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REGIONAL TYPOLOGY OF ZIRCON AND ITS RELATIONSHIP TO ALLANITE/MONAZITE ANTAGONISM (ON AN EXAMPLE OF HERCYNIAN GRANITOIDS OF WESTERN CARPATHIANS)

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Abstract: The paper demonstrates the posibilities of an application of Pupin's typological analysis of zircon to petrogenesis of granitoid rocks. The study of zircons from Hercynian granitoids of various types and units of the Western Carpathians resulted in the determination of regional zoning of Hercynian granitoid intrusions related to the increase of the parameters I. $\bar{T}$ and I. $\bar{A}$ in the direction from external to internal units of the Western Carpathians. Besides this, the zircon typological parameter I. $\bar{T}$ is higher in allanite than in monazite granitoid types, which is consistent with the higher-temperature origin of allanite granitoids in comparison with monazite varieties.

Key words: zircon typology, Western Carpathian granitoids, allanite/monazite antagonism.

Introduction

Accessory minerals are important components of granitoid rocks, since it appears that individual accessory phases are in a complex way qualitatively as well as quantitatively related to each other and they strongly depend on the genesis and composition of the parent rocks. The most informative minerals from petrogenetic viewpoint are zircon, allanite, monazite, garnet, apatite, magnetite, ilmenite and sphene.

In the present paper we shall attempt to show regional zoning of zircon typology in Western Carpathian Hercynian granitoids, as well as its relationship to allanite/monazite antagonism.

Methods of research

Solid samples of granitoid rocks 10-12 *kg* in weight were crushed, sieved, floated and accessory minerals were separated in heavy liquids (bromophorm, methyleneiodide) and electromagnetically, using the adjusted method of Lyakhovich and Rodionov (1961). The study of accessory minerals itself has been carried out with the help of binocular stereoscopic magnifying glass, scanning electron microscope (SEM) and electron microprobe. Typological evaluation of zircons from diamagnetic fraction of accessory minerals has been done using the method of Pupin and Turco (1972), Pupin (1980), with the help of binocular magnifying glass. One of the samples has been evaluated parallelly at greater magnification by SEM; the results of both methods were consistent.

Typological analysis of zircons

The external morphological characteristics of zircon were applied in solving of petrogenetic problems for the first time by Poldervaart (1950), later by Larsen and Poldervaart (1957). The basis for their evaluation was the measurement of elongation of zircon crystals, however, the method was not widely accepted, because no relationship between zircon elongation and magma genesis could be established. The genetical relationship between the morphological features and genesis of host rocks has been studied also by Zavyalova (1966) and Lyakhovich, (1968).

Later on, Pupin and Turco (1972), Pupin (1980) and others laid down the fundaments of a new, genetic classification, which is based on the knowledge that zircons in certain types of magmatic rocks have specific combinations of pyramidal and prismatic crystal faces. Elongation is not taken into consideration in this classification. The only classifying factor is the morphology of crystals – i. e. the combination and relation of prismatic (I. T parameter) and pyramidal (I. A parameter) crystal faces. I. T parameter depends on the temperature of zircon crystallization, I. A parameter on the alkalinity of parent rock. This method can be applied in various geotectonic-magmatic settings.

Pupin's typological method has been applied to the study of all main types of Hercynian granitoids in core mountain ranges of the Western Carpathians which intruded into Lower Paleozoic metamorphosed sedimentary or volcanosedimentary rocks (above all metapelites and metapsammites) (Fig. 1). In all, we have typologically evaluated more than 60

