GEOLOGICKÝ ZBORNÍK — GEOLOGICA CARPATHICA, 38, 2, BRATISLAVA, APRIL 1987, Pp. 171—179

JÁN KRÁĽ* — YURIY GOLTZMAN** — IGOR PETRÍK*

Rb-Sr WHOLE-ROCK ISOCHRON DATA OF GRANITIC ROCKS FROM THE STRÁŽOVSKÉ VRCHY MTS.: THE PRELIMINARY REPORT

(Figs. 3, Tab. 1)

Abstract: Eight samples from different petrographic types of granitic rocks typical of the Strážovské vrchy Mts. crystalline complex show a considerable dispersion in $^{87}Sr/^{86}Sr$ vs. $^{87}Rb/^{86}Sr$ graph. Slope of isochron which is constructed from 5 samples indicates age of 393 ± 6 m.y. of whole rocks and initial ratio of $^{87}Sr/^{86}Sr = 0.7060 \pm 0.0002$. Dispersion of samples is probably caused by removal of alkalies in acid environment or by Sr contamination from the surrounding metamorphic rocks.

Резюме: Восемь проб из разных петрографических типов гранитовых пород характерных для кристалликикума Стражевских гор показывает на графе $^{87}Sr/^{86}Sr$ против $^{87}Rb/^{86}Sr$ значительную дисперсию. Наклон изохроны построенной из пяти проб дает возраст валовых пород 393 ± 6 млн. лет и первичное отношение $^{87}Sr/^{86}Sr = 0.7060 \pm 0.0002$. Дисперсия проб вероятно вызвана выносом щелочей в кислой среде или контаминацией Sr из окружающих пород.

Introduction

Granitoid rocks from the Strážovské vrchy Mts. are typical by their remarkable petrographic variability. Kahan (1979) distinguished 9 rock types starting with biotite-amphibole quartz diorites and ending with aplitic-pegmatitic granites. Their variability is so much remarkable that it changes quickly not only within one magmatic body but even within exposure. Characteristic feature of these rocks is their very close relation to metamorphic cover. Gradual decrease of granitization from granitic rocks towards paragneisses proves close relations between the granitogenesis and migmatization processes. However, for the time being, there is no information on age of these processes. For these reasons we chose at first granitoid rocks for Rb-Sr analysis in order to gain basic data not only on petrogenesis but also on the age of these rocks; the obtained information will serve as a basis for further study. It goes without saying that this work cannot solve fully the problems of age of these rocks, it rather indicates the problems which should be overcome in order to interpret correctly the obtained information. Finally, the obtained data will complete information on granitoid rocks from various localities of the West Carpathian crystalline complex reached by other authors (Burchart, 1968; Bagdasaryan et al., 1982, 1983, 1985, 1986; Kovách et al., 1986).

* RNDr. J. Kráľ, CSc., RNDr. I. Petrík, CSc., Geological Institute of the Centre of Georesearch, Slovak Academy of Sciences, Dúbravská cesta 9, 814 73 Bratislava.

** Dr. Y. V. Goltzman, Institute of Geology of Ore Deposits (IGEM), the U.S.S.R. Academy of Sciences, Staromonetny per. 35, 109017 Moscow.

Geological situation

Metamorphic and granitoid rocks from the Strážovské vrchy Mts. crystalline complex occur in two units: in the crystalline cores of Suchý and Malá Magura Mts. (Fig. 1). Rocks with identical petrographic character occur in the both parts and tectonic style of the both cores is identical too (K a h a n, 1979). According to I v a n o v (1957), granitoid cores represent complicated rock complex whose origin can be ranged to early orogenetic till late orogenetic Hercynian magmatic cycle. Variscan tectogenesis seems to be dominant from the point of view of structural plan, though effects of older tectogeneses cannot be excluded (K a h a n, 1979), they have not been proved by structural analysis (P u t i š, 1979).

Samples used in the present paper were taken from the following rock types of granitoids from Suchý and Malá Magura Mts.:

SR-1. Muscovite-biotite leucogranodiorite with sillimanite. Liešťanská dolina valley, about 2.2 km from the main road, stone cliff on the N slope, Suchý Mt.

Rock is typical by presence of fibrolite sillimanite and secondary muscovite. Sillimanite cuts all present minerals or it is developed in interstices. Plagioclase is subhedral to anhedral, slightly sericitized. Basicity is An = 21—29. Biotite reaches 5 vol. %. It is often overgrown with sillimanite or muscovite. K-feldspar has interstitial character, it is often perthitic.

