CLINOPYROXENE AND SPINEL COMPOSITION OF OPHIOLITIC VOLCANIC ROCKS (SOUTHERN ARGOLIS PENINSULA, GREECE): IMPLICATIONS FOR THE GEODYNAMIC EVOLUTION

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SYNOPSIS

The ophiolitic "mélange" of Upper Jurassic age in the Southern Argolis Peninsula, consists mainly of brecciated and schistose serpentinised harzburgite as matrix, includes two distinct volcanic suite blocks of boninitic and basaltic composition respectively. Both lavas contain numerous well-preserved primary clinopyroxene phenocrysts. The former is associated with a typical greenschist facies mineral paragenesis (albite, chlorite, amphibole of the tremolite- actinolite series, epidote, quartz, calcite, sphene, magnetite) with spinel microphenocrysts and the latter block is associated with zeolitic facies mineral paragenesis (albite, Na-Ca zeolite , chlorite, calcite) and sulfur minerals.

Clinopyroxene phenocrysts microanalyses have been plotted in discriminant diagrams and have shown for the endiopside-augite of boninitic blocks orogenic affinity. This has also been marked by the chemistry composition of spinels (Cr/Cr+Al= 0.7-0.8), which is comparable to Jurassic and Tertiary supra-subduction zone rocks characterised by low-Ti and very low-Ti. In the other part the augite-salite of basaltic blocks are considered as an oceanic crust relic and are clearly related to tholeiitic basalts and more precisely to non-orogenic tholeiites characterised by high-Ti (MORB).

Furthermore these mineralogical results are consistent with previous results for the Northern Argolis Peninsula ophiolitic units where the boninitic rocks are probably formed in a back-arc or inter-arc setting where the compositional variations of MORB-like basalts are attributed to dynamic partial melting of the rising mantle diapir.

ΣΥΝΟΨΗ

Το οφιολιθικό "mélange" Ανώτερου Ιουρασικού της Ν. Αργολίδας αποτελείται απο λατυπογενές και σχιστοποιημένο συνδετικό υλικό σερπεντινιωμένου χαρτσβουργίτη, που περιέχει κυρίως δυο διαφορετικούς τύπους ηφαιστειακών πετρωμάτων υπό μορφή τεμαχών μπονινιτικής και βασαλτικής συστασης καρ΄ότι οι λάβες αυτές περιέχουν ένα ικανό αριθμό διατηρημένων φαινοκρυσταλλων κλινοπυροξένων, εν τούτοις οι μπονινίτες με μικροφαινοκρυσταλλους σπινελλίων συνδέονται με την πρασινοσχιστολιθική φάση ωκεανιου μεταμορφισμού ενώ τα βασαλτικά τεμάχη μ΄αυτήν της ζεολιθικής φάσης.

Η κατανομή των μικροαναλύσεων των φαινοκρυσταλλικων κλινοπυροξένων σε διαγράμματα διαχωρισμού δείχνει οροχενετική συγγένεια για τους ενδιοψίδιους-αυγίτες των μπονινιτικών τεμαχών. Τόσο μαλλον του και η χημική σύσταση των σπινελλίων (Cr/Cr+Al= 0.7-0.8) είναι συγκρίσιμη μ΄αυτήν των ιουρασικών και Τριτογενών πετρωμάτων φτωχών μέχρι πολύ φτωχών σε Τι των "ζωνών υπερ-καταβύθισης".

Εξ΄άλλου οι αυγίτες- σαλίτες των βασαλτικών τεμαχών που θεωρούνται υπολείμματα ωκεανιου τυθμενα συνδέονται με τους θολειιτικούς βασάλτες και πιό ειδικά με τους ανοροχενετικούς θολειιτες πλουσιους σε Τι τύπου MORB.

Επί πλέον αυτά τα ορυκτολογικά αποτελεσματα είναι σύμφωνα με εκείνα των οφιολιθικών ενοτήτων της Β. Αργολίδας, όπου τα μπονινιτικά τετρώματα σχηματισθηκαν πιθανότατα σε περιβάλλον οπισθο-τόξου/ ενδο-τόξου και οι βασάλτες τύπου MORB έχουν αποδοθεί σε μερική τήξη ανοδικού διαπυρικου μανδύα.

ΦΩΤΙΑΔΗΣ, Α.Δ. και ΟΙΚΟΝΟΜΟΥ, Γ.Σ.: Ορυκτοχημεία κλινοπυροξένων και σπινελλίων των οφιολιθικών ηφαιστειακών πετρωμάτων της Νοτιας Αρχολίδας. Συμβολή στην χεωδυναμική εξέλιξη τους.

