JÁN KRÁĽ*

FISSION TRACK AGES OF APATITES FROM SOME GRANITOID ROCKS IN WEST CARPATHIANS

(Fig. 1)

Abstract: Fission track ages were determined in 13 samples of apatite from granitoid rocks of some core mountains and the veporic crystalline. In the core mountains, the ages determined in this way range from 10±2 mil. y. to 52±9 mil. y., in the veporic crystalline, they vary from 53±7 mil. y. to 89±10 mil. y. The ages are interpreted as the ages of an uplift of the massif, differences in ages represent different uplift ages.

Резюме: Возрасты по трекам определялись в 13 пробах апатита из гранитоидных пород ядерных массивов и вепоридного кристаллического комплекса. Полученные возрасты в ядерных массивах колеблются в пределах от 10 ± 2 млн. лет по 52 ± 9 млн. лет; в вепоридном кристаллическом комплексе — от 53 ± 7 млн. лет по 89 ± 10 млн. лет. Возрасты интерпретируются в качестве возрастов надвига, различия в возрастах объясняются как разные возрасты надвигов.

Introduction

The applicability of apatites to fission track dating has already been pointed out by several authors. The ages acquired were either identic with K/Ar or Rb/Sr determinations, or lower. If apatite ages are concordant with the results of other radiometric age determinations, they can be interpreted as the rock's age of crystallization. This kind of determinations is frequent in apatites from younger volcanic rocks. On the other hand, apatite ages from plutonic rocks are very often found to be lower. This lowering caused by instability of fossil fission tracks in the course of geologic history is, almost exclusively, an effect of temperature. In apatites, the reduction of the original density occurs at relatively low temperatures. According to various authors (R. L. Fleischer et al. 1975), a 50 % loss of fission tracks takes place during one hour at the temperature of 322—336 °C. This apparent weakness of the method can be, however, easily turned into its advantage. Annealing experiments have shown that lower apatite ages can be interpreted as ages of the cooling caused by an uplift of the massif (G. A. Wagner 1968, G. A. Wagner — G. M. Reimer 1972). This model enables to date young tectonic processes and is also applicable to the Tatra's crystalline core rocks. Fission track ages in apatites from the West and High Tatras (J. Burchart 1972) vary from 10 to 23 mil. y. The author explains these ages by a post-orogenic uplift and unroofing to the massif during the Miocene era.

* RNDr. J. Kráľ, Geological Institute of the Slovak Academy of Sciences, Dúbravská cesta, 886 25 Bratislava.

Geology of the area

In the West Carpathian crystalline, granitoid rocks are most frequent in the core massifs of the Inner Carpathians (tatric unit) and in the Slovak Ore Mountains (veporic and gemeric unit). In the Gemerides, granitoid rock occurence is only second-rate. Samples for this study were selected from granitoid rocks of the core mountains and the Veporides (fig. 1).

In the granitoid massifs of both tectonic units, biotitic granodiorite with more acidic or basic varieties is most abundant. K/Ar ages of biotites in the granodiorite from the Lower Tatras were determined by J. Kantor (1959) in the range from 305 to 270 mil. y. K/Ar determinations in biotite of the granodiorite from the High Tatras yielded results ranging from 270 to 226 mil. y. (J. Kantor 1959b, 1960). Ages of granitoid rocks of the Polish side of the High Tatras were determined by means of the Rb/Sr method in the range from 315 to 290 mil. y. (J. Burchart 1968). Although both the veporic and tatric crystalline are considered one genetical whole (J. Kamenický in M. Maheľ 1963), their K/Ar determinations are discordant. An overwhelming majority of samples of schists and granitoid rocks from the veporic crystalline was determined by the K/Ar method in the range from 110 to 90 mil. y. (J. Kantor 1960, B. Cambel et al. 1977). Out of the samples used in this work, K/Ar determinations were carried through only in the following specimens: the granite from Hrončok by J. Kantor (1959a): 110 mil. y. –

Fig. 1. General map of the West Carpathian crystalline. Simplified according to M. Maheľ (1963 in M. Maheľ et al. 1967). Core mountains: I — Malé Karpaty Mts., II — Považský Inovec Mts., III — Suchý and Malá Magura Mts., IV — Žiar Mts., V — Tribeč Mts., VI — Malá Fatra Mts., VII — Veľká Fatra Mts., VIII — Tatra Mts., IX — Lower Tatras, X — Branisko and Čierna Hora Mts. Unmarked crystalline South from the Lower Tatras is Veporides. 1 — Cretaceous intrusions of gemeridic granites and the granite from Hrončok (Veporides). 2 — intrusions of paleozoic granitoid rocks, 3 — crystalline schists.