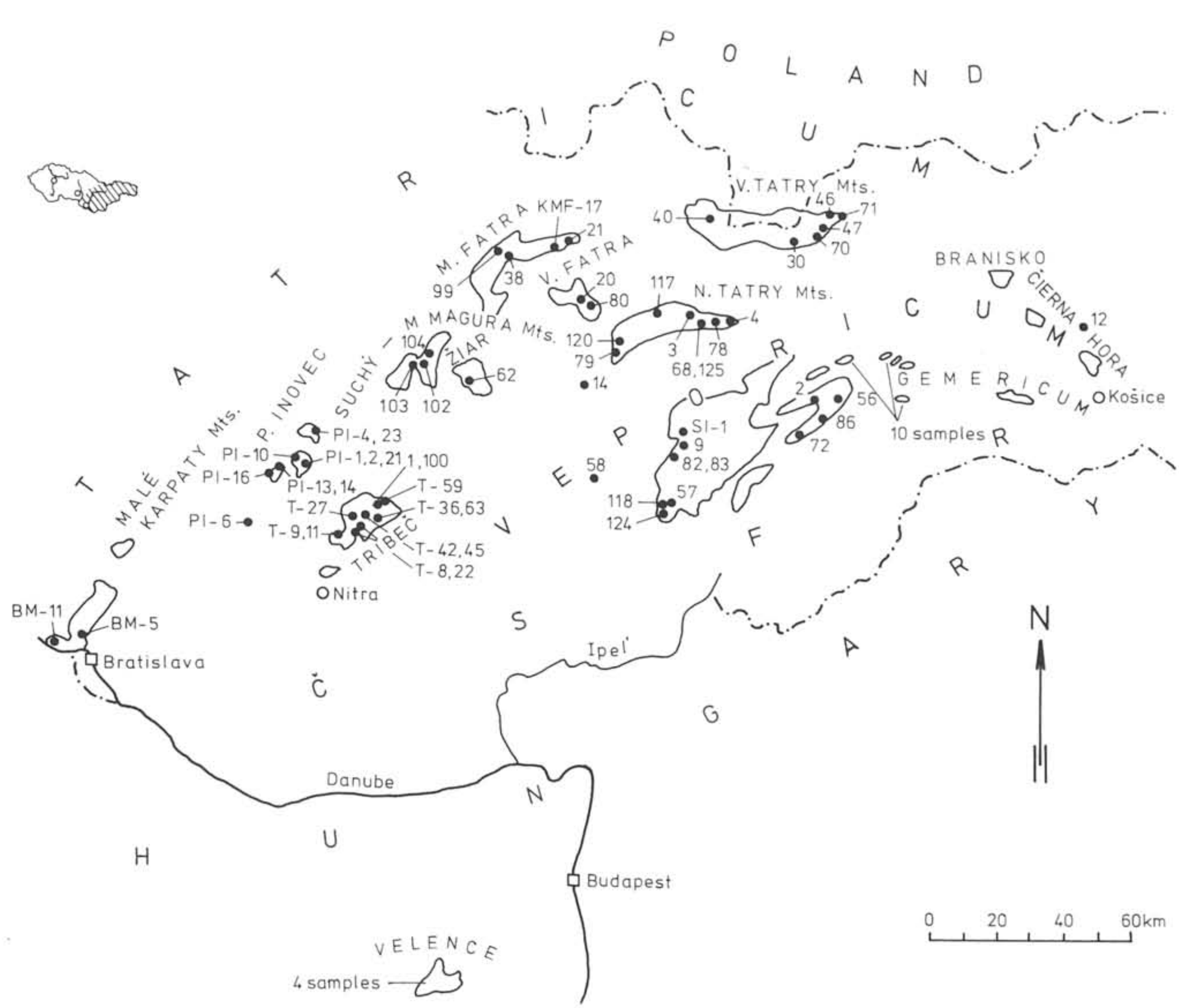

Fig. 1. Location of granitoid samples collected in Western Carpathians with the aim of typological zircon study. (Samples labelled only by a number are „ZK" samples of Macek et al. 1982).
Samples labelled „T" are taken from the paper – Broska et al. (1990), sample KMF-17 – Broska (1986), samples labelled „PI" – Broska & Uher (1988), samples labelled „BM" – unpublished material of the authors, samples labelled „SI-1" – Bibikova et al. 1990, samples from Gemericum – Jakabská & Rozložník (1989), Peteš (1988), samples from the Velence Mts. – Gbelský & Határ (1982).

samples. Zircons from Western Carpathian granitoids were found to be typologically rather varied, since the individual granitoid samples comprise 12-15 zircon types or subtypes. Their size usually vary in the range of 0. 0X-0.5 *mm*.

