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SEDIMENTATION AND MAGMATISM RELATED TO THE TRIASSIC RIFTING AND LATER EVENTS IN THE VARDAR-AXIOS ZONE

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ABSTRACT

Triassic sedimentation and volcanism near the western border of the Vertiscos group (Serbomacedonian massif) accompanied the early stages of the opening of a Mesozoic oceanic basin in the Vardar-Axios zone. Sedimentation on a continental environment indicating extension, block faulting and basin formation during the Permo-Skythian was followed by marine transgression probably in Late Skythian-Early Anisian when acid volcanism also commenced. Basic volcanism was active by Late Triassic. The geochemistry of these basic volcanics is consistent with their extrusion in an extensional regime. Rifting was followed by oceanic spreading till Middle-Late Jurassic and by an eastward subduction, above which the IMHOB ophiolites were emplaced.

ΠΕΡΙΛΗΨΗ

Τα πρώτα στάδια ανοίγματος μιας ωκεάνιας λεκάνης στη ζώνη του Αξιού κατά το Τριαδικό, δυτικότερα από το σημερινό δυτικό όριο των μεταμορφωμένων σχηματισμών της ομάδας Βερτίσκου (Σερβομακεδονική μάζα), συνοδεύτηκαν από χαρακτηριστική ιζηματογένεση και ηφαιστειότητα. Τα πρώτα ιζήματα ήταν ηπειρογενή και χαρακτηρίζουν την εγκαθίδρυση εκτατικής τεκτονικής στην περιοχή και τη δημιουργία μιας λεκάνης κατά το Περμο-Σκύθιο. Περί το τέλος του Σκύθιου ή τις αρχές του Ανίσιου έγινε θαλάσσια επίκλυση στη λεκάνη αυτή, ενώ περίπου τότε εκδηλώθηκε και όξινη ηφαιστειότητα. Βασική ηφαιστειότητα ήταν σε δράση κατά το Ύστερο Τριαδικό. Οι γεωχημικοί χαρακτήρες αυτών των βασικών λαβών υποδεικνύουν τη γένεση βασαλτικού τήγματος σε εκτατικό περιβάλλον ηπειρωτικής ρήξης. Η ρήξη ακολουθήθηκε από ωκεάνια εξάπλωση μέχρι το Μέσο-Ύστερο Ιουρασικό και από προς ανατολάς υποβύθιση, πάνω από την οποία τοποθετήθηκαν οι οφιόλιθοι της ΙΜΗΟΒ.

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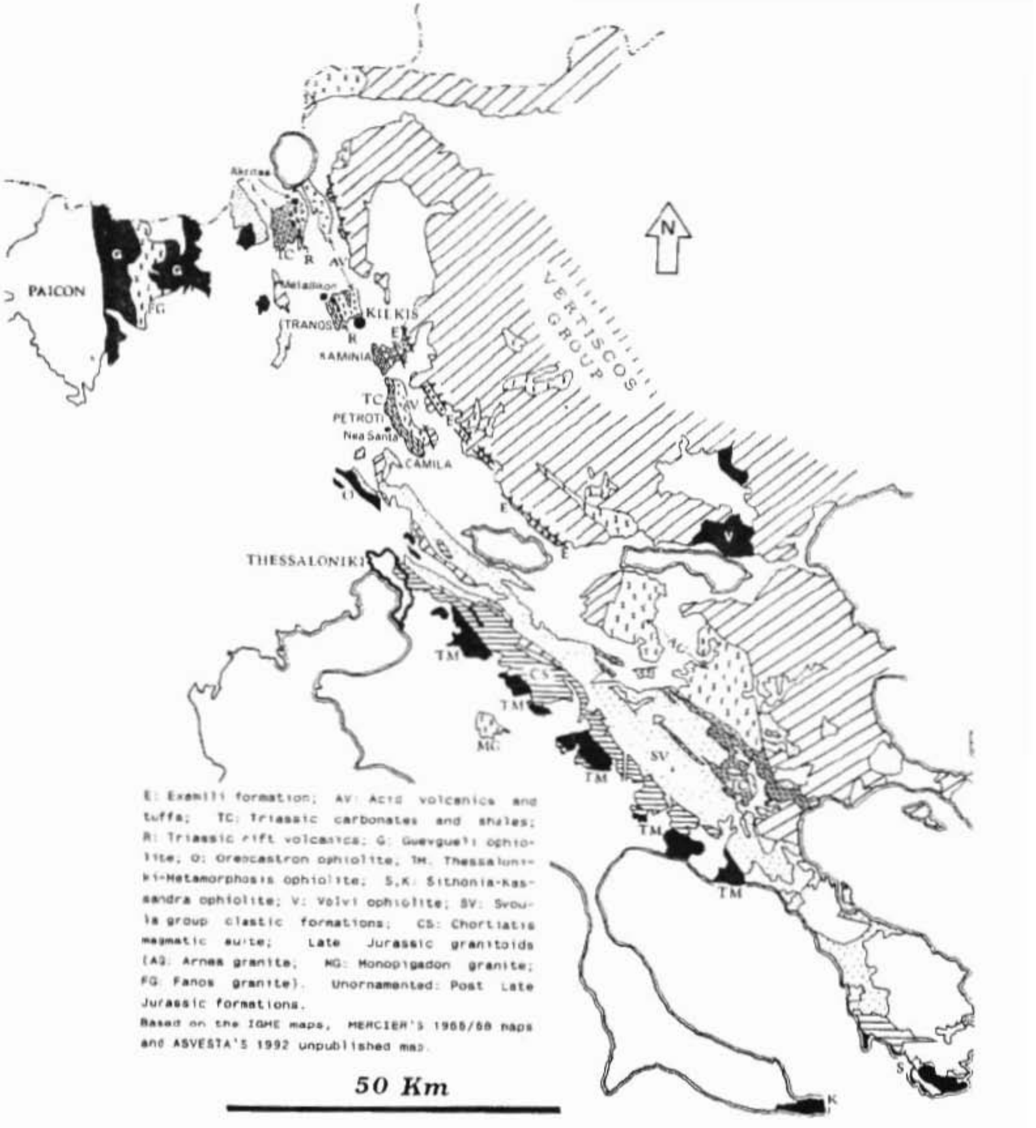
INTRODUCTION

