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PETROLOGY OF PĂULIŞ GRANITES (APUSENI MTS., ROMANIA)

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ABSTRACT

This paper presents new data of the highly evolved part of the Highiş Granitoid Suite. Two types of texture represent the suite: equigranular, medium-grained leucogranites and aplite veins. Main rock forming minerals are quartz, orthoclase, microcline, plagioclase feldspar, biotite and muscovite. Based on geochemical investigations which were performed on both selected mineral phases and whole rock composition the Highiş Granitoids from Păuliş are S-type, felsic-peraluminous alkali granites, with alkali-calcic character, formed in post-collisional (post-orogenic) tectonical setting, mainly from metasedimentary source.

Keywords: Păuliş granites, S-type granitoids, Variscan granitoids, Biharia Nappe System, Highiş Mts., Apuseni Mts., Romania.

INTRODUCTION

The studied rocks are highly evolved Variscan granites from Highiş Mountains which are located in the south-western part of the Apuseni Mts., Romania (Fig. 1A).

The Apuseni Mts. are built up by two major tectono-stratigraphic units, the Tisia Mega-Unit and the Dacia Mega-Unit; these structures were formed during Alpine tectonic events. Their basement is formed of pre-alpine metamorphites and igneous suites from earlier tectonic events, including Variscan granitoids.

Detailed studies on these Variscan granitoids were performed by many authors (Giuşcă 1979, Tatu 1998, Pană 1998); however, their correlations with other variscides have not been well clarified.

Two granitic intrusions can be distinguished within the Highiş Mts.: the Şiria Granitoids in the north-western part and the Highiş Granitoids in the southern part of the massif. There are significant differences between the two intrusions. The Şiria Granitoids are the part of the Codru Nappe System, component of the Tisia Mega-Unit in contrast with the Highiş Granitoids which are the part of the Biharia Nappe System, recently considered to be the part of the Dacia Mega-Unit (Fig. 1B). The studied rocks originate from the countryside of Păuliş, Highiş Granitoid Suite, therefore we use the term Păuliş Granitoids for them.

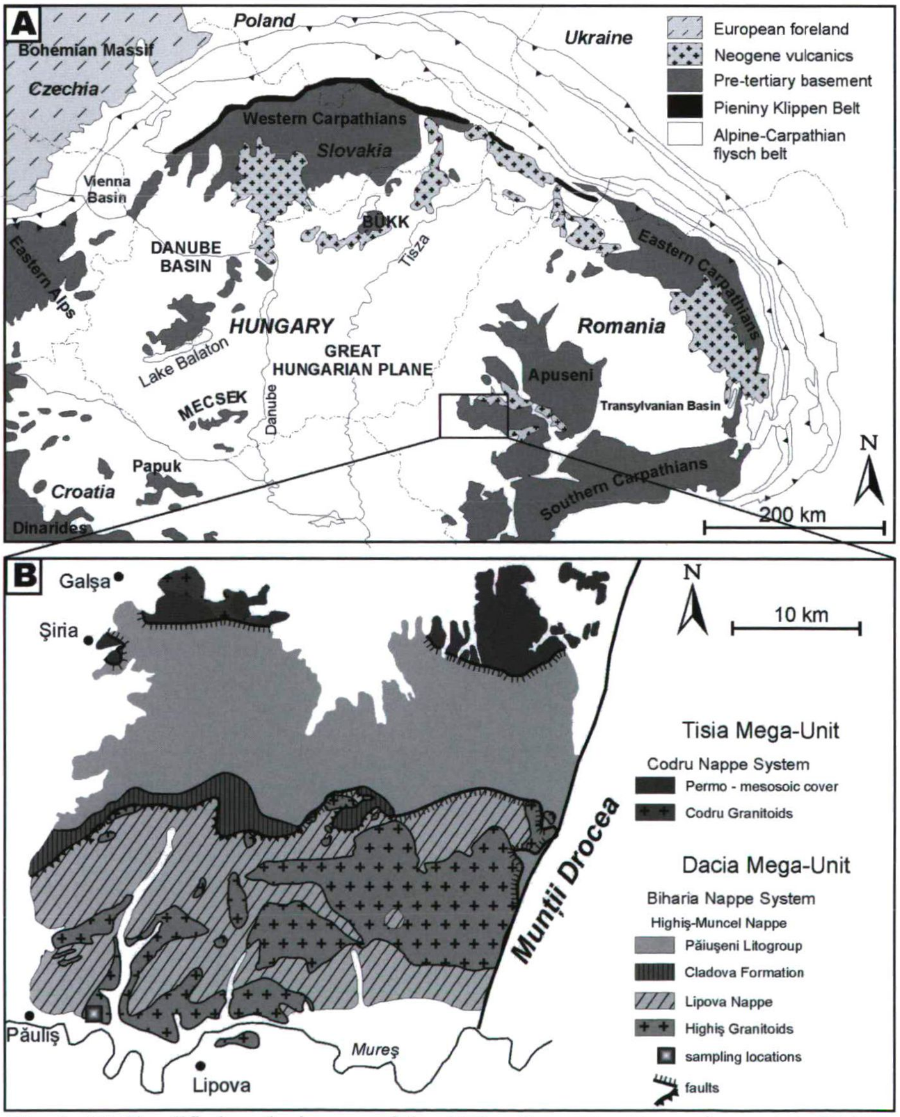

Fig. 1. (A) Simplified geologic map of the Alpine-Carpathian-Pannonian region ***(B)*** Pre-Neogene geology of the Highiş Mts. after Balintoni (1986) and Balintoni and Puşte (2002).

