THREE GROUP-TYPES (COMMON ROCK,TRONDHJEMITIC AND SHOSHONITIC) OF GRANITOID PLUTONS IN THE SOUTH CARPATHIAN GRANITOID PROVINCE, ROMANIA: A COMPARATIVE STUDY

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Within the granitoid province from the western part of the South Carpathians more than 20 granitoid plutons are to be found, which belong to three group-types, like common rock, trondhjemitic and shoshonitic granitoid plutons. Plutons from each group intruded both the Danubian Autochthone and the Getic Nappe. Around the more important plutons large zones of regional-contact metamorphism occur, which show the syn-collision (syn-orogenic to tarde-orogenic) tectonic setting of these plutons, except for the shoshonitic plutons which are post-collision (late-orogenic) intrusions, as phenomena of regional-contact metamorphism occur around the Tismana shoshonitic pluton, too. These tectonic settings have been also proved by the geochemical data. A regional differentiation of these plutons occurs there. Thus, the common rock granitoid plutons are spread all along the occurrence area of the granitoid province, whereas the trondhjemitic plutons are located only within the western bent zone of the South Carpathians and the main shoshonitic plutons occur along the southern margin of the Danubian Autochthone, only. The chemical composition of the granitoid plutons shows that, in comparation with the normal composition of the common rock granitoid plutons, the trondhjemitic plutons are richer in SiO_2 and the shoshonitic plutons present higher contents of alkalies and iron components, and lower of CaO. In the genesis of the plutons from this Carpathian granitoid province the magmatic processes followed two trends. According to the first trend, from the metasomatic mantle a fraction of tonalitic-dioritic magma was generated by partial melting (anatexis), from which an arc calc-alkaline magma derived, in which the common rock granitoid plutons originated. This magma was contaminated by crustal anatectic melts and enriched in silica, a hybrid magma resulting, which was the parental magma of the trondhjemitic plutons. At the same time, or a little later, a monzo-dioritic or even monzo-gabbroic magma occurred, that was the parental magma of the shoshonitic plutons, a process that manifested itself according to the second trend. This complex process of genesis of the granitoid plutons in the South Carpathian granitoid province is supported by the distribution of trace elements and REE and their plot on different diagrams.

Key words: Carpathian granitoid province, common rock granitoid plutons, trondhjemitic plutons, shoshonitic plutons, geochemistry, origin.

1. INTRODUCTION

The old granitoid plutons from the granitoid province in the western part of the South Carpathians have long been considered as being formed of common granitoid rocks like granodiorites and granites, which were sometimes associated

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with quartz-diorites and diorites (see Giuşcă and Pavelescu, 1955). But in 1977 Savu *et al*. showed that the Buta pluton was composed mostly of trondhjemites associated with some common granitoids. Then, there has been found out that the Buchin and Slatina Timiş plutons had the same geochemical characteristics (see Savu, 1997: Savu *et al*., 1997). In 1998 – 1999 Savu and Dobrescu discovered that numerous granitoid plutons from the west part of the South Carpathians consisted of the same rock association. In 1998 Duchesne *et al*. showed that the Tismana pluton was formed of shoshonitic granitoid rocks which, in fact, represented another group of granitoid plutons. Therefore, it resulted that in the South Carpathian granitoid province there are to be found three group-types of granitoid plutons, namely, common rock: trondhjemitic and shoshonitic granitoid plutons. As matters now stand, I considered of interest a comparative study of these three groups of granitoid plutons, in order to establish their geochemical features, origin, tectonic setting, their relationships with the country rocks, as well as their genetic classification, aspects which will be shown further down.

2. PRE-VARISCAN GEOLOGICAL EVOLUTION OF THE SOUTH CARPATHIANS AND THE GRANITOID PLUTONS' EMPLACEMENT AND TECTONICS

Within the South Carpathians area more than 20 granitoid plutons are to be found, among which 18 of them are more important. These granitoid plutons are located in the Pre-Variscan crystalline schists of the Danubian Autochthone and of the Getic Nappe, being distributed along three magmatic alignment or arcs (Fig. 1). The length of these plutons varies between 0.5 and more than 30 km.

Most of the granitoid plutons are located in the Danubian Autochthone. This structural unit represents, in fact, a tectonic window that was formed by the exhumeishen ot the Danubian Autochthone from under the Getic Nappe due to some longitudinal and transversal faults (Savu, in press), starting by the beginning of the Tertiary period. It consists mostly of the Pre-Variscan metamorphic and metasomatic crystalline schists of the Lainici-Păiuş, Poiana Mraconia, Neamțu and Corbu series, as more characteristic. A few less important series like Latorița series at the east and Bărnița series at the north-west are associated with, which are coevals of the Corbu low metamorphic series. Along the inner margin of the Danubian Autochthone occur the Drăgşan, Măru and Ielova series, formed of orthoamphibolites and ultramafic rocks that represent vestiges of the Pre-Variscan ophiolitic suture (Savu, 2003). The age of these crystalline series varies from 820 Ma (Liégeois *et al*., 1996) up to 500 Ma (see Kräutner, Savu, 1978). They have been metamorphosed due to the Dalslandian (Cadomian) – Caledonian movements during the Pre-Variscav tectono-magmatic cycle, that lasted from the Upper Precambrian up to the Late Cambrian, maybe the Middle Ordovician (Savu, 2005 a). Together with the granitoid plutons, these formations constitute the infrastrusture of the Danubian Autochthone, over which Late Paleozoic amd Mesozoic formations (Stănoiu, 1971; Dimitrescu, 1993) from the superstructure are lying.

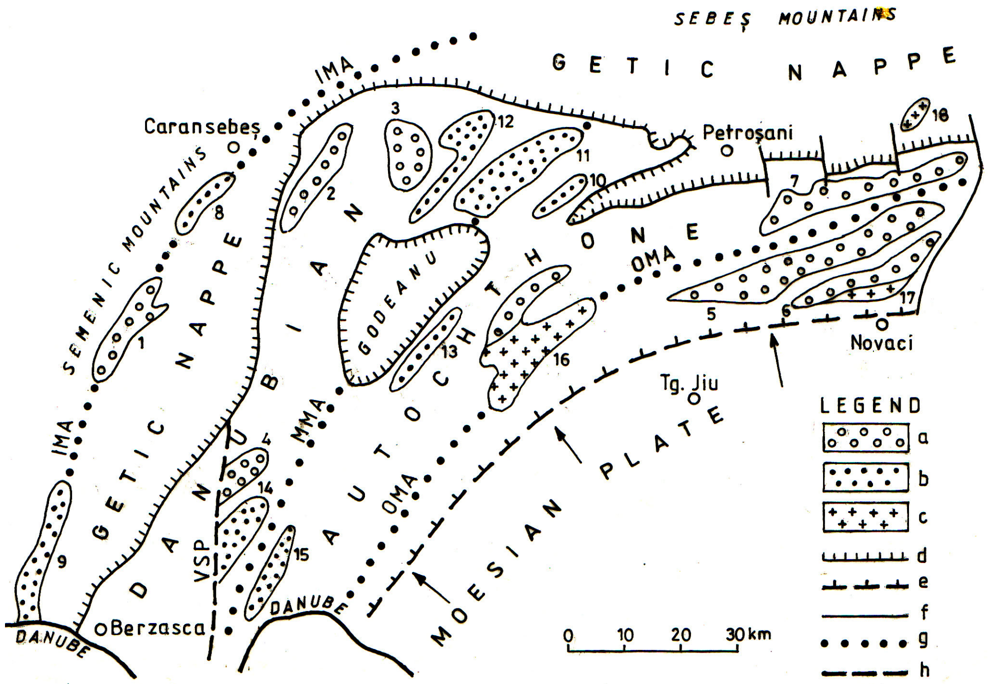

Fig. 1 – Emplacement of the granitoid plutons from the South Carpathians along three magmatic arcs. a, Common rock granitoid plutons: 1, Poneasca; 2, Muntele Mic; 3, Vârful Pietrii; 4, Sfârdin; 5, Şuşiţa; 6, Cărpiniş; 7, Parâng. b. Trondhjemitic plutons: 8, Buchin + Slatina Timiş; 9, Sicheviţa; 10, Buta; 11, Retezat; 12, Petreanu-Furcătura; 13, Culmea Cernei; 14, Cherbelezu; 15, Ogradena. c, Shoshonitic plutons: 16, Tismana; 17, Novaci; 18, Lacul Vidra (Voineasa). d, thrust; e, supposed Getic Nappe initial extension; f, fault; g, magmatic arc, h, Variscan subduction plane (VSP); IMA, inner magmatic arc; MMA, median magmatic arc; OMA, outer magmatic arc. Arrows indicate the direction of the Pre-Variscan subduction of the old Moesian Plate under the initial South Carpathian Chain.

