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FISSION TRACK DATING OF TUFFACEOUS EOCENE FORMATIONS OF THE NORTH BAKONY MOUNTAINS (TRANSDANUBIA, HUNGARY)

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Fission track dating was performed in accessory minerals of strongly altered, clay mineralized tuffite strata lying in the upper part of the Eocene sequence of the North Bakony Mountains. The homogeneity of the fission track (FT) ages measured on apatite and zircon refers only to insignificant redeposition, no remarkable mingling of the detrital matter could be stated. The average of the FT-ages falls to the Bartonian, into the time interval determined by nannoplankton guide horizons for the volcanic activity (41.9 ± 4.1 Ma). As to their biostratigraphic ages the Middle Eocene samples show an FT-average of 44.2 ± 3.4 Ma, the average of the Upper Eocene group is 39.9 ± 4.1 Ma. The difference between the two groups refers to the two phases of the volcanic activity. The first maximum of volcanism generated the Upper Lutetian to Bartonian glauconitic sequence while the second maximum at the Bartonian - Priabonian boundary produced the tuff strata. The strata in the neighbouring areas relate to continuous volcanism in the Upper Eocene, in the studied area, however, the upper part of the Priabonian was eroded.

Keywords: Eocene, volcanism, geochronology, fission track dating, Bakony Mts , Hungary.

Introduction

The Eocene sequences of Hungary contain tuff intercalations of remarkable quantities but only a few geochronological determinations have been carried out in these formations so far. The main reason of this phenomenon is the fact that the volcanogenic minerals suitable to isotope geochronological studied (first of all biotite and amphibole) are strongly altered, often the tuff horizons are clay mineralized and transformed into bentonite strata. This is why the dating by FT method has been carried out on the accessory minerals that did not undergo the clay mineralogical de-

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composition. By means of this method the translucent uraniferous minerals can be studied. In the calc-alkali volcanics of andesitic composition the apatite and zircon are suitable for this purpose.

Measurements were carried out on Eocene tuffaceous or tuff trace bearing rocks deriving from the North Bakony Mountains from boreholes. As a result of the archipelago-like paleogeography of the Middle Eocene of the region tuffaceous intercalations are found in several heteropic formations (Kopek, 1980). The petrographic composition of the studied samples varied from the volcanogenic crystal tuff and bentonite to the pure biogenic limestone containing only a few glauconite grains. It could be stated that in the samples containing only small quantity of glauconite and a few grains of volcanic origin, the minerals zircon, apatite and ilmenite were found in large amounts. These minerals were preserved and indicate the Eocene tuff dusting the material of which decomposed and homogenized in the high energy shallow marine environment.

Investigations aimed at gaining new geochronological data for this formations that have important role in the strata of the Bakony Mountains. When determining the FT ages of certain accessory mineral grains the measure of mingling of the tuffaceous and of the terrigeneous material can be estimated. An attempt was made to state whether this method would be suitable to distinguish between the strata of the volcanism of a relatively narrow period (Upper Lutetian - Priabonian) and whether the fission track method is suitable to refine the stratigraphic classification of a region divided extremely well by plankton stratigraphy.

Extension and petrography of the tuffaceous Eocene strata of the Bakony Mountains

In the Carpathian Basin the Bakony Mountains forms a strip of NE-SW direction (Fig. 1). The mostly shallow water marine Eocene formations lie in the syncline developed after the longitudinal axis of the strip. The pyroclastic-bearing formations can be traced in the total length of the explored strip from the Zala Basin to Recsk belonging to the Bükk unit. Volcanic centres are known from the Zala Basin, from the Velence Hills and from Recsk. The tephrae described from boreholes in the Sári environs close to the explosion centre (Csiky, 1963; Juhász, 1964a, 1964b, 1971; Balázs et al., 1969; Sztrákos, 1975) are of problematic Paleogene age.

