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GEOCHEMISTRY OF LITHIUM, RUBIDIUM AND CESIUM IN METABASITES OF THE WEST CARPATHIANS

(Fig. 1—8, tab. 1—8)

Abstract: The authors determined the contents of Li, Rb, Cs in 68 metabasite samples of the crystalline in the Core-mountains of the West Carpathians and treated the results statistically. The characterization of metabasites from the individual mountain ranges but also from larger units was carried out on the basis of K/Rb, K/Cs, Na/Li, Li/Mg, Rb/Sr, Ba/Rb ratios. The metabasites of the Tatraveporides we may range to the group of basaltoid rocks on the basis of Rb, K distribution. The authors conclude that metamorphism did not result in essential disturbing to the contents and mutual relations between alkalic elements.

Резюме: Авторы установили содержание в 68 образцах метабазитов кристаллических массивов Западных Карпат и эти результаты статистически обработали. Была произведена характеристика метабазитов в отдельных горных ымассивах а также и более крупных комплексов на основании соотношений K/Rb, K/Cs, Na/Li, Li/Mg, Rb/Sr, Ba/Rb. Метабазиты татравепорид на основании расширения Rb, K можно отнести к группе базальтоидных. Авторы считают, что метаморфизм не вел к существенным нарушениям содержаний и взаимных соотношений между щелочными элементами.

At present a complex investigation of West Carpathian metabasites is being carried out and the results of geochemical research of this rock type are before termination. Alkalic elements belong among the so called incompatible elements, the petrological importance of which is generally recognized. On the basis of the content of these elements the mantle or crustal origin of the fundamental rock types may be judged. It is possible to determine whether allochemical or isochemical metamorphism is concerned. On the basis of these elements the individual metabasite types from the individual regions may be characterized.

The Tatraveporide metabasites are most probably part of the Paleozoic metamorphosed complex of rocks of the West Carpathians. In the Tatraveporide region metamorphism of the crystalline schists is a consequence of Caledonian-Variscan plutonism and Variscan intrusive processes of granite magmas, migmatization and granitization of rocks and metamorphism under conditions of amphibolite facies, more rarely also of green schists facies. Diaphthoresis and other younger superimposed processes determined the final petrological character of metabasites. Originally they were mostly submarine extrusive rocks or subsurface hypabyssal rock types. Present-day metabasites have a re-

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latively simple composition (feldspars, amphiboles, magnetite, titanite, rarely garnet, epidote and various secondary minerals). The rocks were originally of various grain size and various representation of dark and light-coloured minerals. At present they are amphibolites and gabbroamphibolites (35—65 % amphibole), melaamphibolites and melagabbroamphibolites (more than 65 to 95 % amphibole); hornblendites (with content above 95 % amphibole). Beside that, in the Tatraveporide region amphibolic gabbros, gabbrodiorites are found, relatively less affected by metamorphism and less recrystallized, with features of hypabyssal derivatives, belonging to geosynclinal basic volcanism. A part of amphibolic gabbros and gabbrodiorites, which is found at the contact with granitoids at their margins or also in their centre, is of unclear genesis and may be also considered as part of granite intrusion, as product of in situ differentiation or as insufficiently resorbed relicts of rocks of xenolithic character.

The investigation of alkalic elements (Li, Rb, Cs) and of dependence of their contents on the main elements in rocks is a part of general geochemical investigation of metabasites. This investigation has made possible to develop analytical methods of various kinds by us (spectral analysis, atomic absorption and neutron activation), concerning metabasites. The results mentioned here are those from the first analytical determination of Li, Rb, Cs, carried out systematically in basic metamorphosed rocks of the West Carpathians. It is necessary to remark that a part of the samples analyzed for this work is selected from groups of metabasite samples, treated by B. Cambel and L. Kamenický (in press) and a part forms the group of samples treated by J. Spišiak, an author of this work. (They are samples mentioned under the symbol AM).

Analytical methods

The contents of Na and K were established by the method of emitting flame spectroscopy, after foregoing decomposition in hydrofluoric and perchlorid acids. Ionization and dissociation equilibria in flame were determined by added solution according to V. Schuhknecht, H. Schinkel (1963), containing Ca-and Al-salts.

Li and Rb were determined from nitrate solution after decomposition in acid, by means of atomic absorption spectroscopy. Ionization interference influences were removed with adding surplus of potassium salt. Correctness of the results of determination of elements of alkalic metals was controlled by reference standard materials: ZGI — BM (basalt) and USGS — BCR-1 (basalt). Sr and Ba contents were detected by spectrochemical analysis under conditions mentioned in the work by Medveď J., Plško E., Cubínek J. (1974). Determination was carried out by E. Martiny, one of the authors of this work.

Detection of Cs was carried out by the method of neutron activation analysis in the Central Laboratory of the Czechoslovak Uranium Industry (ČSUP) Stráž pod Ralskem, Syndicate Establishment of Uranium Industry (UP) Příbram.

The samples were irradiated by neutrons on reactor of ÚJV ČSAV-Nuclear Research Institute of the Czechoslovak Academy of Science in Řež near Prague. There were prevailingly thermal neutrons with admixtures of resonance and quick-acting neutrons. In the analysis the reaction ^{133}Cs (n, p) ^{134}Cs was applied. The analysed nuclide ^{134}Cs has radiation energy — 796 keV and 604,7 keV and half-life period 2,05 r. The gamma spectra were obtained by the method of smallest squares. For these purposes multi-channel analyzer and computer, produced by the firm Intertechnique-France, were used.

The detection limit of Cs with this method and the applied devices is 0,5—1,0 gt [1]. The accuracy of the results given varies within the limits $\pm$ 5—10 %. The analyses in ÚL ČSUP Stráž pod Ralskem were carried out by Ing. Čeněk Urban.

Lithium

Lithium in crystals enters hexagonal coordination in minerals its substitution for magnesium is supposed. On the example of Skaergaard rocks Wagner L. R, et al., (1951) it has been found that lithium accumulates to a larger extent in later crystallizing olivines and pyroxenes. Lithium has more ionic bond with oxygene than magnesium, causing the above mentioned accumulation in later crystallizing iron-magnesium minerals and also its accumulation in the rest magma during crystallization differentiation.

According to K. S. Heier (1962) Na can to a limited extent be substituted also for lithium in plagioclases.

In the publication by M. Prinz (1967) the following arithmetic means of Li in basaltoid rocks are mentioned (A. P. Vinogradov, 1962) 15 g/t, (K. K. Turekian — K. H. Wedepohl, 1961) 17 g/t, (R. L. Horstman, 1957) 17 g/t, (K. S. Heier — J. A. S. Adams, 1973) 7 g/t, for basalts, 10 g/t for gabbros (M. Prinz, 1967) determines 11 g/t and median 10 g/t from 163 analyses of basalts. The arithmetical means from Tatraveporide metabasites are mentioned in Tab. 8. The groups from the individual Core mountains display values 18—42 g/t. It should be remarked that only a few basalt groups mentioned by M. Prinz in Tab. 1, p. 274 have similar high Li values, they are African tholeiites from the Messum complex (18 g/t), basalts from the Messum complex (25 g/t), tholeiites Oknjeje complex (27 g/t), in Europe Scottish Tertiary tholeiites 27 g/t, North-American basalts/Lassen Peak-California 28 g/t and from the Pacific Ocean from Honolulu alkalic basalts 39 g/t.

The investigations show that Li/Mg ratio is characteristic of determination of the degree of differentiation. Alkalic basalts have somewhat more lithium than tholeiites. On the basis of Li contents in minerals and rocks it is supposed that the differences in Li contents in rocks are not primary but conditioned by the degree of differentiation or selective melting (basalts have 10 g/t and granites 30 g/t of lithium). Lithium contents in various basic rocks and minerals according to various authors are mentioned in Tabs. 1, 2, 3. For information we quote in Tab. 1 the contents of alkalic elements in plutonic rocks from the article of K. S. Heier — J. A. S. Adams (1964), Tabs. 14, 15. In this table Na and K contents are calculated according to R. A. Daly (1933).

