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TERTIARY GRANITIC ROCKS ALONG THE SOUTHERN MARGIN OF THE PANNONIAN BASIN

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ABSTRACT

The Oligocene-Miocene granitic magmatism of the Bukulja-Cer-Motajica (BCM) belt developed as follows:

– from about 30 Ma until 25 Ma ago I-type magmas gave in the BCM belt the hornblende bearing granodiorites of Brajkovac and Bukulja, the tonalites of Bogatic and the deep seated facies of the quartz monzonites of Cer as the first and the biotite granites of Bukulja and the dyke rocks of Brajkovac as the final products.

– around 20 Ma ago strng heating along the BCM belt induced mobilization to melting of older granitic rocks. The reomorphic intrusion of mobilized/initially melted rock masses gave the quartz monzonite of Cer and from the intruded highly melted masses originated the biotite graniodiorite of Stražanica.

– about 18 Ma ago S-type magmas were intruded and gave muscovite bearing granites of Bukulja, Cer and Brajkovac (?).

– the magmatism of the first two phases is widespread in all the Central Balkan peninsula, the youngest S-granitic phase is restricted to the BCM belt only because of specific geotectonic conditions along the southern margin of the Pannonian basin.

INTRODUCTION

At the south of the river Sava (and Danube) parallel to the southern margin of the Pannonian basin is situated a belt of Tertiary granitic rocks, extending from Bukulja at the east, westwards to Brajkovac, Cer, Stražanica, Bogatić, all in Serbia, and further to Motajica ad Prosara in northern Bosnia. These granites differ from other Tertiary granitic rocks of the Serbian-macedonian massif, the Vardar zone and the Dinarides in compositions, age, originand geotectonic affinities and in metallogeny. This was the reason to study them in details.

Following the field work, mineralogical and chemical analyses performed by the autjors, the geochemistry and isotope ages were studied. The trace alaments have been determined by Mrs. TATJANA MARCHENKO, IGEM of the Russian Acad. of Sciences, Moscow, and by the spectrochemical laboratory of the GEOINSTITUTE, Belgrade, and the isotopic ages and Sr-isotope ratios by Dr. Z PÉCSKAY, ATOMKI, Hungarian Acad. of Sciences, Debrecen, and dr. YU PUSHKAREV, VSEGEI, Sankt Petersburg. The Serbian Academy of Sciences and Arts, Belgrade enabled the work by the grant "Magmatic rocks of Serbia" as a part of the project "Geodynamics". The authors express their gratitude to the above mentioned colleagues and institutions.

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The granitic rocks of the Oligocene-Miocene Bukulja–Cer–Motajica (BCM) belt are exposed in Serbia at the surface as the massifs and bodies of Bukulja, Brajkovac, Cer and Stražanica and were detected by drillholes and geophysics near Bogatić (*Fig. 1*). They occur further westwards in northern Bosnia as the massif of Motajica and small bodies at Prosara. All these rocks exhibit some common characteristics, but differences are also evident. The granitic rocks of northern Bosnia are less studied and need further investigation, for this reason they will not be presented here.

