A COMPARATIVE STUDY OF TWO VARISCAN CONTRASTING PLUTON COMPLEXES FROM THE HIGHIŞ-DROCEA CRYSTALLINE SCHISTS, ROMANIA

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Abstract. Within the Highiş-Drocea Mountains there are two separate Variscan magmatic complexes of within plate metabasalts, located in the low metamorphic Păiuşeni series. In each complex a pluton complex was intruded. The contrast between the pluton complexes consists in their rock association. Thus, the Highiş pluton complex consists mostly of granitoids, trondhjemitic and shoshonitic granites being associated with. The Bârzava pluton complex consists of syenitic rocks, like syenodiorites, syenites and quartz-syenites as well as of the related dyke rocks. The pluton complexes are also contrasting by the nature of their postmagmatic solutions, which strongly affected both the plutonic rocks and the host crystalline schists, including the metabasalts. The Highiş pluton complex was accompanied by normal granitoid postmagmatic solutions, which determined the alteration of the magmatic minerals into secondary minerals like albite, sericite and chlorite, eventually epidote, and the turmalinization of the magmatic rocks and the surounding crystalline schists. In the Bârzava pluton complex the postmagmatic solutions have been very rich in soda, so that, due to them, the melanocratic minerals have been transformed into secondary alkaline minerals. Large processes of soda and boron metasomatism manifested themselves, too. All these differences between the two twin pluton complexes have been determined by the partial melting degree of the plume-source in the two hotspots, which was different.

Key words: Highiş complex, Bârzava complex, petrology, geochemistry, origin.

Résumé. Dans les monts de Highiş-Drocea il y a deux complexes – Highiş et Bârzava – de roches métabasiques hercyniennes, localisés dans la série de Păiuşeni, faiblement métamorphisée. Dans chaque complexe métabasique des complexes putoniques ont été mis en place. Le contraste entre les deux complexes plutoniques consiste dans leurs association de roches. Le complexe plutonique de Highiş consiste plutôt en granitoides, étant associés avec granites trondhjemitiques et shoshonitiques. Le complexe plutonique de Bârzava consiste essentiellement de roches syénitiques et de syénites à quartz et aussi de dykes de même composition. Les complexes plutoniques sont contrastants aussi par la nature de leurs solutions postmagmatiques, qui ont affecté tant les roches plutoniques que les roches cristallophylliennes, y compris les métabasalts. Le complexe plutonique de Highiş a été accompagné par solutions granitiques normales qui ont determiné l'alteration des mineraux magmatiques en mineraux secondaires, comme albite, sericite et chlorite, éventuellement épidote, et la tourmalinisation des roches magmatiques et des schists cristallines. Dans le complexe plutonique de Bârzava les solutions postmagmatiques ont eté très riches en sodium, à cause desquelles les minéraux mélanocrates ont été transformés en minéraux alcalines secondaires. Larges phénomènes de métasomatisme sodique et borique se sont manifesté aussi. Tous ces différences entre les deux complexes plutoniques ont été déterminées par le degré de la fonte partielle de la *plume-source* dans les deux complexes, qui a été différent.

Mots-clés: complexe de Highiş, complexe de Bârzava, pétrologie, géochimie, origine.

INTRODUCTION

The contrasting pluton complexes are represented by the plutons of Highiş and Bârzava, which are located in the low metamorphic Păiuşeni series of the Highiş-Drocea Mountains from the Apuseni Mountains. Although of the same age and origin, their rock associations differ from one another in an evident manner. As I know the geology of this area, because on the Bârzava magmatic complex I realized my doctor's degree thesis (Savu, 1965), I decided to make a more thorough petrologic and geochemical study of both complexes and to compare their peculiarities. And that, so much so that in the last time's period some inadvertences occurred concerning the genesis of the Păiuşeni series crystalline schists, in which the magmatic complexes are located. On this purpose I used the available data from the literature. The results of this study are presented in the actual paper.

PETROLOGY OF THE HIGHIŞ-DROCEA CRYSTALLINE SCHISTS

In the Highiş-Drocea crystalline schists two metamorphic series are represented: the Pre-Variscan Mădrizeşti series and the Variscan Păiuşeni series. Formerly, the crystalline schists from the Highiş-Drocea Mountains have been generaly considered of Paleozoic age (see Paucă, l937; Papiu, l953), in which the crystalline schists of the actual Mădrizeşti series were presented as a facies of higher metamorphism of this pile of crystalline schists (Papiu, 1953). Later, there was shown (Savu, l962) that the Mădrizeşti series represented, in fact, a Precambrian metamorphic series, over which the Paleozoic Păiuşeni series was transgresivelly lying.

The crystalline schists of the Mădrizeşti series, which occur from under the Păiuşeni series along the northern and the eastern margins of the Highiş-Drocea crystalline schist area (Fig. 1), consist of micaschists, paragneises, rarely amphibolites and a small body of 'Alpine type' ultramafic rocks. The last occurs at Slatina de Mureş, and probably represents an ultramafic olistolith, like those from the South Carpathian Sebeş-Lotru series (see Savu *et al.*, l982).

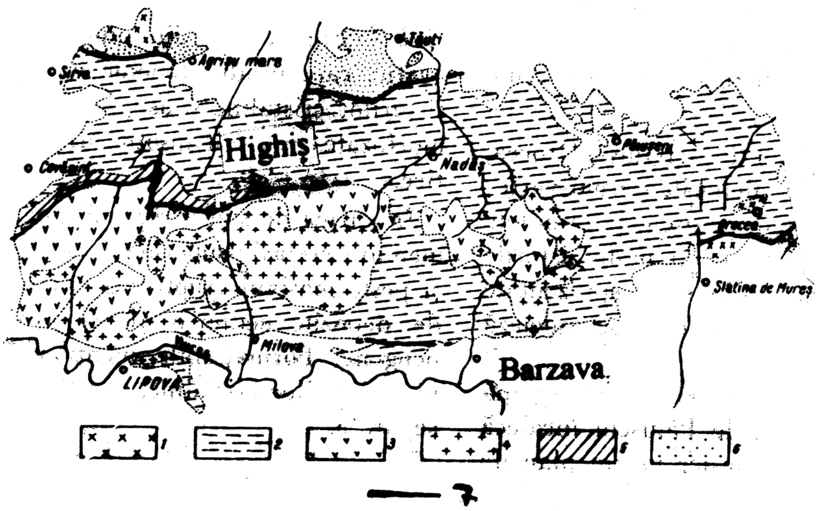

Fig. 1 – Geological map of the Highiş-Drocea crystalline schist area, according to the Map of Romania, sc. 1 : 5000000, with the author's additions. 1, Mădrizeşti series; 2, Păiuşeni series; 3, metamorphosed basic rocks; 4, plutonic rocks; 5, Permo-Carboniferous Cuvin Formation; 6, Permo-Carboniferous deposits from the Zarand Basin; 7, eastwest reverse faults and northsouth normal faults.

The Variscan Păiuşeni series (Savu, 1962), the present study is dealing with, is younger and extends over all surface of the Highiş-Drcea crystalline schist area.