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1. INTRODUCTION

It is generally accepted that ophiolites represent slices of the oceanic lithosphere generated at least in two main geotectonic environments as those of mid-ocean ridges, with major or small width oceanic basins, and those associated with all evolutionary stages of the island arc/ back-arc basin systems (Miyashiro, 1975; Sun and Nesbitt, 1978; Beccaluva et al., 1979; Pearce, 1980; Saunders et al., 1980; Serri, 1981; Pearce et al., 1984).

This distinction is based not only on geochemical and petrological data of the different ophiolitic complexes but also on the clinopyroxene and spinel chemical compositions of extrusive rocks (Sigurdsson and Schilling, 1976; Nisbet and Pearce, 1977; Capedri and Venturelli, 1979, 1980; Beccaluva et al., 1980, 1989; Cameron et al., 1980; Leterrier et al., 1982; Molard et al. 1983; Dick and Bullen, 1984).

This paper based on the crystallochemical study of clinopyroxenes and spinels of the diverse extrusive rocks, constituting the ophiolitic "mélange" of Southern Argolis, aims at the investigation of the geodynamic origin.

2. GEOLOGY AND LITHOSTRATIGRAPHIC POSITION OF OPHIOLITES

In Southern Argolis (Fig. 1), the ophiolites (50 to 150m thick) of the Upper Jurassic in the surroundings of Fourni, Iliokastro, Ermioni, Kouverta and Kranidi, consist exclusively of brecciated and schistosed serpentinitic harzburgites containing blocks and conglomerates of volcanic rocks such as boninites and basalts and blocks of amphibolites, marbles and chromitites (near the Fourni village), in less proportion (Gaitanakis and Photiades, 1991).

As regards their nature and their contents, these ophiolitic formations are similar to those of the ophiolitic "mélange" (serpentinites with boninitic blocks) of the Northern Argolis (Photiades, 1986; Dostal et al., 1991). After Clift and Robertson (1989, 1990a,b,1991) however, the ophiolites of Southern Argolis are comparable to olistostroms composing the "Potami Formation"of Baumgartner (1985) and derive from the Pindos zone.

The ophiolites obducted during the eohellenic phase on the neritic Triassic-Liassic carbonate platform with ammonitico rosso (Vrielynck, 1982), are unconformably overlain by the limestones of Tithonian-Kimmeridgian age (Decrouez et al., 1983). These latter following in turn the limestones of Barremian-Maestrichtian age, are passing gradually into the Paleocene-Eocene flysch (Bachmann and Rich, 1979).

During the early Tertiary tectonic phase, the subduction-accretion complex of Ermioni (flyschoid formations with volcanic slices) (Robertson et al., 1987), as well as the
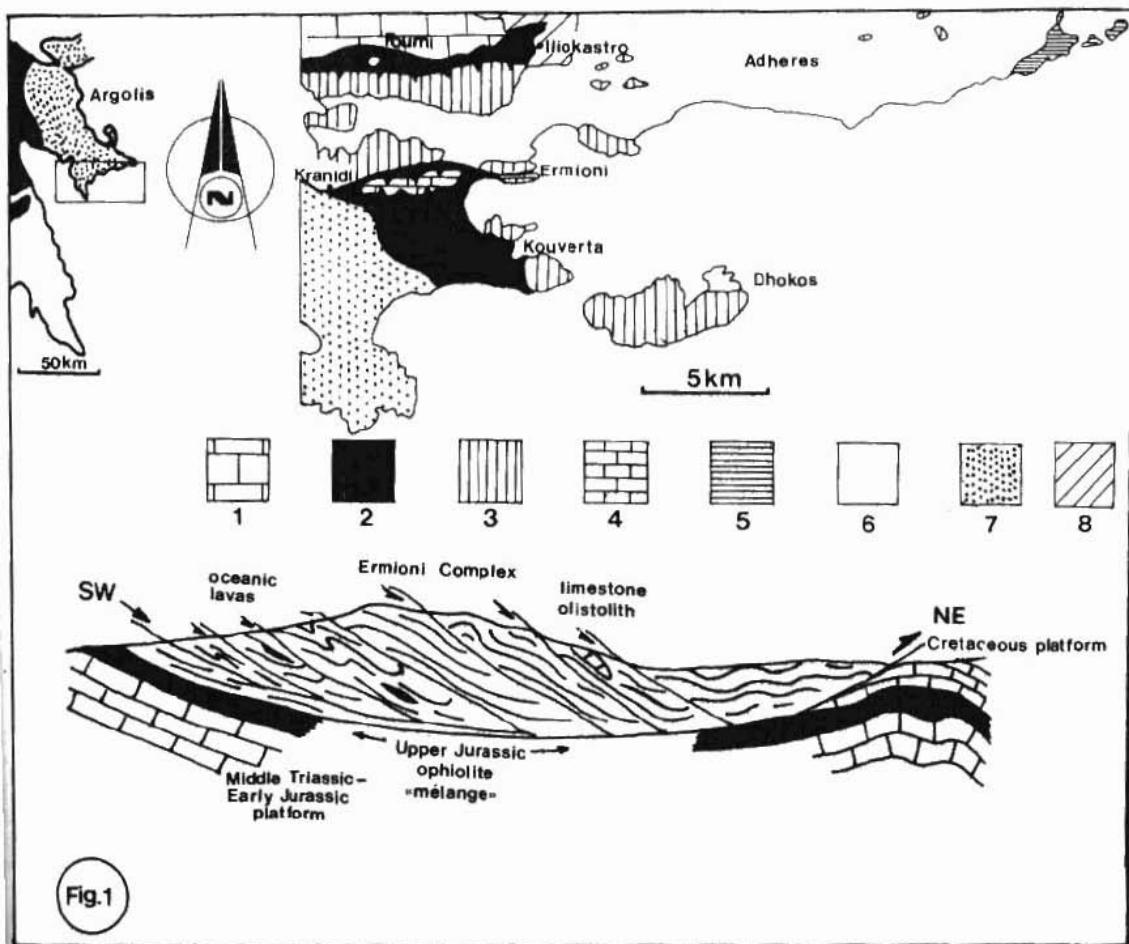
Fig.1: Geological map and synthetic section showing the repartition of the Southern Argolis ophio-
litic 'mélange' (Clift and Robertson, 1989, 1990a,b, 1991)

