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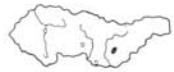
ZIRCON FROM GRANITOID ROCKS OF THE TRÍBEČ-ZOBOR CRYSTALLINE COMPLEX: ITS TYPOLOGY, CHEMICAL AND ISOTOPIC COMPOSITION

(5 Figs., 3 Tabs.)



Abstract: The paper contains typological, chemical and isotopic characterization of zircons from selected granitoids of Tríbeč Mts. Morphometric analysis after Pupin (1980) can characterize the grade of magmatic differentiation of granitoids as well as distinguish monazite and allanite granitoid types. On the other hand, chemical composition of zircons proved to be inapplicable for these purposes. The Zr/Hf ratios in isolated zircon grains decrease from center to peripheral parts, and at the same time they vary from 59 to 35. The age of tonalites with allanite in Tríbeč Mts. is according to U-Pb method on zircons ($^{206}Pb/^{238}U$) concordant and equal to 306±10 m.y.

Резюме: Статья содержит типологическую, химическую и изотопическую характеристику цирконов из выбранных гранитоидов Трибеча. Морфометрический анализ по Пупину (Pupin, 1980) позволяет охарактеризовать степень магматической дифференциации гранитоидов так как отличать моназитовый и алланитовый типы гранитоидов. Химический состав цирконов не было возможно применить для этой цели. Коэффициенты Zr/Hr в отделных зернах цирконов понижаются с центра к периферическим частьям и они колебают между 59 и 35. Возраст тоналитов с алланитом в Трибечи, определенный на осноче U-Pb метода на цирконах ($^{206}Pb/^{238}U$), является конкордандтным и он равен 306±10 м. л.

Introduction

The paper provides information on typology and chemical composition of zircons from principal types of granitoid rocks as well as on U-Pb isotopic composition of zircons from biotite tonalite, the main granitoid variety in Tríbeč Mts. (quartz diorite according to Krist, 1960).

The selection and location of samples has been done on the basis of petrographical and geological criteria with the aim to cover a substantial part of the whole range of granitoids in the relatively extensive Tríbeč-Zobor crystalline complex (Fig. 1). 12 samples have been evaluated by typological analysis, chemical composition of zircons has been studied in 5 samples, isotopic relations in one sample.

So far, only one isotopic datum has been published from the Tríbeč-Zobor crystalline complex – model U-Pb zircon age from a sample of amphibole-biotite tonalite from a location near Jánova Ves (Cambel et al., 1977). Zircons from Tríbeč tonalites and their enclaves have been partly characterized in the paper of Petrík – Broska (1989).

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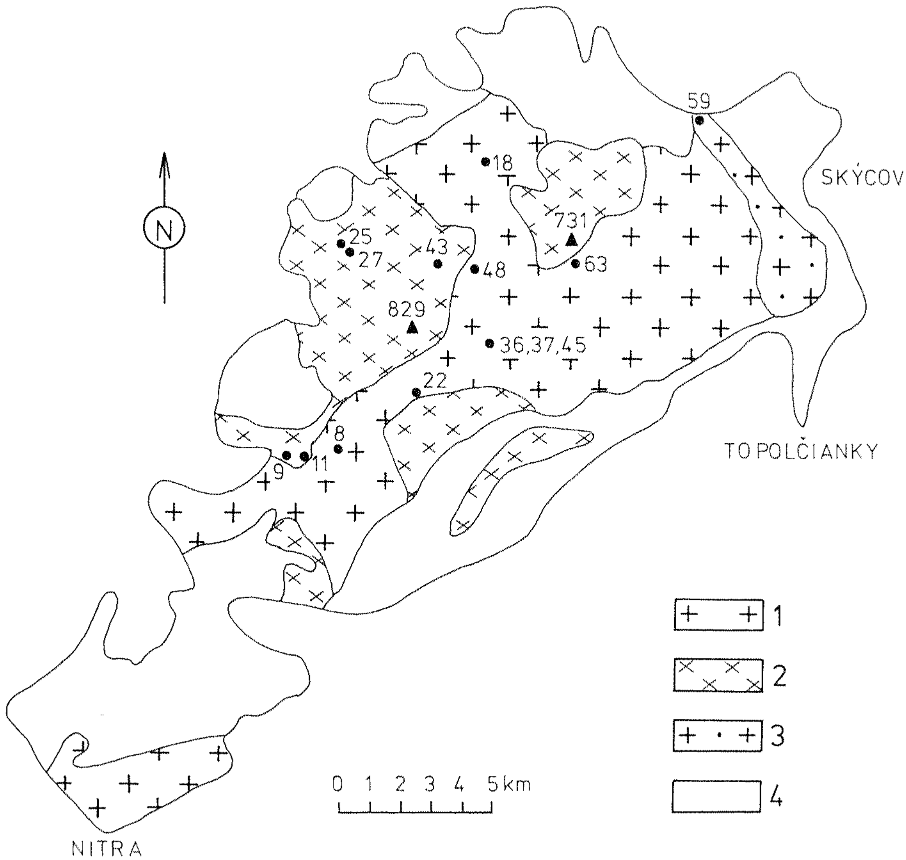


Fig. 1. Geological sketch of the Tríbeč-Zobor crystalline complex (after Krist, 1960) and sample location.