Some authors (B. G. Lutz, 1975) also trace Na/Li ratio. It is shown that in rocks of the basalt group Na/Li ratio decreases from low-potassium tholeiites to alkalic basalts. Kimberlites display Na/Li ratio of the value 82 whereas in chondrites this ratio is 2.500. This ratio is also preserved in spinel hyperbasites. Here Li content is lower than 0,3 g/t and according to E. V. Maximovič

Table 1

Table of alkalic elements contents in rocks according to K. S. Heier, J. A. S. Adams (1964)

	Li g/t	Na %	K %	Rb g/t	Cs g/t	Li/Mg 10^4	K/Na	K/Rb	K/Cs
Gabbros	10	1,89	0,74	28	1	2,2	0,39	270	7500
Diabases standard T-111, Banks Penisula	12,5	1,5	0,53	22	1,08	—	0,35	241	4907
Taylor S. R. et al. (1965) L. H. Ahrens et al. (1960)			1,30	49	1,53	—	—	265	8490
Fairbairn et al. (1953) Ø 43 diabases corrected L. H. Ahrens et al. (1952) Li Ø 12 an according to Pinzon et al. (1953)	7,7	—	0,78	42	—	—	—	186	—

(1972) in Yugoslav hyperbasites Li content is 0,5 g/t. Lithium contents and Na/Li ratios are included in the following table adopted from the work B. G. Lutz (1975), p. 64.

Rubidium

Rubidium is a geochemically important element for three reasons. Its content in rocks and minerals is relatively high (10–1.000 g/t), may be detected by several methods and displays close geochemical relation to potassium and therefore the degree of magma differentiation or process of selective melting decides about its content in rocks. Therefore it is possible to apply this incompatible element to solve petrological problems.

In rock-forming minerals rubidium enters the positions of potassium-more in micas than in feldspars, however, since representation of feldspars in rocks is greater, the main Rb carriers are feldspars. The average content of Rb in the earth crust is 90 g/t and K/Rb ratio around 230. For rocks K/Rb ratios between 150 to 300 are common. Lower ratio values are in pegmatites, in which rubidium increases more than potassium. S. R. Taylor et al. (1965), u. 142, mentions the following values of alkalic elements for the fundamental rock types (Tab. 3).

In detection of Rb in various laboratories an evident dispersion of results was established. Before that increased Rb contents were detected, adjusted and

Table 2

Na and Li average contents of main types of basic rocks according to B. G. Lutz (1975 – p. 64).

Rock	Na	Li	Na/Li	
Chondrite	6 800	2,7	2 500	Mason V., 1965
Oceanic tholeiite	20 000	6,0	3 300	Melson W. G., Thompson G., 1971
Oceanic tholeiite	20 500	4,7	4 360	Engel A. E. J. et al., 1965
Archean tholeiite	20 000	5,0	4 000	Hallberg, Williams, 1972
Alkalic olivine basalt	30 000	11,0	2 730	Engel A. E. J. et al., 1965
Potassium basalt	29 000	24,0	1 200	Tichonenkova R. P., et al., 1971
Potassium basalt	23 000	40,0	5 800	Tichonenkova R. P., et al., 1971
Kimberlite	1 280	15,0	85	Lutz B. G., 1975

lowered later by correlation factor 0,393 (L. H. Ahrens et al., 1952), M, Prinz (1967) mentioned the following survey of average values of rubidium contents in various groups of basalt rocks.

G. Faure – P. M. Hurley (1963) 32 g/t, A. P. Vinogradov (1962) 45 g/t, K. K. Turekian, K. H. Wedepohl (1961) 30 g/t, P. W. Gast (1960) 29 g/t, E. L. Horstman (1957) 30 g/t, H. W. Fairbairn et al. (1953) 43 g/t, S. R. Hart, A. J. Nalwalk (1970) basalts from Puerto-Rico between 1,26 to 3,44 Rb. M. Prinz (1967) mentions the averages of Rb content in basalt groups between the values 18 to 33 g/t and median 10 g/t. B. G. Lutz (1975) in Tab. 17 p. 58 mentions the values of several authors of Rb contents in magmatic basic rocks. Oceanic tholeiites (according the data of 7 authors) have average Rb contents from 1,11 to 4,1 g/t average 2,5. For continental tholeiites and basalts of island arcs are the average values of groups determined between 5–26 g/t and the total average 14,8. For metabasites 23–32 g/t, average 27 g/t, for alkalic olivine basalts are the average of groups in values 41,1 to 33 g/t on an average 30,6 g/t. The arithmetic means of Rb contents from metabasites of individual mountain ranges of the West Carpathians are varying between 8–38 g/t see Tabs. 5, 6, 7, 8 in the text of this

Table 3

Contents of Li, Rb, Cs, Tl in geological materials according to S. R. Taylor et al. (1965 – p. 142).

	Li	Rb	Cs	Tl
Chondrites	2,7	2,3	0,18	0,15
Earth crust	20	90	3	0,45
Ultrabasites	–	–	–	0,05
Basalts	10	30	1	0,1
Syenites	30	110	1	0,3
Granodiorites	25	120	2	0,5
Granites	30	150	5	0,75
Schists	60	140	5	0,3
Arkoses	30	120	3	0,3
Quartzites	5	30	–	–
Limestones	20	5	–	–
Soils	5–200	20–500	–	–

article. For comparison we also mention some data about Rb contents in metabasites, mainly amphibolites mentioned in foreign literature.

I. J. Ambrustmacher, F. S. Simons (1977) determine 50 g/t (average of 15 analyses) in amphibolites of the central Beartooth massif (Montana Wyoming), P. C. Kamp (1969) 85 g/t Rb for amphibolites of the same massif. N. Herz, S. Banerjee (1973) determine that in amphibolites from Brazil (8 analyses) Rb contents vary 18–31 g/t. K/Rb ratio is 74–208, R. K. O'Nions, D. B. Clark (1972) established Rb contents from Tertiary basalts of Baffin Bay to be varying 0,153–3,22 g/t in ten analyses, and two analyses with the contents 25,1 and 16,6 g/t. Ratio values of K/Rb are between 61 and 1250.

As already mentioned rubidium ist mostly concentrated in feldspars and feldspathoids and only insignificantly in late pyroxenes. In plagioclases it depends on contents of Or constituent and in rocks on the amount of orthoclase. According to L. H. Ahrens et al. (1952) K/Rb ratio is equal in meteoric and terrestrial materials (mainly in magmatic rocks/ and varies between 160 to 300. Most frequent is the ratio 240. In fact, however, variation of ratio in basalts is greater and varies between 245 and 512. M. Prinz (1967) detects the value of Rb/Sr ratio 0,06 for tholeiites, 0,05 for alkalic basalt and 0,06 for other basalt types. Rb/Sr ratio in our samples varied from 0,006 to 0,97 with the average value 0,09. Of importance for classification and petrology is K/Rb ratio and B. G. Lutz (1975) uses this ratio to characterize various genetic types of rocks of mantle and crustal character. In Fig. 7 the authors of this work used the graphical base of B. G. Lutz to find out distribution and

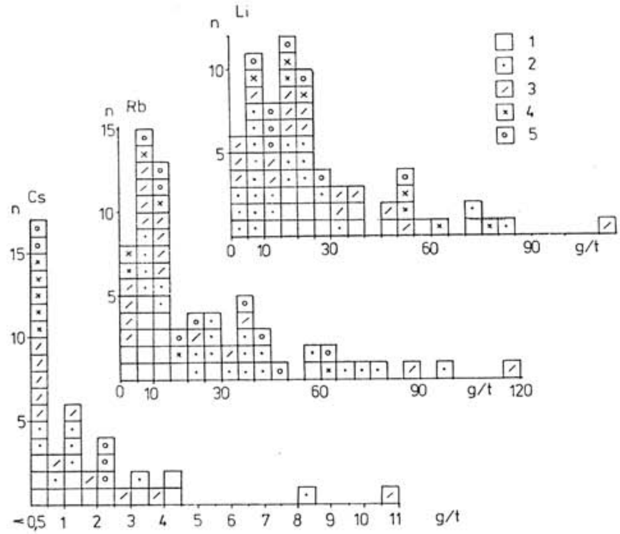


Fig. 1. Histogram of Li, Rb, Cs contents in metabasites of the Tatraveporides. 1 = Little Carpathians, 2 = Low and High Tatra, 3 = Veporides, 4 = Spišsko-gemerské rudohorie mts., 5 = Tríbeč.

