THE NORTH DOBROGEA GRANITE PROVINCE; PETROLOGY AND ORIGIN OF ITS ROCKS

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Abstract. The North Dobrogea granite province, the present paper is dealing with, includes two granite rock-series. One of them is a Permo-Carboniferous calc-alkaline series of syn-collision to post-collision tectonic setting. It occurred during the last movements of the Variscan Orogeny. The parental magma resulted from the partial melting of the crust as well as of the lower crust. The second granite series occurred during the Triassic period, when the North Dobrogea territory was stable, evolving under withinplate geotectonic conditions up to the Jurassic. It includes mostly shoshonitic (K-alkali) and Na-alkali granites as well as the related volcanic rocks. The parental magma originated in plume sources. The rocks of some granite intrusions look like deriving from magmas of mixed sources. In fact, these are shoshonitic magmas contaminated by the crust. The echo of this magmatic activity was a weak acid volcanism that manifested itself during the Upper Jurassic.

Key words: calc-alkaline granites, shoshonitic granites, na-alkali granites, rhyolites, trondhjemitic granites, quartzkeratophyres, petrology, origin.

Résumé. La province des granites de Dobrouja Nordique, de laquelle le présent article s'occupe, inclut deux séries, de roches granitiques. La première est une série permo-carbonifère, calco-alcaline, de type syn-collision – post-collision série des granites. Le magma paternel a resulté par la fonte partielle de la croûte, y compris la croûte inférieure. La seconde série granitique est parue pendant le période triassique, quand le territoire de la Dobrouja Nordique était stable et gouverné par des conditions tectoniques de type intraplaque, et a continué jusqu'à jurassique. Elle inclut tout particulièrement des granites shoshonitiques (K-alcalins) et Na-alcalins, bien que des volcaniques acides. Le magma paternel s'est formé dans des panaches du manteau. Les roches de quelques intrusions granitiques semblent provenir des magmas qui ont l'origine dans des sources mixte. En fait, ce sont des magmas shoshonitiques contaminés par la croûte. L'écho de cette activité magmatique, il semble, a été un faible volcanisme acide qui s'est manifesté pendant le jurassique supérieur.

Mots-clés: granites calc-alcalins, granites shoshonitiques, granites Na-alcalins, rhyolites, granites trondhjemitiques, quartzkératophyres, pétrologie, origine.

INTRODUCTION

In two previous papers (Savu, 1988; Savu, Stoian, 1998) the granitoid plutons from North Dobrogea were shown as syn-collision granites and separated into two series: the calc-alkaline and the alkaline rock series. Now, as new geochemical data concerning these rocks have been obtained, I decided to elaborate a more detailed paper on this subject, at the same time establishing the North Dobrogea granite province. The new observations resulted from these new researches have been presented in the chapters of this paper, as it will be shown further down.

OUTLINES OF THE NORTH DOBROGEA EVOLUTION AND STRUCTURE

The North Dobrogea mobile belt occurred since the Precambrian period, when the Archean continent was separated within this area into two tectonic plates, namely, the East European Plate (EEP) and the Moesian Plate (MP) as shown in Fig. 1 (see also Giuşcă *et al*., 1969, Figs. 1 and 2). Then the mobile belt evolved under the control of the movement of these two tectonic plates during the following tectomagmatic cycles, up to the Variscan Orogeny, because the Carboniferous deposits have also been affected by a weak regional metamorphism. During all this period the North Dobrogea belt evolved as a real ocean, which was a branch of the old Carpathian ocean, extending eastward up to the Caucasus area. The Paleozoic sheeted dyke slice of Gâlmele Înșirate (Savu, Stoian, 1998) represents a clear proof in this respect.

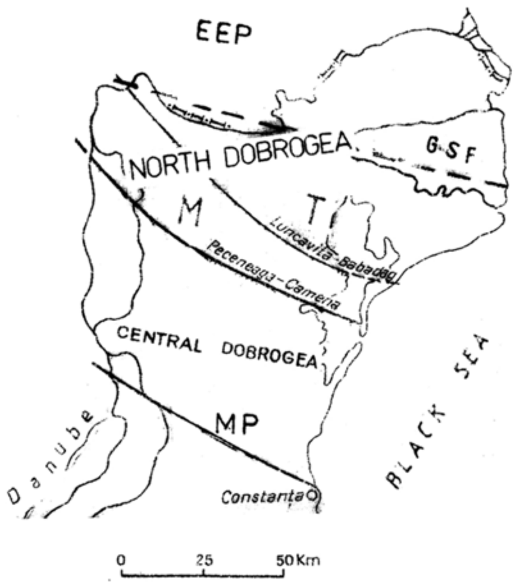

Fig. 1 – Sketch-map showing the position of North Dobrogea between the East European Plate (EEP) and the Moesian Plate (MP), and its two structural units: the Tulcea (T) and the Măcin (M) units, as well as the main tectonic lines.

