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PETROCHEMISTRY AND GEOCHEMISTRY OF SELECTED GRANITOID SAMPLES FROM THE WEST CARPATHIAN REGION

(Figs. 20, Tab. 1)

Abstract: The authors have evaluated 120 petrochemical and geochemical analyses of granitoid samples from a set denoted by the symbol „ZK" (according to the Slovak name of the mountain range). The integrated genetic, petrochemical and geochemical characteristics of the selected samples of Variscan granitoids should serve as a basis for correlation with analogous rock samples from different parts of Czechoslovakia and from abroad. The integrated study of the „ZK" set of samples is conducted by about ten members of a research team at the Geological Institute of the Slovak Academy of Sciences and at the Faculty of Sciences, Comenius University, using a uniform working procedure. Since the West Carpathian granitoids do not show a great scatter of the values of element contents, they can be regarded as belonging to one formation, except for the granites of the Gemerides. The rocks were formed by anatexis of mixed sedimentary (clayey-siliceous) and magmatic (tholeiitic) rocks, which places them in types „I" and „S" of Chappel—White classification scheme (1977). Investigations have shown that the palingenic granitoid magma was subject to fractional crystallization. The primary material of anatexites might have been Palaeozoic shales formed of detritus and residual material of the Precambrian platforms. Endogenic activity manifested by Variscan granite plutonism was caused by orogenic processes towards the end of the Devonian and in the Early Carboniferous. This orogeny led to the contraction of the sea (mobile geosynclinal zone), which extended between the North and South European continents.

The results presented in this paper form a part of the studies that should enable a correlation of analogous granitoid complexes at an international scale.

Резюме: Авторы петрологически и геохимически определили 120 анализ проб гранитоидов из набора обозначаемого символом „ЗК" (пробы Западных Карпат). В работе констатируется, что рассеивание величин содержаний элементов в западнокарпатских гранитоидах не большое, поэтому кроме гемеридных гранитов Западных Карпат их можно считать гранитоидами входящими в единую формацию. Породы возникли анатексисом смешанных осадочных (глинисто-кремнистых и магматических толеитовых) пород, и поэтому они относятся к „И" и „С" типам согласно классификации Чепела Уайта (1977). Исследования доказывают, что палингенетическая гранитоидная магма была подвергнута кристаллизационной дифференциации. Источником анатексиса могли быть и сланцы палеозойского возраста составляемые детритом и остаточным материалом докембрийских платформ. Причиной эндогенной активности проявившейся варисским гранитным плутонизмом были орогенические процессы в конце девона и в нижнем карбоне ведущие к сжатию моря (мобильной геосинклинальной зоны), простиравшейся между североевропейским и южноевропейским континентами.

Результаты являются составной частью работ, которые сделают возможным международную корреляцию аналогичных комплексов гранитоидов и вне ЧССР.

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The interest in granitoids, metamorphites and crystalline rocks in general is recently steadily increasing. Our attempt to throw light on the problems related to the granitoids in the West Carpathian region is based on integrated investigation of selected granitoid samples which we labelled as „ZK" samples (according to the Slovak name of the mountain range). The rock samples to be analysed were selected by Academician B. Cambel, DrSc. and RNDr. L. Kamenický. It can be assumed that our investigations have already brought responses to some questions. It appears, however, that every more detailed research reveals further gaps in our knowledge and many universally accepted opinions have often to be re-evaluated. Consequently, the interpretation of the results needs still to issue from frequently contradictory opinions and hypotheses.

Integrated evaluation of the selected („ZK") samples of the West Carpathian granitoids has the advantage that the scatter of analytical results, is reduced to minimum, which may be considerable when analyses are made by different people in different laboratories and at different time. Planimetric evaluations were also performed by a uniform method introduced by RNDr. Macek, CSc.; planimetric analyses were made by RNDr. J. Macek, CSc., RNDr. I. Petrík and J. Bezáková (Macek et al., 1979). Silicate analyses were made by Ing. E. Walzel, spectrometric analyses by RNDr. J. Medveď, CSc., (Medveď in Cambel — Medveď, 1981), and atomic absorption analyses by Ing. E. Martíny, CSc. Uranium and thorium contents were determined by RNDr. V. Kátlovský, CSc. (Kátlovský, 1981) and rare earths (TR) were determined in the Geol. Institute in Kutná Hora. The feldspars were studied by RNDr. J. Macek and RNDr. Ľ. Vilinovičová (Macek in Macek — Kamenický, 1979) and RNDr. Vilinovičová (Macek — Vilinovičová, in print); accessory minerals by Doc. RNDr. J. Veselský, CSc. and RNDr. J. Gbelský, CSc. (Veselský — Gbelský, 1978) and RNDr. J. Kráľ, CSc. (Kráľ, 1977, 1981); and the micas by RNDr. Petrík (Petrík, 1980). RNDr. M. Dyda (1980) and RNDr. I. Petrík (1980) studied the thermodynamic conditions of the generation of minerals. Classification of the West Carpathian granitoids on the basis of international IUGS system was developed by Macek — Petrík (Macek et al., 1979), and on the basis of mesonorm by Vilinovič et al. (in prep.). Geochronological problems were dealt with by B. Cambel, DrSc., J. Veselský, CSc., G. P. Bagdasarjan and R. Ch. Gukasjan (1980). This uniform treatment and evaluation of 120 „ZK" samples thus provides a set of standard data which will make possible a correlation with existing knowledge and with information to be obtained in the future as well. This integrated approach guarantees a documentation, standardization and correlation significance of our studies.

One of the questions that have not yet been answered satisfactorily concerns, for example, the time intervals and spaces in which the Variscan

Explanation of Table 1: Contents of trace elements in the granitoids of different geochemical types. Table taken from Tauson, 1977, modified. Types 1 to 4 are to be considered as extreme acid types of basaltoid series; the other types were products of palingenic remelting of crustal material. On the basis of element contents the West Carpathian Variscan granitoids approach types 3, 5, 6 and 9.

Table 1

Contents of the trace elements in granieoids of different geochemical types

	Elements	1 Plagiogranites of tholeiite series	2 Granitoids of andesite series	3 Granites of lathite series	4 Agpaite rare-metalic granites	5 Palingenetic granites of calc-alkaline series	6 Plumasite rare-metalic leuco-granites	7 Palingenetic granitoids of alkaline series	8 Rare-metalic granitoids	9 Ultrametamorphic granites	10 Average granite (according to A. P. Vinogradov)
in %	K	0.3	2.0	3.5	3.6	3.3	3.9	4.1	3.8	4.6	3.3
	Na	3.1	3.0	3.4	4.0	2.8	2.8	2.5	3.1	2.3	2.8
	F	0,015	0.07	0.06	0.20	0.08	0.27	0.05	0.09	0.018	0.08
in ppm	B	—	—	23	—	22	27	—	—	—	15
	Li	4.7	18	21	104	50	180	27	52	11	40
	Rb	2.6	100	125	270	175	440	140	270	140	200
	Cs	—	—	—	(1.9)	—	(17.5)	—	—	—	5
	Tl	—	—	1.0	(1.7)	0.9	2.9	0.9	—		15
	Be	0.5	1.5	2.2	11.8	2.0	8.8	2.8	4.8	0.6	5.5
	Sr	139	260	700	12	330	70	650	170	280	300
	Ba	57	550	1700	40	830	175	1550	500	2800	830
	Sn	2.7	2	5	17.7	6.2	22	3.8	5.7	2.8	3
	W	—	—	3.0	—	2.5	8.4	(1.7)	2.1	—	1.5
	Mo	—	1	1.7	—	1.1	1.5	1.5	1.8	1.2	1
	Pb	2.8	10	23	46	27	28	19	20	(14)	20
	Zn	75	43	70	390	51	40	64	43	(43)	60
	Nb	2.4	8	—	320	19	33	22	—	—	20
	Ta	0.4	0.4	—	18.5	(2.9)	7	(1.4)	—	—	3.5
	Zr	89	115	—	2170	190	140	(410)	—	90	200
	Hf	3	4	—	63	—	9	—	—	—	1
	TR + Y	—	135	—	—	330	(350)	480+	—	—	190
	Ga	17	—	—	(27)	17	(23)	—	—	—	20
	V	61	85	45	(2)	(21)	(11)	24	—	9	40
	Cr	—	—	14	—	(38)	(4)	18	—	6	25
	Ni	7.2	15	7	(10)	(17)	(3)	7	—	4	8
	Co	7.1	13	3	—	(11)	—	8	—	3	5
	Cu	1.5	40	8	—	(23)	—	11	—	(17)	20
	K/Rb	1080	200	280	133	200	90	300	140	330	160
	Ba/Rb	22	5.5	14	0.15	5	0.4	11	1.9	20	4.2

intrusive activity occurred in the West Carpathian region. We do not know when the anatectic and palingenic processes had begun and how long periods elapsed between the intrusive phases depending on the overall development and local conditions of the Variscan orogeny. The recognition of the interrelationships between the granitoids is complicated by the Alpine orogeny, which might have separated genetically allied complexes and, on the

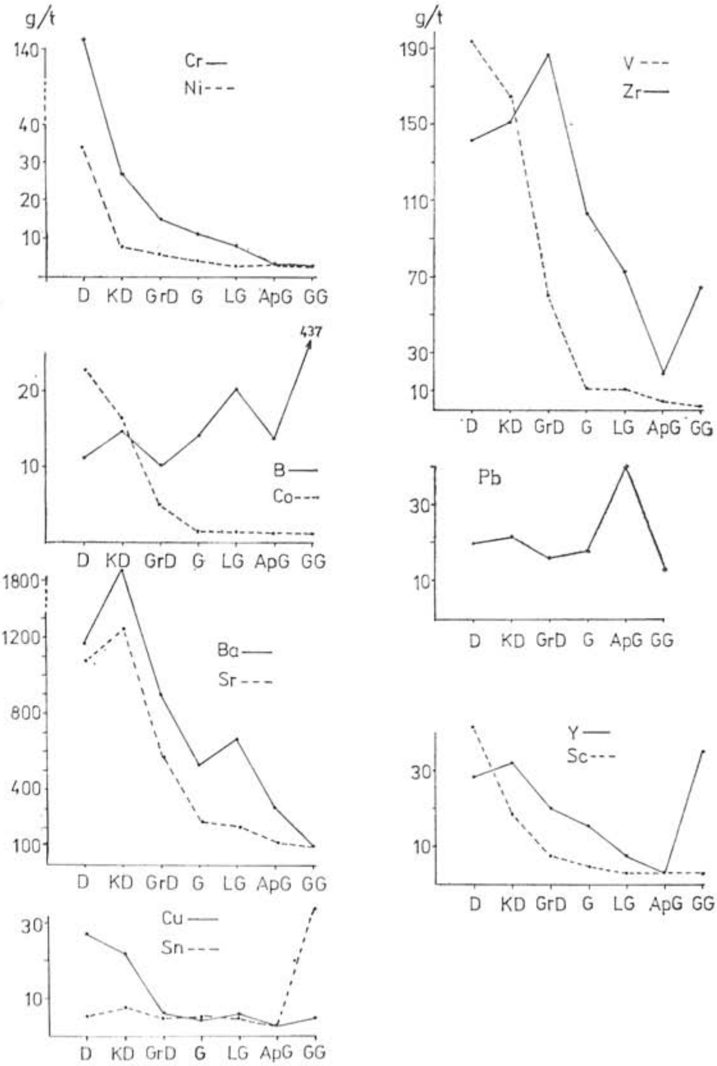


Fig. 1. Graph showing the changes in microelement contents in the granitoids, arranged according to the decreasing basicity of the rocks. D — diorite, KD — quartz diorite; GrD — granodiorite; G — granite; LG — leucocratic granite; ApG — aplitic granitoids; Gemeride granitoids.