The determined types and subtypes can be in many samples interpreted as a result of one evolution process of crystallization, which is idicated by the indentical age of S, L and G types and their Gaussian distribution within a single sample (Bibikova et al. 1988). On the other hand, there were samples containing quite evidently two types of zircons, differing not only typologically, but also by their size, colour and grade of metamictization. These rocks often yield bimodal distribution of individual types and subtypes, which leads us to an assumption of the existence of two zircon generations of different age: an older, magmatic generation consists of tiny (in average 0.0X-0.3 *mm*) transparent specimens of various S subtypes, the younger generation are mostly metamict zircons with an average size of 0.2-0.5 *mm*, usually belonging to the subtype G_1. This younger generation bears a striking resemblance to zircons from pegmatites, probably it formed already in subsolidus area. Such metamict zircons are in some samples absolutely predominant – they comprise 70 to 90 % of the whole population. We observed such zircons e. g. in the Hlohovec body of the Považský Inovec Mts. (Broska and Uher 1988), in magmatic enclaves of granitoids from Tríbeč Mts. (Petrík and Broska 1989) and recently in some granitoid rocks, especially in the Nízke Tatry Mts. and Veporicum. These samples were not taken into consideration, since younger metamict zircon totally obscurs the primary magmatogenic typological trend of zircons.

Typological analysis of zircons in the broader Western Carpathian region

Typological evaluation of zircons on a broader regional scale is very important from the viewpoint of a demonstration of differences in the development of zircons in granitoids of

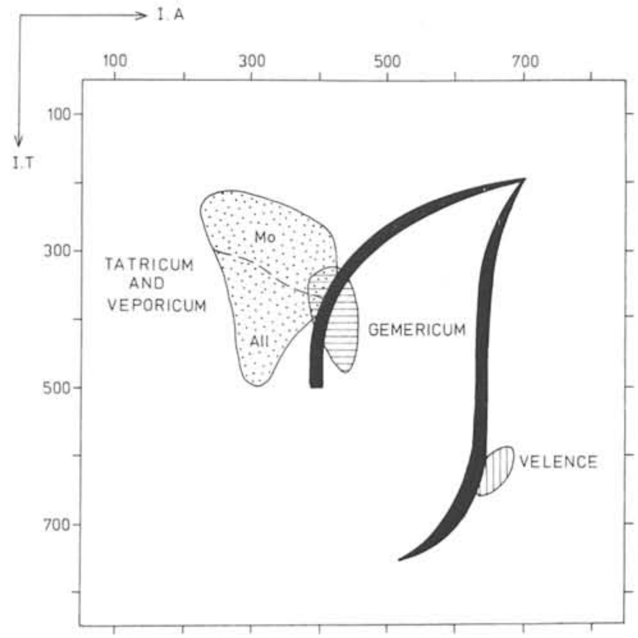

Fig. 2. Projection fields of zircon typological mean points of Hercynian granitoids in individual tectonic units of the Western Carpathians.
Note: Data on Gemerides and Velence Mts. are taken from the papers Jakabská & Rozložník (1989), Peteš (1988), Gbelský & Határ (1982). Mean points were calculated according to Pupin (1980). The thick curves represent boundaries separate fields of crustal-anatectic granites (left side), calc-alcaline and K-calc-alkaline series granites of crustal-mantle granites (middle) and alkaline mainly mantle granites (right side). Mo – granitoids containing monazite, All – granitoids containing allanite.

certain tectonics units, which is necessary for understanding the evolution of granitoid bodies themselves. The regional zonality on the basis of the zircon typological analysis has been successfully documented in Hercynian granitoids of France (Pupin 1985), but also in the other regions (Pupin 1988). By an evaluation of present typological analyses as well as already published data (Gbelský & Határ 1982; Broska & Uher 1988; Peteš 1988; Jakabská & Rozložník 1989; Petrík & Broska 1989; Broska et al. 1990) we obtained a summary typogram of projections of all mean points which can be integrated into larger fields according to tectonic units (Fig.2). The application of the relationship of zircon typology to the petrogenetic type of host granitoid rock (Pupin 1980) in the Western Carpathians yields the following results:

– *Granitoids of Tatricum and Veporicum* manifest clear crustal-anatectic character. Using other accessory minerals, especialy monazite and allanite granitoids, divide into two groups: monazite types of granitoids with zircon typological maximum about S_1-S_2 less S_7, L_1-L_2 (for example: Bratislava Massif, Považský Inovec Mts. Suchý and Malá Magura Mts., Rimavica type). Granitoids of allanite type manifest typological maximum $S_1 - S_{12}$, less at $S_1 - S_2$ (Sihla type in Veporicum unit, SE part of Tríbeč, Čierna Hora Mts.).

– *Granitoids of Gemericum* show transitional trend between crustal aluminous anatectic granitoids and calc-alkaline granitoids of the crustal-mantle sources. They contain frequently the types S_7-S_8, less S_{17}. (Peteš 1988; Jakabská and Rozložník 1989).