Geological Setting and Location

The Highiş Mts. are located in the W-SW part of the Apuseni Mts., Romania. Previous researches of the geological structure of Highiş Mts. were made by Lóczy (1883), Rozlozsnik (1913), Paucă (1941), Giuşcă (1948, 1962, 1979), Giuşcă et al. (1964), Dimitrescu (1962, 1967, 1988), Savu (1965), Balintoni (1986, 1994), Tatu (1998), Pană (1998), Balintoni, Puşte (2002).

In the northern part of Highiş Mts. the crystalline basement is formed by the Tisia Mega-Unit while the center and southern regions are formed by the Dacia Mega-Unit considered as Biharia Nappe System (Schmid et al. 2008). These mega-units are represented in the Highiş Mts. by alpine nappes belonging to Biharia Nappe System (Dacia Mega-Unit) and Codru Nappe System (Tisia Mega-Unit) (Fig. 1B). The Biharia Nappe System shows a two stage poly-metamorphic history within Dacia Mega-Unit, beginning in the Middle to Late Jurasic and finishing in the Early Cretaceous. The final emplacement of both of the nappe systems occurred in Cretaceous (Turonian), during the pre-Gosau tectogenesis but with strikes of opposite direction. The Codru Nappe System is in lower position than the Biharia Nappe System. Both of the nappe systems are positioned in the Biharia Unit (Săndulescu 1984), and both of them contain granitoids of variscan age (Pană 1998).

The granitoids of the Biharia Nappe System, located in the Highiş Mts., are emplaced in the Highiş-Muncel Nappe, in contact with the Cladova Formation, part of the Păiuşeni Litho-group, which is overthrusted by the Lipova Nappe. The Cladova Formation is formed by sandstones, argillites, basic tuffs and basalts, and it is metamorphosed at the contact of the Highiş granitoids. In their contact zones hornfelses do appear. Highiş granitoids are Variscan, postcinematic granites, containing aplitic and pegmatitic veins (Giuşcă 1979). Giuşcă et al. (1964) estimated a 350 Ma age of the Highiş Granitoid Complex by K/Ar (WR) method. Nevertheless, Pană (1998) determined a 264-267 Ma age from zircon fractions by the more reliable U/Pb method, and explained the formation of Highiş granitoids by a short lasting magmatism at the end of the early Permian.

Sampling and Analytical Methods

The studied 28 rock samples were collected from Păuliş (Fig. 1B). During the research 82 mineral chemical analyses were made at Department of Mineralogy and Petrology, University of Graz. Measurements were performed at a 15 kV acceleration voltage and 10 nA current. Spectra were evaluated with Oxford-Isis software. Geochemical analyses were performed on 10 samples at the University of Stockholm with inductively coupled plasma atomic emission spectroscopy (ICP-AES) and inductively coupled plasma mass spectrometry ICP-MS methods. Processing of raw data was made by MinPet 2.0, Mica+1.0 and GCDkit 2.7.0 softwares.

Petrography

On the basis of modal analyses, rocks from Păuliş are alkali granites to syenogranites with moderate mica content (1-3 vol. %) (Le Maitre 1989, not shown). The granitoids have a pinkish, sometimes greyish colour. Their texture is phenocrystalline, equigranular and medium-grained (Pál-Molnár et al. 2004). Light grey coloured aplitic veins are also present cutting the whole mass of the rock in various directions.

Weakly foliation can be observed on some samples, but mostly the phyllosilicates are oriented along fractures. The average size of the main mineral constituents is similar, both quartz and feldspar grain sizes falls between 1-4 mm. The only exception is biotite which is appearing in 2-4 cm clots.

Mineralogy and Mineral Chemistry

Mineral chemical analyses were performed on feldspar, biotite and muscovite. Representative compositions are shown in Table 1 and 2.

Quartz: xenomorphic, mean grain size is between 2-4 mm. It has always undulating extinction and it is frequently recrystallized, which leads to the decrease of grain size and the development of subgrains forming fine grained mosaics.

Orthoclase: hypidiomorphic with tabular habit, mean grain size is 4-5 mm. Carlsbad twins are common, they occasionally have perthitic structure.

Microcline: hypidiomorphic, rarely xenomorphic, 3-4 mm grains, tabular habit and polysynthetic twinning is characteristic.

The analyzed K-feldspars have $Or_{93,70-97,77}Ab_{2,23-6,30}An_0$ composition (Table 1.).

Plagioclase feldspars: hypidiomorphic, tabular, often zoned, mean grain size is 3-5 mm, polysynthetic, albite twins are common. The plagioclase feldspars are albites with anorthit composition between 0,30-1,65wt% (Table 1). The distribution of feldspars according to Or-Ab-An can be seen in Fig. 2.

