippe (Sapountis, 1969). At a larger scale, these preliminary data are indicative that the emplacement of the formation of Cretaceous synmetamorphic nappes in the Rhodope further East (Burg et al., 1990) and to the Cretaceous emplacement of metamorphic rocks as conglomerates, olistoliths and nappes in the Almopias part of the Vardar zone further West (Mercier, 1968; Vergely, 1984; Migiros & Galeos, 1987, Ricou & Godfriaux, 1991).

As they belong to an allochtonous body, the Thessaloniki - Metamorphosis ophiolites can no more be considered part of the same ophiolitic belt as the Guevgueli and Kassandra - Sithonia ophiolites, under the name "Innermost Hellenic Ophiollite Belt" as proposed by Bebien et al. (1986). Petrographers, including Bebien himself, have already pointed out that they belong to different petrographic types (Gauthier, 1984; Bebien et al., 1986; Dimitriadis & Asvesta, 1993). They also belong to different tectonic settings which imply different palaeogeographic origins. As a consequence, the term Innermost Hellenic Ophiolite Belt should be abandonned since it suggest erroneously a common paleogeographic origin: the Guevgueli and Kassandra - Sithonia ophiolites, which show the same petrographic type and are both covered by Late Jurassic reef limestones, constitute the major part of the Peonias ophiolites, in opposition to the Thessaloniki - Metamorphosis meta - ophiolites which are part of the Vertiskos meta - ophiolites.

REFERENCES

ANOMYMOUS (1970). Geological map of S.F.R. Yugoslavia 1/500.000. Federal Geological Institute, Beograd.

ASVESTA, A. (1992). The magmatism of the first steps of opening of the A-

xios oceanic basin in the Triassic. (in Greek; english abst.), 439 p., Aristoteles University of Thessaloniki.
BEBIEN, J., DUBOIS, R. and Gauthier, A. (1986). An example of ensialic ophi-olites emplaced in a wrench zone: the Innermost Hellenic Ophiolite Belt. - Geology, 14, pp. 1016 - 1019.
BURG, J.P., IVANOV, Z., RICOU, L.E., DIMOV, D. and KLAIN, l. (1990). Implications of shear sense criteria for the tectonic evolution of the Central - Rhodopes Massif, southern Bulgaria. - Geology, 18, pp. 451 - 454.
DAVIS, E., MIGIROS, G., TSANGALIDIS, A. and PAVLOPOULOS, A. (1989). L e magmatisme mésozoique basique de Péonias (en grec, rès françès). - Bull. Geol. Soc. Greece, 23, pp. 531 - 544.
DE WET, A.P., MILLER, J.A., BICKLIE, M.J. and CHAPMAN, H.J. (1989). Geology and geochronology of the Arnea, Sithonia and Ouranopolis intrusions, Chalkidiki peninsula, Northern Greece. - Tectonophysics 161, pp. 65 - 79.
DIMITRIADIS, S. and ASVESTA, A. (1993). Sedimentation and magmatism related to the Triassic rifting and later events in the Vardar - Axios zone. - Bull. Soc. Greece, 28, pp. 149 - 168.
GAUTHIER, A. (1984). La ceinture ophiolitique de Chalcidique (Grèce du Nord), 290 p., Universitè Nancy l.
GODFRIAUX I. and RICOU L.E. (1991). Le Paikon, une fenêtre tectonique dans les Helènides enternes (Macédoine, Grece). - C.R. Acad. Sci. Paris, 313, Série II, pp. 1479 - 1484.
KAUFMANN, G., KOCKEL, F. and MOLLAT, H. (1976). Note on the stratigraphic and palaeogeographic position of the Svoula formation in the Innermost Zone of the Hellenides (Northern Greece). - Bull. Soc. Géol. France, 18, pp. 225-230.
KELEPERTSIS, A.E., CHATZIDIMITRIADIS, E. and ANDRULAKIS, J. (1985). Geology, geochemistry and tectonic setting of the Volcanosedimentary series, Kilkis - Central Macedonia, Greece. - Chem. Erde, 44, pp. 151 - 174.
KOCKEL, F., MOLLAT, H. and WALTHER, H.W. (1971). Geologie des Serbo - Mazedonischen Massivs une seines mesozoischen Rahmens (Norg Griechenland). Geol. Jb., 89, pp. 529 - 555.
KOCKEL, F., MOLLAT, H. and WALTHER, H.W. (1977). Erläuterngen zur Geologisches Karte der Chalkidiki und angrenzender Gegiete 1/100 000 (Nord Griechenland), 119 p., Hannover, Bundesanstalt fur Geowissenschaften und Rohstoffe.
KOGOULIS, C., VERANIS, N. and KASSOLI - FOURNARAKI, A. (1990) . Metavolcanic rocks in the Examili formation (Northern Greece). - Chem. Erde, 50, pp. 67 - 79.
MERCIER, J.L. (1968). Etude géologique des zones internes des Hellènides. Macédoine centrale (Grèce), Annales Geologiques des pays Hellèniques, 792 p.
MIGIROS, G. and GALEOS, A. (1987). Tectonic and stratigraphic significance of the Ano Garefi ophiolitic rocks, (Northern Greece). In: Proccedings of the Troodos Symposium. pp. 279 - 284.
MONOD, O. (1964). Etude géologique de massif de Chortiatis (Macédoine greque), 174 p., Université de Paris.
MUSSALA, K. and JUNG, D. (1986). Petrology and geotectonic significance of sialic rocks procceding ophiolites in the Eastern Vardar zone, Greece. - Tschermaks, Mineral. Petrogr. Mitt., 35, pp. 217 - 242.
PAPADOPOULOS, C and KILIAS, A. (1985). Altersbeziehungen swischen Metamorphose