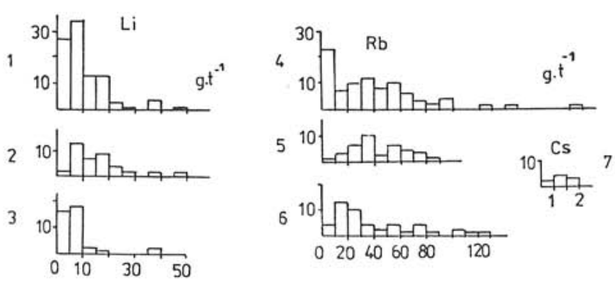


Fig. 2. Histogram of Li, Rb, Cs contents in basic rocks according to K. S. Heier, J. A. S. Adams (1964, p. 281). 1. Li in basalts generally (96 analyses) 2. Li in alkalic basalts (33 analyses) 3. Li in tholeiitic basalts (29 analyses) 4. Rb in basalts (86 analyses) 5. Rb in basalts (36 analyses) 6. Rb in diabases (47 analyses) 7. Cs inbasalts (9 analyses).

dispersion of K/Rb ratio values and delimited in the graph the field, which is characteristic for Tatraveporide metabasites. The graph shows that the field of Tatraveporide metabasites coincides with fields of continental and oceanic tholeiite, olivine basalt and kimberlite. It is also evident that metamorphism has not essentially shifted the dispersion field of potassium and rubidium, compared with nonmetamorphosed rocks and so on the basis of K/Rb ratio in metabasites the character of primary magma, from which metabasites originated, may be determined. According to B. G. Lutz (1975) Rb content in rock-forming minerals increases in the order olivine-pyroxene-enstatite-garnet-diopside. From mantle rocks spinel lherzolites and alpine type hyperbasites display a minimum content of alkalies. The alkalies migrated away with selective melting of the original matter and therefore magmatic rocks rising from depth enriched in alkalies including rubidium. This dependence is evident from the graph showing distribution of potassium and rubidium (Figs. 5, 7). From the graph a good positive correlation between both elements is visible.

Cesium

Cesium is an element, which substitutes with potassium only. It is the largest cation and forms a strong ionic bond with oxygen and only with substitution with potassium the rule of the possibility of substitution of elements with 10 % to 15 % difference in dimension of radii is kept. This narrowed possibility

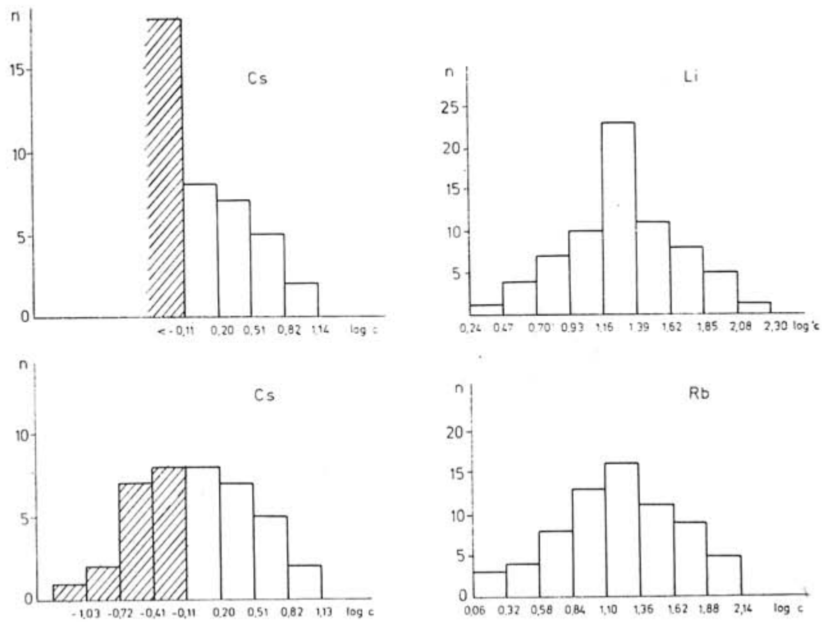
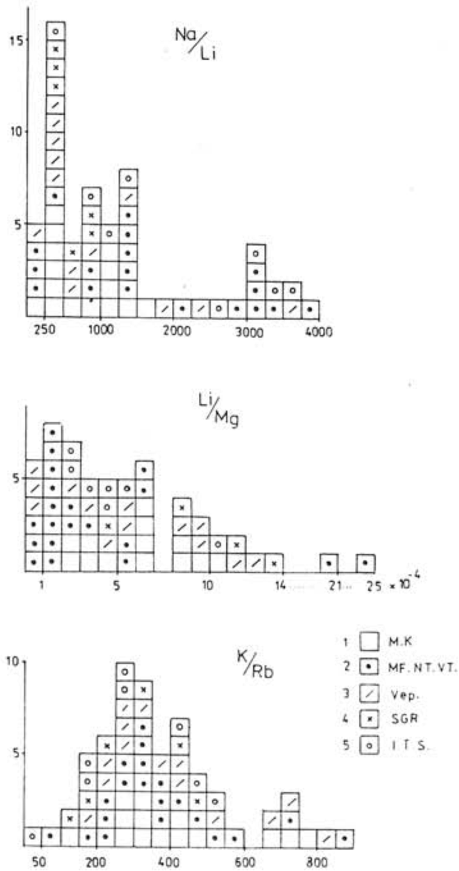


Fig. 3. Histograms Li, Rb, Cs compiled by the method of E. Plško – E. Martiny (1979). The hatched field signifies the calculated division of these values, which have lesser content than the detection limit.

of substitution, in contrast to Rb, results in formation of own minerals in the pegmatite process (e. g. pollucite). Cesium is a suitable indicator of the degree of crystallization differentiation or melting differentiation (selective melting); besides K/Cs ratio also Ba/Cs ratio may serve as index ratio. Low cesium contents are detected relatively difficult and by the method of atomic absorption we did not reach detection limit lower than 3 g/t. L. H. Ahrens et al. (1960) established equal ratio of K-Rb-Cs representation in terrestrial and cosmic materials. L. H. Ahrens considers this phenomenon as an evidence of the origin of rocks from uniform primitive material. Greatest Cs values were found by G. Deleon and L. H. Ahrens (1957) in Yugoslav granites, from 37 to 115 g/t Cs.

B. G. Lutz (1957) mentioned that ultrabasic rocks of the mantle are characterized by very low Cs content, e. g. 0,006 g/t in alpine type ultrabasites. In basalts Ca increases, e. g. S. R. Hart and A. J. Nalwalk (1970) mentioned in basalts from Puerto-Rico Cs values in the range from 0,0338 to 0,2714 g/t and K/Cs ratio between 4,20 and 81.000. Tatraveporide metabasites display K/Cs



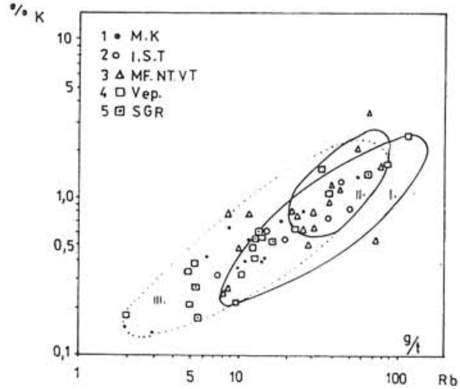


Fig. 5. Graph of dependence of Rb—K contents in Tatraveporide metabasites and comparison with similar graph of K. S. Heier—J. A. S. Adams (1964, p. 282) I = field of diabases, II-field of basalt rocks, III field of Tatraveporide metabasites.

Fig. 4. Histograms of Na/Li; Li/Mg; K/Rb ratios in Tatraveporide metabasites.

Table 4
Contents of Li, Rb, Cs in rocks and minerals according to various authors.