In the eastern part of the Hellenides the Vardar - Axios zone is a NNW-SSE trending belt bounded from both sides by pre-Mesozoic continental elements: the Serbomacedonian massif in the east and the Pelagonian in the west. A three-fold subdivision is in use for this zone based on major tectonic contacts and on facial and lithological characteristics (MERCIER 1966/68). The western part of the Vardar-Axios zone is the Almopias subzone, characterized by its Upper Jurassic ophiolites. This is overthrusted from the east by the Paicon subzone, characterized by spilitic and keratophyric volcanics, by neritic carbonates, marbles and greenish schists. The Paicon subzone is overthrusted from the east b/ the Peonias subzone which has a more complex organization than the previous two. MERCIER (1966/68) further subdivides it in eight different units based on his studies in the norhtern part of the Vardar-Axios zone in Greece. Later, KOCKEL et al. (1971), KAUFFMANN et al. (1976) and KOCKEL & MOLLAT (1977) from their work in the Chalkidiki and adjacent regions proposed a different subdivision for the eastern part of the Vardar-Axios zone. They use the term Peonias subzone for only the westernmost part of MERCIER'S synonym, while they use different names for the rest units up to the Serbomacedonian border. These later units are further combined into a separate geotectonic element, the Peri-Rhodopian belt.

A compromise between the two schemes for the eastern Vardar subzone at the level of different lithofacial units and from west to east is as follows (see fig. 1):

a) The Guevgueli-Peonias (s.s) unit, with Upper Jurassic ophiolites, granites and an older crystalline basement, overlain by phyllytic shales or schists and carbonates. b) The Aspri Vrisi -Chortiatis unit, composed of carbonates, schists, a suite of diorites, trondjemites, and basalts and an incomplete ophiolite suite. c) The Malissochori-Cholomon unit, with carbonates and a thick sequence of detrital sediments of flysch facies (Svoula group). d) The Deve-Koran (Camila)-Doubia unit, mainly consisting of sandstones, coglomerates, a volcanosedimentary group and neritic carbonates.



E: Examili formation; AV: Acid volcanics and tuffs; TC: Triassic carbonates and shales; R: Triassic rift volcanics; G: Guevgueli ophiolite; O: Oreocastron ophiolite; TM: Thessaloniki-Metamorphosis ophiolite; S,K: Sithonia-Kassandra ophiolite; V: Volvi ophiolite; SV: Svoula group clastic formations; CS: Chortiatis magmatic suite; Late Jurassic granitoids (AG: Arnea granite, MG: Monopigadon granite; FG: Fanos granite). Unornamented: Post Late Jurassic formations.

Based on the IGME maps, MERCIER'S 1966/68 maps and ASVESTA'S 1992 unpublished map.

ig.1. Simplified scetch map of the Triassic-Jurassic formations at the eastern ardar-Axios zone.

Slivers and blocks of crystalline basement within the Guevgueli-Peonias unit are considered as a seperate entity, named "the Stip-Axios zone" (KOKCEL, 1986; KOCKEL & MOLLAT, 1977). All the ophiolite bodies in the Guevgueli-Peonias and the Aspri Vrisi-Chortiatis units believed to be subautochthonous, define a belt known as the Innermost Hellenic Ophiolite Belt (IMHOB).

In the present paper we examine aspects of the Triassic rifting in the eastern Vardar-Axios zone and discuss its post-rifting evolution as well as the setting and mechanism of emplacement of the IMHOB ophiolites.

GEOLOGICAL SETTING. PALEOGEOGRAPHIC AND GEOTECTONIC RECONSTRACTIONS. IMPLICATIONS COMMENTS AND PROPOSALS.

Geotectonic reconstructions proposed for the Vardar-Axios zone (MERCIER et al. 1975; GAUTHIER, 1984; SMITH & SPRAY, 1984; VERGELY, 1984; JUNG & MUSSALAM, 1985; SCHUNEMANN, 1985; BEBIEN et al. 1986; 1987; MUSSALAM & JUNG, 1986; BAROZ et al. 1987; DE WET, 1989; MUSSALAM, 1991) have led to the now widely accepted idea that during the Middle to Late Jurassic localised continental break-up and opening of small pull-apart basins (those related with the more or less in situ bodies comprising the IMHOB, i.e. the Guevgueli, Oreocastron, Thessaloniki-Metamorphosis and Sithonia-Kassandra ophiolites) took place at a back-arc setting, although MUSSALAM & JUNG (1986) and MUSSALAM (1991) do not strictly relate the Thessaloniki-Metamorphosis with the Sithonia-Kassandra bodies and rather argue for an intra-arc emplacement, especially for the later.

A mechanism for the opening of these basins has also been proposed, involving a dextral (BEBIEN et al. 1986,1987) or sinistral (DE WET; 1989) strike-slip movement, coupled with an oblique, east dipping as is generally thought or west dipping as MUSSALAM (1991) thinks subduction.

In close proximity to the IMHOB, Upper Jurassic volcanics and volcaniclastics in the Paicon (a suite of spilites and keratophyres, MERCIER 1966/68; BAROZ et al.1987; ΔΑΒΗ et al.1988) and Middle to Upper Jurassic hypabyssal diorites, trondjemites and basalts, comprising the "Chortiatis magmatic suite" (a component of the Aspri Vrisi - Chortiatis unit, KOCKEL & MOLLAT,1977; SCHUNEMANN, 1985; MUSSALAM & JUNG, 1986; MUSSALAM, 1991) have been interpreted as arc-related magmatics. The exact setting of the infered Middle-Late Jurassic arc(s) and its (their) geodynamic relation to the then existing continental and oceanic elements in the wider area remain however poorly constrained; even the arc character of these volcanic and hypabyssal rocks is not unequivocal. The Paicon ones have been subjected to HP-LT metamorphism (MERCIER, 1966/68; BAROZ et al. 1987) implying their possible involvment in subduction processes, while according to DE WET (1989) a close genetic link between the Chortiatis magmatic suite and the Thessaloniki-Metamorphosis ophiolitic rocks probably exists, in which case the Chortiatis suite is an intergral part of these ophiolites (such a link was also implied by JUNG et al. 1979).

