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ISOCHRON REASSESSMENT OF K-Ar DATING FROM THE WEST CARPATHIAN CRYSTALLINE COMPLEX

(Figs. 15, Tabs. 4, App. 1)

Abstract: Published K-Ar ages from the West Carpathian crystalline complex show extreme dispersion of values. Therefore agreement of model data with Harper's (1970) isochron models was confronted and verified. On the basis of this analysis only few numbers — isochron data which have a real importance from the point of view of geological conditions may be presented:
1. 394 ± 24 m.y. — amphiboles, the Malé Karpaty Mts.;
2. 265 ± 18 m.y. — amphiboles, gemerides;
3. 302 ± 40 m.y. — biotites, core mountains;
4. 94 ± 18 m.y. — biotites, veporides.
Only isochron K-Ar ages of amphiboles approximate time of their recrystallization. Isochron ages of biotites belong to the category of cooling ages and they present time since transition through isotherm of ca. 270 °C. Results of muscovite and feldspar dating cannot be interpreted by Harper's (l.c.) models. Substantial part of analyzed material is represented by analyses of whole rocks which are inapplicable to geochronological purposes.

Резюме: Опубликованные K-Ar возрасты пород из кристаллиникума Западных Карпат показывают крайнюю дисперсию значений. Поэтому на 220 анализах сопоставлялось и проверялось сходство модельных данных с изохронными моделями Гарпера (Harper, 1970). На основе этого анализа можно представить лишь несколько номеров — изохронных данных, которые имеют реальное значение с точки зрения геологических отношений:
1. 394 ± 24 млн. лет — амфиболы, Малые Карпаты;
2. 265 ± 18 млн. лет — амфиболы, гемериды;
3. 302 ± 40 млн. лет — биотиты, ядерные горные цепи;
4. 94 ± 18 млн. лет — биотиты, вепориды.
Лишь изохронные K-Ar возрасты амфиболов приближают время их рекристаллизации. Изохронные возрасты биотитов относятся к категории возрастов охлаждения и они представляют время с перехода через изотерму около 270 °C. Результаты датирования мусковитов и полевых шпатов нельзя интерпретировать при помощи моделей Гарпера (Harper, 1970). Значительную часть анализированного материала представляют анализы валовых пород, которые не применимы для геохронологических целей.

Age of great part of the West Carpathian crystalline complex is not yet exactly proved. Postkinematic intrusions in the core mountains and veporides are generally considered to be Variscan. On the basis of analogy, the lower boundary of granitoid bodies age was determined by intrusive contact of granodiorite the with Early Palaeozoic limestones in the Malé Karpaty Mts. (Cambel —

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Valach, 1956), the upper boundary — by the problematic Permian in deeply-eroded crystalline complex (the High Tatra). Crystalline schists were considered pre-Carboniferous or Carboniferous product of metamorphic processes by the Carpathian geologists (Andrusov, 1958; Cambel, 1976; Gorek, 1959; Kantor, 1959 b; Zoubek, 1936). According to hypothesis of Máška—Zoubek (1961), the oldest crystalline schists of the Slovak block tatricum are of Precambrian age, whereby the oldest metamorphic phase is most likely intra-Algonkian (Kamenický, 1967). The depositional age of primary sediments should be Early Proterozoic. Variscan orogeny was manifested in these rocks not only by progressive, but also by retrograde alteration.

There were no adequate means for solving these fundamental stratigraphical problems of the West Carpathian crystalline complexes. Though pioneer K-Ar dating carried out by Kantor (1959 a — d, 1960) brought „Variscan" values for some core mountains, K-Ar ages of veporide crystalline complex (Kantor, 1960) referred to the problems connected with argon loss in Alpine-deformed complexes. Determination of Palaeozoic sporomorphs from metamorphic rocks of the core mountains and veporides (Čorná — Kamenický, 1976; Cambel — Čorná, 1974; Klinec et al., 1975; Klinec — Planderová, 1981; Cambel — Planderová, 1985) and Rb-Sr dating (Burchart, 1968; Bagdasaryan et al., 1982) prove that occurrence of the Palaezoic rocks at the recent surface of the West Carpathian crystalline complex is dominant. However, questions of Precambrian existence in the West Carpathians are discussed even nowadays (L. Kamenický—J. Kamenický, 1983).

Hitherto most frequent radiometric data from the West Carpathian crystalline complex are represented by K-Ar dating. Since the first analysis of Betliar granite porphyry (Kantor, 1957) over 200 analyses of minerals and whole rocks have been published from the region of the West Carpathian crystalline complex; majority of these data came from Laboratory of Absolute Dating of the Institute of Geological Sciences, Academy of Sciences of Armenian Soviet Socialist Republic in Erevan as a result of cooperation with Geological Institute of the Slovak Academy of Sciences in Bratislava. All accessible data published until 1985, as well as several unpublished analyses are given in Tab. 1.

Table 1

K decay constants used in the works from the West Carpathian crystalline complex, 1957—1980

variant	λ_β*	λ_e*	λ*
1	4.90	0.602	5.502
2	4.72	0.557	5.277
3	4.962	0.581	5.543

* all data x 10^{-10} . year^{-1}

It is evident that analytical data form extremely dispersed „cloud" of values corresponding to age interval from the Precambrian to Palaeogene in geological scale of time (V a n E a s i n g a, 1975). Existing dispersion of data requires formulation and solution of two main questions:

— what causes abnormal dispersion of K-Ar data,

— is it possible to use K-Ar dating in solving age and chronology of the West Carpathian crystalline complex evolution.

In the papers dealing with K-Ar dating, only model ages without using this term are given together with basic analytical data. Model age calculated on the basis of measured concentrations of ^{40}Ar, ^{40}K and decay constants represents a real age only in the case when changes in concentrations of radiogenic ^{40}Ar are caused exclusively by decay of ^{40}K and the system did not contain any radiogenic argon at the moment of crystallization. Any deviation from these fundamental conditions causes disturbances of $^{40}Ar/^{40}K$ and, thus, change of apparent age which cannot be in this case a measure of age. Model age can be interpreted as actual age of mineral only in the case if it can be proved that the above-mentioned model conditions were quantitatively fulfilled throughout the existence of mineral. It is known that these conditions are rarely fulfilled in plutonic magmatic and metamorphic rocks. In such way as possibility of argon loss from minerals during their geological history was established, data on excess of argon whose amount is higher than amount of argon which could be formed by ^{40}K decay in situ were obtained. Thus model K-Ar age can be much lower or higher than actual age of sample. Dating of individual samples and especially classical variant of K-Ar method does not allow to disclose complications in evolution of K-Ar radiogenic system. Loss or excess of radiogenic argon can be proved by the following procedures:

a) comparison of results of dating of the same samples by various methods,

b) space distribution of model ages with regard to thermal source, e. g. decrease of ages due to intrusion,

c) "age spectra" in $^{40}Ar/^{39}Ar$ method in combination with step-wise heating of samples,

d) isochron analysis of cogenetic samples group.

K-Ar isochrons have been used for almost 20 years, 3 variants are applied:

1. ^{40}Ar vs. ^{40}K,
2. $^{40}Ar/^{36}Ar$ vs. $^{40}K/^{36}Ar$,
3. $^{40}Ar/^{39}Ar$ vs. $^{40}K/^{39}Ar$.

From published data from the West Carpathians only the most simple, first type of isochrons, i. e. ^{40}Ar vs. ^{40}K may be constructed.

K-Ar model ages from the West Carpathian crystalline complex are often considered to be "true" ages; if they seem to be too high, excess of argon is presupposed, if too low, release of argon is presupposed. Both possibilities are real, but it is necessary to prove it in analyzed material. Besides, it is possible that a part of data is obtained from the samples which were not ideal for K-Ar dating, because of insufficient mineral separation (presence of chlorite in biotite) or besause of unsuitable material (analyses of whole plutonic rocks) differing in alteration degree. Our attempt is to make verification of material, to distinguish those groups of data which may be used in geochronological interpretations and to check whether analytical data may serve as a basis of considerations about release or excess of argon. At the same time, we should like to present such material which might serve geologists as a basis of geological interpretation.

Standardization of data

Analyses given in Appendix I come from the works published in time interval of more than 20 years beginning with work of Kantor (1957) and ending with publication of Cambel et al. (1980). In this period, great changes concerning not only improvement of analytical techniques took place in isotopic geochronology, but also several physical experiments concerning redetermination of decay constants of radioactive elements were carried out. Ample material from results of dating of the same rocks by various geochronological methods was obtained. During this period, age values of stratigraphic boundaries were considerably changed. Unclear situation outlasted for quite a long time in isotopic geochronology, since at the same time different values of decay constants were used in calculation of ages in various world laboratories. Finally, International Geological Congress in Sydney, 1976 recommended the use of uniform values of decay constants used in various methods (Steiger—Jäger, 1977). This procedure enables to make a direct comparison of results in world-wide scale.

It is natural that the same analytical results give different model ages if they are calculated according to various decay constants. Hitherto published data on the age of the West Carpathian rocks were calculated using three different combinations of constants. Accordingly, it was possible to compare the results only after their unification, i. e. recalculation according to uniform system. It should be stated that in the period of the above-mentioned 20 years, values not only of decay constants, but also of isotopic composition of individual elements and of their atomic weight were modified. Measure of K-Ar age is represented by atomic ratio of radiogenic ^{40}Ar and ^{40}K, while direct analytical results yield content of total potassium (in weight percent) composed of three isotopes and argon in cm^3 composed also of three isotopes. Therefore standardization requires recalculation of these values.

K-Ar age is calculated from the formula:

$$t = \frac{1}{\lambda} \ln \left(1 + \frac{\lambda}{\lambda_e} \cdot \frac{^{40}Ar}{^{40}K}\right) \quad (1)$$

where λ is decay constant for the both types of ^{40}K decay, λ_e refers to ^{40}K decay from which ^{40}Ar is formed. We shall discuss gradually all elements of the formula (1), whereby we shall concentrate on influence of differences of constants on age values.

Decay constants

Isotope ^{40}K decays in two ways. 89 % of its nuclides decays by β and changes to ^{40}Ca, the rest 11 % of nuclides changes by K-capture to ^{40}Ar. Therefore constants of both changes must be in the equation (1). Values used in the quoted works are given in Tab. 1. Till 1977 different constants were used in the U.S.A. and Canada.

As it can be easily calculated, relative deviations of used values in the equation (1) in older works are different for inversed value $\lambda_e + \lambda_\beta$ and for λ / λ_e in relation to present ones. Since the latter element of the equation is given in logarithm, its influence decreases with increating age of sample. Therefore in comparison with ages calculated according to Steiger—Jäger (1977) constants, usage of constants in older works of J. Kantor (1st variant, Tab. 1) used in the U.S.S.R.till 1959 causes negative deviations decreasing with age.

Combination No. 2 causes positive deviations growing with age what is illustrated in Tab. 2. These differences are not negligible, especially in comparison of ages calculated according to 2nd variant, because they have opposite sign.

Table 2

Influence of used decay constants values on calculated K-Ar age

age in m.y.	1st variant		2nd variant	
	Kantor 1957; 1959; 1960		Cambel et al., 1979, 1980; Bagdasaryan et al., 1977	
	△	%	△	%
50	—1.72	—3.43	2.16	4.32
100	—3.38	—3.38	4.33	4.33
200	—6.54	—3.27	8.70	4.35
300	—9.50	—3.17	13.10	4.37
500	—14.86	—2.97	22.00	4.40

△ — absolute difference against standard; % — relative difference against standard.

Calculation of ^{40}K concentration value

Since isotopic composition of natural K (composed of isotopes 39, 40, 41) is known, ^{40}K concentration may be obtained from concentration of total K. It is a certain simplification, because evidence about isotopic fractionation during diffusion processes was gained, it can be taken into account in metamorphic conditions. Fractionation refers mainly to the ratio of the heaviest and lightest isotopes, i. e. $^{39}K/^{41}K$. Portion of ^{40}K in natural K = 0.0119 at. % was generally accepted for many years. Unification of 1977 changed this value to 0.01167 at. %. Since K is analyzed in wt. %, atomic weight of total isotopic mixture of elementary K is necessary too. In the course of 20 years this value was changed from 39.102 to 39.948.

In original works from the Carpathian region, both constants according to which ^{40}K value was calculated are most often not given. Therefore coefficient of recalculation joining these constants together was calculated from proportion of the given ^{40}K concentration and K content in %. It was possible only in the case if the authors present together with K (%) content also ^{40}K content. It turned out that value of this empirical coefficient varies from 1.1997 to 1.2002 in J. Kantor's works (1957—1960), 1.2199 — for analyses from Erevan, coefficient is again 1.1928 (all values x 10^{-3}) for combination of constants which is taken as a basis of standardization. Since ^{40}K content in the equation (1) is in logarithm, relative deviations are decreasing with age of sample, it is illustrated in Tab. 3. Values in the table reflect exclusively influence of constants concerning calculation of ^{40}K concentration. Influence of decay constants and constants used in calculation of argon concentration is excluded.

