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# TWO ALTERNATIVE SOLUTIONS FOR THE DEVELOPMENT OF A MARGINAL BASIN IN NE GREECE

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## ABSTRACT

Several ophiolites are exposed intermittently in NE Greece along a NW-SE striking belt from Guevgueli to the Sithonia peninsula (IMHOB). This belt may be extended east- and southeastwards to include the Evros, Samothraki and Lesvos ophiolites (IMHOB plus ESL). Minor mafic exposures running approximately parallel to the IMHOB form the Therma-Volvi-Gomati complex (TVG). All these suites display common features: they are incomplete ophiolite sequences, lack ultramafic members, are broadly autochthonous and display ages 10-20 Ma younger than the ophiolites from western Greece. Chemical variations suggest that these ophiolites were formed in a marginal basin. The salic Chortiatis magmatic suite is found between the IMHOB and TVG, on the Chalkidiki peninsula and represents a volcanic arc formation.

Geological and geochemical characteristics coupled with geographical constraints led us to reconstruct two alternative plate tectonics interpretations for the evolution of this basin. The first suggests a fore-arc environment for the IMHOB plus ESL ophiolites and a back-arc rifting for the TVG, due to the northward subduction of the Axios (Vardar) ocean. The second favours an opposite interpretation for the IMHOB plus ESL and TVG ophiolites, relating their formation to a basin that developed due to the southwards subduction of the Strandza ocean of Paleotethys. In any case, these ophiolites have been formed in a marginal basin regime, where spreading occurred disorderly in randomly oriented ridges.

## INTRODUCTION

The tectonic history of the Eastern Mediterranean region appears to be much complicated, thus several models have been suggested for its geotectonic evolution (for a review see Robertson et al., 1996). Single geological studies on the ophiolites from the broad north Aegean Sea region, have explained their petrogenesis but they have not presented a geotectonic reconstruction including all the mafic suites in that area. The present study aims at providing a new insight on the geotectonic history of the northern Aegean region, based upon geological and petrological information from the ophiolite complexes occurring in this area.

## CHARACTERISTICS OF THE OPHIOLITES IN THE NE AEGEAN REGION

Several ophiolites crop out in the broad NE Aegean Sea region, forming two distinct belts (Fig. 1). The major belt, known as the "Innermost Hellenic Ophiolite Belt" (IMHOB, after Haenel-Remy and Bébien, 1985; Bébien et al., 1986), comprises ophiolitic exposures extending intermittently along a NW-SE trend, from the Greece-FYROM international border to the extremity of the Chalkidiki peninsula.

To the east of the IMHOB, within the Serbo-Macedonian Massif, there are three small ophiolite outcrops, dominated by mafic rocks. They form a minor belt and have been interpreted as a dismembered ophiolite, the Therma-Volvi-Gomati complex (TVG; Dimitriadis, 1980). A salic rocks association, the Chortiatis magmatic suite, lies between the two ophiolitic belts in an approximately parallel strike (Fig. 1). Other ophiolites in NE Greece occur also in the Thracean (eastern) branch of the Circum-Rhodope Zone, as well as in the islands of Samothraki and Lesvos.

### The IMHOB

Figure 2 illustrates comparative geological characteristics of the ophiolites in NE Greece. The Guevgueli ophiolite (which belongs geotectonically to the Peonias zone, after Mercier, 1968) consists of cumulate and non-cumulate gabbros, net-veined hornblende-diorites with juxtaposed plagiogranites, a sheeted-dyke complex and basaltic lavas; these lavas in several places, rest conformably on pelites (Bébien 1982; 1991; Bébien et al. 1987; Ivanov et al., 1987; Zachariadou and Dimitriadis, 1995). K-Ar radiometric dates on gabbroic assemblages yielded Late Jurassic ages (148±3, 149±3, 154±3 and 163±3 Ma; Spray et al., 1984), compatible with radiolarian age data from calcareous silts and mudstones intercalated with mafic volcanic rocks, suggesting an early Late Jurassic age (Danelian et al., 1996). The Guevgueli ophiolite displays a heterogeneous geochemical signature: some rocks display a high-field-strength elements

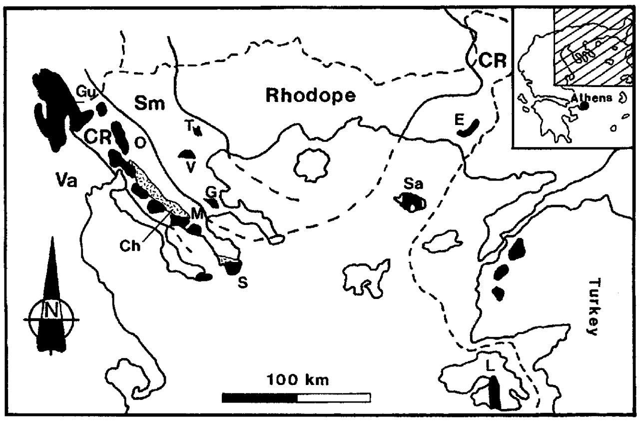


Fig. 1 -Main locations of the ophiolites in NE Greece. Va: Axios (Vardar) zone, CR: Circum-Rhodope Zone, Sm: Serbo-Macedonian Zone, Gu: Guevgueli, O: Oreokastro, M: Metamorphosis, S: Sithonia, T: Therma, V: Volvi, G: Gomati, E: Evros, Sa: Samothraki, L: Lesvos, Ch: Chortiatis magmatic suite.

