ANNALES
UNIVERSITATIS SCIENTIARUM BUDAPESTINENSIS DE ROLANDO EÖTVÖS NOMINATAE

SECTIO GEOLOGICA

TOMUS XXVIII.

BUDAPEST
1988

ANNALES
UNIVERSITATIS SCIENTIARUM BUDAPESTINENSIS DE ROLANDO EÖTVÖS NOMINATAE

SECTIO GEOLOGICA

TOMUS XXVIII.

REDIGUNT
T. BÁLDI
B. GÉCZY
E. VÉGH – NEUBRANDT
M. MONOSTORI (TECHN. ED.)

BUDAPEST
1988

ANNALES
UNIVERSITATIS SCIENTIARUM BUDAPESTINENSIS DE ROLANDO EÖTVÖS NOMINATAE

SECTIO BIOLOGICA
incepit anno MCMLVII
SECTIO CHIMICA
incepit anno MCMLIX
SECTIO CLASSICA
incepit anno MCMLXXIV
SECTIO GEOGRAPHICA
incepit anno MCMLXVI
SECTIO GEOLOGICA
incepit anno MCMLVII
SECTIO HISTORICA
incepit anno MCMLVII
SECTIO IURIDICA
incepit anno MCMLIX
SECTIO LINGUISTICA
incepit anno MCMLXX
SECTIO MATHEMATICA
incepit anno MCMLVIII
SECTIO PEDAGOGICA ET PSYCHOLOGICA
incepit anno MCMLXX
SECTIO PHILOLOGICA HUNGARICA
incepit anno MCMLXX
SECTIO PHILOLOGICA MODERNA
incepit anno MCMLXX
SECTIO PHILOSOPHICA ET SOCIOLOGICA
incepit anno MCMLXII

THE POSITION OF THE PALEOGENE FORMATIONS OF HUNGARY IN THE STANDARD NANNOPLANKTON ZONATION

by

A. NAGYMAROSY

Eötvös University, Department of Geology, Budapest

M. BÁLDI-BEKE

Hungarian Geological Survey, Budapest

(Received: 30th May, 1987)

Abstract

This paper gives a comprehensive review of the nannoplankton stratigraphy in the Paleogene formations of Hungary. Each formation is shortly characterized, followed by the description of the nannofloras. Other important fossils and the basic biozones are mentioned, too. A list of references makes the descriptions complete.

The Paleogene formations of Hungary reach from the Middle Eocene until the top of the Oligocene. The earliest nannoplankton datum published so far is NP 14, Lutetian while the youngest one is NP 25, Egerian (Chattian).

Introduction

The publishing of this paper is motivated by the ascending curve of the development of nannoplankton stratigraphy in the last 30 years. The determination of the geological age using calcareous nannoplankton became one of the most widespread methods of paleontology. At the same way, this is probably the cheapest way too, demanding very few material and technical apparatus to the examinations. This method can be used first of all in the Cenozoic sediments of the oceanic and epicontinental realm. Its remarkable accuracy in the correlation with the radiometrical and magnetostratigraphical scales gives a prominent importance to the nannoplankton investigations not only among the experts of stratigraphy. The method is often used by other experts – sedimentologists, geophysicists, experts of tectonics – too.

The development mentioned above influenced also the research in Hungary, thus the bulk of the Tertiary formations has been dated with the help of the Standard Nannoplankton Zonation by the eighties of this century. This work has been more or less finished for the Paleogene formations, while a great part of the Neogene formations can be regarded as "terra incognita" from the point of view of nannoplankton. Of course the nannoplankton stratigraphy has yet a lot of to do in the field of refined and detailed stratigraphy, in Hungary.

We applied uniformly the Standard Nannoplankton Zonation of MARTINI (1971) to date the formations. This system was elaborated mainly for the epicontinental seas (this is fitting better to the paleogeography of the Pannonian realm, but we took into consideration the zone-defining-

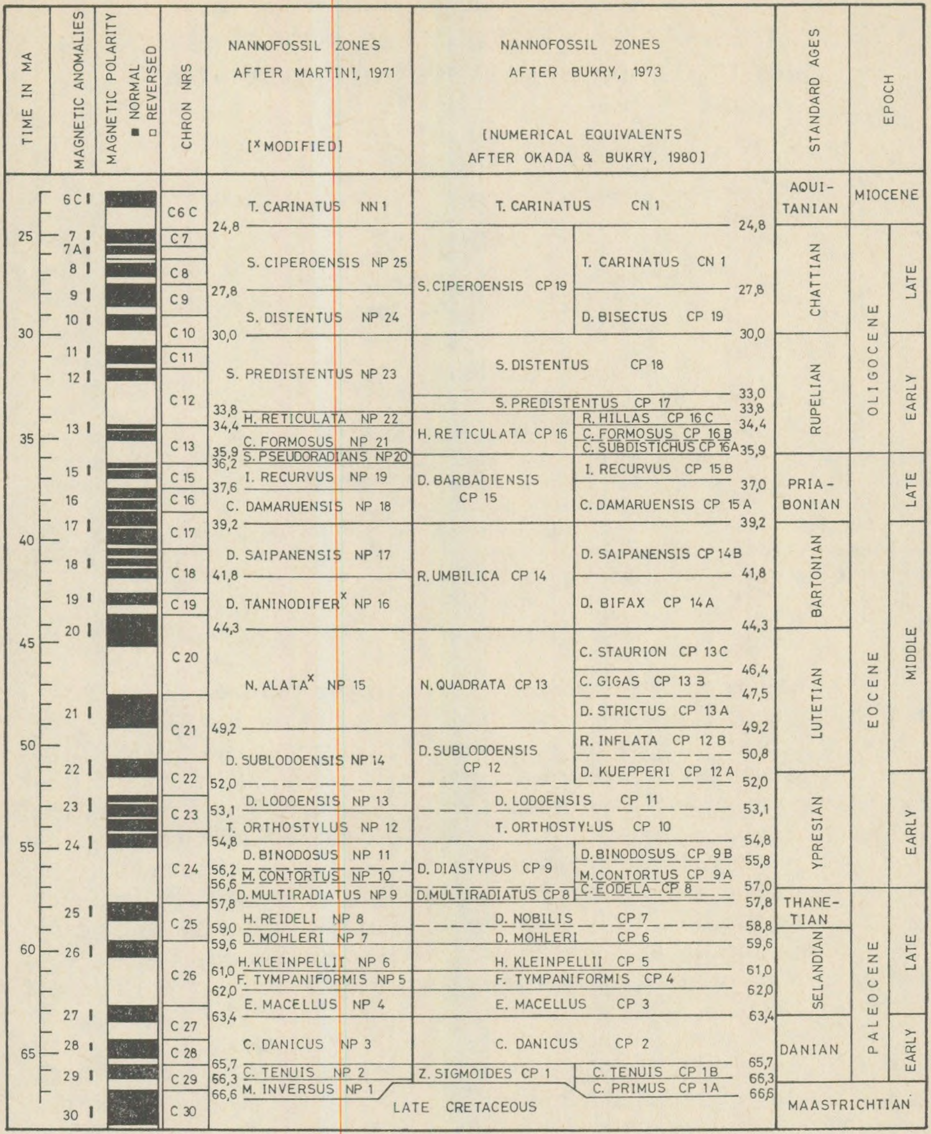


Fig. 1. Standard Nannoplankton Zonations for Paleogene (after HAQ, 1983).

events from the zonation of Okada and Bukry (1980) too, which was based first of all on the evolution of the nannoplankton in the oceans. The correlation of the two zonations is given in the figures 1 and 2. The stratigraphical position of the formations in the Standard Nannoplankton Zonations is shown in figure 3, together with the position of the stratotypes of some important Paleogene stages.

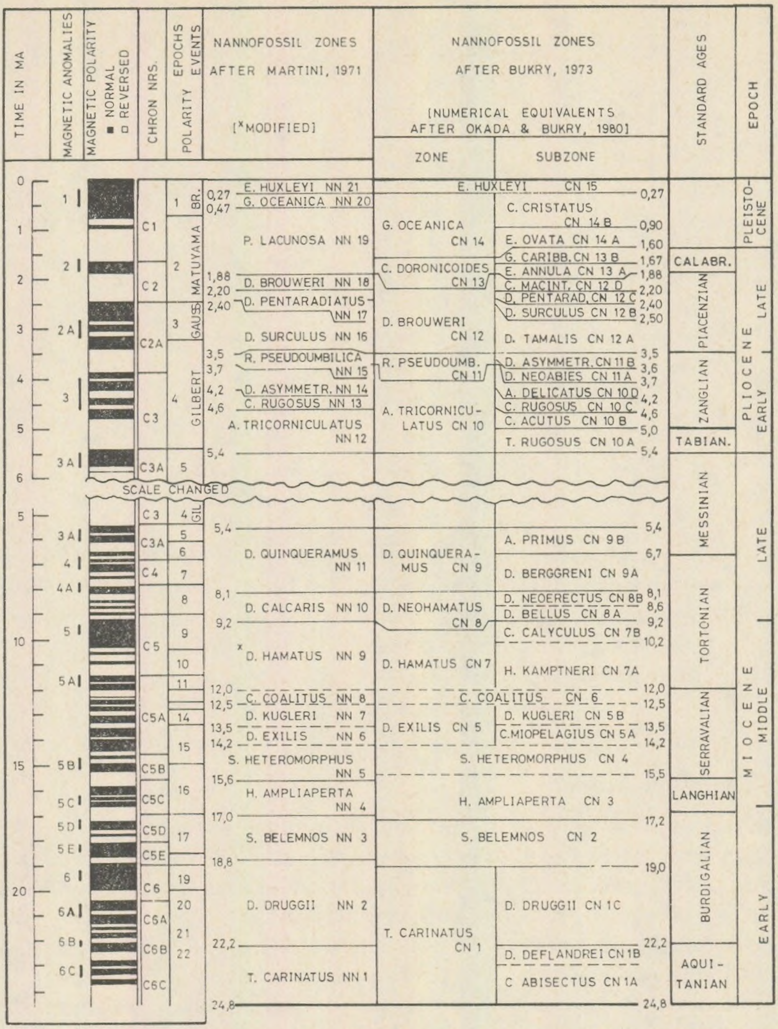


Fig. 2. Standard Nannoplankton Zonations for Neogene (after HAQ, 1983).

At the review of the formations we give a short description of their petrographical character and their areal occurence. After this, the most important nannoplankton species are listed and so the other important and characteristic fossils. Under the title "Biozonation" not only the determined nannoplankton zones will be reviewed, but also the biozones based on other fossil-groups. At the end of the description of the formation we give the references for the titles of the Lexique Stratigraphique International (L. S. I.), which contains the detailed description of the respective formations and also a detailed reference list. Discussing the Oligocene formations,

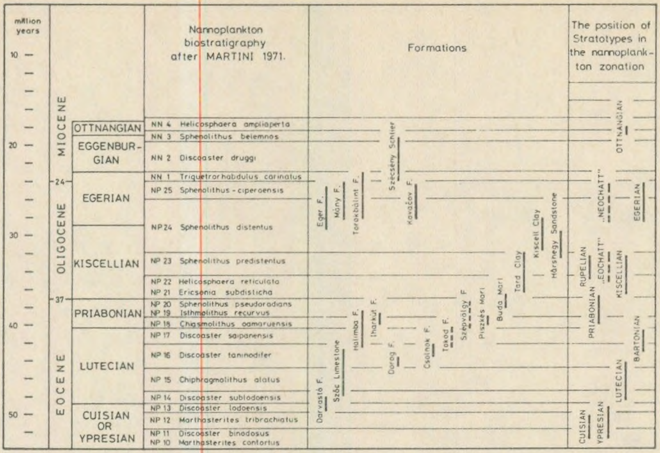


Fig. 3. The stratigraphic position of some formations of Hungary and some Paleogene stratotypes in the Standard Nannoplankton Zonation.

references are given to the modern, comprehensive monography of Báldi published in Hungarian (1983) and English (1986). The distribution of the Paleogene formations of Hungary in time and space is shown in the figures 4 and 5, which were compiled by the consideration of the report of the Hungarian National Committee of Stratigraphy, in 1985.

Eocene Formations

1. Darvastó Formation

The oldest, transgressional clastic sedimentary series in Transdanubia is the Darvastó Formation. It occurs only in the Southwestern Bakony, in a thickness of 25 meters (Dudich 1977, Dudich and Gidai 1980, Kecskeméti and Vörös 1975, Rákosi and Tóth 1980).

Nannoplankton: generally poor, the autochton forms are mixed with reworked Cretaceous forms. *Discoaster lodoensis* was identified in the Darvastó type section by Báldi–Beke (1971). In borehole sections Brokés (1978) found *Discoaster sublodoensis* and *Rhabdosphaera inflata,* too. Controlling the three zone markers in a number of sections, they occur in some boreholes together, while in others one or two of them are missing (Báldi–Beke 1983, 1984). The formation was placed within the zone NP 14, based on the overlapping ranges of the above mentioned three species.

Other fossils: palynomorphs (Rákosi and Tóth 1980), larger foraminifera: Kopek, Kecskeméti and Dudich (1965). Jámbor–Kness (1981) placed the formation within the Cuisian by *Alveolina oblonga* and *A. rütimeyeri.* Kecskeméti and Vörös (1975) by a new revision found *Alveolina stipes* and *Nummulites laevigatus* together, and this proves the Lutetian age of the formation. For brackish and marine molluscs see (Szőts 1956. p. 24.).

Biozonation: NP 14 (BÁLDI – BEKE 1984, BÁLDI – BEKE and KECSKEMÉTI 1983), *Nummulites laevigatus* assemblage zone (KECSKEMÉTI 1983).

References to L. S. I.:

Couches à *Alveolina oblonga* p. 52.
Couches à *Cerithium baconicum* p. 136.
Calcaire *Alveolines et Miliolidés* p. 53.
Marne à *Miliolidés de Urkut* p. 524. (partly)

2. Szőc Limestone Formation

Sublittoral limestone with abundant larger foraminifera ("Hauptnummulitenkalk"). Its greatast thickness is 200 meters (DUDICH 1977, DUDICH and GIDAI 1980).

Nannoplankton: It is extremely rare because of the unfavorable facies, occurs only in the marly beds. In the lower portions of the formation occurs *Rhabdosphaera inflata* (NP 14) together with *Nummulites laevigatus*, in higher portions *Reticulofenestra placomorpha (=R. umbilica)* and *Pemma papillatum* (NP 16). Zone markers for NP 15 are missing, but the continuous sedimentation and the evolutionary trends having been observed in some placoliths *(Reticulofenestra placomorpha, R. bisecta)* marks the presence of this zone (BÁLDI – BEKE 1983, 1984).

Other fossils: Mainly larger foraminifera, *Nummulites laevigatus, Assilina spira, Nummulites perforatus* and *N. millecaput* (from the base to top) occur as dominant forms (KOPEK, KECSKEMÉTI and DUDICH 1965). KECSKEMÉTI (1983 and in BÁLDI – BEKE and KECSKEMÉTI 1983) placed the Szőc Formation within his new *Nummulites* assamblage-zones (from the base): *N. laevigatus* zone (upper part), *N. obesus* and *N. baconicus* zone, *N. lorioli* zone, *N. perforatus* zone and *N. millecaput* zone (lower part).

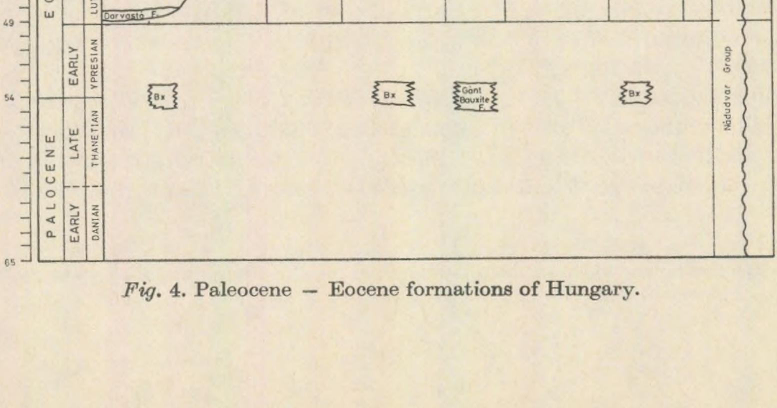


Fig. 4. Paleocene – Eocene formations of Hungary.

Biozonation: NP 14–15–16 (lower part) and the above mentioned *Nummulites* zones (KECSKEMÉTI 1983).

References to L. S. I.:

'Hauptnummulitenkalk" p. 241.
Couches à *Assilina spira* p. 69.
Calcaire à *Alvéolines et Miliolidés* p. 53. (partly)
Couches à *Nummulites laevigatus* p. 368.
Couches à *Nummulites millecaput* p. 370.
Couches à *Nummulites perforatus* p. 371.

3. Halimba Marl formation*

A) Halimba Formation in the SW part of the Bakony Mts

A marly series of pelagic origin in the southwestern Bakony. Its maximal thickness is 250 meters. It is glauconitic in its lower portion, (this was separated earlier as Csabrendek Formation), in the higher portions the tuffaceus intercalations are more frequent (DUDICH 1977, DUDICH and GIDAI 1980).

Nannoplankton: abundant, mainly placoliths, also *Discoasters* and *Sphenoliths* are rather common. Pentaliths, discoliths are extremly rare: this assamblage is an "oceanic type" (BÁLDI–BEKE 1984). In the Uppermost Middle Eocene the coccoliths are overcalcified ("robust *Zygolithus dubius* horizon' BÁLDI–BEKE 1971, BROKÉS 1978).

Zone markers for NP 16 to NP 19. *Reticulofenestra placomorpha*, *Pemma papillatum*, *Lanternithus minutus* from the base of the formation, NP 16. The NP 16/17 boundary is marked by the last occurence of *Chiasmolithus solitus* and *Sphenolithus furcatolithoides*, and by the first occurence of *Sphenolithus predistentus*. In the Upper Eocene portion *Chiasmolithus oamaruensis* (NP 18) and *Isthmolithus recurvus* (NP 19) make their first occurence (BÁLDI–BEKE 1971, 1983, 1984, BROKÉS 1978).

Other fossils: Larger foraminifera are poor, *Nummulites millecaput* (in the lower portion of the formation), *Discocyclina* and *Nummulites fabianii* (in the upper portion) (KECSKEMÉTI 1980, 1983).

The Upper Eocene larger foraminifera were transported from the littoral region to the deeper part of the basin by turbiditic currents in the uppermost part of the formation (BERNHARDT et al. 1985). Planktonic foraminifera are common: *Globorotalia lehneri*, *Truncorotaloides rohri*, *Globigerapsis mexicana* (TOUMARKINE 1971).

Biozonation: NP 16 to 19, *Globorotalia lehneri* to *Globigerinatheca semiinvoluta* zones of BOLLI (TOUMARKINE 1971, and K. HORVÁTH–KOLLÁNYI in BERNHARDT et al. 1985. and personal communication), *Nummulites millecaput* to *Nummulites fabianii* zones (KECSKEMÉTI 1983).

---

* The term "Halimba Formation" is required for the bauxites of the Bakony Mts. In consequence of this, the name is to be changed into "Padrag Formation (resolution of the Hungarian National Comittee of Stratigraphy).

References to L. S. I.:

Marne glauconieuse et tufacée de Bakony p. 77.

B) Halimba Formation in the northeastern part of the Bakony Mts (=earlier named as Mór Formation).

Silts and marls with calcareous sandstone and limestone-intercalations in the Northeastern Bakony (see DUDICH and GIDAI 1980, with the earlier used other names for the Formation: marl with foraminifera and molluscs, Porva marl, marl with *Hantkenina*, marl with *Vasconella*, Mór Formation).

Nannoplankton: common placoliths, holococcoliths, pentaliths, ecologically near-shore-type assemblage, but less typical than that of the Dorog Formation in the lower position. The facies upwards became more pelagic and the nannoplankton assemblage is without the typical near-shore forms (BÁLDI–BEKE 1984). Zone markers for NP 16 to NP 19 as listed from the Halimba Formation (BÁLDI–BEKE 1971, 1983, 1984, BROKÉS 1978). In the lowermost portion of the formation some specimens of *Reticulofenestra tokodensis* appear marking the presence of the same horizon in the same position, above the coal seams, as in the Dorog Formation (BÁLDI–BEKE 1982, 1983, 1984). In the latest Lutetian the coccoliths are commonly represented by overcalcified forms: robust *Zygolithus dubius* and *Discoaster* horizon by BÁLDI–BEKE 1971.

Other fossils: smaller foraminifera: common planktonic and benthonic forms, zone markers for *Globorotalia lehneri*, *Orbulinoides beckmanni*, *Truncorotaloides rohri* and *Globigerinatheca semiinvoluta* zones of BOLLI (SOLDAINI 1970, SAMUEL 1972, HORVÁTH–KOLLÁNYI 1983). HANTKEN 1875: lower portion of the *Clavulina szabói* beds – partly. Larger foraminifera: *Nummulites perforatus*, *N. striatus*, *N. millecaput*, *N. fabianii* (KECSKEMÉTI 1980, 1983, BÁLDI–BEKE and KECSKEMÉTI 1983), "Biarritzian" *Alveolina* species: *A. elongata*, *A. fusiformis*, *A. fragilis* (JÁMBOR–KNESS 1981). Rich mollusc assemblages (SZŐTS 1956, KECSKEMÉTI–KÖRMENDY 1980, KECSKEMÉTI–KÖRMENDY and M. MÉSZÁROS 1980), for the less typical shallow marine facies, see SZŐTS 1953 and STRAUSZ 1963.

Biozonation: NP 16 to NP 19 nannoplankton-zones, *Globorotalia lehneri* to *Globigerinatheca semiinvoluta* planktonic foraminifera zones (SOLDAINI 1970, SAMUEL 1972, HORVÁTH–KOLLÁNYI 1983), *Nummulites perforatus*, *N. millecaput* and *N. fabianii* zones (KECSKEMÉTI 1983).

References to L. S. I.:

Marne de Porva p. 419.

4. Dorog Formation (=earlier named as Tatabánya Formation)

Transgressive series with variegated clay in its lower portion, clays, marls and freshwater limestones with productive coal seams in the upper portion. DUDICH (1977) and DUDICH and GIDAI (1980) separated previously the Kisgyón Formation for the NE Bakony (Dudar, Balinka) and the Tatabánya Formation for the NE Transdanubia (Tatabánya, Pusztavám, Dorog). The name "Dorog Formation" was used by HANTKEN (1871, 1878) for the series with Eocene coal seams.

Nannoplankton: occurs only scattered. The zone markers for NP 16 were found even in the variegated clays: *Reticulofenestra placomorpha*, *Reticulofenestra bisecta* in their typical forms, from boreholes of both subareas (BÁLDI–BEKE 1983, 1984), and *Reticulofenestra placomorpha*, *Pemma papillatum*, *Lanternithus minutus* from the marly intercalations between the coal seams (BÁLDI–BEKE 1971, 1983, 1984).

The Dorog Formation is overlain by marine marls (Halimba and Csolnok Formations). Near to this boundary, mainly above the coal seams, occurs the *Reticulofenestra tokodensis*-horizon with the endemic, brackish nannoplankton species *R. tokodensis* (BÁLDI–BEKE 1982), and zone markers for NP 16 (BÁLDI–BEKE 1982, 1983, 1984).

Other fossils: palynomorphs (RÁKOSI 1973), freshwater and brackish water molluscs (SZŐTS 1956, KECSKEMÉTI–KÖRMENDY 1972).

Biozonation: NP 16 based on nannoplankton, local palynological zonation (RÁKOSI 1972, 1979), *Globorotalia lehneri* zone for the upper portion (HORVÁTH–KOLLÁNYI 1983).

References to L. S. I.:

Formation lignitifère de Dorog p. 185.
Formation lignitifère de Dudar – Balinka p. 188. for the so-called Kisgyón Formation
Argile bigarrée, calcaire d'eau douce Transdanubia NE p. 508.

5. Csolnok Formation (=earlier named as Dorog Formation)

Silty, clayey marls with rich sublittoral faunal assemblages of molluscs and foraminifera. Its thickness is 20–80 meters (DUDICH and GIDAI 1980, GIDAI 1972). It occurs in the northeastern part of Transdanubia.

Nannoplankton: rich nannoplankton assemblages in nearshore facies with common placoliths, pentaliths, discoliths, rhabdoliths, holococcoliths and *Neococcolithes dubius*, rare *Discoasters* and *Sphenoliths* (BÁLDI–BEKE 1984). All the zone markers for NP 16 are present: common *Reticulofenestra placomorpha* and *R. bisecta*, *Lanternithus minutus*, *Pemma papillatum*, *Chiasmolithus solitus*, *Sphenolithus furcatolithoides* (BÁLDI–BEKE 1983, 1984). Mostly the lowermost portion of the formation represents the *Reticulofenestra tokodensis*-horizon with the common occurence of *R. tokodensis* and zone markers for NP 16 (see in the Tatabánya and Mór Formations too, BÁLDI–BEKE 1982, 1983, 1984).

Other fossils: larger foraminifera: *Operculina div. sp.* and *Nummulites subplanulatus*, *N. globulus*, *N. anomalus*, *N. subramondi* (JÁMBOR–KNESS 1972), *N. subplanulatus*, *N. perforatus* (KECSKEMÉTI and VAŇOVÁ 1972). Smaller foraminifera (HORVÁTH–KOLLÁNYI 1983), sporomorphs (RÁKOSI 1973), molluscs (SZŐTS 1956, KECSKEMÉTI–KÖRMENDY 1972, STRAUSZ 1974).

Biozonation: NP 16, *Globorotalia lehneri* zone in its lower portion, *Truncorotaloides rohri – Orbulinoides beckmanni* zone in its upper portion (HORVÁTH–KOLLÁNYI 1983), *Nummulites subplanulatus* zone for the Cuisian by JÁMBOR–KNESS (1972), *Nummulites perforatus* assemblage zone for the Upper Lutetian (KECSKEMÉTI and VAŇOVÁ 1972).

References to L. S. I.:

Marne argileuse a *Operculines* p. 384.
Couches à *Nummulites subplanulatus* p. 374. with earlier synonimes:

HANTKEN 1871: Étage des Mollusques inférieur,

ROZLOZSNIK, SCHRÉTER and TELEGDI–ROTH 1922: Marne à *Operculines*,

SZŐTS 1956: Marne argileuse a Foraminifères et Mollusques,

KOPEK, KECSKEMÉTI and DUDICH 1965: Horizon No. VIII. a *N. subplanulatus*

6. Tokod Formation

Highly variable lithofacies, mostly sands, calcareous sandstones, limestones. Its lower portion is more calcareous, this regressive series is closed with coal seams ("Forna seams") the upper portion is more sandy and the fauna marks increasing salinity in the "striatus beds" (MUNTYÁN 1984 manuscript, DUDICH and GIDAI 1980).

Nannoplankton: occurs only in some lithologically and ecologically favourable beds, poor assemblages of NP 16 were found in the lowermost portion of the formation and NP 17 forms in its upper portion (BÁLDI–BEKE 1983, 1984).

Other fossils: larger foraminifera, *Nummulites perforatus*, common *N. striatus;* molluscs: SZŐTS 1956, KECSKEMÉTI–KÖRMENDY 1972.

Biozonation: NP 16 (partly) and NP 17. *Nummulites perforatus*, *N. millecaput* zones, the lowermost part of the *N. fabianii* zone is uncertain (MUNTYÁN 1984). *Truncorotaloides rohri* and *Orbulinoides beckmanni* planktonic foraminifera zones (HORVÁTH–KOLLÁNYI 1983).

References to L. S. I.:

Grès de Tokod p. 501.
Couches à *Nummulites striatus* de Bakony p. 373.
Couches à Mollusques et à *Nummulites striatus* de Dorog p. 186.
Couches de Forna p. 211.
Gisement de lignite de Forna p. 212.
Calcaire et marne a *Miliolidés* de Gánt p. 217.

7. Szépvölgy Limestone Formation (=earlier named as Nagysáp Formation)

Sublittoral limestones with marly and sandy intercalations (DUDICH and GIDAI 1980). It is underlain by the beds of the Tokod Formation or it lies unconformly on older rocks. It occurs not only in Transdanubia but in

Northeastern Hungary too. A more marly series with coal seams on its base is known near to Kósd (GIDAI 1978).

Nannoplankton: because of the unfavourable facies is extremely poor, however in some marly beds mainly placoliths and *Isthmolithus recurvus* occur (in GIDAI 1978, BÁLDI–BEKE 1984).

Other fossils: abundant larger foraminifera (HANTKEN 1871, VITÁLIS–ZILAHY 1967, JÁMBOR–KNESS 1972): *Nummulites fabianii* and *Discocyclinidae*, abundant calcareous algae *(Lithothamnium)*, few molluscs (KECSKEMÉTI–KÖRMENDY 1972), smaller foraminifera.

Biozonation: NP 18 and NP 19. The formation belongs to the Lower Priabonian (based on the larger foraminifera fauna), and perhaps to the uppermost Middle Eocene in some places (Urhida). The *Globigerinatheca semiinvoluta* zone (HORVÁTH–KOLLÁNYI 1983) has been proved.

References ti L. S. I.:

Calcaire à *Nummulites* – *Orthophragmines* p. 365.
Couches à *Nummulites fabianii* p. 367.
Calcaire marneux à *Nummulites böckhi* p. 367.

8. Piszke Marl Formation

Pelagic marly series, which is known from a small area near Lábatlan (Northern Gerecse Mountains near to the Danube, HANTKEN 1871, VOGL 1910, GIDAI 1968, BÁLDI–BEKE 1984). It is underlain by Middle Eocene marly beds with *Nummulites striatus* as it has been proved in borehole profiles (GIDAI 1968).

Nannoplankton: The zone markers for NP 18 and 19 are common; *Chiasmolithus oamaruensis*, *Isthmolithus recurvus* and *Orthozygus aureus* occur together with *Discoaster barbadiensis* and *D. saipanensis* (BÁLDI–BEKE 1984 and in GIDAI 1968).

Other fossils: smaller foraminifera (HANTKEN 1871), *Bryozoa*, molluscs (VOGL 1910, SZŐTS 1956).

Biozonation: NP 18 and 19, *Globorotalia cerroazulensis* zone (HORVÁTH–KOLLÁNYI 1983).

References to L. S. I.:

Marne de Piszke p. 412.
Aleurite calcaire à Foraminifères de Nyergesujfalu p. 376.

9. Iharkut Formation

Conglomerates, sands with few marly beds (DUDICH 1977, DUDICH and GIDAI 1980, MÉSZÁROS 1980).

Nannoplankton: It occurs only in the marly beds, species from the NP 18 and 19 zones together with reworked Cretaceous forms (BÁLDI–BEKE 1983, 1984).

Other fossils: Nummulites is common in the conglomerate beds, *Nummulites perforatus* occurs in the pebbles from the underlying Szőc Limestone Formation. Few molluscs were found in marly clay, not studied yet.

Biozonation: Highly uncertain. The locally rich Late Eocene nannoplankton assemblage may be most probably reworked. The age of the formation may be Oligocene, because of the lithostratigraphical position. Among the several underlying formations the youngest one is the Szőc Limestone (Middle Eocene). The Iharkut Formation is overlain mainly by the Late Oligocene Csatka Formation.
No references in the L. S. I.

Oligocene Formations

1. Buda Marl Formation

The formation extends from the Buda and Pilis Mountains up to the Bükk-region, toward a northeastern direction. The characteristic rock-types are marl and calcareous marl. Its upper portion contains an increased amount of terrigenous material. This upper portion consists usually of clayey marl with allodapic limestone interbeddings. The formation represents a transgression from the deep – sublittoral until the bathyal environments.

Nannoplankton: The nannoplankton-content of the lower, more calcareous member is usually poorer, while that of the upper, more clayey member is more rich. The cosmopolitan placoliths are rather common *(Reticulofenestra bisecta, Reticulofenestra callida)*, the pentaliths, discoasterids, sphenoliths appear only rarely. The holococcoliths show usually a great abundance, mainly the species *Lanternithus minutus, Zygrhablithus bijugatus* and *Isthmolithus recurvus*. The ratio of the tropical elements in the nannofloras is less, comparing to the Middle-Eocene nannofloras (BÁLDI–BEKE 1972, 1977, 1984, NAGYMAROSY in BÁLDI et al., 1984).

Other fossils: planktonic foraminifera (see SZTRÁKOS 1974, 1978, HORVÁTH in BÁLDI et al., 1984); ostracoda (MONOSTORI 1985a, 1985b, 1986a, 1986b); the benthic foraminiferas were described by HANTKEN (1866, 1873); BÁLDI (1983) dealt with the *Propeamussium* mollusc genus.

Biozonation: The age of the nannoplankton was determined by BÁLDI–BEKE and NAGYMAROSY: zone NP 19–20 (see the titles above). These two zones are not to be easily separated, because the biostratigraphic event – first appearance of the species *Sphenolithus pseudoradians* – defining the base of the zone NP 20 is a rather heterochronous level. The base of NP 19 is well defined by the first appearance of the *Isthmolithus recurvus*, which is rather common in this formation. The boundary between the zones NP 20 and 21, i. e. the Eocene-Oligocene boundary, can be fixed near to the uppermost calcareous marl-intercalations of the Buda Marl. This important horizon is hardly recognizable, because the tropical index species *Discoaster saipanensis* and *Discoaster barbadiensis* occur only rarely and sporadically in this formation. Also the permanent reworking of the Middle Eocene nannofossils makes the determination of this horizon difficult (NAGYMAROSY et al., 1986). KECSKEMÉTI et al., 1985. put the Buda Marl into the *Nummulites fabianii* larger-foraminifera zone, whose upper boun-

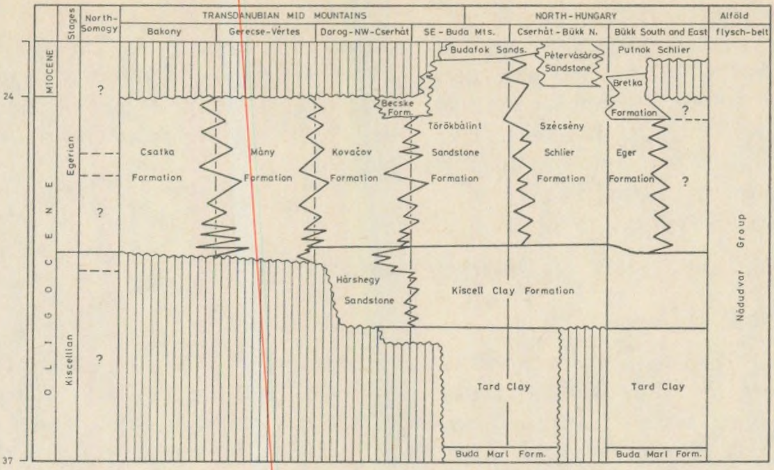


Fig. 5. Oligocene – Lower Miocene formations of Hungary.

dary can be located in the upper portion of the formation. HORVÁTH (1983, in BÁLDI et al., 1984) described planktonic foraminiferas from the marl belonging to the P 17 zone of BLOW, while SZTRÁKOS (1974, 1978) described the Carpathian-Pannonian regional *Globigerina officinalis* zone.

References.

Marne à *Bryozoaires* L. S. I. p. 113
Marne de Buda L. S. I. p. 116
Budai Márga, BÁLDI 1983. p. 19
Buda Marl, BÁLDI 1986. p. 9

2. Tard Clay Formation

This formation – whose typical outcrops have a characteristic "black-shale-like" appearance – consists of different rock-types, i.e. microlaminated clays, silts, non-microlaminated clayey marls and sandstones. It lays conformly on the Buda Marl. The boundary of these two formations can be drawn either at the uppermost calcareous bed or at the lowermost anoxic laminite-bed. The areal occurence of the Tard Clay is similar to that of the Buda Marl.

Nannoplankton: The lower member of the formation contains low-diversity, high-aboundance nannoplankton assemblages. *Reticulofenestra bisecta, Reticulofenestra callida* and *Reticulofenestra hesslandii* are common, while the *Cyclococcolithus formosus* and *Reticulofenestra placomorpha* index-species are rare. (A deal of these two latter fossils may be reworked from the Middle-Eocene rocks.) The acme of *Ericsonia subdisticha* – characteristic for the zone NP 21 – is well recognizable. The cold-water holococcoliths *Zygrhablithus bijugatus, Lanternithus minutus, Isthmolithus recurvus* are especially very abundant.

In the interval of the boundary between the lower and upper members of the Tard Clay the appearance of mono- and duospecific nannofloras was observed due to the slight decrease in the salinity of the surface-water. These mono- or duospecific assemblages consist of big masses of one or two species, while the other species with a less tolerancy appear only sporadically. The characteristic forms of these assemblages are the *Orthozygus aureus*, *Discolithina latoculata*, *Transversopontis obliquipons*, *Reticulofenestra ornata*, *Reticulofenestra lockeri*, etc. (see NAGYMAROSY 1983a). The upper member of the formation is usually free of fossils, except some short blooms of the above mentioned high-tolerancy forms.

Other fossils: Benthic foraminiferas (their detailed investigation has not be completed yet); planktonic foraminiferas (SZTRÁKOS 1974, 1978, HORVÁTH 1983 and in BÁLDI et al,, 1984); ostracods (MONOSTORI 1985a, 1985b, 1986a, 1986b); the rare and badly preserved endemic brackish water *Cardium lipoldi* mollusc-fauna of the Tard Clay was described by BÁLDI (1983, 1986).

Biozonation: The lower member of the Tard Clay corresponds to the zones NP 21 – 22, while its upper member to NP 23 (BÁLDI – BEKE 1977, 1984, NAGYMAROSY 1983b and in BÁLDI et al., 1984). The NP 21/22 zone – boundary cannot be easily drawn because of the reworking of the index-fossils from the older Paleogene beds. The base of the zone NP 23 is indicated by the sudden impoverishing or full extinction of *Reticulofenestra placomorpha* and by the sudden increase in the abundancy of *Reticulofenestra lockeri*. The zone-boundary defining species *Sphenolithus distentus* is extremely rare. In the upper part of the NP 23 zone few specimens of "early" *Helicopontosphaera recta* have been observed.

The endemic "Paratethys-dweller" nannoplankton species occur in the same level as the endemic mollusc fauna does (see BÁLDI 1983). These are: *Reticulofenestra ornata* MÜLLER, and *Transversopontis fibula* GHETA (= *Transversopontis pax* STRADNER = *Zygodiscus vialovi* ANDREYEVA – GRIGOROVICH), whose occurence can be traced from the Bavarian molasse up to Usbekistan. This horizon can be put onto the lower boundary of the zone NP 23. SZTRÁKOS (1974) correlated the lower member of the Tard Clay with the *Globigerina postcretacea* – zone of SAMUEL and SALAJ (1968). HORVÁTH (see the references above) described planktonic foraminifera assemblages corresponding to BLOW's P 18 and P 19/20 zones.

References

Couches de Tard L. S. I. p. 486
Tardi Agyag, BÁLDI 1983 p. 22
Tard Clay, BÁLDI 1986 p. 11

3. Hárshegy Sandstone Formation

The Hárshegy Sandstone is the basal formation for the transgressional cycle of the Kiscell Clay. It has been formed in the zone extending west to the Buda-line, between the Cserhát and the Buda Mountains.

The different rock-types of the Hárshegy Sandstone, – conglomerates, coarse and fine grained sandstones – have formed in the wave-activity belt of the ancient sea. The other rock-variations, as silt, clayey sand, fireclay beds were deposited in nearshore lagoons. The huge body of the Hárshegy Sandstone underwent a strong silification after the sedimentation along the Buda-line, and the silicifying solutions destroyed the greatest part of its fossil-content.

Nannoplankton: The depositional and diagenetic environments of the Hárshegy Sandstone did not favour to the fossilization of nannofossils. Among the few data we have to mention the impoverished placolith assemblages with *Cyclicargolithus abisectus* described by BÁLDI–BEKE (in BÁLDI et al., 1976). Similar nannoplankton assemblages were found by NAGYMAROSY in the Cserhát Mountains (Romhány-block): low-diversity placoliths with *Coccolithus rupeliensis* MÜLLER and rare *Helicopontosphaera recta* HAQ.

Other fossils: The rare foraminifera faunas were described by GELLAI (1966, 1973) and HORVÁTH (in BÁLDI et al., 1976). KECSKEMÉTI dealt with the larger foraminiferas, i. e. with *Lepidocyclinas* and *Nummulites* (in BÁLDI et al. 1976). The mollusc faunas were determined by BÁLDI (in BÁLDI et al. 1976, BÁLDI 1983).

Biozonation: The nannoplankton of the Hárshegy Sandstone may not be older than the upper part of NP 23. The presence of *Cyclicargolithus abisectus* and *Helicopontosphaera recta* suggest an age of NP 24. The larger foraminiferas and molluscs prove a Late Kiscellian age too, in concordance with the nannoplankton.

References:

Grès de Hárshegy L. S. I. p. 235
Hárshegyi Homokkő, BÁLDI 1983 p. 33
Hárshegy Sandstone, BÁLDI 1986 p. 32
Complexe lignitifère d'Esztergom L. S. I. p. 200
Gisement lignitifère de Szápár L. S. I. p. 472

4. Kiscell Clay

A rather uniform formation consisting of calcareous clay and clayey marl. In its lower member there is a typical alternation of clay- and sandstone-beds. The depositional depth of the Kiscell Clay was presumably 400–500 m. The formation extends from the southern foredeep of the Vértes and Gerecse Mountains through South Slovakia up to the Northern Bükk Mountains. West to the Buda-line it is overlying the transgressive Hárshegy Sandstone with a thickness of some dozen meters. East to the Buda-line it is overlying the euxinic Tard Clay. The thickness of the Kiscell Clay may be as much as 800 or even 1000 meters in this area.

Nannoplankton: The Kiscell Clay contains a rich, hemipelagic nannoflora. Its dominating forms are the placoliths (*Reticulofenestra lockeri*, *Reticulofenestra hesslandii*, *Coccolithus pelagicus*, *Cyclicargolithus abisectus*, *Cyclicargolithus floridanus)*, but together with them also helicosphaerids *Helicopontosphaera bramlettei, Helicopontosphaera euphratis)*, discoliths *(Discolithina multipora, Transversopontis pygmaea)* and *Zygrhablithus bijugatus* occur. Some tropical nannoflora elements, as discoasterids are totally lacking, but the sphenoliths are more common. BÁLDI–BEKE (1977) described a rather fixed horizon from the lower part of the formation with common *Sphenolithus distentus, Sphenolithus ciperoensis* and *Sphenolithus predistentus*. In the thick-bedded, hardly stratified clay also microlaminated, anoxic intercalations occur, which contain rich marine nannofloras – in contrary of the Tard Clay –. However, also these diverse nannofloras may be mixed with the blooms of one-one species (NAGYMAROSY 1983).

Other fossils: Almost 500 foraminifera species were described from this formation in the last hundred years (HANTKEN 1975, MAJZON 1966, SZTRÁKOS 1978, HORVÁTH 1983). The ostracods were investigated by MONOSTORI (1982, 1985a, 1985b, 1986a, 1986b). Detailed evaluation of the mollusc fauna was made by BÁLDI (1986).

Biozonation: The depositional interval of the Kiscell Clay corresponds to the lower part of the NP 24 zone. HORVÁTH (1983) put the formation in the *Globorotalia opima opima* zone on the basis of planktonic foraminiferas. According to SZTRÁKOS (1978) it belongs to to the *Globorotalia munda* endemic taxon-interval zone. MAJZON (1942, 1961) divided the Kiscell Clay in North Hungary into four foraminifera-ecozones, but HORVÁTH and SZTRÁKOS found only one stratigraphically fixed level among them. A radiometric measurement on the glauconite of the Kiscell Clay resulted in an age of 33,5 million years (BÁLDI et al. 1975).

References:

Argile de Kiscell L. S. I. p. 271
Kiscelli Agyag, BÁLDI 1983. p. 51
Kiscell Clay, BÁLDI 1986. p. 16

5. Csatka Formation

It consists of alternating fresh-water coarse-grained clastics and variegated clays. Its type occurence is in the Bakony and Vértes Mountains (see KORPÁS 1981).

Nannoplankton: Though this formation might not contain any autochtonous nannoplankton due to its depositional environment, BROKÉS (1978) described impoverished assemblages from grey, fluviatile clays. These assemblages may contain rare specimens of *Sphenolithus distentus, Sphenolithus ciperoensis* and *Cyclicargolithus abisectus* too.

Other fossils: The fresh-water mollusc fauna was investigated by BÁLDI (1973).

Biozonation: Concerning the above mentioned index-species, the Csatka Formation may belong to the Egerian stage, to the nannoplankton zones NP 24–25.

References:

Csatkai (=Móri) Formáció, BÁLDI 1983. p. 92
Csatka (=Mór) Gravels, BÁLDI 1986. p. 39.

6. Mány Formation

Alternation of brackish-water and fresh-water clastics with that of marine origin. Occurence: in the triangle among the Vértes-Gerecse and Buda Mountains.

Nannoplankton: The marine intercalations contain persistent, cosmopolitan forms: *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Helicopontosphaera euphratis*, *Reticulofenestra bisecta*, etc. The index fossils are very rare. The locally very abundant *Discolithina latelliptica* is a typical element of these nannofloras. The greatest deal of the nannoplankton assemblages consists of specimens, which have been reworked from the older Paleogene and Cretaceous beds (see BROKÉS 1978, BÁLDI–BEKE 1977, 1984).

Other fossils: For the typical brackish-water mollusc fauna see BÁLDI 1973.

Biozonation: The age of the formation is NP 24–25. The two zones can not be separated from each other because of the lacking of the index species. Concerning the nannoplankton assemblages of this formation one can determine an age not younger than Early Egerian, so the formation does not overlap the Paleogene/Neogene boundary.

References:

Couches à *Cyrènes* L. S. I. p. 168
Mányi Formáció, BÁLDI 1983. p. 92
Mány Sands, BÁLDI 1986. p. 39

7. Kováčov Formation

Alternating beds of marine and brackish-water sands and sandy silts (BÁLDI 1973). The formation occurs around Esztergom and at the western margin of the Cserhát Mountains. HÁMOR (1985) described its upper, regressive portion as Becske Formation.

Nannoplankton: Poorly studied. The few data show a concordance with the nannoplankton of the Mány Formation (BÁLDI–BEKE 1977, 1984).

Other fossils: foraminiferas (HORVÁTH 1980); molluscs (BÁLDI 1973).

Biozonation: It belongs to the NP 24–25 nannoplankton zones without any more detailed division.

References:

Argile à *Helix* de Mohora L. S. I. p. 339
Kovačovi Formáció, BÁLDI 1983. p. 93
Kovačov Sands, BÁLDI 1986. p. 39

8. Törökbálint Sandstone

Nearshore and littoral sands and sandstones extending from the Buda Mountains through the Pilis up to the Cserhát. West to the Buda-line its upper portion contains some brackish-water interbeddings and it is cut by an erosional unconformity. East to the Buda-line it is conformly overlain by the Budafok Sand of Early Miocene age.

Nannoplankton: The cosmopolitan *(Coccolithus pelagicus, Reticulofenestra bisecta, Cyclicargolithus floridanus)* and the nearshore species *(Discolithina enormis, Discolithina latelliptica, Braarudosphaera bigelowi)* are common. In the uppermost part of the formation also *Helicopontosphaera carteri* appears.

Other fossils: foraminifera (Horváth 1980); molluscs (Báldi 1973).

Biozonation: The formation can be placed into the NP 24 – 25 nannoplankton zone. The Törökbálint Sandstone may overlap the Oligocene/Miocene boundary and extends into the NN 1 zone according to Báldi – Beke (see Budafok – 2 borehole in Báldi et al. 1973).

References:

Sable à *Pectoncles* L. S. I. p. 403
Törökbálinti Formáció, Báldi 1983 p. 93
Törökbálint Sands, Báldi 1986.

9. Eger Formation

It lays conformly on the Kiscell Clay at the southern and eastern margin of the Bükk Mountains. Its typical rock-variant is the deep-sublittoral clayey marl, whose upward transition contains several silty and sandy intercalations. The stratigraphical column terminates in a brackish-water series. A characteristic variation of the Eger Formation is the Novaj Member consisting of clay, marl, limestone and glauconitic sandstone beds with larger foraminiferas.

Nannoplankton: The rich marine nannoplankton of the Eger Formation was described by Báldi – Beke (1975, Báldi – Beke et Báldi 1974, and in: Báldi et al. 1975). In addition to the abundant placoliths some sphenoliths *(Sphenolithus ciperoensis)* and helicosphaerids *(Helicopontosphaera carteri)* occur too. Typical elements of the nannofloras are the reworked specimens from Cretaceous and older Paleogene beds. The upper, brackishwater portion of the formation contains no nannofossils.

Other fossils: foraminiferas (Horváth 1980); larger foraminiferas (Báldi et al. 1961); molluscs (Báldi 1966, 1973, Báldi – Beke et Báldi 1974.

Biozonation: The Eger Molluscan Clay, the brackish-water overlying strata and the Novaj Member all belong uniformly to the upper part of zone NP 24 and to the lower part of zone NP 25. The formation does not overlap the Oligocene/Miocene boundary. Horváth (1980) determined it as belonging to the *Globorotalia opima opima* zone. Drooger (in Báldi et al. 1961) described the larger foraminifera species *Miogypsina septentrionalis* from the Novaj Member.

References:

Couches de Demjén(*Lepidocyclina* and *Heterostegina* bearing beds = Novaj Member)L. S. I. p. 176
Egri Formáció, BÁLDI 1983. p. 94
Eger Formation, BÁLDI 1986. p. 49

10. Szécsény Schlier

This 400–800 m thick neritic formation is located at the northern margin of the Cserhát, Mátra and Bükk Mountains. Its most typical rock-variation is the sandy-clayey silt. It lays conformly on the Kiscell Clay, and it is covered by Lower Miocene sandstones.

The Szécsény Schlier is very similar to the Putnok Schlier formation, also their depositional times show an overlap. However is has not been proved, that there would be any connection between the two rock bodies.

Nannoplankton: In contrary to its hemipelagic, pelitic character, the Szécsény Schlier is relatively poor in nannofossils. Its typical placoliths are *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Reticulofenestra bisecta* (only in the deeper portion of the formation), *Cyclococcolithus leptoporus*(in the higher portion of the formation). Common elements of the nannofloras are *Helicopontosphaera carteri*, *Discolithina latelliptica*, *Sphenolithus moriformis*. The discoasteroids are rare, for example *Discoaster trinidadensis*, *Discoaster lidzii*, *Discoaster druggii* (see HORVÁTH et NAGYMAROSY 1979).

Other fossils: The foraminifera faunas consist mainly of agglutinated forms (see HORVÁTH 1972); the typical mollusc fauna of the schlier is comprehensively described by BÁLDI (1973).

Biozonation: The lower member of the formation belongs probably to the NP 24–25 zones, but this has been proved only in some isolated, point-like outcrops. NAGYMAROSY (in HORVÁTH and NAGYMAROSY 1979) described NN 1 and 2 nannofloras from the upper member of the formation. The uppermost strata of the Szécsény Schlier underlying the Ipolytarnóc Footprinted Sandstone contain the species *Sphenolithus belemnos* in a relatively great abundance, thus their age must be NN 3.

References:

Schlier à *Bathysiphon* L. S. I. p. 89
Parádi Slir, BÁLDI 1983. p. 98
Szécsényi Slir, BÁLDI 1986. p. 98
Szécsény Schlier, BÁLDI 1986. p. 43

11. Nádudvar Group

The flysch-belt extending at the northern margin of the Great Hungarian Plain is not well-studied from the point of view of nannoplankton stratigraphy. Some investigations were carried out from isolated drilling core-materials and a few assemblages have been described from the zones NP 18 to NP 25 (BÁLDI–BEKE et al. 1980). The sampling technique and the tectonized borehole profiles did not enable the continuous sampling and studying of the stratigraphic column.

References:

Formations ,,flyschoides'' de Hajduszoboszló – Tóalmás – Alcsi L. S. I. p. 232

12. Paleogene beds in Buzsák and Táska

NP 22, 24 and 25 zone assemblages were found in the rocks from some boreholes of Buzsák and Táska, south to the lake Balaton. (BÁLDI – BEKE 1984). The paleogeographical and tectonical interpretation of these beds is very uncertain so far.

*

This paper does not deal with those geological formations of North-Hungary, whose age is not fixed by the geological literature uniformly in the Paleogene. Some authors give for them an age of Late Oligocene, others prefer the Early Miocene age. This paper supports the opinion, that all the following formations have a Neogene age. According to our investigations, the age of the overlying strata of the Bretka Limestone is NN 1.
Pétervására Sandstone is NN 1 – 2,
of the Budafok Sand is NN2,
of the Putnok Schlier is NN 1 – 3.

No nannoplankton investigation was carried out on the Felsőnyárád Formation.

The exact position of these formations in the chronostratigraphic scale and in the Standard Nannoplankton zonation must be determined by a comprehensive research program in the future.

REFERENCES

BÁLDI T. (1966): Az egri felsőoligocén rétegsor és molluszkafauna újravizsgálata – Földt. Közl., 96, pp. 171 – 194.

BÁLDI, T. (1973): Mollusc fauna of the Hungarian Upper Oligocene (Egerian). Akadémiai Kiadó, Budapest, 511 pp.

BÁLDI T. (1983): Magyarországi oligocén és alsómiocén formációk kora és képződésük története. – Akad. Kiadó, Budapest, 293 p.

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

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 – Proc. VI. Congr. RCMNS: pp. 315 – 317. Bratislava.

BÁLDI T. – BÁLDI-BEKE M. – HORVÁTH M. – KECSKEMÉTI T. – MONOSTORI M. – NAGYMAROSY A. (1976): A Hárshegyi Homokkő Formáció kora és képződési körülményei. (Alter und Bildungsverhältnisse des Hárshegyer Sandsteins.) – Földt. Közl. 106 (4), pp. 353 – 386.

Báldi T. – Horváth M. – T. Makk Á. (1973): Profile Budafok – 2; Parastratotype proposed for the Paratethyan stages Kiscellian, Egerian, Eggenburgian – Ann. Univ. Sci., Sect. Geol., 17, pp. 3 – 57.

Báldi T. – Horváth M. – Nagymarosy A. – Varga P. (1984): The Eocene/Oligocene boundary in Hungary. The Kiscellian stage. – Acta. Geol. Acad. Sci. Hung., Budapest, 27, pp. 1 – 21.

Báldi T., T. Kecskeméti, R. Nyirő, C. W. Drooger (1961): Neue Angaben zur Grenzziehung zwischen Chatt und Aquitan in der Umgebung von Eger (Nordungarn) – Ann. Mus. Nat. Hung. 53, pp. 67 – 132.

Báldi T. – Seneš J. (1975): OM Egerien. Chonostratigraphie und Neostratotypen. – VEDA Verlag Slow. Akad. Wiss. 5, pp. 1 – 577. Bratislava.

Báldi-Beke M. (1971): The Eocene nannoplankton of the Bakony Mountains, Hungary. – Ann. Inst. Geol. Publ. Hung. 54 (4) I, pp. 13 – 39.

Báldi-Beke M. (1972): The nannoplankton of the Upper Eocene bryozoan and Buda Marls. – Acta Geol. Acad. Sci. Hung. 16, pp. 211 – 228.

Báldi-Beke M. (1975): Lower boundary and vertical range of the Egerian on the basis of the nannoplankton. – Proc. VI. Congr. RCMNS, pp. 237 – 239. Bratislava.

Báldi-Beke M. (1977): A budai oligocén rétegtani és fáciestani tagolódása nannoplankton alapján. (Stratigraphical and faciological subdivisions of the Oligocene as based on nannoplankton) – Földt. Közl. 107 (1), pp. 59 – 89.

Báldi-Beke M. (1982): Új nannoplankton faj a dunántúli eocén kőszénfedő képződményekből. (A new nannoplankton species from sediments overlying the Eocene coal seams in Transdanubia.) – Földt. Int. Évi. Jel. 1980-ról, pp. 297 – 308.

Báldi-Beke M. (1983): Dunántúli eocén nannoplankton és biosztratigráfiája. (Nannoplankton flora and biostratigraphy of the Transdanubian Eocene.) – Ősl. Viták. 29, pp. 25 – 46.

Báldi-Beke M. (1984): The nannoplankton of the Transdanubian Palaeogene formations. – Geologica Hungarica Ser. Palaeontologica Fasc. 43. p. 1 – 307. (in Hungarian and English)

Báldi-Beke M. – Báldi T. (1974): Nannoplankton and macrofauna of the type section at Novaj (Kiscellian-Egerian). – Ann. Univ. Sci. Budapest. Eötvös Nom. 17, pp. 59 – 103.

Báldi-Beke, M., Horváth M., Nagymarosy, A. (1980): Az alföldi flisképződmények biosztratigráfiai vizsgálata. (Biostratigraphic research of the flysh deposits on the Alföld) – Ősl. Viták (Disc. Pal.),26, pp. 51 – 59.

Báldi-Beke M. – Kecskeméti T. (1983): Különböző életterek mikrofaunájának értékelési lehetőségei egyes eocén képződményeknél. (Results of studies on microfossils of different habitats (nannoplankton and larger foraminifers) in Eocene formations.) – Ősl. Viták 29, pp. 177 – 188.

Bernhardt, B., Lantos, M., Márton, P., Báldi-Beke, M., Horváth – Kollányi, K. and Kecskeméti, T. (1985): Magneto- and biostratigraphy of an Eocene sequence from borehole Somlóvásárhely I (SW Bakony Mts, Hungary). – INA Newsletter vol. 7. No. 2, pp. 53 – 56.

Brokés F. (1978): Harmadidőszaki coccolithok a Dunántúli-középhegység bauxitkutató fúrásaiból. (Tertiary coccoliths recovered by bauxite-exploratory drillings in the Transdanubian Central Mountains.) – Földt. Közlöny 108 (4), pp. 499 – 540.

Dudich E. (1977): Eocene sedimentary formations and sedimentation in the Bakony Mountains, Transdanubia, Hungary. – Acta Geol. Acad. Sci. Hung. 21 (1 – 3), pp. 1 – 21.

Dudich E. – Gidai L. (1980): A magyarországi eocén kőzetrétegtani formációi. (Előzetes) (Lithostratigraphic units of the Hungarian Eocene. Preliminary communications.) – Ált. Földt. Szemle. 14, pp. 81 – 112.

Gellai, Á. (1966): A Dorogi-medence oligocén rétegösszletének Foraminifera szintjei. (Foraminiferal zones of the Dorog Basin Oligocene) MÁFI Évi Jel. 1964-ről. Budapest, pp. 361 – 365.

Gellai, Á. (1973): Oligocén foraminiferák Dorog környékéről. (Oligocene Foraminiferas around Dorog) – MÁFI Évk., Budapest, 55, pp. 421 – 495.

Gidai L. (1968): A Nyergesújfalu 29. sz. fúrás földtani eredményei. (Geologische Ergebnisse der Bohrung Nyergesújfalu 29.) – Földt. Int. Évi Jel. 1966-ról, pp. 141 – 148.

GIDAI L. (1972): Adatok a Mór-Pusztavám környéki eocén földtani viszonyainak megismeréséhez. (Contribution a la connaissance de la geologie de l'Eocene des environs de Mór-Pusztavám) – Földt. Int. Évi Jel. 1970-ről, pp. 113–127.

GIDAI L. (1978): Az ÉK-dunántúli eocén képződmények ősföldrajzi viszonyai. (Relations paléogéographiques des formations Éocenes du Nord-Est de la Transdanubie.) – Földt. Közl. 108 (4), pp. 549–563.

HÁMOR G. (1985): A nógrád-cserháti kutatási terület földtani viszonyai – Geol. Hung. Ser. Geol., 22, Budapest, p. 307.

HANTKEN M. (1866): A Buda-Esztergomi vidék szerves testek képezte kőzetei – Math. Term. tud. Közl., IV, p. 12.

HANTKEN M. (1868): A kiscelli tályag foraminiferái – Földt. Társ. Munkálatai IV, pp. 75–96.

HANTKEN M. (1871): Az esztergomi barnaszénterület földtani viszonyai. – Földt. Int. Évkönyve 1, pp. 3–140.

HANTKEN M. (1873): A budai márga. (The Buda Marl.) Földt. Int. Évk. 3. Budapest, pp. 167–191.

HANTKEN M. (1875): A clavulina szabói rétegek faunája. (Fauna of the Clavulina szabói layers.) Földt. Int. Évk., Budapest, IV, p. 88.

HANTKEN M. (1878): Die Kohlenflöze und der Kohlenbergbau in den – Ländern der Ungarischen Krone, Budapest, p. 1–354.

HAQ, B. U. (1983): Jurassic to Recent Nannofossil Biochronology: An Update – in: NANNOFOSSIL BIOSTRATIGRAPHY, Haq B. U. edit. Benchmark papers in Geology vol. 78., pp. 358–378.

HORVÁTH M. (1972): A szécsényi amussziumos slir felső tagozatának mikrofaunája. (Microfauna of the upper member of the Amussium bearing Szécsény Schlier.) – Földt. Közl. 102, pp. 163–175.

HORVÁTH M. (1980): A magyarországi felsőoligocén – alsómiocén típusszelvények foraminifera faunája. (Manuscript, in Hungarian)

HORVÁTH M. (1983): Eocene/Oligocene boundary and the Terminal Eocene Events on the basis of planktonic Foraminifera – Proposalfor the Eocene-Oligocene boundaryin the Alpine-Carpathian Pannonian system; definition of the Kiscellian stage, Visegrád-meeting, manuscript, pp. 26–36.

HORVÁTH M., A. NAGYMAROSY (1979): On the boundaries of Oligocene/Miocene and Egerian/Eggenburgian in Hungary – Ann. Géol. Pays. Hellén. Tome hors série, 1979, fasc II, pp. 543–552.

HORVÁTH-KOLLÁNYI K. (1983): Az ÉK-dunántúli terület eocén plankton Foraminifera zónái. (Eocene planktonic foraminiferal zones in NE Transdanubia.) – Földt. Közl. 113 (3), pp. 225–236.

JÁMBOR-KNESS M. (1972): Nagy-Foraminifera vizsgálatok néhány ÉK-dunántúli mélyfúrás eocénjéből. (Recherches de grands Foraminifères dans l'Éonène de quelques sondages dans le secteur NE de Transdanubie) – Földt. Int. Évi Jel. 1970-ről, pp. 129–144.

JÁMBOR-KNESS, M. (1981): Alvéolines Éocènes de la Hongrie. Geologica Hungarica Ser. Palaeontologica Fasc. 40. p. 1–143. (in Hungarian and French)

KECSKEMÉTI T. (1980): A Bakony hegységi Nummulites fauna paleobiogeográfiai áttekintése. (Apercu paléobiogéographique sur la faune de Nummulites du Bakony.) – Földt. Közl. 110 (3–4) pp. 432–449.

