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PETROLOGICAL CHARACTERISTICS OF ALGYŐ-FERENCSZÁLLÁS-MAKÓ AREA GRANITOIDS (SE HUNGARY)

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ABSTRACT

Boreholes located in the axis zone of the uplifted Algyő High (Csongrád Unit, Békésia Terrane, Tisia Composite Terrane, Pannonian Basin) reached granitoid rocks in the Variscan crystalline basement at a depth of 2250-2550 m. On the basis of their textures, these granitoids can be classified in the following two groups: granites of medium-grained, inequigranular, hypidiomorphic-granular texture and meta-granitoid rocks of medium-grained, inequigranular texture with preferred orientation. However, concerning the mineral composition and the texture of the rocks, significant differences cannot be recorded, they are of similar character. The main rock forming minerals of the studied samples are: quartz + microcline ± orthoclase + plagioclase feldspar + biotite + muscovite. Accessory components are apatite, zircone and garnet. Based on their modal composition, the rocks are syenogranites. According to their major element geochemistry, they are granite sensu stricto (syenogranite), subalkaline rocks with a peraluminous character. Concerning their tectonic origin the studied rocks are orogenous, syn-collisional, continental collisional granites (CCG). The samples generally display an S-type character with respect to their mineralogy and major element composition.

Key words: granite, geochemistry, crystalline basement, Csongrád Unit, Tisia Composite Terrane, Hungary

INTRODUCTION

The Pre-Alpine crystalline basement of SE Hungary, namely the Tisia Composite Terrane can be divided into three large structural units: the Slavonia-Dravia Terrane; the Kunságia Terrane [earlier "Central Hungarian Autochthon" (Szederkényi, 1984; Szederkényi et al., 1991), then "Paraautochthon Terrane" (Kovács et al., 1996/97;, Szederkényi, 1996]; and the Békésia Terrane [earlier "South Hungarian Nappe Zone" (Szederkényi, 1984; Szederkényi et al., 1991)] (Fig. 1). The Békésia Terrane can be divided further into: Kelebia Unit, Csongrád Unit, Battonya Unit and Sarkadkeresztúr Unit. The crystalline rocks of these units are of Variscan age, and covered by a 2500-6500 m thick Miocene-Pliocene sedimentary complex. Thus, the direct analysis of these rocks is only possible with the help of borehole samples. Although, it is not reinforced, based on the events affecting the Variscan Europe, the occurrence of a Pre-Variscan event on the Hungarian part of the Tisia Composite Terrane is still highly possible. The proven Pre-Mesozoic deformation and metamorphic processes in the Tisia Composite Terrane can only be related to Variscan events. The rocks of the Tisia Composite Terrane during the climax of the Variscan tectogenesis went under a medium pressure and temperature (Barow-type) metamorphosis (Kovács et al. 1996/97, 2000; Szederkényi, 1996). At the same time palingenetic granite belts were formed in the axis zones of the synclinoria. Later, these rocks were affected by a low pressure - high temperature event as well (Kovács et al., 2000).

This paper presents the results of the petrographical and major element geochemical analyses performed on the available granitoid and metagranitoid borehole samples that are originating from the Algyő High uplift (Csongrád Unit, Békésia Terrane) from a depth of approximately 2500-3000 m (Fig. 2B).

GEOLOGICAL SETTING AND LOCATION

The research area is located in the Csongrád Unit (earlier Tisza Complex) (Szederkényi, 1984, 1996), that is a part of the Békésia Terrane (the Pre-Alpine basement of the Alpine Békés-Codru zone) (Fig. 1). The morphology of the Csongrád Unit is dominated by the Algyő High (Fig. 2A-B).

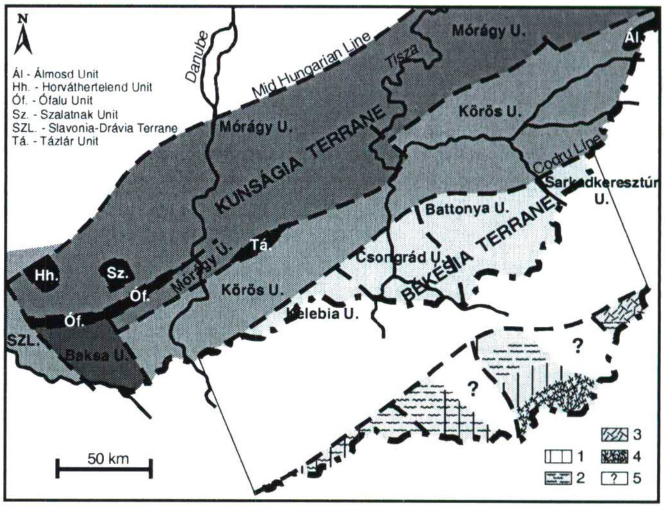

Fig. 1. Pre-Tertiary regional geology of the Tisia Composite Terrane (SE part of the Pannonian Basin); Békésia Terrane highlighted (modified after Kovács et al., 2000).
Legend: 1. Alpine overstep sequence connected to the northern shelf of the Axios/Vardar and related Neotethyan oceanic basins; 2. Variscan medium-grade metamorphosed complex; 3. Migmatic complex; 4. Granitoids; 5. Unknown.