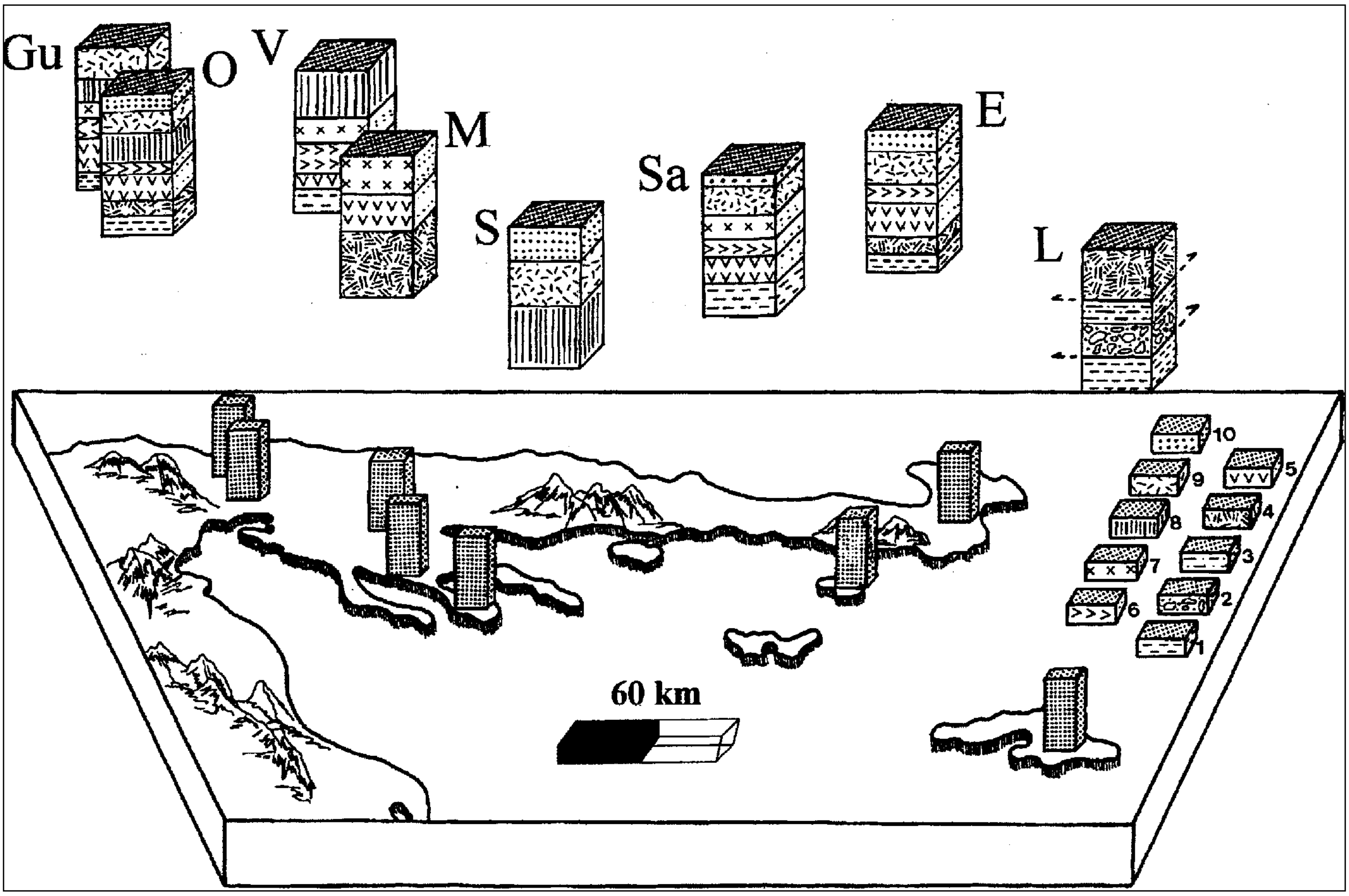


Fig. 2 -Comparative stratigraphic sections of the ophiolites in NE Greece. Abbreviations as in Fig. 1. 1: Basement formations, 2: Ophiolite mélanges, 3: Sub-ophiolitic metamorphic soles, 4: Ultramafic rocks, 5: Cumulate gabbros, 6: Non-cumulate gabbros, 7: Diorites, 8: Sheeted-dyke complexes, 9: Basalts, 10: Sedimentary rocks.

(HFSE) nature similar to MORB, whereas others are rather depleted in HFSE and hence have a major influence from an IAT component (Bébien 1982; Bébien et al., 1986; 1987; Fig. 3f).

