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TERTIARY PLUTON PANTELEJ IN THE VARDAR ZONE, REPUBLIC OF MACEDONIA

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A b s t r a c t: The intrusive magmatism of Tertiary age can be seen near the village of Pantelej in the Vardar zone, the Republic of Macedonia. This intrusive magmatism is present as a relatively smaller pluton built up of quartzmonzonites and monzonites. The chemical composition of the rocks is very similar to the composition of the volcanic rocks that occur in the wider vicinity of the Kratovo – Zletovo volcanic area. The paper also presents data related to the contents of strontium isotopes.

Key words: intrusive rocks; Tertiary; quartzmonzonites; monzonites

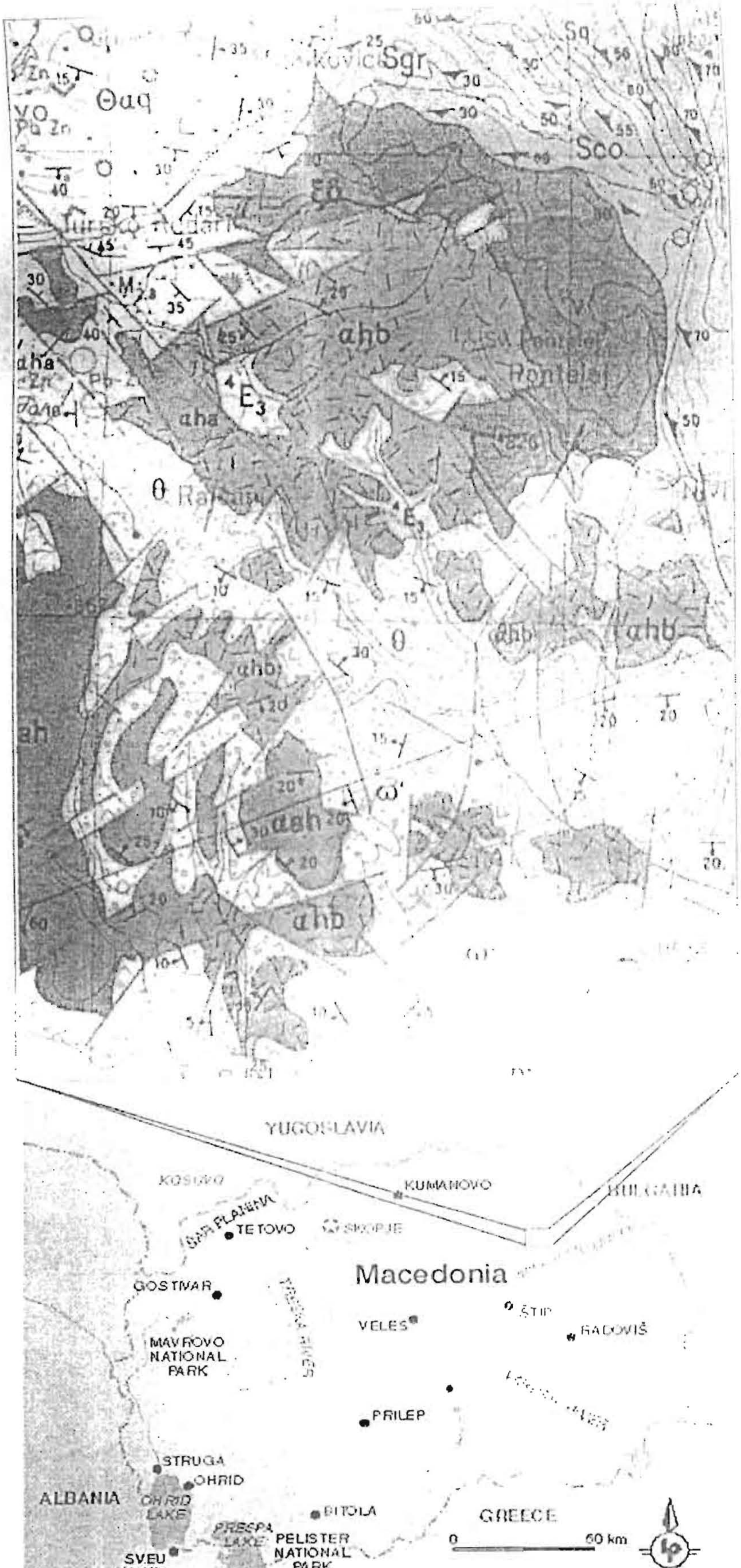
INTRODUCTION

A strong volcanism appears at the end of Paleogene and the beginning of the Neogene in the Vardar zone connected with the processes of closure of the Tethys Ocean (Boev and Yanev, 2001). The literature regarding the intrusive magmatism connected with the mentioned volcanism are very scarce. The pluton is for the first time mentioned in the Explanation note of the Geologic Map – Štip sheet (Dumurdžanov and Petkovski, 1976), later discussed by Boev et al. (1992). In both papers one little body called Pantelej, near the village of Tursko Rudare, and located in the Kratovo–Zletovo volcanic area is shortly presented. It consists of quartz-monzonite porphyrites and monzonites, cut the Mesozoic gabbros and Paleozoic sediments, on the south being in the tectonic contact with the volcanic rocks of the mentioned area (Fig. 1). The scarns and hornfels along the contact of the pluton are developed. Intrusive rocks are also present in other localities, having mainly granodioritic and somewhere dioritic composition. In the boreholes located in the Bučim area, the mafic intrusive bodies are also recognized.

The purpose of this paper is to characterize the most investigated intrusive body called Pantelej presenting the petrographic and the petrochemical characteristics of the plutonic rocks, the K/Ar age as well as the Sr isotope ratio.

GEOLOGICAL SETTING