Starting by the end of Carboniferous and the beginning of Permian, the North Dobrogea mobile belt got into a stable area formed by the Paleozoic accretionary prism or ophiolitic suture (see Savu, Stoian, Fig. 10), over which the Carapelit Formation was deposited (Săndulescu, 1995; Seghedi, Oaie, 1995) onto a sialic basement, and in an epicontinental sea. Then, over the North Dobrogea area a regime of withinplate geotectonic conditions started, it becoming an aulacogen (see also Vlad, 1978). It was reflected in the geochemical character of the granitoid plutons and of the related volcanics emplaced during this last period up to the beginning of Jurassic. Then, there followed the sedimentation of the Jurassic formations and of younger deposits. The withinplate acid volcanism was preceded and accompanied by a withinplate bimodal volcanism (Savu, 1986), which generated an important dyke swarm located in the crystalline schist basement of the Măcin Unit and an important mass of withinplate bimodal volcanics, which unconformabilly lay over the crystalline schist basement in the Tulcea Unit. This unconformability between the withinplate volcanics and the crystalline schist basement was considered by some authors like a thrust plane, at least in the Niculițel area.

All along this period the evolution of North Dobrogea depended on the movement of the East European Plate, which was pushing from NNE toward SSW, against the Moesian Plate. Therefore, during the Alpine movements the narrow belt of North Dobrogea underwent a strong strain; it was practically crushed between the two huge tectonic plates. As a consequence, there occurred two main marginal fractures, between which the North Dobrogea was iuncluded: the Galați–Sfântul Gheorghe fault (G–SF) at the NNE, now covered by the younger deposits of the Pre-Dobrogean Depression, and the Peceneaga–Camena fault (Fig. 1). Both of them are strongly dipping SSW, thus facing the East European Plate. Between these two main marginal faults the Luncavița – Babadag line occurred, too, which separated the North Dobrogea territory into two structural units: the Tulcea Unit (T) at the northeast and the Măcin Unit (M) at the southwest. Thus, there resulted the North Dobrogea intra-continental craton. Microtectonic studies (see Savu in Savu *et al*., 1980, unpub. rep.) made within the Niculițel area, showed that the geological formations have been striked through by a clivage, which was parallel with the main fractures and was dipping in the same SSW direction.

The mentioned strain performed on the North Dobrogea aulacogen, which was an echo of the orogenic movements from the Carpathian Orogen, determined the weak folding of the epicontinental deposits of this area.

OCCURRENCE AND PETROLOGY OF THE GRANITE PLUTONS AND OF THE RELATED VOLCANICS

The North Dobrogea granitoid province includes a big variety of plutronic and related volcanic rocks, which is not known among the granitoid associations from Romania, but maybe in the Paleozoic province from the Highiș – Drocea Mountains (see Savu, 2010a), although there are not just the same rocks like in North Dobrogea. According to the geotectonic evolution of the North Dobrogea territory and to the age of the granitoid rocks, in this paper these rocks have been separated into two main series: the Permo-Carboniferous calc-alkaline granitoid series and the Triassic-Jurassic alkaline granitoid series.

THE PERMO-CARBONIFEROUS CALC-ALKALINE GRANITOID SERIES AND ITS RELATED VOLCANIC ROCKS

In this series the occurrences of granitoids of Paleozoic age like the leucocratic granites of Hamcearca (320 Ma), Uzum Bair (306 Ma) and the Permian granitoid pluton of Greci (248 Ma) were included. The radiometric age of these granitoids was determined by Mânzatu *et al*. (1975) and Pop *et al*. (1985) by the K/Ar method and by the Rb/Sr method, respectively. All these granitoid plutons are located in the Măcin Unit (see Fig. 1). According to the geological map by Seghedi *et al*. (1992), the Hamcearca granite body occurs in an area situated between Greci, Cerna and Horia, in which other Paleozoic occurrences of granitoids and related volcanics are present. At Sarica, east of Niculițel, in the Tulcea Unit, from under the stratigraphic unconformity between the Triassic basaltic volcanics and their Paleozoic crystalline schist basement a small body of granitoid occurs in the last, on a short brook (Savu *et al*., 1980, unpub. rep.). As volcanic rocks related to the Paleozoic granitoids from the Măcin Unit Berbeleac *et al*. (1985, unpub. rep.) described rhyolites within the areas around the Iglicioara Mare and Iglicioara Mică, and Seghedi *et al*. (1992) mentioned trachytes occurring in the Tulce Unit at Tulcea Monument and Mahmudia. The Permian Carapelit Formation includes numerous intercalations of acid volcanics (Seghedi *et al*., 1987), which are the corespondents of the granitoid plutons of the same age.

Among all these granitoid plutons and acid volcanics the Greci one is the most important and more representative for this granitoid group. The pluton was intruded into the Permian Carapelit Formation, the sedimentary deposits of which have been contact-metamorphosed and trasformed into contact rocks like hornfelses and skarns (see A. Seghedi and Oaie, 1995).

