

## **DYKE ROCKS RELATED TO THE GRANITOID PLUTONS FROM THE SOUTH CARPATHIAN GRANITOID PROVINCE, ROMANIA\***

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The present paper is referring to the dyke rocks related to the granitoid plutons from the South Carpathian granitoid province, which includes Late Precambrian to Ordovician intrusions (600 to 350 Ma). The dyke rocks usually inherited the geochemical characteristics of the granitoid plutons they are related to. They form a calc-alkaline series with a weak alkaline tendency. The parental magmas of the dyke rocks originated in the same magma chambers the parental magmas of the related granitoid plutons derived from. The dyke rocks occurred in the granitoid province after the intrusion of the granitoid plutons, when the host crystalline schists and the granitoid plutons had cooled off, and in the consolidated area different types of joints and initial fractures had occurred, along which the dyke rocks intruded.

*Key words:* Dyke rocks; Occurrence; Petrography; Classification; Geochemistry; Tectonic setting; Origin.

### **INTRODUCTION**

The granitoid plutons and the lamprophyres from the South Carpathian granitoid province (SCGP) have been studied in some previous papers (Savu<sup>1-3</sup>), in which their petrology, geochemistry and origin have been presented. But for a full characterization of this petrographic province, there must be studied the dyke rocks related to the granitoid plutons, too. On this purpose I presented in this paper a short but thoroughly description of these rocks, based mostly on the available geochemical data from the geological literature.

### **OCCURRENCE, PETROGRAPHY AND CLASSIFICATION**

The dyke rocks from the SCGP occur in both the related granitoid plutons and the Late Precambrian crystalline schists of the Danubian Autochthone and the Getic Nappe – the host of the

granitoid plutons. The composition and the distribution of these plutons on a general map were presented before<sup>1</sup>. Most of the dyke rocks are located in the granitoid plutons. Therefore, they inherited the main features of these plutons, such as those of common granitoid rocks, trondhjemitic and shoshonitic characteristics. Crossing the host crystalline schists there are few occurrences of dyke rocks, among which, remarkable is the dyke swarm from the springs of the Motru River, described by Berza and Seghedi<sup>4</sup> as the “Motru dyke complex”.

Inside the granitoid plutons the dyke rocks are located along the open initial fractures oriented parallel to the main joint systems like Q, L and S, especially on the first two systems, and along the joints themselves. The general dyke thickness is of 0.5 to 3 meters, rarely more.

More spectacular are the dyke rocks from the Motru dyke swarm. There the dykes and sills are usually oriented parallel to the crystalline schists structures, *i.e.* on the ENE-WSW direction. The dyke

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swarm extends along a visible area of 2 kilometers wide and 25 kilometers long. But, according to the quoted authors, it could extend over a length of about 50 kilometers, because it is running under the Mesozoic deposits from the south of the region. There, the dyke thickness varies from a few decimeters up to several hundreds of meters.

Sometimes the dykes underwent the effects of the autometamorphism process, which partly altered their initial minerals. Moreover, they have been affected by the Variscan deformation along the shearing zones from the areas of the Șușița and Parâng plutons and of the Motru dyke swarm.

The age of these dykes, as for instance of those from the Motru dyke swarm, is Pre-Silurian (see Berza and Seghedi<sup>4</sup>). As a rule, they occurred after the emplacement of the granitoid plutons (600–350 Ma, see Soroiu *et al.*<sup>5</sup> and Balintoni *et al.*<sup>6</sup>). At that time in the SCGP area the granitoid intrusions and the host crystalline schists had already cooled off, and there had started the occurrence of different systems of joints and initial open fractures, along which the dykes intruded<sup>1</sup>.

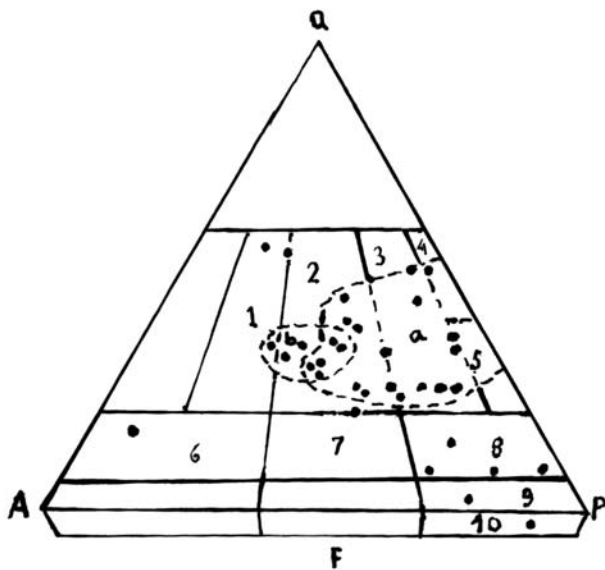


Fig. 1. Plot of the dyke rocks on the QAP diagram, adapted after Streckeisen<sup>7</sup>: 1, potash-feldspar granite; 2, normal granite; 3, granodiorite; 4, plagiogranite, trondhjemitic; 5, tonalite; 6, quartz syenite; 7, quartz monzonite; 8, quartz diorite; 9, diorite; 10, syenodiorite. Field a = acid (leucocratic), intermediate and trondhjemitic dyke rocks; field b = shoshonitic dyke rocks.