The intrusive body is part of the Paleogene-Neogene Kratovo–Zletovo volcanic area. The region is built up of Paleozoic quartz-graphite schists, phyllites, quartzites, quartzitized sandstones and chlorite-seriete schists. These rocks are cut by the Mesosoic gabbros and are covered by the Paleogene sediments. On the other hand, all mentioned rocks are penetrated by the Pantelej pluton. The largely predominated rocks in the Kratovo–Zletovo area are volcanic, whose magmatic activity of Oligocene–Miocene age is discussed by Serafimovski (1990), Stojanov & Serafimovski (1990), Boev & Lepitkova (1991), Karamata et al. (1992), Boev et al. (1992, 1995, 1997), Aleksandrov (1992), Boev (1998), Boev & Yanev (2001). The intrusive rocks from this area are separated from amphibole-augite-biotite andesites by tectonic structures. Some subvolcanic bodies with andesite-latite composition penetrate the pluton. The age of the investigated pluton is 32.2 Ma. The $^{87}Sr/^{86}Sr$ ratio is 0.70883, being a little higher compared to the corresponding values for the volcanic rocks in the same area (0.7063 – 0.7077; Boev et al., 1995).



LEGEND

pr	Prolluvium
αab	**Augite-hornblende-biotite andezites**
ω	Andezite breccia
Θ	Andezitic tuffs
Θαq	Dacitic ignimbrites
αhb	**Hornblende-augite-biotite andezites**
Εδ	Quartzmonzonitic porphyry
$^4E_3$	Upper flych zones
ν	Gabbro
Sgr	Quartz-graphitic schists and phylites
Sco	Chlorite-sericitic schists
M	Marbles

Fig. 1. Area of the Tertiary intrusive rocks in Macedonia

PETROGRAPHY

From a macroscopic point of view these rocks are gray and strongly tectonized. Under microscope they manifest hypidiomorphic structure showing tendency to turn to holocrystalline and porphyritic one. The phenocrysts (Table 1a, 1b) are presented as zonal plagioclase, partly or entirely albitized, biotite very rich in Cl (up to 0.54 wt. %) and quartz. The groundmas consist of K-Na feldspars (cryptopertite where the albite forms irregular spots in the orthoclase). The appearance of slightly altered augite is rare. The accessory minerals are: Ti-magnetite, apatite and titanite. The secondary formed minerals are: albite, quartz veinlets, chlorite and pyrite.