contrary, to unite the complexes differing in genesis or phasal development. The adverse topographical conditions (a thick mantle of debris and overburden) do not allow us to divide the granitoid complex with a satisfactory reliability on the basis of the shapes of intrusions, of their separate position in the present-day relief, or of their relations at the contacts. A hierarchy of regional geological granitoid units, such as was established for the Bohemian Massif by RNDr. K l o m í n s k ý, CSc. (report submitted at the Confe-

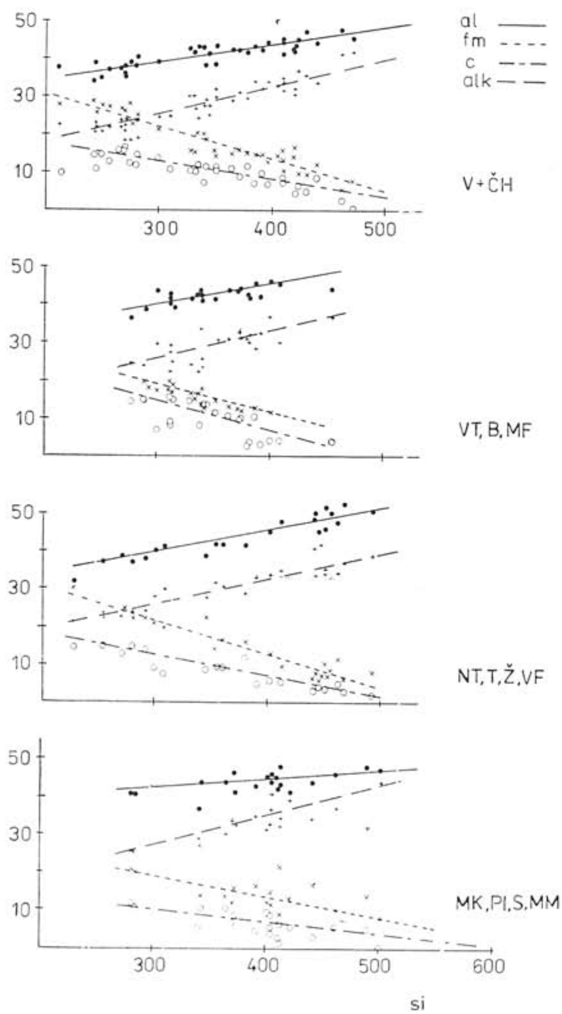


Fig. 2. Relationship between N i g g l i's values al, fm, c, alk and si. MK, PI, S, MM — Malé Karpaty, Považský Inovec, Suchý, Malá Magura; NT,T,Ž,VF — Nízke Tatry, Tribeč, Žiar, Veľká Fatra; VT,B,MF — Vysoké Tatry, Branisko, Malá Fatra; V + CH — Veporides + Čierna Hora. The graph shows the parallelism of the principal lines of Niggli's values in the individual mountain groups, which implies a close similarity of differentiation trends.

rence), has not yet been set up. It is often impossible to determine the time sequence of the individual intrusive types and their genetic interrelations. Distinct sharp contacts are particularly difficult to find between the fundamental granitoid types, i.e. the muscovite—biotite and biotite granitoids; it appears, in contrast, that there are gradual transitions between them. The graphical representation of petrochemical and geochemical data shows the overlapping of the fields of biotite and muscovite-biotite granitoids (granite and granodiorite). Opinions also differ on the origin of porphyritic granitoids and/or different fine-grained rock types.

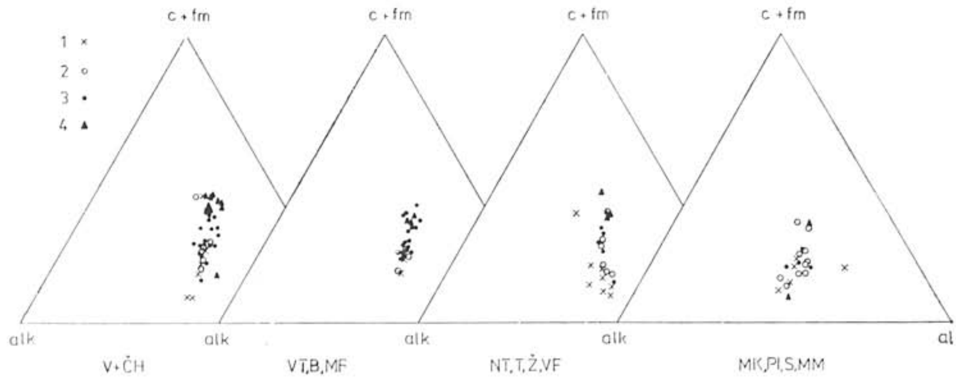


Fig. 3. Diagram of N i g g l i's values c+fm—alk—al. 1 — leucocratic granitoids; 2 — muscovite-biotite granitoids; 3 — biotite granitoids; 4 — tonalites. For other explanation see Fig. 2.

We have recently begun to use the I/S classification of rocks as a suitable discrimination method. This classification scheme permits to divide the rocks according to the primary material of the palingenic granitoids: whether they were formed (at least in part) by anatexis of eruptive (mainly basic) rocks, or of sedimentary clayey—siliceous shales, and which was the proportion of these two components in the autochthonous region of anatexis. For the formation of the „I" types of crustal granitoids a direct influence of magma of basic or other composition may be taken into consideration. The discrimination of „I" and „S" granitoid types was elaborated by C h a p p e l l and W h i t e (1974) on the basis of microelement contents in the granitoids. T a u s o n (1977) who used a similar classification assumes a direct formation of acid rocks differentiation of basic magma (T a u s o n, 1977, Table 1). The first four types of granitoid rocks originated as final acid members of the basaltoid magma and further types are products of palingenic remelting of crustal matter.

The I/S classification method was already used for the granitoids of the Bohemian Massif, the West Carpathians and the Caucasus by K l o m í n s k ý, P a l i v c o v á, C a m b e l, G u r b a n o v (1981). The method brought interesting results, even if they are not quite consistent, depending on the elements whose ratios are applied to classification. According to the paper just mentioned (K l o m í n s k ý et al.), the application of ACF diagrams has shown that in every mountain range of the West Carpathians there are both „I" and „S" granitoid types; the „I" types predominate in the West Carpathian region, whereas „S" types are dominant among the Variscan granitoids of the Bohemian Massif and the central Caucasus. The I/S classification has revealed that the difference between the basic and leucocratic granitoids may be primary, resulting from the original nature of the rocks assimilated, although the petrochemistry of rocks and the succession of intrusions were greatly affected by differentiation processes of the palingenic magma.

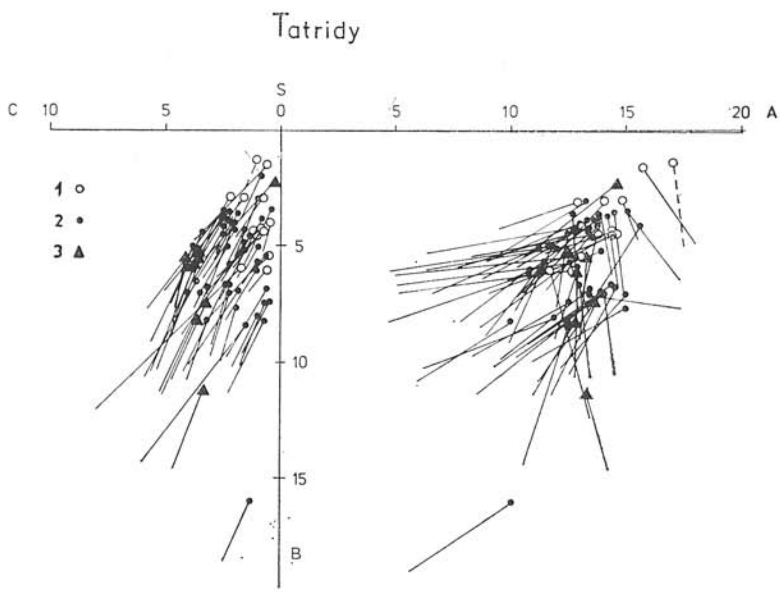


Fig. 4 a.

The differences in geochronological dating and complexity of intepretation of radiometric K/Ar data make is necessary to check the results obtained by K/Ar method against other (Rb/Sr and U-Th-Pb) methods. The data available suggest that the West Carpathian granitoids are of late Variscan age, and since the accumulation of energy and thermal flow began already before the Variscan orogeny, towards the end of the Silurian and in the Early Devonian, the process may be denoted as Caledonian—Variscan. The intrusive activity itself occurred in the late orogenic phase (until the Middle Carboniferous) and even in the postorogenic period in the Permian. The estimated duration of the Variscan orogeny of nearly 100 milion years (between 350—260 Ma) is a long but acceptable period of magmatic activity, particularly if the youngest leucocratic granitoids are thought to be late Variscan (Permian). This idea has been substantiated by the meast recent study of the Gemeride granites.