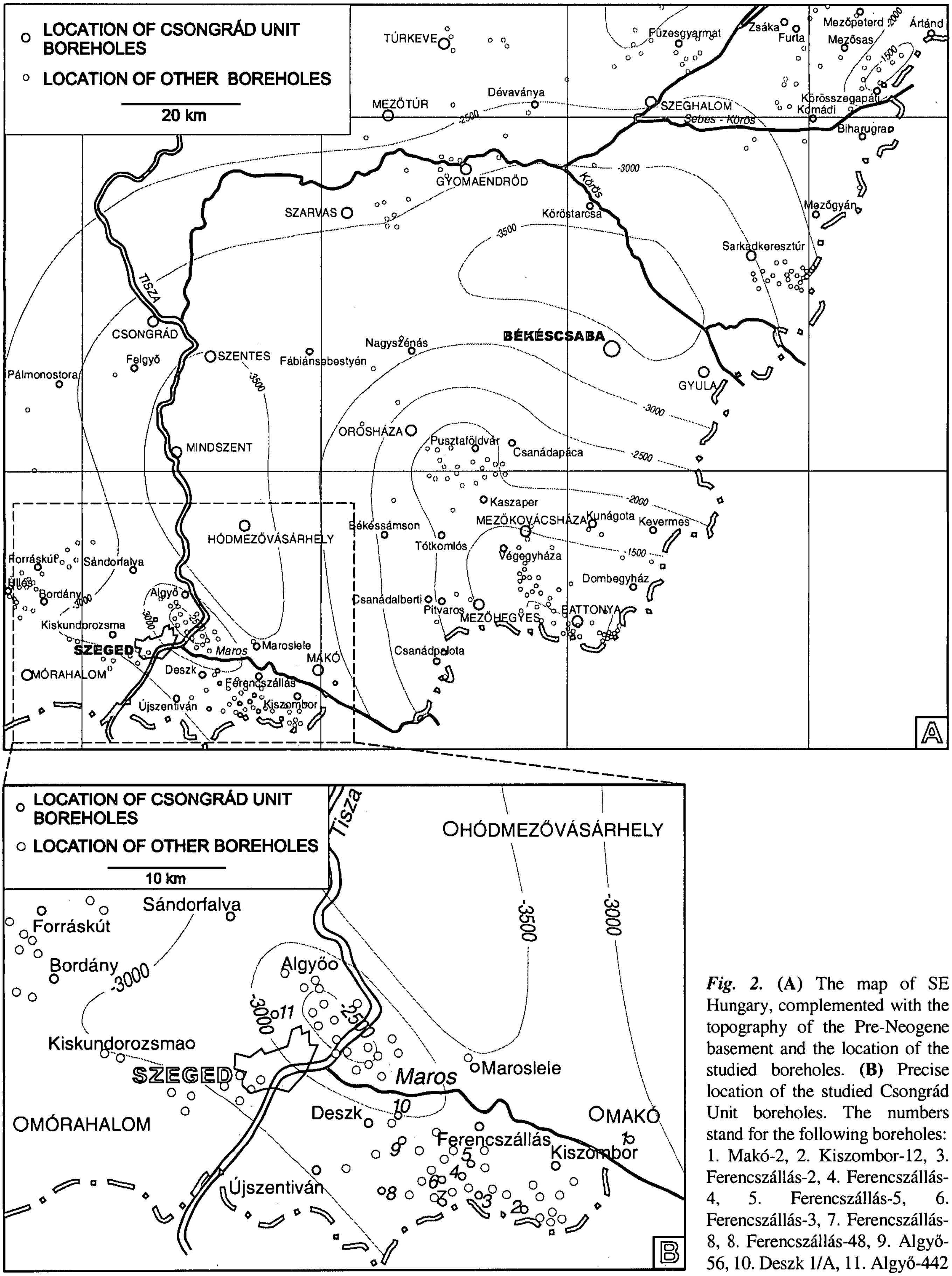

Fig. 2. (**A**) The map of SE Hungary, complemented with the topography of the Pre-Neogene basement and the location of the studied boreholes. (**B**) Precise location of the studied Csongrád Unit boreholes. The numbers stand for the following boreholes: 1. Makó-2, 2. Kiszombor-12, 3. Ferencszállás-2, 4. Ferencszállás-4, 5. Ferencszállás-5, 6. Ferencszállás-3, 7. Ferencszállás-8, 8. Ferencszállás-48, 9. Algyő-56, 10. Deszk 1/A, 11. Algyő-442

The Algyő High is interpreted after Tari et al. (1999) – based on the low-angle normal fault contact separating high-grade metamorphites from unmetamorphosed Mesozoic carbonates; the presence of mylonites; the characteristically retrogade metamorphism within the lower plate (Fülöp, 1994); and fission-track dating – as a subsurface Middle Miocene (Alpine) metamorphic core complex. [The Alpine development of the Tisia Composite Terrane started with the multi stage oceanisation of the Mesozoic Thetys. The first stage of compression can be put to the end of the Lower Cretaceous (Austrian Phase), while the last stage fell to the appearance and formation of the Pannonian Basin (Neogene-Quaternary).]

