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I-type granitoids from the Belassitsa Mountain, SW Bulgaria

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Abstract. Two small igneous bodies (0.07 and 0.13 km^2) of nondeformed fine-grained granitoids of similar chemical composition and structure have been established in the Belassitsa Mountain. The essential rock-forming minerals are plagioclase of andesine-labradore composition (An_{58-44} in cores and An_{50-40} in rims) (40%), amphiboles (magnesiohornblende and actinolite) and biotite of magnesian type with Fe/(Fe+Mg) between 0.44-0.48 (with a total content of 20-25% femic minerals), potassium feldspar (20%) and quartz (15%). Common accessory minerals are early magmatic Fe-Ti oxides - magnetite and ilmenite. Magnetite contains a small amount of Ti, V, Si and occurs as single crystals, with or without ilmenite oxyexsolution lamellae (containing 5-38 mol.% $MnTiO_3$). The chemical composition and mineral assemblages of the studied rocks correspond to high-potassium calc-alkaline quartz-monzodiorite and to quartz-diorite which belong to the magnetite series of the I-type. The igneous rocks have crystallized at pressures 3.1-4.5 kbar and temperatures 710-750^{o}C and are believed to be of Paleogene age.

Key words: I-type granitoids, high-potassium calc-alkaline series, SW Bulgaria
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Тарасова, Е., Н. Зидаров, Н. Халтъкова. 2001. I-тип гранитоиди от Беласица планина, ЮЗ България. – *Геохим., минерал. и петрол.*, **38**, 79-88.

Резюме. В Беласица планина са установени две малки интрузивни тела (площ 0,07 и 0,13 км^2) от недеформирани дребнозърнести гранитоиди с близък химичен състав и текстура. В състава им участват: плагиоклаз с андезин-лабрадоров състав (ядра –An_{58-44}, периферия – An_{50-40}) (40%), амфибол (магнезиев обикновен амфибол и актинолит) и биотит (магнезиев с Fe/(Fe+Mg) от 0,44 до 0,48) (фемични минерали общо 20-25%), калиев фелдшпат (20%), кварц (15%). Най-често срещани акцесори са ранномагматичните Fe-Ti оксиди - магнетит и илменит. Магнетитът формира самостоятелни кристали (с ниски съдържания на Ti, V и Si) и е със или без субсолидусни отсмесвания от илменит (съдържа $MnTiO_4$ от 5 до 38 мол.%). Според химичните им и минерални състави скалите са определени като висококалиеви калциево-алкални кварцмонцодиорити и кварцдиорити от магнетитова серия I– тип. Кристализацията на интрузивните тела се е осъществявала при налягане 3,1-4,5 kbar и температури 710÷750^{o}C. Предполага се палеогенска възраст на гранитоидите.

Ключови думи: I-тип гранитоиди, висококалиево калциево-алкална серия, ЮЗ България
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Geological setting

Two small granitoid bodies exposed in the west part of the Belassitsa Mountain (between Skrut and Yavornitsa villages) are embedded in the widely spread two-mica gneisses from the Ograzhden Supergroup (Zagorchev, Dinkova, 1991a, b) and also in serpentinites and weakly

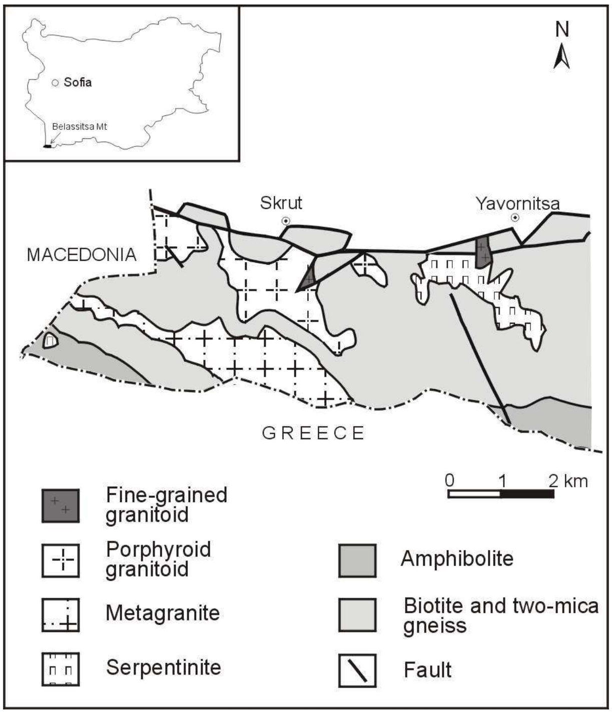


Fig. 1. Schematic geological map of a part of the Belassitsa Mountain after Zagorchev (1991a) with additions by authors

