NEW DATA ON THE AGE OF THE RECSK VOLCANICS AND OF THE ADJACENT SEDIMENTARY ROCKS

György Less
University of Miskolc, Istitute of Mineralogy and Geology, Miskolc
foldlgy@uni-miskolc.hu

Mária Báldi-Beke
Geological Institute of Hungary, Budapest
bal5963@iif.hu

Sarolta Pálfalvi
Geological Institute of Hungary, Budapest
ipolysag@t-online.hu

János Földessy
University of Miskolc, Istitute of Mineralogy and Geology, Miskolc
foldfj@uni-miskolc.hu

Botond Kertész
University of Miskolc, Istitute of Mineralogy and Geology, Miskolc
kertesz.botond@eszakko.hu

Abstract: The directly underlying sediments of the Recsk andesite stratovolcano contain characteristic Priabonian larger foraminifera and on their top the calcareous nannoplankton indicates the NP 21 zone marking about the vicinity of the Eocene/Oligocene boundary. Priabonian limestones of the neighbouring areas do not contain tuffaceous intercalations. Nannofossils of the above age also have been extracted from the intercalations of the lower part of the stratovolcanic andesite, and the older group of relevant radiometric ages detect similar ages (31–37 Ma). The first tuffs in the neighbouring territories appear in the lowermost Oligocene sediments. The younger group of relevant radiometric ages marks 27–30 Ma. Sediments directly overlying the andesite contain characteristic Oligocene larger foraminifera indicating most probably the basal part of the Chattian. Approximately the same age can be given based on the calcareous nannoplankton from the Kiscell clay just above the larger foraminiferal sediments. Tuffitic intercalations in the vicinity of Recsk can be followed throughout the Rupelian and up to about the first one-third of the Chattian. Thus, the polycyclic volcanic activity in Recsk lasted about 7 million years and seems to have been extending during the first two-third of the Oligocene from about 34 to 27 Ma. This interval covers practically the whole duration of the Kiscellian in the Central Paratethyan subdivision corresponding to the whole Rupelian and also to the first one-third of the Chattian.

1. INTRODUCTION AND HISTORICAL REVIEW

The Recsk volcano plays an important role in all the recent paleogeographic reconstructions of the Alpine–Carpathian–Pannonian Paleogene as discussed in Földessy et al., (2008, see also for references). It is considered the north-eastern-most member of the Paleogene magmatic range along the Periadriatic–Balaton Lineament starting in the west from the Bergell. Since it is also important as a Cu-porphyry and gold ore deposit, sufficient material from some boreholes is available.

The age of the Recsk andesite stratovolcano is traditionally believed as late Eocene (with the exception of Kovács et al. 2007 who – based on oral communication and two preliminary abstracts such as Less et al. 2005b and Földessy et al. 2006 – already used our new data to be presented below). This is, however, based on the firm belief of the Priabonian age of both the directly under- and overlying sediments (Baksa et al. 1974, Baksa 1975, Zelenka 1975, Földessy 1975) since the K/Ar radiometric ages extracted from the andesite are heavily affected by alteration processes, and therefore, highly uncertain. Among these, Benedek (2002) still cites 37±10 Ma given by Baksa et al. (1974). The only convincing zircon-based fission-track age of the andesite (from borehole Recsk 357, 356 m) is 34.7±3.0 Ma (Dunkl, I. pers. comm.), which also does not contradict to the Priabonian age of the Recsk andesite.

Since the age of the other two Paleogene volcanic centers in Hungary (in the Zala Basin Shear Zone and in the Velence Hills) is also considered Bartonian or Priabonian, the age of the whole volcanic chain in Hungary has been believed late Eocene for a long time (Tari et al. 1993, Kázmér et al. 2003). The homogeneity of these ages has been seriously doubted by Benedek (2002) who presented several new radiometric data from the two western occurrences of the andesites and showed that Oligocene ages are more characteristic for the Zala Basin Shear Zone and also occur in the Velence Hills (29.1–31.2 Ma according to Balogh 1985). Biostratigraphic data from the tuffs of Western Hungary (Báldi-Beke & Báldi 1991 for the Bakony Mts. closest to the Zala Basin Shear Zone, Less & Gyalog 2004 for Úrhida close to the Velence Hills) suggest, however, rather a late middle Eocene to late Eocene age of the volcanic activity.

Also in Recsk, there is a contradiction between the age of the volcano and that of the surrounding tuffs. Despite the inferred Priabonian age of the stratovolcanic andesite, the shallow-water carbonates of this age (the Szépvölgy Limestone, between which the andesite is believed to be sandwiched, see Földessy 1975) from the neighbouring territories (Bükkszék, 10 km to the NE of Recsk, see Báldi 1983 and the southern foothills of the Bükk Mts., 20–30 km to the E of Recsk, see Less et al. 2005a) do not contain any pyroclastics. At the same time the lower and partly also the upper Oligocene sediments of these territories (and of Recsk as well, Földessy 1985) contain several intercalations of andesitic tuffs. The age of Paleogene sediments in NE Hungary is well established: that of the Priabonian by larger foraminifera is based on Less (1999) and Less et al. (2005a) while that of the Oligocene by calcareous nannoplankton and planktic foraminifera is according to Báldi-Beke (1977) and Horváth (1985).

In this sense, the weakest point is the age of the tuffaceous marls directly overlying the Recsk andesite. The late Eocene age of these sediments is established already by Szabó (1869) based on the presence of small *Nummulites* in them. Since then it provides a massive upper anchor for determining the age of the andesite despite that larger foraminiferal experts like Rozlozsnik (1939) and Jámbor-Kness (1988) attributed rather an early Oligocene age to these sediments. In the meantime other people like Noszky (1927), Szőts (1956) and Majzon (1966), not really familiar with larger foraminifera, emphasized the Priabonian age of the overlying sediments operating with names (e.g. *Nummulites fabianii*, *N. incrassatus* and different orthophragmines) characteristic for this age. Their opinion proved to be stronger, and therefore, the late Eocene age of the Recsk andesite became widely accepted in the geological society. The only exception is due to Varrók (1962) who interpreted the Recsk andesite as a Miocene laccolite having intruded in between the Priabonian sediments. This interpretation is, however, less likely, since the overall thickness of the inferred upper Eocene sediments (including both the under- and overlying beds) does not exceed 50 m which is not comparable with the thickness of the andesite exceeding 500 m.

In this study we revised the age of the underlying, intercalating and overlying sediments based on larger foraminifera and calcareous nannoplankton, and correlated it with both the convincing radiometric ages and the presence/absence data of pyroclastics in the Paleogene sediments of the neighbouring territories.

Figured specimens of fossils marked by E. and O. are deposited in the Eocene and Oligocene collection of the Geological Institute of Hungary.

2. GEOLOGICAL SETTING

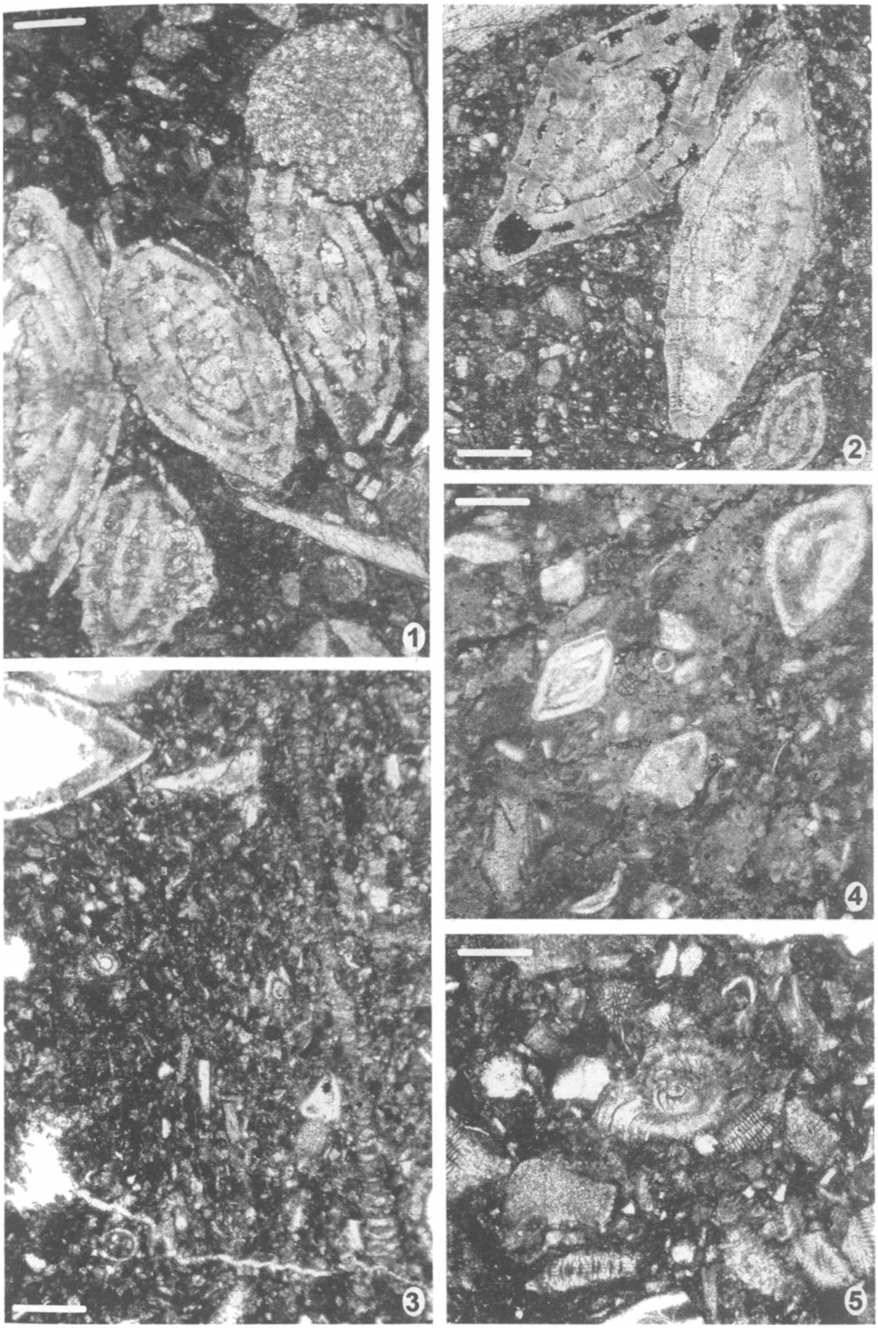
Mesozoic rocks beneath the Recsk stratovolcano (Kovács et al., 2008) are covered transgressively and with angular unconformity by a relatively thin Priabonian sequence (max. 25 m) that is preserved only in some (erosional?) remnants and known only from boreholes. These sediments are the youngest of all the rocks underlying the stratovolcanic andesites.

