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THE CHALKIDIKI SUPRA-OPHIOLITIC FORMATIONS, AND THEIR BEARING ON THE VARDARIAN OBDUCTION PROCESS

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ABSTRACT

From the study of the supra-ophiolitic formations from Kassandra and Sithonia (ophicalcites, volcanoclastic flysch, reefal limestones, conglomerates with acidic rock pebbles, and without continental clasts), we suggest that an intra-oceanic island arc formed there during the Kimmeridgian-Tithonian. Deeper parts of the arc are represented by granodiorite and pegmatite intrusions in the ophiolite, dated between ca. 150 and 120 Ma. The Vardarian obduction would not have occurred before the Early Cretaceous, and would have operated by continental subduction below the detached brittle crust of the arc and back-arc areas.

KEY WORDS: ophiolite, subduction, obduction, Hellenides, Greece

1. INTRODUCTION

Obduction may result from various process (e.g. Michard et al., 1996), which can be recorded in the supra-ophiolitic " autochthonous " formations (Lagabrielle et al., 1986; Immenhauser, 1996). We present new data on the supra-ophiolitic formations from the southeastern Vardar zone (Figure 1), and on the associated arc magmatism, which shed some light the Vardarian obduction history (Vergely, 1984; Dercourt et al., 1993). The Vardarian ophiolites of western Chalkidiki form a NW-trending belt (Thessaloniki nappe in the following, including the Monopigadhon inlier) which prolongates northward in the Oreokastro and Guevgueli massifs (Makris and Moller, 1977; Haenel-Rémy and Bébien, 1985; Bébien et al., 1986; Ferrière and Staïs, 1995). The ophiolitic belt is bounded eastward by the Peri-Rhodopian metamorphics (Kockel and Mollat, 1977; Michard et al., 1994; Burg et al., 1995).

2. THE SUPRA-OPHIOLITIC FORMATIONS

In this section, we informally define four supra-ophiolitic formations from the Kassandra and Sithonia peninsulas of southern Chalkidiki. The *Paliouri formation* from southernmost Kassandra begins with a volcanoclastic flysch (lower member) overlying the spilitic pillow lavas and pillow breccias (Feinberg et al., 1996) (Figure 2 A). This Paliouri flysch includes abundant plagioclase clasts of most probable andesitic origin. The upper member of the formation includes conglomerates with reefal limestone boulders associated with pebbles of both basaltic and trachy-andesitic composition. The *Xenia-Keliphos formation* (Figure 2 B) consists of reefal limestones interlayed with conglomerates in which limestone and spilite boulders and pebbles are associated with granitoid, trachy-andesite, and rhyolite pebbles (Xenia). This formation likely succeeds the Paliouri. Mussallam (1991) described at Keliphos island micro- and macrofossils of late Kimmeridgian age, as well as two intercalated basaltic flows.

More to the east (Sithonia), the *Akra Papadhia formation* overlays a thick volcanic sequence (dyke

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(lower member). Terrigenous inflow develops upward in the volcano-clastic, flysch-type upper member of the formation, which ends with an acidic tuffite layer. The same formation is found till the southern tip of Sithonia, where it tectonically overlays another type of supra-ophiolitic sequence, i.e. the *Akra Dhrepanon formation* (Figure 2 D). The lower member of this formation unconformably overlays the ophiolitic gabbros, and consists of serpentinite sands, ophicalcite layers, radiolarites, and micritic limestones including olistoliths of gabbro and dyke complex. The upper member consists of pyritic shales, manganesiferous quartzites, calcschistes and calcarenites with reworked corals and crinoid ossicles.