According to their main features the dyke rocks have been separated into two general divisions, namely, intermediate and acid (leucocratic) divisions, each of them including common, trondhjemitic and shoshonitic dyke rocks, depending on the granitoid plutons they are related

to (see Savu<sup>1</sup>). This classification is supported by the position of the rocks on the diagram in Figure 1, and by their chemical composition presented in Tables 1, 2 and 3.

a. **The intermediate dyke rocks.** Albeit the intermediate dyke rocks are very rare, yet they occur in association with all the three group-types of granitoid plutons from the SCGP and in the host crystalline schists from the Getic Nappe and the Danubian Autochthone. From west to east, such dyke rocks occur in both the Poneasca<sup>8</sup> and Sichevița<sup>9</sup> granitoid plutons from the Getic Nappe, and in the Cherbelezu, Sfârdin<sup>10</sup> and Cărpiniș<sup>11</sup> granitoid plutons from the Danubian Autochthone. There they are represented by diorite porphyrites.

1. *Dyke rocks related to the common rock granitoid plutons.* In the Cărpiniș<sup>10</sup> granitoid pluton, for instance, there occur diorite porphyrites the texture of which is determined by plagioclase phenocrysts included in a groundmass consisting of plagioclase, deformed quartz and biotite. The plagioclase was altered into a fine mass of sericite including granules of albite and epidote. As a melanocratic phase there occurs a biotite in fine lamellae, partly substituted by chlorite. The accessory minerals are sphene, pistacite, allanite, apatite and magnetite.

2. *Dyke rocks related to the trondhjemitic granitoid plutons.* In the Cherbelezu trondhjemitic pluton also occur dykes of intermediate rocks, represented by porphyritic quartz diorites<sup>11</sup>. These rocks consist of plagioclase, quartz, green hornblende and biotite. As accessory minerals there occur apatite, zircon, sphene and magnetite.

3. *Dyke rocks related to the shoshonitic granitoid plutons.* The Novaci shoshonitic intrusion<sup>10</sup> was cut by a dyke of diorite porphyrite with zoned hornblende phenocrysts of 3 to 5 centimeters long, which are oriented parallel to the dyke walls. Besides, altered phenocrysts of plagioclase occur as well. These are included in a microgranular groundmass formed of partly altered granules of plagioclase, hornblende and biotite and accessory minerals like sphene, apatite and magnetite. It is of note that, sometimes, allanite shows a thin rim of pistacite.

In the Motru dyke swarm, which could be considered as occurring after the intrusion of the Frumosu syn-orogenic granitoid pluton, the intermediate dyke rocks are represented by microdiorite and diorite porphyrites<sup>4</sup>. The microdiorite and quartz microdiorite porphyrites consist of a very fine groundmass, formed of

plagioclase, hornblende, eventually quartz and biotite. The more important dykes consist of porphyritic diorites, which are also formed of plagioclase, hornblende, biotite, apatite, and a little quartz. The last rocks contain autoliths formed of hornblende, plagioclase and biotite.

**b. The acid (leucocratic) dyke rocks.** These are the most numerous dyke rocks in the SCGP, and are also associated with all the three group-types of granitoid plutons from this petrographic province, as well as with the host crystalline schists. Therefore, they were separated into three groups, according to the characteristics of the granitoid plutons they are related to.

1 *Dyke rocks related to the common rock granitoid plutons.* In this category were included most of the acid dyke rocks from the SCGP (Fig. 1 and Table 2), which occur both inside the related granitoid plutons and in the crystalline schists around these plutons.

Inside the granitoid plutons there are characteristic, among others, the dykes from the Poneasca<sup>8</sup> and Sichevița<sup>9</sup> plutons from the Getic Nappe and those from the Cărpiniș granitoid pluton<sup>10</sup> from the Danubian Autochthone. There occur granodiorite and granite porphyries, aplites, pegmatoid granites and quartz porphyries. The granodiorite porphyries consist of a microgranular groundmass in which zoned phenocrysts of plagioclase (An<sub>5-8</sub>), green hornblende ( $c \wedge Ng = 24^\circ$ ) and biotite, partly substituted by chlorite, occur. The granite porphyries also consist of a groundmass formed of quartz, plagioclase (An<sub>8</sub>), biotite and accessory minerals like apatite and zircon. In this groundmass there occur phenocrysts of potash feldspar with perthitic structure. It is worth mentioning that these phenocrysts include small lamellae of biotite oriented parallel to some imaginary zones.

Very numerous among the leucocratic dyke rocks from all of the granitoid plutons from the SCGP are the aplitic dykes. More characteristic are those from the Cărpiniș granitoid pluton<sup>10</sup>. These rocks consist of a microgranular granitic groundmass formed of xenomorphic quartz granules with rolling extinction, plagioclase (An<sub>8</sub>), potash feldspar and biotite. If such a rock was affected by autometamorphism, the plagioclase was transformed, like that from the massif rocks themselves, into an association of sericite, kaolinite, epidote and albite. In such cases biotite was substituted by chlorite and in the altered rock tourmaline occurred, sometimes.

The quartz porphyries consist of an aplitic groundmass formed of deformed quartz, albite and

potash feldspar, most of the last two minerals being substituted by the following mineral assemblage: sericite-kaolinite-zoizite-albite; biotite partly chloritized is also present. In this groundmass quartz phenocrysts do occur.

In this context it is noteworthy to mention the geodes from the Cărpiniș granitoid pluton. Usually, these geodes have been formed at the intersection of two joints or initial faults. They are upholstered by idiomorphic quartz crystals of 1 to 3 centimeters long<sup>10</sup>.

The dykes of pegmatite and pegmatoid granite are more characteristic in the Poneasca pluton<sup>8</sup>. These rocks belong to the *feldspatic-type* category, being constituted mostly of microcline or microcline-perthite and albite with mirmekitic intergrowths with quartz; muscovite and biotite are also present. The normative composition of the potash feldspar from these rocks is Or<sub>78-84</sub>, Ab<sub>14-20</sub>, An<sub>0.8-11</sub>. Sometimes, it forms graphic intergrowths with quartz.