Table 3

Influence of ^{40}K constants used in calculation of K-Ar age in the papers discussed

age in m.y.	Kantor, 1957		Kantor, 1959; 1960		Cambel et al., 1979, 1980; Bagdasaryan et al., 1977	
	△	%	△	%	△	%
50	—0.30	—0.608	—0.28	—0.567	—1.10	—2.19
100	—0.60	—0.600	—0.56	—0.560	—2.16	—2.16
200	—1.17	—0.584	—1.09	—0.545	—4.21	—2.11
300	—1.70	—0.568	—1.59	—0.530	—6.15	—2.05
500	—2.69	—0.539	—2.51	—0.503	—9.73	—1.95

△, % — as in Tab. 2.

Calculation of argon concentration

Recalculation of argon concentration expressed in cm^3 to its atomic proportion in gram of rock requires physical constants. Therefore like in the case of K, empirical coefficient collecting all constants used in the quoted works was calculated from ratio of ^{40}Ar in grams and ^{40}Ar in cm^3. Influence of differences in calculated coefficients on obtained age is not high. In comparison with standard age, "argon coefficients" used by Kantor (1957, 1959 a—d, 1960) cause increase of age by 0.02 %, coefficients used by Bagdasaryan et al. (1977) and Kantor (1980) increase age from 0.38 % for ages till 100 m. y. to 0.33 % for ages of 500 m. y. In the works of Cambel et al. (1979, 1980) these coefficients cause positive deviations from 0.12 to 0.10 %.

Joint effect of deviations in all constants

Each result of dating expressed in years follows not only from values obtained by direct measuring, but also from accepted three groups of constants concerning decay constants, calculation of ^{40}K and ^{40}Ar. Changes in these groups did not take place at the same time, therefore 5 various combinations different from standard ones may be found in the original results discussed in the present work.

Table 4 summarizes relative deviations of age values calculated according to various combinations of constants.

Absolute deviations expressed in m. y. are plotted in Fig. 2. It is typical that various combinations of constants used in various works from the West Carpathian crystalline complex cause approximately symmetrical deviations from standardized values. Absolute values of deviations may be important in stratigraphic scale, especially if values with deviations to opposite sides are compared. Data from the older J. Kantor's works and from the works of Bagdasaryan et al. (1977) and Cambel et al. (1979, 1980) may serve as an example. It appears that process of standardization is necessary and important for obtaining of unified mutually comparable results, because only they can serve as a basis for further calculations and interpretations.

For the above-mentioned reasons, we recalculated all data according to constants accepted as a standard, i.e. decay constants and atomic portion of ^{40}K in total potassium, $\lambda = 5.543 \times 10^{-10} . y^{-1}$, $\lambda_e = 0.581 \times 10^{-10} . y^{-1}$, 0.01167 at. % according to Steiger — Jäger (1977) and atomic weights according to the most recent accessible data (Computope chart, 1982). Original analytical data, age given in original work and age calculated from the same analytical data but according to standard combination of constants are given in Appendix I; these are, of course, model ages (see p. 133). Calculations were not always easy, because it was often necessary to find out constants used by authors by means of backward calculations, whereby not one, but several values are concerned. We corrected also a few found misprints which caused that analytical data did not correspond to the given age.

All isochrons which will be discussed in the following parts are based on standardizet results and, thus, free of evident source of dispersion.

^{40}Ar-^{40}K isochrons from the West Carpathian crystalline complex

Amphiboles

a) Gemerides

Rocks of amphibolite facies (amphibolites, tonalite gneisses, etc.) are distributed in gemerides to a higher degree than it was supposed before. Amphibolites and various rocks of gneiss type described from the area of Dobšiná (Rozložník, 1965) occur in various nappes of gemericum in various localities (V. Klátov, Rudňany, Kojšov, Smolník, etc.). These metamorphites occur stratigraphically in the Early Palaeozoic, but also in the rocks of Carboniferous age (Dianiška — Grecula, 1979; Hovorka et al., 1979; Bajaník — Hovorka, 1981). Original psammites and pyroclastic rocks or basic volcanites were metamorphosed at low pressure and high temperature (Grecula, 1982), as shown by thermodynamic data from the garnet — amphibole pair from Rudňany which indicate 500—600 °C (Hovorka — Spišiak, 1981). Age of this metamorphism was considered to be Alpine or Variscan by various authors.

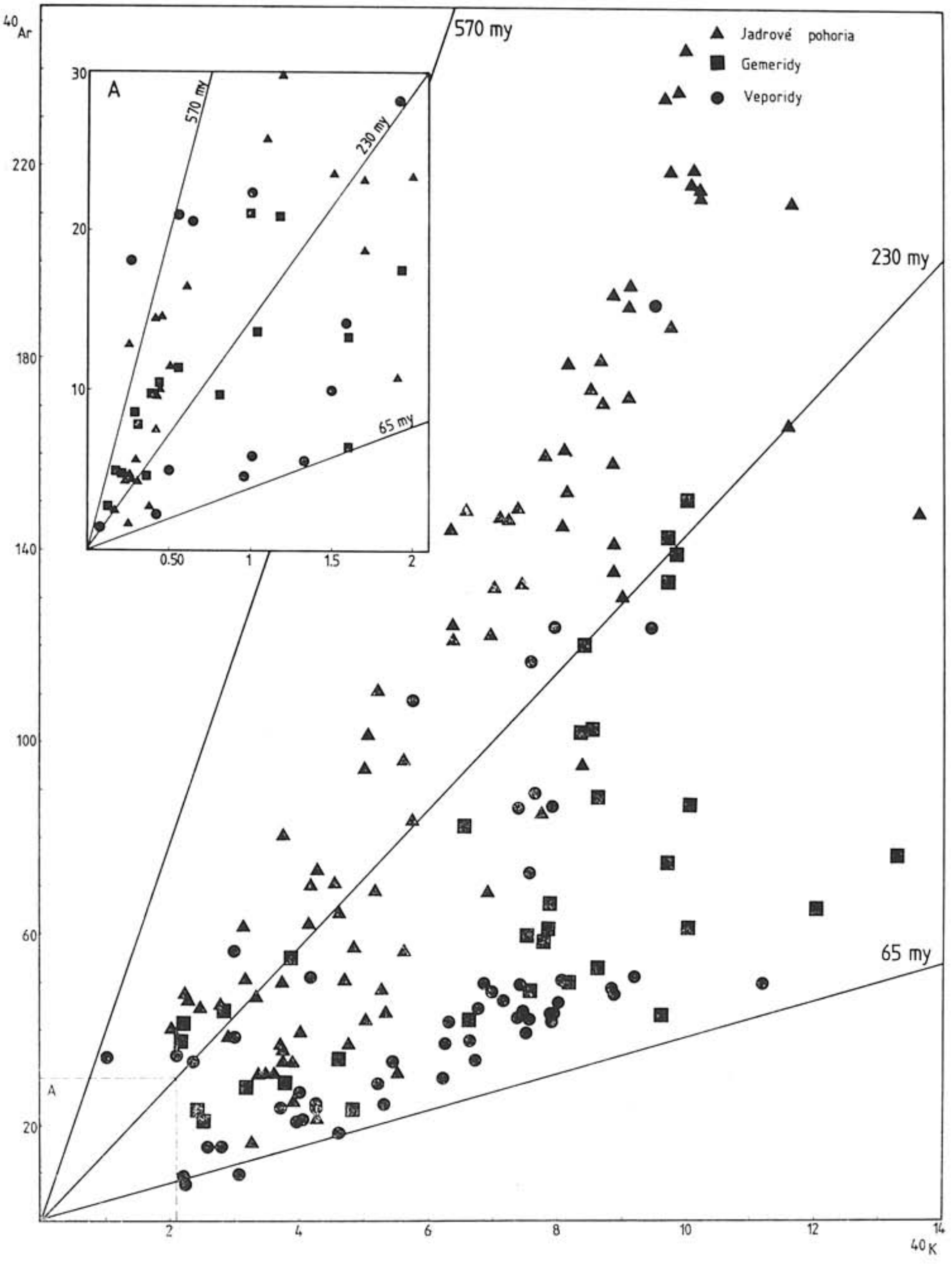

Fig. 1. Values of 220 standardized model K-Ar ages from the West Carpathian crystalline complex published within the time interval 1957—1985 in graph of ^{40}Ar vs. ^{40}K dependence.

Explanations: Section A represents enlarged sector in the left bottom part of the graph. Full lines represent Precambrian Palaeozoic boundary (570 m.y.), Palaeozoic Mesozoic boundary (230 m.y.), Mesozoic/Cenozoic boundary (85 m.y.) after Van Easinga (1975). In the present as well as in other graphs of this type ^{40}Ar values are expressed in $g/g \times 10^{-9}$, ^{40}K values in $g/g \times 10^{-6}$. Analytical data for all given samples are presented in Appendix I.

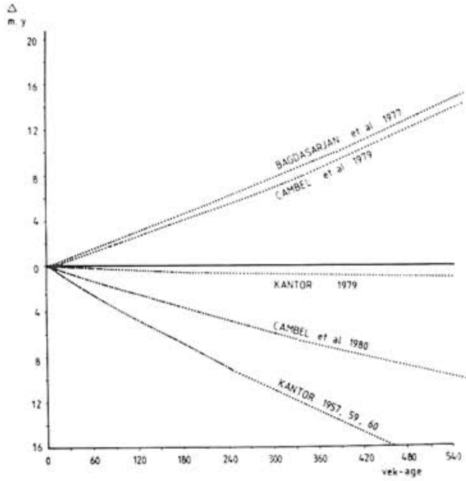

Fig. 2. Differences in K-Ar ages calculated on the basis of different ^{40}K decay constants and other physical data (mainly weights of nuclides and ratio of isotopes in isotopic mixture) as they were used by various authors in K-Ar dating in the West Carpathian crystalline complex.
Explanations: Full line denotes reference level of this work, dotted lines represent deviations (in m.y.) in dependence of age of sample on chosen standard in the published works.

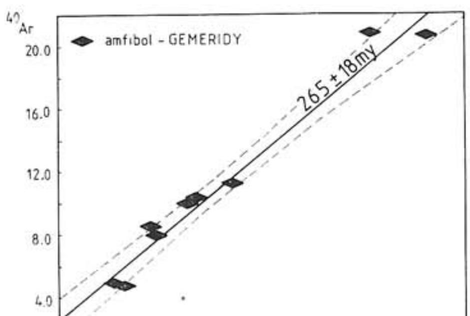

Fig. 3. Dependence of ^{40}Ar content on ^{40}K concentration in amphiboles from gemerides amphibolites.
Explanations: Position of the points in the plot proves a strong dependence (Rxy = 0.987). Model ages of samples vary from 281 to 448 m.y. Isochron age calculated from slope of regression line is 265 ± 18 m.y. Dashed line denotes 95 % confidence interval of the line. Analyses from Appendix I given under the following numbers (according to rising K content): 12, 11, 44, 43, 29, 45, 36, 35, 37 were used for calculation of isochron.

According to the latest analysis carried out by Grecula (l. c.), this type of metamorphism postdated the formation of schistosity s_2 and preceded formation of nappes, i. e. it must be of Eerly-to-Middle Permian age. However, rolled pebbles of such metamorphosed rocks occur in sediments of unmetamorphosed Carboniferous.