Σχ.1 : Γεωλογικός χάρτης και συνθετική τομή με την κατανομή του οφιολιθικού 'mélange' της
Ν.Αργολίδος (Clift και Robertson, 1989, 1990α,β, 1991)

1. neritic limestones of Middle Triassic- Liassic (Pantokrator limestones) / νηριτικοί
   ασβεστόλιθοι μέσο Τριαδικού - Λιασίου (ασβεστόλιθοι Παντοκράτορα).
2. ophiolitic ' mélange ' of Upper Jurassic/ οφιολιθικό 'mélange' Ανώτερου Ιουρασσικού.
3. neritic limestones of Lower Cretaceous to Upper Cretaceous /νηριτικοί ασβεστόλιθοι
   Κατώτερου- Ανώτερου Κρητιδικού.
4. pelagic limestones of Lower Cretaceous to Upper Cretaceous (Ermioni limestones) / πελαγικοί
   ασβεστόλιθοι Κατώτερου-Ανώτερου Κρητιδικού (Ασβεστόλιθοι Ερμιόνης).
5. pelagic limestones of Upper Cretaceous ("Poros Formation")/πελαγικοι ασβεστόλιθοι Ανω. Κρητιδικού
   (Σχηματισμός Πόρου).
6. Tertiary flysch (Ermioni Complex) / Τριτογενής φλύσχης (Σύμπλεγμα Ερμιόνης).
7. Pliocene conglomerats / κροκαλοπαγή Πλειοκαίνου.
8. alluvions / αλλούβιες αποθέσεις.

Ermioni and Poros pelagic limestones of Aptian and Maestrichtian age (Clift and Robertson op.cit.) are overthrust on the top of the previous units.

3. PETROGRAPHY OF EXTRUSIVE ROCKS

In the ophiolitic "mélange", two types of volcanites such as boninites and basalts are distinguished in serpentinitic matrix.

These rocks appearing in the shape of both blocks and conglomerates, can reach a size of 30m in diameter. Based on chemical analyses by XRF spectrometry in bulk rock chemistry, not reported in this paper, the basalts (rich in Ti 1,02-2,0%) are weakly porphyritic and vesicular. On the contrary, the boninites of olive-greenish colour (very low in Ti 0,16-0,4%) are more porphyritic and rarely vesicular.

3.1.Boninites (very low-Ti)

The majority of boninitic lavas are porphyritic and very altered. The only original preserved parageneses contain both clinopyroxene phenocrysts (0.9-8mm) of endiopsidic-augitic chemical composition, often transformed into a tremolite-actinolite amphibole series, chlorite and idiomorphic microphenocrysts (0,2-0,5mm) of chromian spinels. Olivine and orthopyroxene phenocrysts, on the other hand, are completely destabilized in serpentine, iron oxides and amphiboles (Mg-hornblende-actinolitic hornblende).

The mesostasis consists of albitised, sericitised and epidotitised microlaths of plagioclase quartz, microcrystals of primary amphibole (Mg-hornblende), chlorite, devitrified glass, magnetite granulates and sphene. The rare vesicles are filled with epidote, quartz, chlorite and calcite.