Rock (locality)	K %	Na %	Li %	Rb %	Cs %	Sr %
Amphibolite (South Dakota)	—	—	—	0,001	—	—
Limburgite basalt (Texas)	—	—	—	0,001	—	—
Metaperidotite	—	—	—	0,004	—	—
Diabase (Virginia)	—	—	—	0,002	—	—
Average of analyses of 24 basic rocks (Minnesota)	—	—	—	0,004	—	—
Gabbro (average of 10 analyses)	—	—	—	0,003	0,0000n	—
Basalts (Siberia)	—	—	—	0,0027	—	—
Diabases (average of 4 analyses)	—	—	—	0,016	0,0040	—
Andesite (Hongkong)	—	—	—	0,013	0,0004	—
Gabbro-diorite (Susamir)	—	—	—	0,006	0,0004	—
Basalts (average of 84 analyses)	—	—	—	0,0028	—	—
Gabbro (average of 5 analyses)	0,2	1,09	—	0,005	—	—
Gabbrodiorite (average of 12 analyses)	0,38	3,56	—	0,004	—	—
Ultrabasic rocks	—	—	0,0000n	0,00002	0,0000n	0,0043
Basic rocks	—	—	0,0017	0,003	0,00011	0,0405
Intermediate rocks	—	—	—	0,011	0,0002	—
Ultrabasic rocks	—	—	0,00005	0,0002	0,00001	0,001
Basic rocks	—	—	0,0015	0,0045	0,0001	0,044
Intermediate rocks	—	—	0,002	0,010	—	0,08
Ultrabasic rocks	—	—	—	0,0038	0,001	—
Basic rocks	—	—	—	0,006	0,001	—
Intermediate rocks	—	—	—	0,011	0,0006	—
Gabbro (October massif)	0,37	1,55	0,0011	0,001	0,0001	—
Basalts (Puerto Rico)	0,23	—	—	0,0002	0,000012	0,0127
Orthoamphibolites (Kyjev complex)	—	—	0,0022	0,0014	0,0004	0,051
Orthoamphibolites (Polmos-Poros complex)	—	—	0,0022	0,0017	—	0,026
Paraamphibolites (Polmos-Poros complex)	—	—	0,011	0,0029	0,0010	0,0137
Basalts (Slovakia, 80 analyses)	1,55	2,77	0,0092	0,0085	—	0,0636
Andesites (Slovakia, 320 analyses)	1,36	1,84	0,0053	0,0089	—	0,0320
Amphibolic rocks (Little Carpathians)	0,6	2,4	—	—	—	0,0224
Limburgite basalts (Slovakia)	0,66	1,59	0,0064	0,0038	—	0,0320
Common amphibole	—	—	—	0,009	0,001	—
Amphibole	—	—	—	0,0085	0,0009	—
Biotite (from diorites, 12 analyses)	—	—	—	0,0057	0,0047	—

Ba %	Rb/Cs	K/Cs	K/Rb	Mg/Li	References
—	—	—	210	—	Horstman E. L., 1959
—	—	—	850	—	Maxwell R. A., 1949
—	—	—	250	—	Sukoljukov J. A. et al., 1965
—	—	—	270	—	Fairbairn H. W., 1951
—	—	—	140	—	Horstman E. L., 1959
—	—	—	310	—	ditto
—	—	—	263	—	Nesterenko T. V., 1965
—	4	—	—	—	Goišvili V. A., 1965
—	33	—	230	—	Brock R. W., 1943
—	15	4 050	270	—	Stavrov O. D., 1963
—	—	—	—	—	Beus A. A. et al., 1965
—	—	—	40	—	Soboleva S. F. in Kogan V. I., 1971
—	—	—	95	—	ditto
—	20	3 000	150	—	Turekian K. K., Wedepohl K. H., 1961
—	27	7 530	276	—	ditto
—	55	11 500	209	—	ditto
—	20	3 000	150	—	Vinogradov A. P., 1962
—	45	8 300	185	—	ditto
—	—	—	230	—	ditto
—	0,2	95	50	86 300	Solodov N. A., 1971
—	6	640	105	2 250	Solodov N. A., 1971
—	18	3 800	206	1 000	ditto
—	—	—	—	—	Stavrov O. D., 1963
—	83	4560—81000	430—2030	—	Hart S. R., Nalwalk A. J., 1970
0,024	3,5	—	—	—	Sidorenko et al., 1972
0,015	—	—	—	—	ditto
0,020	2,9	—	—	—	ditto
0,0553	—	—	182	—	Forgáč J., Kupčo G., 1974
0,0376	—	—	153	—	ditto
0,0146	—	—	—	—	Cambel B., Kupčo G., 1965
0,0416	—	—	174	—	Spišiak J., 1977
—	9	300	33	—	Ljachovič V. V. et al. in Stavrov O. D., 1965
—	9,4	—	—	—	Borisenko L. F. et al. in Stavrov O. D., 1963
—	12,1	—	—	—	Leontieva A. N. in Kogan et al., 1971

The table of alkalic elements contents and their correlation values of metabasites of the Little Carpathians, Inovec, Tríbeč, Suchý and Little Magura.

Table 5a

Sample No	Na_2O %	Na g/t	K_2O %	k g/t	Mg g/t	Li g/t	Rb g/t	Cs g/t
AM– 1.10–MK	2,39	17 730	0,52	4 310	43 600	29,5	15,0	2,5
AM– 2. 8–MK	1,64	12 160	0,99	8 210	51 400	37,0	26,0	—
AM– 3.10–MK	2,51	18 620	0,49	4 060	53 000	45,7	12,0	1,4
AM– 4.10–MK	1,38	10 230	0,50	4 150	40 500	36,7	15,0	1,7
AM– 5.10–MK	0,74	5 490	0,79	6 550	50 900	21,7	9,0	1,3
AM– 6.10–MK	3,73	27 670	0,08	660	33 400	24,0	6,5	0,8
AM– 7. 1–MK	1,02	7 560	0,21	1 740	52 200	24,0	—	—
AM– 8. 1–MK	2,51	18 620	0,68	5 640	31 500	56,5	13,0	3,3
AM– 9.10–MK	2,03	15 060	0,19	1 570	43 700	12,5	2,0	4,8
AM–10.10–MK	2,86	21 210	1,87	15 520	29 200	19,0	$58,0^+$	—
AM–11.10–MK	2,15	15 950	0,17	1 410	56 000	15,5	3,0	—
AM–12.10–MK	0,34	2 520	0,91	7 550	69 400	$74,2^+$	18,0	4,5
AM–13.10–MK	3,04	22 550	0,45	3 730	28 700	28,5	10,0	—
AM–14.10–MK	3,21	23 810	0,54	4 480	37 300	15,5	6,5	ND
AM–40.10–MK	2,59	19 210	0,20	1 660	—	16,0	5,5	—
A.p.	2,14	15 893	0,57	4 749		27,29	10,88	2,27
$A.p.^+$						$30,42^+$	$14,25^+$	
G.p.						26,70	10,13	1,64
λ.X						1,67	2,36	2,69

Cs — ND = 0,2 Ba — ND = 25
Cs — 0,5 = 0,2 Ba — 50 = 25

Table 5b

Sample No	Na_2O %	Na g/t	K_2O %	K g/t	Mg g/t	Li g/t	Rb g/t
AM–38.13–I	2,98	22 100	0,41	3 400	46 000	17,0	7,5
AM–39.13–I	4,29	31 820	0,87	7 220	22 700	9,0	13,5
180.34. 9–T	3,26	24 180	1,42	11 780	39 400	25,5	45,0
182.34.11–T	3,79	28 110	1,07	8 880	34 000	10,5	50,0
172.34. 1–T	5,46	40 500	0,63	5 230	31 000	12,5	20,0
173.34. 2–T	6,04	44 810	0,73	6 060	55 000	14,5	15,0
175.34. 4–T	3,34	24 770	0,90	7 470	45 300	24,5	39,0
116.18. 1–S	3,00	22 250	0,25	2 070	46 900	52,0	63,0
A.p.	4,02	29 818	0,79	6 514		20,7	31,6
G.p.						17,66	25,30
λX						1,77	2,13

Little Carpathians – MK

Ba g/t	Sr g/t	Na/Li	Li/Mg	K/Rb	K/Cs	Ba/Rb	Rb/Sr
40	288	601	7.10^{-4}	287	1 724	2,7	0,05
55	245	328	7	316	—	2,1	0,47
48	275	407	9	338	2 900	4,0	0,04
195	245	278	9	276	2 441	13,0	0,06
340	224	253	4	728	5 039	37,8	0,04
~1000	540	1152	7	102	825	~153,8	0,01
204	269	315	5	—	—	—	—
650	370	329	18	434	1 709	50,0	0,04
40	355	1204	3	785	327	20,0	0,006
110	680	1116	7	268	—	1,9	0,08
155	182	1029	3	470	—	51,7	0,02
390	60	34	11	419	1 678	21,7	0,3
138	680	791	10	373	—	13,8	0,01
245	340	1536	4	689	>22 400	37,7	0,02
101	440	1201	—	302	—	18,4	0,01

Inovec, Tribeč, Suchý, M. Magura – ITSM

Cs g/t	Ba g/t	Sr g/t	Na/Li	Li/Mg	K/Rb	K/Cs	Ba/Rb	Rb/Sr
ND	45	309	1300	4.10^{-4}	453	>17 000	6,0	0,02
—	170	340	3 536	4	535	—	12,6	0,04
—	256	331	948	6	262	—	5,7	0,13
—	191	412	2677	3	178	—	3,8	0,12
—	92	166	3240	4	262	—	4,6	0,12
ND	28	152	3090	3	404	>30 300	1,8	0,10
2,5	129	400	1011	5	192	2 988	3,3	0,30
—	76	316	428	11	33	—	1,2	0,20

Explantations in Tab. 5; The cross with the numbers means, that in the calculations of arithmetic and geometric menans the value was not included in the group. In the average calculations are given two values; one with leaving out of value (upper) and second (low with cross) including the cross of the designated value. In the calculation of elements ratios are taken corrected values only.

