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A new tie-point candidate for the Paleogene timescale calibration: Fission track dating of tuff layers of Lower Oligocene Tard Clay (Hungary)

By

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With 6 figures and 2 tables in the text

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Abstract: Tard Clay is a marine, partly laminated, stratigraphically well divided formation. Fission track (FT) age determinations were made on euhedral apatite and zircon crystals from thin, argillitised, undisturbed tuff layers of the Tard Clay. The samples were taken from the NP 22 and lower NP 23 nannoplankton zones from the Budapest area. The average of the fission track ages is 32.45 ± 0.54 Ma. This FT age is younger than that of scales which are based on the interpolation of magnetostratigraphical data. On the other hand, the FT result is older than time scales of Odin which are mostly based on glauconite investigations. The average of fission track results on Tard Clay - in contrast to the interpolation method - supports the validity of younger stage boundaries and the necessity of further thickening of tie-points by near-boundary sampling.

Zusammenfassung: An den mit Planktonstratigraphie gut korrelierten unteroligozänen Tarder Tonschichten in der Nähe von Budapest wurden Spaltspurdatierungen durchgeführt. Das durchschnittliche Alter der Proben (Nannoplanktonzonen: NP 22 und untere NP 23) beträgt 32,34 ± 0.54 Millionen Jahre. Dieses Alter ist einerseits jünger als die Zeitangaben, die auf magnetostratigraphischen Interpolationen beruhen, andererseits aber älter als die entsprechenden Glauconitalter von Odin. Wegen der Unzuverlässigkeit von Altersinterpolationen wird die Notwendigkeit der Datierung von Proben aus der Nähe paläogener Zonengrenzen bekräftigt.

Introduction

In the tuff strata intercalated into the Lower Oligocene Tard Clay of the Budapest environs only a few radiometric measurements have been carried out so far. The intense argillitisation has been responsible for the lack of K/Ar investigations. The accessory minerals (apatite and zircon) being suitable to

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fission track determinations remained intact of this alteration, this is why these minerals are very suitable to age determinations. The Tard Clay is biostratigraphically excellently classified. By radiometric investigation of the thin, redeposition-free tuff strata new data can be obtained to the questionable ages of biozones and of the Eocene/Oligocene boundary. The significance of these age determinations relies upon the fact that in the course of the studied time interval only few stratigraphically well-defined formations were generated on a world scale that are suitable to radiometric investigations.

Geological setting

The Tard Clay extends from the Buda Hills to the southern foreground of the Bükk Mountains, most of the drillings exploring this formation are located at Budapest and in the Bükkalja (Fig. 1.). The formation consists of continuous

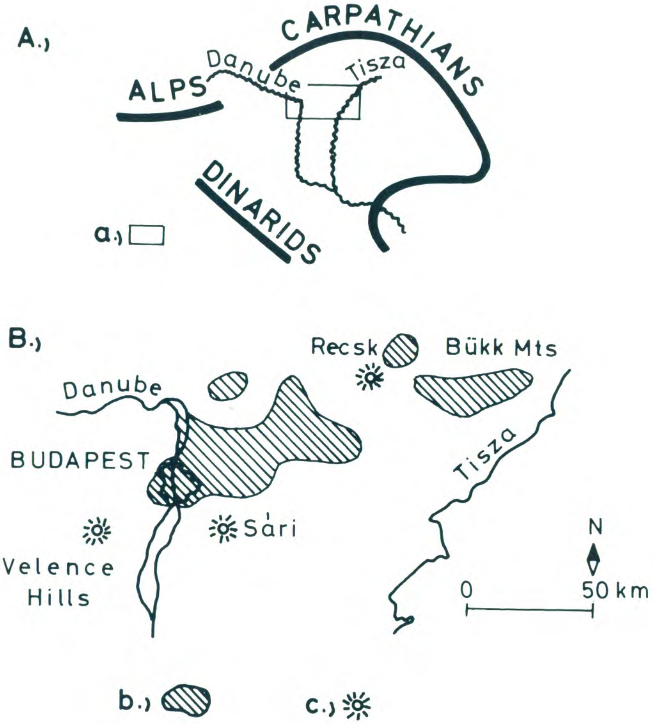

Fig. 1. A): The studied area in the Carpathian Basin. a) Enlarged map.
B): Distribution of Tard Clay. b) Actual distribution. c) Paleogene volcano.

sequences of basin-type pelitic sediments often with laminitic structure, its thickness is roughly 100 m or less (BÁLDI 1986). Usually it develops without unconformity from the underlying Buda Marl and shows continuous transition to the overlying Kiscell Clay (Fig. 2.). In the complete profile of the formation tuff strata are rather common, that amount to 7% of the total thickness e. g. in the borehole Városmajor-1 (KORPÁS 1981).

The tuff strata are usually thin (2 to 12 cm) strongly argillitised crystal tuffs in which the size of the greatest grains does not exceed 2 cm (SZABÓ & SZABÓ-BALOG 1986). In the grey clay-mineralized matrix feldspar, biotite, amphibole, dihexagonal quartz, garnet, apatite, zircon as well as rock detritus and terrigenic quartzite occur. Tuffs are merely of andesitic-dacitic composition, subordinately rhyolitic composition has been also found.

In the Carpathian basin the Paleogene andesitic volcanism can be traced from the Lutetian, the culmination of pyroclastic supply falls to the Bartonian-Priabonian (BÁLDI-BEKE & BÁLDI 1990). Tuffs intercalated into the Lower Oligocene strata refer only to a remote and/or diminishing volcanism. The youngest tuff strata of the Paleogene volcanism are found in the Upper Kiscellian sediments of the Bükkszék environs (BÁLDI 1986).

Based on their age and petrographic character the tuff strata of the Tard Clay are closely related to the formations of the South Alpine tonalite belt (SZEPESHÁZY 1977). In the Hungarian continuation of this strip along a NE-SW strike the Balatonfenyves tonalite (BALOGH et al. 1983) and some partly eroded volcanic fragments covered by young sediments have been found (Fig. 1; BALÁZS et al. 1981). According to the tuff strata of the areas surrounding the volcanic centers the main eruptions of the Zala, Velence and Recsk centers fell to the Eocene but the question, i. e. which volcanoes had supported eruptive material in the Oligocene, cannot be answered by means of radiometric data. Results display a definite series of always younger ages produced by the strong

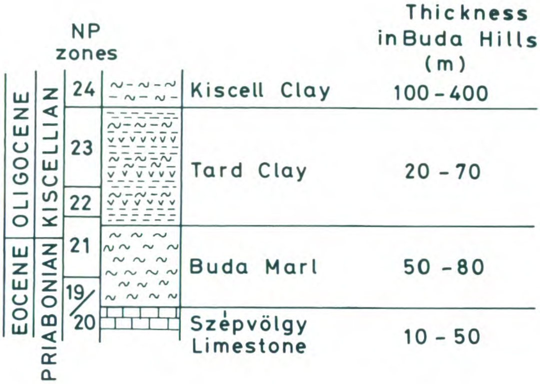

Fig. 2. Schematic sequence of Upper Eocene/Lower Oligocene formations in Buda Hills.

alteration, the continuous hydrothermal activity and at Recsk by the thermal effect of the Neogene volcanism (Balogh , in Darida-Tichy 1988; Dunkl 1990). The K/Ar and FT data referring to Oligocene age measured in the volcanic centres do not show the age of formation but rather the date of subsequent effects.