SR-2. Leucocratic coarse-grained granite-pegmatite. Cross-road Klin, the turning to Zliechov, small exposure at the road, Suchý Mt.

Rock has pegmatoid character, anhedral texture. Plagioclase is anhedral, often slightly sericitized over the whole surface. It reaches basicity An = 4—14. It is sometimes mechanically deformed. K-feldspar is frequent, braid-perthite, often cross--hatched. Biotite is very rare, almost totally chloritized. Muscovite is rare, it has a secondary character.

SR-3. Medium-grained biotite tonalite. Forest road parallel with the main road Klin — Liešťany, about 1 km S of Klin towards the turning to Temeš, Suchý Mt.

Rock has subhedral granular texture. Plagioclase is automorphic to subhedral, strongly zonal. Cores are sometimes partly sericitized. Basicity is An = 40—45 in the centres, An = 30—36 on the margins. Biotite is practically unaltered, abundant. In comparison with plagioclase, it is interstitial. Rock contains frequent fine-grained apatite. K-feldspar is missing, muscovite occurs only as sericite.

SR-4. Fine-grained biotite tonalite. Localization as sample SR-3.

Rock represents fine-grained variety of biotite tonalite. Subhedral plagioclase reaches basicity An = 38—40 in the centres, An = 26—28 on the margins. Biotite is well preserved. Muscovite and K-feldspar are missing.

SR-5. Biotite granodiorite. Beginning of Čavoj village, exposure above brook on the N slope, Suchý Mt.

Rock has subhedral texture. Plagioclase is automorphic to subhedral with strongly sericitized cores. Basicity is An = 34 in the centres and An = 24—26 on the margins. Biotite is abundant, considerably chloritized. Secondary muscovite is quite frequent. K-feldspar is interstitial, it encloses small grains of plagioclase, quartz and biotite. Fine-grained apatite is abundant.

SR-6. Pegmatoid leucogranite. Valley in Rudnianska Lehota. Stone cliff in the end of the valley. Granite forms here 10—40 cm thick conformable penetrations to the surrounding biotite gneisses. Suchý Mt.

Medium- to coarse-grained rock of aplitic-pegmatitic character. Anhedral plagioclases are pure, rarely with sericitized cores. They reach basicity An = 5—8. K-feldspar is frequent, interstitial, perthitic, often cross-hatched (microcline). Muscovite is abundant, subhedral. Biotite is practically absent.

SR-7. Biotite tonalite. Chvojnická dolina valley, exposure at forest road about 1.5 km behind pioneer camp, Malá Magura Mts.

Rock bears the features of orientation which is formed by biotite and plagioclase laths. Texture is subhedral, granular. Automorphic to subhedral plagioclase has strongly sericitized cores. It is zonal with basicity An = 36–38 in the centres and An = 28–32 on the margins. Biotite is frequent, almost unaltered. K-feldspar is absent. Fine-grained apatites and opaque mineral are abundant.