The Oreokastro ophiolitic complex occurs south of Guevgueli and despite its restricted dimensions it exposes a complete ophiolite sequence (Haenel-Remy and Bébien, 1985; Fig. 2). Both the Guevgueli and Oreokastro complexes demonstrate thermal metamorphic phenomena along their contacts with the adjacent formations, with development of andalusite, cordierite and garnet (Karamata et al., 1982; Remy, 1984; Haenel-Remy and Bébien, 1985). Geochemical data indicate that the Oreokastro complex displays significant similarities with MORB rocks similar to those from the Guevgueli ophiolite (Haenel-Remy and Bébien 1985).

The central Chalkidiki (and Metamorphosis) ophiolitic rocks (in the Circum-Rhodope Zone) include peridotites, gabbros and diorites (Fig. 2) of the lower and intermediate members of an ophiolite (Bébien et al., 1986). The Guevgueli and Sithonia ophiolites have been joined by a long, dextral, transform fault. The ophiolites of Central Chalkidiki are thought to have escaped through this discontinuity (Bébien et al., 1986; Figs. 4B and 4C). The lack of mafic rocks and the exposure of peridotites in this ophiolite is related to mantle upwelling (Bébien et al., 1986). Geophysical results in that area are consistent with such a process (Makris, 1977). Hypabyssal rocks from the Central Chalkidiki have low HFSE contents and trace elements variations in several discrimination diagrams that suggest a strong resemblance with IAT formations (Bébien et al., 1986; 1987).

The Sithonia ophiolite (of the Circum-Rhodope Zone), located in the southern tip of the Chalkidiki peninsula, exposes a sheeted-dyke complex (composed mainly of dolerites and minor intermediate and acid rocks) and basalts covered by neritic sediments (Fig. 2). The shallow-water sedimentary cover of the ophiolite contains microfauna and ammonites of Late Jurassic age. It also includes detrital material from the metamorphosed Svoula flysch, indicating that a Late Jurassic basin was formed shortly after the uplift of this flysch. Since there are no other rocks younger than the Early Cretaceous, it has been suggested that the Sithonia ophiolite has been formed between the Late Jurassic and Early Cretaceous (Jung and Mussallam, 1985). Geochemical investigations of dolerites and basalts from this ophiolite, particularly using trace elements discrimination diagrams, show variations which suggest transitional affinities between MORB and IAT (Jung and Mussallam, 1985; Fig. 3a, c, e).

## The TVG complex

Among the exposures of the TVG complex, the Volvi mafic sequence is the best described by Dixon and Dimitriadis (1984). It consists of a succession of limited cumulate and mostly non-cumulate gabbros, a net-veined diorite in a granitic-trondhjemitic matrix and a sheeted dyke complex (Fig. 2). This sequence has suffered an amphibolite facies metamorphism/deformation, during the Late Jurassic - Early

Cretaceous. K-Ar radiometric dates from amphibolites of the Volvi complex yielded Early Cretaceous ages in the range 116-111±3 Ma (Harre et al., 1968). However, these ages have been disputed and it is generally believed that they reset older ages, due to some arbitrary degree of argon loss (Harre et al., 1968; Kockel et al., 1977) or that they represent cooling ages (Dixon and Dimitriadis, 1984). These latter authors claim that deformation started before the end of magmatic activity, implying that the age of the Volvi complex could not be older than Jurassic. The close relationship between deformation and magmatism, the occurrence of granitic melts in the margins of the complex and the higher metamorphic temperatures obtained from the mafic rocks relative to their basement, are all interpreted as evidence for an *in situ* intracontinental rift formation for the Volvi suite. Geochemical data, which show that the basalts are LILE-enriched and display intermediate between alkalic and supra-subduction-zone affinities, are consistent with the above interpretation and moreover show the influence from subducted lithosphere (Dixon and Dimitriadis, 1984).

### The Thracean and north-Aegean Islands ophiolites

The Evros ophiolite lies in eastern Greece near the Greece-Turkey international frontier (Fig. 1). It comprises a dismembered, metamorphosed in greenschist facies suite, consisting of serpentinized peridotites, cumulate and non-cumulate gabbros and basalts (Fig. 2; Magganas et al., 1991). The stratigraphic position of this ophiolite within Jurassic metasediments of the Circum-Rhodope Zone, as well as radiometric dates on fission tracks from apatites in gabbros suggest a Late Jurassic age (Bigazzi et al., 1989). This suite shows, like the Guevgueli one, a heterogeneous geochemical signature. Some rocks (“metavolcanics” in Magganas et al., 1991) have a boninitic and subduction-related affinity, being low in Ti, Zr and absolute REE and rich in Mg, Cr and Ni contents. These geochemical features are indicative for formation in an island arc setting. Other mafic rocks (“greenschists” in Magganas et al., 1991) underlying the “metavolcanics” have a strong IAT chemistry influenced by a minor MORB component, as it is indicated by their negative Nb and Ti anomalies on spiderdiagrams and their higher HFSE contents relative to the “metavolcanics” (Magganas et al., 1991; see also Fig. 3a, c, e).