KECSKEMÉTI T. – VAŇOVÁ M. (1972): Nummulites of the Dorog-Šturovo basin. – Zbornik Geol. Vied. Rad ZK 17, pp. 105–145.

KECSKEMÉTI T., P. VARGA (1985): Adatok az eocén/oligocén határkérdéshez újabb magyarországi szelvényekben, nagyforaminiferák alapján – Földt. Közl. 115, pp. 233–247.

KECSKEMÉTI T. – VÖRÖS A. (1975): Biostratigraphische und paläoökologische Untersuchungen einer transgressiven eozänen Schichtserie (Darvastó, Bakony Gebirge.) – Fragm. Min. et Pal. 6, pp. 63–93.

KECSKEMÉTI – KÖRMENDY, A. (1972): Die eozäne Molluskenfauna des Doroger Beckens. – Annales Inst. Geol. Hung. MÁFI Évkönyve vol. LV. No. 2. (in Hungarian and German)

KECSKEMÉTI–KÖRMENDY, A. (1980): La faune mollusques du facies de bassin éocene du Bakony nord-oriental – Annales Inst. Geol. Hung. MÁFI Évkönyve vol. 63. No. 3, pp. 1–227. (in Hungarian and French)

KECSKEMÉTI–KÖRMENDY, A. and MÉSZÁROS, M. (1980): Mollusques Éocènes du secteur oriental de la Montagne de Bakony (facies archipélagique). – Annales Inst. Geol. Hung. MÁFI Évkönyve vol. 63. No. 2, pp. 1–143. (in Hungarian and French)

KORPÁS, L. (1981): A Dunántúli-középhegység oligocén-alsó-miocén képződményei. (Oligocene-Lower Miocene formations of the Transdanubian Central Mountains in Hungary.) MÁFI Évk., Budapest, 64, 140 p.

KOPEK, G., KECSKEMÉTI, T. and DUDICH, E. (1965): Stratigraphische Probleme des Eozäns im Transdanubischen Mittelgebirge Ungarns. – Acta Geol. Hung. vol. 9, p. 411–426.

L.S.I. = Lexique Stratigraphique International, vol. I. Europe, Fasc. 9, Hongrie, 2e edit. sous la direction du Docteur J. Fülöp (1978), Centre National de la Recherche Scientifique, Paris, p. 666.

MAJZON L. (1942): Bükkszék és környéke oligocén rétegeinek Foraminiferákon alapuló szintézise – Földt. Int. Évi Jel. 1936–38-ról, pp. 907–947.

MAJZON L. (1961): Az Észak-magyarországi oligocén rétegtani tagolódása Foraminifera-tanulmányok alapján – Földt. Közl., 91, pp. 121–125.

MAJZON L. (1966): Foraminifera-vizsgálatok – Akad. Kiadó, Budapest, 939 p.

MARTINI E. (1971): Standard Tertiary and Quaternary calcareous nannoplankton zonation. – Proc. of the II Planktonic Conf. pp. 739–785. Roma.

MÉSZÁROS J. (1980): Magyarázó a Bakony-hegység 20 000-es földtani térképsorozatához. Farkasgyepü. – Földt. Int. Kiadványa.

MONOSTORI M. (1982): Oligocene ostracods from the surroundings of Budapest – Ann. Univ. Sci. Budapest, Sect. Geol. (1979), 21, pp. 31–102.

MONOSTORI M. (1985a): Ostracods of Eocene/Oligocene boundary profiles in Hungary – Ann. Univ. Sci. Budapest, Sect. Geol. 25, pp. 161–243.

MONOSTORI M. (1985b): Ostracodák rétegtani elterjedése magyarországi eocén-oligocén határszelvényekben – Földt. Közl. 115, pp. 149–161.

MONOSTORI M. (1986a): Terminal Eocene and Early Oligocene events in Hungary: Changes of ostracod communities – Acta. Geol. Hung, pp. 99–110.

MONOSTORI M. (1986b): Environmental changes in Eocene/Oligocene boundary stratotypes in Hungary based on ostracod faunas – Ann. Univ. Sci. Budapest, Sect. Geol. 26, pp. 141–158.

MUNTYÁN, I. (1984): The Tokod Formation (manuscript in Hungarian)

NAGYMAROSY, A. (1983a): Mono-and duospecific nannofloras in Early Oligocene sediments of Hungary–Proc. of the Koninkl. Nederlandse Ak. v. Wetensch., Ser. B, 86, pp. 273–283.

NAGYMAROSY, A. (1983b): Calcareous nannofloras at the Eocene-Oligocene boundary and in the Early Oligocene sediments in Hungary – Proposal for the Eocene-Oligocene boundary in the Alpine-Carpathian-Pannonian system; definition of the Kiscellian stage, Visegrád-meeting, pp. 37–51.

NAGYMAROSY A., T. BÁLDI, M. HORVÁTH (1986): The Eocene-Oligocene boundary in Hungary – in: C. Pomerol and I. Premoli-Silva (edit.), Terminal Eocene Events, Elsevier Sci. Publ. Amsterdam, pp. 113–116.

OKADA H.–BUKRY D. (1980): Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry 1973, 1975) – Marine Micropal. 5, pp. 321–325.

RÁKOSI, L. (1973): Palynologie des Formations Paléogènes du Bassin de Dorog. – MÁFI Évkönyve vol. LV. No. 3. (in Hungarian and French)

RÁKOSI, L. (1979): Biozones de l'éocènes de la Montagne Centrale de Transdanubie basées sur les recherches palynologiques. – MÁFI Évi Jel. 1977. évről (Annual Report of the Hungarian Geol. Institute of 1977), pp. 241–256. (in Hungarian with French abstract)

RÁKOSI, L. et TÓTH, K. (1980): Contribution a la litho- et biostratigraphie de l'Éocène au sud de la Montagne Bakony. – MÁFI Évi Jel. 1978. évről (Annual Report of the Hungarian Geol. Inst. of 1978), pp. 239–261. (in Hungarian with French abstract)

ROZLOZSNIK, P., SCHRÉTER, Z. and TELEGDI ROTH, K. (1922): Az esztergomi szénterület bánya-földtani viszonyai. (The mining geology of the Esztergom coal field) – Föld. Int. Gyak. Kiadványa Budapest, (in Hungarian)

SAMUEL O. (1972): Planktonic Foraminifera from the Eocene in the Bakony Mountains (Hungary). – Zbornik Geol. Vied Rad ZK 17, pp. 165–215.

SAMUEL, O., SALAJ, J. (1968): Microbiostratigraphy and foraminifera of the Slovak Carpathian Paleogene. Geol. Ust. D. Stura, Bratislava, p. 232.

SOLDAINI, P. (1970): Ricerche micropaleonotogiche e stratigraphiche sull 'Eocene nel basino di Balinka (Ungheria). – Rivista Ital. Pal. Strat. vol, 76. No. 1, pp. 39–87.

STRAUSZ, L. (1963): Die Eozängastropoden von Dudar in Ungarn. – Geologica Hungarica Ser. Palaeontologica Fasc. 33, 200 p. (in Hungarian and German)

STRAUSZ, L. (1974): Die Eozänmollusken von Neszmély (Ungarn). Geologica Hungarica Ser. Palaeontologica Fasc. 38, 160 p. (in Hungarian and German)

SZŐTS, E. (1953): Mollusques éocènes de la Hongrie I. Les mollusques éocènes des environs de Gánt. – Geologica Hungarica Ser. Palaeontologica Fasc. 22, 270 p. (in Hungarian and French)

SZŐTS, E. (1956): L'Éocène (Paléogene) de la Hongrie – Geologica Hungarica, Ser. Geologica Fasc. 9, 320 p. (in Hungarian and French)

SZTRÁKOS K. (1974): Paleogene Planktonic Foraminiferal Zones in Northeastern Hungary – Fragm. Min. et Pal. 5, pp. 29–81.

SZTRÁKOS K. (1978): Stratigraphie et foraminifères de l'oligocène du Nordest de la Hongrie – These de doctorat, Paris. (Manuscript)

TOUMARKINE M. (1971): Etude des Foraminifères planctoniques de deux sondages (H–849 et Pgyt–31) dans l'Eocène de la Montagne du Bakony (Transdanubie, Hongrie). – Ann. Inst. Geol. Publ. Hung. 54 (4) I, pp. 283–299.

VITÁLIS-ZILAHY, L. (1967): Upper Eocene Foraminifera from the Region of Felsőtárkány (South-Western Bükk Mts.) – MÁFI Évi Jel. 1965. évről (Annual Report of the Hungarian Geol. Inst. of 1965), pp. 393–443.

VOGL V. (1910): A piszkei bryozoás márga faunája. – Földt. Int. Évk. 18, pp. 173–204.

PALYNOLOGICAL STUDIES ON THE INTERCALATED SEDIMENTS OF THE YEMEN VOLCANICS NEAR SANA'A

by

N. M. ABOUL ELA and M. KEDVES

Department of Geology, Cairo University, Cairo, Egypt, and Department of Botany J. A. University, Szeged, Hungary

(Received: 1st March, 1987)

Abstract

On the basis of our palynological results a complex reworking during the sedimentation process of the Yemen volcanics near Sana'a was established. As regards the geological age, the sporomorphs may be grouped as follows: 1. Upper Cretaceous types, 2. Forms, which may occur in the Upper Cretaceous, but are mostly characteristic for the Lower Tertiary layers, 3. Tertiary, mostly Neogene sporomorphs, 4. Pliocene or Plio-Pleistocene forms. In this way the age of the continental intercalated sediments are Upper Neogene, probably Plio-Pleistocene. From palaeophytogeographical point of view some so-called European Upper Senonian and Tertiary taxa (Normapolles, saccate gymnosperm pollen grains) are worth of mentioning.

Introduction

The palynological investigation was carried out on seven surface samples collected from the continental sediments intercalated in the Yemen volcanics. The studied section is located about 4 km of Sana'a, along the Sana'a-Wadi Zahr asphaltic road (Fig. 1).

Stratigraphically, at the end of the Paleocene Epoch, series of volcanic tuffs and lavas of different composition have been formed covering the whole of the intensive eroded surface of the Medj-Zir Formation. These volcanic rocks, covering about a quarter of the whole Yemen, are known as Yemen volcanics (GROLIER and OVERSTREET, 1976). The Yemen volcanics are considered the most characteristic of the country. Indeed, almost the whole of the central and southern plateau of Yemen consist mainly of rocks related to these volcanics.

The Yemen volcanics are made up mainly of lava flows alternated with basalt, andesite, trachyte and varicoloured tuffs, with maximum thickness reaching about 1200 m (GEUKENS, 1966).

During the period in which these Yemen volcanics formed there were intervals during which series of continental sediments have been formed. These sediments, attaining a thickness of a few meters, consist mainly of fresh water shales and clays, fossiliferous in parts and sometimes contain bitumenous beds and plant remains. In some places these sediments are formed of paleosol, generally lateritic. These intercalated sediments are

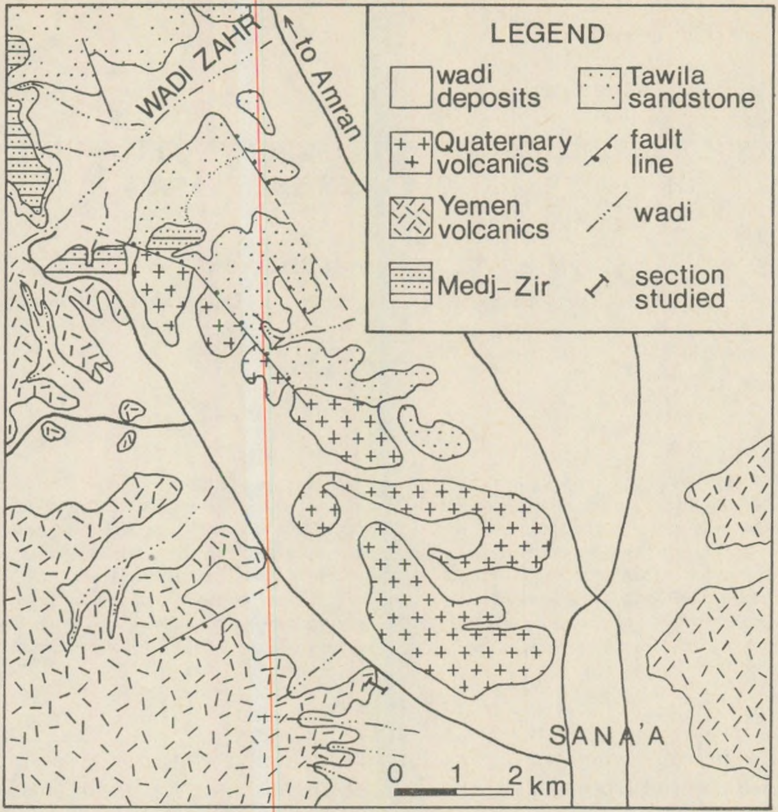


Fig. 1. Geological map of the area NW of Sana'a showing the location of the studied section

fossiliferous with fresh water gastropods, pelecypods and ostracods suggesting Oligocene-Miocene age (MORRIS, of the Arabian American Oil Co., GEUKENS, 1966). The Yemen volcanics probably started toward the end of the Cretaceous but become more intense and extensive during the Tertiary (GEUKENS, 1966).

The present work is devoted to determining, as far as possible, the exact stratigraphic position of these volcanics on the basis of the microfloral contents encountered in the intercalated sediments.

Material and Methods

The section under study measures 2.25 m and consists mainly of reddish, yellowish and greyish shales, mudstones and massive kaolinitic claystone, fossiliferous with fresh water lamellibranchs, gastropods and plant remains (Fig. 2.). The preparation of the samples followed the method pub-

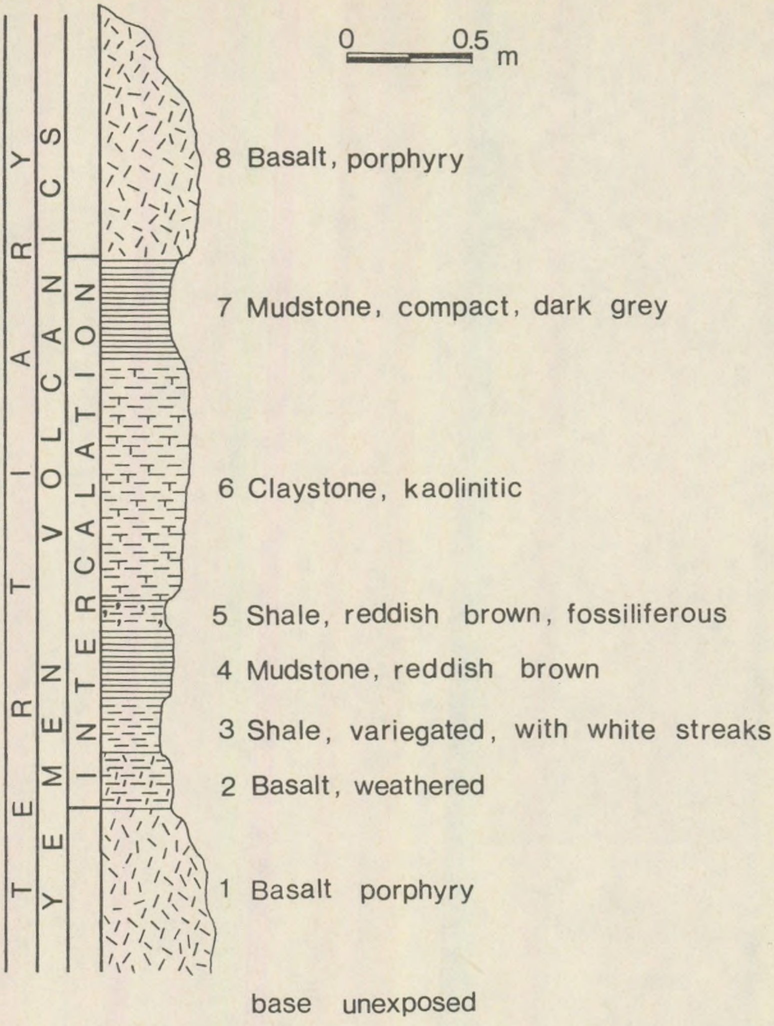
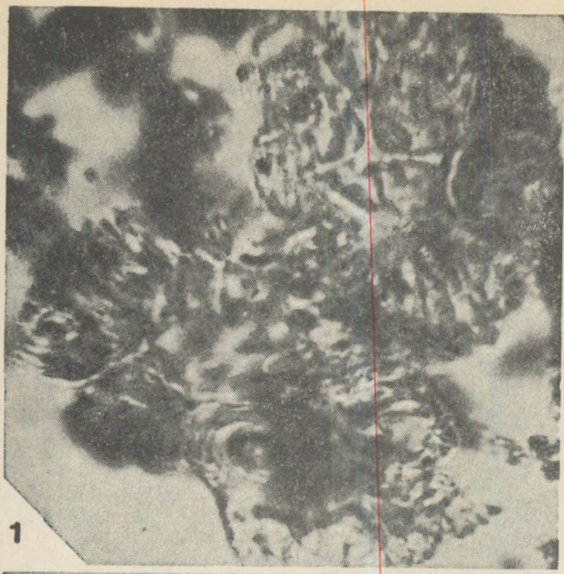


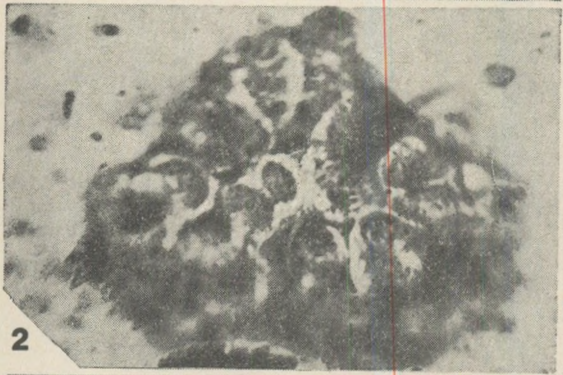
Fig. 2. Columnar section of the intercalated series

lished by KEDVES (1986). In this way the material was soaked in water for 24 hours. The treatment is made with HCl, when the piece of sediment becomes completely homogeneous it was washed with water. The material was centrifuged, then the organic material separated by $ZnCl_2$ solution of 1.89 to 2 specific weight. The $ZnCl_2$ solution comprising the organic matter is thoroughly washed after being strongly diluted. Finally the material is treated with HF, after washing the organic material was mounted in glycerine jelly hydrated in 39.6%. The slides are deposited in the collection of the Department of Botany, J. A. University, Szeged, Hungary.

1



2



3

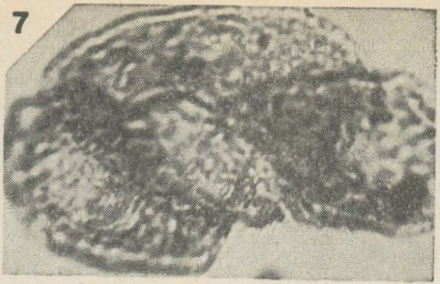
4

5

6

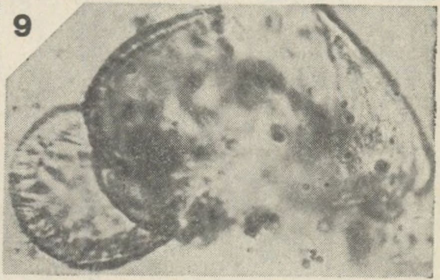
20µm

7



8

9



10

11

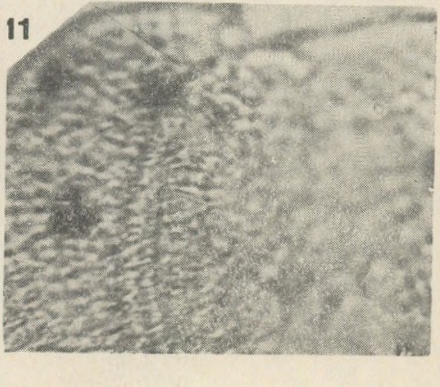


PLATE 1.

Fig. 1. *Botryococcus braunii* KÜTZ. slide: J – 2 – 5; cross-table number: 8.4/106.3.

Fig. 2. *Botryococcus braunii* KÜTZ., slide: J – 3 – 3; cross-table number: 5.3/108.7.

Fig. 3. Conidiophora and conidia, slide: J – 5 – 14; cross-table number: 16.3/110.4.

Figs. 4, 5. *Favoisporis concavus* E. NAGY 1963, slide: J – 4 – 7; cross-table number: 5.0/104.1.

Fig. 6. *Brandenburgisporis tenera* W. KR. 1962, slide: J – 2 – 5; cross-table number: 15.0/112.7.

Figs. 7, 8. *Pityosporites labdacus* (R. POT. 1931b) TH. et PF. 1953 subfsp. labdacus, Abietaceae, Pinus, slide: J – 2 – 14; cross-table-number: 15.0/112.7.

Figs. 9, 10. *Pityosporites longus* (E. NAGY 1985) n. comb., slide: J – 3 – 1; cross-table number: 8.6/112.6.

Fig. 11. *Piceapollenites tobolicus* (PANOVA 1966) E. NAGY 1985, slide: J – 2 – 20; cross-table number: 19.4/101.3.

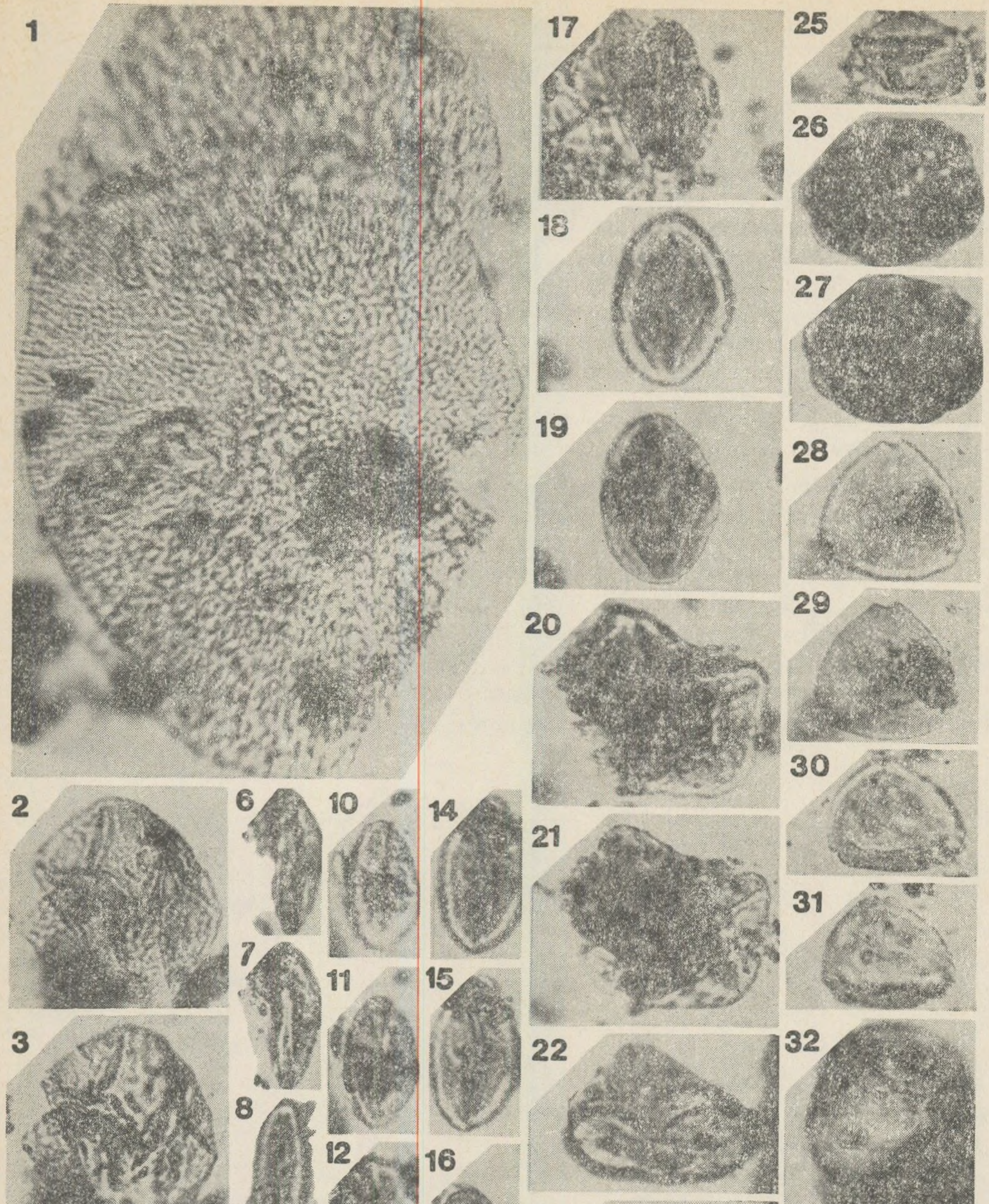

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
20µm

PLATE 2.

Fig. 1. *Piceapollenites tobolicus* (Panova 1966) E. Nagy 1985, slide: J – 2 – 20; cross-table number: 19.4/101.3.

Figs. 2, 3. *Cupressacites hiatipites* (Wodeh. 1933) W. Kr. 1971, Taxodiaceae v. Cupressaceae, slide: J – 2 – 19; cross-table number: 12.7/107.8.

Figs. 4, 5. *Cycadopites cycadioides* (Zakl. 1957) Kds. 1968, Cycadaceae, slide: J – 3 – 14; cross-table number: 13.1/109.9.

Figs. 6, 7. *Cupuliferoidaepollenites liblarensis* (Thoms., in Pot., Thoms. et Thierg. 1950) R. Pot. 1960, Fagaceae v. Leguminosae, slide: J – 2 – 13; cross-table number: 3.5/115.4.

Figs. 8, 9. *Cupuliferoidaepollenites liblarensis* (Thoms., in Pot., Thoms. et Thierg. 1950) R. Pot. 1960, Fagaceae v. Leguminosae, slide: J – 2 – 13; cross-table number: 3.5/115.4.

Figs. 10, 11. *Scabratricolpites hungaricus* Kds. 1978, slide: J – 2 – 12; cross-table number: 7.5/102.6.

Figs. 12, 13. *Scabratricolpites hungaricus* Kds. 1978, slide: J – 2 – 14; cross-table number: 12.3/119.0.

Figs. 14, 15. *Cupuliferoipollenites pusillus* (R. Pot. 1934) R. Pot. 1960, Fagaceae, slide: J – 2 – 17; cross-table number: 20.2/116.6.

Figs. 16, 17. *Cupuliferoipollenites pusillus* (R. Pot. 1934) R. Pot. 1960, Fagaceae, slide: J – 3 – 14; cross-table number: 17.1/107.4.

Figs. 18, 19. *Fususpollenites fusus* (R. Pot. 1934) Kds. 1978, slide: J – 2 – 16; cross-table number: 16.8/108.2.

Figs. 20, 21. *Striatricolporites solé de portai* (Kds. 1965) Kds. 1978, Fabaceae, slide: J – 3 – 10; cross-table number: 15.4/115.4.

Figs. 22, 23. *Semioculopollis croxtonae* Kds. 1979, slide: J – 2 – 21; cross-table number : 20.7/103.7.

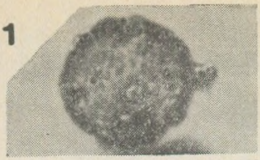
Figs. 24, 25. *Engelhardtioidites microcoryphaeus* (R. Pot. 1931a) R. Pot. slide: J – 3 – 16; cross-table number: 15.3/101.7.

Figs. 26, 27. Cf. Normapolles gen. et sp. indet., slide: J – 4 – 3; cross-table number: 2.9/117.3.

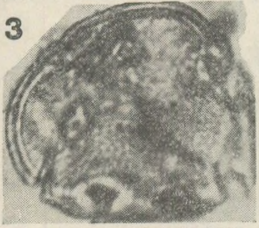
Figs. 28, 29. *Labraferoidaepollenites neerlandicus* (Kds. et Herngr. 1980) n. comb., slide: J – 4 – 6; cross-table number: 15.5/106.7.

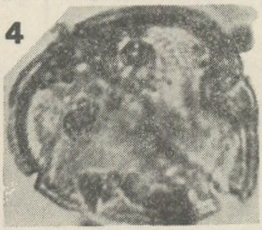
Figs. 30, 31. *Labraferoidaepollenites neerlandicus* (Kds. et Herngr. 1980) n. comb., slide: J – 4 – 18; cross-table number: 10.9/107.4.

Figs. 32, 33. *Graminidites neogenicus* W. Kr. 1970, Gramineae, slide: J – 2 – 13, cross-table number: 9.5/112.3.


1

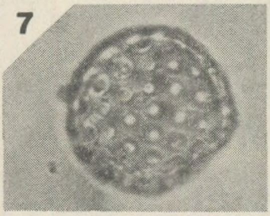

2

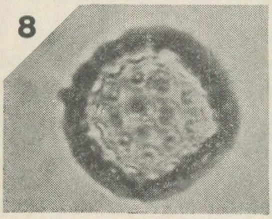

3


4


5

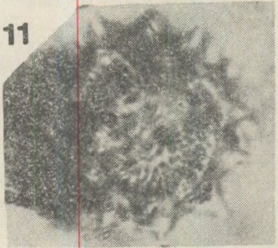

6


7


8

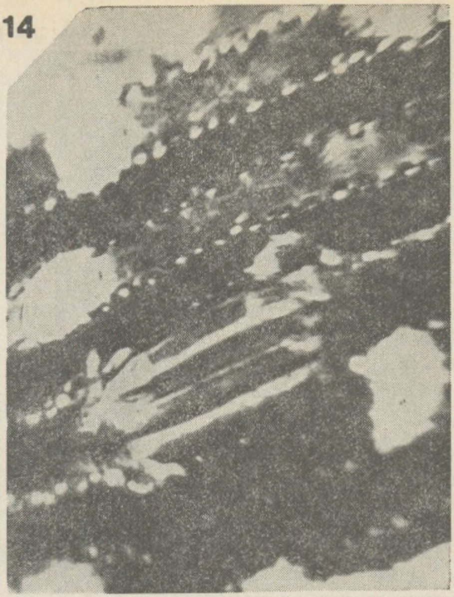

9

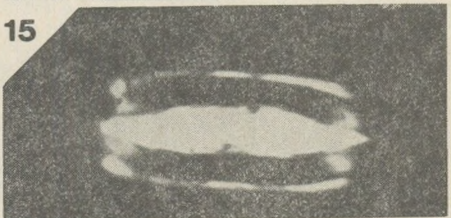

10

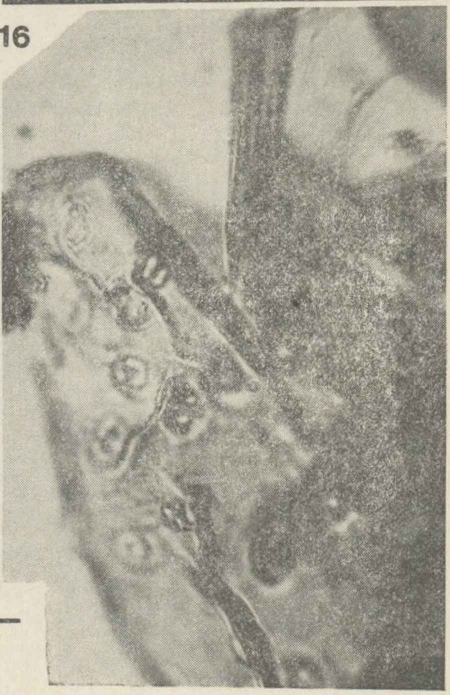

11


12


13


14


15


16

20 µm

PLATE 3.

Figs. 1, 2. *Plantaginacearumpollis miocaenicus* E. NAGY 1963, Plantaginaceae, slide: J – 2 – 21; cross-table number: 8.9/106.5.

Figs. 3, 4. *Intratriporopollenites insculptus* MAI 1961, Tiliaceae, slide: J – 3 – 15; cross-table number: 5.9/117.8.

Figs. 5, 6. *Trivestibulopollenites betuloides* PF. 1953, Betulaceae, Betula, slide: J – 3 – 1; cross-table number: 16.8/107.7.

Figs. 7, 8. *Chenopodiipollis krutzschii* KDS. 1981, Chenopodiaceae, slide: J – 2 – 8; cross-table number: 6.1/116.6.

Figs. 9, 10. *Caryophyllidites barakatii* KDS. 1981. 1981, Caryophyllaceae, slide: J – 2 – 5; cross-table number: 21.2/103.3.

Figs. 11, 12. *Tubulifloridites macroechinatus* (TREV. 1967) E. NAGY 1985, Compositae, slide: J – 3 – 17; cross-table number: 7.9/102.6.

Fig. 13. Gymnosperm secondary wood remnant, slide: J – 3 – 13; cross-table number: 9.9/103.7.

Fig. 14. Burnt epidermis, with Gramineae-type stoma, slide: J – 5 – 13; cross-table number: 15.0/102.7.

Fig. 15. Burnt epidermis, with Gramineae-type stoma, slide: J – 5 – 14; cross-table number: 19.8/115.4.

Fig. 16. Chitinous Foraminiferae shell, slide: J – 2 – 13; cross-table number: 15.7/108.7.

Results

In general, the samples are not rich in sporomorphs. The qualitative data may be summarized in the following groups:

1. From ecological point of view the following is important:
Botryococcus braunii KÜTZ (Plate 1. figs. 1, 2)
Conidiophora and conidia resembling to those of recent *Botrytis cinerea* (Plate 1, fig. 3)
Chitinous Foraminiferae shells (Plate 3, fig. 16)

The importance of the *Botryococcus*, which is a peculiar algue type was emphasized in several publications. The oil shale was formed from the remnants of the colonies of this algue. Its ecologic claim is well know, may correspond to the water of the vulcanic crater lakes. It must be emphasized that these microfossils may also be reworked. Worth of mentioning are the TEM results of the Upper Tertiary colonies, and the experimental studies of the molecular structure of the wall (KEDVES, 1983, and in print). The morphotype of conidiophora with conidia, which occurred in our material. (Plate 1, fig. 3) was observed during our researches (KEDVES and KÖRMÖCZI, 1985) on the microfossil and some selected inorganic element content of the Holocene mud of the Lake Vadkert (Hungary). We have established that when these fungous remnants occur in a huge mass, the spore-pollen and the other kind of plant microfossils are in general strongly destroyed. Later, these forms were observed in several pre-Quaternary spore-pollen assemblages, e. g. in the Maestrichtian of Northern Spain; DE PORTA, KEDVES, SOLÉ DE PORTA and CIVIS (1985), and in the Paleozoic sediments of Ófalu, Hungary; SZEDERKÉNYI and KEDVES (unpublished). The chitinous shells of Foraminiferae (Plate 3, fig. 16) refer to salt water condition.

2. Upper Cretaceous angiosperm pollen types

Semioculopollis croxtonae KDS. 1979 (Plate 2, figs. 22,23)
Cf. *Normapolles* gen. et sp. indet. (Plate 2, figs. 26,27)
Labraferoidaepollenites neerlandicus (KDS. et HERNGR. 1980) n. comb. (Plate 2, figs. 28 – 31)
Basionym: 1980, KEDVES and HERNGREEN, *Triatriopollenites neerlandicus* n. fsp., p. 533, plate XIV, figs. 25, 26.
These, few early angiosperm pollen types were described and found in the European Maestrichtian (Netherlands) and Lower Danian, Fish Clay Formation (Denmark) layers.

3. Mostly Lower Tertiary sporomorphs, which may occur in the Upper Cretaceous sediments too

Cycadopites cycadioides (ZAKL. 1957) KDS. 1968, Cycadaceae (Plate 2, figs, 4, 5)

Cupuliferoidaepollenites liblarensis (THOMS. in POT., THOMS. et THIERG. 1950) R. POT. 1960, Fagaceae v. Leguminosae (Plate 2, figs. 6 – 9)

Scabratricolpites hungaricus KDS. 1978 (Plate 2, figs. 10–13)

Cupuliferoidaepollenites pusillus (R. POT. 1934) R. POT. 1960, Fagaceae (Plate 2, figs. 14–17)

Fususpollenites fusus (R. POT. 1934) KDS. 1978 (Plate 2, figs, 18, 19)

Striatricolporites solé de portai (KDS. 1965) KDS. 1978, Fabaceae (Plate 2, figs, 20, 21)

4. Tertiary, mostly Neogene sporomorphs

Favoisporis concavus E. NAGY 1963a (Plate 1, figs. 4, 5)

Brandenburgisporis tenera W. KR. 1962 (Plate 1, fig. 6)

Cupressacites hiatipites (WODEH. 1933) W. KR. 1971, Taxodiaceae v. Cupressaceae (Plate 2, figs, 2, 3)

Pityosporites labdacus (R. POT. 1931b) TH. ET PF. 1953 subfsp. *labdacus*, Abietaceae, Pinus (Plate 1, figs. 7, 8)

Pityosporites longus (E. NAGY 1985) n. comb. (Plate 1. figs, 9, 10)
Basionym: 1985, E. NAGY, *Pinuspollenites longus* n. sp., p. 129/130, plate LVIII. figs. 2–6.

Piceapollenites tobolicus (PANOVA 1966) E. NAGY 1985 (Plate 1, fig. 11, plate 2, fig. 1)

Engelhardtioidites microcoryphaeus (R. POT. 1931a) R. POT. 1960 (Plate 2, figs. 24, 25)

Plantaginacearumpollis miocaenicus E. NAGY 1963b, Plantaginaceae, Plantago (Plate 3, figs. 1, 2)

Intratriporollenites insculptus MAI 1961, Tiliaceae (Plate 3, figs. 3, 4)

Trivestibulopollenites betuloides PF. 1953, Betulaceae, Betula (Plate 3, figs. 5, 6)

Graminidites neogenicus W. KR. 1970, Gramineae (Plate 2, figs. 32, 33)

5. Pliocene or Plio-Pleistocene forms

Chenopodiipollis krutzschii KDS. 1981, Chenopodiaceae (Plate 3, figs. 7, 8)

Caryophyllidites barakatii KDS. 1981 (Plate 3, figs. 9, 10)

Tubulifloridites macroechinatus (TREV. 1967) E. NAGY 1985 (Plate 3, figs. 11, 12)

6. Plant tissue remnants

Gymnosperm secondary wood remnant, tracheids with developed type pits (Plate 3, fig. 13)

Burnt epidermis, with Gramineae-type stoma (Plate 3, figs. 14, 15)

On the basis of the quantitative data we can establish the following:

It is well shown in fig. 3 that the lower part of the sediments studied is relatively rich in sporomorphs. In samples N° 7 and 5, there are Norma-

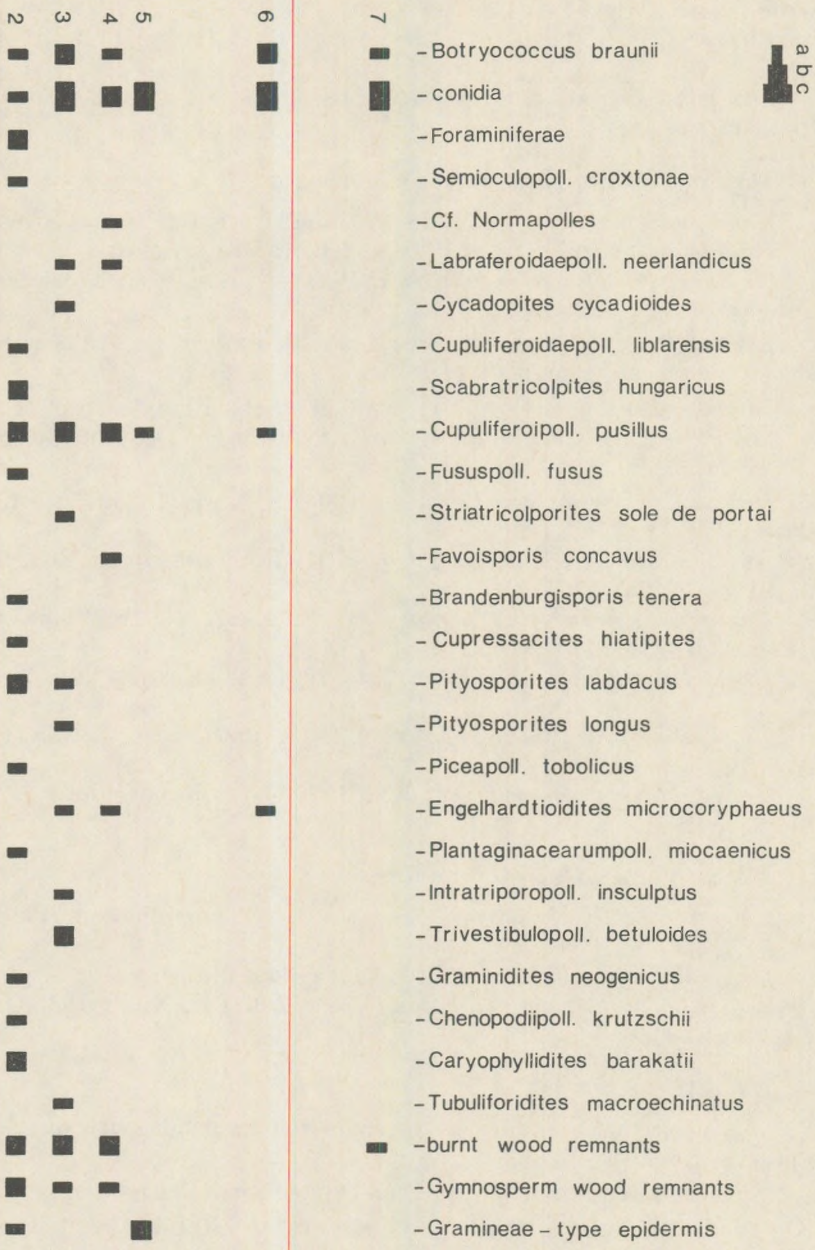


Fig. 3. Diagram of the plant microfossils. a = rare, b = common, c = dominant

polles taxa, referring without doubt to an Upper Cretaceous reworking. In the lowest sample (No 7) occur only chitinous Foraminiferae shells too, indicating that one part of the rebedded sediments was of marine origin. The so-called old Tertiary pollen grains with relative abundance of Longaxones indicate a semiterrestrial swamp ecology. For the Neogene material we can suppose a Cupressaceae-Pteridophyta swamp ecology, with Gramineae, and on the highland Gymnosperm wood with *Pinus* and *Picea*. The few, young Tertiary or Pliocene-Pleistocene angiosperm pollen grains, of the Chenopodiaceae, Caryophyllaceae and Compositae, refer firstly to an ingression of the coastal swamp. It seems that the tissue remnants, in particular the epidermis of Gramineae-type stoma, and the secondary wood remnants with modern pitting are important in the determination of the age of the intercalated sediments. The microfossil content of sample No 6 is essentially the same, only the lack of the Normapolles is worthy of mention. In sample No 4 there are very few plant microfossils, the conidia are dominant, the Gramineae-type epidermis refer only to an Upper Tertiary age. The samples of the upper part of the series of the sediments studied contain in a huge mass conidia, Botryococcus algue and very few pollen grains.

Discussion and conclusions

1. The plant microfossil assemblages of the studied samples of the Yemen volcanics intercalated series near Sana'a refer to an Upper Tertiary age, with reworking of different ages (Upper Cretaceous, Paleogene, Lower Neogene). From ecological point of view important microfossils e. g. the *Botryococcus* algue, and the chitinous shells of Foraminiferae may also be reworked. In connection with this we cite the publication of WILSON (1964), p. 432: "In the clays of the Mississippi River it is not uncommon to find marine microfossils along with spores and pollen of Pennsylvanian, Cretaceous, Tertiary and Recent plants." It was pointed out in several publications, that the colour, and the preservation of the reworked forms are different, we have observed this phenomenon during our investigations, too.

2. The conidia and conidiophora which we have observed in general in a mass in our samples may be the remnants of Fungi, which degrade the organic remains.

3. The Normapolles and the greatest part of the Postnormapolles is characteristic for the European Senonian and Lower Tertiary layers. We must emphasize that our data are not enough for a final palaeophytogeographical conclusion, but we can take into consideration the following; KEDVES (1985), p. 124: "1. From a palaeophytogeographical point of view, in Senonian time, Madagascar is most important, because it is situated near three provinces (Aquilapollenites, Nothofagidites and Monocolpates). Therefore, a peculiar mixed pollen flora may be presumed here. 2. Further interesting areas, for palynological investigations: 2.1. Southern part of Arabia; question: is the genus *Aquilapollenites* present here together with the

so-called Gondwana elements?" It seems, that the results of further investigations on the Cretaceous and Tertiary sediments of Yemen may be very interesting and important in palaeophytogeographical respect too.

REFERENCES

De Porta, J., Kedves, M., Solé de Porta, N. y Civis, J. (1985): Palinologia del Maastrichtiense del Barranco de la Posa (Lérida, España). Problemática regional. – Rev. Inv. Geol. 40, pp. 5 – 28, pl. I – VII.

Geukens, F. P. M. (1966): Geology of the Arabian Peninsula, Yemen. A review of the geology of Yemen as shown as USGS miscellanous geologic investigation map 1 – 270A "Geologic Map of the Arabian Peninsula". – US Government Printing Office, Washington, paper 560 – B., pp. 1 – 23.

Grolier, M. J. and Overstreet, W. C. (1976): Preliminary and simplified geologic map of Yemen Arab Republic LANDSTAT – 1 image No. 1136 – 07012 U.S.G.S., openfile. Report Map scale 1:5000 000.

Kedves, M. (1965): Palynological investigations on the Lower Eocene layers in the surrounding country of Iszkaszentgyörgy III. – Acta Biol. Szeged 11, 1 – 2, pp. 33 – 50, pl. I – VIII.

Kedves, M. (1968): Études palynologiques des couches du Tertiaire inférieur de la Région Parisienne. III. – Pollens inaperturés, à ballonnets, polypliqués, monocolpés, disulquéa, trichotomosulqués, et proxaperturés. – Pollen et Spores 10, 2, pp. 315 – 334, pl. I – III.

Kedves, M. (1978): Paleogene fossil sporomorphs of the Bakony Mountains Part III. – Studia Biol. Acad. Sci. Hung. 15, pp. 1 – 166.

Kedves, M. (1979): Palynological investigations on sediments of the Lower Danian (Fish Clay, Denmark) I. – Acta Miner. – Petr. Szeged 24, 1, pp. 167 – 186, pl. I – V.

Kedves, M. (1981): Études palynologiques sur les sédiments préquaternaires de l'Egypte. Néogène I. – Grana 20, pp. 119 – 130.

Kedves, M. (1983): Étude paléobotanique sur les schistes pétrolifères du Tertiaire Supérieur de Hongrie. – Rev. de Micropaléont. 26, 1, pp. 48 – 53, pl. I – II.

Kedves, M. (1985): The present day state of Upper Cretaceous palaeophytogeography on palynological evidence. – Acta Biol. Szeged 31, 1 – 4, pp. 115 – 127.

Kedves, M. (1986): Introduction to the Palynology of Pre-Quaternary deposits Part I. – Studia Biol. Acad. Sci. Hung. 19, pp. 1 – 164.

Kedves, M. (in print): Dégradation expérimentale des colonies du genre Botryococcus des schistes pétrolifères du Tertiaire supérieur de Hongrie. – Acta Biol. Szeged

Kedves, M. and Herngreeg, G. F. W. (1980): Palynology of the stratotype of the Maestrichtian and the Gulpen Formation, ENCI Section, Maastricht, The Netherlands. – Pollen et Spores 22, 3 – 4, pp. 483 – 544, pl. I – XV.

Kedves, M. et Körmöczi, L. (1985): Sur les problèmes de conservation des sporomorphes dans des conditions differentes. – An. Asoc. Palinol. Leng. Esp. 2, pp. 263 – 271.

Krutzsch, W. (1962): Atlas der mittel- und jungtertiären dispersen Sporen- und Pollensowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lief. I. Laevigate und toriate trilete Sporenformen. – VEB Deutscher Verlag der Wissenschaften, Berlin, pp. 1 – 108, pl. 1 – 46.

Krutzsch, W. (1970): Atlas der mittel- und jungtertiären dispersen Sporen- und Pollensowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lief. VII. Monoporate, monocolpate, longicolpate, dicolpate und ephedroide (polyplicate) Pollenformen. – VEB Gustav Fischer Verlag, Jena, pp. 1 – 175, pl. 1 – 50.

Krutzsch, W. (1971): Atlas der mittel- und jungtertiären dispersen Sporen- und Pollensowie der Mikroplanktonformen des Mikroplanktonformen des nördlichen Mitteleuropas. Lief. VI. Coniferenpollen. – VEB Gustav Fischer Verlag, Jena, pp. 1 – 234, pl. 1 – 74.

Mai, H. D. (1961): Über eine fossile Tiliaceen-Blüte und tilioiden Pollen aus dem deutschen Tertiär. – Geologie 10, BH 32, pp. 54 – 93, pl. IX – XIII.

NAGY, E. (1963a): Spores et pollens nouveaux d'une coupe de la briqueterie d'Eger (Hongrie). – Pollen et Spores 5, 2, pp. 397 – 412.

NAGY, E. (1963b): Some new spore and pollen species from the Neogene of the Mecsek Mountain. – Acta Bot. Acad. Sci. Hung. 9, 3 – 4, pp. 387 – 404, pl. I – V.

NAGY, E. (1985): Sporomorphs of the Neogene in Hungary. – Geol. Hung. 47, pp. 1 – 471, pl. I – CXVIII.

PANOVA, L. A. (1966): Spores and pollen grains from Lower Oligocene sediments. – In.: Andreeva, E. M. et al. (eds.), Paleopalynology III, p. 360. (Russian)

POTONIÉ, R. (1931a): Zur Mikroskopie der Braunkohlen. Tertiäre Blütenstaubformen. 1. Mitt. – Z. Braunkohle 1931, pp. 225 – 233, pl. 2.

POTONIÉ, R. (1931b): Pollenformen aus tertiären Braunkohle. – Jb. Preuss. Geol. Landesamt. 52, pp. 1 – 7.

POTONIÉ, R. (1934): Zur Mikrobotanik des eozänen Humodils des Geiseltales. – Arb. aus Inst. Palaobotanik und Petrogr. Brenngesteine 4, pp. 25 – 125, pl. 1 – 6.

POTONIÉ, R. (1960): Synopsis der Gattungen der Sporae dispersae III. Teil: Nachträge Sporites, Fortsetzung Pollenites. Mit Generalregister zu Teil I – III. – Beih. Geol. Jb. 39, pp. 1 – 189, pl. 1 – 9.

POTONIÉ, R., THOMSON, P. W. und THIERGART, F. (1950): Zur Nomenklatur und Klassifikation der Sporomorphae (Pollen und Sporen). (Zur Geologie der rheinischen Braunkohle 1). – Geol. Jb. für das Jahr 1949 65, pp. 35 – 70, pl. 1 – 3.

THOMSON, P. W. und PFLUG, H. D. (1953): Pollen und Sporen des mitteleuropäischen Tertiärs. – Palaeontographica B, 94, 1 – 4, pp. 1 – 138, pl. 1 – 15.

TREVISAN, L. (1967): Pollini fossili del Miocene superiore nei tripoli del Gabbro (Toscana). – Palaeontographia Italica 62, pp. 1 – 73, pl. I – XXXVI.

WILSON, L. R. (1964): Recycling, stratigraphic leakage, and faulty techniques in Palynology. – Grana Palynologica 5, 3, pp. 425 – 436.

WODEHOUSE, R. P. (1933): Tertiary pollen. II. The oil shales of the Eocene Green River Formation. – Bull. Torr. Bot. Club 60, pp. 479 – 524.

ZAKLINSKAYA, E. D. (1957): Stratigraphic value of the Cenozoic gymnospermous pollen of the Pavlodarsk stretch of the Irtysh river and the northern Aral Coast. – Trud. Geol. Inst. URSS, 6, pp. 1 – 184, pl. I – XVII. (Russian)

TITHONIAN AMMONITES (OPPELIIDAE, HAPLOCERATIDAE AND SIMOCERATIDAE) FROM THE TRANSDANUBIAN CENTRAL RANGE, HUNGARY

by

I. FŐZY

Palaeontological Department, Hungarian Natural History Museum, Budapest

(Received: 30th May, 1987)

Abstract

Rich Upper Jurassic ammonite faunas have been collected recently from several profiles in the Transdanubian Central Range. The present paper gives the first results of the taxonomic work on these faunas from the Bakony Mts, the western part of this range. The Tithonian representatives of three families: Oppeliidae, Haploceratidae and Simoceratidae are described as a first step in the systematic treatment of the ammonite faunas. Genera *Semiformiceras* (with 5 forms), *Neochetoceras, Haploceras* (9 species, incl. one new: *H. cassiferum* nov. sp.), *Pseudolissoceras* (with a single, new species: *P. olorizi* nov. sp.), *Simoceras* (with two species), *Volanoceras* (with 6 forms and a new, unnamed subgenus), *Simolytoceras* (with 3 forms, incl. one new species: *S. vighi* nov. sp.) and *Lytogyroceras* (with two species) are described and figured. The morphological descriptions are completed with discussions on dimorphism, stratigraphic and paleogeographic distribution.

Introduction

The Upper Jurassic of the Transdanubian Central Range is very rich in fossils, especially in ammonites. The here studied and described material contains 2 specimens from the Kálvária Hill of Tata and from the Margit Hill of the Gerecse Mts., but the main sources of ammonites are Bakony Mountains localities: Rendkő, Eperkés Hill, Sümeg, Lókút Hill, Hárskút and Szilasárok. The latter four localities, which yielded the majority of the studied specimens, were described by Vigh (1984) and Főzy (1987, 1988).

The collected huge material (several thousands of specimens) serves as basis for future monographic treatment. The aim of the studies is to reduce the difference now exists between the faunistic knowledge of the Lower, Middle and Upper Jurassic.

Working out the whole Upper Jurassic ammonite fauna of the Transdanubian Central Range, one may expect not only a precise biostratigraphic subdivision of a wide temporal interval, but a paleobiogeographically based paleoenvironmental reconstruction and an evolutionary evaluation also.

Systematic descriptions

The suprageneric categories are used in the system suggested by DONOVAN et al. (1981). The description of the majority of the taxa was ordered as follows:

Material. All mentioned or figured specimens are deposited in the collections of the Hungarian Geological Survey (Budapest), inventory numbers refer to this collection.

Measurements. The majority of the material consits of poorly-preserved, fragmentary specimens, thus the measurements are occasionally uncertain (marked with "?") or incomplete in several cases. The numbers refer to the following dimensions: diameter; whorl-height; whorl-width and umbilical width; the last three in the percentage of the diameter. Whorl-height means the value of the vertical projection of the height. Height and width in the ribbed Simoceratids refer to parameters measured between the ribs. All measurements (or the first ones in the cases of more than one measurements on the same specimens) refer to dimensions measured at the maximal diameter of the specimen.

Description. Here the given taxon or occasionally a single specimen is described.

Remarks. Here comparison to related taxa or specimens are given.

Distribution. This paragraph gives both the stratigraphic and the geographic distributions of the taxon.

Dimorphism. Because of the incompleteness of the material and of some other factors, the identification of dimorphic pairs on the specific level would meet some difficulties. Thus the present work follows the solution suggested by CALLOMON (1969, p. 116) distinguishing micro- and macroconch forms on subgeneric level, where it is possible.

Order Ammonoidea ZITTEL, 1884
Subroder Ammonitina HYATT, 1889
Superfamily Haplocerataceae ZITTEL, 1884
Family Oppeliidae DOUVILLÉ, 1890
Subfamily Streblitinae SPATH, 1925

Genus *Semiformiceras* SPATH, 1925

Type species. *Ammonites Fallauxi* OPPEL, 1865, p. 547 by original designation of SPATH (1925, p. 115).

Diagnosis. Small size, more or less excentrically-coiled body chamber with deep ventral furrow, ventrolateral tubercules, from where ribs arise occasionally. All these features are strongly variable.

Observations. This genus unites forms which have been described under the following names: *S. darwini* (NEUM.), *S. semiforme* (OPP.), *S. gemmellaroi* (ZITT.), *S. domoplicata* (ZITT.). Nevertheless, on the basis of ENAY's work (1983) on the infraspecific variability of the *Semiformiceras* species, it seems sufficient to keep only three names, beacause the two forms described by ZITTEL seem as varieties of *S. fallauxi*.

ENAY and GEYSSANT (1975), realising the stratigraphic significance of the *Semiformiceras* species, introduced a new zonation for the Mediterranean Tithonian. As zonal indices, they suggested *S. darwini* (then included into the genus *Neochetoceras*), *S. semiforme* and *S. fallauxi*.

The first to draw attention to the infraspecific variability of *Semiformiceras* was OLÓRIZ (1978). Based on studies on the rich material from the Betic Cordilleras, he introduced three new subspecies.

ENAY (1983) reviewed and treated the previously described species and subspecies within a comprehensive phylogenetic framework. He enlarged the sphere of the related zonal indices, with ranging NEUMAYR's "*darwini*" into the genus. As a result, *Semiformiceras* attained a distingished role in the biostratigraphy of the Tithonian.

Semiformiceras is an important element in the Hungarian faunas, too: VIGH (1984) recorded *S. fallauxi* and *S. semiforme* from the Bakony Mts.

One should bear in mind, that this genus, despite its relatively rich documentation, poses also numerous unanswered questions. Especially in the light of ENAY's work (1983) it is curious, that the small *S. gemmellaroi* (a close ally of *S. fallauxi*) occurs in the base of the Semiforme Zone of the Rogoznik Beds (KUTEK and WIERZBOWSKI 1979, p. 201). CECCA et al. (1985) recorded a specimen very similar to *S. gemmellaroi* from similar horizon in the Apennines. These latter authors regarded this "*fallauxi*-related" *S. gemmellaroi*, and the stratigraphically older form similar to the zonal index as two independent species. It is noteworthy, that a small-sized, *S. fallauxi* – like ammo nite was found in a similar stratigraphic position in the Hárskut II. profile, Bed 62.

Occurrence. The genus is a characteristic element in the Mediterranean Lower and Middle Tithonian. *S. darwini*, *S. semiforme* and *S. fallauxi* are consecutive indices of the respective zones.

Dimorphism. *Semiformiceras* comprises of microconch forms of a probably dimorphic group. This is suggested by the small size and the anomally coiled body chamber of the species. The macroconchs were supposedly found within the genus *Neochetoceras* by ENAY (1983). It is noteworthy, that the *Semiformiceras*-bearing beds of the Bakony profiles commonly yield *Neochetoceras* specimens, though unfortunately in bad preservation, so undeterminable.

Semiformiceras sp.

Text-figure 1.

Material. A single specimen (J – 10867) from Bed 94 of the Szilasárok profile.

Description. The whorl-section, the rapidly flattened ribs arising at the umbilical seam, and the fine ventral crenulation of this fragmentary internal mould shows close similarity to the forms described by DONZE and ENAY (1961) as *S.* aff. *semiforme*. The Szilasárok ammonite shows additionally the very delicate ribbing confining to the outer lateral edge and the venter.

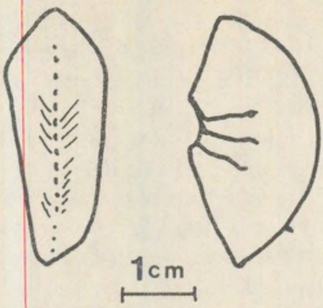


Figure 1. Semiformiceras sp. (J – 10807).
Szilasárok, Bed 94. Semiforme Zone.

Semiformiceras semiforme (Oppel, 1865)

Plate I, figs. 1, 2, 3.

1865 *Ammonites semiformis* Opp. – Oppel, p. 547.
1870 *Oppelia semiformis* Opp. – Zittel, p. 59, pl. 28, figs. 7, 8.
1956 *Semiformiceras semiforme* (Opp.) – Arkell, pl. 43, fig. 1.
non 1961 *Semiformiceras* aff. *semiforme* (Opp.) – Donze and Enay, p. 60, figs. 11 – 13.
1978 *Semiformiceras semiforme semiforme* (Opp.) and subspp. – Olóriz, pp. 68 – 74, pl. 3, figs. 1 – 7.
1983 *Semiformiceras semiforme* (Opp.) – Enay, p. 120, figs. 3/5 – 14.
1984 *Semiformiceras semiforme* (Opp.) – Vigh, p. 143, pl. 1, fig. 6.
1986 *Semiformiceras semiforme* (Opp.) – Sarti, p. 494, pl. 1, fig. 7.
1987 *Semiformiceras semiforme* (Opp.) – Főzy, pl. 1, fig. 2 – 3.

Material. Six internal casts (J – 10867 – J – 10873; J – 10171) from the Bakony profiles.

Measurements.

J – 10871	?61	?31 (50.8)	–	10 (16.3)
J – 10872	64	31 (48.4)	–	8 (12.5)
J – 10869	73	35 (47.9)	–	10 (13.6)

Description. The specimens from Bed 59 of the Hárskút, Közöskút ravine, profile II (J – 10869, J – 10870: Pl. I, fig. 1), with the conspicuously excentric coiling and tubercules on the body chamber resemble most closely the subspecies *S. semiforme tuberosum* Olóriz. One specimen shows a part of the crenulation on the venter of the phragmocone, which is so clearly visible on the lectotype. It is conspicuous, that in the Hárskút specimens the ventral furrow becomes unusually wide, and this resembles rather the species *S. darwini* (Neumayr) than the narrow ventral groove of Zittel's species.

The here figured specimen (Pl. I, fig. 1), on the basis of its comparatively big size, more excentric coiling, may come from the lower or middle part of the biozone.

The specimen from Bed 53 of the Szilasárok profile (Pl. I, fig. 2) is of medium-size and moderately excentric in coiling. The phragmocone is largely gone by dissolution. At the beginning of the body chamber, near to the ventrolateral margin, well-visible are the strong tubercules, the characteristic feature of the species. The ventral furrow is narrow. The flank of the body chamber is smooth, without tubercules or stronger ribs. The few tuberculelike swellings can be probably due to preservational causes. All these features indicate the upper part of the biozone.

The Sümeg profile also yielded several specimens of this species. However, the majority of the material is fragmentary. These *S. semiforme* specimens were metioned in the faunal lists of Vigh (1984), and he figured one example. This specimen (J–10171) is refigured here (Pl. I, fig. 3). This is a medium-sized form with moderately excentric coiling. Its features: sculpture, strong grooves on the flank of the body chamber are typical to *S. semiforme* (at least to the lectotype), thus indicate the middle part of the biozone.

Another Sümeg specimen (Pl. I, fig. 4) is closer to the subspecies *tuberosum* of Olóriz.

Remarks. The specimens from the Bakony, similarly as those from the Subbetics, show great variability in coiling, sculpture and size.

Distribution. This species is the index form of the Semiforme Zone in the Mediterranean Tithonian.

Dimorphism. This species comprises of probable microconchiate forms.