We could study the Priabonian sediments in boreholes Recsk, Rm-28 (793–772 m), Rm-79 (436.0–420.5 m) and Rm-87 (511–487 m), however the sequence of cores appeared to be far not countinuous because these boreholes were drilled in the 1970-s and since then several people studied them. Basal conglomerate could be observed only in Rm-79 (436–429 m) that was followed by dark grey limestone full of *Nummulites fabianii* (a reticulate form identifiable macroscopically), which appeared in all the three boreholes (Rm-28: 793.0–778.5 m, Rm-79: 429–423 m, Rm-87: 511–499 m). The characteristic microfacies are shown in *Plate 1, Figs. 1–4* (see also captions). Only in the borehole Rm-28 the upper part of the dark grey limestone (778.5–777 m) contains abundant orthophragmines instead of *Nummulites fabianii* (microfacies see in *Pate. 1,Fig. 5*). This part of the Priabonian sequence can undoubtedly be identified with the Szépvölgy Limestone of Priabonian age with widespread surface occurrences in N Hungary (in the Buda, Cserhát and Bükk Mts.). The upper part of the Priabonian sequence (Rm-28: 777–772 m, Rm-79: 423–420.5 m, Rm-87: 499–487 m) does not contain larger foraminifera. It is composed of dark grey, silty marl that can be correlated with the Buda Marl in N Hungary, which bears late Priabonian to earliest Oligocene age. We could not observe the contact of the Priabonian sedimentary sequence with the Recsk andesite because the adequate cores have already picked out.

The stratovolcanic complex is described in detail by Földessy et al. (this volume). Here we only mention that silty marl intercalations are found in the lowest and highest of the five cycles, which were accumulated in submarine conditions. Tuffaceous and glauconitic, red algal limestone to sandy marl are intercalated

Plate 1

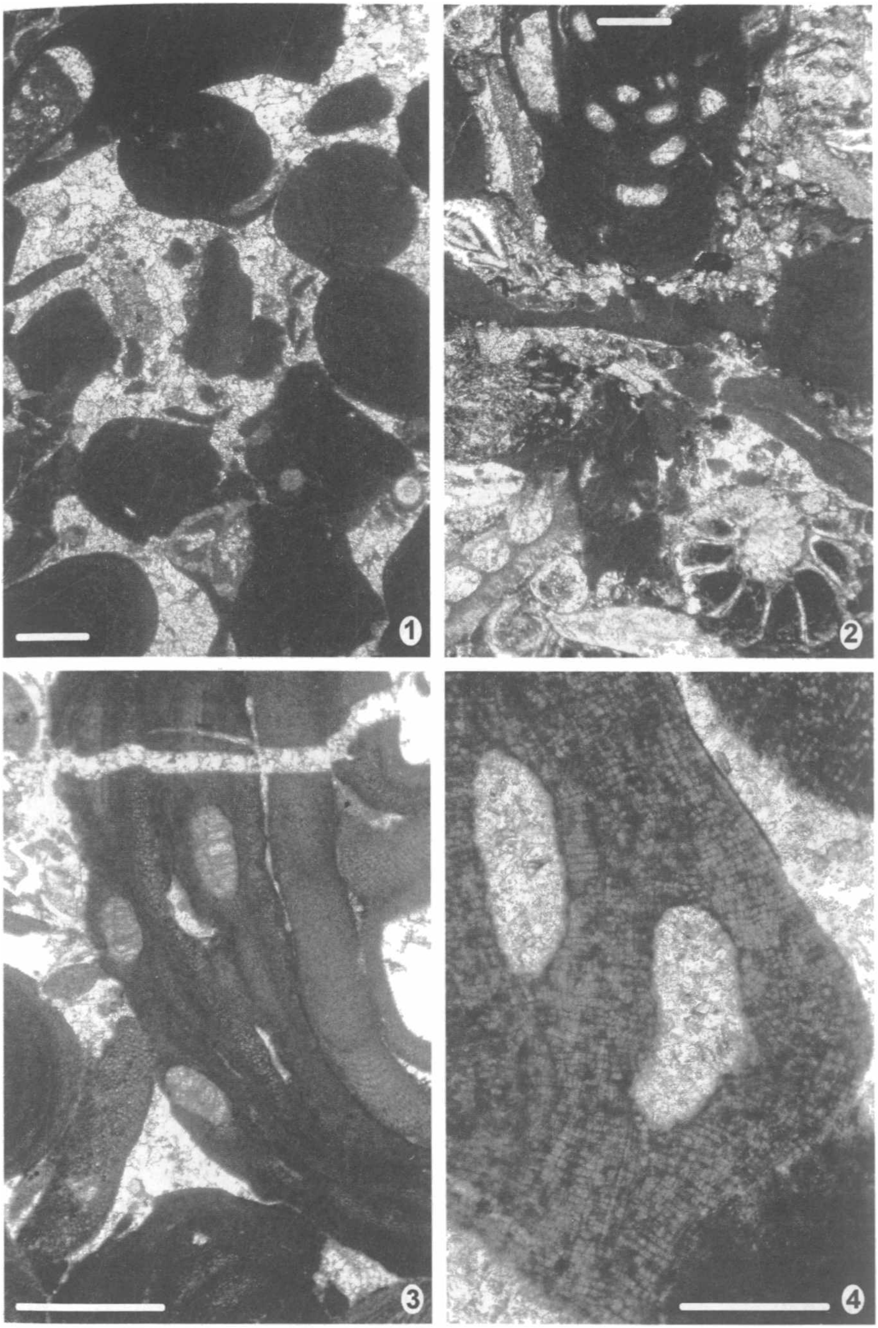
1–5: Different microfacies of the Priabonian Szépvölgy Limestone underlying the Recsk andesite. 1. Nummulites rudstone–floatstone with abundant N. fabianii (Prever) and rare Sphaerogypsina globula (Reuss) on the right top from borehole Recsk, Rm-28 (779.8 m). 2. Silty–sandy Nummulites–Echinodermata floatstone with N. fabianii (Prever) from borehole Recsk, Rm-79 (425.8 m). 3. Nummulites floatstone with radiate Nummulites, Orbitolites (right bottom) and smaller foraminifera from borehole Recsk, Rm-87 (505 m). 4. Sandy Nummulites wackestone with Asterigerina from borehole Recsk, Rm-79 (427.5 m). 5. Orthophragmina floatstone–rudstone with Discocyclina, Asterocyclina and Operculina gomezi Colom et Bauzá (in the centre) from borehole Recsk, Rm-28 (778.0 m). All: ×20; scale bars: 500 μm.


1
2
3
4
5

with the last volcanic stage and also cover them. This volcanoclastic sediment has several surface exposures among which that on the top of the Lahóca Hill is the most famous since Szabó (1869) found small *Nummulites* here and based on them he attributed late Eocene age to these deposits and to the andesite, itself. Among the macrofauna molluscs and echinoids can also be mentioned. Different microfacies of these rocks are shown in *Plate 2, Figs. 1–4* (see also captions). It is worth mentioning that similar sediments are also known from some boreholes (Rm-89, Rm-103, Rm-123). Báldi (1983, 1986), however, interpreted them as the basal beds of the Kiscell Clay, the lowest member of the Oligocene to early Miocene sequence, and thus, suggested an approximately mid-Oligocene age for them. This means that the euxinic Tard Clay of early Oligocene age, characteristic for most of the N Hungarian Oligocene sequences, is missing in Recsk, although it is present and contains several tuffitic intercalations in Bükkszék (10 km to the NE of Recsk) where no andesite could be found.

The tuffaceous and glauconitic limestone to sandy marl is overlain by a middle and upper Oligocene to early Miocene sequence characteristic for N Hungary. It starts with Kiscell Clay of 200–250 m thickness. According to Báldi (1983, 1986) it contains sporadic *Nummulites* and *Operculina*, brachiopods, bryozoans and first of all molluscs whose assemblage is different from that of the Buda and Bükk Mts. The calcareous nannoplankton indicates mostly the NP 24 zone. Thus, the Kiscell Clay in Recsk represents the upper part of the Kiscellian stage in the Central Paratethyan subdivision corresponding to the uppermost part of the Rupelian and to the lower part of the Chattian in the standard scale. The Oligocene to early Miocene sequence terminates with the Egerian (middle–late Chattian and early Aquitanian, see Báldi et al. 1999) Szécsény Schlier and above it with the Eggenburgian (late Aquitanian and early Burdigalian) Pétervására Sandstone. Higher Miocene deposits (building up the main mass of the Mátra Mts.) are described in detail in Varga et al. (1975).

Plate 2
1, 2. Different microfacies of the tuffaceous limestone directly overlying the Recsk andesite, from the top of the Lahóca Hill. 1. Red algal grainstone (maerl facies). 2. Red algal–foraminiferal grainstone with bryozoans and extraclasts. Neorotalia sp. is on the right bottom. 3, 4. Red algae from the red algal grainstone (maerl facies) from the top of the Lahóca Hill. 3. Lithothamnion sp. 4. Mastophoroideae. 1, 2. ×20, 3, 4. ×40. All scale bars: 500 μm.