The boninitic rocks are characterized by secondary mineralogical assemblages of static greenschist facies metamorphism.

3.2.Basalts (high-Ti)

Basalts lavas with or without vesicles reveal cooling textures whose the microlites of albite and the microlaths of oligoclase, represent arborescent and fibrous textures.

The clinopyroxenes of augitic chemical composition, the destabilized olivines-in calcite and iron oxides-and finally the phenocryst of titanomagnetites, constitute the rare primary phases into a mesostasis made up of devitrified glass, chlorite, opaque minerals and sphene.

Besides, a variety of low temperature minerals such as Na-Ca zeolites ΨηφιακήΒιβλιοθήκηΘεόφραστος - Τμήμα Γεωλογίας Α.Π.Θ. observed, filling either the microfractures or the rock vesicles.

It should be noted that the alterations and the observed mineralogical assemblages are comparable to those characterizing a seawater static hydrothermal metamorphism of zeolitic facies (Photiades and Economou, 1991).

4. MINERALOGICAL STUDY OF CLINOPYROXENES AND SPINELS

To study the mineralogical composition of clinopyroxenes and spinels, a series of microanalyses has been realized by the aid of the electronic microprobe (JEOL-733, under work conditions 20 KV, 3nA, counting time 20 sec).

Tables 1 and 2, illustrate the representative analyses for each petrographic type separately (phenocrysts of pyroxenes and spinels at the same time).

4.1. Clinopyroxenes

Chemical composition is a basic element not only for the identification of the type of magma generating the lavas (Kushiro, 1960; Le Bas, 1962; Nisbet and Pearce, 1979; Leterrier et al., 1982), but also for the identification of their geodynamic environment (Nisbet and Pearce, 1979; Leterrier et al., 1982; Molard et al., 1983). For the most part, the boninitic clinopyroxenes are of endiopside type (Wo_{43-38} En_{49-56} Fs_{8-6}) with much less augitic proportion (Wo_{43-34} En_{47-54} Fs_{10-12}): on the other hand, they are comparatively chromiferous and very calcics, while those of the basaltic lavas are of augitic type (Wo_{42-38} En_{37-50} Fs_{21-12}) with a low proportion of chrome, tending towards salitic compositions (Wo_{47-48} En_{34-41} Fs_{19-11}).

This is illustrated on the diagram (Fig. 2) of Poldervaart and Hess (1951), where the clinopyroxene phenocrysts of boninites are situated in the field of endiopside-augite, which, after Beccaluva et al. (1989), characterizes the clinopyroxene rocks with low to very low-Ti. Nevertheless, the abundance of these lavas in phenocrysts of clinopyroxenes, their endiopsidic composition and their high contents in Ca and Mg, characterize rather orogenic lavas than those of MORB-type basalts (Bougault et al., 1981; Gill, 1981; Bébien, 1984).

On the other hand, the clinopyroxene phenocrysts of basalts occupy the field of augite-salite, where the clinopyroxenes of boninites present the following differences (Table 3); It is noted that the clinopyroxenes of boninites show a Mg-index ($Mg/(Mg+Fe^{2+}+Mn)$) much higher than that of the basalts, while the contents in titanium, aluminium and sodium are much lower compared with those of basaltic clinopyroxenes.

Apart from that, the relatively high values in TiO_2 compared with the low values in Cr_2O_3 and in Mg-index of the crystalline structure augite-basalt, reflect differentiated melts.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	53.71	53.37	51.98	52.97	53.94	54.44	53.95	51.87	52.37	53.02	51.39	49.96	53.28	49.63	51.27	53.11	53.35	49.3
Al_2O_3	0.28	0.36	1.56	-	0.79	0.54	-	3.33	2.74	1.01	1.05	0.76	0.44	4.11	2.08	0.82	0.75	2.5
FeO	5.03	6.08	5.37	6.30	4.75	4.11	6.49	6.48	7.02	6.51	6.70	8.60	9.16	8.36	9.29	11.46	11.55	6.7
MgO	17.91	16.78	18.22	19.04	17.90	18.75	16.61	17.57	17.17	16.59	16.24	14.78	17.85	14.50	15.03	13.35	13.11	14.5
CaO	21.17	21.74	20.22	20.06	21.56	21.23	21.43	18.98	18.78	21.23	22.49	21.39	16.65	20.37	19.59	19.39	19.56	23.1
Na_2O	-	-	-	0.20	-	-	-	-	-	0.47	-	0.99	-	-	-	-	-	0.0
K_2O	-	-	0.37	-	0.47	-	-	0.49	0.33	0.40	0.36	0.44	0.40	0.30	0.42	0.20	0.11	0.0
TiO_2	-	0.22	-	0.26	0.18	-	-	0.19	0.79	0.25	0.93	1.66	0.62	1.99	1.10	0.61	0.55	1.
MnO	-	-	0.20	0.20	-	-	0.21	0.28	0.22	0.31	-	0.44	0.56	-	0.36	0.34	0.35	0.
Cr_2O_3	0.44	0.40	0.29	-	0.17	0.62	0.22	-	0.47	0.74	-	-	0.32	-	0.25	-	-	0.
Total	98.54	98.95	98.21	98.83	99.96	99.66	98.91	99.14	99.39	100.03	99.16	98.55	99.27	99.15	99.40	99.28	99.40	99.