The old structures from the crystalline schists of the Danubian Autochthone are parallel to the margin of the Moesian Plate (Fig. 1), that was subducted beneath the Carpathian Chain during the Pre-Variscan cycle and later on.

The Getic Nappe which is situated inside of the Carpathian Chain (Fig. 1) also consists of an infrastructure of metapelitic and metapsamitic crystalline schists, metamorphosed under the conditions of the sillimanite up to the biotite-chlorite Barrowian isogrades (see Savu, 1970; Savu *et al.*, 1978). They belong to the Sebeş-Lotru and Miniş series and have been metamorphosed by the end of the Pre-Variscan cycle, during the Late Caledonian movements, as the ages of 500 to 400 Ma obtained on zircon crystals showed (see Balintoni *et al.*, 2004). Orthoamphibolites derived from IAB-type basalts are associated with, as it results from the diagram in Fig. 2, on which these rocks fall in the AL field.

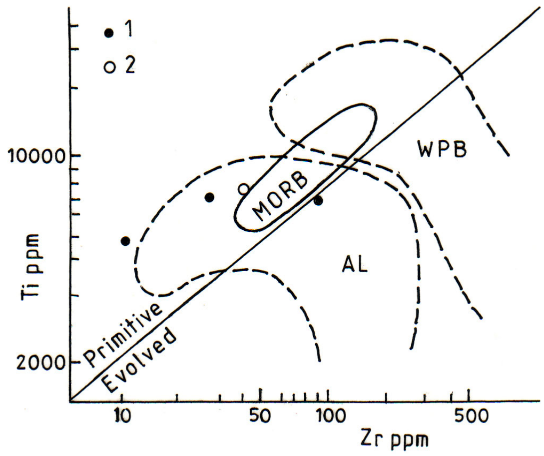

Fig. 2 – Plot of the orthoamphibolites from the Voineasa region on the Ti vs Zr diagram. Fields according to Pearce (1980): WPB, intra plate basalts; MORB, mid-ocean ridge basalts; AL, arc basalt lavas. 1, orthoamphibolites; 2, average of the three analyses.

This observation shows that the sedimentary deposits in which there have been the basaltic rocks of AL-type, the orthoamphibolites came from, were formed during the subduction stage of the Moesian Plate under the old Carpathian island arc, leading to the closing of the Pre-Variscan ocean (Savu, 2005 a). Moreover, this conclusion is supported by the occurrence of ultramafic rock and eclogite olistoliths spread in the Sebeş-Lotru series (Savu, 2004 a). These olistoliths were torn from the subduction plane and insedimented in the deposits the Sebeş-Lotru series resulted from. .

The syn-metamorphic fold structures from both the Danubian Autochthone and the Getic Nappe are parallel to the margin of the subducted Moesian Plate (Fig; 1). In the Sebeş-Lotru Series from the Getic Nappe these structures form a virgation structure, the axial anticline of which occurs in the midle of the Semenic Mountains (Savu, 1965 b). The *vergenz* of these structures from both tectonic units is oriented toward the subducted tectonic plate. These old Pre-Variscan structures have been eroded and affected by the Variscan and Alpine movements, so that new structures occurred there, usually of shear-type (Savu *et al*., 1990). As for instance, in the Variscan shear zone from the Şuşiţa granitoid pluton, crossed by the Gilort Valley, Soroiu *et al*. (1970) obtained K/Ar ages of 219 to 296 Ma, whereas in the normal granitoids the ages were of 402 to 522 Ma. Even granitoids which do not show any effect of the shearing process, like the Tismana pluton, are yet bearing the signature of the Variscan strain (Dimitrescu and Dimitrescu, 2003). The effects of the shearing process are more evident in the granitoid rocks due to their initial homogeneous structure and texture. But they must have been imprinted in the host crystalline schists, too, as it is shown by the variable ages of 850 to 153 Ma determined on these rocks by Soroiu *et al*. (1970), Bagdasarian (1972) and recently by Balintoni *et al*. (2004).

In both tectonic units the granitoid plutons were usually emplaced within the primary anticline axis. These tectonic relationships show that the granitoid plutons are syn-orogenic up to late-orogenic, a tectonic setting supported by the regional-contact metamorphism of the surrounding crystalline schists (Savu, 2005 b), in both Danubian Autochthone and Getic Nappe. Such type of metamorphism occurs at the contact of Sichevița granitoid pluton, Cherbelezu, and along a large area of regional-contact metamorphism of Danubian-type (Savu, 2005 b) extending from the Tismana pluton eastward up to the Cărpiniş pluton. It is supported also by the syn-orogenic arteritic migmatization process that manifested itself at the contact of the Muntele Mic, Şuşița and Parâng granitoid plutons To all these processes there must be added the incipient gneissic structure of the granitoid rocks. The intrusion of the granitoid plutons during the folding and the regional metamorphism of the host crystalline schists is proved, also, by the microtectonic elements from both the crystalline schists and the granitoid plutons. These elements show the same orientation, as it was established in case of the Poneasca granitoid pluton (Fig. 3) and of Şuşița and Cărpiniş plutons (Savu, 1972). From these observation and Fig. 3 it results that the Q-joints from the granitoid plutons are perpendicular onto the lineation elements from the crystalline schists, like the ac-joints from the crystalline schists themselves

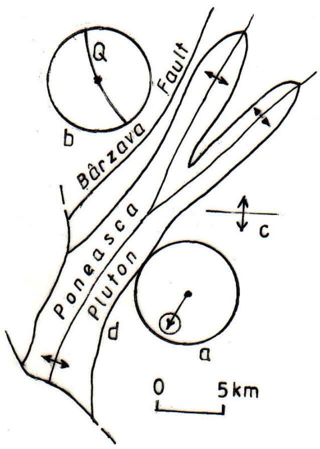

Fig. 3. Relatioships between the microtectonic elements from the crystalline schists of the Sebeş-Lotru series and the Poneasca granitoid pluton (data from Savu *et al.* 1997). a, structural diagram for the lineations from the Sebeş-Lotru series; b, structural diagram for the Q-joints from the Poneasca pluton; c, the main anticlinal axis of the virgation structure from the Semenic Mountains, in which the granitoid pluton was emplaced.

The emplacement of the granitoid plutons all along the western part of the South Carpathians was followed by the intrusion of numerous types of dyke rocks like lamprophyres, porphyritic rocks of different composition (dioritic, granodioritic, granitic) aplites and pegmatoid veins. As an exception, the Poneasca pluton was cut by veins of pegmatites which are almost similar to those that cut the high metamorphic host crystalline schists.

3. PETROGRAPHY, CLASSIFICATION AND AGE OF THE GRANITOID PLUTONS

As shown above, the granitoid plutons from the South Carpathians belong to three groups like common rock, trondhjemitic and shoshonitic granitoid plutons.

a. Common rock granitoid plutons. Such granitoid plutons are distributed all along the South Carpathian western area, from the Semenic Mountains eastward up to the Căpăţâna Mountains, being located all along the three magmatic arcs from Fig. 1. But most of these plutons are to be found within the eastern part of the Danubian Autochthone, where the longest Şuşiţa pluton of more than 30 km long occurs, too. Except for the Vârful Pietrii granitoid pluton which looks rather like a swollen stock, the other plutons occur as elongate granitoid bodies. As shown by Gherasi and Savu (1969) and Savu *et al*. (1973 a) the Muntele Mic pluton presents an *en voûte* structure (see the model in Raguin, 1957). Along the IMA (Fig. 1) there occur the Poneasca pluton. On the MMA (Fig. 1) are to be found the Muntele Mic, Vârful Pietrii, Retezat and Sfârdin granitoid plutons, whereas on the OMA (Fig. 1) Şuşiţa, Cărpiniş and Parâng granitoid plutons are located. It is of note that around Şuşiţa and Cărpiniş plutons nebulitic migmatites with ptygmatic veins are associated with which occur in the Aninişu Mare Brook. Injections of granitoid magma from the Parâng pluton determined the occurrence of reticular migmatites in the amphibolite rocks of the Drăgşan series.

By their general features these granitoid plutons do not differ very much from the previous ones. However, some structural and petrographic aspects are specific to these plutons. Thus, they are formed mostly of granodiorites and granites, some differentiates of quartz-diorites and diorites being associated with (field A in Fig. 5), as for instance in the big Şuşiţa granitoid pluton in which *septa* (Raguin (1957) and melanocratic autoliths do occur (see Savu, 1970; Savu *et al*., 1972)

Another particular aspect of these plutons is the occurrence in their rocks from some places of potash feldspar megacrysts, due to the increasing rock alkalinity, which may reach 1.5 cm. length, like in the Muntele Mic, Şuşiţa and Cărpiniş plutons. In the last pluton the potash feldspar megacrysts exhibit a rather poikilitic structure, including plagioclase and biotite small crystals (Savu *et al*., 1972; 1973). Often, the included crystals are disposed in zones parallel to the margins of the host crystal, like in the Şuşiţa granitoid pluton (Savu *et al*., 1972).