Table 1a

Microprobe analysis on the main minerals from the intrusive rocks Pantelej

wt%	albite	albite	albite	ortho.	ortho.	ortho.	ortho.	plagio. rim	plagio. core
SiO_2	65.08	66.50	66.05	63.76	61.10	62.65	61.72	63.20	60.90
TiO_2	0.06				0.23			0.03	0.11
Al_2O_3	24.65	21.88	21.99	19.11	19.63	19.35	19.51	19.01	25.43
FeO	0.46	0.14	0.08	0.02	0.15	0.26	0.21	0.15	0.49
BaO		0.34	0.07	0.48	0.04	2.02	0.26	0.12	
CaO	1.76	1.59	1.67			0.07	0.16	3.54	6.00
Na_2O	10.43	9.00	8.83	1.01	0.74	0.69	2.33	9.62	7.58
K_2O	0.05	0.05	1.49	15.08	15.15	14.67	13.63	0.14	0.52
Sum of the cations on the basis of 32 (O)									
Si	11.191	11.667	11.589	11.854	11.875	11.750	11.812	11.185	10.740
Al	4.974	4.521	4.541	4.181	4.151	4.274	4.193	4.829	5.281
Ti	0.008				0.032			0.004	0.015
Fe^2	0.066	0.021	0.012	0.03	0.023	0.011	0.032	0.025	0.072
Ba		0.023	0.05	0.035	0.003	0.148	0.019	0.008	
Ca	0.324	0.299	0.311			0.014	0.031	0.671	1.134
Na	3.478	3.062	3.004	0.361	0.266	0.251	0.825	3.301	2.592
K	0.011	0.011	0.354	3.577	3.521	3.510	3.175	0.032	0.117
Cations	20.05	19.62	19.80	20.05	19.93	20.13	20.10	20.06	19.95
X	16.17	16.18	16.13	16.03	16.06	16.02	16.00	16.01	16.03
Z	3.879	3.416	3.669	3.979	3.873	3.961	4.080	4.037	3.915
Ab	91.2	90.8	82.3	9.2	6.9	6.6	20.5	82.4	67.4
An	8.5	8.9	8.6	0.0	0.0	0.4	0.8	16.8	29.5
Or	0.3	0.3	9.1	90.8	93.1	93.0	78.8	0.8	3.0

Table 1b

Microprobe analysis on the biotite from the intrusive rocks Pantelej

wt%	biotite	biotite	biotite	biotite
SiO_2	38.11	37.01	37.61	37.94
TiO_2	5.39	5.64	5.36	4.79
Al_2O_3	14.24	14.14	13.72	12.91
FeO	12.03	11.97	12.24	10.65
MnO	0.24	0.32	0.34	0.54
MgO	17.28	16.87	16.75	18.64
BaO			0.07	
Na_2O	0.37	0.64	0.84	0.89
K_2O	9.72	9.57	9.72	9.50
Cl	0.54	0.54	0.47	0.10
H_2O	1.45	2.73	2.46	3.27
Sum of the cations on the basis of 24 (O)				
Si	5.585	5.361	5.465	5.423
Al^{IV}	2.415	2.412	2.348	2.173
Al^{VI}	0.043			
Ti	0.594	0.615	0.586	0.515
Fe^2	1.474	1.450	1.487	1.273
Mn	0.030	0.039	0.042	0.065
Mg	3.775	3.643	3.628	3.972
Ba			0.004	
Na	0.105	0.180	0.237	0.247
K	1.817	1.769	1.802	1.732
Cations	15.838	15.469	15.599	15.400
CCl	0.268	0.265	0.232	0.048
OH	1.419	2.640	2.386	3.121
O	24.00	24.00	24.00	24.00
Fe–FeMg	0.28	0.28	0.29	0.24
Mg–FeMg	0.72	0.72	0.71	0.76

MAJOR AND TRACE ELEMENT COMPOSITION

The analysis of the main and trace elements was carried out on 12 samples using ICP-MS technique. The composition of the studied samples is shown in Table 2.

The obtained chemical composition of plutonic rocks corresponds to the volcanic rocks from the Kratovo–Zletovo volcanic area (Boev and Yanev, 2001), showing little variation in the content of SiO_2 (from 54.9 to 61.6 wt.%). On the TAS diagram, they plot in the field of latite, which corresponds to the monzonites in plutonic rocks (Fig. 2a). The SiO_2/K_2O diagram (Fig. 2b) determines these rocks as high potassium, because of the prevailing content of potassium (between 4.0 and 4.7 wt.%) over the sodium (between 2.7 and 3.1 wt. %). The more precise determination of the rocks is performed from the diagram of Debon and Le Fort (1983) (Fig. 3). From this diagram it is evident that these rocks are quartz-monzonites. It corresponds with the established petrographic composition.

Table 2a

Chemical analyses for major (wt%) and trace elements (ppm) of selected samples from Pantelej intrusive rocks

