Δελτίο Ελληνικής Γεωλογικής Εταιρίας τομ. XXX/3, 79-88, 1994
Πρακτικά 7ου Επιστημονικού Συνεδρίου, Θεσσαλονίκη, Μάιος 1994

Bulletin of the Geological Society of Greece vol. XXX/3, 79-88, 1994
Proceedings of the 7th Congress, Thessaloniki, May 1994

PETROLOGY AND CHEMICAL CHARACTERISTICS OF DESKATI GRANITIC ROCKS, THESSALY, GREECE

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ABSTRACT

The studied plutonic rocks are granites, with typical S-type characteristics. The petrography of the granites is described and the crystallisation sequence is discussed. Harker variation diagrams of the major elements present very low correlation coefficient. Good positive correlation for Nb, Nd and Y and negative ones for Ba, Rb Sr and V are shown in the plots of the trace elements v. Zr.

ORG normalised geochemical patterns can be attributed to both granites formed in a Volcanic Arc or a Within Plate environment. The mantle normalised patterns indicate granites associated with the subduction of oceanic lithosphere beneath island arc systems and continental margins. They also indicate a large contribution of crustal component to the composition of the parental magma. The REE patterns indicate that the distribution of the REE was strongly controlled by the fractionation of feldspars.

ΣΥΝΟΨΗ

Τα πλουτώνια πετρώματα που μελετήθηκαν είναι γρανίτες με τυπικά χαρακτηριστικά γρανιτών S-τύπου. Περιγράφεται η πετρογραφία των γρανιτών και συζητείται η ακολουθία κρυσταλλώσεως. Τα κύρια στοιχεία παρουσιάζουν μικρό συντελεστή συσχετισμού στα διαγράμματα Harker. Από τα ιχνοστοιχεία, Nb, Nd και Y παρουσιάζουν θετική σχέση ως προς το Zr ενώ Ba, Rb Sr και V παρουσιάζουν αρνητική.

Τα κανονικοποιημένα ως προς ORG διαγράμματα μπορεί να αποδοθούν και σε VA και σε WP γρανίτες. Τα κανονικοποιημένα ως προς τον πρωτογενή μανδύα διαγράμματα υποδεικνύουν γρανίτες συνδεόμενους με υποβύθιση ωκεάνιας λιθόσφαιρας κάτω από συστήματα ηφαιστειακών τόξων και ηπειρωτικών περιθωρίων και μεγάλη συμμετοχή φλοιού στη σύσταση του μητρικού μάγματος. Τα διαγράμματα σπανίων γαιών υποδεικνύουν ότι καθοριστικός ρυθμιστικός παράγων για την κατανομή των σπανίων γαιών ήταν η κρυστάλλωση των αστρίων.

INTRODUCTION

Granitic intrusions in Deskati area were mapped by STAMATIS (1987). A quartz monzonite body appears near Deskati village (Fig. 1), another one exists near Fotino village, while small occurrences of granitic, granodioritic and quartz dioritic composition are scattered in the area. The only available data for the plutonic rocks was a short description of the petrographic types and the mineral constituents.

There are not any published data for these plutonic rocks, concerning

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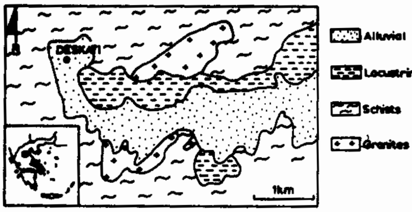


Fig. 1: Geological map of the studied area (from STAMATIS 1987)

Εικ. 1: Γεωλογικός χάρτης της περιοχής που μελετήθηκε (από ΣΤΑΜΑΤΗ 1987)

their mineral chemistry or the bulk rock compositions.

For this study samples from the Deskati granitic rocks have been studied for their petrography and analysed for their mineral chemistry, their major, trace and rare earth element composition. Petrogenetic features of the plutonic rocks are depicted from the correlation of the above data.