– *Granitoids of Velence Mts.* belonging to the Inner Western Carpathians (Maheľ 1986) are the only ones which are of mantle character. According to Pupin' s classification (1980), it is the subalkaline to alkaline granitoid series. They are characterized above all by the types P_4-P_5, less S_{25} (Gbelský and Határ 1982).

Genetic types of Western Carpathian granitoids distinguished on the basis of typological analysis of zircons are mostly consistent with available geological, petrographical and geochemical data (geological setting – the relationship to crystalline schists, the contents of major and trace elements, Sr isotopes etc.). The crustal-anatectic origin of Tatricum and Veporicum granitoids is generally accepted (Hovorka 1979, 1980; Cambel et al. 1985).

Certain discrepances have been observed only in granitoids of Gemericum, they project into a field in the typological diagram exceeding the boundaries of crustal types and it is reaching already into the area of crustal-mantle granitoid rocks (Fig. 2), which is at variance with their generally leucocratic character, increased contents of Li, Rb, B, Sn (tin-bearing granites) and other features typical of well-differentiated crustal S-type granitoids. On the other hand, the Gemericum granites are, because of their general character as well as problematic age (a part of Rb/Sr analysis yields Kimmerian age – Kovách et al. 1986), different from the rest of granitoid rocks occurring in the Central Western Carpathians.

Generally the regional trend is gradual increase of the mean typological parameters I. $\bar{A}$ and I. $\bar{T}$ in zircons in the direction from north to south of the Western Carpathians (Tatricum through Veporicum, Gemericum to the Velence Mts.) (Fig. 2). Probably this is the Hercynian zoning of granitoid bodies reflecting the changes of geotectonic regime and the type of crust (granitoids of collision orogenic regime with thicker continental crust: Tatricum, Veporicum, Gemericum and the type of riftogenic environment with dominant interaction of mantle matter in a thiner crust: Velence Mts). The increased alkalinity of Gemericum and especially Velence Mts. granitoids in comparison with Tatricum and Veporicum is also well known (Cambel et al. 1983). On the other hand, we have to take into consideration the very complicated geological build of the Western Carpathians, where their original, perhaps compact Hercynian structure has been affected by Alpine tectonics (folding, allochthonous position, desintegration into blocks). This does not allow at the present state of knowledge to apply the determined zoning of Hercynian plutons to serious paleogeographic and paleotectonic considerations.

Allanite-monazite antagonism

Typological analysis of zircons from granitoids of Tatricum and Veporicum (Western Carpathians) led to the determination of a strong dependence of zircon typology on the assemblage of other accessory minerals, especially allanite and monazite – the principal light REE minerals in Western Carpathian granitoids. The antagonism of allanite and monazite in granitoids of Western Carpathians has been reported by Hovorka & Hvožďara (1965), Hvožďara & Határ (1978), Chovan & Határ (1978), Veselský & Gbelský (1978), Veselský et al. (1982), Broska et al. (1990) and others.

The results of the present study of a relatively large set of granitoids (63 samples) from Tatrides and Veporides (West-

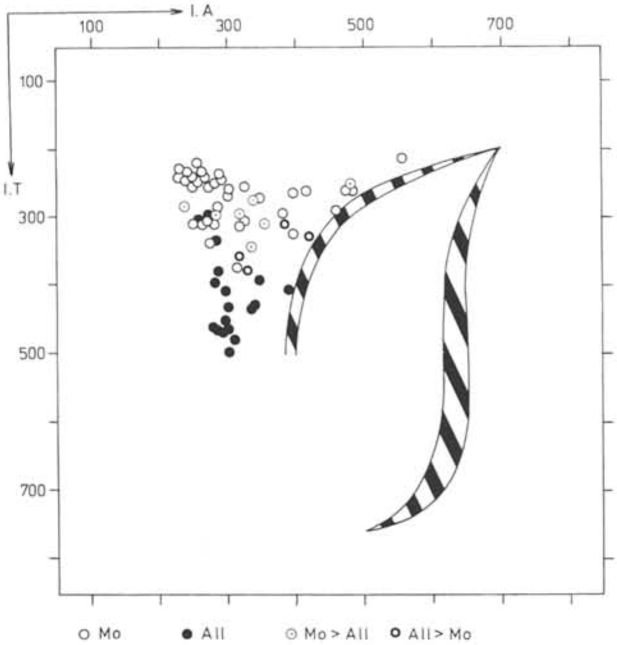

Fig. 3. Pojections of zircon typological mean points in the studied Western Carpathian granitoid types.
Mo – granitoids containing monazite, All – granitoids containing allanite, Mo>All – granitoids with a prevalence of monazite over allanite, All>Mo – granitoids with a prevalence of allanite over monazite.