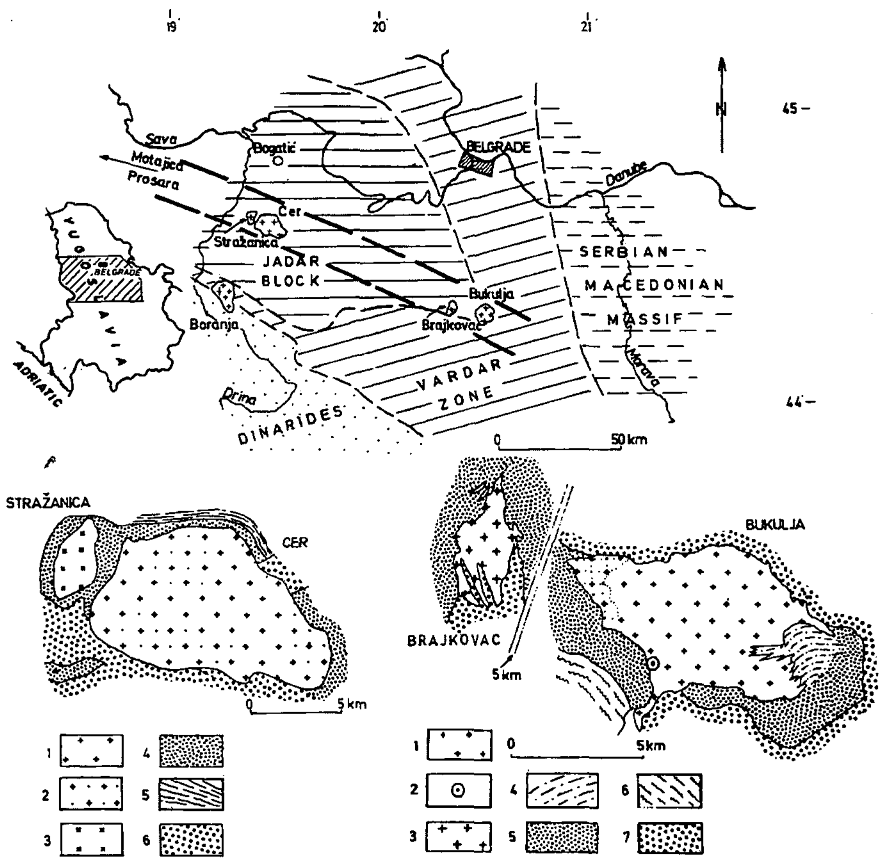

Fig. 1

The position of the Bukulja–Cer Motajica belt of Tertiary granitic rocks. At the lower part of the figure are presented the sketches of the Bukulja and Brajkovac granitic massifs (right) and of the Cer and Stražanica granitic massifs (left).

Legend for the lower left sketch: 1 – quartz monzonite; 2 – leucocratic and muscovite granites; 3 – granodiorite; 4 – conact metamorphic rocks; 5. – Paleozoic; 6 – Neogene and Quarternary. Legend for the lower right sketch: 1 – two mica granite with biotite granite in the deep creeks, leucocratic facies pointed; 2 – drillholes with granodiorite enclaves; 3 – granodiorite of Stražanica; 4 – feldspatizied schists at the contact; 5 – contact metamorphic rocks; 6 – Devonian – Carboniferous; 7 – Neogene and Quarternary.

The BCM belt crosscuts the geotectonic framework built in Upper Cretaceous or even at early Paleogene, i. e. the belt was formed along a young Oligocene-Miocene fracture zone.

The granites are intrusive into Paleozoic, Triassic and Cretaceous sedimentary rocks, exhibiting at them contact metamorphism of different intensity. Locally (at Brajkovac and Bogatić) they are associated with Oligocene andesites and dacites, but the younger Miocene intrusives are without volcanic analogues.

The granitic bodies were exposed at the surface about 12 Ma ago, and the rocks from their contact aureoles and all existing granitic varieties are deposited in Uppermost Middle Miocene sedimentary formations.

PETROLOGY AND GEOCHEMISTRY

The granitic rocks show a wide span of varieties: quartz diorites, tonalites and granodiorites as well as biotite, muscovite and leucocratic granites, sometimes even in the same body (*Fig. 1* and *2*).

A short description of the individual granitic bodies follows, but to avoid descriptions and to shorten the text the mineralogic composition and main chemical data of the varieties in the studied granitic bodies are presented at the Table 1, and the isotopic age data and isotopic Sr-ratios at the Rable 2 (all according to our investigations and the data from KENŽEVIĆ 1962, KOSTIĆ and PAVLOVIĆ 1978, STEIGER *et al.* 1989; KARAMATA *et al.* 1990, DIVLJAN and CVETIĆ 1991; VUKOV and MILIVOJEVIĆ 1993 as well

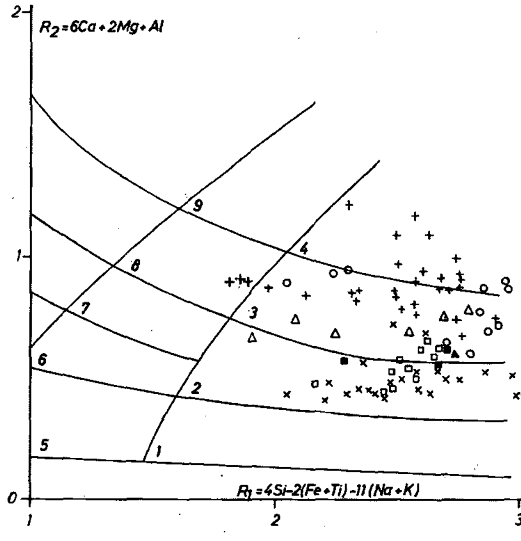

Fig. 2.