GEOLOGIC SETTING

The Deskati plutonic rocks intrude the metamorphic rocks of the Pieria-Kamvounia crystalline massif, a structural element of the Pelagonian Nappe.

According to KILIAS & MOUNTRAKIS (1989) the Pelagonian Nappe consists of:

a. Limestones of the Middle to Upper Cretaceous Transgression and the Palaeocene flysch.
b. The western carbonate cover of Triassic to Jurassic age.
c. The eastern carbonate cover of Triassic to Jurassic age.
d. A metaclastic sequence of Late Permian - Early Triassic age.
e. Three crystalline sequences (Vernon,Voras,Pieria-Kamvounia).
f. Large granitic masses of different ages.

The crystalline sequences crystallised under similar conditions in the Palaeozoic but then differ in their megastructur and their cinematics.

The Pieria-Kamvounia crystalline massif is characterised by a lower "Elassona" sequence, consisting of gneisses and amphibolites with migmatitic interposition and an upper "Kefalovrysson" sequence consisting of schists with metabasite and marble intercalations.

According to KILIAS, & MOUNTRAKIS (1989) the lithological and tectonic study indicates that the granites intrude the metamorphic rocks probably during Upper Jurassic- Lower Cretaceous.

In the Upper Cretaceous - Palaeocene the Pieria-Kamvounia crystalline massif overthrust the blueschists of the Ambelakia unit (MIGIROS 1983, KATSIKATSOS & al. 1986) and in Upper Eocene it is overthrusted onto the carbonate masses of Olympos-Ossa, Rizomata and Krania carbonate sequences.

SAMPLING AND ANALYTICAL METHODS

Special care was taken to collect unaltered samples from well preserved outcrops. The chemical analyses were made in the Department of Geology at the University of Leicester, England.

Major and trace element analyses were carried out by X-ray fluorescence method using a Philips PW 1400 series spectrometer. Details on the analytical procedure, precision and accuracy on the analytical techniques are given in MARSH & al. (1983). Rare Earth Elements were separated by chromatography and determined by inductive-couple plasma spectroscopy on an ICP-Philips PW8210 1.5m.

The mineral phases have been studied by polarised microscope and analysed by an automatic electron microprobe (JXA-8600 Superprobe) using the Energy Dispersive method. The standards used were of pure elements or natural compounds.

PETROGRAPHY

Granite is the only rock type of the intrusion. Light grey to greenish-grey in colour, partly of a porphyric structure and a strong foliation. Late magmatic or hydrothermal activity has affected the plutonic rocks causing decomposition of feldspar and biotite.

In thin section the rock is tectonised in a degree that it still maintains its original granitic texture. It is composed of K-feldspar quartz, plagioclase biotite and allanite porphyroclasts, surrounded by fine fragments of the same minerals and other primary phases such as zircon, apatite and titanite, along with recrystallised and secondary formed minerals.

Vein like aggregates composed of fine grained recrystallised quartz, small fragments of K-feldspar, muscovite flakes and secondary mineral grains, cross the rock parallel to foliation surfaces, arching around the porphyroclasts. All the intermediate grain sizes between the large porphyroclasts and the cryptocrystalline fragments are present, with no dominant size, so as the structure of the rock relative to the grain size can be characterised successive porphyroclastic.

The main characteristics of the mineral constituents are :

a. Quartz is the most abundant mineral constituent. Primary quartz occurs in the form of irregular isodiametric to weakly elongated grains, as porphyroclasts or as oval shaped porphyroclastic aggregates, consisting of grains randomly situated, up to 1 mm in size. Tectonism caused strong undulose extinction and biaxial optical character. Small quartz grains included in albite crystals along cleavage or twining surfaces, are the result of the decomposition of the anorthite component of the primary plagioclase.