The question remains how such a low petrochemical and chemical variability of the West Carpathian granitoids can be reconciled with so long-last-ing plutonism. This fact, after all, points to the late orogenic character of the granitoids. It thus appears that the dispersion of age values, particularly those provided by the K/Ar method, are due to other than time factors and, consequently, that all data giving high ages of the rocks cannot be regarded as authoritative. A plausible explanation is that the manifestations of granite plutonism were associated with the thickening of the earth's crust produced by overthrusts of sedimentary complexes during the Variscan orogeny (towards the end of the Devonian). An analogous process is assumed by D. F. Strong (1980) for the New Foundland region (eastern Canada) and

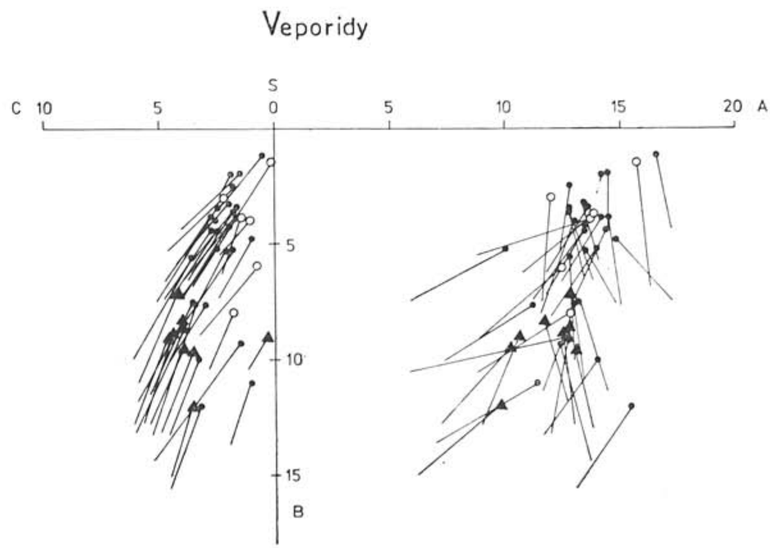


Fig. 4 b.

for West Europe. If we accept the palynological data indicating the Palaeozoic age of the West Carpathian rocks as conclusive, we have to correct the present geotectonic opinions that only the Precambrian rocks may have been the preexisting rocks af the granitoid magma. The most recent studies have confirmed that granitoid intrusions penetrated into Palaeozoic shale complexes which they altered to different degrees and assimilated them.

An attempt should be made to develop such a geotectonic model that would lay stress on the existence of the Palaeozoic and also Upper Precambrian shale complexes, substantiated by palynology, in the present-day relief. These Palaeozoic shales, which contained a large amount of clasts from Precambrian rocks, were an important source of material for Variscan granitoids and metamorphites. We need a deeper insight into the problem concerning the sedimentary complexes of the so-called Central European (pre-Variscan) sea (Patočka in Cambel — Patočka, 1980), and a better knowledge of the origin and character of sediments in the mobile zones and sutures along the margins of the platforms and in the geosyncline intervening between the North European and South European (North African) continents. The waning of the pre-Variscan sea and the crumpling of geosynclinal sediments at the end of the Devonian, and the supply of thermal energy induced the Variscan plutonism connected with intensive folding movements and intrusions of Variscan granitoids. The scheme of the evolution history of the West Carpathian Crystalline postulating only the destruction of emerged Precambrian complexes and total absence of sedimentation in the period between the Assyntian (Baikalian) orogeny and the Late Devonian — Carboniferous, needs to be re-appraised.

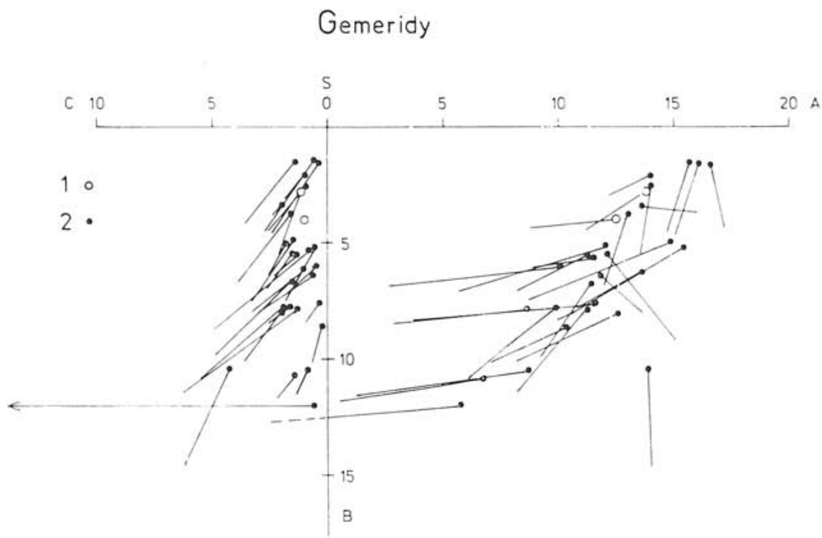


Fig. 4 a,b,c. Graphical representation of Z a v a r i c k i j's values. 1 — leucocratic granitoids; 2 — muscovite-biotite granitoids and biotite granitoids; 3 — tonalites. Most of the samples belong to rocks oversaturated with Al. Graph 4 c also contains values of the Gemeride granitoids, taken from H o v o r k a's catalogue (H o v o r k a, 1972).

Let us return to the significance of petrochemical and geochemical analytical results obtained on the set of „ZK“ granitoid samples for a genetic interpretation. This material, graphically elaborated by RNDr. V i l i n o v i č o v á, is particularly interesting by a small variability of element contents and a considerable chemical uniformity of granitoid rocks derived from single mountain ranges or their groups, or even larger units, such as the Tatrides or Veporides.

Similar changes in contents and a small scatter of values have also been assessed for the microelements in the West Carpathian granitoids (C a m b e l — M e d v e ď, 1981). The gradual decrease in the contents of individual microelements, which occurs in agreement with the postulates of fractional crystalization, confirms the existence of this process in the intrusive granitoids of the West Carpathians. Fig. 1, for example, shows the changes in the microelement contents with decreasing basicity. The regular course of the decrease indicates that the Variscan granitoids can be included in one formation except for the late Variscan (posttectonic, i.e. Neoidic) granitoids of the Spišsko-gemerské rudohorie Mts., which can be placed in a separate formation. Variscan plutonism is characterized by high Ba and Sr contents, a frequent predominance of Na over K, deficiency in Be, Sn, F, Cu and light rare earths (TR), particularly when compared with the Neoidic granites of the Gemerides, which show opposite trends.

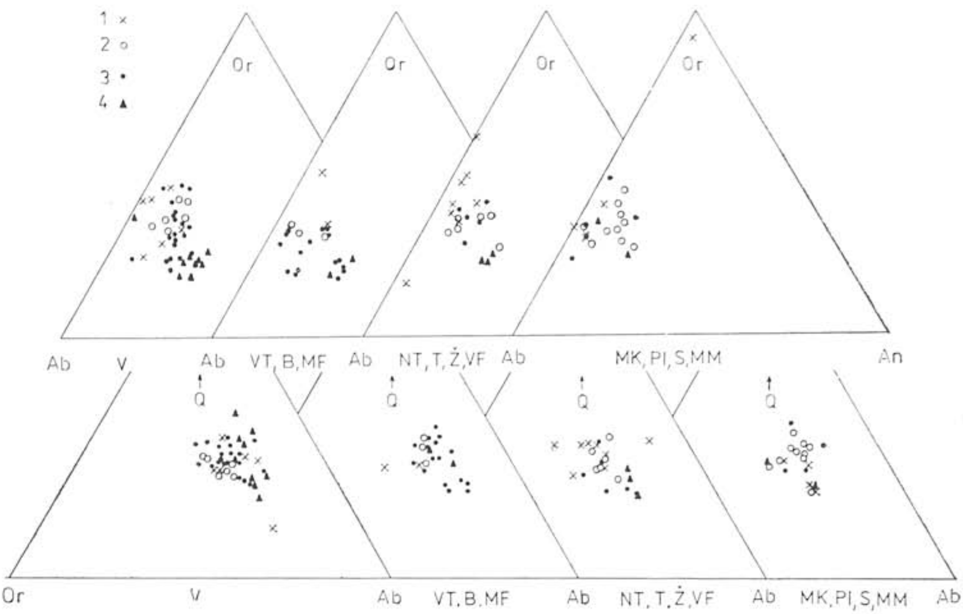


Fig. 5 a, b. Ternary diagrams Or-Ab-An and Q-Or-Ab. For explanation see Fig. 3.

With the overall geochemical uniformity of the magma of Variscan granitoids, the greatest differences in the contents of elements are caused by different basicity of rocks, and the degree of differentation or of anatectic remelting or homogenization of palingenic magma. The Variscan granitoids of higher basicity possess increased contents of microelements from the Fe group (Ni, Co, Sc, V, Cr) and of rare earths (TR) relative to the leucocratic types. According to T a u s o n (op. cit. 1977, Table 1), the elements K, Na, F, microelements Ba, Sr, Zr, TR and the K/Rb and Ba/Rb ratios are of discrimination significance (see Table 1 of this paper).

On the basis of the contents of trace elements and chemistry of the rocks the Variscan granitoids of the West Carpathian Mts. vary (in the sense of this classification) within the limits of granites of the latite type, which are believed to be differentiation products of the basaltoid series of the tholeiitic, calc-alkaline group (type 3 in Table 1), and of palingenic granites of calc-alkaline group (type 5). An extreme member to which sporadic rocks approach is the type of ultrametamorphic granitoids (type 9). These two last types are palingenic rocks of crustal sedimentary origin. After Tauson's classification the Gemeride granitoids correspond to plumasite leucogranites having an increased content of rare metals.

