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GEOCHEMISTRY OF TRACE ELEMENTS IN ACID VOLCANIC ROCKS OF THE UKRAINIAN CARPATHIANS

(Fig. 1, 2)

Abstract: Results of geochemical investigation of trace elements (Rb, Pb, Sr, Y, Th, U, Zr) in the acid volcanic rocks of the Transcarpathian Deep and change in the values of geochemical indices $\frac{K_2O}{Na_2O}$, Rb/Sr, K/Rb, Th/U etc. make possible to consider the rocks as calcalkaline series and to connect their formation with isolated individual deep (undercrustal) slightly differentiated sources of magmas in the subduction zone of the Carpathian island-arcs (Late Cretaceous—Neogene).

Резюме: Результаты геохимических исследований редких элементов (Rb, Pb, Sr, Y, Th, U, Zr) в вулканических образованиях кислого состава Закарпатского прогиба и изменение величин геохимических индексов $\frac{K_2O}{Na_2O}$, Rb/Sr, K/Rb, Th/U) позволило отнести кислые вулканические образования к изест ково-щелочной серии и связывать ее формирование с обособленными глубинными (подкоровыми) слабодифференцированными источниками кислых магм в пределах зоны субдукции островной дуги Карпат (поздний мел—неоген).

The results of geochemical study of trace elements (Rb, Pb, Sr, Y, Th, U, Zr) in acid volcanic rocks of the Transcarpathian Deep and correlation of their contents with some petrogenic elements were given in this paper in order to find out the type of the volcanic rocks, structure conditions of formations and petrogenesis. Zones of acid volcanism extend in different areas of the Carpathians (Apuseni, Hungary, Transcarpathian Deep etc.). Acid volcanic rocks are met in the sequence of Upper Cretaceous, Paleogene and Neogene. Different facies of acid volcanic rocks were found in many structure zones of the Carpathians and adjacent territories.

Neogene acid volcanic rocks of the Transcarpathian Deep have the thickness more than 2,5 km. They associate with molasse. Acid volcanism is separated from andesite in the area (Fig. 1). It is connected with the zones of the Carpathian direction (NW—SE), the fundament of which comprises the deposits of arc melange. It belongs to the subduction zone (L. G. Danilovich, 1976$_2$). Tuff layers of the Upper Cretaceous and Paleogene deposits of the Carpathians (L. G. Danilovich, M. B. Ripun, 1973; L. G. Danilovich, 1976$_1$) may be associated with the eruption in the southern part of the Carpathian island arc.

Acid volcanism had been starting in the Western part and migrated to the east and south—east, forming volcanic arcs: in the Northern arc the evolution occurred in Badenian, in the Southern arc — in the Sarmatian. The dislocation

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of the volcanic zones in time from north to south may be associated with tectonic processes in the Carpathian island arc system (the motion of the European plate southwards or the change of subduction velocity of the Tethys oceanic plate, which caused the migration of the island arc). Analysing the disposition of acid volcanic rocks in Neogene stratigraphic sequence such stages of acid volcanism may be noted: the first stage – the formation of the Novoselitsky tuffs

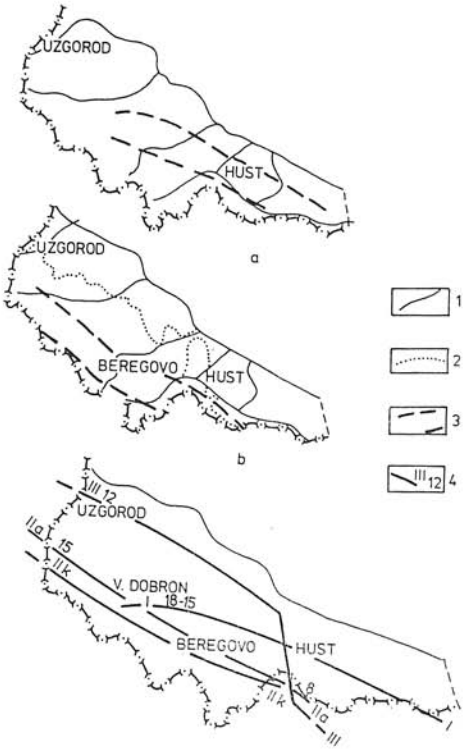

Fig. 1. Disposition of volcanic zones in the Transcarpathian Deep. 1. NE boundary of. Neogene deposits distribution. 2. boundary of volcanic rocks of Vihorlat-Gutin ridge. 3. boundary of the acid volcanism zones: a) Badenian, b) Sarmatian. 4. present location of the volcanic zone axes and absolute age of rocks: I–I. axis of the acid volcanism zone in the Badenian, II–II_k. axis of Sarmatian acid volcanism zone, II–II_a. axis of Sarmatian andesite zone, III–III. axis of Pliocene andesite – basaltic volcanism zone (Vihorlat-Gutin ridge).