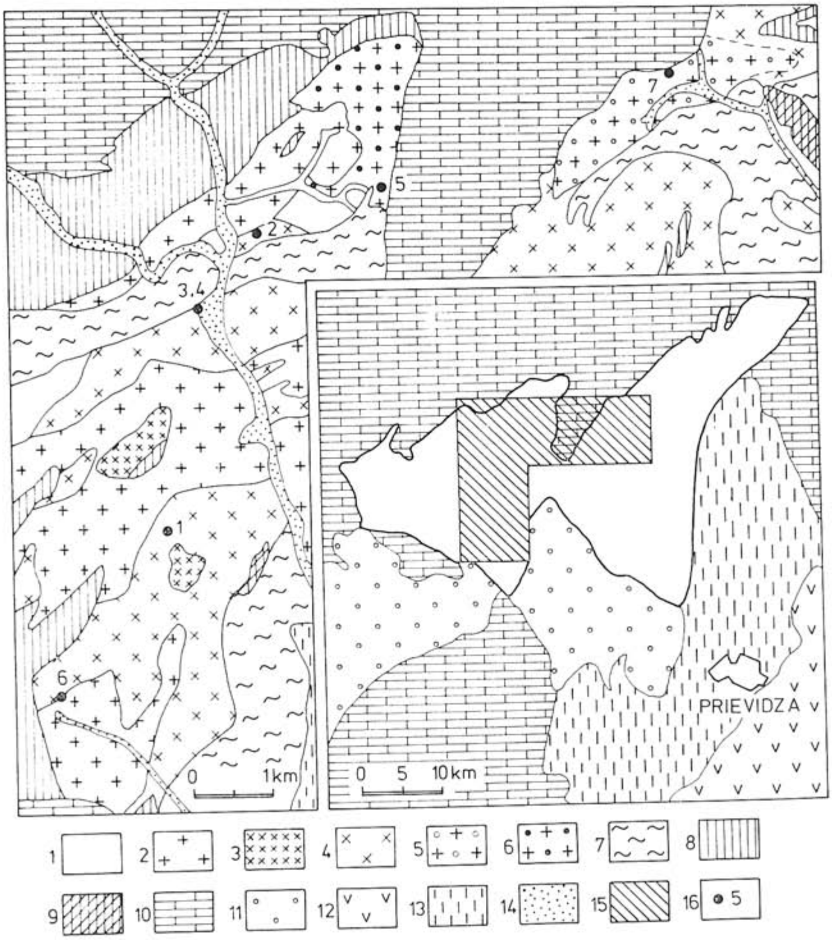

Fig. 1. Geological map of the studied area with localization of samples. Simplified according to M a h e ľ (1985).

Explanatory notes: 1 — rocks of the crystalline core as a whole (granites, gneisses, migmatites); 2 — leucocratic granites; 3 — aplitoid-pegmatitoid granites to granodiorites with autometamorphic manifestations; 4 — aplitic-pegmatitic syntectic granites; 5 — fine-grained biotite granites; 6 — biotite-oligoclase granodiorites to quartz diorites; 7 — migmatites with predominance of metatect; 8 — quartz biotite paragneisses; 9 — amphibolites; 10 — Mesozoic (as a whole); 11 — Palaeogene; 12 — volcanic rocks (Neogene); 13 — Neogene; 14 — Quaternary; 15 — sampled area; 16 — places of sampling (numbers represent samples designation).

Methodic part

Whole-rock samples of ca. 10—15 kg in weigth were pounded and grinded to grains of ca. 1 mm size. Sample was then splitted to 300 g in weight. Part of sample was applied to cleaning of planetary rotary mill where it was grinded to almost analytical fineness. After further splitting, ca. 1 g of sample was pulverized in agate mortar to analytical fineness.

Dissolution of the sample, ion exchange and mass-spectrometry were carried out in the geochronological laboratory at the Institute of Geology of Ore Deposits, the U.S.S.R. Academy of Sciences in Moscow. After decomposition of ca. 0.1 g of rock together with Rb and Sr tracer in HF, Rb and Sr separation was done by eluent chromatography using sulpho-cationite Bio—Rad 50 x 8, 200—400 mesh in column of quartz glass. 2.5 N HCl solution was used as Rb and Sr eluent. Potassium was removed from Rb eluate in column using 1.1 N HCl.

Isotopic ratios were measured in mass-spectrometer MI-1320. "Peak jumping" method was used for measurement of individual ratios, whereby Sr was ionized from one filament, Rb — from two ones.

$^{86}Sr/^{88}Sr = 0.1194$ was applied to normalization of Sr ratios. Sr blank was ca. 10 ng. Repeated analyses of Eimer-Amend standard gave value of 0.70808 ± ± 2. Accuracy of measurement of individual samples in 95 % confidence interval is better than 0.02 % for $^{87}Sr/^{86}Sr$, 1.5 % for Rb and Sr. Details of applied analytical techniques which are standardly used in the geochronological laboratory at the Institute of Geology of Ore Deposits, the U.S.S.R. Academy of Sciences are given in the works of Chernyshev et al. (1983) and Bairova — Goltzman (1983).

Results

Obtained isotopic data are given in Tab. 1. Differences in Rb concentrations are almost threefold, differences in Sr concentrations are almost sixfold between the samples. Three samples in Rb-Sr isochron plot (Fig. 2) show considerable deviation from isochron, it is much larger than established errors of measurement. Isochron calculated from all eight points has the following parameters: $(^{87}Sr/^{86}Sr)_i = 0.7063 \pm 0.0004$, age = 370 ± 17 m.y. with MSWD = 203.9. The latter value exceeds this value in isotopic systems considered for closed and unaffected practically hundred times.