It is of interest that the granitoids of the West Carpathians display such a small scatter of the contents both of macro- and microelements despite their formation under the intricate folding process of the pre-Variscan geosyncline, and marine sediments, accompanied by granite intrusions into the shales being folded and metamorphosed. Petrographical studies (M a c e k,

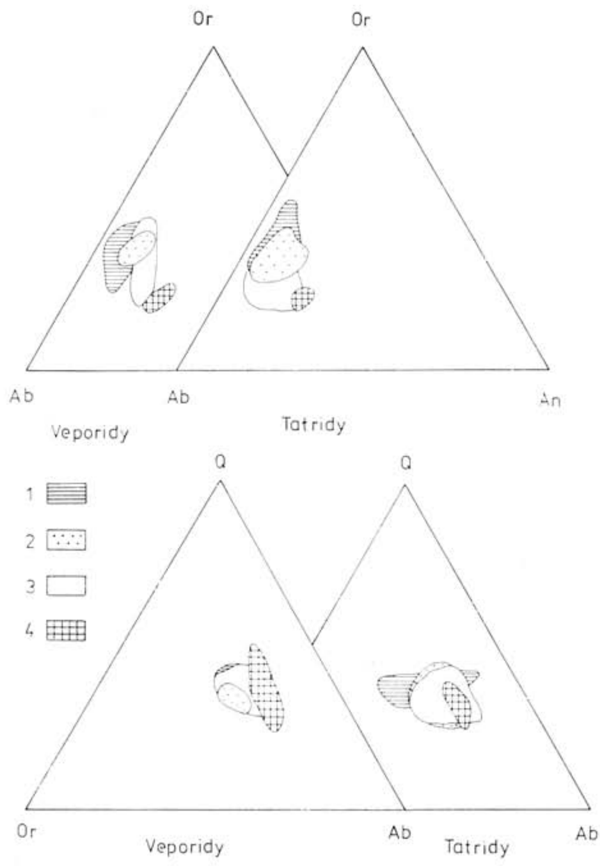


Fig. 6. Summary ternary diagrams Or-Ab-An and Q-Or-Ab. 1 — leucocratic granitoids; 2 — muscovite-biotite granitoids; 3 — biotite granitoids; 4 — tonalites. CIPW classification.

in print) issuing from various populations (generations) of minerals reveal a considerable variance and discontinuity of intrusive activity and interrupted consolidation of magma. The character of the granitoid rocks corresponds obviously with the pulsative and non-uniform folding process in time and space, and with the unstable supply of substances and thermal energy in the individual parts of the region. We are still facing the task to shed light on the problem of the folding of the Palaeozoic geosyncline and on its association with magmatism. A close association of intrusive activity with tectonics and metamorphism has already been mentioned by M a h e ľ (M a h e ľ, 1979).

Petrochemistry and geochemistry of the granitoids

The petrochemical classification of the West Carpathian granitoid rocks is based on 112 silicate analyses and was developed on the principles established on the basis of Streckeisen's proposal (IUGS, S t r e c k e i s e n, 1973). According to this scheme the granitoid rocks have been divided into the following groups:

1. Leucogranitoids — leucogranite / leucogranodiorite

2 Muscovite-biotite granitoids — muscovite-biotite granite / muscovite-biotite granodiorite

3. Biotite granitoids — biotite granite / biotite granodiorite

4. Tonalites — leucotonalite / biotite tonalite

The rocks analysed were collected into four regional groups. The first group involves the rocks from the Malé Karpaty, Považský Inovec, Suchý and Malá Magura mountain ranges (MK, PI, S, MM); the second group comprises the rocks of the Nízke Tatry (Low Tatra), Tríbeč, Žiar and Veľká Fatra Mts. (NT, T, Ž, VF); the rocks from the Vysoké Tatry (High Tatra), Branisko and Malá Fatra (VT, B, MF) are classed with the third group, and those from the Veporides and Čierna hora (V + ČH) with the fourth group. Correlations are made between some major units as, e.g. the Tatrides (T) and the Veporides (V).

To obtain a perfect overview of the distribution and petrochemical relationships between the individual types we have calculated the CIPW, Niggli and Zavarickij values. In addition, graphic representations of relations of some oxides were prepared on the basis of chemical analyses, such as: $Na_2O + K_2O - SiO_2$, $K_2O/Na_2O - CaO$, $K_2O - Na_2O$, triangular diagrams F-A-M, $K_2O - CaO - Na_2O$, and Larsen variation diagram ($SiO_2/3 + K_2O - (CaO + MgO)$).

In the differentiation diagram of Niggli's al, fm, c and alk values and their relation to si, the tendency to differentiation of the granitoids studied is illustrated. From the diagrams (Fig. 2) it follows that the trends of these values are almost parallel in all regional groups. The al and alk values rise with increasing si and the fm and c values decrease. The si value generally ranges from 250 to 500. According to these values the „ZK" rock samples belong to the calc-alkaline series, either to leucogranite, granite or granodiorite and trondhjemite magma. Of 127 „ZK" samples, 55 % show derivation from the trondhjemite magma, 21 % from the leucogranite magma, 13 % from the granodiorite and 10 % from the granite magmas.

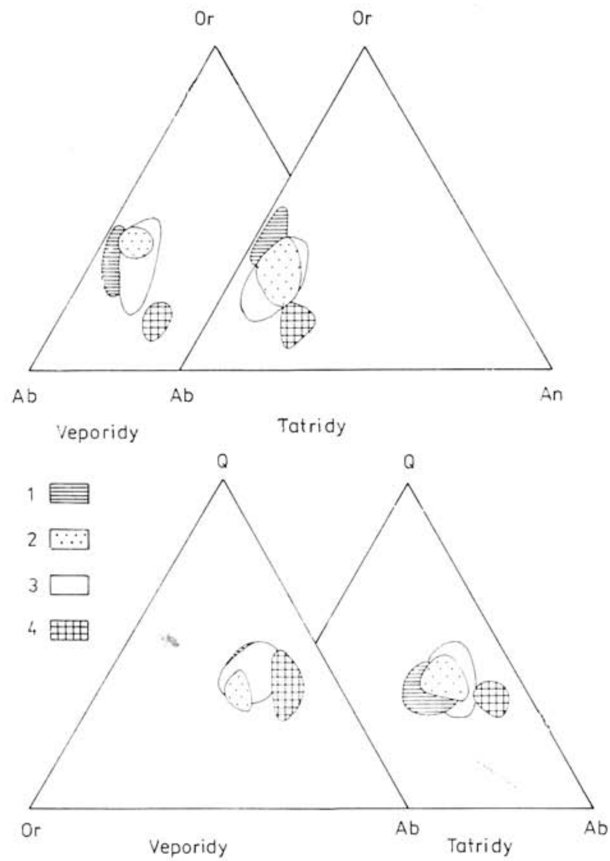


Fig. 7. Summary ternary diagrams Or-An-An and Q-Or-Ab. According to mesonorm classification. For explanation see Fig. 6.

In the c+fm—alk—al diagram (Figs. 3, 11) the differentiation of the rock types is more clearly defined. The c+fm distinctly rises from leucoratic granitoids towards tonalites but the overall distribution of the points over the area of the triangle is nearly identical for all regional groups. Only the rocks of the first group (MK, Pi, S, M) show a certain difference.

On the basis of Zavarickij's diagram (Fig. 4 a, b, c) the „ZK" samples correspond to the rocks of normal composition; they comply with the condition:

$$CaO + Na_2O + K_2O > Al_2O_3 > Na_2O + K_2O.$$

In addition, there is a group of rocks oversaturated with Al; for these it holds:

$$Al_2O_3 > CaO + Na_2O + K_2O.$$

Twenty-six per cent of rock samples analysed are of normal composition and 74 per cent are oversaturated with Al. This ratio is characteristic of the West Carpathian granitoids. The Na content in the granitoids of this mountain range is usually slightly higher or almost equal to the K content. These

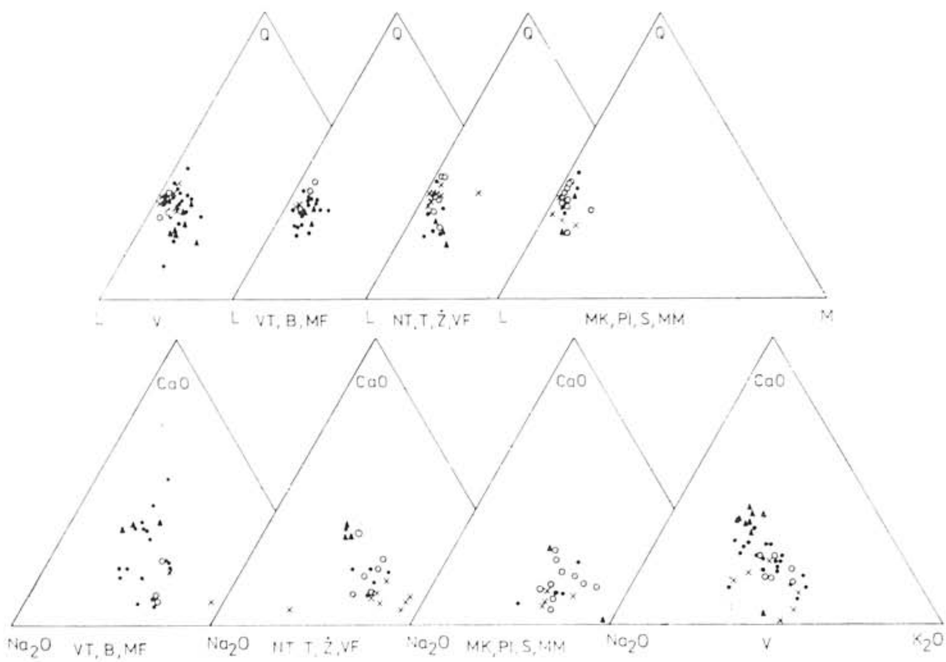


Fig. 8 a,b. Ternary graphs Q-L-M and CaO-Na_2O-K_2O. For explanation see Figs. 2 and 3.

relations are apparent from Figs. 13, 14b and 16b. The similarity of the Tatride and Veporide granitoids is also demonstrated by the last evaluation procedure.

The diagrams in Figs. 5, 6, 7 show the values recalculated as CIPW normative Or-Ab-An and Q-Or-Ab. The Or-Ab-An diagram (Fig. 5a) indicates that of all the rocks described the leucocratic granitoids have the largest amount or normative orthoclase, which is least abundant, on the other hand, in tonalites. Normative albite content increases in the group of biotite granitoids, and in tonalites the field recalculated to mesonorm (Fig. 7) is shifted nearer to the Ab-An connecting line relative to CIPW (Fig. 6). In the triangular Q-Or-Ab diagram the fields of the rock types overlap, mainly those of muscovite-biotite and biotite granitoids (Figs. 6, 7).

For comparison, analogous summary diagrams have been constructed for the Tatride and Veporide regions. According to the recalculation to mesonorm (Fig. 7) the position and overlap of the fields are nearly identical; the only difference is that the field of tonalites in the Q-Or-Ab triangle (Fig. 7) comes nearer to the Q-Ab line, and to the Ab-An line in the Q-Ab-An triangle. This shift is due to that in recalculation to mesonorm a part of potassium is used for normative biotite, whereas in recalculation to CIPW norms all potassium is used for the calculation of normative orthoclase.