PETROLOGY OF THE PĂIUŞENI SERIES CRYSTALLINE SCHISTS

The Păiuşeni series has been studied by Giuşcă (l962; l979), Giuşcă *et al.* (l964), Giuşcă and Papadopol (1977), Dimitrescu (l962), Savu (1962; 1965), and Savu and Tiepac (l982). Its crystalline schists are unconformably lying over the Pre-Variscan Mădrizeşti series. In the crystalline schist pile of this series there are to be distinguished two rock complexes of sedimentary (detrital) origin and a complex of metamorphic basic rocks.

The lower complex of crystalline schists extends mostly along the median zone of the Highiş-Drocea Mountains, where it occurs in the axial zone of the anticlinorium, which characterizes the initial Variscan tectonics of this mountain chain. It consists mostly of metapsamitic and metapsefitic rocks. Sometimes, between the metadetrital layers intercalations of basic metatuffs and of metaquartzkeratophyres occur. The metapsamitic rocks are represented by chlorite-sericite-quartzites, sericite-quartzites and carbonatic quartzites.

The metapsefitic rocks, on the origin of which a controversy occurred, consist of quartz peebles well rolled during their trasportation and lightely flattened during the low metamorphism and folding of the Păiuşeni series (see Savu, l962; l993a, Fig. 4). The peebles consist either of white hydrothermal quartz or rarely of grey quartzite originating in some graphitous quartzites from the Pre-Variscan basement of the Păiuşeni series. There are very interesting the big peebles of white quartz, in which inclusions of alkali-feldspar crystals occur, showing that these peebles originate in some pegmatoid rocks from the same old basement (see Savu, l965, Fig. 2), represented either by the Mădrizeşti series or by other coeval Pre-Variscan series, as for instance, those from the Codru-Moma crystalline schists, a region which was emerging from the Paleozoic epicontinental sea and was eroded, thus supplying the pre-metamorphic deposits the Păiuşeni series resulted from (Savu, l993 a, Fig. 1). All these observations show that the metaconglomerates resulted from sedimentary conglomerates (Savu, l962; l965; l993a) and are not pseudoconglomerates as Pană and Ricman (l988) supposed. Otherwise, Dimitrescu (l995), who statistically determined the shape of the peebles from the Bihor metaconglomerates, and the effects of the strain on them, reported that the shape indicates a sedimentary origin of these rocks. The strain was stronger in the Lower Carboniferous metaconglomerates, which belong to a coeval formation of the Păiuşeni series, than in the Triassic conglomerates affected by the Alpine nappe thrust.

It is noteworthy that in the upper part of the lower complex, the transition zone toward the upper complex, respectivelly, there occur at the springs of the Păiuşeni Brook small lenticular intercalations of uranium concentrations, the mineral assemblage of which is pitchblende-chalcopyrite (Savu, l993b). By weathering of these minerals secondary uranium minerals like autunite, torbernite and uranium hydroxides were formed.

The crystalline schists of the metapelitic upper complex occur along both sides of the anticlinorium of the Highiş-Drocea Mountains. It consists of metapelitic crystalline schists like sericite-chlorite schists, sericite schists, carbonatic schists, graphite schists as well as chloritoide schists. The determination of the chloritoide crystals position showed that they are oriented parallel with the axial zone of the Highiş-Drocea Chain and that they are the product of the Variscan metamorphism.

The complex of the metabasaltic crystalline schists had a complex evolution. The manifestation of the magmatism that produced the rocks this complex came from, started since the sedimentation of the lower complex. But it strongly developed during the period situated between the two sedimentary complexes. The basalts of this complex erupted within two areas, which look like two spots (Fig. 1), namely, the Highiş and the Bârzava spots. This complex consists mostly of metabasalts and basaltic metatuffs, rarely of metagabbros and metadolerites, intercalations of metaquartzkeratophyres being rarely observed. The volcanism was a bimodal one, since it produced only basaltic and acid rocks. According to the mean of the term ophiolites at the beginning of the l960s, that ophiolites were defined as basic rocks erupted within a sea, I considered these rocks as ophiolites, too (Savu, 1962; l965). Later on, when geochemical data have been available (Savu, Udrescu, 1975; Savu, Tiepac, 1982), it was discovered that the Bârzava metabasalts were within plate rocks (Fig. 2), which derived from basalts erupted within an epicontinental sea.

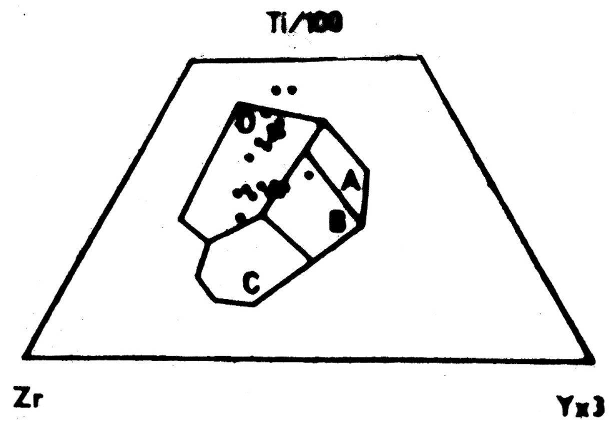

Fig. 2 – Plot of the Bârzava metabasalts on the Ti-Zr-Y diagram. Fields according to Pearce and Cann (1973): A+B, low-K tholeiites; B, ocean floor basalts; C+B, calc-alkaline basalts; D, within plate basalts. Data are from Savu and Tiepac (1982).

Then there was also shown (Savu, 1993a) that the metabasalts from both Highiş and Bârzava magmatic complexes were bearing the same signature (Fig. 3).

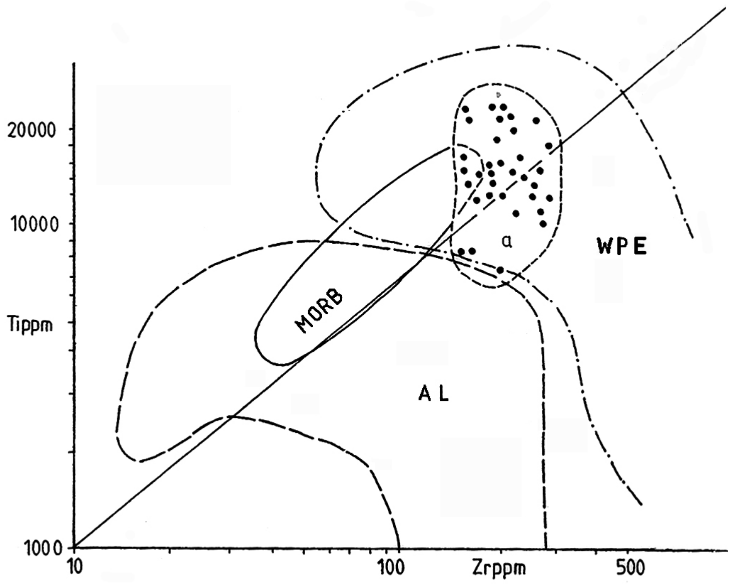

Fig. 3 – Plot of the Highiş and Bârzava metabasaltic rocks on the Ti vs. Zr diagram. Fields according to Pearce (1980): WPB, within plate basalts; MORB, mid-ocean ridge basalts; AL, arc lavas. Data are from Savu, Udrescu (1975) and Savu (1993a).