The borders of the Csongrád Unit are: the northern front of the South Hungarian Nappe Belt in the north, the Ásotthalom-Bordány Depression in the west, the so called Makói Trench in the east, and towards the south it stretches to the Vajdaság, where its border is formed by the northern front of the Biharia Nappe System (Kemeneci et al., 1997). According to Szederkényi (1984), the main phase of the unit's polimetamorphism was a 350-330 Ma Barrow type event with a temperature of 500-570 °C and a pressure of 6-8 Kb. This was followed by a Variscan late kinematic, T = 590-620 °C, P= 2,8-3,9 Kb event 330-270 Ma ago, which resulted in the formation of andalusite in higher grade schists, and the development of small size granite bodies in the migmatite zone, that were significantly homogenised due to a certain upward compression (Deszk, Ferencszállás). This second phase was accompanied by a stronger shear along the cleavage planes, and the formation of blastomilonite in lower grade crystalline schists.

SAMPLING AND ANALYTICAL METHODS

The studied samples were obtained from Csongrád Unit boreholes. The rocks were taken from the rock collection of the Department of Mineralogy, Geochemistry and Petrology, University of Szeged. The samples are drill cores, that were brought to the surface uncontinuously during core sampling, therefore the number and quantity of the samples is limited. The Kiszombor-12, Ferencszállás-3, 4, 5, 8, 48, Deszk 1/A, Algyő-56, 442 boreholes were deepened in the axis zone of the Algyő High, that has a NW-SE stretch, while the Makó-2 borehole originates from the NE wing of the dome (Fig. 3).

The major element analyses were made with an atomic emission spectrometer (ICP-AES) at the University of Stockholm.

MINERALOGICAL AND GEOCHEMICAL CHARACTERISTICS OF THE STUDIED GRANITOID ROCKS

Macroscopic description

The colour of the studied samples is mainly light grey, subordinately pale rose-colour. Their texture is mostly holocrystalline, medium-grained inequigranular and equigranular. Based on the situation of mica, in some places the studied rocks are characterised by a preferred orientation in their texture. The major rock forming minerals are quartz, potassium feldspar, plagioclase feldspar and mica (biotite, muscovite).

Textural features of the studied granite samples

During the microscopic analyses both the modal proportion and the most important textural characteristics were examined in terms of the main rock forming, accessory and secondary minerals. On the basis of their textures, the studied rocks can be classified in the following two groups:

a. rocks of medium-grained, inequigranular, hypidiomorphic-granular texture (Fig. 4A),

b. meta-granitoid rocks of medium-grained, inequigranular texture with preferred orientation (Fig. 4B).

Concerning the mineral composition and the texture of the rocks, significant differences cannot be recorded. On the basis of their composition, the rocks can be considered of similar character. The main rock forming minerals of the studied samples are: quartz + microcline ± orthoclase + plagioclase feldspar + biotite + muscovite.

The textural character of the main mineral components are as follows:

quartz: xenomorphous grains of 1-2 mm average size. As a result of tectonic deformation it is always of undulating absence (Fig. 4C) and it is frequently recrystallised (Fig. 4B), what lead to the decrease of grain size and the development of subgrains. It appears both in microcline and plagioclase feldspars as a rounded grain. Rarely, it forms myrmekite in plagioclase feldspars.

orthoclase: hypidiomorphous, tabular appearance (Fig. 4C) with an average 1-3 mm size. Bifold twinning is common, in some places it is perthitic. It is subordinate compared to microcline.

microcline: a component of hypidiomorphous, xenomorphous, perthitic, tabular character. Its average size is 1-4 mm. Poikiloblastic appearance is common, it contains quartz, plagioclase feldspar, mica and zircon minerals (Fig. 4A). Sometimes, round-shape quartz grains appear in it.

plagioclase feldspar: hypidiomorphous, tabular, often zoned (Figs. 4A, 4C). Its average size is 1-3 mm. Many times it is highly sericitised, moreover, it occurs sometimes that only its sericitic pseudomorph can be found in the rock. Sometimes, there are carbonatised cores in the zoned crystals. Similarly to microcline, it also contains round-shape quartz grains and zircon in the form of inclusions. Due to the deformation it is characterised by bent twin lamellae. It is common in gneiss.