For the shake of argument we won't dispute at this point the validity of the arc character of the Middle-Upper Jurassic Paicon and Chortiatis magmatic suits. The question arrises in that case however whether the two suits could be considered as products of a single "Paicon-Chortiatis arc". Some compositional differences between the two suites hinder such a grouping (for the chemistry of these rocks see MERCIER, 1966/68; ΣΑΠΟΥΝΤΖΗΣ, 1969; KOCKEL & MOLLAT. 1977; SCHUNEMANN, 1985; MUSSALAM & JUNG, 1986; ΔΑΒΗ et al. 1989). Additional restrains are also imposed by spatial relations. he Paicon volcanics were extruded to the west of the IMHOB, while he Chortiatis magmatic suite intruded (and extruded) to the east f it. If the IMHOB ophiolitic bodies and the Paicon and Chortiatis magmatic rocks are indeed subautochthonous units, this elative position needs to be explained.

Granitic rocks of Late Jurassic age intruded close and along e IMHOB. The source and the significance of this magmatic ac vity however is as yet not well understood. Some of them truded out and on either side of the confines of the IMHOB (i.e. e Arnea and Monopigadon granites; RICOU,1965; KOCKEL & MOLLAT, 77; MUSSALAM & JUNG, 1986; DE WET, 1989), others however truded inside this belt, almost contemporaneously with the mag tic emplacement of the ophiolitic rocks (i.e. the Fanos granite; CIER, 1966/68; BEBIEN, 1982; SMITH & SPRAY, 1984). Apart from this pazzling lay out the geochemistry of these granitic rocks is not clearly corresponding to any specific tectonic environment and expressed suggestions are generelly not in agreement (BEBIEN, 1977; BEBIEN & MERCIER, 1977; BEBIEN & GAGNY, 1978; BEBIEN, 1981; DE WET, 1989; PEARCE, 1989; SIDIROPOULOS & DIMITRIADIS, 1989; CHRISTOFIDIS et al. 1990; ΚΟΥΡΟΥ,1991; ΣΙΔΗΡΟΠΟΥΛΟΣ, 1991; PLATEVOET & BEBIEN, 1992).

The Svoula group, which overthrusts from the east the Aspri Vrisi - Chortiatis unit (KAUFFMANN et al. 1976; KOCKEL & MOLLAT, 1977; DE WET, 1989) is of great importance in any attempt to reconstruct the paleogeographic and geotectonic relations in the Vardar-Axios zone during the Mesozoic. Its lithological and textural characteristics - a slightly metamorphosed sequence of sandstones, conglomerates, argillites (some of them bituminous), cherts, detrital limestones and calcareous sandstones, with a large diversity of involved facies, rapid facial changes, syndepositional slumping and folding and incorporation of olistholiths and olistostromes of Triassic shelf carbonates - most probably correspond to a continental slope and rise sequence, as KOCKEL & MOLLAT (1977) already pointed out. We will however discuss some other possibilities bellow.

The deposition of the Svoula group has been thought as post-Triassic, perhaps even post-Lias, (KAUFFMANN et al. 1976; KOCKEL & MOLLAT, 1977) since the basal parts of this group were deposited on top of supposed Middle-Upper Triassic carbonates. The reexamination of these carbonates however (BAROZ et al.1990) established their Early Middle Triassic age. The deposition of the Svoula sediments thus might had already started by Middle-Late Triassic. It lasted until early Late Jurassic (KAUFFMANN et al.1976).

MUSSALAM (1991) argues for a Middle-Late Jurassic westward subduction bellow a "Chortiatis volcanic arc". He interprets the Svoula group as sediments deposited at a fore-arc setting, between the arc and a trench which apparently was lying further to the east. The vergence of early folding and thrusting in the Svoula group, as well as in the Aspri Vrisi - Chortiatis unit and in the IMHOB itself, is however towards the west (KOCKEL & MOLLAT, 1977; DE WET, 1989) favouring an east rather than west - dipping subduction happening somewhere west of the IMHOB. If MUSSALAM (1991) is right, then a cryptic suture of a Mesozoic oceanic tract must exist to the east of the Svoula group. The Upper Jurassic (?) Volvi ophiolite in the Serbomacedonian massif might be thought as a suitable candidate, but we now know that it is an intracontinental in situ intrusive body (DIXON & DIMITRIADIS, 1984; 1989) and therefore cannot be interpreted as indicating an oceanic suture. MUSSALAM (1991) points out similarities in the direction of extention and dyke intrusion between the Volvi, Sithonia and Guevgueli ophiolites, suggesting that they might had been created inside the same frame of an above subduction pull apart system. The location of the supposed Late Jurassic westward subduction must thus be searched to the east and further than Volvi. No evidence for such a subduction seems to exist there however.

Chortiatis type volcaniclastics are not apparent constituents in the Svoula lithologies. KAUFFMANN et al. (1976), KOCKEL & MOLLAT (1977) and DE WET (1989) noticed however that a gradual lithological transition exists between the Aspri Vrisi-Chortiatis unit and the Svoula group. Such a transition conforms to a back-arc setting in which the Chortiatis magmatic suite represents either the arc itself or its backward (easterly) slope, while the Svoula group represents sediments deposited at the opposite continental slope facing this basin. Such an interpretation implies the operation of an east, not a west - dipping subduction bellow the "Chortiatis arc" but leaves the Thessaloniki -Metamorphosis and the Sithonia-Kassandra ophiolites outside the so defined back-arc space; more specificaly sets them at a fore-arc position.

The Svoula sediments have in places been intruded by Chortiatis type dykes or sills and have been thermally affected by them (KOCKEL & MOLLAT, 1977; SCHUNEMANN,1985; DE WET, 1989). Also, microgabbro intrusions of the Oreocastron ophiolite body into the Svoula sediments converted the later close to the contacts to andalusite-cordierite hornfelses (REMY, 1984).

We interpret the Svoula group as a continental slope and rise sedimentary sequence deposited from Late Triassic (?) or Early Jurassic till early Late Jurassic at a passive margin which developed after a Late Triassic continental rifting (see bellow) and opening of an oceanic basin. Elimination of this basin happened during Late Jurassic by east-dipping subduction bellow and obliquely to the previous passive margin. This induced strike-slip motions in the crustal segment above the subduction, opening thus a series of pull-apart basins where the IMHOB ophiolites (and the Volvi body?) emplaced.