One of the most characteristic feature of the common rock granitoid plutons from the eastern part of the Danubian Autochthone is the occurrence in their mass of strong effects of the Variscan shear process, manifested itself mostly in the Şuşiţa granitoid pluton. There, in the nothern part of this pluton, the granitoid rocks have been strongly sheared, so that sometimes they reach the stage of orthoschists, in which the characteristic mineral assemblage is quartz-sericite-chlorite. This process affected also the Cărpiniş and Parâng plutons. In the Latoriţa Valley, especially, the initial Q-joints of the granite, filled with chlorite, are preserved as vestiges besides the new Variscan joints.

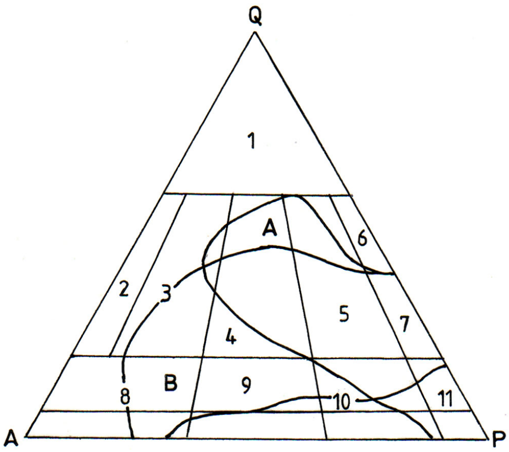

Fig. 4. Plot of the rocks from the common rock granitoid and shoshonitic plutons on the QAP diagram. Fields according to Streckeisen (1967): 1, quartzitic rocks; 2, alaskite, 3, K-granite; 4, normal granite; 5, granodiorite;6, plagiogranite; 7, tonalite; 8, quartz-diorite; 9, quartz-monzonite; 10, diorite; 11, diorite-gabbro. Field A includes the common rock granitoides from Şuşiţa, Parâng and Vârful Pietrii (data from Savu, 1997; Savu *et al*., 1970; Stan *et al*., 2004: Andăr, 1991). Field B includes shoshonitic granitoids from the Tismana and Novaci plutons (data from Savu *et al*., 1973; Duchesne *et al*., 1998).

b. Trondhjemitic plutons. These plutons occur both in the Danubian Autochthone and in the Getic Nappe, and are distributed along the two iinner magmatic arcs from the west bent zone of the South Carpathians (Fig. 1). Along the IMA they are represented by the plutons of Sicheviţa and Buchin, and by the small phacolith of Slatina Timiş. These plutons are located within the main anticline of the virgation from the Semenic Mountains. Therefore, they are elongated plutons parallel to the crystalline schist structures of the Sebeş-Lotru barrovian series. In these plutons *septa* of migmatized crystalline schists are included, which are parallel to the weak oriented structure of the trondhjemotic rocks. It is of note that along the eastern contact of the Sicheviţa pluton a large zone of regional-contact metamorphism occurs. These plutons consist mostly of trondhjemitic rocks associated with common rocks like tonalites, granodiorites, adamellites and granites (Fig. 4)

On the median magmatic arc (MMA, Fig. 1) from the Danubian Autochthone are located the following trondhjemitic plutons: Buta, Retezat, Petreanu-Furcătura, Culmea Cernei, Cherbelezu and Ogradena. These granitoid plutons, except for the Petreanu-Furcătura plutons, are elongate granitoid bodies, oriented parallel to the crystalline schist structures. Like the previous ones, they contain sometimes *septa* of crystalline schists, often migmatized, and melanocratic autoliths formed of the first crystallized minerals in the granitoid magma, like biotite, rarely hornblende and some felsic minerals. The mineral assemblages of these granitoid plutons are similar to the ones mentioned in the plutons from the Getic Nappe (Fig. 4).

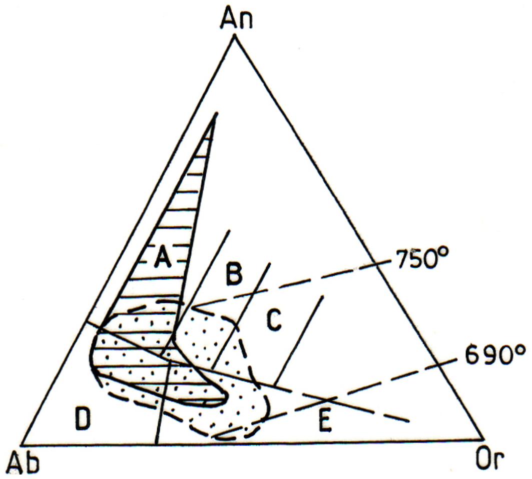

Fig. 5 – Plot of the average normative composition of the rocks from the trondhjemitic plutons on the An-Ab-Or diagram. Fields according to O'Connor (1965): A, tonalite, quartz-diorite, diorite; B, granodiorite; C, adamellite; D, trondhjemite; F, granite. In addition there are represented the PT intervals of Kleeman (1965) and the field (hached area) of the products resulted from the fluid-absent experimental melting of metabasalt, reported by Rapp (1995). Adapted after Ferré *et al.* (1998). Data from Table 2.

c. Shoshonitic plutons. This group of granitoid plutons includes three granitoid bodies. Two of them, like Tismana and Novaci, are located on the southern margin of the Danubian Autochthone (Savu *et al*., 1973; Duchesne *et al*., 1998). A third area with such rocks occurs in the high-grade metamorphic crystalline schists of the Sebeş–Lotru series from the Getic Nappe, north of Lacul Vidra, west of Voineasa. There, four small bodies of shoshonitic rocks occur, which, in contrast with the other granitoid plutons from the South Carpathians, are located along a NE-SW B_2 anticline. The biggest granitoid body is about 3 km. long and the shorter one is of about 0.5 km. long (see Savu, Schuster, 1977). The shoshonitic plutons from this petrographic province are usually formed of large porphyritic granites, normal granites and some dioritic differentiates (see field B in Fig. 4)

Among the shoshonitic plutons the Tismana one, according to its form and size looks rather like a thin laccolith or a big phacolith, that was weakly affected by the Variscan and Alpine deformations (Dimitrescu, Dimitrescu, 2003), but without any visible shear zones. Like in the plutons from the other granitoid groups, in the shoshonitic ones *septa* of crystalline schists and autoliths, especially in the Tismana pluton, do occur. Besides, in the last pluton there occur numerous xenoliths of melanocratic rocks, among which a big mantle xenolith of peridotitic composition.

The Novaci shoshonitic body also contains melanocratic autoliths formed of the first crystallized minerals in the shoshonitic magma, like biotite, rarely hornblende, plagioclase and potash feldspar.

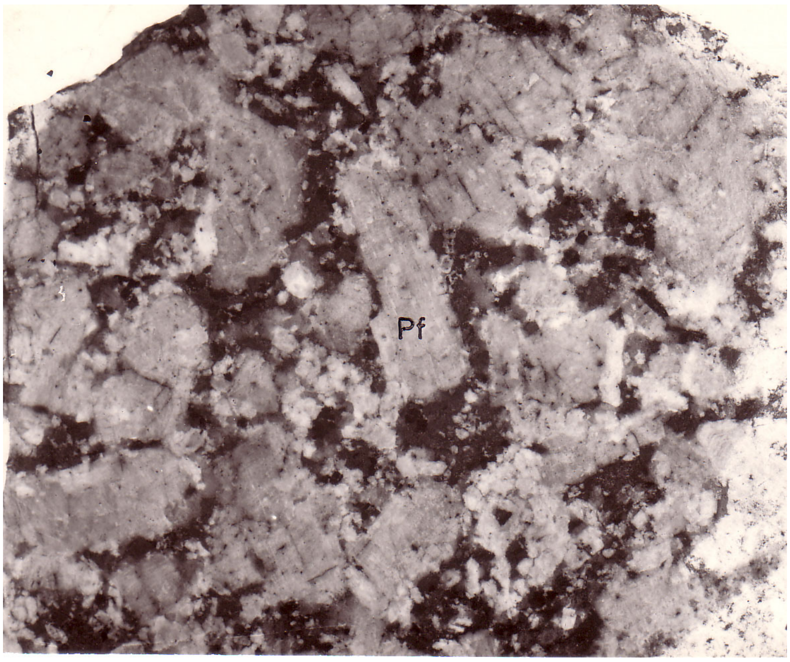

Fig. 6 – Massive structure of the Novaci shoshonitic granite. Pf, potash feldspar megacryst.