Semiformiceras fallauxi (Oppel, 1865)

Plate, I, figs. 5 and 6

1865 *Ammonites Fallauxi* Opp. – Oppel, p. 547.
1870 *Oppelia Fallauxi* Opp. – Zittel, p. 179. pl. 28, figs. 4, 5 and 6.
1870 *Oppelia Gemmellaroi* Zitt. – Zittel, p. 180, pl. 28, figs. 10 and 11.
1870 *Oppelia domiplicata* Zitt. – Zittel, p. 181, pl. 28, figs. 13 and 14.
1890 *Ammonites (Oppelia) Fallauxi* Opp. – Toucas, p. 578, pl. 13, fig. 8.
1928 *Oppelia Gemmellaroi* Zitt. – Blanchet, p. 270, pl. 1, fig. 3.
1976 *Semiformiceras* sp. ex gr. *S. fallauxi* (Opp.) – Patrulius and Avram, p. 18, pl. 9, fig. 5.
1978 *Semiformiceras fallauxi* (Opp.) – Olóriz, p. 74, pl. 13, fig. 8.
1978 *Semiformiceras gemmellaroi* (Zitt.) – Olóriz, p. 76, pl. 3, fig. 9.
1983 *Semiformiceras fallauxi* (Opp.) – Enay, p. 120, figs. 3/14–20.

Material. A single, partly fragmentary specimen (J–10874) from the Sümeg profile.

Measurements.

J–10874	?32	11 (34.3)	8 (25)	12 (37.5)

Description. Vigh (1984) mentions several specimens of *S. fallauxi* in his faunal list from Sümeg. The here figured well-preserved but fragmentary specimen came also from his material. The swellings at the umbilical margin and the arising ribs, as well as the external furrow and the elongated, marginal tubercules are well visible.

Remarks. The specimen has a somewhat broader umbilicus as compared to that on the forms figured by Zittel, and its size and sculpture resembles the specimen of Toucas.

Distribution. The species is the index form of the Fallauxi Zone of the Mediterranean Tithonian.

Dimorphism. This species apparently unites microconchiate forms.

Semiformiceras cf. *fallauxi* (Oppel, 1865)

Material. A single fragmentary specimen (J – 10875) from Bed 54 of the Hárskút, Közöskút ravine profile II.

Remarks. The relatively big size, broad umbilicus and the lateral swellings of the specimen suggest the form described by Olóriz as subspecies *S. semiforme rotundus*. The ventral part cannot be studied. The specimen probably indicates the lowermost part of the biozone.

Genus *Neochetoceras* Spath, 1925

Type species. *Ammonites steraspis* Oppel, 1863, by original designation of Spath 1925, p. 115.

Neochetoceras div. sp.

Text-figs. 2, 3, 4 and 5.

Material. 12 badly-preserved, fragmentary specimens (J – 10876 – J – 10887) from the Bakony profiles.

Measurements.

J – 10876	116	63 (54.3)	–	?16 (?13.7)
J – 10882	49	25 (51.0)	–	? 8 (?16.3)

Remarks. The exceptionally fragile, thin shell of *Neochetoceras* may have been less resistant to mechanical effects, thus all collected specimens are very badly preserved, subsolved, fragmented. All are insufficient for closer determination. Nevertheless, these strongly oxycone shells are so characteristic elements in the Tithonian faunas, that their short description seems to be justified.

The single feature shown in numerous fragments is the whorl-section around the venter. Most common are forms with broadly flattened venter, with partial traces of the conella (Text-figs. 2 and 3). In some specimens the convergent, flat flanks meet in well-defined, marked keel (Text-fig. 4).

Figure 2. Neochetoceras sp. (J – 10876). Cross-section. Lókút Hill, Bed 48. Middle Tithonian, (?) Fallauxi Zone.

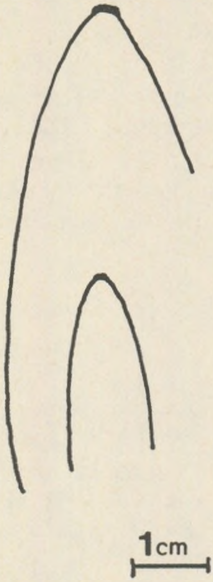


Figure 3. Neochetoceras sp. (J – 10878). Cross-section. Lókút Hill, Bed 26. Microcanthum Zone.

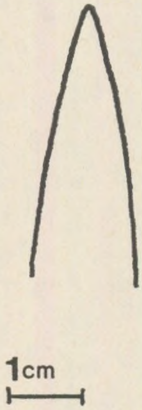


Figure 4. Neochetoceras sp. (J – 10881). Cross-section. Szilasárok, Bed 95. Semiforme Zone.

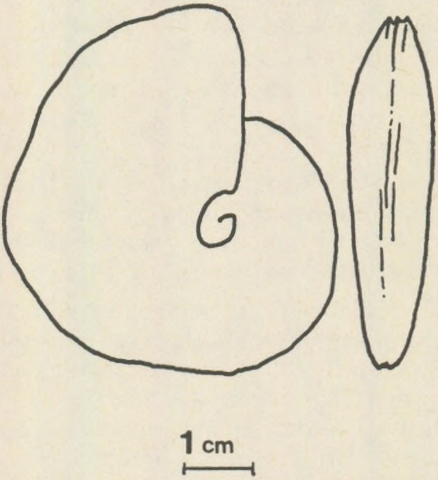


Figure 5. Neochetoceras sp. (J – 10882). Cross-section, Szilasárok, Bed 99. Semiforme Zone.

In one small, but probably adult specimen the venter of the body chamber shows characteristic tricarination (Text-fig. 5). This is similar to that on *N. steraspis* forma *mucronata* of BERCKHEMER and HÖLDER (1959, p. 106).

Distribution. *Neochetoceras* species are characteristic elements in the Mediterranean Tithonian (mainly in the lower and middle parts).

Dimorphism. ZEISS (1968) suggested infrageneric dimorphism in *Neochetoceras*. ENAY (1983) assumed, that the macroconchiate *Neochetoceras* species are the pairs of microconchs ranged into the genus *Semiformiceras*.

Family Haploceratidae Zittel, 1884

Genus *Haploceras* ZITTEL, 1868

Type species. *Ammonites elimatus* OPPEL, 1865, by subsequent designation of SPATH 1923, p. 14.

Observations. Identifications of the related species is greatly hampered by wide variability, especially in faunas of great specimen number, where transitory forms with transitional size, whorl-section and coiling appear between species weith statistically well-established features. Additional problem is that the different *Haploceras* species of relatively simple morphology show great similarity in their inner whorls, thus fragmentary specimens are especially difficult or impossible to identify specifically.

Because of its common occurrence, this group needs special attention. The Szilasárok ammonite fauna of 3,500 specimens has 24%, while in the Hárskút, Közöskút ravine profile II the nearly 3,000 specimens has 30% representation of *Haploceras*. It is worth mentioning, that commonly only a single species, *H. (H.) elimatum* shows extremely high dominance.

Occurrence. *Haploceras* and very close allies occur in the Mediterranean areas and in Mexico, Cuba and in India.

The earliest *Haploceras* is probably *H. toulai* from the Lower Kimmeridgian of Bulagria (SAPUNOV 1979, p. 44). The genus is known mainly from the Tithonian. Its Lower Tithonian representation is subordinate, but great quantities appear from the Semiforme Zone onwards. *Haploceras* evolved with moderate rate, with substage ranges of most species, however within the Tithonian some forms are useful as stratigraphic tools.

Dimorphism. Several attempts have been made to demonstrate dimorphism or establish dimorphic pairs in the species groups of *Haploceras*. BARTHEL (1962) suggested sexual dimorphism surprisingly between the species *H. elimatum* and *H. staszycii*. PATRULIUS and AVRAM (1976) indicated that the microconchiate *Neoglochiceras* is the dimorphic pair of the genera *Haploceras* and *Neolissoceras* macroconchs. However, the name *Neoglochiceras* is an objective synonym, as pointed out by ENAY and CECCA (1986, p. 49), and cannot be used in the interpretation of PATRULIUS and AVRAM.

ENAY and CECCA (1986) interpreted the 9 classic species and the here described *H. (H.) cassiferum* nov. sp. as macroconch and microconch forms of two species altogether. They applied (M) and (m) for dimorphs and they defined morphologically well-distinguished foms (earlierly species) with the word "morphe".

In this present work the microconch *Haploceras* forms are treated – according to the rule of priority – under subgenus name *Hypolissoceras* BREISTROFFER, 1947, while the macroconchs are discussed in the nominate subgenus.

Subgenus *Haploceras (Haploceras)* ZITTEL, 1868

Remarks. This subgenus comprises the big, microconchiate species of *Haploceras*.

Haploceras (Haploceras) elimatum (OPPEL, 1865)

Plate II, figs. 1 and 2, 3.; Text-fig. 6

1865 *Ammonites elimatus* OPP. – OPPEL, p. 549.
1868 *Ammonites elimatus* OPP. – ZITTEL, p. 79, pl. 13, figs. 1–7.
1870 *Haploceras elimatum* OPP. – ZITTEL, p. 169, pl. 27, fig. 7.
1890 *Haploceras elimatum* OPP. – TOUCAS, p. 576, pl. 13, fig. 4.
1925 *Haploceras elimatum* OPP. – SPATH, p. 153, pl. 1, fig. 1.
1960 *Haploceras elimatum* OPP. – COLLIGNON, pl. 142, figs. 536 and 537.
1962 *Haploceras elimatum* OPP. – BARTHEL, p. 11, pl. 1, figs. 12–17.
1966 *Haploceras elimatum* OPP. – PEJO, p. 97, text-fig. 4.
1976 *Haploceras elimatum* OPP. – VIGH in FÜLÖP, p. 72, pl. 25, fig. 4.
1978 *Haploceras elimatum* OPP. – OLÓRIZ, p. 12, pl. 1, figs. 2 and 3.
1979 *Haploceras elimatum* OPP. – SAPUNOV, p. 42, pl. 7, figs. 1 and 2.
1984 *Haploceras elimatum* OPP. – ROSSI, p. 88, pl. 31, figs. 11 and 12.
1986 *Haploceras (Haploceras) charactheis* (M) (Z.) morphe *elimatum* – ENAY and CECCA, pl. 4, figs. 1–5.

Material. 7 numbered (J–10888–J–10894) and several hundred unnumbered, mainly badly-preserved, thus uncertainly identified specimens from the Bakony profiles.

Measurements.

J–10888	?117	?58 (?49.5)	–	?23 (?19.6)
J–10889	?134	?60 (?44.7)	38 (?28.3)	?36 (?26.8)
J–10893	73	34 (46.5)	22 (30.1)	14 (19.1)

Description. Large *Haploceras* with moderately narrow and not too deep umbilicus. The umbilical wall is low and steep, the ventrolateral edge is rounded and the venter is slightly arched. The whorls are compressed with oval whorl-section, the maximal thickness lies near the umbilical margin. The aperture is evenly arched, sinuous.

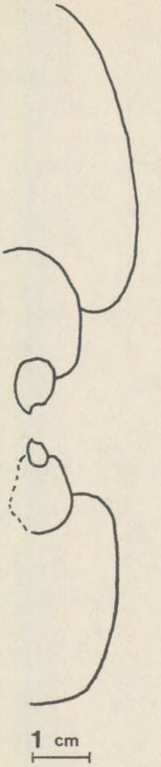


Figure 6. Haploceras (Haploceras) elimatum (OPPEL) (J–10889). Cross-section. Rendkő, a specimen collected from the loose material.

The shell is unsculptured, but some rare specimens show very weak, slightly curved rib-like elements on the upper part of the flanks of the body chamber. Fine growth-lines are shown on the shell of some fairly preserved portions.

The suture-line is well-divided with developed, high first lateral saddle.

Remarks. The closest ally of *H. (H.) elimatum* is *H. (H.) staszycii.* On the basis of the whorl-section, however, the two species are usually easily distinguishable: the compressed whorls of *H. (H.) elimatum* are oval in section, while the other species has less-compressed, subquadrangulate whorls.

H. (H.) elimatum is distinguished from *H. (H.) wohleri* with its narrower and smooth venter, while from *H. (H.) cassiferum* with the lack of the characteristic protrusion.

Distribution. This OPPEL's species is a very common form in the Mediterranean Tithonian. Accordingly, this is a very frequent element all in the Bakony profiles.

Dimorphism. The forms ranged into this species are macroconchs.

Haploceras (Haploceras) staszycii (ZEUSCHNER, 1846)

Text-fig. 7

1846 *Ammonites Staszycii* Z. – ZEUSCHNER, pl. 4, fig. 3.
1868 *Haploceras Staszycii* Z. – GEMMELLARO, p. 34, pl. 7, figs. 1–3.
1870 *Haploceras Staszycii* Z. – ZITTEL, p. 168, pl. 27, figs. 2–6.
1879 *Haploceras Staszycii* Z. – FONTANNES, p. 11, pl. 2, fig. 4.
1960 *Haploceras staszycii* Z. – COLLIGNON, pl. 142, fig. 539.
1976 *Haploceras staszycii* (Z.) – HIMSHIASHVILI, p. 67, pl. 2, fig. 2.
1978 *Haploceras staszycii* (Z.) – OLÓRIZ, p. 15, pl. 1, fig. 1.
1979 *Haploceras staszycii* (Z.) – SAPUNOV, p. 43, pl. 7, fig. 3.
1984 *Haploceras staszycii* (Z.) – ROSSI, p. 89. pl. 31, fig. 8.
1986 *Haploceras (Haploceras) carachtheis* (M.) (Z.) morphe *staszycii* – ENAY and CECCA, pl. 4, fig. 2.

Material. A single numbered specimen (J–10895) from Bed 50 of Hárskút, Közöskút ravine profile II, and some other fragments of unceratin identification.

Measurements.

J–10895	103	50 (48.5)	44 (42.7)	20 (19.4)

Description. Medium-sized forms with relatively narrow umbilicus and quadrangulate whorl-section.

Remarks. The "typical", morphologically well-restricted *H. (H.) staszycii* is a rare ammonite. As is was suggested by previous authors, this species of ZEUSCHNER shows transitions toward other, big *Haploceras* species. Most of the specimens figured in the literature are fragmentary or immature. Thus the specific interpretation is uncertainly based.

For distinguishing *H. (H.) staszycii* from *H. elimatum*, *H. tithonium* and *H. cassiferum*, see the remarks of these species, respectively.

Distribution. This species, usually together with *H. elimatum*, is mentioned by several authors from the Mediterranean Tithonian.

Dimorphism. The species unites macroconch forms.

Haploceras (Haploceras) tithonium (OPPEL, 1965)

Text-fig. 8

1865 *Ammonites tithonius* OPP. – OPPEL, p. 549.
1868 *Ammonites tithonius* OPP. – ZITTEL, p. 82, pl. 14, figs. 1–3.
1976 *Neolissoceras (?) tithonius* (OPP.) – VIGH in FÜLÖP, p. 72, pl. 25, fig. 5.
1976 *Haploceras tithonius Opp.* – HIMSHIASHVILI, p. 67, pl. 2, fig. 1.
1978 *Haploceras tithonium* (OPP.) – OLÓRIZ, p. 20, pl. 1, figs. 4 and 5.
1984 *Haploceras tithonium perumbilicatum* nov. ssp. – VIGH, p. 69, pl. 1, fig. 1.

Material. A single, badly preserved specimen (J–10896) from Bed 42 of the Szilasárok profile.

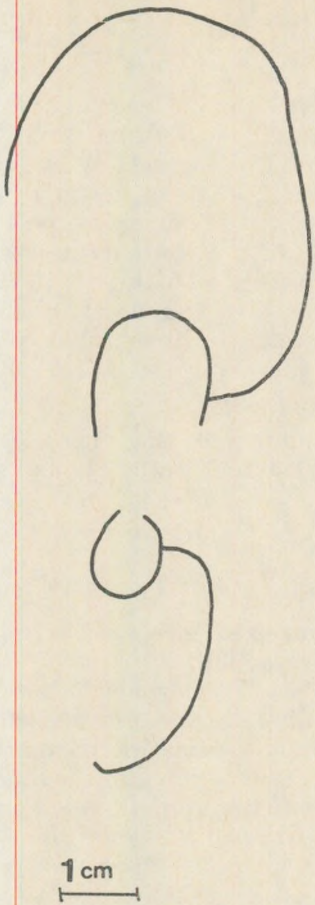


Figure 7. Haploceras (Haploceras) staszycii (ZEUSCHNER) (J – 10895).
Cross-section, Hárskút, Közöskút ravine, profile II, Bed 50. Fallauxi Zone.

Measurements.

J – 10896	60	30 (50.0)	20 (33.3)	?7 (?11.6)

Description. The figured specimen is a wholly septate, slightly corroded fragmentary internal mould. The umbilicus is narrow and shallow. The umbilical wall is low, without definite umbilical edge. The ventrolateral margin is rounded, the flanks are flattened. The whorl-section is compressed, nearly angular.

Remarks. *H. tithonium* is close to *H. staszycii* in its size and whorl-section. This similarity was recognized also by OLÓRIZ (1978) and VIGH (1984). Forms with whorl-section and umbilical width transitional between the two species were described by OLÓRIZ as *Haploceras staszycii* (Z.)

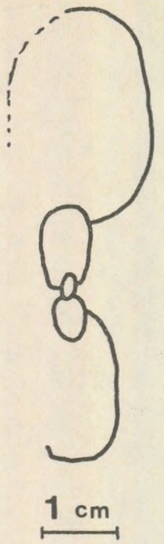


Figure 8. Haploceras (Haploceras) tithonium (Oppel) (J – 10896). Cross-section. Szilasárok, Bed 42. Upper Tithonian.

transiens tithonium (Opp.), and by Vigh as *Haploceras tithonium perumbilicatum* nov. ssp.

On the other hand, *H. tithonium* is close to forms ranged into the genus *Neolissoceras* Spath, 1923. This is why Kilian (1869, p. 644) mentioned an ammonite as *Haploceras Grasi* D'Orb. sp. *tithonium* Opp. sp. Blanchet (1928, p. 292), similarly, cited the species tithonium as a variety of the species of D'Orbigny.

Distribution. This species is characteristic, but not too common in Mediterranean Tithonian faunas. The here figured specimen came from the Upper Tithonian of the Szilasárok profile.

Dimorphism. The species unites macroconch forms.

Haploceras (Haploceras) wohleri (Oppel, 1865)

Plate III, figs. 1 and 2; text-fig. 9

1865 *Ammonites Wöhleri* Opp. – Oppel, p. 549.
1868 *Ammonites Wöhleri* Opp. – Zittel, p. 84, pl. 14, fig. 4.

Material. 4 specimens (J – 10897 – J – 10899, J – 10149) from the Hárskút 12, Eperkéshegy and Sümeg profiles.

Measurements.

J – 10897	105	–	36 (34.2)	–
J – 10898	130	64 (49.2)	?54 (?41.5)	?26 (?20.0)
J – 10899	146	70 (47.9)	?62 (?42.4)	?35 (?23.9)

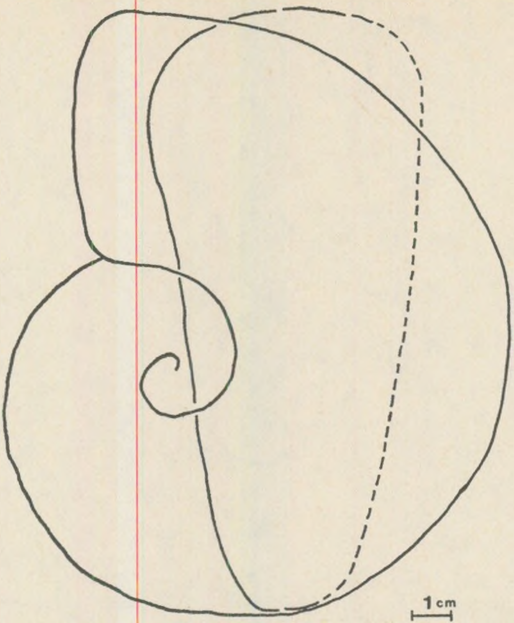


Figure 9. Haploceras (Haploceras) wohleri (OPPEL) (J – 10899).
Eperkéshegy, Bed 6. Lower Tithonian.

Description. This is the biggest *Haploceras* species. The umbilicus is narrow, moderately deep, the umbilical and ventrolateral margins are rounded. The lateral sides are slightly convex, the venter is arched. The whorl-section is compressed oval. The body chamber occupies more than the half of the last whorl. The venter of the last half whorl of the adult specimens is sculptured by characteristic ribs.

Remarks. This rare species has been not figured since ZITTEL (1868) and even its citations are scarce in the literature.

The Hárskút specimen (Pl. II, figs. 1 – 2), with its ribs on the external side of the body chamber and the outline of the aperture matches well the specimen from Stramberg. Whether the strong ribs are continuous down on the flanks (as on ZITTEL's ammonite) cannot be decided because of the corrosion of the Hárskút specimen. On the other hand, the outline of the upper part of the aperture is clearly visible, with the elongated ventral and the deeply sinuous lateral part. The strong lappet shown on ZITTEL's figure is only guessed. There are some conspicuous differences, too: the specimen from Stramberg is bigger, accordingly its body chamber is wider and its ventral ribbing is stronger.

The "typical appearance" (i. e. bigger size, wide venter) is better approached by the specimen from the Eperkéshegy profile. However, these specimens, probably due to the lack of the shell and to subsolution, do not show the characteristic ventral ribs.

Distribution. This species has been cited by Toucas (1890) from Ardèche, with Upper Tithonian – Lower Cretaceous ammonites. Olóriz (1978) described two specimens from the lower part of the Richteri Zone of the Sierra Gorda. Vigh (1984) mentioned numerous specimens from the Middle Tithonian of the Sümeg profile. The Hárskút specimen came from an Upper Tithonian assemblage, while the Eperkéshegy specimen was yielded by a bed ranged into the Lower Tithonian.

Dimorphism. The species comprises of macroconch forms.

Haploceras (Haploceras) cassiferum nov. sp.

Plate IV, figs. 1 and 2, Plate V, figs. 2 and 3,
text-fig. 10

1978 *Haploceras* sp. 1. – Olóriz, p. 30, pl. 1, figs. 9 and 10.

1986 *Haploceras (Volanites) verruciferum* (Zittel) (M) – Enay and Cecca, p. 48, pl. 1, figs. 1 and 9.

Derivatio nominis: cassis (Lat.) = helmet; fero (Lat.) = to bear. The name refers to the protrusion appearing on the ventral termination of the adult body chamber.

Locus typicus: Lókút Hill, Transdanubian Central Range.

Stratum typicum: Bed 56 of Lower Tithonian age.

Diganosis: Relatively big and moderately evolute *Haploceras* with compressed, quadrangular whorls. Behind the adult aperture there is a strong ventral flare resembling that on *H. (Hy.) verruciferum.*

Material. Besides the holotype (J – 9672) there are two good and three poorly-preserved sapecimens from the Bakony profiles and from the Kálvária Hill of Tata (J – 10900 – J – 10903, J – 8048).

Measurements.

J – 9672 (Holotype)	102	?45	(?44.1)	?36	(?35.2)	?23	(?22.5)
J – 8048	105	45	(42.8)	32	(30.4)	26	(27.4)
	83	38	(45.7)	–		20	(24.0)
J – 10900	100	42	(42.0)	–		28	(28.0)
J – 10901	102	43	(42.1)	?43	(?33.3)	?28	(?27.4)

Description. Big *Haploceras* with ca. 10 cm adult diameter. A moderately evolute form, with excentrically coiled body chamber. The umbilicus is shallow, the umbilical wall is steep, leaning back inside, both on specimens with shell and on the casts. The umbilical margin is rounded, the flanks are slightly convex, nearly flat, and meet the arched venter with rounded ventrolateral edge. The whorls are compressed, their section is quadrangular or trapezoidal.

The body chamber occupies about the half of the last whorl. At its termination, behind the aperture, there is a very characteristic ventral flare. This is clearly shown on the shelly specimen (see that from Tata, Pl. V, fig. 3) and on the internal cast as well. Following the flare, there is a

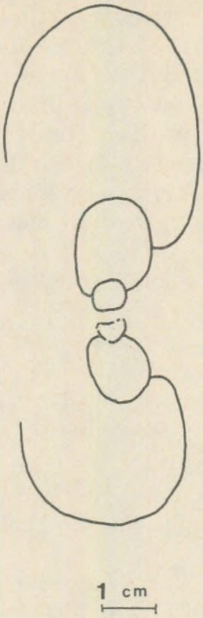


Figure 10. Haploceras (Haploceras) cassiferum nov. sp. (J – 10902). Cross-section. Hárskút. Közöskút ravine, profile II, Bed 63. Darwini Zone.

moderately protruded extension with rounded margin. The lip-like rostrum – as far as it shown on the partly broken specimen – continues laterally in a slightly undulating apertural margin.

The internal moulds are completely smooth. The shelly specimen from Tata shows faint growth-lines.

The suture-line is strongly divided, as it is general in Haploceras. The first lateral saddle is highly elevated.

Remarks. This new species is similar to *H. (Hy.) verruciferum:* both have the terminal flare on the body chamber. However, *H. (H.) cassiferum* can be easily distinguished from ZITTEL's species by the smaller size of this latter. The adult specimens with preapertural flare have ca. 60 mm maximal diameter in *H. (Hy.) verruciferum*, while this adult feature appears at ca. 100 mm diameter in *H. (H.) cassiferum.* The shape of the preapertural flare is also different, and the whorl-section of the two species are also dissimilar. In this latter feature *H. (H.) cassiferum* is close to *H. (H.) staszycii* (ZEUSCHNER). Nevertheless, previously published data suggest, that ZEUSCHNER's species is more involute. The pre-apertural flare, as distinguishing feature needs further considerations. The original of ZEUSCHNER is a relatively young specimen, so lacks the flare, an adult character. ZEUSCHNER did not mention its presence in the description. This is the same with most of the subsequent authors (KILIAN 1889, DEL CAMPANA 1905, BLASCHKE 1911, JEKELIUS 1916, RAMACCIONI 1939, DONZE and

ENAY 1961). Most figured specimens are young or incomplete – thus without flare. Only ZITTEL (1870) and OLÓRIZ (1978) mentions, that ZEUSCHNER's species shows a weak protrusion behind the aperture. OLÓRIZ (loc. cit., p. 33) even gave a drawing of this feature. However, it is probable, that the specimen figured as *H. staszycii*, similarly as that described as *H.* sp. 1. by OLÓRIZ, can be ranged into *H. (H.) cassiferum.*

The form described here as new species, was regarded by ENAY and CECCA (1986) as conspecific and macroconch of the *verruciferum* of ZITTEL. According to their studies, this "species" was separated even in the topmost Darwini Zone. Those forms with pre-apertural flare are ranged by these authors into their subgenus *Haploceras (Volanites).*

Distribution. The holotype came from the Lower Tithonian of the Lókút profile, other specimens were yielded by the Hárskút, Közöskút ravine profile II, Beds 63 and 64, Darwini Zone.

The *Haploceras* sp. 1. specimens of OLÓRIZ from the Subbetics came from the Lower Tithonian (upper Hybonotum Zone – basal Verruciferum Zone). According to the studies of ENAY and CECCA, who interpreted the species in wide sense, gave a distribution from the top of the Darwini Zone to the base of the Fallauxi Zone.

Dimorphism. *H. (H.) cassiferum* includes probably macroconch forms It is possible, that this new species is the dimorph pair of the microconchiate *H. (Hy.) verruciferum.*

Subgenus *Haploceras (Hypolissoceras)* BREISTROFFER, 1947

Type species. *Ammonites carachtheis* ZEUSCHNER, 1847, by original designation of BREISTROFFER.

Observations. This subgenus includes the microconch pairs of th macroconchiate *Haploceras.*

Haploceras (Hypolissoceras) carachtheis (ZEUSCHNER, 1846)

Plate III, figs. 3 and 4

1846 *Ammonites carachtheis* Z. – ZEUSCHNER, pl. 4, fig. 1.
1868 *Ammonites carachtheis* Z. – ZITTEL: p. 84, pl. 15, figs. 1–3.
? 1970 *Ammonites carachtheis* Z. var. *subtilior* Z. – Zittel, p. 172, pl. 27, fig. 11.
1877 *Ammonites (Haploceras) carachtheis* Z. – FAVRE, p. 24, pl. 3, fig. 5.
1879 *Haploceras carachtheis* Z. – FONTANNES, p. 10, pl. 2, fig. 3.
1880 *Ammonites (Haploceras) carachtheis* Z. – FAVRE, p. 29, pl. 2, fig. 10.
? 1890 *Haploceras carachtheis* Z. – TOUCAS, p. 577, pl. 13, fig. 5, pl. 15, figs. 7 and 8.
? 1893 *Haploceras carachtheis* Z. – RETOWSKI, p. 242, pl. 9, figs. 10 and 11.
1939 *Lissoceras carachtheis* (Z.) – RAMACCIONI, p. 196, pl. 13, fig. 13.

1962 *Glochiceras carachththeis* (Z.) – Barthel, p. 17, pl. 2, fig. 1–4, pl. 3, figs. 1–7.
non 1970 *Haploceras (Haploceras) carachtheis* (Z.) – Bernoulli and Renz, p. 597, pl. 5, fig. 2.
1976 *Haploceras (Neoglochiceras) carachtheis* (Z.) – Patrulius and Avram, p. 168, pl. 3, fig. 8.
1978 *Glochiceras (Lingulaticeras) carachtheis* (Z.) – Olóriz, p. 124, pl. 10, figs. 6–8.
1979 *Glochiceras (Glochiceras) carachthais* (Z.) – Sapunov, p. 64, pl. 14, fig. 2.
1983 "*Haploceras*" *carachtheis* (Z.) – Cecca et al., p. 114, pl. 1, fig. 3.
non 1984 "*Haploceras*" *carachtheis* (Z. Z,– Rossi, p. 91, pl. 31, fig. 3.
1984 *Haploceras (Neoglochiceras) carachtheis* (Z.) – Vigh, pp. 145 and 146.
1986 *Haploceras (Haploceras) carachtheis* (m) (Z) morphe *carachtheis* – Enay and Cecca, p. 49, pl. 2, figs. 3 and 4, pl. 3, figs. 1, 2, 10–14 (only)

Material. 6 numbered specimens (J–10904–J–10909) and numerous fragments from the Bakony profiles.

Measurements.

J–10909	45	17 (37.4)	12 (26.6)	13 (28.8)
	35	11 (31.4)	?10 (?28.5)	8 (22.8)

Description. Small to medium-sized species with 60 to 65 mm maximal diameter. The umbilicus is moderately wide and shallow. The umbilical wall is rather low and steep, with rounded umbilical margin towards the hardly convex, almost flat flanks. The ventrolateral edge is rounded, the venter is slightly convex. Accordingly, the whorl-section is nearly rectangular. More than half of the last whorl is occupied by the body chamber. On the ventral side of the body chamber numerous folds appear, which are conspicuous on subsolved specimens only behind the aperture. In exceptional cases even the internal moulds show the aperture, which is very similar to that of the specimens figured by Zittel and Barthel. The terminal ventral protrusion can be seen in several specimens, and occasionally the lateral lappets are also indicated.

This is a rather variable species. Coiling, form of the umbilical margin and depression of the venter show some differences, which were noticed previously by Olóriz. However, those narrowly-umbilicated froms which were figured by Bernoulli and Renz (1970) and Rossi (1984) are probably not conspecific.

Remarks. Except the verruciferum group, all classic *Haploceras* species have been regarded by Enay and Cecca (1986) as the macro- and microconchs and their infraspecific forms of a single species. Accordingly, the name of this so widely interpreted species is *H. carachtheis* (Zeuschner), by priority.

H. (Hy.) carachtheis is most closely allied to *H.* (*Hy.) leiosoma*. The adults of Zeuschner's species, however, are well distinguished by their smaller size, narrower umbilicus and more oblique umbilical wall. Further difference is that *H. (Hy.) carachtheis* has more ventral folds.

Distribution. *H. (Hy.) carachtheis* is a characteristic element in Mediterranean Tithonian faunas. Accordingly, it occurs in all Bakony profiles.

Dimorphism. The group of Zeuschner's species unites microconchiate forms, a fact suggested previously by other authors, too.

Haploceras (Hypolissoceras) leiosoma (Oppel, 1865)

Plate III, figs. 5, 6, 7, text-fig. 11

1865 *Ammonites leiosoma* Opp. – Oppel, p. 550.
1870 *Ammonites leiosoma* Opp. – Zittel, p. 86, pl. 14, figs. 5 and 6.
1890 *Haploceras leiosoma* Opp. – Toucas, p. 594, pl. 15, figs. 9 and 10.
1960 *Haploceras leiosoma* (Opp.) – Raileanu et al., p. 17, pl. 6, fig. 16.
1978 *"Haploceras" leiosoma* (Opp.) – Olóriz, p. 29, text-fig. p. 33.
1986 *Haploceras (Haploceras) carachtheis* (m) (Z.) morphe *leiosoma* – Enay and Cecca, pl. 2, fig. 9, pl. 3, figs. 3–5.
1986 *Haploceras (Haploceras) carachtheis* (m) (Z.) – Enay and Cecca, pl. 2, figs. 1, 8, pl. 3, fig. 6.

Material. Six numbered internal mould (one with partially preserved shell) (J–10910–J–10915), and numerous uncertainly determined fragments from the Bakony profiles.

Measurements.

J–10191	39	19 (48.7)	14 (35.8)	7 (17.9)
	?32	17 (?53.1)	12 (?37.5)	6 (?18.7)

Description. Small form with 40 mm maximal diameter. The umbilicus is narrow, the umbilical wall is slightly oblique and rounds evenly into

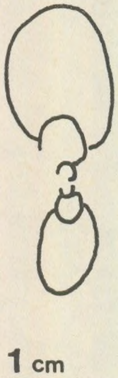


Figure 11. Haploceras (Hypolissoceras) leiosoma (Oppel) (J–10910). Cross-section. Hárskút, Közöskút ravine, profile II, Beds 45. Fallauxi Zone.

the completely flat lateral side. The ventrolateral margin is rounded, the venter is almost flat. The whorls are higher then wide, their section is quadrangular. The extern anterior part of the body chamber in adult specimens bears some (10 to 12) fine ventral grooves, which are deepest in the middle of the venter. The folds between the grooves are hardly elevated above the periphery. One shelly specimen shows, that these folds are continued as slightly curved and weakening riblets onto the ventrolateral margin and somewhat beyond. The body chamber occupies about the terminal half of the last whorl.

Remarks. The closest ally of *H. (Hy.) leiosoma* is *H. (Hy.) carachtheis*. The differences are discussed above, in the description of this latter species.

Distribution. *H. (Hy.) leiosoma* is a characteristic element in the Mediterranean Middle and Upper Tithonian. The Bakony specimens came from beds of Semiforme, Fallauxi, Ponti and Microcanthum Zone ages.

Dimorphism. This species includes microconch forms.

Haploceras (Hypolissoceras) rhinotomum ZITTEL, 1870

Plate III, figs 8 and 9, text-fig. 12.

1870 *Haploceras rhinotomum* ZITT. – ZITTEL, p. 171, pl. 28, fig. 1.
1928 *Lissoceras rhinotomum* ZITT. – BLANCHET, p. 270, pl. 1, fig. 1.
1978 *Haploceras rhinotomum* ZITT. – OLÓRIZ, p. 22, pl. 1, fig. 12.
1986 *Haploceras (Haploceras) carachtheis* (m) (*Z.*) morphe *rhinotomum* – ENAY and CECCA, p. 51, pl. 2, fig. 6.

Material. Three fragmentary internal moulds (J–10916–J–10919 from the Hárskút, Közöskút ravine profile II.

Description. Each specimen is fragmentary body chamber of adult individuals, thus the periumbilical parts cannot be studied. The flanks are flat, the ventral part is rounded. The whorls are compressed. On the terminal part of the body chamber 5 to 6 strong, rectiradiate ventral folds appear. These folds are hardly elevated from the venter, and are separated

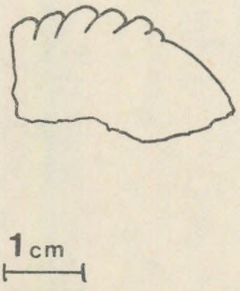


Figure 12. Haploceras (Hypolissoceras) rhinotomum ZITTEL (J–10918). Ventral folds appearing on the adult body chamber. Hárskút, Közöskút ravine, profile II, Bed 45. Fallauxi Zone.

by deep grooves. Deepest grooves and strongest folds appear anteriorly, the folds gradually merge into the venter posteriorly.

Remarks. The ventral folds of the adults are so characteristic, that this is a solid base in distinguishing this species from the other congeneric forms.

Distribution. This species is a characteristic, but not too common element in the Mediterranean province. ZITTEL (1870) and BLANCHET (1928) and TOUCAS (1890) mentions this species from the Upper Tithonian, while OLÓRIZ ranged his material into the "Admirandum – Biruncinatum Zone". The Bakony specimens came from Beds 45 and 47, i. e. from the Fallauxi Zone of the Hárskút profile.

Dimorphism. The forms ranged into this species are microconchs.

Haploceras (Hypolissoceras) verruciferum (ZITTEL, 1869)

Plate IV, figs. 3 and 4, Plate V, fig. 1, Pl. VI, figs. 3 to 6, text-figs. 13 and 14.

1869 *Ammonites verruciferus* MENEGHINI – ZITTEL, p. 145.

1870 *Haploceras verruciferum* MGH. – ZITTEL, p. 52, pl. 27, figs. 8–10.

1890 *Haploceras verruciferum* MGH. – TOUCAS, p. 577, pl. 13, fig. 7.

1905 *Haploceras verruciferum* MGH. – DEL CAMPANA, p. 46, pl. 1, figs. 10 and 11.

1939 *Lissoceras verruciferum* MGH. – RAMACCIONI, p. 197, pl. 13, fig. 14.

1978 *Haploceras verruciferum* MGH. – OLÓRIZ, p. 23, pl. 1, figs. 6–8.

1983 *Haploceras verruciferum* (MGH.) in ZITTEL – CECCA et al., p. 116, pl. 1, fig. 4.

1984 *Hapliceras verruciferum* MGH. – ROSSI, p. 90, pl. 31, fig. 7.

pars 1986 *Haploceras (Volanites) verruciferum* (ZITTEL) (m) – ENAY and CECCA, p. 48, pl. 1, figs. 2–8, pl. 2, figs. 11–15. (only)

1986 *Haploceras verruciferum* (ZITT.) – SARTI, p. 490, pl. 1, fig. 6.

1987 *Haploceras verruciferum* (ZITT.) – FŐZY, pl. 2, fig. 4.

Observations. The first reference to this species is that of ZITTEL (in BENECKE 1869, p. 145). His short description mentions, that one specimen of this characteristic species, kept in that time in the collections in Pisa, had been labelled as "Ammonites verruciferus" by MENEGHINI. On the label there was written – with the very apt name – some remarks only. The first published description and figures, maintaining the name given orginally by MENEGHINI, are those of ZITTEL. Consequently, he should be regarded as the author of the species.

Material. 23 numbered specimens (J–10919–J–10940, J–10210) and some further, fragmentary specimens from the Bakony profiles.

Measurements

J – 10210	43	13 (30.2)	?12 (?27.9)	?16 (?37.2)
J – 10919	61	21 (34.4)	?18 (?29.5)	20 (32.7)
	46	21 (45.6)	?16 (?34.7)	15 (32.6)
J – 10920	64	–	18 (28.1)	21 (32.8)
	51	20 (39.2)	16 (31.3)	17 (33.3)
J – 10927	41	12 (29.2)	12 (29.2)	13 (31.7)
J – 10933	62	–	22 (35.4)	22 (35.4)
J – 10934	45	15 (33.3)	?12 (?26.6)	15 (33.3)
J – 10935	68	22 (32.3)	18 (26.4)	21 (30.8)
	54	21 (38.8)	?16 (?29.6)	16 (29.6)
J – 10938	53	20 (37.7)	16 (31.0)	22 (41.5)

Description. Medium-sized, rather evolute form. The adult diameter is 41 to 68 mm. The umbilicus is broad and shallow, the umbilical margin is rounded. The whorls are slightly higher than wide, with nearly angular section. The usually somewhat excentrically coiled body chamber occupies about 2/3 of the last whorl. The aperture, seen rarely in internal casts, matches well that on the specimens of Zittel. The very characteristic

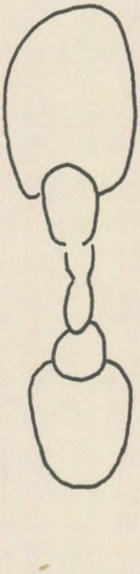


Figure 13. Haploceras (Hypolissoceras) verruciferum (Zittel) (J – 10920). Cross-section. Lókút Hill, Bed 53. Semiforme Zone.

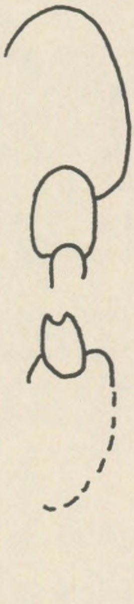


Figure 14. Haploceras (Hypolissoceras) verruciferum (Zittel) (J – 10933). Cross-section. Szilasárok, Bed 94. Semiforme Zone.

wart, or verruca on the external side of the end of the body chamber is shown by several specimens clearly. This small, 3 to 5 mm flare is protruded above the venter, it is slightly curved backward, then abruptly cut or gradually slopes into the venter.

The suture-line is strongly divided, but cannot be traced exactly on the corroded internal casts.

Remarks. This species is easy to recognize but rather difficult to distinguish. The original figures of Zittel show two adult specimens of rather different size: the bigger is 65 mm, the smaller is 43 mm. The large material of Olóriz, just as the Bakony specimens, shows variation within distant extremes, thus the species is rather variable.

Closest form to *H. (Hy.) verruciferum* is that described here as *H. (H.) cassiferum* nov. sp. However, Zittel's species differs in smaller size and in the outline of the characteristic terminal flare on the body chamber.

Distribution. *H. (Hy.) verruciferum* is a characteristic element in Mediterranean Lower Tithonian faunas. The species is recorded from the whole Alp-Carpathian area. Being an easily recognizable and common form, which occurs in a well-defined horizon in the Lower Tithonian, Olóriz (1978) choosed it as a zonal index. However, the Verruciferum Zone corresponds more or less to the previously introduced Semiforme Zone of Enay and Geyssant (1975). The priority of this latter name is not influenced by the fact, that *H. (H.) verruciferum* is usually more common than *S. semiforme* in the fauna.

Dimorphism. Enay and Cecca (1986) described the forms of the *H. verruciferum* group as microconchs. According to these authors, the macroconch pair is the form what described here as *H. (H.) cassiferum* nov. sp. The dimorphic relation of the two forms is quite reasonable.

Genus *Pseudolissoceras* Spath, 1925

Type species. *Neumayria zitteli* Burckhardt, 1903, by original designation of Spath (1925, p. 113).

Occurrence. The genus is recorded outside the Mediterranean region, too. It is also known from Argentina, Cuba and Kurdistan.

Dimorphism. No dimorphism is proved within this genus.

Pseudolissoceras olorizi nov. sp.

Plate IV, figs. 1 and 2, text-fig. 15

Derivatio nominis: Referring to Dr. Federico Olóriz, Spanish paleontologist.

Locus typicus: Hárskút, Közöskút ravine, profile II, Bakony Mountains, Transdanubian Central Range.

Stratum typicum: Bed 66, i. e. Middle Tithonian, Pálihálás Limestone Formation.

Diagnosis: Medium-sized, rather evolute form. Ventral part in middle whorls is characteristically fastigate. Suture-line is *Pseudolissoceras*-type, but conspicuously reduced.

Material. The holotype (J – 10941) and three additional fragmentary specimens (J – 10942, J – 10943, J – 9769).

Measurements.

J – 10941 (Holotype)	89	29 (32.5)	?32 (?35.9)	32 (35.9)
	61	28 (45.9)	?22 (?36.0)	16 (26.2)
J – 10942	57	19 (33.3)	13 (22.8)	20 (35.0)

Description. A medium-sized form with relatively broad and shallow umbilicus. The umbilical wall is steep, but not too high. The umbilical margin rounds into the slightly convex flanks. Maximal width is situated around the middle of the compressed whorls. The whorl-section is characteristic: the venter is fastigate in the middle, and rounded on the outer whorls. The internal moulds do not show sculpture or growth-lines. The aperture is unknown. The holotype shows crowded last sutures. The slightly excentric body chamber occupies nearly the half of the last whorl. All these indicate adult, nearly complete specimen. On the middle whorl the first lateral lobe is clearly visible: it has characteristic, simply-serrated side. The periumbilical elements of the suture-lines are hardly discernible, because of subsolution.

Remarks. This new species is clearly distinguished from the *P. rasile* group [*P. rasile* (Oppel, 1865), *P. planisulcum* (Zittel, 1870), *P. pseudoolithicum* (Haupt, 1907)]. These show subcircular whorl-section or rounded venter, while *P. olorizi* has relatively high, compressed, slightly convex whorls.

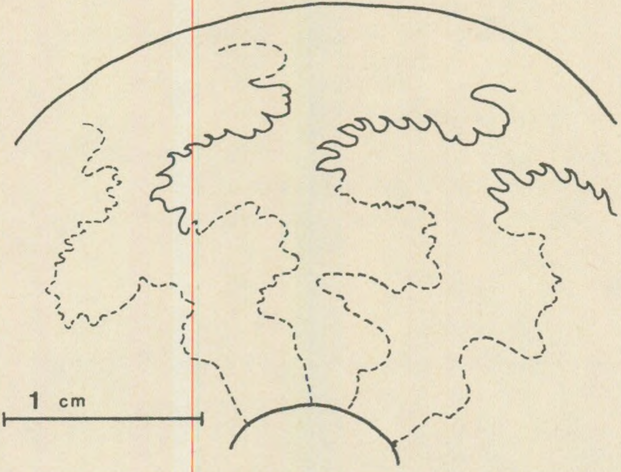


Figure 15. Pseudolissoceras olorizi nov. sp. (Holotype, J – 10904). Suture-line. Hárskút, Közöskút ravine, profile II, Bed 66. Lower Tithonian, (?) Hybonotum Zone.

The species of the *P. zitteli* group [*P. zitteli* (Burckhardt, 1903), *P. concorsi* Donze et Enay, 1961, *P. advena* Spath, 1950, *P. bavaricum* Barthel, 1962] are similar in many characters. The relatively high whorl-section is a common feature. However, *P. olorizi* is distinguished by its wider umbilicus and conspicuously fastigate middle whorls.

The suture-line of this new species is similar to that of *P. bavaricum*. This latter, however, has different, narrower whorl-section. The Bakony specimens ranged into the new species are very near to *Pseudolissoceras* sp. 2. of Olóriz (1978, pl. 2, fig. 4).

Distribution. The holotype came from Bed 66 (probably Hybonotum Zone) of the Hárskút, Közöskút ravine, profile II. Other specimens were yielded by Beds 106 and 93 (Hybonotum and Semiforme Zones) of the Szilasárok profile and Bed 54 of the Lókút Hill profile. *Pseudolissoceras* sp. 2 of Olóriz came from the Verruciferum Zone.

Dimorphism. To trace the possible dimorphic nature of this form needs further studies.

Superfamily Perisphinctaceae Steinmann, 1890

Family Simoceratidae Spath, 1924

Observations. The name *Simoceras* was originally introduced by Zittel in 1870 for some Tithonian ammonites. Subsequently certain Kimmeridgian forms from the several dozens of species ranged into this genus have been grouped into numerous newly designated genera. The same tendency can be followed in the case of the Tithonian forms. Thus the current Tithocian genera of the family are as follows:

- *Simoceras* Zittel, 1870. Medium-sized, shallowly-umbilicated forms with oval whorl-section. The nucleus is ribbed, the middle and outer whorls have an umbilical and a ventrolateral tubercule-row, with denser tubercules in the latter.
- *Virgatosimoceras* Spath, 1925. Medium-sized forms with subrectangular whorl-section. Ribbing is formed mainly by bifurcating ribs with intercalated simple or rarely trifurcating ones.
- *Lytogyroceras* Spath, 1925. Medium- and small-sized, extremely evolute forms with oval whorl-section. The inner whorls bear fine ribs fading out on the middle whorls.
- *Simolytoceras* Olóriz, 1978. Medium-sized forms with oval whorl-section, dense ribbing on the inner whorls, ribs and tubercules on the middle whorls and with smooth outer whorl.
- *Baeticoceras* Geyssant, Enay et Busnardo, 1979. Medium- and big-sized, extremely evolute forms with quadrangular-trapezoidal whorl-section. The shell is ribbed throughout, characteristic is the appearance of split, doubled ribs. The middle and outer whorls bear an umbilical tubercule row and an outer row of well-developed, clavus-like tubercules.

– *Volanoceras* GEYSSANT, 1985. Middle- to big-sized forms with oval-quadrangular whorl-section. The entirely ribbed shell shows an umbilical and a better developed ventrolateral tubercule-row throughout, from early ontogenetic stages.

Recently several works have been pulished on the stratigraphic and geographic distribution of *Simoceras*. The new results suggest, that the detailed outlining of phylogenetic connections may help to arrange the several arbitrary genera into a refined system of fewer categories.

Occurrence. The available data indicate, that the group forms a characteristic element in Mediterranean and Submediterranean faunas. Earliest Simoceratids appear in the Lower Tithonian (Darwini Zone, SANTANTONIO 1985), and the last representatives are *Baeticoceras* described from the Upper Tithonian Microcanthum Zone. Phylogeny within the family seems to follow a trend of size increase and of reduction of dimorphic size ratio.

Dimorphism. Many groups within the family show dimorphism: GEYSSANT (1979) suggested the presence of dimorphic pairs within the genus *Baeticoceras*, while SANTANTONIO (1985) recognized micro- and macroconchs in the species *S. aesiense* and *S. volanense*.

Genus *Volanoceras* GEYSSANT, 1985

Type species. *Ammonites Volanensis* OPPEL, 1869, by original designation of GEYSSANT 1985, p. 679.

Observations. As GEYSSANT (1985) pointed out, several uncertainties arised from the improper designation of *Simoceras* and its type. She restricted the original *Simoceras* name to the *S. biruncinatum* – *S. admirandum* group, and introduced generic name *Volanoceras* for the "S." *volanense*, "*S.*" *schwertschlageri* and "*S.*" *aesinense* species.

Diagnosis. Medium-sized, widely-umbilicated forms with nearly rectangular whorl-section. The inner whorls bear simple or bifurcating ribs, the middle and outer whorls have strong, radial, simple ribs with well-developed umbilical and ventrolateral tubercules. The umbilical tubercules are stronger than the outer ones. The whorls bear strong, slightly prorsiradiate constrictions. The aperture is probably simple, the suture-line is rather simple, *Simoceras*-type.

Occurrence. The *Volanoceras* species are characteristic elements in Mediterranean and Submediterranean Lower and Middle Tithonian faunas.

Dimorphism. The genus shows distinct dimorphism. SANTANTONIO (1985) recognized microconch-macroconch pairs within the species "S." *volanense* and "S." *aesinense*. However, the specific pairing of dimorphs, especially in the case of poorly-preserved material, is uncertain. Accordingly, in this present work the larger (macroconchiate) forms are ranged into the nominate subgenus, while the small (microconchate) forms are grouped in *Volanoceras* nov. of subgeneric rank.

Subgenus *Volanoceras (Volanoceras)* Geyssant, 1985

Volanoceras (Volanoceras) volanense volanense (Oppel, 1863)

Plate VII, figs. 1, 2 and 3, Plate VIII, fig. 2, text-fig. 16

1863 *Ammonites Volanensis* – Oppel, p. 231, pl. 58, fig. 2.
non 1870 *Simoceras Volanense* Opp. – Zittel, p. 213, pl. 32, fig. 7 (?synthetized drawing? – see Geyssant, 1985)
non 1870 *Simoceras Volanense* Opp. – Zittel, p. 213, pl. 32, figs 8 and 9 [= probably *V. (V.) magnum* (Olóriz)]
? 1871 *Simoceras Volanense* Opp. – Gemmellaro, p. 40, pl. 9, fig. 5.
non 1885 *Simoceras Volanense* Opp. – Meneghini, p. 376, pl. 20, fig. 9 [= *V. (V.) aesinense* (Mgh.)]
non 1905 *Simoceras Volanense* Opp. – Del Campana, p. 110, pl. 6, fig. 9 [= *V. (V.) magnum* (Olóriz)]
non 1928 *Simoceras* aff. *Volanense* Opp. – Krantz, p. 13, pl. 3, fig. 7. (Probably different genus)
1939 *Simoceras volanense* Opp. – Ramaccioni, p. 231, pl. 58, fig. 2.
? 1942 *Simoceras* sp. juv. cf. *S. volanense* Opp. – Imlay, p. 1445, pl. 3, figs. 2 and 3.
? 1966 *Simoceras* aff. *volanense* Opp. – Linares and Vera, pl. 3, fig. 5.
non 1970 *Simoceras* cf. *volanense* Opp. – Bernoulli and Renz, p. 600, pl. 6, figs. 4–6.
non 1973 *Simoceras* cf. *S. volanense* (Opp.) – Verma and Westermann, p. 196, pl. 32, fig. 2.
1978 *Simoceras (S.) volanense volanense* (Opp.) – Olóriz, p. 219, pl. 20, fig. 5.
non 1983 *Simoceras (S.) volanense* (Opp.) – Cecca et al., p. 119, pl. 3, fig. 1 [= *V. (V.) aesinense* (Mgh.)]
non 1984 *Simoceras (S.) volanense* (Opp.) – Rossi, p. 115, pl. 35, fig. 12 [= *V. (V.) aesinense* (Mgh)]
1986 *Simoceras volanense* (Opp.) – Sarti, p. 508, pl. 6, fig. 7.
non 1987 *Simoceras* aff. *volanense* (Opp.) - Főzy, p. pl. 1, fig. 1 [= *V. (V.) aesinense* (Mgh.)]

Material. Five fairly preserved specimens (J–10944–J–10947, J–10206) and some additional fragments from the Trandsdanubian Central Range.

Measurements.

J–10944	114	24 (21.0)	?18 (?15.7)	69 (60.5)
	96	19 (19.7)	–	59 (61.4)
	91	18 (19.7)	–	55 (60.4)
J–10206	62	12 (19.3)	?12 (?19.3)	39 (62.9)

Description. Medium-sized forms with wide umbilicus, and whorl-section circular in the beginning and compressed-subangular later. The sculpture of the innermost whorls is a fine, dense, bifurcating ribbing, which becomes rarer, nearly radial with umbilical and ventrolateral tubercules in the middle and outer whorls. The rounded then longitudinally elongated outer tubercules appear earlier, while the later-appearing, somewhat weaker umbilical tubercules show slight radial elongation. The whorls bear strong constrictions. The aperture is apparently simple. The suture-line is similar to that in other *Volanoceras* species, with wide external saddle and less-indented, rather narrow lateral lobe.

A well-preserved specimen (Pl. VII, figs. 1–3) from Bed 25 of the Hárskút, profile 12, though big (maximal diameter 114 mm), is immature, because does not show sutural crowding. Its suture line drawn at 97 mm diameter is shown in Text-fig. 16. An individual peculiarity is that the proximal part of the body chamber shows traces of a repaired shell damage on both the lateral and ventral sides. Unfortunately the inner parts of the cast are strongly corroded, thus the contemporary sutures cannot be seen.

One specimen from the Sümeg profile (Pl. VIII, fig. 2) shows inner tubercule row of gradual differentiation, and attains full development at ca. 16 mm umbilical width. At about 28 mm umbilical width these umbilical tubercules appear on the lower third of the slightly convex flank. The inner tubercules remain weaker than the outer ones. The ribs between the tubercules are slightly arched, prorsiradiate, and reach the umbilical seam.

Remarks. This OPPEL species, as a characteristic form in Tithonian faunas is commonly recorded from Mediterranean areas. Nevertheless, concerning this classic species, and especially its stratigraphic distribution, numerous problems arise. Explanation was needed to interpret the fact, that this species, member of a rapidly evolving group, "diappears" at the end of the Middle Tithonian Semiforme Zone, and "reappears" and becomes relatively common again one zone later. The solution, as it was suggested by CECCA et al. (1985) and SANTANTONIO (1985) is that the specimens

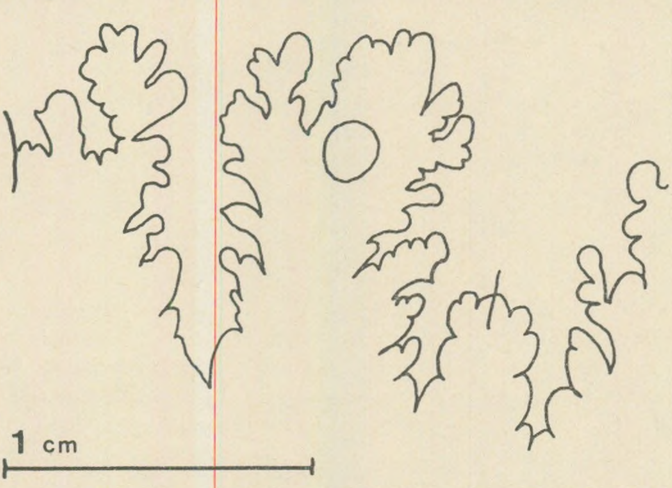


Figure 16. Volanoceras (Volanoceras) volanense volanense (OPPEL) (J–10944). Suture-line. Hárskút, Közöskút ravine, profile 12, Bed 25. Ponti Zone.

previously described uniformly as "*volanense*", belong actually into different species. This problem is reflected in several earlier works as applied open nomenclature, uncertain determinations or interrupted distributions in faunal lists or range tabulations.

GEYSSANT (1982) regarded the Semiforme Zone forms (her *Simoceras* n. sp. gr. *volanense*) as the indirect ancestors of the "true" *volannese* occurring in the Ponti Zone. She based the infraspecific evolutionary connections on the punctuated equilibrium model, and understood the areal distribution of the species by allopatric speciation.

CECCA et al. (1985) called the attention to a species, which was figured as a variety of *volanense* and described as "*aesinense*" by MENEGHINI (1885). According to CECCA et al., who interpreted this form as independent species, this is a *volanense* ally, appearing in the Semiforme Zone.

SANTANTONIO (1985) grouped and described similarly his material from the Central Apennines. He gave detailed descriptions on the species of OPPEL and MENEGHINI. He recognized the associated appearance of small and big forms in the Tithonian beds, he applied microconch and macroconch expressions and treated the dimorphism on species level.

On the basis of the studied Transdanubian material and in accordance with the opinions of authors cited above, the s. str. *V. (V.) volanense* is that form, which appears in the Ponti Zone. This can be separated from OPPEL's species both on morphological and stratigraphical grounds from the older form designated as species by MENEGHINI. It is worth mentioning, that the material of other sections suggests, that the specimens of *Volanoceras* species in this restricted sense (i. e. *Volanoceras (V.) volanense volanense)* are rather rare, while the ammonites of the *V. (V.) aesinense* group are more common.

V. (V.) volanense and the closely allied *V. (V.) aesinense* can be distinguished by the following features. The adult specimens of OPPEL's species are larger, their nuclei show bifurcate ribbing, while *V. (V.) aesinense* has simple ribs. The middle whorls of *V. (V.) volanense* bear weaker inner tubercules than the species of MENEGHINI. This distinction, however, is less clear in mature body chambers. The suture-line of *V. (V.) volanense* is incised with deeply elongated lateral lobe, while the suture is rather simple in *V. (V.) aesinense.* As it was mentioned above, the two species is separated also in stratigraphic range.

Another problem is the distinguishing of these two species from the form described by SCHNEID as *S. schwertschlageri.* As a probably untenable solution, this latter form is treated here as subspecies of *V. (V.) volanense. S. schwertschlageri* is characterized by prorsiradiate ribs and round-based, pointed tubercules, while s. str. *volanense* has nearly radial ribs and longitudinally elongated tubercules. However, the distinction between these forms needs further studies.

OPPEL's species is distinguished from *V. (V.) magnum* and *V. (V.) vicentinum* by its smaller size.

As it is clear from the discussion above, the specimens united previously under the name "*volanense*" can be ranged into some distinct species. Unfortunately the unfigured citations in the literature can be rarely evaluated correctly.

Of the citations mentioned in the synonymy the extra-Eauropean occurrences are of special interest. Krantz (1928) mentions a well-preserved, partly shelly specimen from Argentina. At is was pointed out by Krantz, this form differs from Oppel's species by its whorl-section, special sculpture and in lack of the characteristic constrictions. Thus it is probably not a conspecific, or even not a congeneric form.

The related form figured by Imlay (1942) from Cuba as a juvenile "*volanense*" is probably a microconch.

Distribution. This subspecies is characteristic in the Ponti Zone of the Mediterranean Tithonian.

Dimorphism. In this present work only the bigger, macroconchiate forms are ranged into Oppel's subspecies. The small, probably microconch forms are described in *Volanoceras* nov. subgen. below.

Volanoceras (Volanoceras) volanense schwertschlageri (Schneid, 1915)

Plate VIII, fig. 1

1915 *Simoceras Schwertschlageri* n. sp. – *Schneid*, p. 92, pl. 4, fig. 6.
1978 *Simoceras (S.) volanense schwertschlageri* (Schneid) – Olóriz, p. 224, pl. 20, figs. 3 and 6.
1987 *Simoceras schwertschlageri* (Schneid) – Főzy, pl. 2, fig. 5.

Material. A single specimen (J–10948) from Bed 42 of the Hárskút, Közöskút ravine, profile II, and some uncertain fragments from other localities.

Measurements.

J–10948	?77	14 (?18.1)	?14 (?18.1)	47 (?61.0)

Description. The specimen form the Hárskút profile shows the features described by Schneid, i. e. the slightly prorsiradiate ribs and the row of round-based, pointed outer tubercules. The constrictions, just as in all *Volanoceras*, are deep and prorsiradiate.

Remarks. Geyssant (1982) regarded Schneid's form as an independent species, which forms a transition between the allied species of the Semiforme and Ponti Zones.

The naming of the Hárskút specimen as *schwertschlageri* may be curious, beacause the beds with *S. schwertschlageri* of the Neuburg succession are better correlated with the Semiforme, than the Ponti Zone of the Mediterranean zonal scheme. Thus *schwertschlageri*, as a subspecies, would be better ranged into the species *V. aesiense*. However, the Hárskút specimen came undoubtedly from the Ponti Zone, but shows the characteristics of Schneid's species. To solve this problem, one needs detailed study on the geographic and stratigraphic distributions of these forms.

Distribution. According to Geyssant (1982) the species is knwon only from the Brianconnais and Francony, but its presence in the s. str. Mediterranean areas is also presumbale. Geyssant recorded the species from the Semiforme and Fallauxi Zones, the Hárskút specimen came from the Ponti Zone.

Dimorphism. This subspecies comprises of big forms only. The small forms are discussed together with other Volanoceras microconchs under the name *Volanoceras* nov. subgen.

Volanoceras (Volanoceras) cf. *volanense* (Oppel, 1863)

Material. A single specimen (J – 10949) from Bed 65 of the Szilasárok profile.