In the crystalline schists there are characteristic the acid dyke rocks from the Motru dyke swarm, which are represented by porphyritic microgranite consisting of a fine groundmass, in which phenocrysts of quartz, plagioclase, orthoclase and albite of 2 to 5 millimeters long occur. With the dyke rocks from the dyke swarm there are also associated dykes of porphyritic microgranodiorites, which consist of a fine groundmass in which phenocrysts of plagioclase (An<sub>33-26</sub>) showing a normal zoning, green hornblende, eventually quartz, biotite and accidentally clinopyroxene occur<sup>4</sup>.

2. *Dyke rocks related to the trondhjemitic granitoid plutons.* Among these rock-types the most characteristic are the dykes related to the Cherbelezu trondhjemite pluton, which are represented by porphyritic granodiorites and aplites<sup>11</sup>. The first rocks consist of plagioclase, quartz, green hornblende and biotite and accessory minerals like apatite, zircon, sphene and magnetite. The effects of autometamorphism are very evident in these rocks, which consist in the alteration of plagioclase into sericite and calcite and of the mafic minerals into chlorite. In the extreme cases of alteration the entire rock mass, including phenocrysts, was transformed into a fine aggregate of sericite, chlorite and calcite, in which sometimes remnants of the original minerals are present.

Aplites are light colored rocks with a saccharoid texture. They are formed of quartz, albite-oligoclase, potash feldspar, rarely muscovite, biotite and opaque minerals.

3. *Dyke rocks related to the shoshonitic granitoid plutons.* The aplites from the Tismana<sup>19</sup> shoshonitic granitoid pluton are the most representative in this group. These rocks are represented by numerous dykes, which cut the pluton on different directions. They are massive equigranular rocks, which consist of potash feldspar (microcline or microclin-perite), quartz and plagioclase (An<sub>5-10</sub>).

### GEOCHEMISTRY OF THE DYKE ROCKS

The chemical composition of the dyke rocks is presented in Tables 1, 2 and 3. In these tables the

rocks are separated into the two main categories above presented, namely, intermediate and acid (leucocratic) rocks, each of them including dyke rocks related to the common rock granitoid plutons as well as to the trondhjemitic and shoshonitic plutons.

In the intermediate rock-group (Table 1), in which rocks of dioritic composition are included, the SiO<sub>2</sub> content varies from 52.18 to 63.09 %. The oxides of iron and magnesium (FeO\* and MgO) are the highest in the entire dyke rock-series. The first oxide increases from 2.72 to 6.89 % and the second from 2 to 5.93 %. The alkalies are relatively low in the most rocks, their sum varying from 5.26 to 7.45 %.

Table 1

Chemical composition of the intermediate dyke rocks\*

Number	1	2	3	4	5	6	7	8
SiO <sub>2</sub> %	63.09	58.16	59.99	52.18	53.50	56.65	58.11	60.96
TiO <sub>2</sub>	0.42	0.50	0.79	1.25	1.0	0.80	1.25	0.85
Al <sub>2</sub> O <sub>3</sub>	16.01	15.71	15.75	18.44	19.21	19.0	17.72	16.42
FeO*	2.72	4.69	5.37	6.89	6.37	5.12	5.67	5.15
MnO	0.07	0.09	0.10	0.13	0.10	0.11	0.11	0.05
MgO	2.0	5.93	4.36	4.40	3.60	3.50	2.70	2.30
CaO	3.50	4.56	4.29	7.28	7.0	5.04	5.46	5.18
Na <sub>2</sub> O	4.85	3.85	3.92	3.98	3.53	2.96	3.85	4.20
K <sub>2</sub> O	2.93	3.60	3.23	2.31	2.31	3.30	2.12	2.60
P <sub>2</sub> O <sub>5</sub>	0.40	0.28	0.18	0.27	0.29	0.29	0.29	0.15
Loi	3.69	1.94	2.32	2.32	2.65	3.01	2.10	1.98
Total	99.95	100.01	99.63	99.76	99.92	99.78	99.89	99.87
Pb ppm	24	20	12	-	-	-	-	-
Cu	10	21	46	-	-	-	-	-
Ga	22	20	25	-	-	-	-	-
Sn	2	2	2	-	-	-	-	-
Ni	18	95	55	-	-	-	-	-
Co	5.5	20	13	-	-	-	-	-
Cr	13	190	123	-	-	-	-	-
V	42	120	65	-	-	-	-	-
Sc	4.5	17	11.5	-	-	-	-	-
Y	0.6	0.8	1.4	-	-	-	-	-
Yb	0.6	0.8	1.0	-	-	-	-	-
La	60	42	58	-	-	-	-	-
Zr	130	100	150	-	-	-	-	-
Be	3	3	2.9	-	-	-	-	-
Nb	10	10	10	-	-	-	-	-
Ba	2100	1700	1300	-	-	-	-	-
Sr	3000	1000	970	-	-	-	-	-
Li	18	32	12	-	-	-	-	-

\* The analyses in the Table represent: 1-3, Cherbezeu-Sfărdin quartzdiorite porphyrites and monzodiorite porphyrites<sup>11</sup>; 4-8, Motru dyke swarm monzodiorite porphyrites<sup>4</sup>. FeO\*, represents the total iron oxides.