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	61.00	58.29	56.79	57.97	61.57	60.57	57.94	58.19	56.26	58.62	54.88	56.17
TiO_2	0.61	0.71	0.79	0.75	0.64	0.63	0.79	0.79	0.87	0.75	0.87	0.82
Al_2O_3	15.13	15.92	15.31	15.60	15.46	15.09	15.71	15.48	15.71	15.50	15.95	15.47
Fe_2O_3	5.69	7.49	7.59	7.33	7.92	6.23	7.40	7.44	8.06	7.05	8.13	7.69
MnO	0.18	0.17	0.16	0.16	0.13	0.21	0.14	0.14	0.15	0.15	0.16	0.16
MgO	2.82	3.57	3.71	3.71	1.72	2.05	3.65	3.85	4.13	4.03	4.72	4.04
CaO	5.93	5.87	6.14	5.63	3.54	4.89	5.59	5.74	6.29	4.54	7.12	6.63
Na_2O	2.82	3.06	2.86	2.84	2.98	2.84	2.68	2.78	2.81	2.84	3.01	2.72
K_2O	4.34	4.38	4.62	4.66	4.65	4.56	4.73	4.32	4.02	4.74	4.26	4.63
P_2O_5	0.27	0.29	0.39	0.40	0.28	0.29	0.38	0.39	0.43	0.33	0.40	0.40
LOI	1..35	0.69	2.14	0.93	1.43	2.74	1.14	1.43	0.74	1.66	0.74	1.44
Ba	934	1169	1533	1576	1002	1039	1432	1666	1646	1305	1558	1523
Rb	180	194	198	185	218	201	189	164	152	203	159	190
Sr	560	765	798	843	544	562	746	776	823	650	902	816
Y	30	32	33	34	34	34	36	30	31	35	31	32
Zr	202	196	209	207	200	216	215	184	178	219	172	193
Nb	22	20	21	21	20	24	21	20	18	28.8	20	20
Th	31	36	29	27	30	15	25.9	27.8	25	20	26.4	25.6
Ga	17.8	18.3	19.2	19.5	18.9	17.8	19.9	18.5	19.7	95	19.9	18.5
Zn	75	76	114	121	117	83	86	91	116	57	97	108
Cu	53	49	37	55	19	19	51	62	93	21	58	60
Ni	11	9	22	25	12	11	30	26	27	158	25	25
V	116	118	170	162	145	123	162	164	186	45	186	165
Cr	18	22	69	59	23	31	59	63	50	9	50	60
Hf	7	9	8	8	7	7	11	7	10	5.1	10	10
Cs	7	6	10	8	7	6	4.5	6	6	27.3	4.6	6.5
Sc	25	17	20	21	25.3	20	26.2	5	5	1.2	22.3	20.2
Ta	1.5	2	2	2	1.8	2	1.7	1.9	1.6	14	1.8	1.8
Co	8	8	12	12	2	3	13	22	20	6.5	20	19
U	5.9	9.2	7	5.6	5.8	3.8	3.8	5.2	4.5	2	4.5	5.2
W	5	7	5	3	3	3	2	2	2	1	2	2
Mo	2	5	2	2	2	2	1	2	2		1	1

Table 2b

REE abundance (ppm) of selected samples from Pantelej intrusive rocks

	1	2	3	4	5	6	7	8	9	10	11	12
La	40	51	47	49	48	52	45	48	48	49	49	50
Ce	87	100	95	102	96	100	110	105	102	110	102	98
Sm	5.3	6.9	5.4	6.1	6.6	5.6	6.3	6.1	6.7	7.1	5.8	7
Eu	1.2	1.2	1	1	1	1	1	1	1	1.4	1.1	1.3
Tb	0.7	1	0.9	0.9	1	0.9	0.8	0.9	0.9	0.8	0.9	0.8
Yb	3	3	2	3	3	3	3	3	3	3	3	2
Lu	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Trace elements composition, normalized on the primitive mantle, shows strong enrichment compared to the mantle with LILE + U positive anomaly, less expressed one for the HFSE + Sr and slight but clearly expressed negative anomaly for Nb (Fig. 4a). The content of the typical mantle elements (Cr and Ni) is relatively low. All these facts indicate that the discussed rocks are products of the metasomatized mantle above a subduction zone (suprasubduction mantle) during the subduction of the oceanic crust or during a collision. The rare earth elements (Table 2) are strongly differentiated as LREE towards HREE ratio which is relatively high (La/Lu = 200 – 260). Well expressed Eu anomaly is observed (Eu/Eu' = 2.5 – 3.8) (Fig. 4b). It means that the investigated plutonic rocks are products of the strongly evolved magma.