One of the presumed source of the tuffs may be the volcanic centres explored by drillings in the basin south of Budapest (Csiky 1963; Juhász 1964, 1971; Balázs et al. 1969; Sztrákos 1975). Nevertheless, the Paleogene age of the tephra described in the Sári environs close to the explosion centre is not unambiguously proved due to the disturbed bedding.

It is another aspect when one takes into account the presumed displacement of the Bakony unit during the Paleogene. According to Kázmér (1984) the Bakony-Drauzug unit was extruded off the Eastern and Southern Alps along the bordering transcurrent faults during the Eocene-Oligocene. In accordance with this theory the Transdanubian Central Range was situated far to the west in the Lower Oligocene as compared to its recent position, thus, some the Paleogene volcanic formation of the Alps can be considered to be possible explosion centres of the tephras in Hungary. In the Western Alps the trachyandesites along the Insubric line (Hunziker 1974; Gatto et al. 1976) as well as the tonalite bodies close to the Periadriatic lineament (Exner 1976) may both be the source of the tuff strata. The easternmost Paleogene volcanic region of the Alps is the Smrekovec andesite occurrence but the relationship with the tuffs of the Budapest environs is invalidated by the differing mineral composition and by the younger, i. e. Upper Kiscellian age of the Smrekovec andesite (Hinterlechner-Ravnik & Pleničar 1967; Drobne, in Kázmér 1984).

Stratigraphic position

The formation of the Tard Clay started roughly at the Eocene/Oligocene boundary and it was formed essentially during the Lower Oligocene (Fig. 2.). In this formation the Np 21-23 biozones were determined by Báldi-Beke (1977, 1984), Báldi et al. (1984), Nagymarosy & Báldi-Beke (1988); at the base of the conformly overlying Kiscell Clay the NP 24 zone has been proved. Taking into consideration the relatively small total thickness (90 to 130 m), the formation can be characterized by a low sedimentation rate (Báldi 1986).

Former radiometric results

Báldi et al. (1975) carried out K/Ar determinations on glauconite found in the Kiscell Clay at Pilisborosjenö. The glauconitic layer belongs to the nannoplankton zone NP 24, the measured K/Ar age is 33.5 ± 2.4 million years. They stated that the age determined in the Kiscell Clay fits fairly well to the data obtained for Egerian and Eggenburgian formations in the Paratethys realm. They called the attention to the systematic temporal displacement of about 4 million years between the DSDP results and the data of the Paratethys.

The following K/Ar ages were measured in biotites of andesite tuffs lying close to the Eocene/Oligocene boundary by Balogh (1985):

borehole	million years		stratigraphic position
Kiscell-1 78.0 m	32.4 ± 1.2 32.1 ± 1.2	32.25 ± 0.9	NP 21 Tard Clay
Alcsutdoboz-3			
657.5 m	32.0 ± 1.4		NP 23 Tard Clay
738.0 m	32.0 ± 1.0 31.3 ± 1.3	31.7 ± 0.8	NP 19/20 Buda Marl

Balogh stated that the age of tuff bands lying in different stratigraphic horizons is uniform and is younger than could be expected on the basis of international data. In accordance with his statement the K/Ar ages do not show the data of tuff deposition but rather "these were produced by a subsequent event that affected all the studied samples".

Nagymarosy et al. (1986) reported $^{40}Ar/^{39}Ar$ data of biotites from these tuffs. In the sample deriving from 79.0 m of the Kiscell-1 borehole they determined 34.3 ± 1.3 million years plateau age.

Stratigraphic position of the samples studied

The areal distribution of the studied samples is shown in Fig. 3.

Alcsutdoboz-3 borehole, sample 54 A (643.3 m) and sample 66 (663.5 m).

Both samples derive from the upper member of the Tard Clay Formation, from the top of the Lower Oligocene sequence of the borehole. This part of the member is fossil-free but

Fig. 3. Sketch map of investigated sites.

in the underlying samples deriving from the depth interval of 670-680 m the NP 23 nannoplankton zone was determined. Above our studied samples, in 630 m the poorish nannoflora relating to decreasing salinity can be assigned also to the nannoplankton zone NP 23.

The samples below derive uniformly from Budapest:

Kiscell-1 borehole, sample 57 A (64.0 m), and sample 55 (70.0 m).

Both samples derive from the lower member of the Tard Clay Formation. Their nannoplankton assemblage can be assigned to the NP 22 zone, the sample from 64.0 m underlies directly the zone boundary NP 22/23. The foraminifera fauna of the samples was assigned to the P 18 planktonic foraminifera zone by HORVÁTH (in NAGYMAROSY et al. 1986). The magnetostratigraphic determinations of P. MÁRTON do not harmonize with the nannoplankton ages, since these samples belong to the C 13 chron of normal polarity, while the NP 22 zone corresponds usually the C 12 chron of reversed polarity.

Budapest, Gellért sqaure, H-299 ("Metro") borehole, and sample 82 (58.0 m), sample 78 (96.0 m).

Both samples derive from the upper member of the Tard Clay Formation. Though no biostratigraphic determinations were carried out in these samples, the age of the samples can be fairly well estimated on the basis of the H-300 borehole drilled about 30 m of this borehole and they can be well correlated with each other. Based on the correlation both samples studied belong to the NP 23 nannoplankton zone.

Budapest, Rózsadomb, R6/3F borehole, samples 27 and 50 (20.8 m).

These samples deriving from the top of the lower member of the Tard Clay Formation can be assigned to the lowermost part of the Np 23 zone on the basis of their nannoflora.

Zugliget samples. The samples No. 16 and 57 derive from an artifical exposure, from the forest near the Szarvas Gábor street. The pelitic strata including the tuff contain mixed nannoflora, in which the youngest forms are characteristic of the NP 23 nannoplankton zone. In accordance with the subsequent investigations it was stated that this sequence was redeposited due to Quarternary solifluction and the material as well as the fossils were mixed and contaminated.

Samples No. 31, 30, Z 11 and 26 were collected during the construction of the concrete wall of the converter station in the Szarvas Gábor street, from the lower member of the Tard Clay. In the samples nannofloras belonging to the NP 22 zone were determined.