The most characteristic feature of these granitoids is their large porphyritic structure, like that of the Rapakivi granites in Finland, which I visited in 1973. The potash feldspar phenocrysts are frequently more than 3 cm long (Fig .6) and are represented by varieties of microcline and microcline-perthite. As shown in Fig. 7, the size of the potash feldspar phenocrysts from the South Carpathian granitoid plutons is dependent on the K_2O content in magma and on its alkalinity. It increases all along the granitoid pluton series from the South Carpathian province, from 0.5 cm in the trondhjemitic plutons, in which the K_2O average content is of 1.66%, up to 3 cm in the shoshonitic plutons, in which the K_2O average cointent is of 5.65%. The alkalinity index varies in this granitoid series from 0.62 in the trondhjemitic rocks up to 0.77 in the shoshonitic ones.

The component minerals in the shoshonitic rocks are quartz, potash feldspar either as phenocrysts or as small interstitial crystals, albite-oligoclase, biotite, rarely green hornblende and numerous accessories like zircon, apatite and titanite. In the Novaci pluton melanocratic and rarelz leucocratic autoliths have been observed. The last occur in the dioritic separations, which consist of plagioclase, some quartz in the quartz-diorites, green hornblende, biotite and accessories. The leucocratic autoliths are formed of quartz, plagioclase, rarely green hornblende and accessory minerals. According to their transitional contact with the host diorite and to their internal structure, these leucocratic autoliths seem to represent small separation of gaseous granitoid magma injected into the dioritic magma separation before complete cooling.

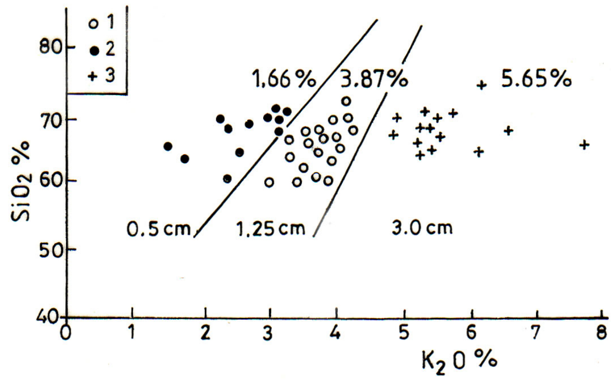

Fig. 7 – The SiO_2 vs. K_2O diagram showing the correlation between the increasing K_2O content and the size of the potash felspar phenocrysts in the three types of granitoid plutons. 1, trondhjemitic plutons (Buchin and Slatina Timiş, Savu, 1997); 2, common rock granitoid plutons (Muntele Mic, Savu *et al.*, 1973); 3, shoshonitic plutons (Tismana and Novaci, Savu *et al.*, 1973; Duchesne *et al.*, 1998); the numbers N % indicate the K_2O average content in rocks: the numbers N_{cm} indicate the size of the potash feldspar phenocrysts.

Like in case of other granitoid plutons the shoshonitic ones are accompanied by post-intrusion dyke rocks, like lamprophyres and porphyritic and aplitic rocks of different leucocratic or intermediate types.

The datings concerning the age of the granitoid plutons from the South Carpathian granitoid province show some discrepancies. Thus, Soroiu *et al.(*1970) published a more comprehensive paper refering to the obtained K/Ar ages on the South Carpathian granitoids and related rocks. The oldest granitoids were those of Tismana, less affected by the Variscan and Alpine deformations, the age of which was of 554 Ma and the 'Şuşiţa-type' granitoids from the Vulcan Mountains, the age of which was of 522 Ma. But, the age of the 'Şuşiţa-type' granitoids from the Parâng Mountains was of 219 Ma and that of the 'gneissic granites'was of 296 Ma. It is obvious that these contrasting values were referring to the undeformed granitoids from the Vulcan Mountains and to granitoids affected by the Variscan and Alpine shear process from the Parâng Mountains, as it was presented above. Unfortunately, these contrasting datings inducted into the opinion of some geologists the false idea that in the Danubian Autochthone there exist two granitoid series: an older and a younger (Paleozoic) granitoid series.

Later on, Grünenfelder *et al.* (1982) showed that the Novaci pluton was emplaced at 588 Ma (U-Pb, zircon). The intrusion of the Tismana pluton, according to Liégeois *et al*. (1996), took place at 567 Ma (U-Pb, zircon). These datings accuratelly fit with the K/Ar datings obtained by Soroiu *et al*. (1970) on the Şuşiţa undeformed granitoids, and all of them show that the emplacement of these granitoid plutons took place at the end of the Cadomian orogeny. In this respect it is notewothy to show that the Tismana shoshonitic pluton, in spite of any invisible shear zones, yet the effects of the Variscan and Alpine tectonic movements were printed in the rock minerals, as the K/Ar datings presented by different authors showed (see data in Berza, 1978).

In contrast with these authors, the datings presented by Stan *et al.* (1992) on the Sicheviţa pluton showed ages varying between 350 and 250 Ma, marking both the Caledonian and the Variscan orogenies.Recently G. Săbău and I. Balintoni (personal comm.) also showed that the ages obtained on zircon crystals from the Sicheviţa granitoid pluton located on the inner magmatic arc (IMA in Fig. 1) in the Getic Nape and on the Cherbelezu pluton from the median magmatic arc (MMA in Fig. 1) from the Danubian Autochthone were of about 350 Ma.. Therefore, the last author considered these granitoid plutons as Early Variscan intrusions.

If the genesis of the granitoid plutons from the inner magmatic arc could be explain as a result of the Variscan subduction along the Variscan subduction plane (VSP in Fig.1), it can not explaines the genesis of the granitoids from the median magmatic arc, because these are located behind this subduction plane. Therefore, the more adequate model to explain the genesis of all these granitoid plutons is the model according to which the South Carpathian granitoid plutons belong to the Pre-Variscan tectono-magmatic cycle. During this cycle at least two main tectonic movements manifested themselves, determined by the subduction of the old Moesian plate under the initial South Carpathian arc (see Savu, 2005 a). According to this model the older granitoids were emplaced at the end of the Cadomian movements and the younger ones at the end of the Caledonian movements; the last granitoids represent Late Caledonian intrusions. They differ from the Variscan granitoids from the west part of the Romanian territory, like the Highiş granites and the Bârzava syenites, which represent intra-plate intrusions, usually formed of alkaline rocks (see Savu, 1965 a; Tatu, unpubl. doctor's degree thesis).

4. GEOCHEMISTRY OF THE GRANITOID PLUTONS

The average chemical composition of the South Carpathian granitoid plutons was presented in Tables 1 and 2, acording to the tectonic unit in which the respective plutons are located. Out of these tables it results that all plutons are formed mostly of acid plutonic rocks. The general average contents of the major elelements, resumed in Table 3 according to the three granitoid pluton groups, support this conclusion. The values show that the chemical compositions of the granitoid plutons from the two tectonic units are very close to each other. They show also that the chemical changes (differentiation) from the common rock plutons to the trondhjemitic ones indicate a normal process. Both these features support the conclusion, above presented, that all these plutons belong to only one granitoid province *i.e.*, the Pre-Variscan granitoid province, as shown above.

Table 1

Average chemical composition (major % and trace ppm elements) of the common rock and shoshonitic granitoid plutons*