1
2
3
4

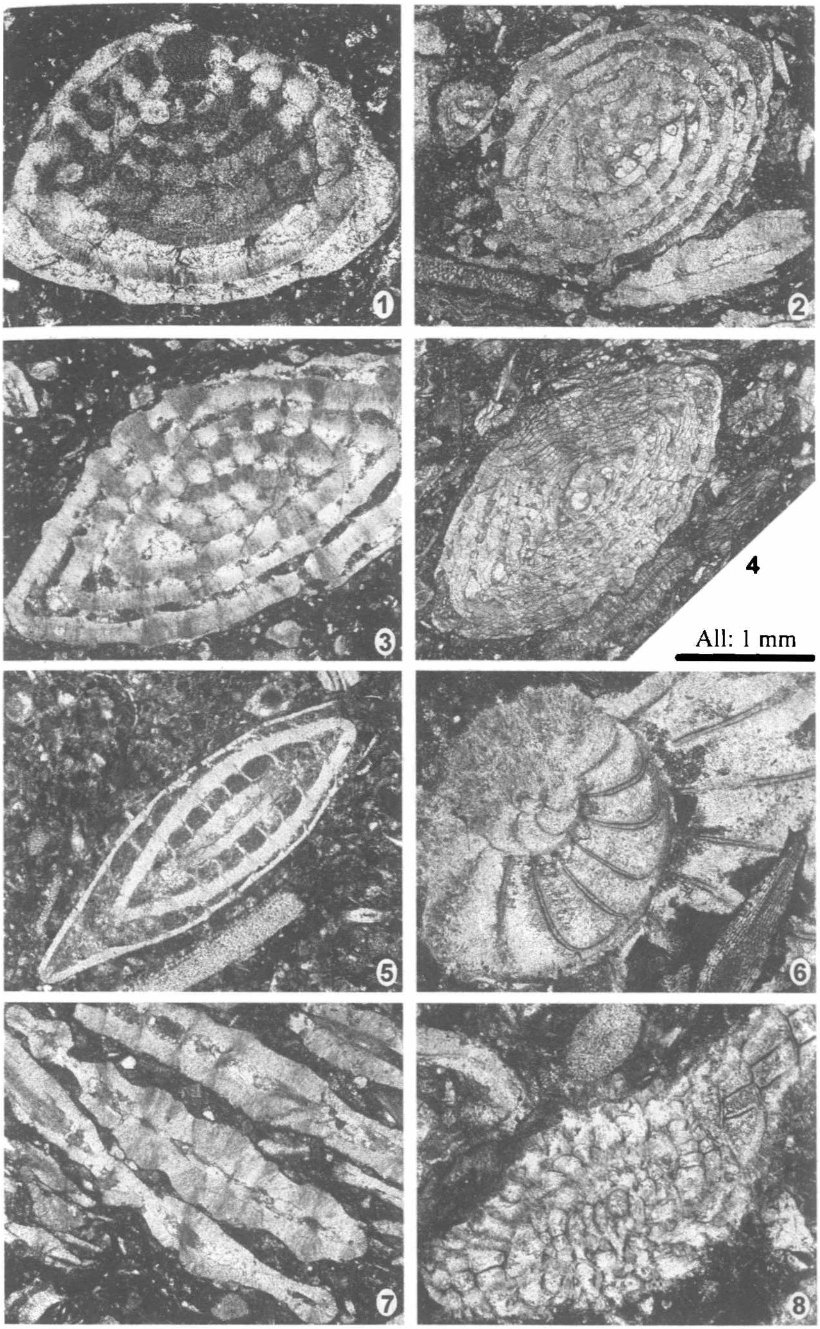
3. NEW BIOSTRATIGRAPHIC DATA

3.1. Sediments underlying the andesite: new data and age

Larger foraminifera from the Szépvölgy Limestone of the Recsk area can be studied only in thin sections. Until now Jámbor-Kness (1988) presented the most complete faunal list (but with no illustrations) from different boreholes (among them from Recsk, Rm-28 and Rm-87, as well). She cites *Nummulites fabianii* (a reticulate form), *N. incrassatus, N. chavannesi, N. budensis, N. bouillei, N. variolarius, N.* aff. *anomalus* (all radiate forms), *Operculina alpina, Heterostegina reticulata, Spiroclypeus carpaticus, Pellatispira madaraszi, Discocyclina nummulitica, D. varians* and *D. sella*. This assemblage, according to her, indicates the early part of the Priabonian.

Our studies confirmed the majority of Jámbor-Kness' determinations. In the lower part of the nummulitic limestone, *Nummulites fabianii* with reticulate surface *(Plate 3, Figs. 1, 3)* and with 200–250 μm internal diameter of the proloculus (the first chamber, *Plate 3 Figs. 2, 4*) predominates in the assemblages. Radiate forms cannot be determined exactly, they are, however, most similar to *N. incrassatus (Plate 3, Fig. 5)*. They associate rarely with *Sphaerogypsina globula (Plate 1, Fig. 1)*. In the sandy limestone *Asterigerina (Plate 4, Fig. 7)* and red algae *(Plate 4, Fig. 8)* can also be found. The fossil assemblage of the upper, orthophragminid limestone is much diverse. *Assilina alpina (Plate 3, Figs. 6, 7)* is the only larger Foraminifera occurring in both parts. *Heterostegina reticulata (Plate 3, Fig. 8), Spiroclypeus carpaticus* (with a large proloculus exceeding 250 μm, *(Plate 4, Fig. 1), Pellatispira madaraszi (Plate 4, Fig. 2), Sphaerogypsina carteri (Plate 4, Fig. 6), Operculina gomezi (Plate 1, Fig. 5)* and different orthophragmines *(Plate 4, Figs. 4–6)* are characteristic for this association. The representatives of this latter group only can be determined in the specific level when the embryon is visible *(Plate 4, Fig. 4)*. Otherwise, only the presence of genus *Discocyclina (Plate 4, Fig. 6)* and *Asterocyclina (Plate 4, Fig. 5)* can be recognised.

Plate 3
Larger foraminifera from the Priabonian Szépvölgy Limestone underlying the Recsk andesite. 1–4. Nummulites fabianii (Prever). 5. Nummulites cf. incrassatus de la Harpe. 6, 7. Assilina alpina (Douvillé). 8. Heterostegina reticulata Rütimeyer.
1, 3, 5. Borehole Recsk, Rm-87 (505.0 m), E. 06.153. 2, 4, 7. Rm-28 (779.8 m), E. 06.154. 6, 8. Rm-28 (778.0 m), E. 06.155. All: oblique sections, ×20.


1
2
3
4
All: 1 mm
5
6
7
8

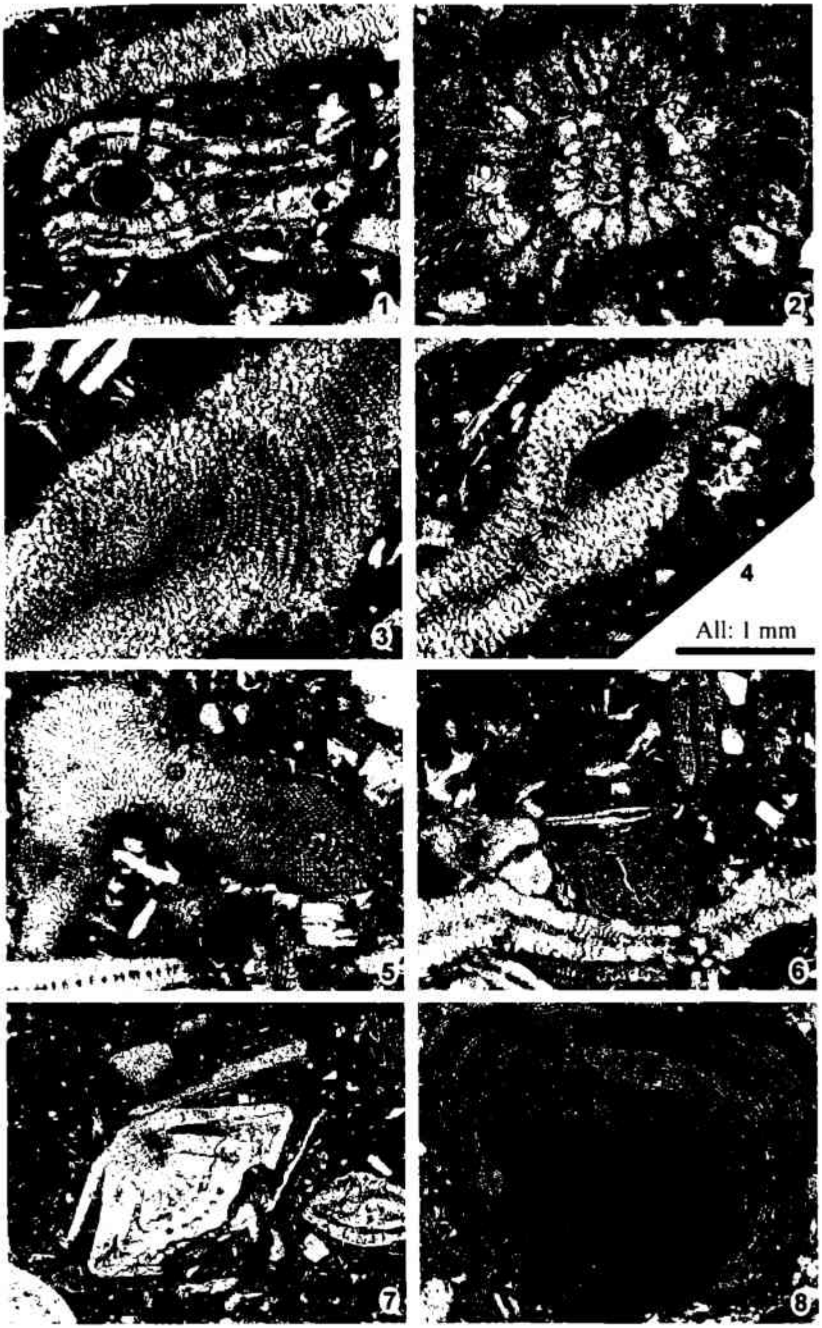
The age of the Szépvölgy Limestone is undoutedly Priabonian, since *Nummulites fabianii* and the genus *Spiroclypeus* first appeared only in this age (Serra-Kiel et al., 1998; Less et al., 2008) whilst all the orthophragmines became extinct at the very end of the Eocene (Less, 1998). Moreover, *Spiroclypeus carpaticus* is only characteristic for the upper part of the Priabonian (Less & Özcan, 2008) corresponding to the SBZ 20 shallow benthic zone of Serra-Kiel et al. (1998). This is also confirmed by the new calcareous nannoplankton age of the overlying Buda Marl, directly underlying the Recsk Andesite.