Remarks. This strongly corroded body chamber fragment shows, that the outer marginal tubercules of the slightly prorsiradiate rib endings are similar to those on Oppel's species. The inner tubercules are undeveloped. The bed which gave the specimen can be ranged into the Ponti Zone.

Volanoceras (Volanoceras) aesinense (Meneghini, 1885)

Plate VIII. fig. 3 and 4, plate IX, figs. 1, 2 and 3, Plate X, fig. 2, text-fig. 17

pars 1870 *Simoceras Volanese* Opp. – Zittel, p. 213, pl. 23, fig. 7. (probably only outer whorls)
1885 *Simoceras Volanense* Opp. – Meneghini, p. 376, pl. 20, fig. 4. (Under the name *aesinense*, as a variety of *volanense* in the text)
1983 *Simoceras (Simoceras) volanense* (Opp.) – Cecca et al., p. 119, pl. 3, fig. 1.
1984 *Simoceras (Simoceras) volanense* (Opp.) – Rossi, p. 115, pl. 35, fig. 12.
v. pars 1984 *Simoceras (Simoceras) volanense volanense* (Opp.) – Vigh, pp. 22, 29.
1985 *Simoceras aesinense* Meneghini – Santantonio, p. 15, pl. 1, figs. 2 and 3, pl. 2, figs. 2, 3 and 6. (only)
1987 *Simoceras* aff. *volanense* (Opp.) – Főzy, pl. 1, fig. 1.

Material. Seven fairly-preserved specimens (J – 10950 – J – 10955, J – 9778) and some further fragments from the Transdanubian Central Range.

Measurements.

J – 10950	91	17 (18.6)	?14 (?15.3)	56 (61.5)
J – 10951	106	23 (21.6)	18 (16.9)	67 (63.2)
	86	?17 (?19.7)	?16 (?18.6)	54 (62.7)
	82	16 (19.5)	?14 (?17.8)	52 (63.4)
	75	16 (21.3)	?14 (?18.6)	44 (58.6)
J – 10952	98	19 (19.3)	18 (18.3)	62 (63.2)
	80	15 (18.7)	14 (17.5)	49 (61.2)
J – 10955	?112	24 (?21.4)	24 (?21.4)	75 (?66.9)

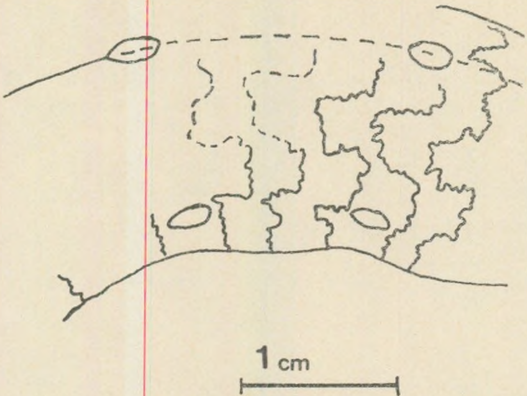


Figure 17. Volanoceras (Volanoceras) aesinense (MENEGHINI) (J – 10981). Suture-line. Hárskút, Közöskút ravine, collected from loose material.

Description. The Hárskút specimen ranged here in this species was previously figured (FŐZY 1987) as *Simoceras* aff. *volanense* (OPP.). This ammonite (Pl. X, fig. 2) has been collected by A. GALÁCZ from the loose material of the section. This is an almost entire specimen, and on the basis of sutural crowding (Text-fig. 17) it is an adult form. The body chamber occupies ca. 2/3 of the last whorl. At the end of the cast the body chamber is narrowed by a strong, constriction-like intercostal space, probably also indicating the ceasing of growth and forming the final aperture. The middle whorls of the specimen are corroded, the nucleus is missing. Though it can be ranged into the aesiense group described in detail by SANTANTONIO (1985), its rarer ribs in the middle whorls and longitudinally more elongated umbilical tubercules are somewhat different.

The *V. (V.) aesinense* specimen from Bed 53 of the Lókút profile (Pl. IX, figs. 1 and 2), with its very strong, cogged outer tubercules in the middle whorls, is very similar to the forms Rin. 1. and NS3 Col. 23. figured by SANTATNONIO (1985).

The specimens from Beds 92 and 93 of the Szilasárok profile (Pl. VIII, fig. 3 and 4) are strongly corroded internal mould fragments. Their identity with MENEGHINI's species is proved by the strong inner tubercules and the well-developed ribs. The radial elongation of the inner ribs, as compared to that of the outer ones, is conspicuous.

The specimen (Pl. IX, fig. 3) from Bed 4 of the Margit Hill Upper Jurassic profile (Gerecse Mts.) is very near to that form which has been described by CECCA et al. (1981) as *S. (S.) volanense*, then subsequently refigured by SANTANTONIO (1985) as *S. aesinense*. Both ammonites have a row of conspicuously elongated, strong umbilical tubercules.

Remarks. SANTANTONIO (1985) gave detailed description on the species. This form differs from the classic *volanense* of OPPEL by its smaller size, more robust sculpture, better-developed inner tubercule-row, single-ribbed nucleus and less-incised suture-line.

Distribution. *V. (V.) aesinense* is a characteristic element in the Semiforme Zone of the Mediterranean Tithonian.

Dimorphism. This is a dimorphic species. SANTANTONIO (1985) distinguished the dimorphic pairs on specific level. In this present work only the big (macroconchiate) forms are ranged into MENEGHINI's species, the macroconchs are treated within *Volanoceras* nov. subgen.

Volanoceras (Volanoceras) magnum (OLÓRIZ, 1978)

Plate X, fig. 1, Plate XI, fig. 1

1905 *Simoceras Volanense* OPP. – DEL CAMPANA, p. 110, pl. 16, fig. 9.
1978 *Simoceras (S.) volanense magnum* subsp. nov. – OLÓRIZ, p. 19, pl. 20, fig. 2.
1984 *Simoceras (S.) volanense magnum* OLÓRIZ – VIGH, p. 16, pl. 2, fig. 1.

Material. There fairly-preserved fragmentary internal casts (J – 10158, J – 10956, J – 9791).

Description. Large form with wide umbilicus. Th whorl-section is slightly compressed, subtrapezoidal with 33 to 44 mm height and 30 to 36 mm corresponding width. Inner whorls are unknown. The middle and outer whorls bear strong, radial ribs, which end on the umbilical and ventrolateral margin in well-developed tubercules. The inner tubercules are thickened into bullae, while the outer tubercules are longitudinally elongated, usually slightly projected. The apertural features are incompletely known. The relatively simple suture-line is characterized by broad external saddle, narrower lateral lobe and strongly indented further sutural elements.

Ammonites ranged into this species were yielded only by the Sümeg profile. The here figured specimens, despite the strong subsolution, show the strong tubercules and the thick connecting ribs clearly. The whorl-section is of characteristically trapezoidal in outline. The beds yielding *V. (V.) magnum* specimens were ranged by VIGH (1984) into the Burckhardticeras Zone.

Remarks. This species attaining 25 cm diameter is hitherto known only by fragments. This is a rare form, and is extremely evolute shell breaks into fragments easily.

The specimens figured by SANTANTONIO (1985) as *Simoceras vicentinum* are very near to this species.

The *Baeticoceras* species of GEYSSANT (1979), with their peculiar doubled ribs and characteristic tubercules are well distinguished from the large-sized *Volanoceras*.

Distribution. This species is characteristic in the Mediterranean ?Middle – Upper Tithonian. The exact stratigraphic range remains to be cleared.

Dimorphism. *V. (V.) magnum* presumably comprises macroconchs of a dimorphis species. The microconchs are to be grouped in *Volanoceras* nov. subgen.

?Volanoceras (Volanoceras) sp. aff. *magnum* (Olóriz, 1978)

Plate XI, fig. 2

Material. One single specimen (J – 10957) from Bed 43 of Hárskút, Közöskút ravine, profile II.

Description. The figured specimen is a badly preserved body chamber fragment, with weak tubercule rows, dense, moderately strong ribs. These features differ from those of the species of Olóriz so, that even the generic arrangement is uncertain. The specimen came from the Ponti Zone.

Subgenus *Volanoceras* nov. subgen.

Observations. Associated to the numerous big Middle Tithonian *Volanoceras*, there are several characteristically small, but similarly sculptured ammonites. Transitional forms are practically missing, thus the small specimens cannot be regarded as nuclei. Most probably these small ammonites are the microconch pairs of the big (macroconchiate) forms.

According to the proposal of Callomon (1969, p. 116) these small forms would need a subgenus of their own, however, in lack of stratigraphically well-controlled, rich material, designation of a new name seems impractical now. A possible solution is the application of open nomenclature. Thus the unnamed new subgenus used here below comprises of the microconchs of the above discussed *V. (V.) aesinense*, *V. (V.) volanense*, *V. (V.) magnum* and *V. (V.) praecursor* (Santantonio, 1985) species.

Occurrence. The forms ranged in this subgenus (just as those of the nominate macroconchiate subgenus) are characteristic elements of the Mediterranean Lower and Middle Tithonian faunas.

Volanoceras nov. subgen. div. sp.

Plate IX, figs. 4, 5 and 6

Material. Three specimens (J – 10958 – J – 10960) from Bakony Mts. profiles.

Measurements.

J – 10958	–	7 (?)	7 (?)	–
J – 10960	21	5 (23.8)	?5 (?23.8)	11 (52.3)

Description. The specimen from Bed 25 of the Hárskút, Közöskút ravine, profile 12 (Plate IX, fig. 6) is an entirely chambered, fragmentary internal mould with preserved traces of shell on the venter. Inner whorls are missing. The ribs are strong, slightly prorsiradiate, ending in well-developed, longitudinally elongated tubercules on the ventrolateral margin.

The specimen from Bed 66 of the Szilasárok profile (Plate IX, fig. 5) is a moderately corroded internal cast. Because of the poor preservation, the style of ribbing is uncertainly deciphered, but simple ribs seem most probable. The slightly projected ribs of the outer whorls end in longitudinally somewhat elongated tubercules.

One specimen (Plate IX, fig. 4) from the Tithonian beds of the Lókút Hill profile (exact horizon is unknown) has damaged inner whorls, but the inner parts seems to be sculptured with bifurcating ribs up to 10 to 15 mm diameter. The level of bifurcation is at the lower third of the flank. At ca. 20 mm diameter the simple ribs are slightly prorsiradiate, and are terminated in strong outer tubercules. Umbilical tubercules remain unconspicuous until the maximal diameter of the fragment. The end of the fragmentary internal mould bears a strong constriction probably showing the ceasing of shell-growth.

Genus *Simoceras* ZITTEL, 1870

Type species. *Ammonites biruncinatus* QUENSTEDT, 1845, by subsequent designation of FISCHER, 1882. For the problematics of interpretation of the type species see GEYSSANT 1985.

Occurrence. The genus is of index value in the Mediterranean Middle Tithonian.

Dimorphism. Dimorphism within this genus is hitherto undocumented.

Simoceras biruncinatum (QUENSTEDT, 1845)

Plate XII, figs. 3 and 4

1845 *Ammonites biruncinatus* Q. – QUENSTEDT, p. 683.
1848 *Ammonites biruncinatus* Q. – QUENSTEDT, p. 260, pl. 19, fig. 14.
pars 1870 *Simoceras biruncinatus* Q. – ZITTEL, p. 92, pl. 32, fig. 6 (only)
? 1961 *Simoceras (Simoceras) biruncinatum* Q. forma *aegera calcar* (ZIETEN 1830) – HOLLMANN, p. 267, pl. 1. fig. 1.
1978 *Simoceras (Simolytoceras?) biruncinatum* (Q.) – OLÓRIZ, p. 241, pl. 20, figs. 7 and 8.
1983 *Simoceras (Simolytoceras) biruncinatum* (Q.) – CECCA et al., p. 120, pl. 2, fig. 2.
1984 *Simoceras (Simolytoceras?) lokutense* nov. ssp. – VIGH, p. 180, pl. 1, fig. 6.
1984 *Simoceras (Simolytoceras) biruncinatum* (Q.) – ROSSI, p. 117, pl. 35, fig. 6.

Observations. In spite being a "classic" species, this QUENSTEDT's form is in fact poorly known.

Of the specimens figured by ZITTEL (1870), that on pl. 32, fig. 3, with weak inner tubercules and two constrictions on the smoothed body chamber should be ranged into the species *Simolytoceras volanensoides* (VIGH).

The specimen of HOLLMANN (1961, pl. 1, fig. 1), as the author pointed out, is a sick, damaged individual.

One of the specimens of Olóriz (1978, pl. 20, fig. 8), with conspicuously well-developed clavi, differs from all previously described specimens, and is most similar to the ammonite from Sümeg (see below).

Only one figure (Cecca et al., 1983, pl. 2, fig. 2) shows the inner whorls of the conspecific forms. This ammonite, however, as noticed by the authors also, differs from the type in having special tubercules on the outerside of the body chamber.

In determining fragments, some problems arised from the fact, that the sculpture is changing with individual growth, even on the body chamber. Entire, adult specimens are extremely rare. One cannot consider unfeasible, that this apparently variable species will be subdivided by further studies.

Material. Two specimens (J – 9792, J – 10961) and few fragments from the Sümeg profile.

Measurements.

J – 9762	?64	?17 (?26.5)	?13 (?20.3)	36 (?56.2)
	?54	?14 (?25.9)	?12 (?22.2)	29 (?53.7)

Description. The figured specimen has a shallow umbilicus, the umbilical margin rounds evenly into the slightly convex flanks. Inner whorls are missing, and the middle whorls are strongly corroded. The last whorl shows clearly the umbilical tubercules, which continue into the flanks as rib-like folds. At ca. 30 mm umbilical diameter the specific outer tubercules are visible. The tubercules are of medium-strength in the beginning, then change into very strong clavi. The well-developed, longitudinally flattened tubercules appear in pairs in each side of the venter of the body chamber. There is only a single constriction at the beginning of the penultimate whorl. The corrosion of the internal cast makes the end of the phragmocone only guessed, however the length of the body chamber can be estimated as a whole whorl. Suture-line cannot be seen, the aperture is missing.

Remarks. The Sümeg specimen cannot be matched exactly with Quenstedt's type. The former is somewhat more evolute, has rarer umbilical tubercules and unusually strengthened clavi on the body chamber. With this last feature it is close to one of the figured specimens of Olóriz (1978, pl. 20, fig. 8). On the other hand, the rare inner tubercules and the few (one) visible constrictions are similar also to those on one of the forms figured by Zittel (1870, pl. 32, fig. 6).

Distribution. This species is characteristic in the Fallauxi Zone of the Mediterranean Tithonian. Olóriz (1978) regarded this Quenstedt's species, together with *S. admirandum* as zonal index. His "Admirandum – Biruncinatum Zone" corresponds to the upper part of the Fallauxi Zone.

Dimorphism. This is undocumented for this species; this aspect needs further studies.

Simoceras admirandum (Zittel, 1869)

Plate XII, figs. 1 and 2, Plate XV, figs. 1, 2 and 3

1869 *Ammonites admirandus* Zittel – Zittel, p. 148.

1870 *Simoceras admirandum* Zittel – Zittel, p. 212, pl. 31, fig. 6, pl. 32, figs. 1–3.

1871 *Simoceras admirandum* Zittel – Gemmellaro, p. 39, pl. 8, figs. 4 and 5.

1885 *Simoceras admirandum* Zittel – Meneghini, p. 374: pl. 20, fig. 5.

1978 *Simoceras (Simoceras) admirandum* Zittel – Olóriz, p. 229, pl. 20, fig. 1.

1984 *Simoceras (Simoceras) admirandum bakonyense* nov. ssp. – Vigh, p. 73, pl. 1, fig. 5.

Observations. This species is a very characteristic element of the Tithonian faunas, nevertheless it is poorly known because of rarity of inner whorls and entire specimens. Well-preserved and rich material may result in the splitting of the forms described until now as *S. admirandum*, and/or in the clearing of dimorphism suggested for this group.

Material. 11 fairly or badly-preserved specimens (J–10962–J–10970, J–9808, J–10272) and some further fragments from the Bakony profiles.

Measurements.

J–10272	?68	16 (?23.5)	18 (26.4)	34 (?50.0)
	59	15 (25.4)	16 (27.1)	31 (62.5)
J–10967	–	39	28	–

Description. Medium-sized, relatively widely-umbilicated form. The flanks are convergent, neither umbilical, nor sharp ventrolateral margin occur. The section of the inner whorls is subcircular, of the middle whorls is oval with maximal width in the lower part. The big-sized body chamber fragments belonging possibly to adult specimens show stronger compression.

As it has been pointed out even by Zittel (1869), the innermost whorls bear fine, simple ribbing. The poorly-preserved Bakony material includes only a single specimen (J–10962) showing this feature. From the second or third whorls onwards, the ribbing changes into rows of rarer umbilical and denser ventrolateral tubercules. This sculpture reminds that on the volanense group, but differs in the consequently alternating position of the tubercules on the venter.

The number of the inner tubercules is the half of the outer ones on the middle and outer whorls. The alternating position of the outer tubercules remains constant. On the middle whorls the ribs arising from the inner tubercules reach only the middle part of the flanks.

The Bakony profiles yielded numerous body chamber fragments of big specimens, which are very close to the similarly fragmentary examples figured by Zittel (1870, pl. 32, fig. 3). Though the internal casts from the

Bakony are strongly subsolved, the bifurcating, tuberculated ribs arising from the umbilical tubercules are shown clearly (Pl. XII, fig. 2). However, these big body chamber fragments came separated from inner whorls, thus their connections remain conditional.

There are one or two constrictions per whorl from early ontogenetic stages. Details of the suture-line and features of the aperture cannot be seen in either Bakony specimens.

Remarks. *S. admirandum* is most closely allied to *S. biruncinatum* and *S. andaluciense*. But its bigger size and different sculpture on its body chamber distinguishes from both.

Distribution. Characteristic in the Mediterranean Tithonian. Olóriz (1978) suggested *S. admirandum* (with *S. birunciantum*) as a zonal index. The "Admirandum + Biruncinatum Zone" of Olóriz is equivalent to the upper part of the Fallauxi Zone.

Dimorphism. Though evidences from the hitherto known material are weak, this species is apparently dimorphic. The inner whorls of the micro-and macroconch form are seemingly very similar, while well-preserved adult specimens are missing. Probable macroconchs are the previously described big specimens (Zittel 1870, pl. 32, fig. 3; Gemmellaro 1871, pl. 8, figs. 4, 5; Olóriz 1978, pl. 20, fig. 1) and the majority of the Hungarian material. Possible microconch is the specimen of Meneghini (1885, pl. 20, fig. 5) and one form from Bed 79 of the Szilasárok profile (Pl. XV, fig. 2) Both ammonites have slightly excentric last whorl, thus despite their small size they are adults and consequently microconchs.

Genus *Simolytoceras* Olóriz, 1978

Type species. *Simoceras (Simolytoceras) andaluciense* Olóriz, 1978, by original designation.

Observations. *Simolytoceras* was introduced by Olóriz as a subgenus of *Simoceras*. Besides the type species, he ranged – with question mark – only one species into this subgenus: *S. biruncinatum*. This present work ranges, additionally to the type species, two further forms from the Bakony as new species.

Occurrence. On the basis of data known until now this genus can be regarded as a characteristic faunal element in the Mediterranean Middle Tithonian.

Dimorphism. No dimorphism has been documented within this genus.

Simolytoceras cf. *andaluciense* Olóriz, 1978

cf. 1978 *Simoceras (Simolytoceras) andaluciense* nov. sp. – Olóriz, p. 238, pl. 20, fig. 4.

Material. A single, badly preserved fragmentary internal mould (J–10971) from Bed 65 of the Szilasárok profile.

Measurements.

J–10971	55	10 (18.1)	10 (18.1)	?32 (?58.1)

Description. A relatively small form with wide umbilicus. The low umbilical wall rounds into the slightly convex flanks without umbilical edge. The whorl-section is circular, its width is nearly equal with its height at 56 mm diameter. The imprint of the fragmentary specimen shows, that it was ribbed up to about 22 mm diameter. With individual growth the ribs become rarer and end in the outer part in longitudinally elongated tubercules. There are 1 or 2 (?3) deep constrictions per whorl with projected outer parts. According to Olóriz (1978) the fading of the sculpture becomes apparent usually from 55 mm diameter. This last state cannot be seen on the fragment from the Szilasárok profile.

Remarks. This species of Olóriz is incompletely known. The single previously figured specimen (the type) is badly preserved, fragmentary.

S. andaluciense is very close to *S. volanensoides*. The distinguishing features are the wider umbilicus and the strong ventrolateral tubercules in the middle whorls of the former species.

Distribution. Olóriz recorded his specimen from the Burckhardticeras Zone of the Subbetics. The Szilasárok specimen came from the same stratigraphic horizon (Ponti Zone).

Simolytoceras volanensoides (Vigh, 1984)

Plate XIII, figs, 1, 2 and 3, Plate XIV. fig. 3, text-fig. 18

1870 *Simoceras biruncinatum* Quenstedt – Zittel, p. 92, pl. 32, fig. 5.

v 1984 *Simoceras (Lytogyroceras) subbeticum volanensoides* nov. ssp. – Vigh, p. 74, pl. 3, figs 1 and 2.

Material. Five well- or fairly-preserved specimens (J – 10972 – J – 10974, J – 9802, J – 9803) from the Bakony profiles.

Measurements.

J – 9803 (Holotype)	86	21 (24.4)	20 (23.2)	46 (53.4)
	67	16 (23.8)	16 (23.8)	36 (53.7)
J – 9802	85	20 (23.5)	?14 (?16.4)	44 (51.7)
	65	17 (26.1)	?14 (?21.5)	33 (50.7)
J – 10972	84	16 (19.0)	?14 (?16.6)	47 (55.9)
J – 10973	82	22 (26.8)	18 (21.9)	47 (57.3)

Description. Medium-sized, evolute form. The umbilical wall is low and steep, the umbilical margin is rounded. The somewhat convergent flanks are slightly convex, the ventrolateral margin is arched. The whorl-section is subtrapezoidal in the middle whorls and suboval on the body chamber.

Nucleus is missing in all specimens. The visible inner whorls are densely ribbed up to ca. 20 mm diameter. Some of the slightly prorsiradiate ribs bear hardly-visible small swellings on the upper part. In one specimen from the Lókút Hill profile the ribbing is ceased abruptly with a strong constriction. On the middle whorls weak umbilical tubercules and oblique ventrolateral tubercules appear. These latter ones become gradu-

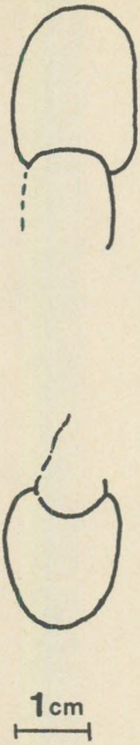


Figure 18. Simolytoceras volanensoides (VIGH) (J – 10973).
Cross-section. Szilasárok, Bed 80, Fallauxi Zone.

ally more elongated, showing similarities to the ventrolateral tubercules of *S. biruncinatum*. The flanks bear feeble, vague ribs arising from the umbilical tubercules. The umbilical and ventrolateral tubercules fade out gradually on the end of the adult whorl, and the terminal part of the body chamber becomes completely smooth.

On each whorl there are 2–3 constrictions which curve slightly forward near the venter. Aperture is unknown, the suture-line, because of subsolution, cannot be studied in detail.

Remarks. VIGH (1984) ranged the Lókút specimens as subspecies of *S. (L.) subbeticum* OLÓRIZ. However, these ammonites are distinguished from the species of OLÓRIZ, because this latter lacks the ventrolateral tubercule row.

The Bakony specimens, especially the holotype, are very close in size and sculpture to that figured by ZITTEL as *S. biruncinatum* (1870, pl. 32, fig. 5). As it was mentioned above in the description of *S. biruncinatum*, ZITTEL's specimen, having a smoothed body chamber, differs from this group.

The here figured ammonites are very similar to those published by Olóriz and Tavera (1977). They ranged those specimens into their new genus *Simospiticeras*. The Bakony specimens are especially close to the species described as *S. lojenense* (p. 184, pl. 1, fig. 1 in Olóriz and Tavera 1977). Common features are in the umbilical tubercules and constrictions. But despite the obvious relations between the two forms, there are some differences, too: the species of Olóriz and Tavera has narrower umbilicus and higher whorls. The figure shows, that the outer tubercules of *S. lojenense* are weaker than those of *S. volanensoides*. However, the Spanish specimens are corroded, their inner whorls are missing, thus the relations between the two species remain problematic.

Distribution. The two specimens described by Vigh came from the *S. fallauxi*-bearing Beds 43 and 44 of the Lókút Hill profile. New collections yielded specimens from the same horizon in the Szilasárok section and from Hárskút, Közöskút ravine, profile II. The related *S. lojenense* has been described from "the base of the Upper Tithonian".

Dimorphism. No dimorphism has been evidenced in the case of this species.

Simolytoceras vighi nov. sp.

Plate XIV, figs. 1 and 2

Derivatio nominis: After the late Gusztáv Vigh, paleontologist, who made very important contributions to the knowledge of the Upper Jurassic faunas of the Transdanubian Central Range.

Locus typicus: Hárskút, Közöskút ravine, profile II; Bakony Mts., Transdanubian Central Range.

Stratum typicum: Bed 49 of the profile, i.e. Middle Tithonian (Fallauxi Zone); Pálihálás Limestone Formation.

Diagnosis: Medium-sized *Simolytoceras*, with rib-like, elongated umbilical tubercules and dense, alternating ventrolateral tubercules on the middel whorls, and dense, strong, projected constrictions at the end of the adult body chamber.

Material. A single, fairly-preserved specimen (J – 10975).

Measurements.

J – 10975 (Holotype)	104	28 (26.9)	?22 (?21.1)	53 (50.9)
	84	20 (23.8)	15 (17.8)	47 (55.9)
	72	19 (26.3)	–	40 (55.5)

Description. Medium-sized, moderately evolute form. The umbilical wall rounds into the almost flattened flank without sharp umbilical edge. The venter is rounded. The flanks are slightly convergent, the whorl-section is subtrapezoidal on the middle whorls and suboval on the adult body chamber.

The inner and middle whorls are partly missing. The tubercules at the umbilical margin are radially elongated and smoothed out at the upper part of the flanks. There are rows of dense alternating, slightly elongated tubercules on the ventrolateral margins. The sculpture reaches the proximal half of the body chamber. The apertural part of the body chamber bears three projected constrictions. The body chamber of the mature specimen occupies about three-quarter of the last whorl.

The aperture is unknown and the details of the suture-line are obscured by subsolution.

Remarks. On the basis of its sculpture, this species is near to *S. admirandum* and *S. volanensoides*. However, *S. vighi* has substantially denser ventrolateral tubercules in the middle whorls. Other difference is that the tubercules are much finer and elongated radially in this new species, while in *S. volanensoides* this elongation is oblique on the stronger tubercules. The closely-spaced constrictions on the adult body chamber are important specific characters, too.

Distribution. The species is hitherto known only from a single bed of the Fallauxi Zone of the Hárskút profile.

Dimorphism. Having only a single specimen, this aspect cannot be discussed.

Genus *Lytogyroceras* Spath, 1925

Type species. *Ammonites fasciatus* Quenstedt, 1848 = *Am. strictus* Catullo, 1846, pl. 6, fig. 2, by original designation of Spath (1925, p. 131).

Observations. The genus has been based by Spath on the species of Quenstedt, which is a senior synonym of *Lytogyroceras strictum* (Catullo, 1846).

Occurrence. On the basis of the scattered data, this genus is a Middle Tithonian element in the Mediterranean region.

Dimorphism. No dimorphism has been shown in connection if this genus.

Lytogyroceras strictum (Catullo, 1846)

Plate XV, fig. 4

1846 *Ammonites strictum* Catullo – Catullo, p. 132, pl. 6, fig. 2.
1848 *Ammonites fasciatus* Quenstedt – Quenstedt, p. 171, pl. 20, fig. 11.
1870 *Simoceras strictum* Cat. – Zittel, p. 90, pl. 32, fig. 4.
1876 *Simoceras strictum* Cat. – Gemmellaro, p. 53, pl. 10, fig. 4.

Material. A single internal mould (J–10208) from the Sümeg profile.

Measurements.

J–10208	?88	?21 (?23.8)	–	?51 (?57.9)
	76	?18 (?23.6)	?14 (?18.4)	44 (57.8)

Description. Medium-sized, very evolute form with shallow umbilicus. The whorl-section is strongly compressed oval. The inner whorls of the specimen are missing, the body chamber is strongly corroded. The smooth shell has strong, slightly projected constrictions. The aperture is missing, suture-line cannot be studied.

Remarks. This species can be easily distinguished from the other congeneric forms by its strongly compressed whorl-section. The style of the constrictions is a further distinguishing feature from the similarly smooth *Protetragonites*.

The Sümeg specimen shows good agreements with the specimens figured by Quenstedt (1848) and Zittel (1870).

Lytogyroceras subbeticum Olóriz, 1978

Plate XIII, figs. 4 and 5

1978 *Simoceras (Lytogyroceras) subbeticum* nov. sp. – Olóriz, p. 232, pl. 19, figs. 2 and 3.
non 1984 *Simoceras (Lytogyroceras) subbeticum* Olóriz – Rossi, p. 116, pl. 35, figs. 1 and 2.
non 1984 *Simoceras (Lytogyroceras) subbeticum volanensoides* nov. ssp. – Vigh, p. 74, pl. 3, figs. 1 and 2.
1987 *Lytogyroceras* sp. – Főzy, pl. 2, fig. 3.

Material. One well-preserved specimen (J – 10976), and two fragments from Bed 42 of the Hárskút, Közöskút ravine, profile II. All are internal casts.

Measurements.

J – 10976	42	10 (23.8)	8 (19.0)	25 (59.5)
	38	9 (23.6)	7 (18.4)	21 (55.2)
	35	7 (20.0)	6 (17.1)	19 (54.2)

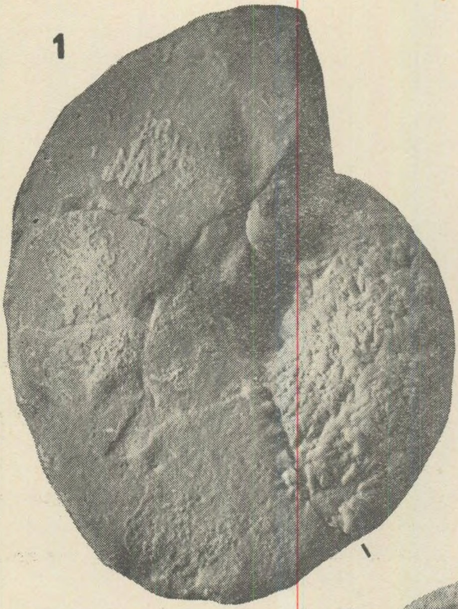
Description. Small form with wide and shallow umbilicus. The low, oblique umbilical wall rounds into the slightly convex flanks without forming sharp margin. The venter is rounded, the whorl-section is circular in the inner whorls and somewhat compressed in the outer whorls.

The inner whorls have fine ribbing. Most ribs bifurcate at the middle-height of the flanks, but some simple ribs also occur. The ribs are radial or slightly curved forward. At about 20 mm diameter the ribbing disappears, and the middle and outer whorls are completely smooth. The thirds whorl is damaged in the Hárskút specimen, thus the transition between these stages cannot be seen. There are 2 – 3 strong, ventrally projected constrictions per whorl.

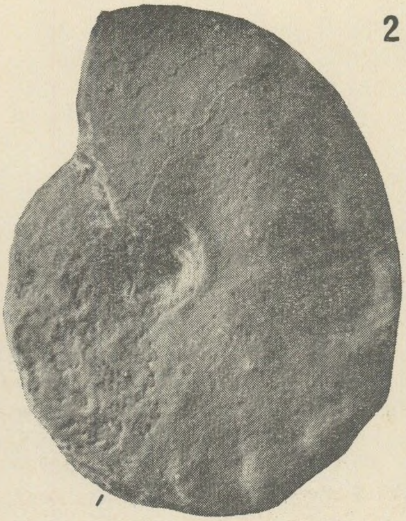
Aperture and suture-line are not visible in the Bakony specimens.

Remarks. *L. subbeticum* is distinguished from *L. lytogyrus* by its bifurcating and finer ribs. A further difference is that the smooth stage appears earlier in *L. lytogyrus*. On the other hand *L. strictum* is characteristically bigger.

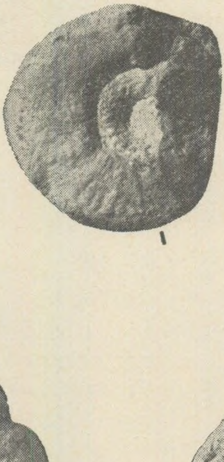
1



2

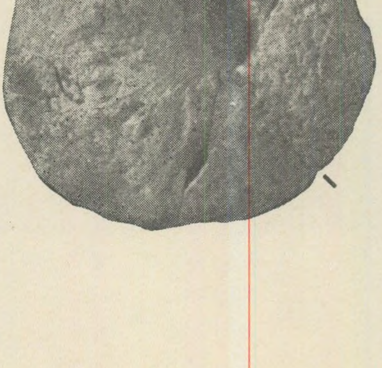


5



6

3



4

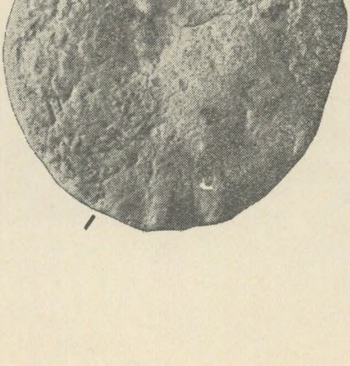


PLATE I.

Fig. 1. *Semiformiceras semiforme* (OPPEL) (J – 10869). Big, adult, nearly complete specimen. Hárskút, Közöskút ravine, profile II, Bed 59. The specimen was figured by FŐZY (1987, Pl. 1, fig. 2.) as *Semiformiceras semiforme* (OPPEL). Semiforme Zone.

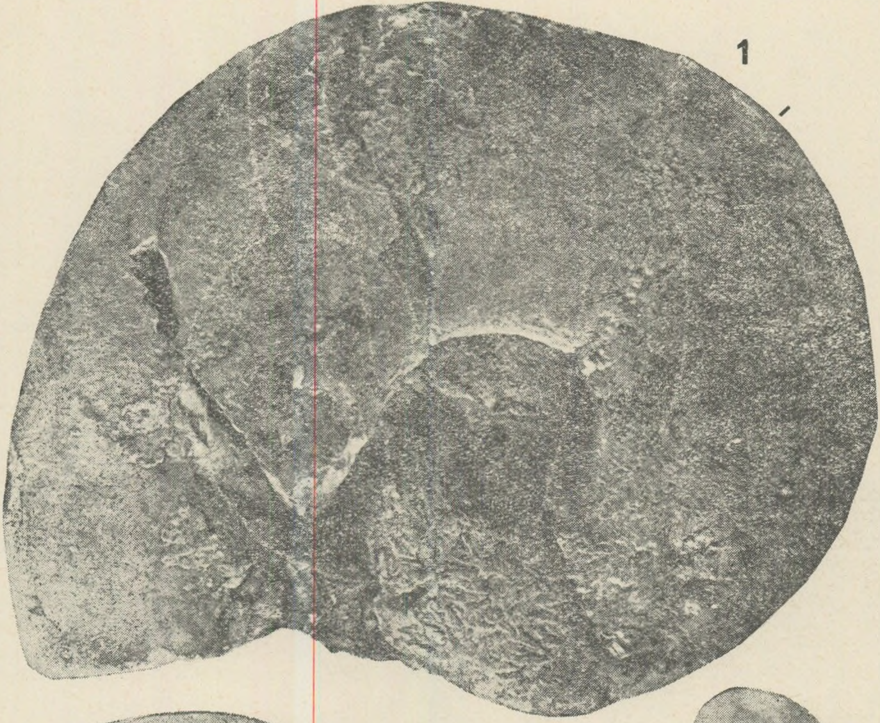
Fig. 2. *Semiformiceras semiforme* (OPPEL) (J – 10871). Medium – sized, adult, nearly complete specimen. Szilasárok, Bed 93. The specimen was figured by FŐZY (1987, Pl. 1. fig. 3.) as *Semiformiceras semiforme* (Oppel). Semiforme Zone.

Fig. 3. *Semiformiceras semiforme* (OPPEL) (J – 10171). Medium-sized, adult specimen with fragmentary body chamber. Sümeg.

Fig. 4. *Semiformiceras semiforme* (OPPEL) (J – 10872). Medium-sized, adult, nearly entire specimen. Sümeg.

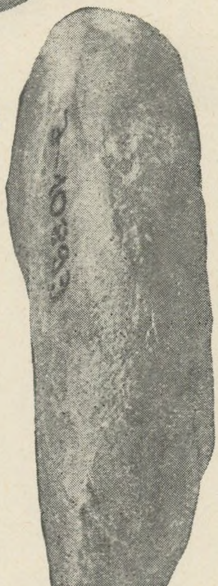
Figs. 5, 6. *Semiformiceras fallauxi* (OPPEL) (J – 10874). Medium-sized specimen, with fragmentary adult body chamber. Sümeg.

(Figures, except Pl. XIV. fig. 2. are in natural size. Arrows indicate beginning of body chamber.)



1

2



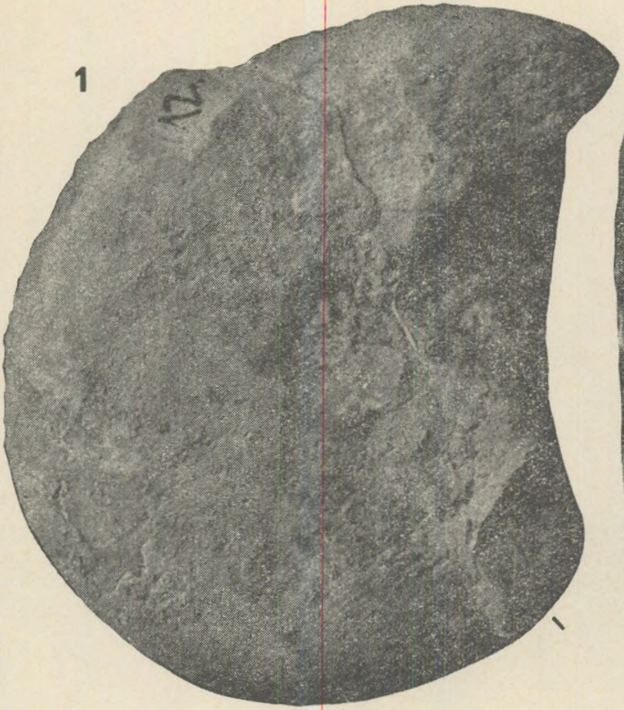
3

PLATE II.

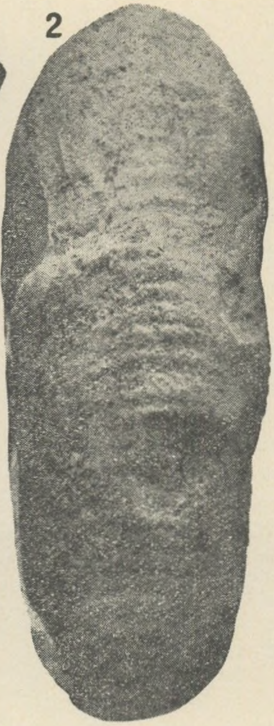
Fig. 1. *Haploceras (Haploceras) elimatum* (OPPEL) (J – 10888). Medium-sized, probably adult, nearly entire specimen. Rendkő.

Fig. 2, 3. *Haploceras (Haploceras) elimatum* (OPPEL) (J – 10893). Small, young, nearly entire specimen. Hárskút, Közöskút ravine, profile II, Bed 51. Fallauxi Zone.

1

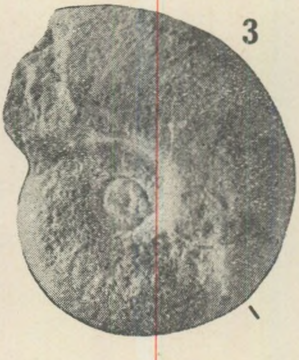


2

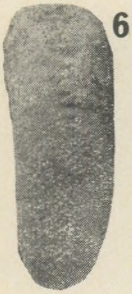


4

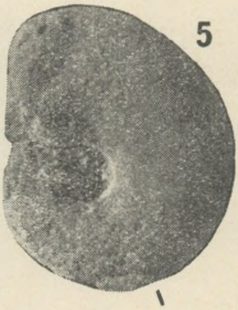
3



6



5



8

9

7

PLATE III.

Figs. 1, 2. *Haploceras (Haploceras) wohleri* (Oppel) (J – 10897) Small, probably adult, nearly entire specimen. Hárskút, Közöskút ravine, profile 12, Bed 12. Upper Tithonian.

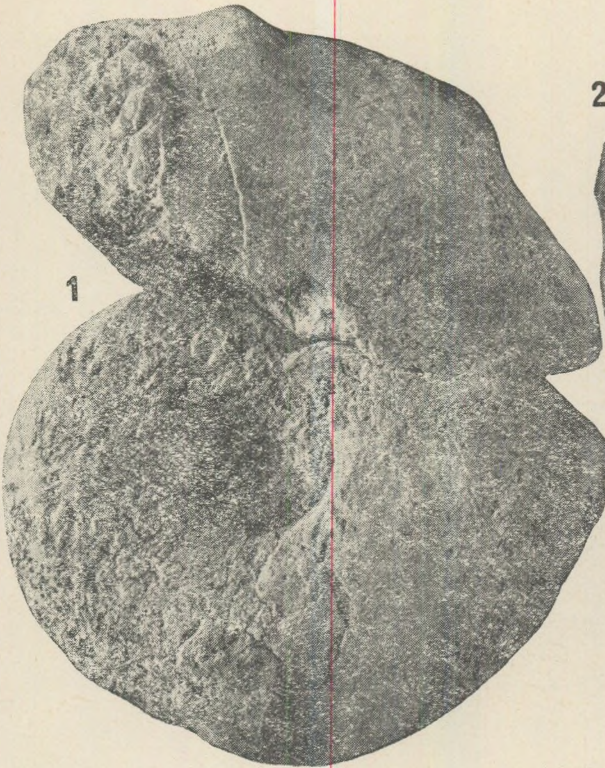
Figs. 3, 4. *Haploceras (Hypolissoceras) carachtheis* (Zeuschner) (J – 10909). Medium-sized, probably adult, nearly entire specimen. Rendkő.

Figs. 5, 6. *Haploceras (Hypolissoceras) leiosoma* (Oppel) (J – 10911). Medium-sized, adult, nearly entire specimen. Hárskút, Közöskút ravine, profile II, Bed 52. Fallauxi Zone.

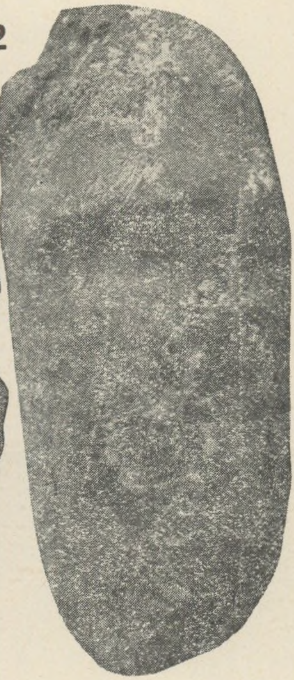
Figs. 7. *Haploceras (Hypolissoceras) leiosoma* (Oppel) (J – 10914). Fragmentary specimen. Rendkő.

Figs. 8, 9. *Haploceras (Hypolissoceras) rhinotomum* Zittel (J – 10918). Fragmentary body chamber of an adult specimen. Hárskút, Közöskút ravine, profile II, Bed 45. Fallauxi Zone.

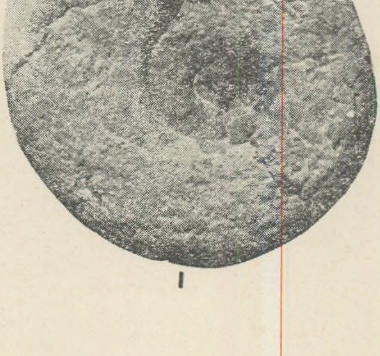
1



2



3



4

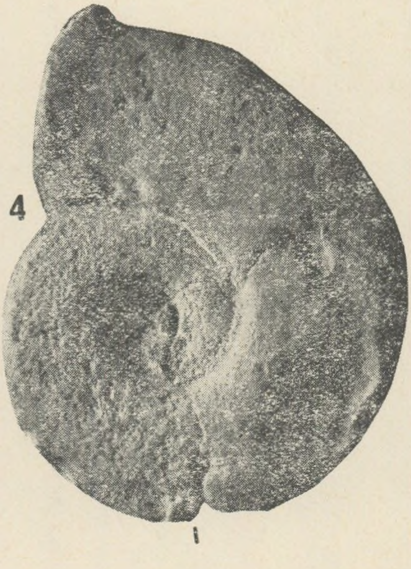
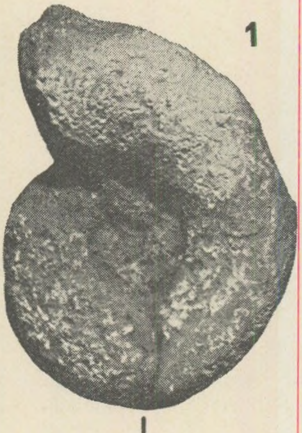


PLATE IV.

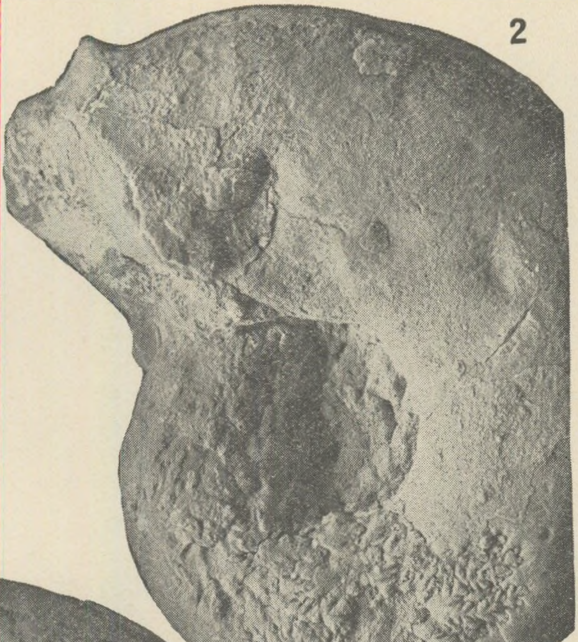
Figs. 1, 2. *Haploceras (Haploceras) cassiferum* nov. sp. (Holotype, J – 9672). Medium-size d adult, nearly entire specimen. Lókút Hill, Bed 56. Lower Tithonian, Darwini or Semiforme Zone.

Fig. 3. *Haploceras (Hypolissoceras) verruciferum* (Zittel) (J – 10919). Medium-sized, adult, nearly entire specimen. Lókút Hill, Bed 53. Semiforme Zone.

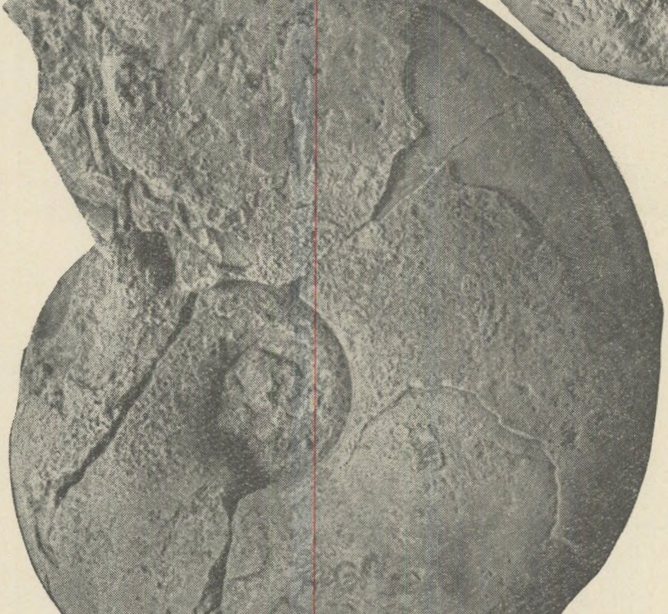
Fig. 4. *Haploceras (Hypolissoceras) verruciferum* (Zittel) (J – 10935). Medium-sized, adult, nearly entire specimen. Szilasárok, Bed 94. The specimen was figured by Főzy, (1987. Pl. II, fig. 4.) as *Haploceras verruciferum* (Mgh. in Zittel). Semiforme Zone.



1



2



3

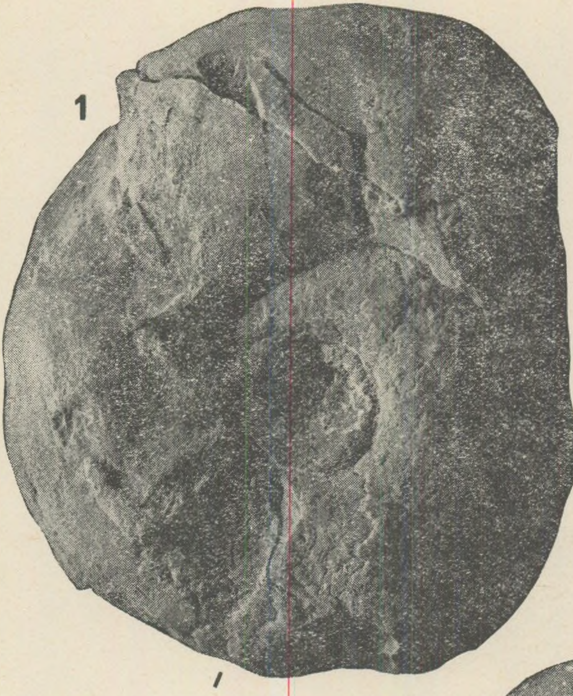
PLATE V.

Fig. 1. *Haploceras (Hypolissoceras) verruciferum* (Zittel) (J – 10938). Small, adult, nearly entire specimen. Szilasárok, Bed 93. Semiforme Zone.

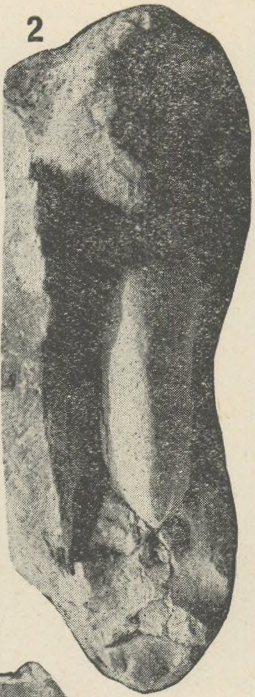
Fig. 2. *Hapolceras (Haploceras) cassiferum* nov. sp. (J – 10901). Medium-sized, adult specimen. Hárskút, Közöskút ravine, profile II, Bed 63. Darwini Zone.

Fig. 3. *Haploceras (Haploceras) cassiferum* nov. sp. (J – 8048). Medium-sized, adult, nearly entire specimen with remnants of shell on the body chamber. Tata, Kálvária Hill, Bed 12/1.

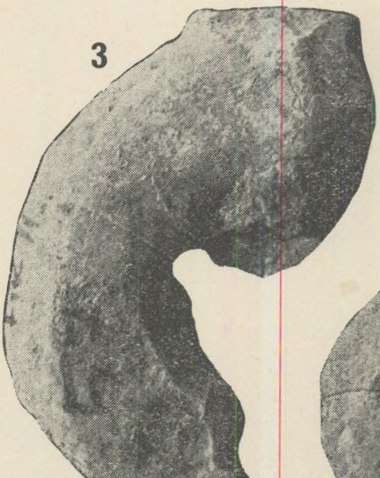
1



2

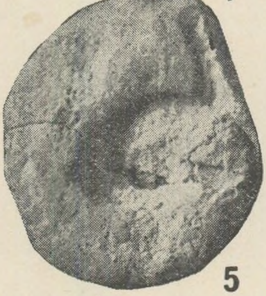


3



4

5



6

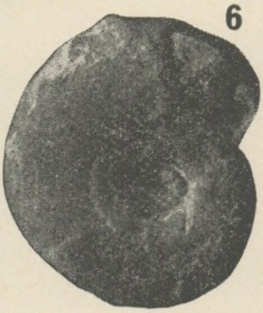


PLATE VI.

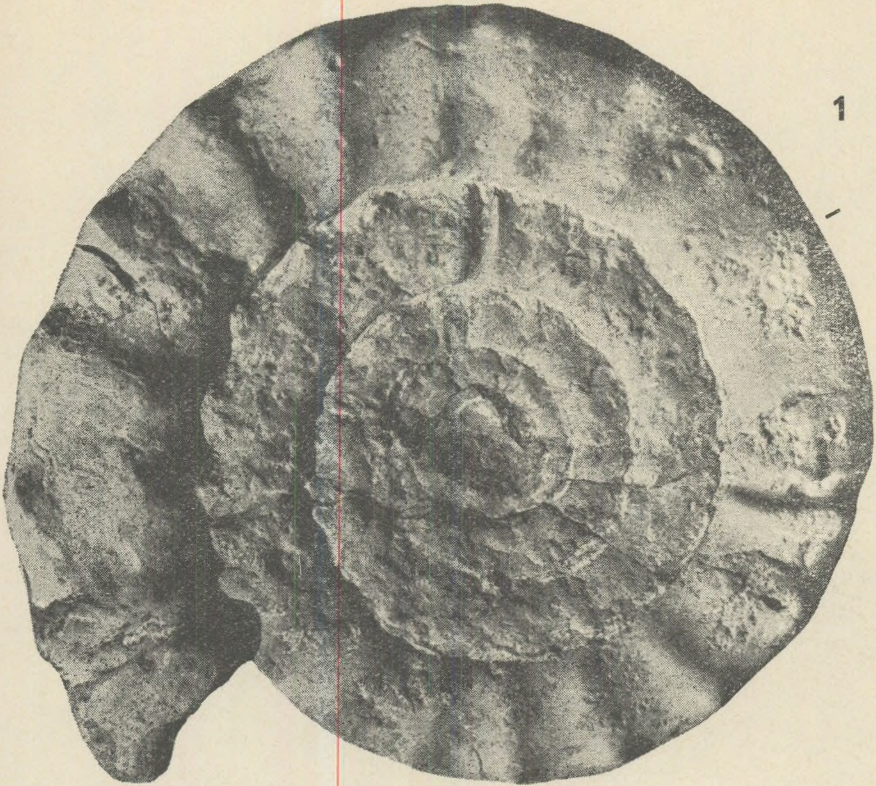
Figs. 1, 2, *Pseudolissoceras olorizi* nov. sp. (Holotype, J – 10941). Adult, nearly entire specimen. Hárskút, Közöskút ravine, profile II, Bed 66. ?Hybonotum Zone.

Fig. 3. *Haploceras (Hypolissoceras) verruciferum* (Zittel) (J – 10926). Big, adult specimen, a body chamber fragment. Hárskút, Közöskút ravine, profile II, Bed 57. Semiforme Zone.

Fig. 4. *Haploceras (Hypolissoceras) verruciferum* (Zittel) (J – 10934). Small, adult, nearly entire specimen. Szilasárok, Bed 94. Semiforme Zone.

Fig. 5. *Haploceras (Hypolissoceras) verruciferum* (Zittel) (J – 10210). Small, adult, nearly entire specimen. Sümeg.

Fig. 6. *Haploceras (Hypolissoceras) verruciferum* (Zittel) (J – 10927). Small, adult, nearly entire specimen. Hárskút, Közöskút ravine, profile II, Bed 55. Semiforme Zone.



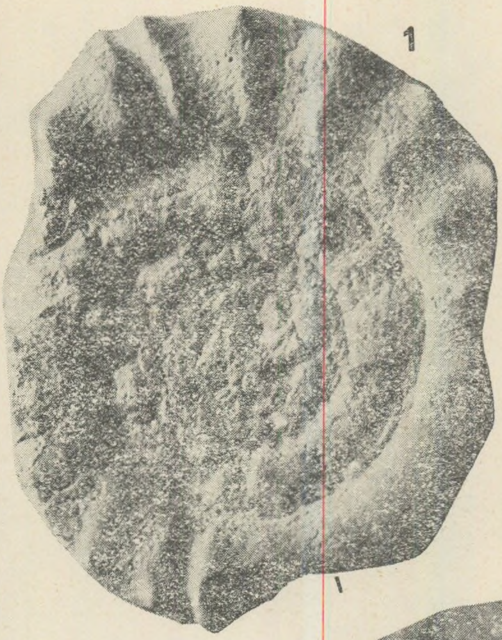
1

2

3

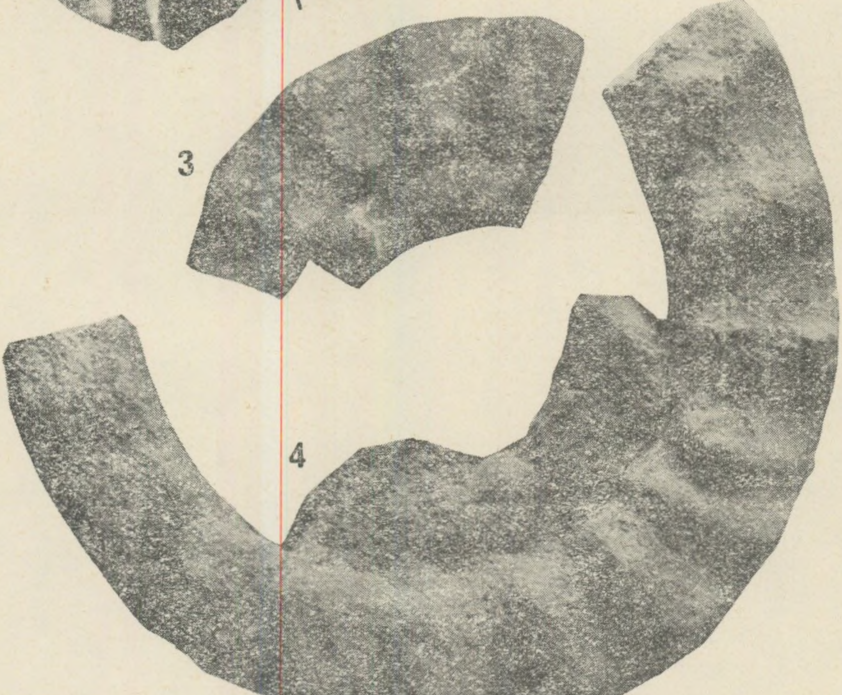
PLATE VII.

Figs. 1, 2, 3. *Volanoceras (Volanoceras) volanense volanense* (Oppel) (J – 10944). Subadult, nearly entire specimen with traces of damaged shell on the posterior part of the body chamber. Hárskút, Közöskút ravine, profile 12, Bed 25. Ponti Zone.



1

2



3

4

PLATE VIII.

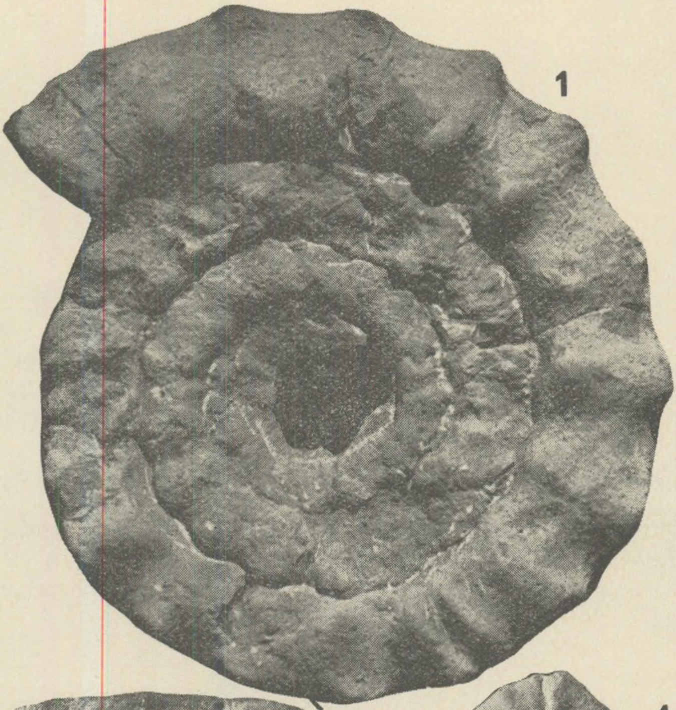
Fig. 1. *Volanoceras (Volanoceras) volanense schwertschlageri* (SCHNEID) (J – 10948). Fragment of a young specimen. Hárskút, Közöskút ravine, profile II, Bed 42. The specimen was figured by FŐZY (1987, Pl. II. Fig. 5.) as *Simoceras schwertschlageri* (SCHNEID). Ponti Zone.

Fig. 2. *Volanoceras (Volanoceras) volanense volanense* (OPPEL) (J – 10206). Fragmentary young specimen. Sümeg.

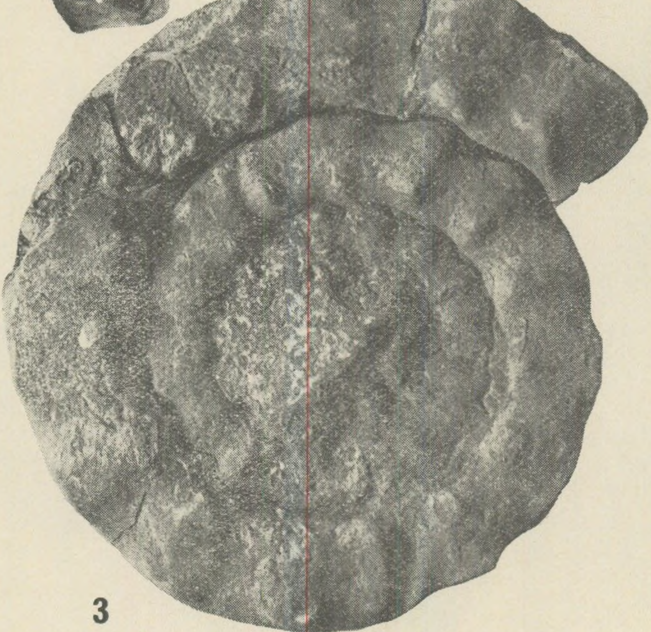
Fig. 3. *Volanoceras (Volanoceras) aesinense* (MENEGHINI) (J – 10954). Phragmocone fragment. Szilasárok, Bed 93. Semiforme Zone.

Fig. 4. *Volanoceras (Volanoceras) aesinense* (MENGHINI) (J – 10955). Fragment of a young specimen. Szilasárok, Bed 92. Semiforme Zone.


2


1


4


3


5


6

PLATE IX.

Figs. 1, 2. *Volanoceras (Volanoceras) aesinense* (MENEGHINI) (J – 10952). Nearly entire young specimen. Lókút Hill, Bed 53. Semiforme Zone.

