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GEOCHEMISTRY AND ORIGIN OF THE BATTONYA UNIT GRANITOIDS, SE HUNGARY

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ABSTRACT

Boreholes deepened in the axis zone of the uplifted Pusztaföldvár-Battonya High (Battonya Unit, Békésia Terrane, Tisia Composite Terrane, Pannonian Basin) reached granitoid rocks in the Variscan crystalline basement at a depth of 1000-2000 m. On the basis of trace and rare earth elements geochemistry and zircon morphology investigations, the granitoids of the Pusztaföldvár-Battonya High have a peraluminous, subalkaline, calc-alkaline character. The studied rocks are S-type, and were formed in a syn-collisional (continent-continent collision zone) environment.

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

INTRODUCTION

The Tisia Composite Terrane Alpine megatectonic unit forms the pre-Neogene crystalline basement of South, Southeast Hungary. As an independent unit the Tisia Composite Terrane existed from the Late Cretaceous, when its rotation began, till the Early Miocene. Concerning the territory of Hungary it involves three large Variscan Terranes (Slavonia-Dravia Terrane, Kunságia Terrane and Békésia Terrane), all of which are covered by an Alpine overstep sequence (Kovács et al., 2000). The Békésia Terrane can be divided into four units: Kelebia Unit, Csongrád Unit, Battonya Unit and the Sarkadkeresztúr Unit (Szederkényi, 1984, 1996). The crystalline mass of the Tisia Composite Terrane is characterised by granitoid ranges and anticline wings of middle and high grade metamorphites.

In this paper, we concentrate on the granitoid rocks located in the characteristic uplift of the basement (Pusztaföldvár-Battonya - [PB] High) of the Békésia Terrane (Battonya Unit) – Tisia Composite Terrane (Pál-Molnár et al., 2001) by presenting trace and rare earth elements geochemistry and zircon morphology investigations.

According to Buda (1996), the granitoid rocks have a compound crustal-mantle origin, and formed in a degrading plate boundary environment, therefore, the S-type origin is mixed with a certain degree of I-type granitoid origin. At Battonya-Mezőhegyes the magma of the abyssical plutonic body was slightly compressed upwards due to an "in situ" melting in the late kinematic phase of the Variscan Orogenesis. As a result of this, a slight contact zone developed (Szepesházi, 1969; Szederkényi, 1984; Kovách et al., 1985).

Petrological and main element geochemistry investigations (Pál-Molnár et al., 2001) have shown that the granitoid rocks of the available Battonya Unit boreholes can be considered of similar character on the basis of their composition. The main rock forming minerals of the studied samples are: quartz ± orthoclase + microcline + plagioclase feldspar (albite-oligoclase) ± biotite + muscovite. Accessory components are apatite, zircon, monacite and less frequently titanite. Their modal composition refers to that of syenogranites, monzogranites and granodiorites. On the basis of their major element geochemical composition the studied rocks are subalkaline and calc-alkaline syenogranites, monzogranites and granodiorites with a peraluminous character. From a tectonical aspect the studied rocks are of orogenous, syn-collisional, continental collisional origin (CCG). Most of the characteristics of the Battonya Unit samples indicate that they are S-type granitoids.

SAMPLING AND ANALYTICAL METHODS

The research was based on samples stored in the rock collection of the Department of Mineralogy, Geochemistry and Petrology, University of Szeged. The following boreholes were examined: Battonya-48, 63, 72, Battonya-K-9, 11, 13, 14, 17, 18; Dombegyháza-DNY-2; Kunágota-1, 2; Mezőhegyes-13, 15, 18, 19, 20; Mezőhegyes-K-1. The samples are drill-cores, and both their number and quantity are very limited.

The trace and rare earth element compositions of samples representing the main rock types were determined with an atomic emission spectrometer (ICP-AES) at the University of Stockholm.

Three samples of the examined granitoid rocks [ÁGK-1610-es (Mezőhegyes-19), ÁGK-1318 (Kunágota-1), ÁGK-1816-os (Battonya-48)] were chosen for the separation of zircon crystals on the basis of previous petrological analyses. After the separation process the zircon crystals were examined by SEM.

Table 1. Trace and REE compositions of the examined samples of Battonya Unit.