Samples used for K-Ar dating are taken from various localities, but from genetically very similar rocks. Standardized K-Ar model ages are characterized by great dispersion of values from 448 m. y. to 214 m. y. Detailed analy-

Table 4

Relative deviations of age values according to various combinations of constants

age in m.y.	Kantor, 1959		Cambel et al., 1980		Cambel et al., 1979		Bagdasaryan et al., 1977		Kantor, 1980	
	Δ	%	Δ	%	Δ	%	Δ	%	Δ	%
50	—2.00	—4.00	—1.04	—2.08	+1.08	+2.15	+1.21	+2.42	—0.128	—0.256
100	—3.93	—3.94	—2.05	—2.05	+2.19	+2.19	+2.46	+2.46	—0.253	—0.253
200	—7.63	—3.82	—3.99	—2.00	+4.53	+2.26	+5.05	+2.52	—0.492	—0.246
300	—11.10	—3.70	—5.83	—1.94	+7.01	+2.34	+7.77	+2.59	—0.719	—0.240
500	—17.39	—3.48	—9.22	—1.84	+12.37	+2.47	+13.58	+2.72	—1.135	—0.227

sis of data in isochron graph proves origin of this dispersion. Regression line with 95 % confidence interval is illustrated in Fig. 3. It does not pass through the origin, but indicates an intercept of $2.63 \pm 0.63 \times 10^{-9}$ g/g ^{40}Ar. Result of analysis proves that initial argon is present in 9 samples of amphiboles. It is a source of dispersion of model ages, whereby it causes increase of model ages especially of those amphiboles which have low K content. The very difference in K content in this situation explains a great difference in model ages of amphiboles from close proximity (see Kantor et al., 1981). Initial argon could be incorporated in amphiboles due to its partial pressure during their recrystallization. Close relation of amphibolites to gneissic rocks with higher K content may explain the source of high partial pressure of ^{40}Ar in wall rocks. It is noteworthy that amount of initial argon is very similar even in the quite remote samples what is evidenced by high value of correlation coefficient. The latter causes that all samples lie near defined isochron whose age is 265 ± 18 m. y. Comparing temperature of amphiboles formation (500—600 °C after Hovorka—Spišiak, 1981) with known thermometric data (only from Rudňany) and with blocking temperature of argon in amhiboles (500 °C after Harrison et al., 1979), it may be presupposed that the isochron age may approximate the age of recrystallization of these amphiboles, what will mean that this value may be interpreted as close to the age of metamorphism.

b) Veporides

From the veporides crystalline complex, only 5 analyses of amhibolites (gabbroamphibolite from Beňuš, Brezno-Vagnár, amphibole from Rochovce granite and amphibole from amphibolite from Rimavská Píla) have been published for the time being. In Fig. 4 these data are supplemented with analyses of whole rocks with low K content. Data in the graph are dispersed and do not define any isochron. This situation cannot be described by Harper's models (1970). The only possibility provided by analyses is combination of 2 amphibole samples with 3 whole rocks samples; owing to their K content we presuppose that they have practically monomineral composition — amphibole with minimum possible amount of plagioclase or quartz. Isochrone passing through these points would have high positive intercept with initial ^{40}Ar $16.87 \pm 0.61 \times 10^{-9}$ g/g and its age would correspond to 96 m.y. High initial argon content would result in very high apparent ages of amphiboles reaching as far as the Precambrian. There are not enough analytical data to confirm this hypothesis. But it is a fact that great dispersion of model ages from the veporides amphibolites (their mutual chronological relations are questionable too) varying from 882 to 169 m.y. proves that these data are apparent without relation to any geological event.

c) Core mountains — the Malé Karpaty Mts.

Amphibole samples from analyzed amphibolites of the core mountains are almost exclusively from the Malé Karpaty Mts. Rocks come from series of strongly metamorphosed rocks, where they form concordant beds of originally basic volcanic rocks in paragneisses. Practically all samples are from amphibolites of Pezinok—Pernek crystalline complex, the only amphibole sample

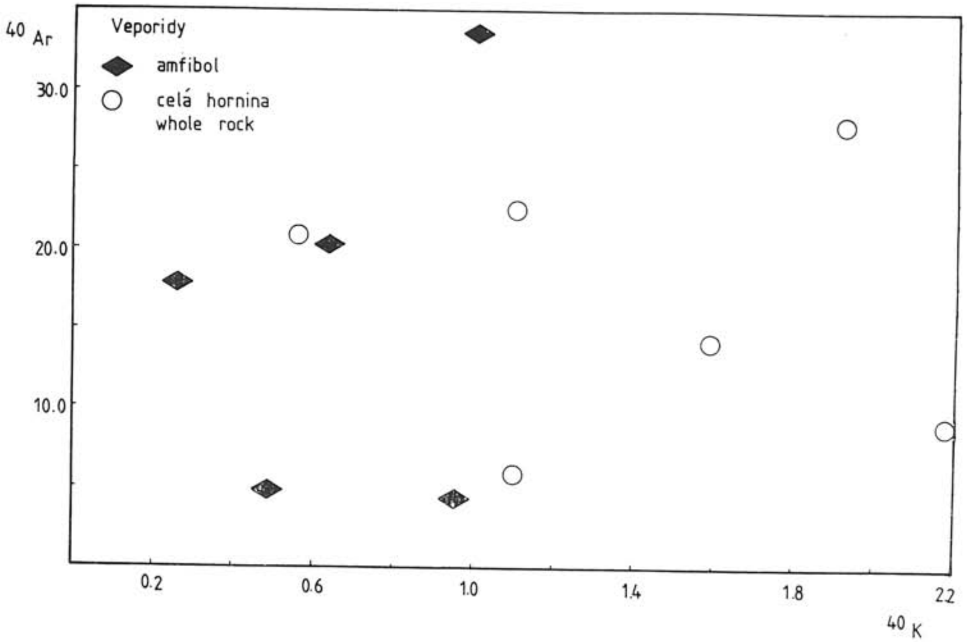

Fig. 4. Relation of ^{40}Ar vs. ^{40}K contents in amphiboles and basic rocks from the veporides.

comes from alkalic granite (Harmónia). Plot of $^{40}Ar/^{40}K$ dependence for amphiboles of amphibolites is given in Fig. 5. Majority of amphiboles is concentrated in the graph within the range of concentrations $0.15—0.55 \times 10^{-6}$ g/g ^{40}K. The only sample has twice as high concentration (diorite from Hlboká cesta road). Localization of this point in the graph has a considerable influence on the slope of regression line. 3 analyses (out of total 12) as well as 3 further analyses from amphibolites of the Low and High Tatra lie outside confidence interval of isochron of the Malé Karpaty Mts. crystalline complex amphiboles; due to a small number of data we shall not deal with the latter in detail. Analyses from the Malé Karpaty Mts. lying outside the confidence interval of isochron hardly influence a change of isochron parameters owing to their symmetrical position to isochron. Therefore if they are excluded from calculations, now calculated slope and intercept are practically identical. In this case, two points mostly remote from confidence interval border were removed from calculation (Appendix I, Nos. 117, 150). Amphibol No. 150 is from sample described as mylonitized epigabbro — reason of extreme position of the sample in the graph may be perhaps sought here.

Age calculated from isochron slope corresponds to 394 ± 24 m.y. Again, the isochron does not pass through the origin. From the results of regression analysis it is evident that $2.36 \pm 0.65 \times 10^{-9}$ g/g of radiogenic argon was released from analyzed group of samples. Differences in amounts of released argon in each sample are small as manifested by high value of correlation coefficient. But amount of released argon is significant, because standard deviation of inter-

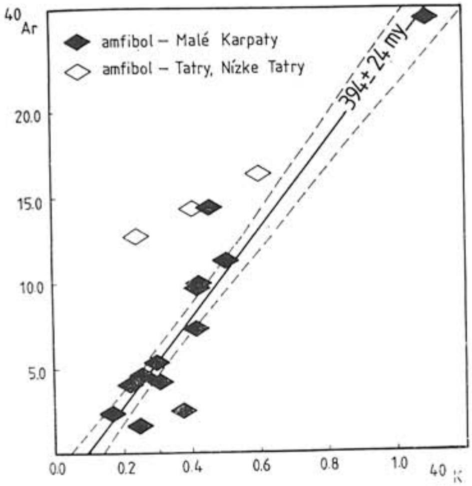

Fig. 5. Dependence of ^{40}Ar content on ^{40}K concentration in amphibole from amphibolites and other basic rocks from some core mountains (mainly the Malé Karpaty Mts.).

Notes: Expressive correlation of ^{40}Ar and ^{40}K for 14 amphibole samples from the Malé Karpaty Mts. crystalline complex (Rxy = 0.910) is even rised after elimination of two remote measurements (Rxy = = 0.985). This variant with 12 analyses gives isochron age of 394 ± 24 m.y. Numbers of analyses (App. I, given according to increasing K content): 148, 149, 146, 124, 170, 145, 169, 119, 147, 120, 180, 118. Dashed line denotes 95 % confidence interval of the line.

cept (as well as confidence interval) does not embrace zero value. Negative intercept causes dispersion of model ages (362—112 m.y.) which are lower than calculated isochron age. This value is within its standard deviation identical with Rb-Sr age determined from the whole metamorphic rocks from the Malé Karpaty Mts. crystalline complex (B a g d a s a r y a n et al., 1983). Rb-Sr isochron ages of whole rocks are interpreted as a time since the last isotope homogenization which may be caused by metamorphism. Accordance of K-Ar isochron with these data confirms the age of last metamorphism of crystalline schists in the Malé Karpaty Mts. and it indicates the same period of Rb-Sr systems homogenization in the samples of metamorphic rocks and of K-Ar system blocking in amphiboles.

M i c a s

M u s c o v i t e

Muscovites seem to be an ideal material for K-Ar dating owing to high potassium contents and high ability of argon retention up to 350 °C. However, isochron analysis strikes a specific problem which follows from the fact that range of K concentration in muscovites is narrow: for this reason the points representing individual samples are concentrated to the area situated far from zero point in the graph. Under such conditions, locating of regression line is problematic from the formal point of view, reliability of calculated intercept and of regression line slope is doubtful and isochron parameters depend very much on position of one point with the lowest K content. Such tendencies are manifested in analyses of muscovites from the West Carpathian crystalline complex. On the other hand, advantage of muscovites lies in the fact that owing to high K contents, calculated model ages are relatively little sensible to intercept value.

For this reason, real meaning of model ages in muscovites is more plansible than in the cases of minerals poor in potassium (e. g. amphibole).

a) Gemerides — muscovite

Isochron calculated for six points (excluding one — No. 4 with extreme position to the others perhaps because of great deficit of argon) gives a high negative intercept -71.08 and slope corresponding to the age of 339 ± 73 m.y. (Fig. 6). Little importance of this result is proved by the fact that elimination of next point (Appendix I, No. 31) gives intercept of only -15.69 and slope corresponding to 257 m.y. and, thus, close to isochron age obtained in amphiboles.

b) Veporides — muscovite

Analytical points for 5 veporides muscovites (Fig. 7) demonstrate abnormally great dispersion of argon concentration. If regression line was determined on their basis routinely, absurdly low intercept (-346.93×10^{-9} g/g) ^{40}Ar would be a result. If one applied Harper's model (1970) interpretation, it would indicate that all muscovites would lose identical volume of radiogenic argon as high as would be produced by these muscovites during 624 m.y. at concentration of ^{40}K — 8 ppm (average content for applied muscovites). Presence of 2 muscovites from diaphtoritized rocks on this line proves the fact that this result cannot be accepted in any case. The highest model age of these muscovites is 317 m.y. This age is probably closest to age of cooling on isotherm of ca. 350 °C.

c) Core mountains — muscovite — the Malé Karpaty Mts.

Muscovites (Fig. 8) document again great dispersion of argon concentrations [fluctuation in argon excess (?), fluctuation in argon loss (?), fluctuation in isotopic ratios of "atmospheric" argon (?)], what is difficult to put into accordance with Harper's model. In such situation, attempts at calculation of isochron ages are irrevelant, mainly because the result will provide again great negative intercept (-144.4×10^{-9} g/g and -83.35 after elimination of the point No. 122) and much higher ages in comparison with Rb-Sr data obtained from this region (Bagdasaryan et al., 1982, 1983).

The High Tatra and western part of the Low Tatra: from the both core mountain ranges only two analyses each were published, therefore no isochron verification is possible.

Biotite

a) Gemerides

Biotites from gemerides create a picture very similar to that of muscovite. The data do not correspond to isochron model and, thus, interpretation of model ages is unclear (Fig. 6).