Samothraki Island lies to the southeast of the Chalkidiki peninsula (Fig. 1) and exposes an ophiolite composed of cumulate and non-cumulate gabbros, a net-veined hornblende-diorite with associated plagiogranites and leucogranites, massive dolerites and basalts, intruded by sparse dolerite dykes (Fig. 2). The Samothraki ophiolite suite was emplaced in a metasedimentary succession of shallow-marine to continental facies; it is a broadly autochthonous sequence as it is indicated by the absence of tectonic processes at its bottom (i.e. cataclastic phenomena, ophiolite mélange, and amphibolite sole) (Kotopouli et al., 1989; Tsikouras and Hatzipanagiotou, 1995). K-Ar radiometric dates gave ages of 154±7 and 155±7 Ma (Tsikouras et al., 1990). Basalts and massive dolerites from Samothraki display variations and ratios of immobile elements in the frame of MORB (Fig. 3b, d, f). Diorites are bimodal: some of them have flat REE profiles and HFSE contents in the frame of MORB, whereas others are richer in LREE, depleted in HFSE and with well-pronounced negative Nb, Zr and Ti anomalies on spiderdiagrams and are similar to subduction-related formations. Two sets of dykes occur: an older one with a MORB chemistry (rich in Ti, Y and Zr, similar to the basalts) and a younger one with a subduction signature (richer in LREE, depleted in HFSE and with negative Nb, Y and Zr anomalies on spiderdiagrams) (Tsikouras and Hatzipanagiotou, 1998).

The Lesvos ophiolite consists of peridotitic tectonites, rare cumulate gabbros and basalts; a subophiolitic metamorphic sole and an ophiolite mélange occur tectonically at its base (Tsikouras et al.; 1994, Miggiros et al., 1998; Fig. 1). K-Ar radiometric data on hornblende separates from the amphibolite sole suggest ages of 153±5 and 158±5 Ma (Hatzipanagiotou and Pe-Piper, 1995). The chemistry of the basaltic rocks from Lesvos is almost identical to those from the Samothraki ophiolite, having a strong MORB signature (Tsikouras et al., 1994; Hatzipanagiotou and Pe-Piper, 1995; Fig. 3b, d, f).

Evidently, there are several analogous geological and geochemical characteristics between the above ophiolites and the IMHOB, which allow us to extend this belt further east- and southeastwards, in order to include the Evros, Samothraki and Lesvos ophiolites (IMHOB plus ESL).

### The Chortiatis magmatic suite

This magmatic suite lies to the east of the IMHOB and comprises Jurassic tonalites, trondhjemites, granophyres and submarine volcanic rocks, that are older than the Chalkidiki ophiolitic rocks (Mussallam and Jung, 1986). Dykes of intermediate composition in the Chortiatis suite have a NE-SW trend similar to those from the sheeted dyke complex in Sithonia, implying that both have been emplaced during extension regimes of similar orientation.

The Chortiatis magmatic suite shows a low-K calcalkaline affinity; its origin is ascribed to multi-stage partial melting of mafic material. The mafic lavas from this suite display low Y, Ti, Zr and P contents, similar to formations originated in an island arc setting (Schünemann, 1985; Mussallam and Jung, 1986).

## DISCUSSION

Several authors have ascribed the origin of the IMHOB plus ESL and TVG ophiolite suites to a marginal basin setting (e.g. Jung and Mussallam, 1985, Bébien et al., 1986; 1987; Kotopouli et al., 1989; Magganas et al., 1991; Tsikouras et al., 1994; Tsikouras and Hatzipanagiotou, 1995; 1998). Mussallam (1991) suggests that the Guevgueli and Sithonia ophiolites developed in the early stages of motion on a ridge-transform margin whose displace did nid not exceed 30 km and whose duration was probably less than 1.5 Ma. A close genetic association of the Chortiatis magmatic suite with the Chalkidiki ophiolites is implied, besides their spatial and temporal relationships by Mussallam and Jung (1986). The latest authors suggest that the Chortiatis plutonic rocks predate the ophiolites, representing products of a volcanic arc; both the Chortiatis and the Chalkidiki ophiolites are associated with a marginal basin. Unfortunately, the sea interrupts the southward extension of this suite, thus it is not possible to define any mutual relationships with the Samothraki and Lesvos ophiolites. However, a lithologically similar formation occurs, with almost E-W strike, in NW Turkey. It comprises the Kirklareli plutonic complex, which intrudes the Paleotethyan Kirklareli Nappe and displays an intrusive event of 144 Ma (Aydin, 1974; Aykol, 1979). This suite rep-