Фиг. 1. Схематична геоложка карта на част от Беласица планина, по Zagorchev (1991a) с допълнения от авторите

deformed porphyroid granites. The bodies cover areas of about 0.07 and 0.13 km^2, respectively, and are attached to faults oriented in N-S direction (Fig.1).

Methods of study

The mineral composition of the rocks was studied by optical microscopy using thin sections and polished surfaces of rock fragments as well as heavy fractions obtained from mechanically disintegrated rock samples. The chemical composition of minerals was analyzed by a electron microprobe (Philips 515SEM with EDS WEDAX-3A spectrometer) at 18 kV using reference standards of albite, diopside, plagioclase, hematite, rutile, sanidine, and V and Mn metals. The main rock forming oxides (in wt.%) were determined by wet chemical analysis and atomic absorption spectrometry (AAS). The content of minor elements, Rb, Sr, Zr, Y, Nb, Cr, V, and Ba was determined by X-ray fluorescence analysis.

Mineral composition

The granitoids studied are fine-grained, with a massive structure and light gray to light green in colour. Their texture is hypidiomorphic. The rocks of the two intrusive bodies have similar mineral compositions represented by plagioclase (40%), hornblende and biotite (with a sum of 20-24%), K-feldspar (20%), quartz (15%), as well as by accessory magnetite, ilmenite, apatite, zircon, scheelite and postmagmatic titanite, hematite, epidote, chlorite, and tourmaline.

Plagioclase forms euhedral, fine-lamellar, zoned crystals with an andesine-labradore composition. The anorthite content decreases

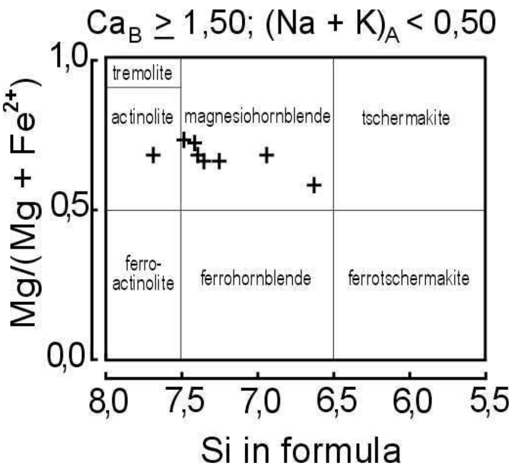
Table 1. *Chemical composition of plagioclase from fine-grained granitoids, wt. %*
Таблица 1. *Химичен състав на плагиоклаз от дребнозърнести гранитоиди, тегл. %*

Sample	108/12 rim	157/33 core	157/34 rim	157/35 core	157/36 rim	158/8 core	158/5 rim	159/25 core	159/27 core	159/24 rim
SiO_2	59.65	57.65	58.57	57.18	58.21	59.22	60.06	56.60	57.48	58.86
Al_2O_3	27.07	27.31	26.75	28.28	27.52	26.73	26.16	28.41	27.75	27.22
CaO	8.06	8.97	8.35	10.30	8.89	7.95	7.19	10.04	9.31	8.53
Na_2O	5.29	4.59	4.96	3.82	5.20	5.45	5.69	4.40	4.47	4.58
K_2O	0.47	0.41	0.41	0.35	0.38	0.21	0.42	0.29	0.29	0.29
Total	100.54	98.93	99.04	99.93	100.20	99.56	99.52	99.74	99.30	99.48
Si	2.633	2.592	2.626	2.551	2.589	2.637	2.671	2.535	2.576	2.622
Al	1.407	1.446	1.412	1.486	1.441	1.402	1.370	1.498	1.464	1.428
Ca	0.381	0.432	0.401	0.492	0.424	0.379	0.343	0.482	0.447	0.407
Na	0.453	0.400	0.431	0.330	0.448	0.471	0.491	0.382	0.388	0.396
K	0.026	0.024	0.023	0.020	0.022	0.012	0.024	0.017	0.017	0.016
Cations	4.900	4.894	4.893	4.879	4.924	4.901	4.899	4.914	4.892	4.869
Ab	52.60	46.80	50.40	39.20	50.20	54.60	57.20	43.40	45.60	48.30
An	44.30	50.50	46.90	58.40	47.40	44.00	40.00	54.70	52.50	49.70
Or	3.10	2.70	2.70	2.40	2.40	1.40	2.80	1.90	1.90	2.00