	ÁGK-1816 Battonya-48 1174-1176 m	ÁGK-1835 Battonya-63 1029-1034 m	ÁGK-1837 Battonya-72 1136-1137 m	ÁGK-1846 Battonya K-9 1058-1060 m	ÁGK-1848 Battonya K-11 1046-1050 m	ÁGK-1849 Battonya K-13 1069-1071 m	ÁGK-1850 Battonya K-14 1075-1077 m	ÁGK-1853 Battonya K-17 1052-1075 m	ÁGK-1854 Battonya K-18 1079-1082 m	ÁGK-1315 Dombegyház DNY-2 1350-1352 m	ÁGK-1317 Kunágota-2 1908-1911 m	ÁGK-1318 Kunágota-1 1797-1804 m	ÁGK-1603 Mezőh.-13 1184,5-1190 m	ÁGK-1605 Mezőh.-15 1194-1198 m	ÁGK-1609 Mezőh.-18 1220-1220,8 m	ÁGK-1610 Mezőh.-19 1180-1182,5 m	ÁGK-1612 Mezőh.-20 1184-1186 m	ÁGK-1613 Mezőh K-1 1328-1330 m
Ba	619,3	450,7	290,3	685,2	405	418,8	613,1	344,9	769,3	301	859,1	279,6	622,6	382,8	568,2	241,7	741,1	404,2
Be	1,63	4,73	5,28	2,42	2,83	3	1,91	2,59	3,22	4,41	3,27	3,94	2,01	2,15	1,07	2,27	0,82	4,02
Co	4,49	2,14	4,12	3,35	4,89	5,15	3,45	2,91	4,13	6,5	8,99	2,61	4,2	8,6	5,24	6,55	4,23	4,52
Cr	5,2	9,6	4,5	7,1	11,8	12,9	7,6	11,1	6,7	118,7	18,6	3,7	7	17,9	4,3	26,2	4,2	4,6
Cu	9,85	18,83	15,03	31,85	33,72	35,64	36,59	18,29	41,03	25,12	23,53	28,51	22,42	23,44	36,39	34,09	14,96	42,19
Ga	18,85	15,21	19,23	18,09	19,73	18,61	18,81	18,16	16,83	19,71	29,13	17,4	14,59	22,37	22,08	20,42	16,32	16,75
Hf	n/a	2,29	n/a	3,39	3,69	3,89	3,21	3,23	2,98	0,51	n/a	2,39	n/a	0,44	4,77	1,28	0,48	3,75
Mo	n/a	2,5	n/a	3,17	2,4	1,64	0,65	0,79	2,21	n/a	n/a	3,69	n/a	n/a	2,74	n/a	n/a	1,27
Nb	5	6	9,8	8,6	12,1	8,9	8,6	8,5	9,2	8,5	8,3	5,4	6,1	8,9	8,2	9,8	3	5,8
Ni	5,09	6	3,16	4,6	7,4	7,1	4,3	5,7	5,2	15,06	13,75	4,3	5,97	9,67	3,9	19,48	4,58	6,1
Pb	23,8	16,7	15,77	17,6	11,3	9,5	195	11,7	20,4	11,54	19,88	39	22,64	10,85	5	19,81	17,02	11,9
Rb	294,5	280,2	417,7	256	219,6	241,4	203,2	211,3	284,6	257,7	402	333	231,8	239	238,5	227,7	318,8	189,5
S	13,71	253,22	33,53	179,69	352,07	348,77	129,69	76,29	194,93	84,78	62,22	62,79	32,21	75,57	327,62	34,44	56,69	88,29
Sc	4,1	2,3	4,39	3,6	4,5	4,5	4,1	3,9	2,9	7,74	7,58	3,4	4,82	8,29	3,5	9,84	4,38	3,1
Sr	132,3	192,2	121,2	277,3	188	204,9	318,4	168,8	269,8	255,1	113,2	109,4	205,6	170,5	266,6	222,6	138,2	218,2
Ta	n/a	1,493	1,869	n/a	0,809	n/a	n/a	n/a	n/a	1,284	n/a	0,416	n/a	n/a	n/a	n/a	n/a	n/a
Tb	n/a	n/a	0,176	n/a	n/a	n/a	n/a	n/a	n/a	0,313	0,443	n/a	n/a	0,616	n/a	0,816	n/a	n/a
V	17,38	12,1	17,1	27,8	34,3	35,3	32,9	29,8	23,7	34,86	49,1	10,9	21,75	62,84	49,9	50,09	16,72	27,8
Y	7,4	8,3	11,1	8,5	11,2	8,9	9,8	8,6	7,7	13,9	6,4	10,3	10,8	9,1	7,1	29,9	9,3	6,8
Zn	42,24	36,58	40,63	48,7	51,88	49,89	51,94	46,34	54,21	56,92	103,72	225,49	41,69	101,3	60	73,49	51,82	44,24
Zr	107,5	69	60,5	115,2	121,4	135	123,8	113,4	110,2	166,7	114,9	53,5	112,2	201,4	182	200,7	164,2	139,1
Ce	42,82	33,44	25,55	57,19	65,61	64,79	66,39	51,27	59,85	59,39	68,61	31,21	35,2	88,75	90,75	69,95	65,92	47,42
Dy	1,42	1,97	1,64	2	2,53	2,21	2,39	2,05	2,15	2,46	1,64	2,37	2,02	1,78	2,04	4,52	2,29	1,78
Er	1,94	2,12	2,34	2,24	2,75	2,4	2,42	2,53	2,21	3,2	2,64	2,19	2,17	2,95	2,69	5,05	2,09	2,35
Eu	0,51	0,581	0,354	0,813	1,019	1,015	1	0,788	0,916	0,792	0,798	0,474	0,545	0,73	1,273	0,846	0,675	0,881
Gd	4,1	2,3	2,87	4,66	5,61	5,66	5,13	4,63	4,82	6,09	7,83	3,51	3,8	7,58	6,59	8,39	5,17	4,5
La	19,16	13,69	n/a	26,26	29,98	30,53	30,45	23,36	29,8	28,52	34,95	13,8	17,73	43,1	42,37	34,83	28,15	20,61
Lu	0,429	0,338	0,416	0,515	0,589	0,595	0,579	0,546	0,463	0,651	0,738	0,469	0,489	0,812	0,594	0,974	0,385	0,537
Nd	12,18	7,64	4,54	16,84	20,15	21,39	21,58	14,67	19,76	19,69	24,76	8,09	9,76	29,39	33,04	25,28	21,31	13,64
Sm	4,94	3,71	3,4	5,52	6,64	6,59	6,58	4,97	6,05	6,49	7,19	3,39	4,1	7,43	8,45	7,87	6,75	4,97
Yb	0,43	0,46	1,03	0,424	0,633	0,477	0,477	0,415	0,302	1,08	0,23	0,683	0,86	0,57	0,115	2,87	0,39	0,246