Recrystallised quartz is present in the form of small grains, with irregular, interpenetrated edges. These grains are more elongated than the primary ones and situated with their long axes parallel to the b, and their optical axes on the ac plane of the structure. They generally present a normal or very weak undulose extinction.

b. K-feldspar

Crosshatched microcline perthite (Or% = 95.05 - 97.28) is the dominant potassium feldspar. It is present in the form of porphyroclasts up to 1 cm in length, or as allotriomorphic interstitial grains up to 100 μ. The larger microcline grains present the tartan twining, as well as simple twining mainly the karlsbad one. The smaller ones are usually free from twining indicating a selective recrystallisation of the neighbouring grains.

Albitic perthites are very common, with the form of vein-perthites. Albite inclusions are usual, while zircon apatite and allanite inclusions are rare.

c. Plagioclase

It is present in the form of stressed grains and fragments up to 1 cm in length, or in porphyroclastic aggregates, composed of allotriomorphic isodiametric grains of albite (Ab = 99.25 to 92.3%), of a size averaging 0.5 mm. Plagioclase grains are always partly replaced by K-feldspar and often decomposed to quartz, sericite, epidote, titanite and garnet. Some of the chemical constituents of these secondary products result from the decomposition of neighbouring biotite. The replacement of plagioclase starts from the edges of the grains, along the cleavage and twining surfaces or along the cracks of the grains, advancing progressively to the interior.

Some of the grains present very fine twining lamellae usually according to the albite low and rarely to the pericline or karlsbad ones.

Both sodium and potassium feldspars up to 0.4 mm in length are included in large albite and microcline grains.

d. Muscovite

Muscovite is always present in greater amounts than biotite It appears in idiomorphic weakly pleochroic crystals (Y, Z light green, X greenish-white), usually 20 - 60 μ. in length and in any case less than 0.5 mm. The elongation ratio usually ranges from 1.5 to 4 sometimes reaching 6. Twining (001) is common.

They were observed as individual crystals or concentrated in thick aggregates along with titanite epidote and other secondary minerals replacing biotite. Due to a selective crystallisation, larger muscovite crystals are developed, bearing on the outer surfaces or along the cleavage and cracks, small isodiametric to weakly elongated opaque mineral grains. The later are probably alteration products of the muscovite itself or of primary biotite crystals.

Small muscovite flakes are enclosed in recrystallised quartz grains, while there are not any muscovite inclusions in primary phases such as K-feldspar. Muscovite flakes occurring among the porphyroclasts or in the vein-like aggregates do not present a single orientation and they are not tectonically affected. So muscovite is considered meta-tectonically crystallised.

e. Biotite

Biotite is present in small amounts, so as in most cases it can be considered an accessory mineral. It usually appears as hypidiomorphic to strongly xenomorphic flakes with a size up to 0.4 mm. The elongation ratio usually ranges from 1.2 to 1.8 sometimes reaching 5. The flakes are either dispersed among the other minerals or concentrated in spindle and band-shaped aggregates up to 3 mm in length.

Most biotite crystals have been decomposed so as only a few unaltered flakes or semi-altered remains can be observed. Its original presence is indicated by secondary phases such as sericite, epidote, titanite, magnetite apatite and garnet, pseudomorphically developed. The decomposition of adjacent plagioclase crystals provided Ca, Si, Al, and K for these phases.

The colour of the biotite flakes is deep green to olive-green, rarely brownish-red parallel to (001) and yellowish parallel to (001). Around zircon or allanite inclusions a pleochroic rim has often been developed, due to the alteration of the biotite from the radiation of the inclusions. Rutile needles form occasionally a sagenitic net.

f. Accessory minerals

Accessory phases include titanite, epidote, allanite, zircon, garnet, apatite and spinel.

Titanite appears as fragments of unhedral crystals, 0.2 to 0.3 mm in length honey-brown in colour.

Epidote appears in the form of small hypidiomorphic or allotriomorphic grains mainly replacing plagioclase and biotite. In association with muscovite, titanite and spinel. Ti also forms microcrystalline cover around allanite grains. The grains are often zoned with a large core and a thin, less refractive rim. They are weakly pleochroic with Y intense yellow-green, Z yellow-green and X greenish-yellow.