The above interpretation implies that the IMHOB ophiolites intruded a previously attenuated continentel basement, which probably underlies most of at least the eastern part of the Vardar-Axios zone and which might be represented by the basement rocks of the Stip-Axios zone. It also implies that any arc magmas produced during the closing stage most probably found their way to the surface intruding the pre-Jurassic continental basement, as well as its slope and rise sedimentary cover deposited during the previous passive margin stage. The continental basement located above the subduction was under these circumstances prone to extensive melting, due to addition of heat by the intruding basic magmas at the pull-aparts, by the arc magmas, and also by the adittion of fluids. A broad zone where anatectic granitic magmas formed and ascented was thus expected at that stage (Upper Jurassic granitoids?). In some places those magmas might interfere with the arc or the pull-apart basic magmas. Rhyolitic extrusions might also bear evidence of this same event (e.g. Upper Jurassic extrusive and hypabyssal rhyolites in the Paicon and in the Aspri Vrissi unit, MERCIER, 1966/68). Alternatively, the Late Jurassic granitic magmatism might be attributed to the collision stage which followed the complete elimination of the westerly oceanic basin. Diachronism of the individual Late Jurassic magmatic intrusions in a transtensional-transpressional terrain might explain existing differences in the deformational state of these intrusions, as well as in the metasediments around them.

One point which needs clarification is the identity of the infered westerly ocean basin which closed during Late Jurassic by east-dipping subduction. This we will consider in the next section where our discussion is concetrated at the early stages of continental rifting and the opening of this basin.

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TRIASSIC RIFTING IN THE VARDAR-AXIOS ZONE

Permo-Triassic sediments and volcanics telescoped against the western margin of the Vertiscos group, possibly during Late Jurassic, bear evidence of early Mesozoic rifting events in the Vardar-Axios zone.

The first sediments overlying the western border of the pre-Mesozoic (Hercynian ?) Vertiscos group (the western part of the Serbomacedonian massif) (fig.1) are terrigenous, immature, poorly shorted, unfossiliferous, slightly metamorphosed arkosic sandstones and conglomerates, known as the "Examili formation" and believed to be Permo-Skythian in age (KAUFFMANN,1976; KAUFFMANN et al. 1976; KOCKEL & MOLLAT,1977). Cross bedding, planar cross stratification and coarse debris flow channel fillings preserved in this formation indicate direction of transport from NE to SW (todays orientation) and suggest the Vertiscos group (VGR hereafter) as the likely source area; the lithology of the clasts in the Examili formation is moreover consistent with this suggestion.

We interpret the Examili formation as fan, perhaps partly also fan-delta deposits accumulated at the foot of block-faults during the initial stages of the formation of an extensional basin to the west of the future western margin of the VGR.

Volcanic debris is lacking from most of the Examili formation indicating absence of volcanic activity in the neighbourhood during most of its deposition time. However, in the stratigraphically uppermost parts of it intercalations of tuffs (KOUGOULIS et al. 1990) testify that volcanism might had started by Late Skythian.

Stratigraphicaly above the Examili formation is a discontinuous belt of low grade metavolcanics and metasediments of supposed Early Triassic age ("volcanosedimentary series" according to MERCIER,1966/68 and KOCKEL & MOLLAT, 1977). Massive rhyolitic ignimbrites and lavas are the main volcanic products. The metasediments are fewer and are phyllitic , cherty or calcareous sandstones and pelitic or carcareous phyllites and shales, usually incorporating limestone or rhyolitic megaclasts and in some cases interbeded with thin recrystallized dark coloured limestones. The best exposures of the sequence occur west of the village of Kolchida, (about 5 km SSE of Kilkis) and also near Krithia, bellow the base of the Camila (Deve Koran) carbonate sequence. The sediments are intricately alternating with the volcanics and it is difficult to decide whether this is due to original interbedding or to tectonic juxtaposition. In the dark coloured pelagic limestones alternating with the calcareous sandstones near Krithia some poorly preserved bivalve fossils and filaments indicate late Triassic age (C. JENNY, personal communication).

Thick, partly dolomitized and recrystallized neritic carbonates of Anisian to Carnian age (mainly exposed in the Camila, Petroti, Kaminia, Agios Georgios and Tranos hills, fig.1) with poorely preserved remnants of coral colonies have been interpreted as stratigraphicaly overlying the "volcanosedimentary series" (MERCIER,1966/68; KAUFFMANN et al.1976; STAIS & FERRIERE,1991). However, rhyolitic hyaloclastites incorporated in the (following STAIS & FERRIERE, 1991) Anisian-Ladinian slaty limestones at the base of the Camila sequence, rhyolitic blisters near Krithia with radial cracks infilled by a mixture of micritic limestone with rhyolitic hyaloclastites, and finally hypabyssal porphyritic rhyolite intruding near Peristeri thick massive carbonates of the Camila sequence (probably the massive Ladinian - Carnian members of the Nea Santa unit of STAIS & FERRIERE, 1991), all suggest that rhyolitic volcanism was actually active during the Middle Triassic when neritic carbonates were deposited near the western margin of the VGR. Unfossiliferous cherty intercalations in these limestones might had been originally acid volcanic dust deposited during carbonate sedimentation.

The rhyolitic hyaloclastites interbedded with the carbonates suggest subaqueous eruptions. However, accretionary lapilli have been also found interbedded with the ignimbrites near Nea Santa suggesting simultaneous(?) subaerial phreatomagmatic eruptions.

Basic and intermediate volcanism near the future western margin of the VGR might had started quite early (Skythian?),while the Examili formation was still depositing (KOUGOULIS et al. 1990). The presence of volcanic tuffs only in the upper parts of the Examili formation and their total absence from its lower parts suggest that the block faulting and the formation of a depositional basin predates the initiation of volcanism near the western VGR margin. This makes a back-arc setting there during the Early Triassic rather improbable.

Most of the basic and intermediate volcanics are however intercalated with Middle and Upper Triassic pelagic sediments (see for example the Levendochori and Metallicon units, MERCIER, 1966/68; STAIS & FERRIERE, 1991).In the Megali Sterna formation, immediately southwest of Acritas, we have seen basic and intermediate rocks intercalated with the Megali Sterna limestones and shales of Upper Norian age (KAUFFMANN et al. 1976). Some of the basic rocks are recognised as pillowed extrusives, most probably interstratified with these sediments. In one case, near the base of a 100 m thick basic "flow", we have found evidence of contact metamorphism in the shales. Close to the contact abundant zoisite with garnet ($Gro_{77}And_{22}$) have been formed in the shales in equilibrium with calcite. Similar evidence of contact metamorphism is absent near the top of the basic "flow". The formation of zoisite and the absence of plagioclase suggest the presence of H_2O, temperatures bellow 550°C and a very low X_{CO_2} in the fluid phase, further suggesting that the basic rock came in contact with a loose hydrated sediment rather than with a dry and compact rock.