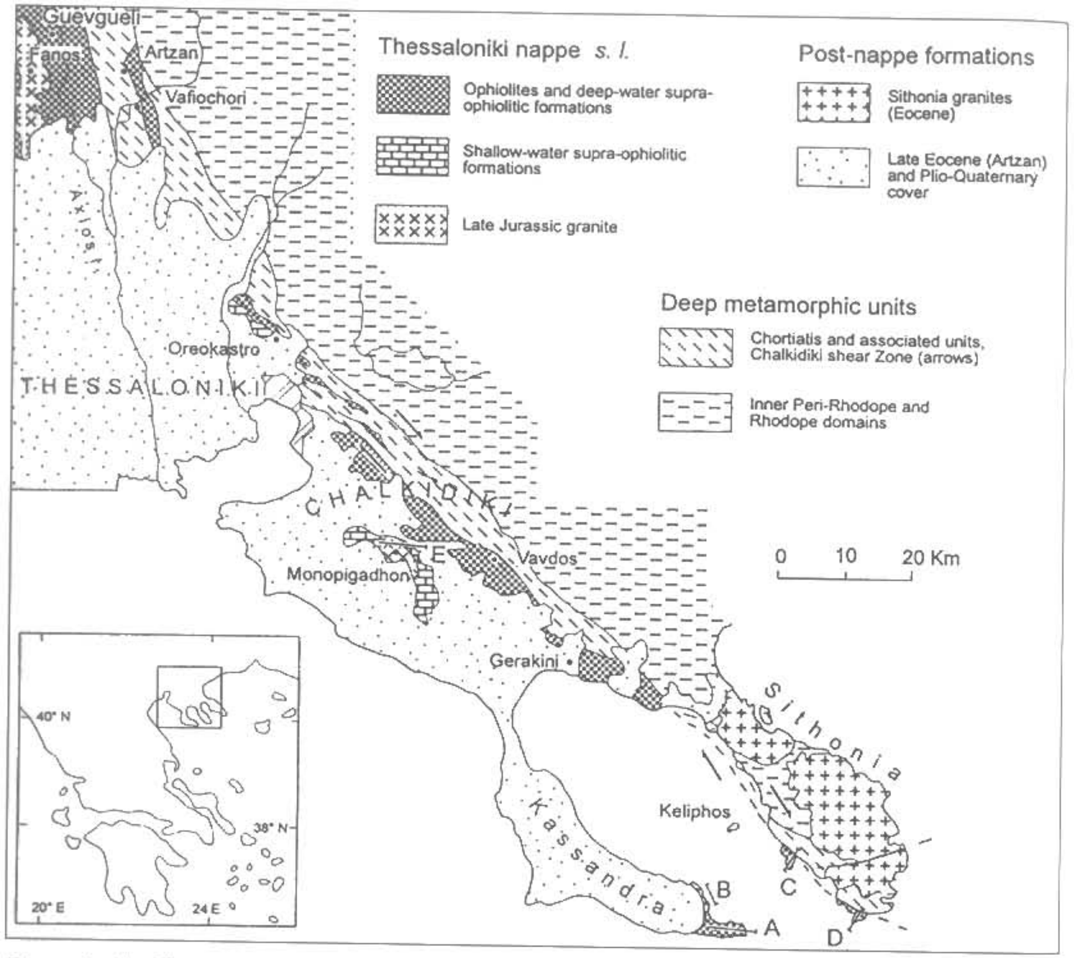

Figure 1: The Thessaloniki ophiolitic nappe of Chalkidiki, and its northern equivalents in the Guevgueli area (Thessaloniki nappe sensu lato). Geological sketch map after Kockel and Mollat (1977) and personal observations. A-E: location of cross-sections fig. 2.

3. GRANITIC INTRUSIONS AND POST-GRANITIC COVER

The *Monopigadhon granite* (Figure 2 E) is a granophyric, biotite-hornblende-garnet-bearing granodiorite onlapped by the Kimmeridgian-Tithonian, peri-reefal Petralona limestones (Ricou, 1965; Kockel and Mollat, 1977; Gauthier, 1984). The granite itself was ascribed to the Late Jurassic by comparison with the 153-148 Ma Fanos granite which intrudes the Guevgueli ophiolite (Borsi et al., 1966; Spray et al., 1984). In addition to a previous K/Ar age of 149 Ma (Kreuzer, in Mussallam and Jung, 1986), we measured by the same method an age of 141±3 Ma on biotite from the Monopigadhon granite (Table 1).