from the center (An_{58-44}) to the periphery (An_{50-40}) (Table 1). The plagioclase crystal cores are partially affected by postmagmatic sericitization.

Amphibole occurs as individual crystals or aggregates with biotite. Its pleochroic color is green (*z, y*) to yellow-green (*x*). The amphiboles studied are assigned to the group of calcium amphiboles (Ca_B 1.76-1.89, K_A 0.05-0.19 p.f.u., $Mg/(Mg+Fe^{2+})$ 0.58-0.75) and are in the fields of magnesiohornblende and actinolite (according to Leake et al., 1997) (Table 2, Fig. 2). These amphiboles are poor in Al^{IV} and rich in Ti. They often include magnetite and, in some cases, are replaced by epidote, chlorite, and titanite.

Biotite is uniformly distributed in the rocks as individual flakes or intergrowths with amphibole. It displays a clear pleochroism from yellowish-brown to dark brown. The composition of biotite from the two bodies is similar and characterized by fm = $100.Fe_{tot}/(Fe_{tot}+Mg)$ from 44 to 48, and by a



Фиг. 2. Position of amphibole in the classification diagram of Leake et al. (1997)
Fig. 2. Положение на амфибола в класификационната диаграма на Leake et al. (1997)

Table 2. *Chemical composition of amphibole from fine-grained granitoids, wt. %*
Таблица 2. *Химичен състав на амфибол от дребнозърнести гранитоиди, тегл. %*

Sample	108/13	108/15	108/17	157/29	158/1	158/3	159/19	159/20
SiO_2	48.01	52.21	51.85	44.50	49.96	53.42	50.66	51.33
TiO_2	1.22	0.66	0.86	1.16	1.06	0.33	1.01	0.82
Al_2O_3	8.32	4.03	4.32	9.19	5.35	3.09	5.13	4.87
FeO_{tot}	14.08	11.87	12.48	18.66	14.63	12.51	13.43	13.41
MnO	0.50	0.77	0.68	0.65	0.97	0.64	0.61	0.65
MgO	13.72	16.22	15.95	10.40	14.10	15.27	14.52	14.77
CaO	11.48	11.50	11.67	11.80	11.28	12.23	11.59	11.70
K_2O	0.55	0.28	0.36	1.01	0.51	0.23	0.45	0.45
Total	97.88	97.54	98.17	97.37	97.86	97.72	97.40	98.00
Si	6.95	7.49	7.42	6.64	7.26	7.69	7.36	7.40
Al^{IV}	1.05	0.51	0.58	1.36	0.74	0.31	0.64	0.60
Sum T	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Al^{VI}	0.36	0.17	0.14	0.26	0.18	0.22	0.24	0.23
Fe^{3+}	0.32	0.14	0.19	0.65	0.24	0.00	0.10	0.11
Ti	0.13	0.07	0.09	0.13	0.12	0.04	0.11	0.09
Mg	2.96	3.47	3.40	2.31	3.06	3.28	3.14	3.18
Fe^{2+}	1.22	1.15	1.17	1.65	1.42	1.47	1.41	1.40
Sum C	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Fe^{2+}	0.16	0.14	0.13	0.03	0.12	0.04	0.12	0.11
Mn	0.06	0.09	0.08	0.08	0.12	0.08	0.08	0.08
Ca	1.78	1.77	1.79	1.89	1.76	1.89	1.80	1.81
Sum B	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
K	0.10	0.05	0.07	0.19	0.10	0.04	0.08	0.08
Cations	15.10	15.05	15.07	15.19	15.10	15.04	15.08	15.08