We have tried to explain in detail the mutual petrogenetic relations of analyzed samples. Relation of Rb to Sr concentrations in granite samples from Suchý and Malá Magura Mts. is plotted in Fig. 3. Samples 1, 2, 7 in this graph show the greatest deviation from the primary trend (full and dashed lines). Trend was verified by modelling using distribution coefficients and taking fractional crystallization into consideration (e.g. McCarthy—Hasty, 1976; Vilinovič—Petrík, 1984). We do not present more detailed results, they will be published in prepared work on petrology of the Suchý granites. The very great deviation of samples 1, 2, 7 from primary trend make us to presume that these samples do not belong to primary trend and, thus, they cannot be used in construction of isochron. After elimination of these samples, 5 points defining Rb-Sr isochron with the following parameters are left: $(^{87}Sr/^{86}Sr)_i = 0.7060 \pm$ ± 0.0002, age 393 ± 6 m.y., MSWD = 14.67.

Table 1

Rb and Sr analytical data of whole-rock samples from the Suchý and Malá Magura Mts.

No.	Sr (ppm)	^{86}Sr (ppm)	Rb (ppm)	^{87}Rb (ppm)	$^{87}Rb/^{86}Sr$ ($\pm$1 SIGMA)	$^{87}Sr/^{86}Sr$ ($\pm$1 SIGMA)
SR-1	312.2	30.18	40.22	11.38	0.3729$\pm$ 9*	0.70870$\pm$3*
SR-2	120.7	11.66	73.30	20.75	1.7590$\pm$43	0.71496$\pm$4
SR-3A	704.6	68.14	64.53	18.27	0.2645$\pm$ 6	0.70751$\pm$4
SR-3B	660.3	63.85	80.83	22.88	0.3535$\pm$ 8	0.70809$\pm$5
SR-4	687.6	66.49	79.76	22.57	0.3357$\pm$ 8	0.70769$\pm$3
SR-5	426.2	41.21	77.81	22.02	0.5283$\pm$13	0.70900$\pm$4
SR-6	115.9	11.18	115.6	32.72	2.8913$\pm$70	0.72211$\pm$3
SR-7	543.3	52.52	113.7	32.20	0.6045$\pm$17	0.71005$\pm$3

* The given error after ratio refers to the last digit of the given ratios.

Errors are on 1σ level, decay constant λ $^{87}Rb = 1.42 \times 10^{-11}$ a^{-1} was used for age calculation.

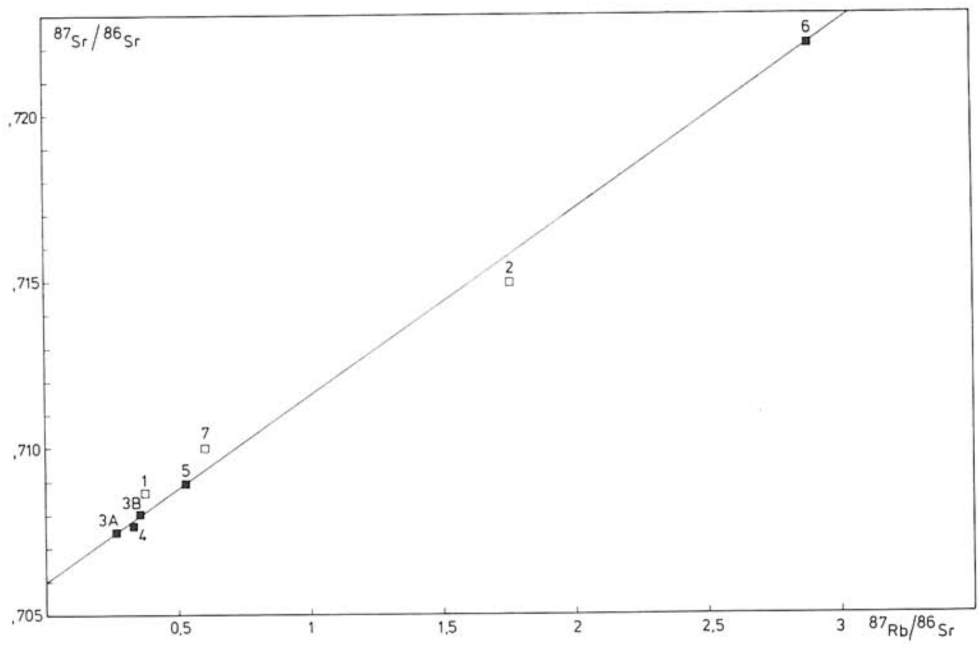

Fig. 2. $^{87}Sr/^{86}Sr$ vs. $^{87}Rb/^{86}Sr$ isochron plot from analyzed granitic rocks from the Suchý and Malá Magura Mts. Error is calculated on 1 σ level.