Legend: 1 – coarse-grained biotite tonalite to granodiorite (basic rock type); 2 – medium-grained tonalite to granodiorite (basic rock type); 3 – leucocratic muscovite and two-mica granite; 4 – Mesozoic cover rocks (mainly quartzites).
Note: In all figures T label is omitted.

Methods of study

Zircon fractions for our studies have been obtained from originally 10–12 kg samples by crushing, sieving, floating on a concentrating table, separation in heavy liquids and by magnetic separation. Zircons from the sample selected for isotopic study have been further separated by hand under a binocular magnifying glass and divided into 3 fractions according to their grain-size. Zircons from samples destined for typologic study and microprobe evaluation have been studied in the fraction $D = > 2.8\ g\ .\ cm^3$. Typologic determination of zircons has been controlled by the scanning electron microscope BS-300 Tesla and the composition of zircons in secondary electrons by the scanning electron microscope Jeol. Chemical analyses have been carried out on the X-ray microanalyzer Superprobe Jeol (accelerating voltage 25 kV, current 4.0 × 10 A).

Typologic analysis of zircons

The studied granitoid samples contained fresh, uncorroded zircons, slightly metamictic forms constituting the lesser part. The prevalent majority of zircons is represented by idiomorphic transparent grains, light-pink or light-yellow in colour.

The morphology of zircons in the studied samples has been statistically evaluated according to Pupin's typologic classification and its results are presented in Tab. 1 and Fig. 2

Table 1

Percentual contents of individual zircon types in the studied granitoid rocks

	T-8	T-22	T-36	T-11	T-27	T-37	T-43	T-45	T-48	T-9	T-18	T-59
H	—	—	—	—	3	14	2	5	—	—	—	—
L_1	—	—	—	32	40	37	35	26	45	2	—	11
L_2	—	—	—	11	15	3	15	15	15	3	—	6
L_3	—	—	1	10	4	2	5	9	6	6	1	3
L_4	—	—	3	5	3	1	1	2	2	4	3	2
L_5	1	2	7	5	2	—	1	5	6	4	4	2
G_1	—	1	1	2	8	1	3	2	5	12	1	15
Q_1	—	—	—	—	—	3	10	2	—	—	—	—
S_1	—	3	2	7	8	6	11	6	12	8	12	3
S_2	2	1	3	4	6	3	4	10	7	24	8	2
S_3	5	2	11	2	4	1	5	4	5	12	22	2
S_4	8	9	6	2	—	3	—	—	3	5	7	6
S_5	3	—	4	—	—	—	—	—	1	—	2	3
S_6	6	—	5	5	4	6	3	3	2	1	10	2
S_7	17	26	15	8	2	2	1	8	—	11	16	15
S_8	11	10	3	—	—	—	—	2	—	4	3	16
S_9	—	3	—	—	—	—	—	—	—	—	—	1
S_{11}	9	—	6	4	1	3	1	—	—	3	8	3
S_{12}	37	42	32	3	—	2	3	1	—	1	3	9
S_{13}	1	1	1	—	—	—	—	—	—	—	—	—
I.A	341	344	353	304	293	190	253	293	330	386	338	398
I.T	427	422	389	264	233	221	250	243	250	293	342	322