The initial sedimentary formations and the basaltic rocks have been affected by a low-grade regional-metamorphism during the Variscan orogeny, most probably the Sudete movements, as the age of 300 Ma, determined by Dallmeyer *et al.* (1994) suggests. It was obtained on a sample of metaconglomerate. The metamorphism manifested itself under the PT conditions of the greenschist facies, at temperatures of about 250 to 400°C. In the metamorphic rocks the following mineral-assemblages occurred:

1. albite-epidote-chlorite-sphene±quartz, in the basic rocks;
2. quartz-sericite-chlorite, in the pelitic rocks.

The age of the premetamorphic sedimentary deposits the Păiuşeni series derved from, resulted from two sources. Thus, V. Iliescu determined a microspore association, which indicates a Sillurian-Lower Carboniferous age of these deposits (see Savu, 1993b). In the southern part of the Apuseni Mountains Slavin (l963) determined different forms of *Zonotriletes* in a coeval formation of the Păiuşeni series, which indicated a Carboniferous age. The radiometric age of 300 Ma of the Păiuşeni series (Dallmeyer *et al.*, 1994) very well correlates with the Sillurian-Lower Carboniferous age determined by mean of the spore-polen association from the premetamorphic formations.

The crystalline schists of the Păiuşeni series have been rejuvenated during the Alpine movements, probably the Late Kimmerian and Laramian movements, as the ages of 175 to l00 Ma obtained on samples of phyllites from the region (see Tatu, l998) show. These last movements also manifested themselves in the neighbouring Mureş ophiolitic suture, too (see Savu, 2007), still the ophiolites were not affected by any deformation process. These movements determined the Alpine tectonics of the Highiş-Drocea Mountains, as it will be shown further down.

The first tectonics of the Pîiuşeni series was realized during the Variscan metamorphism. It consists of an almost eastwest low anticlinorium with large satellite anticlines and synclines on both sides. On the southern side of this structure a hemianticline occurred, in which the Bârzava magmatic complex was inscribed (Savu, l965, Pl. XIII).

Here is the place to mention that some geologists like Pană and Ricman (l988) considered that the lower coplex of the Păiuşeni series would represent a huge mass of shear rocks, determined by the thrust of an imaginary Alpine nappe over the Păiuşeni series basement and that, as shown above, the metaconglomerates from this complex would represent pseudo-conglomerates. In reality they interpreted the original unconformity between the Pre-Variscan Mădrizeşti series and the sedimentary deposits the Păiuşeni series derived from, as a thrust plane along which an huge Alpine nappe would have slid, thus resulting the lower complex of the Păiuşeni series as a shear rock complex. And it not happened in an oceanic zone, as normal, but in a continental area under within plate tectonic conditions. Moreover, Tatu (l998) considered that the entire Păiuşeni series would represent a shear formation and that the granitoid plutons intruded in it would represent rocks non-affected by the supposed shear process.

Such a simplistic vision of the complex geology of the Highiş-Drocea Mountains is in contradiction with the following observation facts, besides the arguments above presented at the discution on the metaconglomerates origin.

1. Above all the value of 300 Ma (Dallmeyer *et al*., l994) showed that the age of the Păiuşeni series was not Mesozoic, if it should have been if its metamorphism would have been determined by an Alpine shear process. 2. The granitoid plutons not only escaped the shear process invoked by Tatu (l998), but on the contrary, they intruded and contact-metamorphosed the so-called shear rocks of the Păiuşeni serie. 3. The Alpine tectonics resulted not in a general shear process, but as it will be shown further down, it determined only the occurrence of a system of reverse faults.

PETROLOGY AND GEOCHEMISTRY OF THE CONTRASTING PLUTON COMPLEXES

Although the metamorphic basic rocks of the two magmatic complexes of the Highiş-Drocea Mountains are similar, still their pluton complexes differ from one another, as in the Highiş pluton complex the rocks are represented mostly by granitoid rocks and in the Bârzava pluton complex by syenitic (albite monzonitic) rocks.

PETROLOGY OF THE HIGHIŞ GRANITOIDS AND RELATED ROCKS

The Highiş granitoid rocks intruded the Highiş metabasalt complex within the most part of its extending area, they occurring especially as granitoid plutons oriented eastwest (Fig. 1), which are associated with gabbros, diorites and ultramafic rocks.

The ultramafic rocks are represented by wehrlites, which occur as very small bodies in different part of the region. They are surrounded by gabbros and dioritic rocks (see Giuşcă, l979; Tatu, l998). As shown by the last author, in all occurrences the contact with the host rocks is a net one. According to their shape, dimension and composition the small bodies of wehrlites look rather like big xenolites, which have been torn by the gabbro and dioritic magmas from a mantle plume and antrained toward the surface.

According to Table 1, the wehrlite are ultramafic rocks with low SiO2 and very high MgO contents. They excel by their very low content of V and Cr, in comparison with other rocks of the sort. Indeed, on the diagram in Figure 4, the analysed wehrlite sample plots in the field of the mantle pume xenoliths from the Perşani Mountains trachybasalts, near a similar xenolith from the Tismana shoshonitic granitoid pluton (Savu, 2006–2008).

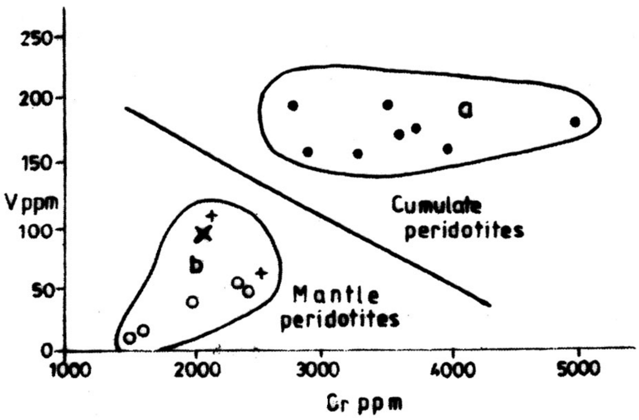

Fig. 4 – Plot of the Highiş wehrlite xenolith on the V vs. Cr diagram. Fields according to Savu (2008): a, field of the cumulate peridotites from the Mureş ophiolitic suture; b, field of the mantle plume xenoliths from the Perşani Mountains trachybasalts; dot, cumulate peridotites from the Mureş ophiolitic suture; o, mantle plume xenoliths from the Perşani Mountains trachybasalts; cross, wehrlite xenoliths from the Tismana shoshonitic granitoid pluton; x, wehrlite from the Highiş magmatic complex. Data are from Table 1.