biotite: hypidiomorphous, 0,5-1 mm in average. Its pleochlorism is brownish yellow – greenish. Due to the transformation, often only its pseudomorph, built up of chlorite, opaque minerals and/or rutile needles can be detected (Fig. 4C). It occurs as a secondary component in plagioclase feldspar, in microcline as an inclusion, too. It contains apatite and zircon inclusions. In some places in mica-rich zones it has a preferred orientation. It may turn into muscovite, as well. In textures of preferred orientation it developed after biotite, by intersecting the foliation, marked by the later.

muscovite: hypidiomorphous grains of an average 0,5-1,5 mm size; it can form kink bands (Figs. 4B, 4D). Often it occurs in intercrescense of biotite, in some cases it grows through the biotite.

Accessory components are apatite, zircone and garnet (Fig. 4D). These can be found in any of the rock forming minerals.

The studied rocks went under certain transformational processes too, such as chloritisation, sericitisation, carbonatisation.

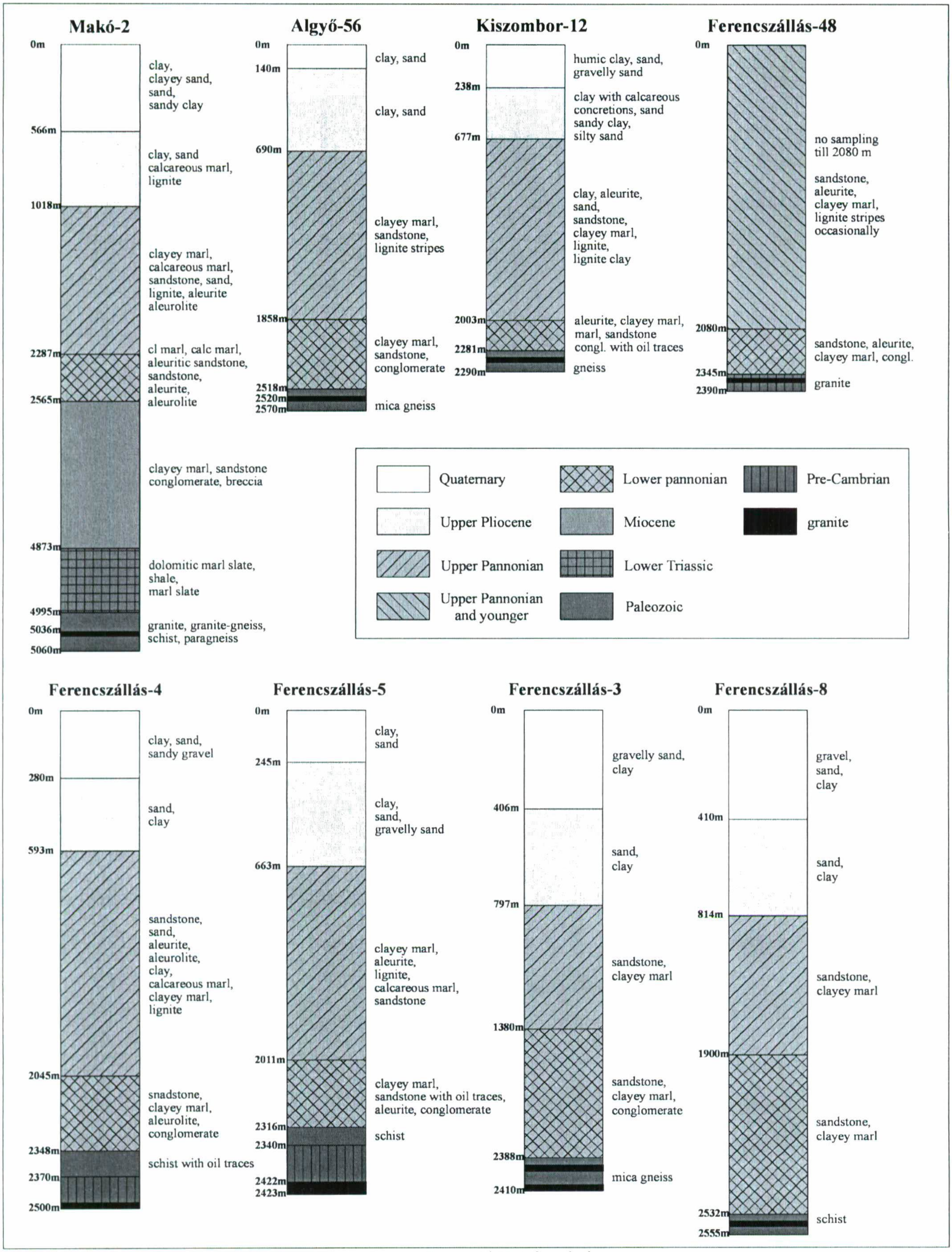

Fig. 3. The stratigraphical columns of the most relevant Csongrád Unit boreholes.