Biotite group

The representative chemical compositions of the minerals of the biotite group are presented in Table 2. Hypidiomorphic tabular or xenomorphic grains are characteristic, mean grain sizes are 1-3 mm. Their pleochroism is light brown to dark green. In intergrown with muscovite they often contain opaque minerals, apatite and zircon. Along microtectonical deformations they have a slight orientation. Biotites frequently compose clots of 2-4 cm.

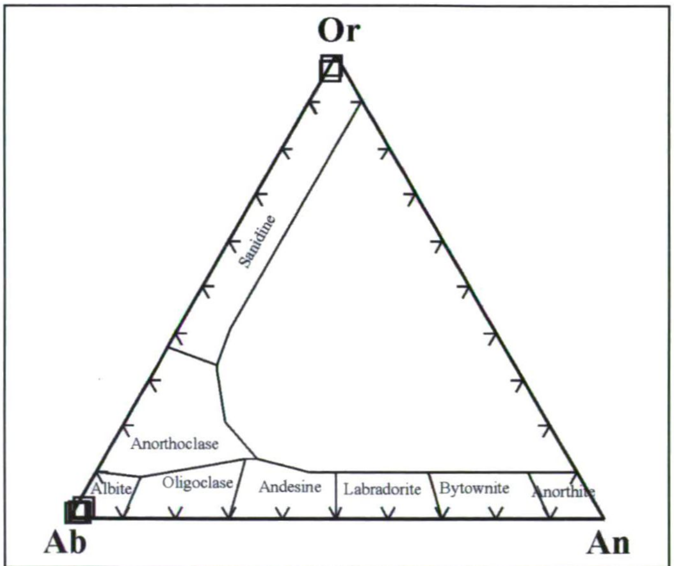

Fig. 2. Feldspar compositions plotted in the Ab-Or-An diagram.

Table 1. Representative chemical composition of the feldspars.

	Plagioclase feldspars											K-feldspars					
	7260/18	7260/22	7260/23	7262 /1	7262/5	7262/10	7262 /11	7264 /1	7264/3	7264 /5	7264 /7	7260 /1	7260/2	7260/17	7260 /21	7264 /2	7264 /11
Na_2O	10.44	10.77	10.87	10.96	10.38	10.75	9.54	10.66	10.98	10.41	10.70	0.33	0.55	0.70	0.31	0.30	0.26
MgO	0.05	0.00	0.01	0.06	0.29	0.00	0.22	0.20	0.19	0.09	0.00	0.10	0.22	0.23	0.00	0.16	0.00
Al_2O_3	19.90	19.64	19.84	18.68	19.44	19.00	19.21	19.68	19.97	19.66	19.36	17.87	18.00	17.60	17.64	17.92	18.39
SiO_2	70.49	70.62	71.02	66.57	69.60	68.88	69.89	70.57	69.87	70.76	71.05	64.15	63.99	63.7	65.17	64.74	64.57
K_2O	0.08	0.09	0.07	0.07	0.04	0.06	0.85	0.11	0.10	0.06	0.08	16.21	16.17	15.81	16.23	16.63	16.63
CaO	0.32	0.14	0.19	0.06	0.06	0.07	0.08	0.32	0.46	0.13	0.23	0.00	0.00	0.00	0.00	0.02	0.00
TiO_2	0.02	0.00	0.05	0.02	0.01	0.02	0.00	0.01	0.00	0.04	0.04	0.06	0.02	0.07	0.00	0.01	0.00
MnO	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.02	0.00	0.07	0.04	0.02	0.06	0.01	0.11	0.11
FeO	0.13	0.11	0.07	0.02	0.09	0.00	0.02	0.16	0.06	0.05	0.00	0.06	0.05	0.01	0.10	0.00	0.02
$\sum$oxide	101.43	101.38	102.12	96.45	99.91	98.86	99.82	101.72	101.65	101.21	101.52	98.82	99.02	98.18	99.47	99.89	99.98
Na	0.87	0.90	0.90	0.96	0.87	0.92	0.81	0.89	0.92	0.87	0.89	0.03	0.05	0.06	0.03	0.03	0.02
Mg	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.00	0.01	0.00
Al	1.01	0.99	1.00	0.99	1.00	0.99	0.99	0.99	1.01	1.00	0.98	1.00	0.99	0.98	0.97	0.97	0.99
Si	3.02	3.03	3.03	3.01	3.02	3.03	3.05	3.02	3.01	3.04	3.05	3.00	2.99	3.00	3.04	3.01	3.02
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.97	0.96	0.95	0.96	0.98	0.97
Ca	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
$\sum$cation	4.91	4.93	4.94	4.96	4.91	4.94	4.86	4.94	4.98	4.93	4.93	5.01	5.01	5.01	5.00	5.00	5.00
Or	0.43	0.54	0.41	0.41	0.18	0.30	5.51	0.66	0.52	0.31	0.42	97.01	95.09	93.7	97.18	97.30	97.77
Ab	97.92	98.81	98.69	99.29	99.51	99.39	94.11	97.77	97.23	99.06	98.96	2.99	4.91	6.30	2.82	2.66	2.23
An	1.65	0.65	0.90	0.30	0.31	0.30	0.37	1.57	2.25	0.63	0.61	0.00	0.00	0.00	0.00	0.04	0.00

Table 2. Representative chemical composition of the micas.