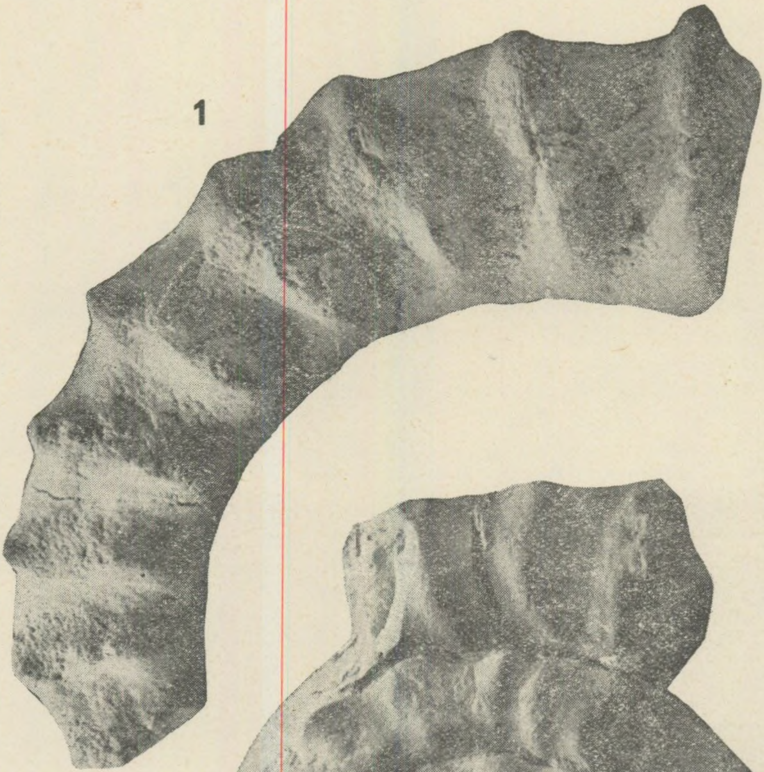
Fig. 3. *Volanoceras (Volanoceras) aesinense* (MENGHINI) (J – 10950). Fragment of a young specimen with partially preserved shell. Margit Hill, Gerecse Mountains, Bed 4. Semiforme Zone.

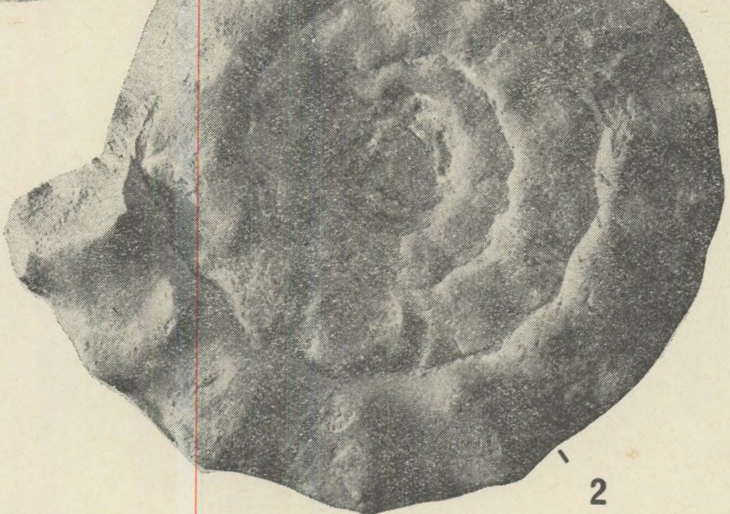
Fig. 4. *Volanoceras* nov. subgen. sp. (J – 10958). Probably adult, fragmentary specimen. From the loose material of the Lókút Hill profile.

Fig. 5. *Volanoceras* nov. subg. sp. (J – 10960). Fragmentary specimen. Szilasárok, Bed 66. Ponti Zone.

Fig. 6. *Volanoceras* nov. subgen, sp. (J – 10959). Fragmentary young specimen. Hárskút, Közöskút ravine, profile 12, Bed 25. Ponti Zone.

1





2

PLATE X.

Fig. 1. *Volanoceras (Volanoceras) magnum* (OLÓRIZ) (J – 10158). Phragmocone fragment. Sümeg.

Fig. 2. *Volanoceras (Volanoceras) aesinense* (MENEGHINI) (J – 10951). Adult specimen with damaged body chamber and nearly entire aperture. Hárskút, Közöskút ravine, from the loose material. The specimen was figured by FŐZY (1987, Pl. I. Fig. 1.) as *Simoceras* aff. *volanense* (OPPEL).

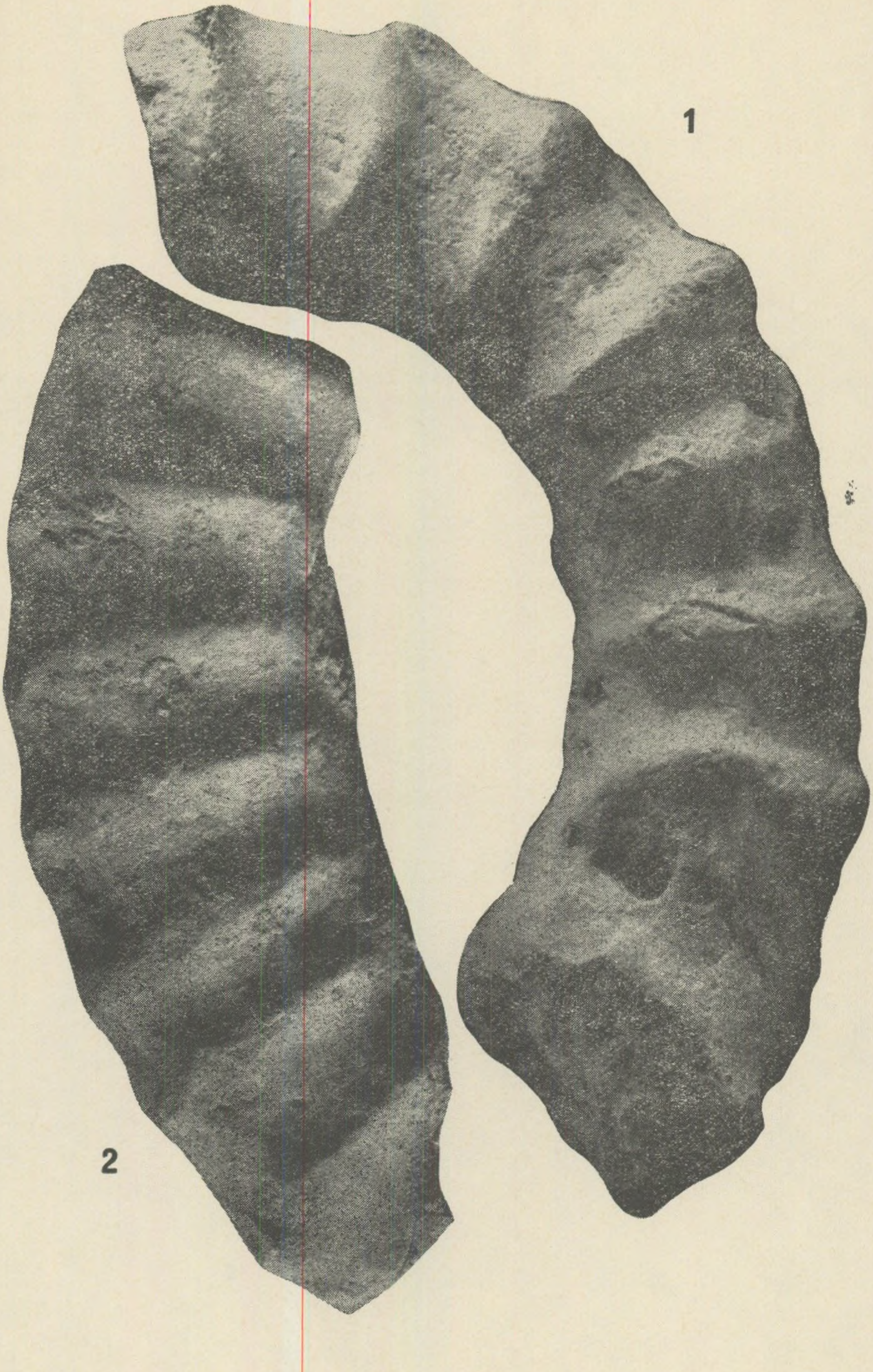
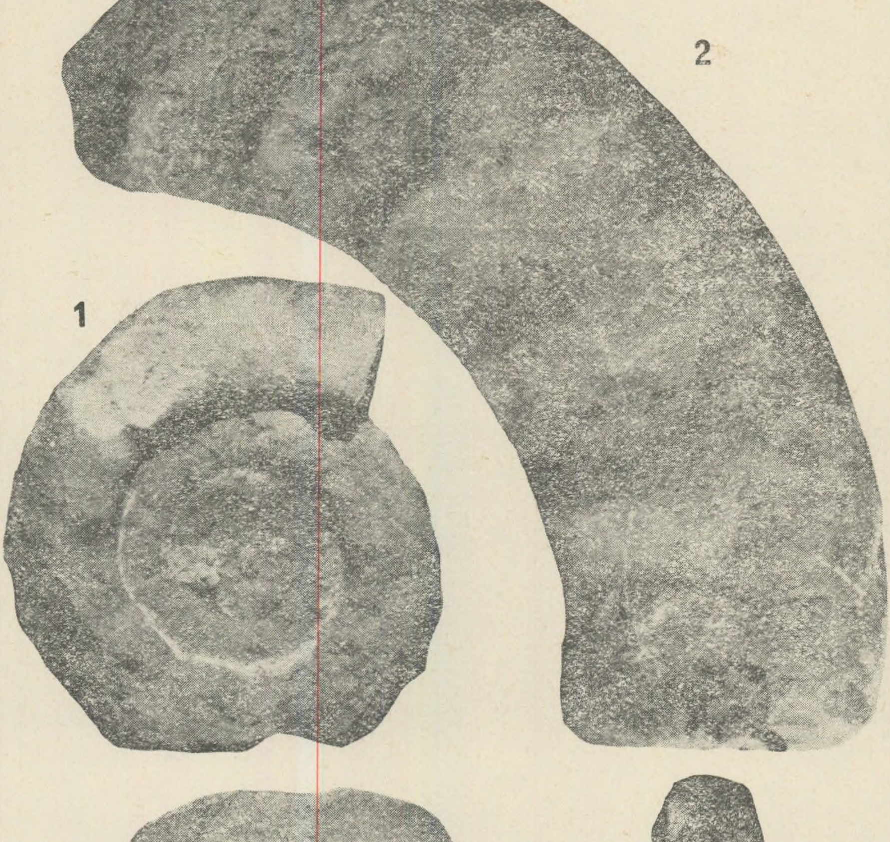

1
2

PLATE XI.

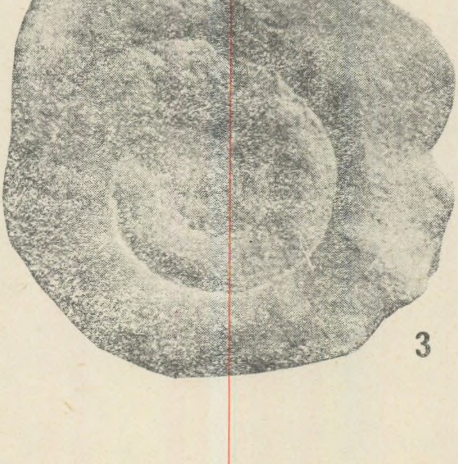
Fig. 1. *Volanoceras (Volanoceras) magnum* (OLÓRIZ) (J – 9791). Body chamber fragment. Sümeg.

Fig. 2. ? *Volanoceras (Volanoceras)* sp. aff. *magnum* (OLÓRIZ) (J – 10957). Body chamber fragment, Hárskút, Közöskút ravine, profile II, Bed 43. Ponti Zone.

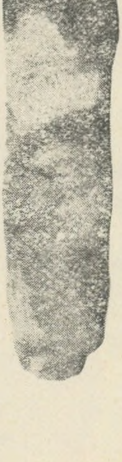


2

1



3



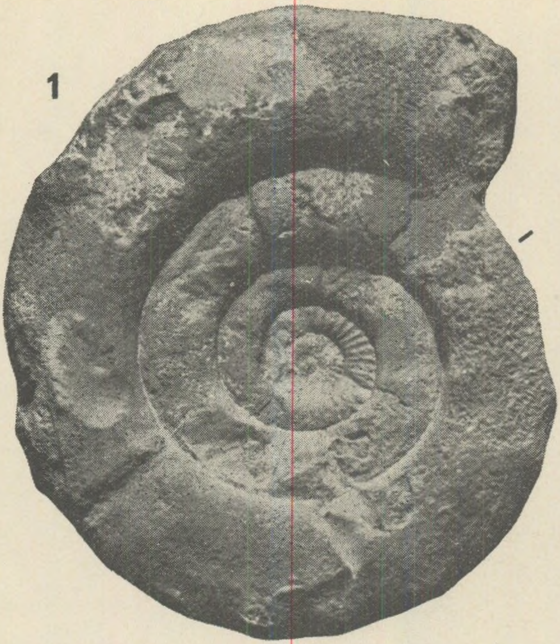
4

PLATE XII.

Fig. 1. *Simoceras admirandum* (Zittel). (J – 1097). Body chamber fragment of a young specimen. Figured by Vigh, G. (1984, pl. 1, fig. 5) as *Simoceras (Simoceras) admirandum bakonyense* nov. ssp. Lókút Hill, Bed 43. Fallauxi Zone.

Fig. 2. *Simoceras adirandum* (Zittel) (J – 10967). Fragment of the body chamber and a portion of the phragmocone of a big specimen. Hárskút, Közöskút ravine, profile II, Bed 47. Fallauxi Zone.

Figs. 3, 4. *Simoceras biruncinatum* (Quenstedt) (J -- 5792). Relatively small, adult specimen with damaged body chamber and missing middle whorls. The strong, „V"-shaped incision is resulted by preparation mistake. Sümeg.


1


2


4


3


5

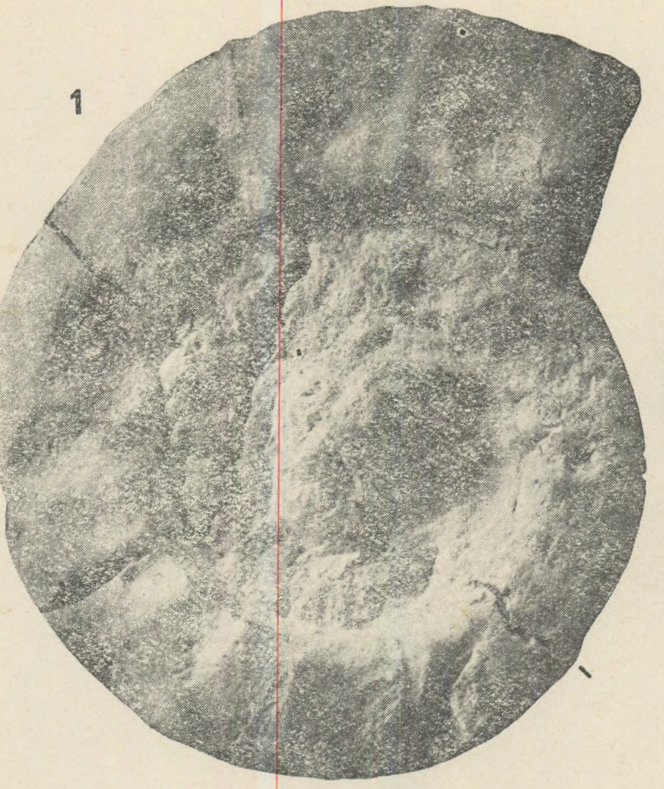
PLATE XIII.

Figs. 1, 2. *Simolytoceras volanensoides* (VIGH) (J – 9803). Adult, nearly entire specimen, figured by VIGH, G. (1984, pl. 3, fig. 1) as *Simoceras (Lytogyroceras) subbeticum volanensoides* nov. ssp. Lókút Hill, Bed 44. Fallauxi Zone.

Fig. 3. *Simolytoceras volanensoides* (VIGH) (Holotype, J – 9802). Adult, nearly entire specimen, figured by VIGH, G. (1984, pl. 3, fig. 2) as *Simoceras (Lytogyroceras) subbeticum volanensoides* nov. ssp. Lókút Hill, Bed 43. Fallauxi Zone.

Figs. 4, 5. *Lytogyroceras subbeticum* OLÓRIZ (J – 10976). Young, nearly entire specimen. Hárskút, Közöskút ravine, profile II, Bed 42. Ponti Zone. The specimen was figured by FŐZY (1987, Pl. II. Fig. 3.) as *Lytogyroceras* sp. Ponti Zone.

1



2

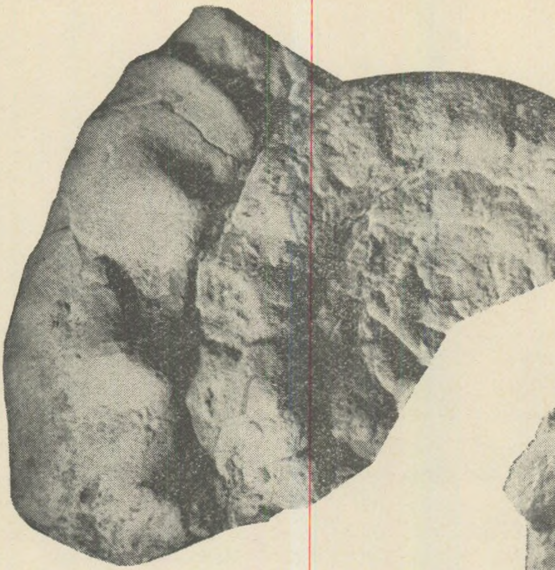
3

PLATE XIV.

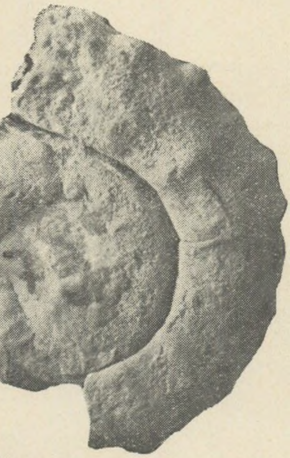
Figs. 1. *Simolytoceras vighi* nov. sp. (Holotype, J – 10975). Adult specimen without inner whorls. Hárskút, Közöskút ravine, profile II, Bed 49. Fallauxi Zone.

Fig. 2. *Simolytoceras vighi* nov. sp. (Holotype, J – 10975). Ventral view of an inner whorl. About two times enlarged. Közöskút ravine, profile II, Bed 49. Fallauxi Zone.

Fig. 3. *Simolytoceras volanensoides* (Vigh) (J – 10972). Adult, nearly entire specimen. Hárskút, Közöskút ravine, profile II, Bed 50. Fallauxi Zone.



1



2

3

4

PLATE XV.

Fig. 1. *Simoceras admirandum* (ZITTEL) (J – 10968). Fragment of a medium-sized specimen. Lókút Hill, Bed 43. Fallauxi Zone.

Fig. 2. *Simoceras admirandum* (ZITTEL) (J – 10963). Fragment of an adult (?), small specimen. Szilasárok, Bed 79. Fallauxi Zone.

Fig. 3. *Simoceras admirandum* (ZITTEL) (J – 10962). Inner whorl of a big specimen. Szilasárok, Bed 77. Fallauxi Zone.

Fig. 4. *Lytogyroceras strictum* (CATULLO) (J – 10208). Probably adult, nearly complete specimen. Sümeg.

The species of Olóriz may be identical with that described by Ramaccioni (1939) as *S. costariccіense*. However, the incomplete description and the photograph of the badly preserved specimen is insufficient for strict decision.

The ammonites figured by Rossi (1984) are more tightly coiled, more rapidly grown than the type, and they have fewer constrictions. Further difference is that the ribs are more projected on Rossi's specimens than on the holotype.

Those forms described by Vigh (1984) as new subspecies, with characteristic sculpture (i. e. elongated tubercules on the ventrolateral margin) can be ranged into the genus *Simolytoceras* (see above).

Distribution. The species was hitherto known only from the Burckhardticeras Zone of the Betic Cordilleras. The Bakony specimens came from the same stratigraphic horizon (i. e. Ponti Zone).

Dimorphism. No indications are known in this context.

* * *

Acknowledgements. Most of the material was collected and made available by the Hungarian Geological Survey. I am grateful to Dr. G. Császár and Dr. J. Konda for providing the material. I thank Prof. B. Géczy and Dr. A. Galácz (Department of Paleontology, Eötvös L. University) for their help and advice during the studies. I am grateful to Dr. F. Cecca (Servizio Geologico d'Italia, Roma) for helpul discussions and to Dr. G. Schrairer (Bayerische Staatsammlung für Paläontologie und Historische Geologie, München) for sending a plaster cast of *Simoceras* kept in the collections of Munich.

REFERENCES

Arkell, W. J. (1956): Jurassic Geology of the World. Oliver and Boyd, 806 p. Edinburgh.

Barthel, K. W. (1962): Zur Ammonitenfauna und Stratigraphie der Neuburger Bankkalke. Abh. Bayer. Akad. Wiss., mathem. – naturwiss. Kl., N. F. 105, pp. 1 – 30, pls. 5. München.

Berckhemer, F., Hölder, H. (1959): Ammoniten aus dem oberen Weissen Jura Süddeutschlands. Beih. Geol. Jb., 35, pp. 1 – 135, pls. 27. Hannover.

Bernoulli, D., Renz, O. (1970): Jurassic carbonate facies and new ammonite fauna from Western Greece. Eclogae Geol. Helv., 63, 2, pp. 573 – 607, pls. 6, Basle.

Blanchet, F. (1928): Étude paléontologique d'une nouveau gisement fossilifére dans le Tithonique intra-alpin entre Briancon et Chateau-Queyras (Hautes-Alpes). Ann. Univ. Grenoble, n.s. 2, pp. 259 – 295, pl. 1. Grenoble.

Blaschke, F. (1911): Zur Tithonfauna von Stramberg in Mahren. Ann. k.-k. Natur-híst. Hofmus., 25, pp. 1 – 143, pl. 1, Wien.

Breistroffer, M. (1947): Notes de nomenclature paléozoologique. I. Ammonites jurassiques et crétacées. Proc. Verbaux mens. Soc. Sci. Dauphiné, 26, 196, 5 pp., Grenoble.

Burckhaddt, C. (1903): Beiträge zur Kenntniss der Jura und Creideformation der Cordillere. Palaeontographica, 50, pp. 1 – 140, pls. 16, Stuttgart.

Callomon, J. H. (1969): Dimorphism in Jurassic ammonites, In: Westermann, G. E. G. (Ed.): Sexual Dimorphism in Fossil Metazoa and Taxohomic Implications. IUGS, Ser. A, No. 1, pp. 111 – 121, Stuttgart.

Catullo, T. A. (1846): Memoria geognostica paleozoica sulla Alpi Venete. Mem. Soc. It. Sci., 4, pp. 1 – 158, pls. 11, Padova.

Cecca, F. (1985): Alcune ammoniti provenienti dalla "Maiolica" dell' Appenino Centrale (Umbria, Marche e Sabina). Boll. Serv. Geol. It., 103, pp. 133 – 162, pls. 6, Roma.

Cecca, F., Cresta, S., Giovagnoli, M. – C., Nanni, R., Mariotti, N., Nicosia, U., Santantonio, M. (1981): Tithonian "Ammonitico Rosso" near Bolognola (Marche – Central Apennines): a shallow water nodular limestone. In: Farinacci, A., Elmi, S. (Eds.): Rosso Ammonitico Symposium Proceedings., pp. 91 – 111, Roma.

Cecca, F., Cresta, S., Pallini, G. Santantonio, M. (1985): Remarks on the Kimmeridgian – Lower Tithonian ammonite biostratigraphy of two sections in the Central Apennines (Italy). Newsl. Stratigr., 15,1, pp. 28 – 36, Stuttgart.

Cecca, F., Cresta, S., Santantonio, M. (1983): Ammoniti del Malm dell' Appenino marchigiano conservate nel Museo del Servizio Geologico d'Italia. Boll. Serv. Geol. It., 102, pp. 109 – 132, pls. 5, Roma.

Collignon, M. (1960): Atlas des fossiles caractéristiques de Madagascar. Fasc. VI. (Tithonique). Rep. Malgache Serv. Géol., 137 – 175 pls., Tananarive.

Del Campana, D. (1905): Fossili del Giura Superiore di Sette Comuni in provincia di Vicenza. Pubblic. R. Inst. Studi Sup. Firenze, 28, pp. 1 – 140, pls. 7, Firenze.

Donovan, D. T., Callomon, J. H., Howarth, M. K. (1981): Classification of the Jurassic Ammonitina. In: House, M. R., Senior, J. R. (Eds.): The Ammonoidea. Syst. Ass. Spec. Vol., 18, Academic Press, pp. 101 – 157, London.

Donze, P., Enay, R. (1961): Les Céphalopodes du Tithonique inférieur de la Croix-de-Saint-Concors prés Chambéry (Savoie). Trav. Lab. Géol. Lyon, N. S. No. 7, pp. 1 – 236, pls. 22, Lyon.

Enay, R. (1983): Spéciation phylétique dans le genre d'Ammonite téthysien *Semiformiceras* Spath du Tithonique inférieur des chaines bétiques (Andalousie, Espagne). In: Modalités, rythmes et mécanismes de l'évolution biologique. Gradualisme phylétique ou équilibres ponctués? Coll. Intern. du CNRS, No. 330, Paris. pp. 115 – 123.

Enay, R., Cecca, F. (1986): Structure et évolution des populations tithoniques du genre d'ammonites téthysien *Haploceras* Zittel, 1868. In: Commemorazione di Raffaele Piccinini, Atti i convegno Pergola, 25 – 28 ottobre 1984, Fossili Evoluzione Ambiente, pp. 37 – 53, pls. 4, Pergola.

Enay, R., Geyssant, J. R. (1975): Faunes tithoniques des chaines bétiques (Espagne méridionale). In: Colloque sur la limite Jurassique-Crétacé, Lyon – Neuchatel, septembre 1973, Mém. BRGM No. 86, pp. 39 – 55, Paris.

Favre, E. (1877): La zona à *Ammonites acanthicus* dans les Alpes de la Suisse et de la Savoie. Mém. Soc. Paléont. Suisse, 14, pp. 1 – 113, pls. 7, Basle.

Favre, E. (1880): Description des fossiles des couches tithoniques des Alpes Fribourgeoises. Mém. Soc. Paléont. Suisse, 16, pp. 1 – 72, pls. 5, Basle.

Fischer, P. (1882): Manuel de conchyliologie et de paléontologie conchyliologique. Edit. Savay, 4, pp. 305 – 416; Paris.

Fontannes, F. (1879): Description des Ammonites des calcaires du Chateau du Crussol (Ardéche). Trav. Univ. Lyon, pp. 1 – 122, pls. 13, Lyon.

Főzy, I. (1987): Upper Jurassic ammonite biostratigraphy in the Transdanubian Central Range (Hungary). Preliminary results. Ann. Univ. Sci. Budapest., Sect. Geol., 27, Budapest (in press)

Főzy, I. (1988): Kimmeridgian and Tithonian ammonite biostratigraphy in the Bakony Mts. (Hungary). Pergola (in press).

Gemmellaro, G. G. (1868 – 1876): Studi pal. sulla fauna del Calcare a *Terebratula janitor* del Nord di Sicilia. Giorn. Sci. Nat. Ecoenom. Part I. pp. 1 – 56; pls. 12; Part II, pp. 57 – 92, pls. 15; Part III, pp. 1 – 100, pls. 13). Palermo.

Geyssant, J. R. (1979): Évolution, systématique et dimorphisme d'un nouveau genre d'ammonite: *Baeticoceras* (Ammonitina, Simoceratinae) dans le Tithonique supérieur des Cordilleres bétiques (Espagne). Palaeontographica, 166, pp. 1 – 36, pls. 4, Stuttgart.

Geyssant, J. R. (1982): L'équilibre intermittent: une modalité d'évolution presente chez les Simoceratidae (Ammonites du Tithonique). 9^{e} Réun. Ann. Sci. Terre, Paris, 1982. p. 275, Paris.

GEYSSANT, J. R. (1985): Révision taxonomique du genre d'ammonite téthysien *Simoceras* et création d'un nouveau genre *Volanoceras* (Ammonitina, Simoceratidae). Geobios, 18, 5, pp. 677 – 680, Lyon.

HAUPT, O. (1907): Beiträge zur Fauna des Malm und der unteren Kreide in der argentinischen Cordillera. N. Jb. Miner. Geol. Palaeont., B. – B. 23, pp. 187 – 236, pls. 4, Stuttgart.

HIMSHIASHVILI, N. G. (1976): Ammonoidei Titona i Berriasa Kavkasa. 180 p, 25 pls., Mecniereba, Tbilisi.

HOLLMANN, R. (1961): *Simoceras (Simoceras) biruncinatum* (QUENSTEDT, 1845) forma *Aegra Calcar* ZIETEN, 1830 (Ammonoidae) aus dem Untertithon der Sette Comuni (Norditalien). Mem. Mus. Civ. Stor. Nat., 9, pp. 267 – 272, pl. 1, Verona.

IMLAY, R. W. (1942): Late Jurassic fossils from Cuba and their economic significance. Bull. Geol. Soc. Am., 53, 10, pp. 1417 – 1478, pls. 12, New York.

JEKELIUS, E. (1916): A brassói hegyek mezozoós faunája. III – VII. A brassói dogger és malmfauna. M. Kir. Földt. Int. Évk., 24, 3, pp. 221 – 314, pls. 3, Budapest.

KILIAN, M. (1889): Études paléontologiques les terrains sécondaires et tertiaires de l'Andalousie. Mission d'Andalousie, Mém. Acad. Sci. Inst. France, 30, 2, pp. 601 – 739, pls. 33, Paris.

KRANTZ, F. (1928): La fauna del Titono superior y medio de la Cordillera Argentina en la parte meridional de la provincia de Mendoza. Acad. Nac. Cienc. Rep. Arg., 10, pp. 2 – 57, pls. 4, Buenos Aires.

KUTEK, J., WIERZBOWSKI, A. (1979): Lower to Middle Tithonian ammonite succession at Rogoznik in the Pieniny Klippen Belt. Acta Geol. Pol., 29, 2, pp. 196 – 205, pls. 2, Warszawa.

LINARES, A., VERA, J. A. (1966): Precisiones estratigraficas sobre la serie mesozoica de Sierre Gorda, Cordilleras Béticas (provincia de Granada). Estudious Geol., 22, pp. 65 – 99, pls. 14, Madrid.

MENEGHINI, G. (1885): Nuove ammoniti dell' Appennino Centrale raccolte dal Reverendo Don A. Moriconi. Mem. Soc. Tosc. Sci. Nat., 6, 2, pp. 363 – 382, pls. 3, Pisa.

NEUMAYR, M. (1873): Die Fauna der Schichten mit *Aspidoceras acanthicum*. Abh. k.-k. Geol. Reichsanst., 5, 6, pp. 141 – 257, pls. 12, Wien.

OLÓRIZ, S. F. (1978): Kimmeridgiense-tithonico inferior en el sector central de las Cordilleras Béticas (Zona Subbética). Paleontologia, Bioestratigrafia. Tesis doct. Univ. Granada, No. 184, pp. 1 – 758, pls. 57, Granada.

OLÓRIZ, S. F., TAVERA, J. M. (1977): *Simospiticeras* (Ammonoidea) gen. nov. avance sobre nuevas morfologias pertenecientes a la base del Tithonico superior en las Cordilleras Béticas (Zona Subbética). Cuadernos Geol., 8, pp. 183 – 189, pl. 1. Granada.

OPPEL, A. (1863): Über jurassische Cephalopoden (Fortsetzung). Paläont. Mitt. Mus. k. bayer. Staat., 3, pp. 163 – 266, pls. 23, Stuttgart.

OPPEL, A. (1865): Die tithonische Etage. Zeitschr. Deutsch. geol. Ges., 17, pp. 535 – 558, Berlin.

PATRULIUS, D., AVRAM, E. (1976): Les céphalopodes des couches de Carhaga (Tithonique supérieur – Barrémien inférieur). Mém. Inst. Géol. Géophys., 24, pp. 153 – 201, pls. 10, Bucharest.

PEJO, I. (1966): Fauna e Jurese siperme e zones tektonike Mirdita. Bul. Shkenc. Nat., 4, pp. 94 – 101, Tirana.

QUENSTEDT, F. A. (1845 – 1849): Petrefactenkunde Deutschlands. Abt. I, Die Cephalopoden. pp. 1 – 104 (1845); pp. 105 – 184 (1846); pp. 185 – 264 (1847); pp. 265 – 472 (1848)? pp. 473 – 580 and Atlas (1849), Tübingen.

RAILEANU, G., NASTASEANU, A. (1960): Contributii la cunoasterea faunei de ammoniti din Jurasicul superiore la Svinita (Banat). Stud. Cerc. Geol., 5, pp. 7 – 38, pls. 11, Bucharest.

RAMACCIONI, G. (1939): Fauna giuraliassica e cretacea de Monte Cucco e dintorni (Appennino Centrale). Paleont. It., 39, pp. 143 – 214, pls. 5, Pisa.

RETOWSKI, O. (1893): Die tithonische Ablagerungen von Theodosia. Ein Beitrag zur Palaeontologie der Krim. Bull. Soc. Imp. Nat. Moscou, N. S. 7,2 – 3, pp. 1 – 95, 6 pls., Moscou.

ROSSI, F. (1984): Ammoniti del Kimmeridgiano superiore – Berriasiano inferiore del Passo del Furlo (Appennino umbro-marchigiano). Mem. Soc. It. Sci. Nat. Mus. Civ. St. Nat. Milano, 23, 3, pp. 73 – 136, pls. 8, Milano.

SANTANTONIO, M. (1985): *Simoceras volanense* (OPPEL), *Simoceras aesinense* MENEGHINI e forme affini nel Titonico inferiore dell Appennino umbro-marchigiano. In: Commemorazione di Raffaele Piccinini, Atti i convegno Pergola, 25 – 28 ottobre 1984, Fossili Evoluzione Ambiente, pp. 11 – 23, pls. 6, Pergola.

SAPUNOV, I. G. (1979): Les Fossiles de Bulgarie. III. 3, Jurassique supérieur, Ammonoidea. Acad. Bulg. Sci., pp. 1 – 237, pls. 59, Sofia.

SARTI, C. (1986): Faune e biostratigrafia del Rosso Ammonitico del Trentino centrale (Kimmeridgiano – Titonico). Boll. Soc. Paleont. It., 23, 3, pp. 473 – 514, pls. 7, Modena.

SCHNEID, T. (1915): Die Ammonitenfauna der obertithonischen Kalke von Neuburg a. d. Donau. Geol. Paläont, Abh., N. F. 13, pp. 305 – 416, pls. 13, Jena.

SPATH, L. F. (1923 – 43): A monograph of the Ammonoidea of the Gault. Palaeontogr. Soc., pp. 1 – 787, pls. 72, London.

SPATH, L. F. (1924): On the Blake collection of ammonites from Kachh, India. Mem. Geol. Surv. India, Paleont. Ind., N. S. 11, 1, pp. 1 – 29, Calcutta.

SPATH, L. F. (1925): On the collection of fossils and rocks from Somaliland. VII. Ammonites and aptychi. Monogr. Geol. Dep. Hunterian Mus. 1, pp. 111 – 164, pls. 2, Glasgow.

SPATH, L. F. (1950): A new Tithonian ammonoid fauna from Kurdistan, Northern Iraq. Bull. Brit. Mus. (Nat. Hist.), 1, pp. 93 – 137, pls. 4, London.

TOUCAS, A. (1890): Étude de la faune des couches tithoniques de l'Ardéche. Bull. Soc. géol. France, 3, 18, pp. 560 – 629, pls. 5, Paris.

VERMA, H. M., WESTERMANN, G. E. G. (1973): The Tithonian (Jurassic) ammonite fauna and stratigraphy of Sierra Catorce, San Luis Potosi, Mexico. Bull. Am. Paleont., 63, No. 277, pp. 1 – 320, pls. 56, Ithaca, New York.

VIGH, G. (1976): In: Fülöp, J.: The Mesozoic basement horst blocks of Tata. Geol. Hung., Ser. Geol., 16, pp. 1 – 229, pls. 52, Budapest.

VIGH, G. (1984): Die biostratigraphsiche Auswertung einiger Ammoniten-Faunen aus dem Tithon des Bakonygebriges sowie aus dem Tithon-Berrias des Gerecsegebirges. Ann. Inst. Geol. Publ. Hung., 67, pp. 1 – 210, pls. 7, Budapest.

ZEISS, A. (1968): Untersuchungen zur Palaeontologie der Cephalopoden des Unter-Tithon der Südlichen Frankenalb. Abh. Bayer. Akad, Wiss., math,-naturwiss. Kl., N. F. 132, pp. 1 – 190, pls. 5, München.

ZEJSZNER, L. (1846): Howe Lubniedokladnie opisane gatunki skamienialosci Tatrowych. Poszyt 1, pp. 1 – 32, pls. 4, Warszawa.

ZITTEL, K. A. (1868): Die Cephalopoden der Stramberger Schichten. Paläont. Mitt. Mus. k. bayer. Staat., 2, 1, pp. 1 – 118, pls. 24, München.

ZITTEL, K. A. (1869): Geologische Beobachtungen aus den Central-Apenninen. Geogn. Palaeont., Beitr. 2, pp. 88 – 178, München.

ZITTEL, K. A. (1870): Die Fauna der älteren Cephalopoden führenden Tithonbildungen. Paläont. Mitt. k. bayer. Staat., 2, 2, pp. 119 – 310, 15 pls., Cassel.

TRACE FOSSILS ON BADENIAN (MIOCENE) GASTROPODS FROM VÁRPALOTA, HUNGARY

Á. GÖRÖG, Á. SOMODY

Department of Palaeontology, Eötvös University,

H – 1083 Budapest, Kun Béla tér 2, Hungary

(Received: 30th May, 1987)

Abstract

Traces of predation and settlement were studied on gastropods of the Badenian (Middle Miocene) Szabó sand pit at Várpalota. Traces of predation were made by gastropods and malacostracans; settlement traces were produced by sponges, cirriped larvae, annelids and bivalves. The trace-bearing gastropods are inbenthonic or epibenthonic herbivores or carnivores. Number of specimens in each gastropod species, number of damaged shells and quantity of trace fossils are given. An outline of part of the ancient ecological system is provided. The trace fossils provided information on animals without hard skeleton (annelids, poriferans, cirriped larvae, malacostracans). Data have been obtained on the mode of life of certain species, on the feeding habits of naticids and murex, and on their food, species by species. Bioerosion is an important factor in making differences in preservation of fossil faunae.

Introduction

Several authors have studied the Middle Miocene Mollusca fauna of the former Szabó's sand pit at Várpalota. Systematic studies were made by TELEGDI ROTH (1924), SZALAI (1943), WENZ and STRAUSZ (1954) and KECSKEMÉTI – KÖRMENDI (1961).

The fauna is extremely rich in species; besides, many specimens bear damages. Our studies were centered at the latter ones. We examined the several types of trace fossils, and tried to identify the way and the organism which made them. Character and quantity of damages on the representatives of each species was determined; similar studies have not been made before on this material.

The collection of gastropods, which we studied, was made by several collectors in different times, therefore we are not certain, if it represents the composition of the fauna correctly. The studied 75 species are represented by 6200 specimens. Fourtyseven of them bear damages.

The different kinds of holes on the shells were filled by epoxy resin; dissolving the shell by hydrochloric acid the internal mould of the traces could be examined. The forms were enhanced by a thin ammonium chloride film. Traces of boring sponges were studied by X-ray photography to find the siliceous sponge spicules; this method gave negative results.

The whorls of the gastropods were numbered beginning with the last one, as mostly the apex is missing.

Broken lines of the plots represent Poisson standard deviation.

The damages and their agents

Traces of feeding and settlement occur on the studied gastropod shells. Traces of feeding were produced by gastropods and malacostracans, while settlement traces were made by cirriped larvae, annelids, and bivalves.

Damages made by gastropods

Most of the damages are gastropod borings. Considering the mode of life of living gastropods (Tatishvili et al., 1968; Bromley, 1981) the following predators lived at Várpalota: *Terebra*, *Natica*, *Murex*, and *Conus*. *Murex* and *Natica*-type gastropods make borings into the shell of their victim.

a) Naticids

Infaunal mode of life; most of the diet consists of venerid bivalves (Tatishvili et al., 1968, p. 77; Bromley, 1981). Prey gastropods are: *Nassa*, *Aporrhais*, *Turritella*, etc. The boring process consists of a mechanical boring by the proboscis, and a chemical one by solving the carbonate shell by acids. SEM studies helped recognizing the two processes. Cross section of the bored hole is circular forming a semi-globular or crater-like shape (Plate I, figs. 1, 2). Its long axis encloses a variable angle with the surface of the shell (plate I, fig. 3). If the boring was unsuccessful, i. e. the process was stopped, the bottom of the unfinished hole bears a small bulge (plate I, figs. 4 – 6). The predator usually makes the borings through thin areas of the shell; rarely the hole was prepared at the junction of the whorls, where the shell is extremely thick (plate I, fig. 7). Traces of cannibalism can be observed on some species (plate I, fig. 6). Size of the predators is usually 1 to 2,5 cm.

The following species belong to this group: *Natica millepunctata* Lamarck, *Natica redempta* Michelotti, and *Natica josephinia olla* Serres.

b) Muricids

Motile, active predators. Epibenthonic forms. Different methods are applied to reach the soft tissues of the victims (Tatishvili et al., 1968). Valves of some bivalves are forced away, and the tissues are sucked by the proboscis. Peristomes or valve edges of certain bivalve and gastropod species are broken away to reach the animal itself.

The boring is a common result of mechanical and chemical processes.

The muricids feed themselves by epibenthonic forms. The trace of boring is cylindrical, being perpendicular to the surface (Arua, 1981) (plate I, fig. 8). If the boring process ios unfinished, the incomplete hole bears a smooth surface (plate I, fig. 9). Most of the holes are prepared in areas, where the shell is thin; however, holes along sutures have been observed, too (plate I, fig. 10). Specimens of *Potamides gamlitzensis* HILBER display regenerated borings (plate I, fig. 11).

The following species belong to this group: *Murex rudis syrticus* MAYER, *Hadriania boeckhi* HOERNES, & AUINGER, *Ocinebrina crassilabiata* HILBER, *Murex turonensis pontileviensis* TOURNOUER and *Murex (Tubiconda) spinicostata* BRONN.

Traces of malacostracans

Larger gastropods frequently bear damages made by malacostracans. These are located on the aboral side of the shell, mostly continuing towards the peristome. It is the thinnest part of the shell, containing most of the soft parts of the animal. The opening is 6 to 15 mm in diameter. Its outline is circular, frequently with sharp edges and corners (Fig. 1).

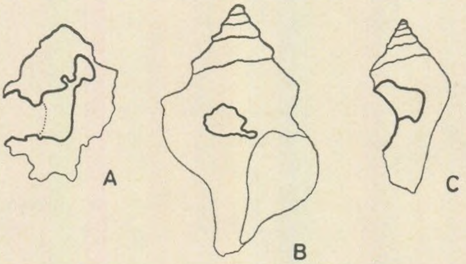


Fig. 1. Traces of malacostracans on gastropod shells.

Traces of sponges

Much less in number than the gastropod borings, pores made by sponges were observed on the genera *Cerithium*, *Melongena*, *Potamides*, *Turritella*, *Vermetus*, and *Dorsanum*. The traces were produced by the sponge *Cliona* sp. (ARUA, 1981). The pores are observable on the external and internal sides of the shells (Plate I, figs. 12 – 13).

Two morphological types were recognized up to now (ARUA, 1981; BISHOP, 1975): linear (plate II, fig. 14) or irregular (plate I, figs. 12 – 13) arrangement of pores with 0.6 – 1 mm in diameter; or the rare case of spotlike arrangement of very small pores (0.03 – 0.07 mm). The latter type was not observed in the collection from Várpalota. Frequently the extreme bioerosion of the sponges cause complete damage of the attacked part of the shell (plate II, fig. 15).

Traces of cirripeds

Cirriped larvae belonging to the order Acrothoracica preferred sessile epibenthonic hosts and settled mostly on living animals (Fig. 2).

Two types of traces have been recognized. The first one consists of drop-shaped openings of 1.0 – 1.8 mm length and 0.15 – 0.08 mm width.

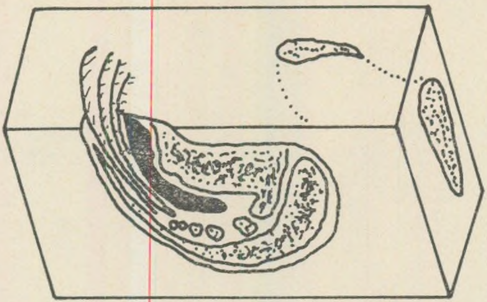


Fig. 2. The cirriped larva in skeletal carbonates (after Seilacher, 1969, fig. 7)

The hole is somewhat larger within the shell. The plastic internal mould shows the form of an apple-seed (plate II, figs. 16 – 18). Part of them lies in irregular arrangement, while others are oriented with their sharp ends towards the aperture of the host. The second type consists of fissure-like depressions forming a linear network, which resembles tiny scratches on the shell. Their length varies between 0.08 and 0.03 mm, while the width is more or less constant (0.01 – 0.03 mm) (ARUA, 1981; SEILACHER, 1969; BISHOP, 1975) (plate II, figs. 19 – 20).

Ultramicroscopic photography revealed traces of etching, proving common activity of mechanical and chemical processes (SEILACHER, 1969).

Traces of cirriped larvae occur on definite parts of the shell: mostly in depressions, like along growth lines, sutures of whorls. They rarely occur on the internal parts of the shell, except in those ones which were inhabited by hermit crabs.

Traces of annelids

Borings of annelids occur only on adult specimens. These are 1 – 3 mm long, 0.5 – 1 mm wide and form two groups. The smaller one is dumb-bell-shaped, not exceeding 1 mm (plate III, fig. 21). The other type is U-shaped (plate III, fig. 22) or irregularly bent (plate III, figs. 23 – 25).

Traces of bivalves

The genera *Vermetus*, *Turritella*, *Hadriania*, *Melongena*, and *Cerithium* bear traces of borers, the valves frequently preserved in the hole. These occur mostly in the thickest parts of the shells (plate IV, figs. 27 – 30). A rare occurrence is shown on Plate IX, fig. 56, displaying a minor *Turritella vermicularis* BROCCHI bored by a relatively large bivalve.

Neither of the above-listed damages have been recognized on the following species (number of specimens shown in brackets): *Tudicla rusticula* BASTEROT (24), *Rissoa (Alvania) curta* DUJARDIN (20), *Calyptraea chinensis* LINNÉ (14), *Pedipes (Nealexia) myotis pisolinus* DESHAYES (14), *Terebra acuminata* BARSAN (11), *Littorina (Littoringosis) scabra alberti*

DUJARDIN (10), *Nassa (Tritia) styriaca* AUINGER (7), *Brotia escheri* BRONGNIART (5), *Pleurotoma badensis* R. HOERNES (5), *Terebra (Subula) fuscata modesta* TRISTAN (5), *Hipponix sulcatus* BORSON (4), *Melanopsis impressa* KRAUSS (4), *Nerita plutonis* BASTEROT (4), *Bittium reticulatum* COSTA (3), *Calyptraea (Bicatillus) deformis* LAMARCK (3), *Clavatula interrupta vitalisi* STRAUSZ (3), *Solarium simplex* BRONN (3), *Crepidula cochlearis* BASTEROT (2), *Dorsanum nodosocostatum ternodosum* HILBER (2), *Ringicula (Ringiculina) auriculata buccinea* BROCCHI (2), *Terebra fuscata plicaria* BASTEROT (2), *Acteon cf. woodi* MAYER (1), *Capulus sulcosus* BROCCHI (1), *Clavatula interrupta* BROCCHI (1), *Conus (Conolithus) dujardini brezinae* HOERNES & AUINGER (1), *Cypraea (Zonaria)* sp. aff. *fabagina* STRAUSZ (1), *Fasciolaria (Pleuroploca) tarbelliana* GRATELOUP (1), *Murex (Muricanthus) turonensis pontileviensis* TOURNOUER (1), *Murex (Tubicauda) spinicostata* BRONN (1), *Potamides (Ptychopotamides) papaveraceus* BASTEROT (1).

The species occurring with more than 10 specimens are discussed below (smaller number of specimens, due to problems of statistics, does not indicate the improbability of traces occurring on them).

Tudicla rusticula BASTEROT

Large size specimens (8 – 10 cm). The very thick shell is ornamented with strong spines. Predators could rardly reach the animal. Almost all specimens were mechanically damaged. Probably the shell was easily damaged after the decay of the animal, thus providing poor substrate for borer settlement.

Rissoa (Alvania) curta DUJARDIN

Usually occurs in large masses on algae or stems of plants. Herbivorous, feeding on lower algae, and diatoms. Very small size (3 – 4 mm only). These are very small pieces of prey for the predators.

Calyptraeans

Phytophagous, feeding on planktonic organisms or detritus feeder. Mode of life: fixed to hard objects, like bivalves or rocks, in the wave agitated zone. It selects a place, where there is low probability of being covered by sediments. Neither the naticids, nor the muricids attack in this zone. Usually this zone is not suitable for the settlement of the other producers of the investigated trace fossils.

Pedipes (Neatexia) myotis pisolina DESHAYES

Smaller than 9 mm. We have no information on its mode of life, therefore we have no idea why it does not bear damages. Possibly it was simply of bad taste for the predators. (Actual observations proved that the predators are selective, do not attack all available species.)

Terebra acuminata BORSON

Inbenthonic predator. The shell is extremely elongated, with a very small apical angle. Possibilities include too small size of the soft tissues, hardly accessible soft parts, or that the species itself was dangerous to the attacker.

Littorina scabra alberti DUJARDIN

Feeding mostly with diatoms and other algae, but is omnivorous. Lives in the fissures of a rocky bottom in the shallow intertidal zone. The shell is small (14 mm), having a thin wall. It escaped attack due to its habitat.

Trace fossil-bearing species

Table I consists numerical data on the occurrence of the discussed types of trace fossils on each species. Detailed description of the species follows the sequence in Table II, displaying species with high damage percentage. The species are ordered according to their mode of life and feeding habits and size.

A) Inbenthos

a) Herbivores

Turritellids

Turritellids feed on diatoms and other algae, filtered from the water adjacent to the bottom. There are several theories on their mode of life (TATISHVILI et al., 1968). Most probable is their burrowing in the mud, supported by our observations. Unfinished borings bear the small bulge in their bottoms made by naticids; these holes occur mostly on the 2nd or 3rd coil (Fig. 3). Preys of the naticids are inbenthonic animals; and the borings are located on the coil which is most close to the surface, but contains relatively much food.

Turritella aquitanica TOURNOUER

It is the 5th species in numbers of our material. Most of the borings are located on the 2nd and 3rd coils (Fig. 3), some of them occurring on the suture between them (plate I, fig. 7). One of the specimens bear trace of pinching by a crab (plate IX. fig. 51).

Turritella (Haustator) eryna partschi ROLLE

Three specimens bear gastropod borings on the 2nd and 3rd coils (plate IX, fig. 53). Pores of sponges were observed on 4 specimens.

Turritella turris badensis SACCO

Three specimens bear gastropod borings on the 3rd and 4th coils. Several sponge traces occur. The tiny pores form intersecting lines (plate II, fig. 25). The shell became porous, and broke in after a minor mechanical damage (plate IX, fig. 54).

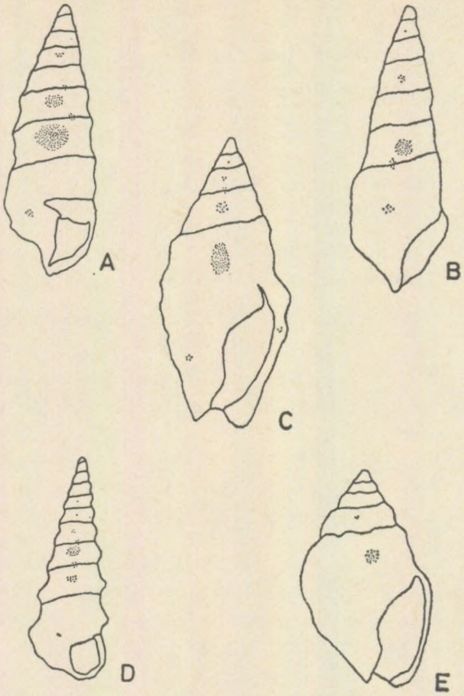


Fig. 3. Position of gastropod borings on the shells.

Turritella vermicularis Brocchi

The specimen of plate VIII, fig. 55 bears much sponge traces on all sides of the shell, ordered irregularly, Gastropod borings are bowl-shaped, their size suggesting naticids as agents. The damage on plate IX, fig. 56 was made by a boring bivalve; its upper part bears a boring by a naticid. It is supported by the strongly damaged internal part, the missing septa and columella. Probably the boring bivalve chose the empty shell of a gastropod, victim to a naticid. The 2,5 cm long shell – which was not a very stable point on the sea bottom – provided habitat for a relatively large bivalve.

Turritella bicarinata subarchimedes Orbigny

The boring is located at the suture between coils 2 and 3 (plate IX, fig. 57).

Protomids

These ones bear borings made by naticids, with circular openings on both the external and internal surfaces. The protomids are related to the genus *Turritella*, therefore these were frequently attacked by naticids preferring inbenthonic animals.

Protoma proto BASTEROT

There are damages of the 2nd and 3rd coils. The animals attacked range is size from 1.5 to 3 cm: juvenile specimens were among the victims, too.

Protoma proto quadriplicata BASTEROT

Usually bored on the 3rd coil (plate X, fig. 59).

Species belonging to other groups

Genota ramosa elisae HOERNES & AUINGER

It is the seventh species in number of specimens of the collection. Few gastropod boring; no other trace fossils. The boring is bowl-shaped, located above the aperture on coil 2 (plate IX, fig. 58). Its shape indicate a naticid predator, suggesting inbenthonic mode of life for the genus *Genota*. Elongated shape of the shell, the narrow, long aperture and the presence of siphonal canal does not contradict this hypothesis.

Aporrhais pespelecani alatus EICHWALD

Feeding on plant detritus and on diatoms and other algae. Burrows into the soft mud up to the apex. The shells are positioned horizontally, with apertures down. The naticid turned the Aporrhais out of the mud and bored it near the aperture (plate X, fig. 60).

b) Carnivores

Nassa dujardini edlaueri BEER

Burrows deep into the mud, appearing to feed only. Predator, but mostly scavenger. Eats fishes, crabs, molluscs.

75% of the damaged specimens were bored on the last coil, part of the traces being located near the inner lip (Fig. 3, plate X, fig. 61). It can be explained by the occurrence of most of the soft parts there. There is a specimen, in which the boring displays bowl-shape, but with smooth bottom (plate X, fig. 62). The latter suggests a naticid as the predator.

Nassa styriaca AUINGER

Eleven specimens bear one gastropod boring each, all located on the 2nd coil.

Nassa hungarica MAYER

Plate XI, fig. 63 displays injure regenerated by the animal.

Dorsanum nodosocostatum HILBER

It belongs to the inbenthonic Nassas. It is eaten by molluscs, either living or after the death (TATISHVILI et al., 1968). The specimens bear gastropod and sponge traces. There is a regenerated injure on the 2nd coil, on the aboral side (plate XI, fig. 64). There is the conspicuous bulge on the bottom of the unfinished borings, characteristic of the naticids (plate I, fig. 4). Eighty percent of the traces is located on the last coil, above the inner lip (Fig. 3). It also indicated the relationships with the Nassas. Unfinished borings were not completed not due to the thickness of the shell, but the predator might have been disturbed. There are 3 borings on the last coil on one of the specimens. Plate IX, fig. 65 shows a specimen bearing a circular boring with half-globular cross-section. There is the small bulge on the bottom of the unfinished boring. Plate I, fig. 1 shows a circular trace, too, but the hollow is elliptical. Plate IX, fig. 66 displays a biscuit-shaped boring due to the ornamentation of the shell. The locations of the attack on 142 specimens are plotted on Fig. 3.

Terebra basteroti NYST

Predators, burrowing in sandy bottom. One of the 8 specimens bears a gastropod boring on the 4th coil. Form of the hole and mode of life of the gastropod indicate the predators as naticids (Plate XI, fig. 67).

Naticids

Natica redempta MICHELOTTI

A single one of 51 specimens display a boring; the predator might have been a naticid, supplying evidence for cannibalism.

Natica josephinia olla SERRES

Unfinished borings occur on 2 specimens. Bottom of the holes are smooth, indicating *Murex* as predator (plate VII, fig. 42). There is a strong round, bulging thickening in the umbilicus. The predator bored just in the middle of it. So unfortunate selection of the location of the boring is very rare (plate I, fig. 9; plate VII, fig. 43).

Natica millepunctata LANARCK

Six borings were observed; four of them are located on the inner lips of the victim, two of them are on the aboral side. Traces of cannibalism can be observed. A regular, cylindrical boring was prepared, hollowing downwards. There is a tiny bulge in the centre of the bottom of the unfinished boring, indicating the predators as naticids (plate VII, figs. 44–45).

B) Epibenthos

a) Herbivores

Theodoxus picta FÉRUSSAC

Only 3 specimens bear borings among a population of 142. It may be due to the small (5.5 cm) size of the shell. Epibenthonic form, the predator might have been a muricid.

Drillia allionii BELLARDI

Gastropod borings occur on coils 2 and 3. Probably the most sensitive soft part of the animal was located here. Half of the bored specimens bear two completed borings (plate V, fig. 31); either the same predator prepared the two holes, because one was not sufficient to empty the shell of the victim, or two gastropods attacked simultaneously. A third answer to the problem of the double borings may be that the victim escaped after the preparation of the first one, but was catched again.

If the boring process was begun in a thick area, the hole lies obliquely to the surface. Identity of the predator cannot be determined from the traces.

Potamids

Largest number of specimens. Epibenthonic, herbivorous, feeding on algae. Depth range coincides with that of the algae: occur down to 50 m Prefer sandy bottom (TATISHVILI et al.' 1968).

Potamides (Pirenella) gamlitzensis HILBER

One gastropod boring occurs on each shells. The borings were rarely prepared on the sutures between the coils. Apparently the boring is oblique to the surface at the sutures and nodes (plate I, fig. 8). Smooth bottom of unfinished borings indicate *Murex* predators. Mode of life of the animals suggests the same.

One specimen bears a regenerated boring (plate I, fig. 11).

Location of the boring is on coils 2 or 3 (plate V, fig. 32). This area might have yielded the largest or best food for the predator (Fig. 3).

Potamides (Pirenella) moravicus HÖRNES

Almost 10% of the specimens bear Murex traces. Most of the borings are on coil 2, like on *P. gamlitzensis* (Fig. 3). There are no unfinished borings. The suture between the coils was bored in 9 cases, forming two openings on the shell. The trace is circular on the surface (plate V, fig. 33).

Two of 80 specimens of *Potamides (Pirenella) pictus* DEFRANCE & BASTEROT, and one of 75 specimens of *Potamides (Pirenella) gamlitzensis* ROLLE were bored by muricids.

Potamides (Terebralia) bidentatus perrugatus HILBER

Large size (6 – 7 cm), thick-shelled forms. One of them bears traces of boring bivalves, located in depressions among the ornaments (plate IV, fig. 30).

Potamides (Terebralia) bidentatus lignitarium EICHWALD

There are sponge-made pores on a well-worn, broken shell.

Potamides (Terebralia) bidentatus margaritifer SACCO

Dumb-bell-shaped worm traces occur on the lower part of the last coil (plate VI, fig. 40). Traces of boring bivalves occur, too (plate IV, figs. 28 – 29).

Cerithids

Their mode of life is similar to that of the potamids, consequently their attacker was the same.

Cerithium exdoliolum SACCO

There is a gastropod boring between the 2nd and 3rd coils. It is circular on the surface and is cylindrical downwards; its side is perpendicular to the surface (plate I, fig. 10). Plate IV, fig. 27 displays a boring bivalve within the shell. Traces os sponges were observed on plate V, figs. 34 – 35. The shell is broken between the linear pores.

One of 15 specimens of *Cerithium rubiginosum pseudobliquostoma* SZALAI and two of 12 specimens of *Cerithium vulgatum europaeum* MAYER were bored by muricids.

Species belonging to other groups

Columbella (Alia) helvetica MAYER

Preferred sandy bottom. Worm trace is shown on plate III, fig. 21.

Pusionella pseudofusus palatina STRAUSZ

Three of 18 specimens display trace fossils: two gastropod borings and the third specimen bears traces of cirriped larvae. Both types of the latter one – the apple-seed-like and the scratch-like – are shown on plate V, fig. 36 and plate VI, fig. 37.

Ancilla glandiformis LAMARCK

95 specimens of robust, thick-walled shells (3 – 4 cm). Several traces occur, except gastropod borings (probably due to the thick wall). There are six specimens with crab pinches. The crabs attacked on the aboral side (Fig. 1, plate VI, fig. 38). If the location is not good, the crab breaks the shell at the outer lip (plate VI, fig. 39). The other damages were formed after the death of the animal. Cirriped larval traces were found on a single specimen only, but both types occurred on the same shell (plate II, figs. 17 – 20). (A detailed description see under 'Damages and their agents'.) The larger, drop-shaped traces occur on the columella only, while the smaller, scratch-like traces cover almost the whole surface, even the inner sides (habitat of a hermit crab). Sponge pores occur, too. One of the shells served as bottom for a boring bivalve. It bored itself into the apex. The open-

ing is 2 mm long, 1.5 mm wide, ellipsoidal in shape. There is a worm trace above the aperture of one of the specimens. The U-shaped 'tunnels' and other traces are not more than 6 mm long, and occur above the aperture. The worm has settled after the death of the gastropod, since the aperture must have turned upwards to provide a good substratum.

Vermetus arenarius LINNÉ

Epibenthonic, phytophagous forms. There are minor bivalves bored into the thick shells; also sponge pores occur (plate I, figs. 12–13).

Melongena cornuta AGASSIZ

Largest specimens at Várpalota, with the thickest shell (up to 15 cm). It was embedded in the sandy bottom due to its considerable weight. Therefore one side is intact, while the other served as substratum for several sessile organisms. All the traces were formed after the death of the animal. Most of the boring organisms are bivalves (plate VII, fig. 41), and worms. Plate II, fig. 14 displays pore lines of sponges.

b) Predators

Muricids

Ocinebrina crassilabiata HILBER

There are several crab pinches on the shells, located aborally. It was the most easily available part of the animal with the thinner shell than around the aperture. The damage is always on the last coil, because most of the soft parts occur here (plate VIII, fig. 46).