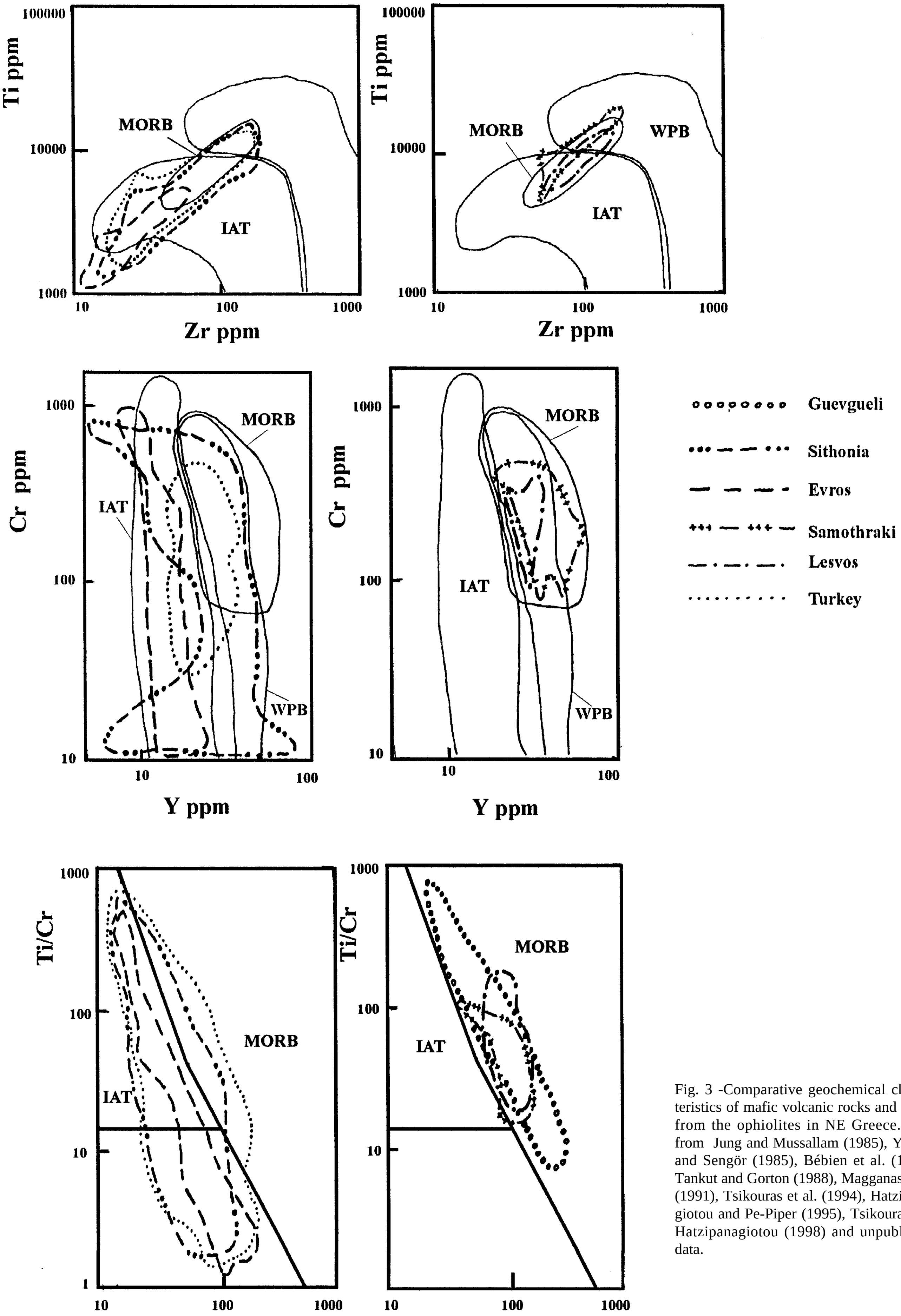


Fig. 3 -Comparative geochemical characteristics of mafic volcanic rocks and dykes from the ophiolites in NE Greece. Data from Jung and Mussallam (1985), Yilmaz and Sengör (1985), Bébien et al. (1986), Tankut and Gorton (1988), Magganas et al. (1991), Tsikouras et al. (1994), Hatzipanagiotou and Pe-Piper (1995), Tsikouras and Hatzipanagiotou (1998) and unpublished data.

resents arc magmatism due to the southward subduction of Paleotethys (Sengör et al., 1984). The reason why the Chortiatis suite does not extend to the north and hence it is not spatially related to the Guevgueli ophiolite is not fully understood. The Paikon volcanic arc rocks (located to the west of Guevgueli) cannot be correlated to the Chortiatis magmatic suite due to their different compositions and geotectonic settings (see e.g. Sharp and Robertson, 1993; Bébien et al., 1994, Mountrakis, 1994). However, both the Guevgueli and Evros ophiolites contain mafic rocks of island arc origin, thus we must accept that the two extremities of the volcanic arc were of mafic composition. This probably happened because spreading that generated the ophiolites in these two areas, occurred within the arc (inter-arc basins?) and hence these volcanic arc rocks were less evolved. In addition, partial melting of mafic rocks and/or high-level contamination of melts by terrigenous sediments at the base of the Chortiatis arc could generate a more acidic magma.

The investigated ophiolites are significantly different from those located in western Greece, in displaying weaker IAT affinities (except for the central Chalkidiki ophiolites). The western Greece ophiolite complexes have strong Supra-Subduction-Zone trace element characteristics with evolution from MORB to IAT and occasionally to boninites (e.g. Capedri et al., 1980; 1985; Simantov and Bertrand, 1987; Hatzipanagiotou, 1990; Jones et al., 1991; Smith, 1993; Hatzipanagiotou et al., 1994).