	Biotite					Muscovite											
	7260 /3	7260 /10	7260/13	7260 /19	7264 /8	7260/8	7260/9	7260/15	7260/16	7260/20	7262/4	7262/8	7262/9	7262/12	7262/13	7264/4	7264/10
Na_2O	0.24	0.05	0.7	0.05	0.16	0.30	0.45	0.83	0.69	0.16	0.15	0.20	0.09	0.12	0.12	0.14	0.11
MgO	5.29	5.43	4.38	5.27	4.72	1.87	1.81	2.10	1.85	1.71	2.98	3.35	3.35	2.67	3.39	1.29	1.85
Al_2O_3	13.63	13.42	12.74	14.12	13.77	28.04	25.59	25.61	25.32	27.31	25.48	27.41	28.62	29.76	27.46	28.53	26.73
SiO_2	34.38	34.88	34.79	35.87	37.62	49.55	45.41	47.13	47.29	48.40	45.77	50.52	50.29	48.00	50.11	48.70	48.54
K_2O	9.38	9.29	3.06	9.58	6.50	9.33	9.19	10.17	8.86	9.76	8.66	8.68	9.38	7.87	9.41	9.37	9.50
CaO	0.00	0.02	0.33	0.06	0.25	0.07	0.00	0.00	0.04	0.00	0.07	0.07	0.00	0.80	0.06	0.05	0.00
TiO_2	1.47	1.51	0.15	1.52	0.04	0.30	0.46	0.40	0.39	0.44	0.24	0.28	0.33	0.26	0.24	0.34	0.37
MnO	0.48	0.40	0.43	0.46	0.37	0.05	0.05	0.00	0.00	0.06	0.00	0.00	0.08	0.00	0.01	0.05	0.07
FeO	27.34	26.49	27.95	27.28	26.03	7.48	7.24	6.89	6.95	6.95	2.46	2.73	2.94	3.00	2.79	6.70	7.44
∑oxide	92.21	91.49	84.53	94.22	89.46	96.99	90.20	93.13	91.39	94.78	85.81	93.24	95.09	92.48	93.58	95.17	94.62
Na	0.08	0.01	0.24	0.02	0.05	0.08	0.13	0.23	0.19	0.04	0.04	0.05	0.02	0.03	0.03	0.04	0.03
Mg	1.31	1.34	1.14	1.27	1.16	0.37	0.39	0.44	0.39	0.35	0.66	0.67	0.66	0.54	0.68	0.26	0.38
Al	2.66	2.62	2.63	2.69	2.68	4.42	4.37	4.25	4.24	4.42	4.43	4.36	4.50	4.78	4.37	4.56	4.33
Si	5.70	5.79	6.09	5.79	6.21	6.62	6.58	6.64	6.72	6.65	6.75	6.82	6.70	6.54	6.77	6.61	6.67
Cl	0.05	0.05	0.08	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
K	1.98	1.96	0.68	1.97	1.37	1.59	1.70	1.83	1.61	1.71	1.63	1.49	1.59	1.37	1.62	1.62	1.67
Ca	0.00	0.00	0.06	0.01	0.04	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.12	0.01	0.01	0.00
Ti	0.18	0.19	0.02	0.18	0.01	0.03	0.05	0.04	0.04	0.05	0.03	0.03	0.03	0.03	0.02	0.03	0.04
Mn	0.07	0.06	0.06	0.06	0.05	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01
Fe	3.79	3.67	4.10	3.68	3.59	0.84	0.88	0.81	0.83	0.80	0.30	0.31	0.33	0.34	0.32	0.76	0.85
O	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
∑cation	15.82	15.69	15.1	15.72	15.16	13.98	14.11	14.24	14.03	14.03	13.84	13.75	13.84	13.75	13.83	13.90	13.98
mg#	26	27	22	26	24												
Al(IV)	2.29	2.20	1.91	2.21	1.79												
Al(VI)	0.38	0.43	0.73	0.48	0.89												

According to Foster (1960) the sum of cations in X position and in Y position of biotites is between 1,60 – 2,20 (mean: 1,91) and above 5,00 (mean: 5,15), respectively. The average TiO_2 content of biotites is 0,90%. The Mg content of biotites is low (mg#=21,8-26,8; mean mg#=24,8), and they are replaced by phlogopites along fractures: mg#= 67,8-69,5 (mean mg#=68,7). Based on compositional classifications and the IMA nomenclature, biotites are Magnesian-siderophyllites (Fe-biotites; Foster 1960) and Ferroan-phlogopites, respectively (Fig.3A).

According to the Mg vs. Al_{tot} distribution of biotites (Nachit et al. 1985), the Păuliş granitoids are of subalkaline character (Fig. 3B).