Sample Z 23 was taken from the Zugliget-2 borehole (47.8 m). The borehole is situated above the exposures mentioned above and it traversed practically the complete Oligocene sequence including the strata explored in the Szarvas Gábor street. The Lower Tard Clay that can be characterized by many *Spiratella* sp. as the host rock of the tuff contained nannofossils belonging to the NP 22 zone, only several metres below the NP 22/23 zone boundary.

Sample 98 B derives from the brickyard, Csillaghegy, from the upper abandoned part, from the glauconitic basal strata of the Kiscell Clay, somewhat above the Tard Clay Formation. In the sample the index nannofossils of the NP 24 zone is found.

Experimental procedure

The accessory minerals were enriched from rock samples of 0.5 to 1.5 kg by crushing, sieving, panning, heavy liquid separation and magnetic separation. The apatite and zircon 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 °C) than suggested by the prescriptions of ZAUN & WAGNER (1985). Etching was carried out for different durations in each preparate (40 to 80 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 Prague, Czechoslovakia). The neutron fluence was determined by the NBS SRM 962a uranium glass standard. The external detector method was used (GLEADOW 1981), after irradiation the induced fission tracks in mica detectors were etched by HF during 40 to 60 min. Counting of spontaneous tracks was made in oil immersion under Zeiss NU 2 microscope, with magnification of 1600, in case of mica detectors dry optics of 800-time magnification were used. Only the crystals embedded parallel to 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, we tried to count 30 grains in each preparate or 1000 tracks. 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 & 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. If the crystals displaying extreme age belong to the main population with a probablity 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 & GREEN 1983). The limits or error are given by the classical procedure, i. e. by the double Poisson dispersion (GREEN 1981).

Results

The position of the samples and the measurement results are given in Table 1. In case of some samples several preparates were made and some of the preparates were several times irradiated. Ages measured on crystals of each sample are uniform and lie within the range of statistical uncertainty. In the samples detrital accessory population older than Oligocene could not be determined.

Table 1. Fission track ages of Lower Oligocene tuff layers.

Sample code	Locality	Borehole deep	inerv.	Nanno. zone	No. of data	Ns	Ps	Ni	Pi	P(χ^2) (%)	Nd	Pd	Fission track age ±2s (Ma)
Tuff layers in Tard Clay													
A 54a	Alcsutdoboz	Ad-3	643.3 m	NP 23	21/21	650	.73	2120	2.36	1	15651	4.13	32.3 ± 3.9
A 66	Alcsutdoboz	Ad-3	663-5 m	NP 23	32/32	499	.72	1643	2.53	25	18236	4.43	33.7 ± 4.9
A 66a	-II-	-II-	-II-		17/17	258	.74	795	2.37	> 99	18236	4.43	26.8 ± 6.2
A 57a	Kiscell	Kl-1	64.0 m	NP 22	26/26	799	.93	5523	6.37	75	11268	7.93	29.8 ± 3.8
A 57a5	////	////	////		26/26	799	.93	2777	3.25	80	15651	4.34	32.1 ± 3.6
A 57a13	////	////	////		26/25	763	.91	1299	1.58	40	4746	2.28	33.8 ± 4.7
A 55	Kiscell	Kl-1	70.7 m	NP 22	30/30	1440	1.14	4788	3.81	1	15651	4.13	31.6 ± 3.1
A 82	Gellért sq.	Metro- 299	58 m	NP 23	26/25	586	1.17	3988	7.89	85	11268	7.93	30.5 ± 4.1
A 78	Gellért sq.	Metro- 299	96 m	NP 23	23/23	154	.43	906	2.51	20	11268	7.93	35.8 ± 7.3
A 27	Rózsadomb	R6/3F	20.8 m	NP 23	30/30	732	.76	4760	5.07	85	11268	7.93	31.1 ± 4.1
A 27a	-II-	-II-	-II-		20/20	404	.62	2739	4.3	25	11268	7.93	29.8 ± 4.4
A 50	-II-	-II-	-II-		30/30	770	.74	2263	2.42	10	15651	4.26	33.0 ± 4.1
A 16	Zugliget	Zug-2	47.8 m	NP 22	30/30	706	.72	4179	4.26	70	11268	7.93	34.6 ± 4.5
A 16a	-II-	-II-	-II-		8/8	184	.67	1245	4.57	> 99	11268	7.93	30.0 ± 5.7
Z 23	-II-	-II-	-II-		31/31	3727	48.1	3019	38.9	80	5826	1.48	38.0 ± 3.9
Z 23-9	////	////	////		31/31	3727	48.1	1998	25.8	> 99	4100	.84	32.5 ± 2.8
Z 23a	-II-	-II-	-II-		15/15	1197	49.4	1109	46.0	75	5826	1.48	32.9 ± 3.5
Z 23a5	////	////	////		15/15	1197	49.4	2841	117.6	> 99	15651	4.14	36.0 ± 3.8
Z 23a9	////	////	////		15/15	1197	49.6	606	25.3	98	4100	.84	33.6 ± 4.0
A 17	Zugliget	Zug-2	47.5 m	NP 22	18/18	905	1.19	2890	3.83	8	9120	4.35	34.5 ± 3.7
A 17a	-II-	-II-	-II-		19/19	782	1.12	1652	3.93	97	9120	4.35	32.3 ± 3.6
A 57b	Zugliget	outcrop		NP 22/ 23	25/25	209	.61	1235	3.66	< 1	11268	7.93	34.1 ± 6.2
A 57b5	////	(14th bed, redeposited)			25/25	209	.61	628	1.88	6	15651	4.34	36.3 ± 6.5
A 31	Szarvas Gábor	street	1. bed	NP 22	30/30	470	.78	3740	6.34	80	11268	7.93	25.9 ± 3.7
A 31-4	////		////		30/30	470	.78	9234	15.4	60	16781	19.2	25.6 ± 3.1
A 30	Szarvas Gábor	street	2. bed	NP 22	30/30	819	.90	5518	6.0	80	11268	7.93	30.6 ± 3.9

A 30a	-II-	-II-		20/20	469	.81	3370	6.16	50	11268	7.93	27.6 ± 3.9
Z 11	-II-	3. bed	NP 22	34/34	1908	22.5	1801	21.2	> 99	5826	1.50	33.3 ± 3.7
Z 11-9	////	////		34/34	1908	22.5	1146	13.5	98	4100	.94	32.6 ± 3.3
A 26	-II-	4- bed	NP 22	30/30	528	.79	3245	4.87	70	11268	7.93	33.4 ± 4.7
Glauconitic layers at the basis of Kiscell Clay												
A 98b	Csillaghegy	brickyard	NP 24	21/20	226	.79	766	2.69	20	12204	4.14	31.3 ± 5.0
Age standards												
Fish Canyon zircon				55/55	4962	40.8	4642	37.7	> 99	3781	1.24	
Fish Canyon apatite				48/48	1593	1.28	6136	4.96	70	12204	4.17	