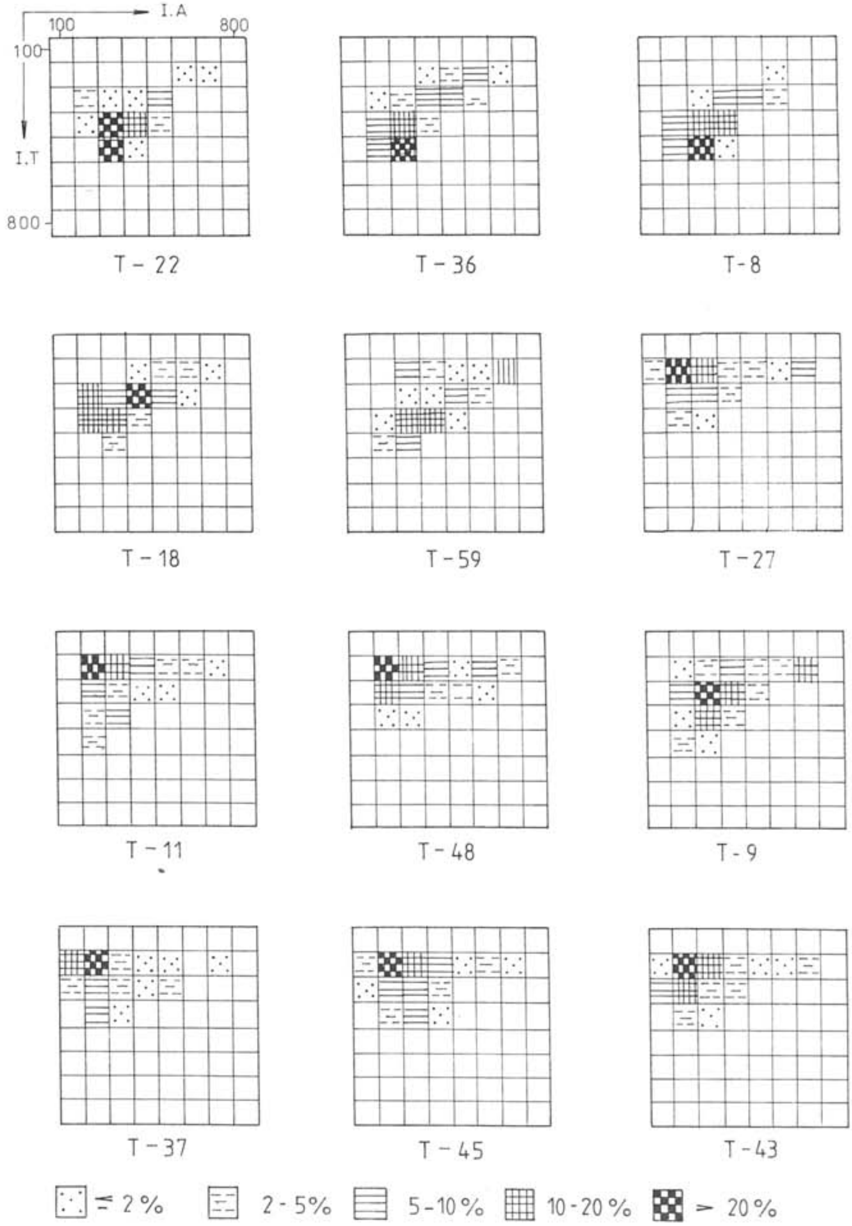


Fig. 2. Distribution of zircon types in Tríbeč granitoids, after P u p i n (1980).
Explanations: In the samples T-8, 22, 36 zircon associates with allanite, the rest of the samples belongs to the monazite type. The I.A parameter is a function of agpaicity, T index (I.T) a function of temperature. The values of I.A parameter determines the combination of pyramidal planes in zircon (211), (101), (211), and (301), I.T parameter prismatic planes (110) and (100).