We present here analyses of basic and intermediate Triassic rocks (all now metamorphosed to greenschist facies) collected from southwest of Akritas village (Megali Sterna formation) and from near Metallikon (Deve Koran-Doubia unit). All the analyses were performed by XRF in the Department of Geology and Geophysics, Edinburgh University using standard procedures.

The metabasaltic rocks (analyses 1-7, table I) are olivine tholeiites with a transitional MORB to WP character (fig.2) and with no detectable arc signature (fig.3) excluding an above subduction setting and contrasting thus with the Guevgueli, the Paicon and the Chortiatis Late Jurassic extrusives.

Two of the seven analysed basalts are highly enriched in potassium but otherwise more typical MORBs than the others, bearing no indication of significant continental contamination. Their K-enrichment is probably due to secondary alteration. The basalts are mildly differentiated, resembling in this respect typical MORBs (Mg'=60-80, Cr=150-450ppm, Ni=50-150ppm, SiO_2<50%).

Sample	KM	A681	B39	B43	B80	B127	B128	B46	B116	B121	B122
SiO_2	48.38	46.55	46.7	48.19	46.95	48.00	46.17	55.16	53.57	61.90	63.47
Al_2O_3	14.91	16.40	15.89	15.16	17.27	15.78	16.03	13.20	13.18	14.21	13.67
Fe_2O_3	10.14	9.02	11.31	10.22	8.82	11.09	12.24	13.50	13.30	8.94	9.73
MgO	7.57	8.95	8.54	6.89	10.75	9.08	8.03	4.20	3.92	1.65	0.87
CaO	6.08	10.10	9.23	10.26	6.53	10.74	8.49	2.13	3.32	2.15	1.69
Na_2O	4.78	1.44	2.2	3.52	1.45	1.91	3.19	3.81	4.01	6.96	5.77
K_2O	0.06	2.20	1.37	0.34	3.09	0.80	0.29	3.28	1.93	0.39	1.37
TiO_2	1.49	1.24	1.94	1.72	1.20	1.72	2.22	2.50	2.50	0.96	0.84
MnO	0.14	0.18	0.17	0.19	0.17	0.18	0.20	0.19	0.23	0.17	0.18
P_2O_5	0.13	0.11	0.19	0.17	0.10	0.16	0.25	0.39	0.40	0.23	0.20
Total	93.68	96.19	97.54	96.66	96.33	97.46	97.11	98.36	96.36	97.56	97.79
Ni	61	143	122	54	152	142	92	8	7	6	7
Cr	145	317	319	430	381	359	254	2	0	1	1
V	242	204	259	280	197	257	281	154	135	3	2
Sc	38	33	39	55	34	38	40	30	32	23	20
Cu	42	38	25	101	52	94	44	-	-	-	-
Zn	71	86	84	84	71	103	111	156	156	132	163
Sr	270	580	313	631	100	1156	1047	71	98	120	194
Rb	1	68	38	9	133	33	12	110	51	18	51
Zr	137	77	132	127	72	146	201	359	354	784	732
Nb	4	2	6	5	2	4	7	15	12	26	25
Ba	2	269	131	52	337	124	56	161	207	99	183
Pb	1	-	3	4	2	2	-	1	2	3	6
Th	2	-	-	-	-	-	-	6	5	16	15
La	16	-	0	1	5	1	5	26	26	37	44
Ce	22	9	16	12	6	8	17	64	69	104	101
Nd	9	8	12	10	9	7	12	38	41	66	57
Y	32	23	30	29	24	31	36	82	71	111	99

Table I. Chemical analyses of major and trace elements of the Late Triassic basic and intermediate rocks.

The intermediate rocks (analyses 8-11, table I) have features resembling typical anorogenic (not subduction related) andesites (see GILL, 1981). They are thus, in comparison to orogenic andesites, Fe rich and Mg poor (their ferromagnesians are biotite and/or stilpnomelane) enriched in Mn, P and Ti and depleted in Al and Ca.

We interpret these basic and intermediate Triassic volcanics from Akritas and Metallikon as members of a rift related tholeiitic suite.

We are not dealing in this article with the petrogenesis of the Triassic acid volcanics. This has been done to some extent in ΑΣΒΕΣΤΑ (1992). One possibility is that they are the products of melting of the continental crust, induced by underplating basaltic

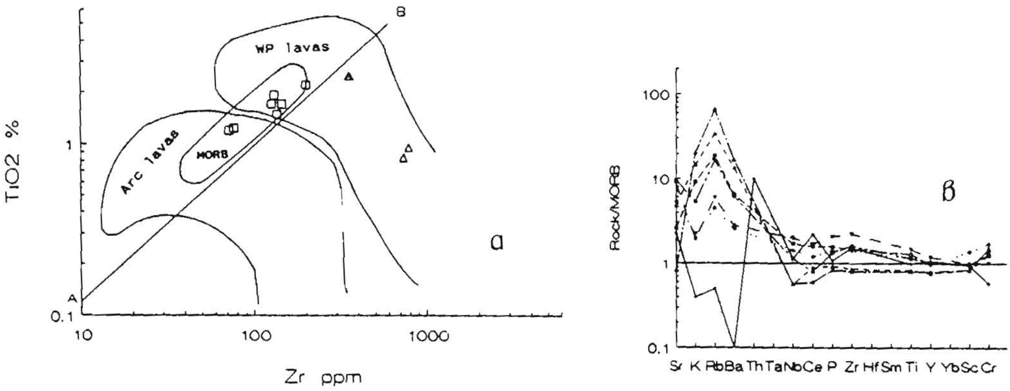
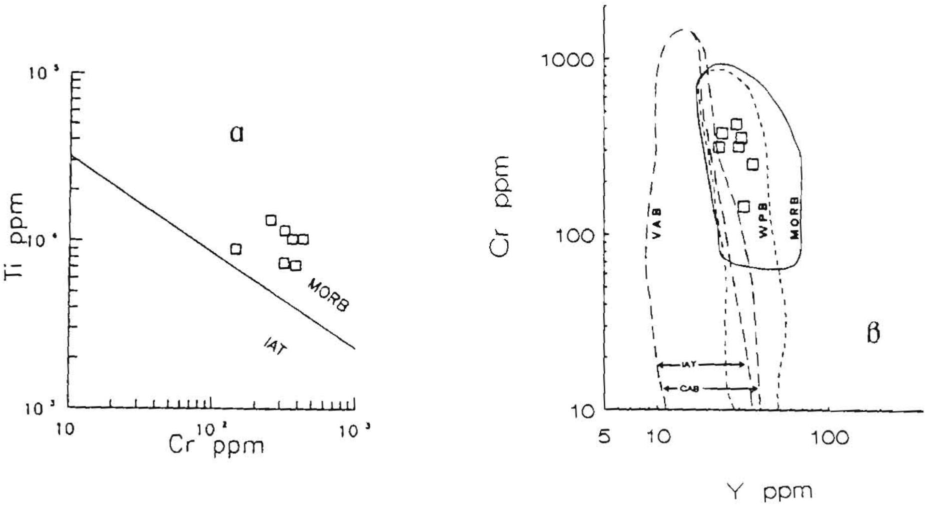