Distribution of rock varieties in the granitic massifs of the Bukulja–Cer–Motajica belt in the R_1–R_2 diagram (according to LA ROCHE *et al.* 1980).

Fields: 1– alkali granite; 2 – granite; 3 – granodiorite; 4 – tonalite; 5 – quartz alkali syenite; 6 – quartz syenite; 7 – quartz monzonite; 8 – quartz monzodiorite; 9 – quartz diorite; Signs: 1 – Bukulja granodiorite; 2 – biotite granite of Bukulja; 3 – two mica granite of Bukulja; 4 – granodiorite of Brajkovac; 5 – quartz monzonite of Cer; 6 – leucocratic and muscovite granites of Cer; 7 – granodiorite of Stražanica.

as unpublished data by Z. Pécskay and Yu. Pushkarev). At the table 1 is given also the intensity of the contact metamorphism associated to each rock type. The same data for the Oligocene granodioritic massif of Boranja (after Karamata 1955, Karamata *et al.* 1992), as a typical example for the Tertiary granitic rocks in Dinarides originated in one phase are presented for comparison at the Tables 1 and 2.

The granitic massif of Bukulja (*Fig. 1*) consists mainly of two mica and muscovite granites, but in deep creeks biotite granites occur too. It is important that hornblende biotite granodiorites and quartz diorites were found in some drillholes as enclaves (?) within the granites. The two mica granites exhibit strong contact metamorphism and feldspatization of surrounding rocks. The granodiorites and biotite granites correspond to I-type, but the muscovite bearing granites to the S-type (Tables 1 and 2). The I-typerocks show a magmatic (volcanic) arc affinity, the S-type ones have character of "collisional granites" (*Fig. 3*). The biotite from the biotite granite shows a K/Ar age 27–25 Ma, the whole rock analyses give however K/Ar age of only 18 Ma probably because of a K-feldspar rejuvenation. In the two-mica granites the biotite, muscovite as well as the K-feldspar give 19–15 Ma. The data on biotite from the biotite granite are probably close to the age of their intrusion possibly only somewhat younger. The biotite granitic magmas represent probably the last most acidic differentiates of magmas which gave the hornblende bearing rocks. The ages of the minerals from the two-mica granites (muscovite bearing granites of S-type) correspond to the crystalliza-

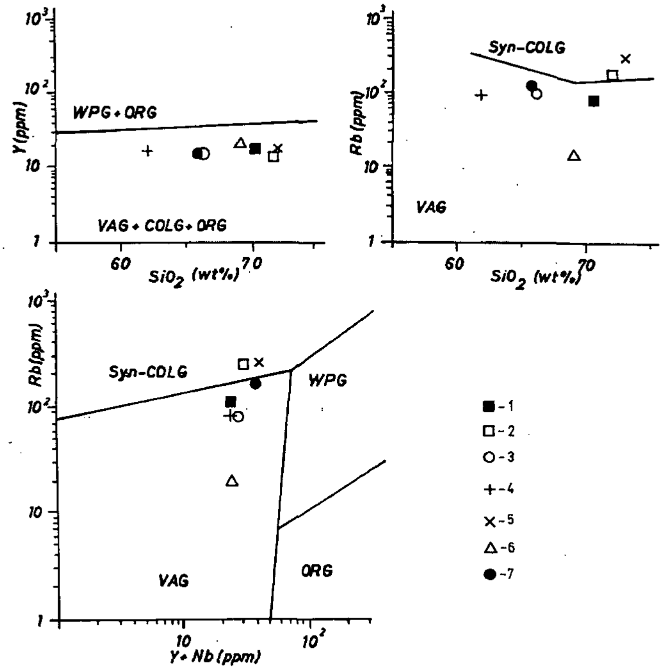

Fig. 3.

Distribution of data (mean values) for the granitic rocks of the Bukulja–Cer–Motajica belt in the discrimination diagrams for geotectonic affinity (after Pearce et al. 1984).