TRACE AND RARE EARTH ELEMENT GEOCHEMISTRY

Eighteen samples of the Battonya Unit were analysed with respect to their major element (Pál-Molnár et al., 2001), trace element and rare earth element (REE) compositions (Table 1).

On the Harker's variation diagrams for trace elements (not shown) the patterns of the plotted samples are not as regular as it is in the case of major elements. Ni, Cr, V, Zn, Zr and Ga decrease with increasing SiO_2. Y and Nb contents are more or less constant. Sr shows a slight increase, while Ba and Rb are scattered. However, Ba decreases with increasing CaO, and the Sr vs. CaO diagram shows an inverse relation too.

We found some differences in the pattern of samples originating from different areas of the Battonya Unit. Nb/Ta ratio indicates heterogeneity in the studied samples, as it ranges between 4.02 and 14.96. Ce/Yb (24.4-789.1) and Ce/Nb (2.6-22.0) ratios represent a wide range, while the Ba/La ratio varies from 1.96 to 2.44. The fractionation trend is quite clear on the basis of trace elements as well. It seems that samples from the Mezőhegyes area are less fractionated.

Zircon saturation temperatures were calculated (after Watson and Harrison, 1983) in order to determine accurate temperatures at which zircons formed. Values of T_s range between 708-828 °C. However, these results seem to be slightly high. A reason for this can be that the inherited cores of zircons might have crystallised under different conditions than the examined samples, and this way increased Ts values can be received. Ts values can also be characterised with a differentiation trend shown by the Ts vs. SiO_2 and TiO_2 diagrams (Fig 1). The most fractionated samples have the lowest Ts value and the least fractionated ones represent the highest.

On the basis of discrimination diagrams for trace elements, the studied samples plotted in the field of orogenic granite type (OGT) (unfractionated I and S-type granites) and syn-collision granites (Fig. 2), which correspond to the results of tectonic discrimination given by major elements (Pál-Molnár et al., 2001).