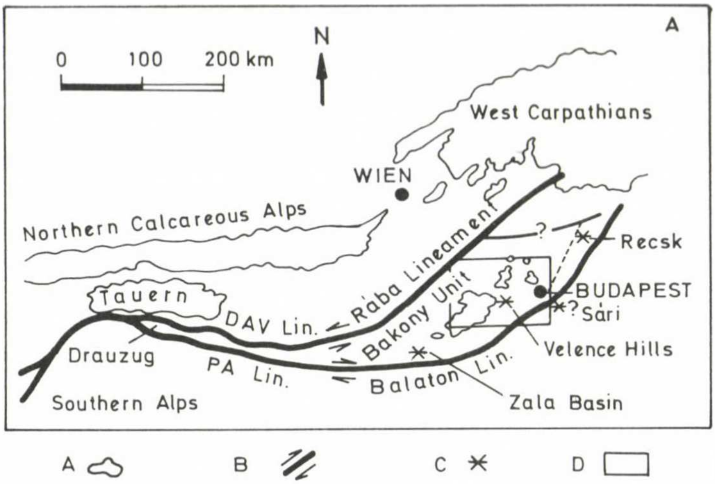

Fig. 1. Tectonic setting of the Bakony unit in the Alpine-Carpathian region (after Kázmér, 1984 and Balla, 1988). A - surface extension of the Paleo-Mesozoic of some characteristic formation groups; B - fault lines characterized by horizontal displacement; C - Paleogene volcanic centres; D - position of the studied area; PA Lin. - Periadriatic Lineament; DAV Lin. - Defereggental-Anterselva-Valles Lineament

Concerning the structural relationships of volcanism Szalai (1937) stated that the Paleogene volcanic centres lie in one strip that is parallel to the main strike direction of the Bakony Mountains. According to Wein (1969) the Balaton line constituting the southern border of the Bakony unit is the continuation of the Periadriatic line. Szepesházy (1977) found relationship between the Hungarian Paleogene volcanites explored in the northeastern continuation of the tonalite strip and the tonalite formations of the Southern Alps. Based on facies data and tectonic considerations Balla (1981) assigned a southeastward dipping subduction plane to the subduction proceeding during the Middle to Upper Eocene. According to Csillag et al. (1983) the volcanism is of island arc character and as against Balla's opinion they believed the Periadriatic oceanic plate to be subducted from the southeast. To relate the Paleogene calc-alkali volcanites to the subduction of the Alpine ocean is in harmony with the observations in the Alps since in the flysch formations of the Western Alps and of the Helveticum the matter of andesitic volcanism is present in form of detritus from the Maastrichtian to the Oligocene (Homewood, 1983).

As to Kázmér (1984) the Bakony unit got its recent position in the Eocene-Oligocene by squeezing out from the Southern and Eastern Alps. It is in harmony with this picture that the Paleogene volcanic strip is situated close to a fault line, that it is of andesitic chemical composition and that close to its recent position other formations referring to subduction are lacking.

The volcanic centres are characterized by large sized stratovolcanic structures the thickness of which may be as high as 700 m in the Zala Basin (Dubay, 1962; Kőháti, 1965; Balázs et al., 1969, 1981; Mészáros, 1970; Ravasz, 1980; Kőrössy, 1988). In the Velence Hills intrusions and peculiar metasomatites formed from stratovolcanic sequences are known (Darida-Tichy, 1987, 1988). In the Recsk structure porphyry copper deposit and polymetasomatic ore mineralization are also known (Földessy, 1975, 1984). The rocks are mostly of andesitic composition and are strongly altered. Amphibole and biotite, subordinately pyroxene are the mafic constituents.

The provenance of the tuff and tuffite strata that deposited farther of the explosion centres is not always unambiguous. When studying the tuffs and tuff-bearing rocks only the partly decomposed mafic silicates can be used due to the strong alteration. Having studied the tuff horizons interbedded in the Eocene sequences of the Bakony Mountains Széky-Fux and Barabás (1953) recognized the areal separation of each type. Based on the extension of the rocks they believed the amphibole-bearing tuff to come from the Velence Hills, the biotite-bearing tuff to come from the Budapest environs or from norther lying areas, respectively. Nevertheless, Gidai (1971) believed that volcanic activity north of the Buda Hills is improbable. As to the micromineralogical studies of Örkényi-Bondor (1971) the tuff materials of the small basins of the Bakony Mountains lying close to each other (Mór, Balinka, Dudar, Halimba Basins) differ from each other. The glauconitic formations contain almost in all cases volcanogenic material, the glauconite formation proceeds often from biotite, volcanic glass or volcanic rock grains.