The high Mg content of the phlogopites signs postgenetic transformations, which is supported as well by the fact that phlogopites occur only along fractures, they are often weathered, and appear in combination with muscovite. Textural orientation is also characteristic.

Muscovite: hypidiomorphic tabular and elongated lamellar, the mean grain size is 1–3 mm. It appears often along with biotite, and at some places it is oriented. Small sized muscovite grains are frequent in the fractures of the rock. The studied rocks contain ferrum-rich muscovites, the FeO content of Păuliş Granites varies between 2,46% and 7,48%, with significant magnesium content (1,29%–3,35%). The representative chemical compositions of muscovites are shown in Table 2.

Accessory minerals are apatite, monazite and zircon

Apatite crystals usually have an idiomorphic, partly hypidiomorphic shape, and often appear in biotite crystals. Zircon crystals are idiomorphic, rarely hypidiomorphic, and represent two types of habit. The one is squattish, reddish-brown, and yellowish-brown; the other one is colorless, pinkish with an elongated columnar appearance. Opaque inclusions are quite frequent; numerous grains are zoned, which refers to several crystallization phases.

GEOCHEMISTRY

Representative geochemical compositions are shown in Table 3. Păuliş syenogranites have high silica content, between 70.95 and 72.30 wt% (mean value 71.60), aplites are even more saturated in SiO_2, with mean 75.44 wt% of SiO_2. Their alkaline content is also high, K_2O content is higher (4.42-49.0 wt%, mean 4.56 wt%) than Na_2O (3.25-3.68 wt%, mean 3.48 wt%), K_2O/Na_2O ratio ranges from 1.26 to 1.49.

Modified alkali lime index (MALI) shows alkali-calcic character (Frost et. al 2001) (Fig. 4E). Low concentrations of CaO (0.40 to 0.55 wt%) and MgO (0.26 to 0.30 wt%) along with low TiO_2 (Ti mineral phase is absent) and Sr (which is coordinated by basic plagioclase feldspar phase) concentrations suggest a highly fractionated rock. $Fe_2O_3/(Fe_2O_3+MgO)$ ratio is relatively high, 0.81. According to Chappel and White (2001) on the basis of CaO and Fe_2O_3 content, the studied rocks are S-type granitoids (Fig. 4A). Based on the R1-R2 multicationic distribution diagram (De La Roche et al. 1980) Păuliş granitoids are alkali granites [R1=4Si-11(Na+K)-2(Fe+Ti) and R2=6Ca+2Mg+Al] (Fig. 4D).

Based on their saturation in alumina, the studied rocks are slighty peraluminous, mean A/CNK value is 1.07. This feature is also supported by the presence of modal muscovite, and CIPW normative corundum (Shand 1943) (Fig. 4B). For further subdivision within peraluminous group *A* [Al - (K + Na + 2 Ca)] *vs.* *B* [Fe + Mg + Ti] distribution diagram has been chosen (Villaseca et al. 1998). The studied rocks have felsic-peraluminous character (Fig. 4C).