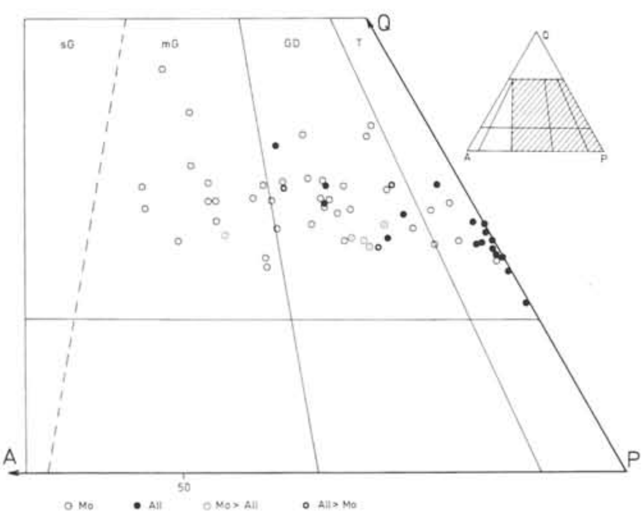

Fig. 4. Projection of Western Carpathian allanite and monazite granitoids in Streckeisen's diagram.
Explanations as in Fig. 3.

ern Carpathians) show that allanite is present mostly in those granitoids where zircon has an average value of I. $\bar{T}$ index exceeding 350. On the other hand, monazite occurs as a rule in granitoids with I. $\bar{T}$ below 350 (Fig. 3). Assuming that zircon and allanite coexist in melt, Pupin's I. T parameter – directly proportional to the crystallization temperature of zircon – indicates that allanite should also crystallize at relatively higher temperatures than monazite (Fig. 3). This is indicated also by the distribution of allanite and monazite in the principal varieties of Western Carpathian granitoid rocks, where highest allanite contents are in the least differentiated and most basic rocks – in biotite tonalites to granodiorites, and late differentiates of felsic melts – especially two-mica and leucocratic granites as well as their derivates – aplites and pegmatites – contain monazite (Fig. 4), sometimes along with xenotime.

Allanite attains frequently considerable concentrations in tonalites – 0.0X-0.X wt.% (Gbelský 1982). It is usually idiomorphic or hypidiomorphic, developed either in interstitial spaces or in biotites. Petrographic observations indicate its magmatic origin, even though in some cases we cannot exclude the possibility of its formation in secondary processes (Hovorka 1971).

The main process of magmatic differentiation of granitoids in the Malé Karpaty Mts. as well as otherwhere in the Western Carpathians is considered to be fractionation crystallization in situ (Vilinovič & Petrík 1984; Cambel et al. 1985; Jacko & Petrík 1987); the crystallization of allanite would be then the result of compatible behaviour of LREE in granitoid melt. Allanite becomes a part of cumulate as one of the first crystallizing minerals, contributing thus substantially to the control of the general distribution of LREE (Gromet & Silver 1983). The capture of LREE in the structure of allanite leads to the decrease of the contents of LREE in residual melts, which not only causes a decrease of LREE concentration in peripheral parts of allanite, but it can result in the growth of epidote around allanite in the concluding phase of crystallization (Broska 1986).

Since allanite and monazite behave antagonistically, allanite and monazite should have different theoretical levels of LREE saturation, depending on many factors, but probably very strongly on temperature. We assume this because of the fact that allanite in tonalites is associated with higher-temperature zircon (Fig. 3).

Initial LREE concentrations in basic melts at first increase, i. e. rare earth elements behave incompatibly (Miller and Mittlefehldt 1982).