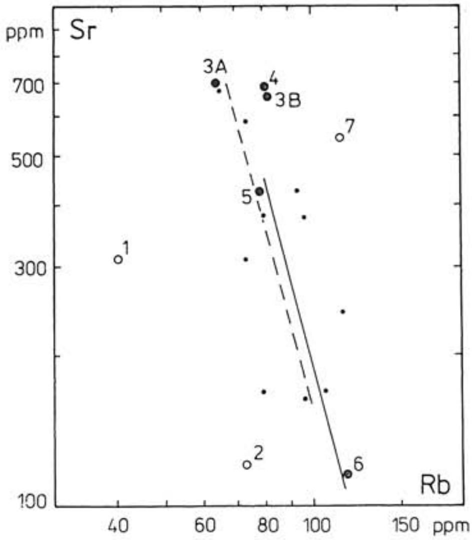

Fig. 3. Relation of Rb to Sr in the Suchý and M. Magura granitoids.
Explanatory notes: solid circles — samples belonging to the isochron in Fig. 2, open circles — samples excluded from the isochron in Fig. 2, dots — unpublished data from the Suchý and M. Magura granitoids. The fractionation trend (Rayleigh fractional crystallization) is superimposed on the diagram using bulk distribution coefficients $D^{Sr} = 1.57$, $D^{Rb} = 0.85$ and initial liquid composition $C^{Rb} = 80$ ppm, $C^{Sr} = 450$ ppm. Solid line — evolution of liquid composition, dashed line — evolution of coexisting solid cumulate composition (for details see e.g. McCarthy — Hasty, 1976 and Vilinovič — Petrík, 1984).

Initial ratio of Sr isotopes is within the error conformable to the data obtained from the other core mountains of the West Carpathians. Analyzed rocks belong to granite group (as almost half of all world granites) lying closely above the upper boundary of basalt field (Faure—Powell, 1972). The obtained age is hitherto the highest one from the known Rb-Sr data from the West Carpathian crystalline complex.

Discussion

Remarkable dispersion of Rb-Sr data from granitic rocks of Suchý and Malá Magura Mts. may be caused by three factors:

1. Analyzed samples are not members of one comagmatic series and genetically they are not connected with each other.

2. Part of samples underwent contamination by strontium comming from surrounding metamorphic rocks.

3. In the part of samples, Rb-Sr system was open and disturbed by subsolidus alterations.

Granodiorites of older intrusive phase are considered for the oldest granites in succession by Ivanov (1957). Our sample SR-1 belongs probably to this type. Other samples SR-3, SR-4, SR-5 and SR-7 are from the region of "Magura type" (biotite granodiorites and tonalites). Pegmatoid samples SR-2 and SR-6 belong to the 3rd type presented by I v a n o v (l.c.).

Irregular deviation of the above-mentioned samples excludes construction of separate isochron. On the other hand, if we put isochron through 2 points from tonalite (3A, AB), age of this hypothetical internal isochron would be 543 m.y. with initial ratio $^{87}Sr/^{86}Sr = 0.7058$. But, for the time being, there are no such data which would support this hypothesis.

Contamination of the samples by extraneous strontium could explain position of the samples lying above the isochron (version No. 2). Regarding low initial ratio, it may be presupposed that original magma source was poor in Rb. During intrusion into the Palaeozoic metamorphic rocks of gneissic composition, some samples could be contaminated by Sr of these rocks, whereby it is probable that contamination by ^{87}Sr was preferred (C a r m i c h a e l et al., 1974). It may be presupposed that surrounding metamorphic rocks will be richer in ^{87}Sr and that they will have higher $^{87}Sr/^{86}Sr$ ratio (cf. B a g d a s a r y a n et al., 1983). This process might take place during intrusion of totally isotopically homogenized body before its solidification; contamination might occur in the period of warm melt effection on cooler rocks of metamorphic cover. Described process may be applied e.g. to the sample SR-7 whose minerals are oriented and it has increased Rb content (Fig. 3).