Nanno. zone: Nannoplankton zone of the sample.
No of data: Number of investigated/considered crystals.
Ns, Ni: Number of spontaneous and induced tracks.
Ps, Pi: Density of spontaneous and induced tracks (10^5 track/cm^2).
P(χ^2): Probability of obtaining χ^2-value for n-1 degrees of freedom (where n=number of considered crystals).
Nd, Pd: Number and density of induced tracks on NBS 962a standard glass (10^5 track/cm^2).
//// indicates the repeated measurements.
-II- indicates when more samples were taken from one site.
The first letter of sample code represents the investigated mineral (A = apatite, Z = zircon).
Zircon zeta using NBS 962 standard glass = 415.
Apatite zeta using NBS 962 standard glass = 507.
Independent age used for Fish Canyon standard is 27.8 ± 0.7 Ma (Hurford & Hammerschmidt 1985).

Fission track results fall between 25.6 and 38.0 million years. When taking into consideration that the range of double Poisson error of the measurements usually covers the time interval of the sampled biostratigraphic units, occasionally that of the whole formation, it can be accepted that it would be unrealible to evaluate separately the results and to use these results to a classification finer than the biostratigraphic one. Thus, in the present state of knowledge the evaluation of results can be realized by fusion of the data. Averaging is possible since:

– the sequence is continuous,

– samples derive from a sequence representing a short time interval (mainly from the thin NP 22 zone),

– results show normal distribution (at $\alpha = 5\%$ level, according to the Shapiro-Wilk test; see also Fig. 4.).

As GREEN (1986) pointed out the around ± 10% (2σ) error of fission track dating for timescale calibration is far too large. We could reduce the error to the precision required by increasing the number of samples and by fusion of data (some of them are repeated determinations).

The weighted average of the fission track ages measured in the tuffs of the Tard Clay is 32.45 ± 0.54 million years. We prefer the weighting of data by $\frac{1}{\frac{1}{\sqrt{n_s}}+\frac{1}{\sqrt{n_i}}}$ since the numbers of spontaneous and induced tracks counted (and so the Poisson error of the age) express an actual difference between the reliability of data. The error bar given to the average of the data set is the sample standard error of the mean ($\frac{s}{\sqrt{n}}$).

The average of the zircon ages is slightly older than the average of apatite determinations (unweighted data respectively: 34.1 and 31.9 Ma). However, the broad distribution of the populations results in these groups do not differ significantly from each other (by t-test at $\alpha = 5\%$ level, based on the uniformity of variances by F-test at $\alpha = 5\%$ level).

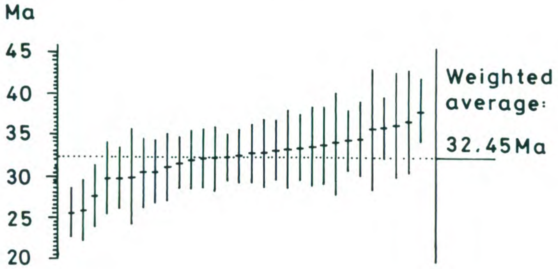

Fig. 4. The "rake diagram" of results. Vertical lines represent the Poisson error (2σ).

Let us investigate what this average express, i. e. is there any rejuvenation in the apatite ages or in a part of them? We can exclude the rejuvenation of FT ages since:

A): the burial of the Paleogene sequences is negligible in the studied area. According to BRUKNER-WEIN et al. (1990) the organic matter can be consider unmaturated based on Rock-Eval investigations ($T_{max} < 420°$ C).

B): Though low temperature hydrothermal activity proceeded in two periods in the Buda Hills (in the Oligocene to Lower Miocene and in the Pleistocene), the rejuvenating effect of this type of origin, however, can be hardly presumed. The overall warming of rock bodies of the area did not exceed 60-70 °C, -the upper boundary of fission track stability in apatite according to WAGNER (1988) and GREEN et al. (1989)- because the average lenght of the spontaneous tracks in three characteristic apatite samples identical with the track lenght in the thermally undisturbed Fish Canyon tuff apatite (Fig. 5.). On this basis the FT results can be regarded as formation ages.

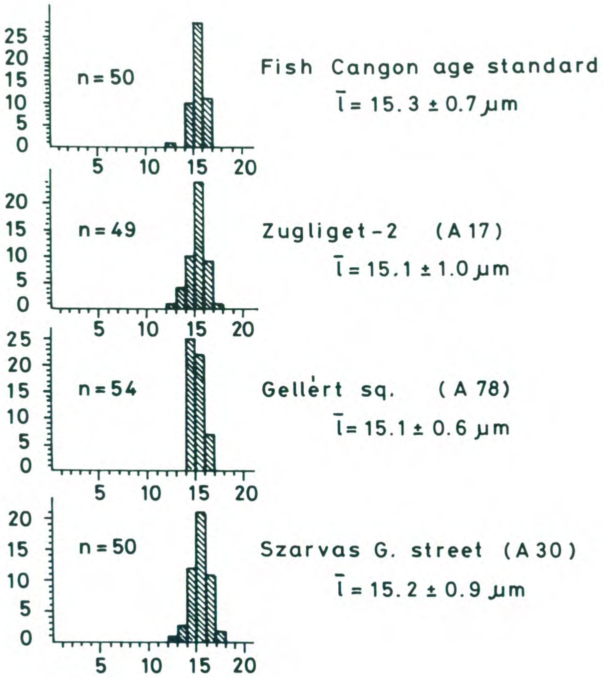

Fig. 5. Fission track length distributions in apatites from tuffs of Tard Clay and Fish Canyon tuff, measured by TINT and TINCLE methods.

Table 2. Significant publications concerning the age of E/O boundary. The results, published before 1977, are not recalculated by new decay constant of Steiger & Jäger (1977). The table does not contain compiled time scales, only original data.