Table 2

Chemical composition of the acid (leucocratic) dyke rocks related to the common rock granitoid plutons\*

Numb.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO <sub>2</sub>	69.11	73.76	64.80	72.98	66.13	76.68	75.06	75.78	69.04	69.38	72.20	60.96	64.69	69.70	71.25
TiO <sub>2</sub>	0.41	0.05	0.46	0.40	0.30	-	0.10	0.66	0.47	0.37	0.13	0.85	0.70	0.50	0.55
Al <sub>2</sub> O <sub>3</sub>	15.89	15.80	15.70	16.05	17.16	14.31	14.66	14.20	18.33	15.78	15.62	16.42	17.0	14.22	14.0
FeO*	2.44	0.50	4.53	0.69	1.99	0.35	0.53	0.46	0.33	2.39	0.55	4.35	3.19	2.10	1.78
MnO	0.05	0.03	0.14	0.14	0.03	0.01	0.20	0.03	0.01	0.02	0.02	0.05	0.06	0.04	0.04
MgO	1.04	0.27	1.08	0.22	1.52	0.71	0.52	0.08	0.21	1.20	0.42	2.30	3.0	0.70	0.30
CaO	3.45	1.12	4.20	0.66	2.18	3.16	3.44	0.55	0.67	2.25	1.47	5.18	1.68	2.52	2.38
Na <sub>2</sub> O	3.67	4.35	3.00	4.41	3.62	-	0.08	4.62	10.03	4.75	4.43	4.20	4.28	4.20	4.0
K <sub>2</sub> O	2.32	3.62	3.60	4.62	4.38	4.42	4.60	3.98	0.21	2.63	3.96	2.60	2.84	4.52	4.62
P <sub>2</sub> O <sub>5</sub>	0.12	0.07	0.18	0.04	0.17	0.21	0.15	0.08	0.12	0.11	-	0.15	0.17	0.09	0.08
Loi	1.39	0.32	1.02	0.14	1.89	0.13	0.33	0.41	0.29	1.03	0.73	1.98	1.95	0.93	0.82
Total	100	100	99.96	100	99.87	100	99.72	99.78	99.75	100	99.94	99.87	99.75	99.79	99.81
Pb	7	-	-	49	21	190	35	105	6	65	23	-	-	-	-
Cu	5	-	-	20	25	12	6	5	29	8	10	-	-	-	-
Ga	17	-	-	20	23	25	26	36	31	29	20	-	-	-	-
Sn	-	-	-	9	-	9	3	26	-	-	-	-	-	-	-
Ni	10	-	-	5	16	2.5	2	4	5	9.5	5	-	-	-	-
Co	7	-	-	5	6.5	1	2	2	-	-	5	-	-	-	-
Cr	19	-	-	5	21	3.5	3	4	5	20	5	-	-	-	-
V	26	-	-	5	22	3.5	5	5	4	4	10	-	-	-	-
Sc	-	-	-	-	6	2	2	3.5	-	-	-	-	-	-	-
Y	-	-	-	10	5	18	-10	-5	18	-	-	-	-	-	-
Yb	-	-	-	-	0.8	0.5	2	-	-	-	1.3	-	-	-	-
La	30	-	-	-	-	30	30	-	-	-	30	-	-	-	-
Zr	150	-	-	-	-	38	18	26	-	-	108	-	-	-	-
Be	-	-	-	6.9	7.0	9	8.5	10	2.3	1.6	2.4	-	-	-	-
Nb	-	-	-	-	22	12.5	20	-	-	-	15	-	-	-	-
Ba	850	-	-	80	900	53	38	68	900	53	38	-	-	-	-
Sr	480	-	-	34	330	50	40	-	330	50	40	-	-	-	-
Li	23	-	-	3	20	3	65	3	2	24	16	-	-	-	-

\* The analyses in the table represent: 1, Parang aplite<sup>13</sup>; 2-5, Poneasca aplites<sup>8</sup> ( besides the values in the table, in one aplite there were determined: 13.4 La; 24.6 Ce; 2.7 Sm; 0.92 Eu; 0.52 Tb; 0.90 Yb; 2.2 Hf; 2.7 Ta; 9.35 Th; and 160 Rb<sup>18</sup>); 6, Muntele Mic aplite<sup>14</sup>; 7, Sfardin aplites<sup>11</sup>; 8-10, Susița aplites<sup>15</sup>; 11, Sadu-Stancesti aplite<sup>16</sup>; 12-15, acid dyke rocks from the Motru dyke swarm. Fe\* represents all iron oxides.

According to their main major elements, these rocks are calc-alkaline in composition, so that on the diagram in Figure 2 they plot within the upper part of the calc-alkaline array, thus showing a higher iron content in comparison with the other rock-groups from the SCGP.

The acid (leucocratic) dyke rock-group, which is related to the common rock granitoid plutons (Table 2) includes terms of granodioritic and granitic composition, in which the SiO<sub>2</sub> content varies from 64.80 up to 75.96 %. FeO\* and MgO are low. The sum of alkalis varies in high ranges, situated between 6 and 8.88 %. According to the mentioned characteristics, on the diagram in Figure 2 the acid rocks plot along the left branch of the

calc-alkaline array, too, but gathered in two distinct fields, which mark the composition of the granodioritic and granitic dykes.

The dyke rocks related to the trondhjemitic plutons are characterized by their high contents of SiO<sub>2</sub> and Na<sub>2</sub>O, as the diagram in Figure 3 suggests. On this diagram most of these rocks plot within the field D. Their SiO<sub>2</sub> varies between 64.69 and 75.78 % and Na<sub>2</sub>O between 4 and 4.65 % (Table 3). These data are consistent with the values established by Savu and Dobrescu<sup>22</sup> for the igneous rocks from the trondhjemitic plutons of the SCGP. On the diagram in Figure 2 most of these rocks plot within the granodioritic area of the calc-alkaline array.