Mobility of alkalies in subsolidus conditions (version No. 3) is well-known (K o r z h i n s k y, 1953; L u t h et al., 1964) and in the Suchý crystalline complex it was described by K o r i k o v s k y et al. (1987). Sample SR-1 comes from Lieštanská dolina valley where the crystalline rocks are affected by high-temperature subsolidus alteration — by alkalies removal in acid environment (K o r i - k o v s k y, 1963). This alteration affects all rock-forming minerals and it causes formation of modal quantities of sillimanite and secondary muscovite. Rb and Sr concentrations either increase or decrease depending on kind of mineral entering the reaction. Reactions of plagioclase cause increase of K and Rb concentrations due to muscovitization. On the other hand, reactions of K-feldspar cause Rb loss due to sillimanite, quartz and muscovite formation. Sample SR-1 has the lowest Rb concentration, sample SR-2 has low Rb and Sr contents. Another sample from the same locality has much higher concentrations (PGS-1, 114 ppm Rb, 290 ppm Sr). If we consider this sample unaltered, sample SR-2 lost ca. 33 % of original Rb content and as much as 60 % of Sr content. Position of samples SR-1, SR-2 on and below the isochron may be explained in a following way: After Rb-Sr system blocking (solidification of magma) and after a certain period, Rb loss and Rb/Sr ratio decrease occurred (SR-1), or Sr loss and subsequent increase of Rb/Sr ratio ocurred (SR-2). Sample SR-1 obtained excess of ^{87}Sr by cumulation of radiogenic ^{87}Sr up to the present, whereby this excess corresponds to strontium inhereted from the period when the sample had original, higher Rb/Sr ratio. ^{87}Sr decrease in the sample SR-2 may be explained analogically: After autometamorphic event during which increase of Rb/Sr ratio occurred, the sample became poorer in that part of radiogenic ^{87}Sr which corresponds to the period when the sample had still original, lower Rb/Sr ratio. It should be stressed that episodic process of loss and open system have to be presupposed for such explanation; such alteration had to be of considerably younger age than primary solidification.

Conclusion

The most probable age of intrusion of the Suchý and Malá Magura Mts. granites is 393 ± 6 m.y. Initial ratio $^{87}Sr/^{86}Sr$ is 0.7060, it means that original source from which magma was formed had to be poor in Rb, with low Rb/Sr ratio. Therefore, it is improbable that metamorphic sediments of considerably older age than granites could be the source rocks. It cannot be proved from documented material whether granitic body is composed of intrusions of different ages.

Rb-Sr system of whole rocks did not remain closed after solidification. Dispersion of some samples outside the constructed isochron is probably caused by combination of two possible processes: by radiogenic ^{87}Sr from surrounding rocks (SR-7) during intrusion of granitic body or by high-temperature subsolidus alteration — by removal of alkalies in acid environment (SR-1, SR-2). This process had to be considerably younger than solidification of the body.

Acknowledgment: The authors are very much obliged to Dr. I. V. Chernyshev for providing facilities in the geochronological laboratory in IGEM. One of the author (J. K.) expresses thanks to Mrs. E. D. Bairova for initiation into eluent chromatography and sample processing.

Translated by O. Mišániová

REFERENCES

BAGDASARYAN, G. P. — GUKASYAN, R. Ch. — CAMBEL, B., 1986: Rb-Sr isochron age of granites from the veporic pluton. (In Russian). Geol. Zbor. Geol. carpath. (Bratislava), 37, 3, pp. 336—365.

BAGDASARYAN, G. P. — GUKASYAN, R. Ch. — CAMBEL, B. — VESELSKÝ, J., 1982: The age of Malé Karpaty Mts. granitoid rocks determined by Rb-Sr isochrone method. Geol. Zbor. Geol. carpath. (Bratislava), 33, 2, pp. 131—140.

BAGDASARYAN, G. P. — GUKASYAN, R. Ch. — CAMBEL, B. — VESELSKÝ, J., 1983: Results of Rb-Sr determinations of age of metamorphic rocks from the Malé Karpaty Mts. crystalline complex. (In Russian). Geol. Zbor. Geol. carpath. (Bratislava), 34, 4, pp. 387—397.