The reaching of allanite saturation level in felsic melts is manifested by the crystallization of allanite in considerable quantitites in earlier differentiates. Theoretically the fractionation of allanite is accompanied by a decrease of light REE contents, as well as of the temperature of the melt, whereas the precipitation of allanite decreases continually. With further temperature decrease, allanite becomes unstable, monazite, on the contrary, becomes more stable and acquires the function of principal REE concentrator (Petrík and Broska 1985; Fig. 5). This could have occurred in felsic melts of the Western Carpathians at I. $\bar{T}$ zircon parameter cca 350 (about 650–700 *°C*) and about 100 *ppm* of total LREE contents (Figs. 6, 7). Our theoretical model is not always applicable in the whole range of saturation curve in the Western Carpathians because in reality LREE mineral fractionation can start from any point of theoretical level of allanite-monazite saturation. We assume that in the most cases allanite and monazite granitoid types have different starting points on the saturation curve and thus also their evolution this granitoids are different. Experimental data which could support our observations are incomplete. So far, only data on monazite saturation in felsic melts are available (Rapp and Watson 1986; Montel 1986), there are no data on allanites.

The differences in the participation of zircon types and subtypes in allanite and monazite granites are represented by a summary typogram where all typological analyses have been

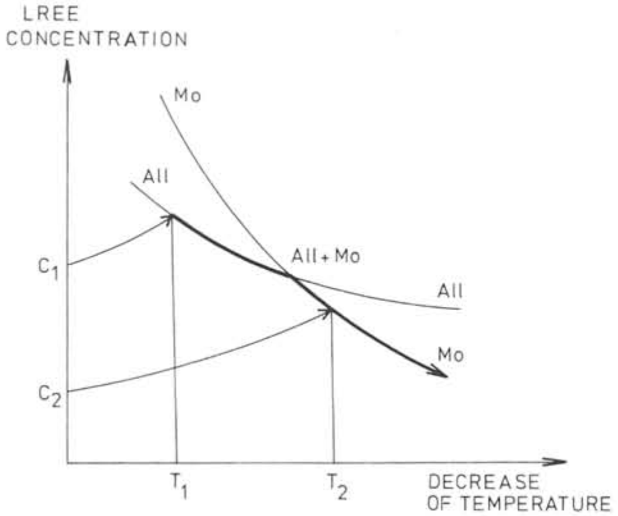

Fig. 5. Schematic illustration of the relationship between temperature of granite melt and saturation interval of allanite and monazite. Model suggested for Western Carpathian granitoids (Petrík & Broska 1985, after Miller & Mittlefehldt 1982).
Mo – monazite, All – allanite, T_1 – assumed temperature of the beginning of allanite crystallization, T_2 – assumed temperature of the beginning of monazite crystallization, C_1 – initial LREE concentration at allanite saturation, C_2 – initial LREE concentration at monazite saturation.

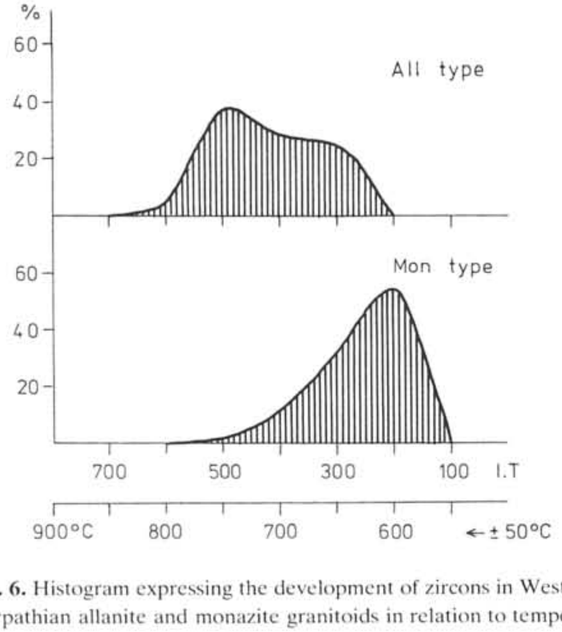

Fig. 6. Histogram expressing the development of zircons in Western Carpathian allanite and monazite granitoids in relation to temperature.

plotted (Fig. 8). The typograms clearly indicate that in allanite granitoids of the Western Carpathians the zircon mean point plots into the field of the subtype S_{12}, in monazite granitoids into the fields of the subtypes L_1-S_1 to L_2-S_2. Typological evolution trends, obtained by a projection of average I. $\overline{T}$ values into summary typograms (T.E.T. 2, Pupin 1976) of allanite and monazite granitoids, are parallel, which is an evidence of similarity of source rocks of the granitoids (Fig. 9).