Allanite is present as porphyroclasts up to 1.5 mm or as inclusions up to 0.1 mm. The porphyroclasts are strongly pleochroic: parallel to Y dark brown, almost opaque, parallel to Z brownish-red and parallel to X yellowish-grey. They are usually surfaced by an epidote mantle. Between this mantle and the allanite crystal a thin goethite layer is often developed.

Zircon appears in hypidiomorphic crystals, with length ranging from 0.1 to 0.2 mm and breath from 0.05 to 0.2 mm. The elongation ratio averages 2. Some crystals present zoning and a darker core.

Garnet is present in small (30 - 50 μ) isodiametric isotropic crystals. It was usually found in secondary mineral aggregates, as a product of biotite and feldspar alteration.

Only a few apatite crystals were observed. The largest are hypidiomorphic with a diameter about 0.1 mm perpendicular to c axis.

Spinel was usually found in hypidiomorphic or skeletal grains up to 0.5

Table 1: Modal analyses of representative samples

Πιν. 1: Πραγματική ορυκτολογική σύσταση αντιπροσωπευτικών δειγμάτων.

	DE-3	DE-4	DE-6	DE-8	DE-9
	n=3041	n=2909	n=2514	n=2952	n=2277
Quartz	43.7	39.0	40.2	37.7	41.6
Microcline	23.4	35.3	34.8	36.9	31.4
Albite	17.4	19.2	18.5	16.4	18.3
Muscovite	13.0	3.0	4.0	6.7	5.9
Biotite	0.3	0.1	1.2	0.1	0.2
Epidote	0.7	0.3	0.5	0.6	0.4
Titanite	1.1	0.5	0.3	0.4	0.7
Garnet	0.2	0.2	0.1	0.7	0.3
Opaque	0.2	2.3	0.4	0.5	1.1
Zircon	tr	tr	tr	tr	tr
Apatite	tr	0.1	tr	tr	tr
Allanite	tr	tr	tr	tr	0.1

n = counts tr = traces

n = μετρήσεις tr = ίχνη

mm usually in contact with muscovite, epidote and other products of the biotite alteration. In some cases magnetite is oxidised to hematite. Goethite in small grains was always observed as a cover around allanite.

Modal analyses of representative samples is given in Table 1. According to IUGS classification (STRECKEISEN 1976) all the studied samples plot in the granite field of the Q-A-P ternary diagram.

Aplite veins with no preferred orientation, consisting of quartz, albite, and muscovite, cut the granites.

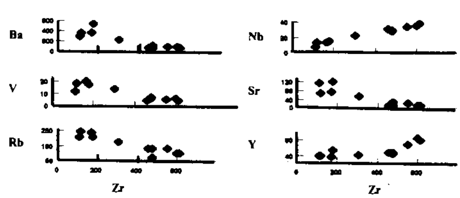


Fig. 2: Trace element variation diagrams.

Εικ. 2: Διαγράμματα μεταβολής ιχνοστοιχείων.

CHEMICAL RESULTS

The major element analytical results along with the CIPW norms of representative analyses are given in table 2 and the trace along with the rare earth element results are given in Table 3.

In Fig 2 the geochemical trend is shown in the plots of various trace elements v.

Table 2: Representative major element analyes.
Πίν. 2: Αντιπροσωπευτικές χημικές αναλύσεις κυρίων στοιχείων.