According to the formation division for the Eocene of the Bakony Mountains (Dudich, 1977) the Halimba and Csernye Formations contain the pyroclastics. The Halimba Formation has been later called Padrag Formation (Nagymarosy and Báldi-Beke, 1988). It is characterized by the predominance of magmatogenic heavy minerals over the metamoprhic ones in all strata. The proportions of biotite and amphibole varies in the profiles, amphibole is usually more frequent. Their total quantity may be as high as 100% of the heavy mineral content. Concerning the variability of pyroclastic compositions in the Eocene sediments of the Bakony Mountains, Dudich (1979), Dudich and Kopek (1980) as well as Dudich and Gidai (1980) stated: "These are dacitic in the southwest with more volcanic glass, amphibole predominates as mafic silicate. In the east these are andesitic with alternating amphibole-biotite, the proportion of biotite increases upward."

The provenance of the tuff formations of different composition can be traced with difficulties since several fault lines associated with remarkable horizontal displacement are known in the Bakony Mountains and especially the region of the Velence Hills is of complicated structure, the tectonic lines being covered by young sediments.

Chronological problems of Eocene volcanism in the Bakony Mountains

The Eocene sedimentation started in the Bakony Mountains with the Lower Lutetian transgression. The oldest sediments of the marine inundation from the southeast (Dudich and Kopek, 1980) fall into the nannoplankton zone NP-14. In the studied area the start of sedimentation can be fixed in the Upper Lutetian (NP-16 zone, Báldi-Beke, 1984). In the father, northeastern continuation of the strip (Recsk) only Priabonian sediments are known (Zelenka, 1975).

In the Bakony Mountains, in the Lower Lutetian the micromineralogical analyses determined igneous (volcanic) minerals of subordinate quantities as compared to the metamorphic ones. The uppermost part of the Lutetian sequence is characterized by high glauconite content and the volcanogenic grains are also present and become more abundant upwards in forms of heavy minerals (Sárközi-Farkas, 1964; Radócz-Komáromi, 1971). The tuff strata are found in the Uppermost Lutetian and Priabonian sediments.

The rejuvenation of volcanism presumed to follow from the southwest to the northeast (Csillag et al., 1983) seems to be less founded since in the Zala Basin there are no Lower Eocene formations and the duration of the volcanic activity in the Velence Hills and at Recsk is hardly known. It can be only stated that the maximal intensity of volcanism fell to the Upper Eocene, the pyroclastic production was more considerable than in the Late Lutetian.

Based on the nannoplankton and magnetostratigraphic data the volcanic activity recorded in the sediments of the Bakony Mountains was characteristic of the Bartonian between 43 and 40 Ma (Báldi-Beke, 1990). When taking also the whole Priabonian, the Eocene volcanic phase lasted for about 6 to

7 Ma, if accepting the 36.6 Ma value published by Berggren et al. (1985) to the Eocene/Oligocene boundary.

It is to be noted here that concerning the Bartonian there is no uniform concept in Hungary. Most of the micromineralogical and stratigraphic works cited in this work takes the s.l. Lutetian as Middle Eocene, only the researchers dealing with plankton stratigraphy started to apply the internationally accepted Bartonian to the upper part of the Middle Eocene in the Hungarian stratigraphic classification. The historic review of the so-called Bartonian problem together with the details is found in the work of Báldi-Beke et al. (1990). Since the chronostratigraphic scales published on a world scale contain the Bartonian, it will be referred to when interpreting the radiometric data.

Summing up the former geochronological studies it can be stated that 1) only a few radiometric measurements were made from the tuff strata; 2) the rocks of the volcanic centres show for the most part the age of subsequent effects.