Structure formula in base of 6 (0)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Si	1.988	1.981	1.940	1.966	1.974	1.983	2.004	1.916	1.934	1.957	1.925	1.904	1.980	1.862	1.924	2.001	2.008	1.1
Al	0.012	0.016	0.069	-	0.034	0.023	-	0.145	0.097	0.044	0.047	0.034	0.019	0.177	0.092	0.036	0.033	0.
Fe	0.156	0.189	0.168	0.195	0.145	0.175	0.201	0.200	0.217	0.201	0.210	0.274	0.285	0.762	0.291	0.361	0.364	0.
Mg	0.988	0.928	1.013	1.053	0.975	1.018	0.920	0.967	0.944	0.912	0.906	0.839	0.988	0.810	0.840	0.749	0.735	0.
Ca	0.839	0.864	0.809	0.798	0.845	0.827	0.853	0.752	1.743	0.840	0.903	0.874	0.663	0.819	0.788	0.783	0.789	0.
Na				0.014						0.034		0.073						0.
K			0.018		0.022			0.023	0.016	0.019	0.017	0.021	0.019	0.014	0.020	0.010	0.009	
Ti		0.006		0.007	0.005			0.005	0.022	0.007	0.026	0.046	0.017	0.056	0.031	0.017	0.016	0.
Mn			0.006	0.006			0.006	0.009	0.007	0.010		0.014	0.018		0.011	0.011	0.011	
Cr	0.013	0.011	0.009		0.005	0.018	0.006		0.013	0.007			0.009		0.008			0.2
$\frac{Mg}{Mg+Fe^{2+}}$	0.86	0.83	0.85	0.84	0.87	0.89	0.81	0.83	0.80	0.81	0.81	0.74	0.76	0.75	0.73	0.66	0.66	1

Table 1. Representative analyses and clinopyroxene structure formula of boninites (1--10) and of basalts (11--18).
Πίνακας 1. Αντιπροσωπευτικές αναλύσεις και δομικοί τύποι των κλινοπυροξένων των μπονινιτών (1--10) και των βασαλτών(11--18).

	1	2	3	4	5	6	7	8	9	10
SiO_2		0.17	–	0.32	0.20	–	–	–	0.27	–
Al_2O_3	13.27	14.94	12.28	8.30	7.94	11.95	12.04	14.40	11.55	10.03
FeO	10.17	11.36	14.67	14.91	16.21	14.82	18.81	18.85	20.18	15.96
MgO	14.88	14.52	12.38	12.37	11.39	12.87	9.21	9.88	7.96	11.35
CaO	0.08	–	0.13	–	0.14	–	0.19	–	0.31	–
TiO_2	–	–	–	–	–	–	–	0.31	–	–
MnO	1.61	1.52	1.50	1.55	1.21	0.64	2.30	1.26	2.35	1.87
Cr_2O_3	56.62	54.66	56.67	58.79	61.74	57.19	53.40	51.41	14.16	59.16
NiO	0.39	0.41	–	–	–	0.36	–	–	–	–
V_2O_5	0.56	0.57	0.97	1.05	0.77	0.97	0.92	0.55	0.58	0.83
Fe_2O_3	2.48	1.83	0.66	2.70	1.17	1.37	3.22	2.66	2.60	1.69
Total	100.06	99.98	99.26	99.99	100.77	100.17	100.02	99.32	99.98	100.89

Structure formula in base of 32 (O)