As it was presented by Rotman (1913) the Greci pluton was considered to represent a laccolith. But according to the geological map of this author the granitoid body looks like a somehow zoned pluton, elongated on the NW-SE direction. It is formed on the margins by an amphibole granite, which was considered as representing a marginal facies. This amphibole granite passes toward the inner part of the body to a granodiorite, which includes in the center of the pluton an important mass of tonalite and gabbro. According to A. Seghedi and Oaie (1995), hornblende granodiorites and tonalites form the most important rocks of the pluton, which are passing to the diorites and the gabbroic rocks from the center of the pluton. Within the pluton mass autoliths and xenoliths of different hornfelses are to be observed.

After the emplacement of the Greci pluton there occurred different dykes of plagiaplites, amphibole granites and porphyry rocks, which intruded both the granitoid pluton and the country formations. The dyke composition and their structure show that the differentiation of the granitoid magma took place both in the depth, in the magmatic chamber, and during the intrusion of the granitoid pluton. In the Table 1 are represented the most important chemical elements of the North Dobrogea granitoid plutons and of their related rocks.

Table 1

The averages of the most important chemical elements from the North Dobrogea granitoid plutons and their related rocks*

Rock group	SiO_2	K_2O	Na_2O	K_2O/Na_2O	$Fe_2O_3 + FeO$
Paleozoic Greci granitoids	73.52	2.30	4.31	0.53	–
Hamcearca leucocratic granites	77.30	3.99	4.66	0.85	–
Related volcanics	70.0	5.69	1.97	2.8	–
Trondhjemitic rocks	84.75	1.82	5.03	0.36	1.71
Quartzkeratophyres	86.4	0.11	5.88	0.01	1.24
Triassic Shoshonitic granites	74.70	5.55	2.84	1.95	–
Related volcanics	76.36	7.65	0.93	8.22	–
Triassic Na-alkali granites	70.18	4.32	4.68	0.92	3.06
Related volcanics	73.74	4.62	4.33	1.06	–

* The average values from the table were calculated on the data from Rotman (1913), Cantuniari (1915), Savul (1937), Dimitrescu (1959), Berbeleac *et al*. (1985, unpub. rep.), Seghedi *et al*.(1987), Intorsureanu *et al*. (1989), Seghedi *et al*.(1992), Ştefan *et al*. (1992) and Tatu *et al*. (1993, unpub. rep.).

Concerning the Greci and Hamcearca granitoid bodies, in the table was shown that both plutons are formed by acid rocks, which contain 73.52 % SiO_2 in the Greci pluton and 77.30 % SiO_2 in the Hamcearca body, the leucocratic rocks of the last being highly differentiated. The value of the K_2O/Na_2O ratio is higher in the Hamcearca rocks than in those of the Greci pluton, which includes less potash feldspar, it being formed of acid up to basic rocks. On the diagram in Fig. 2 the rocks of the Greci pluton plot in the Low-K and Medium-K fields, a fact that points out the calc-alkaline character of the Paleozoic granitroids and especially of those from the Greci pluton. The Hamcearca leucocratic granites are very dispersed on the diagram, they plotting from the Low-K up to the shoshonitic granite field.

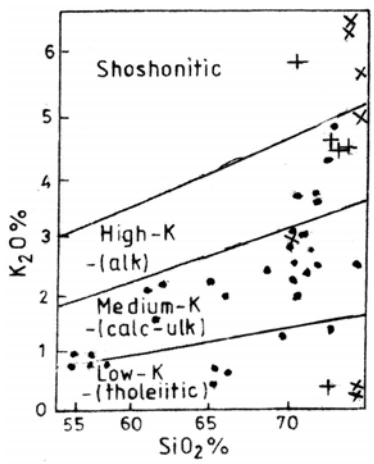

Fig. 2 – Plot of the Greci and Hamcearca granitoid rocks and their related volcanic rocks on the Rickwood (1989) K_2O vs. SiO_2 diagram. Dot, Greci rocks; cross, Hamcearca rocks; eks, Intra-Carapelit rhyolites. Data from Berbeleac *et al.* (1985, unpub. rep).

On the diagram in Fig. 3 the granitoid rocks from the Greci pluton and the Hamcearca leucocratic granites plot *à califourchon* over the lines which separe the three fields of the diagram. This behaviour is more evident in case of the Greci granitoids than in case of the Hamcearca rocks, which extends only between syn-COLG and WPG fields (see also Savu and Stoian, 1998). The plot of some Greci rocks in the ORG field indicates the presence among the rocks of this pluton of some basic rocks. On the whole, the distribution of the Paleozoic rocks in the three fields of the diagram shows that the intrusions of these rocks manifested themselves under geotectonic conditions of syn-collision to post-collision type, *i.e.* under the transition period, when the North Dobrogea territory evolved from the syn-collision toward the withiplate geotectonic conditions.