Moreover, on the diagram in Figure 5 the Highiş wehrlite plots at the right of the plume-surce line, together with granitoid rocks from the same Highiş magmat The group of basic and intermediate plutonic rocks is represented by gabbros, diorites and quartz-diorites which have been described by Giuşcă (l979) and Tatu (l998). They occur as small bodies so that on the elaborated maps they were not presented. These are massive phaneritic rocks with hypidiomorphic texture, sometimes ophitic or subophitic. In their composition enter plagioclase, clinopyroxene, hornblende, biotite and quartz mostly in diorites and especially in quartz-diorites. The plagioclase is a labrador-bitownite in gabbros and an andesine with zoned structure in diorites and quartz-diorites. Sometimes the mineral has been altered into secondary minerals like sericite, albite, occasionally epidote and calcite. The accessory minerals are apatite, magnetite and ilmenite. Clinopyroxene usually occurs in euhedral crystals often substituted by amphibole or biotite and chlorite, there occurring secondary iron oxides. Sometimes, in these rocks there occurs the poikilitic texture, determined by large hornblende crystals which are including the former minerals. ic complex. It shows that the wherlite represent, in fact, the original mantle plume from which the xenolith was torn.

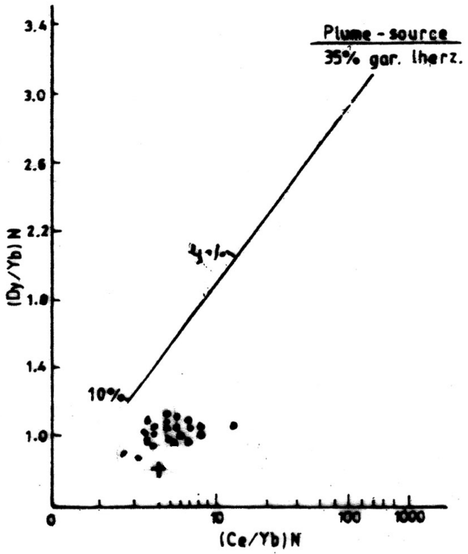

Fig. 5 – Plot of the Highiş wehrlite and granitoid rocks on the (Dy/Yb)N *vs.* (Ce/Yb)N diagram. The plume-source line was drew according to Haase and Devey (1996); dot, granitoids from the Highiş pluton complex; cross, Highiş wehrlite xenolith. Data are from Table 1.

According to Table l, the average composition of gabbros consists of 48.28 % SiO_2, almost equal MgO and CaO and very low contents of K_2O. In diorites and quartz-diorites SiO_2 is of about 60 %, MgO and CaO are lower than in gabbros and Na_2O and K_2O differ from one another, the first component being of more than 5 % and the second only of 0.38 %, a situation which could also indicate an incipient albitization process. On the diagram in Figure 6 these rocks plot in the fields number 9 and 10, of the rocks with monzonitic characteristics, according to the classification of Streckeisen (l967). In some rocks the normative nepheline is present, so that these rocks plot under the A-P line of the diagram, in the APF domain.

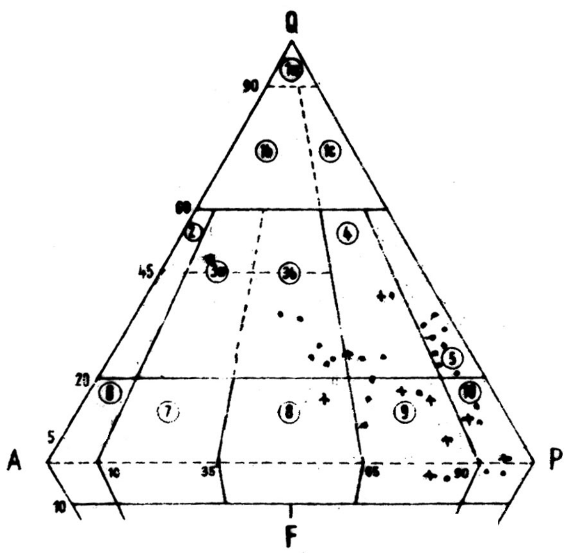

Fig. 6 – Plot of the Highiş and Bârzava plutonic rocks on the QAPF diagram. Fields according to Streckeisen (l967): 1, quartz rocks; 2, alkali granite; 3, granite; 4, ganodiorite; 5, quartz-diorite, including trondhjemitic rocks and latites; 6, alkali syenite; 7, syenite; 8, monzonite; 9, monzodiorite and monzogabbro; 10, gabbro, diorite and norite. Data are from Tatu (1998) and Savu (1965).

Table l

Average chemical composition of rocks from the Highiş pluton complex
(data are from Tatu, l998)*

Rocks	L (1)	2 (2)	3 (6)	4 (4)	5 (5)	6 (7)	7 (4)	8 (11)	9 (3)
SiO_2 %	39.49	48.28	59.95	64.85	74.32	73.48	74.34	75/50	74.20
TiO_2	0.68	1.61	1.41	0.73	0.29	0.32	0.32	0.20	1.50
Al_2O_3	5.94	14.44	15.55	16.15	13.51	12.35	12.54	11.89	12.93
Fe_2O_3	5.67	4.75	3.28	3.71	1.36	1.87	2.09	1.48	2.14
FeO	6.88	7.31	2.83	1.38	0.80	0.70	0.60	0.38	0.31
MnO	0.16	0.13	0.08	0.04	0.03	0.03	0.03	0.02	0.01
MgO	27.37	8.75	3.05	1.64	0.30	0.20	0.28	0.21	0.21
CaO	3.13	8.27	3.05	2.33	1.38	0.98	1.02	0.73	1.26
Na_2O	0.10	3.11	5.39	6.67	6.82	4.52	4.45	3.76	7.35
K_2O	0.03	0.93	0.82	2.29	0.43	5.62	3.92	5.20	0.56
P_2O_5	0.21	0.28	0.33	0.18	0.07	0.09	0.08	0.01	0.11
LOI	9.15	1.95	0.96	0.66	0.58	0.52	0.49	0.41	0.29
Total	99.56	99.72	99.73	99.83	99.75	100	100.1	99.95	100
Pb ppm	3.24	6.5	3.75	31/33	15.55	9.0	21.2	1.53	2
Cu	54.0	45	33.4	16.87	44.0	16.2	31.0	14.2	5.0
Zn	111.0	195	61.8	55.0	51.0	37.4	88.1	33.5	26.6
Sn	1.16	3.5	6.52	5.47	5.84	4.78	6.16	32.5	10.2
Ga	8/21	22.5	19.46	23,7	22.36	19.0	27.0	21.8	12.0
Mo	0.20	2.0	1.54	1.16	1.49	2.35	1.62	1.86	2.0
Ni	828.0	40	19.16	12.2	12.78	8.02	11.8	10.26	7.76
Co	93.40	31	15.3	4.55	2.97	2.50	2.03	2.62	2.90
Cr	2094.0	11.5	34.4	14.4	19.32	11.30	19.0	16.8	16.4
V	97.8	280	105.2	120.5	9.75	7.29	9.37	2.50	10.7
Sc	9.0	35.5	19.7	3.75	2.52	3.0	2.33	4.32	8.13
Y	13.10	44.0	56.55	69.6	42.29	42.5	57.0	132.6	64.0
Zr	80.4	280.0	393.5	520.0	337.9	469.8	344.4	737.0	562.9
Nb	3.09	13.5	13.5	24.3	19.94	14.94	17.5	82.9	28.7
Hf	1.74	2.75	10.3	12.71	10.61	10.94	10.5	36.8	20.9
Ta	0.23	-	1.15	1.91	1.37	1.14	1.48	6.20	3.15
Rb	2.04	12.5	25.2	85.3	29.12	150.5	134.3	205.3.	122.2
Sr	29.04	217.5	128.4	103.8	20.3	35.05	32.8	20.3	16.26
Ba	16.0	97.5	93.9	254.5	70.89	274.5	246.2	239.4	82.0
U	0.15	0.96	2.82	4.74	5.22	4.35	5.74	10.4	9.24
Th	0.66	5.95	7.15	15.56	17.65	14.5	18.0	57.6	16.5
La	6.27	16.0	24.15	40.24	35.25	37.24	35.29	48.0	31.8
Ce	14.08	17.5	58.57	92.32	86.07	88.15	87.7	115.3	8.63
Pr	2.10	-	6.10	12.17	12.67	10.07	10.6	11.9	3.46
Nd	9.16	-	30.2	49.7	45.47	37.0	40.9	16.3	23.3
Sm	2.37	4.35	5.84	10.24	8.58	7.12	10.1	10.04	8.14
Eu	0.40	1.03	1.64	1.69	0.88	0.92	0.89	0.47	0.81
Gd	2.56	-	7.13	11.58	9.55	7.09	9.70	8.37	6.83
Tb	0.57	0.38	0.78	1.51	1.22	0.90	1.19	4.71	1.04
Dy	2.23	-	6.28	11.3	10.0	7.43	9.98	14.2	11.97
Ho	0.51	-	1.30	2.85	2.68	1.45	2.94	4.4	4.04
Er	1.24	-	3.56	7/10	7.56	4.28	7.04	13.4	13.46
Yb	1.16	5.0	5.58	7.22	6.42	6.21	7.22	12.8	10.1
Lu	0.18	-	0.68	1.17	1.10	0.78	1.05	3.11	1.72