	1	2	3	4	5	6	7	8	9	10
Si		0.042		0.084	0.052				0.073	
Al	3.948	4.425	4.085	2.566	2.455	3.620	3.743	4.438	3.623	3.075
Fe^{2+}	2.145	2.387	2.466	3.268	3.536	3.185	4.150	4.123	4.495	3.472
Mg	5.597	5.437	5.374	4.833	4.455	4.930	3.621	3.851	3.161	4.400
Ca	0.021		0.051		0.039		0.033		0.090	
Ti								0.061		
Mn	0.343	0.324	0.354	0.345	0.269	0.139	0.515	0.279	0.531	0.412
Cr	11.297	10.858	10.916	12.187	12.807	11.621	11.138	10.626	11.404	12.165
Ni	0.080	0.084				0.074				
V	0.094	0.095	0.101	0.182	0.133	0.164	1.600	0.095	1.020	0.142
Fe^{3+}	0.472	0.347	0.607	0.532	0.231	0.264	0.640	0.524	0.521	0.332
$\frac{Cr}{Cr+Al}$	0.74	0.71	0.72	0.82	0.84	0.76	0.75	0.70	0.76	0.79
$\frac{Mg}{Mg+Fe^{2+}}$	0.72	0.69	0.68	0.59	0.55	0.60	0.47	0.48	0.41	0.55

Table 2. Representative analyses and chromian spinel structure formula of boninites.

Πίνακας 2. Αντιπροσωπευτικές αναλύσεις και δομικοί τύποι των χρωμιούχων σπινελλίων των μπονινιτών.
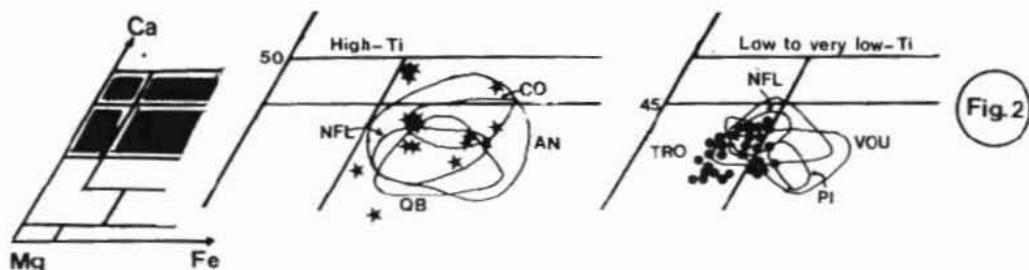
Fig.2: Ca-Mg-Fe diagram for the basaltic (✱) and boninitic (●) Ca-clinopyroxenes of Southern Argolis, showing respectively the repartition fields of high-Ti and low to very low-Ti ophiolitic basalts (Beccaluva et al., 1989). NFL: Newfoundland, CO: Corsica, AN: Northern Apennines, QB: Québec, TRO: Troodos, VOU: Voorinos, PI: Pindos.

Σχ.2 : Διάγραμμα Ca-Mg-Fe των κλινοπυροξένων των βασαλτών (✱) και των κλινοπυροξένων των μπονινιτών (●) της Ν. Αργολίδας που δείχνει τα πεδία κατανομής των πλούσιων και πτωχών σε Ti οφιολιθικών βασαλτών αντίστοιχα (Beccaluva et al., 1989).
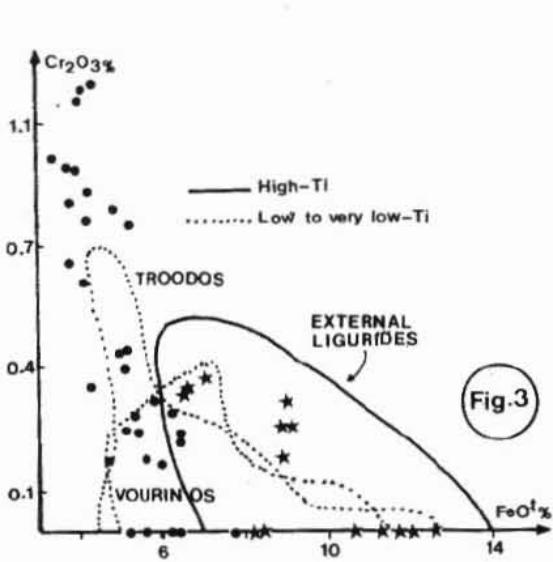
Fig.3: Cr₂O₃-FeOᵗ covariation in Ca-clinopyroxenes of boninites (●) and basalts (✱) of the Southern Argolis.

Σχ.3 : Συμμεταβολή Cr₂O₃-FeOᵗ των κλινοπυροξένων των μπονινιτών (●) και των βασαλτών (✱) της Ν. Αργολίδας.

Fig.4: Distribution of the Southern Argolis boninitic (●) and basaltic (✱) Ca-clinopyroxenes with the Northern Argolis clinopyroxene fields (Dostal et al., 1991) in the Leterrier et al., (1982) (Ti+Cr) vs Ca diagram.