Group	Common rock granitoid plutons								Shoshonitic plutons			
Pluton	1 (12)	2 (18)	3 (22)	4 (12)	5 (14)	6 (30)	7 (14)	X	8 (15)	9 (4)	10 (2)	Y
SiO_2	68.58	65.70	64.63	69.10	67.89	67.67	67.78	67.87	68.98	65.82	67.93	67.56
TiO_2	0.29	0.48	0.23	0.45	0.34	0.42	0.44	0.36	0.58	0.66	0.22	0.48
Al_2O_3	16.66	16.61	16.23	15.2	15.18	16.69	15.57	16.28	14.74	15.81	14.80	15.03
Fe_2O_3	0.62	1.03	0.96	0.86	1.17	1.0	1.31	-	3.47•	2.66	2.99	-
FeO	1.66	1.79	0.88	1.50	1.74	1.52	1.66	2.33•	-	1.81	2.99	3.54*
MnO	0.07	0.64	0.06	0.05	0.66	0.04	0.06	0.15	0.04	0.05	0.42	0.17
MgO	1.27	1.94	1.78	1.93	1.0	1.54	1.35	1.43	0.87	0.82	1.07	0.94
CaO	2.12	2.25	3.0	2.15	3.74	1.85	2.63	2,36	1.57	1.28	2.22	1.82
Na_2O	4.04	3.73	3.92	4.16	3.98	3.53	3.51	3.92	2.56	3.33	3.75	3.02
K_2O	3.74	3.87	2.43	3.34	2.15	3.87	3.82	3.49	5.86	5.45	4.63	5.14
P_2O_5	0.12	0.48	0.06	0.11	0.12	1.41	0.44	0.38	0.23	0.23	0.16	0.20
Loi	0.80	0.32	1.40	0.74	2.08	0.46	1.58	-	0.50	1.05	1.19	-
Total	99.92	99.93	99.68	99.96	100	99.94	100.0	-	99.50	97.93	100.7	-
Ni	11.25	11.6	4.2	8.58	3.37	12.95	7.77	8.65	-	3.25	-	-
Co	4.80	6.27	2.4	4.25	4.0	5.34	5.63	4.51	9.72	5.37	-	7.54
P_2O_5	20.65	26.6	5.0	23.33	1.5	22.5	8.39	16.59	11.45	5.37	-	6.47
Loi	32.0	23.27	5.5	26.16	18.25	52.4	28.7	26.26	28.6	16.25	-	22.4
Sc	5.54	6.69	2.3	4.7	-	6.0	7.75	5.04	-	-	-	-
Y	15.0	-	19.1	21.33	-	11.15	11.65	16.64	23.5	-	-	-
Zr	124.	273	108	135	127.5	141 2	200.5	151.4	337.4	530	-	195.2
Ba	1167	950.5	695	786	647.5	903.7	824.6	858.2	1212	1305	-	1258
Sr	413	270.5	218	277.5	530	346	254.2	342.5	312	247.5	-	280
Pb	24.6	33.8	21.2	-	15.0	59.0	14.01	30.72	22.8	15.75	-	19.3
Cu	14.64	15.3	7.0	-	69.5	7.82	25.1	22.85	-	95	-	-
Zn	-	-	-	-	-	-	-	-	51.9	-	-	-
Ga	20.3	23.5	18.3	21.66	12.54	24.9	20.4	23.14	22.0	14.50	-	18.2
Rb	105.8	-	154	107.3	-	127.8	-	123.7	202.8	-	-	-
Nb	12.55	-	18.5	11.9	-	11.4	-	11.08	33.11	-	-	-
Sn	-	-	-	-	5.15	5.15	4.37	4.76	-	-	-	-
Be	-	4.91	5.3	-	1.90	7.03	2.52	4.78	-	2.47	-	-
Li	-	65.0	9.7	-	31.7	5.20	41.7	27.9	-	20.2	-	-
La	22.7	-	30.8	35.3	-	32.4	50.5	30.3	80.3	-	-	-
Ce	37.7	-	-	44.4	-	60.7	-	47.6	14.9	-	-	-
Nd	-	-	-	-	-	-	-	-	9.72	-	-	-
Sm	8.93	-	-	3.73	-	4.90	-	5.85	8.65	-	-	-
Eu	1.48	-	-	0.94	-	1.07	-	1.16	1.78	-	-	-
Gd	-	-	-	-	-	-	-	-	3.38	-	-	-

Table 1 (continued)

Tb	0.53	-	-	0.48	-	0.41	-	0.47	3.44	-	-	-
Dy	-	-	-	-	-	-	-	-	3.84	-	-	-
Er	-	-	-	-	-	-	-	-	2.08	-	-	-
Yb	1.82	-	2.3	1.51	--	0.84	1.67	1.51	2.04	-	-	-
Lu	0.14	-	-	0.14	-	0.09	-	0.12	0.31	-	-	-
Hf	2.54	-	-	3.17	-	4.26	-	3.32	8.08	-	-	-
Th	7.27	-	1187	9.5	7.86	17.5	-	10.8	23.6	-	-	-
U	-	-	3.0	2.36	-	4.3	-	3.39	2.17			
Ta	2.49	-	-	0.99	-	1.19	-	1.55	-	-	-	-

* The average chemical analyses in the table are referring to the following granitoid plutons: 1, Poneasca (Savu, Vasiliu, 1969; Savu, Udrescu, 1971); 2, Muntele Mic (Savu *et al*., 1973); 3, Vârful Pietrii (Andăr, 1991); 4, Şuşiţa (Savu *et al*., 1972; Stan *et al*., 2001); 5, Cărpiniş (Savu *et al*., 1973); 6, Sfârdin (Stan *et al*., 1985); 7, Parâng (Savu *et al*., 1976); X, general average chemical composition of the common rock granitoid plutons; 8, Tismana (Berza, 1978; Duchesne *et al*., 1998); 9, Novaci (Savu *et al*. (1973); 10, Vidra Lake (Savu Schuster, 1977); Y. general average chemical composition of the shoshonitic plutons; the N• numbers indicates total content of the iron components. The numbers of the calculated analyses are in brackets.

Table 2

Average chemical composition of the trondhjemitic plutons from the South Carpathians*

Pluton	1 (18)	2 (8)	3 (12)	4 (37)	5 (10)	6 (5)	7 (21)	8 (6)	Z
$SiO_{2\ \&}$	71.0	71.23	70.29	70.58	70.41	70.0	71.41	74.2	71.12
TiO_2	o.o7	0.15	0.37	0.26	0.22	0.36	0.21	0.16	0.22
Al_2O_3	17.78	16.0	14.66	16.16	15.96	16.0	16.0	14.0	16.26
Fe_2O_3	0.60	0.85	0.86	1.07	0.83	1.3	0.73	0.04	
FeO	1.54	0.86	1.03	0.50	0.66	1.14	0.49	0.26	1.70
MnO	0.05	0.07	0.04	0.03	0.08	0.05	0.03	0.04	0.04
MgO	0.7	0.44	0.93	0.6	0.7	0.85	0.65	0.77	0.66
CaO	2.0	1.4	2.27	2.13	1.75	2.35	1.65	1.0	1.72
Na_2O	3.7	4.25	4.10	4.8	4.51	4.5	4.6	4.6	4.24
K_2O	1.66	3.54	2.7	2.5	2.54	2.0	2.7	3.0	2.59
P_2O_5	0.08	0.09	0.11	0.07	0.09	0.11	0.08	0.05	0.08
Loi	0.86	1.10	2.06	1.30	2.70	1.30	1.45	2.08	-
Total	99.97	99.98	99.94	100	99.95	99.06	99.95	100	-
Ni ppm	8.50	6.25	4.22	5.0	3.76	74.75	9.7	3.0	14.39
Co	4.65	2.75	4.22	2.17	2.91	14.75	2.86	2.0	4.53
Cr	19.25	8.75	6.55	4.9	2.69	1.46	11.02	4.0	8.97
V	19.66	17.0	21.66	20.3	17.7	49.0	13.52	3.9	20.34
Sc	4.55	4.5	4.22	2.2	3.13	10.0	3.08	2.2	4.23
Y	38.8	2.9	12.3	10.0	11.25	11.65	9.25	17.5	14.12
Zr	280	117.5	114.0	113.0	113.0	200.0	94.33	49.25	100.48
Ba	835	725	545	1064	1136	460.5	702	735	775.3
Sr	127.5	155	222.2	575	610	360	525	228	342.63
Pb	20.16	30.0	10	15.2	24.3	18.8	56.4	18.9	24.22

Table 2 (continued)

Cu	81.83	17.75	18	3.14	8.19	56.8	7.0	4.0	24.5
Zn	-	-	-	-	40	-	-	-	-
Gaq	17.66	18	24.88	15.76	16.84	20	20.3	13.6	18.38
Rb	111.3	145	-	-	96.9	135.3	104	77	111.58
Nb	15.33	15	-	10.8	12.2	11.75	13.75	1o	12.69
Sn	5.16	5.25	-	2.0	1.5	3.12	3.28	3.0	3.33
Be	-	3	3.30	-	-	2.15	4.79	-	3.31
A	25.8	29	36	20.7	26.6	17.8	22.7	12.45	23.88
Ce	71.4	35	-	50.34	43	24.7	42.7	20.4	41.93
Sm	3.75	3.6	-	6.80	3.6	2.4	2.7	2.0	3.69
Eu	0.89	0.88	-	1.58	0.97	0.74	0.77	0.58	0.91
Tb	0.50	0.43	-	0.55	0.65	0.8	0.29	0.43	0.52
Yb	1.18	1.95	1.84	0.30	1.5	1.26	0.53	1.4	1.42
Lu	0.59	0.10	-	0.38	-	0.19	0.07	0.2	0.25
Hf	6.10	3.28	-	-	3.7	3.26	3.65	1.67	3.62
Ta	1.6	0.50	-	-	-	1.02	1.77	1.1	1.19
Th	17.26	9.9	9.17	-	9.83	-	-	2.2	9.67
U	-	5.3	3.30	-	-	6.3	-	-	4.96
Cs	-	3	-	-	-	5.52	28.44	-	12.32

*The average chemical analyses in the table are referring to the folowing plutons: 1, Buchin and Slatina Timiş (Gridan, 1981; Savu, 1997); 2, Sicheviţa (Stan, Tiepac, 1996); 3, Buta (Savu *et al.*, 1977); 4, Retezat (Berza *et al*., 1994); Petreanu-Furcătura (Andăr, 1991); 6, Culmea Cernei (Iancu *et al*., 1994); 7, Cherbelezu (Stan *et al*., 1985; Stan, Tiepac, 1996); 8, Ogradena (Anastasiu, 1972; Stan, Tiepac, 1996); Z, general average composition of the trondhjemitic plutons. The numbers of the calculated analyses are in brackets.