The ophiolites of the IMHOB plus ESL and TVG show some common peculiar features compared to the well-known complexes from western Greece:

1. They can be interpreted as parautochthonous (except Lesvos) on the basis of the following facts: i) the thermal metamorphic overprint in the country rocks of the Guevgueli and Oreokastro suites, ii) the occurrence of lavas conformably overlying upon pelites from the Guevgueli ophiolite, iii) the absence of ophiolitic mélanges, mylonitized zones or amphibolite soles at the bottom of the ophiolites (with the exception of Lesvos), iv) the close relation of the IMHOB and Samothraki complexes with Late Jurassic, K-rich granitic intrusions (Bébien et al., 1986; Tsikouras et al., 1998), v) the local intrusion of the Samothraki hornblende-diorite into pelites (Tsikouras and Hatzipanagiotou, 1993; 1995).

2. They are incomplete series, usually lacking ultramafic members. Since there is no evidence that they were extensively obducted, a reasonable interpretation is that these ophiolites were simply uplifted and/or have been slightly transported and tilted. Tilting is suggested by the non-vertical dipping of the dykes within the ophiolites of this area (Jung and Mussallam, 1985; Mussallam, 1991; Tsikouras and Hatzipanagiotou, 1995). In such a case, a considerable uplift is required before the underlying ultramafic rocks could be exposed by erosion.

3. Their ages (when available) are similar and appear to be 10-20 Ma younger than the ophiolites from western Greece.

4. They display a characteristic horizon of net-veined hornblende diorites and plagiogranites.

5. They formed in an ensialic environment, as is suggested by their close relationships with granitic rocks, as well as their shallow marine basements consisting of Triassic and Jurassic sediments with associated lavas and pyroclastic rocks (Ohnenstetter, 1980; Bébien et al., 1986; Tsikouras and Hatzipanagiotou, 1995).

These features suggest that all these ophiolite assemblages may share a common origin. Geological and geochemical data, mentioned above, imply a petrogenetic influence from a subducted slab. Eventually, all these ophiolites may have formed along the same marginal basin, since they are associated to similar marine sedimentary sequences.

A similar marginal basin setting has also been proposed for the Meglenitsa ophiolite (Almopias Zone, Greece; Sharp and Robertson, 1994), the Rocas Verdes ophiolite in southern Chile (Saunders et al., 1979; Aberg et al., 1984) and the modern Bransfield Strait back-arc basin, which has separated the ensialic block of the South Shetland islands from the Antarctic peninsula during the last 2 Ma (Weaver et al., 1979; Keller and Fisk, 1992).

## GEOTECTONIC EVOLUTION: TWO ALTERNATIVE SOLUTIONS

A major problem in reconstructing the geotectonic evolution of the investigated area is to evaluate the subducted ocean, which was responsible for the development of a marginal basin. The onset of rifting that evolved into a marginal basin, is probably defined by the rhyolites and mafic rocks intercalated in the Permo-Triassic arkoses and fanglomerates (Mussallam and Jung, 1986; Dimitriadis and Asvesta, 1993), as well as by the metavolcanic rocks intercalated within the Jurassic pelitic schists in Samothraki (Tsikouras, 1992). The present geographic location of the Chortiatis magmatic suite indicates the position of the volcanic arc relative to the Chalkidiki ophiolites.

### Model 1

If the ophiolites in NE Greece are in direct genetic relationship with the northwards Axios (Vardar) ocean subduction, then geographic constraints require that the ophiolites of the IMHOB plus ESL originated in a fore-arc basin, while those of the TVG formed in a back-arc environment (Fig. 4A-D).