Signs: 1 – biotite granite of Bukulja (10); 2 – two mica granite of Bukulja (17); 3 – granodiorite of Brajkovac (26); 4 – quartz monzonite of Cer (36); 5 – leucocratic and muscovite granites of Cer (43); 6 – granodiorite of Stražanica (4); 7 – granodiorite of Boranja (81).

TABLE 1

Mineralogy, main chemical data and data on contact metamorphism

	Contact metamorphism	Q	Kf*	Pl	Ho	Bi	Mu	Tn	Ort	Ap	Zr	MM	Ep	Tour	Gr	SiO_2	CaO	Na_2O/K_2O
BUKULJA,																		
Quartzdiorite and granodiorite		++	(+)+	+++ 40–55	(+)+	+		X	X	X	X	X				72,0	2,0	0,66
Biotite granite	St	++	++ 95	++ ~30		+	(+)+	X		X	X	X				71,9	1,9	0,89
Twomica and leucocratic granite	SB	++	++	++ 20			+			X	X			X	X	74,9	0,7	0,88
BRAJKOVAC																		
granodiorite	St	++	+	+++ 30–40	(+)	+		X	X	X	X	X	X			65,6	4,0	1,5
Aplitic granite	SB	++	++	++ ~15			+									71,7	2,7	0,24
CER																		
quartzmonzonite	W	++	++	+++ 36–40	+	+		X	X	X	X	X				65,4	4,2	1,18
Leucocratic granite	SB	++	++	++ ~10		(+)	+	X		X	X			X	X	72,0	1,3	0,78
Muscovite granite		+++	+++	++ 10–20			+				X			X		72,0	1,6	0,68
STRAŽANICA																		
Granodiorite	St	++	+	+++ 20–35		+	(+)	X	X	X	X	X				68,8	3,1	1,45
BOGATIĆ																		
Tonalite	?	++	(+)	+++	+	+		X	X	X	X	X				65,7	5,2	1,87
BORANJA																		
Granodiorite	St	++	++	+++ ~40	+	+		X	X	X	X	X				64,6	3,9	1,07

Contact metamorphism: St – strong; W – weak; SB – small bodies
* Kf with Or-content; *Pl with An-content

Signs: +++ main constituent; ++ abundant; + present; (rare).
X present accessory minerals

TABLE 2

K/Ar ages, Sr-isotope ratios and minimal residence age of crustal material (MRACM)

	K/Ar age, Ma	87Sr/86Sr	MRACM
BUKULJA, granodorite Biotite granite Two mica and leucocratic granite	 Bi:27, wr:18+/-4 Bi, Mu, Kf:15–19	 .7078 +/-2	
BRAJKOVAC granodiorite granodiorite porphyrite	 wr:31–30 Bi:18+/-2 wr:25+/-5	 .7066 +/-4	
CER quartz monzonite leucocratic granite muscovite granite	 Ho:30, wr:22 Bi:15–18 Bi:14–18 Mu:15–18 Mu:15–18	 .708078 0.708238 .721239- .721313 .719714	 1 Ga 1.6 Ga
STRAŽANICA granodiorite	 wr:18 +/-4 Bi:17.17 +/-.65 KF:18 +/-2 F:19.1 +/-0.8	 .706637 – .707049	
BOGATIĆ tonalite	 F:36–37		
BORANJA granodiorite	 wr, Bi, Ho:32.5–30	.70815 – .70864	 1 Ga

wr – whole rock
Bi – biotite
Ho – hornblende
Kf – K-feldpsar
Mu – muscovite
F – feldspar

tion of crustal melts which gave these rocks. By this intrusion the K-feldspar from the biotite granites ere probably rejuvenated and therefore the whole rock K/Ar data are close to the data of ages of the minerals in the muscovite bearing granites. The intrusions were of high thermal capacity: especially of the late S-granitic phase which induced strong contact metamorphosm, feldspatization of rocks at the contacts, and rejuvenated the older granites, but the intrusion which gave the biotite granites was probably too.

