БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES

ГЕОХИМИЯ, МИНЕРАЛОГИЯ И ПЕТРОЛОГИЯ • 36 • СОФИЯ • 1999
GEOCHEMISTRY, MINERALOGY AND PETROLOGY • 36 • SOFIA • 1999

Rila-West Rhodopes Batholith: Petrological and geochemical constraints for its composite character

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Abstract. The new structural, mineralogical, petrological, geochemical and isotopic data of the granitoids of the Rila-West Rhodopes Batholith reveal that they are fragments of two different in age and tectonic position plutons. Unit 1 granodiorites are constituents of an older (~80 Ma) synmetamorphic pluton with calc-alkaline affinity and crust-contaminated mantle-derived composition. Units 2 and 3 granites (35-40 Ma) are genetically related in between phases of a post-metamorphic pluton with HKCA signature. Isotopically they show mixed mantle-crust features, but with a significantly higher crust contribution, compared with the Late Cretaceous bodies. Tectonic discriminations provide some evidences for tectonic settings: subduction-related for unit 1 and mixed, but mainly late/to post-collision-related - for units 2 and 3 granitoids. Mineral evolution and geochemical data variations are indicative of crystallization under moderate total pressure and temperature of crystallization. It is difficult to reconcile the model outlined here with the former claim that the West Rodopes Batholith consists of four phases granitoids related with a common magma evolution.

Keywords: Rila-West Rhodopes granitoids, mineralogy, geochemistry, I and S types granitoids
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Каменов, Б., И. Пейчева, Л. Клайн , К. Арсова, Ю. Костицин, Е. Салникова. 1999. Рило-Западнородопският батолит - петроложки и геохимични доводи за съставния му характер. - *Геохим., минерал. и петрол.,* **36**, 3-27

Резюме. Новите структурни, минераложки, петроложки, геохимични и изотопни данни за гранитоидите от Рило-Западнородопския батолит разкриват, че те са фрагменти от два различаващи се по възраст и тектонска позиция плутона. Гранодиоритите от единицата 1 са съставка на един по-стар (~80 Ma) синметаморфен плутон с калциево-алкален характер и мантийно създадена магма, замърсена с корово вещество. Гранитите от единиците 2 и 3 гранити (35-40 Ma) са генетически свързани помежду си фази от един постметаморфен плутон с HKCA характер. Изотопно те показват смесени мантийно-корови особености, но със значително по-висок коров принос, в сравнение с късно кредните тела. Тектонските дискриминации осигуряват известни доказателства за обстановките - свързана със субдукция за единицата 1 и смесена, но предимно късно- до следколизионна - за единиците гранитоиди 2 и 3. Измененията в минералния състав и геохимичните данни са показателни за кристализация при умерени общо налягане и температура. Очертаният в работата модел трудно се съгласува с предишните твърдения, че батолитът е изграден от четири фази, свързани с обща магмена еволюция.

Ключови думи: Рило-Западнородопски гранитоиди, минералогия, геохимия, I и S тип гранити
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Introduction

The magmatism is one of the important clues to the riddle of the geological evolution of the Rhodopes. In an attempt to throw a new light on the long-lasted discussions about this region, we present here our recent structural, mineralogical, petrological, geochemical and isotopic data, concerning the granitoids of the Rila-West Rhodopes Batholith. The studied plutonites (West Rhodopes, Belmeken, Grancharitza and Gargalitza bodies) are emplaced with metamorphic sequences in amphibolite facies of still unclear age (Fig. 1).

Background and motivation

The so-called *"South Bulgarian Granitoids*" (Dimitrov, 1939) have been objectives of study and long-lived discussions for over 50 years. The West Rhodopes granitoids are one of the examples. During all these years a large volume of new data have been collected for them which stimulated the rise of many conflicting ideas about the structural development of the area, to mention only several of them:

1. The granitoids of the Rila and West Rhodopes Mountains were thought as monotonous in composition, structures and origin bodies and they were unified in one unit together with the granitoids of Sredna Gora, Sakar and Osogovo Mountains (Dimitrov, 1947; Boyadjiev, 1960, 1963, 1993). The collected observations and data between the 60-ies and 80-ies years of this century proved out that the granitoids outcropped in the Southern Bulgaria were formed in different times, crystallized from various types magmas at different *P-T*, fO_2 and PH_2O conditions and that they followed different magma evolution paths (Arnaudov et al., 1974, 1977, 1989; Arnaudov, 1979; Arnaudov, Arnaudova, 1981; Arnaudova, Arnaudov, 1982; Zagorchev et al., 1987; Machev, 1993; Verguilov et al., 1986).
2. The notion for the availability of an old sialic crustal fragment situated between the both branches of the Alpean Orogene in Balkan Peninsula Area (Bonchev, 1971; Boyanov, Kozhoukharov, 1968) gradually steps back in favour of the idea for an intensive structure-forming of orogenic type during Alpean time (Ivanov, 1988; Burg et al., 1996). 3. The geodynamic settings of the granitoids have been determined as island-arc, collisional or post-collisional one.
4. The emplacement of the bodies was postulated in one stage (Boyadjiev, 1960, 1963) or in several stages (Verguilov et al., 1961; Valkov et al., 1989; Boyadjiev, 1993; Kamenov et al., 1997).
5. Proterozoic, Paleozoic, Cretaceous and Tertiary emplacement ages have been assumed for Rilo-Rhodopes granitoids (Kozhoukharov, Ivanov, 1961; Dabovski, 1968; Dimitrov, 1958; Valkov et al., 1989; Verguilov et al*.*, 1961), but firm radiometric support for these ages is not unequivocal.
6. The problem of the magma source of the granitoids still exists unresolved. Ideas of crust-derived magmas are based on lead isotope data, but mixed crust-mantle origin is suggested for some of the granitoids of Sakar Mountains as well (Verguilov et al, 1986).

The corollary deduced from the brief statement of the knowledge up to date is that notwithstanding the intensive research carried out on this magmatism in recent years numerous fundamental petrogenetic problems

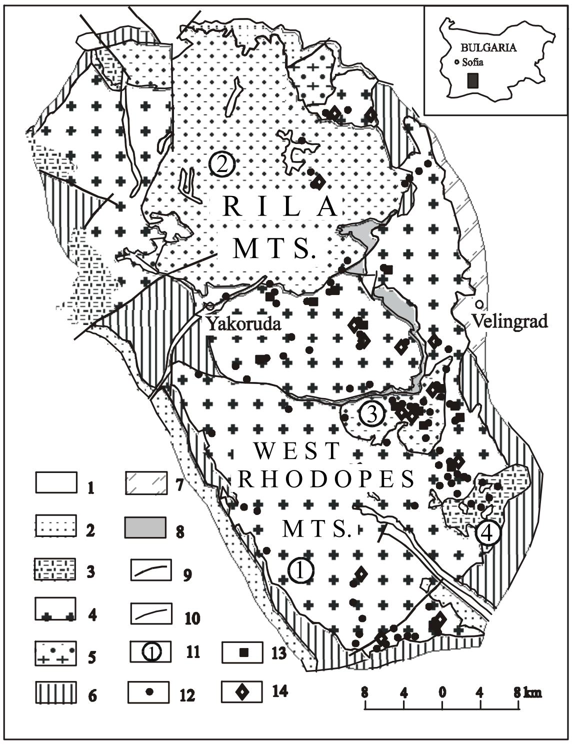

Fig. 1. Shematic geological map of Rila - West Rhodopes Batholith (after Valkov et al., 1989; Verguilov et al., 1961): 1 - Quaternary sediments; 2 - Paleogene sediments and volcanics; 3 - unit 3 granodiorites; 4 - unit 2 granitoids; 5 - unit 1 granites; 6 - metamorphites of the "Rhodopean Supergroup"; 7 - metamorphites of the "Prerhodopean Supergroup"; 8 - Babek-Grashevo dislocation; 9 - faults; 10 - lithological boundary; 11 - main plutonic bodies: ① - West Rhodopes; ② - Belmeken; ③ - Grancharitza; ④ - Gargalitza. Sample localities: 12 - mineralogical and petrographical examinations; 13 - heavy mineral concentrates; 14 - whole-rock samples for Rb-Sr isotopic investigation

Фиг. 1. Схематична геоложка карта на Рило-Западнородопския батолит (по Вълков и др., 1989; Вергилов и др., 1961): 1 – кватернерни седименти; 2 – палеогенски седименти и вулканити; 3 – гранодиорити от единицата 1; 4 – гранитоиди от единицата 2; 5 – гранити от единицата 3; 6 – метаморфити от т.н. “Родопска супергрупа”; 7 – метаморфити от т.н. “Дородопска супергрупа”; 8 – Бабек-Грашевската дислокация; 9 – разломи; 10 – литоложка граница; 11 - главни плутонични тела: ① – Западнородопско; ② – Белмекенско; ③ – Грънчаришко; ④ – Гаргалишко. Места на опробване: 12 – за минераложко и петрографско изследване; 13 – за изкуствени шлихи; 14 – общи проби за Rb-Sr изотопни изследвания.

remain poorly understood. Careful and detailed new examination on these granitoids has the potential to allow the following major issues to be addressed: unravel the magmatic history of the area; contribute to high precision radiometric dating of the granitoid units; evaluate any temporal variation in the rock geochemistry; contribute to an understanding of the impact of tectonic history on the magmatic events. Research on these fields would support ideas about magma sources; aid inter-regional correlation; use the new structural data in the deformed parts of the granitoids to clear up the relationship between granitoid magmatism and metamorphism.

Methods

The observations and resampling are carried out during the field seasons 1993, 1995, 1996 and 1997. Most of the specimens are from the West Rhodopes Mountains (Grantsharitza, West Rhodopes and Gargalitza bodies), but Bellmeken body of the Rila Mountains is sampled too. 16 large artifical heavy concentrates present the petrographic variety of the rocks and they are processed to extract monomineral fractions for mineralogical study. X-ray diffractometry reveals the structural peculiarities of 16 monomineral representative samples of K-feldspars (Operator Tz. Stanimirova). 124 thin sections are examined petrographically and they cover all varieties of granitoids. Modal analyses of 20 representative samples confirmed the rock nomenclature. Mineral microprobe analyses were performed on 10 thin sections covering the petrographical range of the plutonic rocks. They were performed in the Geological Survey Mineralogical Laboratory by a JEOL JSM 35 CT electron microprobe (Tracor Northern TN-200 microanalyser on EDS with standards and with counting times of 100 sec. at 20 kV with sample current of 2. 10^{-9} nA, analyst Ch. Stanchev). A total of 134 analyses of plagioclase, biotite, muscovite, K-feldspar, hornblende, chlorite, epidote, magnetite, ilmenite were used.

A set of 40 new whole-rock silicate geochemical data, including major and trace elements was performed in the laboratories of the Department of Petrology, Sofia University and of "Geology and Geophysics" Co, Sofia. Rb-Sr (21 samples) and U-Pb (6 samples) isotope data (Peytcheva et al., 1998) are the ground for age speculations.

Petrography and structural data

The new field observations (Fig. 1), microscopic (Table 1) and chemical examinations are the basis to distinguish three units granitoids. They are not separate phases from the evolution of a common parental magma or melt-products of a common source, but rather different in emplacement age and geodynamic setting stages of the building up the composite Rila-Western Rhodopes Batholith. The rocks units have different fabric, petrographical and geochemical peculiarities:

- Unit 1 is a coarse-grained, inequigranular, sometimes porphyritic, melanocratic, mainly hornblende-biotite granodiorite and rarely biotite granite. Plastic deformations such as a metamorphic foliation and a mineral lineation are clearly noticeable.
- Unit 2 is an equigranular in texture, mesocratic and medium-grained, mostly biotite granite and rarely muscovite-biotite leucogranite. The overprinted anysotropic fabric features are less pronounced, but they have the same orientation as in the type 1 and generally they are in line with the schistosity of the country rocks.
- Unit 3 is fine-grained, leucocratic, biotite-muscovite granite occurring as small stocks or vein type aplitoid bodies.

The most often observed textures are porphyroid, monzonitic, granitic, perthitic, microperthitic, cataclastic, mylonitic, lepidoblastic.