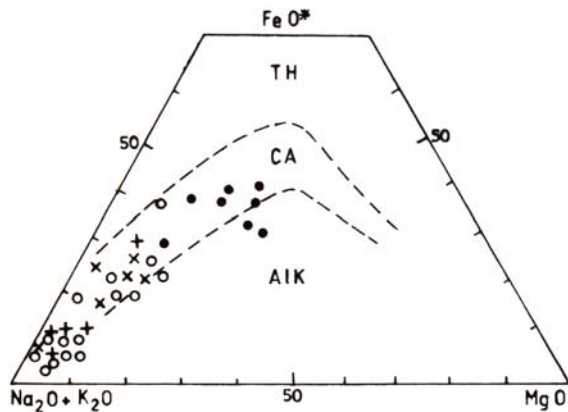


Fig. 2. Plot of the dyke rocks on the  $\text{FeO}^* - \text{Na}_2\text{O} + \text{K}_2\text{O} - \text{MgO}$  diagram. Fields according to Irvine and Baragar<sup>20</sup> and Hutchinson<sup>21</sup>: TH, tholeiitic; CA, calc-alkaline; Alk, alkaline. Legend: ●, intermediate rocks; ○, acid (leucocratic) rocks; ×, trondhjemitic rocks; +, shoshonitic rocks.

Like the massif rocks from the shoshonitic granitoid plutons the related dyke rocks are rich in  $\text{SiO}_2$  and alkalis, especially  $\text{K}_2\text{O}$  (see Savu<sup>1,3</sup>). Thus, their  $\text{SiO}_2$  varies from 69.83 to 75.26 % (Table 3). The sum of alkalis is higher in comparison with most of the granitoid dyke rocks from SCGP. It increases up to 6.16 %. Iron and magnesium oxides are very low, the first oxide varying from 0.2 to 0.11 % and the second between

0.03 and 0.78 %. On the diagram in Figure 2 the shoshonitic dyke rocks plot in the lowest part of the calc-alkaline array, together with some alkali-rich granitoid dykes. It is of note that by extreme differentiation of granitoid magma there resulted dyke rocks the composition of which get near the composition of the the shoshonitic rocks, as shown by Table 3 (sample 10) and Figure 4.

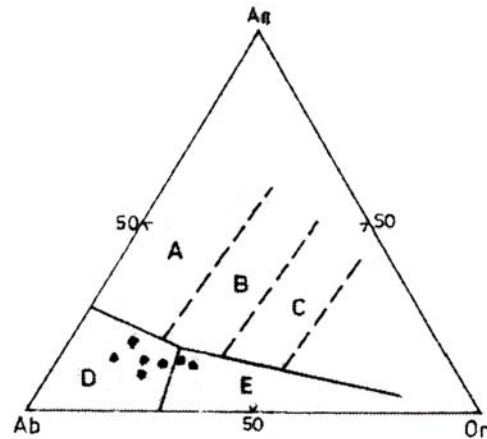


Fig. 3. Plot of the dyke rocks related to the trondhjemitic granitoid plutons on the An-Ab-Or diagram. Fields according to O'Connor<sup>23</sup> (see also Streckeisen<sup>7</sup>): A, tonalites (dacites); B, granodiorites (dacites, rhyolites); C, quartz diorites, quartz monzonites; D, trondhjemitic (quartzkeratophyres); E, granites (rhyolites).

Table 3

Chemical composition of the acid (leucocratic) dyke rocks related to the trondhjemitic (1-6) and shoshonitic (7-10) granitoid plutons\*

Numb	1	2	3	4	5	6	7	8	9	10
$\text{SiO}_2$	68.68	70.44	74.40	75.09	73.40	75.78	74.02	75.32	69.83	71.68
$\text{TiO}_2$	0.40	0,28	-	0.08	-	0.60	0.05	0.05	0.52	0.94
$\text{Al}_2\text{O}_3$	14.40	15.51	14.92	14.96	14.30	14.26	13.58	14.30	14.49	15.56
$\text{FeO}^*$	2.74	2.01	0.65	0.70	1.80	0.46	0.98	0.54	3.38	0.91
$\text{MnO}$	0.06	0.04	0.02	0.04	0.02	0.03	0.03	0.02	0.05	0.11
$\text{MgO}$	1.30	0.98	0.50	0.17	0.50	0.08	0.29	0.36	0.78	0.34
$\text{CaO}$	1.96	2.54	1.06	1.30	1.50	0.55	0.69	1.20	1.03	1.15
$\text{Na}_2\text{O}$	3.86	1.92	2.85	4.08	3.50	3.98	6.16	4.27	5.02	6.29
$\text{K}_2\text{O}$	3.86	1.92	5.45	3.78	4.40	3.98	6.16	4.77	5.02	6.29
$\text{P}_2\text{O}_5$	0.10	0.12.	0.03	0.06	-	0.08	0.62	0.01	0.16	0.03
Loi	1.75	1.35	0.88	0.62	0.80	0.37	0.71	0.36	1.31	0.45
Total	99.46	99.85				99.72	99.13	100.2	99.85	99.84
Pb	-	15	-	40	-	35	35	14	20	7
Cu	-	2.5	-	7.5	-	6	-	2.5	15	7
Ga	-	1.5	-	13	-	26	15	20	4.5	27
Ni	-	7	-	2.5	10	-	1		35	5
Co	-	6	-	2	-	2	22	-	-	5
Cr	-	1	-	3.5	-	3	7	1	2	5
V	-	2.3	-	4.5	-	5	5.6	2	16	8
Sc	-	2.5	-	2	-	2	-	-	-	-
Y-	-	6	-	5.5	-	5	28	-	-	-
Yb	-	0.5	-	0.5	-	0.5	-	-	-	-

Table 3 (continued)

La	-	30	-	30	-	30	-	-	-	-
Zr	-	175	-	130	-	18	90	40	410	-
Be	-	1.8	-	1.8	-	8.5	-	1.0	3.2	2.7
Nb	-	-	-	10	-	12.5	4.0	-	-	-
Ba	-	450	-	1100	-	38	683	390	1050	1000
Sr	-	280	-	220	-	40	165	230	240	290
Li	-	27	-	-	-	6.5	-	-	-	-