	DE1	DE2	DE3	DE4	DE5	DE6	DE7	DE8	DE9
SiO2	76.02	75.37	77.66	76.61	74.98	77.15	75.54	77.06	75.10
TiO2	0.29	0.30	0.25	0.24	0.26	0.25	0.25	0.25	0.22
Al2O3	12.63	12.53	11.94	11.72	12.44	11.88	12.35	11.46	13.32
FeO	1.60	1.99	1.51	2.62	2.84	2.89	2.67	2.49	1.61
MnO	0.02	0.02	0.01	0.01	0.01	0.01	0.04	0.04	0.02
MgO	0.34	0.40	0.40	0.13	0.24	0.10	0.24	0.20	0.30
CaO	0.61	0.81	0.33	0.20	0.26	0.26	0.46	0.30	1.03
Na2O	3.10	2.50	2.65	2.31	2.88	2.97	2.62	2.59	2.48
K2O	4.86	5.24	5.31	5.64	5.15	4.77	5.53	5.05	5.15
P2O5	0.05	0.06	0.05	0.02	0.03	0.02	0.03	0.03	0.06
L.O.I.	0.40	0.61	0.52	0.25	0.35	0.40	0.40	0.35	0.31
Total	99.92	99.83	100.62	99.75	99.44	100.70	100.12	99.82	99.61
Norm wt %									
Ap	0.12	0.14	0.12	0.05	0.07	0.05	0.07	0.07	0.14
Il	0.55	0.57	0.47	0.46	0.50	0.47	0.48	0.48	0.42
Or	28.86	31.21	31.35	33.50	30.17	28.11	32.77	30.00	30.65
Ab	26.36	21.32	22.40	19.65	24.59	25.06	22.23	22.03	21.14
An	2.71	3.66	1.31	0.87	1.10	1.16	2.09	1.30	4.75
C	1.29	1.43	1.35	1.51	1.74	1.40	1.29	1.27	1.95
Hy	3.36	4.23	3.37	4.78	5.45	5.15	5.18	4.76	3.40
Q	36.75	37.45	39.63	39.20	35.82	38.61	35.89	40.09	37.55

Table 3: Representative trace and REE element analyses (ppm).
Πίν. 3: Αντιπροσωπευτικές χημικές αναλύσεις ιχνοστοιχείων και σπανίων γαιών (ppm).

	DE-1	DE-2	DE-3	DE-4	DE-5	DE-6	DE-7	DE-8	DE-9	DE-10	De-11
Sc	2	3	2	2	7	4	5	4	3	4	3
V	18	20	19	5	7	7	5	8	12	14	6
Cr	8	15	17	9	19	5	24	0	23	10	11
Co	43	44	45	36	38	45	29	50	20	39	42
Cu	0	0	0	2	2	2	2	2	0	1	0
Ba	541	350	367	70	97	122	77	74	291	223	104
Nb	15	14	14	38	36	29	31	30	8	22	34
Zr	177	169	120	613	597	479	460	480	113	306	551
Y	54	37	40	81	84	44	48	47	38	42	69
Sr	118	73	66	10	13	25	14	13	112	51	21
Rb	203	235	241	105	102	73	133	130	205	180	132
Th	19	25	21	12	11	13	12	16	12	14	17
Ga	19	17	15	23	22	21	22	21	20	20	18
Zn	27	25	20	35	33	20	41	35	39	24	22

	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	Er	Yb	Lu
DE-1	25.9	47.2	7.1	34.6	4.5	0.56	4.2	5.47	3.44	3.71	0.46
DE-3	22	41.7	5.9	25.5	3.6	0.48	3.58	3.58	2.29	1.93	0.27
DE-9	12.1	25.7	3.2	19.7	2.46	0.41	2.96	3.08	1.89	1.76	0.25

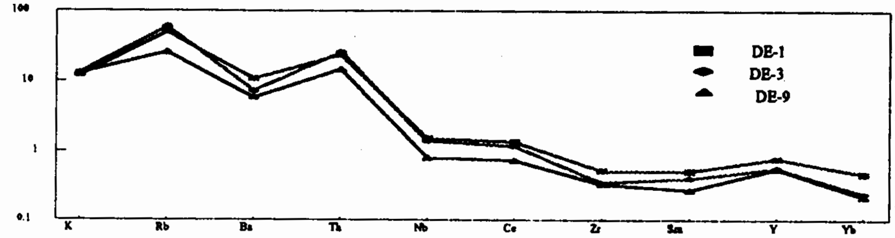


Fig. 3: ORG normalised plots (after PEARCE & al. 1984).
Εικ. 3: Κανονικοποιημένα ως προς ORG διαγράμματα (σύμφωνα με PEARCE & al. 1984).