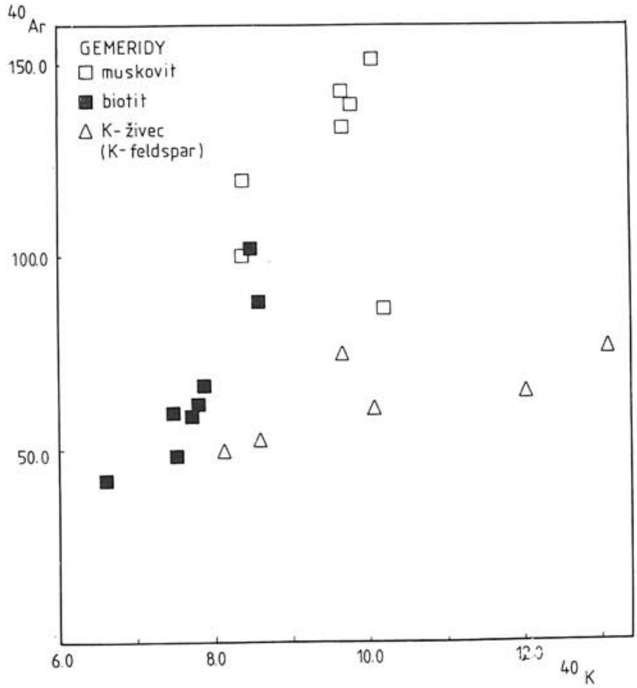

Fig. 6. Graph of ^{40}Ar vs. ^{40}K dependence in muscovites, biotites and K-feldspars from granitoid rocks of the gemerides.

b) V e p o r i d e s

K-Ar model ages calculated by K a n t o r (1960) and later by C a m b e l et al. (1979, 1980) from biotites of the veporides crystalline complex are concentrated around the values of 100 m.y. At the same time, sedimentation age of metamorphosed rocks which form the present relief is undoubtedly Palaeozoic, as it was evidenced by numerous palynological analyses (P l a n d e r o v á—M i k o, 1977; K l i n e c—P l a n d e r o v á, 1981, etc.), Rb-Sr data of the whole rocks from the Vepor pluton lie in the interval 360—280 m.y. (B a g d a s a r y a n et al., 1986). K-Ar ages are interpreted as a result of Alpine orogenetic processes taking place in the Upper Cretaceous or due to „heating" of the crystalline massif resulting argon loss in the whole region.

All analyses of biotites from the veporides crystalline complex are illustrated in the graph No. 17. Majority of samples (25 analyses) is concentrated around the isochron of 94 ± 18 m.y., 6 analyses are dispersed (Appendix I, Nos. 74, 55, 65, 87, 105, 98). Calculated regression line has not the best parameters. Only very few biotites lie directly on it, confidence interval of the line is quite narrow in the part where majority of samples is concentrated and, on the other hand, wide outide this part. Confidence interval of slope of isochrone forms almost 20 % of its value. Technically it would be possible to set two lines which

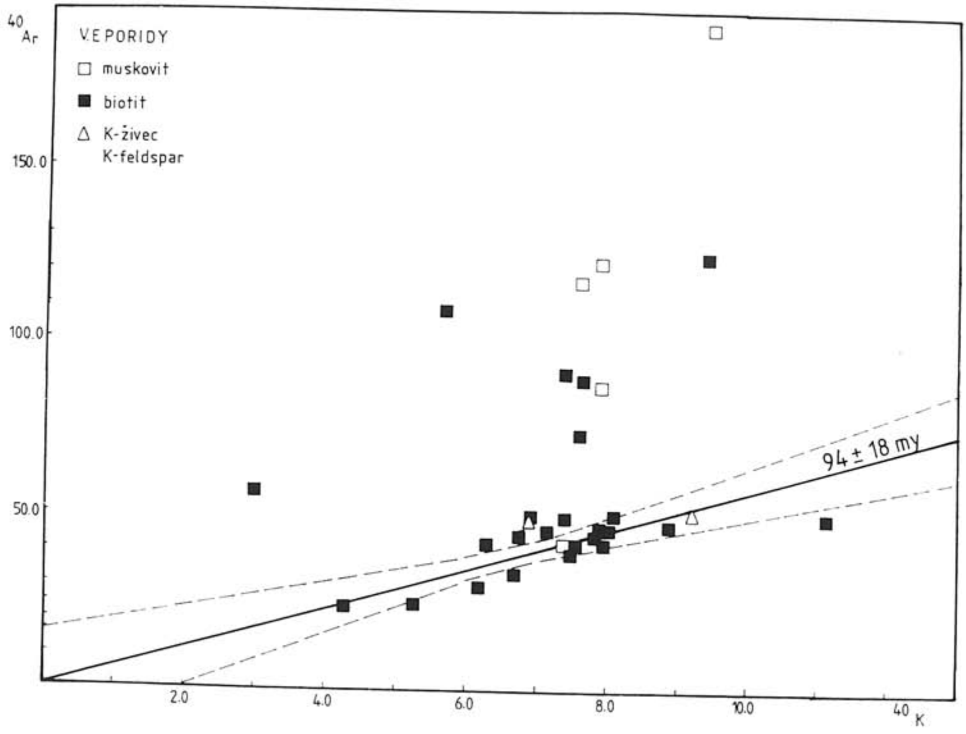

Fig. 7. Muscovites and biotites from granitoid and metamorphic rocks from the veporides crystalline complex in graph ^{40}Ar vs. ^{40}K.

Notes: Majority of biotites forms a linear dependence with high correlation coefficient ($Rxy = 0.975$). Value of regression coefficient of the line gives the age of 94 ± 18 m.y. Samples given in Appendix I under the following numbers (according to increasing K content): 88, 68, 100, 95, 79, 82, 71, 86, 84, 99, 76, 61, 109, 72, 89, 63, 77 were used for calculation of isochron age. Model ages of these samples vary from 78 to 120 m.y.

would be practically parallel with different intercept through this group of samples. In this situation all 17 points would lie practically on isochrons and also other statistical parameters would be considerably improved. But we have not found any geological reason for such selection from the given localization of samples; it is unclear why majority of veporide biotites should correspond to two types of isochrons concordant in age but with different intercept values.

Isochron of veporide biotites practically passes through the origin of the graph. Therefore we can argue that since period of calculated age no loss of ^{40}Ar has occurred and, thus, we may consider this system for blocked. Because production of radiogenic argon must have taken place since Palaeozoic times in these rocks, it is evident that majority of biotites lost this argon. On the basis of known data on argon blocking temperature in biotites it may be presupposed that this date corresponds to the time when the rocks cooled down to the temperature of ca. 270—300 °C. This cooling may be connected with strong

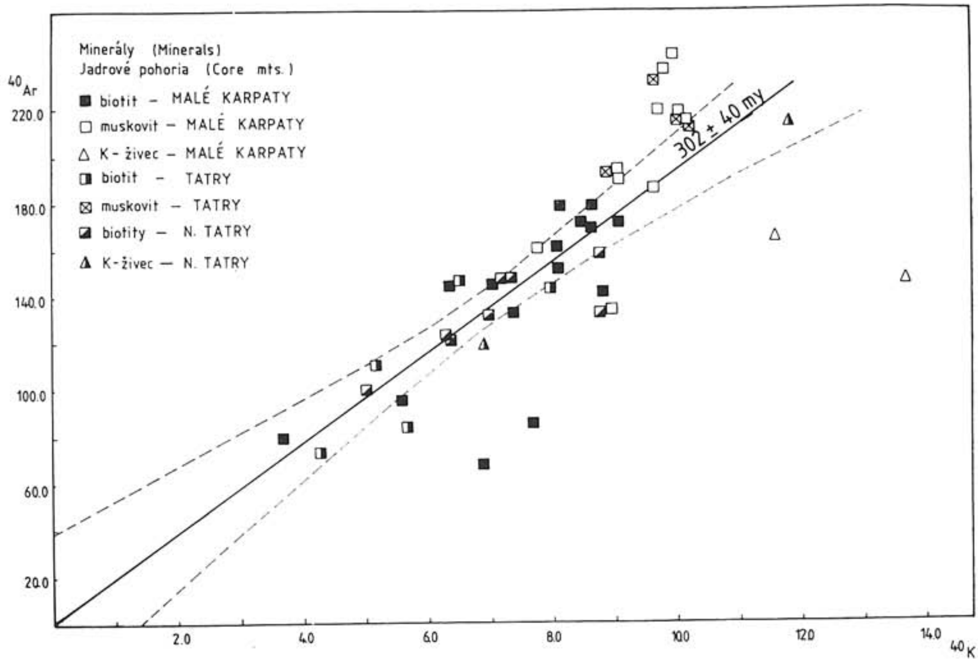

Fig. 8. Dependence of ^{40}Ar contents on ^{40}K content in minerals of granitoid and metamorphic rocks from the core mountains crystalline complex.

Notes: Regression line (with dashed 95 % confidence interval) is calculated only for biotites from granitoid and metamorphic rocks from the Malé Karpaty Mts., the High Tatra and the Low Tatra. Age calculated from slope of regression line is 302 ± 40 m.y. Slope is calculated for 19 biotite samples ($Rxy = 0.969$) which are given in App. I under the following numbers (according to increasing K content): 116, 198, 208, 202, 135, 209, 210, 215, 134, 216, 214, 132, 198, 125, 155, 171, 130, 126, 154. Model ages of used biotite samples vary from 325 to 284 m.y.

tectonic uplift of the region with subsequent erosion of the surface. Reason of dispersion of six points above isochron is unclear. It is surprising that samples taken practically from the same localites (samples from Píla, Sihla) have different ^{40}Ar contents. 2 samples from Píla lie very close to the calculated isochron, the third one very far from it. Character of dispersion of these samples is irregular and potential hypotheses of its explanation cannot be analytically proved because of absence of data necessary for construction of other types of K-Ar isochrons.

c) Core mountains

All accessible K-Ar data of minerals from the core mountains are plotted in the graph No. 8. Most of analyses come from the Malé Karpaty Mts., smaller part from the Low and High Tatra. From the other core mountains no K-Ar data have been published.

The isochron is calculated from data obtained from biotites of granitoid and metamorphic rocks. Except 2 biotite samples from the Malé Karpaty Mts. lying far from line and its confidence interval, other samples are more or less within calculated slope. But dispersion of data around isochron is considerable. Rb-Sr isochron dating of whole rocks from the crystalline complexes of individual core mountains proves considerable differences in their age. These differences throw doubt on the fact whether interpretation of K-Ar ages from various core mountains may be generally uniform, since it may be expected that differences recorded by Rb-Sr system will be manifested also by difference in evolution of K-Ar system. The question is not purely theoretical, because differences between individual tectonic parts of the crystalline complex on ca. 100 °C temperatures level (FT dating of apatite, Kráľ, 1977) are expressive. Situation may be complicated also by the fact that present surface of the crystalline complex may be formed by the rocks with different thermal history occurring on different temperature levels which certainly must influence the evolution of K-Ar system.

Regression analysis of 5 biotite samples from the High Tatra, of 7 biotite samples from the Low Tatra and 11 biotite samples from the Malé Karpaty Mts. leads to similar results. It means that these samples follow approximately the same dependence in the common plot. 19 biotite samples (out of 28) lie in 95 % confidence interval of the line which passes through the origin and corresponds to an age of 302 ± 40 m.y. Comparing this value with Rb-Sr data (Burchart, 1968; Bagdasaryan et al., 1982, 1985), this age is, within an error, concordant with (or lower than) Rb-Sr age of granitoid rocks from the Malé Karpaty Mts., the Low Tatra and High Tatra. This difference may be explained due to different closure temperatures of Rb-Sr and K-Ar systems. It is typical that biotites from metamorphic and granitoid rocks of the Malé Karpaty Mts. lie together within 95 % confidence interval. This fact proves, in spite of different Rb-Sr ages of granitoid and metamorphic rocks and different intrusion or metamorphism temperatures, that the samples pass the isotherm of ca. 270 °C at the same time.

Feldspars

a) Gemerides

From granitoid rocks of the gemerides 6 analyses of K-feldspars were published. In graph No. 6 they clearly follow a dependence excluding 1 sample. If we eliminate this point, result of regression analysis for 5 feldspar samples gives slope corresponding to 79 m.y. with expressive intercept of $12.22 \pm 6.19 \times 10^{-9}$ g/g of radiogenic ^{40}Ar. Positive intercept is a source of relatively great dispersion of K-Ar model ages. However, this result cannot be considered an argument for hypothesis of argon capture. Also release of argon from minerals may lead finally to positive intercept, if argon loss is proportional to potassium content. Low closure temperature for argon in feldspars and relatively great interval of potassium concentrations create in the given case optimum conditions for this variant, mainly if cooling was not too fast and the rocks, as a whole, represented from the point of view of argon release incompletely open system. If we accept this conception, calculated age will not give direct information on time which has passed since reaching of complete Ar blocking in feldspars.

b) Core mountains

Analyses of feldspars from the core mountains plotted in isochron graph (Fig. 6) do not form any dependence which will enable to make isochron verification of data, besides it, number of samples is too small (3 samples): 1 from the Malé Karpaty Mts. and 2 from the Low Tatra.

Whole rocks

K-Ar data from the whole rocks from the core mountains, veporides and gemerides crystalline complexes form interesting and characteristic picture, typical of all three tectonic units (Figs. 9, 10, 11). In the ^{40}Ar vs. ^{40}K graph they form spectrum of 2—4 isochrons each with high correlation coefficient. Intercept value of regression lines is proportional to their slope. The greater the slope, the higher the intercept. As it is seen from numeric data, this spectrum of apparent ages is not in relation to any geological event.