Hadriania boeckhi (Tritonalia sublavata) HOERNES & AUINGER

There is a pinch of crab on plate VIII, fig. 47. There are worm traces above the crab pinches. Another gastropod bears a boring bivalve within the thickened peristome (plate IV, fig. 26).

Murex rudis syrticus MAYER

There was a single, highly bored specimen. The animal might have been killed by a crab (plate VIII, fig. 49). The trace of the pinch can be well observed; after the initial pinch the predator broke the shell all along to the aperture. After death the shell was inhabited by bivalves (plate VIII, fig. 50).

Eutriofusus burdigalensis DEFRANCE

Three of 37 specimens were bored by gastropods, all of them are juvenile ones. One of them bear a crab pinch (plate VIII, rig. 48).

Conclusions

The trace fossils of the Várpalota fauna have preseved information on the non-fossilizable elements of the community: worms, sponges, cirriped larvae. Besides data have been obtained on the mode of life and habitat of certain species (e. g. *Genota ramosa elisae*) .Information was collected on the special feeding habits of some gastropods: the boring. The location of the best point to bore might have been selected according to vulnerability of the soft parts (position of the visceral sack), availability, thickness of shell, location of the most digestable soft tissue. Most of the borings are located on certain areas of the shell (Fig. 3). The position of borings is the same on similar shells (Fig. 3). Besides this general rule, several ill-located borings have been observed (e. g. at the suture between two coils).

Unfinished borings indicate that the victim had escaped. It may be one of the reasons that in some cases there are two, even three borings on the shell. The victim had escaped, but another predator have attacked it, killing it finally. We can wonder, why it did not use the existing boring. Successful escapes are indicated by regenerated borings. The double borings may have been made by two predators simultaneously, or by a single one, which needed two holes to fully extract the soft tissues. In the previous case the quantity of food was not enough to cover the energy needs of boring.

Table II – containing the important damaged species – shows that herbivorous gastropods dominate the population, in number of species and specimens as well, corresponding to the composition of the natural food chain.

Some palaeoecological conclusions have been drawn. Altogether 8 boring gastropod species lived in the Badenian sea of Várpalota, represented by 385 specimens. These have bored 30 herbivorous species, represented by 650 specimens. Figures 4 and 5 show the species distribution of the victims of muricids and naticids. Looking both the specimen number and the percentage we can observe that the species with most members were most

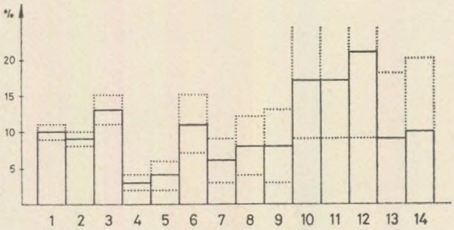


Fig. 4. Percentage of bored specimens of the species attacked by naticids (the species represented by more than 10 individuals are listed only). 1. *Dorsanum nodosocostatum* 2. *Nassa dujardini edlaueri* 3. *Turritella aquitanica* 4. *Genota ramosa elisae* 5. *Rimella (Dientmochilus) decussata* 6. *Drillia allionii* 7. *Turritella partschi* 8. *Protoma proto* 9. *Turritella turris badensis* 10. *Nassa hungarica* 11. *Protoma inaequiplicata* 12. *Turritella vermicularis* 13. *Nassa styriaca* 14. *Aporrhais pespelecani alatus*

Table I.

Number of damaged specimens of each species and their trace fossils

Species	Gastropod	Sponge	Worm	Crab	Cirriped	Bivalve	Number of specimens
Potamides (Pirenella) gamlitzensis .	257	0	0	0	0	0	1669
Dorsanum nodosocostatum	142	2	0	0	0	0	1493
Potamides (Pirenella) moravicus . .	92	0	0	0	0	0	951
Nassa dujardini edlaueri	48	0	0	0	0	0	521
Turritella aquitanica	59	4	1	1	0	0	444
Natica millepunctata	6	0	0	0	0	0	215
Genota ramosa elisae	4	0	0	0	0	0	149
Theodoxus picta	4	0	0	0	0	0	142
Ancilla glandiformis	0	0	0	6	1	0	95
Potamides (Pirenella) pictus	2	0	0	0	0	0	80
Rimella (Dientmochilus) decussata .	2	0	0	0	0	0	78
Potamides gamlitzensis theodiscus . .	1	0	0	0	0	0	75
Drillia allionii	8	0	0	0	0	0	71
Turritella partschi	3	4	0	0	0	0	52
Natica redempta	1	0	0	1	0	0	51
Protoma proto	3	0	0	1	0	0	39
Natica josephinia olla	3	0	0	0	0	0	38
Turritella turris badensis	3	3	1	0	0	3	37
Potamides bidentatus margaritifer . .	0	0	1	0	0	3	37
Euthriofusus burdigalensis	3	0	0	1	0	0	32
Potamides bidentatus lignitarum . . .	0	1	0	0	1	0	36
Hadriania boeckhi-Tritonalia sublavata	0	0	1	2	0	1	32
Potamides bidentatus perrugatus . . .	0	0	0	0	0	1	31
Nassa hungarica	4	0	0	0	0	0	24
Vermetus arenarius	0	1	0	0	0	1	20
Protoma inaequiplicata	4	0	0	0	0	0	24
Pusionella pseudofusus palatina . . .	2	0	0	0	1	0	18
Cerithium rubiginosum pseudobliquistoma	1	0	0	0	0	0	15
Cerithium exdoliolum	2	1	0	1	0	0	15
Turritella vermicularis	3	0	0	0	0	0	14
Brotia escheri inornata	1	0	0	0	0	0	13
Columbella (Alia) helvetica	0	0	0	2	0	0	12
Cerithium vulgatum europaeum	2	0	0	0	0	0	12
Nassa styriaca	1	0	0	0	0	0	11
Ocinebrina (Tritonalia) crassilabiata	0	0	0	3	0	0	10
Aporrhais pespelecani alatus	1	0	0	0	0	0	10
Turritella bicarinata subarchimedes .	1	0	0	0	0	0	9
Columbella fallax	1	0	0	0	0	0	9
Melongena cornuta	0	3	1	0	0	0	8
Terebra basteroti	1	0	0	0	0	0	8
Columbella moravica	1	0	0	0	1	0	7
Gibbula buchi	1	0	0	0	0	0	6
Gibbula biangulata	1	0	0	0	0	0	4
Solarium semiquamosum bisulcatum	2	0	0	0	0	0	2
Murex rudis syrticus	0	0	0	1	0	1	1

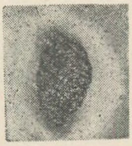
Table II.

Damaged species and their damages, grouped according to their mode of life, and their size within each group.

(N = naticids, M = muricids).

		SPECIES	Gastr.		Crab	Sponge	Cirriped	Bivalve	Worm	Number of specimens
			N	M						
INBENTHONIC	HERBIVORE	*Turritella aquitanica*	59		1	4		1		444
		Turritella eryna partschi	3			4				52
		Turritella turris badensis	3			3		1	3	37
		Turritella vermicularis	3							14
		Turritella bicarinata subarchimedes	1							9
		Genota ramosa elisae	4							149
		Protoma proto	3		1					39
		Protoma inaequiplicata	4							24
		Aporrhais pespelecani alatus	1							10
	CARNIVORE	*Nassa dujardini edlaueri*	48							521
		Dorsanum nodosocostatum	142			2				1493
		Terebra basteroti	1							8
		Nassa styriaca	1							11
		Nassa hungarica	4							24
		Natica redempta		1	1					51
		Natica josephinia olla	1	2						38
		Natica millepunctata	2	4						215
EPIBENTHONIC	HERBIVORE	*Theodoxus picta*		4						142
		Drillia allionii		8						71
		Potamides (Pirenella) gamlitzensis		257						1669
		Potamides (Pirenella) moravicus		92						951
		Potamides (Pirenella) pictus		2						80
		Potamides gamlitzensis theodiscus		1						75
		Cerithium exdoliolum		2	1	1				15
		Columbella (Alia) helvetica			2					12
		Pusionella pseudofusus palatina		2			1			18
		Ancilla glandiformis			6		1			95
		Vermetus arenarius				1			1	20
		Potamides bidentatus perrugatus							1	31
		Potamides bidentatus lignitarum				1	1			36
		Potamides bidentatus margaritifer						1	3	37
		Melongena cornuta				3		1		8
	CARN.	*Ocinebrina (Tritonalia) crassilabiata*			3				1	10
		Hadriania boeckhi-Tritonalia sublavata			2			1	1	32
		Euthriofusus burdigalensis		3	1					32
		Murex rudis syrticus			1				1	1

Pl. I


1

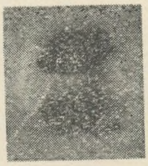

2


3

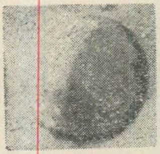

4


5


6

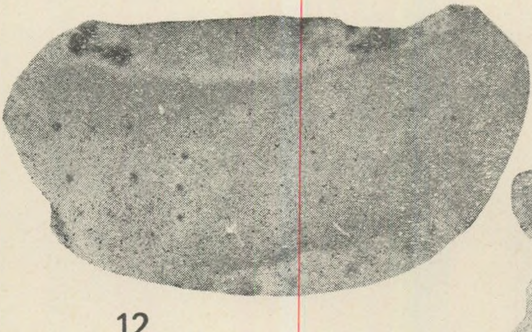

7


8


9


10


11


12

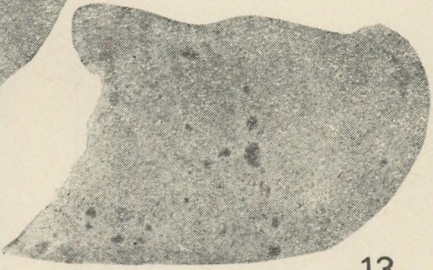
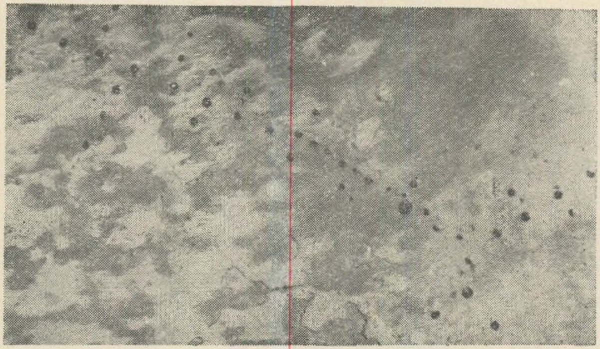

13

PLATE I.

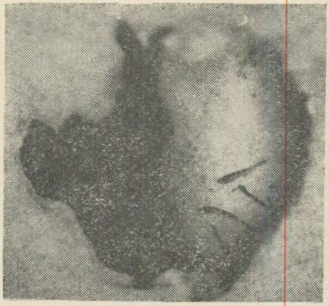
1. Naticid boring on the gastropod *Dorsanum nodosocostatum* (7,5x)
2. Naticid boring on the gastropod *Nassa dujardini edlaueri* (6x)
3. Naticid boring on the gastropod *Turritella vermicularis* (1.5x)
4. Naticid boring on the gastropod *Dorsanum nodosocostatum.* (7.2x)
5. Naticid boring on the gastropod *Turritella vermicularis* (4x)
6. Naticid boring on the gastropod *Natica millepunctata* (5x)
7. Naticid boring on the gastropod *Turritella aquitanica* (5x)
8. Muricid boring on the gastropod *Pirenella gamlitzensis* (2.4x)
9. Muricid boring on the gastropod *Natica josephinia olla* (2.2x)
10. Muricid boring on the gastropod *Cerithium exdoliolum* (1.8)
11. Muricid boring on the gastropod *Pirenella gamlitzensis* (3x)
12. Sponge pores on the gastropod *Vermetus arenorius* internal surface (4.5x)
13. Sponge pores on the gastropod *Vermetus arenorius* external surface.

Pl. II



14

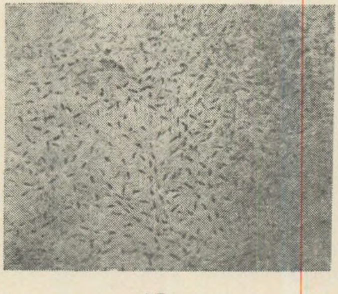
15



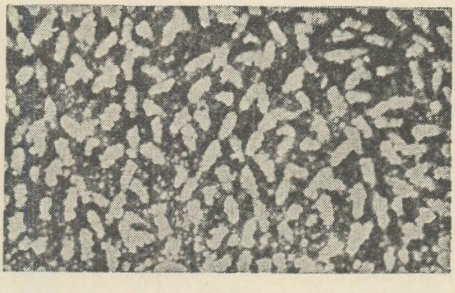
16

17

18



19



20

PLATE II.

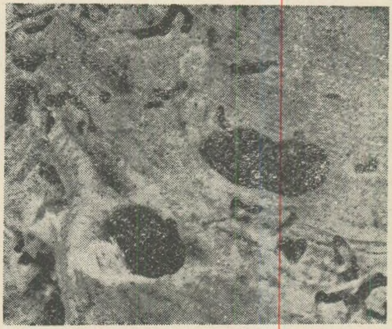
14. Sponge pores on the columella of *Melongena (Galeodes) cornuta* (3.2x)
15. Broken pores of sponges in *Turritella turris* (2.5x)
16. Cirriped larval traces on the columella of *Ancilla glandiformis* (3.2x)
17. Plastic internal mould of the shell fragment on Fig. 16. (8x)
18. Cirriped larval traces on the shell of *Tritonalia sublavata* (3.5)
19. Cirriped larval traces on the spire of *Ancilla glandiformis* (5x)
20. Plastic internal moulds of the shell fragment on Fig. 19. (10x)

Pl. III

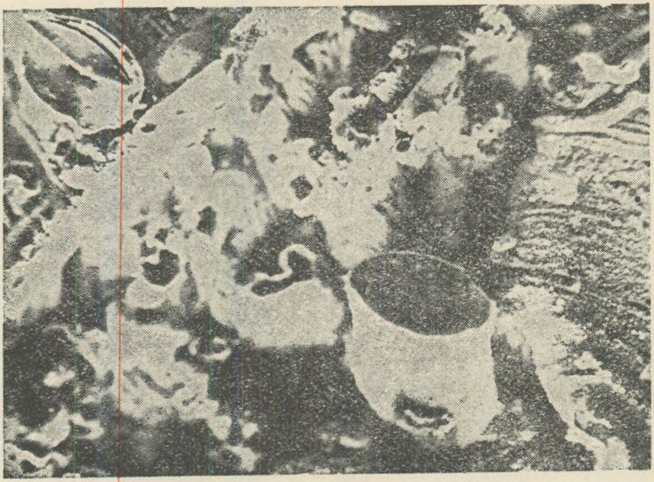
21

22

23



24



25

PLATE III.

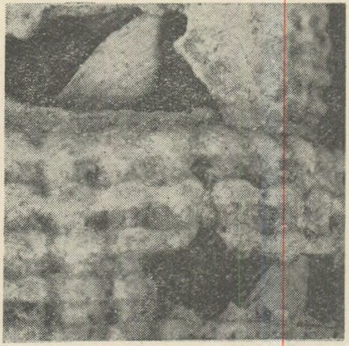
21. Dumb-bell-shaped worm traces on the spire of the gastropod *Columbella (Alia) helvetica* Mayer (2x)
22. Plastic internal mould of U-shaped worm traces (4x)
23. Sites of worm tracks and boring bivalves on the spire of *Melongena cornuta* (2.5)
24. Sites of worm tracks and boring bivalves on the spire of worm tracks and boring bivalves (2.5x)
25. Plastic internal mould of worm tracks and boring bivalves on the spire of *Melongena cornuta* (2.5x)

Pl. IV

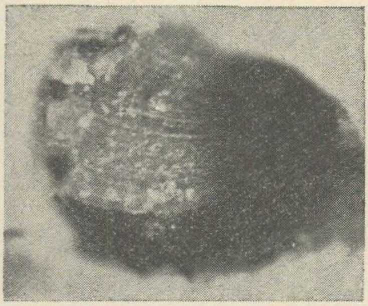
26

27

28



29

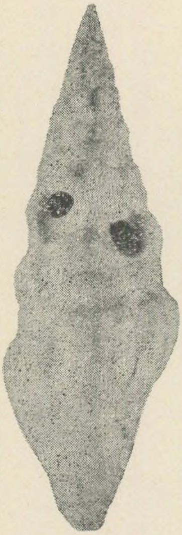


30

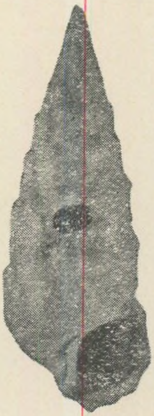
PLATE IV.

26. Boring bivalve on the outer lip of *Hadriania boeckhi* (6x)
27. A boring bivalve located in the shell of *Cerithium exdoliolum* (9.5x)
28. Boring bivalve in the shell of *Potamides bidentatus* (4x)
29. Boring bivalve in the shell of *Potamides bidentatus* (4x)
30. Boring bivalve among the nodes of the shell of *Potamides bidentatus* (40x)

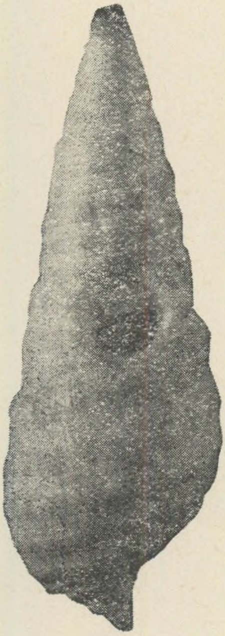
Pl. V



31

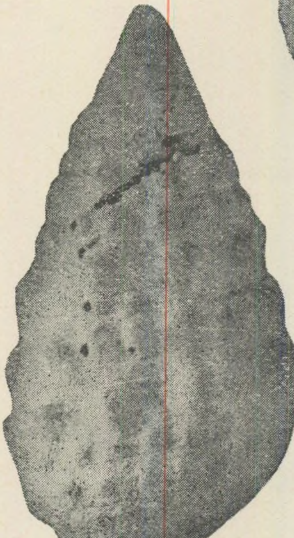


32



33

34



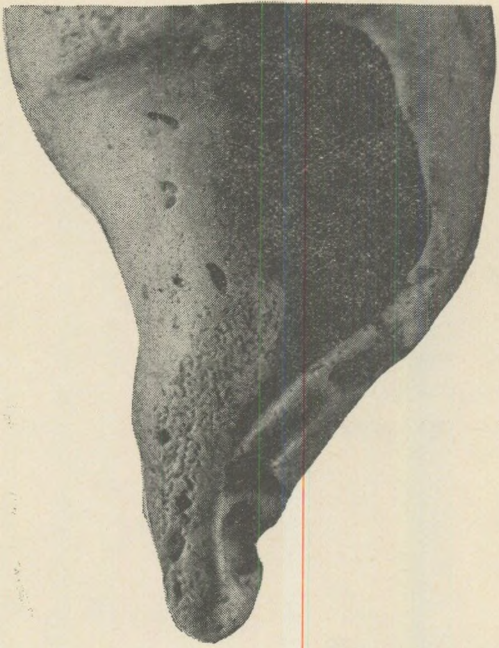
35

36

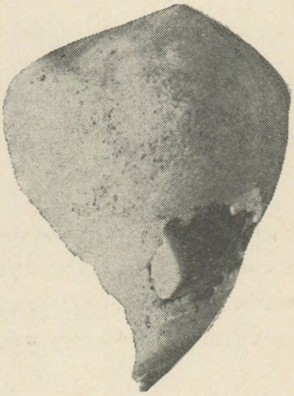
PLATE V.

31. *Drillia allionii* with two muricid borings (3.8)
32. *Pirenella gamlitzensis* with muricid boring (2.5)
33. *Pirenella moravicus* with muricid boring (3.8x)
34. *Cerithium exdoliolum* with sponge pores (3.5x)
35. *Cerithium exdoliolum* with sponge pores and their breaks (4.8)

Pl. VI

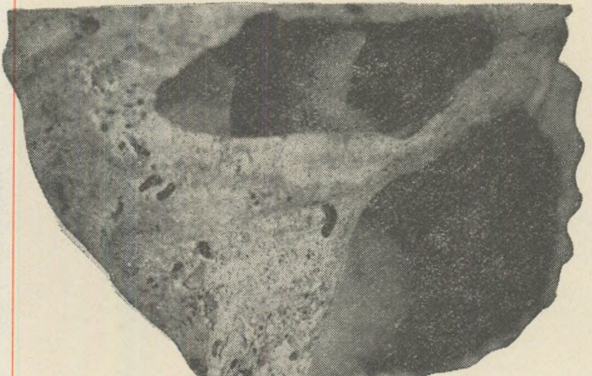


37



38

39

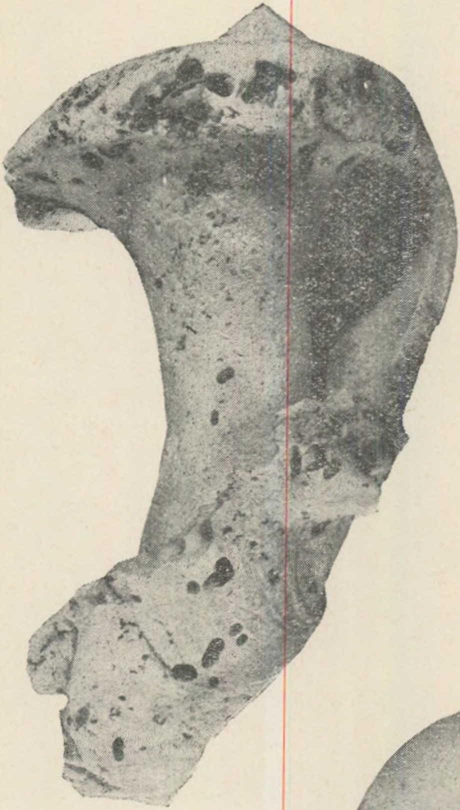


40

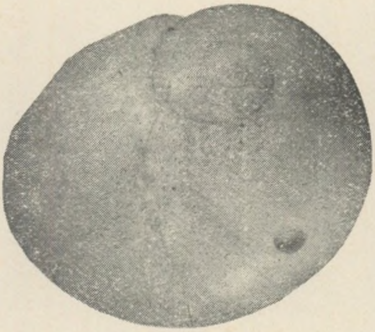
PLATE VI.

37. *Pusionella pseudofusus palatina* with both types of cirriped larval stages (10x)
38. *Ancilla glandiformis* with crab-made injure (2x)
39. *Ancilla glandiformis* with crab-made injures (2x)
40. *Potamides bidentatus margaritifer* with worm traces (4x)

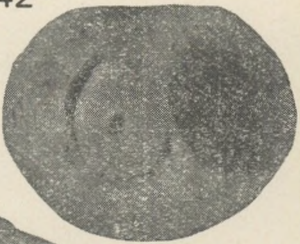
Pl. VII



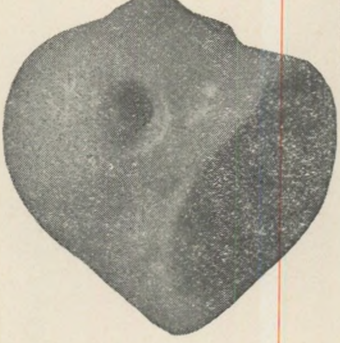
41



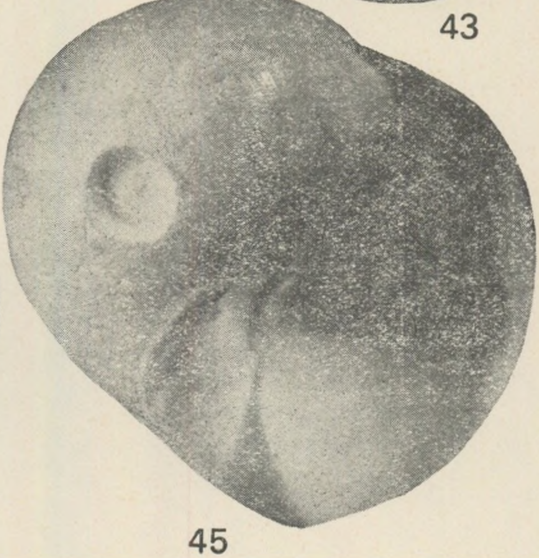
42



43



44



45

PLATE VII.

41. *Melongena cornuta* with worm traces and boring bivalves (1x)

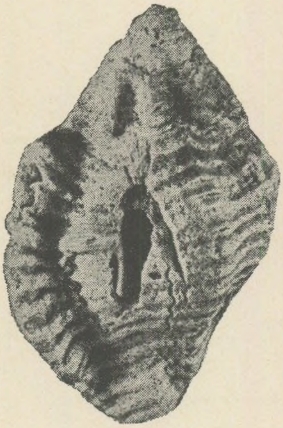
42. *Natica josephinia olla* with naticid boring (2.2x)

43. *Natica josephinia olla* with naticid borehole

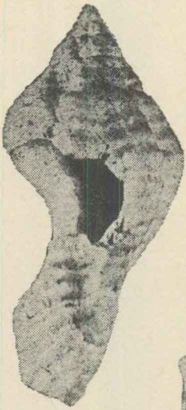
44. *Natica millepunctata* with naticid boring (4.5x)

45. *Natica millepunctata* with naticid boring (5.3x)

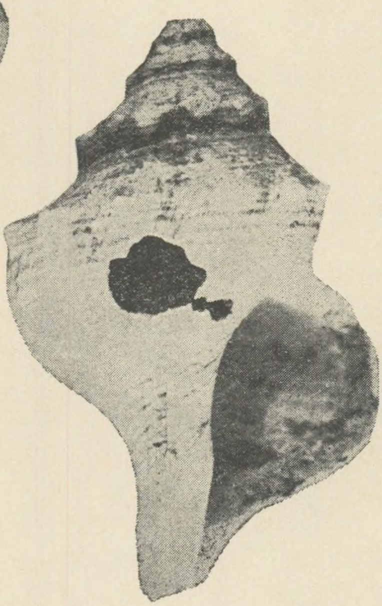
PI.VIII



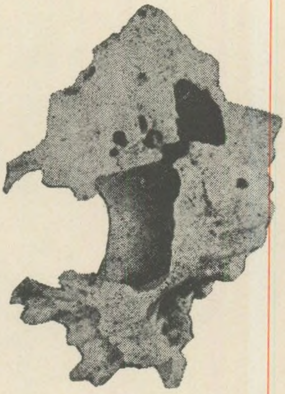
46



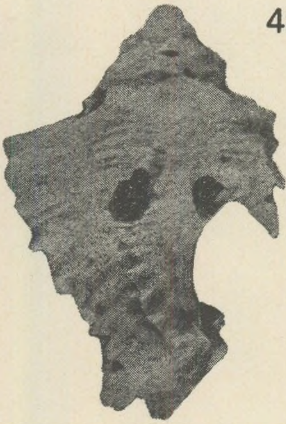
47



48



49



50

PLATE VIII.

46. *Ocinebrina crassilabiata* with crab pinch (2.4x)

47. *Hadriania boeckhi* with crab pinch (2.4x)

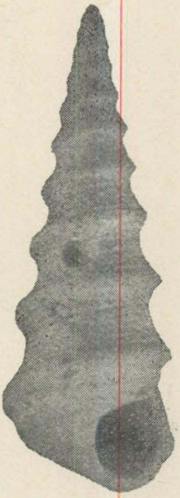
48. *Euthriofusus burdigalensis* with crab pinch. (2.3x)

49. *Murex rudis syrticus* with crab pinches and boring bivalves. (1.5x)

50. *Murex rudis syrticus* with crab damages and the location of boring bivalves (1.5x)

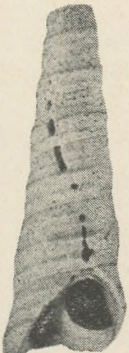
Pl. IX

51

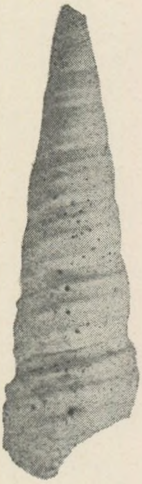


52

53

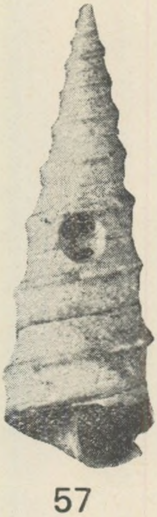


54

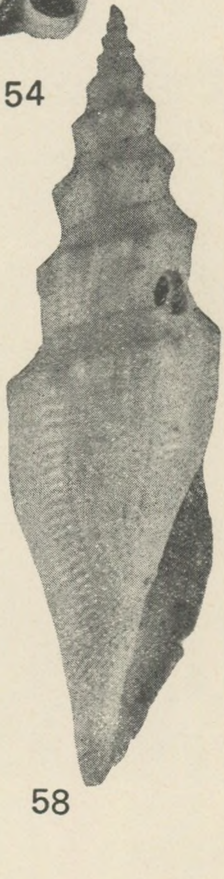


55

56



57

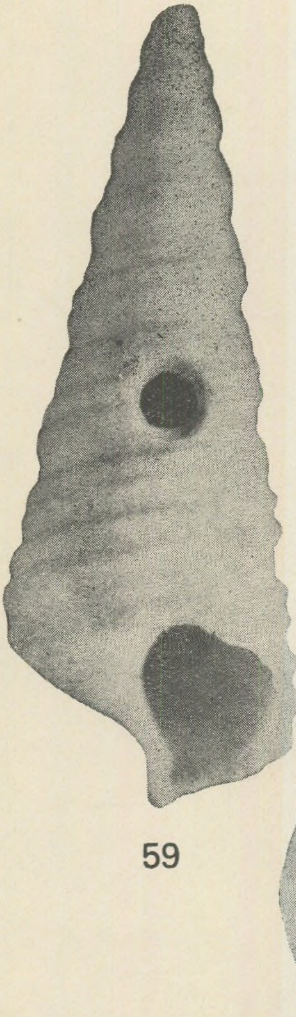


58

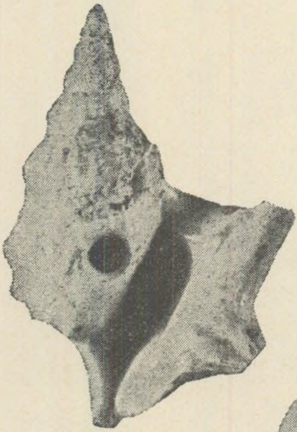
PLATE IX.

51. *Turritella aquitanica* with crab pinch (1.8x)
52. *Turritella aquitanica* with an unfinished boring of a naticid (3x)
53. *Turritella eryna partschi* with naticid borings (3.2?)
54. *Turritella turris badensis* with sponge pores (2.55)
55. *Turritella vermicularis* with sponge pores (3x)
56. *Turritella vermicularis* with naticid borings
57. *Turritella bicarinata subarchimedis* with naticid boring (3x)
58. *Genota ramosa elisae* with naticid boring (4x)

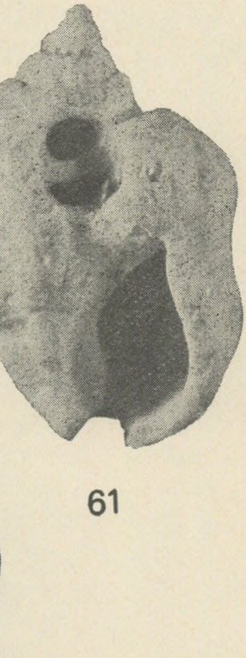
Pl. X



59



60



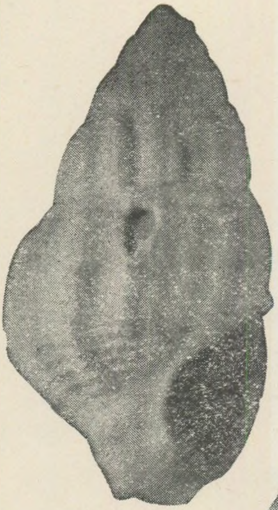
61

62

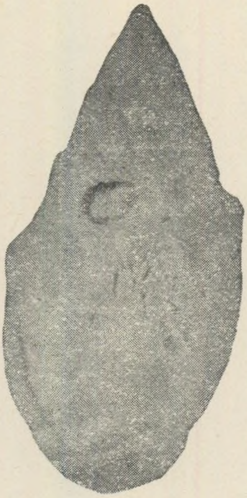
PLATE X.

59. *Protoma proto quadriplicata* with naticid boring (3.5x)
60. *Aporrhais pespelecani alatus* with naticid boring in the inner lip (4.6x)
61. *Nassa dujardini edlaueri* with naticid boring (5x)
62. *Nassa dujardini edlaueri* with naticid borings (5x)

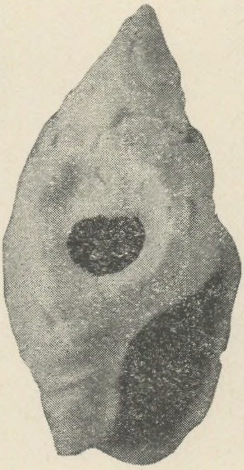
Pl. XI



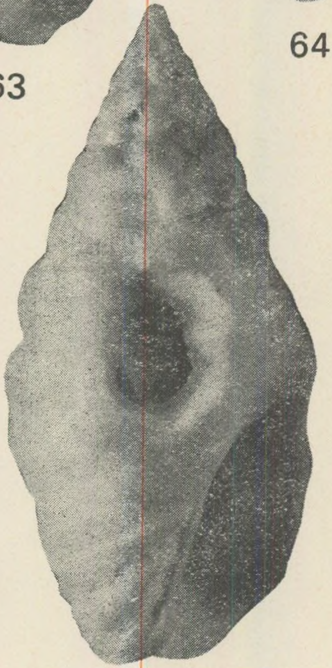
63



64



65



66

67

PLATE XI.

63. *Nassa hungarica* with regeneration (6.5x)

64. *Dorsanum nodosocostatum* with traces of regeneration (5x)

65. *Dorsanum nodosocostatum* with naticid boring (5x)

66. *Dorsanum nodosocostatum* with naticids (6.5x)

67. *Terebra basteroti* with naticid borings (2.2%)

often attacked by the predators. The order within this major grouping was determined by the size, motility, shell thickness, ornamentation, and probably "taste" of the victim. For example 49 of 521 specimens of *Nassa dujardini edlaueri*, and 58 of 444 specimens of *Turritella aquitanica* were attacked by naticids. The case of it might have been the larger size of *Turritella*, thus yielding more food with the same effort; or the predator Nassas are more motile than the Turritellas living in the mud with their apex below the surface.

Plot of the victims of the muricids (Fig. 5) shows that though the several *Potamides* species are the same in habitat, size and shape, differing in their ornamentation only, the predators made important distinctions among them; possibly these were of different taste.

Table II indicates that the naticids and muricids attacked only some individuals of the too small *Theodoxus pictus*, and none of the too big *Potamides bidentatus perrugatus*.

A full picture on the diet of the predators can be drawn only if the traces on the bivalves will be studied, too. The main food of naticids and muricids are bivalves (TATISHVILI et al., 1968). Our results support it: 308 naticid predators were compated with only 289 gastropod victims, while 81 muricids were compated with 362 victims.

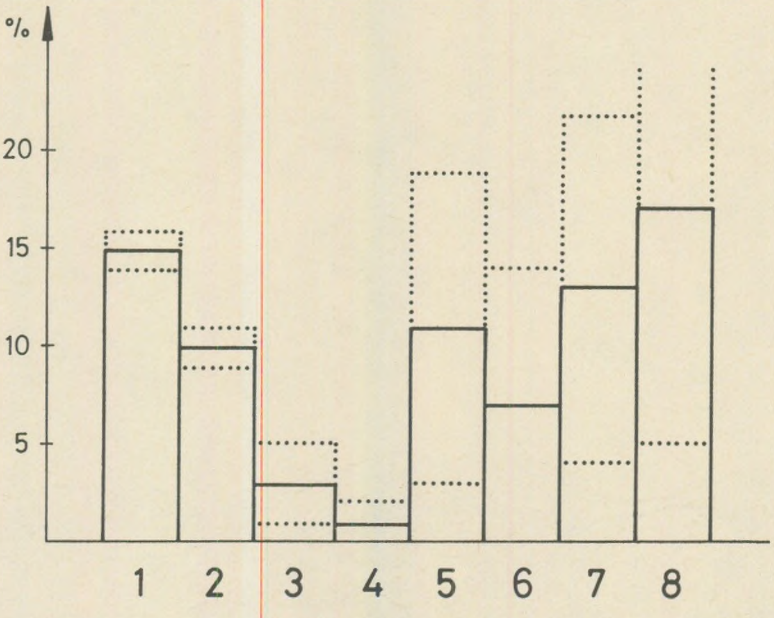


Fig. 5. Percentage of bored specimes of the species attacked by muricids (the species represented by more than 10 individuals are listed only). 1. *Potamides (Pirenella) gamlitzensis* 2. *Potamides (Pirenella) moravicus* 3. *Potamides (Pirenella) pictus* 4. *Potamides gamlitzensis theodiscus* 5. *Pusionella pseudofusus palatina* 6. *Cerithium rubiginosum pseudobliquistoma* 7 *Cerithium exdolium* 8. *Cerithium vulgatum europaeum*

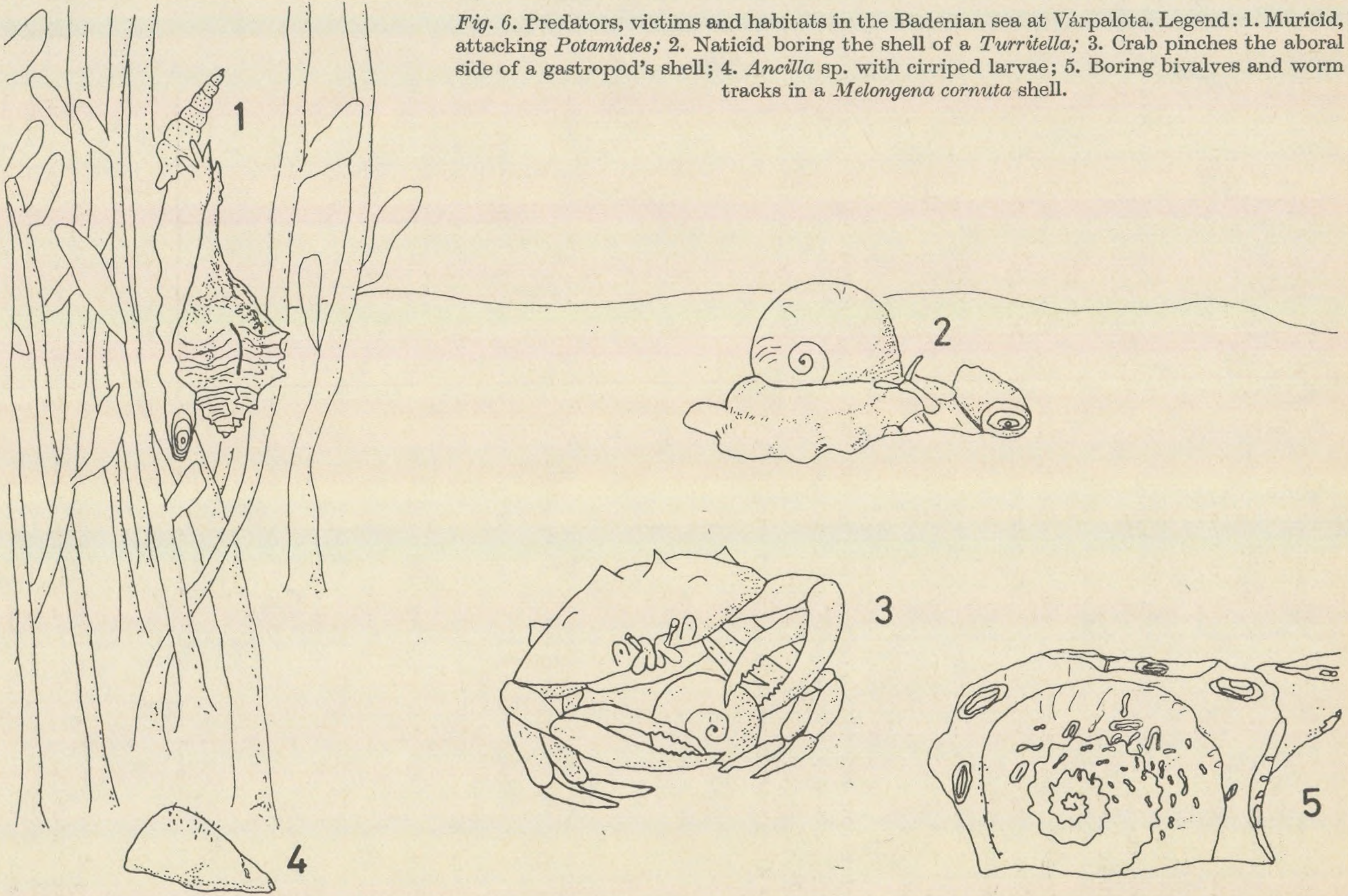


Fig. 6. Predators, victims and habitats in the Badenian sea at Várpalota. Legend: 1. Muricid, attacking *Potamides;* 2. Naticid boring the shell of a *Turritella;* 3. Crab pinches the aboral side of a gastropod's shell; 4. *Ancilla* sp. with cirriped larvae; 5. Boring bivalves and worm tracks in a *Melongena cornuta* shell.

Trace fossils made by different organisms usually occur on certain areas of the shell: traces of malacostracans are on the aboral side, traces of cirriped larvae are located in less exposed parts of the external side of the shells, and traces of boring bivalves occupy the regions with thick shell.

Trace fossils on gastropods indicate the major role of bioerosion in the preservation of shells.

The Badenian sea bottom is figured on Fig. 6. Habitats and feeding habits of fossilized animals and of animals which produced the trace fossils are figured in their natural environment.

REFERENCES

Arua, J. (1982): Borings and shell damage in Eocene Gastropoda: Southeastern Nigeria. – Palaeogeography, Palaeoclimatology, Palaeoecology 38, 269 – 282.

Bishop, G. A. (1975): Traces of predation. In: Frey, R. W. (ed.): The Study of Trace Fossils), pp. 261 – 283: Springer, Berlin.

Boucot, A. (1981): Proinciples of Benthic Marine Paleoecology. Academic Press, London.

Brande, W. (1982): Epibiont analysis of the fossil interactions among benthic infaunal bivalve, a barnacle and a drilling gastropod. – Journal of Paleontology 56, 1230 – 1234.

Bromley, J. G. (1981): Concepts in ichnotaxonomy, illustrated by small round holes in shell. – Acta Geologica Hispanica, Concepts and Methods in Palaeontology 16/1 – 2, 55 – 64.

Dörjes, J., Hertweck, G. (1975): Recent biocoenoses and ichnocoenoses in shallow-water marine environments. In: *Frey*, R. W. (ed.): The Study of Trace Fossils, pp. 459 – 493, Springer, Berlin

Lawrence, D. R. (1969): The use of clionid sponges in paleoenvironmental analyses. – Journal of Paleontology 43, 539 – 543.

Kecskeméti – Körmendi, A. (1961): Feinstratigraphische Untersuchungen im Naturschutz-Gebiet von Várpalota. – Földtani Közlöny 91/4, 426 – 431.

Kecskeméti – Körmendi, A. (1962): Neue Molluskenarten aus dem Mittelmiozän von Várpalota. I. Gastropoden. – Földtani Közlöny 92/1, 81 – 99.

Rhoads, D. C. (1975): The palaeoecological and environmental significance of trace fossils. In: Frey, R. W. (ed.): The Study of Trace Fossils, pp. 147 – 161, Springer, Berlin.

Seilacher, A. (1969): Palaeoecology of boring barnacles. – American Zoologist 9, 705 – 719.

Strausz L. (1969): Les gastropodes du méditerranéen supérieur (tortonien) de Várpalota. – Geologica Hungarica, series Palaeontologica 25.

Strausz, L. (1966): Die Miozän-Mediterranen Gastropoden Ungarns. Akadémiai Kiadó, Budapest.

Tatishvili, K. T., Bagdasarian, K. G., Kazahashvili, Zh. P. (1968): Spravochnik po ekologii morskikh bryukhonogikh. (Handbook on the ecology of marine gastropods). Nauka, Moscow (in Russien).

Warme, J. E. (1975): Boring as trace fossils and the process of marine bioerosion. In: Frey, R. W.: The Study of Trace Fossils, pp. 181 – 229, Springer, Berlin.

LOWER CRETACEOUS FACIES ZONES IN THE BAKONY UNIT OF HUNGARY

by

M. KÁZMÉR

Department of Palaeontology, Eötvös University, H–1083 Budapest,
Kun Béla tér 2, Hungary

(Received: 30th May, 1987)

Abstract

Contrasting lithology, highly varied sediment thickness and differences in the timing of pelagic sedimentation provide a tripartite division of the Bakony unit in the Neocomian. A deep basin in the Zala region, containing thick Biancone limestone and pelagic, dark marl, corresponds to the Lombardian basin of the Southern Alps. An elevated ridge (below the photic zone) with condensed sedimentation corresponds to the Trento plateau, and a contemporaneous flysch basin in the Gerecse to the Belluno trough.

Introduction

The Bakony unit is situated in the NW part of the Pannonian basin. It is bordered by the Rába and Balaton strike-slip faults, which are parts of the Periadriatic lineament system (KÁZMÉR, 1986) (Fig. 1.). It has been displaced from the Alps to its actual position by an Oligocene continental escape (KÁZMÉR and KOVÁCS, 1985). Its Lower Cretaceous formations, among others, are closely similar to those of the Southern and Eastern Alps (FÜLÖP, 1964). The marked differentiation of the Southern Alps into distinct facies zones: the Friuli platform, the Belluno trough, the Trento plateau, and the Lombardian basin with several internal swells and troughs (AUBOUIN, 1963; BOSELLINI, 1973), made us to look for similar features in the Bakony unit. This paper summarizes the results for the Lower Cretaceous (Neocomian).

Twelve published Neocomian surface and subsurface profiles, ranging from the Zala region in the west to the Gerecse region in the east are correlated with each other, emphasizing lithology and sediment thickness (Fig. 2). Their interpretation is given in the framework of a basin and ridge submarine topography.

Stratigraphy (Fig. 2)

Up to now the most important works on the Neocomian of the Bakony unit were prepared by FÜLÖP (1958, 1964), more than two decades ago. His data are still reliable and form the basis for the present paper. Further refe-

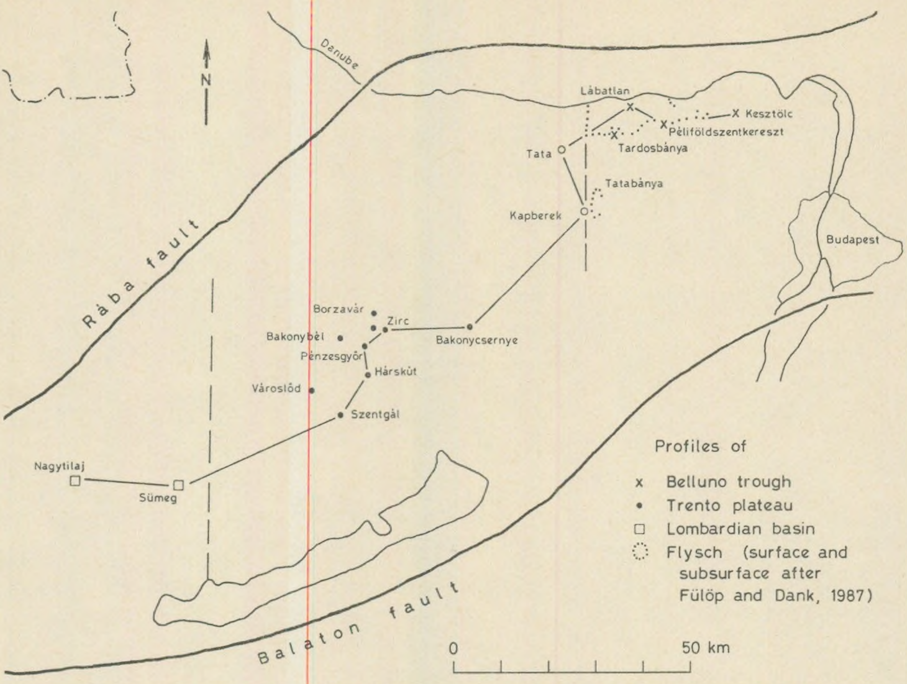


Fig. 1. Location of Lower Cretaceous profiles in the Bakony unit of Hungary. The dashed lines indicate the approximate position of basin-plateau boundaries.

rences on the lithology, biostratigraphy and sedimentology of the formations are provided by KÁZMÉR (1986).

Biancone (Tithonian – Lower Hauterivian)

(= Mogyorósdomb Limestone Formation). White, thin-bedded limestone with dark chert nodules and beds. The Berriasian – Lower Hauterivian section is about 250 m thick in a surface profile, but isoclinal folding makes this number imprecise. Its stratigraphy is based on calpionellids (TARDI – FILÁCZ, 1986), ammonoids (VÍGH in HAAS et al., 1985), and magnetostratigraphy (MÁRTON, 1986). The Tithonian – Berriasian boundary is localized in the Mogyorósdomb surface profile at Sümeg, but the other occurrence in Nagytilaj – 2 borehole is poorly dated.

Grey marl (Hauterivian – Aptian)

(= Sümeg Marl Formation). Light grey, poorly bedded marl and siltstone, without sandstone layers (FÜLÖP, 1964, HAAS et al., 1985). Thickness: 250 m in Süt – 17 borehole (no tilt correction). The rich nannoflora and planktonic foraminifer fauna and ammonite shells indicate deposition in a

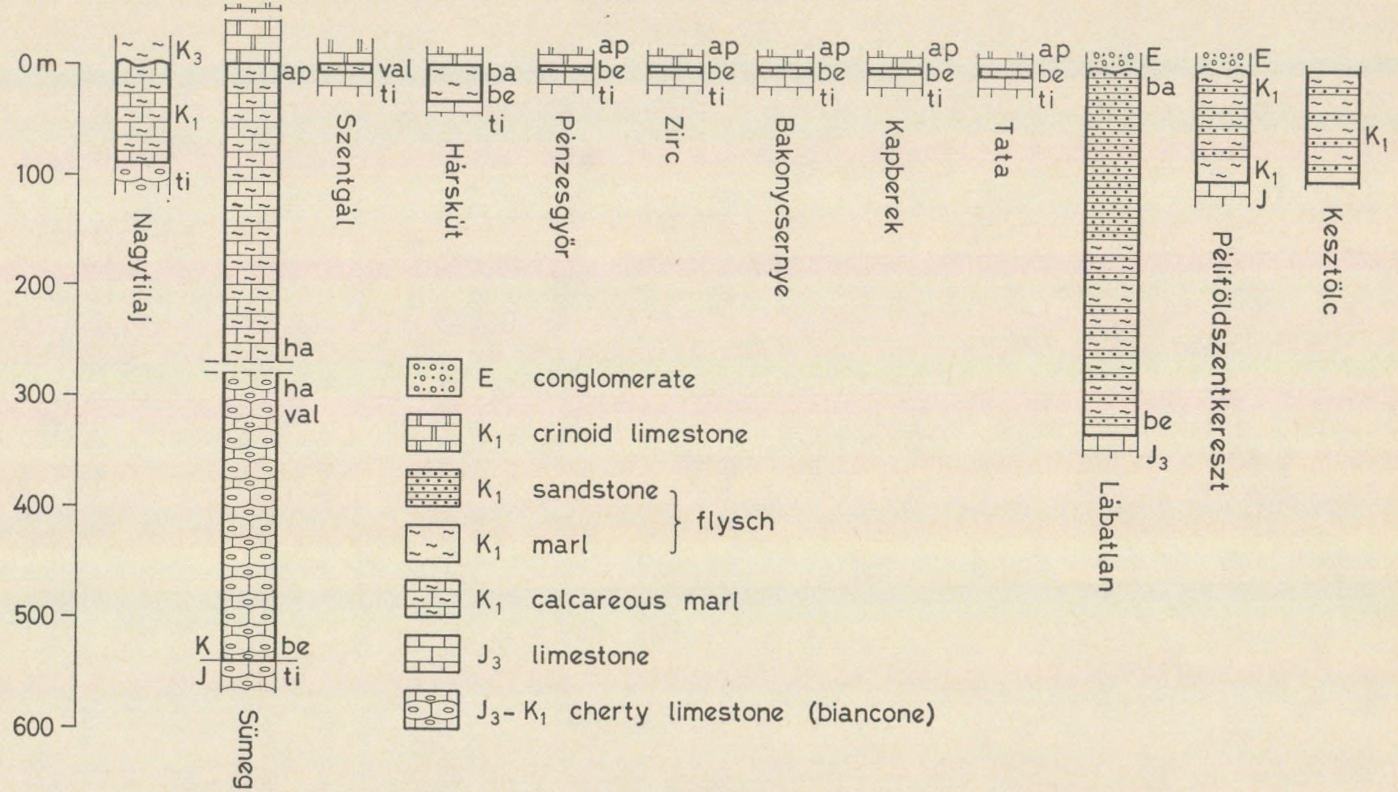


Fig. 2. Stratigraphic columns of Lower Cretaceous profiles in the Bakony unit. Thick Biancone (white cherty limestone) and dark marl sequence characterizes the Zala basin, highly condensed limestone and marl sequences occcur on the Bakony plateau (including a minor trough at Hárskút). The Gerecse basin displays thick shaly and sandy flysch.

Sources: Nagytilaj – 2 borehole: Kőrössy (1987); Sümeg: Biancone (Mogyorósdomb Hill): Haas et al. (1985), marl: Süt – 17 borehole: Haas et al. (1985); Szentgál – 1 borehole: Fülöp (1964); Hárskút, Közöskút ravine (Fülöp (1964); Pénzesgyőr, Somhegy: Fülöp (1964); Zirc, Bocskorhegy: Fülöp (1964); Bakonycsernye, Tűzköves ravine Fülöp (1964); Vértessomló, Kapberek – 43/K – I. borehole: Fülöp et al. (1965); Tata, TVG – 59 borehole: Fülöp (1976); Lábatlan, MÁK – II borehole: Fülöp (1958); Péliföldszentkereszt (drawn from a section): Gidai (1985); Kesztölc, Esztergom – 91 borehole: Nagy (1968), Rákosi (1971).

pelagic environment above aragonite compensation depth. Its subsurface exposures are known in the Sümeg region only.

A ca. 90 m thick profile in Nagytilaj – 2 borehole (1048 – 1140 m) exposes "unbedded, calcareous marl, brownish red with green spots, hard rock of conchoidal fracture. SZEPESHÁZY and DUBAY considered it Valanginian" (KŐRÖSSY, 1987, p. 116); however, lithological correlation with the Hauterivian – Aptian Sümeg Marl is more probable. Unfortunately, biostratigraphical data are not available. The marl is underlain by Biancone limestone.

Calpionellid limestone (Tithonian – Berriasian)

(= Szentivánhegy Limestone Formation). Red, compact, pelagic limestone with rich fauna: *Calpionella alpina, Globochaete* (FÜLÖP, 1976) and ammonoids (VIGH, 1984). Thin beds: thickness range from 0,2 to 2,0 m in the Berriasian. Frequent hardgrounds and dissolved ammonites occur (VIGH, 1984). Localities: Zirc, Bakonycsernye, Kapberek and Tata.

Condensed limestone beds (Berriasian to Barremian)

(Mogyorósdomb Formation and Borzavár Formation). Thin (0,3 to 2 m) limestone beds with rich ammonite fauna, and phosphate oncoids (FÜLÖP, 1964; MISZLIVECZ and POLGÁRI, 1987). Age is mostly Berriasian, rarely Valanginian and Barremian. Locally encrinite occur with well-preserved calyxes (SZÖRÉNYI, 1959).

Flysch (Berriasian to Barremian)

(Bersek Marl and Lábatlan Sandstone Formations). Upper Tithonian calpionellid limestones, covered by limonitic hardgrounds, are overlain by thin Berriasian sandstone and calcareous breccia (FÜLÖP, 1958; VÍGH, 1984). Valanginian – Lower Hauterivian grey and red marls, with graded sandstone layers follow. The upper part is Upper Hauterivian – Barremian sandstone with interbedded marls, displaying graded bedding, flute casts, trace fossils etc. The sequence is capped by Barremian chert breccia and conglomerate (FÜLÖP, 1958; CSÁSZÁR in CSÁSZÁR and HAAS, 1984). The more than 300 m thick Neocomian sequence is a prograding submarine fan: distal turbidites (Bersek Marl), proximal turbidites (Lábatlan Sandstone) and a fan channel sequence (breccia and conglomerate) (KÁZMÉR, 1987a). Rare molds of ammonites and frequent aptychi indicate deposition between aragonite and calcite compensation depths.

Crinoid limestone (Aptian)

(Tata Limestone)

Grey crinoid limestone with rare chert nodules, siliceous sponge spicules and sandy intercalations. Mostly biosparite, less biomicrite. Contains glauconite. Brachiopod and ammonite faunulas occur at the bottom, and benthic and planktonic foraminifers above. Besides crinoid ossicles it contains much carbonate extraclasts (LELKES, 1985). It has been deposited below the photic zone, in a deep neritic to shallow bathyal environment. References: FÜLÖP (1964, 1976); HAAS et al., (1985).

Facies zones

Lithological and thickness variations (Fig. 2) make possible to recognize three facies zones in the Bakony unit of Hungary. Similar positions of Lower Liassic facies zones based on South Alpine analogues (KÁZMÉR and KOVÁCS, 1985; KÁZMÉR, 1987b) provided considerable help.

Zala basin

It covers the present-day geographic region of the North Zala hydrocarbon basin, and the westernmost part of Bakony Mts. around Sümeg. This palaeogeographic unit is based on two localities, the Nagytilaj – 2 borehole, and two boreholes (Süt – 17, Sp – 1) and a single outcrop at Sümeg.

However, the similar sequence: Upper Jurassic (to Hauterivian) biancone (more than 250 m thick), covered by more than 280 m grey, pelagic marl indicate a deep marine depositional environment above aragonite compensation depth. Conspicuous isoclinal folding (unknown elsewhere in the Bakony unit) (HAAS et al., 1985) and a surplus number of magnetostratigraphic zones (MÁRTON, 1986) in the Biancone may be due to slumps and slump folds in the sequence, indicating bathyal, slope environment. This basin shows close relationships to the Lombardian basin of the Southern Alps (KÁZMÉR and KOVÁCS, 1985).

The Sümeg locality has belonged to the neritic Bakony (=Trento) plateau in Hettangian time (KÁZMÉR, 1987b). Its shift to a basin environment before Neocomian indicate the eastward "prograding" of the Zala basin. A detailed investigation in terms of the Lombardian basin – Trento plateau border zone in the Southern Alps (CASTELLARIN, 1972) will provide more details.

Bakony plateau

Instead of the more than 500 m thick Neocomian sequence at Sümeg in the Zala basin, the Bakony plateau – extending from Szentgál to Tata – displays sequences usually less than a metre thick (but never exceeding 27 m). These beds are Biancone-like marls at the three western localities: Szentgál, Hárskút and Pénzesgyőr, and micritic limestones and encrinites in all other places. Absence of organisms which need light indicate deposition below the photic zone. Small thickness, condensation, frequent stratigraphic gaps, hardgrounds and phosphatic nodules indicate currents sweeping the plateau, preventing deposition of sediments.

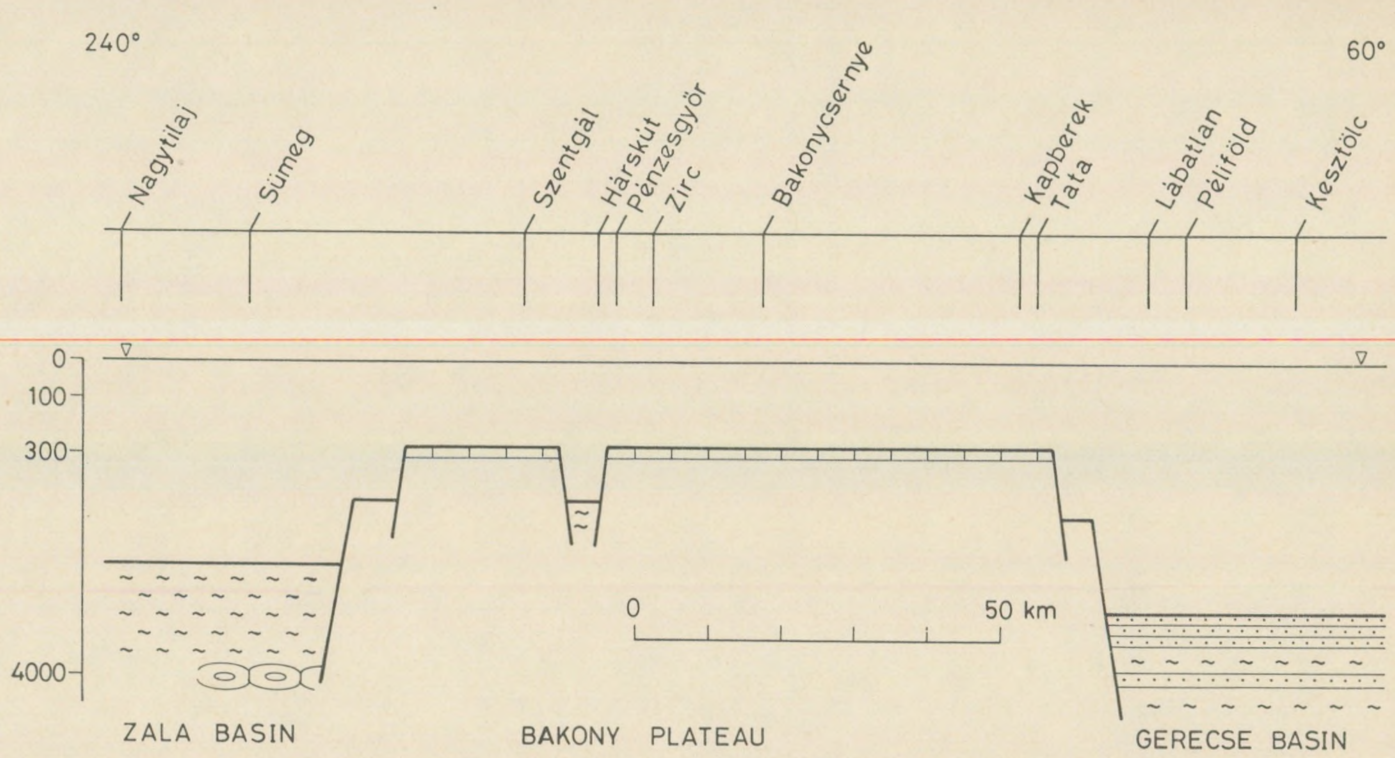


Fig. 3. Schematic palaeogeographic section of Bakony unit in Early Cretaceous (Berriasian – Barremian) time. The depth scale on the left indicates intervals only: 100 to 300 m: deep neritic; 300 to 4000 m: bathyal environment. The Zala basin contains a thick Biancone and dark marl sequence deposited above ACD. The Bakony plateau displays a highly condensed, sometimes less than 1 m thick limestone and marl sequence, with frequent gaps. The Gerecse basin is filled by a thick turbidite sequence, deposited between ACD and CCD. (Localities of Neocomian profiles are projected on a 240° – 60° line, representing the long axis of the Bakony unit.