The granodiorite body of Brajkovac (*Fig. 1*) is built mainly of hornblende biotite granodiorite (with local transitions to tonalite). There are small intrusions of aplitic granites and very rare dykes of granodiotiteporphyrites, aplites and pegmatites. The host rocks are strongly contact metamorphosed. The granodiotitic rocks are of I-type (Tables 1 and 2), and of magmatic (volcanic) arc affinity (*Fig. 3*). The obtained radiometric data by K/Ar method gave for the main variety a whole rock age of 30 Ma and for the granodioriteporphyrites 25 +/- 5 Ma but for the biotite only 18 +/- 2 Ma indicating probably a reheating to temperature above 300 °C.

The granitic massif of Cer (*Fig. 1*) is built mainly of quartz monzonite penetrated at margins and near the roof by leucocratic and muscovite granites. The quartz monzonite is a rock of I-type (Tables 1 and 2), magmatic (volcanic) arc affinity (*Fig. 3*), exhibiting however different isotopic age data: hornblende givers 30 Ma, the whole rocks analyses 22 Ma, but the biotite 15–18 Ma only. The muscovite granites and the leucocratic ones are of S-type (Tables 1 and 2), and of "collisional" affinity (*Fig. 3*). They have crystallized (according to the K/Ar ages of biotites and muscovites) 18 to 14 Ma age, i. e. simultaneously with the rejuvenation of biotite in the quartz monzonite. The contact metamorphism related to all these rocks is weak. The obtained data suggest that the quartz monzonite crystallized deeper in the crust 30 Ma ago but later mobilized probably because of the regional heating phenomenon and around 22 Ma ago reomorphic emplaced at the present place as a mass of low thermal capacity. Later on a second phase gave small masses of S-granites. These late melts because of small amounts could not induce additional metamorphism on surrounding rocks, but because of high fluid content (tourmaline, muscovite etc) locally produced a weak feldspatization of host rocks. The older quartz monzonites were by the intrusions of these younger granites heated up to temperatures only weakly exceeding 300 °C (biotite is rejuvenated, the feldspars mostly, but the hornblende is by all these processes influenced not at all).

It is very interesting that the minimal residence age of crustal rocks which contributed to the melts giving the quartz monzonites is about 1 Ga, but the material which gave the younger muscovite bearing granites 1.6 Ga.This may be explained either by a deepening of the magma generation area in the crust with time, what is not probable, or by intensive overthrusting of units existing in the deeper crust.

In the neighbourhood of the granitic massif of Cer occurs the small granodioritic body of Stražanica (*Fig. 1*). These granodiorites exhibit some peculiarities compared to most of the rocks of Cer. The are of I-type (Table 1 and 2), and of magmatic (volcanic) arc affinity (*Fig. 3*). The contact metamorphism associated to this granodiorite is strong. The granodiorites crystallized according to isotopic K/Ar data about 18 +/- 4 Ma ago (age of the whole rock and its mineral constituents). It is however probable that the magmas intruded earlier and that the obtained K/Ar age data 17–19 Ma indicate the time of a rejuvenation because of heating above 300 °C. Since in the Stražanica area does not occur any younger intrusions the rejuvenation, if happened, can be connected with a regional heating phenomenon only.

North of Cer, in the neighbourhood of Bogatić in some drillholes hornblende-biotite tonalities were found (*Fig. 1*). These tonalites belong to I-type granites (table 1); they crystallized about 37–36 Ma ago and are associated with Oligocene andesites and dacites.

DISCUSSION

The garnitic Bukulja–Cer–Motajica (BCM) belt differs from the granitic association of the Dinarides, Vardar zone and the Serbo-macedonian massif, i. e. from the central part of the Balkan peninsula (CBP) in the presence of the felsic varieties, geochemistry and especially in the origin. The ones from the CBP are of the I-type and some originated about 30–32 Ma ago, others about 20 Ma ago but all in one phase (except the Zeljin massif) (KARAMATA *et al.* 1992). The granitic rocks of the BCM belt however originated in one two or even three phases, I-types as well as S-types are present and their development not uniform. Since some of the early phases in the BCM belt are similar to the CBP granitic rocks the data for the granodioritic rocks of Boranja, as their typical representative, are for comparison presented at the tables and at the *Fig. 3* (after KARAMATA 1955). The similarities of the first phases of Cer, Bukulja and of the Brajkovac granodiorite and Bogatić tonalite with the Boranja rocks are evident, the main intrusive phases at Bukulja and Stražanica are of I-type but differ in general from the Boranja anf other CBP granitic rocks, even from those of Miocene age, and the late phases of granite from Bukulja and Cer are of S-type, i. e. quite different from the CBP intrusives (even from the most similar Polumir granite).