with more than 1000 m thickness – Lower Tortonian (Badenian in present interpretation), the second stage – the formation of 5–6 tuff layers with thickness from 20 to 100 m in the Upper Tortonian, the third stage – formation of Sarmatian deposits with more than 1000 m thickness, the fourth stage – the formation of the layer in the Pannonian with thickness to 100 m.

Methods of work

The contents of important trace elements, expecially Rb, Pb, Sr, Y, Th, U, Zr were investigated in the studied rocks (Table 1). Sr, Rb, U, Th and Pb were determined in total samples of rocks in the Chemical Analytical Laboratory of All-Union geological Institute (Leningrad) using the method of X-ray-spectrometric fluorescence analysis with the spectrometer FRS-2. The sensibility limit of determinations is $3–5.10^{-4}$, the reproduction of result determinations

on the limit level contents is near 30 and on the level — 0,01—3. Chemical analyses of petrogenic element contents were made in the Laboratory of the Institute of Geology and Geochemistry of Combustible Minerals of the USSR Academy of Sciences (Lvov).

Petrologic characteristics of the rocks

Ignimbrite deposits (cover flood tuffs) predominate in the acid volcanic complexes, where air-fall tuffs, flood and extrusive lavas and tufflavas are also developed (L. G. Danilovich, 1976[1]). The studied complexes are located in two zones: Nothern and Southern. Volcanic rocks have acid composition (dacite—liparite) with predomination of dacitic composition rocks. SiO_2 contents differs from 58 to 75 percent (predominance of the rocks with 60—66 % of SiO_2), Al_2O_3 contents vary from 11 to 15 % and not more than 17 % the ratio $\frac{0{,}9\ Fe_2O_3 + FeO}{MgO}$ from 1,0 to 4,0. The sum $0{,}9\ Fe_2O_3 + FeO$ is almost constant (3,3—3,7) in all age complexes of the Neogene acid volcanic rocks while the total of iron decreases from 3,5—3,7 to 2,1—1,2 in last magmatic products with increasing SiO_2 and increases in the dacitic rocks (4,1—4,8). To contract the AFM diagrams we made use of 150 analyses data. Points of the acid volcanic rocks are in the field near the line AF (Fig. 2, 1). The curves for calc-alkaline and alkaline associations of the Banatitic province are shown for comparison (Fig. 2, 2—4). The field of the Transcarpathian Deep acid volcanic rocks on the AFM diagram shows little or no iron enrichment and the tendency to increase in alkaline contents. K-alkalinity increases in the last magmatic products of each volcanic stage.

The sum of normatives of albite, orthoclase, quartz changes from 75 to 85. Everywhere sodium predominates over potassium while contents of K_2O increase in liparites, completing volcanic activity (domes). The average contents of K_2O are 2,1—2,5. K_2O contents in the Transcarpathian acid volcanic rocks vary close to K_2O content in the typical dacitic rocks of the Circumpacific island arcs (P. Jakeš, A. J. R. White, 1972). Na_2O does not change as much as K_2O in sequence of rocks with given SiO_2 contents, and consequently the ratio $\frac{K_2O}{Na_2O}$ increases with increasing K_2O from approximately 0,1 in the low K rocks to 1,0 in high K rocks, but may reach 2 or 4, on an average 0,7 (Table 2, 3). These data are similar to $\frac{K_2O}{Na_2O}$ values in the eruptive rocks of the Banatitic Province (M. Boccaletti-P. Manetti-S. Peltz, 1973). Rittmann's serial index < 4.

Some dacitic rocks shows analogies with tholeiitic associations. They are characterized by low Al_2O_3 contents (11—12 %), K_2O contents are less than 1,5 %, $\frac{K_2O}{Na_2O}$ ratio is 0.3 the sum of alkalies is < 5, $\frac{Fe_2O_3}{FeO}$ ratio is low (0.1—0.5), extremly low are the MgO contents. These rocks belong to the early eruption phases of Tortonian and Sarmatian volcanic stages.