Source	Age of E/O boundary Million years 32 34 36 38 40		Method						Investigated minerals				Stratigraphy		
			Compilation	K/Ar	Ar/Ar	Rb/Sr	FT	U-Th-Pb	biotite	glauconite	tectite	zircon	magneto–	plankton–	mammal–
Holmes (1959)	◇	40	C	.	.	.	.	.	.	.	.	.	.	.	.
Kulp (1961)	◆	36 ± 2	C	K	.	.	.	.	b	g	.	.	.	.	.
Evernden et al. (1961)	◆	33	C	K	.	.	.	.	b	g	.	.	.	.	.
Funnel (1964)	◆	37-38	C	.	.	.	.	.	.	.	.	.	.	.	.
Afanassyev et al. (1964)	◆	37 ± 2	C	K	.	.	.	.	b	.	.	.	.	.	.
Berggren (1969)	◇	36	C	.	.	.	.	.	.	.	.	.	M	P	.
Berggren (1972)	◇	37.5	C	.	.	.	.	.	.	.	.	.	M	P	M
Odin (1973)	◆	37	.	K	.	.	.	.	.	g	.	.	.	.	.
Odin (1975)	◆	35	.	K	.	.	.	.	.	g	.	.	.	.	.
Tarling & Mitchell (1976)	◇	35	C	.	.	.	.	.	.	.	.	.	M	P	.
La Brecque et al. (1977)	◇	38.0	C	.	.	.	.	.	.	.	.	.	M	.	.
Odin et al. (1978)	◆	33.0	C	K	.	R	.	.	.	g	.	.	.	P	.
Hardenbol & Berggren (1978)	◆	37	C	.	.	.	.	.	.	.	.	.	M	P	.
Rubinstein & Gabunia (1978)	◆	(35-36)	C	K	.	.	.	.	.	.	.	.	.	.	.
Van Couvering et al. (1981)	(A)	37-38	.	.	.	.	F	.	.	.	.	z	.	P	.
Lowrie & Alvarez (1981)	◇	38	C	.	.	.	.	.	.	.	.	.	M	P	.
Curry & Odin (1982)	◆	34	C	K	.	.	.	.	.	g	.	.	.	P	.
Prothero et al. (1982)	◆	37.0	C	K	.	.	.	.	.	.	.	.	M	P	M
Glass & Crosbie (1982)	◆	32.3 ± 0.9	.	K	.	.	F	.	.	.	t	.	.	P	.
Harland et al. (1982)	◇	38.0	C	.	.	.	.	.	.	.	.	.	M	P	M
Harris et al. (1984)	◆	34	.	.	.	R	.	.	.	g	.	.	.	P	.
Hsü et al. (1984)	◇	37.1	C	.	.	.	.	.	.	.	.	.	M	P	.

Berggren et al. (1985)	◇	36.6	C	.	.	.	.	.	.	.	.	.	M	P	M
Montanari et al. (1985)	◆	35.7 ± 0.4	.	K	.	R	.	.	b	.	.	.	M	P	.
Glass et al. (1986)	◆	34.4 ± 0.6	.	.	A	.	.	.	.	.	t	.	.	P	.
Haq et al. (1987)	◇	36.0	C	.	.	.	.	.	.	.	.	.	M	P	.
Montanari et al. (1988)	◆	33.7 ± 0.5	.	K	A	R	.	.	b	g	.	.	M	P	.
Odin et al. (1988)	◆	34.5	.	K	A	.	.	.	b	.	.	.	M	P	.
Odin (1988)	◆	33.7 ± 0.5	C	.	.	.	.	.	.	.	.	.	.	P	.
Oberli & Meier (1991)	◆	33.7 ± 0.1	.	.	.	.	.	U	.	.	.	z	.	P	.
Odin et al. (1991)	◆	33.4 ± 0.4	C	K	A	R	.	.	b	.	.	.	M	P	M

◆ Samples near to E/O boundary also investigated.
◇ The age of E/O boundary based mainly on interpolation of magnetostratigraphical data.
(A): The results “accord with glauconite K/Ar ages in western Europe by which the E/O boundary age is estimated at 37-38 Ma“.

Geochronometric problems of the Eocene/Oligocene boundary

Having reviewed the publications dealing with the age of the E/O boundary it can be stated that there are significant differences among the data (Table 2). Even in the data published in the past years a difference of 6 million years occurs. The problem is very serious since the relative value of the differences is rather high, i. e. about 17%, and it is to be taken into account that Oligocene is a young period, reliable magneto-, and plankton-stratigraphy are available to its correlation, furthermore the Oligocene sediments are widespread in the oceanic basins and usually are free of metamorphism.

The source of the problem is the fact that close to the E/O boundary there are only a few rocks of definite biostratigraphic position, suitable to radiometric measurements, so in the course of construction a part of the geochronological scales the interpolation based on magnetostratigraphy was used. With respect to the Cenozoic, these interpolations are related only to a few points. Another difficulty is that the data of PROTHERO et al. (1982) concerning the Lower Oligocene (and which have been used as tie points) are based on vertebrate stratigraphy, furthermore the applicability of magnetostratigraphic correlation is also questionable due to the changing sedimentation rate and to the frequency of hiati (MONTANARI et al. 1985). The two neighbouring tie points lying closest to the E/O boundary and accepted by BERGGREN et al. (1985) fall to the Upper Miocene and Middle Eocene; these time interval is remarkable, i. e. about 41 million years. LA BRECQUE et al. (1977) carried out the interpolation to a much wider time span, i. e. about 62 million years. Within such a long time span the determination of chronostratigraphic boundaries is based on the assumption that the spreading rate of the ocean basement is constant. Nevertheless, on the basis of the investigations of ODIN & CURRY (1985) the spreading rate has considerably changed in the course of the earth's history and they believe the interpolation of long sections of the magnetostratigraphic scales to be an erroneous method.

The other type of publications dealing with the age of the E/O boundary is based on the age determinations carried out in samples close to the boundary (ODIN et al. 1978; CURRY & ODIN 1982; HARRIS et al. 1984). These results being systematically younger than those obtained by interpolation, are usually queries by methodological reservations (THOMPSON & HOWER 1973; BERGGREN et al. 1978) since part of these determinations is based on dating the so-called low temperature phase (glauconite) and on tectites where track diameter corrections have been used in case of the FT method (GLASS et al. 1973). It is worth mentioning, however, that in minerals of volcanogenic origin data referring to the young age of the boundary were also measured (biotite K/Ar, Ar/Ar: MONTANARI et al. 1985, 1988; NAGYMAROSY et al. 1986; ODIN et al. 1988; biotite K/Ar, Rb/Sr: ODIN et al. 1991; apatite and zircon FT: HURFORD et al. 1987; zircon, monacite U-Th-Pb: OBERLI & MEIER 1991).

Conclusions

Samples derive from the lower part of the Tard Clay, from the short NP 22 zone, and from the NP 22/23 zone boundary, respectively; only four samples were taken from the middle part of the NP 23 zone. The main point of the stratigraphic position of samples can be put to the NP 22/23 zone boundary or to the lowermost part of the NP 23 zone.

Let us review how the new result can be fitted to the time scales of different publications containing partly nannoplankton stratigraphy, too. Our fission track age of 32.45 million years measured to the NP 22/23 zone boundary lies closest to the scale constructed by PROTHERO et al. (1982; see Fig. 6.). This age is younger more than 2 million years than indicated by the scales of BERGGREN et al. (1985) and HAQ et al. (1987), while as compared to the scales of ODIN the FT age measured in the Tard Clay is older by about 2.5 and 1.5 million years. It can be summarized that the result falls between the ages obtained by interpolation and the ages of directly measured boundaries (based partly on glauconite data), somewhat closer to the former ones.