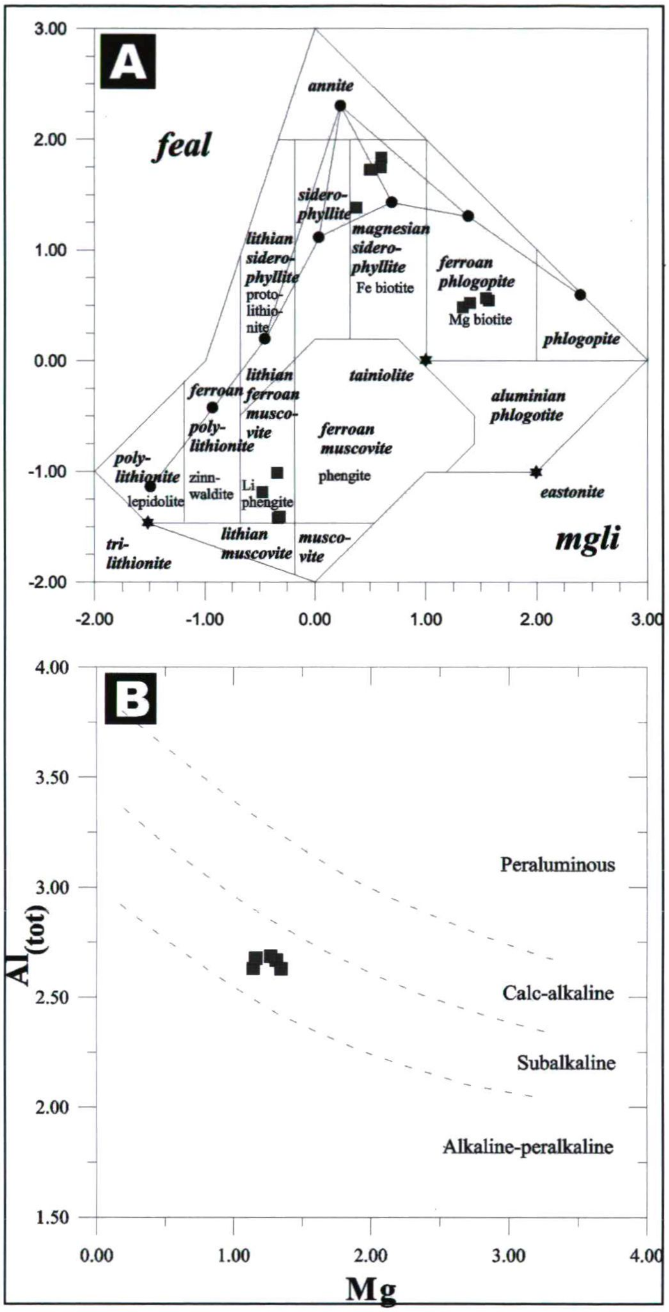

Fig. 3. ***(A)*** Compositional classification of the biotites after Tischendorf et al. (1997). ***(B)*** Mg vs. Al_{tot} plot after Nachit et al. (1985).

The MORB-normalized (Pearce 1983) trace element patterns show that Păuliş granites are enriched in LILE, mostly in Rb, K, Ba with the exception of Sr which is strongly depleted, and are slightly enriched in HFS elements (Zr, Hf, Nb) (Fig. 5B).

The chondrite-normalized (Nakamura 1974) REE concentrations of most granites and aplites show smooth patterns. The studied aplites are less enriched in LREE than

Table 3. Representative whole rock chemical composition.

	SiO_2	Al_2O_3	Fe_2O_3*	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	Total	Ba	Be	Ce	Co	Cr	Cu	Dy	Er	Eu	Ga
7259	71.66	11.87	1.27	0.02	0.26	0.47	3.57	4.49	0.18	93.80	316.46	3.15	61.78	2.72	6.35	18.52	6.57	4.82	0.38	<42.83
7260	71.40	11.85	1.16	0.01	0.26	0.45	3.44	4.47	0.17	93.20	313.02	3.15	55.44	2.11	4.68	18.46	6.21	4.76	0.41	<42.83
7261	71.15	12.50	1.17	0.02	0.27	0.43	3.30	4.42	0.17	93.44	306.37	3.13	55.80	2.11	5.38	17.82	6.16	4.73	0.43	<42.83
7263	72.12	12.09	1.32	0.02	0.30	0.49	3.66	4.90	0.21	95.11	321.06	3.15	61.98	2.78	6.69	19.12	6.58	4.91	0.38	<42.83
7264	72.30	12.57	1.28	0.02	0.31	0.55	3.68	4.64	0.18	95.52	326.37	3.15	65.95	3.24	7.03	16.83	6.98	4.95	0.35	<42.83
7265	70.95	12.68	1.19	0.02	0.28	0.40	3.25	4.42	0.17	93.36	302.48	3.13	55.87	2.09	5.90	17.53	5.97	4.69	0.43	<42.83
7269	75.20	11.95	0.49	0.00	0.19	0.10	3.51	4.90	0.08	96.41	225.40	2.34	38.96	3.52	3.65	20.63	5.48	4.14	<0.07	<42.83
7270	75.68	12.03	0.42	0.01	0.17	0.11	3.43	5.10	0.06	97.01	216.55	2.29	39.37	3.67	3.48	22.18	5.13	4.07	<0.07	<42.83

	Gd	Hf	La	Lu	Mn	Mo	Nb	Nd	Ni	Pb	Rb	S	Sc	Sm	Sr	V	Y	Yb	Zn	Zr
7259	7.81	4.84	30.24	0.79	80.36	6.77	5.58	20.03	4.68	122.83	400.76	55.78	3.33	7.45	23.59	7.42	42.00	3.57	32.13	148.91
7260	7.33	3.76	30.53	0.78	76.61	2.61	5.42	19.97	3.20	118.56	398.58	37.28	3.21	7.45	23.34	7.36	36.70	3.50	33.44	143.18
7261	7.27	4.13	29.68	0.77	74.70	3.04	5.41	18.86	3.12	116.76	379.16	37.45	3.24	7.25	23.26	7.51	34.90	3.48	33.71	139.81
7263	8.00	6.59	29.95	0.81	92.47	7.82	6.08	20.32	5.38	126.84	405.32	60.89	3.38	7.86	26.75	7.63	42.34	3.86	30.90	161.73
7264	8.46	6.51	33.69	0.86	100.17	8.91	6.43	23.42	6.64	129.82	413.98	67.36	3.58	8.33	28.98	8.57	40.94	3.90	31.48	171.66
7265	7.18	4.25	28.34	0.77	70.64	3.67	5.21	18.67	3.03	115.67	359.54	39.73	3.26	7.24	23.11	7.52	34.30	3.34	33.83	137.61
7269	5.30	6.95	16.11	0.74	22.22	10.57	9.64	10.24	81.56	48.86	305.53	35.75	1.55	6.16	11.12	3.46	30.89	3.50	11.11	118.13
7270	5.41	7.24	17.33	0.73	15.67	11.95	9.45	10.35	92.63	42.62	288.32	35.75	1.24	6.02	13.67	3.64	31.68	3.54	9.08	102.28