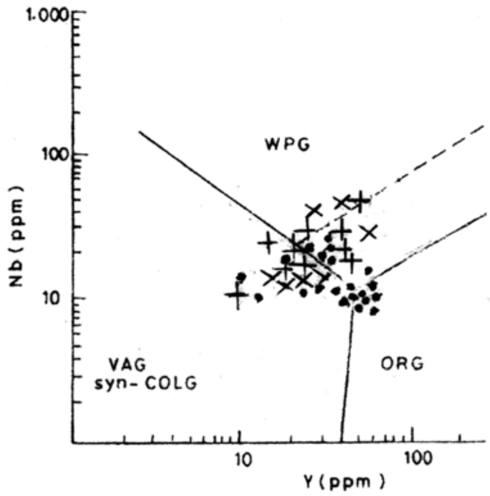

Fig. 3 – Plot of the Greci and Hamcearca granitoid rocks as well as of the Intra-Carapelit rhyolites on the Pearce *at al*. (1984) Nb vs. Y diagram. Data from Berbeleac *et al*. (1985, unpub. rep.). Dot, Greci rocks; cross, Hamcearca rocks; eks, Intra-Carapelit rhyolites.

Here is the place to show that among the Paleozoic granitoid rocks from the Măcin Unit, rocks with an evident trondhjemitic character are present, as the diagram in Fig. 4 shows. On this diagram such rocks plot within the field D, which is the field of the trondhjemitic granitoids and of their volcanic corespondents, the quartzkeratophyres from the Carapelit Formation, or near this field.

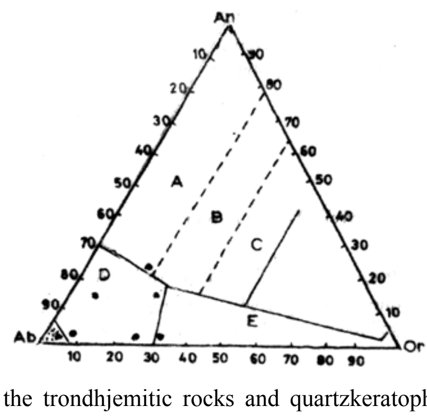

Fig. 4– Plot of the trondhjemitic rocks and quartzkeratophyres from North Dobrogea on the O'Connors (1965) An-Ab-Or diagram. Dot, trondhjemitic rocks; the small triangle from the Ab corner represents the plot area of the quartzkeratophyres. Data from Berbeleac *et al*. (1985, unpub. rep.).

Table 1 shows that the trondhjemitic rocks have the lowest content of K_2O and the highest content of SiO_2 as against the granitoid rocks from the North Dobrogea granitoid province. Their content of 5.03 % Na_2O is even higher than that from the Na-alkali granites. In spite of this content, in the trondhjemitic rocks aegyrine and riebeckite have not been formed. The reason that in these rocks such minerals did not occurr is their low content in iron compounds. Thus, while the aegyrine and riebeckite granites contain up to 3.06 % iron compounds (see Table 1), in the trondhjemitic rocks the sum of iron compounds is of 1.71 % and in the quartzkeratopyres it is only of 1.24 %. These contents are both to low to satisfy the $NaFeSi_2O_6$ formula of aegirine and that of riebeckite, which is $Na_2Fe_3Fe_2(OH)Si_8O_{22}$.

THE TRIASSIC-JURASSIC ALKALI GRANITES AND RELATED ROCK SERIES

The Triassic-Jurassic granitoid and related rock series also includes a big variety of granites (Seghedi *et al.* 1994) and related volcanics. All these granites and related volcanics have been emplaced during the evolution stage when the old mobile belt of North Dobrogea became completely stable and sutured to the two old convergent plates, the East European Plate (EEP) and the Moesian Plate (MP), forming together a single continent in the Carpathian Foreland. Therefore, the Triassic-Jurassic magmatic activity manifested itself under the conditions of a continental plate regime. According to their general characteristics, the alkaline granites and the related rocks have been separated into two groups: the shoshonitic (K-alkali) granites and the related volcanics group, and the Na-alkali granites and related volcanics group.

a. THE SHOSHONITIC (K-ALKALI) GRANITES AND THE RELATED VOLCANIC GROUP

Bodies of shoshonitic (K-alkali) granites and related acid volcanics occur everywhere on the North Dobrogea aulacogen. But the most important manifestation of this magmatism took place in the Măcin Unit during the Triassic and lasted up to the Lower Jurassic. There volcano-plutonic associations occur along a NW-SE alignment, situated in the south of this tectonic unit and accompanying the important Peceneaga-Camena fault (Fig. 1). This fault probably had an important role in the intrusion and the eruptions of shoshoniyic and Na-alkaline magmas. According to the geological maps by Seghedi *et al*. (1992) and Ștefan *et al.* (1992) along this main fault the volcano-plutonic associations of shoshonitic and Na-alkali granites occur within the Turcoaia and Cârjelari areas as individual occurrences; an important volcanic association of rhyolites occurs at Camena, in the southeast of the alignment. Among the shoshonitic granites the most characteristic are the Pricopan (222 Ma) and the Coșlugea (238–193 Ma) plutons. The Pricopan granite was described by Giușcă (1934) as formed of a large granular biotite granite, which was affected by a process of mylonitization, probably during the North Dobrogea cratonization. Within the pluton mass there occur microgranular autoliths and leucocratic dykes as well as basic dykes (see Tatu *et al*. 1993, unpub. rep). The granite consists of quartz with ondulatory extinction, sometimes recrystallized, microclineperthite which prevails on the albite-oligoclase and biotite. In the pluton mass some albitization zones occur, too. On a QAP diagram the Pricopan granites fall in the field of the syenogranites (Nedelcu *et al*., 1986, unpub. rep.).