* The analyses in the table represent: 1, wehrlite; 2, gabbros; 3, diorites; 4, granodiorites; 5, trondhjemitic rocks; 6, monzogranites; 7, granites; 8, rhyolites and granophyres; 9, albitites. The numbers in parentheses indicate the number of the calculated analyses. For the average contents there have been calculated the most complete analyses, only.

As regards the tectonic setting of the plutonic basic rocks, it is consistent with that of metabasalts, since they are within plate rocks, too. This conclusion clearly results from the diagram in Figure 7, on which all the plutonic basic rocks plot in the WPB field.

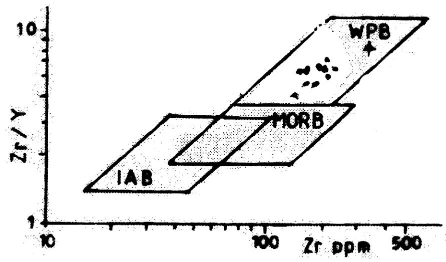

Fig. 7 – Plots of the Highiş plutonic basic rocks and the Bârzava sienodioritic rocks on the Zr/Y *vs*. Zr diagram. Fields according to Pearce and Norry (1979): WPB, within plate basalts; MORB, mid-ocean ridge basalts; IAB, island arc basalts; dot, Highiş rocks; cross, Bârzava rocks. Data are from Tatu (1998) and Savu and Tiepac (1982).

The group of plutonic acid rocks is represented by different varieties of granitoid rocks. Thus, there occur alkali granites, hybrid rocks and trondhjemitic, monzogranitic and shoshonitic granitoids. On the diagram in Figure 6 the granitoid rocks plot in the granodiorite, granite and trondhjemite fields.

The hybrid rocks represent, in fact, the so-called 'facies mixte' of Tatu (1998). These rocks resulted by the contamination of the granitoid magma by the basic rocks or magma, there resulting rocks of granodiorite composition, as it results from the average chemical analysis number 4 in Table 1. These rocks consist of quartz, plagioclase, alkali-feldspar and melanocratic minerals. The difference as against the other granitoids consists in their melanocratic minerals, the amount of which is higher in the hybrid rocks. These minerals are represented by biotite, green hornblende and, as it was shown by Tatu (1998), even the clinopyroxene would be present in some facies of the hybrid rocks.

The trondhjemitic granitoids include the so-called Na-granites of Tatu (1998). These rocks are close associated with the monzonitic and alkali granites, as it results from Tables 13.4 to 13.6 of Tatu (1998). Sometimes, rocks with this composition occur as independent small bodies. These rocks consist of quartz, albitic plagioclase, lesser alkali-feldspar, biotite, rarely green hornblende and accessories like zircon and apatite. The albitic composition of plagioclase explains the high content of Na_2O in these rocks, which varies around the average of 6.82 %, as it results from Table 1, analysis 5, and low content of K_2O and CaO. Biotite is sometimes dark green like the biotites from the Bârzava plutonic rocks (Savu, 1956) or red-brown, being rich in Ti. Another magmatic mineral is a green hornblende, which, like biotite, includes crystals of zircon and apatite. On the diagram in Figure 8 all the analysed rocks of this category plot in the field D of the trondhjemitic granitoids (see also Figure 6, field 5).

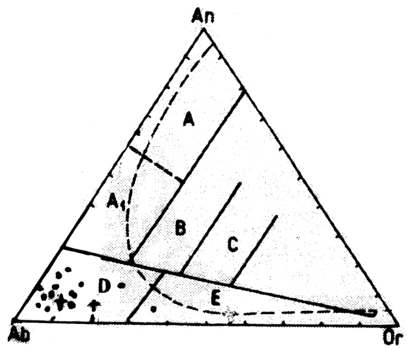

Fig. 8 – Plot of the trondhjemitic rocks from the Highiş pluton complex on the An-Ab-Or diagram. Fields according to O'Connor (1965): A and A_1, quartz-diorites and tonalites; B, granodiorites; C, adamelites; D, trondhjemites; E, granites. Data are from Tatu (1998).

The average chemical composition of monzonitic rocks is presented in Table 1, analysis 6. It shows high SiO_2, Na_2O and K_2O. On the diagram in Figure 6 one reprentative analysis plots in the field 8 of the monzonitic rocks.

The high-K granites and the shoshonitic granites are the most frequent leucocratic rocks from the Highiş acid plutonic rocks. These rocks are formed of a mineral assemblage consisting of quartz, potash feldspar, albite-oligoclase, melanocratic minerals as well as accessory minerals. Quartz occurs as xenomorphic crystals located between other minerals of the rocks. In some pegmatoid facies of these granitoids quartz makes graphic intergrows with the potash feldspar. Usually, the last mineral occurs as microcline and microcline-perthite, in which inclusions of apatite, zircon and opaque minerals do occur. The plagioclase occurs in prismatic crystals showing albite twins, which sometimes are altered into a secondary mineral assemblage consisting of albite, epidote and sericite. The melanocratic minerals are represented by light olive biotite and rarely green hornblende.

The average chemical compostion of these rocks is presented in Table 1, analysis 7, which shows high contents of SO_2, Na_2O and K_2O. This last component reaches an average of 5.62 %. On the diagram in Figure 9 the rocks plot in the high-K granite and the shoshonitic granite fields.