Crystallochemical formulae were recalculated on the basis of 23 oxygen atoms

low Al content ($100.Al/(Al+Si+Fe_{tot}+Mg+Mn)$ ratio is from 18.6 to 19.8) (Table 3, Fig. 3). The Ti content is high, being controlled by a replacement of the type $Ti^{IV} + (Fe^{2+})^{V} = 2Al^{VI}$, as proposed by Harrison (1990). This type of isomorphism accounts for the positive correlation observed between the Ti content and the fm value. The biotite contains inclusions of apatite and magnetite, and is partially replaced by chlorite or epidote, a process accompanied by formation of titanite and magnetite.

Potassium feldspar forms xenomorphic grains and fills the interstices between earlier femic

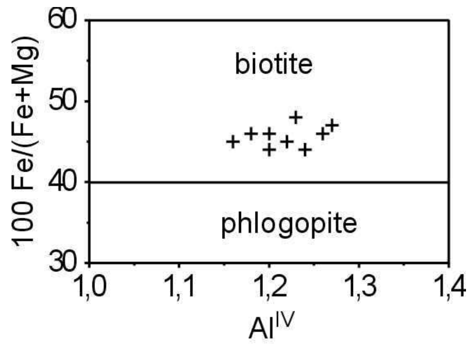


Fig. 3. Position of biotite in the plot 100.Fe/(Fe+Mg) vs. Al^{IV}

Фиг. 3. Положение на биотита в диаграмата

100.Fe/(Fe+Mg) - Al^{IV}

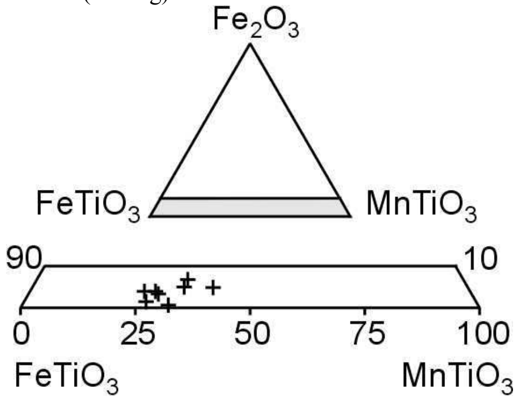


Fig. 4. Composition (mol.%) of ilmenites in $FeTiO_3$-$MnTiO_3$-Fe_2O_3 triangular diagram.
Фиг. 4. Състав (мол.%) на илменити, нанесен върху $FeTiO_3$-$MnTiO_3$-Fe_2O_3 диаграма.

minerals and plagioclase. Fine intergrowths of K-feldspar with quartz are rarely observed as well. The composition of K-feldspar corresponds to Or_{100}. *Quartz* is anhedral and occupies the interstices between other rock forming minerals.

Magnetite is the most abundant accessory mineral. It crystallizes simultaneously with or after plagioclase, but before amphibole. Magnetite forms homogeneous crystals as well as such inclusions of ilmenite resulting from the oxidizing exsolution of primary spinelide. Magnetite contains small amounts of minor elements such as Ti, V, and Si (Table 4). *Ilmenite* inclusions are in the form of thin plates, sometimes containing hematite. Ilmenite occurs also as individual crystals. The mineral is characterized by a high Mn content and considerable variations of the pyrophanite component, in the range 38 mol.% (Table 5, Fig. 4). In co-existing magnetite and ilmenite, V is concentrated selectively in magnetite, while Mn is concentrated in ilmenite. However, the great variations observed in the contents of Mn and Fe^{3+} in ilmenite support the idea that the mineral composition is affected by postmagmatic processes. Late magmatic magnetite, formed during the alteration of femic minerals, is also identified. Magnetite on the crystal peripheries is replaced by hematite, and ilmenite is replaced by titanite. *Zircon* is identified as well-shaped long prismatic crystals in plagioclase. *Apatite* forms small crystals included in biotite, and large ones associated with secondary epidote. Poor vein mineralization, represented by quartz veinlets with pyrite and rarely with pyrrhotite, chalcopyrite, and sphalerite, is established in granitoids.