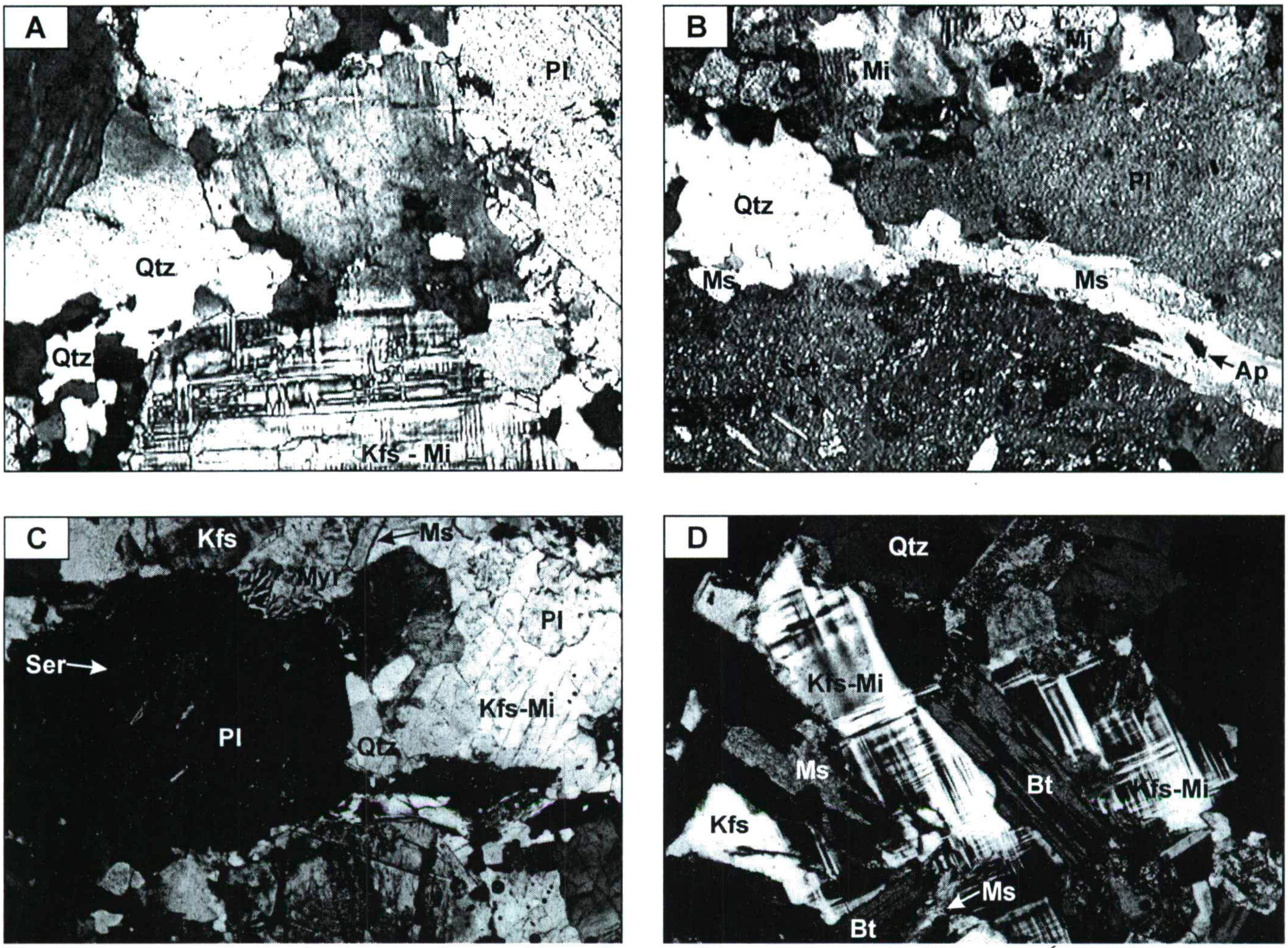

Fig. 4. Photomicrographs showing the mineral composition and texture of the studied granitoids. (**A**) sample ÁGK-1782 (Algyő-442), syenogranite (+N, x50); (**B**) sample ÁGK-1659 (Ferencszállás-8), syenogranite (+N, x50); (**C**) sample ÁGK-1782 (Algyő-442), syenogranite (+N, x50); (**D**) sample ÁGK-1241 (Deszk 1/A), syenogranite (+N, x100). Abbreviations: Ap – apatite, Bt – biotite, Chl – chlorite, Kfs – K-feldspar, Mi – microcline, Mnz – monazite, Ms – muscovite, Pl – plagioclase, Qtz – quartz, Ser – sericite.