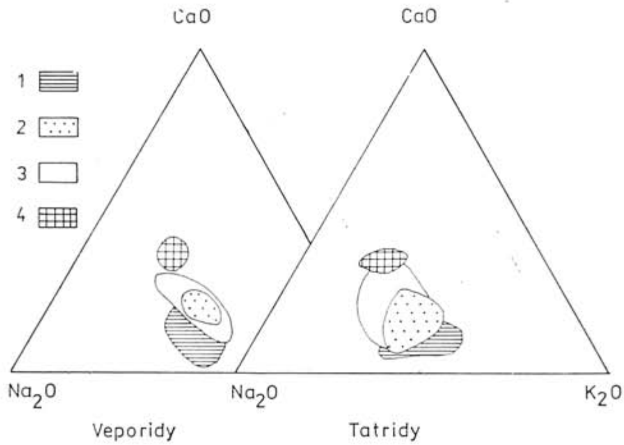


Fig. 9. Summary ternary CaO-Na_2O-K_2O graph for the granitoids of the Tatrides and Veporides. For explanation see Fig. 6.

Geochemical and petrochemical trends of the rock type development are illustrated in triangular F-A-M and K_2O—CaO—Na_2O diagrams, which demonstrate the share of fractional crystallization in the formation of the granitoids under study (Fig. 8 a, b). The diagrams reveal that the rocks belong to the alkalic and calc-alkalic association and that the position and scatter

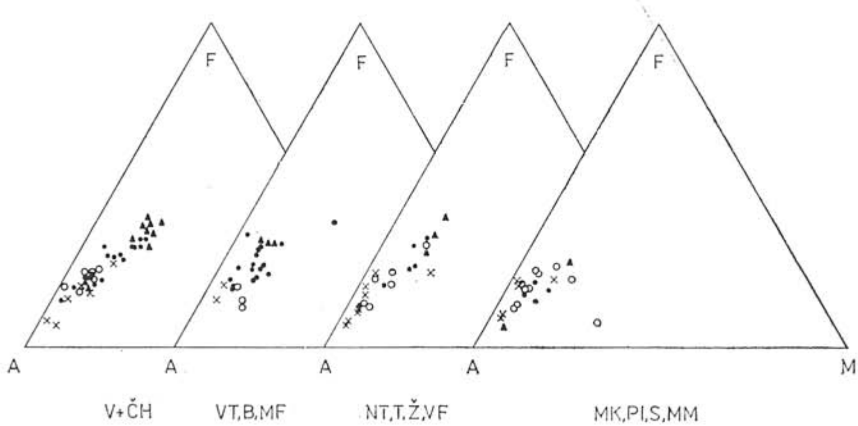


Fig. 10. Three-component F-A-M graph. For explanation see Figs. 2 and 3.

of the points is very similar. Tonalites (Fig. 8) are nearest to apex Ca. Graph 8a shows a considerable clustering of the points and their small differentiation according to the groups.

The summary $CaO-Na_2O-K_2O$ graph for the Tatride and Veporide granitoids (Fig. 9) confirms the overlapping of the fields, particularly of muscovite—biotite and biotite granitoids, and analogous distribution of the points of these rocks.

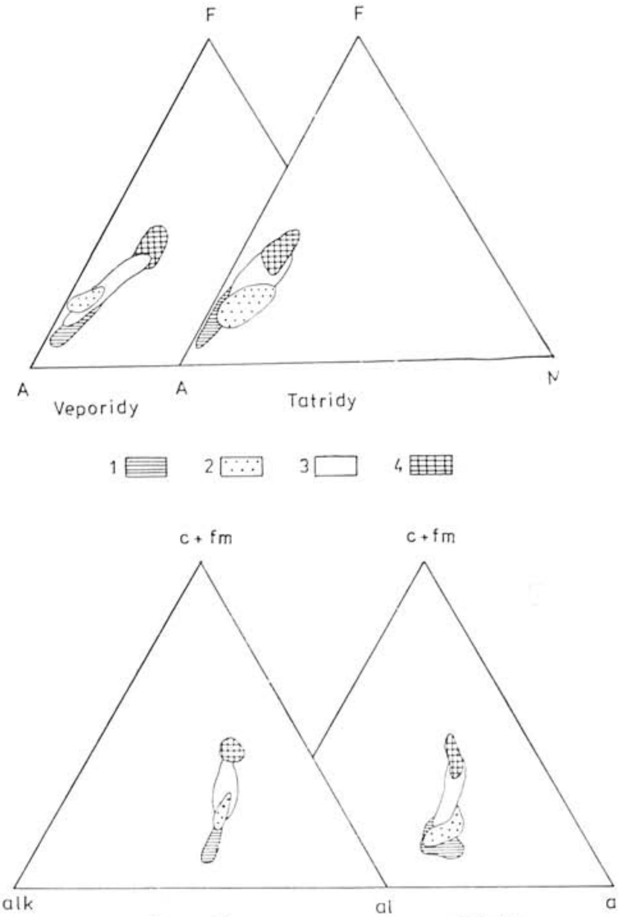


Fig. 11. Summary three-component graphs F-A-M and of Niggli's values c+fm—alk—al. For explanation see Fig. 6.

Figures 10 and 11 show most distinctly the differentiation trends and positions of the rock types in the graph. The Veporide and Tatride rock types display similar trends. The tonalite field is closest to F and C+fm apices.

The mode of magma differentiation, irrespective of its origin, is also characterized by correlation diagrams showing the relation between the oxide

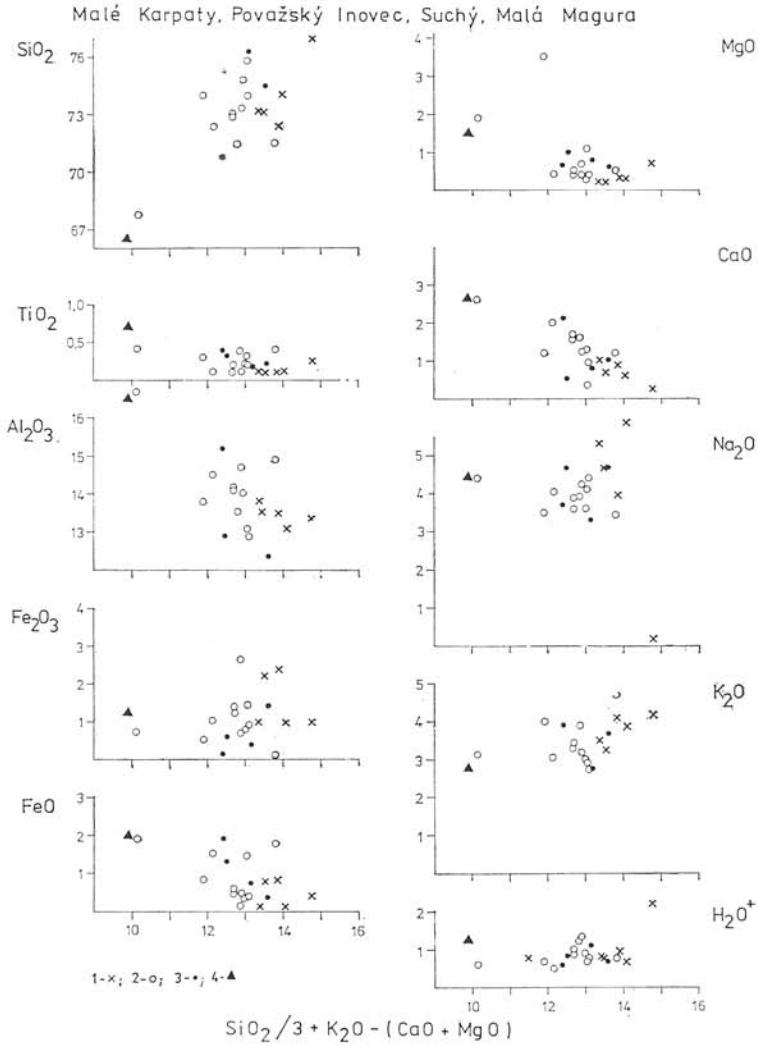


Fig. 12 a.

contents and the acidity of the rock — Larsen coefficient — $SiO_2/3$ + K_2O — $(MgO+CaO)$ (Fig. 12 a, b, c, d). According to these relations, the granitoids are distinguished by a normal differentiation trend. Proceeding from the tonalites towards granitoids SiO_2 and K_2O increase and TiO_2, Al_2O_3, FeO, MgO and CaO decrease in amount.

The relations between Na_2O, K_2O, SiO_2 and CaO for every regional group are plotted in diagrams, Figs. 13, 14, 15 and 16. The alkali content rises moderately from tonalites to leucocratic granitoids, depending on the SiO_2 content; the K_2O/Na_2O ratio increases slightly with the decrease in CaO, chiefly

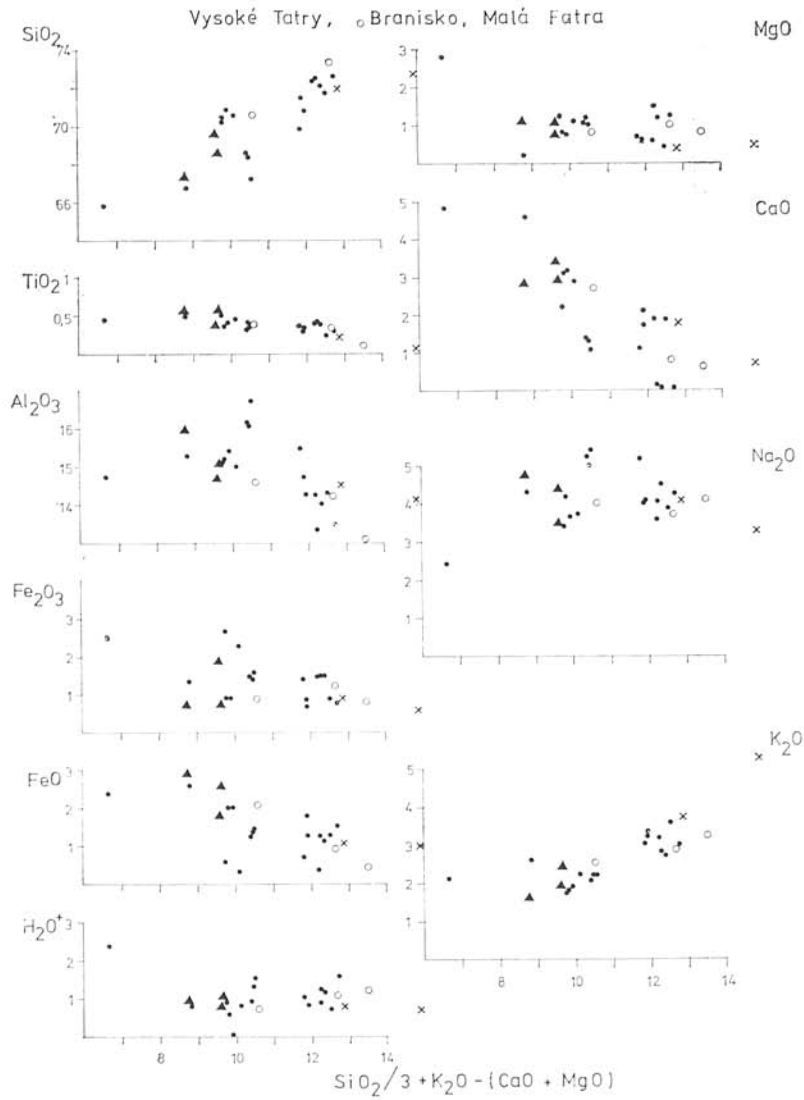


Fig. 12 b.

in leucocratic granitoids. The Na_2O content has an almost equal range in all granitoids and tonalites analysed, but K_2O rises definitely from tonalites towards leucocratic granitoids. The position and overlapping of the fields of individual rock types are well seen from summary correlation diagrams (Fig. 13). The overlapping is more pronounced in muscovite-biotite and biotite granitoids than in leucocratic granitoids and tonalites.