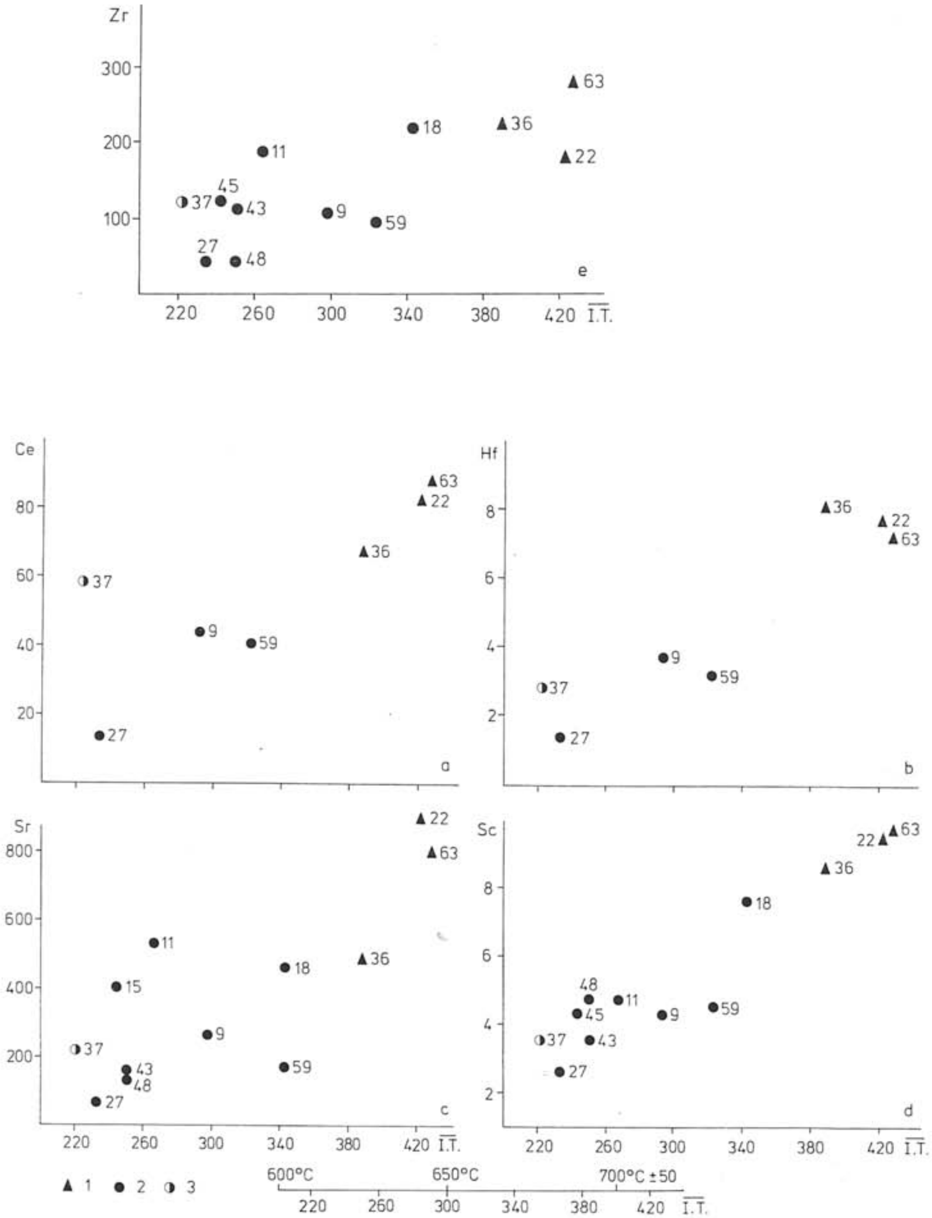


Fig. 3. Selected trace elements (ppm) vs. $\overline{\text{I.T}}$ typologic zircon parameter.
Explanations: 1 – allanite is present in the sample; 2 – monazite is present in the sample; 3 – monazite prevails over allanite in the sample. Temperature scale after P u p i n (1980). Only samples with available analyses have been included.

(Pupin – Turco, 1972; Pupin, 1980). On the basis of this classification it can be said that granitoid rocks of Tríbeč Mts. belong to the group of crustal anatectic granitoids.

Generally it can be said that granitoids form two zircon typologic groups: 1. maximum content of zircons is represented by the subtypes S_{12} (T-8, 22, 36); 2. maximum content of zircons is represented by the subtypes L_1 (T-11, 27, 37, 43, 45, 48), or S_2, S_3 (T-9, 18) while transitional forms are represented only by the sample T-59 (Tab. 1, Fig. 2). Granitoids with maximal content of S_{12} type zircons contain in their mineral assemblage allanite, on the other hand, the rest of the samples contains monazite. Allanite and monazite are present simultaneously only in the samples T-37 and T-18. Thus, zircons in samples of the most basic granitoid rocks of the Tríbeč Mts. with zircon typologic parameter $\overline{I.T}$ exceeding 350 associate with allanite and they represent the allanite type of granitoids; zircons in samples with $\overline{I.T}$ parameter lower than 350 associate with monazite and they represent the monazite type of granitoids (Fig. 3, Tab. 1).

Morphometric zircon parameter $\overline{I.T}$ nevertheless does not correspond only to the rest of the mineral assemblage, but it is related also to the distribution of trace elements, as it can be demonstrated on a selected group of elements – Zr, Hf, Ce and Sr (Fig. 3).

From the viewpoint of a confrontation of independent parameters like trace elements in rocks with the content of allanite or monazite in the assemblage and with the value of zircon typologic $\overline{I.T}$ parameter it follows that $\overline{I.T}$ parameter has a petrologic meaning and it is directly related to the grade of differentiation of granitoid melt. The close relationship of geochemical and mineralogical criteria in Tríbeč Mts. allows the suggestion that the lower the $\overline{I.T}$ zircon typologic parameter, the higher is the magmatic differentiate represented by the granitoid rock. Thus, the least differentiated rocks from our set of samples are T-8, 22, 36, i.e. tonalites with allanite occurring in the south-eastern part of the mountain range. The rest of the samples collected in the central and western part of the region, even though in one case the sample was petrographically also classified as tonalite (T-11), cannot be compared with the previously mentioned group of tonalites in any of the studied parameters: they have a different development of zircons (Fig. 2), lower contents of trace elements, lower $\overline{I.T}$ parameter and their assemblages contain monazite. However, it cannot be excluded that our typological determinations could indicate the presence of more than one differentiation series of granitoids in the Tríbeč-Zobor crystalline complex. Regardless of the presence of a separate intermediate magma in the region which occurs in enclaves (Petrík – Broska, 1989), we assume that on the basis of different zircon typologic patterns (Fig. 2) tonalites with allanite, in contrast to granitoids with monazite, could also represent a separate magmatic body with its own differentiates. In spite of this our data without a detailed petrologic study are not sufficient for making definite conclusions as far as the magmatic differentiation series in Tríbeč Mts. are concerned.

Chemical composition of zircons

Representative microprobe analyses of zircons from the granitoids of the Tríbeč-Zobor crystalline complex are listed in Tab. 2.

Chemical composition of zircons in individual samples is very similar, regardless of the fact that they belong to a relatively wide range of granitoid differentiates. Increased are the contents of the elements Y, La, Ce, Th and above all Hf (Tab. 2).

Trace elements in zircons of the Tríbeč granitoids – taking into account the detection limit of microprobe analysis – cannot be applied for the characterization of granitoid magma differentiates.