Explanations: p_s — fossil tracks density (cm^2), p_i — induced tracks density (cm^2). Samples were irradiated by thermal neutron flux of $3{,}99 \times 10^{15}$ n. cm^{-2}.

Localization of samples:

Core mountains:

20 — biotitic granodiorite, road to Smrekovica, Veľká Fatra Mts.

22 — granodiorite, porphyric type, road to the Roháče Mts., 500 m from the parking-site, High Tatras.

23 — metasomatic porphyric granite, big parking-site below the Roháče Mts., High Tatras.

24 — Prašivá type granite, leucocratic facies, road Sopotnica — Hronov, ending of the valley, Lower Tatras.

25 — Prašivá type of granite, new road Sopotnica — Hronov, Lower Tatras.

38 — granodiorite, uppermost floor, Dubná skala quarry, Malá Fatra Mts.

40 — granodiorite biotitic, fine-grained, road below the Roháče Mts., 1500 m.

47 — biotitic granodiorite, Mt. Hrebienok, cliff near the parking-site, High Tatras.

Veporides:

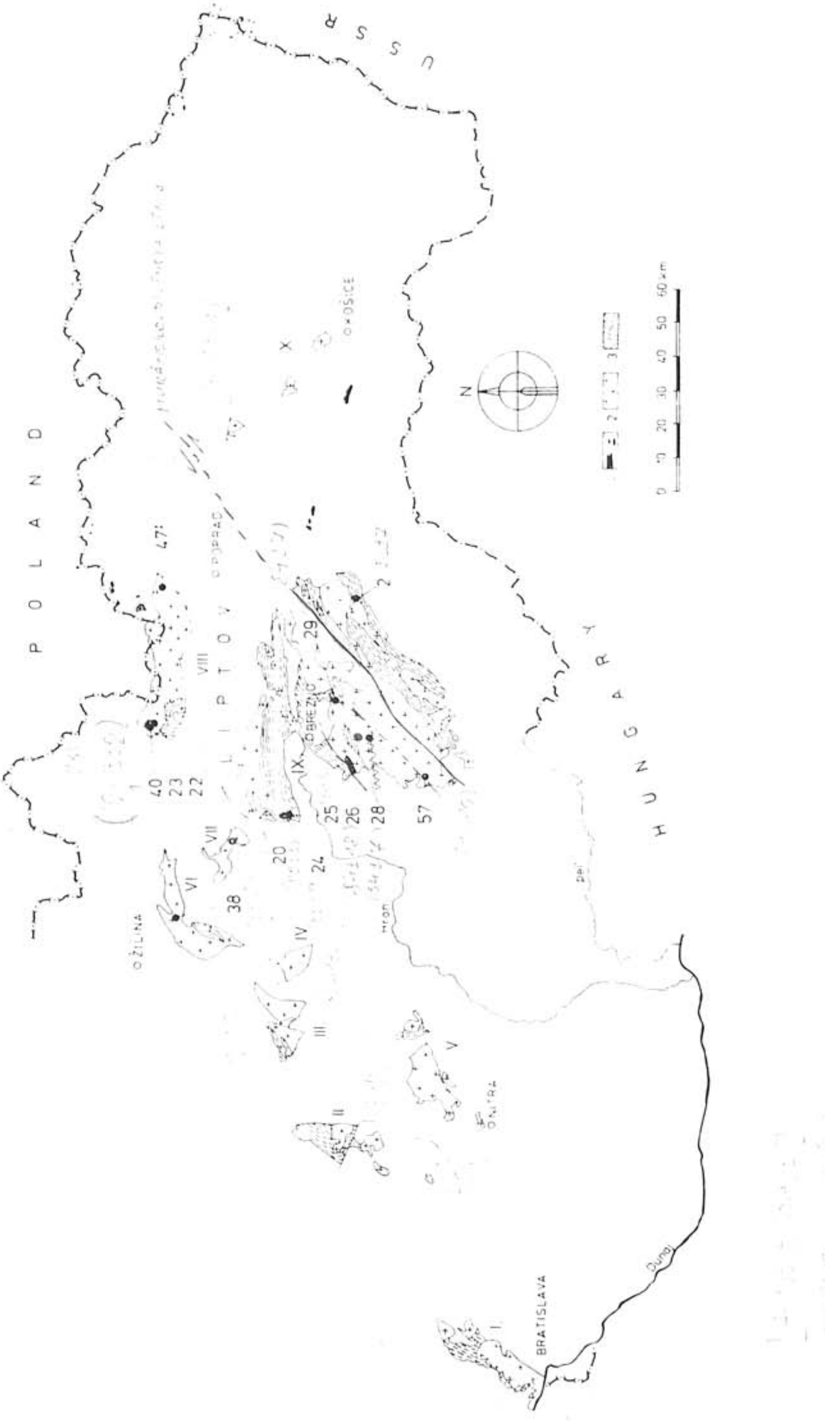
2 — granit, Chyžné, Hladomorná valley, Kohút zone.