Mechanism which caused final distribution of analytical points in this scheme cannot be found out in at least one type of isochrons. It is evident that number of factors and their combinations, such as variability of mineral composition of samples, degree of secondary alterations, thermal history of the samples, degree of tightness of the system controlling the subsequent Ar loss, etc. may take place in this case.

Attempt at reconstruction of thermal history of the West Carpathian crystalline massifs

In accordance with the views commonly accepted already for 25 years, the so-called ages obtained by dating of minerals from the plutonic rocks by means of K-Ar method do not reflect chronology of crystallization processes, but only time which passed since transition through certain temperature levels different for various minerals. This principle concerns also fission track dating. Therefore, these two methods practically inapplicable directly to study of plutonic magmatism and metamorphism evolution are valuable methods in the study of thermal history of regions and dynamics of vertical movements in a large scale. In this place the following works should be quoted: Wagner—Reimer (1972), Wagner—Reimer—Jäger (1977), Gleadow—Brooks (1979) and Harrison et al. (1979). Comming out from the above works we tried to construct a hypothetical picture of thermal history in the studied area recorded in the rocks forming the today's surface. Coordinates of the points through which hypothetical cooling curves pass represent blocking temperatures of the system and result of dating (Figs. 12, 13, 14, 15). Temperature of 700 °C as estimation of crystallization temperature of granitoid rocks and their age determined by Rb-Sr method on the whole rock samples were accepted for initial values. Temperature of 500 °C was accepted for temperature of metamorphic recrystallization of amphibolites and their age corresponds to K-Ar isochron age of amphiboles. Purely geological information especially on existence of sedimentary contact between deeply-denuded granodiorite and the Permian (?) or the Lower Triassic sediments was applied to the core mountains. Nice examples of it have been known for a long time from the High Tatra but also from the other core mountains. There are not many points through

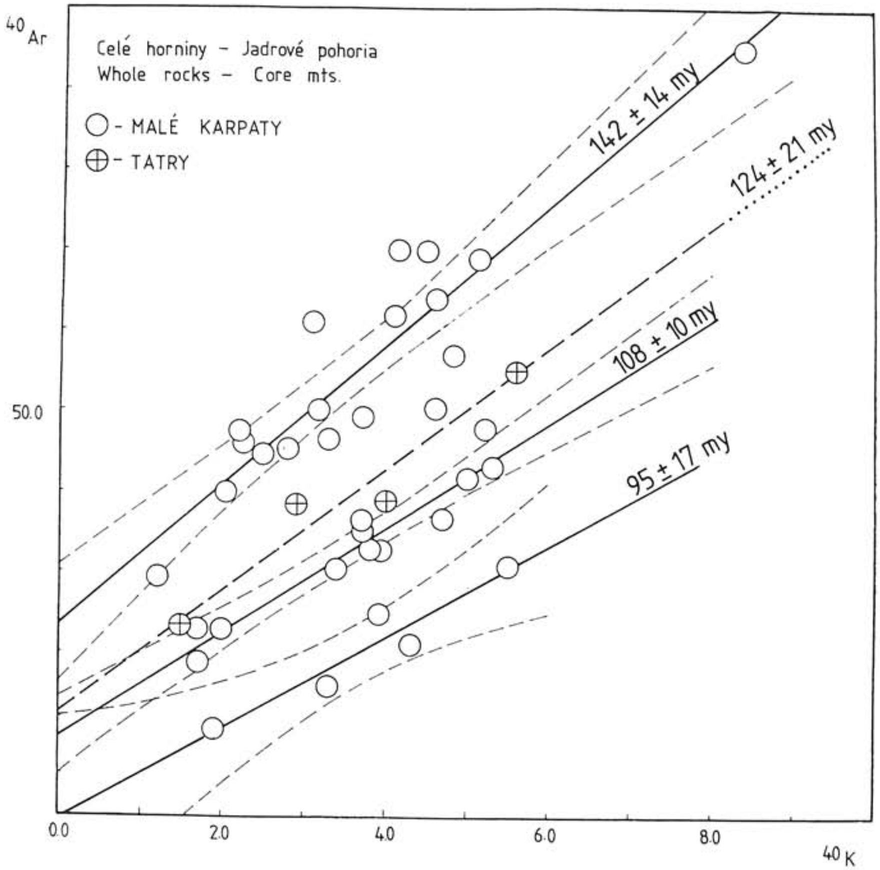

Fig. 9. Relation between ^{40}Ar and ^{40}K contents in the whole rocks from the core mountains, especially from the Malé Karpaty Mts.

Notes: Regression line 144 ± 15 m.y. (Rxy = 0.932) for 17 analyses used for calculation given in App. I under the following numbers: 165, 190, 191, 160, 161, 152, 173, 174, 153, 192, 188, 123, 172, 184, 164, 144, 186. Model ages of samples vary between 185 and 379 m.y. Line 124 ± 21 m.y. for the whole rocks from the High Tatra crystalline complex. Rxy = 0.973, numbers of analyses: 205, 204, 197, 206. Model ages range within 161 and 253 m.y.

Line 108 ± 10 m.y. (Rxy = 0.958) is calculated from the analyses given under the following numbers: 166, 89, 193, 156, 187, 182, 176, 175, 138, 185, 163, 139. Model ages of these samples lie within the interval of 128—219 m.y.

Analyses Nos. 178, 177, 183, 140, 167 lie on the line 95 ± 17 m.y. Rxy = 0.957. Model ages range from 83 to 106 m.y.

which the curve passes and their uncertainty interval is large, mainly due to different estimations of blocking temperature made by various authors. Another which reduces reliability of this reconstruction is a fact that the data were obtained from the samples which were not taken especially for this purpose. Therefore errors resulting from comparison of rocks occurring at various denudation levels and also from laterally remote ones are possible. Besides this fact, the graphs are based on assumed view that cooling had monotonous course without fluctuations of temperatures in the history of the region and that the results of dating correspond to time of transition through border temperatures.

Just one more fact should be commented on. If we neglect questions of thermal flow changes coming from the earth interior, as well as local sources of heat (due to radioactive decay), we may distinguish two main reasons of cooling:

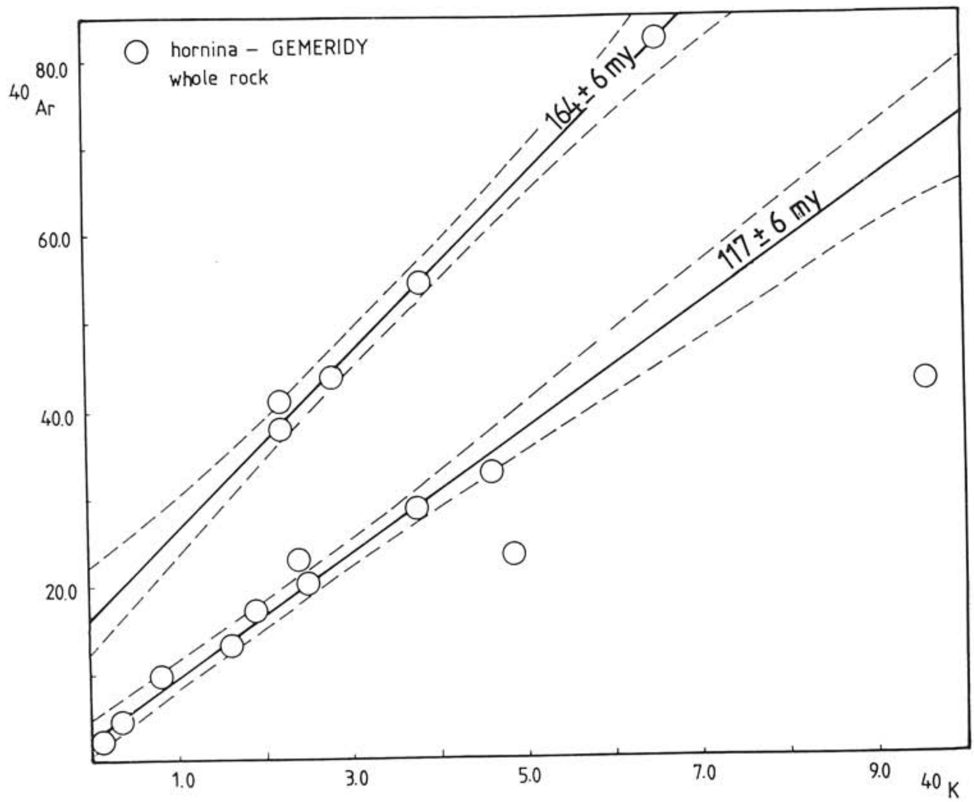

Fig. 10. Dependence of ^{40}Ar on ^{40}K contents in the samples of the whole rocks from the gemerides.

Notes: Line 164 ± 6 m.y. (Rxy = 0.998) is calculated from analyses given in App. I under the following numbers: 14, 40, 13, 27, 41. Model ages the samples lie within the range of 293 and 205 m.y.

Line 117 ± 6 m.y. (Rxy = 0.991) is calculated from the analyses Nos. 28, 49, 15, 7, 42, 9, 26, 27, 25. Model ages of the samples vary from 330 to 122 m.y.

1. slow cooling of plutonic body which intruded into metamorphosed cover at a considerable depth;

2. postorogenetic uplift of the whole massif, i.e. intrusion together with its cover.

In the first case gradual equalization of temperatures between intrusion and wall rocks occur. Rates of intrusion cooling are gradually lowered in the course of time until the temperature reaches a level which results from depth and local geothermal gradient. In the second case changes of temperatures are effected by rate of uplift and by geothermal gradient.

Though we use practically semiquantitative data, we have calculated average rate of cooling separately for the period over 300 °C and for the period from 300 °C to surface temperatures. First temperature interval is considered for purely "intrusive" part, the second one — for purely "tectonic" part, though these mechanisms cannot be so sharply separated from each other in nature. In the cases where it was possible we calculated also average rate of postorogenetic uplift terminating Hercynian era (evidenced by biotite ages and pre-Upper Permian or Lower - most Triassic denudation) and of the Alpine uplift documented by FT dating (B u r c h a r t, 1972; K r á ľ, 1977).

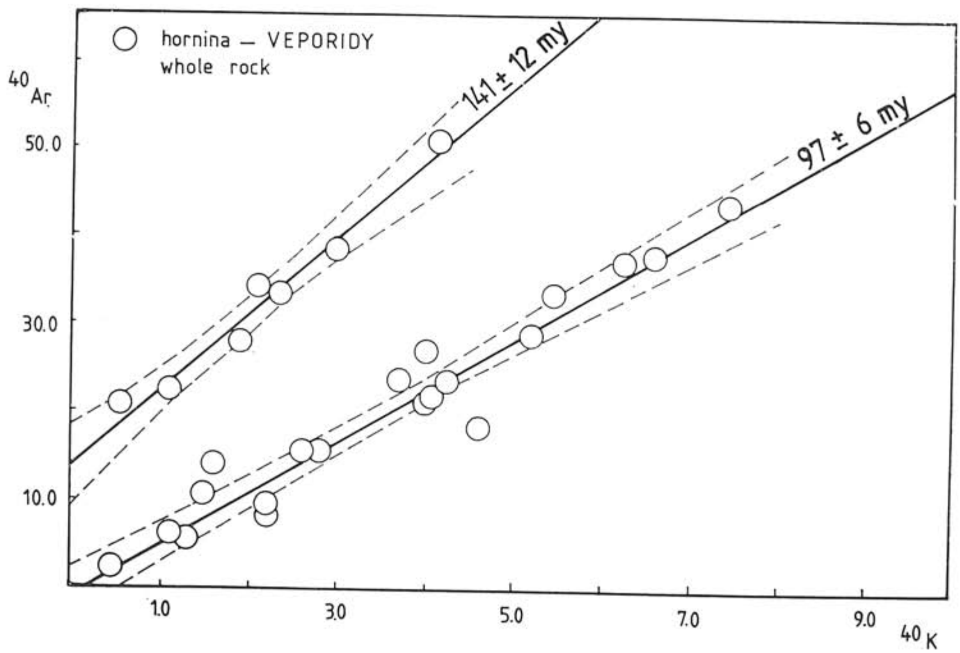

Fig. 11. Dependence of ^{40}Ar on ^{40}K contents in the whole rocks samples from the veporides crystalline complex.

Notes: Regression line (with 95 % confidence interval) 141 ± 12 m.y. (Rxy = 0.983) is calculated from the analyses Nos. 59, 54, 62, 52, 115, 91, 103. Model ages of these samples vary from 199 to 544 m.y. Line 97 ± 6 m.y. (Rxy = 0.966) is based on analyses Nos. 83, 53, 104, 60, 85, 81, 102, 50, 51, 75, 110, 66, 64, 92, 101, 111, 73, 69, 108, 93. Model ages of these samples vary from 148 to 67 m.y.