Table 1. Representative major element data for the Algyő-Ferencszállás-Makó area granites

Sample	Ferencsz.-5 ÁGK-1657	Ferencsz.-8 ÁGK-1659	Makó-2 ÁGK-1209	Ferencsz.-3 ÁGK-1214	Kiszom.-12 ÁGK-1219	Deszk-1/A ÁGK-1241
SiO_2	75.7	75	68.3	72.3	84	73
TiO_2	0.176	0.103	0.378	0.143	0.294	0.206
Al_2O_3	14.9	14.14	14.91	13.81	8.6	14.92
$Fe_2O_3^*$	1.391	0.995	2.821	1.39	1.483	1.643
MnO	0.029	0.013	0.028	0.026	0.013	0.02
MgO	0.316	0.31	1.441	0.389	0.461	0.449
CaO	0.608	0.617	0.886	0.825	0.134	0.735
Na_2O	3.07	3.297	2.387	3.176	1.703	3.158
K_2O	5.56	4.676	4.801	4.494	2.582	5.06
P_2O_5	0.176	0.231	0.36	0.239	0.047	0.295

(*given as total iron content)

Concerning their modal composition (450 points/sample were counted) the rocks plot to the syenogranite field in the Q-A-P diagram of Le Maitre et al. (1989) (the field is not shown).

Some representative results of the major element analyses are listed in Table 1.

The granites are fractioned from a moderate to high extent. The SiO_2 content varies between 68.3 and 84.00 wt% (mean value: 74.71 wt%). The alkali content is high: K_2O is between 2.58 and 5.56 wt% (mean value: 4.51 wt%), Na_2O is between 1.70 and 3.29 wt% (mean value: 2.79 wt%). The K_2O/Na_2O-ratios range between 1.41 and 2.01. Calcium and magnesium contents are low; 0.13-0.88 wt% CaO and 0.31-1.44 wt% MgO. The iron content is 0.99-2.82 wt% $Fe_2O_3^*$ (total Fe). The $Fe_2O_3^*/(Fe_2O_3^*+MgO)$ ratio varies between 0.66 and 0.81.

Based on the chemical analyses, the studied samples represent granites in the alkalis *vs*. silica diagram [Cox et al. (1979) adapted by Wilson (1989)] (Fig. 5). When applying the geochemical system of De la Roche et al. (1980) the rocks prove to be syenogranites (Fig. 6). This is in absolute correspondence with the modal Q-A-P classification.The granites are subalkaline (Fig. 5), calc-alkaline (after Irvine et al., 1971 – not shown). Considering the distribution of molar ratios $Al_2O_3/(Na_2O+K_2O)$ (A/NK) *vs.* molar ratios $Al_2O_3/(CaO+ Na_2O+K_2O)$ (A/CNK) (Shand's index, modified by Maniar et al., 1989) the granites are of peraluminous character (Fig. 7).

The chemical characteristics of granitoid rocks from different tectonic environments can be summarised in the following classes (1) island arc granitoids (IAG); (2) continental arc granitoids (CAG); (3) continental collision granitoids (CCG); (4) post-orogenic granitoids (POG); (5) rift-related granitoids (RRG); (6) continental epirogenic uplift granitoids (CEUG); (7) oceanic plagiogranites (OP) (Maniar et al., 1989). After discriminating OP from the rest of the granitoid classes (Maniar et al., 1989) (Fig. 8A), and considering the richness of the studied rocks in potassium feldspars it is obvious that the samples are not OP. The discrimination between the IAG+CAG+CCG group and the RRG+CEUG group can be seen on the MgO *vs*. $Fe_2O_3^*$ (total Fe) and the CaO *vs*. $Fe_2O_3^*$ +MgO diagrams (Fig. 8A-B) (Maniar et al., 1989). Hence, the studied samples are orogenic granitoids, i.e. plot to the IAG+CAG+CCG group. The discrimination of CCG from IAG+CAG can be made on the basis of the A/CNK molar ratio (Fig. 7), the Na_2O/CaO wt% ratio, the Na_2O/K_2O wt% ratio, the $MgO/Fe_2O_3^*$ wt% ratio and the MgO/MnO wt% ratio. The value of the A/CNK ratio in the samples is higher than 1.05 (A/CNK = 1.19-1.47); the mean value of Na_2O/CaO = 5.74; the mean value of Na_2O/K_2O = 0.59; the mean value of $MgO/Fe_2O_3^*$ = 0.3; the mean value of MgO/MnO = 34.25. In the end, this means that the studied rocks are CCG (Maniar et al., 1989) granitods, what is reinforced by the biotite, muscovite ± garnet mineral composition, as well.

When considering Batchelor, Bowden's (1985) R1 vs. R2 system (Fig. 9), that gives a good estimation on the tectonic environments during granitoid formation, the analysed granitoids turn to be of Syn-Collisional type.

The ASI $[Al_2O_3/(CaO+K_2O+Na_2O)]$ value of the samples is > 1.15, the CIPW norm yields > 1% corundum (mean value: 3.4 %), and the samples are characterised by a relatively low Na/K ratio. These are characteristics of S-type granites(Zen,1988).