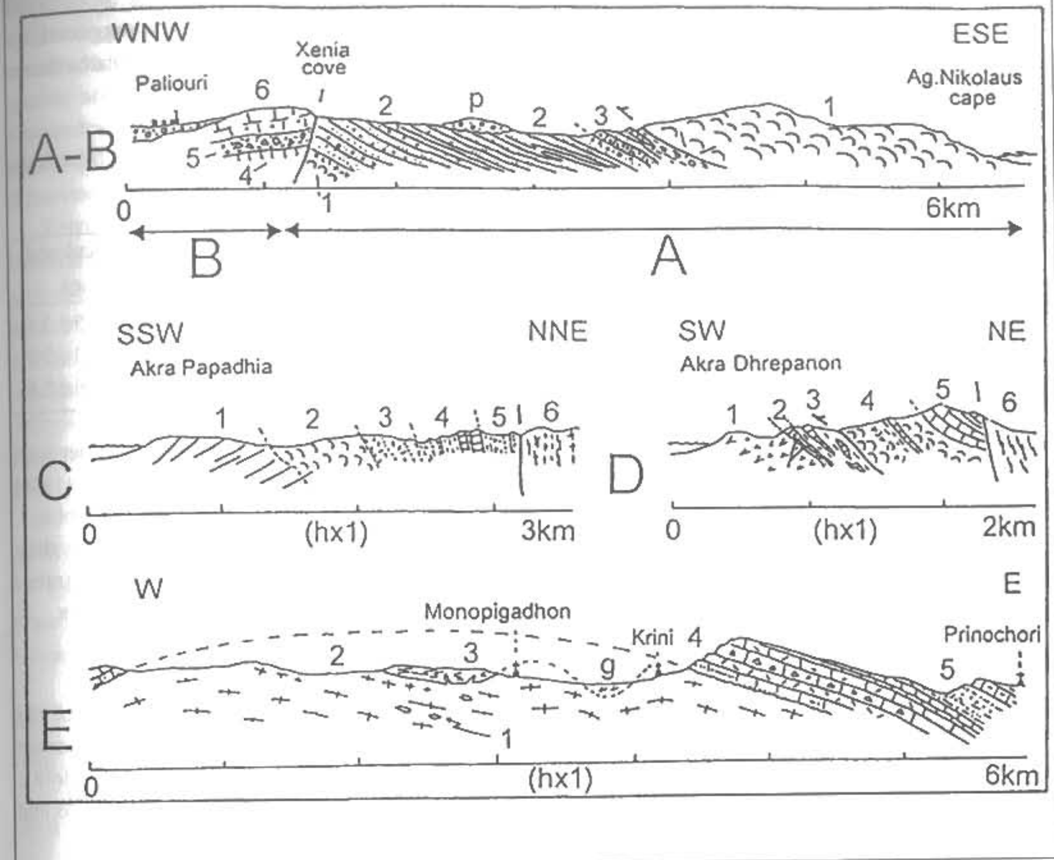

Figure 2: Cross-sections of the Thessaloniki nappe units from Chalkidiki, in areas involving supra-ophiolitic " autochthonous " formations. Location: fig. 1.

A: 1: spilitic pillow lavas and pillow breccias; 2: Paliouri formation, lower member: volcano-clastic andesitic flysch; 3: Paliouri formation, upper member: conglomerates with reefal limestone, basaltic and trachy-andesitic pebbles, metagreywackes, mass-flow with limestone and metagreywcke boulders, detrital mica and garnet grains.- p: Pliocene.