The deformed in various degree granitoids are remarkable for its low-grade (10-25^o) schistosity dipping to NNW-NNE (340-35^o). Within the unit 2 granitoids the porphyry feldspars form sigmoidal structures, i. e. in the valley of Gerzovitza River, Sofan Dere, Belmeken quarry, on the road between Yundola and Yakoruda, etc.

The aplitoid veins are deformed in the same manner. Near the southern margin of the granitoids along the valley of Kanina River a marked tendency for elongated minerals to be aligned with their major axes more or less parallel is observed often, as to produce a distinct lineation. Also, slight concentration of light- and dark-coloured minerals in alternating streaks may produce a planar banding, and mafic schlieren and inclusions often become abundant.

Table 1. *Summary data for mean mineral size and modal composition of the granitoids of the three units in Rila-West Rhodopes Batholith*

Таблица 1. *Обобщени данни за средни размери и количество на скалообразуващите минерали*

Units	1		2		3	
Mineral	vol. %	∅ mm	vol. %	∅ mm	vol. %	∅ mm
Plagioclase	35-55	0.9 x 0.6	26-55	0.7 x 0.5	45-60	0.4 x 0.2
Quartz	25-37	0.60	23-46	0.40	24-33	0.30
K-feldspar	10-18	1.0 x 0.6	10-39	0.6 x 0.5	9-25	0.5 x 0.4
Biotite	9-15	0.4 x 0.1	4-18	0.3 x 0.2	0-10	0.3 x 0.1
Hornblende	0-5	0.8 x 0.4	-	-	-	-
Muscovite	-	-	0-5	0.2 x 0.1	1-6	0.3 x 0.1
Garnet	-	-	-	-	+	+

The mean size is deduced from at least 200 measurements for a granitoid unit

Средният размер е извлечен от поне 200 измервания за гранитоидна единица

There the schistosity is entirely conformed with the one of the country mylonitic gneisses. It dips at a slant (15-25°) to SSE-SSW in the span of 160-220°. The granitic veins and apophyses (several meters in thickness) in the very zone are with similar orientation of their schistosity. Not very different is the contact south of Velingrad in the valley of Lepenitza River, but there skarned marbles represent the country rocks. The foliation in the granites and the schistosity in the marbles dip to the NE - 45/12°. The alignement of mica flakes or quartz-feldspare aggregates manifest the mineral lineation in the deformed parts of the granitoids. Everywhere in the studied area the lineation is orientated analogous to the one in the country metamorphites - dipping at low-angle (10-20°) to NNW-NNE (340-22°) or to SSE-SSW (165-195°). The synkinematic criteria (sigma-delta complex, asymmetric drag folds, s/c relationships – Dimov, 1994) show that the direction of the syntectonic transport is top to SSE-SSW, coinciding with the one of the synmetamorphic shear in the country metamorphites.

The outcrops around and north of the Babek-Grashevo Dislocation Zone are subjects of cataclastic deformations. Zones of mylonitization occur often there.

Mineral composition

The essential rock-forming minerals are plagioclase, quartz, K-feldspar. Biotite is the basic minor mineral, but in the granitoids of unit 1 the hornblende is more typical and in

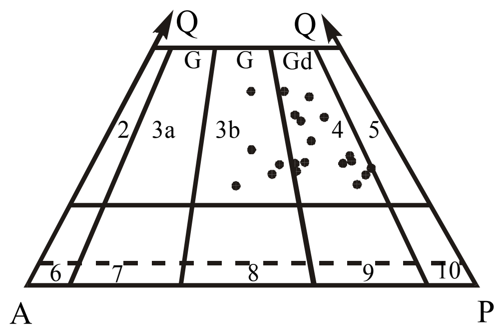

Fig. 2. Modal composition of the studied granitoids (after LeMaitre et al., 1989). Fields: 3b - granite; 4 - granodiorite

Фиг. 2. Модален състав на изследваните гранитоиди (по LeMaitre et al., 1989). Полета: 3b – гранит; 4 – гранодиорит

Table 2. *Representative microprobe analyses of plagioclases from Rila-West Rhodopes Batholith*

Таблица 2. *Представителни микросондови анализи на плагиоклази от Рило-Западнородопския батолит*

Rocks	Amphi-bolite	Unit 1			Unit 2						Unit 3		
Sample	125-б	II	V	122-a	X	XIII c	XIV r	107 c	107 r	112	VII	IX	IX
SiO_2	59.01	60.76	55.92	62.97	64.57	63.12	62.70	62.65	68.98	61.04	64.56	62.98	62.54
TiO_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.07	0.00	0.03
Al_2O_3	26.23	25.05	28.22	24.18	21.99	23.64	23.94	23.69	19.38	25.48	22.26	23.05	23.21
FeO_t	0.13	0.15	0.03	0.10	0.02	0.05	0.03	0.00	0.09	0.00	0.00	0.07	0.07
MnO	0.00	0.00	0.12	0.00	0.00	0.10	0.03	0.00	0.00	0.00	0.17	0.09	0.06
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	7.44	6.98	9.92	2.99	4.05	4.34	4.46	5.49	0.54	3.13	4.43	5.32	5.37
Na_2O	7.02	6.77	5.59	9.61	8.88	8.48	8.53	8.62	11.28	9.43	8.09	8.00	8.32
K_2O	0.31	0.28	0.20	0.09	0.19	0.16	0.22	0.31	0.18	0.13	0.33	0.39	0.40
BaO	-	0.00	0.00	0.00	0.13	0.10	0.00	-	-	-	0.00	0.00	0.00
Total	100.14	99.96	100.00	99.94	99.83	99.89	99.99	100.76	100.43	99.88	99.91	99.90	100.00
An %	36.3	35.7	48.9	14.6	19.9	21.8	22.1	25.6	2.6	15.4	22.8	26.3	25.6
Ab %	61.9	62.7	49.9	84.9	79.0	77.2	76.5	72.6	96.3	83.8	75.2	71.4	72.1
Or %	1.8	1.7	1.2	0.5	1.1	1.0	1.4	1.8	1.1	0.8	2.0	2.3	2.2

c - core, r - rim

c - ядро, r – периферия

the ones of units 2 and 3 - the muscovite. Common accessories are magnetite, allanite, titanite, zircon, apatite, ilmenite, pyrite. The following secondary minerals are found: muscovite, epidote, clinozoisite, chlorite, calcite, hematite, sericite, clay minerals, Fe-hydrooxides. The modal composition of the rocks is shown on Table 1 and Fig. 2. All rock samples plot in the fields of granodiorite and granite.

Plagioclase occurs in three generations (Pl^{I}, Pl^{II} and Pl^{III}) and its composition varies in the different rock units (Table 2). Only two generations are observed in the rock unit 1 where the prevailing plagioclase is sodic andesine in the cores (Pl^{I}=An_{33-37}, $Or_{0.5-2.0}$) and sodic oligoclase in the rims (Pl^{II}=An_{12-14}, $Or_{0.5-1.0}$). Simple normal zoning is exhibited. The similarity with the composition of the plagioclase from the amphibolite xenoliths ($An_{35}Or_2$) is remarkable. The orthoclase component gradually increases towards the periphery of the individual grains. Thin secondary lamelae are spread sometimes within the outer parts of some grains. The cases of entirely obliterated by metamorphic alteration lamelae are not rare. Part of the plagioclases are cracked and twisted under the pressure and with deformed polysynthetic lamelae. Sericite and sometimes calcite are developed along the cracks. The plagioclase composition in the micromyrmekite is $An_{18-19}Or_{1-3}$. Occasionally the myrmekites are coarse-grained and they embrace the whole area of the plagioclase crystal.

Pl^{I}, Pl^{II} and Pl^{III} occur in unit 2 granodiorites. Reverse zoning is more often noted than a simple normal one, especially for the intermediate zones. At times, the anorthite composition is the highest in the intermediate zones. The size of the grains made up by Pl^{I} (An_{20-26}, $Or_{0.4-2.3}$) is smaller than of the Pl^{II} (An_{14-18}, $Or_{0.6-1.7}$) and they could be rimmed by Pl^{III} ($An_{2.6-3.2}$ $Or_{0.1-1.1}$). The coarser grains of Pl^{II} are nearly without lamelae or they have ill-defined remnants of them. Pl^{III} is superimposed postmagmatically. Close to the outer zones of the rock body and to the north of the Babek-Grashevo Dislocation, the plagioclases are strongly deformed, sometimes fragmented and bent. The recrystalization is exhibited also by their segregation in separate leucocratic bands along with the other salic minerals. There the micromyrmekites or the coarser parallel-arranged myrmekites are typical and often met. The secondary products on the plagioclase are muscovite and sericite. The first one is with well-formed thin and long flakes and it is developed in most of the cases on the inner cores of the plagioclase. The second one is advanced irregularly along cracks and twinning surfaces. Frequently, such process affetcs the whole area of the grains. The intensity of the muscovitization increases to the southern margin of the massif.

Unit 3 comprises essentially basic oligoclase ($Pl^{II}=An_{20-26}$, $Or_{1.1-2.5}$) and normal or never to be seen zoning is characteristic. Plagioclases are relatively fine-grained. Pl^{III} occurs uncommonly in this unit. There are also plagioclase grains without clear compositional difference between the inner and the outer zones. In comparison with other rock units, the myrmekites are finer grained and quite rare. The cores are corroded and almost entirely replaced by muscovite. The sericite and the clay minerals are developed as irregular set of microfissures and cracks cutting the whole crystal. The plagioclases included in the larger K-feldspar crystals are not twinned at all and nearly entirely they are albitized.

Potassium feldspar is unevenly distributed and with changeable participation in the different rock types. The sizes of the porphyroid large crystals of K-feldspar in the unit 1 are over 10 mm and frequently they include small plagioclase crystals. Microperthitic lamelae are noted occasionally (plagioclase composition in them is clear albite). The extinction of the large grains is uneven obscured or block-domain like. Here and there, the initiation of the dim microcline cross-hatching formation could be seen in separate sections of porphyroid individuals. The cross-hatching is clear exhibited only in the fine-grained K-feldspars. The potassium component is very high in the sections and in the grains with clear grid twinning where it reaches up to 100%. Sometimes the crystals are broken to fragments and together with the other salic minerals they form leucocratic linear segregations. The main alterations on the K-feldspars are the sericite and other clay minerals.

The K-feldspar in the unit 2 rocks is fine-grained in most of the cases. It exhibits clear cross-hatching, but large porphyroids (up to 20-30 mm in diameter) with spotty extinction and microcline grid twinning only within some small sectors colud be found as well. Perthitic exsolutions are noted more often in the marginal parts of the crystals and very rare they may spread over the whole area of the crystal. Then they are quite coarse-grained. The secondary alterations are mainly calcite and clay minerals developed more intensively than in the feldspars from the rock unit 1.

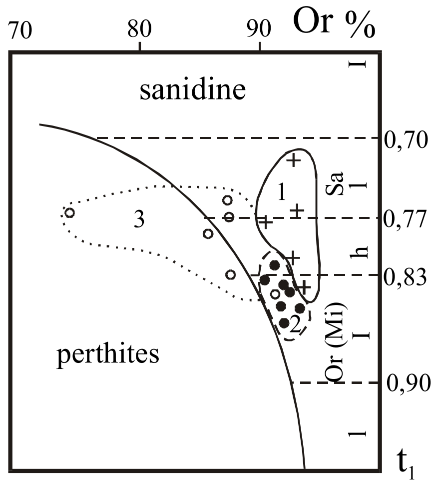

Fig. 3. Classification of the potassium feldspars from different units: 1 (crosses), 2 (filled circles) and 3 (open circles), (Smith, 1974). Abbreviations: Or - orthoclase; Mi - microcline; l - low; I – interm.; h - high; Sa - sanidine

Фиг. 3. Класификация на калиеви фелдшпати от различни единици гранитоиди: 1 (кръстчета), 2 (запълнени точки) и 3 – (празни кръгчета), (Smith, 1974). Съкращения: Or – ортоклаз; Mi – микроклин; l – нисък-; I – междинен-; h – висок-; Sa – санидин

Unit 3 granitoids contains two different in size generations of K-feldspar. The fine-grained one consists always of clear microcline with cross-hatching, but the porphyroid K-feldspar shows uneven extinction and the microcline grid twinning is manifested only within separate small sections. The fine-grained generation prevails.