Chemical characterization

The composition of rocks represented on the (Na_2O+K_2O) vs. SiO_2 diagram (Bogatikov et al., 1983) range between quartz-monzodiorite and quartz-diorite and a tendency of increasing the content of alkaline elements with increasing that of SiO_2 is observed (Table 6, Fig. 5). This is a characteristic feature of the calc-alkaline magmatic series (CA). According to the K_2O content (2.84-3.12 wt.%), the rocks belong to the high-potassium calc-alkaline magmatic series (HKCA) (Peccerillo, Taylor, 1976). This fact is also confirmed by the composition of biotite on the Al_2O_3 vs. FeO_t diagram (Abdel-Rahman, 1994), being in the field of the CA series (Fig. 6). The ASI coefficient, which is

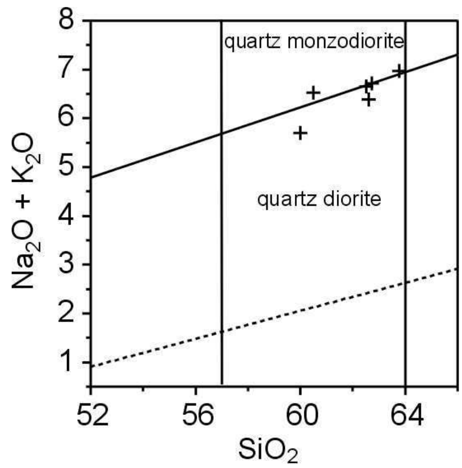


Fig. 5. Classification diagram (Na_2O+K_2O) vs. SiO_2 (Bogatikov et al., 1983), illustrating magmatic series of granitoids
Фиг. 5. Класификационна диаграма (Na_2O+K_2O) vs. SiO_2 (Bogatikov et al., 1983), илюстрираща сериалната принадлежност на гранитоидите

lower than 1.1 (0.98-1.05) and the relatively high content of Na_2O, are proofs that these rocks are I-type granitoids (Fig. 7) (according to Chappell, White, 1974; White, Chappell, 1983). The formation of early magmatic accessory associations of Fe-Ti oxides defines the granitoids as I-type magnetite series (Fershtatter et al., 1982; Ishihara, 1977; Whalen, Chappell, 1988).

Conditions of crystallization

The composition of minerals and the mineral associations themselves, being sensitive indicators of physicochemical parameters such as pressure (P), temperature (T), and fugacity of O_2 (fO_2), were used to evaluate the conditions of crystallization of the granitoids studied. The pressure during granitoid crystallization, according to the Al content in the investigated amphiboles (Hammarstrom, Zen, 1986; Hollister et al., 1987) as well as with respect to the contents of Si and Al in the co-existing amphibole and plagioclase (Fershtatter, 1990), is determined to be within the range of 3.1–4.5 kbar. The crystallization temperature for the equilibrium pair of amphibole-plagioclase is 750-740^oC (Blundy, Holland, 1990), while that for the pair of amphibole-biotite is 730-710^oC (Perchuk, Ryabchikov, 1976). These temperatures are

Table 3. *Chemical composition of biotite from fine-grained granitoids, wt. %*
Таблица 3. *Химичен състав на биотит от дребнозърнести гранитоиди, тегл. %*