The list of the calcareous nannoplankton can be found in Table 1. Based on them, the age of the two samples from borehole Recsk, Rm-87 (496.5 and 488.1 m) only can be given as NP 16–21 (terminal Lutetian to earliest Rupelian). The relative abundance of *Lanternithus minutus* in the sample from borehole Rm-28 (775.0 m), however, allows supposing the short NP 21 zone that crosses the Eocene–Oligocene boundary. Unfortunately, no planktic foraminifera have been found in the Buda Marl.

3.2. Sedimentary intercalations in the andesite: new data and age

Until now no biostratigraphic data are known from the sedimentary intercalations. Our samples from boreholes Recsk, Rm-63 (63.0 m) and Rm-7 (324.5 m) turned out to be free of both the planktic foraminifera and the calcareous nannoplankton, however the latter could be found in the two samples (608.0 and 612.0 m, the list is shown in *Table 1*) of borehole Recsk, Rm-28. Based on the relative abundance of *Zygrhablithus bijugatus* and *Lanternithus minutus*, these assemblages indicate the short NP 21 zone, passing through the Eocene/Oligocene boundary. Since these sedimentary intercalations take place in the lower part of the Recsk Andesite (more than 400 m of magmatites can be found above them), this age can be considered only characteristic for this part of the andesite.

Plate 4
Larger foraminifera and red algae from the Priabonian Szépvölgy Limestone underlying the Recsk andesite.
1. Spiroclypeus carpaticus (Uhlig). 2. Pellatispira madaraszi (Hantken). 3. Discocyclina sp. B-form. 4. Discocyclina dispansa (Sowerby) cf. umbilicata (Deprat). 5. Asterocyclina sp. 6. Orthophragmina floatstone–rudstone with Discocyclina and Sphaerogypsina carteri (Silvestri). 7. Asterigerina sp. 8. Lithothamnium sp.
1–6. Borehole Recsk, Rm-28 (778.0 m), E. 06.155. 7. Rm-87 (505.0 m), E. 06.153. 8. Rm-79 (427.5 m), E. 06.156. All: oblique sections, ×20.


1
2
3
4
All: 1 mm
5
6
7
8

Relation to the andesite	Underlyer				Inter-calation		Overlyer		
Sample	Rm-87: 496.5 m	Rm-87: 488.1 m	Rm-28: 775.0 m	Rm-7: 750.0 m	Rm-28: 612.0 m	Rm-28: 608.0 m	Rm-7: 268.0 m	Rm-7: 220.0 m	Rm-117: 232.1 m
Taxon / **Age**	NP 16–21	NP 16–21	NP 21	NP 16–20	NP 21	NP 21	NP 24–25	NP 24	NP 24–25
Transversopontis pulcher (Deflandre)		1		1				1	
Discolithina multipora (Kamptner)			1	2			1	2	
D. latelliptica Báldi-Beke							4	2	
Helicosphaera bramlettei (Müller)							1		
H. compacta Bramlette et Wilcoxon								1	
H. euphratis Haq		1		1	1			1	
Zygrhablithus bijugatus (Deflandre)			1	1	3	3		1	
Lanternithus minutus Stradner		1	3		3	3			
Coccolithus pelagicus (Wallich)	2	3	2	2	3	3	1	2	1
C. eopelagicus (Bramlette et Riedel)		1		1					
Cyclococcolithus formosus Kamptner	1	2	1	1				1	
Cyclicargolithus floridanus (Roth et Hay)	2	3	1	3	3	3		3	1
C. abisectus (Müller)							1	1	
C. sp. [?*C. abisectus* (Müller)]									1
Reticulofenestra placomorpha (Kamptner)	1	2	1	1	1			1	
R. bisecta (Hay et al.)	2	3	3	2	3	3	2	3	2
R. lockeri Müller							3	2	
Discoaster saipanensis Bramlette et Riedel				1					
D. sp. ind.				1				1	
Braarudosphaera bigelowi (Gran et Braarud)	1	1	1	1				1	

Micrantholithus vesper Deflandre				1				1	
M. cf. *flos* Deflandre			1						
Sphenolithus pseudoradians Bramlette et Wilcoxon				1					
S. moriformis (Brönnimann et Stradner)		1	1		2			1	1
S. sp.	1	2							
Redeposited Cretaceous taxa								2	

Table 1 Distribution of calcareous nannoplankton from different samples in Recsk. Abundancy of specimens: 1: 1–2, 2: some, 3: few, 4: many.

3.3. Sediments overlying the andesite: new data and age

The presence of larger foraminifera in the tuffaceous, sandy limestone directly overlying the andesite (and also partly interfingering with its uppermost levels) is well known since Szabó (1869). The most well-known outcrop is located on the top of the Lahóca Hill where the superposition is unambiguous. Noszky (1927) mentions an other outcrop (where the superposition is also undoubtful) from the southern periphery of Mátraderecske. Unfortunately, this outcrop is lost. Two different and contradicting larger foraminiferal assemblages can be found in the literature. Noszky (1927) lists *Nummulina intermedia* (=*Nummulites fabianii* according to the recent nomenclature), *Operculina* cf. *granulosa*, *Orthophragmina patellaris* and *O.* sp. without illustrating them. Based on the presence of orthophragmines and *Nummulites fabianii*, this association cannot be younger than Priabonian (compare with Serra-Kiel et al., 1998). It is worth mentioning, however, that Noszky had no special skills on larger Foraminifera. Nevertheless, the Priabonian age of the sediments overlying the andesite (and consequently the same age of the andesite, itself) remained a governing idea among the Hungarian geologists (Pantó 1951, Szőts 1956, Majzon 1966, Zelenka 1975, Kecskeméti 1998) and affected very much the paleogeographic and tectonic reconstructions (see the list publications in the first paragraph of the Introduction).

On the other hand, Rozlozsnik (1939) writes: "I handed over the majority of fossils, collected by me in 1925, to Jenő Noszky, who published their determination in his monography [Noszky, 1927]. These fossils are, however, not age-markers, and based on them, these deposits can also be placed into the Oligocene. The nummulinas, collected by me, belong to a small, radiate, degenerate species, whose main [equatorial] section is already somewhat similar to that of the amphisteginas, but it resembles most of all to *N. budensis* described by Hantken from the Kiscell Clay. Moreover, since these deposits are directly overlain by the Kiscell Clay, I consider them lower Oligocene. Nevertheless, it differs e.g. from the upper Eocene limestone of the Southern Bükk [=Szépvölgy Limestone], in which *N. fabianii*, *N. incrassatus* and *N. chavannesi* can be found." It is worth mentioning that this author was one of the leading European *Nummulites*-experts of that time (Rozlozsnik 1927, 1929). Unfortunately, he did not gave any illustrations. The assemblage that Jámbor-Kness (1988) published from the sediments overlying the andesite (*Nummulites budensis*, *Operculina gomezi*, *Planoperculina* aff. *complanata*, *P. complanata heterostegina* – the only illustrated form) resembles rather to that of Rozlozsnik (1939) since she cites neither *Nummulites fabianii* nor orthophragmines. Based on this association she attributed a latest Eocene to earlist Oligocene age to these deposits. Jámbor-Kness (1988), however, did not present the exact location of her sites.

We have inspected the tuffaceous, sandy marl and limesone, directly overlying the andesite for larger foraminifera in several places, however only two of them

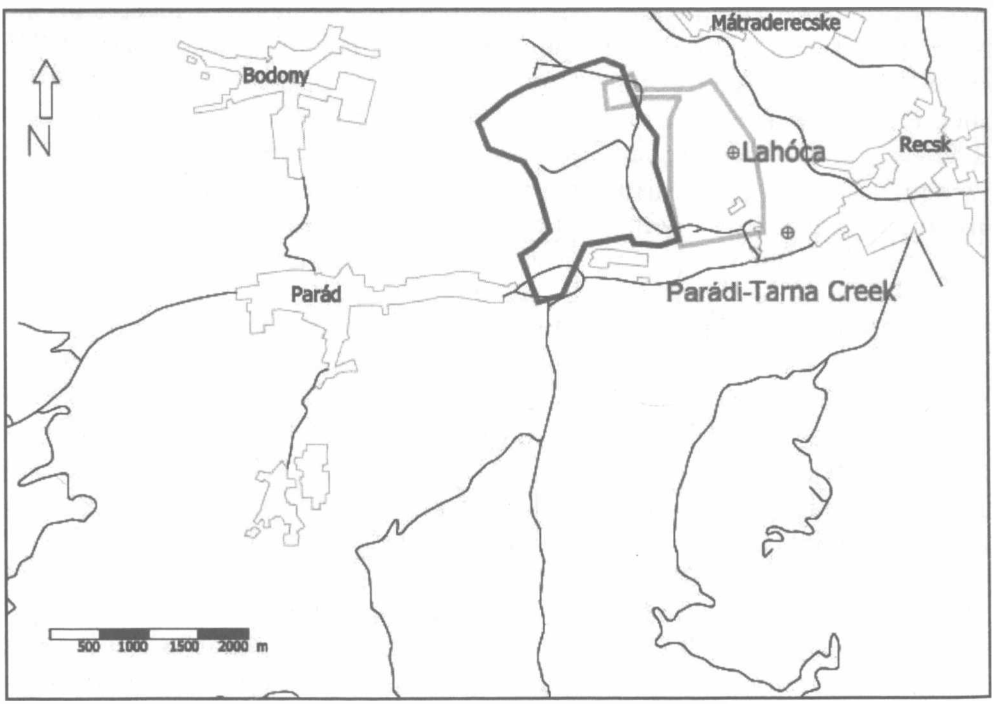


Fig. 1 Location map of outcrops of tuffaceous limestone with larger foraminifera directly overlying the andesite.