Σχ.4 : Κατανομή των κλινοπυροξένων των μπονινιτών (●) και των βασαλτών (✱) της Ν. Αργολίδας στο διάγραμμα των Leterrier κ.α. (1982) (Ti+Cr) vs Ca σε σχέση με τα πεδία των κλινοπυροξένων της Β. Αργολίδας (Dostal κ.α.,1991).

Table 3:	Boninites (very low-Ti)		Basalts (high-Ti)
number of analyses	endiopside 42	augite 12	augite 20
$Mg/Mg+Fe^{2+}+Mn$	0.82-0.90	0.78-0.81	0.62-0.81
SiO_2	50-55	51-54	47-53
Al_2O_3	0.00-2.20	0.00-2.20	0.00-4.70
FeO^t	3.30-6.30	6.50-7.10	6.70-12.70
Na_2O	0.00-0.75	0.00-0.57	0.00-1.00
TiO_2	0.00-0.40	0.00-2.50	0.50-2.66
Cr_2O_3	0.00-1.27	0.00-0.47	0.00-0.38

In addition to the differences already mentioned above, the boninitic clinopyroxenes are also rich in chromium and much poorer in iron compared with the basaltic clinopyroxenes.

Diagram Cr_2O_3-FeO^t (Fig.3) shows that the boninitic clinopyroxenes are associated to those of Troodos and Vourinos (ophiolitic basalts with low to very low-Ti), while the basaltic clinopyroxenes are rather similar to those of rocks with high-Ti of the Western Mediterranean (Beccaluva et al., 1979). Progressive enrichment in iron is observed during the evolution, accompanied by the decrease of chromium. Moreover, the presence of chromium is the characteristic of premature pyroxenes in tholeiitic series (Schweitzer et al., 1978).

Using the discriminant diagrams of Leterrier et al. (1982), all the phenocrysts of boninitic clinopyroxenes can be grouped on the orogenic field (Fig. 4), revealing in this way, their relations with the arc-tholeiites, besides, the basaltic clinopyroxenes are concentrated on the anorogenic field and approach the MORB-type basalts.

Therefore the chemical compositions of the phenocrysts of boninitic and basaltic rocks of Southern Argolis are similar to those of Northern Argolis (Photiades et al., 1989; Dostal et al., 1991).

4.2. Spinels

According to classification by Stevens (1944), the chromian spinels constitute an accessory phase in the boninitic lavas either in the form of inclusions within the altered olivines or in the form of microphenocrysts in the groundmass of the rock.

The microanalyses carried out by a microprobe (table 2), have given variable values of $Mg/(Mg+Fe^{2+})$ from 0.4 to 0.7 and high values of $Cr/(Cr+Al)$ from 0.7 to 0.84 in such a way that these high values characterize very refractory peridotitic sources (Duncan and Green, 1987; Crawford et al., 1989).

It is also noted that the studied chromian spinels (Fig. 5)
occupy the field of recent boninites (Umino, 1986) and the
boninites deriving from the ophiolites of Northern Pindos
(Capedri et al., 1981) of the island of Aegina (Dietrich et
al., 1987), of Northern Argolis (Photiades, 1989; Dostal et
al., 1991) and of Betts Cove of Newfoundland (Coish, 1989).

For this reason, these high values in Cr and Al of the
Southern Argolis spinels, are in contrast with those of the
MORB-type basalts (Sigurdsson and Schilling, 1976; Dick and
Bullen, 1984).

5. DISCUSSION ON THE GEODYNAMIC ENVIRONMENT-CONCLUSIONS

In the ophiolitic "mélange" (serpentinites with blocks) of
Southern Argolis, two major types of volcanic rocks are
distinguished, in the form of blocks as those of boninites with
greenschist facies and those of basalts with zeolitic facies of
metamorphism.

Actually, there are at least two types of boninites the
recent boninites first described from the island of Chichi-jima
in the Bonin Islands at Cape Vogel, Papua, New Guinea, the
Mariana Trench slope, the Mariana forearc and at the Tonga
Trench occur only in arc-trench setting and, the boninites
associated with ophiolites reported in several ophiolite
complexes including Eastern Mediterranean (Pindos, Vourinos,
Troodos) and Betts Cove where an arc related history (Bloomer
and Hawkins, (1987) and references therein).

Based on the study of primary magmatic phases of
clinopyroxenes and spinels, the emphasis on their main
differences has been allowed;

- the composition of the boninitic clinopyroxene rocks
originated from orogenic domains associated with arc-tholeiites
and are similar to those of the Eastern Mediterranean
ophiolitic rocks characterized by low to very low-Ti.

- the chromian spinels, from the point of view of their
composition, are genetically associated with refractory
peridotitic sources and are similar to recent boninites as well
as to those accompanying the ophiolitic complexes of the
Eastern Mediterranean and finally,

- the chemical compositions of the clinopyroxenes of basaltic
rocks are similar to those of anorogenic rocks being rich in Ti
and chemically associated with the MORB type.