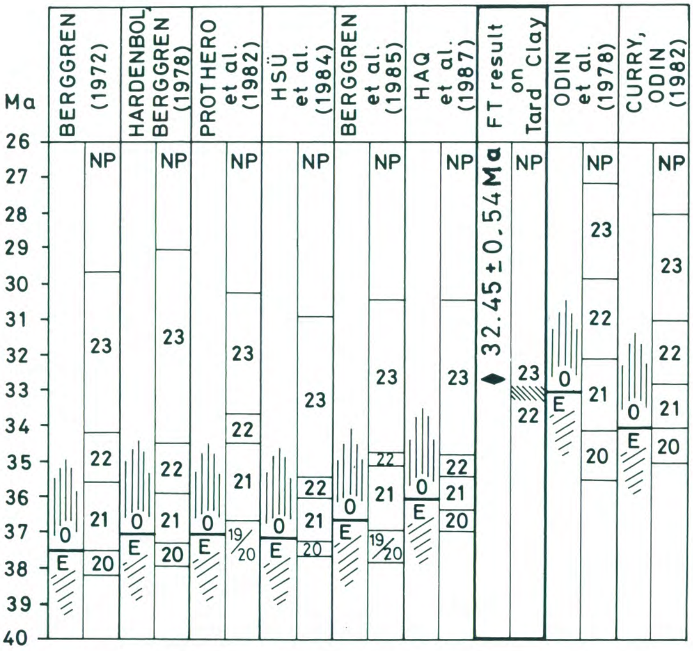

Fig. 6. Compilation of time scales containing nannoplankton zonation. Our new fission track result is in a separate column. The centre of stratigraphical position of samples is very close to the NP 22/23 nannoplankton zone boundary.

Due to the remarkable difference between the methods and philosophies it is not surprising that the new FT result does not uniformly coincide with the previous data. The fact that the new value is younger than interpolated scales of BERGGREN et al. (1985) and HAQ et al. (1987) supports the validity of younger data measured on samples close to the E/O boundary by different methods. We believe that to determine the debated Cenozoic stage and biozone boundaries the method of direct dating is more suitable than the interpolation between far tie-points. In the future the sequences of well-defined plankton stratigraphy have to be used, the phases that can applied for radiometric measurements have to be marked and by means of these investigations the tie-points of the Tertiary time scale have to be multiplied.

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References

AFANASSYEV, G. D. et al. (1964): The project or a revised geological time-scale in absolute chronology. – In: AFANASSYEV, G. D. et al. (ed.): Absolute age of geological formations: 287-324; Moscow (Nauka).

BALÁZS, E., BÁLDI, T., DUDICH, E., GIDAI, L., KORPÁS, L., RADÓCZ, GY., SZENTGYÖRGYI, K. & ZELENKA, T. (1981): Structural-facial outline of the formations of Eocene/ Oligocene boundary in Hungary. – Földt. Közl., **111:** 145-156; Budapest. [In Hung.]

BALÁZS, E., MATYÓK, I. & JUHÁSZ, Á. (1969): Assessment of Tertiary formations of Hungary from the point of hydrocarbon prospecting. – 148 p.; Budapest. [Ms., Nat. Oil Trust, Docum. Dept.; in Hung.]

BÁLDI, T. (1986): Mid-Tertiary stratigraphy and paleogeographic evolution of Hungary. – 201 p.; Budapest (Akad. Kiadó).

BÁLDI, T., BÁLDI-BEKE, M., HORVÁTH, M., NAGYMAROSY, A., BALOGH, K. & SÓS, E. (1975): On the radiometric age and the biostratigraphic position of the Kiscell Clay in Hungary. – Földt. Közl., **105:** 188-192; Budapest. [In Hung. with Engl. abstr.].

BÁLDI, T., HORVÁTH, M., NAGYMAROSY, A. & VARGA, P. (1984): The Eocene-Oligocene boundary in Hungary. The Kiscellian stage. – Acta Geol. Hung., **27:** 41-65; Budapest.

BÁLDI-BEKE, M. (1977): Stratigraphical and faciological subdivisions of the Oligocene as based on nannoplankton. – Földt. Közl., **107:** 59-89; Budapest. [In Hung. with Engl. abstr.]

–,– (1984): The nannoplankton of the Transdanubian Paleogene formations. – Geologica Hung., Ser. Paleont., **43:** 307 p.; Budapest.

BÁLDI-BEKE, M. & BÁLDI, T. (1990): Subsidence-history of Eocene basins in Bakony Mountains (Hungary). – Általán. Földt. Szemle, **25:** 83-118; Budapest. [in Hung.]

BALOGH, K. (1985): K/Ar dates of some Hungarian Late Eocene - Early Oligocene samples. – Öslénytani Viták, **31:** 43-51; Budapest. [In Hung. with Engl. abstr.]

BALOGH, K., ÁRVA-SÓS, E. & BUDA, GY. (1983): Chronology of granitoid and metamorfic rocks of Transdanubia (Hungary). – Anarul Inst. Geol. Geofiz., **61:** part A, 359-364; Bucharest.

BERGGREN, W. A. (1969): Cenozoic chronostratigraphy, planktonic foraminiferal zonation and the radiometric time-scale. – Nature, **224:** 1072-1075; London.

–,– (1972): A Cenozoic time scale - Some implications for regional paleogeography and paleobiogeography. – Lethaia, **5:** 195-215; Oslo.

BERGGREN, W. A., KENT, D. V., FLYNN, J. J. & VAN COUVERING, J. A. (1985): Cenocoic geochronology. – Geol. Soc. Amer. Bull., **96:** 1407-1418; Boulder.

BERGGREN, W. A., MCKENNA, M. C., HARDENBOL, J. & OBRADOVICH, J. D. (1978): Revised Paleogene polarity time scale. – J. Geol., **86:** 67-81; Chicago.

BRUKNER-WEIN, A., HETÉNYI, M. & VETÖ, I. (1990): Organic geochemistry of an anoxic cycle: A case history from the Oligocene section, Hungary. – Org. Geochem., **15:** 123-130; Oxford.

BURCHART, J. (1972): Fission-track age determinations of accessory apatite from the Tatra Mountains, Poland. – Earth Planet. Sci. Lett., **15:** 418-422; Amsterdam.

–,– (1981): Evaluation of uncertainties in fission-track dating: some statistical and geochemical problems. – Nuclear Tracks, **5:** 87-92; Oxford.

CURRY, D. & ODIN, G. S. (1982): Dating of the Paleogene. – In: ODIN, G. S. (ed.): Numerical Dating in Stratigraphy: 607-630; London (Wiley and Sons).