Thus, SiO_2 increases from 67.77 % in the rocks of the common rock granitoid plutons up to 7114 % in the trondhjemitic plutons. In the shoshonitic plutons SiO_2 is almost similar to that from the common rock granitoid plutons. A tendency of decreasing in this sense is evident in case of K_2O and MgO. Other major components like Al_2O_3 and CaO present variable values in this respect. The last component and FeO, for instance, decrease down to the trondhjemitic plutons, then increase toward the shoshonitic plutons. On the contrary, K_2O is increasing along this series of granitoid plutons. Very spectacular is the increase of this component, which goes from 2.61% in the trondhjemitic plutons of the Getic Nappe up to 5.65% in the shoshonitic plutons from the Danubian Autochthone. This behaviour of K_2O is clearly represented in the diagram in Figure 8, which discriminates the three groups of granitoid pluton from the South Carpathian granitoid province. According to this diagram the characteristics of the rocks from these plutons are medium-K (calc-alkaline) in the trondhjemitic plutons, high-K (alkaline) in the common rock granitoid plutons and reach the very high-K aspect in the shoshonitic plutons. This trend resulted also from the diagram in Fig. 7.

The South Carpathian shoshonites are characterized by the following average values: K_2O+Na_2O = 8.16; K_2O/Na_2O = 1.7; Al_2O_3 = 15% These values are much higher than the standard values established by Eklund *et al.* (1998) for the Svecofennian post-collision shoshonitic granitoids.

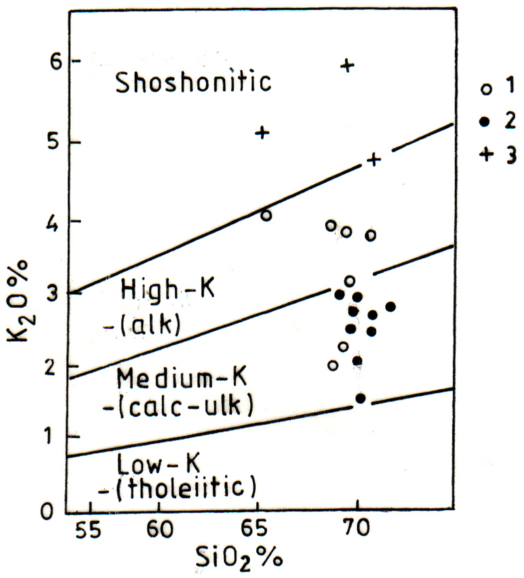

Fig 8 – Plot of the average composition of the granitoid plutons from Tables 1 and 2 on the K_2O vs. SiO_2 diagram. Fields presented by Peccerillo and Taylor (1976), Rickwood (1989) and Laméyre and Bonin (1991) in different forms, but close to one another: 1, common rock granitoid plutons; 2, trondhjemitic plutons; 3, shoshonitic plutons.

As shown by the diagram in Fig. 9, most of the granitoid plutons plot in the CA field, which indicates their calc-alkaline characteristics. Few of these plutons enter into the Alk field, which shows a weak alkaline tendency of this granitoid pluton series. Even the alkali richest shoshonitic plutons consist of calc-alkaline rocks.

The trace elements (Tables 1and 2), which are dependent on the behaviour of the major elements, they substitute in the network of some minerals, are closely following the variation of the respective major elements. Thus, the siderophilc elements like Ni, Co. Cr, V and Sc show variable contents in the three pluton groups (see columns x, y, z in Tables 1 and 2), but most of them are higher in the trondhjemitic plutons. Elements like Zr, Ba, Rb and Nb are increasing toward the shoshonitic plutons, while Sr shows close values in the three groups of granitoid plutons. It is noteworthy that the Sr/Y ratio (Table 4) presents, especially in the trondhjemitic plutons, values which are characteristic for the adakitic rocks (see Sajona, 1995; Martin, 1999), as it was shown in some previous papers (Savu, 1997; 2004). The Nb/Ta ratio decreases from the common rock granitoid plutons to the shoshonitic ones, whereas the Zr/Hf ratio manifests an increase tendency in this way.

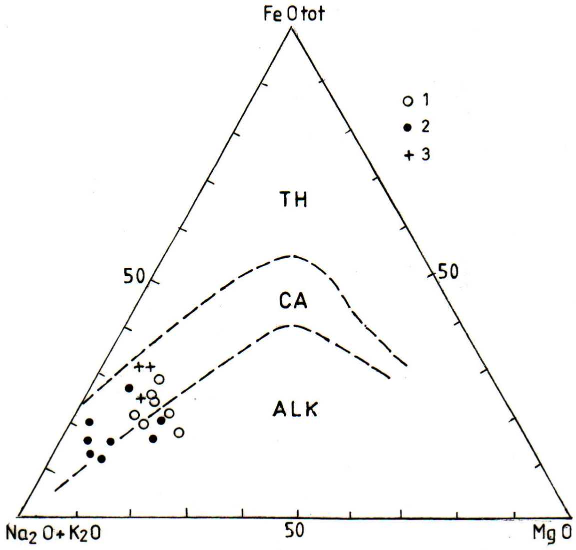

Fig. 9 – Plot of the average chemical composition of the granitoid plutons from Tables 1 and 2 on the FeO-Na_2O+K_2O-MgO diagram. Fields according to Irvine and Baragar (1971) and Hutchinson (1982). 1, common rock granitoid plutons; 2, trondhjemitic plutons; 3, shoshonitic plutons.

The REE contents (Tables 1 and 2) also underline some features of the three granitoid pluton groups. The contents of the REE, like La, Sm, Eu, Yb and Lu are increasing from the common rock granitoid plutons to the shoshonitic ones. Other elements show variable contents. The ∑REE varies from 93.90 ppm in the Danubian Autochthone common rock granitoid plutons down to 64.98 ppm in the trondhjemitic plutons from the same tectonic unit. The first group of granitoid plutons is the richest group in REE contents. The LREE/HREE ratio shows a tendency of decrease in this way, except for the same common rock granitoid plutons from the Danubian Autochthone. A similar tendency was remarked also in case of the Nb/Ta ratio. The values of other ratios presented in Table 4 are variable. The Eu/Eu* ratio decreases along this granitoid pluton series, which shows a constant fractionation of the parental magmas (Haskin, l984)

Most of the REE chondrite-normalized patterns (Boyntons' normalizing values, 1984) of the South Carpathians granitoid plutons are, according to their shape, similar to other granitoid series (see also Stan and Tiepac, 1996; Robu, unpubl. doctor's degree thesis). An exception occurs in case of the patterns of Buchin and Slatina Timiş trondhjemitic plutons from the Getic Nappe (Fig. 10).

The pattern of the Buchin and Slatina Timiş plutons shows a Tb negative anomaly and a strong Lu positive anomaly (Savu *et al.* 1997). The same tendency was remarked at some samples from the Sicheviţa trondhjemitic pluton, which is located on the same outer magmatic arc from the Getic Nappe, like the Buchin and Slatina Timiş plutons.

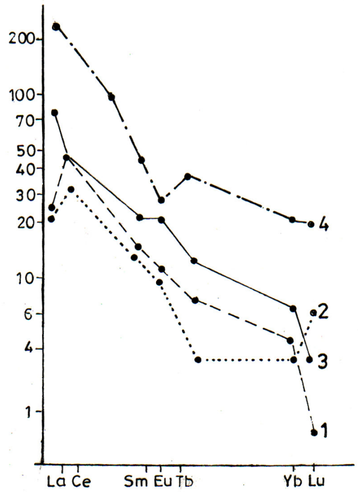

Fig. 10 – Chondrite-normalized REE patterns of the South Carpathian granitoid plutons. 1, Getic Nappe common rock granitoid plutons; 2, Getic Nappe trondhjemitic plutons; 3, general pattern of the common rock granitoid plutons; 4, shoshonitic plutons. In cases when Gd from the relation Eu/Eu• = (Eu)N/ ½ (Sm+Gd)N was not analytically determined, (Gd)N was directly estimated by plotting this element on the REE patern of the respective rock.