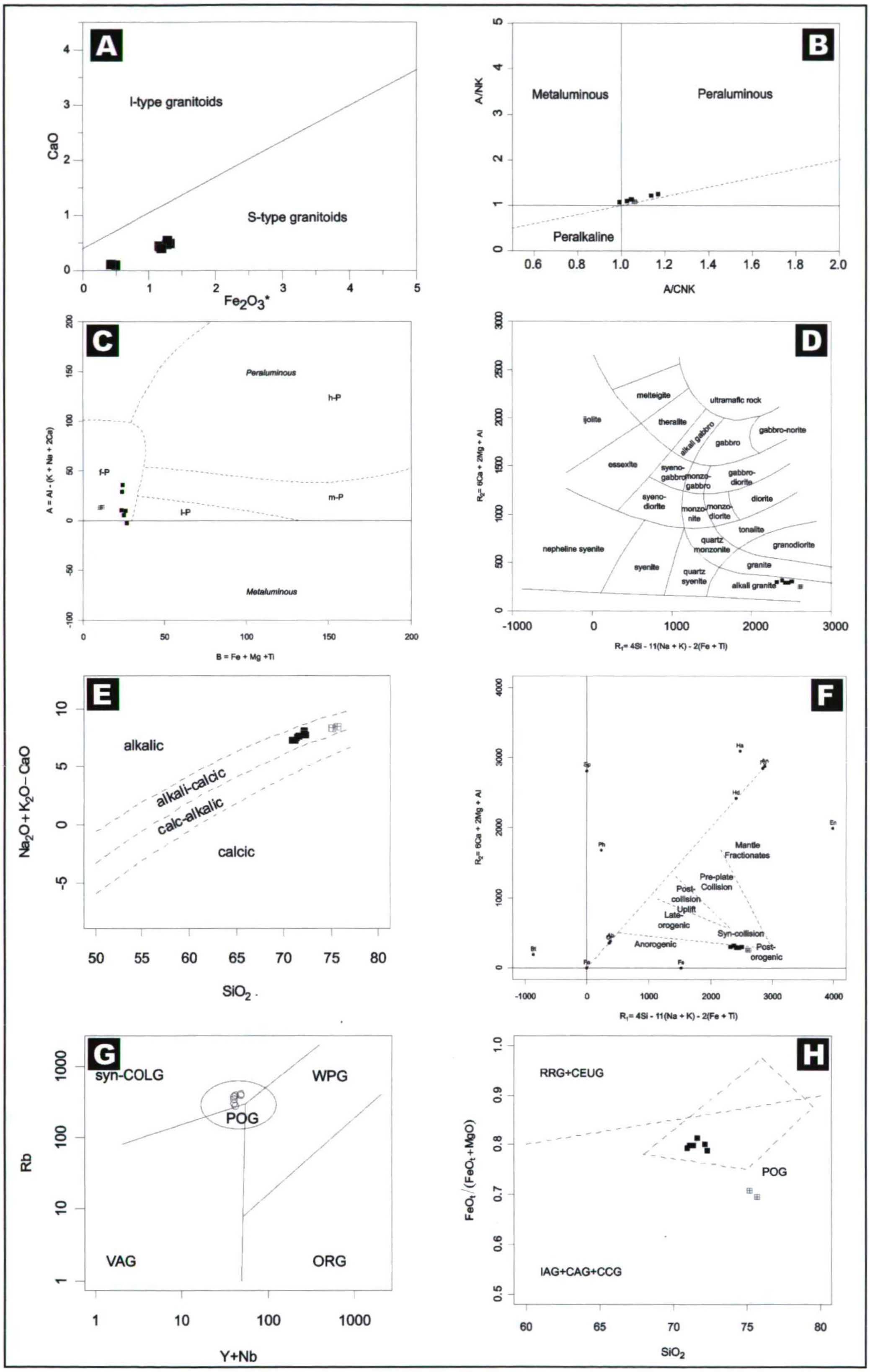

Fig. 4. (A) CaO vs. Fe_2O_3 diagram (Chappell and White, 2001) discriminating I-type (Igneous) and S-type (Sedimentary) source. ***(B)*** A/CNK vs. A/NK diagram of Shand (1943) discriminating metaluminous, peraluminous and peralkaline compositions. ***(C)*** BA plot modified by Villaseca et al. (1998) (f-P; h-P; m-P; l-P; – felsic-; high-; medium-; and low-peralumious granitoids). ***(D)*** Granite classification diagram based on R1 vs. R2 distribution plot after De la Roche et al. (1980). ***(E)*** Modified Alkali-Lime Index (MALI) (Frost et al., 2001). ***(F)*** Tectonic discrimination diagram based on R1 vs. R2 after Batchelor, Bowden (1985). ***(G)*** Tectonic discrimination diagram based on Y+Nb vs. Rb (Pearce, 1996). ***(H)*** Tectonic discrimination diagram based on $FeO^t/(FeO^t/MgO)$ vs. SiO_2 (Maniar, Piccoli, 1989).