The presence of boninitic rocks in the "mélange" suggests a
furthermore island arc environment, since the boninitic magmas
poor in Ti, are generated in convergent (destructive),
lithospheric margins (Dietrich et al., 1978; Cameron et al.,
1980; Ψηφιακή Βιβλιοθήκη Θεόφραστος - Τμήμα Γεωλογίας. Α.Π.Θ. Beccaluva
and Serri 1988).
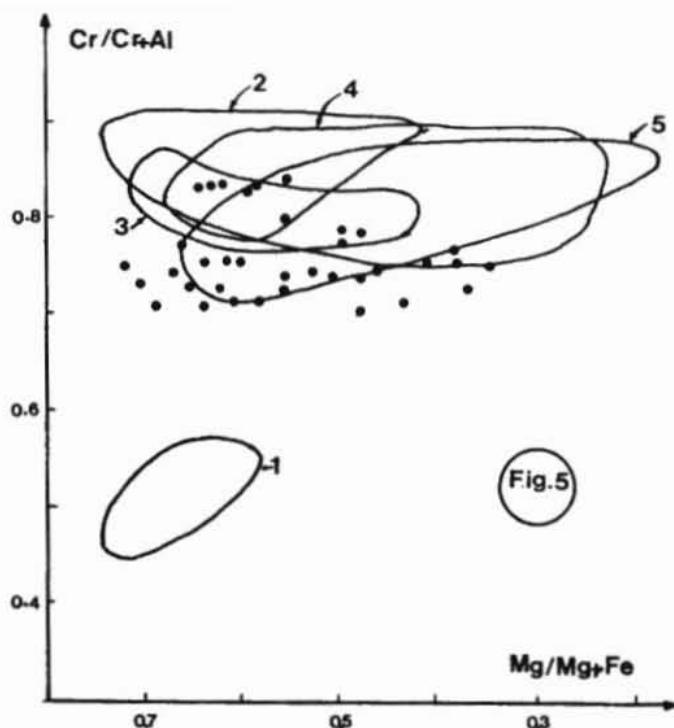
Fig.5: Distribution of the Southern Argolis boninitic Cr-spinels, in 100 Cr/(Cr+Al) vs 100 Mg/(Mg+Fe) diagram, compared with those of MORB (1), recent boninites (2) and the Betts Cove (3), Northern Pindos (4) and Northern Argolis (5) boninitic ophiolites (in Dostal et al., 1991).

Σχ.5 : Κατανομή των χρωμιούχων σπινελλίων των μπονινιτών της Ν.Αργολίδας στο διάγραμμα 100Cr/(Cr+Al)-100Mg/(Mg+Fe) συγκρινόμενη μ'αυτούς των MORB(1),των προσφάτων μπονινιτών (2) και με τους οφιολιθικούς μπονινίτες των περιοχών Betts Cove (3), Β.Πίνδου (4) και Β. Αργολίδας (5)(in Dostal κ.α., 1991).

Recent studies on the emplacement of boninites within the West Philippine region (Crawford et al., 1981; HicKey and Frey, 1982) have shown that these boninites occur adjacent to and/or above arc lavas with tholeiitic affinities. Obviously the boninitic lavas are produced only slightly after incipient island arc volcanics and erupt preferably in the fore-arc regions of an oceanic island arc.

According to Crawford et al. (1981, 1989) the formation of boninites is related to the initial stages of back-arc basin development, early after the island arc volcanism (tholeiitic lavas) had ceased.

Consequently the occurrence of boninites is thus an indication of back-arc spreading in an incipient island arc (Crawford et al., 1981, 1989), leading to the envolement of MORB type lavas (equivalent to back-arc basins after Pearce et al., 1984) deriving from a mantle, which does not contain any component of the previously subducted oceanic lithosphere.

Clinopyroxene compositional data from the Southern Argolis confirm that high-Ti ophiolites compare favorably with the magmatic association occurring at mid-ocean ridges and marginal basins, whereas low-Ti and very low-Ti ophiolites are best equated with the magmatic series of island-arc boninitic type, respectively, generated above subduction zones.

The coexistence of boninitic and basaltic lavas, proves that these lavas had been generated before their obduction in supra-subduction zone (SSZ) tectonic setting. Nevertheless, the same petrological elements characterize the ophiolites of the Northern Argolis, whose the boninitic rocks were probably formed in a back-arc/inter-arc setting, where the various basalts of MORB type are attributed to dynamic partial melting of the rising mantle diapir (progressive depleted upper mantle peridotites) (Dostal et al., 1991).

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