B: Xenia-Keliphos formation. 4: coral-bearing limestones, conglomerates with spilite and limestone pebbles; 5: arkosic calcschists with conglomeratic limestone olistolith, coarse conglomerates with limestone, spilite and reddish tuffite boulders, and dolerite, granite, trachy-andesite, rhyolite, and perlite pebbles; 6: peri-reefal limestones with chert and spilite pebbles.

C: 1: sheeted dyke complex; 2: spilitic pillow lavas; 3: spilitic breccias; 4: Akra Papadhia formation, lower member: shales and fine-grained, resedimented limestones layers; 5: idem, upper member: slaty flysch with graded calcarenites, volcano-clastic turbidites, spilite pebbles, and acidic tuffite (uppermost layer); 6: Chortiatis metamorphics, undifferenciated.

D: 1: pegmatitic or medium-grained, massive gabbros with dolerite dykes; 2: Akra Dhrepanon formation, lower member: serpentinite sands with gabbro, dolerite and spilite clasts, ophicalcite, radiolarites, micritic limestone with olistoliths of gabbro and sheeted dykes; 3: idem, upper member: pyritic shales, manganiferous quartzites, calcschists and calcarenites with reworked corals and crinoid ossicles; 4: Spilitic pillow lavas, with tuffitic and calcschist intercalations upward; 5: Micritic limestones (cf. Akra Papadhia formation); 6: Chortiatis metamorphics.

E: 1: Monopigadhon granodiorite with hornfels inclusions, and shallow dipping, heterogeneous foliation; 2: aplite, greisen; 3: amphibolitic and calc-silicate hornfels, isolated gabbro outcrop (g); 4: Petralona peri-reefal limestones and dolostones, with arkose and conglomerate (base); 5: Prinochori beds, calcschists, calcarenites, conglomerates with slate and quartz pebbles.

younger than the magmatic emplacement age, which is likely close to 150 Ma as at Fanos.

The Monopigadhon granite did not intrude the Petralona limestones, as unduely suggested by Chatzidimitriadis, (1988), but a carbonate-bearing volcanoclastic sequence (amphibolite and calc-silicate hornfelses), likely similar to the Paliouri formation.

Table 1: New K/Ar data from granitoid intrusives emplaced in the Thessaloniki ophiolite. Analyst: R. Montigny, Strasbourg. le = 0.581 x 10-10 a-1; lb = 4.962 x 10-10 a-1; 40K/Ktotal = 1.167 x 10-4 mol/mol.

Sample # and origin	Rock type	Mineral	K20 (wt%)	^{40}Ar* (10^{-11} mol/g)	100x^{40}Ar*/ $^{40}Ar_{tot}$	Calculated age
G9442 Monopigadhon	grano-diorite	biotite	7.74	163.75	97	141.5 ± 3.1
G9465 Vavdos	meta-pegmatite	muscov.-phengite	8.29	157.20	97.8	127.3 ± 2.7
G9468 Vavdos	meta-pegmatite	muscov.-phengite	10.75	192.85	98.9	120.6 ± 2.5

Near to the Monopigadhon granite, the *Vavdos and Gerakini pegmatite dykes* intrude, together with other granitoid dykes, the ultrabasic section of the ophiolite. Kreuzer, in Mussalllam and Jung (1986) obtained an age of 156 Ma " on a post-emplacement perigranitic pegmatite in the Thessaloniki ophiolite ". We measured K/Ar white mica ages of 120±2 and 117±2 Ma on the Vavdos pegmatite. Since their magmatic muscovite crystals are deformed and partly recrystallized into tiny, intrafolial muscovite grains, we consider that these ages are intermediate between those of the magmatic and metamorphic events.

4. INTERPRETATION AND CONCLUSION

The age of the Paliouri andesitic flysch is bracketed between the Early-Middle Jurassic age of the ophiolite (Spray et al., 1984; Kreuzer, in Mussallam and Jung, 1986), and the late Kimmeridgian-Tithonian age of the Xenia-Keliphos formation. The age of the lower members of the Sithonia supra-ophiolitic formations can be considered as late Kimmeridgian-Tithonian by correlation with the Xenia-Keliphos and Petralona formations.