(shown in *Fig. 1*) proved to be positive in this respect. In the "classical" locality, on the top of the Lahóca Hill, rather hard, tuffaceous, red algal limestone is present, in which larger Foraminifera are seldom in general. In places, however, they are recognisable and have been studied in thin sections. The microfacies and some red algae of this rock are shown in *Plate 2, Figs. 1–4*. The other outcrop is located at the almost vertical bank of the Parádi-Tarna creek *(Fig. 2)* where the rock is a more sandy, free of red algae and a little bit less hard, and therefore, isolated specimens of larger Foraminifera could be extracted from it. Although the facies of the rock in the two sites are remarkably different, the specific composition of larger foraminiferal fauna proved to be almost identical, the proportion of the different components are, however, slightly different. In general, the preservation of the fauna is of medium quality.

In both localities, the vast majority (95–99%) of larger foraminifera is represented by the "degenerate" *Nummulites*, determined by Rozlozsnik (1939) and Jámbor-Kness (1988) as *N. budensis*, and by the operculinids mentioned by the latter author. *Neorotalia* sp. *(Plate 2, Fig. 2)* can be found in some thin sections

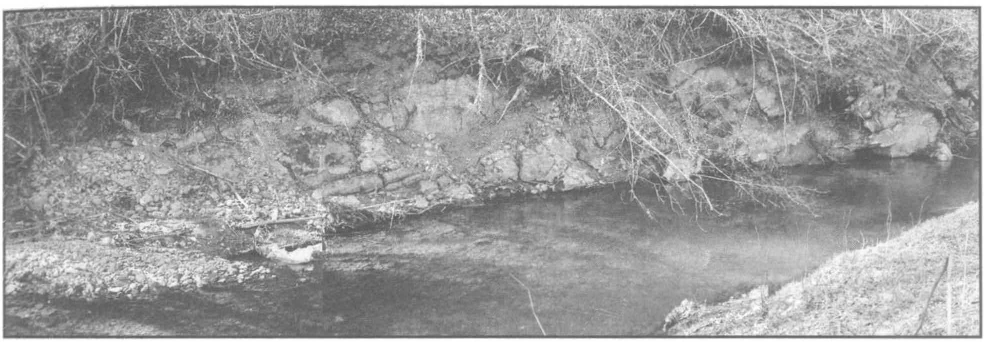


Fig. 2 Outcrop of tuffaceous sandy marl directly overlying the Recsk andesite in the Parádi-Tarna Creek.

from the top of the Lahóca Hill. Lepidocyclinids are, unfortunately, extremely rare in the Parádi-Tarna Creek outcrop: we could collect a few specimens only during our first visit, but could not repeat it later. These fossils, however, could be recognised in a little bit greater quantity in the thin sections of the rocks collected from the top of the Lahóca Hill. Since they play a key-role in our age-revision we start our review with them.

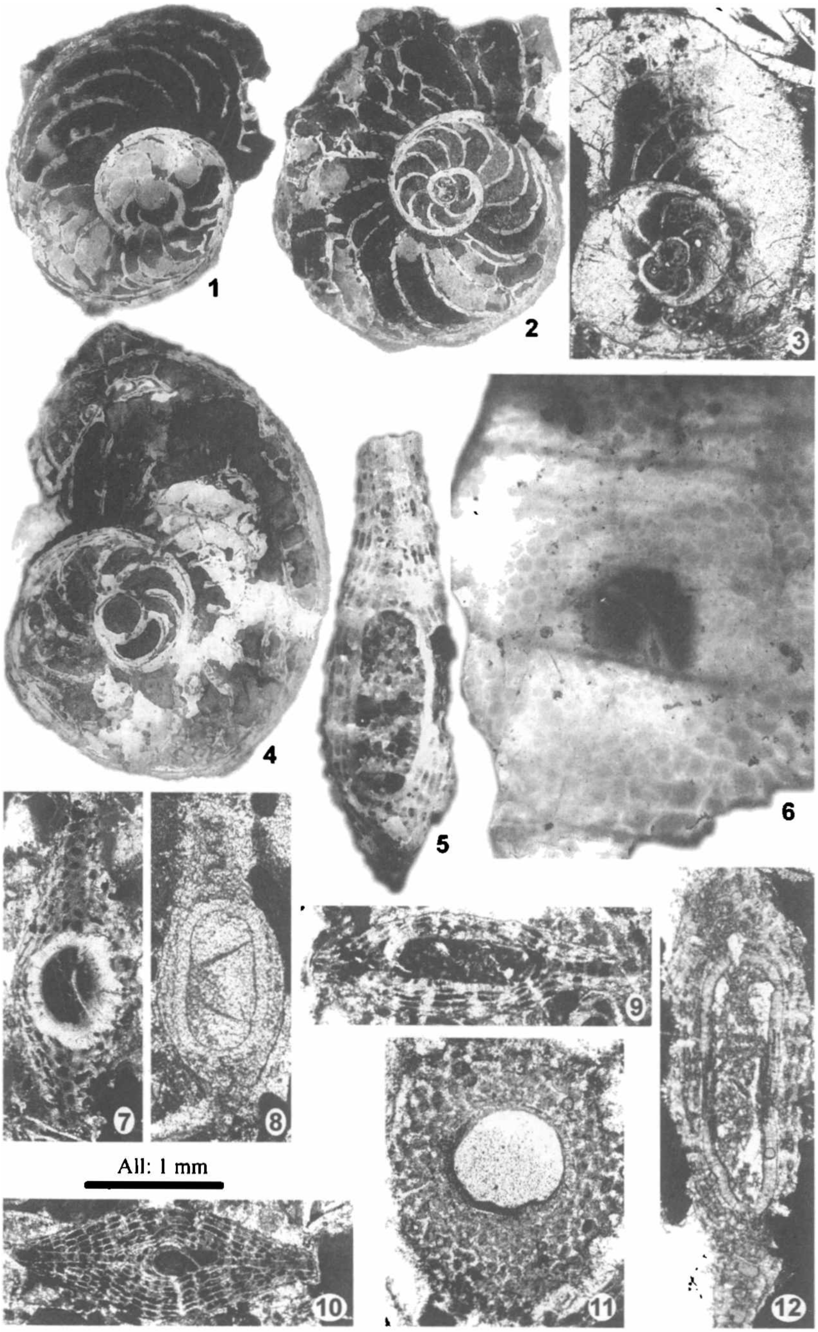
Although lepidocyclinidis are extremely seldom, both their European representatives are present in the tuffaceous carbonates. We have found genus *Eulep-*

idina (Plate 5, Figs. 5–9, 11, 12) both in the Parádi-Tarna Creek and the Lahóca Hill outcrop whereas *Nephrolepidina (Plate 5, Fig. 10)* is present only in the latter. The only equatorial section of *Eulepidina (Plate 5, Fig. 6)* clearly shows the spatulate equatorial chamberlets, while in the other sections the characteristic thick wall of the deuteroconch (the second chamber) is well visible. These two features make the generic identification of *Eulepidina* unambiguous. The only section of *Nephrolepidina* that crosses the embryon *(Plate 5, Fig. 10)* demonstrates the single-layered equatorial layer and also the relatively small embryon distinguishing this genus from *Eulepidina*. The lack of well-oriented sections hampers the specific identification. In the case of genus *Nephrolepidina* it is also impossible because of the very low number of specimens. Although most of the sections of *Eulepidina* do not cross the deuteroconch at its greater diameter, we can assume that its mean value should be around 1200–1300 μm. Özcan et al. (in review) proposed to place the biometric limit of *Eulepidina formosoides* (characteristic for the late Rupelian SBZ 22A shallow benthic zone of Cahuzac et Poignant, 1997) and *E. dilatata* (indicating the Chattian SBZ 22B and 23 zones) at 1250 μm. Thus, the *Eulepidina* stock of the tuffaceous carbonates overlying the andesite can be determined as *E.* cf. *formosoides–dilatata*.

The "degenerate" *Nummulites (Plate 6, Figs. 1, 2, 4–6)* can be found in great quantity in the Parádi-Tarna Creek outcrop and they can be identified also in thin sections from the Lahóca Hill. They have a radiate surface; however it is hardly visible in most cases because of the sediment attached to the shells. Naturally exposed equatorial sections are common and they can be opened very easily also by pliers. We concentrate in this study on the megalospheric (A) forms, since they predominate, only two microspheric (B) forms have been found. The three similar "degenerate" *Nummulites* of the Priabonian to Chattian time-span (*N. budensis* in the late Priabonian, *N. bouillei* in the early Rupelian and *N. kecskemetii* in the Chattian, see Less 1999 and Özcan et al. in review) can be distinguished with great certainty by using biometry-based statistical methods. Based on Drooger et al. (1971) Less (1999) introduced a measurement and parameter system to char-

Plate 5

Larger foraminifera from the tuffaceous limestone directly overlying the Recsk andesite. 1–4. Operculina complanata Defrance, morphotype 2. 1. O. 06.45, 2. O. 06.44, 3. O. 06.46, 4. O. 06.43. 5–9, 11, 12. Eulepidina cf formosoides Douvillé–dilatata (Michelotti). 5. O. 06.34, 6. O. 06.33, 7, 9. O. 06.46, 8. O. 06.48, 11. O. 06.47, 12. O. 06.49. 10. Nephrolepidina sp., O. 06.46. All A-forms. 1, 2, 4, 6. equatorial sections, 3, 7–12. oblique sections, 5. axial section. 1, 2, 4–6. Recsk, Parádi-Tarna Creek, 3, 7–12. Recsk, top of the Lahóca Hill. All: ×20.