The concentration of Zr in whole-rock samples decreases with the grade of differentiation

Table 2

Microprobe analyses of zircons from various granitoid rock varieties from the Tríbeč-Zobor crystalline complex

	T-18				T-22				T-9	
	1st grain		2nd grain		1st grain		2nd grain		1st grain	
	rim	core	rim	core	rim	core	rim	core	rim	core
SiO_2	33.54	33.49	33.77	32.97	33.08	33.40	34.22	34.09	34.01	33.77
ZrO_2	65.50	66.06	66.16	66.82	64.94	64.33	62.67	63.60	62.64	64.45
HfO_2	1.52	1.49	1.59	1.30	1.34	1.11	1.65	1.30	1.62	1.86
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00
FeO	0.02	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Y_2O_3	0.01	0.19	0.00	0.17	0.00	0.18	0.01	0.18	0.10	0.01
La_2O_3	0.05	0.00	0.06	0.02	0.08	0.00	0.06	0.12	0.18	0.09
Ce_2O_3	0.09	0.18	0.05	0.13	0.01	0.00	0.03	0.02	0.10	0.06
ThO_2	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.03
Total	100.75	101.42	101.66	101.41	99.45	99.04	98.66	99.33	98.71	100.27
Zr/Hf	37.62	38.70	36.32	44.87	42.30	50.56	33.16	42.71	33.75	30.25
	Numbers of ions on the basis of 16 0									
Si	4.0697	4.0434	4.0617	3.9943	4.0619	4.1009	4.1927	4.1585	4.1762	4.0745
Zr	3.8751	3.8883	3.8803	3.9470	3.8885	3.8515	3.7444	3.7832	3.7512	3.8512
Hf	0.0524	0.0507	0.0542	0.0444	0.0464	0.0384	0.0574	0.0447	0.0568	0.0638
Mg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Al	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ca	0.0000	0.0007	0.0007	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
Fe	0.0014	0.0000	0.0014	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000
Y	0.0058	0.0116	0.0000	0.0102	0.0000	0.0118	0.0014	0.0117	0.0059	0.0058
La	0.0021	0.0000	0.0028	0.0014	0.0029	0.0000	0.0030	0.0051	0.0089	0.0044
Ce	0.0005	0.0007	0.0021	0.0058	0.0007	0.0000	0.0014	0.0008	0.0044	0.0029
Th	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0011	0.0015	0.0007

1st continuation of Tab. 2

	T-27						T-59			
	1st grain		2nd grain		3nd grain		1st grain		2nd grain	
	rim	core	rim	core	rim	core	rim	core	rim	core
SiO_2	33.97	33.40	34.20	33.13	33.74	33.81	33.63	33.21	34.27	33.86
ZrO_2	62.16	63.58	64.94	65.09	64.04	64.26	63.89	66.33	64.74	66.12
HfO_2	1.73	1.73	1.59	0.96	1.46	1.49	1.59	1.33	1.48	1.41
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Al_2O_3	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01
FeO	0.11	0.08	0.01	0.03	0.00	0.00	0.00	0.01	0.00	0.00
Y_2O_3	0.00	0.23	0.00	0.22	0.61	0.23	0.08	0.34	0.00	0.01
La_2O_3	0.12	0.06	0.10	0.11	0.16	0.15	0.01	0.05	0.06	0.00
Ce_2O_3	0.12	0.10	0.09	0.03	0.06	0.09	0.16	0.11	0.12	0.20
ThO_2	0.05	0.10	0.07	0.06	0.00	0.00	0.00	0.02	0.02	0.02
Total	98.27	100.22	101.01	99.60	100.10	100.03	99.37	101.46	100.70	101.63
Zr/Hf	31.36	32.08	35.65	59.19	38.29	37.65	35.08	43.53	38.18	40.93
	Numbers of ions on the basic of 16 0									
Si	4.1616	4.1032	4.1203	4.0597	4.1081	4.1144	3.9827	4.0168	4.0495	4.0696
Zr	3.7605	3.8086	3.8155	3.8889	3.8023	3.8132	3.6895	3.9122	3.8947	3.8752
Hf	0.0611	0.0605	0.0543	0.0331	0.0505	0.0519	0.0533	0.0457	0.0506	0.0476
Mg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0029	0.0000	0.0000
Al	0.0000	0.0044	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ca	0.0015	0.0015	0.0000	0.0000	0.0000	0.0015	0.0007	0.0000	0.0007	0.0007
Fe	0.0112	0.0081	0.0007	0.0000	0.0029	0.0000	0.0000	0.0036	0.0007	0.0000
Y	0.0000	0.0148	0.0000	0.0139	0.0395	0.0146	0.0042	0.0218	0.0000	0.0000
La	0.0060	0.0030	0.0043	0.0044	0.0073	0.0073	0.0014	0.0014	0.0014	0.0000
Ce	0.0060	0.0044	0.0043	0.0015	0.0029	0.0044	0.0056	0.0043	0.0043	0.0086
Th	0.0015	0.0059	0.0022	0.0022	0.0000	0.0000	0.0000	0.0007	0.0007	0.0007