1) Only one radiometric result was published so far from the Hungarian stratigraphically proved Eocene tuffs. Balogh (1985) determined a biotite K/Ar age of 31.7 $\pm$ 0.8 Ma in the tuff horizons lying in the Buda Marl and explored by the Alcsútdoboz-3 borehole. Author is doubtful concerning the meaning of this age, the result being much more younger than the geological age reflects probably subsequent effects.

Bagdasarjan (lecture, 1989) measured 42.3 Ma in the whole rock sample of the Upper Eocene tuff of the Urhida-1 borehole.

2) The K/Ar data measured in the Paleogene volcanic formations of the Velence Hills fall for the most part between 30 and 38 Ma (measurements of Balogh K. in: Darida-Tichy, 1988). He obtained 42.5 Ma, i.e. older than Upper Eocene only in one biotite sample. Bagdasarjan (lecture, 1989) measured 34 to 35.6 Ma in whole rock samples of lava banks of the stratovolcanic sequence. The apatite fission track ages measured in andesites fall between 30 and 36 Ma, the zircon ages vary around 36 Ma (Dunkl, 1990).

It can be stated that in the formations available from recent exposures of the volcanic centres:

- either the age of the last volcanic events
- or the rejuvenated ages due to the hydrothermal activity lasting also during the Oligocene can be measured.

Methods

The accessory minerals were enriched from rock samples of 1.5 to 2.0 kg by crushing, sieving, panning, heavy liquid separation and magnetic separation. The apatite and circon crystals were picked up by needle from the concentrate, the former was embedded in epoxi resin, the latter in FEP-teflon. The spontaneous fission tracks of the minerals were etched after slow, careful polishing. In case of apatite nitric acid of 1% was used with 2.5 to 4 min etching time (Burchart, 1972). In case of zircon crystals the eutectic melt of NaOH-KOH-LiOH was used at somewhat lower temperature (190 ^{o}C) than suggested by the prescriptions of Zaun and Wagner (1985). Etching was carried out for different durations in each preparate (41 to 85 hours), the duration was determined by the optimal etching state of fission tracks and by means of the widening of polishing cracks. Neutron irradiation was made at the Technical University of Budapest and in the reactor of Řež (close to Praha, Czechoslovakia). The neutron fluence was determined by the NBS SRM 962a uranium glass standard. The external detector method was used (Gleadow, 1981), a mica external detector was put onto the preparates and the standard and after irradiation the induced fission tracks were etched by HF during 40 to 60 min. Counting of spontaneous tracks was made in oil immersion under Zeiss NU 2 microscope, with a magnification of 1600, in case of mica detectors dry optics of 800-time magnification were used. Only the crystals embedded parallel with the c-axis, polished down to 20 microns at least and free of dislocations and near-surface inclusions were considered. Conforming to the number of suitable crystals and to the spontaneous track density, respectively, we tried to count 30 grains in each preparate or 1000 tracks, respectively. To compensate the different track registration geometry ($2\pi/4\pi$) between the external detector and the dated minerals, the geometry factor of 0.5 determined by Gleadow and Lovering (1977) was applied.

The homogeneity of ages measured in each crystal was tested by the Chi-square method (Green, 1981). Track density data measured in the crystals were plotted in the Ps/Pi coordinate system (Burchart, 1981). When the measurement results fitted well on the isochron line and extreme values occurred, this was controlled by the Grubbs and Dixon tests (Réthái, 1985). If the crystal displaying extreme age belong to the main population with a probability of less than 5%, the doubtful result was omitted in the subsequent calculations. If in the Ps/Pi diagram the group of measurement results was diffuse (first of all due to low number of spontaneous tracks in the crystals) the elimination of the extreme data pairs was not used.

The age was calculated on the basis of the weighted average of the measured track density proportions, by the zeta-method (Hurford and Green, 1983). The limits or error are given by the classical procedure, i.e. by the double Poisson dispersion (Green, 1981).