In multi-element diagrams the examined samples show a similar pattern, with Ba, Nb, Hf, Ti and Yb depletion and enrichment in other LILE and LREE (Fig. 3).

The total REE contents are moderate or low, varying between 0.12 and 90.75 ppm. The REE contents of the studied samples and their ratios normalised on chondrite (Masuda et al. 1973) are summarised in Table 1. On the basis of these ratios the examined granites are enriched in the LREEs, since the $(La/Lu)_{ch}$ ratio ranges between 3.05 and 7.57. The REE spider diagrams (Fig. 3) represent similar features: the LREEs slightly decrease and reflect the $(La/Sm)_{ch}$ ratio (2.31-3.64). Furthermore, the HREEs display a more or less flat pattern which is marked by the low values of the $(Gd/Lu)_{ch}$ ratio (0.84-1.65). Nevertheless, these diagrams can be characterised by negative Nd, Eu, Dy and Yb anomalies.

The value of $(Eu/Eu^*)_{ch}$ represents the degree of fractionation: the highest value is 0.56 and belongs to the least fractionated sample (ÁGK-1835), while the most fractionated sample has the lowest value (0.29) (ÁGK-1605). Thus, the average $(Eu/Eu^*)_{ch}$ value of the Battonya area is slightly smaller than in the samples of the Mezőhegyes area. The Eu anomalies are indicative for plagioclase feldspar fractionation, however, plotted samples in the diagrams of $(Eu/Eu^*)_{ch}$ vs. SiO_2 and CaO are rather scattered (Fig. 4). There is not any clear trend among the samples. However, Ba increases with $(Eu/Eu^*)_{ch}$, which can be caused by potassium feldspar fractionation.

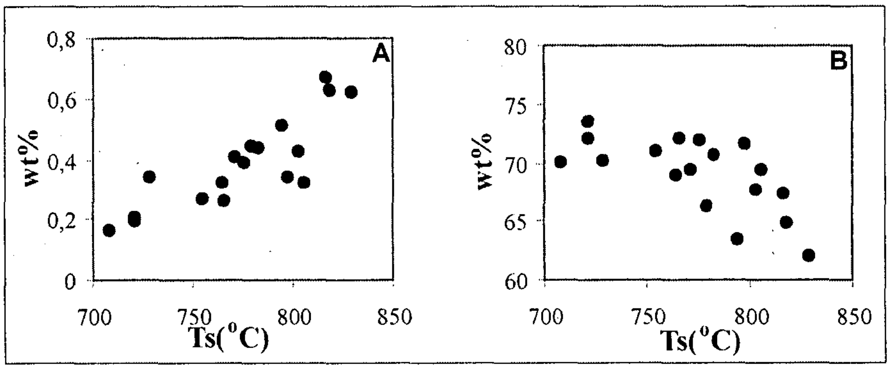

Fig. 1. Zircon saturation temperatures vs. TiO_2 *(A)* and SiO_2 *(B)* according to the calculation from Watson and Harrison (1983)