Sample	108/14	108/16	108/18	157/31	157/32	158/2	158/4	159/21	159/22
SiO_2	36.15	36.37	37.47	36.43	36.11	37.90	37.29	38.01	38.42
TiO_2	5.79	5.44	5.61	4.09	4.42	3.87	3.03	3.39	3.58
Al_2O_3	13.74	13.97	14.09	14.94	14.73	14.94	14.75	14.35	14.34
FeO_{tot}	19.00	18.15	18.19	18.94	19.13	18.77	18.55	19.68	18.60
MnO	0.49	0.64	0.52	0.55	0.59	0.45	0.57	0.40	0.29
MgO	11.72	12.75	12.31	12.46	12.14	12.48	13.12	12.93	12.91
CaO	0.11	0.13	0.14	0.15	0.11	0.02	0.10	0.20	0.17
K_2O	9.41	9.45	9.45	9.3	9.51	9.44	9.16	8.74	9.06
Total	96.41	96.90	97.78	96.86	96.74	97.87	96.57	97.7	97.37
Si	2.74	2.73	2.78	2.74	2.73	2.80	2.80	2.82	2.84
Al^{IV}	1.23	1.24	1.22	1.26	1.27	1.20	1.20	1.18	1.16
Al^{VI}	0.00	0.00	0.01	0.06	0.04	0.10	0.10	0.07	0.09
Ti	0.33	0.31	0.31	0.23	0.25	0.22	0.17	0.19	0.20
Fe^{2+}	1.20	1.14	1.13	1.19	1.21	1.16	1.16	1.22	1.15
Mn	0.03	0.04	0.03	0.04	0.04	0.03	0.04	0.03	0.02
Mg	1.32	1.43	1.36	1.40	1.37	1.38	1.47	1.43	1.43
Ca	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.01
K	0.91	0.91	0.89	0.89	0.92	0.89	0.88	0.83	0.86
Cations	7.77	7.81	7.74	7.81	7.83	7.78	7.83	7.79	7.77
fm	48	44	45	46	47	46	44	46	45
al	18.8	18.8	18.8	19.8	19.7	19.5	19.3	18.6	18.7
t	11.5	10.5	11.0	7.9	8.7	7.5	5.8	6.6	7.0

fm = $100.Fe_{tot}/(Fe_{tot}+Mg)$; al = $100.Al/(Al+Si+Fe_{tot}+Mg+Mn)$; t = $100.Ti/(Ti+Al)$; crystallochemical formulae were recalculated on the basis of 11 oxygen atoms

Table 4. *Chemical composition of magnetite from fine-grained granitoids, wt. %*
Таблица 4. *Химичен състав на магнетит от дребнозърнести гранитоиди, тегл. %*

Sample	108/2	108/4	108/7	157/9	157/11	157/18	158/20	158/22	158/23
Fe_2O_3	67.42	66.36	66.63	66.43	67.20	67.81	67.36	66.75	67.95
FeO	31.57	31.53	30.83	31.21	31.44	31.00	31.63	31.16	30.92
TiO_2	0.21	0.46	0.16	0.29	0.25	0.19	0.19	-	-
MnO	0.07	0.14	0.17	0.14	0.25	-	0.21	0.20	0.06
V_2O_3	0.46	0.35	0.36	0.43	0.32	0.42	0.38	0.35	0.29
SiO_2	0.32	0.36	0.25	0.33	0.37	-	0.44	0.50	0.12
Total	100.05	99.20	98.40	98.83	99.83	99.42	100.21	98.95	99.33
Fe^{3+}	1.953	1.938	1.963	1.948	1.950	1.980	1.947	1.953	1.984
Fe^{2+}	1.017	1.023	1.009	1.017	1.014	1.006	1.016	1.013	1.004
Ti	0.006	0.013	0.005	0.009	0.007	0.005	0.005	-	-
Mn	0.002	0.005	0.006	0.005	0.008	-	0.007	0.007	0.002
V	0.009	0.007	0.008	0.009	0.007	0.009	0.008	0.006	0.005
Si	0.013	0.014	0.009	0.012	0.014	-	0.017	0.019	0.005
Cations	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
ULV	0.6	1.3.	0.5	0.9	0.7	0.6	0.6	-	-

Content of FeO and Fe_2O_3 was obtained after recalculation of the analyses; ULF - $FeTiO_4$ mol.%

characteristic of moderate–to-high temperature conditions for the rock consolidation. This is also confirmed by the biotite composition, which is poor in Fe and Al and rich in Ti. According to Ivanov (1970), this composition indicates a high chemical potential of K in the melt.

The distribution of Mn in the co-existing amphibole and biotite exhibits a higher content of Mn in amphibole than in biotite (Panejah, Fedorova, 1973) and could serve as evidence for a small depth of the rock consolidation. The crystallization of early magmatic magnetite and the established values of the Fe/(Fe+Mg) ratio in amphibole (Anderson, Smith, 1995) are proofs of the high oxidation potential in the original magma.