The Coșlugea pluton, which was first decribed by Savul (1937), represents an intrusion of 5 km long. It intruded the Devonian formations, which have been contact-metamorphosed into different types of hornfelses. The pluton consists of several granite varieties, which occur in distinct zones. Thus, in its northern part a zone of red granite with red feldspar occurs. A little south of this zone, there follows a zone in which the granite contains little red feldspar and more white plagiocase. Toward the southwest a zone of light coloured granite occurs, in which the potash feldspar is almost absent. The pluton eastern margin is formed of microgranites and graniteporphyries. It is of interes the red granite, which in North Dobrogea is to be found in the Coșlugea pluton, only. It has a hypidiomorphicgranular texture and consists of much microperthitic red feldspar, which forms granophyric intergrowths with quartz. The biotite lamelae have been transformed into a dark green chlorite, associated with iron oxides, epidote and sometimes calcite. As accessory minerals rutile, zircon and apatite occur.

On the diagram in Fig. 5 the Pricopan and Coşlugea granites plot in the shoshonitic field of the K-alkali granites. A few of them fall in the High-K (alk) field. This position of the shoshonitic granites on the diagram is in concordance with their mineralogical composition, as they are made mostly of potash feldspar, as shown above.

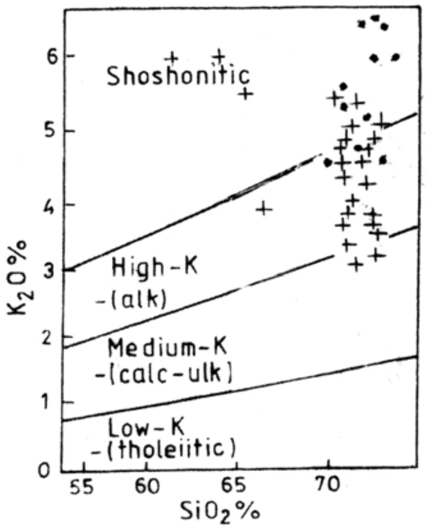

Fig. 5 – Plot of Pricopan and Coşlugea shoshonitic granites (dot) and of Na-alkali granites (cross) on the Rickwood (1989) K_2O *vs*. SiO_2 diagram. Data for the Pricopan rocks are from Giuşcă (1934) and for Coşlugea rocks from Savul (1937) and Tatu *et al*. (1993, unpub.rep); data for the Na-alkali granites from Iacobdeal and Piatra Roşie are from Cantuniari (1913) and Tatu *et al* (1993, unpub. rep.); data for the rocks from the Sacar pluton are from Dimitrescu (1959).

On the diagram in Fig. 6 the Pricopan shoshonitic granites fall in the withinplate field. See also Savu and Stoian (1998). This position of the rocks on the diagram is consistent with their intrusion into a continental plate.

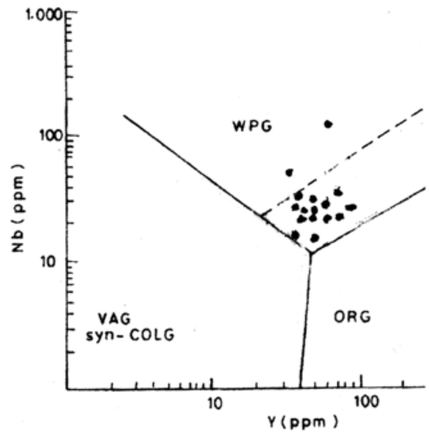

Fig. 6. Plot of the shoshonitic granites on the Pearce *et al*. (1984) Nb *vs*. Y diagram. Data from Tatu *et al*. (1993, unpub. rep.)

The acid volcanism related to the shoshonitic granites occurs all over the Noth Dobrogea territory (see Seghedi *et al.,* 1992). For instance, in the Tulcea Unit rhyolites and sometimes trachytes form a short alignment extending between Isaccea, Somova and Mineri (Savu *et al.*, 1985). But the most important volcanic association of acid rocks (220 Ma) occurs around Camena, in the southeast of the main volcano-plutonic alignment from the Măcin Unit. As shown by Cădere (1925) and Ştefan *et al.* (1992) this volcanic association consists of rhyolites, fluidal rhyolites, vitroclastic rhyolites, biotite rhyolites, perlitic rhyolites, granophyric rhyolites as well as biotite microgranites and granophyres. Ştefan *et al.* I (1992) considered that these volcanics erupted during the Oxfordian, an opinion in contrast with the radiometric age.