26 — Hrončok type granite, Hrončok, ending of the asphalt road.

28 — granodiorite „Sihla", road Čierny Balog — Hriňová.

29 — hybridic granodiorite, Dobroč, Páleníčnô valley.

57 — hybridic granodiorite, Podkriváň, rock exposure near the road.


P O L A N D
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ŽILINA
NITRA
KOŠICE
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BRATISLAVA
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2
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0 10 20 30 40 50 60 km

K-feldspar; 115 mil. y. — biotite; and the granodiorite from Sihla by B. Cambel et al. (1977) — 190 mil. y. — whole rock; 219 mil. y. — biotite.

After a granodiorite intrusion, the whole crystalline complex had been uplifted and later deeply denuded as far as the granodiorite level. This is proved by the transgressive position of the lower Mesozoic directly on the granodiorite; further, by the conglomerate from Meďodoly as well as by discoveries of metamorphosed and granitoid rocks in Carboniferous and Upper Permian pebbles Gradual sinking took place later in the Lower Triassic era (M. Maheľ — A. Matejka in M. Maheľ et al. 1967).

Inspite of many common features, the ensuing tectonic development of the core mountains and the veporic crystalline was different. Alpine orogeny resulted in breaking a part of the crystalline into separate units — core mountains — which, in the form of individual horsts, have formed the present relief. In contrast to this, veporic crystalline ascends to the surface as a compact whole.

Method

The apatite grain concentrate (200—300 from each sample) was divided into two halves. In one half, determined for counting induced tracks, spontaneous tracks were removed by annealing (for 6 hours at 550 °C). Then the samples were irradiated by thermal neutrons in the IBJ reactor in Świerk (Poland). Along with the samples, uranium glass standard which served for the calculation of an integral dose of thermal neutrons, was irradiated. Both spontaneous and induced tracks were counted in individual grains under identic conditions without immersion, enlarged 625 times. Tracks were then etched in a 1 % HNO_3 solution at 20 °C temperature for 4—5 minutes (J. Burchart 1972).

For the calculation of age and uranium concentration, G. A. Wagner's formulas (1969) were used. Fission track ages were calculated with the value of the fission constant of ^{238}U λ_f $6{,}85 \cdot 10^{-17} \cdot r^{-1}$ (R. L. Fleischer — P. B. Price 1964). Uranium concentration value in individual grains does not include uranium contents from inclusions in minerals abundant in uranium (mostly zircons). Since great differences were discovered in uranium contents of the particular grains, t-statistics by Student (G. S. Koch — R. F. Link 1970) at 95 % confidence level was used for the calculation of the confidence interval for the mean.

Results and discussion

Dating results are presented in Tab. 1. Uranium contents in apatites vary from 15 to 34 ppm. Probability plot of the number of fission tracks in an unit area is constructed in a way allowing to accept the assumption of normal distribution of concentrations.

Fission track ages of apatites are different in the core mountains and the Veporides. In the core mountains, the highest ages were found in the samples from the Lower Tatras (No. 24, 25) average age being 45 mil. y., Eocene. Ages determined in samples from the core mountains range from 10 to 24 mil. y. — average 16 mil. y., Miocene. Ages of apatite from the veporic crystalline are higher, average from 5 datings being 73 mil. y.

From the well-known annealing characteristics of fission tracks in apatite it follows that, in the course of rock cooling, the process of fossil track formation passes through 3 stages:

a) interval of high temperatures not allowing any fossil track to survive;
b) partial fossil tracks stability interval;
c) fossil tracks stability interval.

As proved by G. A. Wagner – G. M. Reimer (1972), the temperature at which fission tracks gain stabiliyt in the range from 0 to 100 %, depends on the cooling rate. For cooling rate $1^0/10^5$ yr, $50^0/_0$ of fission tracks are stable at about 125 °, for 10^0/yr at about 215 °C.