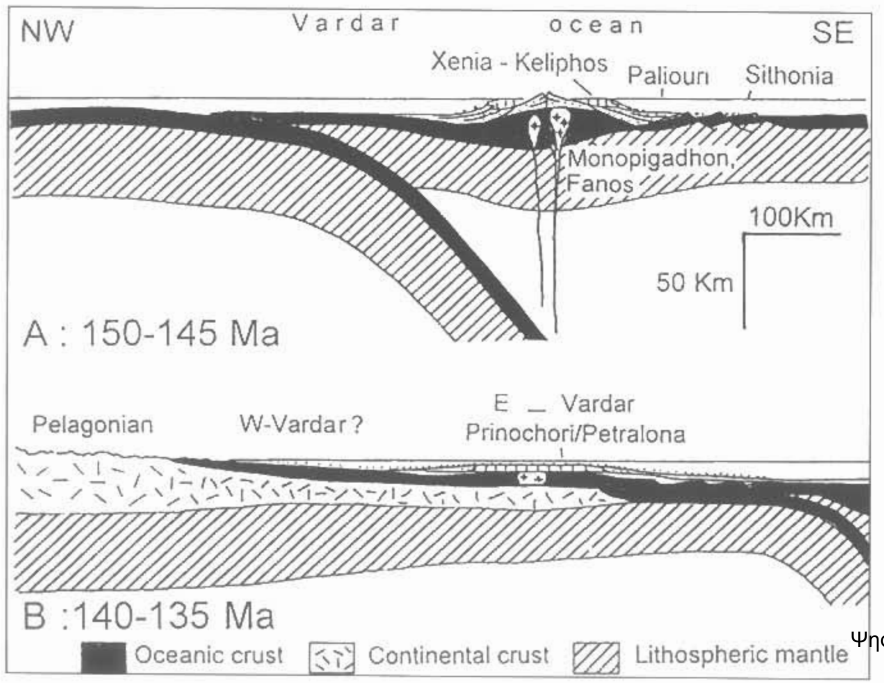

Figure 3: Two stages of the Vardarian obduction, as suggested by the reported data. A: Late Jurassic intra-oceanic subduction. B: Late Tithonian (?)-Early Cretaceous obduction.

Dhrepanon, and Petralona formations is ophiolitic, [illegible] magmatic arc environment. Since continental clasts are virtually lacking in these formations, we suggest an island-arc setting, linked to a Late Jurassic, intra-oceanic subduction (Figure 3 A). The Monopigadhon granite and Vavdos pegmatites would belong to deeper sections of the same island arc, here named Kassandra-Sithonia island arc. This hypothetic intra-oceanic arc and back-arc setting likely prolongated northward through Oreokastro and Vafiochori (Ferrière and Staïs, 1995) till the Guevgueli massif (Platevoet and Bébien, 1992).

Terrigenous material is typically found in the post-Tithonian layers (Akra Papadhia flysch, and Prinochori beds above the Petralona limestones). This late, continental clastic inflow would record the arrival of the ophiolite close to a continental block, i.e. the beginning of obduction (Figure 3 B). The Eastern Vardar obduction i) would have occurred through subduction of continental crust under the delaminated brittle crust of the arc and adjoining domains, and ii) would postdate the sedimentation of the late Kimmeridgian-Tithonian reefal and conglomeratic limestones, in contrast with earlier interpretations (Mercier, 1968; Mercier et al., 1975; Vergely, 1984). Provided the Paikon massif would actually be a window in the middle of the Vardar zone (Godfriaux and Ricou, 1991; discussion in Mercier and Vergely, 1995), both the latter conclusions could apply to the whole Vardar zone.

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