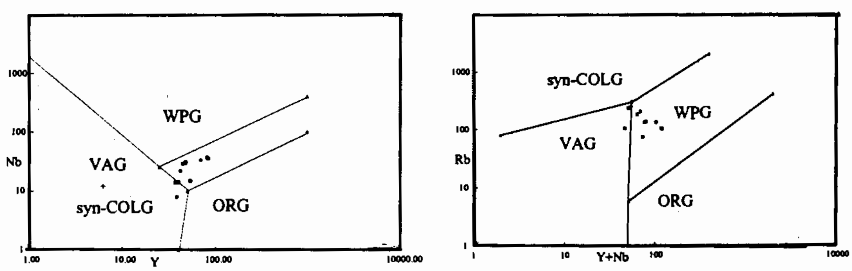
Zr. Mantle and ORG normalised plots and trace element diagrams for the discrimination of the geotectonic environment are shown in figures 3 - 6. Finally, chondrite normalised REE patterns are drown in Fig. 7.

DISCUSSION AND CONCLUSIONS

The successive crystallisation of the granites is as follows. The oldest authigenic mineral phases of the studied rocks are zircon, apatite, allanite and partly titanite, which were formed during a primary stage of the magma crystallisation. Consequently crystallised plagioclase and K-feldspar. The formation of the later is partly overlapped and followed by the primary quartz and biotite crystallisation. On the same time the Na-component of the alkali feldspar was exsoluted, causing the perthite formation and in some cases, crystallisation of small plagioclase grains.

Recrystallisation of quartz took place during tectonism, while on the same time crystallised fine quartz, K-feldspar and muscovite from the existing liquid phase, filling the cracks and the fissures among the porphyroclasts.

The hydrothermal alteration caused the biotite and plagioclase decompo-



Figs. 4, 5: Nb v. Y & Rb v. (Y+Nb) plots (after PEARCE & al. 1984).
Εικ. 4, 5: Προβολές Nb v. Y & Rb v. (Y+Nb) (σύμφωνα με PEARCE & al. 1984).

sition, giving rise to secondary quartz, muscovite, titanite, garnet and magnetite.

All the studied samples of the Deskati granitic body show typical S type characteristics, as muscovite is the main mica present, plagioclase is albite, CaO content is low (0.2 - 1.0), the Rb/Sr ratio is high (1.0 - 10.5), normative anorthite content is low, ranging from 0.87 - 4.75, Na_2O content averages 2.8 for K_2O averaging 5.3.

The molar ratio $Al_2O_3/(CaO+Na_2O+K_2O)$ is higher than 1.1 for all the analysed samples, so as normative corundum values range from 1.27 to 1.95.

S- type granitoids in Greece have been reported in Macedonia (N. Greece) and in Paros island, (Aegean See). In N. Greece the Sochos plagiogranite and the Arnea leucogranite, both belonging to the Circum Rhodope belt of the

Hellenides, show typical S-type characteristics (BALTATZIS & al. 1992), In Paros island that belongs to the Attico-Cycladic unit, ALTHER (1981) and ALTHER & al. (1982) reported a granitic body also presenting S-type properties.

The major element analytical results of the Deskati granites plotted in Harker variation diagrams, present very low correlation coefficient in relation to SiO_2. According to CHAPPELL and WHITE (1974) and WHITE & al. (1986) this is a typical characteristic of the S type granites indicating the heterogeneity of the source.

A positive correlation for Nb, Nd and Y and a negative one for Ba, Rb Sr and V are shown in the plots of the trace elements v. Zr, a typical immobile

Fig. 6: Mantle normalised LIL and HFS element plots of representative samples (after WOOD & al. 1979).