(Fig. 4), similarly as Hf (Fig. 3) and thus with a decrease of the content of zircons in the rock these changes are not reflected in the change of the Zr/Hf ratio in zircons in individual granitoid differentiates. The trend of decreasing Zr/Hf ratio in zircons of magmatic rocks with progressing differentiation process (Fleisher, 1955; Gottfried – Waring, 1964; Butler – Thompson, 1965; Chessex – Delaloge, 1965; Brooks, 1970;

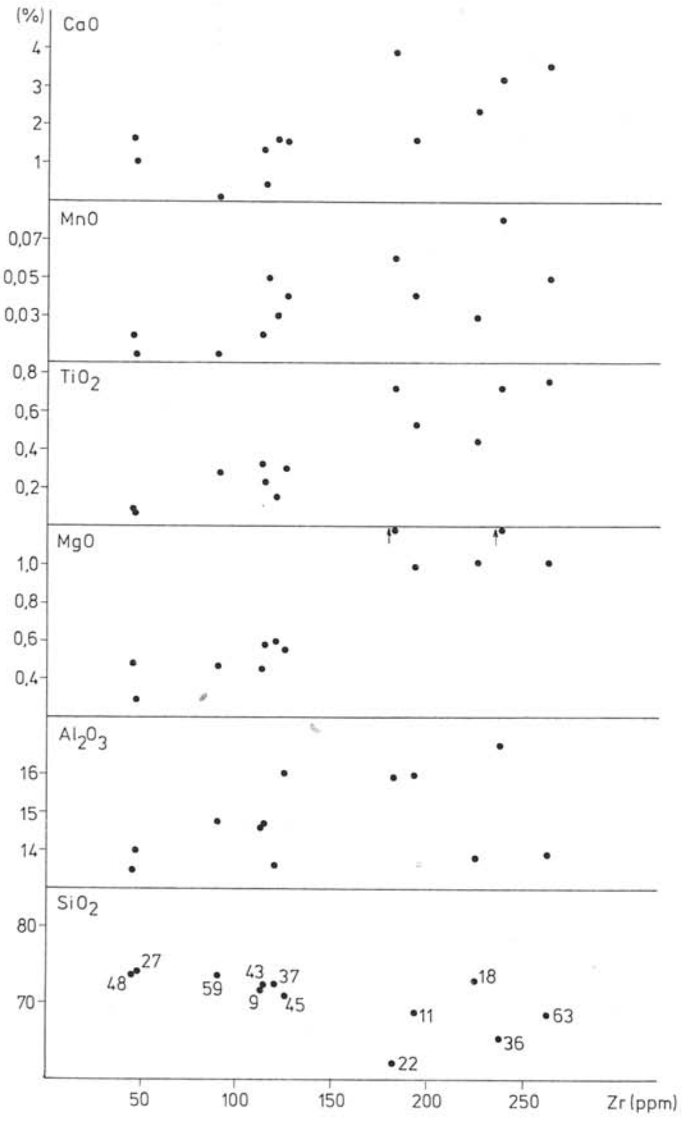
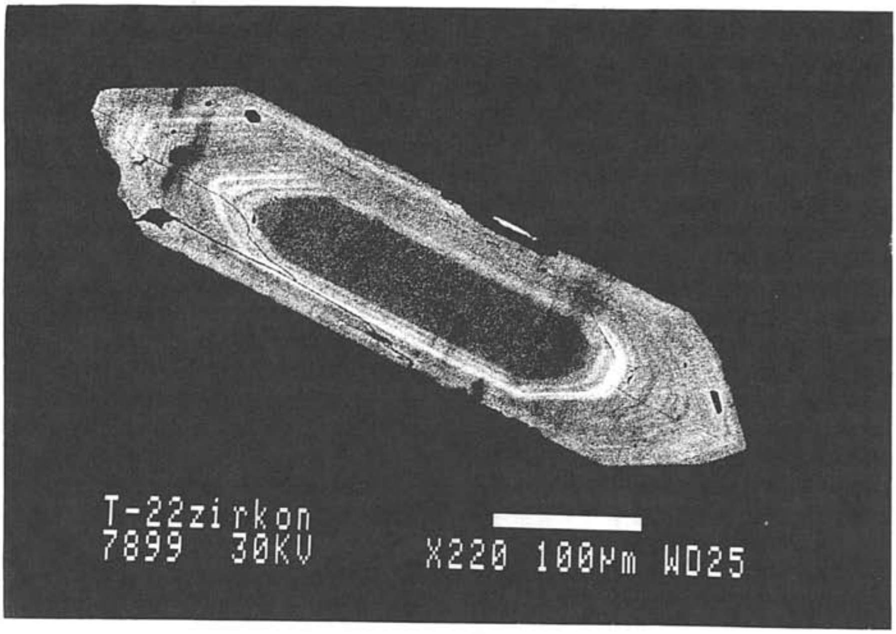


Fig. 4. – Variation diagrams of principal oxids (wt. %) vs. whole-rock Zr content (ppm).