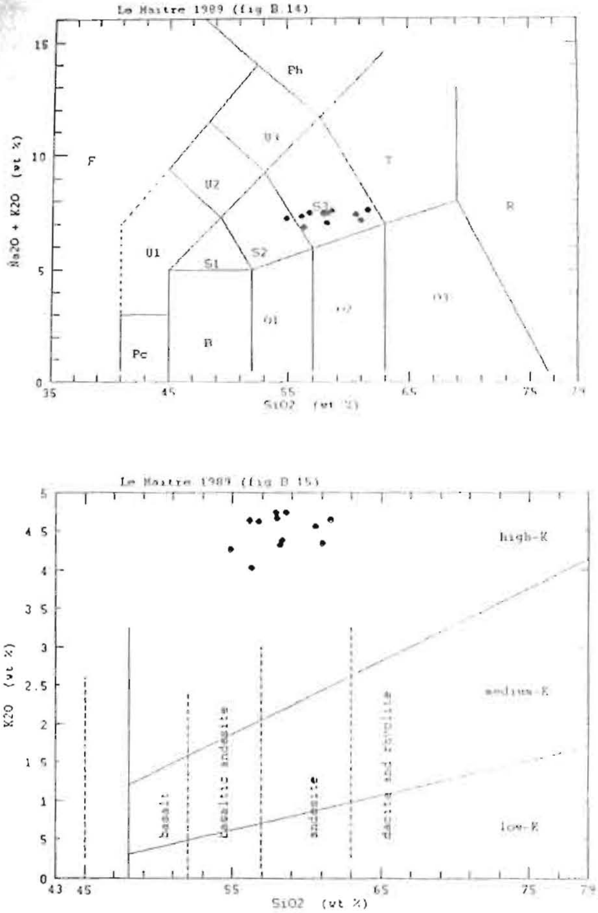


Fig. 2. TAS and SiO_2 vs. K_2O diagrams (after Le Maitre, 1989) for Tertiary intrusive rock in Pantelej, Republic of Macedonia

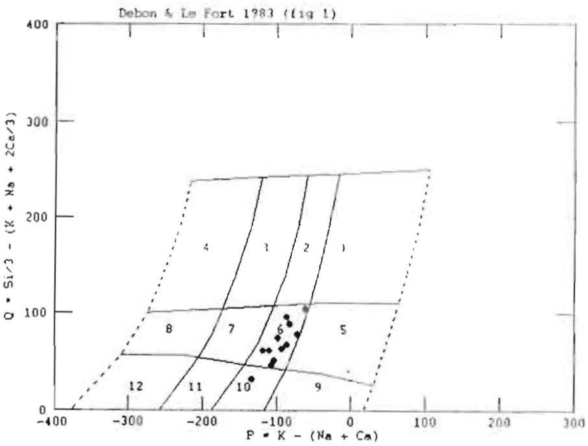


Fig. 3. Classification of the Tertiary intrusive rock from Pantelej according Debon & Le Fort, 1983. Field circle are ploted in the field 6 (quartzmonconite) and in the field 10 (monzonite)

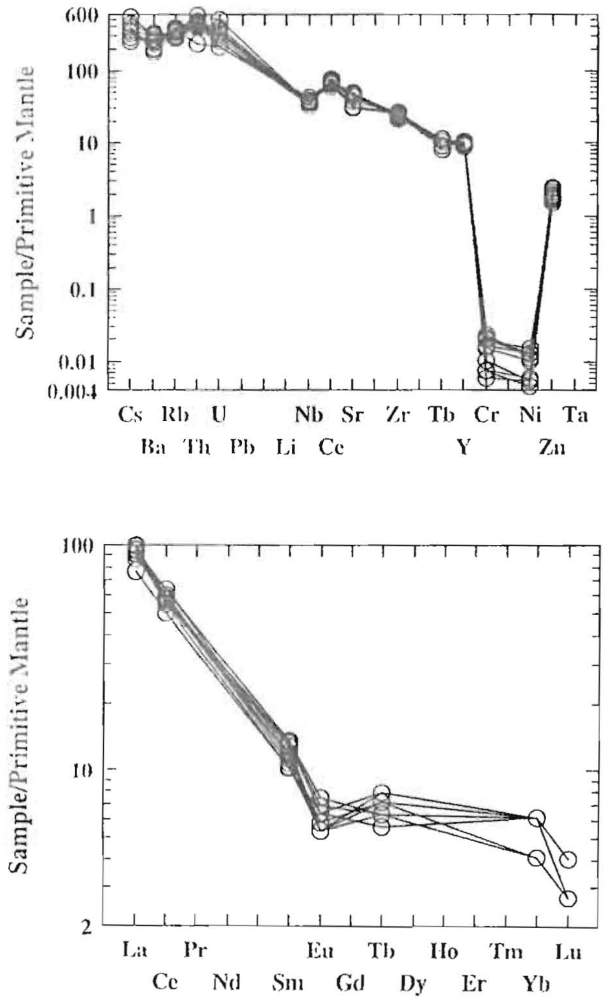


Fig. 4. Trace elements distribution spiderdiagram (top) and REE distribution pattern (botom) for the intrusive rock of the Pantelej