Gerecse flysch trough

It extends from the immediate eastern neighbourhood of Tata (CSÁSZÁR and HAAS, 1979) to at least Kesztölc in the east. Following the detailed description of FÜLÖP (1958), the flysch character of the Gerecse Neocomian was recognized by CSÁSZÁR and HAAS (1979). The sediments of a prograding submarine fan (KÁZMÉR, 1987a) have been deposited in a relatively quickly subsiding basin (330 m flysch at Lábatlan vs. 0,3 m limestone at Kapberek and 6,3 m crinoid limestone at Tata (TVG – 59 borehole). The western margin was a fault, as shown by the immediate neighbourhood of the reduced Kapberek sequence and the Tatabánya flysch (data for the latter locality are available only from the pre-Cenozoic map of FÜLÖP and DANK, 1987).

Close similarities between the Gerecse flysch and the Rossfeld beds in the Northern Calcareous Alps have been known for a long time (FÜLÖP, 1958). Their relationship can be understood in the palinspastic framework of KÁZMÉR and KOVÁCS (1985), which placed the Bakony tectonic unit to the south of the Northern Calcareous Alps.

A possible palaeogeographic section emphasizing topographic differences during Neocomian time is shown in Fig. 3. The boundaries between the basins and the plateau are considered as faults, since no transition between them has been observed.

The pelagic feed-up model of pre-Neocomian basins as described by GALÁCZ et al. (1985) is valid for the Bakony plateau itself; the Zala and especially the Gerecse basins show an increase in differential subsidence.

Conclusions

The Bakony unit contains three facies zones in Hungary: the Zala basin in the west filled by 550 m carbonate and pelitic sediments; the Gerecse basin in the east with more than 330 m flysch and the Bakony ridge between them with condensed carbonate sedimentation. Their similarity with the Southern Alpine Lombardian basin, Belluno (equals to North Alpine Rossfeld) basin and Trento plateau, respectively, provides further support for the Mesozoic position of the Bakony unit within the Alps.

REFERENCES

AUBOUIN, J. (1963): Essai sur la paléogéographie post-triasique et l'évolution secondaire et tertiaire du versant sud des Alpes orientales (Alpes méridionales; Lombardie et Vénétie, Italie; Slovénie occidentale, Yougoslavie). – Bull. Soc. Géol. France (7) 5, 730 – 766, Paris

BOSELLINI, A. (1973): Modello geodinamico a paleotettonico delle Alpi meridionali durante il Giurassico – Cretacico. Sue possibili applicazioni agli Apennini. – Accademia Nazionale dei Lincei, Quaderno 183, 163 – 205, Roma

CASTELLARIN, A. (1972): Evoluzione paleotettonica sinsedimentaria del limite tra "piattaforma veneta" e "bacino lombardo" a nord di Riva del Garda. – Giornale di Geologia 38/1, 11 – 212, Bologna

Császár, G., Haas, J. (1979): Review of facies and paleogeography of the Cretaceous in Hungary. – In: Wiedmann, J. (ed.): Aspekte der Kreide Europas, IUGS Ser. A 6, 413–424, Schweizertbart, Stuttgart

Császár, G., Haas, J. (1984): Hungary. 27th Int. Geol. Congr., Excursion 104: Mesozoic formations in Hungary, Guidebook, 92 p. Vízdok, Budapest

Fülöp, J. (1958): Die kretazeischen Bildungen des Gerecse-Gebirges. – Geologica Hungarica, ser. Geol. 11, 124 p., Budapest

Fülöp, J. (1964): Unterkreide-Bildungen (Berrias-Apt) des Bakonygebirges. – Geologica Hungarica, ser. Geol, 13, 194 p., Budapest

Fülöp, J. (1976): The Mesozoic basement horst blocks of Tata. – Geologica Hungarica, ser. Geol. 16, 229 p., Budapest

Fülöp, J., Dank, V. (eds.) (1987): Magyarország földtani térképe a kainozoikum elhagyásával. (Geological map of Hungary without Cenozoic cover.) Magyar Állami Földtani Intézet, Budapest, 1:500 000

Fülöp, J., Knauer, J., Vígh, G. (1965): Ein Juraprofil imVértesgebirge. – Földtani Közlöny 95/1, 54–61, Budapest (in Hungarian with German abstract)

Galácz, A., Horváth, F., Vörös, A. (1985): Sedimentary and structural evolution of the Bakony Mountains (Transdanubian Central Range, Hungary): Paleogeographic implications. – Acta Geologica Hungarica 28/1–2, 85–100, Budapest

Gidai, L. (1985): Conditions stratigraphiques de l'Oligocène dans la partie ouest du Bassin de Dorog (Hongrie). – Földtani Közlöny 115/4, 369–384, Budapest

Haas, J., J.-Edelényi, E., Gidai, L., Kaiser, M., Kretzoi, M., Oravecz, J. (1985): Geology of the Sümeg area. – Geologica Hungarica, ser. Geol. 20, 365 p., Budapest

Kázmér, M. (1986): Tectonic units of Hungary: Their boundaries and stratigraphy (A bibliographic guide). – Annales Univ. Sci. Budapest, Sect. Geol. 26, 45–120, Budapest

Kázmér, M. (1987a): A Lower Cretaceous submarine fan sequence in the Gerecse Mts., Hungary. – Annales Univ. Sci. Budapest., Sect. Geol. 27, 101–116

Kázmér, M. (1987b): Lower liassic facies zones in the Bakony unit of Hungary. – Annales Unic. Sci. Budapest., Sect. Geol. 27, 89–100

Kázmér, M., Kovács, S. (1985): Permian–Paleogene paleogeography along the eastern part of the Insubric–Periadriatic lineament system: Evidence for continental escape of the Bakony–Drauzug unit. – Acta Geologica Hungarica 28/1–2, 71–84, Budapest

Kőrössy, L. (1987): Hydrocarbon geology of the Little Plain in Hungary. – Általános Földtani Szemle 22, 99–174, Budapest (Hungarian with English abstract)

Lelkes, Gy. (1985): Quantitative petrography and depositional environment of the Tata Limestone Formation (Aptian) in the northern Bakony Mountains (Transdanubia). – Annual Report Hung. Geol. Inst. for 1983, 303–319, Budapest

Márton, E. (1986): The problems of correlation between magnetozones and calpionellid zones in Late Jurassic–Early Cretaceous sections. – Acta Geologica Hungarica 29/1–2, 125–131, Budapest

Miszlivecz, E., Polgári, M. (1987): Fe–P bearing calcareous concretions from Zirc "Marble quarry" (Transdanubian Central Range, Hungary). – Annales Univ. Sci. Budapest., Sect. Geol. 27, 121–134

Nagy, G. (1968): Magyarázó a Dorogi-medence földtani térképéhez, 10.000-es sorozat, Kesztölc. (Explanations to the 1:10.000 geological map of the Dorog basin, Sheet Kesztölc). Magyar Állami Földtani Intézet, Budapest, 50 p.

Rákosi, L. (1971): Palynologische Untersuchung des Neokom-Untergrundes des Doroger Braunkohlenbeckes. – Annual Report Hung. Geol. Inst. for 1968, 267–292, Budapest (Hungarian with German abstract)

Szörényi, E. (1959): Les Torynocrinus (Crinoides) du Crétacé inférieur de la Hongrie. – Acta Geologica Acad. Sci. Hung. 6, 231–271, Budapest

Tardi-Filácz. E. (1986): Investigation of Calpionellidea remnants from the Tithonian-Berriasian basic profiles of Tata and Sümeg. – Acta Geologica Hungarica 29/1–2, 37–44, Budapest

Vígh, G. (1984): Die biostratigraphische Auswertung einiger Ammoniten-Faunen aus dem Tithon des Bakony-Gebirges sowie aus dem Tithon-Berrias des Gerecsegebirges. – Annales Inst. Geol. Publ. Hung. 67, 210 p., Budapest

TRENDS AND PROBLEMS OF THE RESEARCHES OF FOSSIL SPORES AND POLLEN GRAINS

by

M. KEDVES

Department of Botany J. A. University, Szeged, Hungary

(Received: 1th March, 1987)

Abstract

This paper summarizes the most important fields of researches and problems of the investigations of fossil sporomorphs. The synthesis of TEM data of the fossil spore-pollen wall is first published here. The chemistry and molecular structure of the biopolymer units of the sporopollenin, and the importance of the biogeochemistry in the investigation of the fossil palynomorphs is emphasized.

Introduction

The methodical study of fossil sporomorphs started in the thirties of this century. In contrast, the investigations of the spores and pollen grains of the recent taxa began till to the XVIII century. In this way the results got on the recent taxa necessarily have an effect on Paleopalynology, but its special characteristic features, namely the geological uses in the researches of the raw material, became an important influential factor of this field of research.

The peculiar, interdisciplinar position of the researches of the fossil sporomorphs happened in consequence of this reason.

The classical light-microscope method is important in the solution of the following problems:

1. The geological age may be determined by the data of well preserved spore-pollen assemblages.
2. It yields opportunity to get data for the circumstances of the sedimentation processes.
3. Quantitative palynological data are useful for local stratigraphic correlations.
4. The rebedding of the sediments may be established by palynological methods, too.
5. The continental movements may also be followed by the regional distribution of the fossil sporomorphs.

The morphological and taxonomical knowledge of the new fossil spore and pollen types isolated from the sediments of different geological ages influenced the general palynological concepts, which were based exclusively on data of the recent taxa, and modified the attitude of this branch of research. From this point of view the following may be worth of mentioning:

1. Among the fossil sporomorphs a number of new types were also found, which occured not at the recent taxa. E. g.: some spores of the paleozoic ferns; *Emphanisporites, Reinschospora,* the monosaccate gymnosperm pollen types from the Upper Permian.

2. Trough evaluation of the different spore and pollen types in the chronological order of the geological time table the evolutionary significance of the sporomorphs, and of their morphological characteristic features may be established. For example the trilete spore is earlier than the monolete one. From among Angiospermatophyta pollen grains, Longaxones are more primitive rather than Brevaxones. The augmentation of the number of the aperture is also a sign of the evolution. The pore, as aperture is more developed than the furrow. The history of the air bladded gymnosperm pollen grains is interesting, too.

3. The spore-pollen data are important in the researches of plant phylogeny.

4. Paleoecology, Paleophytogeography and Paleoclimatology are largely cultivated fields of researches based on palynological data.

The reciprocal effect developed in this way between the researches of the recent and fossil sporomorphs, in optimal case is stimulating for both fields of researches.

In connection with the study by the LM method, one sometimes negligated point of view must be mentioned. It is desirable that the investigations were extended to the full microremnants assemblage in the literatural sense of the word to the following too:

1. Algal remnants (*Botryococcus, Pediastrum,* Hystrichosphaeridae, etc.), Mycophyta spores.

2. Epidermis, xylem and other kind of tissue remnants.

3. Organic walled, microscopical animal remnants, e. g.: chitinous Foraminiferae shells, Thecamoeba.

In some cases, the tissue remnants, occurring in the spore-pollen assemblages have a primary role in the solution of the problem investigated. E. g.; the transport of the radioactive material may be carried out by xylem remnants too, connected to aromatic lignin derivates. From the point of view of Geochemistry, the cellulose (parenchym cell walls) and cutin (epidermis) occurring in the coal layers are also important.

The scanning electron-microscope method is important firstly in the taxonomic spore-pollen researches. Connected TEM and SEM characteristic features from phylogenetic point of view were established at the early brevaxonate angiosperm pollen grains, The earliest Brevaxones; Probrevaxones have a columellar infratectum, the surface ornamentation is relatively diversified. The ultrastructure of the infratectum of the developed Normapolles and Postnormapolles taxa is granular and there are submicroscopic coni on the surface of the tectum. The basis diameter and the number of coni per 1 square micron, have taxonomical value.

The chemical composition of the spore-pollen wall interested the researchers for ages. The first data were published by JOHN (1814). Later ZETZSCHE and KÄLIN (1931), ZETZSCHE et al. described several characteristic features of the sporopollenin, among these we emphasize the autoxydation. The first period of the knowledge of the chemistry of the sporopollenin was summarized by TOMSOVIC (1960). On the basis of previous results it was concluded that the sporopollenin is a high polymerized terpene derivate, similar to the cutin. The new results of SHAW and YEADON (1964, 1966), BROOKS and SHAW (1968, 1971, 1978), fundamentally changed this first concept of the sporopollenin. They established that the precursors of the sporopollenin are ß caroten and esters of carotenoids. The stability of these elementary base molecules is assured by aromatic lignin derivates; MANSKAYA, KODINA and GENERALOVA (1973). Following POTONIÉ and REHNELT (1971) in the course of coalification the aliphatic part of the sporopollenin becomes more and more aromatised. For this matter, they introduced the term "sporin" (POTONIÉ and REHNELT, 1969).

On the basis of the results on the exine of recent Epacridaceae FORD (1971) established the following: the outer layer, the ectexine is composed of sporopollenin, the endexine has a high lignin content, and the material of the intine is cellulose. On the surface of the pollen exine thorium and other kind of metals were discovered by ROWLEY (1971). FAEGRI (1971) concerning the enzymatic destruction of the sporopollenin emphasized that our knowledge is poor regarding the enzymes which may be degraded the sporopollenin. As regards the microbial destruction the publications of ELSIK (1966) and ERDTMAN (1971) are important.

Summarizing the results concerning the chemistry of the sporopollenin it may be concluded, that there are several questions to solve, moreover there are several problems which were not be mentioned here.

The higher level of the knowledge of the chemistry of the sporopollenin is themolecular structure of the biopolymers. The most important fields of research of this problem are as follows:

The twofold refraction of light of the exine was studied by SITTE (1959, 1960, 1963) and by FREYTAG (1964). Based on the results they supposed that the sporopollenin is composed of globular units arranged in fibrillar order. In contrast to this, ROWLEY (1962) emphasized the fibrillar units of the sporopollenin. By the TEM study of degraded fossil exines KEDVES, STANLEY and ROJIK (1974) published pictures from the biopolymer units of the sporopollenin, and probably from the polymers of the aromatic lignin derivates. All observed particles have globular morphology. ROWLEY (1975) established that in the exine there are lipopolysaccharide filaments. These filaments may be solved in 2-amino-ethanol, and the higher biopolymer units of the sporopollenin may be studied by the transmission electron microscope. Rowley, with several co-workers published a number of papers concerning this problem, and the helical sub-units of the exine was described. My own enzymatic, and oxidizing experiments combined with the TEM method resulted globular biopolymer units. In this paper it is necessary to emphasize that the globular biopolymer units may be the basic elements of the helical structures. During our TEM study of the plant microfossils of the manganese ore layers, helical structures were also found.

Finally it is necessary to emphasize the opportunity of the methods, and results of Biogeochemistry and of Biophysics, in the researches of the organic remnants. It established the remnants of several biologically important compounds from sedimentary rocks. Breger (1960), Jones and Vallentyne (1960) respectively reviewed the earlier results, following these publications, in 1944, Fox, Updegraf and Novelli published carotenoids, and chlorophyll-like pigment remnants from marine sediments. It may be hoped to get data for the evolution of the chemistry of the sporopollenin and for the molecular structure of the sporoderm.

It may be concluded from the formerly mentioned facts that the effectual co-operation of the researches of the different fields (Biology, Geochemistry, Paleobiology, Geology) may be resulted in a very valuable synthesis.

The application of the transmission electron microscopical method in the Palynology of the recent taxa started in 1952; Fernández–Morán and Dahl. The first TEM data on fossil exines were published by Ehrlich and Hall (1959). Later, in particular henceforth in the seventies, the number of publications on the subject of the sporoderm ultrastructure of the fossil dispersed and associated sporomorphs have increased. On the basis of the up-to-date results, the general concepts may be established as follows:

1. During the evolutionary process of the sporoderm fine structure a trend of simplification happened. Irregular submicroscopical units become regularly arranged ultrastructural elements. The wall ultrastructure of the early types is in general more complicated than the evoluted ones. This process may be followed by the decrease of the number of the layers of the sporoderm.

2. The phylogenetical, and taxonomical value of certain sporoderm layers is different.

3. The lamellar ultrastructure is earlier than the granular or homogeneous one.

4. The ultrastructure phylogenetical conclusions based on TEM data of the fossil spores and pollen grains are in each case identical with the most important steps of the sporoderm ontogeny of the recent taxa. E. g.: The development of the nexine – it was established on recent and fossil taxa too that in the first step of development both are of lamellar ultrastructure.

Among the details, the following results can be mentioned. Remark. – These results and conceptions are in the basis of two books by the author, which are under publication.

1. The wall ultrastructure of the earliest spores from the Devonian is composed from ramifying roods of sporopollenin with spongy appearance, or by characteristic lamellar ultrastructure elements.

2. The richness in types of the Carboniferous appear in the wall ultrastructure too, beside the early structures, the developed homogeneous may also occur.

3. In the case of the heterospory, in particular from the Mesozoic it is relatively common that the wall ultrastructure of the megaspore is of an earlier type than those of the microspore. The wall structure of the miospores is often homogeneous, namely the developed type, the wall is sometimes channeled.

4. Henceforth of the Upper Cretaceous the homogeneous wall ultrastructure is common. The fine structure of the perispore of the megaspores is reminiscent to those of the exine of the angiosperm pollen grains – tectum, infratectum, foot layer.

5. The earliest gymnosperm pollen – *Archaeoperisaccus* – from the Devonian (the age may be in question) has a spongy-alveolar ectexine, and a lamellar endexine. This is essentially identical with the ultrastructure of the wall of the earliest spores.

6. Inside the saccate type the charateristic alveolar intratectum ultrastructure appeared in the Carboniferous time, but the ultrastructure of the inner layer of the exine is lamellar.

7. The so-called modern gymnosperm exine ultrastructure appeared in the Trias – Jura period. The submicroscopic structure of the inaperturate gymnosperm pollen types is well known from the Jurassic-Cretaceous period. In contrast to the relatively uniform light-microscope morphology, the fine structure of the exine is heterogeneous.

7.1. The exine ultrastructure of the genus *Balmeiopsis* is of an early type, its ectexine is spongy, the ultrastructure of the endexine is lamellar.

7.2. The exine ultrastructure of the pollen grains of Spheripollenites has angiospermous characteristic features.

7.3. The evolved exine ultrastructure type of the inaperturate gymnosperm pollen grains, which is identical with those of the recent taxa is known until from the Cretaceous period. The endexine is lamellar, the ectexine is granular, but this granular ultrastructure has an angiosperm type.

8. The exine ultrastructure of the Circumpolles Group, which is characteristic for the Trias – Cretaceous period is particularly complicated, but some characteristics are similar to those of the angiosperms.

9. As regards the evolutionary significance of the fossil angiosperm exines, primarily early characteristic feature is the columellar infratectum and the lamellar endexine and/or foot layer.

10. During the differentiation, which started henceforth in the Upper Cretaceous, the phylogenetic value of certain characteristic features may change. Namely, primarily early characteristic may be developed to secondary. E. g.; The columellar infratectum of the Tertiary species of the Postnormapolles, and Eubrevaxones is more developed opposed to the granular structure of the Eunormapolles.

REFERENCES

Breger, I. A. (1960): Organic Geochemistry. – Pergamon Press, London, pp. 1 – 658.

Brooks, J. and Shaw, G. (1968): The post-tetrad ontogeny of the pollen wall and the chemical structure of the sporopollenin of Lilium henryi. – Grana Palynologica 8, 2 – 3, pp. 227 – 234.

Brooks, J. and Shaw, G. (1971): Recent developments in the chemistry, biogeochemistry, geochemistry and ontogeny of sporopollenin derived from pollen and spores. – In: Pollen: development and physiology, ed.: Heslop – Harrison, J. Butterworth Press, London, pp. 99 – 114.

Brooks, J. and Shaw, G. (1978): Sporopollenin: a review of its chemistry, palaeochemistry and geochemistry. – Grana 17, 2, pp. 91 – 97.

Ehrlich, H. G. and Hall, J. W. (1959): The ultrastructure of Eocene pollen. – Grana Palynologica 2, 1, pp. 32 – 35.

Elsik, W. C. (1966): Biologic degradation of fossil pollen grains and spores. – Micropaleontology 12, 4, pp. 515 – 518, 1 pl.

Erdtman, G. (1971): Notes on the resistance and stratification of the exine. – In: Brooks, J., Grant, P. R., Muir, M., van Gijzel, P. and Shaw, G.: Sporopollenin. Academic Press, London, New York, pp. 248 – 255.

Faegri, K. (1971): The preservation of sporopollenin membrancs under natural conditions. – In: Brooks, J., Grant, P. R., Muir, M., van Gijzel, P. and Shaw, G.: Sporopollenin. Academic Press, London, New York, 256 – 272.

Fernández-Morán, H. and Dahl, A. O. (1952): Electron microscopy of ultrathin frozen sections of pollen grains. – Science 116, pp. 465 – 467.

Ford, J. (1971): Ultrastructural and chemical studies of pollen wall development in the Epacridaceae. – In: Brooks, J., Grant, P. R., Muir, M., van Gijzel, P. and Shaw G.: Sporopollenin. Academic Press, London, New York, pp. 130 – 173.

Fox, D. L., Updegraf, D. M. and Novelli, D. G. (1944): Carotenoid pigments in the ocean floor. – Arch. Biochem. 5, pp. 1 – 23.

Freyteg, K. (1964): Polarisationsmikroskopische Beobachtungen an Nexinen von Malvaceen-Pollen. – Grana Palynologica 5, 3, pp. 277 – 288, pl. I. II.

John, J. F. (1814): Über Befruchtenstaube nebst eine Analyse des Tulpen pollens. – Journal für Chemie und Physik 12, pp. 244 – 261.

Jones, J. D. and Vallentyne, J. R. (1960): Biogeochemistry of organic matter-I. – Geochimica et Cosmochimica Acta 21, pp. 1 – 34.

Kedves, M., Stanley, E. A. et Rojik, I. (1974): Observations nouvelles sur l'ectexine des pollens fossiles des angiospermes de l'Éocene inférieur. – Pollen et Spores 16, 3, pp. 425 – 437, pl. I – IV.

Manskaya, S. M., Kodina, L. A. and Generalova, V. N. (1973): Chemical investigation of pollen and spores walls (Russian, with English summary). – Proc. of the III Internat. Palynological Conf., Palynology in Medicine, pp. 71 – 74.

Potonié, R. und Rehnelt, K. (1969): Zur chemischen Konstitution der Sporenexine karbonischer Lycopsida. – Bull. Soc. Sci. Liege 38, 5 – 6, pp. 259 – 273.

Potonié, R. and Rehnelt, K. (1971): On the aromatisation of sporin of carboniferous Lycopsids. – In: Brooks, J., Grant, P. R., Muir, M., van Gijzel, P. and Shaw, G.: Sporopollenin. Academic Press, London, New York, pp. 295 – 304.

Rowley, J. R. (1962): Stranded arrangement of sporopollenin in the exine of microspores of Poa annua. – Science 137, 3529, pp. 526 – 528.

Rowley, J. R. (1971): Implications on the nature of sporopollenin based upon pollen development. – In: Brooks, J., Grant, P. R., Muir, M., van Gijzel, P. and Shaw, G.: Sporopollenin. Academic Press, London, New York, pp. 147 – 219.

Rowley, J. R. (1975): Lipopolysaccharide embedded within the exine of pollen grains. – 33rd Ann. Proc. Electron Microscopy Soc. Amer., pp. 572 – 573.

SHAW, G. and YEADON, A. (1964): Chemical studies on the constitution of some pollen and spore membranes. – Grana Palynologica 5, 2, pp. 247 – 252.

SHAW, G. and YEADON, A. (1966): Chemical studies on the constitution of some pollen and spore membranes. – J. chem. Soc. C, p. 16.

SITTE, P. (1959): Polarisationsmikroskopische Untersuchungen an Sporodermen. – Z. Naturforsch. 14, pp. 575 – 582.

SITTE, P. (1960): Die optische Anisotropie von Sporodermen. – Grana Palynologica 2, 2, pp. 16 – 37.

SITTE, P. (1963): Zur Kenntnis der Zwischenschichte im Sporoderm von Pinus mugo. – Grana Palynologica 4, 1, pp. 41 – 52.

TOMSOVIC, P. (1960): Bemerkungen zum Feinbau des Sporoderms und zu seiner Terminologie. – Preslia 32, pp. 163 – 173.

ZETZSCHE, F. und KÄLIN, O. (1931): Untersuchungen über die Membran der Sporen und Pollen V. 4. Zur Autoxication der Sporopollenine. – Helv. Chim. Acta 14, pp. 517 – 519.

PLANKTONIC FORAMINIFERA OF THE PÉNZESKÚT MARL FORMATION (ALBIAN-CENOMANIAN), TRANSDANUBIAN MIDMOUNTAINS, HUNGARY.

PART I: THE JÁSD J – 42 STRATOTYPE PROFILE

by

I. BODROGI

Hungarian Geological Institute, Budapest

(Received: 1st April, 1987)

Abstract

The planktonic foraminifer fauna of the Pénzeskút Marl is described, providing stratigraphical and ecological interpretation. A short introduction to the geology of the formation is given. First and last occurrences and quantitative distribution of the fauna in the Jásd – 42 borehole are described in detail. Two zones and two subzones were recognized: 1. Rotalipora appenninica Zone (a: R. ticinensis – Planomalina buxtorfi Subzone; b: R. appenninica – Guembelitria cenomana Subzone; Lower and Upper Vraconian, respectively); 2. Rotalipora brotzeni Zone: Lower Cenomanian.

Introduction

This paper is the result of the author's participation in the National Key Section Programme and in the International Geological Correlation Programme, Project 58, during the years 1979 – 1984.

Stratigraphy of the Pénzeskút Marl is based on ammonite studies of SCHOLTZ (1973, 1979) and HORVÁTH (1985). Planktonic foraminifers were studied by MAJZON (1940, 1966) at the first time. SIDÓ recognized foraminifer assemblages, planktonic zones and benthonic biofacies horizons (SIDÓ, 1966, 1971).

The Middle Cretaceous sedimentary cycle of the Transdanubian Midmountains consists of 6 formations (Fig. 1). The Pénzeskút Marl is the youngest member of the cycle. It occupies a narrow zone along the axis of the Midmountains syncline, of about 60 km length and 3 – 10 km width (Fig. 2). Thickness extends up to 476 m (Jásd – 42 borehole), divided into three subunits (after CSÁSZÁR, 1985; Fig. 3). The lower subunit is made of 140 m dolomitic silty marl with calcareous nodules. Its lowermost, 0,5 to 1 m thick bed is a glauconitic horizon, the glauconite content swiftly decreasing upwards. It contains 0.2 to 0.6 m thick breccia made of the underlying limestone and fossil fragments. The 199 m thick middle subunit is poorly bedded, dark gray dolomitic marl, while the upper, 145 m thick subunit is characterised by alternating dolomitic, silty marl, siltstone and sandstone.

The Pénzeskút Marl is underlain by the Zirc Limestone, usually by a hiatus, but deposition was uninterrupted in the southwest.

---

* Doctoral thesis defended at Eötvös University.

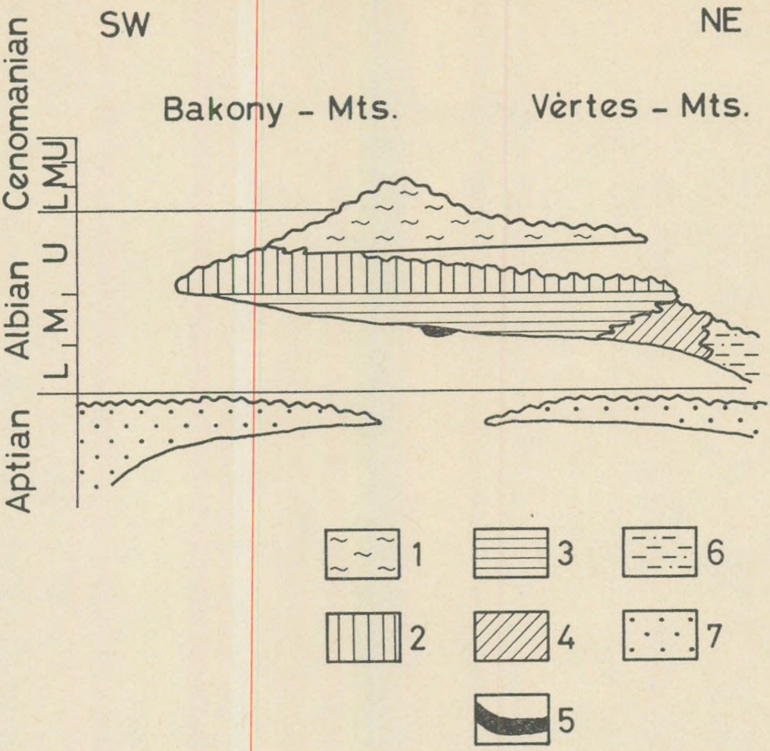


Fig. 1. Aptian-Cenomanian formations of Bakony and Vértes Mts., Legend: 1. Pénzeskút Marl; 2: Zirc Limestone; 3: Tés Marl; 4: Környe Limestone; 5: Alsópere Bauxite; 6: Vértessomló Siltstone; 7. Tata Limestone.

The Jásd – 42 stratotype profile

About 200 forms were recognized in the extremely rich foraminifer fauna, 134 of which were determined to the species level.

Mode of life of the genera and species

	Genera	Species
Planktonic	8: 15,3%	22: 15,7%
Calcareous benthonic	30: 56,6%	78: 58,2%
Agglutinated benthonic	15: 28,1%	35: 26,1%

Age of the planktonic foraminifer species

Individuals of the genera *Rotalipora, Hedbergella, Globigerinelloides, Praeglobotruncana,* and *Planomalina* dominate the planktonic fauna. The benthonic groups with great diversity, but less individuals has a more significant facies indicator role.

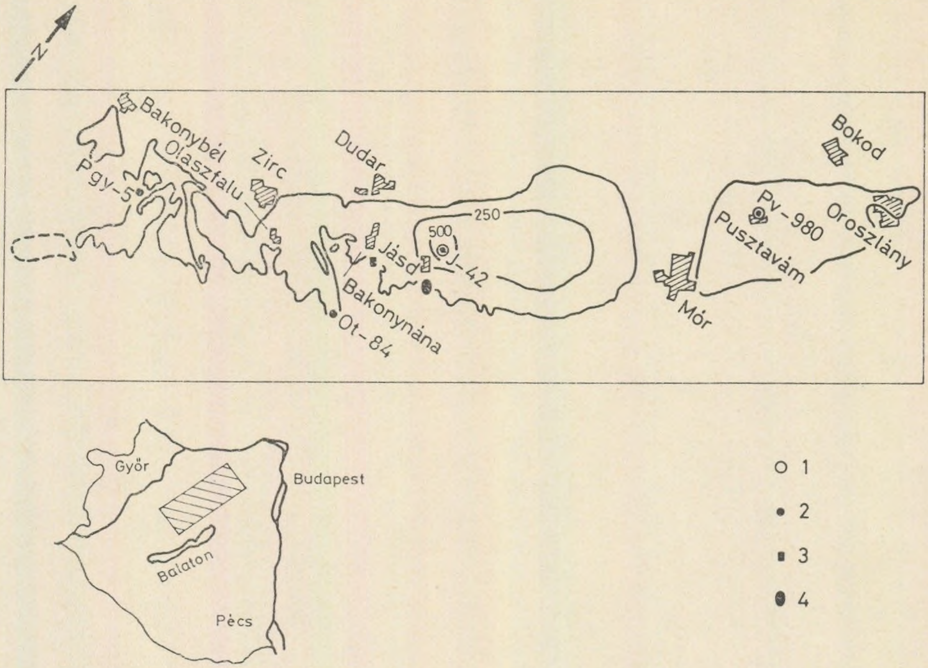


Fig. 2. Location of the investigated sections. Legend: 1: borehole stratotype; 2: borehole reference section; 3: surface boundary stratotype; 4: surface reference section.

Table I.

Appearance	Number	Percentage
Lower Cretaceous	7	31,81%
Lower Albian	4	18,18%
Lower Vraconian	6	27,27%
Upper Vraconian	3	13,65%
Lower Cenomanian	2	9,09%
Total	22	100,00%

Except the lowest metres at the beginning of the transgression and the upper 135 metres, interpreted as a regressive facies, the planktonic fauna is characterised by great diversity, fast evolution of single-keeled Rotaliporas, their increasing species diversity, great number, and extreme intraspecific and interspecific variability.

Range of the species is shown in Fig. 4, while some of them are illustrated on six plates.

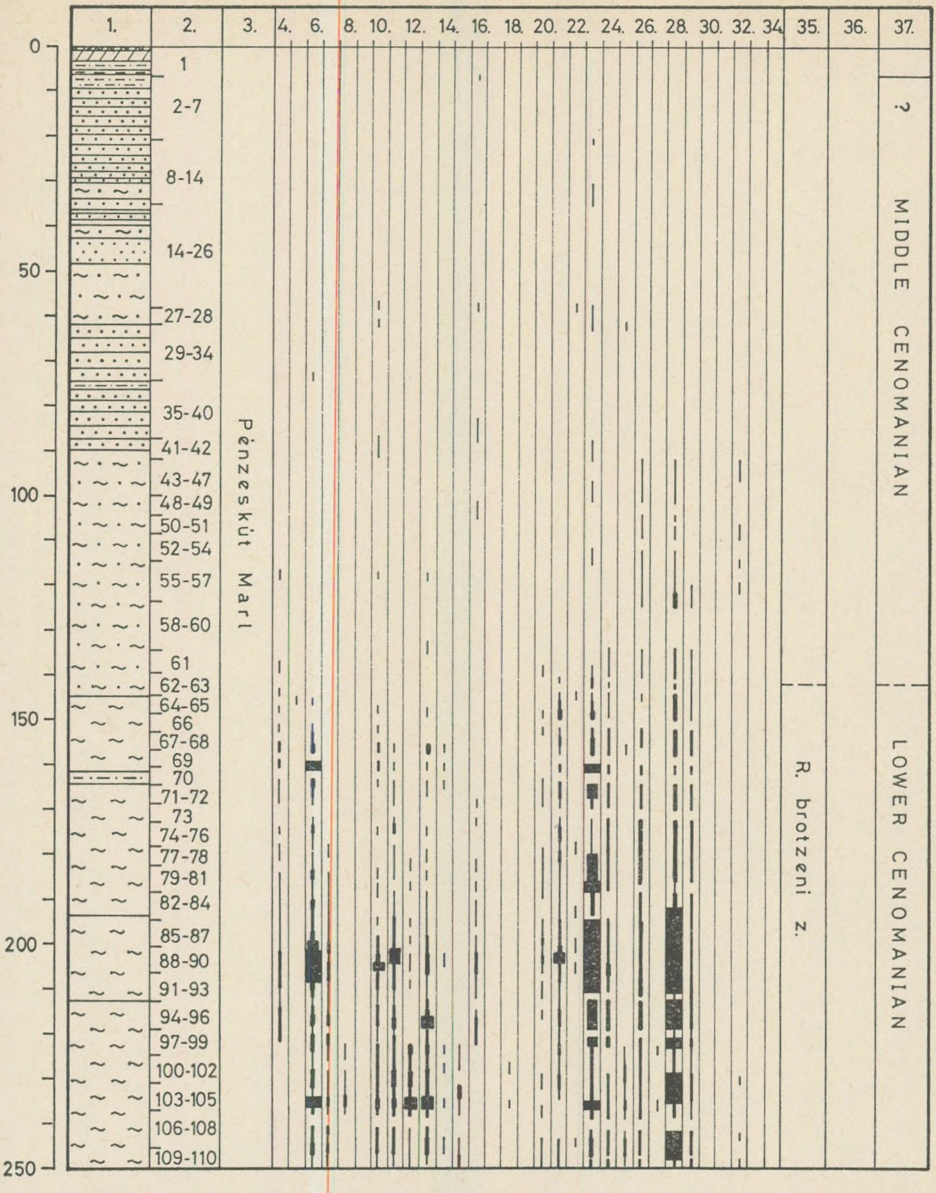
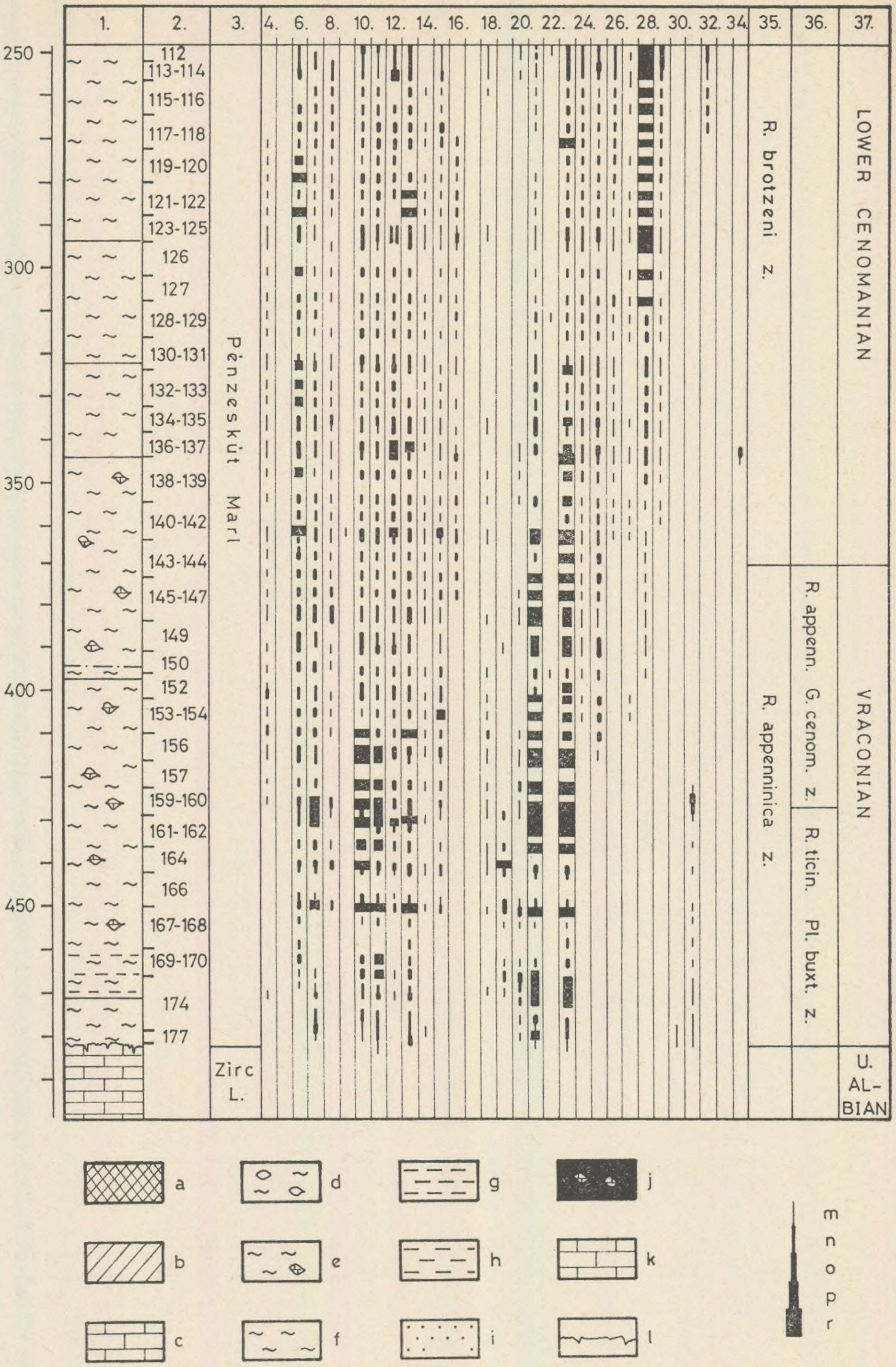


Fig. 3. Planktonic foraminifer fauna of the Jásd – 42 stratotype profile. Legend: 1: stratigraphic column; 2: sampling location (washed samples); 3: lithostratigraphic formations 4: *Favusella (H.) washitensis;* 5: *F.* cf. *washitensis;* 6: *Globigerinelloides bentonensis;* 7: *G escheri;* 8: *G.* sp.; 9: *Guembelitria cenomana;* 10: *Hedbergella delrioensis;* 11: *H. infracretacea;* 12: *H. simplex;* 13: *H. trocoidea;* 14: *H. planispira;* 15: *H. brittonensis;* 16: *H.* sp.; 17: *Heterohelix moremanni;* 18: *H. washitensis;* 19: *Planomalina buxtorfi;* 20: *Praeglobotruncana delrioensis;* 21: *P. stephani;* 22: *P.* sp., 23: *Rotalipora appenninica;* 24: *R. globotruncanoides;* 25: *R. appenninica* var. *evoluta;* 26: *R. brotzeni;* 27: *R.* aff. *brotzeni;* 28: *R. gandolfii;* 29: *R. micheli;* 30: *R. subticinensis;* 31: *R. ticinensis;* 32: *R.* sp., 33: *Ticinella praeticinensis;* 34: *T.* sp.; 35: planktonic foraminifer zones; 36: subzones; 37: geological age.

Fig. 3. (continued)



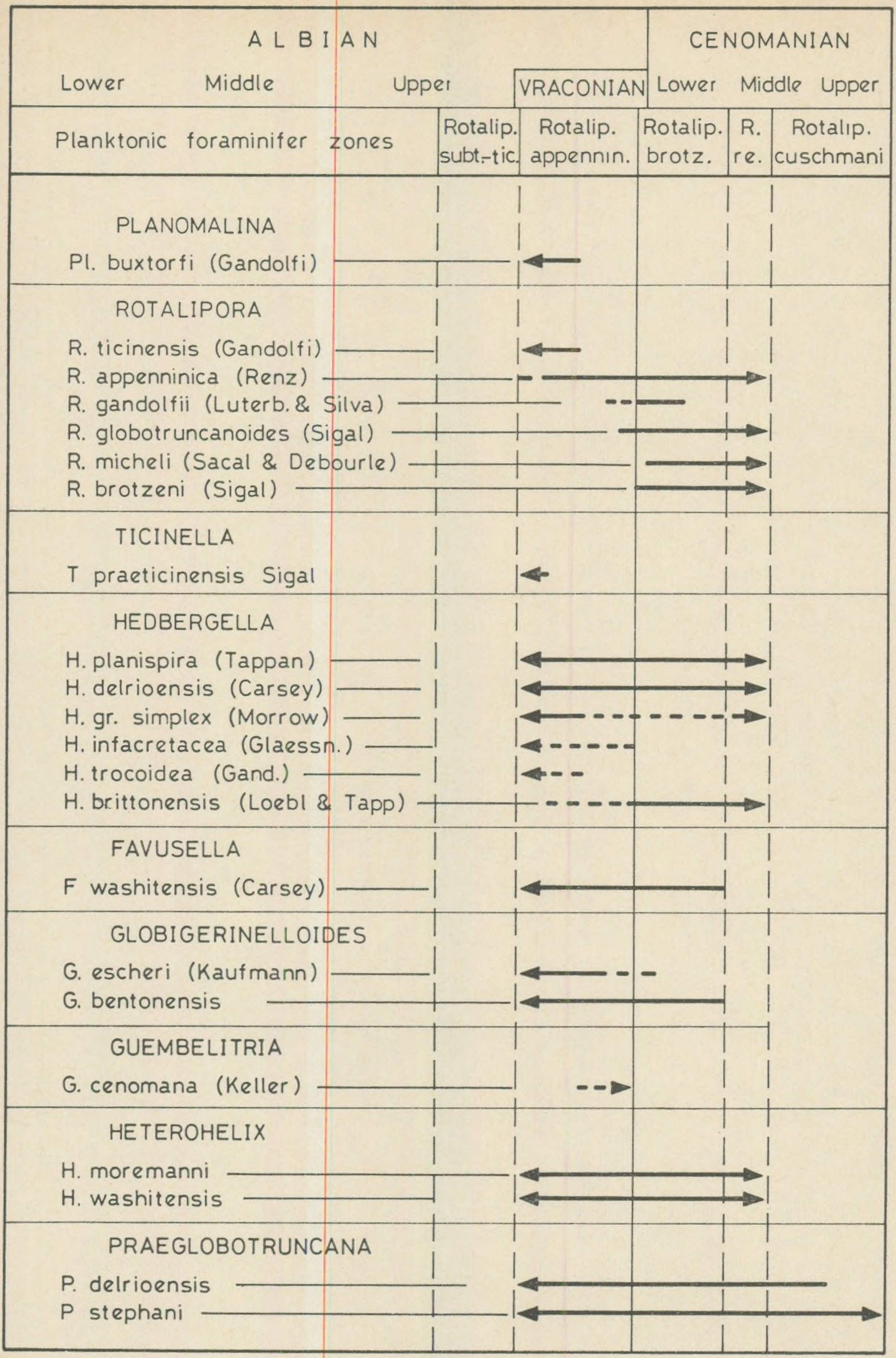


Fig. 4. Stratigraphic range of planktonic foraminifers.

Underlying beds of the Pénzeskút Marl

The Jásd – 42 borehole cut below the Pénzeskút Marl the Mesterhajag Member of the Zirc Limestone (lower faunal level, *Orbitolina* limestone, microfauna limestone).

Thin sections of an 1,7 m thick bed (483,1 – 484,8 m) contained *Rotalipora*? sp., *Hedbergella* sp., and *Hedbergella* cf. *planispira* (TAPP.).

Orbitolinas were recognized only in thin sections from the 484,8 – 485,2 m section.

Between 485,2 – 499,0 m there is platform limestone with typical Albian benthonic foraminifer assemblage (*Debarina hahourenensis* FOURCADE et al., *Nezzazata simplex* OMARA, *Nummoloculina heimi* BONET).

Basal beds of the Pénzeskút Marl

Lowermost beds of the Pénzeskút Marl are strongly glauconitic, dolomitic marls (5 m). Members of the genus *Rotalipora* appear from 483,1 m onwards: *Rotalipora ticinensis* (GANDOLFI), *R. appenninica* (RENZ) *primitiva* (BORSETTI), *Rotalipora* sp. The species *Planomalina buxtorfi* (GANDOLFI) appears at 479,0 m. In the redeposited material of the underlying Zirc Limestone *Rotalipora subticinensis* (GANDOLFI) was recognized (477,0 m).

Specimens of *Rotalipora appenninica* (RENZ) and *Rotalipora appenninica* (RENZ) *primitiva* BORSETTI are sporadic, small, strongly papillated, of primitive, archaic character. Specimens of *Planomalina buxtorfi* (GANDOLFI) are also small.

The associated planktonic assemblage contains *Hedbergella (infracretacea, delrioensis, planispira)*, *Globigerinelloides (escheri)*, *Praeglobotruncana (delrioensis)*, and *Favusella* (*washitensis*, cf. *washitensis)* species. All of them are older, Aptian-Albian transition forms. About 9 m above the boundary (476,0 m) sharply increases the diversity of the plankton, including the zonal index forms.

Planktonic foraminifer zonation

The planktonic foraminifers are represented by 8 genera[*Globigerinelloides, Hedbergella (Clavihedbergella), Heterohelix, Guembelitria, Planomalina, Praeglobotruncana, Rotalipora*], *Ticinella* and 22 species (BODROGI, 1985). The single-keeled *Rotalipora* species with swift evolution, *Planomalina buxtorfi*, and *Guembelitria cenomana* species were applied for zonation. Two zones and two subzones were recognized, and an upper, regressive series, unsuitable for zonation (Fig. 5).

1. Rotalipora appenninica Zone (363,0 – 483,1 m)
   Thickness: 120,1 m
   Age: Vraconian

   1/a. Rotalipora ticinensis – Planomalina buxtorfi Subzone (427,0 – 483,1 m)
   Thickness: 56,1 m
   Age: Lower Vraconian

ACE		Ammonite zones		Planktonic foraminifer zones				← first → last occurrences of forams
		JUIGNET 1976, 1978 Type region Sarthe	A. Horváth 1982 (J–42)	Robaszynski et Coron 1979	Wonders 1980 Sigal 1977	Bodrogi I. 1982 (J–42)		
CENOMANIAN	UPPER	Sciponoceras gracile		W.arch	W.arch			R.cushmani →
		Eucalicoceras pentogonum		Rotalipora cushmani	Rotalipora cushmani			R.brotzeni → R.monts. →
	MIDDLE	Acanthoceras jukes brownei						R.appenninica → R.reicheli →
		T.acutus						← R.cushmani
		Turr. costatus	A.rothomagense	Rotalipora reicheli	Th. globotruncanoides	Regression ?		← R.reicheli ← R.montsalv.
	LOWER	Mant.dixoni	M.mantelli	Rotalipora brotzeni		Rotalipora brotzeni		
		Mant. saxbii						
		Hypoturr carcitanensis						← R.brotzeni ← R.globotrunc.
UPPER ALBIAN	VRACONIAN	St.dispar bergeri	St.dispar bergeri	Rotalipora appenninica	Th.appenninica	Rotalipora appennica	R.appenninica et Guembelitria cenomana	Pl.buxtorfi → R.ticinensis →
		St.dispar blanchetti	St.dispar blanchetti		Th.app.-Pl buxt. Ps.ticin. Pl.praegbuxt		R.ticinensis Pl.buxtorfi	← Pl. buxtorfi
		M.inflatum			Ps.subticinensis			← R.appeinninca ← Prglobotr. ← R.ticinensis

Fig. 5. Ammonite and foraminifer zones of the Pénzeskút Marl.

1/b. Rotalipora appenninica – Guembelitria cenomana Subzone
(363,0 – 327,0 m)
Thickness: 61,4 m
Age: Upper Vraconian

2. Rotalipora brotzeni Zone (141,0 – 363,0 m)
Thickness: 222,0 m
Age: Lower Cenomanian

The uppermost, about 135 m thick section is interpreted as a regressive series.

Phylogenetic relationships of and the biozones based on the *Rotalipora* species are displayed on Fig. 6.

Characteristics of the zones

1. Rotalipora appenninica Zone
Lower boundary: appearance of *Rotalipora appenninica* (RENZ).
Age: Vraconian (Upper Albian)
Section: 363,0 – 483,1 m.
Thickness: 120,1 m
Planktonic foraminifer species:

Globigerinelloides bentonensis (MORROW, 1934)
Globigerinelloides escheri (KAUFMANN, 1919)
Guembelitria cenomana (KELLER, 1938)
Hedbergella delrioensis (CARSEY, 1936)
Hedbergella brittonensis (LOEBLICH ET TAPPAN, 1961)
Favusella (H.) washitensis (CARSEY, 1926)
Hedbergella aff. trocoidea (GONDOLFI, 1942)
Hedbergella planispira (TAPPAN, 1940)
Heterohelix moremanni (CUSHMAN, 1938)
Planomalina buxtorfi (GANDOLFI, 1942)
Praeglobotruncana delrioensis (PLUMMER, 1931)
Praeglobotruncana stephani (GANDOLFI, 1942)
Rotalipora appenninica (RENZ, 1936)
Rotalipora globotruncanoides (SIGAL, 1942)
Rotalipora ticinensis (GANDOLFI, 1942)
Rotalipora gandolfii LUTERBACHER et PREMOLI SILVA, 1962
Ticinella praeticinensis SIGAL, 1966

Zonation is based on the following species:

Rotalipora appenninica (RENZ, 1936)
Rotalipora ticinensis (GANDOLFI, 1942)
Rotalipora globotruncanoides (SIGAL, 1942)
Rotalipora gandolfii LUTERBACHER et PREMOLI SILVA, 1962
Planomalina buxtorfi (GANDOLFI, 1942)

This zone, enclosing the about 120 m thick lower section of the borehole (lithostratigraphic unit No. 1) is made of dark grey, dolomitic limestone, calcareous marl, nodular marl; the lowest 5 m section is strongly

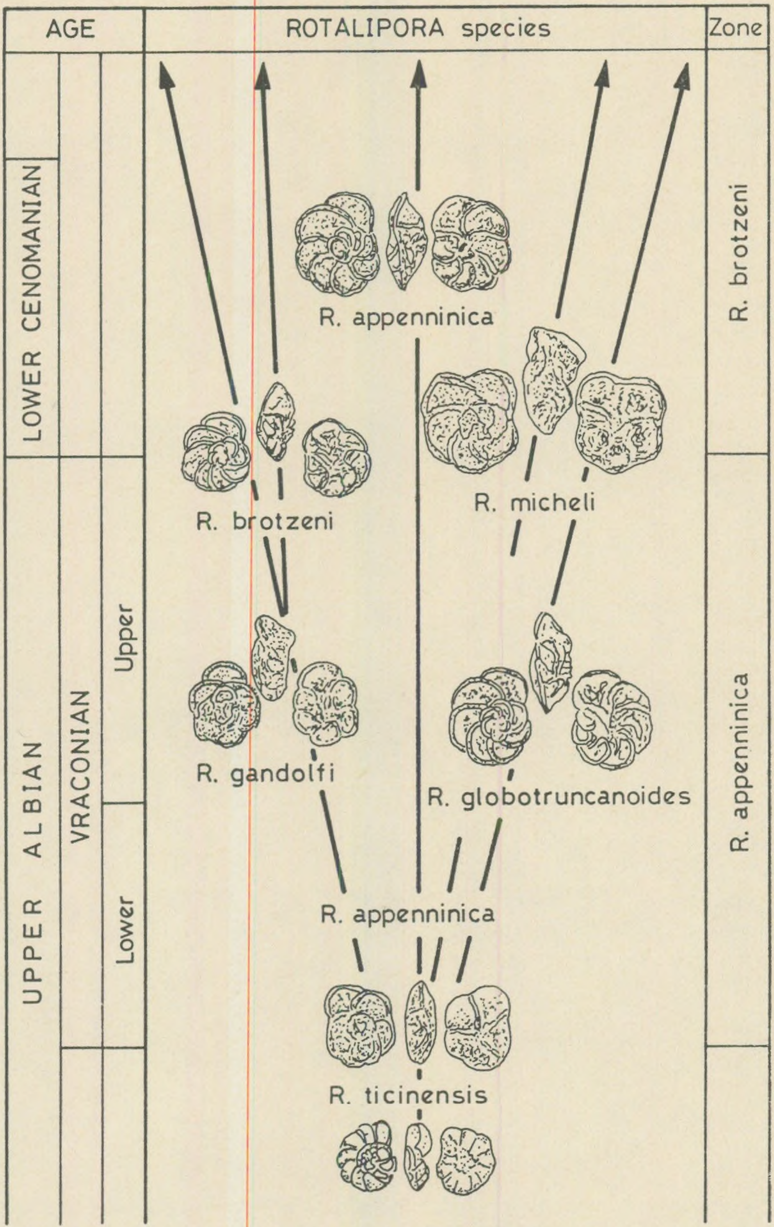


Fig. 6. Phylogenetical relationships of *Rotalipora* species.

glauconitic. The lower boundary of the biozone and the lithostratigraphic unit is equal. At the upper boundary, where no sharp lithological change was observed, the planktonic foraminifer fauna changes with 19,3 m difference.

The zone index *Rotalipora appenninica* (RENZ) appears in the first sample, but sporadically only. This variable species with high diversity appears from 450 m in most samples in great quantities. Its intraspecific variability is extremely high. In the lower part of the zone (1/a subzone) the species is represented by the small, primitive, strongly papillated *Rotalipora appenninica* (RENZ) *primitiva* BORSETTI and the *Rotalipora balernaensis* (GANDOLFI) with flat dorsal side, the latter being synonymous with the former one since 1969. Besides the typical specimens of *Rotalipora appenninica* (RENZ) occur, too (Fig. 7).

In the upper part of the zone (1/b subzone) the intraspecific variation increases: flat, conical, nearly symmetrical and variably asymmetrical forms appear.

Near the subzone boundary some species of Rotalipora appenninica bear thickening of the suture on the ventral chambers, developing into praeumbilical keel (WONDERS, 1978). Besides the regular right coiling, some left-coiling specimens occur.

Besides the older, involute varieties there are evolute types with elongated last chamber (1/b subzone), represented by the synonymous *Rotalipora evoluta* SIGAL, appearing at 415 m. It is frequent in 1/b subzone and at the bottom of the Rotalipora brotzeni Zone.

The small, globular, weakly keeled forms are atavistic, indicating the *Rotalipora ticinensis* – *Rotalipora subticinensis* lineage.

Chamber surface of *Rotalipora appenninica* and its variations change from strong papillation towards a smooth surface. The suture pattern of the dorsal side, with 90° angle or very near to it, is an important, Mediterranean character. The diameter of the test gradually grows: it is about 25 micrometres at the top of the zone, while it is about half of it at the lower boundary.

The species *Rotalipora ticinensis* (GANDOLFI) appears between 420,0 – 438,1 m, between 425,0 – 430,0 m occurring in large numbers. The species *Rotalipora globotruncanoides* appears in the upper part of the zone (405 m), together with *Rotalipora gandolfii* LUTERBACHER and PREMOLI SILVA (402 m), *Rotalipora* aff. *brotzeni* (SIGAL) (400 – 402 m, 220 – 363 m). All three taxa are represented by sporadic specimens only. *Planomalina buxtorfi* (GANDOLFI) appears between 427 – 479 m sporadically, but it is frequent between 440 – 450 m. The boundary of the two subzones was drawn at its last occurrence (427 m).

The genus *Praeglobotruncana*, represented by the species *P. stephani* (GANDOLFI) and *P. delrioensis* (PLUMMER) decrease in number upwards. The former one is frequent up to 460 m, while the latter one is frequent in the lower samples only, decreasing upwards, being sporadic above 421 m.

The unkeeled, globular planktonic group includes the genera *Favusella*, *Hedbergella*, *Globigerinelloides*, *Heterohelix*, *Ticinella*. Most of the *Hedbergella* species are frequent, except the sporadic *H. aff. trocoidea* (GANDOLFI).

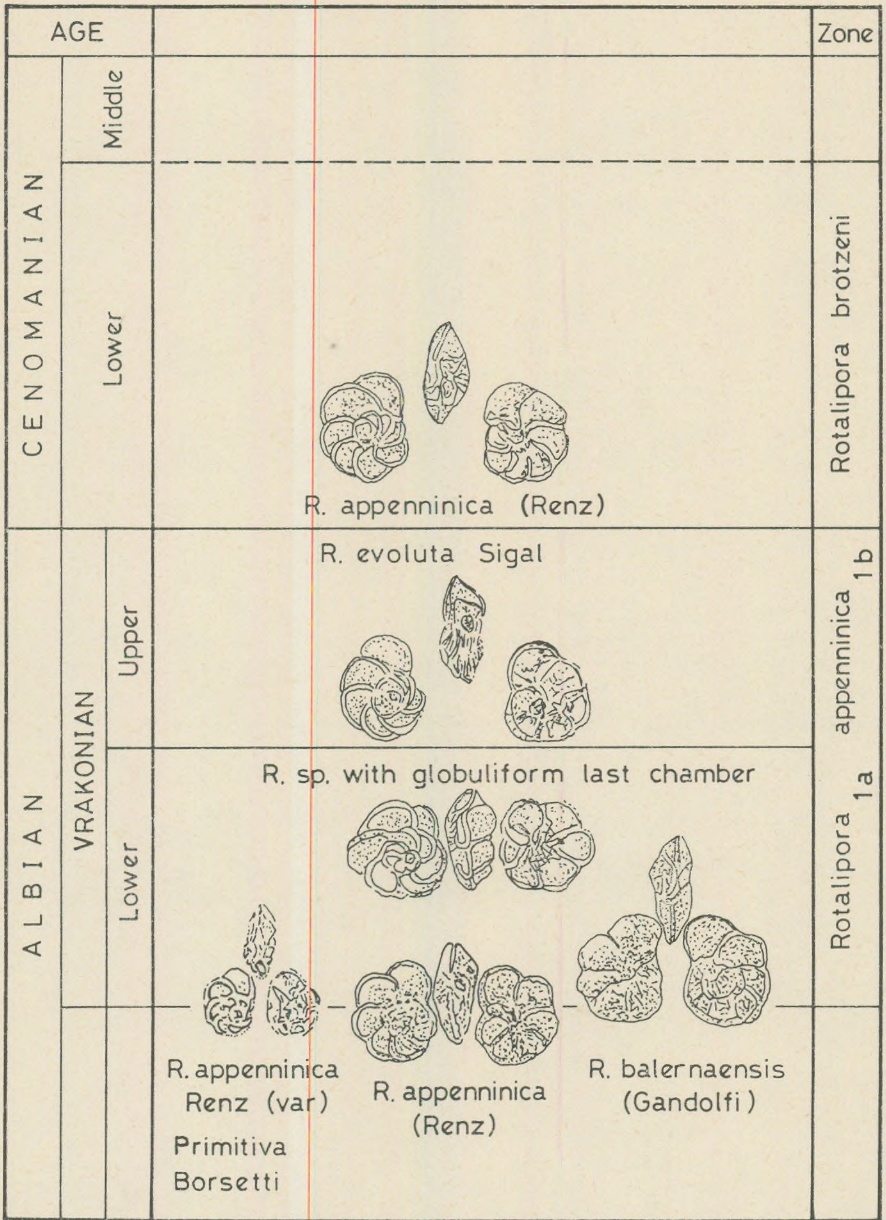


Fig. 7. Intraspecific variations of *Rotalipora appenninica*

The species *Favusella washitensis* (CARSEY), *Heterohelix* species, and *Ticinella praeticinensis* SIGAL are sporadic. Persistent species is *Globigerinelloides escheri* (KAUFMANN). The species *Globigerinelloides bentonensis* (MORROW) appears at 470 m, in middle to frequent numbers. CARTER and HART (1979) considers *Globigerinelloides aeglefordensis* MOREMANN as a junior synonym of *Globigerinelloides bentonensis* (MORROW). The *Guembelitria cenomana* species occurs in one sample only (363 m) as a single specimen.

At the lower and upper boundary of the zone a phylogenetic radiation of the genus *Rotalipora* occurs. At the lower boundary the zonal index *Rotalipora appenninica* appears, evolved from the *Rotalipora ticinensis* branch. Near the upper zone boundary from *Rotalipora appenninica* two species, *R. globotruncanoides* and *R. gandolfii* evolve at the uppermost part of Vraconian, while appearance of *R. brotzeni* indicates Lower Cenomanian (363 m). *R. micheli* appears at the lower part of Lower Cenomanian (358 m).

Subzones of Rotalipora appenninica Zone

1/a. Rotalipora ticinensis – Planomalina buxtorfi Subzone

Lower boundary: appearance of *Rotalipora ticinensis* (GANDOLFI) and *Planomalina buxtorfi* (GANDOLFI).