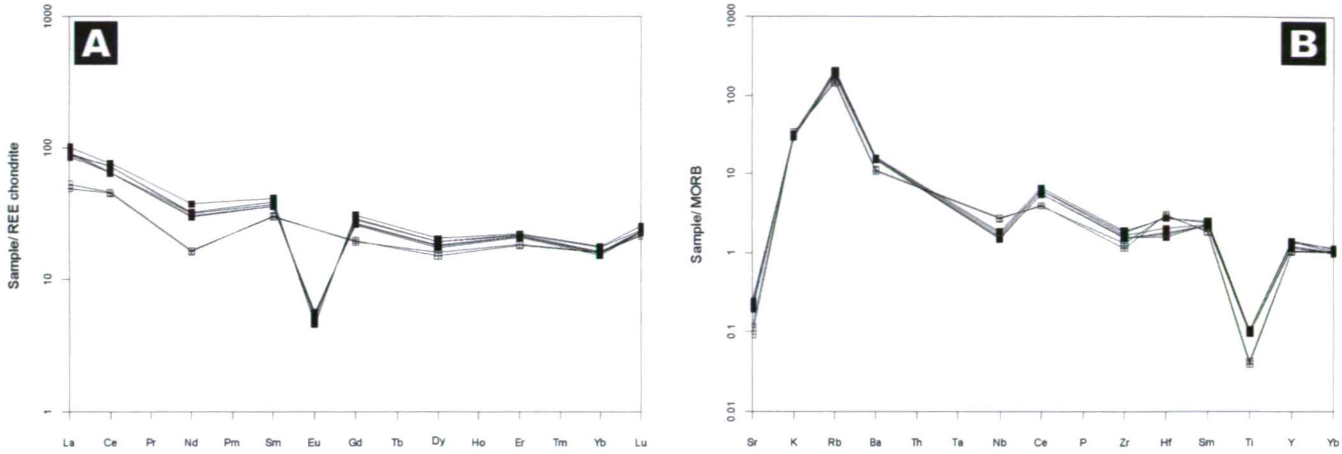

Fig. 5. ***(A)*** Chondrite-normalized REE pattern (Nakamura, 1974). ***(B)*** MORB-normalized trace element pattern (Pearce, 1983).

the granites. The granites have very strong negative Eu anomaly (mean value of Eu/Eu* is 0.16), while the Eu content of the aplites is below the detection limit (Fig. 5A). The low CaO/Na_2O and medium Al_2O_3/TiO_2 ratios in the studied granites (excluding aplites), (mean CaO/Na_2O is 0,13; mean Al_2O_3/TiO_2 is 68,59) are typical for peraluminous variscan granitic suites (Sylvester 1998). Low values of CaO/Na_2O ratio suggest pelitic origin of the granites, and medium values of Al_2O_3/TiO_2 ratio suggest medium to high temperatures (~875-900 ^{0}C) of the melts. Rb/Sr vs. Rb/Ba distribution also confirms the pelitic source (Sylvester 1998).

Based on the distributions of SiO_2 vs. $FeO^t/(FeO^t+MgO)$ (Maniar and Piccoli 1989) (Fig. 4H), Rb vs. Y+Nb (Pearce 1996) (Fig. 4G), and R1 vs. R2 (Batchelor and Bowden 1985) (Fig. 4F) multiple discrimination diagrams Păuliş granites were formed in post-orogenic tectonic setting.

CONCLUSIONS

Păuliş Granites except aplites are holocrystalline, equigranular and medium-grained. In some samples textural orientation can be observed, but it is unusual regarding the whole studied suite.

The main rock forming minerals are: quartz, orthoclase, microcline, plagioclase feldspar (albite), biotite and muscovite. Apatite, monazite and zircon occur as accessory minerals. Păuliş Granites are leucogranites with very high silica and relatively high alkali content. Based on the concentration of major elements the studied rocks are alkali granites. According to their alumina saturation, Păuliş Granites are felsic peraluminous granites. Muscovite which is a typical mineral phase for slightly peraluminous granites is present in the studied rocks as a significant component. The composition of biotites indicates subalkali character of the granites, while whole rock compositions plotting in the modified alkali lime index (MALI) show alkali-calcic character. Păuliş Granites are highly evolved S-type granites (Chappell and White 2001). Due to crystal fractionation, their CaO and Sr^{2+} content is very low, plagioclase feldspars are albites. First generation of biotites is ferric type as well. Păuliş granites are enriched in Rb, K and Ba. The chondrite-normalized (Nakamura 1974) Rare earth elements show smooth pattern, with very strong Eu anomaly. These characteristics of granites are well known from late Variscan suites (Sylvester 1998) where due to the relatively thin lithosphere the main source of heat is provided from the asthenosphere. The source of the highly evolved Păuliş Granites is proposed mainly pelitic. Previous authors assigned mixed source for the whole suite which contains rock types from alkali granites to more basic type of igneous rocks. According to Tatu (1998) it is confirmed that Păuliş Granites were formed in post-orogenic tectonic setting in a late Variscan tectogenetic stage, following the main collision event.

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