CSIKY, G. (1963): Deep structure and paleogeography of Danube-Tisza interfluve. – Föld. Közl., **11:** 19-35; Budapest. [In Hung. with Russ. abstr.]

DARIDA-TICHY, M. (1988): Distribution and character of Eocene formations at the environments of the Balatonfö-Velence Hills (Hungary). – 77 p.; Budapest. [Ms., Hung. Geol. Inst., in Hung.]

DUNKL, I. (1990): The fission track method and application in solving geochronological questions. – (Ph. D. Theses:) 177 p. Lab. Geochem. Res.; Budapest. [In Hung.]

EVERNDEN, J. F., CURTIS, G. H., OBRADOVICH, J. & KISTLER, R. W. (1961): On the evaluation of glauconite and illite for dating sedimentary rocks by the potassium-argon method. – Geochim. Cosmochim. Acta, **23:** 78-99; London.

EXNER, CH. (1976): Die geologische Position der Magmatite des periadritischen Lineamentes. – Verh. Geol. Bundesanst., **1976** (2): 3-64; Wien.

FUNNEL, B. M. (1964): The Tertiary Period. The Phanerozoic time-scale, a symposium. – Quart. J. Geol. Soc. London, **120:** 171-191; London.

GATTO, G. O., GREGNANIN, A., PICCIRILLO, E. M. & SCOLARI, A. (1976): The "andesitic" magmatism in the south-western Tyrol and its geodynamic significance. – Geol. Rdsch., **65:** 691-700; Stuttgart.

GLASS, B. P., BAKER, R. N., STORZER, D. & WAGNER, G. A. (1973): North American microtectites from the Caribbean Sea and their FT age. – Earth Planet. Sci Lett., **19:** 184-192; Amsterdam.

GLASS, B. P. & CROSBIE, J. R. (1982): Age of Eocene/Oligocene boundary based on extrapolation from N-American microtektite layer. – Amer. Ass. Petrol. Geol. Bull., **66:** 471-476; Tulsa.

GLASS, B. P., HALL, C. M. & YORK, D. (1986): Ar/Ar laser-probe dating of North American tektite fragments from Barbados and the age of the Eocene-Oligocene boundary. – In: ODIN, G. S. (ed.): Calibration of the Phanerozoic time scale; Chem. Geol. (Isot. Geosci. Sect.), **59:** 181-186; Amsterdam (Elsevier).

GLEADOW, A. J. W. (1981): Fission-track dating methods: what are the real alternatives? – Nuclear Tracks, **5:** 3-14; Oxford.

GLEADOW, A. J. W. & LOVERING, J. F. (1977): Geometry factor for extermal detectors in fission track dating. – Nuclear Tracks Detection, **1:** 99-106; Oxford.

GREEN, P. F. (1981): A new look at statistics in fission track dating. – Nuclear Tracks, **5:** 77-86; Oxford.

–,– (1986): A role for apatite fission track analysis in timescale calibration studies. – Bull. Liais. Inf. IGCP Proj. 196, **6:** 32-36; Paris.

GREEN, P. F., DUDDY, I. R., GLEADOW, A. J. W. & LOVERING, J. F. (1989): Apatite fission track analysis as a paleotemperature indicator for hydrocarbon exploration. – In: NAESER, N. D. & MCCULLOH, T. H. (eds.): Thermal History of Sedimentary Basins, Methods and Case Histories: 181-195; Berlin/Heidelberg/New York (Springer).

HAQ, B. U., HARDENBOL, J. & VAIL, P. R. (1987): Chronology of fluctuating sea levels since the Triassic. – Science, **235:** 1156-1167.

HARDENBOL, J. & BERGGREN, W. A. (1978): A new Paleogene numerical time scale. – In: COHEE et al. (ed.): Contributions to the geologic time scale., Amer. Assoc. Petrol. Geol., Stud. Geol., **6:** 213-234; Tulsa.

HARLAND, W. B., COX, A. V., LEWELLYN, P. G., PICKTON, C. A. G., SMITH, A. G. & WALTERS, R. (1982): Geological Time Scale. – 131 p.; Cambridge (Cambridge Univ. Press).

HARRIS, W. B., FULLAGAR, P. D. & WINTERS, J. A. (1984): Rb-Sr glauconite ages, Sabinian, Claibornian and Jacksonian units, southeastern Atlantic Coastal Plain, U.S.A. – Palaeogeogr. Palaeoclimatol. Palaeoecol., **47:** 53-76; Amsterdam.

HINTERLECHNER-RAVNIK, A. & PLENIČAR, M. (1967): The Smrekovec andesite and its tuff. Geologija **10:** 219-236; Ljubljana.

HOLMES, A. (1959): A revised geological time-scale. – Trans. Edinb. Geol. Soc., **17:** 183-216; Edinbourgh.

HSÜ, K. J., LA BRECQUE, J., PERCIVAL, S. F., WRIGHT, R. C., GOMBOS, A. M., PISCIOTTO, K., TUCKER, P., PETERSON, N., MCKENZIE, J. A., WEISSER, H., KARPOFF, A. M., CARMAN, M. F. JR. & SCHREIBER, E. (1984): Numerical ages of Cenozoic biostratigraphic datum levels: Results of South Atlantic Leg 73 drilling; Geol. Soc. Amer. Bull., **95:** 863-876; Boulder.

HUNZIKER, J. C. (1974): Rb/Sr and K/Ar age determination and the Alpine tectonic history of the Western Alps. – Mem. Ist. Geol. Min. Univ., **31:** 1-55; Padova.

HURFORD, A. J. & GREEN, P. F. (1983): The zeta age calibration of fission-track dating. – Chem. Geol. **41:** 285-317; Amsterdam.

HURFORD, A. J. & HAMMERSCHMIDT, K. (1985): Ar/Ar and K/Ar dating of the Bishop and Fish Canyon Tuffs: Calibration ages for fission-track dating standards. – Chem. Geol., **58:** 23-32; Amsterdam.

HURFORD, A. J., ODIN, G. S., BARBIN, V., WINKLER, W. & ZELVEDER, M. (1987): Fission track dating of Paleogene pyroclastic zirkons and apatites: the Priabonian of Priabona (stratotype area); the earliest Thanetian of Northern Alps. – EUG IV, Terra Cognita, **7,** (2-3): 251; Strasbourg.

JUHÁSZ, Á. (1964): Beitrag zur Tiefengeologie des N-Teils des Donau-Theiss-Zwischenstromlandes. – Földt. Közl., **94:** 184-194; Budapest. [In Hung. with German abstr.]

JUHÁSZ, Á. (1971): Tertiäre Vulkanite des Donau-Theiss-Zwischenstromlandes. – Földt. Közl., **101:** 1-12; Budapest. [In Hung. with German abstr.]