Fig.2. Geochemical plots of Late Triassic metabasaltic and intermediate rocks. **a)** TiO_2 against Zr (PEARCE,1980; 1982) (squares: basic rocks; triangles intermediate rocks). **b)** MORB normalized trace element patterns of the basic rocks. MORB values from PEARCE (1982).



ig.3. **a)** Ti against Cr (PEARCE,1975). The Late Triassic basalts plot outside he IAT field. **b)** Cr against Y (PEARCE,1980). The same basalts occupy that part f the WPB field which overlaps the MORB field.

melts produced during the Triassic extension (according to the model of HUPPERT & SPARKS, 1988). Most of the acid volcanics have trace element contents indistinguishable from the western VGR basement migmatites and schists, supporting the idea of their anatectic origin. A certain group of them however has a different chemistry, consistent with them been derived by extreme differentiation of the basaltic magma (work in progress). If the acid volcanism was however mainly due to crustal melting, we expect similar rhyolites to be related not only to the Triassic rifting, but also to the subduction related Late Jurassic pull-apart magmatism.

We envisage the western VGR margin during the Triassic as a shelf bordering from the east an epicontinental extensional basin which started forming during the Permo-Skythian. Marine transgression in this basin probably occured sometime during the Skythian to early Anisian (see also BAROZ et al.1990) and made the growth of reefs there possible for the first time. Rhyolitic volcanism probably started by that time. The shelf floor was uneven and unstable due to continuing extension, block faulting and perhaps block rotations. Reefal built-ups were forming within the rift zone on basement horsts or on volcanic mounts. By Late Triassic argillaceous sediments with few pelagic limestone intercalations were accumulating in intra-shelf deeps, where fine limestone debris, calciturbidites and olistoliths were also coming down from nearby reefs or volcanic mounts. One such major intra-shelf deep basin might had been the pelagic Triassic narrow zone framed by neritic facies in the "innermost Hellenic zone" (KAUFFMANN et al. 1976; their fig.1). Basement clastics deriving from the VGR mainland or from emerged basement horsts and volcanic debris were also accumulating in these intra-shelf basins. Rhyolitic lavas and pyroclastics were extruding either subaerially near the shore or subaquesly on the floor of the intra-shelf basins, which probably formed between faults bounding basement blocks. In these basins the fewer basic and intermediate lavas were also extruding mainly during Late Triassic.

Such a complex and unstable environment with large vertical and lateral variations in the depositing materials must be responsible to a large degree for the complexity of the Triassic sequences. Later tectonism telescoped and imbricated the shelf making these sequences even more perplexing .

There is thus ample evidence for the initiation of a Permo-Triassic rifting west of the todays western margin of the VGR. We presented our view of the complex depositional environment of the rift basin in which different Triassic formations were deposited laterally rather than in a vertical chronosrtatigraphic succession. We believe that this Permo-Triassic rifting substantialy weakens the possibility that a Paleotethyan branch existed west of the Paicon and Peonias zones before the Mid-Jurassic (one of the alternatives discussed in ROBERTSON & DIXON, 1984, and also by DE WET, 1989).

What was the width of this basin and what was its evolution after Late Triassic? Did it evolved to an ocean basin in which spreading occured till Late Jurassic? Was the subduction of its lithosphere towards the east by Late Jurassic responsible for the formation of the IMHOB ophiolites, of the Paicon and the Chortiatis volcanic arcs(?) and of the Upper Jurassic granitoids? Was it on its bordering from the east continental rise and slope that the Svoula group sediments were deposited during the spreading period?

One should imagine that the western margin of this basin must coincide with the opposing eastern margin of the Pelagonian continental block. This is of little help however, since we do not know the distance, or even the relative positions between the Serbomacedonian and the Pelagonian blocks in the Triassic. Moreover, complex tectonic events at the eastern Pelagonian margin during the Jurassic and the Cretaceous (see for example SHARP at al. 1991) must have consealed most of the evidence of a possible earlier rifting there.

A deep basin certainly existed in the Almopias zone during the Jurassic and possibly also during the Triassic (STAIS et al. 1990; STAIS & FERRIERE, 1991). There is no convincing evidence however that this basin was oceanic before the Mid Jurassic. Dolerites and basic lavas in the Mavrotakkos unit (STAIS & FER-

RIERE, 1991) intercalated with Upper Jurassic radiolarites might very well represent rift volcanism in an epicontinental basin. Ophiolites, believed to be Almopian in origin and Late Jurassic in age (MERCIER,1966/68) are now interpreted as allochthonous in relation to the Almopias basin (SHARP et al. 1991). Even if they were Almopian however their age do not confirm the existence of a pre-Mid Jurassic ocean basin within the confines of the Almopias zone, arousing thus questions as to the validity of the proposed models for the Vardar-Axios zone. The only way to reconcile the facts with the models would then be to accept that an ocean basin did actually exist somewhere in the Almopias zone before Late Jurassic; its lithosphere was however totaly consumed by an eastward subduction during Late Jurassic without leaving behind any recognisable traces of its existence. The now exposed Almopias ophiolites in that case have nothing to do with this ocean basin, which might had actually been opened by a Late Triassic - Early Jurassic continental break-up inside the Permo-Triassic rift. Speading from Early to Middle-Late Jurassic was then followed by an eastward subduction in Late Jurassic.