The majority of acid volcanic rocks have the parameters of calcalkaline series (Table 1—3, Fig. 2), which makes possible to consider the acid volcanic rocks

Table 1

Contents of Elements in acid volcanic rocks

Type of rocks, age	Quantity of analyses	Rb	Pb	Sr	Y	Th	U	Zr	SiO_2	K_2O	Na_2O	Sr	87/Sr	86**
		n . 10^{-3}, %												
The Chechvensky tuffs (Paleogene)	2	11,4	2,0	20,6* / 6,3–35	2,35	1,6	0,6	9,4	69,0	3,60	2,20	—		
The Novoselitsky tuffs (ignimbritic) bore well Zaluzh-2, depth 1548 m	1	8,8	0,5	31	3,4	0,8	0,5	13,7	69,3	2,40	3,60	—		
The Novoselitsky tuffs (ignimbritic) bore well Soki nitsa 1 and 3 (early Badenian)	9	11,8 / 7,6–14,5	0,6 / 0,5–1,0	13,6 / 4,6–20	3,4 / 2,4–4,8	1,1 / 0,6–1,5	0,5	16,6	67,2	2,45	4,17	—		
The Novoselitsky tuff, bore well Danilovo-1	5	11,2 / 7,1–21	0,8 / 0,6–1,2	15,5 / 11,9–20	3,8 / 2,5–4,4	1,2 / 1,0–1,5	0,5	14,9	67,6	1,44	3,72	—		
The Novoselitsky tuffs, bore well Tereblia 1,4 and Novoselitsa locality	4	12,6	0,6	9,5	3,2	1,4	0,6	20,0	70,6	2,01	4,47	—		
Late Badenian tuffs, bore well Teresva 4 Tiachevo 4, 10, 12, 14	12	12,5	1,1	7,8	4,9	1,5	0,6	15,5	65,7	2,20	3,63	—		
Late Badenian tuffs, bore well Tiachevo 6	10	10,9 / 2,1–25	1,7 / 0,7–3,7	13,7 / 4,3–33	4,3 / 2,0–7,8	1,3 / 0,6–3,2	0,6 / 0,5–1,3	18,8 / 8,2–41	66,53	2,32	4,0	—		
Tuffolava, bore well 365, Began village (Sarmatian)	5	9,5	1,7	19,5	3,6	1,2	0,5	23,0	66,4	3,17	2,66	—		

Dacites, bore well 66, Beregovsky region (Sarmatian)	4	8.6	1,0	18,4	3,4	0,7	0,5	16,7	66,7	2,5	3,5	0,7078
Ignimbritic tuffs, bore well 50 Beregovsky region (Sarmatian)	6	9,2	0.9	30,1 8,8–47	3.4	1,1	0,5	17,7	65,7	2,5	2,8	–
Ignimbritic tuffs, bore well 15 Beregovsky region (Sarmatian)	8	17,8 7,0–38	1,2 0,5–3,5	13,3 7,0–30	3,6 2,0–5,3	1,4 0,7–1,6	0,5	12,4 9,0–25	–	–	–	–
Tuffolavas and ignimbritic tuffs bore well 45, Beregovsky region (Sarmatian)	8	11,2	2,2	16,8 3,5–27	4,0	1,2	0,6 0.5–1.0	21,2	67,1	2,20	3,06	0,7073
Liparites Beregovsky region (Sarmatian)	3	11,7	1,7	10,8	3,5	1,6 1,2–2,0	1,1 0,5–1,9	19,1	72,16	3,42	3,50	–
Dacites and ignimbritic tuffs Oash Mountain range (Pannonian)	6	10.2	1,7	21,4	3,8	1,0	0,5	22,1	65,7	2,75	2,84	0,7057

* boundaries – denominator, mean values – numerator
** Bartnitsky, Danilovich, 1976; Danilovich, 1977.

formation in the island arc as the second type according A. Miyashiro (1974).

The evolution of the Carpathian island arc was of less activity than Japan or Kuril-Kamchatka island arcs where tholeiitic series predominated.