1
2
3
4
5
6
7
8
9
10
11
12
All: 1 mm

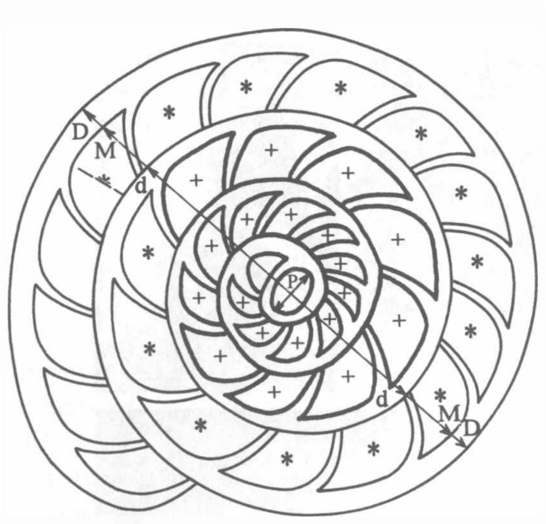
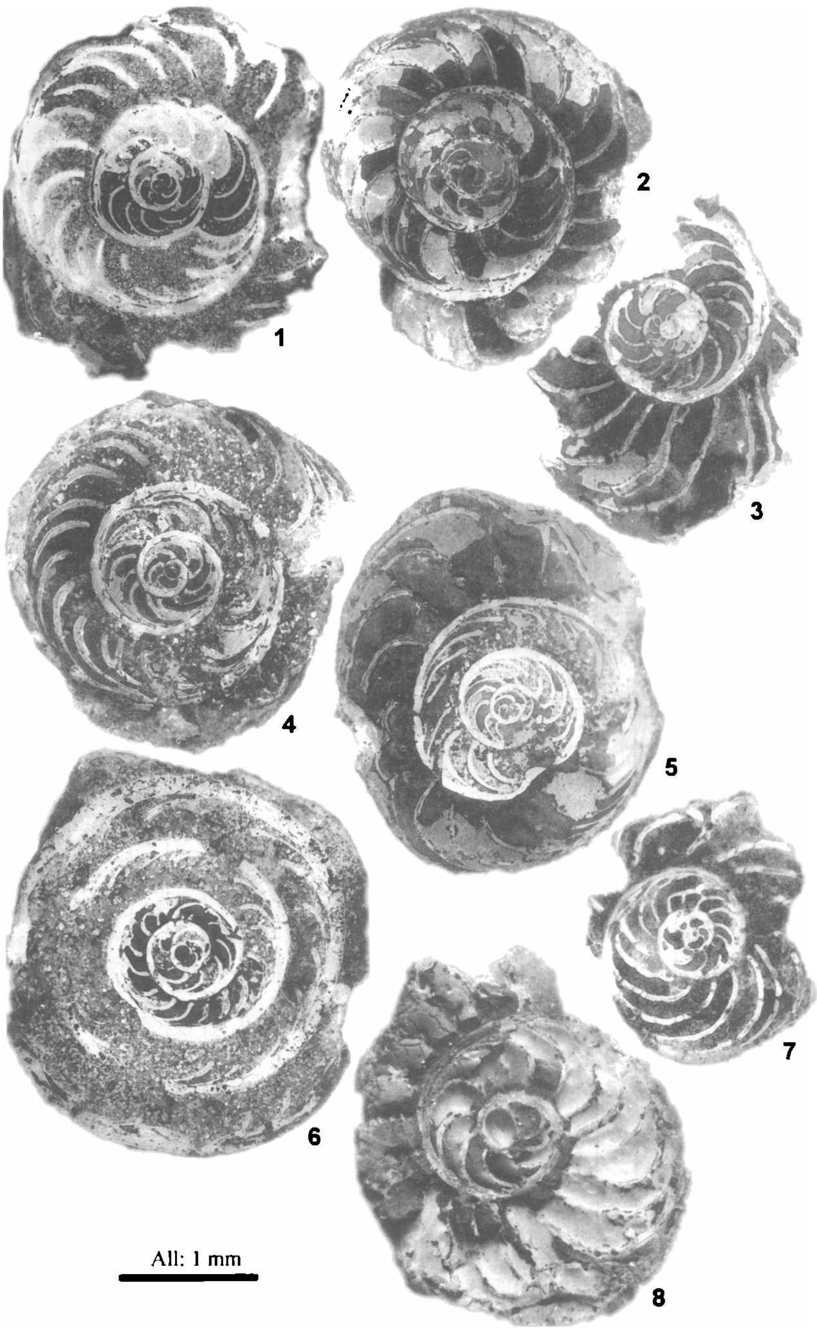


*Fig. 3 The measurement system of megalospheric Nummulites. D and M: outer and inner diameter of the third whorl; in this figure E=19 (marked by +), N (exact number of chambers in the third whorl, marked by *) = 13.6. Other parameters are explained in Table 2.*

acterize the equatorial section of A-forms that is slightly modified here *(Fig. 3)*. Seven parameters (explained in *Table 2*) are used to characterize the megalospheric specimens of *Nummulites* whose statistical evaluation is shown in *Table 2*. Biometric data of the populations of the three taxa mentioned above from different localities are plotted in *Fig. 4*, which clearly shows that the Recsk population of „degenerate" *Nummulites* belongs to *N. kecskemetii*.

The representatives of genus *Operculina* can also be found in great quantity in both localities. A-forms are also in great majority among them. Two morphotypes could be identified: one without secondary subdivisions of the chambers *(Plate 6, Figs. 3, 7, 8)*, and these can be easily identified with *Operculina complanata* (compare them with Less 1991 and Özcan et al. in review). The late chambers of the other morphotype *(Plate 5, Figs. 1–4)* are subdivided into chamberlets. The secondary septa can be both complete and incomplete, and the secondary chamberlets are characteristically irregular, similar to Hottinger's (1977) anasteginid type. These forms differ from *Operculina heterostegina* described by Less (1991, *Plate 3, Figs. 5, 6; Plate 4, Figs. 1–3)* as *Planoperculina heterostegina* whose secondary septa are always incomplete and the secondary chamberlets are regular. Biometric data presented in *Table 3* confirm the present statement, since the size of the proloculus (P) and the diameter of the first whorl (d) are practically

Plate 6
Larger foraminifera from the tuffaceous limestone directly overlying the Recsk andesite. 1, 2, 4–6. Nummulites kecskemetii Less. 1. O. 06.36, 2. 0.06.35, 4. O.06.37, 5. O. 06.38, 6. O. 06.39. 3, 7, 8. Operculina complanata Defrance, morphotype 1. 3. O. 06.42, 7. O. 06.40, 8. O.06.41. 3. B-form, all the others are A-forms. All: equatorial sections, Recsk, Parádi-Tarna Creek, ×20.


1
2
3
4
5
6
7
8
All: 1 mm

Parameters			№	mean ± s.e.	range
Inner cross-diameter of the proloculus		P (mm)	38	86,50 ± 2,04	55 – 110
Outer diameter of the first two whorls		d (mm)	37	1157 ± 34,0	760 – 1560
Number of post-embryonic chambers in the first two whorls		E	37	20,24 ± 0,27	16 – 24
Index of spiral opening (third whorl vs. first three whorls)		K=100×(D−d)/(D−P)	25	46,90 ± 1,26	35,9 – 60,0
Third whorl	average length of chambers	L=d×p/N (mm)	24	187,03 ± 6,14	136 – 243
	average shape of chambers	F=100×(D−d)/(D−d+2d×p/N)	24	70,49 ± 1,17	60,3 – 84,4
	relative width of the spiral cord	m=100×(D−M)/(D−d)	25	16,46 ± 1,18	7,7 – 28,1

Table 2 Statistical data of the Nummulites kecskemetii population from Recsk, Parádi-Tarna Creek. s.e.: standard error.

Parameters	Inner cross-diameter of the proloculus			Outer diameter of the first whorl			Number of post-embryonic pre-heterosteginid chambers					
	P (μm)			d (μm)			X			K = 100 × (D-d)/(D-P)		
	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.	№	range	mean ± s.e.
Morphotype 1	25	90 – 355	209,2 ± 11,7	25	555 – 1740	1246 ± 63				5	44,4 – 59,8	51,3 ± 2,3
Morphotype 2	18	150 – 265	210,0 ± 8,8	18	930 – 2060	1298 ± 63	17	6 – 16	10,71 ± 0,73	47	35,9 – 61,5	49,5 ± 1,0
Morphotype 1+2	43	90 – 355	209,5 ± 7,7	43	555 – 2060	1273 ± 45	17	6 – 16	10,71 ± 0,73	5	36,7 – 54,9	46,3 ± 2,7

Table 3 Statistical data of the Operculina complanata population from Recsk, Parádi-Tarna Creek. s.e.: standard error.

identical for the two morphotypes. Thus, both they represent *Operculina complanata*.

The age of the tuffaceous carbonates directly overlying the andesite is unambiguously Oligocene since all the forms discussed above are only characteristic for this age. According to Cahuzac & Poignant (1997) *Operculina complanata* is characteristic for the whole range of this epoch. Based on the lepidocyclinids, the early Rupelian can also surely be excluded since they are known in Europe only from the beginning of the late Rupelian SBZ 22A shallow benthic zone of Cahuzac & Poignant (1997). Based on our new data from the W Taurids in SW Turkey (Özcan et al., in review), the stratigraphic range of *Nummulites kecskemetii* covers the whole Chattian, since in one locality (Dazkırı A7) it co-occurs with *Nummulites bormidiensis*, the end-member of the reticulate *N. fabianii* evolutionary lineage and also with *Nephrolepidina praemarginata* and with a less advanced *Eulepidina dilatata*. Although it is difficult to exactly determine the lepidocyclinids from Recsk (because of their very small quantity), however they seem to be rather less advanced as well, and it is rather unlikely that they come from the higher part of the Chattian. Thus, larger foraminifera suggest the early Chattian SBZ 22B shallow benthic zone of Cahuzac & Poignant (1997) for the tuffaceous carbonates of Recsk directly overlying the andesite. Taking also into account that the age of the overlying Kiscell Clay is still not younger than early Chattian (see below), the earliest Chattian seems to be the most reliable age for these rocks. It also means that they no longer can be called as Szépvölgy Limestone (of Priabonian age), but the name of the Csókás Formation of Chattian age (Less 1991, 1999, Báldi et al. 1999) from the Bükk Mountains and containing a similar larger foraminiferal association should be applied for them.