The lack of isotope-geochronological data does not allow to age exactly the granitoids formation. On the basis of general geological considerations, it is only the granitoids that can be Paleogene aged, since, according to Zagor-

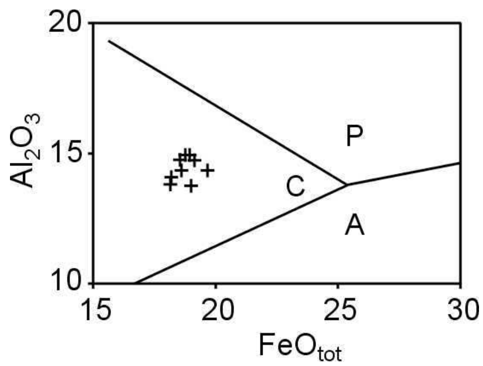


Fig. 6. Position of biotite in Al_2O_3-FeO_{tot} (wt.%) diagram of Abdel-Rahman (1994). Fields of the discriminated granites: A - alkaline; C - calc-alkaline; P - peraluminous

Фиг. 6. Положение на биотита в дискриминантната диаграма Al_2O_3 - FeO_{tot} (тегл.%) на Abdel-Rahman (1994). Полета на дискриминираните гранити: A - алкални; C - калциево-алкални; P – пералуминиеви

Table 5. *Chemical composition of ilmenite from fine-grained granitoids, wt.%*
Таблица 5. *Химичен състав на илменит от дребнозърнести гранитоиди, тегл.%*

Sample	108/1	108/3	108/5	157/8	157/10	157/16	158/21	159/26
TiO_2	49.71	51.25	48.97	48.33	51.86	49.38	47.79	49.78
FeO	31.80	33.73	31.99	28.66	31.79	33.39	28.07	26.18
Fe_2O_3	5.52	2.32	5.89	7.43	0.64	5.91	10.23	7.38
MnO	12.74	12.20	12.42	14.95	14.83	11.36	14.93	18.20
CaO	-	-	-	-	-	0.22	-	0.12
SiO_2	-	-	0.45	0.29	0.15	0.41	0.18	-
Total	99.77	99.50	99.72	99.66	99.27	100.67	101.20	101.66
Ti	0.95	0.98	0.93	0.92	0.99	0.93	0.96	0.93
Fe^{2+}	0.67	0.72	0.68	0.61	0.68	0.69	0.63	0.54
Fe^{3+}	0.11	0.04	0.11	0.14	0.01	0.12	0.07	0.14
Mn	0.27	0.26	0.27	0.32	0.32	0.24	0.34	0.38
Ca	-	-	-	-	-	0.01	-	-
Si	-	-	0.01	0.01	-	0.01	-	-
Cations	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Ilm	67.4	71.6	67.8	60.8	67.5	70.2	58.7	54.6
Phyr.	27.3	26.3	26.6	32.1	31.9	24.2	31.6	38.5
Hem	5.3	2.1	5.6	7.1	0.6	5.6	9.6	6.9

Contents of FeO and Fe_2O_3 were obtained after recalculation of the analyses

chev and Dinkova (1991), the intrusive bodies are closely related to Paleogene faults. On the discrimination diagram for Rb/Zr vs. SiO_2 the composition of the rocks studied lies in the field corresponding to the post-collision and volcanic-arc granite (Fig. 8). The proposed Paleogene age of the granitoids correlates well with their post-collision genesis.

The data obtained allow to correlate the granitoids under study with other intrusives in the region of Belassitsa. For example, the Teshevo pluton (Machev, Rashkova, 1995) shows petrochemical and mineral characteristics similar to those of the studied granitoids.