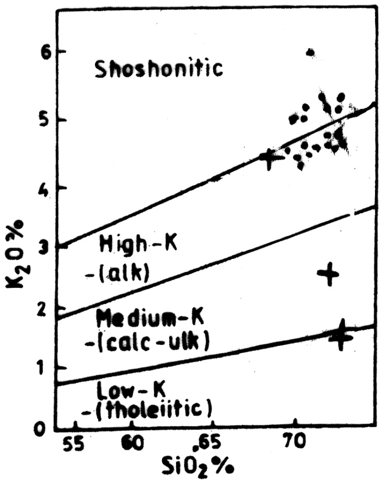

Fig. 9 – Plots of Highiş and Bârzava granitoids on the K_2O vs. SiO_2 diagram. Fields, according to Rickwood (1989): dot, Highiş rocks; cross, Bârzava rocks. Data are from Savu (1965) and Tatu (1998).

Although the Highiş granitoids include shoshonitic rocks, the big mass of granitoids show a calc-alkaline character, as it results from the diagram in Figure 10, a character that was also remarked by the previous authors who studied these granitoids.

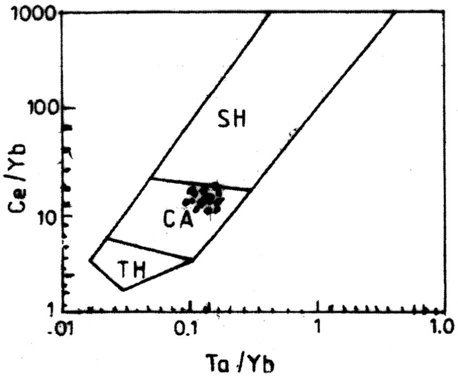

Fig. 10 – Plots of some Highiş granitoid rocks on the Ce/Y vs. Y diagram. Fields according to Pearce (1982): SH, shoshonitic rocks; CA, calc-alkaline rocks; TH, tholeiitic rocks. Data are from Tatu (1998).

At the end the Highiş granitoid plutons have been intruded by a suite of dyke rocks like granophyres, microgranites, quartz-porphyries and albitites, which are crossing the Cuvin Formation, too.

Concerning the tectonic setting of the Highiş plutonic rocks, it was already shown (Fig. 7) that the melanocratic plutonic rocks are within plate rocks. Tatu (1998, Fig. 88 b) showed that, according to their Nb and Y contents, most of the granitoids plot on the adequate diagram of Pearce *et al.* (1984) in the triple junction of the WPG, VAG + syn COLG and ORG fields, with an evident tendency towards the WPG field. An obvious WPG tectonic setting is shown by the granitoid dyke rocks, which are crossing the Cuvin Formation.

PETROLOGY OF THE BÂRZAVA SYENITES (MONZONITES) AND RELATED ROCKS

The plutonic rocks from the Bârzava magmatic complex belong to five groups, namely, dioritic, alkaline, granitic, hybrid and dyke rocks (Savu, 1965; Savu and Tiepac, 1982).

The dioritic rock group includes diorites, meladiorites, porphyritic diorites and dioritic micropegmatites. Diorites represent the most part of this rock category. They are massive rocks consisting of plagioclase, green hornblende, biotite and chlorite. The plagioclase crystals are substituted by albite and are surrounded by an aureola of fine twinned albite of low temperature. Although plagioclase was substituted by albite, in its structure can still be observed a more basic core of (An_{10}), surrounded by an albite (An_8) zone. The green hornblende occurs as xenomorphic crystals in which remnants of a brown hornblende are to be observed. In meladiorites instead or besides the green hornblende there occurs a clinopyroxene, that is characterized by a weak pleochroism in redish-violet colors, which indicates an augite rich in iron. It was partly substituted by green hornblende. In these rocks a brown hornblende is present, too, which shows a poikilitic structure. It includes plagioclase crystals. According to its optical constants this mineral represents a backevikitic hornblende. It was substituted first by a hastingsitic hornblende and then by a green hornblende (Savu, 1965). In both rock varieties lamelae of a green-brown biotite occur, which include zircon crystals surrounded by a pleochroic aureola, The accessory minerals are represented, beside zircon, by apatite, sphene and pistacite.

The chemical analysis of meladiorite (Table2) indicates 48.56 % SiO_2 which may refer to a gabbrodiorite, too. The chemical analysis of diorite contains 55.95 % SiO_2. On the diagram in Figure 6 the dioritic rocks plot in the fields 9 and 10. Those from the field 9, according to the Streckeisen (1967) classification, would indicate monzodiorites like in case of the Highiş diorites. The tectonic setting of these rocks is that of intra plate rocks, since according to the average contents of Zr and Y (Table 3) they plot on the diagram in Figure 7 within the WPB field.

In some rocks from the porphyritic diorites large plagioclase phenocrysts of 1 to 2.5 cm long occur which were partly substituted by secondary minerals like zoizite and sericite. The dioritic micropegmatites are characterized by a divergent texture, formed of elongate albite crystals, green hornblende, pistacite, apatite and opaque minerals.

The alkaline rock group includes syenodiorites and syenites, both of them in different varieties (Savu, 1965). Such rocks occur mostly on the northeastern part of the Bârzava pluton complex (Fig. 1). The syenodiorites are represented by varieties like pyroxene syenodiorites, hornblende syenodiorites and pegmatoid syenodiorites. The pyroxene syenodiorites, which occur on the Radeviţa Hill, are massive rocks consisting of feldspar (78 %), augite or aegirine, hornblende, rarely quartz and accessories. These rocks underwent autometamorphism, which affected the initial magmatic minerals. Thus, pyroxene was partly substituted by aegirine-augite and aegirine. The last mineral also occurs as independent euhedral zoned crystals. There occur also nests of small crystals of aegirine, probably resulted by the substitution of the clinopyroxene. Another transformation of the clinopyroxene consists in its substitution by an amphibole from the barkevikite–hastingsite series. Further on, it was substituted by arfvedsonite, pleochroic in bluish and light violet colors. Accessory minerals are represented by zircon, apatite and magnetite.

Table 2

Chemical composition of the Bârzava syenitic and related rocks (data are from Savu 1965)*

Rock	1	2	3	4	5	6	7	8	9	10	11(2)
SiO_2	48.53	55.95	57.08	59.20	60.91	61.10	61.45	61.75	65.64	68.83	75.74
Al_2O_3	14.87	14.50	17.23	16.91	19.58	19.22	15.19	13.63	15.35	14.69	9.125
Fe_2O_3	10.78	6.91	7.52	6.69	6.65	2.70	6.60	5.80	5.25	3.66	44.03
FeO	4.40	3.37	0.84	1.42	0.98	2.90	1.00	0.45	0.07	0.51	0.74
MnO	0.31	0.25	0.14	0.17	0.20	0.10	0.18	0.08	1.10	0.05	0.08
MgO	3.70	4.45	1.47	1.47	1.30	1.44	1.80	3.50	1.26	0.66	1.25
CaO	6.15	4.20	3.82	4.24	2.83	1.20	2.40	2.37	0.90	0.74	1.10
Na_2O	6.45	5.24	5.97	6.59	5.45	5.80	5.42	7.76	10.10	5.57	5.23
K_2O	1.00	0.80	3.03	0.20	0.91	1.90	1.60	1.56	0.60	4.47	1.09
TiO_2	1.80	1.70	1.36	1.13	0.75	1.25	2.50	1.00	0.37	0.59	0.74
P_2O_5	0.44	0.40	0.32	0.25	0.20	0.20	0.25	0.54	0.13	0.12	0.02
H_2O^-	0.20	0.21	0.40	0.09	0.22	0.18	0.12	0.40	0.13	0.23	0.39
H_2O^+	0.71	0.80	0.57	0.27	0.06	0.48	0,60	1.02	0.50	0.52	0.38
Total	99.58	99.58	99.75	99.57	100.04	99.77	100.08	99.86	100.4	100.14	100.5

* The analyses in the table represent: 1, meladiorite; 2, diorite; 3, syenodiorite; 4, syenodioritic micropegmatite; 5, dioritic porphyrite; 6, porphyritic quartz-syenite; 7, micropegmatite 8, hornblende quartz-syenite; 9, aegirine syenite; 10, alkali granite; 11, average of two porphyries.