Results

Samples derived from the North Bakony Mountains except that of Somló-vásárhely. The aim was to select boreholes investigated thoroughly by bio-stratigraphic and other methods. The detailed description and biostrati-graphic processing of some sequences from which the samples studied by the FT method are found in the works of Bálid-Beke (1984), Kókay (1961), Hor-váth-Kollányi (1983), Bernhardt et al. (1988).

The areal distribution of the studied profiles is demonstrated in Fig. 2. The depth intervals of the dated samples as well as the rock ma-terial are found in Table I together with the measurement results. The last column of the Table refers to the stratigraphic position that is based on the publications above and on the oral communications of Báldi-Beke, M. and Bernhardt, B. It is to be noted that the major part of the samples derive from the proximity of the Middle/Upper Eocene boundary.

The ages measured in the crystals of each sample are uniform in each preparate and lie within the range of statistical uncertainty. The mingling of accessory populations of different ages could not be demonstrated, thus the rounded, fractured glauconite grains described Csernák and Dudich (1968) refer only to an infra-Eocene insignificant redeposition and erosion.

The FT results fall between 48 and 32 Ma which according to the scale of Berggren et al. (1985) include the time interval from the Lower Lutetian to the Lower Oligocene (Table I). This duration is longer than that of the formation of the tuffaceous sequence. When taking the samples of the profiles divided by plankton- and magneto-stratigraphy (Somlóvásárhely, Bakonyszentkirály) it is found that differences exceeding the duration of the biostratigraphic units can also be observed. Thus, the individual evaluation of the data and the refinement of the stratigraphic division have to be neglected even in this area being faunistically well dated. Nevertheless, the comprehensive evaluation of the measurement results is

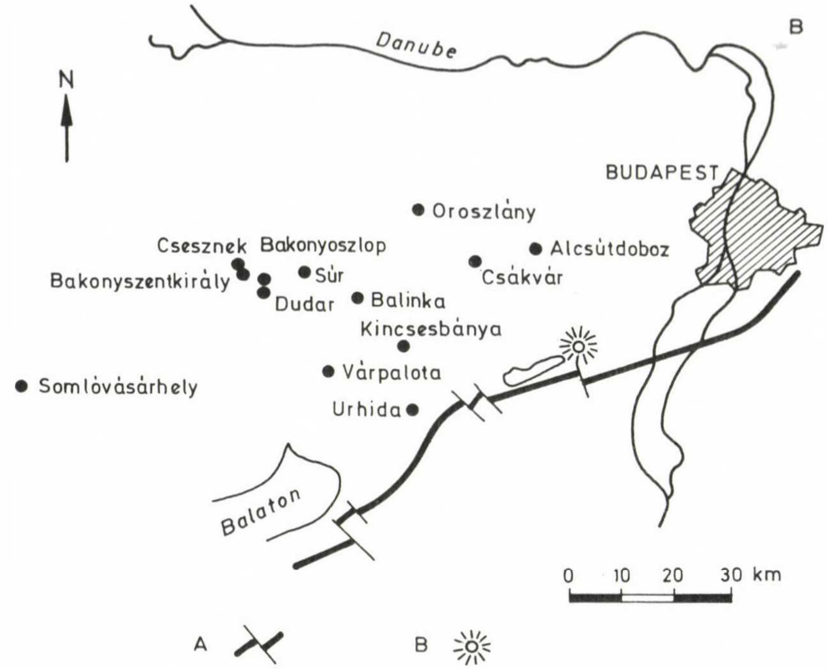

Fig. 2. Areal distribution of the studied Eocene profiles in the NE Bakony Mountains. A - The Balaton Line dissected by transversal faults after the map of Fülöp and Dank (1987); B - Paleogene volcanic centre of the Velence Hills

possible since based on the geological evidences the volcano-sedimentary sequence is uniform and was generated within a relatively short duration.