Consequently the earlier phases of granitic magmatism of the BCM belt, which gave the hornblende bearing granodiorites of Brajkovac and Bukulja, the quartz diorite of Bukulja, the tonalite of Bogatić and probably the first deep crystallized equivalents of the quartz monzonites of Cer are similar to the granitic rocks of the CBP group, and can be considered as postcollisional I-granites of magmatic arc affinity identical to the granitic rocks widespread in the central part of the Balkan peninsula (Tables and *Fig. 3*). They were formed during Oligocene about 30 Ma ago as typical magmatic intrusions. The proof of their magmatic character is the strong contact metamorphism as well as the presence of associated volcanics (Brajkovac, Bogatić). At Bukulja the granodioritic rocks occur only as blocks in the younger granites and at Cer they were located deeper and later mobilized and reintruded, therefore their primary contact metamorphism can not be observed.

The biotite granitic rocks of I-type and magmatic arc affinity represent the main intrusions at Bukulja and Stražanica. At Stražanica there is a wide contact aureole, at Bukullja existed probably such one too, but is masked by the contact phenomena related to younger intrusions. The older K/Ar isotope age data (27–25 Ma) corresponding to Late Oligocene, were only determine at the biotite of the biotite granite of Bukulja. The whole rock age for the biotite granite of Bukullja, as well as the data for Stražanica biotite granodiorite (whole rock and feldspars) are around 18 Ma (Table 2). Here has to be mentioned that at Brajkovac granodioriteporphyrite dykes formed 25 Ma ago occur. These older aga data indicate a continuity of magmatic activity from about 30 Ma ago, when the early hornblende bearing granitic phase formed, until at least 25 Ma ago, when the biotite granite of Bukulja and the granodioriteporphyrite dykes of Brajkovac crystallized. Considering these data together with the almost identical Sr-isotope ratios (Table 2) of the early phases of the BCM magmatism (the Brajkovac granodiorite and the Cer quartz monzonite) and of the biotite granitic rocks (Bukulja and Stražanica) a consanguinity of both groups of rocks is indicated. The biotite bearing rocks, especially the one of Bukulja, can be the last most felsic differentiates of the deep seated magmas which gave the hornblende bearing granitic rocks. However the biotite granites could originate from magmas of the same provenance in deep crust an Upper Mantle as those which gave the hornblende bearing rocks too, or also, most probably the Stražanica granodiorite, from magma deriving by strong remelting of older granitic rocks connected with the heating phenomenon along the BCM belt. To this event also can be connected the mobilization and partial melting of the quartz monzonitic masses below Cer and their emplacement at the present position. The age of this mobilization and melting phenomenon can not be exactly determined. It was after the first phase i. e. after 25 Ma ago, but before about 18 Ma ago when the muscovite bearing granites intruded the quartz monzonites of Cer and rejuvenated the minerals of the older rock of Cer and Stražanica. This event is probably simultaneous with the Miocene phase of the granitic magmatism in the CBP, which happened about 20 Ma ago.

After a short interruption a new phase of magmatic activity originating however from a quite different crystal level gave the S-type muscovite bearing rocks of Bukulja, Cer and small masses at Brajkovac (?) (muscovite-biotite, muscovite, muscovite +/- tourmalline +/- garnet granites). These granites were intruded about 18 Ma ago and crystallized until about 15 Ma ago. They intruded the older granitic rocks added some contact alterations at the surrounding rocks, especially feldspatization and tourmalinization, and together with a related low intensity heat flow along the BCM belt, rejuvenated the minerals of the older granites (all minerals of the Bukulja biotite granite, biotite of the Brajkovac granodiorite and the Cer quartz monzonite as well as of the Stražanica granodiorite). The Sr-isotope ratios of these rocks proove that they have crystallized from magmas originated by melting of metasedimentary rocks and probably some very old granitic rocks in the deep crust.

CONCLUSION

The final conclusions about the development of the granitic magmatism in the Bukulja–Cer–Motajica belt can be summarized as follows:

1) About 30 Ma ago I-type magmas were intruded and their differentiation and crystallization lasted until about 25 Ma ago. They gave the hornblende bearing granodiorites of Brajkovac and Bukulja, the deep seated facies of the quartz monzonites of Cer and the tonalites of Bogatić as the first and biotite granites of Bukulja and dyke rocks of Brajkovac as final products.