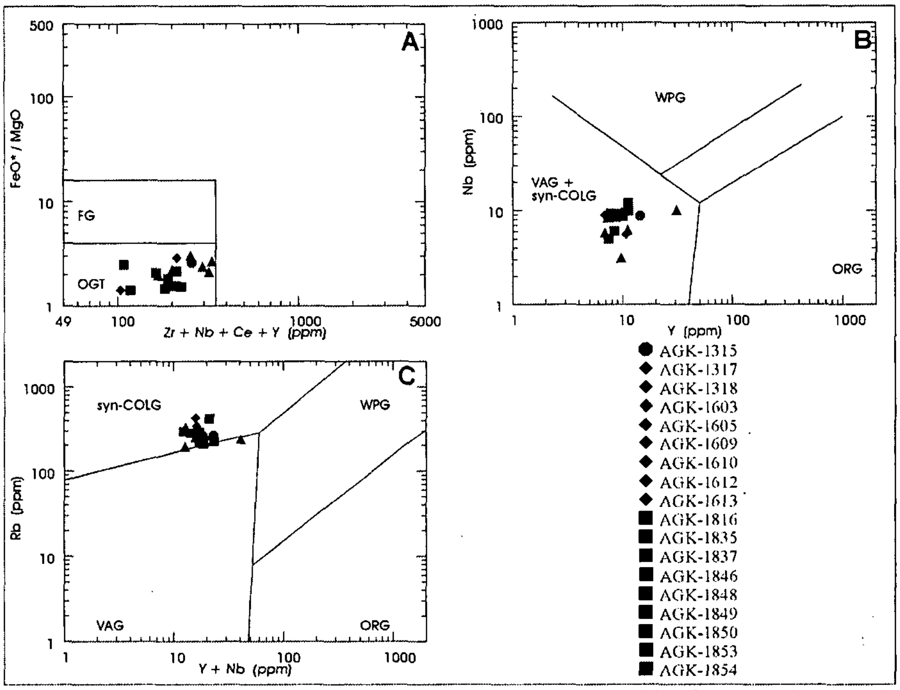

Fig. 2. Tectonic discrimination diagrams of samples: *(A)* after Whalen et al. (1987), and *(B)*, *(C)* after Pearce et al.

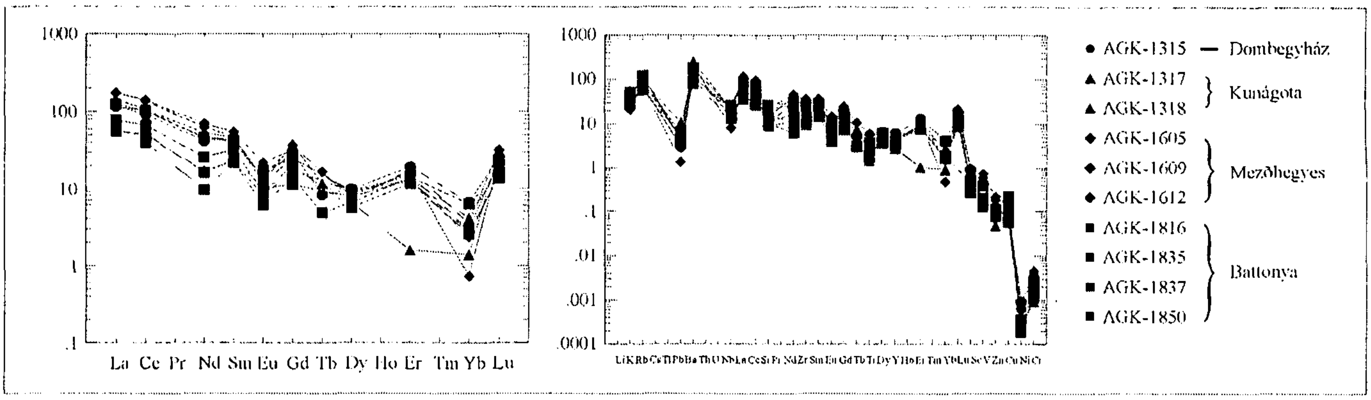

Fig. 3. Chondrite normalized (Masuda et al., 1973) REE-patterns and multielement plots for the Battonya Unit granite

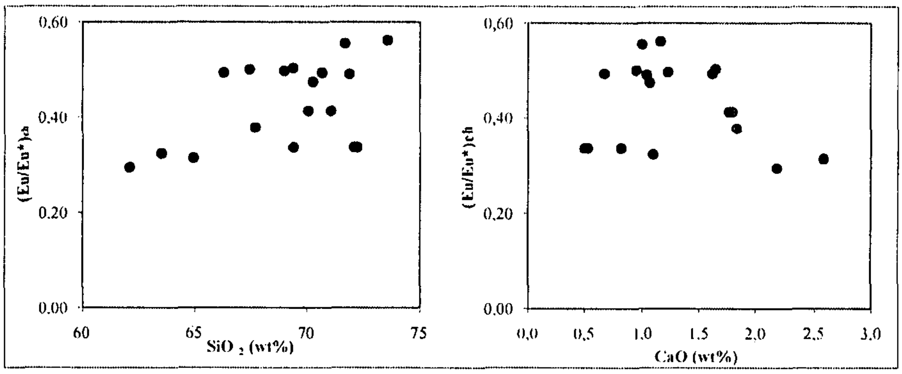

Fig. 4. Variation diagrams on $(Eu/Eu^*)_{ch}$ vs. SiO_2 and CaO

ZIRCON MORPHOLOGY INVESTIGATIONS

Zircon crystals are transparent, colourless or slightly pink, brownish red. Zoning and opaque inclusions are also characteristic. Almost 250 granules were analysed for identifying different morphological types. The identified classes correspond well to the expected character of zircon population, which was predicted on the basis of main rock forming and accessory minerals. Therefore, the morphological classification of zircon crystals provides the location of zircon population in the typology diagram (Pupin, 1980). The most frequent types of zircon in the examined population are S17, S12, S22, S21, S10, S18, S7, S6, S4, S2 (Fig 5). Based on the present investigation, it can be claimed that the studied granites plot neither to the field of alkali nor to that of thoeliitic granites. It is highly probable then that they are closest to the subalkaline, calc-alkaline series.