\*The analyses in the table represent: 1. Ogradena microgranodiorite porphyry<sup>17</sup>; 2, Buta aplite<sup>18</sup>; 3-5, Sichevița aplites<sup>9</sup>; 6, Cherbezeu aplite<sup>11</sup>; 7, Tismana aplite<sup>19</sup> (besides the data from the table this rock contains: 27 La; 64 Ce; 25 Nd; 50 Sm; 1.06 Eu; 3.1 Gd; 0.58 Tb; 3.03 Dy; 3.16 Er; 4.61 Yb; 0.79 Lu); 8-9, Novaci aplites<sup>10</sup>; 10, Poneasca aplite<sup>26</sup> FeO\* represents the total iron oxides.

The shoshonitic character of these rocks is very well evidenced by the diagram in Figure 4, on which most of these rocks plot in the shoshonitic field, at high values of SiO<sub>2</sub>, and partly in the field of the high-K granitoid rocks.

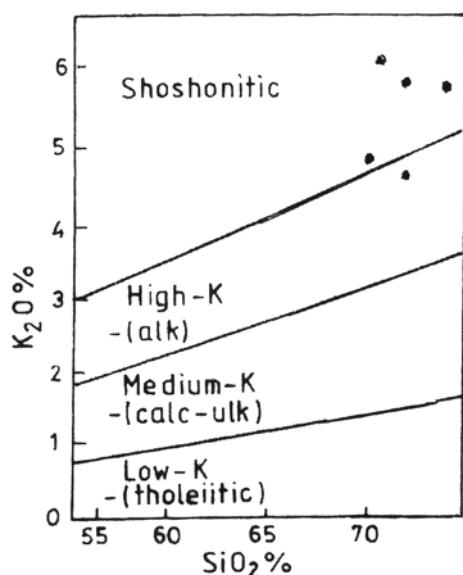


Fig. 4. Plot of the dyke rocks related to the shoshonitic granitoid plutons on the K<sub>2</sub>O vs. SiO<sub>2</sub> diagram. Fields according to Rickwood<sup>24</sup>. Data from Table 3.

The general features of the dyke rocks from the SCGP show that all of them belong to the ferriferous granitoid series. As it results from the diagram in Figure 5, except for a few more melanocratic intermediate dyke rocks, most of the acid (leucocratic) dyke rocks plot on this diagram in the ferriferous rocks domain, like the rocks of the granitoid plutons they are related to (see Savu<sup>3</sup>).

The trace elements from the dyke rocks of the SCGP (Table 1 to 3), although in incomplete sets, are contributing to the completion of the geochemical characteristics of the dyke rocks from

this petrographic province. Thus, elements such as Pb, Cu, Ga and Sn show generally low or very low contents in all of the rock-groups. Among these elements Ga presents the highest contents and Sn the lowest. Low contents show Be and Li, too. But the most remarkable elements for their high contents along the entire dyke rock-series are Sr and Ba. Both of them show high contents, especially in the intermediate rock-group.

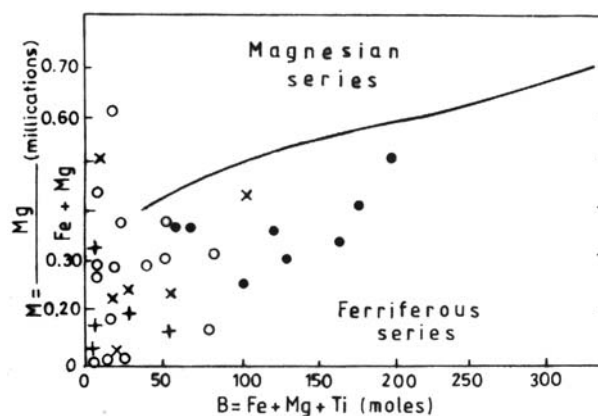


Fig. 5. Plot of the dyke rocks on the Mg / Fe\* + Mg vs. Fe\* + Mg + Ti diagram. Fields according to Debon and Le Fort<sup>25</sup>. Fe\* includes the total iron cations. Legend as in Figure 2.

The siderophile elements like Ni, Co, Cr, V and Sc show higher contents in the intermediate rocks, too, because these rocks are the richest rocks in iron and magnesium, in the position of which these trace elements enter into the network of different melanocratic minerals. The lowest contents of these elements occur in the more leucocratic shoshonitic rocks. Other trace elements like U, Th, Zr, Hf, Nb and Rb have been rarely determined. Amid these elements Zr was more often determined, which showed the highest contents. Higher values of Zr also occur in the dyke rocks related to the shoshonitic granitoid plutons.

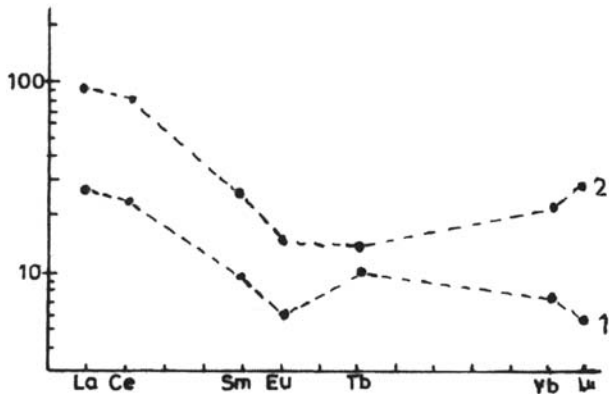


Fig. 6. Chondrite-normalized REE patterns of two aplites from the SCGP. Data from Tables 2 and 3. 1, Poneasca acid (leucocratic) aplite<sup>26</sup>; 2, Tismana shoshonitic aplite<sup>19</sup>.