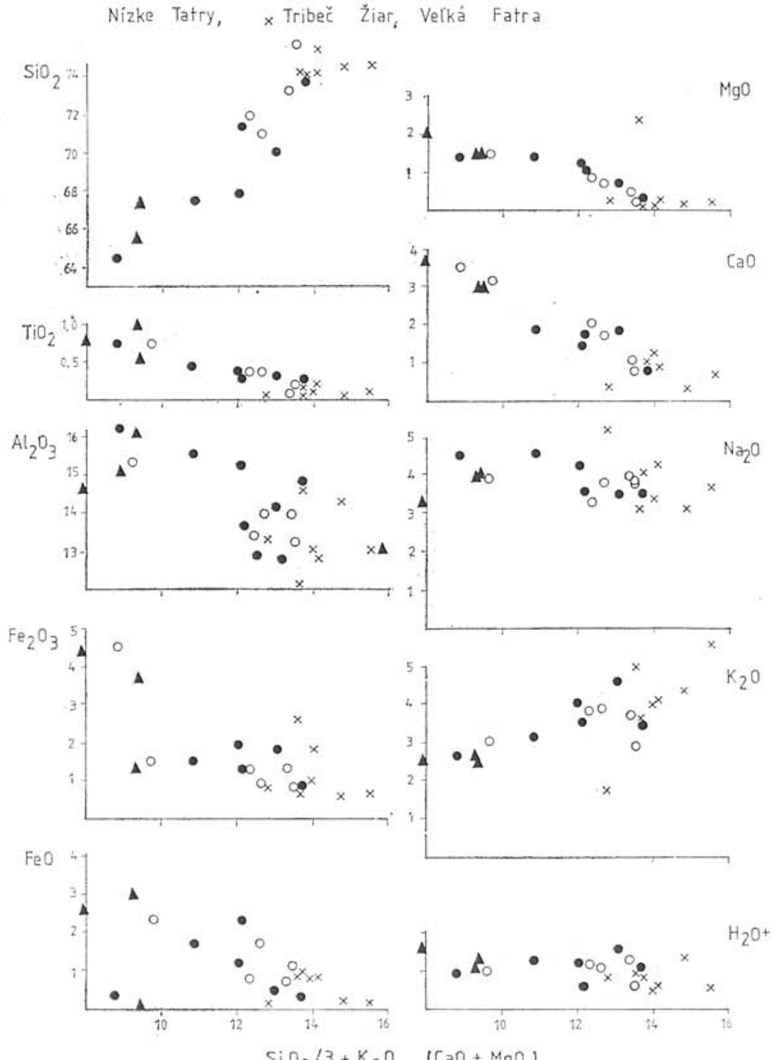


Fig. 12 c.

Histograms of the element contents for the Tatride region and Veporide region are in Figs. 17 and 18, respectively. Fig. 19 is a summary histogram of granitoids of the Tatro-Veporides. For regional groups the frequency curves of the macroelement contents have been constructed (Fig. 20). The frequency curves differ depending on the type of the rocks (leucocratic, muscovite-biotite and biotite granitoids and tonalites).

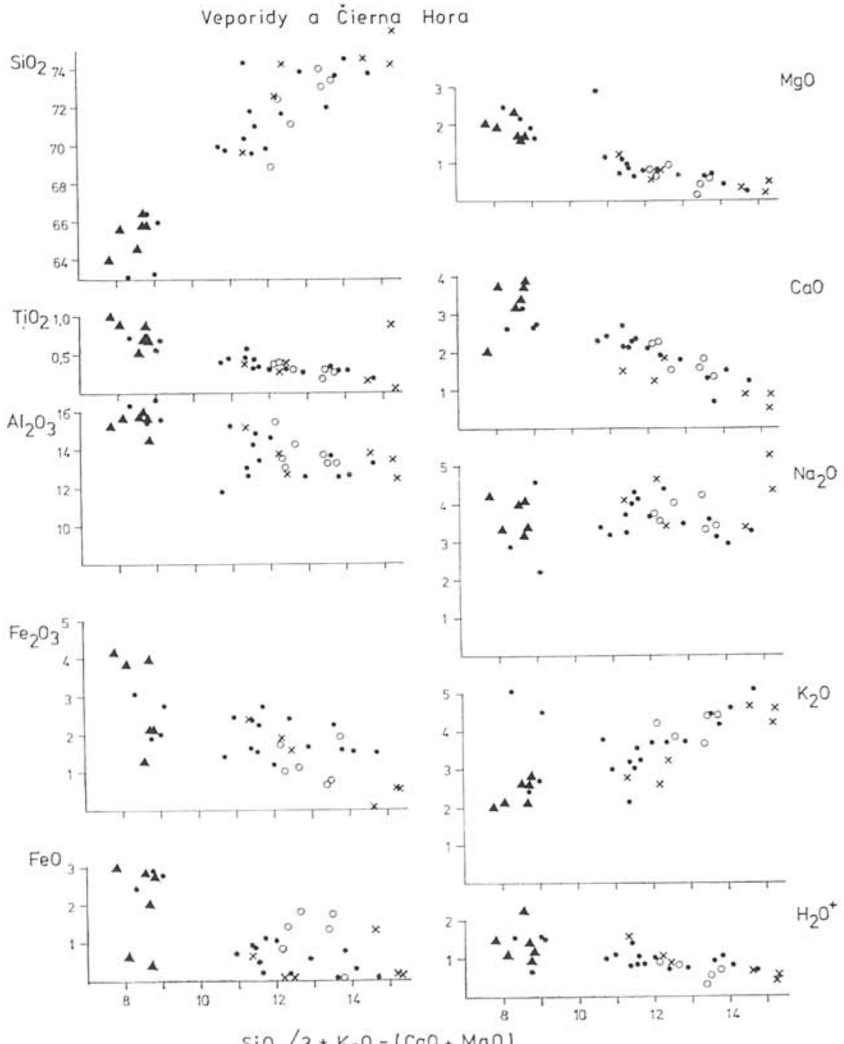
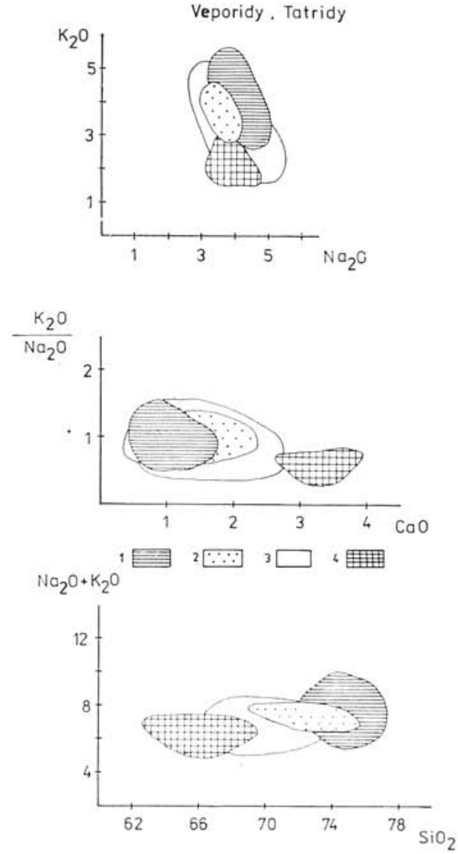


Fig. 12 a,b,c,d. Differentiation graphs of elements in dependence on Larsen's coefficient. Explanation of Fig. 12 a: 1 — leucocratic granitoids; 2 — muscovite-biotite granitoids; 3 — biotite granitoids (granodiorites); 4 — tonalites.

Conclusion

1. The authors present some considerations on the genesis of granitoid rocks, based on the study of a set of „ZK" granitoid samples of the West Carpathians. They think these rocks to be products of anatexis and palingenesis of crustal sedimentary complexes interspersed with different portions of basic tholeiitic volcanites. As a result of this derivation, the West Car-

Fig. 13. Summary graphs of Tatride and Veporide granitoids and of the ratios: K_2O/Na_2O, K_2O+Na_2O/CaO and K_2O+ $+ Na_2O/SIO_2$.



pathian granitoids display features of the „I"types as well as of „S" types or mixed „I+S" types of the Chappell-White's classification (1974). The assumed origin also agress with Tauson's classification scheme (1977) developed on the principle of the contents of microelements.

2. The authors admit the possibility that granite magma originated from the Palaeozoic rocks which consisted of the material derived from Precambrian platform complexes in mobile geosynclinal regions situated between the North European and South European (North African) continents. The waning of this sea followed by the thickening of the crust due to crumpling of shale complexes and translation of thrust nappes, was connected with the supply of energy and Variscan granite plutonism at the end of the Devonian and in the Early Carboniferous. The intrusive granitoid phase ocurred in the late stage of Variscan orogenic process. Analogous interpretation of the formation of granitoids was put forward by D. F. Strong (1980) for granitic rocks in New Foundland (eastern Canada) and in West European regions. The authors suggest that the proved presence of the Palaeozoic shale complexes in the West Carpathians requires the development of such a tectonic hypothesis which would respect these facts.

3. The study has shown very small differences in the contents of macro- and microelements in the Variscan granitoids, except for those of the Gemerides. This indicates that the West Carpathian Variscan granitoids are members of one granite formation. It has also been demonstrated that palingenic magma underwent fractional crystallization, which in places led up to the aplite-pegmatite phase.