GEODYNAMIC SETTING

The development of the Tethys Ocean in the East Mediterranean during the Upper Cretaceous – Paleogene period is connected with successive closing of some ocean branches (Ricou, 1994). Consequently, the subduction zones successively migrate towards the south. During the closing of the corresponding branch, the collision of the continental microplates block the subduction producing the break-off and sinking of the subducted plate. It is followed by the rise of the thermal diapire from the low part of the mantle, generating the magma in the metasomatized mantle (Yanev et al., 1998; Yanev, 2003).

In order to relate the investigated magmatism with the corresponding process, the discrimination diagrams based on the content of the some trace elements are used. The diagrams confirm that the investigated quartz-monzonites are related to the subductive processes. The conclusion that quartz-monzonites are generated under collision conditions (according to the diagram of Thiebelmont & Tegyey, 1994), postcollision processes (according to the diagram of Batchelor & Bowden, 1985) or are connected to the oceanic subduction under active continental margine (according to the diagram of Müller et al., 1992) (Fig. 5) are contradictory. According to the discrimination diagrams of Pearce et al. (1984) the ratio Rb and Y+Yb suggests the relation with the last process. On the other hand, on the Nb vs. Y diagram presented by the latter authors, these rocks are plotted in the non-determined field between the orogenic granites and the within- plate granites (Fig. 6).