Minerals of the early stage of crystallization are represented by plagioclase, quartz, less by sanidine, biotite, hornblende, hypersthen, garnet, still less by

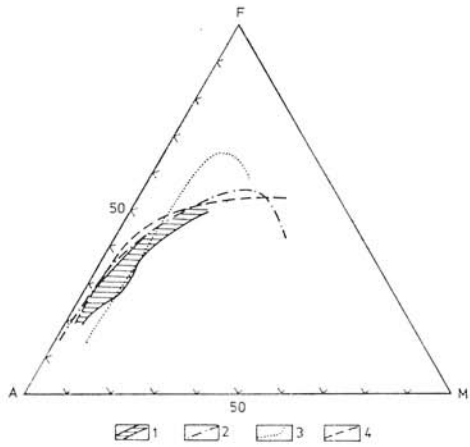

Fig. 2. AFM diagram for acid volcanic formation of the Transcarpathian Deep. 1. the field of the Transcarpathian Deep acid volcanic rocks, 2. the curve for the Apuseni-Timok effusive rocks of calc-alkaline association, 3. the curve for effusive rocks of Srednogora calc-alkaline association, 4. the curve for effusive rocks of Srednogora K-alkaline association. 2–4. for M. Boccaletti, P. Manetti and S. Peltz (1973).

aegirite. Detailed petrographical and petrochemical characteristics of acid volcanic rocks were given in the papers of V. S. Sobolev et al. (1955), V. P. Rostiuk (1961), L. G. Danilovich (1976$_1$), etc. All volcanic deposits of acid composition (Upper Cretaceous–Neogene) are included in the liparite–dacitic formation.

Distribution of elements

The contents of Rb, Pb, Sr, Y, U, Th, Zr were investigated in hundreds samples of acid volcanic rocks of different ages. Their contents and some geochemical indices are shown in Table 2, 3. In order to study the distribution variations of trace elements the rocks are grouped according to their age with the division according to the genetical type of facies: ignimbrite rocks, extrusive rocks, tuffs, tuffolavas etc. Elementary contents of trace elements in some sequences of bore wells are shown in Table 3.

Elements in the volcanic rocks and complexes are represented in different variations, but the mean values are close to the data given for analogous group of rocks by A. P. Vinogradov (1962).

Rubidium has very low values and occurs in the range of 2.1 to 38 in individual examples (all contents are given in $n.10^{-3}$ %) and in the range of 8.8 to 18 in average ones (Table 1, 2). Positive correlation between the contents of Rb and K_2O is established as well as between these elements and SiO_2, although the degree of accumulation of Rb is not high. It is clearly seen from Table 3 that the contents of Rb in all rocks are very low. Rubidium a lithophyllic element and a good indicator of the process of differentiation (O. D. Stavrov, 1966;

Table 2

Mean contents of trace elements in age complexes of transcarpathian acid volcanic rocks and some other regions

Types of rocks, age	Quantity of analyses	Rb	Pb	Sr	Y	Th	U	Zr	K_2O/Na_2O	K/Rb	Rb Sr	Th U
		n . 10^{-3}, %										
Tuffs (Paleogene)	2	11,4	2,0	20,6	2,35	1,6	0,6	9,4	0,9	316	0,5	2,6
The Novoselitsky tuff (ignimbritic deposits and tuffs; Badenian)	19	11,1	0,6	17,4	3,4	1,1	0,5	16,3	0,7	200	0,6	2,2
Tuffs (Upper Badenian)	22	11,7	1,4	10,7	4,6	1,4	0,6	17,1	0,9	250	1,0	2,3
Ignimbritic deposits, tuffolavas, liparites, dacites, (Sarmatian)	33	11,1	1,4	18,1	3,6	1,2	0,5	18,3	0,7	300	0,6	2,4
Ignimbritic deposits, dacites (Pannonian)	6	10,2	1,7	21,4	3,8	1,6	0,5	22,1	0,9	270	0,4	2,0
Mean contents of trace elements of Carpathian liparite-dacitic formation	—	11,1	1,4	17,6	3,6	1,2	0,5	16,6	0,8	270	0,6	2,3
Mean contents of elements in acidic rocks according to Vinogradov (1962)	—	20,0	2,0	30,0	3,4	1,8	0,35	20,0	—	—	—	—
Mean contents of elements in rhyolites of East Slovakia (Forgač, 1975)	—	—	—	—	3,3	1,4	0,6	11,5	—	—	—	2,4
Taupo volcanic zone (New Zealand) according to Ewart, Steep in												
„Igneous Petrology" (1975)*: Dacites	—	63,3	—	315,5	—	7,78	1,93	—	—	280	0,2	4,0
Rhyolites	—	106,6	—	106,6	—	11,5	2,64	—	—	251	1,0	4,0
Ignimbritic rocks	—	112,2	—	140,1	—	11,14	2,48	—	—	251	0,8	4,0
Pumice	—	90,6	—	164,4	—	10,2	2,22	—	—	244	0,5	4,0