BAGDASARYAN, G. P. — GUKASYAN, R. Ch. — CAMBEL, B. — VESELSKÝ, J., 1985: Rb-Sr isochron dating of granitic rocks from the Ďumbier zone of the Low Tatra (West Carpathians). (In Russian). Geol. Zbor. Geol. carpath. (Bratislava), 36, 5, pp. 637—645.

BAIROVA, E. D. — GOLTZMAN, Y. V., 1983: Comparative characteristics of some variants of Rb and Sr microquantities chromatographic determination method for isotopic analysis. (In Russian). In: Mass spectrometry and isotope geology. (In Russian). Ed.: I. D. Ryabchikov — I. V. Chernyshev, Nauka (Moskva), pp. 60—67.

BURCHART, J., 1968: Rubidium-strontium isochron ages of the crystalline core of the Tatra Mountains, Poland. Amer. J. Sci. (New Haven), 266, 10, pp. 895—907.

CARMICHAEL, I. S. E. — TURNER, F. J. — VERHOOGEN, J., 1974: Igneous petrology. McGraw-Hill, New York, 739 pp.

CHERNYSHEV, I. V. — SERDYUK, N. I. — ZHURAVLEV, D. Z. — KOSTITSIN, J. A., 1983: Precise isotopic analysis of strontium by one filament regime of ionization. (In Russian). In: Mass spectrometry and isotope geology. (In Russian). Ed.: I. D. Ryabchikov — I. Chernyshev, Nauka (Moskva), pp. 30—43.

FAURE, G. — POWELL, J. L., 1972: Strontium isotope geology. Springer-Verlag, Berlin and Heidelberg, 188 pp.

IVANOV, M., 1957: Genéza a vzťahy granitoidných intrúzií k superkrustálnym sériám kryštalinika Suchého a Malej Magury. Geol. Práce, Zoš. (Bratislava), 47, pp. 85—113.

KAHAN, Š., 1979: Geologické profily kryštalinikom Strážovských vrchov (Suchý a Malá Magura). In: Tektonické profily Západných Karpát. GÚDŠ (Bratislava), pp. 153—160.
KORIKOVSKY, S. P., 1963: Quartz—sillimanite facies of acid leaching in granite-gneisses complexes. (In Russian). Dokl. Akad. Nauk SSSR (Moskva), 152, 1, pp. 187—190.
KORIKOVSKY, S. P. — KAHAN, Š. — PUTIŠ, M. — PETRÍK, I., 1987: The metamorphic zoning in the crystalline complex of Suchý and high-temperature automeṭasomatism in Al-granites from the Strážovské vrchy Mts. (In Russian). Geol. Zbor. Geol. carpath. (Bratislava), 38, 2, pp. 181—203.
KORZHINSKY, D. S., 1953: Outline of the metasomatic processes. (In Russian). In: Fundamental problems in the study on magmatic ore deposits. (In Russian). Izd. Akad. Nauk (Moskva), pp. 332—452.
KOVÁCH, A. — SVINGOR, E. — GRECULA, P., 1986: Rb-Sr isotopic ages of granitoids from the Spišsko-gemerské rudohorie Mts., Western Carpathians, Eastern Slovakia. Miner. slov. (Bratislava), 18, 1, pp. 1—14.
LUTH, W. C. — JAHNS, R. H. — TUTTLE, O. F., 1964: The granite system at pressures 4—10 kilobars. J. Geophys. Res. (Richmond, Va.), 69, 4, pp. 759—773.
MAHEĽ, M., 1985: Geologická stavba Strážovských vrchov. GÚDŠ, Brtislava, 221 pp.
McCARTHY, T. S. — HASTY, R. A., 1976: Trace elements distribution patterns and their relationship to the crystallization of granitic melts. Geochim. Cosmochim. Acta (Oxford), 40, 11, pp. 1351—1358.
PUTIŠ, M., 1979: Príspevok k štruktúrnej analýze kryštalinika Suchého a Malej Magury. In: Tektonické profily Západných Karpát. GÚDŠ (Bratislava), pp. 161—166.
VILINOVIČ, V. — PETRÍK, I., 1984: Petrogenetické modelovanie diferenciácie granitoidných magiem: kumulátový charakter modranských granitoidov. Acta Montana (Praha), pp. 205—224.

Manuscript received October 28, 1986.