As regards some samples, the notes below can be added.

a) Based on the apatite and zircon FT ages and on the accessory mineral assemblage of the Kincsesbánya sandstone rich in amphibole, being of peculiar composition and derived earlier from the erosion of metamorphites (Gőbel, 1955) it can be unambiguously stated that the rock nearly as a whole is the erosion product of Paleogene volcanics.

b) The youngest FT age is produced by the amphibole andesite of Csákvár (32.7 Ma). The question arises whether very young age being in unconformity with the geological setting bears some geological meaning or it is an extreme value produced by the statistical uncertainty of the measurement results.

Based on the Dixon test the datum in question belong to the other measurement values on a probability level of 90%, but geological arguments

Table I

FT ages measured on Eocene tuffaceous formations

Sign of prep.	Locality	Borehole	Depth interval	Rock	Number of data	Ns	Ni	Ps	Pi	FT Age Mill. year	+-2s Poiss.	Uranium (ppm)	Geol. Age
7	Úrhida	foundations		bentonite	15/15	1144	5909	2.47	13.2	38.9	+- 4.7	23.6	(E-3)
C 14 A	-II-	-II-		-II-	13/13	2029	1582	67.6	52.7	39.9	+- 3.8	345	
18	Csákvár	Csv-18	297.4 m	amphibole andesite	30/30	453	2856	1.1	6.84	32.7	+- 4.7	12.3	(E-3)
C 14 B	-II-	-II-	-II-	-II-	37/37	2336	2108	25.2	22.8	34.8	+- 3.7	145	
35	Somlóvásár-hely	Sv-1	573.2 m	andesite tuff	20/19	1094	2530	2.39	5.57	44.2	+- 7.4	19.2	(E-3)
42	Bakony-	Bszk-3	417 m	andesite tuff	45/45	2224	5444	2.34	5.83	44.9	+- 4.2	19.8	(E-3)
C 13	szentkirály	-II-	-II-	-II-	22/22	2702	1917	49.2	34.8	43.7	+- 4.7	222	
54 B	Alcsútdoboz	Ad-3	741.5 m	tuff	12/12	181	525	0.73	2.16	35.6	+- 6.8	7.4	(E-3)
59	-II-	-II-	803.6 m	and.agglomerate	40/40	780	2114	1.27	3.43	39.2	+- 4.5	11.6	(E-3)
C 26	-II-	-II-	803.6 m	-II-	33/33	2579	1489	32.3	18.5	34.9	+- 3.3	189	
60	Súr	Sr-20	215.4 m	bentonitic tuff	33/33	2594	5965	3.0	6.92	45.6	+- 4.2	23.5	(E-3)
C 25	-II-	-II-		-II-	33/32	4585	2480	69.2	37.4	37.3	+- 3.8	400	
36	Csesznek	Cse-8	93.2 m	glaukonitic marl	30/30	1687	8240	2.41	12.0	41.3	+- 4.8	21.5	(E-2-3)
39	Várpalota	V-133	264.7 m	bentonitic tuff	36/35	348	877	0.77	2.1	41.1	+- 6.1	8.4	(E-2)
10	Kincsesbánya	pit-head		amphibole-bearing	30/29	1038	4509	3.69	16.2	46.5	+- 5.8	29.0	(E-2)
10-7	////	////		sandstone	30/29	1038	2562	3.69	8.72	46.8	+- 5.9	28.0	
C 12	-II-	-II-		-II-	16/16	1678	1145	41.9	28.6	45.3	+- 5.3	183	
29	Balinka (2)	coal mine,		glauconitic	30/30	1492	7726	2.22	11.5	39.9	+- 4.8	20.6	(E-2)
25	-II- (4)	8th blind shaft		calc-arennite	25/24	1497	8052	2.56	13.6	37.8	+- 4.4	24.2	
C 17	-II- (4)	-II-		-II-	23/23	3339	2305	59.0	40.6	45.0	+- 4.7	260	
40	Balinka	Bat-5	53.0 m	bentonitic tuff	41/40	1147	2539	1.49	3.22	47.5	+- 5.1	11.6	(E-2)
37	Oroszlány	O-2274	520.2 m	glauconitic limestone	30/30	970	4214	1.35	5.77	48.0	+- 6.0	10.4	(E-2)
41	B.szentkirály	Bszk-3	473.5 m	crystal tuff	27/26	460	1116	1.23	2.91	46.3	+- 6.3	10.7	(E-2)

Table I (cont.)