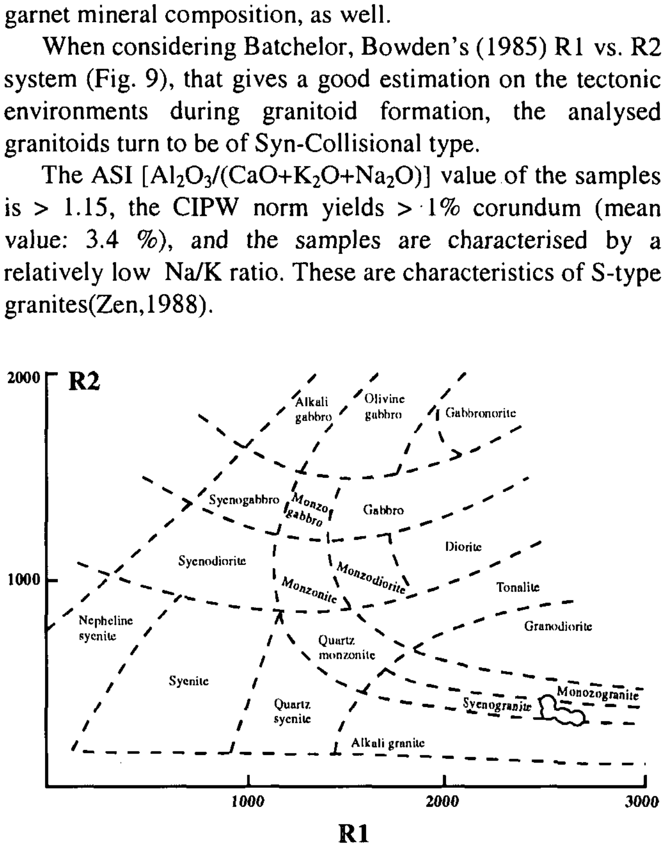

Fig. 6. Geochemical classification of plutonic rocks using parameters R1 and R2 (after De la Roche et al., 1980), calculated from milication proportions. R1 = 4Si-11(Na+K)-2(Fe+Ti); R2 = 6Ca+2Mg+Al

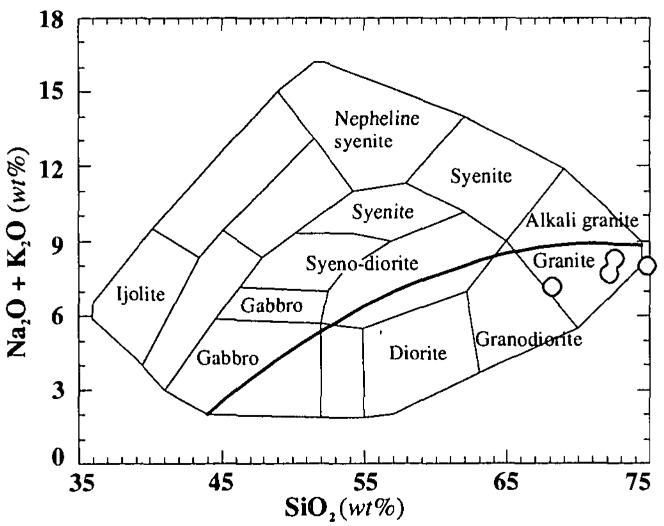

Fig. 5. The chemical classification and nomenclature of plutonic rocks using the total alkalis versus silica (TAS) diagram of Cox et al. (1979) adapted by Wilson (1989) for plutonic rocks. The curved solid line subdivides the alkali from subalkali rocks

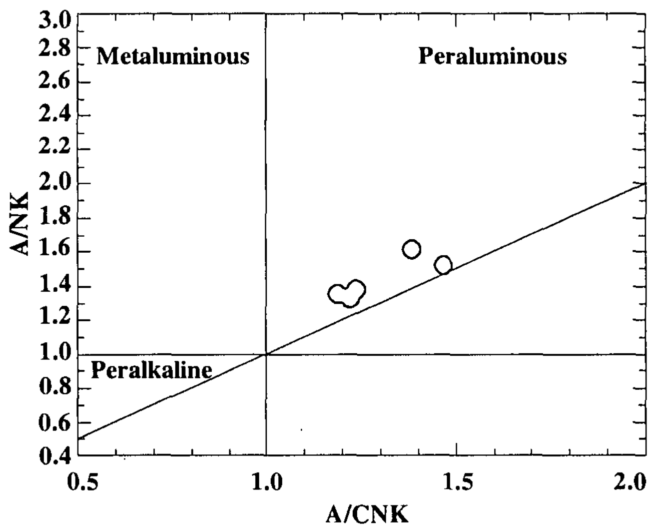

Fig. 7. Plots of molar ratios $Al_2O_3/(Na_2O+K_2O)$ (A/NK) *vs.* molar ratios $Al_2O_3/(CaO+Na_2O+K_2O)$ (A/CNK) (Maniar, et al., 1989).