The anorthite component of the K-feldspar (Table 3) is very low and only in some separate single analysis reaches to 5%. The albite component in the K-feldspars of the unit 1

Table 3. *Morphological, chemical and X-ray data for potassium feldspars in the three units granitoids*
Таблица 3. *Морфоложки, химични и рентгеноструктурни данни за калиеви фелдшпати от трите единици на батолита*

a. Chemical composition and morphology

Rock units	1	2	3
Morphology	Coarse-grained	Fine grained + phenocrysts	Fine grained + phenocrysts
Mole percents An	0-1 (av. 0.1)	0-1.5 (av. 0.7)	0-5.7 (av. 1.4)
Ab	0-12.6 (av. 6.1)	3–25(av. 9.4)	9.6-25.6 (av. 13.2)
Or	85-97 (av. 92.4)	85-96 (av. 89.9)	67-90 (av. 84
Cn	0.9-1.9 (av. 1.4)	0-2.1 (av. 0.7)	0.7-1.7 (av. 1.4)

b. X-ray data

Rock units	1	2	3
Structural type	High Or + interm. Or + interm. Mi	Interm. Mi	Microperthitic and cryptoperthitic, high Or
Ragland's δ	0.35	0.52	0.36
Av. T_1	0.80	0.84	0.79
Av. T_1O	0.48	0.58	0.59
Av. T_1m	0.33	0.26	0.20
Av. Δp	0.25	0.32	0.37
Δ a=a_{obs}-a_{est}	>0.12	>0.12	>0.12
Type after Stewart & Wright (1974)	"strained"	"strained"	"strained

Or – orthoclase, Mi – microcline. The chemical composition is determined using 27 microprobe analyses
Or – ортоклаз, Mi – микроклин. Химичният състав е определен от 27 микросондови анализа

granitoids has its lowest values and the orthoclase composition there shows the highest figures. The celzian mole-percentage of the K-feldspars from the same unit is relatively the highest. These peculiarities imply for higher degree of subsolidus re-equilibration, probably provoked by the overprinted metamorphism. The noted zoning in the distribution of Ba with decreasing of its contents to the periphery of the crystals probably reflects the preceding magmatic conditions of crystallization. It could be related with a decreasing of the temperature, but it is most likely to testify to quick drop of the concentration of Ba in the remnant melt after the crystallization of the relatively earlier porphyries.

The following differences between the compositions of the K-feldspars from the granitoids of units 2 and 3 in comparison with the ones from unit 1 could be noted: relatively lower mean content of the orthoclase component, higher albite and anorthite compounds at more or less equal celzian contents. The comparison between the K-feldspars from rock units 2 and 3 in this sense shows regularly variations connected with a common process of fractional crystallization under conditions of higher temperature of the dehydrated aplitoid magma as the unit 2 granitoids were formed by richer in water magma.

The analyzed cross-hatched microclines which are imposed over the monoclinic K-feldspars some later on have relatively higher content of the K-feldspatic nearly pure minal (up to Or_{98}). This fact points to process of structural ordering related to the influence of metamorphic solutions. Obviously such process could clean out the albite components and it is relatively low temperature. The higher average celzian contents in the potassium feldspars from rock unit 3, compared to the ones from unit 2 are noted. Probably they are due to the crystallization of the aplitoid residium melt poorer in water and on account of a locally increasing of the Ba concentration in regard to the fact that in this rock unit there is no essential porphyry formation.

X-ray data of separated monomineral samples of K-feldspars (Table 3) show that the predominant part out of them in the rocks from unit 1 are assigned to high orthoclase and even low sanidine and only one sample is high microcline. The mean value of the coefficient δ (Ragland, 1970) for K-feldspars of rock unit 1 is 0.35, which is typical for the intermediate orthoclase. Almost all K-feldspars of unit 2 are intermediate microclines and their mean δ coefficient is 0.52. The samples from unit 3 granitoids are mainly microperthitic and cryptoperthitic high orthoclases, but an insignificant participation of triclinic high microclines occurs in some of the specimens. The ordering of the Al and Si in tetrahedral sites is studied by the "method of the three peaks" (Stewart and Wright, 1974). The determined statistical occupancy of Al in the four possible crystallographical sites in the cell demonstrates the intermediate ordering degree too. According to these data the rocks from unit 1 are of primary magmatic origin and their K-feldspars are relatively the most unordered. The position of the fields of the studied K-feldspars divided into rock inits (Fig. 3) shows that a common process of magma evolution between the rocks from unit 1 from one side and the ones from units 2 and 3 from the other side did not exist. The smaller size of the rock bodies of unit 3 requires faster cooling rate in comparison with the rocks from unit 2 and this points to the relatively lower ordering degree of their K-feldspars.

Almost all K-feldspars of the Rila-West Rhodopes Batholith are assigned to the so-called "anomalous K-feldspars" (Stewart and Wright, 1974). Their value of "Δa" is higher than 0.12. It follows from this that the K-feldspars are affected by deformations (strained abnormal ones) and direct correlation between

Table 4. *Representative microprobe analyses of amphiboles from unit 1 granitoids*

Таблица 4. *Представителни микросондови анали-зи на амфиболи от единицата 1 гранитоиди*

	II/WR		125/WR	
	Hb-1	Hb-2	Hb-42	Hb-44
SiO_2	42.90	43.51	40.92	41.11
TiO_2	0.80	0.43	0.64	0.44
Al_2O_3	11.35	10.83	11.55	11.31
FeO_t	19.13	19.43	21.45	21.53
MnO	0.76	1.01	0.60	0.83
MgO	8.71	8.34	8.75	8.84
CaO	11.66	11.70	11.26	11.57
Na_2O	1.22	1.05	1.46	1.04
K_2O	1.58	1.42	1.39	1.54
BaO	0.04	0.20	-	-
NiO	0.13	0.00	-	-
Cr_2O_3	0.11	0.11	-	-
V_2O_5	0.00	0.00	-	--
L.O.I.	1.59	1.97	1.98	1.79
Total	98.41	98.03	98.02	98.21
K	0.30	0.27	0.27	0.30
Na	0.30	0.26	0.33	0.23
A	0.60	0.53	0.60	0.53
Na	0.06	0.05	0.09	0.07
Ca	1.89	1.90	1.82	1.87
Mn	0.05	0.05	0.08	0.06
Fe^{2+}	0.00	0.00	0.01	0.00
M4	2.00	2.00	2.00	2.00
Mg	1.96	1.88	1.97	1.99
Mn	0.04	0.08	-	0.05
Fe^{2+}	2.10	2.15	1.80	1.68
Fe^{3+}	0.31	0.31	0.91	1.03
Al^{VI}	0.49	0.52	0.25	0.21
Ti	0.09	0.05	0.07	0.05
M1+M3 +M2	5.00	5.00	5.00	5.00
Si	6.47	6.60	6.19	6.20
Al^{IV}	1.53	1.41	1.81	1.80
Fe^{3+}	0.00	0.00	0.00	0.00
T	8.00	8.00	8.00	8.00
Mg #	0.48	0.47	0.52	0.54

Fe^{3+} of amphiboles is calculated according to Spear and Kimball (1984); H_2O – by the difference to 100 %

Fe^{3+} в амфибола е изчислено по метода на Spear and Kimball (1984); H_2O – като разлика до 100 %

the temperature of crystallization and the Al/Si ordering degree should not be traced out because of the influence of other factors. The estimated with the help of the structural characteristic t_1 (variation between 0.75 and 0.88) temperatures are within the borders of 580-670^{o}C without essential displace in the different rock units. Apparently these temperatures reflect also a subsolidus equilibration, accomplished in the process of the structural metamorphic deformations and they are not crystallization temperatures.

Comparissons of the contents of Al in the tetrahedral sites of the K-feldspars from the batholith with these from other “South Bulgarian granitoids” (Arnaudov et al., 1988) point that the most closest similarity in this respect could be the K-feldspars from the Central Pirin pluton. Up to the certain degree, the K-feldspars from Baroutin-Boujnovo pluton and the complex Elatia in Greece (Kamenov et al., 1990) resemble to the ones from the Batholith.

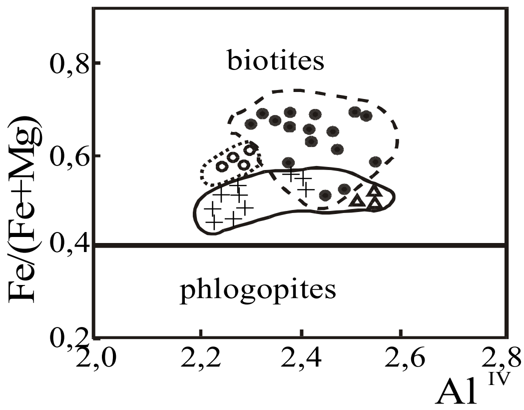

Fig. 4. Composition of biotites in the plot Fe/Fe + Mg) vs. Al^{IV}. Units: 1 (crosses), 2 (filled circles); 3 (open circles); from country amphibolites - triangles

Фиг. 4. Състав на биотити в диаграмата Fe/(Fe+Mg) – Al^{IV} от гранитоидните единици 1 (кръстчета), 2 (плътни кръгчета) и 3 (празни кръгчета)

Amphiboles are rare and poorly developed minor constituents of the granitoids from unit 1 only. Assigned to the group of the calcium amphiboles they are ferropargasites, magnesio-hastingsite and ferroedenite, according to Leake's classification scheme (Table 4). Regarding the correlation of the sum (Ca + K + Na) and Si p.f.u. amphibole of unit 1 granitoids is typical for an island-arc setting (Jakes and White, 1972), in spite of the fact that such a conclusion is quite rough generalization (Gill, 1981). The relatively low contents of Al^{VI} (0.5 at 23 O, after Ujike and Onuki, 1976) indicate crystallization at $PH_2O < 9$ kbar (Allen and Boettcher, 1978). The close similarity of the “mg” values between the amphiboles from unit 1 granitoids and the ones from the country amphibolites points to the possible role of assimilation in the crystallization of the rocks of unit 1.

Biotite is presented the best in the granitoids of unit 1. It is less frequent in the unit 2 and in unit 3 it may absent at all. Commonly the biotite occurs as well-formed tabular crystals but in the unit 1 the flakes are longer, sometimes bent and often arranged in subparallel way. Small-sized flakes with unravelled brush-like breaking at the ends are set up in thin strips stream-lined around the other salic minerals. The secondary minerals on the biotite are often noted: chlorite, muscovite and epidote. Sometimes biotite contains allanite inclusions.

Chemically (33 microprobe analyses) all samples fall within the biotites with normal Al-bearing varieties (Table 5). The “mg” ratios averages 52 for the unit 1, 37 - for the unit 2 and 45 - for the unit 3. The evolution of the biotite composition can be followed on the Al^{IV} versus Fe/Fe+Mg diagram (Fig. 4), where three distinct fields are delineated.