In the syenodiorites melanocratic autoliths are to by found, which are formed of the same minerals as the host rock, but in different proportions, in which the opaque minerals are more frequent. The hornblende syenodiorites are almost similar to the above presented rocks, from which they differ by the mineral composition, which consists of feldspar, a hastingsitic or a blue hornblende, rarely pyroxene and accessories. In the mass of syenodiorites there occur separations of pegmatoid quartz-syenodiorites, which consist of plagioclase, potash feldspar, hornblende and accessories. The micropegmatitic syenodiorites are characterized by the graphic intergrowth between quartz and potash feldspar, the last occurring, like in other syenodiorites, as microcline or microcline-perthite. According to their chemical composition (Table 2), these rocks plot on the diagram in Figure 6 within the fields of monzodiorites and monzonites, in accordance with the Streckeisen classification (1967).

The syenite rock group occurs along the northeastern part of the Bârzava pluton complex. They are represented by aegirine-syenites, arfvedsonite-syenites and aegirine-augite-granophyres, all of them occurring as independent intrusions. The aegirine-syenites consist of albite, potash feldspar almost entirely substituted by fine-twinned albite of low temperature, aegirine, arfvedsonite, rarely quartz and accessories like sphene, zircon and iron oxides.

The hornblende-syenites, among which the most characteristic are the arfvedsonite-syenites, are massive rocks. The last rocks, which occur at the springs of the Monorăştia Brook, consist of albite, potash feldspar partly substituted by fine-twinned albite, arfvedsonite and accessory minerals. Like in other syenitic rocks, in the arfvedsonite syenites melanocratic autoliths occur, too, which consist of 36 % feldspars, 53 % arfvedsonite and 11 % opaque minerals. These autoliths show a divergent texture made up by the elongated arfvedsonite crystals, between which albite crystals and opaque minerals are situated.

The granitoid rock group includes quartz-diorites, quartz-syenites, alkali granites and hybrid granitoides. The quartz-diorites are associated with the quartz-syenites and both of them occur as marginal facies of the main granite intrusion situated north of Bârzava. The common rocks in this group are the quartz-syenites, among which there are to be distinguished the hornblende-quartz-syenites and the biotite-quartz-syenites. Light colored, the hornblende-quartz-syenites are massive rocks, often showing a tendency towards the divergent texture. They consist of quartz, albite, potash feldspar, green hornblende and accessory minerals. The plagioclase, which occurs in elongated crystals, presents on its margins a fine-twinned albite aureola, in which quartz in myrmekitic intergrouths with albite occurs, too. The green hornblende, which was often substituted by a fibrous amphibole, includes small zircon crystals showing a pleochroic aureola. The accessory minerals are zircon, sphene, apatite, sometimes epidote and magnetite. On the diagram in Figure 9 the granite (N^{o}. 9 in Table 2) plots in the High-K alkaline field, like some Highiş granitoids.

Table 3

Distribution of the average values of some major and trace elements in the Bârzava rocks (data are from Savu and Tiepac, 1982).

Rocks	1 (1)	2 (2)	3 (3)	4 (17)	5 (4)	6 (11)	7 (24)	8 (12)	9 (5)
CaO %	8.84	8.18	7.65	5.56	5.70	1.96	1.67	3.29	0.63
TiO_2	1.81	1.79	1.99	1.25	0.94	0.90	0.76	1.02	0.43
Fe_2O_3	11.50	11.35	12.05	9.31	4.24	5.51	4.50	5.77	2.83
K ppm	0.72	0.40	0.84	1.27	1.95	0.92	2.16	2.8-	2.78
Rb	33	28	30.6	58.7	75.5	21.3	74.1	76.0	67.9
Sr	146	213	174	139.8	99.7	54.6	40.9	71.5	13.2
Y	22	27	31.4	28.24	33.2	40.1	39.2	39.0	53.4
Zr	121	145.5	149.2	163	171	431	386.3	365.3	443.4
U	0.8	1.1	1.0	1,78	2.09	5.09	4.68	4.77	4.24
Th	4.6	3.35	1.4	5.20	12.2	13.3	14.72	13.215.3	

* The average analises in the table represent: 1, metagabbro; 2, metadiorites; 3, metameladiorites; 4, metabasalts; 5. metamorphozed and migmatized basic rock; 6, alkaline rocks; 7, granitoid rocks; 8 contaminated granitoid rocks; 9, porphyritic rocks (porphyries; granophyres).

The biotite-quartz-syenites occur on the Irişoru Brook. They are almost similar to the previous rocks, from which differ by the melanocratic mineral, which is a brown-greenish biotite and by the variable texture, there occurring nests of fine granulation or pegmatoid textures. Besides biotite, in these rocks occur quartz, albite, perthitic potash feldspar and accessories. The chemical analysis of this rock (Table 2) indicates an alkali granite, the CIPW norm of which shows the following relationships between the feldspar rations: ab > or > an. In these rocks quartz reaches up to 10 %. On the diagram in Figure 6 the Bârzava granitoid rocks plot mostly within the granodiorite field.

The hybrid granitoid rock group includes rocks contaminated with basic materials from the metabasalts, from which they included numerous xenoliths. Such rocks occur on the marginal zone of the main granitoid intrusion. They are more rich in melanocratic minerals than the normal granitoid rocks. These rocks consist of quartz, feldspar, biotite and accessories. The melanocratic mineral reaches up to 18 %.

The dyke rock group related to the Bârzava pluton complex contains micropegmatites with the following varieties: hornblende-biotite-micrpegmatites and biotite-micropegmatites. There occur also aplites, granophyres, and luxulianites. Among this group the luxulianites are the most spectacular rocks. They are grey up to black rocks which consist of quartz, plagioclse, turmaline up to more than 20 %, pistacite and accessory minerals like sphene, apatite, iron oxides as well. Often, turmaline makes rosettes. Other dyke rocks from this group are spherulitic porphyries, syenitic porphyries, micrgranitic porphyries and quartz porphyries. On the diagram in Figure 9 the two dyke rocks plot in the Low-K and the Medium-K calc-alkaline rock fields.