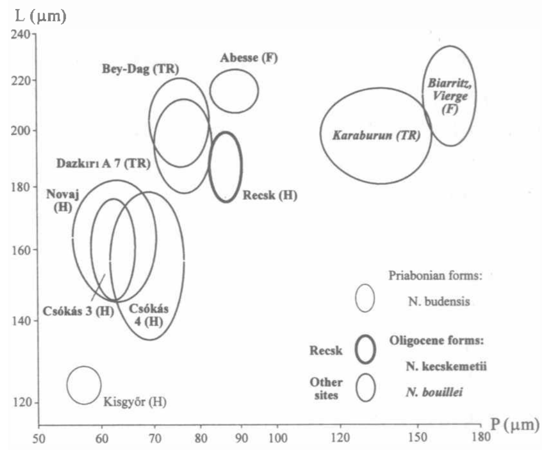


Fig. 4 Distribution of populations of the Nummulites bouillei-group (mean values at the 95% confidence level) on the P–L (proloculus diameter vs. chamber length in the third whorl, both scales are logarithmic) bivariate plot. Data for Kisgyőr are from Less (1999), those for Csókás 3, 4 and Novaj are from Less (1991), for Turkey from Özcan et al. (in review) while for Abesse (France) unpublished data by Less are used

The age of the Kiscell Clay, overlying the tuffaceous carbonates but still containing rare tuffaceous intercalations in their basal layers can be well determined by calacareous nannoplankton (some of them are figured in *Plate 3*). According to Báldi (1983, 1986) its major part belongs to the NP 24 zone. Our new results (see *Table 1*) from samples of borehole Recsk, Rm-7 (222.0 and 268.0 m) and Rm-117 (232.1 m) confirm this determination since *Cyclicargolithus abisectus* first appears at the base of this zone whereas *Helicosphaera compacta* last appears at its top. According to Berggren et al. (1995) the NP 24 zone characterizes the late Rupelian to early Chattian time span. Unfortunately our samples turned out to be free of planktic foraminifera.

4. RADIOMETRIC DATA FROM THE ANDESITE

Radiometric age data from the andesites are analysed in detail in Földessy et al., (2008). Here we only list those ones that can be considered relevant for the age of the andesitic stratovolcano and its postvolcanic activity:

Borehole Recsk, R-307, 108.7 m	33.5±2.3 Ma and 34.9±4.9 Ma
"Háromhányás" outcrop	31.4±1.4 Ma
Borehole Recsk, Rm-16, 1019–1020 m	29.7±2.2 Ma
Borehole Recsk, Rm-36, 887–890 m	29.6±1.6 Ma, 27.5±3.4 Ma and 25.6±2.5 Ma
Borehole Recsk, R-424, 149 m	28.40±0.91 Ma and 27.29±0.89 Ma
"Timsós" outcrop	27.92±0.75 Ma and 27.84±0.67 Ma
Borehole Recsk, Rm-16, 924–926 m	24.5±2.2 Ma

These data can be grouped into two clusters with some reservations. Older ages (31–37 Ma), corresponding to the Priabonian and early Rupelian are indicated from borehole R-307 and the "Háromhányás" outcrop, whereas other data (with the exception of the last age listed) indicate rather late Rupelian and early Chattian (27–30 Ma). The last record form borehole Rm-16 (924–926 m) is linked most probably with the postvolcanic activity.

5. PYROCLASTICS IN THE PALEOGENE SEDIMENTS OF NE HUNGARY

In order to encounter the age of the Recsk andesite, itself – beside the biostratigraphic and radiometric data presented above – we also have to take into consideration the presence or absence of pyroclastic material in the Paleogene sediments of the surrounding areas in the Mátra and Bükk Mountains. We cannot be sure that all of the tuffitic intercalations can be connected with the activity of the Recsk volcano. We have no knowledge, however, about any other volcanic centre in the close neighbourhood. Thus, most of these pyroclastic intercalations can reasonably be linked with the volcanic activity in Recsk.

The Szépvölgy Limestone of Priabonian age does not contain any pyroclastics either in the boreholes of Bükkszék, about 10 km to the NE of Recsk (Báldi 1983) or in the Bükk Mountains (Less 1999, Less et al. 2005a).

Báldi (1983, 1986) reports the first tuffitic intercalations in the Buda Marl from the boreholes of Bükkszék and Fedémes (about 5 km further to the N of Bükkszék) where reworked andesitic, quartzitic-sandy tuffs are interlayered. The age of the Buda Marl in the Buda Hill is the late Priabonian NP 19/20 calcareous nannoplankton zone (Báldi-Beke 1977), however in the Bükk Mts. the drowning of the Priabonian carbonate platform seems to have happened somewhat later, at about the Eocene/Oligocene boundary (Less 1999, Less et al. 2005a) and the sedimentation of the pelagic Buda Marl started only in the very beginning of the Oligocene. Since the territory of Bükkszék and Fedémes occupies an intermediate position between the Buda and Bükk Mts., the Buda Marl found in the boreholes can be placed both to the topmost Priabonian and the lowermost Rupelian.

Tuff intercalations in the form of laminae up to several cm thickness are common and characteristic in the deeper half of the overlying, euxinic Tard Clay not only in the area of Bükkszék–Fedémes and the S Bükk but also in the Buda Hills (Báldi 1983, 1986). The Tard Clay is considered as the mother rock for the NE Hungarian oil deposits (Demjén, Mezőkeresztes). The tuffs are of andesitic origin and deposited on the sea bottom after aerial transport without any reworking in the sea. Based on Báldi-Beke (1977) the lower horizon of the Tard Clay belongs to the early Rupelian NP 21–22 calcareous nannoplankton zones in the Buda Mts. whereas the middle and upper horizons have been correlated with the middle Rupelian NP 23 zone. In the Central Paratethyan subdivision the age of the Tard Clay corresponds to the early part of the Kiscellian. The volcanic signal in the NP 22 zone also can be found in the NE foot of the Bükk Mts. in borehole Varbó, V-75, where smectite of volcanic tuff origin could be found in the Kiscell Clay substituting here the Tard Clay of the more western territories (Less et al., 2005a).

The Kiscell Clay characteristic for the major territory of NE Hungary (excepting the NE foot of the Bükk Mts.) belongs to the NP 24 calcareous nannoplankton zone of the late Rupelian and early Chattian corresponding to the late Kiscellian in the Central Paratethyan subdivision (Báldi et al. 1999). Tuffs of andesitic and dacitic origin are limited to the lowermost and uppermost parts of the Kiscell Clay and restricted areally to the Mátra and Bükk Mts. The upper, sometimes 20–30 m thick tuffaceous layers are often bentonitised around Eger (the SW foot of the Bükk Mts., about 25 km to the E of Recsk). A good outcrop of these pyroclastics from Bükkszék is also figured in Báldi (1983, 1986).

The major part of the overlying Eger Formation (in the Bükk Mts.) corresponding to the middle and late Chattian and also to the early and middle Egerian in the Central Paratethyan subdivision (based on the calcareous nannoplankton belonging to the NP 25 zone) does not contain tuffitic intercalations. This is valid also for the Szécsény Schlier of the same age in the vicinity of Recsk, Bükkszék and Fedémes on the NE foot of the Mátra Mts. The basal part of the Eger Formation (the so-called Noszvaj Member), however, is built up of glauconitic, tuffaceous sandstone that contains a one meter thick intercalation of red algal limestone and *Lepidocyclina* marl directly covered by another one meter thick larger foraminiferal clay. Less (1991, 1999) studied the larger Foraminifera in Novaj, Nyárjas-tető and arranged them into the base of the middle–late Chattian SBZ 23 shallow benthic zone of Cahuzac& Poignant (1997).

Fresh biotite crystals having originated from contemporaneous dacitic tuffs can also be found in the basal layers of the Csókás Formation in the NE part of the Bükk Mts. These rocks consist of a rich larger foraminiferal fauna (Less 1991, 1999), somewhat younger than that in Recsk but a little bit older than in Novaj, but still characterising the base of the SBZ 23 zone. The Csókás Formation at its type locality lies directly on metamorphosed Triassic carbonates, its sedimentary cover has been eroded.

6. THE AGE OF THE RECSK ANDESITE

By summarising all the biostratigraphic and radiometric data and also the location of the pyroclastic intercalations in the neighbouring territories, the beginning of the activity of the Recsk volcano can be placed to about the Eocene/Oligocene boundary at about 34 Ma. This is confirmed by the age of both the directly underlying and the intercalating Buda Marl (the NP 21 calcareous nannoplankton zone), by the older group of the relevant radiometric ages (31–37 Ma) and by the first tuffaceous intercalations in the Buda Marl.

Several volcanic cycles have to be supposed during the Rupelian since numerous tuffaceous intercalations can be found in the sedimentary rocks of this age in the neighbouring territories. The oil and bituminous indications in the andesite may have been originated from the euxinic sediments of the later Tard Clay. Very heavy explosions are assumed during the second half of the time of sedimentation of the Kiscell Clay falling to about the Rupelian/Chattian boundary since the thickest tuffitic intercalations can be found in the upper part of these deposits. Also, the younger group of the relevant radiometric ages (27–30 Ma) is concentrated around this date.

The volcanic activity gradually decreased during the first one-third of the Chattian as reflected in the age of the sediments directly overlying the andesite and in the location of the presumably corresponding tuffs in the adequate sediments.

To sum up: The polycyclic volcanic activity in Recsk lasted about 7 million years and seems to have been extending during the first two-third of the Oligocene from about 34 to 27 Ma. This interval covers practically the whole duration of the Kiscellian in the Central Paratethyan subdivision corresponding to the whole Rupelian and also to the first one-third of the Chattian.

Acknowledgements

This paper has been supported by the National Scientific Research Fund of Hungary (OTKA, Grants № T 032370, 037619 and K 60645). We are grateful to Szabolcs Tóth (Recsk), who showed us several localities of tuffaceous sediments directly overlying the andesite, and also to Sándor Kovács (Budapest) for some very useful suggestions.