The above mentioned 3 stages of fossil track formation show that fission track ages represent the time of passing through the temperature threshold above which the fission tracks are stable. In the territory of the West Carpathians, such rock's passing into the field of fission track thermal stability can be interpreted as an uplift. Different apatite ages determined in the core mountains and the Veporides are thus indicators of different tectonic history. Samples from the veporic crystalline passed this boundary at the end of the Cretaceous era; samples from the Lower Tatra crystalline, during the Eocene; samples from other core mountains, in the Miocene.

This, however, is not the only plausible explanation of higher ages in the examined samples. Ages determined in samples from the veporic crystalline might as well be „mixed ages" caused by the presence of older fossil tracks which had already existed before the uplift. This theory is challenged by the following:

1. Small differences between the K/Ar method results in biotites and whole rocks and the results shown in Tab. 1. Data by J. Kantor (1960) have given an average age of 94 mil. y., i. e. actually the same as the new results by B. Cambel et al. (1977). The difference between fission track datings and the K/Ar ages – approximately 20 mil. y. – presents probably the cooling rate from „blocking temperature" of the K-Ar system in biotite up to the „effective closing temperature" (term introduced by U. K. Haack 1976) of fission tracks in apatite.

2. Well-known paleogeographic data from the West Carpathian region. Transport directions of Middle Priabonian strata exposures in the river Hron valley are SE to NW and W (R. Marschalko 1968) and that is why the author places the presupposed continent into the area of the present Veporides.

Results from the Lower Tatras are not likely to be „mixed ages" either. R. Marschalko – M. Vaňová (1963) and D. Andrusov – E. Köhler (1963) presume the existence of the „Liptov island" in the neighbourhood of the present Lower Tatras. E. Köhler (1975) pointed out certain divergences in large foraminifera assemblages between the upper stream of the river Hron and the Liptov region indicating the existence of a barrier – a continent. P. Gross (1971) discovered in the Paleogene of the Liptov region sediments of submarine alluvial cones created by the activity of a river that had flown from the South northwards into the Paleogene sea. All the above mentioned data as well as dating results hint at the possibility of the Lower Tatras being the oldest of all investigated core mountains.

Table 1

Results of fission track dating of granitoid rocks from the West Carpathians

	No.	ρ_s (cm^{-2})	ρ_i (cm^{-2})	Age (m . y)	U_{ppm}
Core mountains	20	1,07 . 10^5	1,13 . 10^6	22 ± 3	21
	22	4,71 . 10^4	8,06 . 10^5	15 ± 2	15
	23	4,41 . 10^4	1,06 . 10^6	10 ± 2	20
	24	3,89 . 10^5	1,83 . 10^6	52 ± 9	34
	25	1,55 . 10^5	1,02 . 10^6	37 ± 5	19
	38	1,03 . 10^5	9,90 . 10^5	25 ± 18	18
	40	8,36 . 10^4	1,31 . 10^6	15 ± 2	24
	47	3,74 . 10^4	8,33 . 10^5	10 ± 2	15
Veporic unit	2	3,60 . 10^5	1,68 . 10^6	53 ± 7	31
	26	4,81 . 10^5	1,40 . 10^6	84 ± 18	26
	28	2,54 . 10^5	1,15 . 10^6	54 ± 7	21
	29	4,98 . 10^5	1,47 . 10^6	84 ± 7	27
	57	5,47 . 10^5	1,52 . 10^6	89 ± 10	28

Explanations to Tab. 1 — see p. 270 (Fig. 1).

It is necessary to remark, however, that the above mentioned interpretations must as yet be considered preliminary with regard to the small number of samples from the particular massifs. Tectonic interpretations can be so far applied only to the examined samples and thus do not allow generalization for the whole massifs.

Conclusion

Fission track ages in apatites in 13 samples of granitoid rocks from the West Carpathians vary from 10 ± 2 to 89 ± 2 mil. y. These results are interpreted as ages of the massifs' uplifts. The uplift age of samples from the veporic crystalline is probable Upper Cretaceous (average 73 mil. y.), uplift age of samples from the core mountains 16 mil. y. (Miocene) or 45 mil. y. (samples from the Lower Tatras, Eocene).

Results of preliminary datings confirm the possibility of dating tectonic processes in the West Carpathians by means of fission tracks in apatites. These data may be of great use for paleogeographic reconstructions in those regions, where the application of other methods is restricted.

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