*Middle (?) - early Late Jurassic*

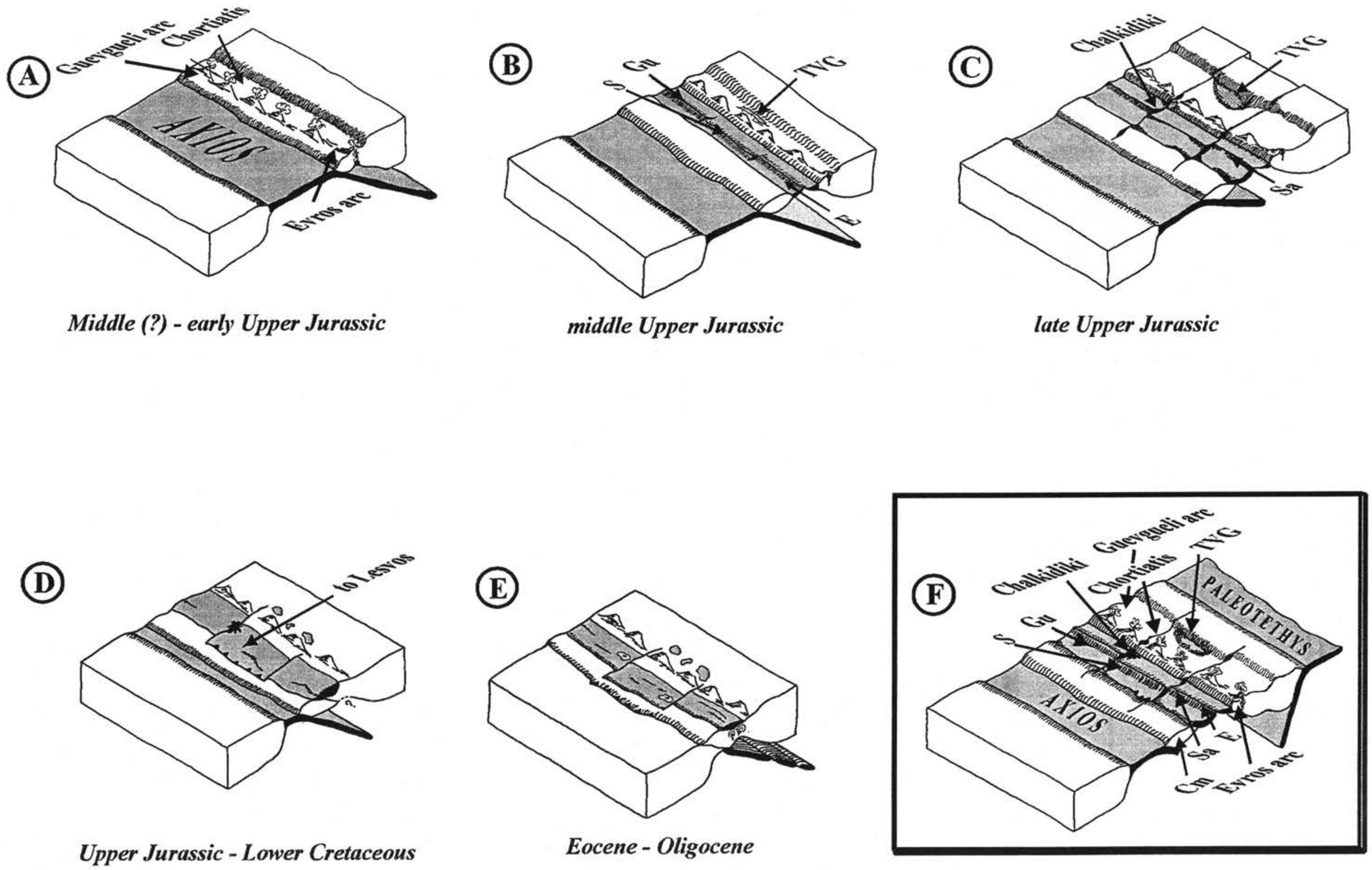
The Axios oceanic slab was being consumed beneath the Eurasian continent, which is represented by the Rhodope Massif. The Chortiatis volcanic arc and the Guevgueli and Evros arc-parts formed on the margin of the Eurasian continent (Fig. 4A)

*Middle Late Jurassic*

The Guevgueli and Evros complexes developed. Their present geographic position requires them to have evolved in fore-arc regime relative to the already active volcanic arc. These complexes are thought to have formed in close proximity of this arc or within it (inter-arc basins ?). The arc activity must have ceased as the fore-arc basin widened (remnant volcanic arc) while a northwards (backwards) arc-migration is also required. Consequently, the Sithonia ophiolite (and possibly those exposures located in NW Turkey with similar chemistry, see Fig. 3a, c, e) formed. Most probably this suite is related to early stages of spreading, due to the significant contribution of an arc component to its geochemistry. An uncertainty arises considering the precise age of the TVG complex since there are no available radiometric data. However, geological evidence points to a Jurassic age. Accordingly, it is possible that at that time an intracontinental rift was also beginning to form in a back-arc position, succeeded by generation of the TVG ophiolites (Fig. 4B).

*Late Late Jurassic*

The Guevgueli and Sithonia ophiolites have been joined



*Middle (?) - early Upper Jurassic*

*middle Upper Jurassic*

*late Upper Jurassic*

*Upper Jurassic - Lower Cretaceous*

*Eocene - Oligocene*

Fig. 4 - Plate tectonics interpretation for the evolution of a marginal basin in NE Greece. Abbreviations as in Fig. 1, see text for details.

by a transform fault and the ophiolites of Central Chalkidiki appeared. The Samothraki and Lesvos ophiolites are thought to have formed shortly after the Sithonia ones, when the influence of the subducted lithosphere diminished (Fig. 4C). The limited dimensions of the TVG complex, coupled with geochemical data suggest a limited spreading, resulting in the development of a possibly restricted (aborted ?) basin (Fig. 4C).

*Late Jurassic - Early Cretaceous*

After the closure of the ocean and the initiation of collision, the Lesvos ophiolite (the only allochthonous suite) was detached and transported to its present-day site (Fig. 4D). The age of the collision is indicated by the 150 Ma, post-collisional Fanos granite which intrudes the Guevgueli ophiolite (Borsi et al., 1966; Bébien, 1977; Spray et al., 1984; Christofides et al., 1990b), as well as by the post-collisional leucogranitic veins within the Samothraki ophiolite (Tsikouras et al., 1998)

*Eocene - Oligocene*

During this period, a subsidiary subduction resulted in partial melting of the already sunk slab. These melts generated several granitic bodies with similar ages and post-collisional features (e.g. Kyriakopoulos, 1987; Christofides et al., 1986; 1990a; Seymour et al., 1996).