Εικ. 6: Κανονικοποιημένα ως προς πρωτογενή μανδύα διαγράμματα αντιπροσωπευτικών δειγμάτων (σύμφωνα με WOOD & al. 1979).

element that is considered a good indice of differentiation (Fig. 2). Probably, part of the mobile elements was washed away during the tectonism and the hydrothermal alteration.

In terms of the criteria proposed by PEARCE & al. (1984) the studied samples exhibit the geochemical characteri-stics that can be attri-buted to both granites formed in a Volcanic Arc environment or Within Plate granites. The ORG normalised geochemical diagrams for representative samples (Fig. 3) have shapes similar to the plots of typical Volcanic Arc granites and especially the granite from Chilie (PEARCE & al. 1984). They are characterised by strong enrichment in K, Rb, Ba, and Th, relative to Nb, Ce, Zr, Sm, Y, and Yb, negative anomalies for Nb and Zr and low Y and Yb values relative to the normalising compositions.

On the same time, the studied rocks could be considered Within Plate Granites, according to the criteria proposed by PEARCE & al. (1984), as their ORG normalised geochemical patterns (Fig 3.) are similar to this of Skaergaard granite, which is considered a typical Within Plate intrusion. They present high ratios of Rb and Th relative to Nb, a characteristic of "crust dominated" pattern and flat trends from Zr to Yb with values close to the normalising ones.

Figures 4 and 5 show the Nb v. Y and Rb v. (Y+Nb) plots proposed by PEARCE & al 1984 for the discrimination of the geotectonic environment of granitic rocks. The studied samples plot in the VAG and the WPG fields.

In figure 6 the mantle normalised large ion lithofile and high strength element spider-diagrams (WOOD & al. 1979) for three representative samples are shown. All of them present geochemical characteristics such as high LIL/HFS element ratios and marked negative Nb and Ti anomalies, typical of all subduction zone magmas, precluding the within-plate genesis partly indicated by the diagrams in Figs. 4 and 5.

These characteristics indicate a relation of the studied plutonic rocks to a subduction zone geotectonic environment, in accordance to the petrographic observations mentioned above, which indicate a syn-tectonic intrusion.

The plot of some samples in the WPG field of the Nb v. Y and Rb v. (Y+Nb) plots (Figs 4, 5) may be attributed to various types of alteration (PEARCE & al. 1984) which are common in the studied rocks (KATERINOPOULOS, 1993).

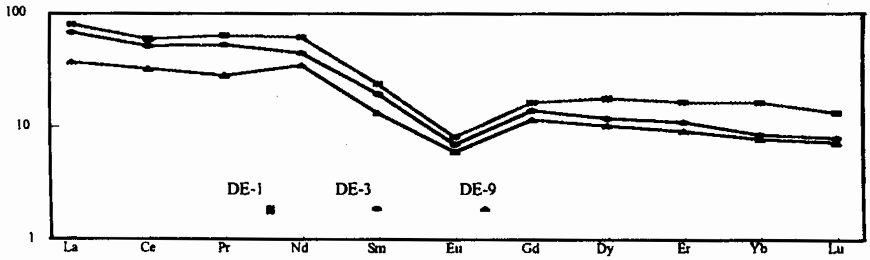


Fig. 7: Rare Earth Element patterns of selected samples (normalisation after HASKIN & al. 1968).

Εικ. 7: Διαγράμματα σπανίων γαιών αντιπροσωπευτικών δειγμάτων (κανονικοποίηση σύμφωνα με HASKIN & al. 1968).

In relation to other granitic rocks in Greece (BALTATZIS & al. 1992, KATERINOPOULOS & al. 1992) the studied samples have larger Ba, Sr, Nb, P and Ti negative anomalies. Average continental crust has quite significant negative anomalies for these elements (JONES & al. 1992), so we can assume an increased crustal involvement to the composition of the parental magma.

The chondrite normalised (HASKIN & al. 1968) REE patterns of selected samples (fig. 7) show very high LREE/HRRE ratios and strong Eu negative anomalies, indicating that the distribution of the REE was strongly controlled by the fractionation of feldspars.