REFERENCES

ΑΣΒΕΣΤΑ,Α. (1992). *Ο μαγματισμός και η συνοδός του ιζηματογένεση κατά τα πρώτα στάδια ανοίγματος της ωκεάνιας λεκάνης του Αξιού στο Τριαδικό.* Διδακτορική διατριβή, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, Επιστ. επετ. Τμήμ. Γεωλογίας, Σχ. Θετικών Επιστ., παράρτημα αριθμ. 18, 439σ.

BAROZ,F., BEBIEN,J. & IKENNE,M. (1987). An example of high - pressure low - temperature metamorphic rocks from an island-arc: the Paikon series (Innermost Hellenides, Greece). *J. metamorphic Geol.*, **5**, 509-527.

BAROZ,F., MARTINI,R., ZANINETTI,L. (1990). Un aspect de la plateforme carbonatee triasique dans les Hellenide internes: le chainon d Oreokastro. *Riv. It. Paleont. Strat.*, **96**, 21-38.

BEBIEN,J. (1977). Mafic and ultramafic rocks associated with granites in the Vardar zone. *Nature*, **270**, 232-234.

BEBIEN,J. (1981). A propos de l'association de certaines formations ignees basiques a caracteres ophiolitiques avec des granites et des migmatites. *C. R. Acad. Sci. Paris*, 292, serie II, 733-735.

BEBIEN,J. (1982). *L'association ignee de Guevgueli (Macedoine Grecque), expression d'un magmatisme ophiolitique dans une dechirure continentale.* These doctorat d'Etat, Univ. Nancy I, 470p.

BEBIEN,J. & MERCIER,J.-L. (1977). Le cadre structural de l'association ophiolites-migmatites-granites de Guevgueli (Macedoine, Grece): une croute de bassin inter-arc? *Bull. Soc. geol. France (7)*, **XIX**, 927-934.

BEBIEN,J. & GAGNY,C. (1978). Influence de phenomenes de decrochement sur l'organisation du magmatisme dans l'association ophiolites-granites de Guevgueli (zone du Vardar, Macedoine grecque). *C. R. Acad. Sci. Paris*, **286**, serie D, 815-818.

BEBIEN,J.,DUBOIS,R. & GAUTHIER,A. (1986). An example of ensialic ophiolites emplaced in a wrench zone: the Innermost Hellenic Ophiolites belt. *Geology*, **14**, 1016-1019.

BEBIEN,J., BAROZ,F., CAPERDI,S. & VENTURELLI,G.(1987). Magmatismes basiques associes a l ouverture d un bassin marginal dans les Hellenides internes au Jurassique. *Ofioliti*, **12**, 53-70.

CHRISTOFIDES,G., SOLDATOS,T. & KORONEOS,A. (1990). Geochemisrty and evolution of the Fanos Granite, N. Greece. *Mineral. Petrol.*, **43**, 49-63.

ΔΑΒΗ,Ε, JUNG,D., ΤΣΑΓΚΑΛΙΔΗΣ,Α. & ΠΑΥΛΟΠΟΥΛΟΣ,Α. (1988). Οι σπιλίτες-κερατοφύρες του Πάικου. *Ορυκτός Πλούτος*, no 53, 13-26.

ΔΑΒΗ,Ε., ΜΙΓΚΙΡΟΣ,Γ., ΤΣΑΓΚΑΛΙΔΗΣ,Α. & ΠΑΥΛΟΠΟΥΛΟΣ,Α. (1989). Ο Μεσοζωικός βασικός μαγματισμός της Παιονίας. *Bull. Geol. Soc. Greece*, **XXIII/2**, 531-544.

DE WET,A.P. (1989). *Geology of part of the Chalkidiki peninsula, Northern Greece.* Ph.D.thesis, Cambridge university, 177pp.

DIXON,J.E. & DIMITRIADIS,S. (1989). The geochemistry of the Volvi body: an in-situ Mesozoic within-plate ophiolite, Northeast Greece. *Terra abstr.* p.165.

GAUTHIER,A. (1984). *La ceinture ophiolitique de Chalcidique (Grece du Nord): Etude d'un cas de variations longitudinales, petrologiques et structurales.* These 3• cycle, Univ. Nancy I, 290p.

GILL,J. (1981). *Orogenic andesites and plate tectonics.* A. El Goresy & W. Von Engelhardt (eds), 390pp.

HUPPERT,H.E. & SPARKS,R.S.J. (1988). The generation of granitic magmas by intrusion of basalt into continental crust. *J.Petrol.*,**29**, 599-624.

JUNG,D & MUSSALLAM,K. (1985). The Sithonia Ophiolite: a fossil oceanic crust. *Ofioliti*, **10**, 329-342.

JUNG,D, MUSSALLAM,K., BURGATH,K., KOCKEL,F., MOHR,G. & RASCHKA,H. (1979). Mineralogy and geochemistry of the Chalkidiki mafic - ultramafic rocks. *Abstr. Internat. Ophiolite Sumposium, Nicosia (Cyprus)*, 40-41.

KAUFFMANN,G. (1976). Perm und Trias im ostlichen Mittelgriechenland und auf einigen agaischen inseln. *Z. dt. geol. Ges.*,**127**, 387-398.

KAUFFMANN,G., KOCKEL,F. & MOLLAT,H. (1976). Notes on the stratigraphic and paleogeographic position of the Svoula Formation in the Innermost Zone of the Hellenides (Northern Greece). *Bull. Soc. geol. France (7)*,**XVIII**, 225-230.

KOCKEL,F. (1986). Die Vardar- (Axios-) zone. In: *Geologie von Griechenland*, V. Jacobshagen (ed). Gebruder Borntraeger, 150-168.

KOCKEL,F. & MOLLAT,H. (1977). Erlauterungen zur Geologischen Karte der Chalkidiki und angrenzender Gebiete 1:100.000, Nordgriechenland), Bundesanstalt fur Geowissenschaften und Rohstoffe, Hannover, 119p.

KOCKEL,V.F., MOLLAT,H. & WALTHER,H.W. (1971). Geologie des Serbo - Mazedonischen Massivs und seines mesozoischen Rahmens (Nordgriechenland). *Geol. Jb.*, **89**, 529-551.