The location of these fields and their crosscutting relations tend to exclude the possibility of their origin by process of simple fractional crystallization of a common parental magma. It is interesting to note that the composition of the biotite from the country amphibolites fall in the field of the biotites from unit 1. The internal crystallization history (the elongation of field 1) is directed to the temperature - decrease and μK_2O - increase in the final stages of crystallization. In this respect

Table 5. *Representative microprobe analyses of biotites from Rila-West Rhodopes Batholith*

Таблица 5. *Представителни микросондови анализи на биотити от Рило-Западнородопския батолит*

	unit 1 granodiorites			unit 2 granites					unit 3 granites		amphibolites	
	10	II	VI	124	112	132	XIII	XIV	VII	IX	125-a/c	125-a/r
SiO_2	38.14	37.45	37.38	35.77	36.39	36.05	35.64	35.00	37.75	36.17	35.00	35.53
TiO_2	1.50	2.04	2.83	1.44	1.62	1.90	2.47	3.17	1.80	2.86	2.04.	1.68
Al_2O_3	15.75	14.60	15.23	17.66	18.20	18.25	16.63	17.06	15.77	14.64	14.39	15.37
FeO_t	17.56	19.10	20.11	23.04	18.47	21.01	22.54	24.26	20.74	21.03	22.15	21.20
MnO	0.36	0.58	0.72	0.81	0.61	1.22	0.37	0.96	1.49	0.38	0.60	0.33
MgO	12.45	11.74	9.67	6.96	10.55	7.69	6.26	5.59	8.78	7.97	11.51	12.28
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Na_2O	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K_2O	10.07	9.99	10.03	10.33	9.94	9.76	10.18	9.98	10.29	10.08	10.17	9.91
L.O.I.	4.17	4.28	4.03	3.99	4.30	3.52	4.46	3.90	3.16	5.95	4.14	3.71
Total	95.83	95.95	96.31	96.01	95.70	96.48	95.54	96.09	96.84	94.05	95.86	96.29
K	1.93	1.94	1.95	2.04	1.92	1.91	2.03	1.99	2.00	2.03	2.02	1.94
Na	0	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
X	1.93	2.00	1.95	2.04	1.92	1.91	2.03	1.99	2.33	2.03	2.02	1.95
Mg	2.79	2.67	2.20	1.61	2.38	1.76	1.46	1.30	1.99	1.88	2.67	2.81
Mn	0.05	0.07	0.09	0.11	0.07	0.16	0.05	0.13	0.19	0.05	0.08	0.04
Fe_t	2.21	2.43	2.56	2.99	2.34	2.69	2.95	3.17	2.64	2.78	2.89	2.72
Al^{VI}	0.52	0.32	0.44	0.78	0.75	0.82	0.63	0.61	0.58	0.45	0.10	0.23
Ti	0.17	0.23	0.32	0.17	0.18	0.22	0.33	0.37	0.21	0.34	0.24	0.19
Y	5.74	5.72	5.61	5.65	5.72	5.65	5.42	5.58	5.61	5.50	5.97	5.99
Si	5.73	5.70	5.70	5.55	5.51	5.53	5.57	5.47	5.75	5.72	5.45	5.45
Al^{IV}	2.27	2.30	2.30	2.45	2.49	2.47	2.43	2.43	2.25	2.28	2.55	2.55
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
fm	44.2	47.6	53.8	65.0	50.0	60.0	66.9	70.9	59.7	59.6	52.0	49.0
al	20.6	19.5	20.8	24.1	24.0	24.8	23.5	24.0	21.4	20.8	19.3	20.2

$fm=100.Fe_t/(Fe_t+Mg)$; $al=100.Al/(Al+Si+Mg+Fe_t)$

the biotite composition of the country amphibolites has fixed the conditions of the highest chemical potential of K_2O. It means that fluids originated with the magma of unit 1 granitoids influence the biotite composition of the country rocks. Biotites from the granitoids of units 2 and 3 form two trends directed to the relatively higher alkalinity of the biotites of unit 3 in comparison with the ones from unit 2. Biotites from unit 3 granitoids are with higher "mg" values than these from unit 2 because at the conditions of higher P_{H2O} in which muscovite is more stable the biotite is the only one rock-forming mineral capable to include Mg in its cell.

The compositional changes of the biotites related to the chemical potentials of K_2O and H_2O are demonstrated on the diagram of Ivanov (1979) - Fig. 5. The fields of biotites from the Central Pirin granite and from the Demyanitza granite are plotted on the same diagram. The biotites from rock unit 1 form a common field with the biotites from the country amphibolites. The Central Pirin Granite biotites (Machev, 1993) delineate a filed which overlaps the field of the biotites from unit 1. In the interpretation of this diagram, granitoids of unit 1 are slightly lower temperature and with relatively lower alkalinity of their magma than the one of the Central Pirin Granite.

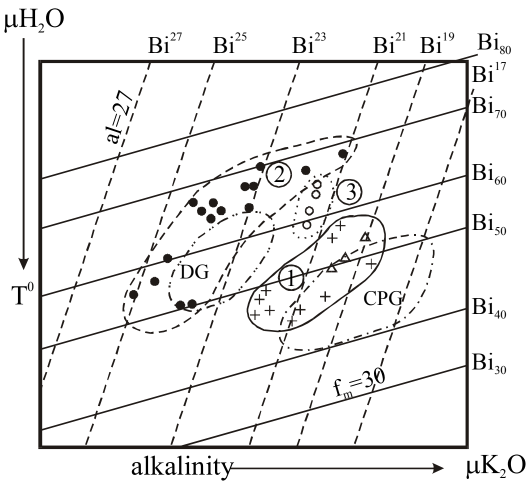

Fig. 5. Composition of biotites of Rila-West Rhodopes Batholith in co-ordinates H_2O activity vs. K_2O activity (after Ivanov, 1970). Unit 1 - crosses; unit 2 - solid circles; unit 3 - open circles. Fields: CPG - Central Pirin granite and DG - Demyanitza granite (Machev, 1993). $al=100.Al/(Al + Si + Ti + Fe_{tot})$; $fm = 100. Fe_{tot}/(Fe_{tot} + Mg)$

Фиг. 5. Състав на биотити от Рило-Западнородопския батолит в координати активност на K_2O – активност на H_2O (по Иванов, 1970) от единиците 1 (кръстчета), 2 (плътни точки), 3 – (празни кръгчета). Полета: CPG – Централно-пирински гранит; DG – Дамянишки гранит (Мачев, 1993). $al=100.Al/(Al+Si+Ti+Fe_{tot})$; $fm=100.Fe_{tot}/(Fe_{tot}+Mg)$

Muscovite displays considerable variation in composition (Table 6) and fall in the field of secondary muscovites (Spear, 1984). The minimum pressure of crystallization of muscovites from garnet-bearing two-mica granitoids is 3.4 kbar (Kistler et al., 1981). This data and the intercept of the experimental line of stability of the association muscovite + H_2O with the water-saturated granite solidus (Spear, 1984) could suppor the likely magmatic origin of the muscovites from the unit 2 granitoids. The confirming of this assumption needs more accurately estimation of the total pressure of crystallization of the unit 3 granitoids.

Quartz in the unit 1 granitoids is mostly fine-grained, but larger grains grouped as polycrystalline lenticular aggregates with undulatory extinction and granoblastic texture are common as well. The bands are bent under a strain and the traces of recrystallization and cataclastic deformations are obvious. In the unit 2 granitoids the quartz with fine-grained morphology is fragmentated and arranged in long strips sometimes. This peculiarity more often is observed to the north of the dislocation fault zone and in the marginal parts of the batholith. Near to the zones of mylonitization the optical axes are reorientated in the planar schistosity and a distinct foliation is marked.

Table 6. *Representative microprobe compositions of muscovites from Rila - West Rhodopes Batholith*
Таблица 6. *Представителни микросодови състави на мусковити от Рило- Западнородопския батолит*

	unit 2					unit 3	
	XX	XIV	124	132	107	VII	VII
SiO_2	48.72	44.49	45.21	44.93	45.32	48.98	49.61
TiO_2	1.57	0.58	0.76	0.52	0.09	0.30	0.37
Al_2O_3	33.60	32.80	29.42	32.96	33.10	31.13	30.55
FeO_t	3.89	3.93	5.08	5.08	3.39	4.65	5.80
MnO	0.01	0.05	0.08	0.17	0.00	0.19	0.15
MgO	0.00	0.00	0.50	0.96	0.00	0.00	0.00
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na_2O	0.13	0.30	0.79	0.00	0.00	0.28	0.00
K_2O	11.61	10.16	11.17	10.24	11.15	11.40	11.76
BaO	0.44	0.25	-	-	-	0.35	0.20
NiO	0.03	0.00	-	-	-	0.00	0.00
Cr_2O_3	0.00	0.00	-	-	-	0.88	0.00
V_2O_5	0.00	0.05	-	-	-	0.00	0.00
Na	0.03	0.08	0.21	0.00	0.00	0.07	0.00
K	1.92	1.80	2.00	1.78	1.97	1.89	1.96
Ba	0.02	0.02	-	-	-	0.02	0.01
A	1.97	1.90	2.21	1.78	1.97	1.98	1.97
Mn	0.00	0.01	0.01	0.02	0.00	0.02	0.02
Mg	0.00	0.00	0.10	0.20	0.00	0.37	0.31
Fe^{2+}	0.42	0.46	0.60	0.58	0.39	0.51	0.63
Cr	0.00	0.00	-	-	-	0.09	0.00
Ti	0.15	0.06	0.08	0.05	0.01	0.03	0.04
Al^{VI}	3.42	3.57	3.23	3.43	3.65	3.15	3.17
Y	3.99	4.11	4.02	4.28	4.05	4.16	4.16
Si	6.30	6.19	6.35	6.13	6.26	6.37	6.47
Al^{IV}	1.70	1.81	1.65	1.87	1.74	1.63	1.53
Z	8.00	8.00	8.00	8.00	8.00	8.00	8.00

The inner parts of the unit 2 granitoids contain larger quartz grains (1.1-1.4 mm in diameter). The quartz from the unit 3 granitoids is predominantley coarse-grained, but very fine grains take part in micrographic textures on some places.

Ore minerals are presented in the unit 1 granitoids mainly by magnetite grains associated with biotite. Magnetites including thin lamellae of hematite and titanite are noted rarely. They are understood as remnants of ilmenite exsolutions, altered postmagmatically by high-PO_2 fluids. Except magnetite, ilmenite as isometric inclusions or coarse-lamellar exsolutions occurs in unit 2 granitoids. The primary textural relationships are often obliterated by the strong developed postmagmatic hematitization. Pyrite replaces the magnetite as well. The prevailing ore mineral in the unit 3 granitoids is the ilmenite. Hematite exsolutions in it are established.

Representative analyses of ilmenite, titanite, magnetite, and the secondary epidote and allanite are shown in Table 7.

Intensive variables

1. *Temperature*. The termal history of crystallization is deduced from the detailed mineralogy. All applied geothermometers for the rocks in the batholith centre to the estimations between 550 and 650°C (Panejah, Fedorova, 1973; Perchuk, 1966; Perchuk,

Table 7. *Representative microprobe analyses of some accessory and secondary minerals*
Таблица 7. *Представителни микросодови анализи на някои акцесорни и вторични минерали*

Unit	1	2	3	amphi bolite	1			
Mineral	ilmenite	titanite	magne tite	epidote			allanite	chlorite
Sample	VII	II	VII	125-a	II	V	V	II
SiO_2	0.32	31.25	0.26	38.85	38.61	37.34	34.55	27.49
TiO_2	41.84	33.87	0.00	0.00	0.31	0.25	0.44	0.11
Al_2O_3	0.13	2.29	0.16	21.45	22.76	24.55	19.39	16.75
Fe_2O_3	-	-	-	14.45*	-	-	-	-
FeO	32.02	1.11*	94.77*	-	13.77*	11.99*	13.22	24.85*
MnO	15.95	0.23	0.00	0.19	0.33	0.53	0.00	0.69
MgO	0.09	0.07	0.18	0.00	0.00	0.00	0.12	14.62
CaO	0.00	27.47	0.00	22.85	22.80	23.63	15.49	0.08
Na_2O	0.00	0.01	0.00	0.00	0.07	0.00	0.00	0.00
K_2O	0.01	0.21	0.04	0.00	0.21	0.08	0.00	0.07
BaO	9.48	3.17	0.00	-	0.00	0.04	0.00	0.00
Cr_2O_3	0.15	0.32	0.15	-	0.00	0.00	0.00	0.10
La_2O_3	0.00	0.00	0.00	-	0.00	0.00	2.82	0.00
Ce_2O_3	0.00	0.00	0.00	-	0.00	0.00	6.07	0.00
Nd_2O_3	0.00	0.00	0.00	-	0.00	0.00	6.01	0.00
L.O.I.	0.00	0.00	0.00	2.21	1.14	1.59	2.00	5.14
Total	99.99	100.00	95.56	97.49	98.86	98.41	100.01	100.00

The marked with star values are total iron oxides
Отбелязяните със звездичка стойности са сумирани железни окисиди

Ryabchikov, 1976; Ferstater, 1990; Stormer, 1975) and they reflect the subsolidus-reequilibration of the rocks. Only the distributions of Ti in the biotite-hornblende equilibria in the unit 1 granitoids provide the estimations between 700 and 800^{o}C. Reliable geothermometric estimations for the other units granitoids were not found.