Used symbols: MK = Malé Little Carpathians, I. T. S. M. = mountains Inovec, Tríbeč, Suchý, Malá Magura; MF, NT, VT = Little Fatra, Low and High Tatra; VEP = Veporides; SGR = Spišskogemerské rudohorie mts., A = amphibolites (from 35 to 65 % amphibole); MeA = melaamphibolites (above 65 to 95 % amphibole); C = hornblendites (over 95 % amphibole); GA = gabbroamphibolite; MeGa = melagabbroamphibolite; G = gabbro; S = serpentinite; P = metapyroclastics; Mi = migmatite-amphibolites, AAS = method of atomic absorption, NA = method of neutron activation; SPA = method of spectral analysis.

Table 6a

Tab. 6. Contents of alkalic elements and their correlation values in metabasites of Fatra-Tatric crystalline. (MF, VT, NT), Expalanations in Tab. 5.

Sample No	Na_2O %	Na g/t	K_2O %	K g/t	Mg g/t	Li g/t	Rb g/t	Cs g/t
AM–17.22–MF	2,26	16 760	0,82	6 800	43 300	7,5	26	ND
123.22.5–MF	4,44	33 820	0,97	8 050	43 800	10,5	30	<0,5
126.22.2–MF	1,79	13 280	1,01	8 380	57 500	4,0	22	—
127.22.3–MF	2,51	18 620	0,82	6 800	48 900	12,5	31	—
123.22.4–MF	2,85	21 140	1,02	8 460	37 200	7,5	22	—
131.24.1–MF	3,26	24 180	0,95	7 880	28 200	4,0	9	—
132.24.2–MF	3,26	24 180	0,95	7 880	28 200	4,0	11	—
133.24.3–MF	1,30	9 640	0,57	4 730	26 500	6,5	10	1,0
136.25.2–MF	2,09	15 500	1,63	13 530	46 100	15,5	39	1,2
AM–35.36–NT	0,46	3 410	0,80	6 640	71 500	16,0	16	1,3
188.37.1–NT	1,34	[illegible]	0,70	5 810	40 800	84,0	79	7,6+
AM–21.33–NT	2,14	15 870	1,61	13 360	44 700	20,0	43	3,3
AM–22.33–NT	0,35	2 590	2,39	19 840	33 800	27,5	80	—
143.20.2–VT	3,51	26 040	0,60	4 980	35 800	8,5	20	ND
149.20.3–VT	3,69	27 370	2,55	21 170	31 500	78,0	58	—
152.20.6–VT	3,74	27 740	0,31	2 570	33 900	7,0	8,5	—
154.20.3–VT	3,33	23 410	1,15	9 540	31 200	22,5	39	—
165.31.1–VT	2,37	17 530	0,71	5 890	25 600	5,5	11	—
171.33.1–B	3,93	29 150	4,67	33 770	33 800	20,2	68	2,4
AM–15.20–VT	1,69	12 530	0,31	2 570	48 600	9,5	8	<0.5
A.p.	2,54	18 838	1,23	10 183		18,54	31,98	1,11
A.p.+								1,76+
G.p.						11,99	24,59	0,83
λX						2,40	2,15	3,86

contents ratio within the limits from 327 to >22400. Cs values increase from tholeiites through alkalic olivine basalts to potassium basalts and kimberlites.

Evaluation of results

The starting point for evaluation of the original results are Tables 5, 6, 7, 8, in which analytical data of the contents of alkalic elements from individual metabasite samples are mentioned, sorted according to mountain ranges or tectonic units. In Tab. 8 the fundamental statistical data are quoted, calculated from groups of analyses from the individual mountain ranges or from larger groups, including apart the Tatrides, Tatraveporides or also the total group of analyses. The arithmetic and geometric means and their standard deviations were calculated from the data. In the table are also ratios (mutual correlation) of alkalic elements /K/Rb, K/Cs, Na/Li, Li/Mg, Rb/Sr, Ba/Rb. We note that we

Malá Fatra, Low Tatra, High Tatra — MF, NT, VT

Ba g/t	Sr g/t	Na/Li	Li/Mg	K/Rb	K/Cs	Ba/Rb	Rb/Sr
112	141	2 234	2.10^{-4}	262	>34 000	4,3	0,18
167	256	3 221	2	268	16 100	5,6	0,12
263	632	3 320	0,7	381	—	11,9	0,03
254	137	1 490	3	219	—	8,2	0,23
96	173	2 819	2	385	—	4,4	0,13
32	120	6 045	1	876	—	3,6	0,07
278	90	6 045	1	716	—	25,3	0,12
190	257	1 483	2	473	4 730	19,0	0,04
807	492	1 000	3	347	11 275	20,7	0,03
101	166	213	2	415	5 108	6,3	0,10
234	115	118	21	74	765	3,0	0,69
104	234	794	4	311	4 049	2,4	0,18
135	288	94	8	248	—	1,7	0,28
167	302	3 064	2	172	>24 900	5,8	0,10
770	1200+	351	25	365	—	13,3	0,05
67	235	3 963	2	302	—	7,9	0,03
193	779	1 263	7	245	—	4,9	0,20
89	179	3 196	2	535	—	8,1	0,06
472	567	1 443	6	570	16 154	6,9	0,12
39	71	1 319	2	321	5 140	4,9	0,11

Table 7a

Tab. 7. Contents of alkalic elements and their vorrelation values in metabasites
Veporides and Gemerides (VEP, SGR). Explanations in Tab. 5.

Sample No	Na_2O %	Na g/t	K_2O %	K g/t	Mg g/t	Li g/t	Rb g/t
AM–18–VEP	3,69	27 370	0,26	2 150	31 700	19,0	5,0
AM–19–VEP	1,49	11 050	0,60	4 980	32 400	15,0	13,0
AM–23–VEP	2,84	21 060	0,20	1 660	63 300	4,0	2,0
AM–24–VEP	4,55	33 750	0,42	3 480	32 300	14,0	5,0
AM–25–VEP	2,18	16 170	0,32	2 650	43 900	17,0	5,5
AM–26–VEP	2,48	18 390	0,72	5 970	31 100	20,0	13,5
AM–27–VEP	0,99	7 340	1,33	11 040	54 700	37,0	38,5
AM–28–VEP	3,42	25 370	0,48	3 980	38 400	5,0	5,5
195.47. 1–VEP	1,89	14 020	3,38	28 060	47 800	49,0	118,0+
196.47. 2–VEP	2,04	15 130	2,05	17 010	64 500	37,0	89,0
200.48. 4–VEP	0,71	5 260	2,08	17 260	36 900	20,0	34,0
201.48. 5–VEP	1,26	9 340	0,51	4 230	27 000	34,0	14,0
202.48. 6–VEP	4,49	33 310	0,28	2 320	29 900	122,5+	10,0
235.57.12–VEP	5,43	40 280	0,78	6 470	25 900	22,0	24,0
A.p.	2,68	19 846	0,96	7 947		22,53	19,8
A.p.+						29,68+	26,9
G.p.						21,04	14,1
λX						2,39	3,2

Table 7b

Sample No	Na_2O %	Na g/t	K_2O %	K g/t	Mg g/t	Li g/t	Rb g/t
AM–29–SGR	4,30	31 900	0,06	490	45 100	62	2,5
AM–30–SGR	2,41	17 870	0,63	5 230	45 500	52	16,0
AM–31–SGR	4,70	34 860	1,86	15 440	17 900	77+	63,5+
AM–32–SGR	2,67	19 800	0,71	5 890	49 500	24	13,5
AM–34–SGR	2,89	21 440	0,04	330	27 400	55	2,5
A.p.	3,39	25 174	0,66	5 476		48,25	8,63
A.p.+						54,00+	19,6+
G.p.						50,48	9,70
λX						1,56	3,55

excluded from the group sporadical extremely high values of elements and th values are indicated with cross. The arithmetic mean is calculated for co parison without the mentioned values (upper number) but also with the me tioned value (lower number with cross).