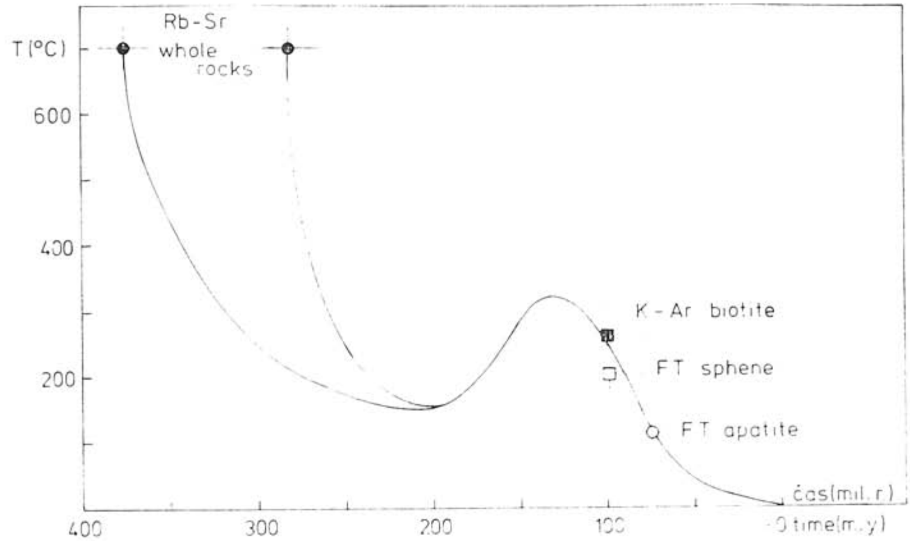

Fig. 12. Reconstruction of thermal history of the veporides crystalline complex on the basis of geological and geochronological data.

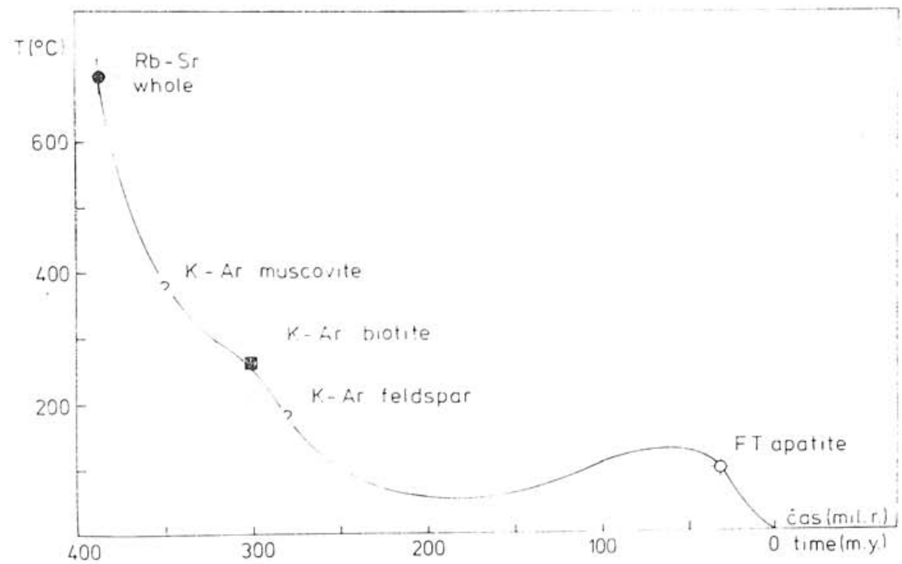

Fig. 13. Reconstruction of thermal history of the Low Tatra crystalline complex.

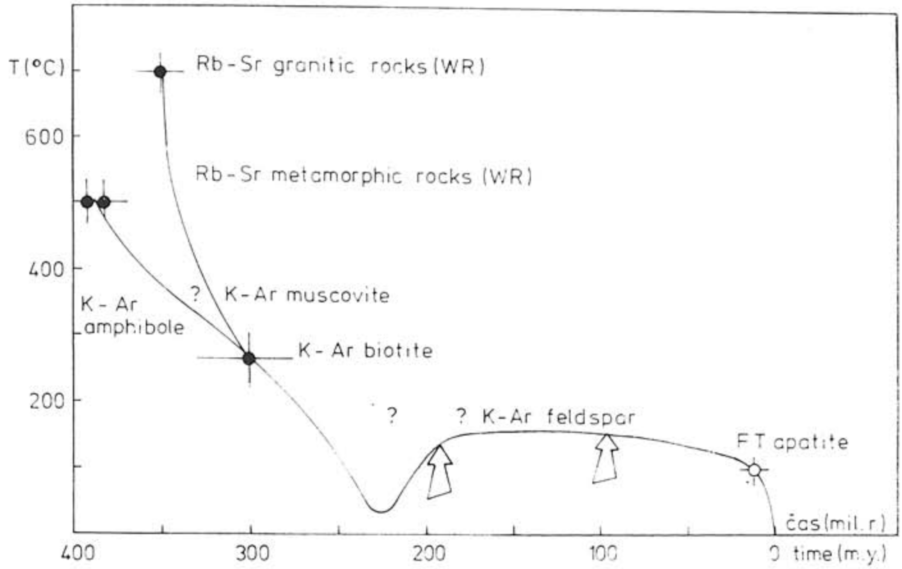

Fig. 14. Reconstruction of thermal history of the Malé Karpaty Mts. crystalline complex.

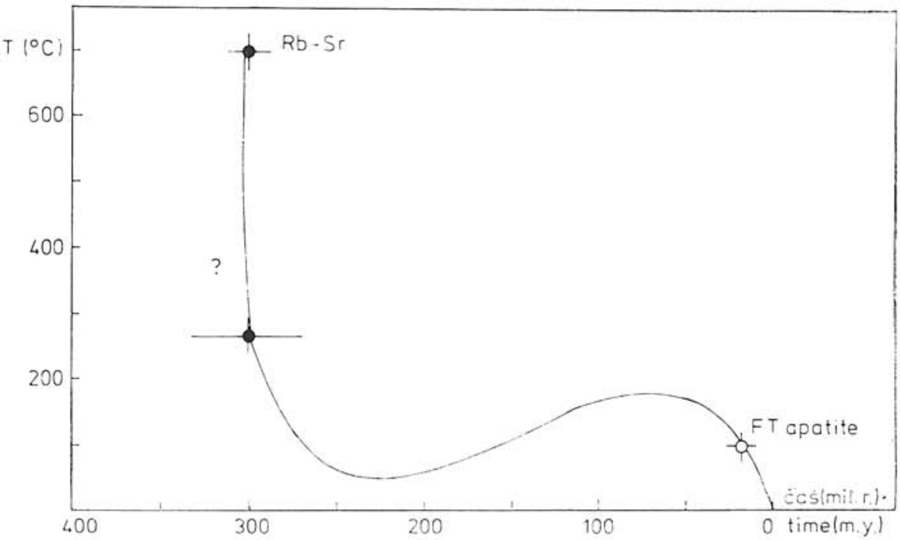

Fig. 15. Reconstruction of thermal history of the High Tatra crystalline complex

Calculated rates of cooling for "intrusive interval" vary from 2 to 25 °C/1 m.y. for different tectonic units. The lowest cooling values are typical of the veporides. Analogical results for "tectonic interval" vary from 1 to 5 °C/1 m.y. Rates of uplift for purely "tectonic interval" (for the lowest interval of temperatures) are calculated from geothermal gradient of 30 °C/km. It is very typical that values obtained for the Hercynian and Alpine uplifts are very similar, they vary around the value of 0.1 mm/year. Alpine uplift of the High Tatra has the highest value (0.22 mm/year), the gemerides have the lowest value (0.06 mm/year). We do not present more detailed results of calculations, since a part of them is based on questionable data (e.g. feldspar ages).

Conclusion

The main goal of the present work was to check whether dispersion of model K-Ar ages can be interpreted by isochron models described by Harper (1970). Isochron ages may be ascribed a real importance only after verified agreement. After confrontation with blocking temperatures of Ar in minerals, these results may be applied to formulation of hypotheses on thermal history of the studied region. Analyses of the whole rocks represent an important part of analyses. They are beyond any isochron control of isotopic system and, therefore, they are inapplicable to geochronological purposes. We tried to document this fact and, at the same time, to avoid using of the so-called "ages" of the whole rocks as information on temporal evolution of the West Carpathian crystalline complex. Similarly, acceptance of K-Ar ages of K-feldspars as cooling ages on defined thermal level seems to be unsuitable for chronology. So far negative conclusions of this work.

Positive result is represented by calculation of isochron ages of biotites and mainly of amphiboles. From a great number of K-Ar model ages which were often considered as crystallization ages in literature, we present only few numbers — isochron ages which can be considered to have a real importance from the point of view of geological processes:

1. 394 ± 24 m.y. — amphiboles, the Malé Karpaty Mts.;
2. 265 ± 18 m.y. — amphiboles, gemerides;
3. 302 ± 40 m.y. — biotites, core mountains;
4. 94 ± 18 m.y. — biotites, veporides.

On the other hand, results of muscovites and feldspars dating cannot be interpreted by Harper's models (l.c.). Isochron ages of biotites represent a time which passed since transition through the isotherm of ca. 270 °C during cooling of rocks; in the case of amphiboles, the results date transition through the isotherm of ca. 500 °C which is already close to metamorphic conditions. It means that only isochron ages of amphiboles approximate time of recrystallization and, thus, only these ages have relation to petrogenesis. All other ages may be applied to explanation of cooling history which is a direct result of tectonic evolution. Dating of K-Ar minerals of plutonic rocks is most often used for such purposes in the world literature. Information on true ages of minerals and rocks with complicated plutonic history, i.e. on time which passed since their crystallization, may be expected from application of other methods of isotopic geochronology, mainly from Rb-Sr method. Simply speaking, K-Ar method is unsuitable for such aims.

Translated by O. Mišániová

Appendix I

K-Ar data from the West Carpathian crystalline complex published in the period 1957—1985: basic data

No.	Orig. No.	Mineral	Rock	Locality	K (%)	$^{40}Ar^*$ $cc/g.10^{-6}$	Model age new	Model age orig.	Constants	Literary reference
				GEMERIDES						
1	84	biotite	granite	Betliar	6.570	34.31	130	130	3	Kantor—Rybár, 1979
2	1	K-feldspar	granite	Betliar	7.198	29.52	103	98	1	Kantor, 1957
3	2	K-feldspar	granite	Betliar	6.849	27.92	102	98	1	Kantor, 1957
4	85	muscovite	granite	Čučma	8.56	48.73	141	141	3	Kantor—Rybár, 1979
5	77	biotite	granite	Čučma	6.29	33.41	132	132	3	Kantor—Rybár, 1979
6	B	microcline	quartzy veinlet	Čučma	(11.04)	42.73	97	93	1	Kantor, 1959
7	G-12	—	granite	Čučma	1.345	7.48	138	141	2	Bagdasaryan et al., 1977
8	H-5	microcline	ore veinlet	Čučma	10.1	36.55	91	94	2	Bagdasaryan et al., 1977
9	5773/27	—	gneiss	Dedinky	2.01	12.84	157	154	3	Cambel et al., 1980
10	5773/29	—	phyllite	Dedinky	3.20	30.69	231	227	3	Cambel et al., 1980
11	A-42	amphibole	amphibolite	Dobšiná	0.18	2.68	347	339	3	Cambel et al., 1980
12	A-22	amphibole	amphibolite	Dobšiná	0.175	2.75	365	358	3	Cambel et al., 1980
13	B-9	—	met. rock	Dobšiná	2.36	24.75	251	258	3	Cambel et al., 1980
14	5773/31	—	gneiss	Dobšiná	1.82	21.24	278	273	3	Cambel et al., 1980
15	5773/32	—	carb. silic. rock	Dobšiná	0.68	5.44	195	191	3	Cambel et al., 1980
16	G-114	—	biot. porphyry	Helcmanovce	8.06	24.14	75	74	3	Bagdasaryan (unpub.)
17	72	biotite	granite	Hnilec	7.195	49.58	169	169	3	Kantor—Rybár, 1979
18	71	biotite	granite	Hnilec	7.142	57.51	196	196	3	Kantor—Rybár, 1979
19	74	K-feldspar	granite	Hnilec	8.128	41.85	128	128	3	Kantor—Rybár, 1979
20	75	K-feldspar	granite	Hnilec	8.433	34.39	102	102	3	Kantor—Rybár, 1979
21	70	muscovite	granite	Hnilec	8.241	78.23	229	229	3	Kantor—Rybár, 1979
22	68	muscovite	granite	Hnilec	8.444	84.47	241	241	3	Kantor—Rybár, 1979
23	76	muscovite	granite	Hnilec	8.134	80.15	237	237	3	Kantor—Rybár, 1979
24	73	muscovite	granite	Hnilec	8.157	74.93	222	222	3	Kantor—Rybár, 1979