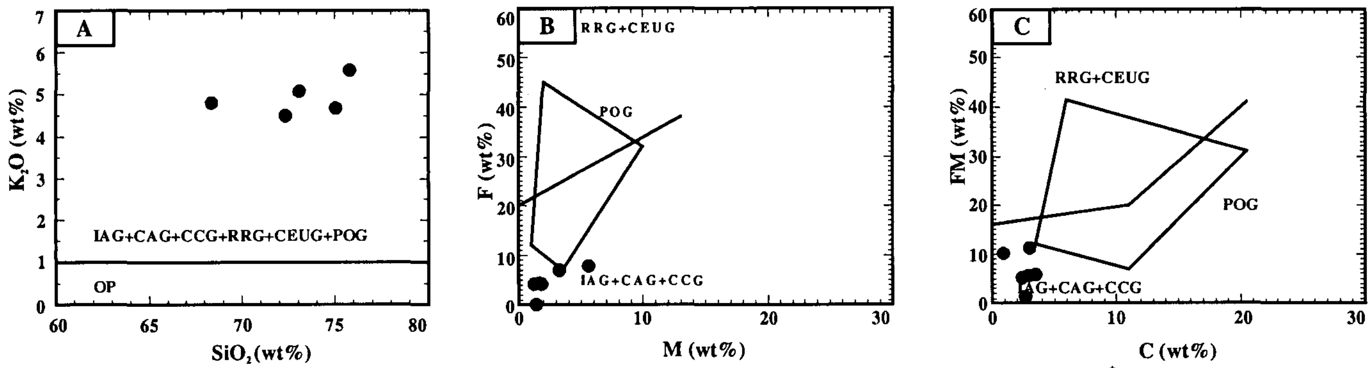

Fig. 8. A selection of diagrams after Maniar et al. (1989). **(A)** SiO_2 *vs.* K_2O; **(B)** MgO (M) *vs.* $Fe_2O_3^*$ (F) (*=total iron); **(C)** CaO vs. ($Fe_2O_3^*$+MgO) (*=total iron).

Abbreviations: IAG = island arc granitoids, CAG = continental arc granitoids, CCG = continental collision granitoids, POG = post-orogenic granitoids, RRG = rift-related granitoids, CEUG = continental epirogenic uplift granitoids, OP = oceanic plagiogranites.

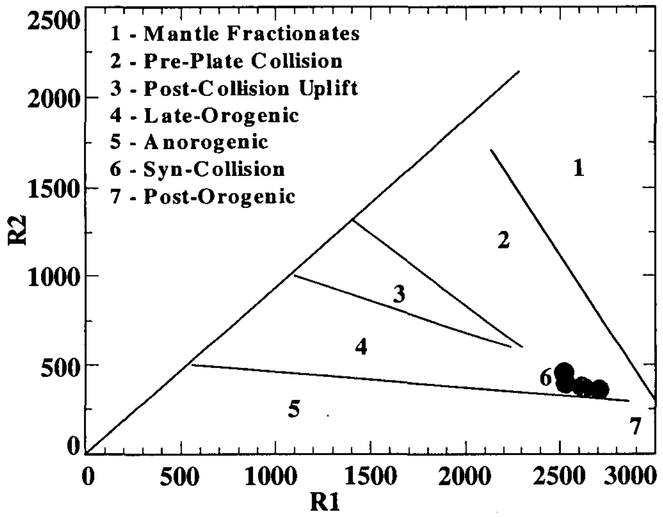

Fig. 9. Tectonical discrimination plots of Batchelor, Bowden (1985). R_1=4Si-11(Na+K)-2(Fe+Ti); R_2=6Ca+2Mg+Al

Conclusions

(1) On the basis of their textures, the studied granites of the Csongrád Unit can be classified in the following two groups:

a. granites of medium-grained, inequigranular, hypidiomorphic-granular texture;

b. meta-granitoid rocks of medium-grained, inequigranular texture with preferred orientation.

Concerning the mineral composition and texture of the rocks, significant differences cannot be recorded. On the basis of their composition, the granites can be considered of similar character. The main rock forming minerals of the studied samples are: quartz + microcline ± orthoclase + plagioclase feldspar + biotite + muscovite. Accessory components are apatite, zircone and garnet. The rocks modal composition refers to that of syenogranites.

(2) According to the major element analyses, the granites of the Csongrád Unit are granite sensu stricto (syenogranite), they are subalkaline with a peraluminous character.

(3) From a tectonical aspect the studied rocks are of orogenous, syn-collisional, continental collisional origin (CCG).

(4) The granites of the Csongrád Unit generally display an S-type character with respect to their mineralogy and major element composition.

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