Sign of prep.	Locality	Borehole	Depth interval	Rock	Number of data	Ns	Ni	Ps	Pi	FT Age Mill.	+-2s Poiss. year	Uranium (ppm)	Geol. Age
63	Bakonyoszlop	Bob-681	312.2 m	tuffaceous marl	25/24	1383	6285	2.02	9.23	44.5	+- 5.3	16.6	(E-2)
Paleogene volcanite pebble													
22	Dudar (2)	coal mine		biotite-amphibole-andesite pebble	26/25	558	2822	1.38	7.05	40.3	+- 5.6	13.4	

If the sign of preparate begins with numbers, the measurement was made on APATITE, C refers to ZIRCON.

-II- denotes several preparates from one locality.
//// denotes multiplied measurement of one preparate.

Number of data = Crystal or field number measured and used for the results.
Ns. Ni = Spontaneous and induced track number.
Ps. Pi = Spontaneous and induced track density (10^5 track/cm^2).
Uranium (ppm) = uranium content measured in the crystals.

favour the separate discussion of it. The Csákvár sample derives from a stratovolcanic structure older than Priabonian (Báldi, 1983) that lies relatively close to the huge volcanic centre of the Velence Hills. The measured apatite FT age of 32.7 Ma fairly well correlates with the apatite FT ages for the andesites of the Velence Hills, their average being 33.6 Ma (Dunkl, 1990). Since the possibility exists that the Eocene volcanic sequence traversed by the borehole Csv-18 endured subsequent thermal effects similarly to the case of andesites of the Velence Hills, the measurement result of youngest age was omitted from averaging the data.

c) When assigning the samples to the Middle or Upper Eocene (see below) the results of Csesznek and Dudar will be omitted since

- the sample deriving from the borehole Csesznek-8 falls to the Middle/Upper Eocene boundary,

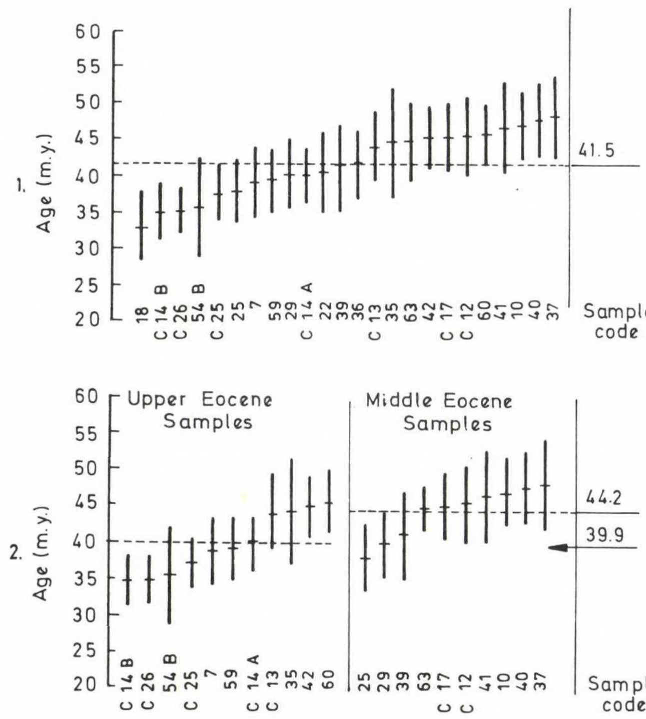

Fig. 3. Rake diagrams showing the measurement results in increasing sequence with the double Poisson dispersion range. On the right the unweighted averages are found. A - All the Eocene samples; B - Samples of known stratigraphic position, in groups