KÁZMÉR, M. (1984): Continental escape of the Bakony-Drauzug unit in the Paleogene. – Általán. Földt. Szemle, **20:** 53-101; Budapest. [In Hung. with Engl. abstr.]

KORPÁS, L. (1981): Oligocene - Lower Miocene formations of the Transdanubian Central Mountains in Hungary. – Ann. Inst. Geol. Publ. Hung., **64:** 140 p.; Budapest.

KULP, J. L. (1961): Geological time scale. – Science, **133:** 1105-1114; Washington.

LA BRECQUE, J. L., KENT, D. V. & CANDE, S. C. (1977): Revised magnetic polarity time scale for the Late Cretaceous and Cenozoic time. – Geology, **5:** 330-335; Boulder.

LOWRIE, W. & ALVAREZ, W. (1981): One hundred million years of geomagnetic polarity history. – Geology, **9:** 392-397; Boulder.

MONTANARI, A., DEINO, A. L., DRAKE, R. E., TURRIN, B. D., DE PAOLO, D. J., ODIN, G. S., CURTIS, G. H., ALVAREZ, W., BICE, D. M. (1988): Radioisotopic dating of the Eocene-Oligocene boundary in the pelagic sequence of the North-eastern Apennines. – In: SILVA, P. et al. (ed.): The Eocene-Oligocene Boundary in the Marche-Umbria Basin (Italy); Int. Subcomm. Paleog. Strat., Spec. Publ., **IV:** 195-208; Ancona.

MONTANARI, A., DRAKE, R., BICE, D. M., ALVAREZ, W., CURTIS, G. M., TURRIN, B. T. & DE PAOLO, D. J. (1985): Radiometric time scale for the upper Eocene and Oligocene based on K-Ar and Rb-Sr dating of volcanic biotites from the pelagic sequence of Gubbio, Italy. – Geology, **13:** 596-599; Boulder.

NAGYMAROSY, A. & BÁLDI-BEKE, M. (1988): The position of the Paleogene formations of Hungary in the standard nannoplankton zonation. – Ann. Univ. Budapest., Sect. Geol., **28:** 3-25;

NAGYMAROSY, A., TAKIGAMI, Y. & BALOGH, K. (1986): Stratigraphic position and the radiometric age of the Kiscellian stratotype, Hungary. – In: ODIN, G. S. (ed.): Bull. Liais. Inf. I.G.C.P., Proj. 196, **6:** 29-32; Paris.

OBERLI, F. & MEIER, M. (1991): Age of Eocene-Oligocene boundary in the Marche-Umbria basin, Italy, by high resolution U-Th-Pb dating. – Terra Abstract, **3:** 286; Oxford.

ODIN, G. S. (1973): Résultats de datations radiométriques dans les séries sédimentaires du Tertiaire de l'Europe occidentale. – Rev. Géog. Phys. Géol. Dyn., **15** (3): 317-330; Paris.

–,– (1975): Les glauconites: constitution, formation, age. – Thèse de doctorat d'état des sciences naturelles, Univ. P. et M. Curie: 250 p.; Paris.

–,– (1988): Ages radiométriques récemment obtenus dans la séquence stratigraphique Paléogene. – Bull. Liais. Inf. IGCP, Proj. 196, **7:** 23-31; Paris.

ODIN, G. S. & CURRY, D. (1985): The Paleogene time scale: radiometric dating versus magnetostratigraphic approach. – J. Geol. Soc. London, **142:** 1179-1188; London.

ODIN, G. S., CURRY, D. & HUNZIKER, J. C. (1978): Radiometric dating by glauconites from NW Europe and the time scale of the Paleogene. – J. Geol. Soc. London, **135:** 481-497; London.

ODIN, G. S., GUISE, P., REX, D. C. & KREUZER, H. (1988): K-Ar and Ar/Ar geochronology of late Eocene biotites from the Northeastern Apennines. – In: SILVA, P. et al. (ed.): The Eocene-Oligocene boundary in the Marche-Umbria Basin (Italy); Int. Subcomm. Paleog. Strat., Spec. Publ., **IV:** 239-244; Ancona.

ODIN, G. S., MONTANARI, A., DRAKE, R., GUISE, P. G., KREUZER, H. & REX, D. C. (1991): Reliability of volcano-sedimentary biotite ages across the Eocene-Oligocene boundary (Apennines, Italy). – Chem. Geol., **86:** 203-224; Amsterdam.

PROTHERO, D. R., DEUNHAM, C. R. & FARMER, H.G. (1982): Oligocene calibration of the magnetic polarity time scale. – Geology, **10:** 650-653; Boulder.

RUBINSTEIN, M. & GABUNIA, L. (1978): On dating of the Paleogene. – In: COHEE, G. V. et al. (eds.): Contribution to the geologic time scale; Amer. Assoc. Petrol. Geol., Stud. Geol., **6:** 205-211; Tulsa.

STEIGER, R. M. & JÄGER, E. (1977): Subcomission on geochronology: convention on the use of decay constants in geo- and cosmochronology. – Earth Planet. Sci. Lett., **36:** 359-362; Amsterdam.

SZABÓ, CS. & SZABÓ-BALOG, A. (1986): Mineralogy and petrography of pyroclastics in Eocene/Oligocene boundary profiles (Hungary). – Ann. Univ. Sci. Budapest., Sect., Geol., **26:** 33-41; Budapest.

SZEPESHÁZY, K. (1977): Mesozoic igneous rocks of the Great Hungarian Plain. – Földt. Közl., **107:** 384-397; Budapest. [In Hung. with Engl. abstr.]

SZTRÁKOS, K. (1975): Paläogen Paläogeographie des im NO von Budapest liegenden Gebietes. I. Teil: vom oberen Lutet zur Tarder Ton-/Kisceller-Ton-Grenze. – Öslénytani Viták, **22:** 51-80; Budapest. [In Hung. with German abstr.]

TARLING, D. M. & MITCHELL, J. G. (1976): Revised Cenozoic polarity time scale. – Geology, **4:** 133-136; Boulder.

THOMPSON, G. R. & HOWER, J. (1973): An explanation for low radiometric ages from glauconite. – Geochim. Cosmochim Acta, **37:** 1473-1491; London.

VAN COUVERING, J. A., AUBRY, M. P., BERGGREN, W. A., BUJAK, J. P., NAESER, C. W. & WIESER, T. (1981): The Terminal Eocene Event and the Polish connection. – Palaeogeogr. Palaeoclimatol. Palaeoecol., **36:** 321-362; Amsterdam.

WAGNER, G. A. (1988): Apatite fission-track geochrono-thermometer to 60°C: projected length studies. – Chem. Geol., **72:** 145-153; Amsterdam.

ZAUN, P. E. & WAGNER, G. A. (1985): Fission-track stability in zircon under geological conditions. – Nuclear Tracks, **10:** 303-307; Oxford.

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