2. *Pressure*. The empirical amphibole geobarometer (Schmidt, 1992) is applicable for unit 1 granitoids as the mineral assemblage is similar to the experimental one and the obtained temperatures of around 700^{o}C are close to the isothermal solidus. The averaged result is close to 6.4 kbar (~18 km.) According to this estimate the structural facies is mesoabyssal. Fershtatter's method (1990) based on the plagioclase - hornblende Al-Ca equilibria yields 5 to 6 kbar pressure estimations for the same type granitoids.

3. *Fluid pressure*. The magma of the unit 1 granitoids should have been relatively poorer in water and others fluids than those of units 2 and 3. Muscovite and biotite as essential minerals in the last granitoids point to PH_2O>3.5 kbars in their magmas.

Major element chemistry

Two trends are delineated on the TAS-classification diagram (Bogatikov et al., 1981), where besides our 40 new whole-rock silicate analyses (Table 8), selected published analyses (Valkov et al., 1981) are used as well (Fig. 6). The first trend envelops the field of the unit 1 granitoids and the internal chemical evolution in it points to the SiO_2 increase without noticeable increase in the alkalies. The second one is extracted out from the elongation of the fields of units 2 and 3 granitoids and it is directed to the higher increase of the alkalies.

The same two trends are clearly visible on the K_2O vs. SiO_2 plot (Peccerillo and Taylor,

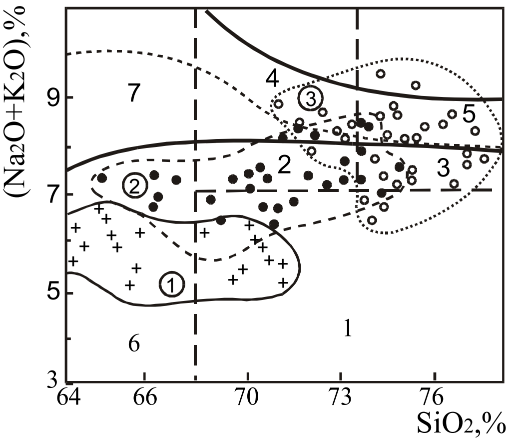

Fig. 6. SiO_2 vs. (Na_2O + K_2O) classification plot (Bogatikov et al., 1981) with the points for unit 1 (crosses), unit 2 (solid circles), unit 3 (open circles) and their fields. Selected published analyses of Valkov et al. (1981) are included as well. Rock families: 1 - low-K granite; 2 - granite; 3 - leucogranite; 4 - transitional granite; 5 - transitional leucogranite; 6 - granodiorite

Фиг. 6. Класификационна диаграма SiO_2 – (Na_2O + K_2O) по Богатиков и др. (1981) с точки на проби от единиците 1 (кръстчета), 2 (плътни точки) и 3 – (празни кръгчета) и техните полета с включени и избрани анализи от Вълков и др. (1981). Скални семейства: 1 – ниско-К гранит; 2 – гранит; 3 – левкогранит; 4 – преходноалкален гранит; 5 – преходноалкален левкогранит; 6 – гранодиорит

1976) - Fig. 7. The unit 1 granitoids falls entirely within the calc-alkaline series (CA), whereas those from units 2 and 3 are transitional HKCA mainly rocks. This fact rejects the possibility for a common genetical relation by a fractionation between the melts produced the both trends.

Trace element geochemistry

The trace element variations repeat the above-outlined two different trends. The contents of Ti, Zr are higher in the unit 1 granitoids, while those of Ba and Rb are lower in comparison with the rocks of units 2 and 3. The granitoids of unit 1 are relatively richer of Co, Cr and Ni and with lower level of concentrations of Cu, Zn and Pb, comparing those of units 2 and 3. Many peculiarities of the variations are consistent with fractionation of an assemblage dominated by increasing proportions of feldspars to mafic minerals.

The Rb vs Sr correlation for the granitoids of units 2 and 3 only (Fig. 8) is juxtaposed with some vectors of fractionation, calculated for different degrees (F = 0, 0.2 and 0.4) and D_s for acid melts. The combined fractionation of biotite and hornblende explains this high negative correlation.

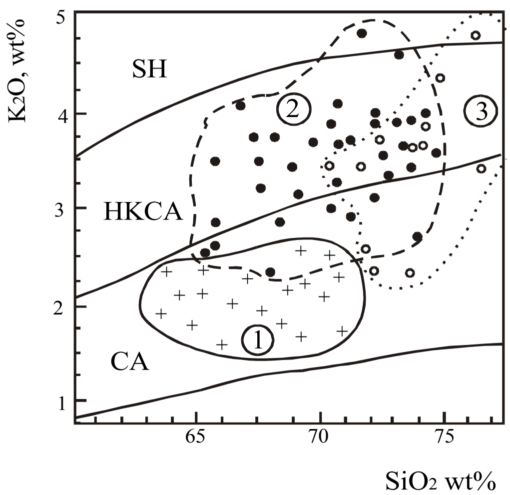

Fig. 7. SiO_2 vs. K_2O plot, according to Peccerillo & Taylor (1976) with the fields of unit 1 (crosses), unit 2 (solid circles), unit 3 (open circles) granitoids of Rila-West Rhodopes Batholith. Series: CA - calc-alkaline; HKCA - high-K calc-alkaline; SH - shoshonitic. The boundary between calc-alkaline and high-K calc-alkaline series in the interval of 70-78% wt. SiO_2 is given according to Ewart (1979). The boundary between HKCA and SH series in the same interval is after Yanev et al. (1995)

Фиг. 7. Диаграма SiO_2 – K_2O по Peccerillo & Taylor (1976) с полета за единиците 1 (кръстчета), 2 (черни точки) и 3 (празни кръгчета). Серии: CA – калциево-алкална; HKCA –високо-К калциево-алкална; SH – шошонитова. Границата между сериите CA и HKCA в интервала от 70 до 78% SiO_2 са по Ewart (1979), а тази между HKCA и SH серии е по Янев и др. (1995)

Table 8. *Representative new chemical analyses of the granitoides from the Rila-West Rhodopes Batholith*
Таблица 8. *Представителни нови химични анализи на гранитоидите от Рило-Западнородопския батолит*

Rock	1			2						3			
Samp.No	II\WR	IV\WR	VI\WR	XIII\WR	107\WR	109\WR	115\WR	132\WR	110\WR	83\WR	123\WR	125a\WR	IX\WR
SiO_2	64.39	66.11	69.39	70.48	71.86	73.07	72.11	71.90	73.02	73.99	74.01	76.25	73.69
TiO_2	0.60	0.37	0.35	0.27	0.20	0.16	0.17	0.13	0.25	0.38	0.08	0.08	0.29
Al_2O_3	15.62	16.37	16.90	14.83	14.29	14.26	14.11	12.70	14.03	14.49	12.80	12.36	14.48
Fe_2O_3	2.47	3.01	0.98	0.98	1.29	0.48	1.44	3.40	1.17	0.65	1.32	1.58	1.01
FeO	3.08	1.75	1.35	1.36	0.88	0.85	1.16	0.50	0.83	0.38	1.50	0.55	0.90
MnO	0.06	0.07	0.03	0.02	0.04	0.02	0.03	0.03	0.03	0.05	0.04	0.03	0.04
MgO	1.81	1.18	1.60	0.65	0.40	0.18	0.50	0.60	0.34	0.42	0.64	0.35	0.50
CaO	4.89	4.50	4.34	2.20	2.08	2.12	2.13	2.09	2.24	1.36	1.40	1.42	1.81
Na_2O	3.17	3.80	3.77	4.44	3.97	3.77	4.31	4.38	2.90	3.43	4.21	3.77	4.74
K_2O	2.16	1.63	1.68	4.09	4.80	4.69	3.85	3.85	3.97	3.73	3.81	3.37	2.26
P_2O_5	0.19	0.15	0.16	0.22	0.04	0.17	0.03	0.17	0.07	0.40	0.16	0.02	0.03
H_2O^-	0.19	0.12	0.11	0.13	0.20	0.14	0.15	0.22	0.13	0.08	0.18	0.15	0.10
L.O.I.	0.92	0.90	0.25	0.33	0.44	0.31	0.50	0.44	0.14	0.48	0.17	0.37	0.20
Total	100.08	99.96	100.08	99.98	100.49	100.22	100.49	100.41	100.38	99.58	100.32	100.30	100.85
Cr	49	30	26	17	11	15	16	41	17	30	24	20	32
V	66	35	26	31	20	18	30	35	28	2	5	10	12
Co	10	-	10	5	5	5	5	8	5	3	3	2	-
Y	26	18	19	19	17	28	28	30	34	10	21	17	20
Nb	18	8	-	10	10	11	10	13	12	14	10	8	9
Sr	739	719	647	336	207	131	183	255	173	627	180	237	180
Rb	107	75	76	163	176	188	144	167	155	415	179	127	74
Ba	771	333	347	588	560	250	380	147	410	890	430	450	647
Zr	201	224	218	160	103	79	120	103	126	118	36	80	169
Pb	-	-	24	28	60	58	54	34	40	32	70	46	165
ASI_{bulk}	0.95	1.02	1.06	0.93	0.91	0.94	0.93	0.84	0.95	1.20	0.94	0.99	1.07

Major element were analyzed by wet silicate analysis (analysts R. Spassova, K. Krasteva, T. Kurteva). Co, Ni, Cu, Zn ,and Pb were determined by AAA (E. Landjeva). Cr, V, Ba, Sr, Zr, Y and Nb were obtained by X-ray fluorescence on fused discs (M. Karadjov, Geological Institute, BAS and E. Ivanova, Geological Survey Geochemical Laboratory)

Главните елементи са определени с мокър силикатен анализ (аналитици Р. Спасова, К. Кръстева, Т. Куртева). Co, Ni, Cu, Zn и Pb са определяни чрез ААА (Е. Ланджева). Cr, V, Ba, Rb, Sr, Zr, Y и Nb са получени по метода РФА върху стопилки (М. Караджов, Геологически институт на БАН и от Ел Иванова, Геохимична лаборатория на АД “Геология и геофизика”)

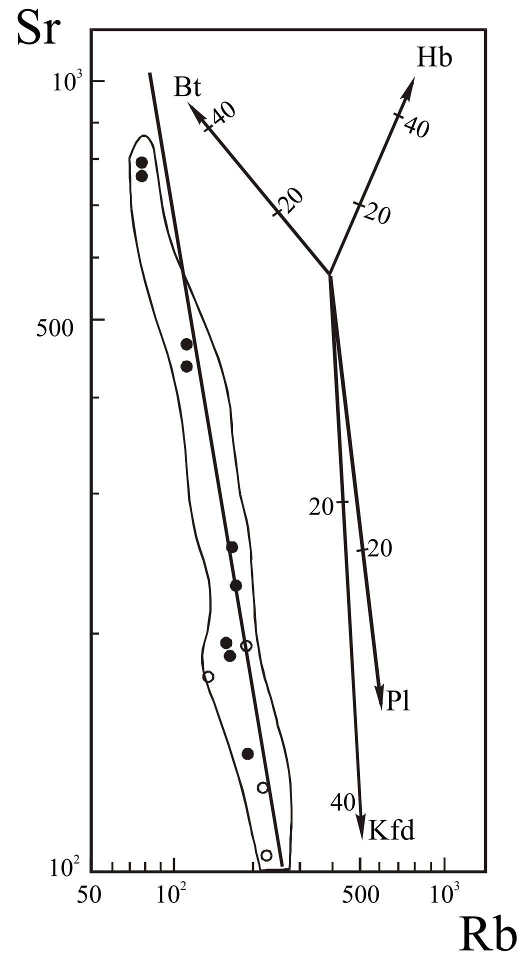

Fig. 8. Rb vs. Sr plot with fractionation vectors for biotite (Bt), hornblende (Hb), plagioclase (Pl), and K-feldspar (Kfd). The proportions of fractionated minerals from a provisional parental magma are marked to produce comparable changes in the concentrations of Rb and Sr. Only selected analyses of unit 2 and unit 3 are used

Фиг. 8. Диаграма Rb – Sr с вектори на фракционирането за биотита (Bt), амфибол (Hb), плагиоклаз (Pl) и К-фелдшпат (Kfd). Отбелязани са пропорциите на фракциониращите се минерали от условна родоначална магма за сравними изменения в концентрациите на Rb и Sr. Използвани са само избрани анализи от единиците 2 и 3

The Rb/Sr ratio increases with differentiation (Fig. 9). This fact clearly indicates the involvment of plagioclase and biotite+hornblende in their magma evolution. The average geochemical types granitoids A, S and I (taken from Harris et al., 1986) are plotted on the same figure. The trend of the common evolution of the granitoids of units 2 and 3 demonstrates the geochemical changes directed from the geochemical I-type to S-type granitoids (Chappel and White, 1974).