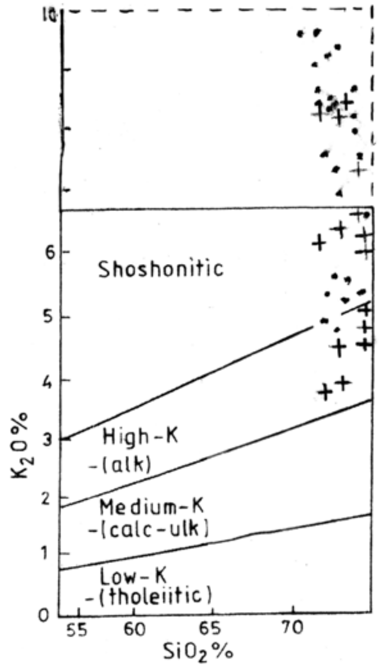

Fig. 7 – Plot of rhyolites on the Rickwood (1989) K_2O vs. SiO_2 diagram. Dot, rhyolites from North Dobrogea (data from Seghedi *et al.*, 1987); cross, Camena rhyolitea (data from Ştefan *et al.*, 1992).

On the diagram in Fig. 7 the rhyolite plots extend from the High-K field, through the shoshonitic rock field, up to an upper additional field of quartz rock very rich in K_2O.

b. THE Na-ALKALI GRANITES AND RELATED VOLCANICS GROUP

The group of Na-alkali granites includes three important alkaline plutons like Iacobdeal, Piatra Roşie and Sacar. These plutons are accompanied by Na-alkaline volcanics and different dyke rocks. As shown by Întorsureanu *et al.* (1989) the Na-alkali granites and the related rocks are distributed along two alignments. The northern alignment is marked by the Iacobdeal (193 Ma) and Piatra Roşie plutons. The second alignment, which is situated at the southwest of the first, consist mostly of porphyritic rocks occurring in Dealul lui Manole, Iglicioara Mare, Iglicioara Mică and Gorganu. These alignments extends toward southeast up to the volcano-plutonic association of Cârjelari. The Rb/Sr age of the Na-alkali granites is of 197 to 193 Ma. Cantuniari (1913) and Întorsureanu *et al.* (1989) showed that among the Na-alkaline rocks from these plutons there occur quartzsyenites, riebeckite granites, aegirine and riebeckite granites and dykes of granophyric alkali granites, alkaline microgranites, porphyritic alkali granites, granophyric aegyrine micrinto granites, riebeckite aplites, riebeckite rhyolites and alkaline rhyolites.

The most characteristic alkaline rocks from the Iacobdeal and Piatra Roșie plutons are the aegyrine and riebeckite granites and the aegyrine granites. The first granites consist of microclineperthite, quartz, riebeckite, arfvedsonite, aegyrine and accessories like zircon, apatite, magnetite, titanite and fluorite. The riebeckite and aegyrine granites are formed of orthoclase, quartz, aegyrine, riebeckite, magnetite, zircon, titanite and apatite. Dykes of riebeckite rhyolites and basic rocks often cross the region.The Na-alkaline plutons determined important phenomena of contact metamorphism on the Devonian and Silurian formations as well as on the rocks of the Carapelit Formation. These resulted in hornfelses formed in the albite-epidote facies at temperatures of 400 to 530°C.

The Sacar pluton (196 Ma), which is accompanied by the Cîrjelari rhyolites, was studied by Dimitrescu (1959). It consists on its northern margin mostly of riebeckite granites, which pass toward south to a granite with riebeckite and little aegyrine. On the northeast part of the pluton a facies of amphibole and titanite granite was separated and on its extremity the aegyrine granite is the prevalent component rock. The riebeckite granite consists of microperthitic feldspar, quartz and riebeckite. In the aegyrine granite the potash feldspar is represented by orthoclase and in a low extent by microperthitic feldspar. In association with the alkaline plutons there also occur granophyres, which consist mostly of micropegmatitic intergrowths.

The Cârjelari rhyolites (282 Ma) form a mass of volcanic rocks consisting in its southwest part of grey-redish rhyoliyes and in the northeast part of felsic rhyolites. The rhyolites are formed of a quartzo-feldspatic groundmass with phenocrysts of quartz and anorthoclase. The groundmass shows a fluidale texture, in which rare microcrystalline schlieren are present.