ACKNOWLEDGEMENTS

The authors are grateful to Prof. J. Tarney, University of Leicester, for making available the analytical facilities in the Department of Geology.

REFERENCES

ALTHER, R. (1981). Zur petrologie der miozanen granitoiden der zentralagais (Griechenland). Habil-Schrift *Techn. Univ. Braunsch.*, 218 p.

ALTHER, R., KREUZER, H., WENDT, I., LENZ, H., WAGNER, G.A., KEKKER, J., HARRE, W. and HOHNDORF, A. (1982) A Late Oligocene/Early Miocene high temperature belt in the Attic-Cycladic crystalline complex (SE Pelagonian, Greece). *Geol. Jb.*, E23, 97-164.

BALTATZIS, E., ESSON, J. and MITROPOULOS, P. (1992) Geochemical characteristics and petrogenesis of the main granitic intrusioons of Greece: an application of trace element discrimination diagrams. *Min. Mag.*, 56, p. 487 - 501.

CHAPPEL, B. W. and WHITE, A.J. (1974) Two contrasting granite types. *Pas. Geol. (Tokyo)*, 8, 173-147.

HASKIN, L.A., HASKIN, M.A., FRAY, F.A. and WILDEMAN, D.R. (1968). Relative and absolute terrestial abudances of the rare earths. In L.A. Ahrens ed. Origin and distribution of the elements. *Pergamon, Oxford*, p. 889 - 912.

JONES, C.A., TARNEY, J., BAKER, J. and GEROUKI, F. (1992). Tertiary granitoids of Rhodope, N. Greece: magmatism related to extentional collaps of the Hellenic orogen?. *Tectonoph.*, 210, p. 1 - 21.

KATERINOPOULOS, A. (1993) Minaralogy of the Deskati granitic rocks, Thessaly,

Greece (in print)
KATERINOPOULOS, A., KYRIAKOPOULOS and K. MARKOPOULOS, T. (1992) Distribution in time and space of the acid plutonic complexes in Greece. *International IGCP congress No 276. Paleozoic Geodynamic Domains and their Alpidic Evolution in Tethys*. (In print)
KATSIKATSOS, G., MIGIROS, G., TRIANTAPHYLLIS, M. and METTOS, A. (1986). Geological structure of internal Hellenides. Geol. Geoph. Res., Sp. issue, p. 191-212.
KILIAS, A. and MOUNTRAKIS, D. (1989). The Pelagonian Nappe. Tectonics, metamorphism and magmatism. Bull. Geol. Soc. Greece, 23/1 p. 29-46.
MARSH, N.G., TARNEY, J. and HENDRY, G.L. (1983). Trace element geochemistry of basalts from Hole 504B, Panama Basin, DSDP Legs 69 and 70. *Init. Rept. Deep Sea Drilling Project*. 69, 747-764. (U.S. Govt. Printing Office, Washington).
MIGIROS, G. (1983). Geological study of the Kato Olympos area Thessaly. Ph.D. Thesis, Patra, p.204.
PEARCE, J.A., HARRIS, N.B.W. and TINDLE, A.J. (1984) Trace elements discrimination diagrams for the tectonic interpretation of the granitic rocks. *J. Petrol.*, 25, p.956-983
STAMATIS, A. (1987). Geological map of Greece, (1:50000) Deskati sheet, *Publication IGMR.*
STRECKEISEN, A. (1976). To each plutonic rock its proper name. *Earth-Sci. Rev.*, 12, pp. 1-33
WHITE, A.J., CLEMENS, J.D., HOLLOWAY, J.R., SILVER, E.T., CHAPPEL, B. W., and WALL, V.J.(1986). S-type granites and their probable absence in southwestern North America. *Geology*, 14, 115-118.
WOOD, D.A., JORON, J.L., TREUIL, M. and TARNEY, J. (1979). Elemental and Sr isotope variations in basic lavas from Iceland and the surrounding ocean floor. *Contrib. Min. Petr.*, 70, p. 319-339.