4. The intrusive process which synchronous with the folding of the Variscan orogen and was accompanied by intensive metamorphism of shales (periplutonic metamorphism), effected a close petrogenetic and geochemical conjunction of the granitoids with their mantle of metamorphosed and mig-

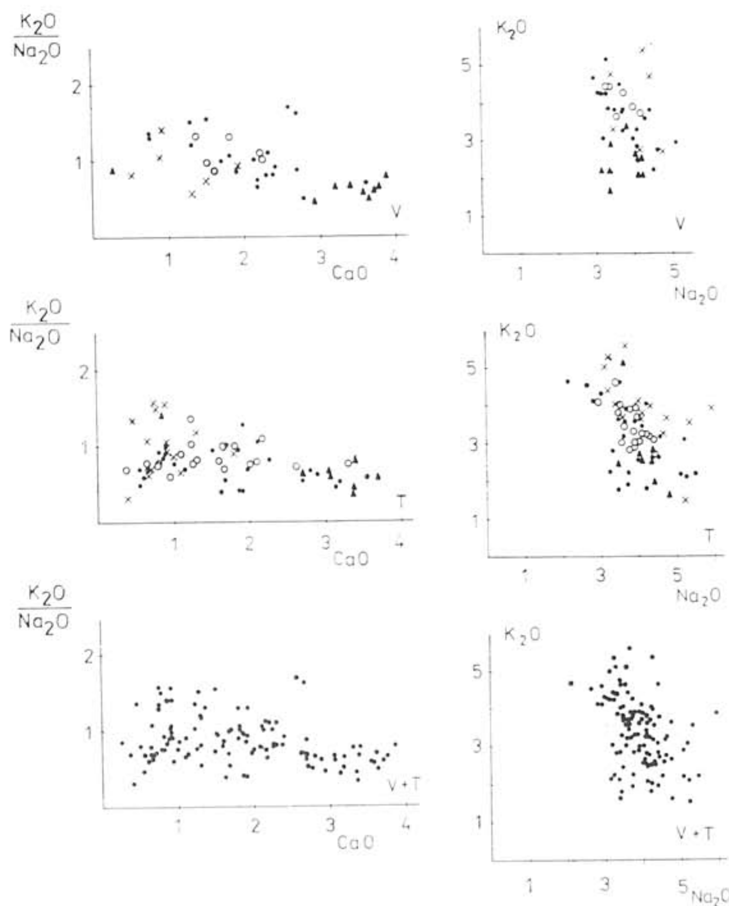


Fig. 14 a , o. Graphs showing the K_2O+Na_2O/CaO and K_2O/Na_2O ratios. In Fig. 14 a the ratios are plotted separately for the Veporide and Tatride granitoids. Fig. 14 b is a common graph for all types of Tatro-Veporide rocks. For explanation see Fig. 12 a; V — Veporides, T — Tatrides, V+T — Tatro-Veporides (rock types are not discriminated).

matized shales. The intricacy of these processes is reflected in the complexity of the granitoid petrology. M a c e k (in print) discerned several crystallization phases and several generations of minerals which were formed under different thermodynamical conditions of the evolution of the orogen.

5. The paper contains a rich graphical documentation. Numerous graphs demonstrate the geochemical and petrochemical patterns of the rocks studied, interrelationships between the elements, the trends of magma differentiation and the history of the genetic processes of granitoids, which throw light on the thermodynamic and physico-chemical conditions of crystallization. The

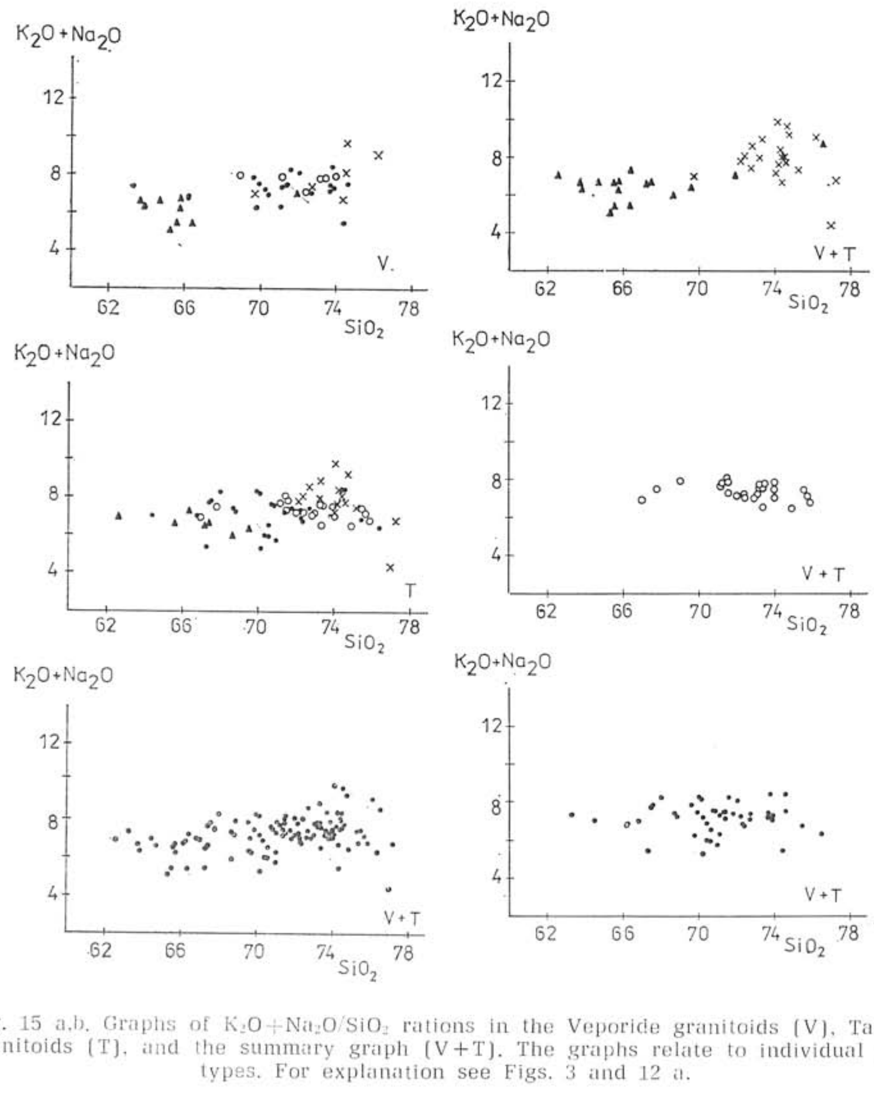


Fig. 15 a,b. Graphs of K_2O+Na_2O/SiO_2 rations in the Veporide granitoids (V), Tatride granitoids (T), and the summary graph (V+T). The graphs relate to individual rock types. For explanation see Figs. 3 and 12 a.

time was particularly appropriate for preparing the geochemical and petrochemical documentation of the selected West Carpathian granitoids because the rocks are at present the subject of integrated study, and the samples are collected in such amounts and at such localities that sampling and analyses may be easily repeated. Many of the samples can be used as comparative and documentary standard material. As it was studied by a team of co-workers using uniform methodical procedures, the dispersion of results, which cannot be well eliminated when analyses are made by individual researchers in different laboratories, has thus been reduced.

Translated by H. Zárubová

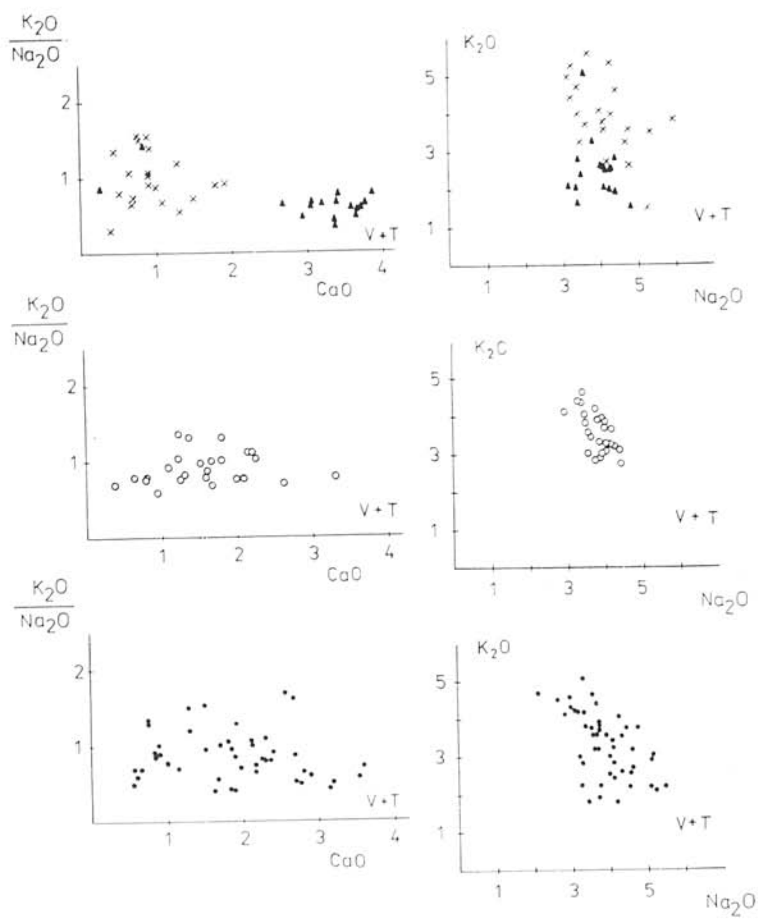


Fig. 16 a,b. The $K_2O + Na_2O/CaO$ and K_2O/Na_2O ratios in the granitoids of the Tatrides (T), Veporides (V) and Tatro-Veporides (V+T). The graphs relate to individual rock types. For explanation see Figs. 3 and 12 a.