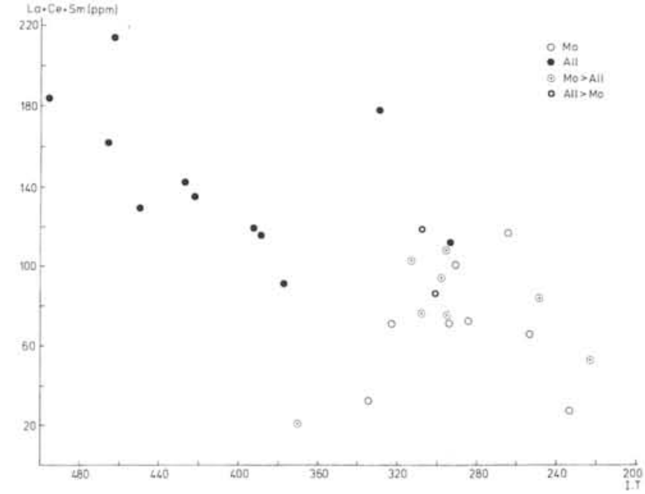

Fig. 7. Diagram of the relationship of LREE distribution in Western Carpathian granitoids and zircon typological parameter I. $\overline{T}$.

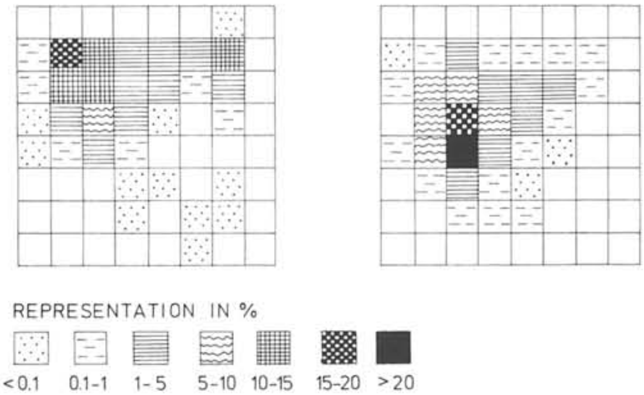

Fig. 8. Summary typograms for monazite (left, n = 43 samples) and allanite (right, n = 20 samples) granitoid type.

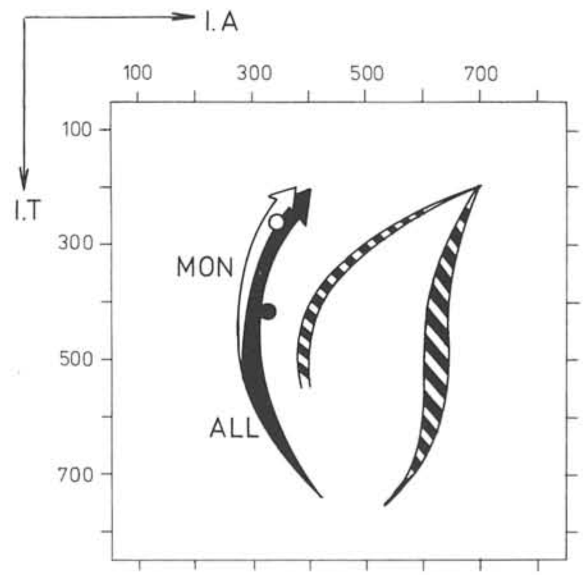

Fig. 9. Typological evolution trends (T.E.T. 2 – Pupin 1976) of Western Carpathian allanite (ALL), and monazite (MON) granitoids.
Full cirle – mean point of allanite granitoids, open circle – mean point of monazite granitoids.

Conclusions

Typological analysis of magmatic zircon from Western Carpathian Hercynian granitoid rocks yielded the following results:

1. Zircons from basic geotectonic units of the Western Carpathians indicate zoning of various Hercynian intrusions. Alkalinity and zircon crystallization temperature increases in the direction from outer arc of Central Western Carpathians inwards (Tatricum and Veporicum – Gemericum – Velence Mts.);

2. It appears that there is a relationship between the value of I. $\bar{T}$ parameter of zircon and the monazite-allanite antagonism in granitic magmas characterized by a prevalence of Ca over alkalies (granodiorite-trondhjemite type of magma in Tatricum and Veporicum of the Western Carpathians). More basic, less differentiated allanite granitoids crystallized at generally higher temperatures than more leucocratic and more differentiated monazite granitoids. We assume that in the most cases the allanite and monazite granitoids are magmatic bodies with different evolution.

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