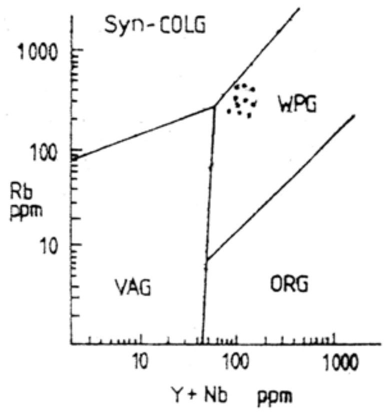

Fig. 8 – Plot of the Na-alkali granites on the Pearce *et al*. (1984) Rb *vs*. Y + Nb diagram. Data from Întorsureanu *et al.* (1989)

On the diagram in Fig. 5 the Na-alkali granites plot within the High-K (alk) field, which is in concordance with their alkaline character. Like the K-alkali shoshonitic granites, the Na-alkali granites plot on the diagram in Fig. 8 in the withinplate granite field, which shows their intrusion through a continental plate.

ORIGIN OF THE NORTH DOBROGEA GRANITOIDS AND RELATED ROCKS

In the former chapters it was shown that the granitoid rocks from the petrographic province of North Dobrogea belong to two rock-series of different age, rocks which occurred under different geotectonic conditions. Therefore, the researches on their origin must be approached in different ways and with different methods. The Paleozoic granitoids were emplaced probably during the last stage of the Variscan Orogeny, as the Permian formations have been partly affected, too. Therefore, these intrusions must be considered as resulted from an almost orogenic magmatic activity. By consequence, on the Na_2O vs K_2O diagram (Fig. 9) rocks like the Greci and Hamcearca granitoids as well as the Intra-Carapelit acid volcanics plot in the field I, in which rocks of igneous origin fall.

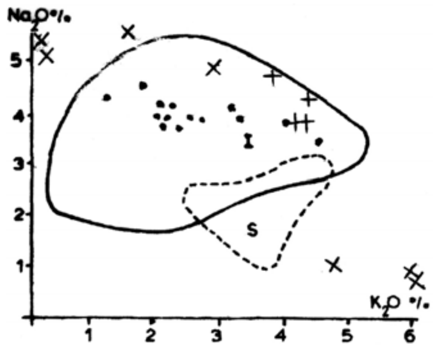

Fig. 9 – Plot of the Greci and Hamcearca granitoids and of the Intra-Carapelit rhyolites on the Chappell and White (1974) Na_2O *vs*. K_2O diagram. I, field of the granitoids originating in endogenous magmas; S, field of the granitoids originating in magas of sedimentary origin. Data from Berbeleac *et al*. (1985, unpub. rep.) and Seghedi *et al*. (1992). Dot, Greci granitoids; cross, Hamcearca granitoids; eks, Intra-Carapelit rhyolites.

A number of five analyses from each important rock-associations like Greci, Hamcearca and the Intra-Carapelit rhyolites and quartzkeratophyres have been plot on the diagram in Fig. 10. On this diagram almost all rocks, save a few Hamcearca granites, fall in the field A2 of the granite derived from magmas formed during the stage of the continent/continent collision or of an island arc magmatism. The rock position on this diagram is consistent with their position on the diagram in Fig. 3, where they occur as syn-collision to post-collision rocks.

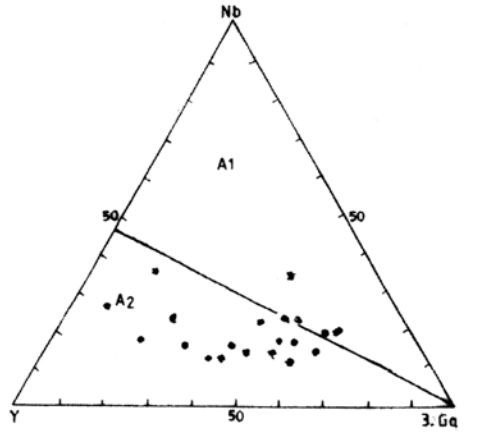

Fig. 10 – Plot of the granitoids and of their related rocks on the Eby (1992) Nb-Y-3.Ga diagram. A1, field of the granites derived from oceanic-island basaltic magma but emplaced in continental environments; A2, field of the granitoids derived from continental or underplated crust during continent/continent collision or island arc magmatism. Data from Berbeleac *et al*. (1985, unpub. rep.) and Seghedi *et al*. (1992).

Moreover, the average value of the Y/Nb ratio from the North Dobrogea Paleozoic granitoids and their related rocks varies from 1.15 up to 3.33, values which indicate the origin of these granitoids and of the related rocks in crustal parental magmas (see Eby, 1992). If such a possibility is reasonable for the trondhjemites and the Intra-Carapelit quartzkeratophyres, rocks rich in SiO_2 and Na_2O, it is difficult to apply it for the Greci pluton, in which besides the granitoids gabbros occur, too. Therefore, for this pluton is better to accept an origin of the parental magma in the lower crust, where crustal and mantle materials are mingled together, especially that on the diagram in Fig. 3 such rocks plot in the oceanic granite field.