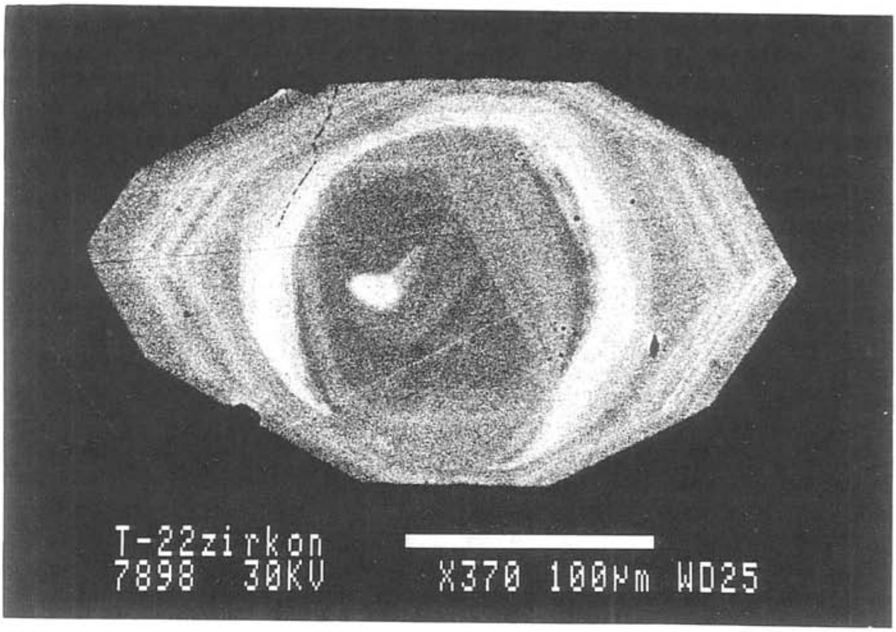


Fig. 5. Examples of zoned internal structure of zircons caused by varying Hf concentration. *Note:* The higher Hf content in zircon, the lighter is the phase of the composition. Oscilation zoning of zircon is an indication of magmatic conditions during its formation. (Sample T-22).

Lyakhovich, 1973; Gbelský, 1979 and others) did not appear in our differentiation range, but nevertheless in the most basic differentiate (T-22) we could observe one of the lowest Hf contents in zircon cores as well as a trend of an increase of Hf content towards the rims of zircon grains (Gulson, 1969; Lyakhovich, l.c.; Broska, 1986 and others), quite evident in the Tríbeč granitoids (Tab. 2). The Zr/Hf ratio in zircons of Tríbeč granitoids varies in a range of 30 to 59. Maximal increase of the Zr/Hf ratio in zircon has been determined in a sample of altered granite T-27, where central parts of zircons has the ratio 35 and the rim 59.

Observed in greater detail, above all in the most basic differentiates, the increase of Hf content towards the rims of grains appears to be a result of hafnium oscilation zoning in micron scale, while the maximum of hafnium concentration does not necessary lie on the edge of the grain, but it can be in one of the rim zones (Fig. 5). This can be explained by the variation of chemical composition of the crystallization environment, by the trend of the crystalls to attain a surface equilibrium with the environment, by the movement of zircon in the melt as well as by its relatively low rate of growth in a range of approx. 200 °C, which started in tonalites with allanites already at a temperature of 750 °C ± 50 °C (Fig. 2). The assumed movement of zircons in felsic melts of the Tríbeč Mts. was a result of the movement, or currents, in the melt (Vernon, 1983; Schermerhorn, 1987) which in Tríbeč Mts. caused that the tonalitic melt enclosed even deeper lying intermediate material crystallizing as mafic enclaves in the tonalites (Petrík – Broska, 1989).

Isotopic study of Tríbeč zircons

Isotopic studies have been carried out on a sample of biotite tonalite with allanite (T-22) collected from and old quarry near the road Kostoľany pod Tríbečom – Zlatno.

Biotite tonalite with allanite (T-22) is a medium- to coarse-grained rock, with hypidiomorphic texture. Autometamorphic processes which affected the tonalite took place in subsolidus state and during these processes biotite was chloritized, epidotized and Ti was to a great extent divided into sagenite and tiny grains of secondary sphene or leucoxene. Plagioclase was in the whole rock intensively sericitized and saussuritized and replaced by albite. These alterations are related to the period immediately after the formation of the body because parts of altered tonalites have been determined in pebbles already in the Permian of Tríbeč Mts. (Korikovsky et al., in prep.).

Zircons from the sample T-22 contain relatively low concentrations of radioactive elements and high contents of common lead which negatively affects the precision of the calculation of isotopic ratios. In the view of the fact that in Variscan zircons the isotope ^{206}Pb, as a product of fission of ^{238}U, considerably prevails, the age of zircons is calculated on the basis of the ratio ^{206}Pb/^{238}U (Tab. 3). According to this ratio the age of all zircon fractions is basically concordant and equal to 306 ± 10 m.y.