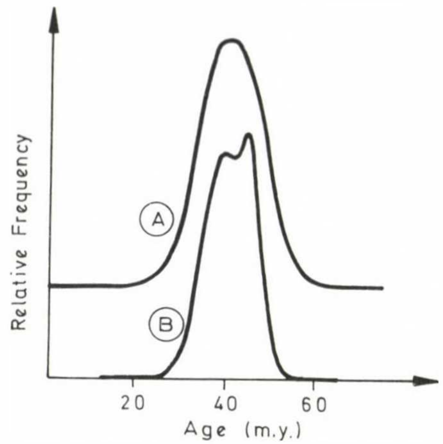

Fig. 4. Age spectra calculated by the Hurford et al. (1984) method from the measurement results. The procedure fits a Gaussian curve corresponding to the dispersion to the ages measured in each sample and the "age spectrum" is given by their summary. A - The distribution picture obtained with double Poisson dispersion is symmetric, nearly ideal; B - In the curve of higher resolution obtained with single dispersion two maxima can be distinguished

- due to the detrital origin the FT age of the andesite gravel of Dudar bears no significance from the point of view of finer stratigraphic division, the measured age proves only the Eocene formation of andesite.

The rake diagram (Fig. 3A) is most suitable to the comprehensive evaluation of the results that shows the data in increasing sequence and the reliability limits, as well. It can be stated that

- there are no extreme data, the distribution of the results shows a symmetric slightly negative skewness in first approximation,

- close to the distribution average there is a gap, no measurement results are between 41.3 and 43.7 Ma. This division is represented also by the double maximum of the age spectrum calculated with higher resolution (Fig. 4). It is remarkable that grouping the results into two fields according to the stratigraphic position this division occurs both in the Middle and in the Upper Eocene group.

The unweighted average of the FT ages measured on all Eocene samples is 41.5 Ma. Due to the subsequent possible thermal effect described under b) above, when omitting the FT age of the Csákvár apatite the average will be 41.9 $\pm$ 4.1 Ma. This value falls to the middle of the Bartonian and fits fairly well to the duration determined for the volcanism by plankton data.

When grouping the data according to the stratigraphic position of the samples it can be stated that the range of the results measured on Middle and Upper Eocene samples is practically the same. Nevertheless, there is a remarkable difference between the averages of the groups (Fig. 3B). The average of the FT ages of the stratigraphically Middle Eocene samples is 44.2 ± 3.4 Ma. This value falls to the s.s. Uppermost Lutetian and is somewhat older than the date of appearance of the tuffaceous material documented by fauna in the strata in question.

The average of the FT ages measured on Upper Eocene samples is 39.9 ± 4.1 Ma that falls to the Bartonian/Priabonian boundary of the scale published by Berggren et al. (1985), i.e. 40 Ma. The FT age falling to the Lowermost Priabonian agrees with the geological built up of the North Bakony Mountains since in the area the infra-Oligocene denudation eroded the upper part of the Priabonian formations. This is why only the lowermost part of the Upper Eocene can be locally found and this represents about 1 million years (Báldi-Beke, 1983 and personal communication, 1990).

Conclusions

The average of the fission track results falls to the range of volcanism marked also by biostratigraphy. Nevertheless between the averages of the FT ages measured on the Middle and Upper Eocene samples grouped according to their stratigraphic position, there is a difference of more than 4 million years. As to the Shapiro-Wilk test both the Middle and the Upper Eocene data group is of normal distribution at a level of p = 95%, thus the significance of the difference of the two average values can be interpreted. Based on the t-test the average values of the two groups differ from each other on a statistical probability level of 98%.

Based on the FT data, in the studied area two phases or two periods of increased intensity can be outlined in the Late Eocene volcanism. The initial volcanic activity producing less pyroclastics generated the glauconite-bearing thicker sequence in the Upper Lutetian in which less pure tuffaceous strata are found. Based on the samples' data the younger, about 40 Ma maximum of the volcanic activity produced the tuff strata close to the Bartonian/Priabonian boundary. Since based on geological grounds no division occurs in the strata, there was no break between the maxima of the volcanism, only its intensity decreased temporarily.

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