On the basis of Li, Rb, Cs contents histograms were compiled (Fig. 1). I

Veporides — VEP

Cs g/t	Ba g/t	Sr g/t	Na/Li	Li/Mg	K/Rb	K/Cs	Ba/Rb	Rb/Sr
ND	81	126	1 441	6.10^{-4}	430	>10 750	16,2	0,04
ND	224	195	737	5	383	>24 900	17,2	0,07
ND	40	60	5 265	0,6	830	>8 300	20,0	0,03
ND	36	200	2 411	4	696	>174 000	7,2	0,03
ND	51	295	951	3,8	482	>13 250	9,3	0,02
3,9	110	575	920	6	442	1 531	8,1	0,02
1,8	302	510	198	7	287	6 133	7,8	0,08
—	46	229	5 074	1	724	—	8,4	0,02
—	697	122	286	10	238	—	5,9	0,97
11,0⁺	331	224	409	6	191	1 547	3,7	0,40
—	264	740	263	5	508	—	7,8	0,05
—	171	875	275	13	302	—	12,2	0,02
<0,5	75	179	272	41	232	4 640	7,5	0,06
3,0	274	529	1 831	8	270	2 157	11,4	0,05

Spišsko-gemerské rudohorie mts. — SGR

Cs g/t	Ba g/t	Sr g/t	Na/Li	Li/Mg	K/Rb	K/Cs	Ba/Rb	Rb/Sr
ND	21	138	515	$13{,}7.10^{-4}$	196	>2 450	8,4	0,02
ND	166	204	344	11,4	327	>26 150	10,4	0,08
—	257	295	453	43,0	243	—	4,0	0,22
ND	42	112	825	4,8	436	>29 450	3,1	0,12
ND	79	760	390	20,0	132	>1 650	31,6	0,003

comparison we also mention histograms compiled by K. S. Heier, J. A. S. Adams (1964), p. 281, and concerning the contents of Li, Rb and Cs in basalts and diabases (Fig. 2). Fig. 1 shows that mainly in Cs are enough values below the detection limit, i. e. 20,5 g/t (Fig. 3) of this element with application of neutron activation. From Fig. 1 is visible that all analyses of gabbroid amphibolic rocks and gabbro-amphibolites from the Spišsko-gemerské rudohorie mts. fall to this category, which fact may be considered as characteristic of this type of rocks. Almost one half of metabasite samples studied by us (17 from 40) displays cesium values less than 0,5 g/t.

Table 8

Tab. 8. Summarizing table of arithmetic and geometric means of studied groups of the Tatraveporides and Gemerides. Explanations in Tab. 5.

Mountain range		Na_2O %	Na g/t	K_2O %	K g/t	Li g/t	Rb g/t	Cs g/t
MK	A.p.	2,14	15 893	0,57	4 749	27,29	10,88	2,27
n = 15	št.o.	0,96	7 103	0,45	3 766	12,79	6,66	1,62
	G.p.					26,70	10,13	1,64
	λ X					1,67	2,36	2,69
ITSM	A.p.	4,02	29 818	0,79	6 514	20,7	31,60	
n = 8	št.o	1,16	8 618	0,37	3 072	14,03	20,27	
	G.p.					17,66	25,30	
	λ X					1,77	2,13	
MF, NT, VT	A.p.	2,54	18 888	1,23	10 183	18,54	31,98	
n = 20	št.o.	1,17	8 739	1,00	8 335	22,42	23,21	
	G.p.					11,99	24,59	
	λ X					2,40	2,15	
VEP	A.p.	2,68	19 846	0,96	7 947	23,53	19,88	
n = 14	št.o.	1,45	10 776	0,93	7 747	13,19	23,66	
	G.p.					21,04	14,10	
	λ X					2,39	3,23	
SGR	A.p.	3,39	25 174	0,66	5 476	48,25	8,63	<0,2
n = 5	št.o	1,03	7 668	0,74	6 141	16,70	7,15	
	G.p.					50,48	9,70	<0,2
	λX					1,56	3,55	
Tatrides	A.p.	2,67	19 877	0,92	7 605	21,87	25,22	
n = 43	G.p.					17,04	18,14	
Tatr + VEP	A.p.	2,68	19 869	0,93	7 689	22,26	23,93	
n = 57	G.p.					17,94	17,05	
Tatr + VEP + SGR	A.p.	2,73	20 297	0,91	7 510	24,02	22,88	
n = 62	G.p.				19,50		16,29	0.96

A.p. = arithmetic mean
št.o. = štandard. deviation of arithmetic mean
G.p. = geometric mean
λX = factor, by which the geometrical mean is divided and multiplied

The histogram of Rb values shows that the Little Carpathians have low Rb values, in contrast to the group of the Fatra and Tatra mountains (Tab. 6), showing higher Rb values. In Li it is contrary. The Little Carpathians have higher Li values 10–30 g/t whereas the group of samples from the Fatra-Tatra region evidently lower ones (Fig. 1). This fact may confirm the assumption of bond of Li to sodium as Little Carpathian rocks have a relatively higher amount of light-coloured components and less potassium than rocks of the group of Fatra and Tatra mountains.

The main frequency range of lithium contents in metabasites is 5—25 g/t (see Fig. 1) and similarly as Rb contents they generally agree with data in literature if concerning metabasites.

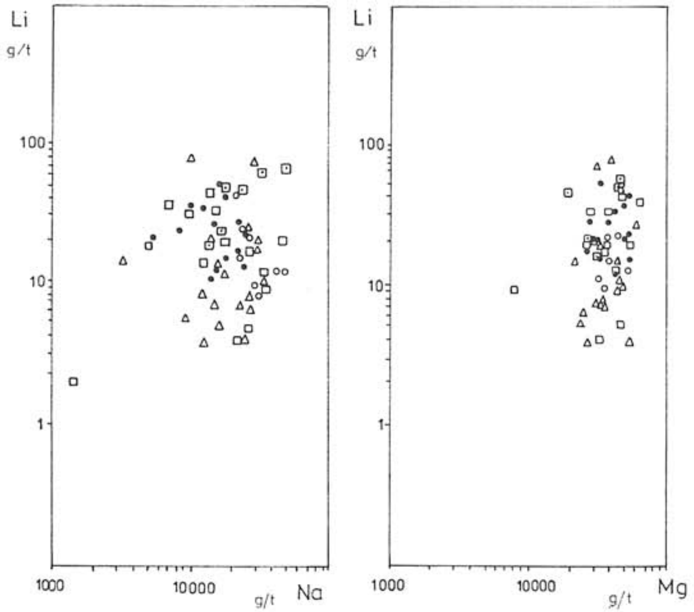


Fig. 6. Graph of dependence of Li—Na and Li—Mg contents in Tatraveporide metabasites.

Mostly different are Cs contents. This element, according to various authors, has somewhat higher values when compared with our ones. It is difficult to decide wether it is overestimation of analytical results or a characteristic feature of amphibolic rocks of the Tatraveporide crystalline.

On the contrary to Rb content histograms in basaltoid rocks, compiled by K. S. Heier, J. A. S. Adams (1964), p. 281, the histogram of Rb of Tatraveporide metabasites is not of symmetrical form because the maximum of values is concentrated to the side of low values (5—15 g/t) whereas according to K. S. Heier, J. A. S. Adams rubidium contents from 86 basalt samples have the frequency of most abundant contents 20—60 g/t. The histogram of Rb contents of Heier—Adams, from diabases, however, displays a similar trend as Tatraveporide metabasites.

The reader has the possibility to compare Rb, Li, Cs contents from Tatraveporide metamorphites with data mentioned in literature. We see that mainly the analyses of S. R. Hart et al. (1970) and B. I. Kogan et. al. (1970) and others are often in cesium orderly lower than in Tatraveporide metamorphites.

There are also several data from other authors with analogical results as were obtained by the authors of this work, justifying us to consider the values of cesium contents mentioned by us as real. The authors performed graphical comparison of Rb distribution depending on potassium contents (Fig. 5). As base the analogical graph of K. S. Heier – J. A. S. Adams (1964, p. 282) was taken. When we compare the dispersion of values in the graph of K. S.