* Contents of trace elements are given in parts per million (ppm)

A. Erlank, 1972). Therefore the presence of deep source of magma and lack of its differentiation is supposed.

Potassium contents vary from relatively low (0.7—1.5) to high ones (4.8—5.1 %). The analysis of data shows the particular importance of a tendency towards K-alkalinity. At the same time $^{K}/_{Rb}$ decreases and $^{Rb}/_{Sr}$ increases. Potassium — rubidium ratios slightly vary within the limits of volcanism zones (Table 2), some variations of $^{K}/_{Rb}$ take place apart from the age stages of volcanism (Table 3). Potassium — rubidium value (200—500) is the evidence of formation of the rocks in island-arc conditions. These values are close to the $^{K}/_{Rb}$ values for typical calc-alkaline and shoshonitic series of the present island-arcs and indicates undercrustal source of magma (L. K. Leonova, N. J. Udaltsova, 1970; S. E. De Long, 1974; B. B. Doe, 1968; P. Jakeš; A. J. R. White, 1972).

Strontium fractionates during the crystallization of plagioclase (G. Faure, R. Powell, 1974) that stipulates contents in rocks. There is a slight correlation of Sr to K_2O in the acid volcanic rocks of the Transcarpathian Deep, but while SiO_2 increases the amount of Sr somewhat decreases (Table 3). Isotopic composition of Sr was investigated. Sr^{87}/Sr^{86} ranges from 0.705—to 0.707 for acid volcanic rocks of the Transcarpathian Deep (E. N. Bartnitsky, L. G. Danilovich, 1976; L. G. Danilovich, 1977) and from 0.702 to 0.706 for the Tokaj Mountains (Kovach et al., 1968) what testifies to the presence of undercrustal source of acid magmas. The value of $^{Rb}/_{Sr}$ ratio differs in the range 0.1—1.0, on an average 0.5.

The distribution of lead is characterized by homogeneous and very low absolute concentrations and also occurs in very small amounts (Table 1, 3). The lowest lead contents is in Novoselitsky tuffs. Isotopic ratios of lead (V. V. Naumenko, 1974) in the acid volcanic rocks are similar ($Pb\frac{206}{204} = 19.1—19.4$, $Pb\frac{208}{204} = 37.9$), there they are in accordance with the data for rocks with mantle source of magma (M. Tatsumoto, 1966; B. R. Doe, 1968).

Zirconium is distributed in the range from 8—41 in individual examples, and 12—23 on an average (Table 1, 3). The highest contents of zirconium are in the rocks of the latest stages of acid volcanism (Sarmatian, Pannonian).

All studied volcanic acid rocks of the Transcarpathian Deep are characterized by extremely low contents of radioactive elements (Table 1—3), especially of U, Th, Pb. The same low contents of U and Th can be found only for tholeiitic basalts in oceans (Engel et al., 1965), which are considered to be the direct product of partial melting of the upper mantle. Average values are as follows: uranium content varies from 0.5 to 2.0, thorium from 0.5 to 3.5, yttrium from 2 to 7.8. $^{Th}/_{U}$ ratio does not attain up to 3. These values are extremely low, similar values are typical of the volcanic rocks of the Kuril island-arc and Kamchatka (L. L. Leonova, N. I. Udaltsova, 1970), some island-arcs of the southwestern part of the Pacific ocean and rhyolites of Eastern Slovakia (J. Forgáč, 1975). In liparites uranium and thorium are concentrated in the matrix of rocks (glass), only a small quality of them is found in minerals of the early crystallization stage (J. Forgáč, 1975) because the elements yttrium, uranium and thorium have the tendency to accumulate in the residual magmas.