Similar diagram K/Rb vs. Rb (Fig. 10) includes our new analyses from all rock units. The field of unit 1 granitoids owes its trend to a fractionation of hornblende and plagioclase (we must add to this association titanomagnetite, as well). The unit 2 trend is explicable by a combined control of biotite (strong) and of K-feldspar (weaker and concerning only the varieties with porphyry textures). Natural continuation of the trend 2 is that one of the unit 3, where the average geochemical S-type is plotted. The modification of the slope of this field is almost parallel to the vector of K-feldspar fractionation and the average S-type granite falls here as well. These features emphasize the much greater role of the fluid

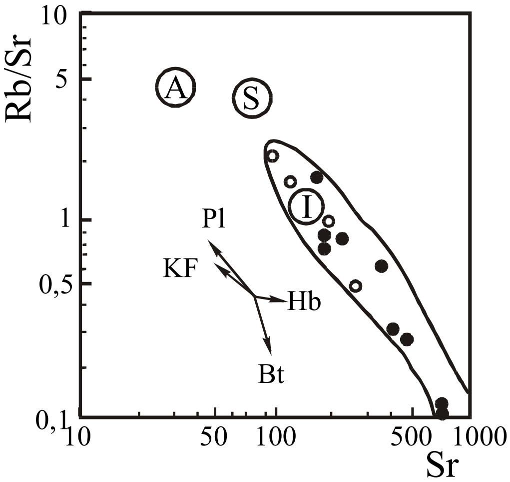

Fig. 9. Rb/Sr vs. Sr plot for units 2 (closed circles) and 3 (open circles) selected analyses. The average compositions of the geochemical I, S and A types granites and the fractionation vectors are taken from Harris et al. (1986). The other symbols as in Fig. 8

Фиг. 9. Диаграма Rb/Sr – Sr за избрани проби от единиците 2 (черни точки) и 3 (празни кръгчета). Средните състави на геохимичните типове гранити I, S и A и векторите на фракциониране са взети от Harris et al. (1986), а другите символи са както на фиг. 8

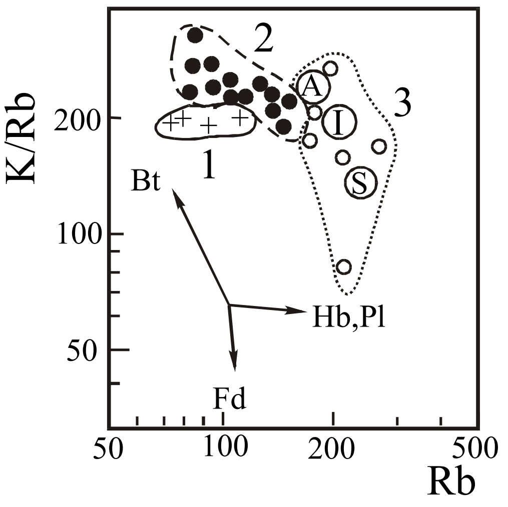

Fig. 10. K/Rb vs. Rb plot for representative analyses of all rock units. The fractionation vectors are for biotite (Bt), amphibole (Hb), plagioclase (Pl), and K-feldspar (Fd). S, A and I are the average geochemical types granitoids (Harris et al., 1986)
Фиг. 10. Диаграма K/Rb – Rb за представителни анализи от всички скални единици. Нанесени са векторите на фракциониране за биотит (Bt), амфибол (Hb), плагиоклаз (Pl) и K- фелдшпат (Fd). S, A и I са средните геохимични типове гранитоиди (Harris et al., 1986)

differentiation in the final stages of the magma evolution of granitoids of unit 2.

The petrographical, mineralogical and chemical criteria (Atherton and Tarney, 1979; Pitcher, 1983) point to the assignment of the unit 1 granitoids to the I-type (Cordillierian subtype), those of unit 2 are similar to I-type (Caledonian subtype) and the ones of unit 3 - to the S-type. The initial Sr-isotopic ratio (0.70727, Peytcheva et al., 1998) also supports such provisional assignment.

Variations of K/Rb and K/Ba ratios with $^{87}Sr/^{86}Sr$ are investigated. The average K/Rb ratio of the unit 1 granitoids is 175, which is slightly lower than of the metapelitic metamorphic rocks (average ~210, Cherneva et al., unpubl. report, cited after Marchev et al., 1998). The mantle source with slight crust contamination is therefore possible. The average K/Rb ratios of the units 2 and 3 are 250 and 280 respectively, suggesting that derivation of their magmas directly from the magma of unit 1 granitoids is not logical and that a contribution of the upper crustal contamination is more plausible.

Table 9. *Representative rare earth element analyses (in ppm) of Rila-West Rhodopes Batholith*
Таблица 9. *Представителни анализи на редкоземни елементи от скалите на Рило-Западнородопския батолит*

	1				2				3		
	II	IV	V	VI	X	XI	XII	XIII	III	VII	IX
La	23	25	25	22	47	19	20	27	2	28	29
Ce	54	63	60	53	107	43	47	63	5	3	12
Nd	24	26	24	20	40	21	21	26	2	27	29
Sm	3.30	3.50	3.40	2.60	4.90	2.70	2.80	3.60	1	3.50	2.90
Eu	0.34	0.25	0.22	0.33	0.42	0.26	0.23	0.24	0.10	0.50	0.34
Gd	3.00	3.20	3.10	2.90	3.60	2.60	2.70	3.30	0.50	3.40	2.90
Yb	1.00	0.88	0.81	1.10	0.60	0.81	0.78	0.82	0.10	0.52	0.82
Lu	0.14	0.12	0.11	0.14	0.09	0.10	0.09	0.11	0.08	0.08	0.11

ICP-AES was performed of selected samples on trace element solutions, preconcentrated (x10), from which the major elements had been removed by ion-exchange (L. Alexieva, Sofia University)
Анализите са извършени по метода ICP-AES върху разтвори на елементите-следи от избрани проби, преконцентрирани (x10), от които главните елементи са били отстранени чрез йонен обмен (Л. Алексиева, Софийски университет)

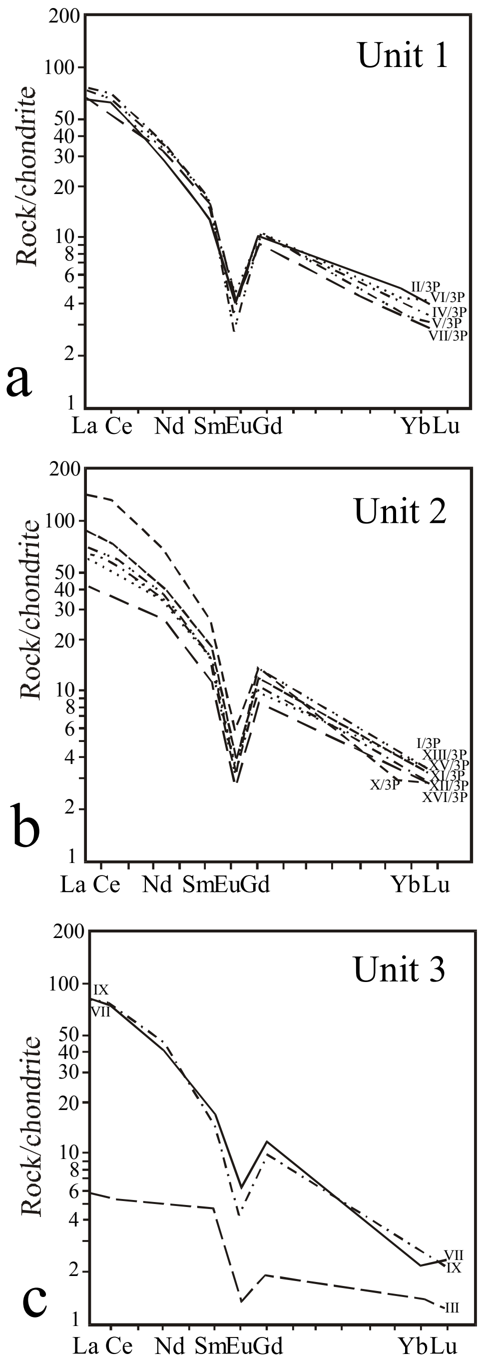

Fig. 11. Chondrite-normalized REE distributions
Фиг. 11. Хондрит-нормализирани разпределения на редкоземни елементи

The K/Ba ratios of the rocks from the batholith with different $^{87}Sr/^{86}Sr$ ratios are higher than those of the lower crustal material, which typically has lower K/Rb ratios (~19, Taylor and McLennan, 1985). The average K/Ba ratio of the unit 1 granitoids is 37 (23-43) and it does not differ considerably from the one of the lower crust. It means that either the low crust (amphibolites for example) source or the mantle one, slightly contaminated with upper crustal material, is possible for their magmas. The average K/Ba ratios of the units 2 and 3 rocks are 106 (58-217) and 154 (32-397) respectively and they are consistent with the stronger contamination of their parental magmas with upper crustal matter.

Selected chondrite-normalized REE distributions are presented in Fig. 11 (Table 9).

From the calc-alkaline (CA) unite 1 granitoids to high-K calc-alkaline (HKCA) unit 2 granites there is a progressive LREE enrichment, whreas the HREE remain constant low. La_n/Yb_n ratio varies from 13 to 21

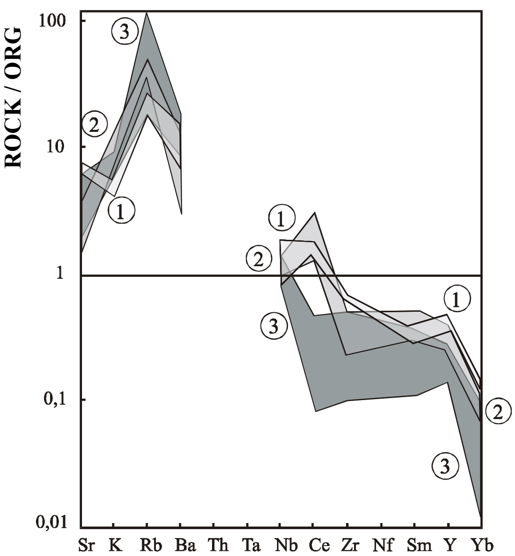

Fig. 12. ORG-normalized trace element diagrams (Pearce et al., 1984): 1 - unit 1 field; 2 - unit 2 field; 3 - unit 3 field
Фиг. 12. Нормализирани към океанско-хребетен гранит спайдерграми за елементите-следи (Pearce et al., 1984): 1 – поле за анализи от единицата 1; 2 – поле за единицата 2 и 3 – поле за единицата 3

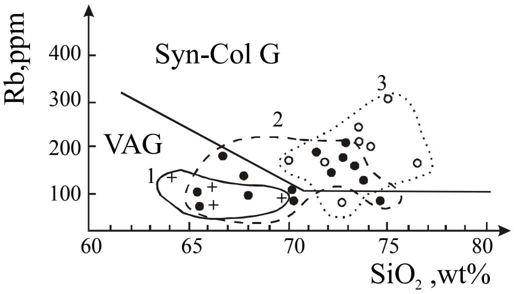

Fig. 13. Rb vs. SiO_2 discriminant diagram (Pearce et al., 1984). VAG - volcanic-arc granites; Syn-Col G- syn-collisional granites. The figures to the fields mark the units 1, 2 and 3 granitoids

Фиг. 13. Дискриминантна диаграма Rb – SiO_2 (Pearce et al., 1984). VAG – вулканско-дъгови гранити; Syn-Col G – синколизионни гранити. Цифрите в полетата отбелязват гранитоидите от единиците 1, 2 и 3

(average 17) for unit 1 patterns, which are less fractionated. In the more fractionated patterns of unit 2 granites this ratio varies between 16 and 52 (av. 27). In the patterns of unit 3 the average La_n/Yb_n ratio is comparable with the

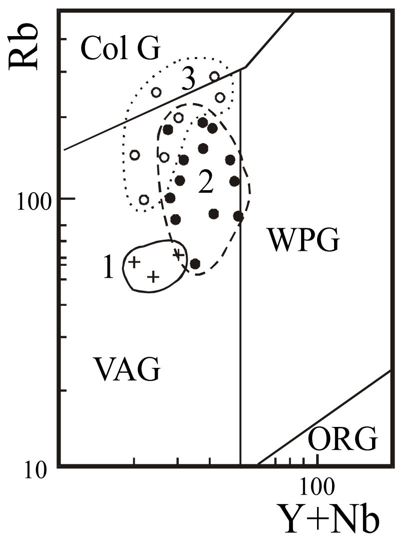

Fig. 14. Rb vs. Y + Nb discriminant diagram (Harris et al., 1986). Abreviations are as in the Fig. 13 except WPG - within-plate granite and ORG - ocean-ridge granite

Фиг. 14. Дискриминантна диаграма Rb – Y + Nb (Harris et al., 1986). Съкращенията са както на фиг. 13, с изключение на WRG – вътрешно-плочови гранити и ORG – океанско-хребетни гранити

one for unit 2 and this supports the idea of their genetical common evolution. In part of the two-mica aplitoid granites a typical for depleted remnant melts REE distribution is noted: low sum of REE and flat REE pattern (Fig. 11, c).