The rare earth elements (REE) have been determined in two aplites, only: one from the Poneasca common rock granitoid pluton<sup>26</sup> and other from the Tismana shoshonitic pluton<sup>19</sup>. What is interesting for these aplites, is the fact that their chondrite-normalized REE patterns (Boynton normalizing values<sup>27</sup>) are almost parallel in the LREE segment, from La to Eu, and are diverging in the HREE segment (Fig. 6). It is also of note that the Poneasca aplite shows a strong Eu negative anomaly and the Tismana aplite a Tb negative anomaly.

### TECTONIC SETTING OF THE DYKE ROCKS

Before, there was shown that the common rock granitoid plutons from the SCGP plot in the island arc granitoids (VAG field)<sup>1</sup> save the shoshonitic granitoid plutons the average chemical composition of which indicates withinplate granitoids (WPG field)<sup>3</sup>. The dyke rocks related to the first granitoid plutons are also belonging to the island arc (syn-collision) granitoid category, as shown by the diagram in Figure 7. On this diagram even the aplite related to the within plate Tismana shoshonitic granitoid pluton fall in the syn-collision granitoid field. This situation shows that there is not always a strict correlation between the direct products of the parental magma and those of the highly differentiated fractions of this magma, like the aplitic rocks, for instance.

However, the relationships between the low-content major elements like Ti, Mn and P (Fig. 8) show that a few dyke rocks occur under the tectonic conditions of an island arc. Most of them are plotting in the within plate rock field and out of

any characteristic fields. This discrepancy was probably determined by the fact that the dyke rocks came from different granitoid magma chambers, the magmas of which had their own differentiation trend.

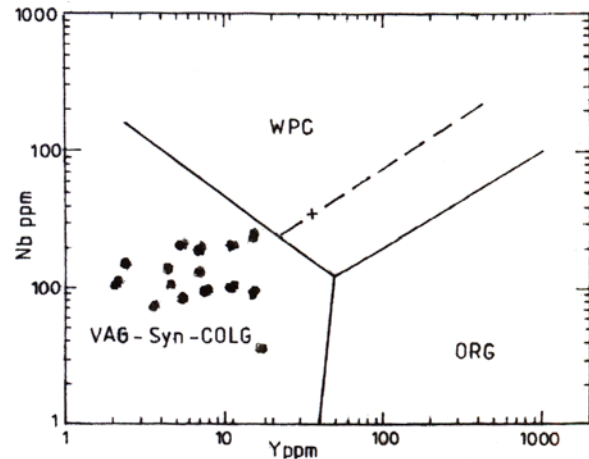


Fig. 7. Plot of the dyke rocks on the Nb vs. Y diagram. Fields according to Pearce *et al.*<sup>28</sup>: VAG + syn - COLG, volcanic arc granitoids + syn-collision granitoids; WPG, within plate granitoids; ORG, ocean ridge granitoids. Data are from Tables 1, 2 and 3.

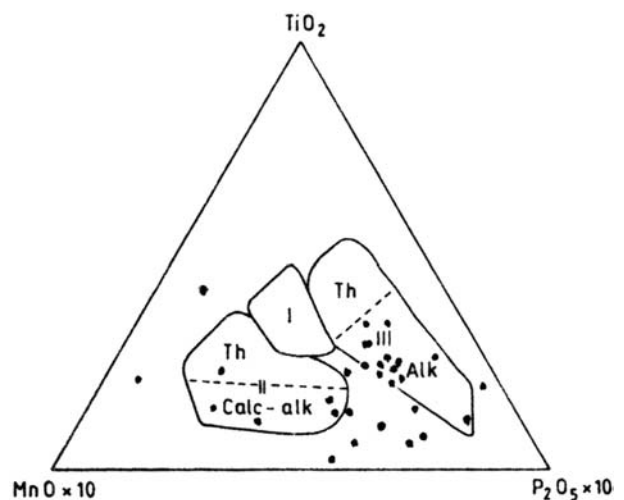


Fig. 8. Plot of the dyke rocks on the Ti - Mn - P diagram. Fields according to Mullen<sup>29</sup>: I, ocean floor rocks; II, arc calc-alkaline rocks; III, within plate rocks. Data from Tables 1, 2 and 3.

The discrepancy between the dyke rocks from the SCGP are also manifest on the diagrams in Figure 9, in which the relations  $\text{FeO}^*/\text{FeO}^* + \text{MgO}$  vs.  $\text{SiO}_2$  and  $\text{TiO}_2$  vs.  $\text{SiO}_2$  are taken into consideration. On the first diagram the dyke rocks plot at random within its different fields. A clear feature of the dyke rocks results from the  $\text{TiO}_2$  vs.  $\text{SiO}_2$  diagram. On this diagram all of the dyke rocks plot in the CEUG field, in which rocks occurring under the continental epeiorogenic uplift conditions are usually situated.