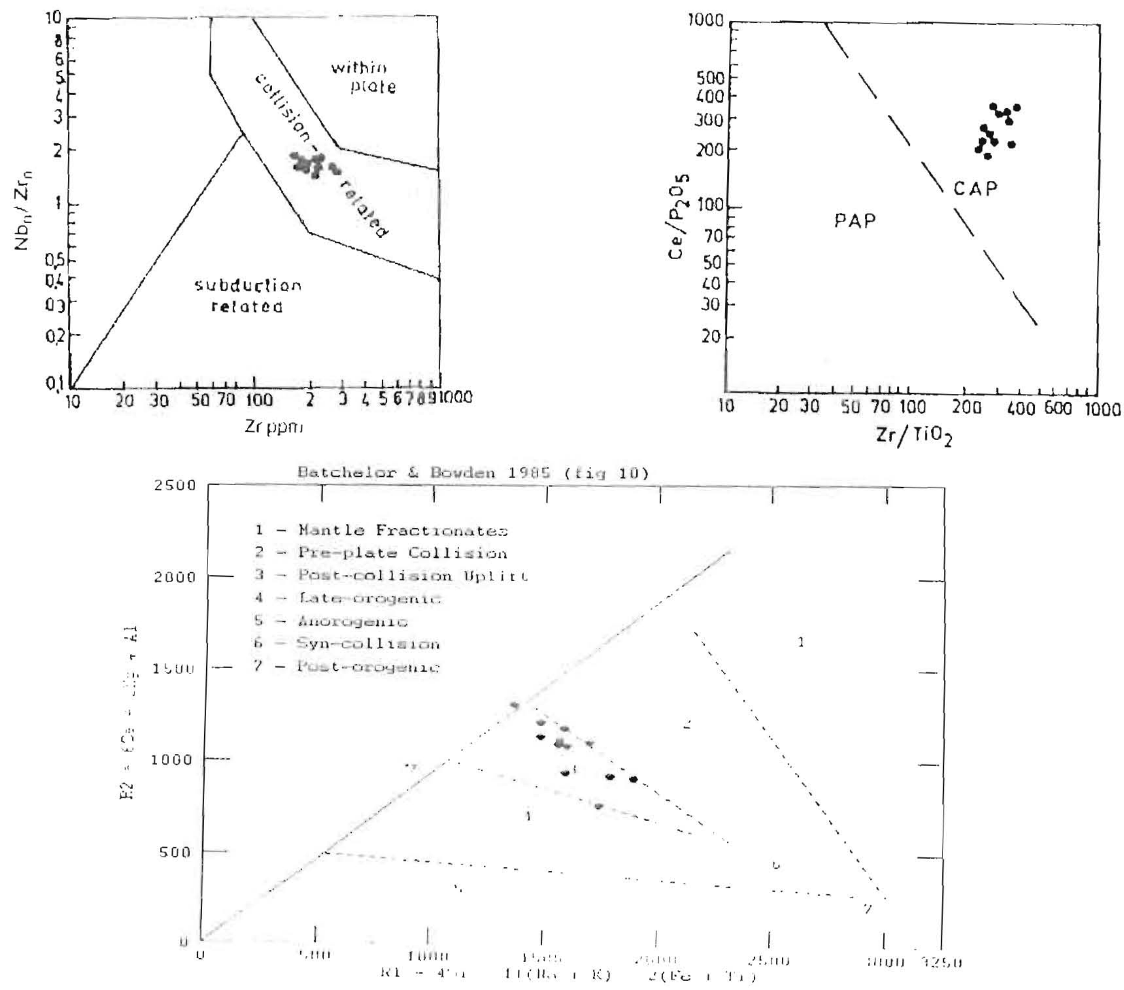


Fig. 5. Left: Zr vs.Nb_n/Zr_n (after Thiebelmont & Tegyey, 1994) discrimination diagram of the intrusive rocks of the Pantelej area. Right: Ce/P_2O_5 vs. Zr/TiO_2 discrimination diagram according to Müller et al. (1992) for the intrusive rocks of Pantelej area: CAP –continental arc, PAP – postcollisional ars magmatic rocks. Bottom; Petrogenetic interpretation of granitoid rock series using multicationic parameters (Batchelor & Bowden, 1985)

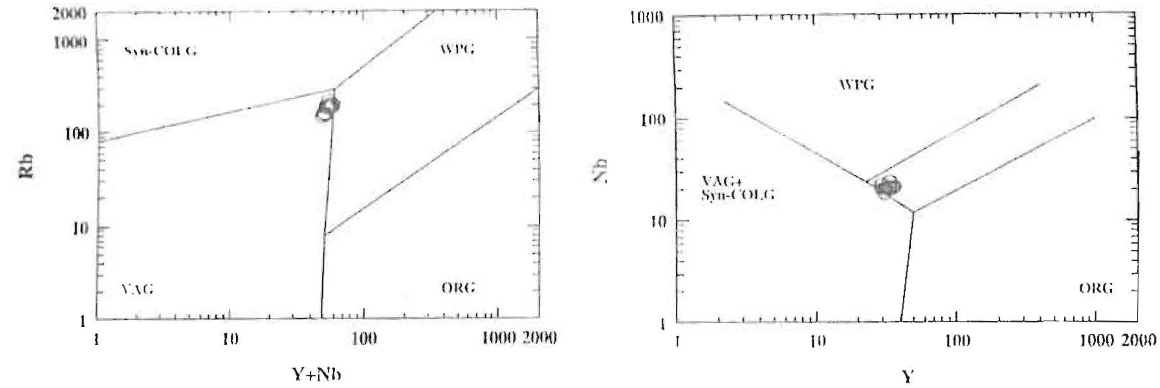


Fig. 6. Discrimination diagrams for intrusive rocks of Pantelej according to Pearce et al. 1984 (WPG – within plates granites, Syn-COLG – syncollision granites, and VAG – volcanic arc granites, ORG – orogenic granites)

Having in mind the geological setting during the Oligocene and the absence of the oceanic subduction in this part of Tethys (Ricou, 1994), the conclusion that Tertiary magnatism (including the investigated quartzmonzonite pluton) is related to the collision processes, is more acceptable. The magmatic activity probably are product of melting of the lower, amphibolitized parts of the mantle (Pearce et al., 1990), metasomatized during a older suduction process.

REFERENCES

Aleksandrov, M., 1992: Metallogenetic Characteristics of the Sasa Polymetallic Ore Field. Ph. D. Thesis. Faculty of Mining and Geology, Štip, 264 pp.

Batchelor, R. A., Bowden, P., 1985: Petrogenetic interpretation of granitoid rock series using multicationic parameters, *Chemical Geology*, Vol. 48, 43–55.

Boev, B., 1988: Petrological, Geochemical and Volcanological Characteristics of the Volcanic Rocks of Mt. Kožuf. Ph. D. Thesis, Faculty of Mining and Geology, Štip, 195 pp.

Boev, B., Lepitkova, S., 1991: Petrologic features of the volcanic rocks from the vicinity of Alšar. Geologica Macedonica, 5, 1, 15–30.

Boev, B., Čifliganec, V., Stojanov, R., Lepitkova, S., 1992: Oligocene-Neogene magmatism in the region of Bucim block. *Geologica Macedonica*, 6, 1, 23–32.

Boev, B., Janković, S., Serafimovski, T., 1997: *Magmatism and Tertiary Mineralization of the Kožuf Metallogenetic District, the Republic of Macedonia with Particular Reference of the Alšar Deposit.* Spec. Publ., 5. Faculty of Mining and Geology, (Ed.), Štip, 262 pp.