Appendix I — 1st continuation

25	5773 36	—	tourm. granite	Hnilec	3.84	18.91	122	120	3	Cambel et al., 1980
26	5773 37	—	diaphtorite	Hnilec	2.09	11.57	137	135	3	Cambel et al., 1980
27	5773 25	—	phyllite	Jahodná	3.14	16.28	129	127	3	Cambel et al., 1980
28	H-9	—	amph. gabbro	Kojš. Hoľa	0.106	1.49	330	310	2	Bagdasaryan et al., 1977
29	211	amphibole	amphibolite	Koš. Belá	0.339	5.535	378	337	3	Kantor, 1980
30	79	muscovite	granite	Podsúľová	7.047	67.37	231	231	3	Kantor—Rybár, 1979
31	78	muscovite	granite	Podsúľová	7.005	57.17	199	199	3	Kantor—Rybár, 1979
32	80	biotite	granite	Poproč	6.314	26.81	106	106	3	Kantor—Rybár, 1979
33	81	biotite	granite	Poproč	6.501	32.74	125	125	3	Kantor—Rybár, 1979
34	H-6	stilpnomelan	sid. vein	Rožňava	1.345	3.60	68	70	2	Bagdasaryan et al., 1977
35	245 ZL II-46	amphibole	amphibolite	Rudňany	0.867	11.797	320	320	3	Kantor et al., 1981
36	246Ry-2-58	amphibole	amphibolite	Rudňany	0.463	6.384	324	324	3	Kantor et al., 1981
37	262Ry-II-Z	amphibole	amphibolite	Rudňany	0.99	11.688	281	281	3	Kantor et al., 1981
38	H-10	fuchsite	sid. vein	Rudňany	0.91	7.68	205	210	2	Bagdasaryan et al., 1977
39	H-16	fuchsite	—	Rudňany	2.69	15.69	144	147	2	Cambel et al., 1979
40	B-10	—	gneiss	Rudňany	1.86	22.96	293	287	3	Cambel et al., 1980
41	5773 26	—	phyllite	Rudňany	5.48	46.22	205	201	3	Cambel et al., 1980
42	5773 38	—	graph. ser. schist	Smolník	1.62	9.87	150	148	3	Cambel et al., 1980
43	217	amphibole	amphibolite	Vyš. Klátov	0.261	4.429	391	391	3	Kantor, 1980
44	218	amphibole	amphibolite	Vyš. Klátov	0.244	4.820	448	448	3	Kantor, 1980
45	A-38	amphibole	amphibolite	Vyš. Klátov	0.365	5.82	370	363	3	Cambel et al., 1980
46	82	biotite	granite	Zlatá Idka	5.54	23.30	105	105	3	Kantor—Rybár, 1979
47	86	biotite	granite	Zlatá Idka	6.59	37.20	140	140	3	Kantor—Rybár, 1979
48	G-13	—	granite	Zlatá Idka	4.03	13.17	85	87	2	Bagdasaryan et al., 1977
49	5773 30	—	gabbro-amphibolite	?	0.30	2.65	214	210	3	Cambel et al., 1980
				VEPORIDES						
50	G-23	—	porphyroid	Bacúch	2.16	8.74	101	104	2	Bagdasaryan et al., 1977

Appendix I — 2nd continuation

51	G-24	—	porphyroid	Bacúch	2.34	8.76	94	97	2	Bagdasaryan et al., 1977
52	B-14	—	gneiss	Beňuš	1.77	19.42	262	257	3	Cambel et al., 1980
53	H-12	—	amphibol. gabbro	Beňuš	0.93	3.30	89	91	2	Bagdasaryan et al., 1977
54	G-28	—	amphibol. gabbro	Beňuš	0.935	12.54	316	324	2	Bagdasaryan et al., 1977
55	G-26a	biotite	amphibol. gabbro	Beňuš	4.81	60.90	299	308	2	Bagdasaryan et al., 1977
56	G-26	amphibole	amphibol. gabbro	Beňuš	0.88	19.35	492	507		Bagdasaryan et al., 1977
57	G-63	amphibole	gabbro-amphibolite	Beňuš	0.54	11.54	480	492	2	Cambel et al., 1979
58	A-46	amphibole	gabbro-amphibolite	Brezno--Vagnár	0.23	10.17	882	867	3	Cambel et al., 1980
59	5773/46	—	gabbro-amphibolite	Brezno--Vagnár	0.475	11.73	544	534	3	Cambel et al., 1980
60	G-78	—	microgranite	Budiná	1.26	5.63	111	109	3	Cambel et al., 1980
61	G-108	biotite	leucocratic granite	Budiná--Vígľaš	6.64	24.38	92	90	3	Bagdasaryan (unpub.)
62	A-32	—	amphibolite	Čes. Brezovo	1.62	15.80	235	231	3	Cambel et al., 1980
63	G-41	biotite	granodiorite	Čier. Lehota	7.42	26.53	90	92	2	Bagdasaryan et al., 1977
64	5773/40	—	leptinite	Čier. potok	3.40	11.95	88	86	3	Cambel et al., 1980
65	G-70	biotite	leucogranite	Dobroč	6.42	50.02	190	186	3	Cambel et al., 1980
66	5773/43	—	granite	Dobroč	3.32	15.19	114	112	3	Cambel et al., 1980
67	M-13	muscovite	gran. schist	Hačava	6.18	23.90	97	99	2	Bagdasaryan et al., 1977
68	2	biotite	mica schist gneiss	Hnúšťa	4.44	13.70	78	75	1	Kantor, 1960
69	G-17	—	pegmatite	Hriňová--Kokava	5.25	20.83	99	102	2	Bagdasaryan et al., 1977

Appendix I — 3rd continuation

70	1	K-feldspar	granite	Hrončok	5.81	26.87	115	110	1	Kantor, 1959 c
71	2	biotite	granite	Hrončok	5.768	27.79	120	115	1	Kantor, 1959 c
72	G-35	biotite	granite	Hrončok	6.70	25.64	96	98	2	Cambel et al., 1979
73	G-27	—	aplite	Hrončok	4.55	18.75	103	106	2	Bagdasaryan et al., 1977
74	G-32	biotite	biot. schist	Chorepa	2.48	31.65	302	310	2	Bagdasaryan et al., 1977
75	G-15	—	granite	Ipeľ	3.10	13.33	107	110	2	Bagdasaryan et al., 1977
76	G-21	biotite	paragneiss	Klenovec	6.63	24.35	92	95	2	Bagdasaryan et al., 1977
77	G-19	biotite	paragneiss	Klenovec	7.42	27.26	92	96	2	Bagdasaryan et al., 1977
78	G-16	K-feldspar	hybr. rock	Klenovec--Rozt. road	7.70	28.55	93	96	2	Bagdasaryan et al., 1977
79	G-20	biotite	biot. schist	Kokava	5.67	24.95	110	113	2	Bagdasaryan et al., 1977
80	G-18	biotite + amphibole	biot. chert	Muráň	2.57	5.43	54	54	2	Bagdasaryan et al., 1977
81	G-18	—	biot. chert	Muráň	1.87	4.39	59	61	2	Bagdasaryan et al., 1977
82	3	biotite	mica schist gneiss	Mur. Dlhá Lúka	5.62	18.85	84	80	1	Kantor, 1960
83	G-33	—	lept. gneiss	Mur. Huta	0.363	1.28	89	91	2	Bagdasaryan et al., 1977
84	5	biotite	gran. gneiss	Mur. Zdychava	6.21	27.7	111	107	1	Kantor, 1960
85	A-50	—	amphibolite	Mýtna--Píla road	1.33	8.00	148	145	3	Cambel et al., 1980
86	B-25	biotite	biotite granite	Píla	6.00	25.78	107	105	3	Bagdasaryan, (unpub.)
87	G-105	biotite	biotite granite	Píla	6.17	50.38	199	195	3	Bagdasaryan, (unpub.)
88	B-15	biotite	migmatite	Píla	3.58	13.68	96	94	3	Cambel et al., 1980
89	G-109	biotite	hybr. granite	Píla	6.76	28.29	105	102	3	Bagdasaryan (unpub.)
90	G-112	muscovite	migmatite	Píla	7.97	107.32	317	311	3	Bagdasaryan (unpub.)

Appendix I — 4th continuation

91	M-20	—	diaphtorite	Podtaj-chová	2.51	21.54	208	204	3	Cambel et al., 1980
92	G-77	—	leucogranite	Podtaj-chová	3.58	13.26	93	91	3	Cambel et al., 1980
93	G-115	—	palaeodacite	Polomka	6.25	24.69	99	97	3	Bagdasaryan (unpub.)
94	G-22	biotite	biot. chert	Rimavica	6.35	23.65	93	96	2	Bagdasaryan et al., 1977
95	—	biotite	paragneiss	Rim. Baňa	5.27	23.40	111	106	1	Kantor, 1960
96	A-33	amphibole	amphibolite	Rim. Píla	0.41	2.83	169	166	3	Cambel et al., 1980
97	48	amphibole	granite	Rochovce	0.80	2.616	82	82	3	Kantor—Rybár, 1979
98	47	biotite	granite	Rochovce	9.365	27.89	75	75	3	Kantor—Rybár, 1979
99	44	biotite	granite	Rochovce	6.295	22.03	88	88	3	Kantor—Rybár, 1979
100	G-74	biotite	granite	Rochovce	5.185	16.59	81	79	3	Cambel et al., 1980
101	G-74	—	granite	Rochovce	3.86	10.24	67	66	3	Cambel et al., 1980
102	A-49	—	basic rocks	Rochovce	1.85	5.23	71	70	3	Cambel et al., 1980
103	B-12	—	paragneiss	Rochovce	3.49	28.55	199	195	3	Cambel et al., 1980
104	B-13	—	paragneiss	Rochovce	1.11	3.13	71	70	3	Cambel et al., 1980
105	G-107	biotite	biotite granodiorite	Balog--Sihla	6.34	40.77	158	155	3	Bagdasaryan (unpub.)
106	H-3	chlorite	vein in gra-nodiorite	Sihla--Hriňová	0.064	0.815	301	309	2	Bagdasaryan, et al., 1977
107	G-31	biotite	Sihla grano-diorite	Sihla--Hriňová	7.91	69.58	213	219	2	Bagdasaryan, et al., 1977
108	G-14	—	granodiorite	Sihla-Hron-čok road	5.57	21.20	95	98	2	Bagdasaryan, et al., 1977
109	4	biotite	gran. arcose	Slavošovce	6.64	23.20	88	84	1	Kantor, 1960
110	5773/45	—	mylonitiz. granodiorite	Vojtkovo	3.32	11.85	90	88	3	Cambel et al., 1980
111	G-44	—	granite	Vydrovo	4.36	16.11	93	95	2	Bagdasaryan, et al., 1977
112	M-19	muscovite 2	diaphtorite	Vydrovo	6.65	69.46	251	260	2	Cambel et al., 1979