Table 3

General verage of the main major chemical elements from the South Carpathian granitoid plutons (data from Tables 1 and 2)

Element	SiO_2	Al_2O_3	FeO*	MgO	CaO	Na_2O	K_2O
Common rock granitoid plutons							
Danubian Autochthone	67.77	15.91	2.45	1.59	2.60	3.80	3.24
Getic Nappe	68.58	16.60	2.21	1.27	2.12	4.04	3.74
Trondhjemitic plutons							
Danubian Autochthone	71.14	15.63	1.53	0.75	1.85	4.51	2.57
Getic Nappe	71.11	16.89	1.84	0.57	1.70	3.97	2.61
Shoshonitic plutons							
Danubian Autochthone	67.20	15.27	2.90	0.84	1.42	2.29	5.65
Getic Nappe	67.93	14.80	4.19	1.07	2.22	3.75	4.63

Table 4

General average of some characteristic ratios from the South Carpatians granitoid plutons (data from Tables 1 and 2)

Group	Common rock granitoid plutons		Trondhjemitic plutons		Shoshonitic plutons
Tectonic Unit	Danubian Autochthone	Getic Nappe	Danubian Autochthone	Getic Nappe	Danubian Autochthone
ΣREE	93.90	73.37	64.98	87.64	80.36
LREE/HREE	29	17.48	24.07	22.75	14.68
Eu/Sm	0.23	0.16	0.28	0.24	0.20

Table 4 (continued)

Eu/Eu•	0.64	0.56	0.93	0.60	0.69
(La/Lu)N	12.13	16.90	15.95	17.32	26.94
(La/Yb)N	16.29	8.43	16.34	9.39	20.55
(Ce/Yb)N	5.84	5.30	13.08	6.58	18.84
Nb/Ta	5.15	5.08	11.26	9.78	4.09
Y/Nb	1,39	1.19	0.92	2.13	0.70
Sr/Y	19.19	27.53	24.85	4.16	3.27
Zr/Hf	37.14	48.85	31.21	41.65	41.75

5. ORIGIN OF THE GRANITOID PLUTONS

The distribution of the granitoid plutons from the South Carpathians along three alignments (magmatic arcs) shows that during the Pre-Variscan tectono-magmatic cycle the subduction of the old Moesian Plate under the initiall South Carpathian arc underwent three impulses. These resulted in the moving forward of the subducted plate and in the genesis of the three arcs of granitoid plutons. The first movement, the Cadomian one, resulted in the occurrence of the granitoid plutons from the outer magmatic arc (OMA in Fig. 1), the age of which is of 588 Ma. The second movement generated the median magmatic arc (MMA) of 522 Ma and during the third movement (450–350 Ma), the Caledonian one, the inner magmatic arc (IMA) and its granitoid plutons were formed.

The fact that these granitoid plutons originated in granitoid magmas is proved by the high values of the Eu/Eu• ratio in Table 4 (see Zhongang, 1982). The parental magma (magmas) was formed in a metasomatic mantle situated over the subduction plane, under conditions of high H_2O/CO_2 ratio (Savu, 1997). It was an intermediate tonalitic magma, as the diagram in Fig. 5 showed. According to Rapp (1995).the experimental melting of metabasalt resulted in products of intermediate composition, which on the diagram in Fig. 5 plot within the tonalite field. The magmatic origin of the granitoid plutons is also proved by the position of their plot within the I-type field of the Na_2O vs. K_2O diagram (Fig. 11).

The diagram in Fig. 5 showed that the granitoid plutons were formed at temperatures variing between 690^0 up to 750^0 C. Such a very hot magma, accompanied by its very hot fluids that slowly circulated through the continental crust, could have determined the partial melting (anatexis) of important amounts of crustal materials (see Obota *et al.*, 1994). These fractions of anatectic melts were added to the magma of ‘medium to high-K-type (Fig. 8), thus changing its initial character into a hybrid magma of two origin, the granitoid plutons resulting from.

The geochemical data (Table 4) also show that the parental magmas of the granitoid plutons resulted from both mantle and crustal materials (see also Savu and Dobrescu, 1998–99). Thus, (Ce/Yb)N ratio presents a large variation at small variations of Ce in some granitoid plutons, thus marking less contaminated rocks. On the contrary, in other granitoid plutons this ratio shows a linear correlation with Ce, indicating contaminated rocks with crustal material (see Scott and Vogel, 1980).

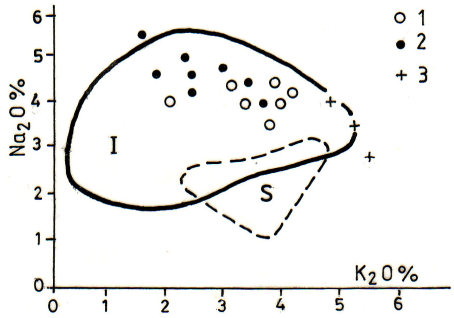

Fig. 11 – Plot of the South Carpathian granitoid plutons on the Na_2O vs. K_2O diagram. Fields according to Chappell and White (1974). I, granitoid magmas of juvenile origin; S, granitoid magmas resulted from sedimentary materials. Data from Tables 1 and 2. 1, common rock granitoid plutons; 2, trondhjemitic plutons; 3, shoshonitic plutons.

The Y/Nb average values are in the Danubian Autochthone trondhjemitic and shoshonitic plutons lower than the standard value of 1.8 established by Taylor and Lennan (1985), indicating magmas generated in the mantle (see also Eby *et al.*, 1992), most probably a metasomatic mantle (see Roden and Murthy, 1985). In some of trondhjemitic plutons the value of this ratio is higher then 1.8, indicating contaminated magmas with crustal material. Moreover, the high value of Zr/Hf ratio also indicates the presence of crustal material in the granitoid parental magma.Thus, these data show two sources of the parental magma of the granitoid plutons from the South Carpathians. This conclusion is well supported by the diagram in Figure 12, on which the plots of the granitoid plutons fall both in the field A_1 and A_2

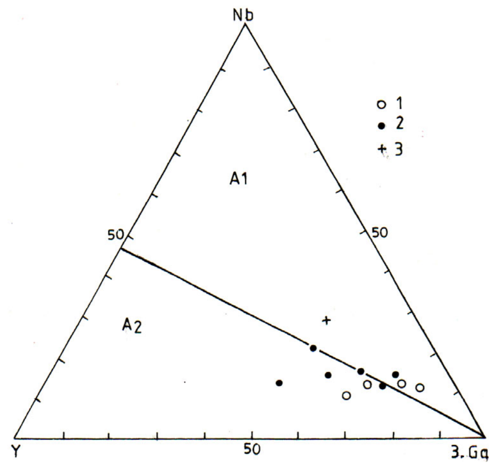

Fig. 12 – Plot of granitoid plutons with adequate analyses on the Nb-Y-3Ga diagram. Fields according to Eby (1992): A_1, granites derived from oceanic-island basalt magmas but emplaced in continental environments; A_2, granites derived from continental crust or underplated crust during continent/continent collision or island arc magmatism. Data from Tables 1 and 2. 1, common rock granitoid plutonms; 2, trondhjemitic plutons; 3, shoshonitic plutons.

All these data show that the parental magmas of the granitoid plutons have been generated by the partial melting (anatexis) of two sources (see Miller and Wooden, 1994): the metasomatic mantle and the continental crust. Their initial composition was that of a tonalite (see Fig. 5), which is proved by the separation of dioritic composition occurring in some of these plutons.

The occurrence of the hybrid parental magma was favoured by the geotectonic environments ruling over the South Carpathians area during the Late Precambrian and Early Paleozoic, at the end of the Cadomian orogeny (600-500 Ma), when the old Moesian Plate was subducted under the primitive South Carpathian arc (Savu *et al.*, 1972), colliding to one another (Savu, Dobrescu, 1998-99; Savu, 2005). As a consequence of this collision, the three magmatic arcs (Fig.1) were successively formed, along which the granitoid plutons were emplaced. According to the diagram in Fig. 13 the common rock granitoid plutons intruded along the three magmatic arcs under syn-collision conditions, save the shoshonitic plutons of Tisnana-type which have been emplaced under intra-plate conditions at 567 to 588 Ma (see Duchesne *et al.*, 1998).