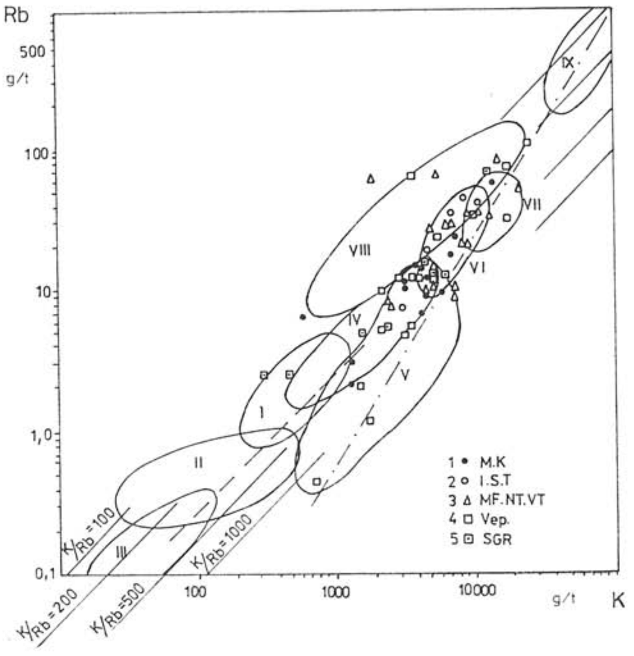


Fig. 7. Graph of dependence of Rb–K contents in Tatraveporide metabasites and comparison with analogous graph of B. G. Lutz (1975, p. 52).
Explanations: 1 Little Carpathians (MK); 2 = Inovec, Tríbeč, Suchý, Little Magura (I. T. S. M.). 3 = Little Fatra, Low Tatra, High Tatra (MF, NT, VT): 4 – Veporides (VEP); 5 = Spišsko-gemerské rudohorie mts. (SGR). Dashed line is the straight line of mean contents of mantle rocks, the dotted-and-dashed line is that of mean contents of basalts and tholeiites. Fields: I = garnet peridotite; II – spinel peridotite; III – alpine type hyperbasites, IV = mantle eclogites; V = oceanic tholeiites; VI = continental tholeiites; VII = alkalic-olivine basalt; VIII – kimberlite; IX = potassium basalt.

Heier, J. A. S. Adams (1. c.) and of values of Tatraveporide metabasites, overlapping of the field formed by diabases (I) and basalt rocks (II) of Heier's graph with the field of Tatraveporide metabasites (dotted delimitation) may be established. Tatraveporide metabasites, however, show more values with lower Rb and K contents. The mentioned graph also confirms analytical correctness of our data and the fact that Tatraveporide metabasites geochemically belong to the group of basalt and diabase rocks with lesser K and Rb contents. Fig. 6 shows dependence of Li and Na values and is compiled on logarithmical scale. It indicates only very weak dependence of Li contents on sodium content. In Fig. 7 we do not observe dependsence of Li on Mg content.

The authors plotted the values of Rb and K contents in the studied samples in the graphical base of B. G. Lutz (1975, p. 52) (Fig. 7). The projection points

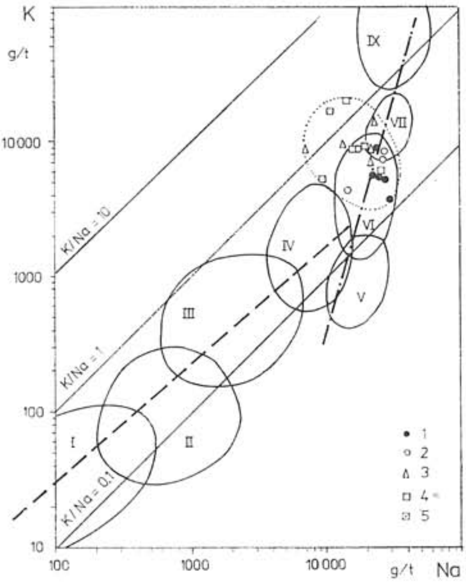


Fig. 8. Graph of dependence of Na–K contents in Tatraveporide metabasites on the graphical base of B. G. Lutz (1975, p. 61). In the graph the average values of Na and K contents from groups of Tatraveporide metabasites adopted from the work of B. Cambel – L. Kamenický (in press) are plotted. The field of Na and K contents in Tatraveporide metabasites is indicated with dotted lines in the graph. Explanations with Fig. 7.

of analyses of Tatraveporide metabasites fall to the fields of continental tholeiite, alkalic olivine basalt and oceanic tholeiite and partly also kimberlite. This location of Rb/K values in Fig. 7 also indicates that no distinct shifts or disturbing of the ratios of alkalic elements took place with metamorphism and that the present state of alkalii ratios in metabasites essentially corresponds to premetamorphic composition of Tatraveporide metabasites.

Fig. 9 shows Na-K dependence on similar graphical base (B. G. Lutz, 1975, p. 61). The values of Na–K contents plotted in the graph are concentrated in the field of alkalic olivine basalt and continental tholeiite. In the graph the average values of Na and K contents from groups of Tatraveporide metabasites, adopted from the work by B. Cambel, L. Kamenický (in press), are indicated.

Conclusions

1. The authors determined Li, Rb, Cs contents in 68 samples of Tatraveporide metabasites and calculated values of K/Rb, K/Cs, Na/Li, Li/Mg, Rb/Sr, Ba/Rb ratios. Besides the arithmetical and geometrical means they mentioned the standard deviations of these values. The calculations of averages do not concern only rocks from the individual mountain ranges but also from larger regional units. All these original data are mentioned in Tabs. 5, 6, 7, 8.

2. In the text as well as in particular tables (Tabs. 1, 2, 3, 4) the values of element contents or the values of their ratios, already published in literature, are mentioned so that comparison of the results could be confirmed. The data mentioned confirm that the data published by us correspond to up to present determination of the contents of these alkalic elements of low concentrations except Cs, which element displays higher contents in our work when compared with some results mentioned by S. R. Hart et al. (1970) and other authors. The authors mention histograms of contents of alkalic elements, making possible to compare data of the authors with other data, treated and expressed in histograms by K. S. Heier, J. A. S. Adams (1964).

3. The authors state that on the basis of potassium and rubidium distribution Tatraveporide metabasites agree with rocks of basalt and diabase type (K. S. Heier, J. A. S. Adams l. c.). According to comparison with the graphical bases of B. G. Lutz (1975), (the graph of Rb-K dependence) the projecting points of potassium and rubidium contents in Tatraveporide metabasites fall to the field of alkalic olivine basalts of continental and oceanic tholeiite and partly of kimberlite. They are regularly distributed along the line of average composition of basaltoid rocks (dotted-and-dashed) with small shift to the left (towards lower concentrations of potassium). The authors conclude that such a relatively conforming situation of projecting points of analyses of metabasites and nonmetamorphosed rocks of basaltoid character testifies that in alkalic elements metamorphism did not lead to essential disturbing of contents and mutual relations. Although Rb and K contents have a wide interval of dispersion, the prevailing part of projection points lies in the fields of tholeiitic rocks. We may consider the discussed rocks as metamorphosed equivalents of rocks of basalt character of geosynclinal origin. Our work shows that, as a consequence to dispersion of the values of chemical analyses, geochemical classification of rocks can determine rough petrogenetic assignment only. This is not always in accordance with the endeavour to work out a precise petrogenetic characterization on the basis of geochemical classification only. Precise genetic assignment of rocks is possible after complex evaluation from all viewpoints only.

4. The method of lithium and rubidium detection in metabasites by atomic absorption was verified. Detection of Cs by this method has not led to satisfactory results with given technical equipment of the laboratories and therefore the authors applied the results obtained by neutron activation.

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List and documentation of samples

180.34.9–T	Tribeč – Skýcov, forester's house Gubo – amphibolite
182.34.11–T	Tribeč – Drahošická Huta, forester's house Gubo, 600 m NW, quarry – amphibolite
172.34.1–T	Tribeč – Skýcov, NE, 1,5 km N from elev. p. 688,7 m – amphibolite
173.34.2–T	Tribeč, SE from elev. p. 517 m in deep valley-amphibolite
116.18.1–S	Suchý, road cutting N of Križná, in the curve-amphibolite, fine-grained