Boev, B., Stojanov, R., Serafimovski, T., 1995: Tertiary magmatism in the south-western parts of the Carpatho-Balkanides with a particular reference on magmatism in the area of the Republic of Macedonia. Geologica Macedonica, Vol. 9, 23–38.

Boev, B., Yanev, Y., 2001: Tertiary magmatism within the Republic of Macedonia: A review. *Acta Volcanol.* Vol. **13**, 1–2, 57–71.

Debon, F., Le Fort, P., 1983: *A chemical-mineralogical classification of common plutonic rocks and associations.* Transsections of the Royal Society of Edinburght, 73, 135–149.

Dumurdžanov, N., Petkovski, P., Rakičević, T., 1976: Explanation to the basic geological map, sheet for Štip, *Geol. Ass. of Macedonia*, 87 pp.

Karamata, S., Stojanov, R., Serafimovski, T., Boev, B., Aleksandrov, M., 1992: Tertiary magmatism in the Dinarides and the Serbo-Macedonian massif. Geologica Macedonica, 6, 2, 127–186.

Le Maitre, R. W., 1989: *A Classification of Igneous Rocks and Glossary of Terms.* Recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks. Blackwell Sci. Public., Oxford, 193 pp.

Müller, D., Rock, N. M. S. & Groves, D. I., 1992: Geochemical discrimination between shoshonitic and potassic volcanic rocks in different tectonic setting: a pilot study. *Mineral. Petrol.*, 46, 259–289.

Pearce, J. A., Harris, N. B. W. & Tindle, A. G., 1984: Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. *J. Petrol.*, 25, 956–983.

Pearce, J. A., Bender, J. F., De Long, S. E., Kidd, W. S. F., Low, P. J., Guner, Y., Saraglu, F., Yilmaz, Y., Moorbath, S. & Mitchell, J. G., 1990: Genesis of collision volcanism in Eastern Anatolia, Turkey. *J. Volcanol. Geotherm.Res.*, 44, 189–229.

Ricou, L. E., 1994: Tethys reconstructed: plates, continental fragments and their boundaries since 260 Ma from Central America to Southestern Asia. *Geodynam. Acta*, 7, 169–218.

Serafimovski, T., 1990: *The Metalogeny of the Lece-Halkidiki Zone.* Ph. D. Thessis, Faculty of Mining and Geology, Štip, 264 pp.

Stojanov, R., Serafimovski, T., 1990: The volcanism in the Zletovo--Kratovo volcanic ore. In: *XII Congress of Geologist in Yugoslavia.* Ohrid, 405–424

Thiebelmont, D & Tegyey, M., 1994: Une discrimination geochemique des roches differencies temoin de la dicersite d'origine et de situation tectonique des magmas calcoalcalines. *C. R. Acad. Sci. Paris*, 319, ser. II, 87–94.

Yanev, Y., 2003. Mantle source of the Paleogene collision-related magmas of the Eastern Rhodopes (Bulgaria) and Western Thrace (Greece): Characteristics of the mafic magmatic rocks. *N. Jb. Miner. Abh.*, **178**, 131–151.

Yanev, Y., Innocenti, F., Manetti, P. & Serri, G., 1998. Upper Eocene-Oligocene collision-related volcanism in Eastern Rhodopes (Bulgaria) – Western Thrace (Greece): Petrogenetic affinity and geodynamic significance. In: *Tertiary Magmatism of the Rhodopian Region. Acta Vulcanol.* **10**, 2, 279–291.

Р е з и м е

ТЕРЦИЕРНИОТ ПЛУТОН ПАНТЕЛЕЈ ВО ВАРДАРСКАТА ЗОНА ВО РЕПУБЛИКА МАКЕДОНИЈА

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Клучни зборови: интрузивни карпи; терцијар; кварцмонцонити; монцонити

Интрузивната активност од терцијарна старост досега е многу малку претставена во геолошката литература во Република Македонија. Оваа активност која се појавува во неколку локалитети во вардарската зона во Република Македонија најдобро е изучена во рамките на кКратовско-злетовската вулканска област. Тука во непосредна близина на селото Пантелеј се појавува еден плутон кој по своите дименизи е многу поголем во однос на другите интрузивни тела (во околината на Бучим и во околината на Боровиќ) кои се појавуваат во рамките на варадарската зона. Овој плутон е во основа изграден од кварцмонцонити и монцонити и неговата старост изнесува 32,2. милиони години.