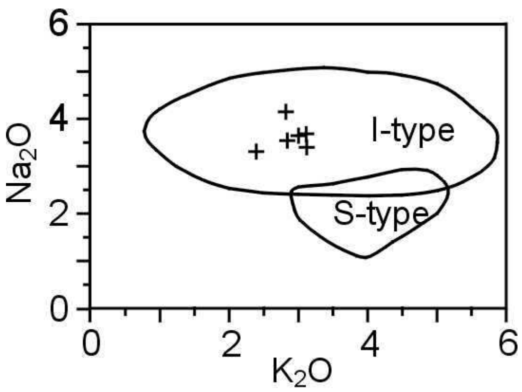


Fig. 7. Na_2O vs. K_2O (wt.%) discrimination diagram for S- and I-type granites of White and Chappell (1983), illustrating correspondence of granitoids to I-type
Фиг. 7. Na_2O-K_2O (тегл.%) диаграма за дискриминиране на S- и I-тип гранити на White & Chappell (1983), илюстрираща принадлежност-та на гранитоидите към I тип

Conclusion

The investigation of the fine-grained granitoids from the western parts of Belassitsa has shown that the rocks are: post-metamorphic, post-

Table 6. *Chemical composition of fine-grained granitoids, wt. %*
Таблица 6. *Химичен състав на дребнозърнести гранитоиди, тегл. %*

Sample	108	157	158	159	7021	988
Major elements, wt.%						
SiO_2	62.50	62.60	60.50	60.00	62.73	63.76
TiO_2	0.75	0.75	0.92	0.92	0.50	0.41
Al_2O_3	17.40	17.44	17.34	17.40	17.62	16.31
Fe_2O_3	2.52	2.57	2.46	2.82	2.49	1.65
FeO	1.92	1.56	2.52	2.52	2.12	2.62
MnO	0.09	0.07	0.09	0.07	0.14	0.10
MgO	2.00	1.83	2.41	2.49	2.12	2.62
CaO	4.66	4.34	4.69	4.72	4.62	3.50
Na_2O	3.65	3.54	3.40	3.31	3.66	4.15
K_2O	3.00	2.84	3.12	2.39	3.05	2.82
H_2O^-	0.12	0.24	0.22	0.40	0.09	0.09
H_2O^+	0.50	1.19	1.06	1.60	0.33	1.24
Total	99.11	98.97	98.73	98.64	99.55	99.20
ASI*	0.98	1.02	0.99	1.05	0.99	1.00
Trace elements, ppm						
Ba	970	940	870	700	-	-
Rb	118	105	109	110	-	-
Sr	450	458	406	405	-	-
Nb	25	25	27	27	-	-
Zr	119	208	214	221	-	-
Y	37	40	39	43	-	-
V	70	60	70	100	-	-
Cr	13	11	20	9	-	-

ASI = $Al_2O_3/(CaO+K_2O+Na_2O)$ (mol. %) is calculated without correction for the CaO content in apatite; analyses 7021 и 988 are according to Zidarov (unpublished data, 1966)

collisional, high-potassium calc-alkaline quartz monzodiorites and quartz diorites of the I-type magnetite series. Their crystallization has occurred under pressures of 3.1 to 4.5 kbar and at temperatures from 710 to 750° C. On the basis of the data discussed, the granitoids studied can be of Paleogene age. All these data allow to correlate the granitoids under study with other intrusives in the region of Belassitsa.

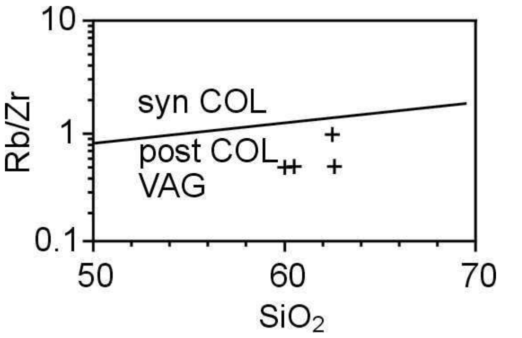


Fig. 8. Position of granitoids on Rb/Zr vs. SiO_2 discrimination diagram of Harris at al. (1986). Fields of the discriminated granites: syn COL - syn-collisional; post COL - post-collisional and VAG - volcanic-arc
Фиг. 8. Положение на гранитоидите в Rb/Zr - SiO_2 дискриминантна диаграма на Harris at al. (1986). Полета на дискриминираните гранити: syn COL - синколизионни; post COL – постколизионни и VAG - вулканско-дъгови

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