The REE patterns are in accord with an enriched mantle source for unit 1 magma, containing garnet and plagioclase. The more dispersed patterns of unit 2 in their LREE ends admits not only different melting degrees, but possibilities for existence of a heterogenic source in the base of the crust or subduction-enriched mantle. The patterns do not exclude the contamination phenomenae in the formation of this type magma.

The negative Eu-anomalies are distinct. The relatively slight decrease of this anomaly in the unit 3 granitoids shows the role of the fluid differentiation, connected with relatively enrichment of K-feldspars in these rocks.

Tectonic discriminations

Incompatible element patterns on ocean-ridge granite (ORG)-normalized spidergrams (Fig. 12), according to Pearce et al., (1984) show marked enrichment in K, Ba and Rb relative to Zr, Sm, Y, Yb (HFSE). These features are typical of volcanic-arc (VAG) and collision-related granites (ColG). The pattern for unit 1 granitoids exhibits lower positive Rb anomaly and less depleted HFSE model. K and Rb normalized abundances increase progressively from the CA - unit 1 to HKCA - units 2 and 3 granitoids. This corresponds to the transitional to collision-related setting of these granitoids. The pattern of unit 3 granites is more dispersed in its HFSE end and resembles the typical for acid magma-remnants affinity.

On the Rb vs. SiO_2 (Pearce et al., 1984) diagram (Fig. 13) the unit 1 samples fall in the field of VAG. The field of unit 2 rocks falls in volcanic-arc setting (VAG) and in the neighbouring syn-collisional field. Samples of unit 3 are entirely in the syn-collisional granites.

The plot Rb vs. Y + Nb (Pearce et al., 1984) implies volcanic-arc environment for the

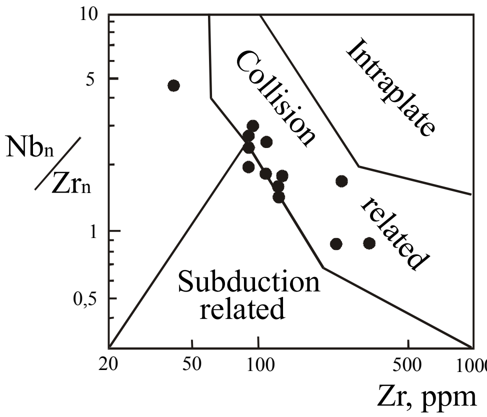

Fig. 15. Zr vs. Nb_n/Zr_n discrimination plot (after Thieblemont, Tegyey, 1994). The normalization is to the values of Nb and Zr in the primordial mantle, using the estimations of Hofmann (1988). Only selected analyses of the units with controversial discriminations 2 and 3 are plotted

Фиг. 15. Дискриминантна диаграма Zr – Nb_n/Zr_n (по Thieblemont, Tegyey, 1994). Нормализацията е към стойностите на Nb и Zr в примитивна мантия по оценките на Hofmann (1988). Нанесени са избрани анализи с противоречиви дискриминации от единиците 2 и 3

units 1 and 2 granitoids. The prevailing part of unit 3 granites falls partially in the collisional granite field (Fig. 14).

The contents of some HFSE (Nb and Zr) and LILE (Rb) elements (Fig. 15) classify the units 2 and 3 granitoids as typically collision-related (Thieblemont, Tegyey, 1994), when only the new analyses of these units are plotted.

The ambiguity in the discriminations is manifested also in the diagrams of Abdel-Rahman (1994) providing discrimination for studied biotites. Three distinctive biotite compositional fields are exhibited on Al_2O_3 vs. FeO_t plot (Fig. 16). The trends of the fields for units 1 and 2 biotites are with similar characteristics, but they do not suggest a common magma evolution by fractional crystallization. The negative correlation between Al_2O_3 and contaminated mantle-derived composition, which in age and petrological characteristics is a separate older FeO_t in the biotite composition assumes isomorphism between Al and Fe in the octahedral sites ($2Fe^{2+} \Leftrightarrow 2Al$, for instance). Such type replacement is more typical in the alkalic systems than in the systems with subduction-related signature of their plutonites. The calc-alkaline affinity of the unit 1 granitoids and the peraluminous one of the unit 2 granitoids are in line with the idea of their subduction-related and collision-related settings. The position of the field of unit 3 biotites is difficult to be understood. It may be the case of crystallization of the aplitoid remnant at shallower depth.

The geochemical discrimination between syn-collisional and post-collisional magmatism is still equivocal. It is quite possible the units 2 and 3 granitoids having a mixed geochemical signature to be assigned to the post-collisional granites. The thermal relaxation after the collision would lead to temperature increasing of the Lower Crust, which would initiate melting when the temperature exceeded the tonalite solidus. But in case the area was subject to quick uplifting, as a result of adiabatic decompression, the melting should start in the Upper mantle, as well. The both conditions are possible to be coincided and then magmas with mixed geochemical charateristics could be produced. The LILE-enriched mantle wedge above the subducted oceanic lithosphere could be the mantle source and the later crustal melts in the base of the Crust - its contaminant.

Isotopic results

According to our new Rb-Sr and U-Pb isotope investigations (Peytcheva et al., 1998) unit 1 granitoids (Grancharitza and Belmeken bodies) are with mixed crustal-mantle source and represent an older (~80 Ma, U-Pb zircon method) synmetamorphic pluton. Ages of 42 Ma, U-Pb zircon method, and 35-37 Ma, (Rb-Sr isochrones) have been determined for the granitoids from unit 2 and respectively unit 3. Isotope-geochemical data suggest their magma-generation during the late- to post-orogenic extension.

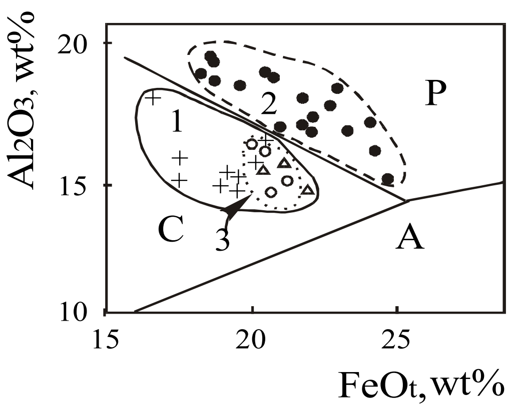

Fig. 16. FeO_{tot} vs. Al_2O_3 (wt.%) biotite discrimination diagram (after Abdel-Rahman, 1994). Fields of discriminated granites: P - peraluminous; C - calc-alkaline; A - alkaline. The figures 1, 2 and 3 stand for the units granitoids

Фиг. 16. Дискриминантна диаграма FeO_{tot} – Al_2O_3 (тегл.%) по състава на биотити (по Abdel-Rahman, 1994). Полета за дискриминираните гранити: P – свръхалуминиеви; C – калциево-алкални и A – алкални. Цифрите 1, 2 и 3 означават полетата единици гранитоиди

It is striking peculiarity that the initial $^{87}Sr/^{86}Sr$ ratio of the Rila-West Rhodopes Batholith is rather low (0.7079) in contrast to the ones of the Pirin plutons, believed to be crust-derived. This ratio is 0.71209 for the Dautovo pluton (Zagorchev, Moorbath, 1983), 0.71062 for the Bezbog pluton, as well as 0.71052 for the Central Pirin pluton (Zagorchev, Moorbath, 1987). Similar to the investigated granitoids is the Elatia pluton, showing even lower Sr-characteristics (0.70604, Soldatos, Christofides, 1986) and having probably higher mantle contribution.

Summary and conclusions

The geochemical features, equivocal tectonic discriminations (similar to those of arc-related suites and at the same time close to the post-orogenic affinity) might reflect involvement of mantle sources, modified by previous subduction processes. Geological and tectonic restorations, as well as the newly obtained timing of the intrusions, indicate that the acid plutonites of the studied massifs are related mostly to the late/post orogenic lithospheric extension. Therefore, the calc-alkaline affinity and isotopic data of the granitoids of unit 1 (Grancharitza body) demonstrate a crust - (Late Cretaceous) fragment of a synmetamorphic pluton. Units 2 and 3 granitoids are genetically related in between phases of a much younger in age (40-35 Ma) post-metamorphic pluton. Isotopically they show mixed mantle-crust features, but with significantly higher involvement of crustal component than the Late Cretaceous bodies.

Two-stage model is proposed for the formation of the studied granitoids. In the first stage mantle-derived magmas had obtained much of their hybrid character at a melting and mixing zone near the base of the continental crust through a complex interplay of recharge, assimilation and fractional crystallization. The older plutonic bodies of the granitoids of unit 1 could be one of the possible candidates for the source of the parental magma of granitoids of units 2 and 3, but amphibolites from the country rocks could not be excluded, as well. The second stage is an intracrustal process dominated by fractional crystallization, associated with limitted assimilation of crustal material. Biotite and feldspars made up the likely fractionation assemblage. The crustal contamination and the advanced crystallization increased the water contents of the magmas so that unit 3 granitoids are genetically connected with unit 2 with a common fluid-crystallization differentiation. The revealed genetical trends of the geochemical and mineralogical features of the rocks from units 2 and 3 are in line with such a speculation. Further isotopic constraints are needed to support or refute this model, but we believe that here-presented data infuses a new sense in the notion of the Rila-West Rhodopes Batholith.

*Acknowledgements.*This work was financed partially by the Bulgarian Fund "Scientific Research" (Project HZ-529/95). We acknowledge the help in the electronic drawing of the figures by I. Maslarov.

References

Abdel-Rahman, D. M. 1994. Nature of biotites from alkaline, calc-alkaline and peraluminous magmas. – *J. Petrol.*, **35**, 525-542.

Allen, J. C., A. Boettcher, 1978. Amphiboles in andesite and basalt II: Stability as a function of P - T - fH_2O - fO_2. - *Amer. Mineral,* **63**, 1074-1087.

Arnaudov, V. 1979. Controversial questions about the age of the "Southbulgarian granites". - *Geologica Balc*., **9**, 2, 37-50 (in Russian).

Arnaudov, V., R. Arnaudova. 1981. Granitoid formation sequence in Pirin, Rila and Rhodopes: Structural investigations of potassium feldspars. - *Geologica Balc*., **11**, 2, 33-42 (in Russian).

Arnaudov, V, M. Pavlova, B. Amov, T. Baldjieva. 1974. Age and genesis of pegmatites from Southern Bulgaria: Pb isotopic data of their feldspars. – In: *Mineral Genesis*, Sofia, Bulgarian Acad. Sci., 315-331 (in Bulgarian).