Table 3

Trace elements distribution in some sequences of acid volcanic rocks of the transcarpathian deep

Type of rocks	Rb	Pb	Sr	Y	Th	U	Zr	SiO_2	K_2O	Na_2O	K_2O/Na_2O	K/Rb	Rb/Sr	Th/U	Age
	n . 10^{-3}, %							%							
Bore well 45 (Beregovo) Liparite depth 32 m	11,8	1,7	10,1	3,5	1,6	1,6	19,5	72,32	5,16	1,82	2,8	437	1,0	1,0	Early Sarmatian
Strongly welded tuffs, 95 m	16,9	2,3	3,5	4,5	1,6	0,7	9,3	72,50	4,50	1,83	2,4	266	—	2,2	Early Sarmatian
Strongly welded tuffs, 107 m	11,0	1,5	14,0	4,3	1,0	0,5	2,6	68,12	3,55	1,68	2,0	322	0,8	2,0	Early Sarmatian
Strongly welded tuffs, 111 m	9,8	4,5	15,3	3,8	1,2	0,5	26,0	66,24	3,35	1,84	4,0	321	0,6	2,4	Early Sarmatian
Welded ash-pumice flow tuffs, depth 136 m	10,2	2,0	27,0	4,4	1,0	0,5	26,0	67,56	2,98	2,0	1,5	292	0,4	2,0	Early Sarmatian
Welded ash-pumice flow tuffs depth 163 m	5,1	1,6	22,0	4,3	1,0	0,5	18,6	60,84	2,59	1,08	2,4	507	0,2	2,0	Early Sarmatian
Bore well 66 (Beregovsky region) Dacite, depth 119 m	8,6	1,0	18,8	3,7	0,7	0,5	18,1	68,88	2,46	3,70	0,6	290	0,4	1,4	Early Sarmatian
Dacite, depth 240 m	8,8	1,0	19,3	2,5	0,6	0,5	17,1	64,60	2,63	3,57	0,7	249	0,4	1,4	Early Sarmatian
Dacite, depth 316 m	8,3	1,1	17,0	4,0	0,9	0,5	14,5	66,01	2,49	3,46	0,7	300	0,5	1,8	Early Sarmatian
Pumice flow tuff, depth 383 m	11,4	1,4	16,6	4,2	1,2	0,6	18,0	67,46	2,84	3,21	0,8	294	0,6	2,0	Early Sarmatian
Bore well 6-Tiachevo (Solotvianskaia Deep) Tuffs, interval 369—374 m	9,7	0,7	4,3	2,3	1,0	0,5	8,2	72,64	4,20	3,72	1,1	432	—	2,0	Late Badenian first
Tuffs, interval 399—407 m	9,0	1,4	23,0	1,6	0,5	0,5	12,5	66,26	3,60	3,73	0,9	400	0,4	1,0	tuff layer
Tuffs, interval 450—472 m	25,0	2,3	6,9	6,5	1,6	0,7	10,9	69,94	3,18	3,92	0,9	127	—	2,2	Late Badenian second
Tuffs, depth 490 m	10,4	3,7	10,7	6,0	1,2	0,5	11,7	70,38	2,95	4,29	0,7	283	0,9	2,4	tuff layer
Tuffs, depth 665 m	1,7	1,1	31,0	2,0	0,9	0,5	27,0	59,28	0,70	4,88	0,1	410	0,1	1,8	Late Badenian, third tuff layer
Tuffs, depth 887 m	21,0	1,3	5,8	7,8	3,2	1,3	41,0	71,45	4,80	3,69	1,2	228	—	2,4	Late Badenian, fourth
Tuffs, depth 937 m	9,5	0,9	8,7	4,7	1,4	0,5	20,0	62,42	1,90	4,10	0,4	422	1,1	2,8	tuff layer
Tuffs, interval 953—966 m	2,1	1,1	33,0	2,3	0,5	0,5	22,0	57,92	0,82	5,05	0,1	400	0,1	1,0	

U, Th, Y are distributed homogeneously in the rocks of different ages and genetical type. During the evolution of acid volcanism the lack of U and Th enrichment is marked on the whole territory of acid volcanic rocks development, except liparites with slight enrichment in thorium and uranium (Table 1–3). When comparing the liparites of Slovakia (J. Forgáč, 1975) with those in the Transcarpathian Deep, correlation relationship between Th, U and Y, Th, U, Y and SiO_2 in the latter is observed in the rocks of one eruption cycle (Table 3) and the contents of yttrium increase with enrichment of thorium contents.