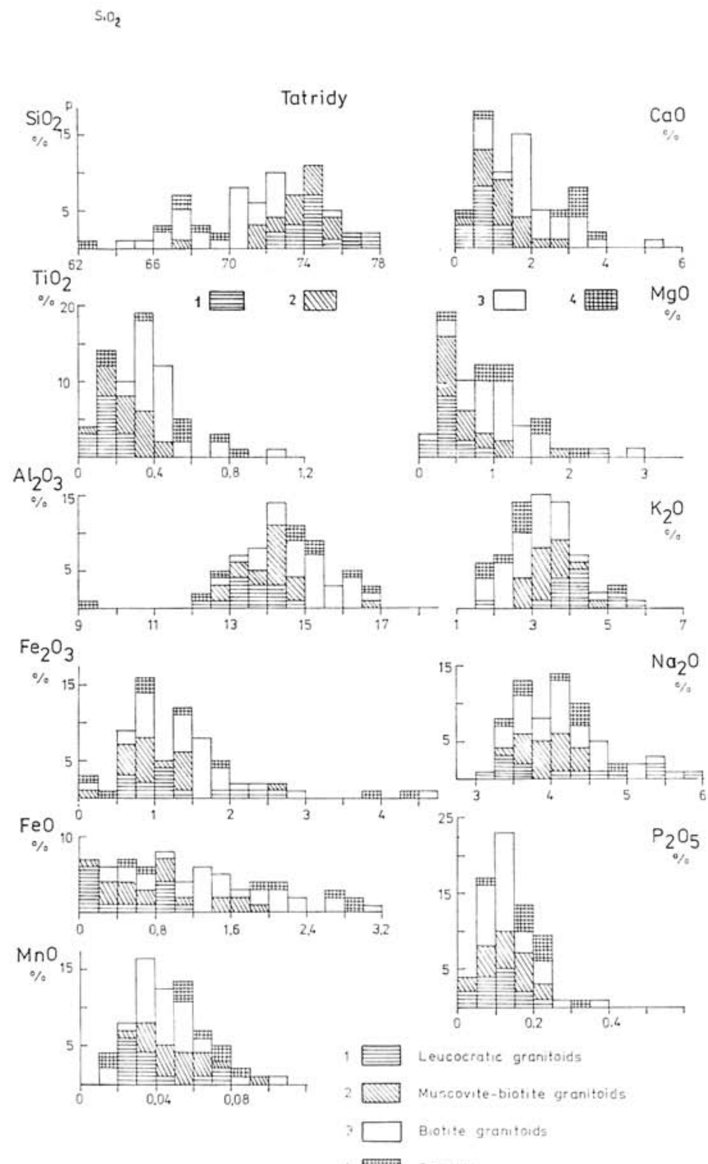


Fig. 17. Histogram of microelement contents in Tatride granitoids. 1 — leucocratic granitoids; 2 — muscovite-biotite granitoids; 3 — biotite granitoids; 4 — tonalites.

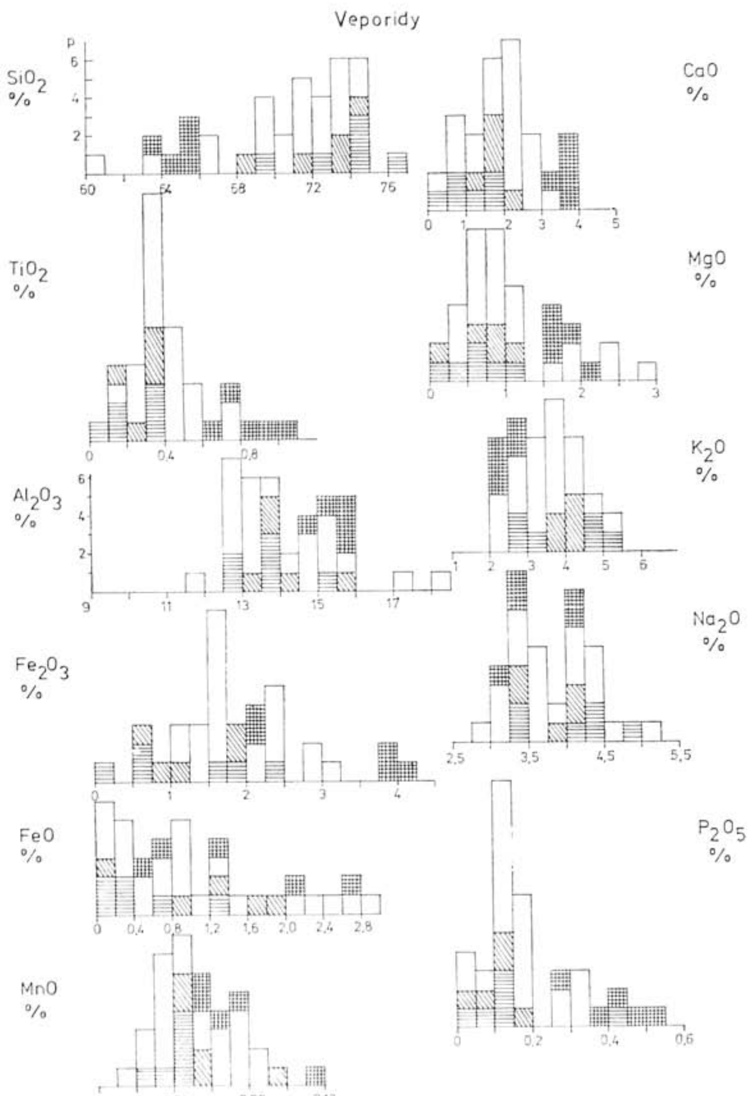


Fig. 18. Histogram of macroelement contents in Veporide granitoids. For explanation see Fig. 17.

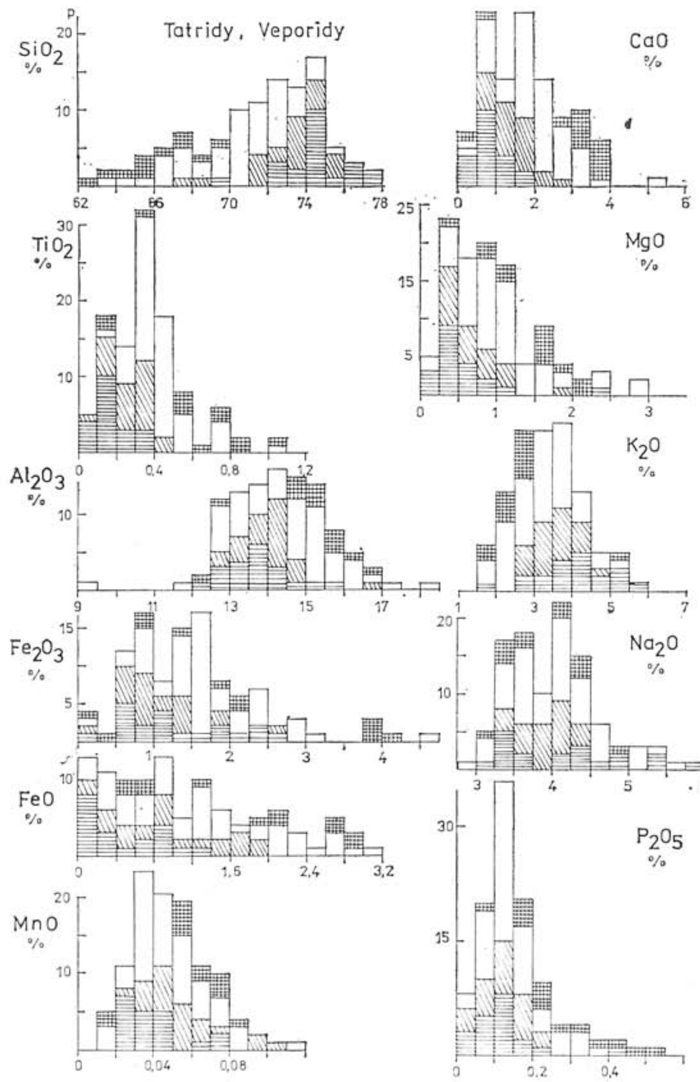


Fig. 19. Summary histogram of element contents in the granitoids of the Tatrides and Veporides (Tatro-Veporides). For explanation see Fig. 17.

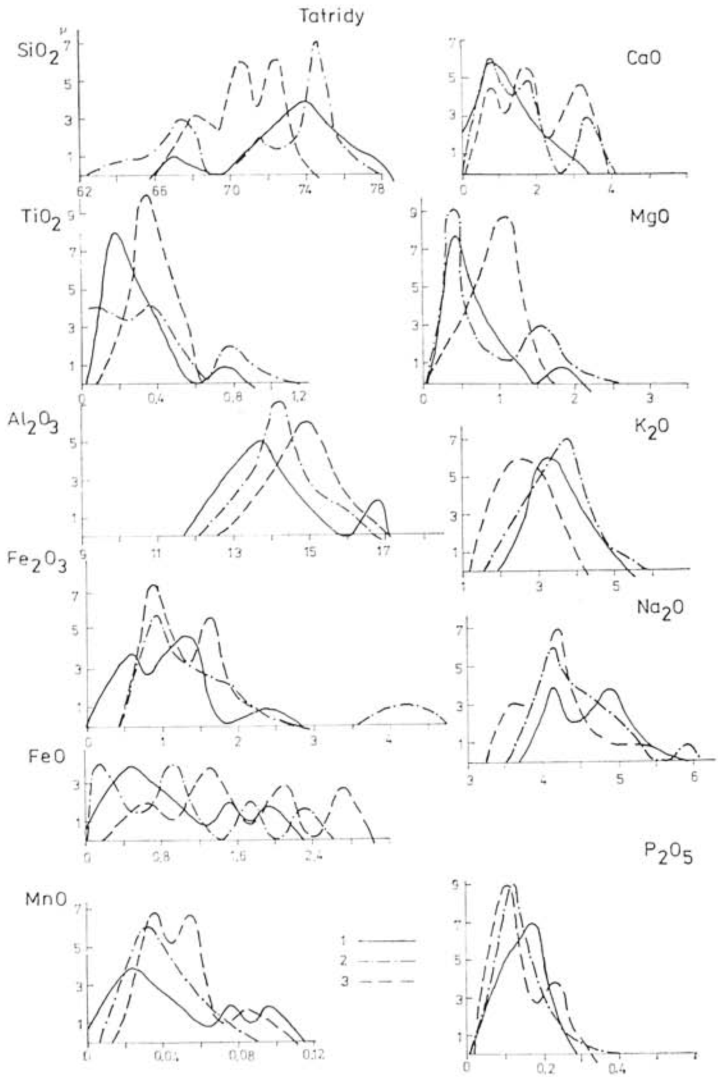


Fig. 20. Frequency curves of element contents in the granitoids, arranged according to the Tatride mountain groups. Explanation: 1 — Malé Karpaty, Považský Inovec, Suchý, Malá Magura; 2 — Nízke Tatry, Tribeč, Žiar, Veľká Fatra; 3 — Vysoké Tatry, Branisko, Malá Fatra.

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