Arnaudov, V., R. Arnaudova, G. Panajotov. 1977. Distribution of lead in the granitoids of South Bulgaria and their correlation. - *Geologica Balc*. **7**, 2, 85-98 (in Russian).

Arnaudov, V., R. Arnaudova, G. Panajotov 1988. Distribution of Ba in the potassium feldspar phenocrysts in granitoids from Southern Bulgaria. – *Rev. Bulg. Geol. Soc.*, **49**, 2, 81-92 (in Bulgarian).

Arnaudov, V., B. Amov, B. Bartnitskii, M. Pavlova. 1989. Isotope geochronology of the igneous and metamorphic rocks in the Balkanides and in the Rhodopes. - *XIV Congr. CBGA Ext. Abstracts*, Sofia, 1150-1153 (in Bulgarian).

Arnaudova, R., V. Arnaudov. 1982. Correlative geochemistry and origin of the "South Bulgarian granites". - *Geologica Balc*., **12**, 4, 21-36 (in Russian).

Atherton, M. P., J. Tarney (eds.). 1979. *Origin of granite batholiths: Geochemical evidence*. - Kent, Shiva Publ., 65-75.

Bogatikov, O. A., N. P. Michailov, V. I. Gonshakova. 1981. *Classification and Nomenclature of the Magmatic Rocks.* Moscow, Nedra. 160 p. (in Russian).

Bonchev, E. 1971. *Problems of the Bulgarian Geotectonics*. Sofia, Technika. 204 p. (in Bulgarian).

Boyadjiev, S. 1960. Igneous rocks in Western Rhodopes. – *Yearb. Geol. Surv.*, A, **10**, 1-43 (in Bulgarian).

Boyadjiev, S. 1963. On the age of the South Bulgarian granites. – *Rev. Bulg. Geol. Soc*.**,** **24**, 2, 155-164 (in Bulgarian).

Boyadjiev, S. 1993. Comparative geological correlation of the South Bulgarian granitoids. - *Rev. Bulg. Geol. Soc.,* **54**, 2, 19-35 (in Bulgarian).

Boyanov, I., D. Kozhoukharov. 1968. Structure and block dismembering of the Rhodopes Massif. – *Bull. Geol. Inst., Ser. Geotect., Stratigr. and Lithology*, **17**, 199-226 (in Russian).

Burg, J. P., L. Ricou, Z. Ivanov, I. D. Godfriaux, D. Dimov, L. Klain. 1996. Syn-metamorphic nappe complex in the Rhodope massif: Structure and kinematics. - *Terra Nova*, **8**, 6-15.

Chappel, B. W., A. J. R. White, 1974. Two contrasting granite types. - *Pac. Geol*., **8**, 173-174.

Dabovski, C. 1968. Paleozoic magmatism: South Bulgarian granitoid Formation. - In: *Stratigraphy of Bulgaria.* Sofia, Science and Art, 121-134 (in Bulgarian).

Dimitrov, S. 1939. Ergebnisse und Problemme der petrographischen Forschungen in Bulgarien. – *Ann. Univ. Sofia, Fac. Phys.-Mathem.*, **35**, 3, 225-253 (in Bulgarian).

Dimitrov, S. 1947. The metamorphic and igneous roks of Bulgaria. - In: *Fundamentals of Bulgarian Geology. - Yearbook of the Direction of Geological and Mining Prospecting*, A, **4**, 61-93 (in Bulgarian).

Dimitrov, S. 1958. On the magmatic development and on the related with it ore deposits in Bulgaria. – *Izvest. Akad. Nauk USSR*, ser. Geology, **8**, 3-9 (in Russian).

Ferstatter, G. 1990. Empirical plagioclase-hornblende barometer. - *Geochemistry*, **3**, 328-335 (in Russian).

Gill, J. 1981. *Orogenic Andesites and Plate Tectonics*. Berlin, Heidelberg, New York, Springer, 390 p.

Harris, N. B. W., J. A. Pearce, A. G. Tindle. 1986. Geochemical characteristics of collision-zone magmatism. - In: *Collision Tectonics*, Geol. Soc. Spec. Publ., **19**, 67-81.

Ivanov, V. 1970. The influence of temperature and chemical activity of the potassium on the biotite composition. - *Izvest. Akad. Nauk USSR, ser. Geology,* **7**, 20-30 (in Russian).

Ivanov, Z. 1988. Apercu general sur l'evolution geologique et structurale du massif des Rhodopes dans le cadre des Balkanides. - *Bull. Soc. Geol. France*, **8,** IV, 2, 227-240.

Jakes, P., A. J. R. White. 1972. Hornblendes from calc-alkaline volcanic rocks of island arcs and continental margins. - *Amer. Mineral.*, **57**, 887-902.

Kamenov, B. K., T. Soldatos, S. Sklavounos, A. Andreev. 1990. Petrological comparison between Baroutin-Boujnovo, Elatia and Paranesti plutons from Rhodopes - North Greece and South Bulgaria. - *Geologica Rhodopica*, **2**, 197-213.

Kamenov, B. I. Peytcheva, L. Klain, Y. Kostitsin, K. Arsova. 1997. New mineralogical, petrographical, isotopic-geochemical and structural data on the West-Rhodopes Batholith. – In: *50-years Subject Geology*. Sofia, Univ. Press, 95-98 (in Bulgarian).

Kistler, R. W., E. D. Chent, J. R. O'Neill. 1981. Petrogenesis of garnet two-mica granites in the Ruby Mountains, Nevada. - *J. Geophys. Res.*, **86**, 10591-10606.

Kozhoukharov, D., J. Ivanov. 1961. Some petrostructural peculiarities of the granites westward of Velingrad. – *Trav. Geol. Bulg., ser. Stratigr. et Tect.*, **3**, 339-359 (in Bulgarian).

Leake, B. E., A. R. Woolley, C. E. S. Arps, W. D. Birch, M. C. Jilbert, J. D. Grice, F. C. Hawthorne, A. Kato, H. J. Kish, V. G. Krivovichev, K. Linthout, J. Laird, J. Mandarino, W. V. Maresch, E. H. Nickel, N. M. S. Rock, J. C. Schumacher, D. C. Smith, N. C. N. Stephenson, L. Ungaretti, E. J. W. Whittaker, G. Youzhi. 1997. Nomenclature of amphiboles: Report of the Subcommittee on amphiboles of the IMA Commission on new minerals and mineral names. - *Eur. J. Mineral.*, **9**, 623-651.

LeMaitre R. W., P. Bateman, A. Dudek, J. Keller, M. .J. Lameyre, P. A. Le Bas, H. Sabine, A. Sorensen, A. Streckeisen., A. R. Wolley, B. Zanetin 1989. *A Classification of Igneous Rocks and Glossary of Terms. Recommendations of the IUGS Subcommission on the systematics of igneous rocks*. Oxford, Blackwell, 193 p.

Machev, F. 1993. Petrology of Central Pirin Pluton. – *Rev. Bulg. Geol. Soc.*, 54, 123-137 (in Bulgarian).

Marakushev, A., I. Tararin. 1965. Mineralogical critera for the alkalinity of granitoids. - *Izvest. Akad. Nauk USSR, ser. Geol.*, **3**, 20-38 (in Russian).

Marchev, P., G. Rogers, R. Conrey, J. Quick, O. Vasseli, R. Raicheva. 1998. Paleogene orogenic and alkaline basic magmas in the Rhodope zone: relationships, nature of magma sources, and role of crustal contamination. - *Acta Vulc.*, **10**, 2, 217-232.

Panejah, N. A., M. E. Fedorova. 1973. Hornblende-biotite equilibrity in granitoids. - *News of Moscow Univ.,* Geology, **4**, 94-98 (in Russian).

Pearce, J. A., N. B. W. Harris, A. G. Tindle. 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. – *J. Petrol.*, **25**, 4, 956-983.

Peccerillo, A., S. R. Taylor. 1976. Geochemistry of Eocene calc-alkaline volcanic rocks from the Kastamonu area, northern Turkey. - *Contr. Mineral. Petrol.*, **110**, 304-310.

Perchuk, L. L. 1966. Correlation between the temperature and the distribution coefficient of Ca amongst co-existing amphiboles and plagioclases. – *Dokl. Akad. Nauk USSR*, **169**, 6, 1436-1438 (in Russian).

Perchuk, L. L., I. Ryabchikov. 1976. *Phase Equilibria in the Mineral Systems*. Moscow, Nedra, 258 p. (in Russian).

Peytcheva, I., Y. Kostitsin, E. Salnikova, B. Kamenov, L. Klain. 1998. Rb-Sr and U-Pb isotope data for the Rila-Rhodopes batholith. - *Geochem., Mineral. and Petrol.*, **35**, (in Bulgarian).

Pitcher, W. S. 1983. Granite types and tectonic environment. In: Hsu, K. (ed.) *Mountain Building Processes*. London, Acad. Press, 19-40.

Ragland, P. C. 1970. Composition and structural state of the potassic phase in perthites as related to petrogenesis of a granite pluton. - *Lithos*, **3**, 1, 167-189.

Schmidt, M. W. 1992. Amphibole composition in tonalite as a function of pressure: An experimental calibration of the Al-in hornblende barometer. - *Contrib. Mineral. Petrol.*, **110**, 304-310.

Soldatos, T., G. Christofides. 1986. Rb-Sr geochronology and origin of the Elatia Pluton, Central Phodope, North Greece. - *Geologica Balc.*, **16**, 1, 15-23.

Spear, J. A. 1984. Micas in igneous rocks. In: Bailey (ed.) *Micas*. Reviews in Mineralogy, **13**, 299-355.

Stewart, D. B., T. L. Wright. 1974. Al/Si order and symmetry of natural alkali feldspars and the relationships of strained cell parameters to bulk composition. - *Bull. Soc. Fr., Mineral. Cryst.,* **97**, 356-377.

Stormer, J. C. Jr. 1975. A practical two-feldspar geothermometer. - *Amer. Mineral.*, **60**, 667-644.

Taylor, S. T., S. M. McLennan. 1985. *The Continental Crust: Its Composition and Evolution*. Oxford, Blackwell. 312 p.

Thieblemont, D., M. Tegyey, 1994. Une discrimination geochimique des roches differencie temoin dela diversite d'origine et de situation tectonique des magmas calco-alkaline. - *C. R. Acad. Sci. Paris*, **319**, II, 87-94.

Ujike, O., H. Onuki, 1976. Phenocrystic hornblende from Tertiary andesites and dacites, Kagawa Prefectura, Japan. - *J. Japan. Assoc. Mineral. Petrol. Econ. Geol.,* **71**, 389-399.

Verguilov, V., D. Kozhoukharov, B. Mavroudchiev. 1961. Notes on the West-Rhodope Batholith and its metamorphic mantle. – *Bull. Geol. Inst.*, **9**, 153-197 (in Bulgarian).

Verguilov, V., B. Kamenov, C. Dabovski, S. Savov, I. Haidutov, I. Genov, L. Ivchinova, I. Verguilov. 1986. New data of the petrology and geochemistry of the Sakar Batholith. - In: *Sakar-Strandja Symp.*, **4**, 8, 145-157 (in Bulgarian).

Valkov, V., N. Antova, K. Doncheva. 1989. Granitoids of the Rila-West Rhodopes Batholith. - *Geologica Balc.*, **19**, 2, 21-54 (in Russian).

Zagorchev, I., S. Moorbath. 1983. Rb-Sr data on the age of the Dautovo Pluton (granitoids Pirin type), Southwestern Bulgaria. - *Geologica Balc*., **13**, 4, 31-37 (in Russian).

Zagorchev, I., S. Moorbath, P. Lilov. 1987. Radiogeochronological data of the Alpean metamorphism in the western parts of the Rhodope Massif. - *Geologica Balc*., **17**, 2, 59-71 (in Russian).

Zagorchev, I., P. Lilov, S. Moorbath. 1989. Results of the Rb-Sr and K-Ar radiogeochronological investigations of metamorphic and igneous rocks in South Bulgaria. - *Geologica Balc*., **19**, 3, 41-54 (in Russian) .

Accepted October 18, 1999
Приета на 18. 10. 1999