CONCLUSIONS

Based on trace and rare earth elements geochemistry, petrographical characteristics and main element geochemistry (Pál-Molnár et al., 2001), and considering also the results of the zircon morphological investigations, the granites of the PB High are of uniform character. They are peraluminuous, subalkaline, calc-alkaline granitoids of high K-content. On the basis of trace element distributions, a fractionation difference can be detected in terms of PB High

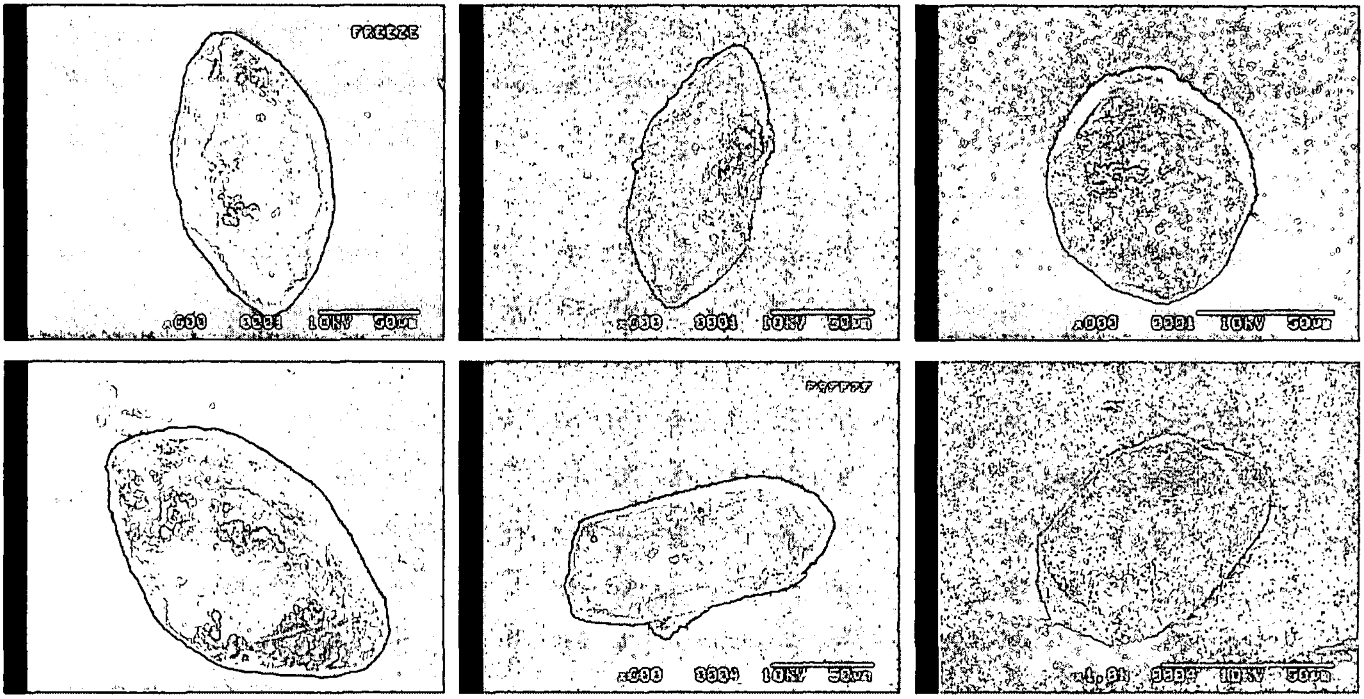

Fig. 5. Morphological types of the zircon population in the examined rocks (SEM images)

samples. In this sense the samples of the Mezőhegyes area are less fractioned.

The studied rocks are S-type, and were formed in a sycollisional (continent-continent collision zone) tectonical environment.

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