129.22.5–MF	Malá Fatra, quarry in the valley of the Mlynický potok brook near Martin – fine-grained massive amphibolite
126.22.2–MF	Malá Fatra, valley E of the Kunerád castle-augen-amphibolite
127.22.3–MF	Malá Fatra, Martinské Hole mts. (Martin 2 km from' Stráne), quarry in the valley, gabbro-amphibolite, fine-grained, schisto se
128.22.4–MF	Malá Fatra, quarry in the valley of the Mlynický potok brook near Martin – amphibolite, fine-grained, schistose
131.24.1–MF	Malá Fatra, road cutting 1,5 km NW of the village Lásky near Martin – garnet amphibolite with massive structure, fine-grained
132.24.2–MF	Malá Fatra, road cutting 1,5 km NW of the village Lásky near Martin – garnet amphibolite, fine-grained distinctly schistose
133.24.3–MF	Malá Fatra, cutting of new road rom Priekopa to the Martinské hole mts., 800 m WNW of elev. p. 903,4 – migmatitic amphibolite
136.25.2–MF	Malá Fatra, valley E from the Kunerád castle-biotitic amphibolite, schistose, green
188.37.1–NT	Low Tatra, Srdiečko, ridge N of the hotel, about 400 m-amphibolite
148.29.2–VT	High Tatra, groove between Ostredok and Nižná Magura at altitude 1075 m-amphibolite
149.29.3–VT	High Tatra, elev. p. 1906 m on ridge, Košiar-amphibolite
152.29.6–VT	High Tatra, ridge Bryšno-amphibolite
154.29.8–VT	High Tatra, quarry in the mouth of the Žiarska dolina valley-amphibolite, medium-grained, schistose
165.31.1–VT	High Tatra, groove from the Žiarska dolina valley to the Jalové sedlo saddle, altitude 1662 m-amphibolite, fine-grained schistose, with garnet
171.33.1–T	Branisko, quarry at the road between the saddle of the mountain range and the village Široké – biotitic augen amphibolite
195.47.1–VEP	Lopej, Čelno, 350 m N of elev. p. in the road cutting-amphibolite, fine-grained
196.47.2–VEP	Muráň valley, 100 m W of elev. p. 699,4 m-amphibolite, medium--grained
200.48.4–VEP	Muráň valley, 600 m S of elev. p. 968,2 m-amphibolite biotitized, medium-grained
201.48.5–VEP	Brzačka valley, 500 m SE of elev. p. 797,5 m-amphibolite schistose, chloritized and epidotized, with admixture of quartz and carbonates
202.48.6–VEP	Lopejské Čelno, elev. p. 942,6 m-amphibolite fine-grained or schistose, locally calcified
235.57.12–VEP	Valley of Veľký Zelený potok brook near Beňuš-amphibolite
AM–1.10–MK	Little Carpathians, Železná Studnička, upper quarry for amphibolites-fundamental rock type-spotted amphibolite
AM–2.8–MK	Little Carpathians, Železná Studnička, upper amphibolite quarry--more bazic type-melaamphibolite
AM–3.10–MK	Little Carpathians, Železná Studnička, lower amphibolite quarry--fundamental type-fine-grained amphibolite.
AM–4.10–MK	Little Carpathians, Bratislava-Dúbravka, area of Brižitice (256,6) new excavation, end of Kaletova street, schistose amphibolite
AM–5.10–MK	Little Carpathians, Záhorská Bystrica, about 400 m S of elev. p. 325,2 Holý vrch, upwards the valley from the building site of "Elektrovod" in the brook cut, medium-grained amphibolite
AM–6.10–MK	Little Carpathians, Pernek, about 800 m in the brook cut N from Pleš (elev. p. 471,3) – outcrops of metabasites of pillow-lava type
AM–7.1–MK	Little Carpathians, Pernek about 800 m at the road above the brook N of Pleš (471,3) – Tortonian pebbles-amphibolic gabbro
AM–8.1–MK	Little Carpathians, Pernek, margin of the village, outcrop of metabasites in the road cutting, about 30 m of road-blocks, foothill of Klokočiny (542,1) blastomylonitic metagabbro
AM–9.10–MK	Little Carpathians, outcrop of amphibolites in the road cutting Pernek-Baba, Misársky Ostrobec-500 m SW of elev. p. 516,2 – fine-grained schistose amphibolite
AM–10.10–MK	Little Carpathians, outcrop of amphibolites in the cutting of road

	Pernek-Baba, Misársky Ostrobec – 500 m SW of elev. p. 516,2 – medium-grained amphibolite
AM–11.10–MK	Little Carpathians, Kolárova dolina valley, about 500 m SW of Peterklín (584,2) and 60 m of crossing, fine-grained cherty amphibolite
AM–12.10–MK	Little Carpathians, Harmónia, Dolinkovský vrch hill, SW slope – amphibolite without pores
AM–13.10–MK	Little Carpathians, Harmónia, Dolinkovský vrch hill, SW slope – amphibolite with pores
AM–14.10–MK	Little Carpathians, Bratislava-Rača, Potočná dolina valley, beginning of forest, former forester's house, cherty amphibolite
AM–15.29–VT	High Tatra, Pribylina – Jamnická dolina valley, Brišné dolina valley, about 1500 m up the brook (from the road), rock cliff on the left side of the brook, amphibolite
AM–16.29–VT	High Tatra, Žiarska dolina valley, quarry on the right side of the brook near the camping ground, amphibolite
AM–17.22–VT	Malá Fatra, Martin-Podstráne, up the brook, about 1500 m, quarry on the left side of the brook, amphibolite
AM–18.VEP	Low Tatra, Brezno, Ježova dolina valley, about 1000 m from the valley mouth, quarry on the left side of the brook-Ježová, medium--grained amphibolite
AM–19–VEP	Veporides, Beňuš, behind the village to the right about 2 km up the valley of the Veľký Zelený potok brook, outcrop on the right side above the brook, garnet amphibolite
AM–21.36–NT	Low Tatra, road Jarabá-Čertovica about 2 km above Jarabá, quarry in the curve left of the road-amphibolite
AM–22.36–NT	Low Tatra, road Tále-Srdiečko, below Srdiečko right of the road, outcrops of amphibolites
AM–23–VEP	Veporides, Pohronská Polhora, Gajdošovo valley, quarry about 800 m right of the road, medium-grained amphibolite
AM–24–VEP	Veporides, Rimavská Pila, in the middle of the village to the right about 50 m road cutting, gabbroamphibolite
AM–25–VEP	Veporides, Hnúšťa-Mútnik, ore mines-dump, schistose amphibolite
AM–26–VEP	Veporides, Kokava on Rimavica, opposite to the road to Klenovec, through the railway about 50 m in the cut of brook-schistose amphibolite
AM–27–VEP	Veporides, České Brezovo about 0,5 km before the the village from Kokava, quarry left of the road, coarse-grained amphibolite-xenolith in granite
AM–28–VEP	Veporides, Muráň, SE margin of the village about 50 m near the first small forest (road to Mur. Dlhá Lúka) – amphibolite
AM–29–SGR	Spišsko-gemerské rudohorie mts., Dobšiná, Veľká Vlčia dolina valley about 100 m below the dam-medium-grained amphibolite
AM–30–SGR	Spišsko-gemerské rudohorie mts., road Dobšiná-Dedinky, deviation to Kugel, outcrop opposite to the dump, medium-grained amphibolite
AM–31–SGR	Spišsko-gemerské rudohorie mts., road Dobšiná–Dedinky, deviation to Kugel, outcrop opposite to the dump, gabbro-amphibolite
AM–32–SGR	Spišsko-gemerské rudohorie mts., Vyšný Klatov, abandoned quarry above the village, opposite to JRD (Unified Farmers Cooperative) – gabbro-amphibolite
AM–33–SGR	Spišsko-gemerské rudohorie mts., Nižný Klatov, quarry JRD working – gabbroamphibolite
AM–34–SGR	Spišsko-gemerské rudohorie mts., Hnilčík about 1400 m down the valley from the crossroads (Bint), quarry on the right side, gabbro-amphibolite
AM–35.36–NT	Low Tatra, Malužiná, about 9 km of the village, above the acidulous water spring, outcrop opposite to the hedge-coarse-grained amphibolic gabbro
AM–36.36–NT	Low Tatra, Malužiná, about 9 km of the village, above the spring

	of acidulous water, outcrop opposite to the dam — medium-grained gabbroamphibolite
AM—37.18—S	Suchý, road cutting in the valley NE of Závada, about 3 km of the Monument of Slovak National Uprising in Závada-amphibolite
AM—38.13—I	Považský Inovec, Duchonka — Nemečky, opposite to the railway station, behind the ramp left by forest way about 5 km in the cut of brook, amphibolite
AM—39.13—I	Považský Inovec, Hrádok near Piešťany, Hrádocká dolina valley, up the valley about 6 km, amphibolite
AM—40.10—MK	Little Carpathians, Kuchynská Baba 400 m NE of the meadow, cherty amphibolite
AM—41.34—T	Tribeč, road Skýcov—Veľké Uherce, about 6 km from Skýcov, quarry at the forest about 500 m from the main road, coarse-grained amphibolite
AM—42.34—T	Tribeč, valley N of Hostie, about 9 km of the crossroads to Skýcov, amphibolite
AM—43.36—VEP	Low Tatra, Beňuš, behind the village, second valley in direction to Červená Skala, outcrop at the road, amphibolic gabbro

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