Zircons from the studied sample T-22 contain a slight admixture of radiogenic lead. The presence of ancient lead has been frequently observed in Variscan granitoids, which is an evidence of the participation and formation of granitoid melt from the matter of old continental crust. However, it is not possible to determine the age of this old material by isotopic study of zircons.

The age of tonalites with allanite in Tríbeč Mts. is according to U-Pb dating 306 ± 10 m.y., while in the view of the coexistence of acid and intermediate magma in the crystalline complex of Tríbeč Mts. we can consider mafic enclaves in the tonalites to be of the same age (Petrík – Broska, l. c.).

Table 3

U-Pb isotopic study of accessory zircon from tonalite with allanite in the Tríbeč-Zobor crystalline complex

Sample No. fraction	Contents, %		Isotopic composition of lead				Isotopic relations (radiogenic)		Age acc. to $^{206}Pb/^{238}U$ m.y
	Pb	U	204	206	207	208	$^{207}Pb/^{206}Pb$	$^{207}Pb/^{235}U$	
T-22/86 fr +100	0.0032	0.058	0.101	77.295	5.969	16.625	0.05647	0.3808	308
T-22/86 fr −100	0.0037	0.0632	0.148	74.733	6.171	18.948	0.05348	0.3581	306
T-22/86 fr −100+75	0.0034	0.0607	0.133	76.037	6.065	17.765	0.5405	0.3584	304

Correction was made to common lead of 350 m.y.: $^{206}Pb/^{204}Pb = 18.230$; $^{207}Pb/^{204}Pb = 15.639$.

Conclusions

Typological classification of zircons allowed to class the granitoids of Tríbeč Mts. with crustal-anatectic granitoids, with two basic typologic patterns: granitoids with monazite have the I.T parameter lower than 350, granitoids with allanite have the I.T parameter higher than 350. Two different typological patterns, as well as the character of assemblages of accessory minerals indicate the presence of two different intrusive events.

Zirconium together with hafnium is in felsic melts compatible and its content, as well as that of hafnium, decreases with the grade of magmatic differentiation. This is the reason for the fact that in spite of the Zr/Hf ratio clearly decreasing within the grains toward the peripheral parts, this does not show in the change of Zr/Hf ratios in zircons of various magmatic differentiates, making thus impossible the application of this ratio for their characterization.

The most basic granitois of Tríbeč Mts. – biotite tonalites with allanite – dated by the U-Pb method on zircons have concordant age, according to $^{206}Pb/^{238}U$ equal to 306 ± 10 m.y. This age appears to be synchronal with the age of the Sihla tonalite in the Veporide crystalline complex (Bibikova et al., 1990), which will perhaps in the future allow to search for closer relationships between both rock types in the two tectonic units: in Veporides and south-eastern part of Tríbeč Mts. (Tatrides).

Translated by K. Janáková

LIST OF SAMPLES – *description and location*

T-8 – *biotite tonalite.* Kostoľany pod Tríbečom. Road Jelenec-Kostoľany pod Tríbečom, in the curve near the crossing of the creek Drevenica. 1250 m S from the elev. p. Drža (499).

T-9 – *leucocratic granite.* Horné Lefantovce – sanatorium. Old quarry 600 m above the water reservoir in the valley. 120 °/400 m from the elev. p. 285.

T-11 – *biotite leucotonalite.* Horné Lefantovce. From debris on the mountain ridge near a timber-slide. 15 °/400 m from the elev. p. 407.

T-18 – *biotite granodiorite.* Krnča. Timber-slide on the N slope of Ostrá Hôrka Hill. 10 °/800 m from the elev. p. 446 Ostrá Hôrka Hill.

T-22 – *biotite tonalite* with amphibole. Kostoľany pod Tríbečom. Old quarry on the road Jelenec-Zlatno. 350 °/750 m from the elev. p. 407.

T-27 – *muscovite leucocratic monzogranite.* Kovarce. On the timber-slide from Čeladince to Malá Kurňa (300 °/300 m from the elev. p. Malá Kurňa).

T-36 – *biotite tonalite.* Velčice. Near the red-sign path, small cliff 280 °/750 m from the elev. p. Kozlišov.

T-37 – *granite* (vein in biotite tonalite T-36). The same as T-36.

T-43 – *muscovite granodiorite.* Nitrianska Streda. Road Solčany-Velčice, 200 m behind an old quarry on the NW slope of the Medvedí Hill, road-cut near the crossing of blue-sing touristic path with the road.

T-45 – *leucocratic granodiorite.* The same as T-36.

T-48 – *muscovite monzogranite.* Solčany. Debris on the elev. point Medvedí Hill.

T-59 – *leucocratic granodiorite.* Veľký Klíž. 1 km SE above the gamekeeper's lodge Slače from debris on the slope. 2.5 km W from the elev. p. Brala (558 m).

T-63 – *biotite tonalite.* Zlatno. 1500 m S from elev. p. 731 m, Javorový Hill.

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