2) Around 20 Ma ago a strong heating happened along the BCM belt, inducing mobilization and partial to more advanced elting of the previously formed granitic rocks. The mobilized and only initially melted rocks rose diapirically and gave reomorphic intrusions of quartz monzonites at Cer. The melts originated by more advanced melting wrere separated from the restite and intruded as magmas which gave the biotite granodiorite of Stražanica. These rocks are of I-type.

3) About 18 Ma ago were intruded S-type magmas originated by melting of metasedimentary and old felsic units in the crust because of strong heat flow in the roots of the BCM belt. These magmas were intruded along the BCM belt, mostly at the earlier preferred sites where the older granites were intruded earlier and gave muscovite bearing granites of Bukulja. Cer and probably Brajkovac.

4) The magmatism of the first and the second phase is widespread all around the central part of the Balkan peninsula and all over similar rocks are present. It is of postcollisional character referred to compressional processes in the crust and probably disturbances in the uppermost Mantle. The youngest S-type magmatism is restricted (with exception of the similar Polumir granite) to the BCM belt. It is confined to southernmost fracture zone of the set of faults at the southern margin of the Pannonian basin. Along this deep fault the heat advanced upwards and melted the metasedimentary (+/- very old granitic) rocks. It has to be stressed that there was not any collision even not any important vertical or horizontal displacement at that time in this region and therefore the "collisional" affinity of these granites is not related to any collision bu to the character of metamorphic rocks which gave the melts. Simillar geological conditions did not exist southwards in the CBP and for this reason such rocks only in the BCM belt occur.

REFERENCES

DIVLJAN, S. CVETIĆ, S. (1991): Novi pogledi na genezu magmatskih stena bukuljsko-brjakovačkog horstantiklinorijuma. Radovi Geoinstituta **25**, 221–228. Beograd.

KARAMATA, S. (1955): Petrološka studija magmatskih i kontaktno-metamorfnih stena Boranja. Glasnik Prir. Muzeja Srbije. **A**, **6**, 1–130. Beograd.

KARAMATA, S. STEIGER, R., Djordjević, P., KNEŽEVIĆ, V. 1990: New data on the origin of granitic rocks from western Serbia. Bull. Acad. of Sci. and Arts Serbe. **CII**, Classe des Sci. Math. et NAtur. **32**, 1–9, Beograd.

KARAMATA, S. DELALOYE, M., LOVRIĆ, A. and KNEŽEVIĆ, V., (1992): Two genetic groups of Tertiary granitic rocks of central and western Serbia. Ann. Geol. Penins. Balk. **56** (1), 263–283. Belgrade.

KNEŽEVIĆ, V. (1962): Postanak i petrohemijski karakter magmatskih i kontaktno metamorfnih stena Cera. Zbornik Rud.-Geol. Fakulteta za 1959/1960 **7**, 190–201 Beograd.

KOSTIĆ, A. PAVLOVIĆ, Z. 1978: Granodiorit Brajkovca kod Lazarevca i njegovi kontaktno metamorfni produkti. Glasnik Prir. Muz. **A**, **33**, 113–131 Beograd.

LA ROCHE, H. DE LATERRIER, J., GRANDCLAUDE, P. and MARSHAL, M. (1980): A classification of volcanic and plutonic rocks using R_1R_2 diagram and major element analyses. Its relationships with current nomenclature. Chem. Geol. **29**, 183–210.

PEARCE, J. A., HARRIS, N. B. W., TINDLE, A. G., (1984):Trace element discrimination for the tectonic interpretation of granitic rocks. J. Petrol. **25**, 956–983.

STEIGER, R. H. KNEŽEVIĆ, V., KARAMATA, S., (1989): Origin of some granitic rocks from the southern margine of the Pannonian basin in western Serbia, Yugoslavia. Fifth meeting og the European Union of Geosciences, Strasburg, TERRA abstract. **1**, 52–53, Oxford.

VUKOV, M., MILIVOJEVIĆ, M. (1993): Prvo otkriće tonalita tercijalne starosti u Mačvi. Geol. Anali Balk. Poluostrva. **57**, (in press).

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