une Deformation im Zentralen Teil des Serbomazedonischen Massivs (Vertiskos Gebirge, Nord - Greichenland). - Geol. Rdsch., 74, pp. 77 - 85.

PAPASTAVROU S.E. and CHATDZIDIITRIADIS E.A. (1981). Beitrag zur Geologie der Serbo - Macedonischen zonen Die Karnisch - Norischen schichten von Walti (Z - Maezdonien Giechenland). Bull. Geol. Soc. Greece, 15, pp. 1 - 23.

PATRAS, D., KILIAS A., CHADZIDIMITRIADIS, E. and MUNTRAKIS, D. (1986). Study of the formation phases of the internal Hellenides in Northern Greece. - Bull. Geol. Soc. Greece, 20, pp. 139 - 157.

RICOU, L.E. (1965). Contribution à l'étude géologique de la bordure sud - ouest du Massif Serbo-Macédonien aux environs de Salonique, 121 p., Université Paris.

RICOU, L.E. and GODFRIAUX, I. (1991). Une coupe à travers les ophiolites et gneiss allochtones entre le masif Pélagonien et la fenêtre du Paikon (Grèce du Nord). - C.R. Acad. Sci. Paris, 313, Série II, pp. 1595 - 1601.

SAPOUNTIS, I.S. (1969). Petrographic and geologic study of the green gneisses of Thessaloniki. (in Greek; enlgish abst.), 124 p., Aristotles University of Thessaloniki.

SPRAY, J.G., BÉBIEN, J., REW, D.C. and RODDICK, J.C. (1984). Age constraints on the igneous and metamorphic evolution of the Hellenic - Dinaric ophiolites. In: The geological evolution of the Eastern Mediterranean. Edited by Dixon. J.E. & Robertson A.H.F. pp. 618 - 627. Blackwell.

STAIS, A. (1993). Evolution géodynamique des bassins mésozoïques vardariens, domaines d' Almopias et de Péonias, Héllènides orientales., 218 p., Université de Lille.

STAIS, A. and FERRIERE, J. (1991). Nouvelles données sur la paléogéographie mésozoïque du domaine vardarien: les bassins d' Almopias et de Peonias (Macédoine, Hellenides internes septentrionales). - Bull. Soc. geol. Greece, 25, pp. 491-507.

VERGELY, P. (1984). Tectonique des ophiolites dans les Hellènides internes, 661 p., Université Paris - Sud.