Uranium and thorium, as well as rubidium, appear to be indicators of magma melt differentiation process. Hence, low concentrations of these elements in the acid volcanic rocks of the Transcarpathian Deep and low values of $^{Th}/_{U}$ (Table 2) are evidence of the fact that during volcanism process the melt ascended without differentiation.

The analysis of trace elements distribution in the particular sequences (separate eruption cycles) shows positive correlation of thorium, uranium, lead, rubidium with alkalies (particularly with potassium) and these elements with SiO_2 (Table 3).

When the obtained geochemical characteristics and the values of geochemical indices of the studied acid volcanic rocks (Table 1–3) are compared with volcanic rocks of island-arcs and active continental margins (B. Doe, 1968; A. Ewart, – J. J. Stipp, 1968; L. L. Leonova, N. J. Udaltsova, 1970; P. Jakeš, A. J. R. White, 1972; S. De Long, 1974), we see that our results are similar to geochemical parameters of island-arcs rocks. Variations in SiO_2 and potassium contents, alkali sums, predominance of sodium over potassium, the value of $\frac{K_2O}{Na_2O}$ ratio make possible to regard the Carpathian acid volcanic rocks as a typical series of island-arcs. It is confirmed also by low contents of thorium, uranium, by values of $^{Th}/_{U}$, $^{Rb}/_{Sr}$, $^{K}/_{Rb}$ etc. In the rocks studied by us the total of iron is somewhat more or similar to the island-arc rocks.

Summing up the results of geochemical investigations and geological evolution, lateral zoning of structure and magmatic formation distribution (L. G. Danilovich, 1975 1976_2), geophysical data (S. J. Subbotin et al., 1968, A. V. Tshekunov et al., 1969), and data of deep drillings in the Transcarpathian Deep, it may be considered that they testify to the formation of acid volcanic rocks on island-arcs, but not on the active continental margins. Taking into account the petrochemical nature of the volcanic series of the Transcarpathian Deep and zoning of their distribution (V. S. Sobolev et al., 1955; V. P. Kostijuk, 1961; L. G. Danilovich, 1976_1), the Neogene Transcarpathian island – arcs may be considered as the second group according to Miyashiro's classification (1974).

Conclusion

1. Uranium, thorium, yttrium, rubidium, lead distribution is homogeneous in the acid volcanic rocks of different ages, what excludes deep differentiation of magmatic melts during the definite stages and assimilation of crustal material.

2. Transcarpathian acid volcanic rocks have low mean contents of potassium – type elements for example: Ba, Pb, Sr, Rb, and Zr – type: Zr, Th, U, which is similar to the volcanic series of island-arcs.

3. Acid volcanic rocks have low absolute uranium and thorium concentrations in both the volcanic zones. Thorium constantly predominates over uranium. The mean value of $^{Th}/_{U}$ ratio appears to be extremely low and equals to 2.4. We may assume that during the acid volcanism the magma rose from deep zones, without differentiation. The values of $^{Th}/_{U}$, $^{K}/_{Rb}$ testify to this assumption and make possible to connect the formation of Carpathian volcanic rocks with subduction zones of island – arcs but not with active continental margins.

4. The constancy of Rb, Pb, Th, U mean contents and their low concentration may be an evidence of petrogenesis of acid volcanic rocks from homogeneous slightly differentiated independent undercrustal source of acid magma. Similar data suit for andesite formation of the Transcarpathian Deep. The occurrence of important trace and minor elements in very small amounts and their common contents in different andesite facies as mentioned by B. V. Merlich et al. (1975) is absolutely impossible under fractional crystallization or prolonged differentiation of magma. It appears to be possible only in the presence of isolated source of andesite volcanism is connected with different sources of magma. Investigation of strontium isotopic composition (E. N. Bartnitsky – L. G. Danilovich, 1976; L. G. Danilovich, 1977) confirms this notion and testifies to undercrustal source of magmas.

5. The comparison of geochemical indices (Table 1–3) of acid volcanic rocks of the Transcarpathian Deep and some island-ars of the Pacific Ocean showed their similarity and the contents of studied elements correspond to their quantities in the calc - alkaline series of present island-arcs.

6. The results of investigation allow to regard the formation of calc – alkaline series in the Transcarpathian Deep as island – arcs products.

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