Appendix I — 5th continuation

113	M-19	muscovite 1	diaphtorite	Vydrovo	6.62	48.67	180	184	2	Cambel et al., 1979
114	M-11	muscovite	musc. schist mylonitiz.	Vydrovo-Čier. Balog	6.35	65.45	247	253	2	Bagdasaryan, et al., 1977
115	5773/42	—	granodiorite	Sihla (?)	1.975	18.65	228	223	3	Cambel et al., 1980
CORE MOUNTAINS										
116	A-15	biotite	diorite	Bratislava	3.13	45.12	337	345	2	Cambel et al., 1979
117	A-25	amphibole	amph. gabbro	Bratislava	0.39	8.16	471	483	2	Cambel et al., 1979
118	A-15	amphibole	diorite	Bratislava	0.93	14.38	359	368	2	Cambel et al., 1979
119	G-29	amphibole	amph. gabbro	Bratislava	0.35	5.46	362	373	2	Bagdasaryan et al., 1977
120	G-14	amphibole	amph. gabbro	Bratislava	0.365	5.61	358	365	2	Bagdasaryan et al., 1977
121	2	K-feldspar	pegmatite	Bratislava	(9.63)	93.1	233	225	1	Kantor, 1959 d
122	1	muscovite	pegmatite	Bratislava	(7.47)	73.27	236	227	1	Kantor, 1959 d
123	G-8	—	pegmatite	Bratislava	3.48	39.13	268	275	2	Bagdasaryan et al., 1977
124	A-12	amphibole	amphibolite	Žel. Studnička	0.22	2.49	270	276	2	Cambel et al., 1979
125	G-50	biotite	gneiss	Žel. Studnička	6.79	90.55	314	322	2	Bagdasaryan et al., 1977
126	G-38	biotite	granodiorite	Žel. Studnička	7.31	94.80	306	314	2	Bagdasaryan et al., 1977
127	G-38	muscovite	granodiorite	Žel. Studnička	8.36	137.15	379	389	2	Bagdasaryan et al., 1977
128	M-5A	clay minerals	mylonite	Žel. Studnička	3.45	17.17	147	150	2	Bagdasaryan et al., 1977
129	M-5B	clay minerals	mylonite	Žel. Studnička	3.03	17.20	140	144	2	Bagdasaryan et al., 1977
130	G-39	biotite	granodiorite	Karlova Ves-Devín	7.26	100.65	325	334	2	Bagdasaryan et al., 1977
131	G-40	biotite	granodiorite	Karlova Ves-Devín	5.78	38.35	163	167	2	Bagdasaryan et al., 1977
132	Ž-2	biotite	granite	Karlova Ves-Devín	6.23	74.51	284	278	3	Cambel et al., 1980
133	G-40	muscovite	granite	Karlova Ves — Devín road	8.50	123.10	339	348	2	Bagdasaryan et al., 1977
134	G-51	biotite	gran. gneiss	Lamač	5.96	81.45	321	330	2	Bagdasaryan et al., 1977

Appendix I — 6th continuation

135	G-47	biotite	granite	Borinka	4.70	53.90	273	281	2	Bagdasaryan et al., 1977
136	G-46	muscovite	granite	Borinka	8.16	104.55	303	311	2	Bagdasaryan et al., 1977
137	G-47	muscovite	granite	Borinka	6.53	89.95	324	331	2	Bagdasaryan et al., 1977
138	M-1	—	ultramylonite	Borinka	3.97	20.55	128	132	2	Bagdasaryan et al., 1977
139	M-2	—	mylonite	Borinka	4.47	24.30	135	138	2	Bagdasaryan et al., 1977
140	M-6	—	mylonite	Borinka	3.58	11.83	83	85	2	Bagdasaryan et al., 1977
141	G-45	biotite	granodiorite	Cymbal	6.47	47.73	180	186	2	Bagdasaryan et al., 1977
142	G-45	muscovite	granodiorite	Cymbal	7.64	109.57	336	345	2	Bagdasaryan et al., 1977
143	G-48	muscovite	granodiorite	Marianka	8.25	132.35	372	382	2	Bagdasaryan et al., 1977
144	G-10A	—	leucogranite	Marianka	4.305	38.57	217	222	2	Bagdasaryan et al., 1977
145	A-4	amphibole	amphibolite	Pernek	0.252	3.12	293	301	2	Bagdasaryan et al., 1977
146	A-1	amphibole	amphibolite	Pernek	0.21	0.943	112	115	2	Bagdasaryan et al., 1977
147	A-3	amphibole	gabbro-amphibolite	Pernek	0.355	4.19	281	288	2	Bagdasaryan et al., 1977
148	A-10	amphibole	gabbro-amphibolite	Pernek	0.14	1.36	234	239	2	Cambel at al., 1979
149	A-2	amphibole	amph. gabbro	Pernek	0.192	2.39	295	303	2	Bagdasaryan et al., 1977
150	A-8	amphibole	mylonitiz. epigabbro	Pernek	0.32	1.44	112	115	2	Bagdasaryan et al., 1977

Appendix I — 7th continuation

151	G-53	biotite	paragneiss	Pernek	5.34	81.15	354	363	2	Bagdasaryan et al., 1977
152	G-49	—	phyllite	Pernek	2.34	25.49	261	267	2	Bagdasaryan et al., 1977
153	B-5	—	phyllite	Záh. Bystrica	2.79	26.10	226	232	2	Bagdasaryan et al., 1977
154	G-54	biotite	granite	Jur	7.60	96.65	301	309	2	Bagdasaryan et al., 1977
155	G-52	biotite	migmatite	Jur	6.82	85.55	297	305	2	Bagdasaryan et al., 1977
156	M-7	—	mylonite	Jur	2.83	17.13	149	152	2	Bagdasaryan et al., 1977
157	G-111	biotite	granodiorite	Jur--Myslenice	7.41	79.29	256	251	3	Bagdasaryan (unpub.)
158	G-111	muscovite	granodiorite	Jur--Myslenice	7.60	106.23	328	321	3	Bagdasaryan (unpub.)
159	G-119	muscovite	pegmatite	Jur--Myslenice	8.17	123.11	351	344	3	Bagdasaryan (unpub.)
160	G-117	—	migmatite	Jur--Myslenice	1.89	25.87	322	315	3	Bagdasaryan (unpub.)
161	G-118	—	migmatite	Jur--Myslenice	2.08	25.00	285	281	3	Bagdasaryan (unpub.)
162	G-120	—	biot. granite	Jur--Myslenice	4.20	52.99	298	293	3	Bagdasaryan (unpub.)
163	G-10	—	leucogranite	Limbach	4.395	26.90	151	155	2	Bagdasaryan et al., 1977
164	H-1	—	vein granite	Pezinok	4.04	31.85	192	198	2	Bagdasaryan et al., 1977
165	H-2	—	albitic rock	Pezinok	1.01	16.55	379	390	2	Bagdasaryan et al., 1977
166	B-1	—	phyllite	Pezinok	1.43	10.51	180	185	2	Bagdasaryan et al., 1977
167	H-19	—	granodiorite	Pezinok	4.60	17.28	94	92	3	Bagdasaryan (unpub.)
168	H-18	—	granodiorite	Pezinok, pyrit. adit	3.90	28.24	177	174	3	Bagdasaryan (unpub.)
169	A-6	amphibole	amphibolite	Augustín	0.265	2.39	218	223	2	Bagdasaryan et al., 1977

Appendix I — 8th continuation

170	A-7	amphibole	amphibolite	Augustín	0.22	2.59	280	281	2	Bagdasaryan et al., 1977
171	G-110	biotite	granodiorite	Cajla borehole KB24/72	7.14	96.44	318	312	3	Bagdasaryan (unpub.)
172	G-113	—	aplite	Cajla borehole 15—16 m	3.80	39.40	249	244	3	Bagdasaryan (unpub.)
173	G-116	—	biot. granite	Cajla borehole 72 m	2.59	34.38	313	307	3	Bagdasaryan (unpub.)
174	G-123	—	biot. granite	Cajla borehole 79—80 m	2.66	28.10	253	249	3	Bagdasaryan (unpub.)
175	G-121	—	porphyroid	Cajla borehole 269 m	3.24	18.45	141	138	3	Bagdasaryan (unpub.)
176	G-122	—	porphyroid	Cajla borehole 269—270 m	3.15	18.41	144	141	3	Bagdasaryan (unpub.)
177	H-17	—	porphyroid	Cajla borehole	2.75	9.00	82	80	3	Bagdasaryan (unpub.)
178	A-43	—	augitite	Petrklín	1.60	6.00	94	92	3	Bagdasaryan (unpub.)
179	G-124	K-feldspar	granite	Modra—Harmónia	11.40	82.79	178	174	3	Bagdasaryan (unpub.)
180	G-9	amphibole	alk. granite	Harmónia	0.43	6.43	349	358	2	Bagdasaryan et al., 1977
181	G-36	biotite	granite	Harmónia	6.83	100.50	344	353	2	Bagdasaryan et al., 1977
182	M-3	—	mylonite	Harmónia	3.11	20.38	161	166	2	Bagdasaryan et al., 1977

Appendix I — 9th continuation

183	M-4	—	mylonite	Harmónia	3.29	13.90	106	108	2	Bagdasaryan et al., 1977
184	G-2	—	aplite	Harmónia	3.85	36.10	226	232	2	Bagdasaryan et al., 1977
185	G-3	—	alk. granite	Harmónia	4.18	23.35	138	142	2	Bagdasaryan et al., 1977
186	G-4	—	granodiorite	Harmónia	7.03	53.25	185	190	2	Bagdasaryan et al., 1977
187	G-7	—	microgranite	Harmónia	3.10	19.90	158	162	2	Bagdasaryan et al., 1977
188	G-7A	—	vein granite	Harmónia	3.46	34.85	242	248	2	Bagdasaryan et al., 1977
189	B-3	—	schist	Častá	1.43	12.93	219	225	2	Bagdasaryan et al., 1977
190	B-6	—	schist	Častá	1.73	22.30	304	313	2	Bagdasaryan et al., 1977
191	G-6	—	acid meta-volcanites	Častá	1.865	26.60	334	342	2	Bagdasaryan et al., 1977
192	B-7	—	schist	Doľany	3.11	27.60	215	221	2	Bagdasaryan et al., 1977
193	G-72	—	granodiorite	Ťahanovce	1.66	13.03	191	188	3	Cambel et al., 1980
194	G-68	muscovite	pegm. granite	V. Matej-kova	8.55	120.13	329	323	3	Cambel et al., 1980
			HIGH TATRA							
195	2	biotite	granodiorite	Batizovská valley	4.814	46.73	234	226	1	Kantor, 1959 b
196	G-69	muscovite	pegmatite	Gordičko-va valley	8.43	120.97	336	328	3	Cambel et al., 1980
197	—	—	green schist	Chocho-lovská valley	3.33	(22)	161	165	2	Sedletsky et. al., 1965
198	—	biotite	gneiss	Chocho-lovská valley	6.74	(81)	284	300?	2	Sedletsky et. al., 1965
199	1	biotite	paragneiss	Jamnická valley	3.584	40.86	272	264	1	Kantor, 1959 b
200	—	amphibole	amphibolite	Kasprový hill	0.51	9	413	425	2	Sedletsky et. al., 1965

Appendix I — 10th continuation

No.	Orig. No.	Mineral	Rock	Locality	K (%)	$^{40}Ar^*$ cc/g . 10^{-6}	Model age		Constants	Literary reference
							new	orig.		
201	—	biotite muscovite	grey granite	Morské Oko	5.50	83	350	360	2	Sedletsky et al., 1965
202	G-37	biotite	granodiorite	Starý Smokovec	4.35	62.12	334	343	3	Bagdasaryan et al., 1977
203	G-76	muscovite	granodiorite	Tichá valley	8.56	120.34	330	324	3	Cambel et al., 1980
204	G-76	—	granodiorite	Tichá valley	2.44	21.43	213	208	3	Cambel et al., 1980
205	5773/34	—	granodiorite	Tichá valley HT	1.25	13.18	253	248	3	Cambel et al., 1980
206	5773/35	—	granodiorite	Tichá valley	4.69	31.31	164	161	3	Cambel et al., 1980
207	A-26	amphibole	amphibolite	Žiarska valley	0.355	8.13	510	522	2	Cambel et al., 1979
				LOW TATRA						
208	7	biotite	Ďumbier granite	Nižná Boca	4.23	56.86	316	305	1	Kantor, 1959 a
209	5	biotite	Ďumbier granite	Stredná Boca	5.32	67.60	300	290	1	Kantor, 1959 a
210	6	biotite	Ďumbier granite	Stredná Boca	5.32	69.80	300	300 321	1, 2	Kantor, 1959 a
211	4	K-feldspar	pegmatite	Stredná Boca	5.81	68.35	280	270	1	Kantor, 1959 a
212	9	muscovite	pegmatite	Vyšná Boca	7.44	108.5	341	330	1	Kantor, 1959 a
213	—	biotite	granite	Dol. Studenec	7.413	(88.82)	285	296	2	Kantor, 1964
214	G-104	biotite	granodiorite	Dúbrava	6.18	83.63	318	312	3	Bagdasaryan (unpub.)
215	2	biotite	Prašivá granite	Križianka	5.88	74.27	299	288	1	Kantor, 1959 a

Appendix I — 11th continuation

216	3	biotite	Prašivá granite	Križianka	6.05	82.30	320	330	1	Kantor, 1959 a
217	1	K-feldspar	Prašivá granite	Križianka	9.753	119.3	290	280	1	Kantor, 1959 a
218	A-31	amphibole	gabbro-amphibolite	Malužiná	0.22	7.19	690	677	3	Cambel et al., 1980
219	G-106	biotite	granodiorite	Prašivá	7.40	76.06	247	242	3	Bagdasaryan (unpub.)
220	8	muscovite	musc. granite	Trangoška	8.12	131.6	375	360	1	Kantor, 1959 a

Note: Data given in parentheses are recalculated by the authors of the paper on the basis of original published data.

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