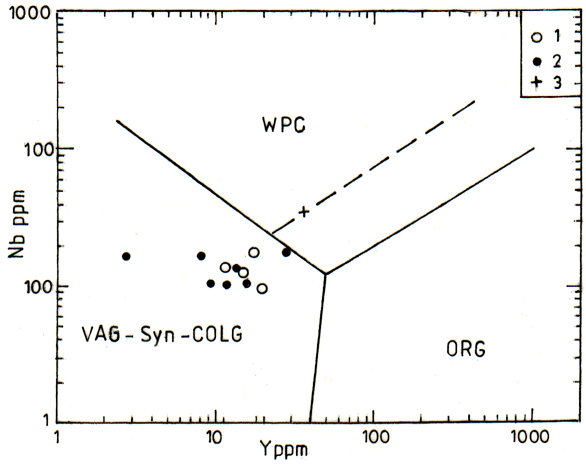

Fig. 13 – Plot of South Carpathian granitoid plutons on the Nb vs.Y diagram. Fields according to Pearce *et al.* (1984). VAG – Syn-COLG, island arc to syn-collision granitoids; WPG, intra-plate granitoids; ORG, ocean ridge granitoids. 1, common rock granitoid plutons; 2, trondhjemitic plutons; 3, shoshonitic plutons.

The emplacement of the common rock granitoid plutons and of the trondhjemitic plutons during the collision of the Moesian continent with the Carpathian island arc clearly results from the diagram in Fig. 14 A. It also shows that the shoshonitic plutons have been emplaced under within-plate conditions during the continental epiorogenic uplift (Fig. 14 B). After those episodes of the Pre-Variscan tectono-magmatic cycle, the Caledonian episode followed when the Sebeş-Lotru series was metamorphosed (450–400 Ma) and the emplacement of some syn-orogenic granitoid plutons (400–350 Ma), mostly trondhjemitic plutons.

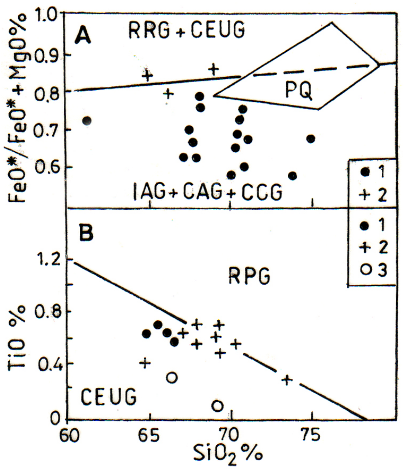

Fig 14 – Plot of of granitoid ploton rocks on the FeO* / Fo* + MgO vs. SiO_2 and TiO_2 vs. SiO_2 diagrams. Fields according to Maniar and Piccoli (1989): RRG, lift related granitoids; CEUG, continental epeiorogenic uplift granitoids; POG, post-orogenic granitoids; IAG, island arc granitoids; CAG, continental arc granitoids; CCG, continental collision granitoids. A: 1, common rock and trondhjemitic granitoid plutons; 2, shoshonitic granitoid plutons; B-shoshonitic plutons: 1, Novaci; 2, Tismana; 3, Lacul Vidra (Voineasa).

Under these geotectonic conditions the genesis of plutons fron the Carpathian granitoid province followed two trends. First of all, an initial tonalitic-dioritic magma resulted by the anatectic melting (see Miller and Wooden, 1994) of the metasomatic mantle. The composition of this metasomatic mantle probably was similar to that of the big peridotitic mantle xenolith from the Tismana shoshonitic pluton, from which the mantle xenolith was torn by the fast ascending magma.It geochemically fits with xenoliths from basalts. From this initial magma an arc calc-alkaline magma (magmas) was formed by fractional crystallization, from which the common rock granitoid plutons resulted (Fig. 15) The initial composition of this magma could be characterized by the following main components: SiO_2 = 67.87%; Na_2O = 3.92%; K_2O = 3.49%; CaO = 2.36% (Table 1). Then, this magma was contaminated with crustal anatectic melts and enriched in silica, resulting a hybrid magma. The last differentiate of this magma was the trondhjemitic magma the trondhjemitic plutons resulting from. The composition of the trondhjemitic magma could be characterized as follows: SiO_2 = 71.12%; Na_2O = 4.24%; K_2O = 2.59%; CaO = 1.72% (Table 2). It shows a higher content of SiO_2 in comparison with the parental magma, a little higher alkalies and a low CaO content.

According to the datings by Soroiu *et al.* (1970), Grünenfelder *et al.* (1982) and Liégeois *et al.* (1998) almost at the same time as the common grnitoid melt derived from the metasomatic mantel by the partial melting process, there occurred by the same way a special pyrolite from which a monzonitic melt resulted the shoshonitic plutons derived from. But it seems that there was needed a long period to differentiate a shoshonitic magma from this monzonitic one; than it was neccesary to the calc-alkaline granitoid melt to be mantel-contamined and to differentiate the trondhjemitic magma from which the trondhjemitic plutons of syn-collision (syn-orogenic) nature resulted (see Figs. 13 and 14). Therefore, the shoshonitic plutons have been emplaced a little later, during the post-orogenic uplift of the old Carpathian orogen (Fig. 14), under within-plate conditions (Fig. 13). The shoshonitic magma could be characterized by the following parameters: SiO_2 = 67.56 %; Na_2O = 3.02 %; K_2O = 5.14 %; CaO = 1.82 % (Table 1).. This composition shows that Si_2O is almost simmilar to that of the common rock ganitoids, but K_2O is very high, and a little higher are the iron components, too.

• Crg---------------->Tr--------> Trondhjemitic trend
/
● Mm ----------> • To -------->
● Py ----------> • Mz---------------> • Shosh---------------------------->Shoshonitic trend.

Fig. 15 – Set-up showing the differentiation of the initial melts into granitoid magmas: Mm, metasomatic mantle; To, tonalitic-dioritic magma; Cgr, common granitoid magma; Tr, trondhjemitic magma. Py, special pyrolite; Mz, monzo-dioritic to monzo-gabbroic magma; Shosh, shoshonitic magma.

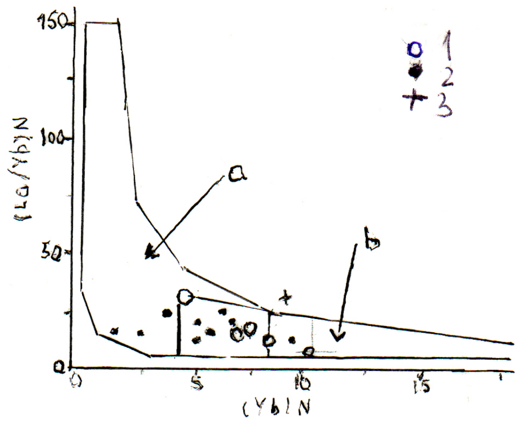

Fig. 16. Plot of the South Carpathian granitoid plutons on the (La/Yb)N vs. (Yb)N diagram. Fields according to Martin (1986): a, field of 319 Archean adakitic granitoids; b, field of 325 Proterozoic and Cenozoic typical island arc non-adakitic granitoids. 1, common rock granitoid plutons; 2, trondhjemitic plutons; 3, shoshonitic plutons.

On the diagram in Fig. 16 most of the throndhjemitic plutons plot within the Archean adakitic granitoid field or in the intermediate area situated between this field and the island arc non-adakitic pluton field. Otherwise, as shown above, most South Carpathian granitoid plutons present average values of the Sr/Y ratio (Table 4) that are similar or close to those of the adakitic volcanics (see Savu, 2004).

6. CONCLUSIONS

Within the western part of South Carpathians numerous granitoid plutons are to be found. These plutons belong to three group-types like common rock, trondhjemitic and shoshonitic granitoid plutons. The plutons from each group intruded both the Danubian Autochthone and the Getic Nappe

Around the granitoid plutons large zones of regional-contact metamorphism usually occur, which show the syn-collision (syn-orogen, tarde-orogen) tectonic setting of these plutons, a characteristic that was also shown by the geochemical data. Except for the shoshonitic plutons, which are paulo-post-collision (late orogenic) plutons, a feature supported by the fact that around the Tismana pluton the regional-contact metamorphism also occurs.

The common rock granitoid plutons occur all along the western part of the South Carpathians, while the trondhjemitic plutons are situated only within the western bent zone of this mountain chain. The main shoshonitic plutons occur along the southern margin of the Danubian Autochthone, only.

As regards the chemical composition, this differentiates very well the three groups of plutons, because in comparison with the normal common rock granitoid magma the trondhjemitic magma is richer in SiO_2, and the shoshonitic magma shows high contents of alkalies, especially K_2O and iron components, and low content of CaO.

Concerning the origin of the parental magmas, it was the metasomatic mantle situated over the subduction plane of the Moesian Plate under the initial chain of the South Carpathians. First of all, a tonalitic-dioritic magma was separated from which an arc calc-alkaline magma derived, in which the common rock granitoid plutons originated. Then, this magma was contaminated with anatectic melts from the crust, when it was slowly moving through. This hybrid magma differentiated by fractional crystallization into a trondhjemitic magma, from which the trondhjemitic plutons resulted. At the same time or a little later, from the metasomatic mantle a special pyrolite resulted, from which a fraction of monzo-dioritic or even monzo-gabbroic magma was separated, the shoshonitic plutons derived from.

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