Application of this model requires the development of a younger volcanic arc, due to progressive subduction; this arc ought to occur south of the Samothraki, which represents the frontal part of the basin. However, there is no evidence for the existence of an analogous formation.

### Model 2

An alternative solution ascribes the development of the above marginal basin to the southward subduction of the Strandza ocean, part of the Paleotethys, beneath the Cimmerian microcontinent (Dewey et al., 1973; Bogdanov et al., 1974; Sengör and Yilmaz, 1981; Sengör et al., 1980; 1984; Robertson and Dixon, 1984; Chatalov, 1990; Koukouvelas and Doutsos, 1990, Ustaömer and Robertson, 1997). The extension of the Cimmerian continent in Greece is still a matter of debate. Smith and Spray (1984) and Mountrakis (1986) suggest that the Pelagonian and Serbo-Macedonian zones were parts of the Cimmerian continent. Mountrakis (1986) based on lithostratigraphic and tectonic evidence interprets the Axios zone ophiolites as representing the Paleotethys ocean. Moreover, Pe-Piper and Kotopouli (1994) record the extension of the Paleotethyan Karakaya complex in the Chios and Lesvos Islands in NE Aegean, while Gocev (1991) and von Braun (1993) recognise several similarities between the Paleotethyan Kirklareli Nappe in Turkey and the Circum-Rhodope Zone in Greece. It has been suggested that both Neotethys and Paleotethys must have closed in the Late Jurassic-Early Cretaceous, within a limited time span (Smith and Spray, 1984; Mountrakis, 1986; Koukouvelas and Doutsos, 1990).

In the case of the involvement of Paleotethys in NE Greece, the IMHOB plus ESL ophiolites may have developed in a back-arc basin, whereas the TVG ophiolite would have formed along a rift in a fore-arc region (Fig. 4F). The evolutionary stages of this basin would have been similar to these stages of the first model. However, this model does not require cessation of the volcanic arc, thus the Chortiatis suite, as well as the Guevgueli and Evros arc-parts would represent a continuously active volcanic arc.

In any case, the development of this marginal basin must have had a complex tectonic history as it is indicated by the complex geological structures of that area, as well as by the variable spreading directions. The non-vertical dykes in the Guevgueli ophiolite suggest extension in a WNW-ESE direction (Bébien et al., 1986). The Sithonia dykes show after rotation to their original position, an approximate 65° dip and suggest spreading in a WNW-ESE orientation (Jung and Mussallam, 1985; Mussallam 1991). The dykes in the Volvi complex are steeply dipping or almost vertical with a general NE strike suggesting a NW - SE spreading (Dixon and Dimitriadis, 1994). Dykes from the Samothraki ophiolite dip at about 60-80° and indicate spreading in a NNE-SSW direction (Tsikouras and Hatzipanagiotou 1995). These variable spreading directions indicate that the ophiolites were generated along randomly oriented ridges, where spreading have taken place disorderly.

## CONCLUSIONS

Two discontinuous ophiolite belts running approximately NW-SE are found in continental NE Greece: the IMHOB and the TVG. Comparative geological and geochemical investigations reveal the close resemblance of the IMHOB ophiolites with those of the Evros Valley and Samothraki and Lesvos Islands, enabling us to extend the IMHOB in order to include these last three suites (IMHOB plus ESL).

The salic Chortiatis magmatic suite represents a volcanic arc formation, closely related to the ophiolites. We suggest two alternative plate tectonics interpretations for the evolution of this basin. The first involves the northward-dipping Axios ocean and the evolution of a fore-arc basin for the formation of the IMHOB plus ESL ophiolites while the TVG may have been formed in a back-arc regime. The second favours the existence of the Paleotethys ocean in NE Greece. Its southwards subduction would be responsible for the evolution of a fore-arc rift that generated the TVG ophiolites, as well as a back-arc basin where the IMHOB plus ESL ophiolites originated.

The second model is consistent with the ideas presented by Sengör et al. (1984), Mountrakis (1986) and Ustaömer and Robertson (1997) for the evolution of the Paleotethys and Cimmerian continent in Greece. It is significantly supported by the fact that the Chortiatis suite (the volcanic arc) displays a highly evolved calcalkaline character, which probably suggests that it was operating until the final evolutionary stages of the marginal basin. Contrarily, the first model demands the Chortiatis magmatic suite to be a relict volcanic arc, which migrated backwards in the basin. In this case, its operation must have ceased early, and there was limited time for such an extensive magmatic evolution. To our knowledge, there is no modern example of a similar process. Moreover, in several modern fore-arc basins (e.g. Mariana and Izu-Bonin) the fore-arc ophiolitic rocks constitue the basement of arcs and are usually older than them (Charvet and Ogawa, 1994), which is not the case considering the ages of the Chortiatis and Chalkidiki ophiolites. If the Chortiatis magmatic rocks are interpreted as products originated from the subduction of the Strandza Ocean, then they could be directly related to the Kirklareli magmatic suite in NW Turkey.

The petrological-geochemical studies on this area will greatly benefit from a detailed, conjugated tectonic investigation on these ophiolites for the elucidation of the tectonomagmatic history of the north Aegean Sea region.

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