The Triassic-Jurassic shoshonitic granites and Na-alkali granites occurred under different geotectonic conditions. They have been emplaced when the North Dobrogea territory consolidated into an aulacogen, in which an intra-continental craton was formed. Therefore, all the granites and related rocks emplaced during this period are bearing the withinplate signature. This character, it seems, started to be imprinted in the magmatic rocks even from the last stage of the Permian period. For establishing the origin of these rocks there are more adequate analyses of REE, but unfortunately for the related volcanics, only. On the diagram in Fig. 11 the rhyolites from different places of North Dobrogea and the Camena rhyolites, the related rocks of the plutonic rocks, plot along the plume source line and at the right of it. Some rhyolites fall on the diagram in the area of the mixed source line, showing that they resulted from magmas contaminated with crustal materials or magmas coming from the lower crust.

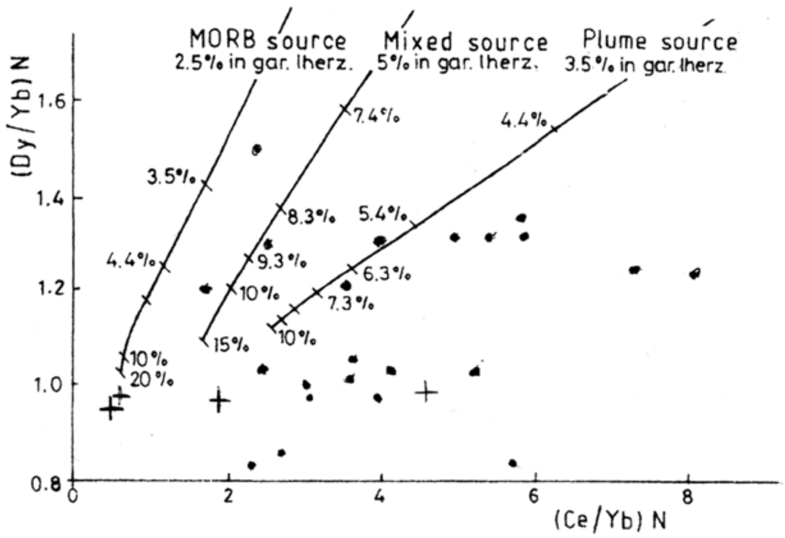

Fig. 11 – Plot of the rhyolites from different places of North Dobrogea and of the Camena rhyolites on the Haase and Devey (1996) (Dy/Yb)N *vs*. (Ce/Yb)N diagram. Dot, rhyolites from different places of North Dobrogea (data from Seghedi *et al.*, 1992); cross, Camena rhyolites (data from Ştefan *et al.*, 1992).

It is noteworthy to add that in a previous paper (Savu, 2008) it was shown that the shoshonitic granitoids originated in plume sources. The origin of the Triassic-Jurassic granitoids and related volcanics fron North Dobrogea in plume sources is acceptable, too, the more so as the aspect of the volcano-plutonic associations distributed along the main Peceneaga–Camena tectonic line look like hotspots with volcanics spread around the granitoid plutons or near them (see the geological map by Seghedi *et al.*, 1992).

CONCLUSIONS

First of all, this paper established the concept of North Dobrogea granite province and the classification of the granites, including the related rocks, into four main types, based on modern criteria. The petrology and the origin of these rocks were also presented. According to the above presented observations it results that the North Dobrogea granitoid province includes two principal granitoid series. The first series is a Permo-Carboniferous one, which consists of granitoid and related rocks, occurred during the syn-collision to post-collision stage of the Paleozoic Orogeny. The rocks are calc-alkaline and their parental magmas came from the crust, including the lower crust.

It is noteworthy to show that there is not a clear moment, when the first geotectonic stage passed to the second, because withinplate magmatic rocks start occurring even from the last Permian stages, as for instance in the Carapelit Formation.

The rocks of the second granitoid series occurred mostly during the Triassic period, their eruption lasting up to the Jurassic. The magmatism that generated these rocks manifested itself during the Early Mesozoic, when the old mobile belt of North Dobrogea became stable and an intra-continental craton was formed. Both the intrusive rocks like the shoshonitic (K-alkali) granites and the Na-alkali granites are bearing the withinplate signature. Their parental magmas origated in plume sources or occurred under the influence of mantle plumes, which were formed during the distension period that followed the last Paleozoic compression. The granitoid intrusions determined the occurrence of contact rocks, among which skarns with *palimpsest* structure like those of Iulia, and poor mineralizations of fluorite. The echo of this intense magmatic activity was, it seems, a weak acid volcanism that manifested itself up to the Oxfordian.

The North Dobrogea province presents some similitudes with the Triassic–Jurassic Carpathian alkaline province (Savu, 2010b), with the difference that the first contains alkali granites and the second nepheline syenites. Nevertheless, drillings made north of Dobrogea aulacogen, in the southwest extremity of the East European Plate, after crossing the young sedimentary deposits, penetrated some plutonic rocks. In a thin section on such a rock, which was offered to me for an examination, I discovered that the rock was a liebnerite syenite. There is no doubt that these nepheline syenites belong to the North Dobrogea petrographic province, too.

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