KOUGOULIS,CH., VERANIS,N. & KASSOLI-FOURNARAKI,A. (1990). Metavolcanic rocks in the Examili formation (North Greece). *Chem. Erde*,**50**, 67-79.

KOYPOY,A. (1991). *Λιθολογία, τεκτονική, γεωχημεία και μεταμόρφωση μέρους του δυτικού τμήματος της ομάδας Βερτίσκου. Η περιοχή ΒΑ από τη λίμνη Αγίου Βασιλείου (Κορώνεια).* Διδακτορική διατριβή, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, Επιστ. επετ. Τμήμ. Γεωλογίας, Σχ. Θετικών Επιστ., παράρτημα αριθμ. 15, 461σ.

MERCIER,J. (1966/68). 1re These (vol.1): Etude geologicque des zones internes des Hellenides en Macedoine Centrale (Grece). 2^{e} These (vol.2): Contribution a l'etude du metamorphisme et de l'evolution magmatique des zones internes des Hellenides. *Ann. Geol. Pays Hellen.*,**20**, 1-792.

MERCIER,J-L, VERGELY,P. & BEBIEN,J.(1975). Les ophiolites helleniques "obductees" au Jurassique superieur sont-elles les vestiges d une mer marginale peri-europeenne? *C. R. somm. S.G.F.*

MUSSALAM,K. (1991). Geology, geochemisrty and the evolution of an oceanic crustal rift at Sithonia, NE Greece. In: *Ophiolite Genesis and Evolution of the Oceanic Lithosphere,* Tj. Peters et al. (eds), 685-704.

MOUSSALAM,K., & JUNG,D. (1986). Petrology and geotectonic significance of the salic rocks preceding ophiolites in the Eastern Vardar zone, Greece. *TMPM Tschermaks Min. Petr. Mitt.*, **35**, 217-242.

PEARCE,J.A. (1975). Basalt geochemistry used to investigate past tectonic environments in Cyprus. *Tectonophysics*,**25**, 41-68.

PEARCE,J.A. (1980). Geochemical evidence for the genesis and eruptive setting of lavas from Tethyan ophiolites. In: *Ophiolites Proceedings of the International Ophiolite Symposium,* Nicosia, Cyprus 1979, 261-272.

PEARCE,J.A. (1982). Trace element characteristics of lavas from destractive plate boundaries. In: *Andesites*, R.S. Thorpe (ed.), 525-548, J.Wiley & Sons.

PEARCE,J.A. (1989). High T/P metamorphism and granite genesis beneath ophiolite thrust sheets. *Ofioliti*, **14**, 195-211.

PLATEVOET,B. & BEBIEN,J. (1992). Diversite des formations granitiques appartenant a l'etude typologique du zircon. *C. R. Acad. Sci. Paris*, **314**, serie II, 173-179.

REMY,P. (1984). Mise en evidence d'un metamorphisme dynamothermal dans les sediments au contact des ophiolites d'Oreokastro (Macedoine grecque). *C. R. Acad. sci. Paris*, **299**, serie II, 27-30.

RICOU,L.-E. (1965). *Contribution a l'etude geologique de la bordure Sud-Oest du massif Serbo-Macedonien aux environs de Salonique.* These 3• cycle, Univ. Paris, 122p.

ROBERTSON,A.H.F. & DIXON,J.E. (1984). Introduction: aspects of the geological evolution of the Eastern Mediterranean. In: *The geological evolution of the Eastern Mediterranean,* J.E. Dixon & A.H.F. Robertson (eds), 1-74, Geol. Soc. Sp. Publ. No 17.

ΣΑΠΟΥΝΤΖΗΣ,Η.Σ. (1969). *Πετρογραφία και γεωλογική τοποθέτησις των πρασίνων γνευσίων της Θεσσαλονίκης.* Διατριβή επί διδακτορία, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, 124σ.

SHARP,I., ROBERTSON,A.H.F. & DIXON,J.E. (1991). Tectonic and sedimentary history of the Eastern margin of the Pelagonian zone, NE Greece. *Terra Abstracts,* 3, 323p.

SCHUNEMANN,M. (1985). *Contributions to the geology, geochemistry and tectonics of the Chortiatis series metamorphic calc-alkaline suite, Chalkidiki, Northern Greece.* Dissertation Doktorgrades, Univ. Hamburg, 182p.

ΣΙΔΗΡΟΠΟΥΛΟΣ,Ν. (1991). *Λιθολογία, γεωχημεία, τεκτονική και μεταμόρφωση του βορειοδυτικού τμήματος της ομάδας Βερτίσκου. Η περιοχή του όρους Δύσωρο (Κρούσια), βόρεια από το Κιλκίς.* Διδακτορική διατριβή, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, Επιστ. επετ. Τμήμ. Γεωλογίας, Σχ. Θετικών Επιστ., παράρτημα αριθμ. 14, 592σ.

SIDIROPOULOS,N. & DIMITRIADIS,S. (1989). Extension and melting of the continental crust during intracontinental emplacement of the Guevgueli ophiolite, Eastern Vardar zone. *Terra Abstracts,* 1, 57p.

SMITH,A.G. & SPRAY,J.G. (1984). A half-ridge transform model for the Hellenic-Dinaric ophiolites. In: *The geological evolution of the Eastern Mediterranean,* J.E. Dixon & A.H.F. Robertson (eds), 629-644, Geol. Soc. Sp. Publ. No17.

STAIS,A., FERRIERE,J., CARIDROIT,M., DE WEVER,P., CLEMENT,B. & BERTRAND,J. (1990). Donnees nouvelles sur l histoire ante-obduction (Trias-Jurassique) du domaine d Almopias (Macedoine, Grece). *C. R. Acad. Sc. Paris.*

STAIS,A. & FERRIERE,J. (1991). New data on Mesozoic paleogeography of the Vardar domain: Almopias and Peonias basins (Macedonia, Northern Internal Hellenides). *Bull. Geol. Soc. Gr.*,**XXV/1**, 491-507.

VERGELY,P. (1984). *Tectonique des ophiolites dans les Hellenides internes (deformations, metamorphismes et phenomenes sedimentaires). Consequences sur l evolution des regions Tethysiennes occidentales.* These D Etat, Univ. de Paris-Sud Centre D Orsary, vol.I, 250p. vol.II, 411p.