References

Baksa, Cs. (1975): The subvolcanic body of Recsk (in Hungarian with English summary). ***Földtani Közlöny***, 105 (suppl.), 612–624

Baksa, Cs., Csillag, J., Földessy, J. (1974): Volcanic formations of the NE-Mátra mountains. ***Acta Geologica Acad. Sci. Hung.*** 18, 387–400

Báldi, T. (1983): Magyarországi oligocén és alsómiocén formációk (The Oligocene and Lower Miocene formations of Hungary). ***Akadémiai Kiadó***, Budapest, 293

Báldi, T. (1986): Mid-Tertiary stratigraphy and paleogeographic evolution of Hungary. ***Akadémiai Kiadó***, Budapest, 201

Báldi, T., Less Gy. & Mandic, O. (1999): Some new aspects of the lower boundary of the stage Egerian (Oligocene, chronostratigraphic scale of the Paratethys area). ***Abhandlungen des Geologisches Bundesanstalt***, 56, 2, "Geologie ohne Grenzen - Festschrift 150 Jahre Geologische Bundesanstalt", 653-668

Báldi-Beke, M. (1977): A budai oligocén rétegtani és fáciestani tagolódása nannoplankton alapján [Stratigraphical and faciological subdivisions of the Oligocene of Buda Mountains based on nannoplankton]. ***Földtani Közlöny*** 107 (1), 59–89

BÁLDI-BEKE, M. & BÁLDI, T. (1991): Palaeobathymetry and palaeogeography of the Bakony Eocene Basin in western Hungary. *Palaeogeography, Palaeoclimatology, Palaeoecology* 88, 25–52.

BALOGH, K. (1985): K/Ar dates of some Hungarian Late Eocene-Early Oligocene samples. *Discussiones Palaeontologicae* 31, 49–51

BENEDEK, K. (2002): Paleogene igneous activity along the easternmost segment of the Periadriatic-Balaton Lineament. *Acta Geologica Hungarica*, 45/4, 359–371

BERGGREN, W.A., KENT, D.V., SWISHER, C.C., AUBRY, M.P. (1995): A revised Cenozoic geochronology and chronostratigraphy, In: Berggren, W.A., Kent, D.V., Aubry, M. P., Hardenbol, J. (Eds), Geochronology, time scales and global correlation: an unified temporal framework for an historical Geology. *SEPM (Society of Economic Paleontologists and Mineralogists) Special Publication*, 129–212

CAHUZAC, B., POIGNANT, A. (1997): Essai de biozonation de l'Oligo-Miocène dans les bassins européens à l'aide des grands foraminifères néritiques. *Bulletin de la Société géologique de France*, 168, 155–169

DROOGER, C.W., MARKS, P., PAPP, A. (1971): Smaller radiate *Nummulites* of northwestern Europe. *Utrecht Micropaleontological Bulletins*, 5, 137

FÖLDESSY J. (1975): The stratovolcanic andesite formation of Recsk (in Hungarian with English summary). *Földtani Közlöny* 105 (suppl.), 625–645

FÖLDESSY J., LESS GY., ZELENKA T. & SERESNÉ HARTAI É. (2006): A recski (ÉK-Magyarország) paleogén vulkáni-üledékes összlet fejlődéstörténeti vázlata. VIII. Bányászati–kohászati és földtani konferencia, Sepsiszentgyörgy, 2006. április 6–9., 139–144. *Erdélyi Magyar Műszaki Tudományos társaság*, Kolozsvár (Cluj-Napoca)

FÖLDESSY J., ZELENKA T., BENEDEK K., PÉCSKAY Z., MÁDAI F. (2008): The Recsk Paleogene magmatism in a regional context. *In this volume*

HORVÁTH M. (1985): The foraminifera of the type sections of Novaj and Eger. *Ann. Univ. Sci. Budapest R. Eötvös Nom. Sect. Geol.*, 25, 9–32

HOTTINGER, L. (1977): Foraminifères Operculiniformes. *Mémoires du Muséum National d'Histoire Naturelle*, 57, 1-159

JÁMBOR-KNESS, M. (1988): Les grands Foraminifères éocènes de la Hongrie. Geologica Hungarica series Palaeontologica, 52, 629

KÁZMÉR, M., DUNKL, I., FRISCH, W., KUHLEMANN, J., OZSVÁRT, P. (2003): The Palaeogene forearc basin of the Eastern Alps and Western Carpathians: subduction erosion and basin evolution. Journal of the Geological Society, London, 160, 413–428

KECSKEMÉTI, T. (1998): Magyarország epikontinentális eocén képződményeinek rétegtana. In: Bérczi I. & Jámbor Á. (eds.).: Magyarország geológiai képződményeinek rétegtana. *Magyar Olaj- és gázipari Rt. és Magyar Állami Földtani Intézet*, 403-417

KOVÁCS, I., CSONTOS, L., SZABÓ, CS., BALI, E., FALUS, GY., BENEDEK, K., ZAJACZ, Z. (2007): Paleogene–early Miocene igneous rocks and geodynamics of the Alpine-Carpathian-Pannonian-Dinaric region: An integrated approach. In: Beccaluva L., Bianchini G., Wilson M. (eds.) Cenozoic Volcanism in the Mediterranean Area. *Geological Society of America Special Paper*, 418, 93–112

KOVÁCS, S., HAAS, J., SZEBÉNYI, G., GULÁCSI, Z., JÓZSA, S., PELIKÁN, P., BAGOLY-ÁRGYELÁN, G., GÖRÖG, Á., OZSVÁRT, P., GECSE, ZS., SZABÓ, I. (2008): Permo-Mesozoic formations of the Recsk-Darnó Hill area: stratigraphy and structure of the Pre-Tertiary basement of the Paleogene Recsk orefield. *In this volume*

Less, Gy. (1991): Upper Oligocene larger Foraminifers of the Bükk Mountains (NE Hungary) [A Bükk-hegység felső-oligocén nagyforaminiferái]. A Magyar Állami Földtani Intézet Évi Jelentése, 1989, 411-465

Less, Gy. (1998): The zonation of the Mediterranean Upper Paleocene and Eocene by Orthophragminae. *Opera Dela Slovenska Akademija Znanosti in Umetnosti* IV, 34 (2), 21-43

Less, Gy. (1999): The late Paleogene larger foraminiferal assemblages of the Bükk Mts. (NE Hungary). *Revista Española de Micropaleontología*, 31, 3, 51-60

Less, Gy., Kovács, S., Pelikán, P. (ed.), Pentelényi L. & Sásdi L. (2005a): A Bükk hegység földtana [Geology of the Bükk Mountains]. 284 p., *Magyar Állami Földtani Intézet*, Budapest

Less, Gy., Báldiné Beke, M., Zelenka, T., Földessy, J., Kollányi, K. & Kertész, B. (2005b): A Recski Andezit korának revíziója. 8. Magyar Őslénytani Vándorgyűlés, Hátszeg–Őraljaboldogfalva, 2005. május 18-21, 17-18, *Magyarhoni Földtani Társulat Őslénytani-Rétegtani Szakosztálya*, Budapest

Less, Gy., Özcan, E., Papazzoni, C.A. & Stöckar, R. (2008): Middle to late Eocene evolution of *Heterostegina*, nummulitid Foraminifera, in the Western Tethys. *Acta Palaeontologica Polonica* (in press)

Less, Gy. & Gyalog L. (2004): Eocén (Eocene). In: Gyalog L. & Horváth I. (ed): A Velencei-hegység és a Balatonfő földtana [Geology of the Velence Hills and the Balatonfő], 80-86 [209-214], *Magyar Állami Földtani Intézet*, Budapest

Less, Gy. & Özcan, E. (2008): The late Eocene evolution of *Spiroclypeus*, nummulitid Foraminifera, in the Western Tethys. *Acta Palaeontologica Polonica* (in press)

Majzon, L. (1966): Foraminifera-vizsgálatok. *Akadémiai Kiadó*, Budapest, 939

Noszky, J. (1927): A Mátra-hegység geromorfológiai viszonyai. *A Debreceni Tisza István Tudományos Társulat Honismertető Bizottság Kiadványai 3*

Özcan, E, Less, Gy., Báldi-Beke, M., Kollányi, K. & Acar, F. (in review): Oligo-Miocene Foraminiferal Record (Miogypsinidae, Lepidocyclinidae and Nummulitidae) from the Western Taurides (SW Turkey): Biometry and Implications for the Regional Geology. *Journal of Asian Earth Sciences*

Pantó, G. (1951): A recski Lahóca felépítése és érce. *Földtani Közlöny*, 81 (4–6), 146–152

Rozlozsnik, P. (1927): Einleitung in das Studium der Nummulinen und Assilinen. *Mitt. Jb. kgl. ung. geol. Anstalt*, 26, 1-156

Rozlozsnik, P. (1929): Studien über Nummulinen. *Geologica Hungarica series Palaeontologica* 2, 164

Rozlozsnik, P. (1939): Geológiai tanulmányok a Mátra északi oldalán Parád, Recsk és Mátraballa községek között [Geologische Studien am Nordfusse des Mátra-Gebirges in der Umgebung der Gemeinden Parád, Recsk und Mátraderescke] (in Hungarian with German summary). *Magyar Állami Földtani Intézet Évi Jelentése* 1933-35 (2), 545–601

Serra-Kiel, J., Hottinger, L., Caus, E., Drobne, K., Ferrández C., Jauhri, A.K., Less Gy., Pavlovec, R., Pignatti, J.S., Samsó, J.M., Schaub, H., Sirel, E., Strougo, A., Tambareau, Y., Tosoquella, J. & Zakrevskaya, E. (1998): Larger Foraminiferal Biostratigraphy of the Tethyan Paleocene and Eocene. Bulletin de la Societé géologique de France, 169, 2, 281-299

Szabó, J. (1869): Heves- és külső Szolnok-megyék földtani leírása. *A magyar orvosok és természetvizsgálók munkálatai* 13

Szőts, E. (1956): Magyarország eocén (paelogén) képződményei [L'Eocène (Paléogène) de la Hongrie] *Geologica Hungarica series Geologica* 9, 318

TARI, G., BÁLDI, T. & BÁLDI-BEKE, M. (1993): Palaeogene retroarc flexural basin beneath the Neogene Pannonian Basin: a geodynamical model. *Tectonophysics*, 226, 433–455

VARGA, GY., CSILLAGNÉ TERPLÁNSZKY, E., FÉLEGYHÁZI, ZS. (1975): A Mátra hegység földtana. *A Magyar Állami Földtani Intézet Évkönyve* 62 (1), 575

VARRÓK, K. (1962): Recsk – Parádfürdő környékének földtani viszonyai. *A Magyar Állami Földtani Intézet Évi jelentése* 1959, 37–59

ZELENKA, T. (1975): Structural-igneous setting of the deep-seated bases metal ore deposit of Recsk (in Hungarian with English summary). *Földtani Közlöny*, 105. (suppl.) 582-597