REGIONAL-CONTACT AND CONTACT METAMORPHISM

The effects of the regional-contact metamorphism have been observed (Savu, 1965) along the northern contacts of the Bârzava pluton complex, on the Irişoru and Crivaciu Brooks. This metamorphism manifested itself at the same time with the regional metamorphism, under the conditions of the greenschist facies and stress. But, at the temperature which controled the regional metamorphism, there was added the temperature of the pluton intrusions. Thus there resulted biotite contact schists.

Since these rocks occurred under stress conditions, they present an evident foliation. There have been affected both the pelitic and the basic metamorphic rocks in which the following mineral assemblages occurred:

1. quartz-albite-epidote-muscovite-biotite, in the pelitic rocks;
2. quartz-albite-biotite, in the quartzitic rocks;
3. albite-epidote-(actinolite)-biotite ± quartz, in the metabasaltic rocks.

The contact metamorphism *stricto sensu* manifested itself after the stress conditions had ceased, so that there resulted biotite hornfelses especially at the contact of the Highis granitoid complex with the country rocks represented either by the metabaslts or by the pelitic schists (see Giuşcă, 1962; Savu, 1965). These biotite hornfelses occurred under the PT conditions of the epidote-biotit facies of the contact metamorphism.

It is noteworthy mentioning that in 1963, I found out on the Cladova Valley from the Highiş Mountains a garnet skarn. It was formed at the contact of a granite dyke with a limestone layer from the Cuvin Formation. This rock occurred at a little higher temperature than that which controled the biotite hornfelses genesis.

AUTOMETAMORPHISM AND METASOMATISM PROCESSES

The residual magmatic solutions determined phenomena of autometamorphism and metasomatism in the plutonic rocks and in the host crystalline schists from the both regions. Due to the autometamorphism processes the minerals from the plutonic rocks were transformed into secondary minerals.

In the granitoid rocks the plagioclase was albitized or substituted by an association of albite, sericite eventually epidote. The potash feldspar was substituted by fine-twinned albite and sericite. The green hornblende from the quartz-syenites passed into a brown-green biotite or a green biotite, the last being substituted by chlorite.

But the most spectacular autometamorphism processes manifested themselves in the Bârzava alkaline rocks (see Savu, 1965). Under the influence of the Na-rich magmatic solutions minerals like clinopyroxene and hornblende have been transformed into secondary minerals. Na-rich minerals like aegirine and arfvedsonite also reacted with these solutions and were substituted by other Na-rich minerals. As for instance, the following general reaction-series took place in the syenodioritic rocks: augite – aegirine-augite – aegirine – arfvedsonite. So rich in Na were these magmatic solutions that, even around the magnetite crystals, an aureola of fine acicular aegirine crystals occurred by reaction.

The metasomatism processes manifested themselves in both the Highiş and Bârzava pluton complexes. These processes can by separated into two types: the boron metasomatism and the soda metasomatism.

In the Bârzava plutonic complex phenomena of boron metasomatism occurred on the Cigher Brook. There intrusions of diorite and syenodiorite and the surounding crystalline schists have been impregnated with turmaline crystals (see Savu, 1965, Pl. III, Fig. 2). It is interesting that the turmaline crystals show a zoned structure. In the Highiş pluton complex I observed the effects of the boron metasomatism in the crystalline schists situated along the southwestern contact of the granite intrusion, east of Păuliş.

The soda metasomatism manifested itself through all the plutonic intrusions of Bârzava and Highiş plutonic complexes, where it affected not only the initial magmatic minerals, as shown above, but the crystalline schists around the plutonic complexes as well. As for instance, such a phenomenon occurred in the crystalline schists situated between the two branches of the Bârzava pluton complex (Fig. 1). There the soda metasomatism activity resulted in the occurrence of rocks with migmatic aspect, represented by regional-contact schists with ocular and lenticular albite metasomatic depositin (see Savu, 1965, Fig. 76). The neosome consists of albite, pistacite, biotite, rarely allanite, apatite, magnetite, hematite and calcite.

VARISCAN AND ALPINE TECTONICS OF THE HIGHIŞ-DROCEA MOUNTAINS

In the genesis of the Highiş-Drocea Mountains tectonics there are to be distinguished two main stages: the syn-metamorphic Variscan stage and the Alpine stage.

During the Variscan period the related syn-metamorphic tectonics manifested itself concomitantly with the Variscan metamorphism of the Păiuşeni series and of the Cuvin Formation. It determined the eastwest anticlinorium of the mountain chain. On the southern flank of this anticlinorium there was formed the parasite Bârzava hemianticline, in which the Bârzava magmatic complex was inscribed.

The only clear effects of the Alpine tectonics in the Highiş-Drocea Mountains resulted in the occurrence of three eastwest reverse faults, the *vergenz* of which was northnorthwest (Fig. 1), which determined little thrust phenomena. Thus, along the northern margin of the Păiuşeni series crystalline schists the Şiria – Agrişu Mare – Tauţ reverse fault occurred, which is facing the Zarand Basin. It thrust over the Permo-Carboniferous formations described by Istocescu (1971), situated along the southern margin of the Zarand Basin (Fig. 1). Along the median zone of the Highiş-Drocea Mountains there occurs the Cuvin-Nadaş reverse fault. Along this fault the Highiş plutone complex thrust a little over thr Cuvin Formation. The thrusting granitoids underwent shear processes along the reverse fault plane, deformations that have been remarked by Giuşcă since 1962. Along the southern margin of the Highiş-Drocea Mountains the Milova – Bârzava reverse fault occurred. Along this reverse fault the Halta Nadaş crystalline series thrust over the Upper Cretaceous deposits transgresively setting on the Păiuşeni series (Savu, 1988). This fault represnts the terminal extension of the Groşi thrust described by Papiu (1953) in the Drocea Mountains area.

CONCLUSIONS

The Păiuşeni series resulted from a pile of Sillurian – Lower Carboniferous formations deposited within an epicontinental sea. This pile of pre-metamorphic formations consisted of conglomerates, sandstones, siltstones and layers of within plate basalt tuffs. Over the Păiuşeni sries the Permo-Carboniferous Cuvin Formation resulted from pelitic black deposits.The Highiş-Drocea basic rocks form two separate spots of within plate metabasalts and rarely metagabbros. Within the Highiş metabasic rocks there occur wehrlite blocks of plume-source origin.

The evident cotrast between the Highiş and Bârzava magmatic complexes consists in what concerns the petrographic characters of the pluton complexes. Thus, in the Highiş pluton complex the rocks are represented mostly by granitoids, trondhjemitic and shoshonitic granites being associated with, while in the Bârzava pluton complex the component rocks are represented mostly by syenitic (monzonitic) rocks.

Like the wehrlite rocks, the Highiş within plate granitoids, the Bârzava syenites as well, are of plume-source origin.

The real Alpine tectonics of the Highiş-Drocea Mountains consists of some eastwest reverse faults, the *vegenz* of which is northnorthwest. It excludes the idea of a regional shear process, by which the Păiuşeni series would have resulted.

The origin of the contrasting characters of the Highiş and Bârzava twin pluton complexes was dependent on the partial melting degree of the plume source in the two hotspots, which was different.

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