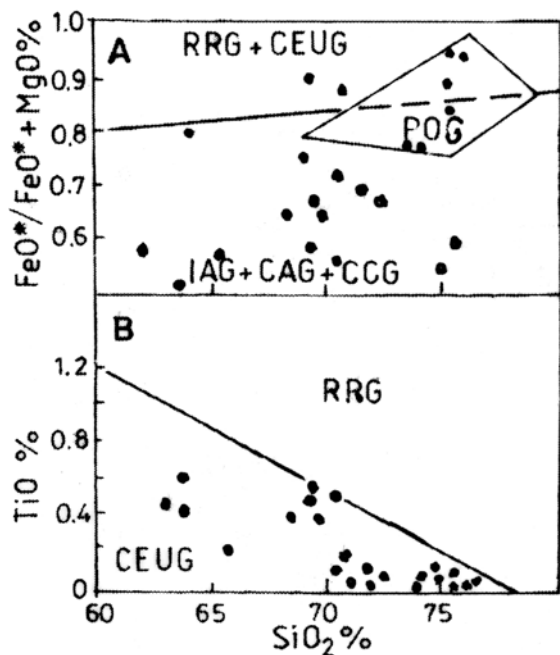


Fig. 9. Plot of the dyke rocks on the  $\text{FeO}^* / \text{FeO}^* + \text{MgO}$  vs  $\text{SiO}_2$  (A) and  $\text{TiO}_2$  vs.  $\text{SiO}_2$  (B) diagrams. Fields according to Maniar and Piccoli<sup>30</sup>: RRG, rift related granitoids; CEUG, continental epeirogenic uplift granitoids; POG, post orogenic granitoids; IAG, island arc granitoids; CAG, continental arc granitoids; CCG, continental collision granitoids.

The last observation is consistent with that obtained from the diagrams in Figures 7 and 8. All of them suggest that the dyke rocks intruded after the emplacement of the syn-orogenic and late-orogenic granitoid plutons, during the Late Precambrian to Ordovician period. Then the Pre-Carpathian framework was uplifted under the late-collision to post-collision conditions (see the model in Savu<sup>31</sup>).

### ORIGIN OF THE DYKE ROCKS PARENTAL MAGMAS

The chemical composition (Tables 1 to 3) of the dyke rocks shows that they originated in calc-alkaline magmas of mantle-source. According to the data from these tables, in the dyke rocks the  $\text{Al}_2\text{O}_3 / \text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O}$  ratio is higher than 1.1. The  $\text{SiO}_2$  content varies between 62 and 75 % and the value of the  $\text{K}_2\text{O} / \text{Na}_2\text{O}$  ratio is usually very low. According to Chappell and White<sup>32</sup> all of these values indicate granitoid rocks originating in juvenile magmas. Besides, in the mineralogical composition of the rocks mineral assemblages including green hornblende, sphene and magnetite

do occur; sometimes a clinopyroxene is present, too. The presence of these minerals in the dyke rock composition shows, according to the same quoted authors, their origin in juvenile parental magmas i.e. mantle source magmas. This conclusion clearly results from the diagram in Figure 10

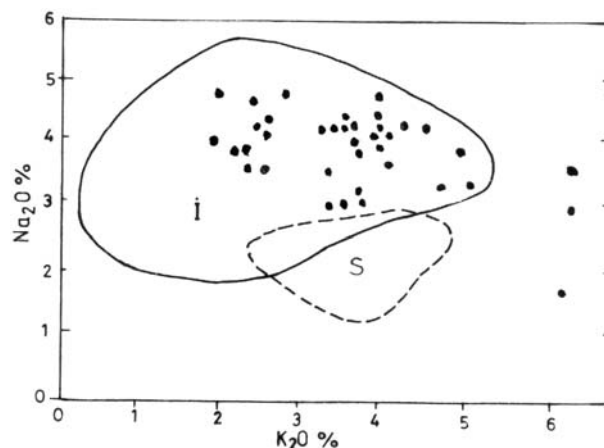


Fig. 10. Plot of the dyke rocks on the  $\text{Na}_2\text{O}$  vs.  $\text{K}_2\text{O}$  diagram. Fields according to Chappell and White<sup>32</sup>. I, magmas of juvenile origin; S, magmas resulted from sedimentary materials. Data are from Tables 1, 2 and 3.

The parental magmas of the dyke rocks were calc-alkaline magmas, which derived from a metasomatic mantle source (see Roden and Murthy<sup>33</sup>), occurred over the subduction plane of the subduction system above mentioned<sup>1</sup>.

It seems that in this metasomatic mantle numerous magma chambers were formed, because the dyke rocks associations derived from these calc-alkaline magmas are variable in composition.

From these parental magmas there resulted both the common rock dykes and the trondhjemitic dykes, the compositions of which are very close to that of the rocks from the related granitoid plutons. It is of note that the features of the highly differentiated dyke rocks, such as some aplites, somehow differ from that of the related pluton, as shown above.

The Tismana aplite (Table 3) related to the shoshonitic granitoid pluton, also shows shoshonitic characteristics, because its value of  $(\text{Dy} / \text{Yb})_N$  ratio of 0.21 and that of  $(\text{Ce} / \text{Yb})_N$  ratio of 3.6 would place this rock in the plume-source domain (see Savu<sup>3</sup>). In spite of all these observations, on the diagram in Figure 7 this aplite did not fall in the within plate field, thus differing from the average of the Tismana massif rocks.

## CONCLUSIONS

Within the South Carpathian area dyke rocks occur all along the SCGP, but they are mostly located inside or around the granitoid plutons they are related to.

Depending on their general features, the dyke rocks belong to two main categories, each of them including common rock, trondhjemitic and shoshonitic dyke rocks.

The chemical composition of the dyke rocks evidenced a general calc-alkaline dyke rock-series with a weak alkaline tendency.

The parental magmas of the first two groups, above, shown originated in a metasomatic mantle source, occurred above the subduction plane of the subduction system that generated the process of mantle metasomatism and the genesis of the calc-alkaline parental magmas. The Tismana aplite dykes are an exception, because they derived from a mantle plume-source, like the Tismana shoshonitic pluton itself.

The tectonic setting indicates syn-collision to post-collision intrusion of the dyke rocks, which were intruded within the SCGP area when the precursor granitoid plutons had cooled off and different types of joints and initial fractures had started to occur, along which the dykes intruded in both the plutons and crystalline schists.

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