Upper boundary: disappearance of *Planomalina buxtorfi* (GANDOLFI) and *Rotalipora ticinensis* (GANDOLFI), as no new species appear.

Age: Lower Vraconian
Section: 427,0 – 483,1 m
Thickness: 56,1 m

Characteristic planktonic foraminifer species of the subzone:

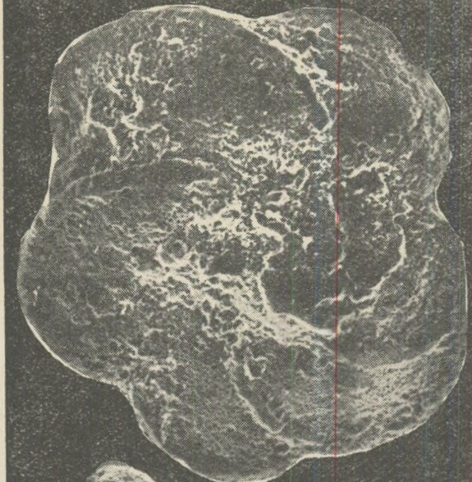
Heterohelix moremanni (CUSHMAN, 1938)
Heterohelix washitensis (TAPPAN, 1940)
Planomalina buxtorfi (GANDOLFI, 1942)
Rotalipora appenninica (RENZ, 1936)
Rotalipora ticinensis (GANDOLFI, 1942)

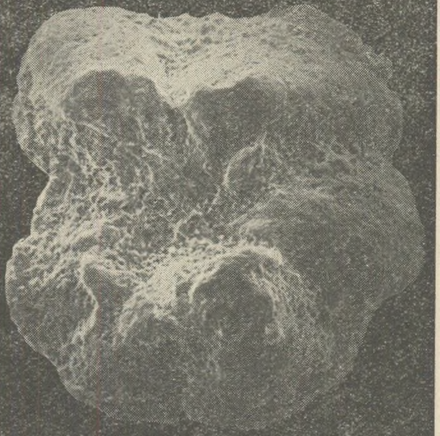
Zonation is based on the following species:

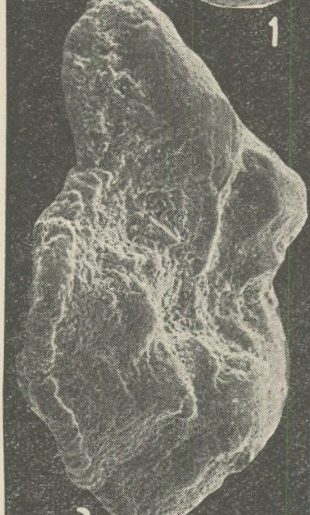
Rotalipora ticinensis (GANDOLFI, 1942)
Rotalipora appenninica (RENZ, 1936)
Planomalina buxtorfi (GANDOLFI, 1942)

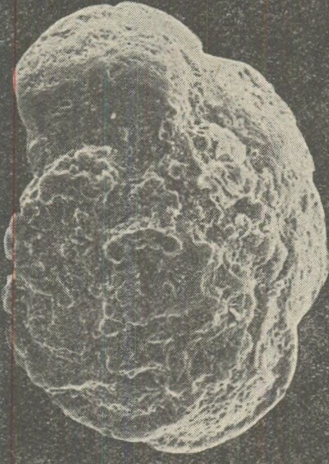
Boundary of the two subzones was drawn at the last appearance of *Planomalina buxtorfi* (GANDOLFI) (425 m); *Rotalipora ticinensis* (GANDOLFI) sporadically occurs to about 5 m above the boundary.

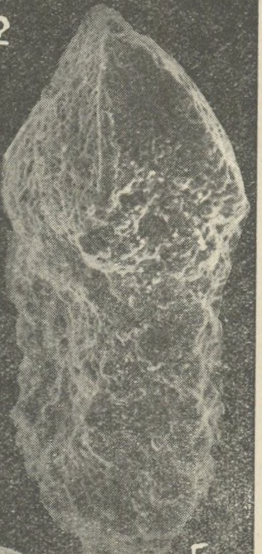
Immediately above the boundary no new species appear, but from 415 m onwards *Rotalipora appenninica* (RENZ) var. *evoluta* (SIGAL), a synonym of *R. appenninica* (RENZ) appears.

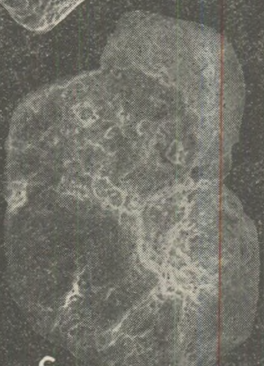

1


2


3


4


5


6

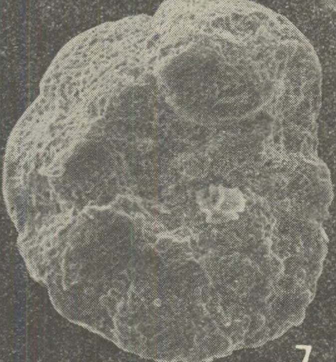

7

PLATE I.

1 – 3. *Rotalipora appenninica* (Renz)
1.dorsal view; 2. ventral view; 3. lateral view. 120x 249 m

4, 7. *Rotalipora ticinensis* (Gandolfi)

4. dorsal view 160x 464,5 m

7. ventral view 150x 464,5 m

5 – 6. *Planomalina buxtorfi* (Gandolfi)

5. lateral view 180x

6. 120x

SEM photographs; Jásd – 42 stratotype borehole

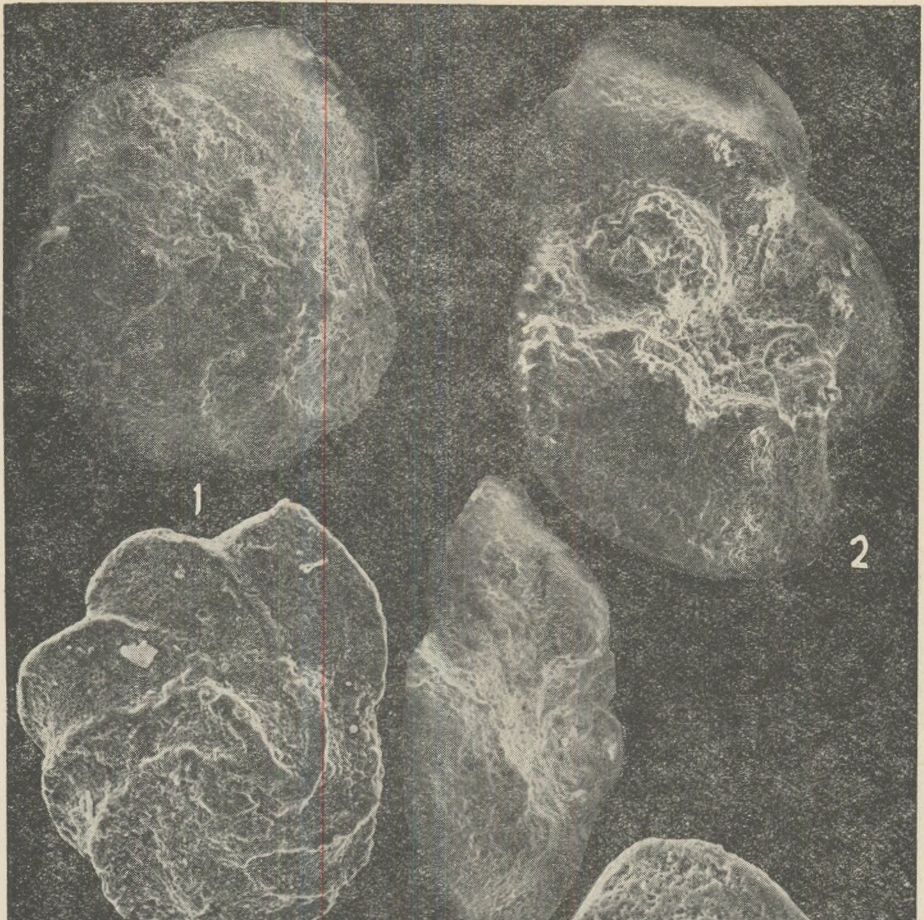

1
2
3
4
5
6

PLATE II.

1, 2, 4. *Rotalipora gandolfii* Luterbacher et Premoli Silva

1. dorsal view. 120x

2. ventral view 150x

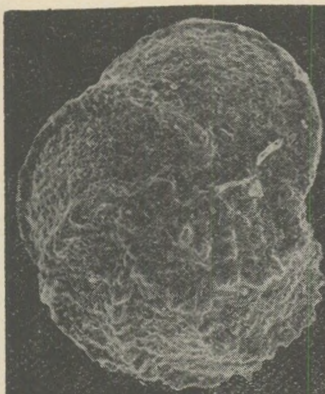
3. lateral view 120x
305 m

3, 6. *Rotalipora brotzeni* (Sigal)

3. dorsal view 120x 171 m

6. ventral view 150x 171 m

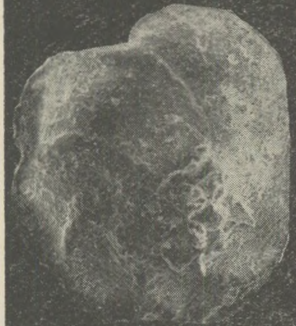
5. *Rotalipora gandolfii* Luterbacher et Premoli Silva
vental view 120x 305 m



1

2

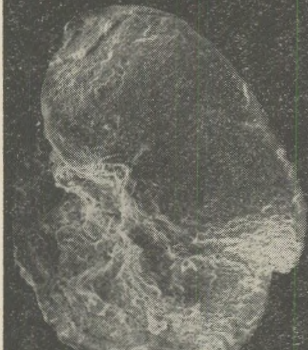
4



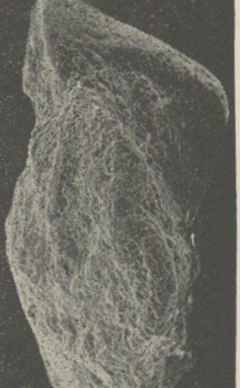
3

5

7



6



8

PLATE III.

1, 2. *Rotalipora appenninica* (RENZ)
primitive type

1. dorsal view. 2. lateral view
150x 469 m

3 – 4, 6 – 7. *Rotalipora brotzeni* (SIGAL)
juvenile specimens, except Fig. 4.

3. dorsal view 200x 171 m

4, 7. ventral views 120x 171 m

6. ventral view 20x 171 m

8. *Rotalipora globotruncanoides* (SIGAL)
177 m 200x

SEM photographs, Borehole Jásd – 42

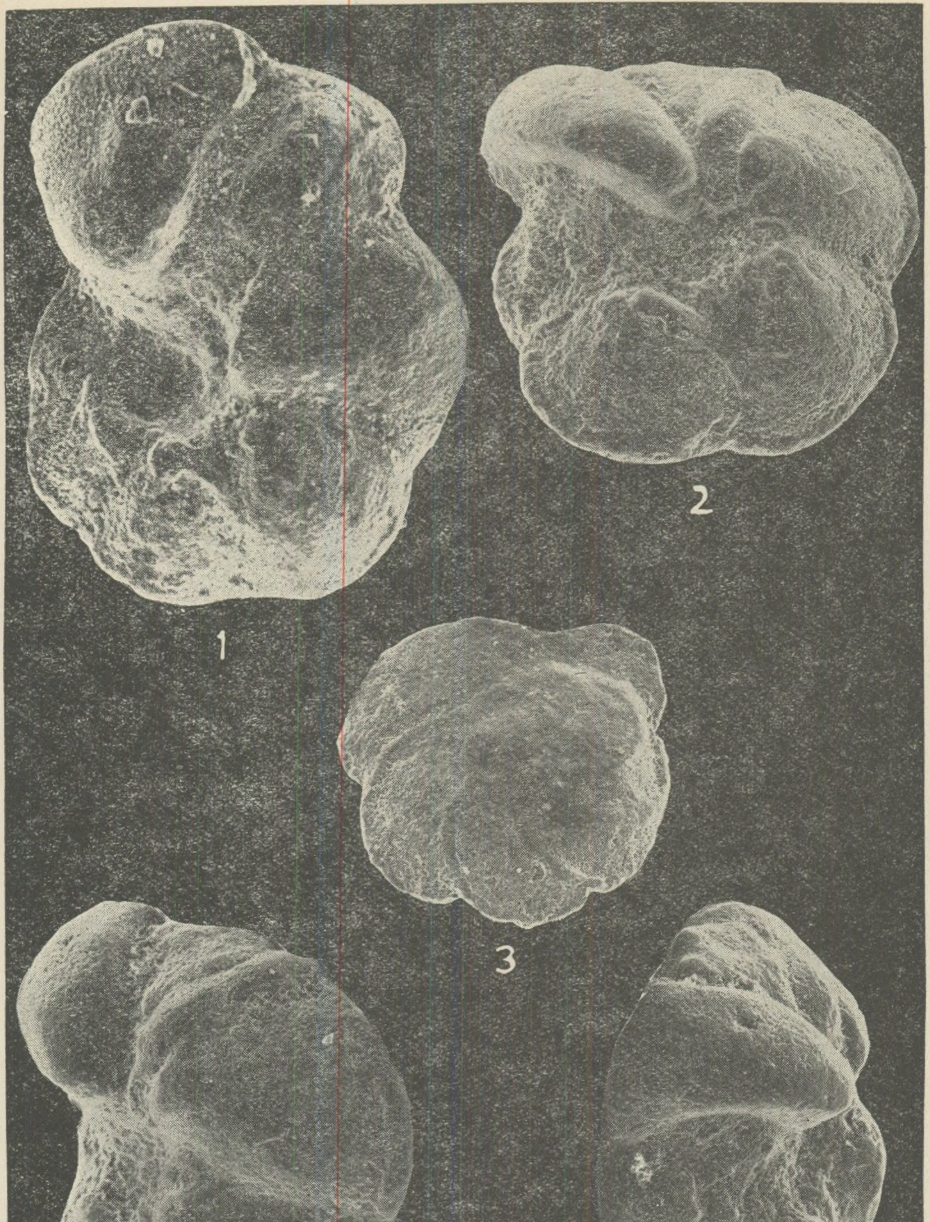

1
2
3
4
5

PLATE IV.

1. *Rotalipora appenninica* (RENZ)
ventral view 130x 293 m

2 – 5. *Rotalipora micheli* (SACAL et DEBOURLE)

2. ventral view, 3. dorsal view, 4 – 5. lateral views.

3.: 100x, 2,4. 5: 130x 177 m

SEM photographs, Jásd – 42 stratotype borehole

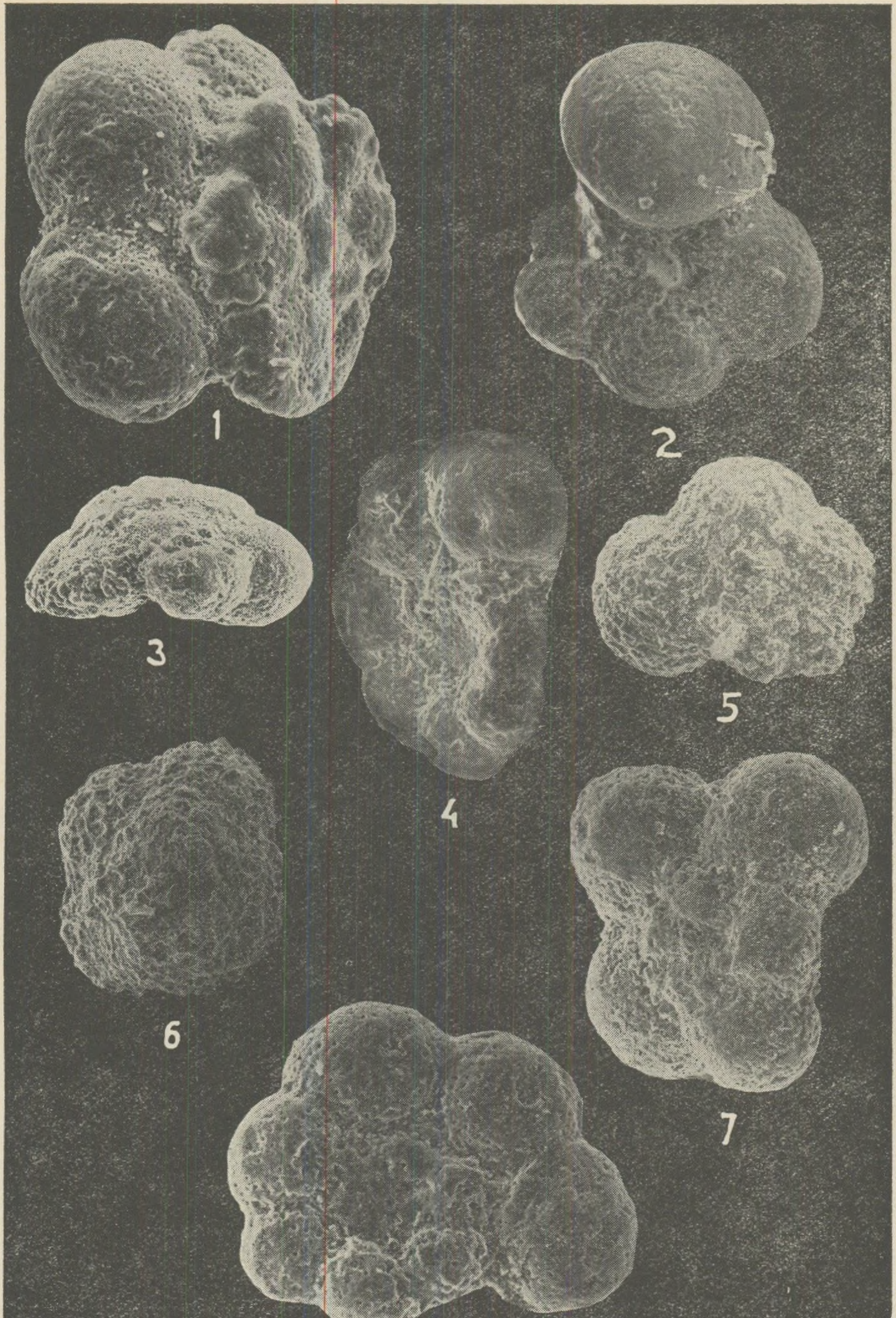

1
2
3
4
5
6
7
8

PLATE V.

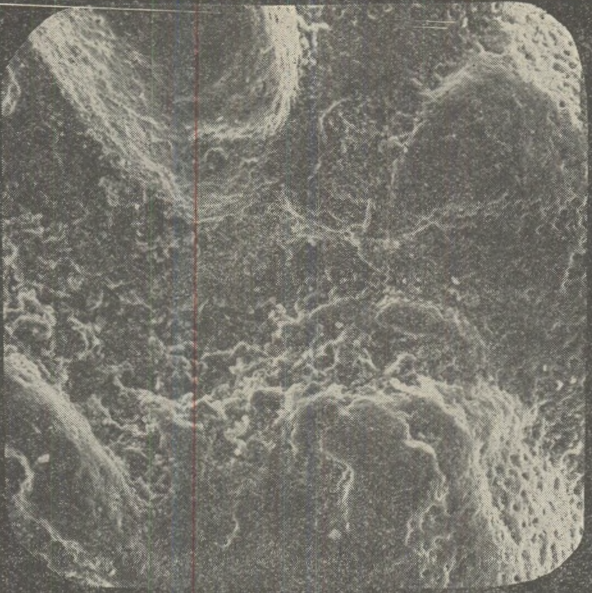
1. *Praeglobotruncana delrioensis* (PLUMMER)
   dorsal view, 100x, 171 m
2. *Globigerinelloides bentonensis* (MORROW)
   171 m, 200x
3. *Praeglobotruncana stephani* (GANDOLFI)
   lateral view, 449 m, 100x
4. *Globigerinelloides bentonensis* (MORROW) – aeglefordensis type
   171 m, 150x
5. *Hedbergella delrioensis* (CARSEY)
   dorsal view, 427 m, 200x
6. *Favusella washitensis* (CARSEY)
   dorsal view, 47 m, 100x
7. *Hedbergella simplex* (MORROW)
   dorsal view, 427 m, 120x
8. *Hedbergella planispira* (TAPPAN)
   dorsal view, 171 m, 130x

SEM photographs, Jásd – 42 stratotype borehole

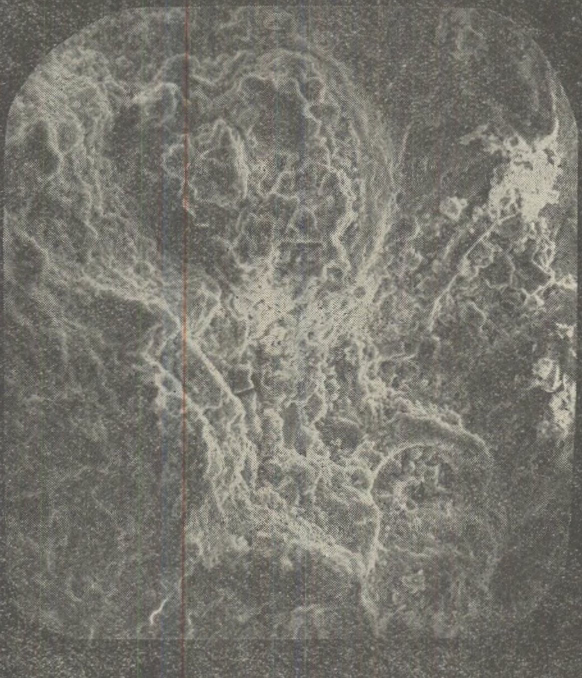
PLATE V.

1. *Praeglobotruncana delrioensis* (Plummer)
   dorsal view, 100x, 171 m
2. *Globigerinelloides bentonensis* (Morrow)
   171 m, 200x
3. *Praeglobotruncana stephani* (Gandolfi)
   lateral view, 449 m, 100x
4. *Globigerinelloides bentonensis* (Morrow) – aeglefordensis type
   171 m, 150x
5. *Hedbergella delrioensis* (Carsey)
   dorsal view, 427 m, 200x
6. *Favusella washitensis* (Carsey)
   dorsal view, 47 m, 100x
7. *Hedbergella simplex* (Morrow)
   dorsal view, 427 m, 120x
8. *Hedbergella planispira* (Tappan)
   dorsal view, 171 m, 130x

SEM photographs, Jásd – 42 stratotype borehole



1



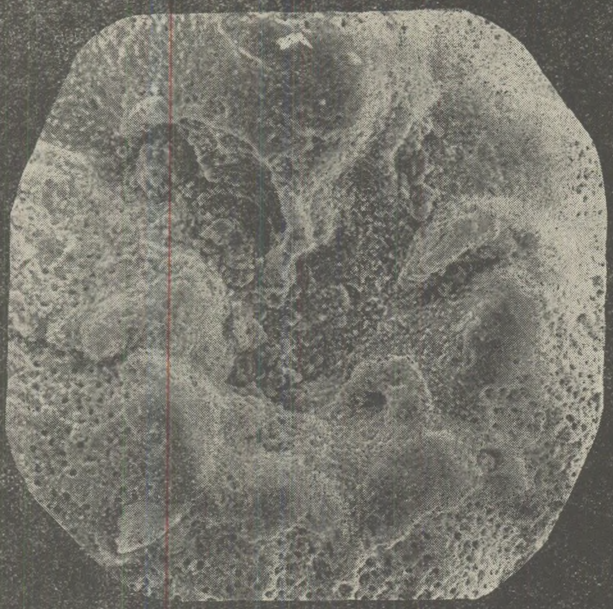
2

PLATE VI.

1. *Rotalipora appenninica* (RENZ)
umbilical region with secondary apertures, and thickening of sutures on older chambers
295 m, 400x

2. *Rotalipora gandolfii* LUTERBACHER et PREMOLI SILVA
umbilical region with the main aperture, with secondary apertures, and with umbilical thickening on the chambers
Part of Plate II, fig. 2. 400x 305 m

SEM photographs, Jásd – 42 stratotype borehole



1

2

PLATE VII.

1. *Rotalipora brotzeni* (SIGAL)
   umbilical region with main aperture, with secondary apertures and umbilical ring
   171 m, 400x
2. *Globigerinelloides bentonensis* (MORROW)
   umbilical region with secondary apertures and main aperture
   171 m, 480x

SEM photographs, Jásd – 42 stratotype borehole

Photographs: Takács and Bodrogi, laboratory works: Pellérdy

1/b. Rotalipora appenninica – Guembelitria cenomana Subzone

Lower boundary: disappearance of *Planomalina buxtorfi* (GANDOLFI) and *Rotalipora ticinensis* (GANDOLFI)

Upper boundary: apperance of *Rotalipora brotzeni* (SIGAL)

Section: 363,0 – 427,0 m

Age: Upper Vraconian

Thickness: 64 m

Zonation was based on the following species:

Guembelitria cenomana (KELLER, 1938)

Rotalipora appenninica (RENZ, 1936)

Rotalipora globotruncanoides (SIGAL, 1948)

Rotalipora gandolfii LUTERBACHER et PREMOLI SILVA, 1962

Separation of the two subzones is problematic; we could not carry out the separation by apperance of new species, as designated by the Subcommission on Cretaceous Stratigraphy (BIRKELUND, 1983). Without appearing new species, two disappearing species, *Rotalipora ticinensis* (GANDOLFI) (disappears at 420 m), *Planomalina buxtorfi* (GANDOLFI) (disappears at 425 m), and appearance of a conspicuous variation of *Rotalipora appenninica* (RENZ), the *R. appenninica* (RENZ) var. *evoluta* (SIGAL) (415 m) represents the boundary of the two subzones, containing 10 metres of marl. The middle of this section (about 421 m) is very near to the lower boundary of the ammonite subzone (422, 5 m)

Lower boundary of Rotalipora appenninica Zone is the same as the lower boundary of 1/a subzone, while its upper boundary equals with the upper boundary of 1/b subzone.

2. Rotalipora brotzeni Zone

Lower boundary: appearance of *Rotalipora brotzeni* (SIGAL)
Upper boundary: not determined due to facies change
Age; Lower Cenomanian
Section: 141,0 – 363,0 m
Thickness: 222,0 m

The zone contains the middle lithostratigraphic unit of Pénzeskút Marl: dark grey dolomitic marl (293,4 – 363,0 m), dark grey dolomarl (145,0 – 293,0 m), and the lowest 4 metres of the upper lithostratigraphic unit: dolomitic, silty marl with clayey marl intercalations. Lithological change is continuous in the two zones; above 145 m pelitic sedimentation is gradually changed to clastic deposition.

The very rich foraminifer fauna consists of 15 planktonic species of high diversity and in large numbers.

Planktonic foraminifer species:

Globigerinelloides bentonensis (MORROW, 1934)
Globigerinelloides escheri (KAUFMANN, 1919)
Favusella (H.) washitensis (CARSEY, 1926)
Hedbergella delrioensis (CARSEY, 1926)
Hedbergella brittonensis (LOEBLICH ET TAPPAN, 1961)
Hedbergella planispira (TAPPAN, 1940)
Heterohelix washitensis (TAPPAN, 1940)
Heterohelix moremanni (CUSHMAN, 1938)
Praeglobotruncana delrioensis (PLUMMER, 1931)
Praeglobotruncana stephani (GANDOLFI, 1942)
Rotalipora appenninica (RENZ, 1934)
Rotalipora globotruncanoides (SIGAL, 1942)
Rotalipora micheli (SACAL et DEBOURLE, 1957)

Rotalipora brotzeni (SIGAL, 1948)

The zonation is based on *Rotalipora brotzeni* (SIGAL, 1948). Lower boundary is drawn at its first appearance. Its diversity is low, the specimens are small but easily recognizable.

The evolution of the fauna is continuous, no sudden changes were recognized. First overview of the material indicated a monotonous series of samples. Detailed examination revealed a multitude of transitional forms between the well-defined species, with divergences form the type species, trends in variation and morphological varieties.

The zone cannot be subdivided by the appearance or disappearance of species; however around 250 m large size *Rotalipora appenninica* (RENZ) varieties appear with flat dorsal side, and coarsely ornamented *Favusella washitensis* (CARSEY) appear.

With the beginning of clastic sedimentation (between 141 – 208 m) the fauna became poorer in specimens, while above 141 m taxa began to disappear, together with decrease in size.

A new species, *Rotalipora montsolvensis* (MORNOD, 1950), common in the upper two thirds of the Rotalipora brotzeni Zone, was not found in our material. Probably, the facies change has began before its appearance (BODROGI, 1985).

The regressive series

is represented by the Jásd Sandstone (6,9 – 141 m). Its foraminifer fauna contains poorly preserved forms of the Rotalipora brotzeni Zone, without the appearance of stratigraphically important species. (Fig. 3). Its planktonic assemblage is not suitable to solve stratigraphical problems, due to ecological problems.

MONOSTORI M. considers the Jásd Sandstone as a non-regressive series by ostracod studies. Depositional encivironment of this thick clastic series may be determined by further lithological, and palaeontological investigations. However, we know, that at the boundary of Upper Albian (s. str.) and Vraconian there was considerable deterioration of the climate, contemporaneously with strong tectonic activity.

Deposition of the platform-type Zirc Limestone underlying the Pénzeskút Marl was stopped by a brief emersion of the area, connected with glauconisation (Tabular Limestone Member). The following sedimentary cycle, (Pénzeskút Marl) began with strong glauconite deposition, with phosphoritic, condensed sediments, subtropical and temperate zone mega- and microfauna. The area subsided suddenly; coagulated chemical sediments were deposited in a sublittoral environment, changed to clastic sedimentation by the end of Early Cenomanian, with contemporaneous death of the fauna.

The most probable cause of the clastic sedimentation might have been the emersion of the source area, with increasing relief energy and rapid erosion with fluviatile transport. However, there is trace of decrease in salinity. This event did not affect the nannoflora. Among the contemporaneous effects of several factors the cooling of the climate might had the most significant role, with dominance of clastic sedimentation and impoverishment of the fauna.

Correlation of the Jásd – 42 stratotype profile, ecological conditions, and faunal relationships will be discussed in the second part of this paper.

REFERENCES

BIRKELUND, T. (1983): Setting the Stage and drawing the Line. – Cretaceous Stage Boundaries, p. 1 – 5, Coppenhagen, October 18 – 21.

BODROGI, I. (1985): Die stratigraphische Untergliederung die Pénzeskuter Mergel – Formation mit Hilfe von Foraminiferen. – Beiträge zur Stratigraphie und Paläogeographie der Mittleren Kreide Zentral-Europas. Ergäbnisse der Mitteleuropäische Gruppe im Projekt 73/1/58 – Mid Cretaceous Event, Österreischische Akademie der Wisseschaften, Schriftenreiche der Erdwissenschaftlichen Komissionen, Band 7:97 – 113, Tafel 1 – 4, figs. 1 – 28, Wien, New York.

CSÁSZÁR, G., HAAS, J. (1984): The Cretaceous in Hungary: A Review. – Acta Geologica Hungarica 27/3 – 4); pp. 417 – 428: figs. 7., Budapest.

CSÁSZÁR, G. (1985): Übersicht der Referenzprofile der Mittelkreide Ungarns. – Beiträge zur Stratigraphie und Paläogeographie der mittleren Kreide Zentral-Europas. Ergäbnis der Mitteleuropäischen Gruppe im Projekt 73/1/58 – Mid Cretaceous Events. Österreichische Akademie der Wissenschaften, Schriftenreihe der Erdwisseschaftliche Komissionen, Band 7:67 – 93, figs. 21., Wien, New York.

HORVÁTH, A. (1985): Ammoniten-Stratigraphie der Pénzeskut Mergel-Formation. – Beiträge zur Stratigraphie und Paläogeographie der mittleren Kreide Zentral-Europas. Ergäbnis der Mitteleuropäischen Gruppe in Projekt 73/1/58 – Mid Cretaceous Events. Österreischische Akademie der Wissenschaften, Schriftenreiche der Erdwissenschaftliche Komissionen, Band 7:149 – 173, Tafel 1 – 4, figs, 35, Wien, New York.

JUIGNET, P. (1976): Presentation du Crétacé moyen dans L'Ouest de la France – Remarque sur les stratotypes du Cenomanien et du Turonien. Ann. Mus. Hist. Nat. Nice. 4/2/: 1 – 12, 4 figs., 15 tab., Nizza.

JUIGNET, P. (1978): Le Cenomanien du Maine: formation sedimentaires et faunes d'Ammonites du stratotype. – Geol. Mediterannéenne, 5/1/:87 – 100, figs. 1 – 11, Marseille.

MAJZON, J. (1943): Előzetes jelentés a Zirc-Bakonycsernye közötti terület földtani viszonyáról. – MÁFI Évi Jelentés 1939 – 1940-ről, pp. 263 – 270, Budapest.

MAJZON L. (1966): Foraminifera vizsgálatok. – Akadémiai kiadó, p. 1 – 600, Budapest.

SCHOLZ, G. (1973): Geologische und stratigraphische Verhältnisse der mittelkretazischen Schichten des Bakony-Gebirges bei Nána und Pénzeskút. – Földtani Közlöny 103/2, 175 – 188, 2 figs., 2 pl., Budapest

SCHOLZ, G. (1979): Die Ammoniten des Vracons (Oberalb, dispar-Zone) des Bakony-Gebirges (Westungarn) und eine Revision der wichtigsten Vracon-Arten der westmediterranen Faunenprovinz. Teil 1 und 2. – Palaeontographica, Abt. A. 165/1 – 2, 1 – 80, 13 pl, 21 figs., 165/3 – 6, 81 – 136, 17 pl., 20 figs., Stuttgart.

SIDÓ, M. (1966): A bakonyi cenoman rétegek Foraminifera vizsgálata. Studium der cenomanischen Abteilungen des Bakony-gebirges anhand von Foraminiferen. MÁFI Évi Jelentés 1964-ről, pp. 223 – 243, 2 tabl., 4 ábra, Budapest.

SIDÓ, M. (1971): A bakonyi és vértesi rotalipórás-turriliteszes márgaösszlet Foraminifera-társulásai. – Földtani Közlöny, Bull. of the Hungarian Geol. Soc., 101/1/: 44 – 52.

SIGAL, J. (1977): Essai de zonation de Crétacé mediterrannéen á l'aide des foraminifers planctoniques. – Geol. Mediterannéenne, 4/2/:99 – 108, Marseille.

WONDERS, A. A. H. (1978): Phylogeny, classification and biostratigraphic distribution of keeled Rotaliporinae (I.) Proc. Kon. Nederl. Wet. B., 81/1/:113 – 124,5 figs., Amsterdam.

MOLLUSC FAUNA AND FLORA OF THE PANNONIAN QUARTZ SANDSTONE AT MINDSZENTKÁLLA, HUNGARY

by

I. MAGYAR

Department of Palaeontology, Eötvös University, Budapest

Present address: Hungarian Hydrocarbon Institute,

H – 2443 Százhalombatta, P.O. Box 32, Hungary

(Received: 30th May, 1987)

Abstract

The mollusc fauna and flora collected from the Pannonian Kálla Sandstone at Mindszentkálla are preserved as internal and external moulds. The frequent *Congeria* sp., *Lymnocardium* cf. *sopronionse* and *Unio atavus* indicate the E zone of the Vienna basin. The flora (determined by L. Hably and Zs. Debreczy) includes Mediterranean species, which occur also in the Sarmatian flora of the Tokaj Mts.

Introduction

The margins of the Transdanubian Midmountains and the shores of Lake Balaton display classical localities of Pannonian and Pontian flora and fauna. Description of the exposures and their rich fossil content was made by several authors from 1835 up to now, e. g. Partsch (1835), Fuchs (1870), Halavàts (1911), Lőrenthey (1911), Vitális (1911), Strausz (1942a), Bartha (1959), Korpás – Hódi (1983), Müller – Szónoky (in prep.).

Besides the older, well-known localities some new ones have been established, like the quarry at Mindszentkálla. Its fossils have been mentioned by the lithostratigraphic study of Jámbor (1980) only. The species of this flora and fauna are discussed in the present paper.

Pannonian formations of the Kál basin (Fig. 1)

The basement of the Kál basin is made of Permian red sandstone to the southwest and Triassic carbonate rocks to the northeast. Pannonian sedimentary rocks overlie them disconformably: clay, sand and sandstone, gravel and conglomerate (Kálla Gravel – Quartz Sandstone Formation, Jámbor, 1980). The often similar Permian and Pannonian sandstones were first distinguished by Lóczy (1916). He said, that the sand and sandstone margins of the Kál basin were formed by beach dunes of a former embayment of the Pannonian lake. The mouth of the bay was at Káptalantóti towards the Tapolca basin. Hajós (1954) indicated that the sandstone and the underlying sand have the same grain size distribution. The siliceous

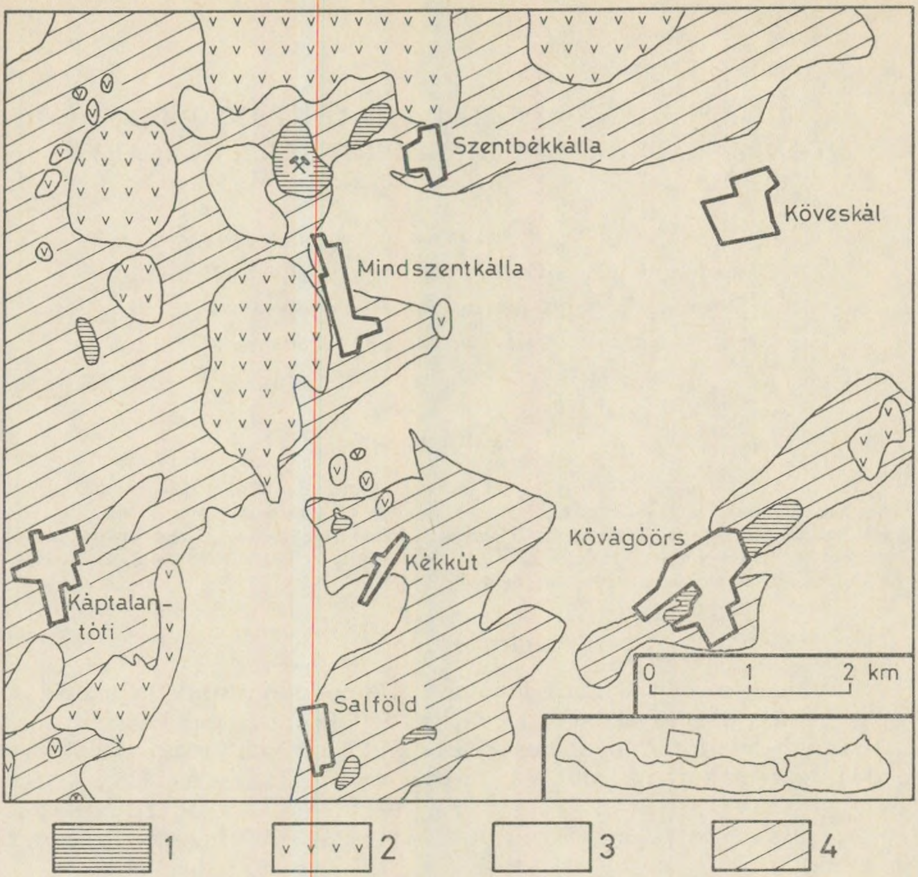


Fig. 1. The Pannonian sandstone in the Kál basin. Legend: 1: Pannonian quartz sandstone; 2: Pannonian basalt; 3: Pre-Pannonian rocks; 4: Pannonian basement (sand, clay).

matrix cemented the sand as lenses and banks; the latter preserved the underlying sand from erosion. There is a strong correlation between the cementation and gravel content of the sand (BIHARI, pers. commun.). Fragmentation and tilting of the sandstone and conglomerate beds and boulders formed the boulder fields at Kővágóörs, Salföld, Mindszentkálla and Szentbékkálla, parts of which are nature conservation areas.

The Mindszentkálla quarry

Mindszentkálla village lies at the NW margin of Kál basin, 9 km E of Tapolca. The quarry is located 1 km N of the village.

The Km – 133 borehole, drilled in the quarry yard, hit the Triassic basement at 28 m depth. The Trias is overlain by 17 m clay, 3 m silty sand

and 8 m fine sand. The latter is partly exposed by the quarry. The sand is overlain by some cm or dm thick limonite-cemented red sandstone, and by 2 – 5 m thick quartz sandstone. The latter is fine-grained at the bottom, pebbly sand at middle levels; the top is formed of some cm to 1 m thick conglomerate. The sand and gravel grains are made of quartzite, the cement is silica, therefore SiO_2-content exceeds 98,5%.

The pebbles are well rounded, 2 – 10 cm in diameter. These form some mm to dm thick graded beds in the sandstone, frequently displaying cross-bedding. Also occur in small lenses (with graded bedding) and as isolated pebbles. The orientation of small pebbles behind a larger one indicate SW to NE current transport, parallel with the supposed shoreline.

The quartz sandstone bed is cut by vertical fractures, filled by loess and soil.

Preservation of fossils

The fossils recovered from the quartz sandstone bed are external and internal moulds. During the fossilization process the calcareous shell was simultaneously being dissolved from the external and internal side as well. On specimens of the bivalve *Lymnocardium* cf. *sopronìense* the outline of the ribs clearly follow the internal morphology of the shell, while muscle scars are missing (i. e. cut by the ribs). Growth lines, mostly characteristic for the external morphology, are clearly visible.

The plant fossils are mostly external moulds, but internal moulds occur, too (e. g. stems of Monocotyledonae). Plastic casts of external moulds of fir cones were prepared to facilitate determination and photography.

External and internal moulds are frequently coloured by iron and mangenese precipitates.

Fauna and flora

Fossils of the Mindszentkálla quarry were first mentioned by JÁMBOR (1980, p. 201): „M. Korpás-Hódi identified a *Congeria* sp. belonging to either *C. subglobosa* or *C. sopronensis* as well as the forms *Lymnocardium* cf. *schmidti* (M. HÖRN.) and and *Lymnocardium variocostatum* VITÁLIS. As for the biostratigraphic position of this formation, it must certainly belong, as indicated by its fauna, to the Congeria ungulacaprae Horizon."

The following forms were determined by the present author:

Congeria sp.	(7 specimens)
Lymnocardium cf. *sopronìense* VITÁLIS	(21)
Lymnocardium cf. *majeri* (HÖRNES)	(2)
Lymnocardium sp. (indet.)	(4)
Unio atavus HÖRNES	(5)
Melanopsis cf. *fossilis* (MARTINI – GMELIN)	(1)
Gastropoda sp. (indet.)	(1)

I think, that this fauna is older than that of the Congeria ungulacaprae Horizon, i. e. it is not Pontian, but Pannonian. It is similar to the fauna of Sopron, Eisenstadt and the Vienna basin (E zone).

Angiosperm plants were kindly determined by L. Hably, and pines by Zs. Debreczy:

Myrica sp. I.	(1)
Myrica sp. II.	(1)
Rhamnus alaternus Linné	(1)
Liriodendron (?) sp.	(3)
Pinus halepensis Miller	(2)
Pinus cf. *rostrata* (Miller)	(2)
Pinus cf. *sylvestris* Linné	(2)
Pinus sp.	(1)

Other plant fossils, which locally abundantly occur, are mostly indeterminable fragments of monocotyledonous and dicotyledonous stems and leaves. The species *Rhamnus alaternus* and *Pinus halepensis* – together with several *Myrica* species – occur in the Sarmatian flora of the Tokaj Mts. (Andreánszky, 1959).

Congeria sp.

(Plate 1, fig, 1 – 2)

Large size, extremely variable specimens of the form group *Congeria subglobosa – Congeria pancici*. Lueger (1980, Taf. 2, Fig. 4a – b) published similar Congerias from Eisenstadt (Fölligberg). Like those ones, the specimens from Mindszentkálla display quadrangular outlines and bear two sharp ribs *(C. pancici)*, and have a strongly concave lunule (*C. subglobosa)*.

The species *Congeria subglobosa* is known from several localities in the Pannonian basin, but is not a good index fossil due to its long range according to Hungarian authors (Strausz, 1942b).

Lymnocardium cf. *sopronîense* Vitális, 1934

(Plate 1, fig. 4)

It is the most frequent fossil at Mindszentkálla. This species was described by Vitális (1934) from the Pannonian exposures at Sopron, with special care to determine the characters distinguishing it from other large-size Lymnocardiums *(L. schmidti, L. penslii, L. variocostatum)*. Strausz (1942a) indicated that *L. sopronîense* is an intraspecific, local variety of *L. variocostatum*, the latter being a subspecies of *L. penslii*. The latter two fossils are index fossils of the Pontian, so-called *Congeria ungulacaprae* beds. Although the evolutionary relationships of these forms are not clear, I think, that the *L. sopronîense* cannot be considered as a local variety, since it occurs in great numbers, for example in the Mály Clay in Northern Hungary.

The characters typical for *L. schmidti* and *L. variocostatum* have not been found on the internal moulds from Mindszentkálla. The keel characteristic for *L. schmidti* is missing from the edge of the area; also, the "auricle" of *L. variocostatum* is missing at the junction of the anterior and dorsal margins. Therefore, our specimens belong to the *L. soproniense* VITÁLIS species due to their outline, size and number of ribs.

Lymnocardium cf. *majeri* (HÖRNES, 1870)

(Plate 1, fig. 3)

The specimen from Mindszentkálla differs from the type *L. majeri* in the number of ribs: the species of HÖRNES bears 12 – 13 ribs, our specimen bears 22 ribs. Possibly, this character is not enough for determination, since HALAVÁTS (1886) and others indicated great variability in the number of ribs.

L. majeri is not known from the Vienna basin. However, in Hungary it occurs in a wide range: associated with *Congeria czjzeki* (KORPÁS – HÓDI, 1983) and with *Congeria balatonica* (STRAUSZ, 1952a).

Unio atavus (HÖRNES, 1870)

(Plate 1, fig. 5)

1870 *Unio atavus* PARTSCH – HÖRNES, Taf. 37, fig. 2
non 1870 *Unio bielzi* FUCHS – FUCHS, Taf. 17, fig. 8 – 10
non 1902 *Unio halavatsi* BRUSINA – BRUSINA, Taf. 24, fig. 1 – 4
1953 *Psilunio atavus* (PARTSCH, HÖRNES) – PAPP, Taf. 17, fig. 3
non 1959 *Unio atavus* PARTSCH – BARTHA, Taf. 7, fig. 1 – 2
1980 *Psilunio atavus* (HÖRNES) – LUEGER, Taf. 4, fig. 7 – 8

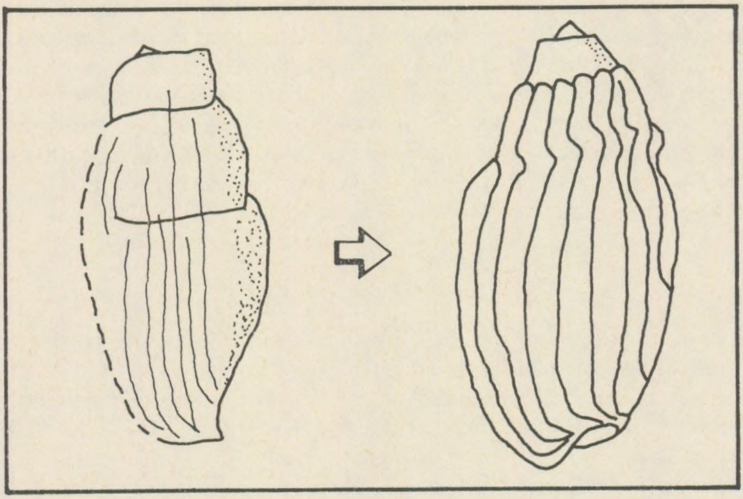


Fig. 2. Reconstruction of a *Melanopsis fossilis* internal mould.

While this species is characteristic for the E zone (Papp, 1953) in the Vienna basin, it is considered as a poor index fossil in Hungary. Its differentiation from *Unio mihanovici* (= *Unio halavatsi*) was unclear for a long time (Strausz, 1942a). Müller has shown lately (Müller – Szónoky, in prep.) that there is a definite difference between the form *brunni* described by Hörnes, and the Tihany specimens of *radmanesti* described by Brusina in the position of the umbo. The Mindszentkálla specimens belong to the species *Unio atavus* Hörnes after their less eccentric umbo raised above the dorsal margin.

Melanopsis fossilis (Martini – Gmelin, 1790)

(Fig. 2; Plate 1, fig. 6)

Single, poorly preserved specimen. It is an internal mould, boundaries of the whorls are indicated by constrictions. Growth lines crossing the last two whorls indicate that the last whorl of the original shell has covered the preceding ones in great heights. This "reconstruction" suggests ranging to the. *M. fossilis* species.

Rhamnus alaternus Linné

(Plate 2, fig. 5)

Typical plant of the macchia. It can withstand arid climate better than other plants of the macchia (Andreánszky, 1959). The species and its relatives today live under Mediterranean climate, from the Canary Islands through Europe to Anatolia.

Pinus halepensis Miller

(Plate 2, fig. 6)

The Aleppo Pine (Jerusalem Pine) is the most widespread pine in the Mediterranean realm. Its present area extends from Gibraltar to Lebanon. It is one of the few pine species native in North Africa. It prefers arid, rocky habitats, especially made of limestone; well adapted to long, dry summers. Rarely occurs in closed forests, but lives mixed with Mediterranean vegetation. Its upper limit is 200 m above sea level in Dalmatia and 1700 m in Morocco. Most frequent along the seashores, However, fossil Aleppo Pines indicate an area extending far to the north (Mirov, 1967).

Environment and climate

Litho- and biofacies of the Mindszentkálla Sandstone indicate a high energy, lakeshore environment with waves (Fig. 4).

Several authors (e. g. Szatmári, 1971) studied the formation of pure quartz sand. During sand deposition the Kál basin might have been an embayment bordered by fracture-formed cliffs. The pure quartz sand was deposited in a wet climate, in the lake with insignificant salinity. Organic acids might had influence on the composition.

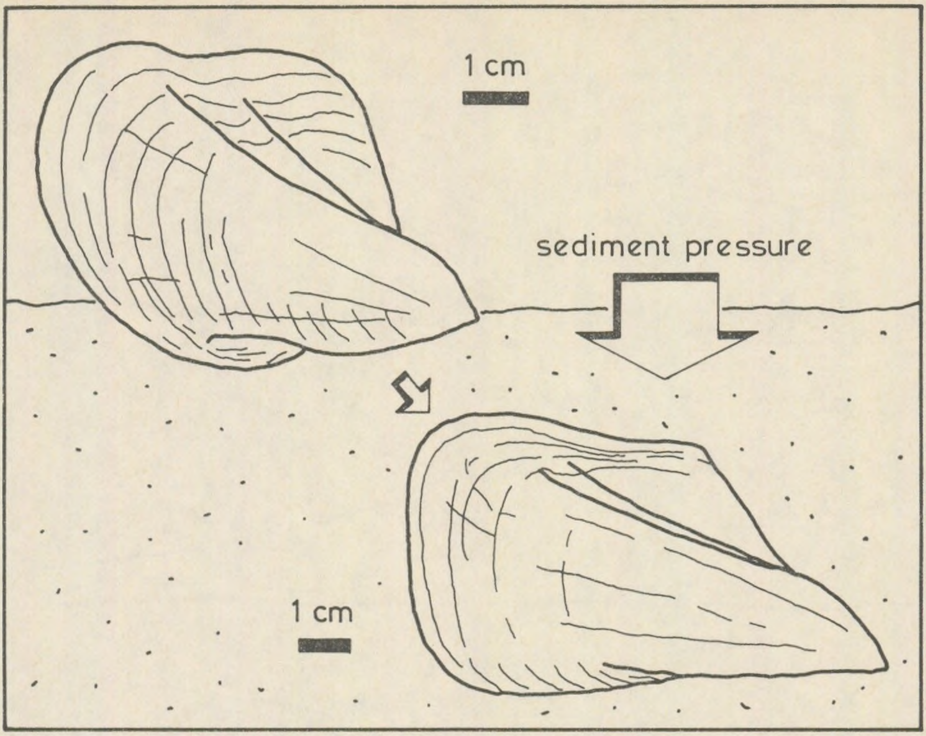


Fig. 3. Deformation of *Congeria* buried in life position.

Due to unfavourable conditions, the largest, thick-shelled fossils have remained only. Their presence indicate strongly agitated, shallow water. The thick shell is a means of even the byssate Congerias of mechanical stabilisation on a moblile substratum. *Lymnocardium* valves occur mostly impaired due to intense agiatation of water. The Unios were fossilized as open, but paired valves, while most of the Congerias as closed, double valves. These differences in preservation are due to different toughness of the ligament.

Proximity of the shore is indicated by the local abundance of plant fragments. Sand deposition might have been periodical: occasionally the molluscs were buried in life position, as observed on some *Congeria* specimens, compressed parallel with the comissure plane (Fig. 3).

It is very hard to give numerical estimates for the salinity of this bay, although there are detailed scales (BARTHA, 1971; KORPÁS–HÓDI, 1983) based on fossil assemblages. While there are living species of the genera *Congeria, Unio, Melanopsis,* but their environmental needs are hard to compare with their Pannonian ancestors. We know, that Recent species themselves are not uniform in this point of view: Congerias live both in the caves of Dalmatia and in the harbour of Antwerp (DAVITASHVILI and MERKLIN,

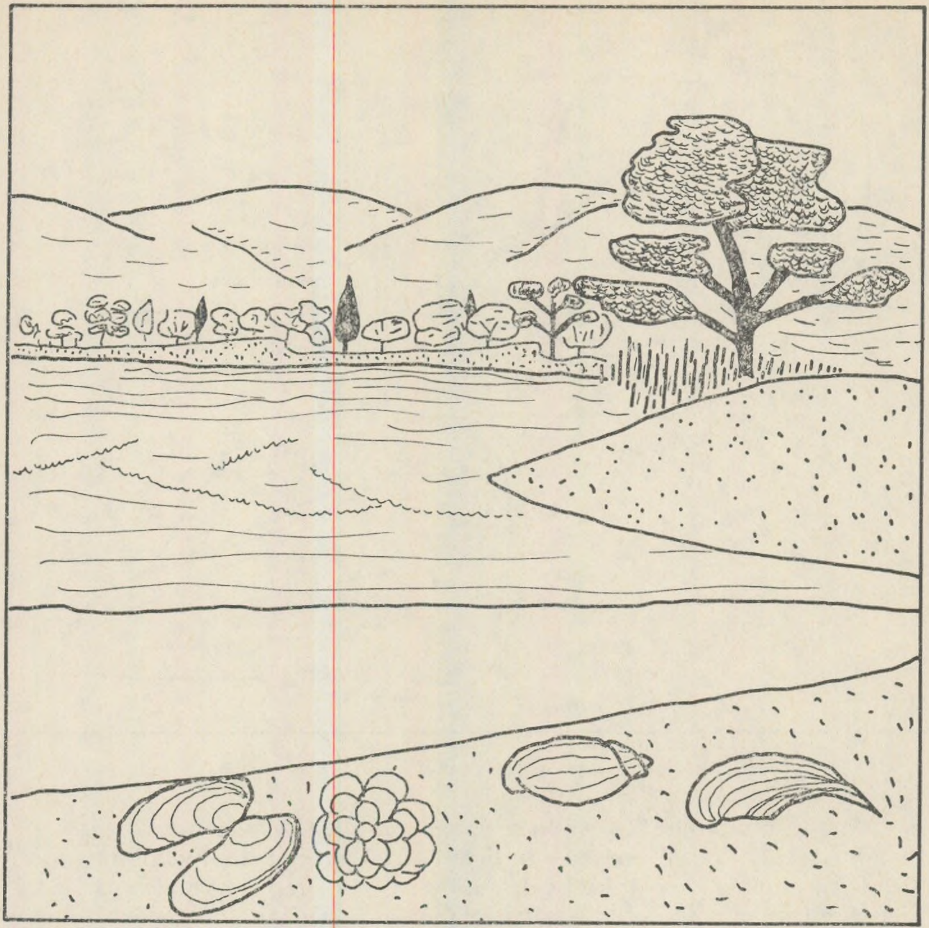


Fig. 4. The Pannonian landscape at Mindszentkálla.

1966). Also, the today exclusively freshwater *Unio* genus contains Pannonian species *(U. atavus, U. mihanovici),* which occur together in great numbers with the marine, probably brackish water Lymnocardiums.

The plant community unanimously indicates Maditerranean climate of the lakeshore, due to the moderating influence of the large mass of water of the Pannonian lake. Recent *Myrica* species live along sea and lake shores, mostly on brackish water marshes and on dunes. Majority of them keep their leaves or evergreen. The *Rhamnus alaternus* and the Aleppo Pine exclusively live in Mediterranean regions with winter rainfall, and 15 – 18 °C yearly median temprerature. The contradiction between the xerophilous flora and the high rainfall needed to form pure quartz sand can be solved. For example, the Aleppo Pine lives in southern Dalmatia, under 2000 mm yearly rainfall, too. The distribution of precipitation, the microclimate and the rocks on the surface – Pannonian dune sand or Triassic karst here – are the major factors for the formation of the edaphic plant community.

Acknowledgements

Sincere thanks are due to ZOLTÁN VASS, quarry-master, for collecting the fossils during quarrying; to GYÖRGY BIHARI and PÁL MÜLLER, geologists, for professional help; and to LILLA HABLY and ZSOLT DEBRECZY, palaeontologists, for the determination of plant fossils.

REFERENCES

ANDREÁNSZKY G. (1959): Die Flora der Sarmatischen Stufe in Ungarn. – Akadémiai Kiadó, Budapest

BARTHA F. (1959): Feinstratigraphische Untersuchungen am Oberpannon der Balatongegend. – Annales Inst. Geol. Publ. Hung. 48 pp. 1–191.

BARTHE F. (1971): A magyarországi pannon biosztratigráfiai vizsgálata. – in: A magyarországi pannonkori képződmények kutatásai pp. 9–172. Akadémiai Kiadó, Budapest (In Hungarian)

BRUSINA S. (1902): Iconographia molluscorum fossilium in tellure tertiaria Hungariae, Croatiae, Slavoniae, Dalmatiae, Bosniae, Herzegovinae, Serbiae et Bulgariae inventorum. – Zagreb.

DAVITASHVILI L. S. – MERKLIN R, L. (eds.) (1966): Spravochnik po ekologii morskih dvustvorok. – Moscow

FUCHS TH. (1870): Beiträge zur Kenntnis fossiler Binnenfaunen 4 und 5: Die Fauna der Congerienschichten von Tihany am Plattensee und Kup bei Pápa in Ungarn. – Jahr˙ buch d. k. k. Geol. Reichsanstalt 20 pp. 351–548.

HAJÓS M. (1954): Quarzsandstein-, Glas- und Giessand-Vorkommen aus Alsókőhát und Nyárvölgy in Kővágóörs. – Földtani Közlöny 84 pp. 356–361.

HALAVÁTS GY. (1886): Őslénytani adatok Délmagyarország neogén korú üledékei faunájának ismeretéhez. – A m. kir. Földt. Int. Évk. 8 pp. 117–135 (In Hungarian)

HALAVÁTS GY. (1911): Die Fauna der pontischen Schichten der Umgebung des Balatonsees. – in: Resultate der wissenschaftlichen Erforschung des Balatonsees 1/1/Pal. Anh. 4/2 pp. 1–80.

HÖRNES M. (1870): Die fossilien Mollusken der Tertiärbeckens von Wien. – Abh. d. k. k. Geol. Reichsanstalt, Wien.

JÁMBOR Á. (1980): Pannonian in the Transdanubian Central Mountains. – Annales Inst. Geol. Publ. Hung. 62

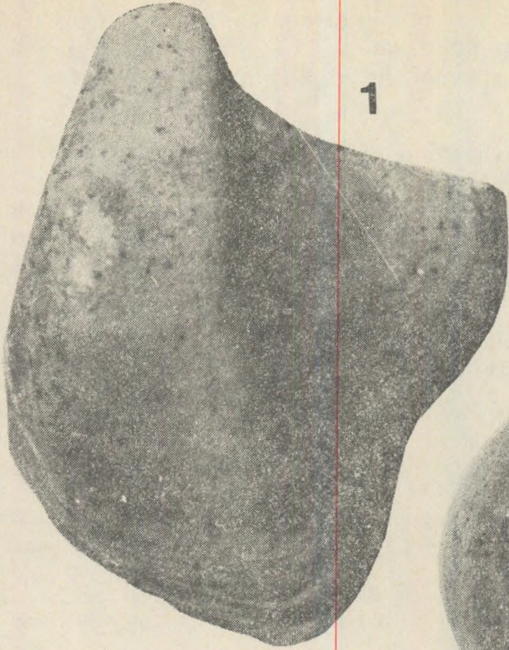
KORPÁS-HÓDI M. (1983): Paleoecology and biostratigraphy of the Pannonian Mollusca fauna in the northern foreland of the Transdanubian Central Range. – Annales Inst. Geol. Publ. Hung. 66.

LÓCZY L. (1916): Die geologischen Formationen der Balatongegend und ihre regionale Tektonik. – in: Resultate der wissenschaftlichen Erforschung des Balatonsees, Wien.

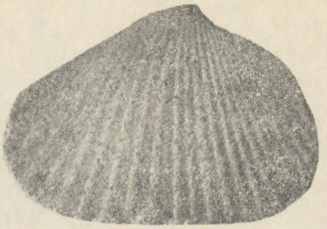
LŐRENTHEY I. (1911): Beiträge zur Fauna und stratigraphischen Lage des pannonischen Schichten in der Umgebung des Balatonsees. – in: Resultate der wissenschaftlichen Erforschung des Balatonsees 1/1/ Pal. Anh. 4/3 pp. 1–215.

LUEGER J. (1980): Die Molluskenfauna aus dem Pannon (Obermiozän) des Fölligberges (Eisenstädter Bucht) im Burgenland (Österreich). -- Mitt. österr. geol. Ges. 73 pp. 95–134.

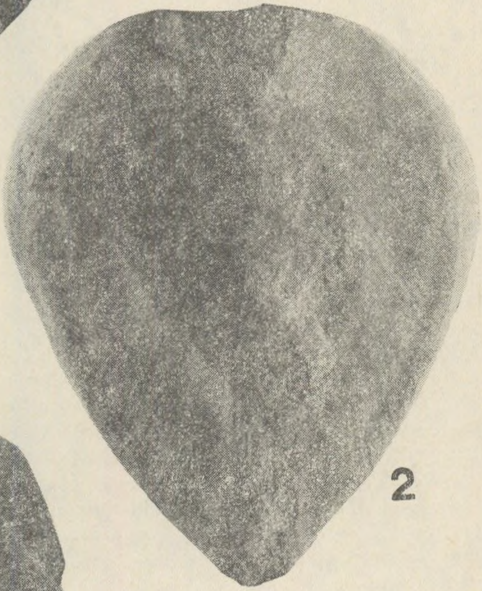
MIROV N. T. (1967): The genus Pinus. – The Ronald Press Co., New York



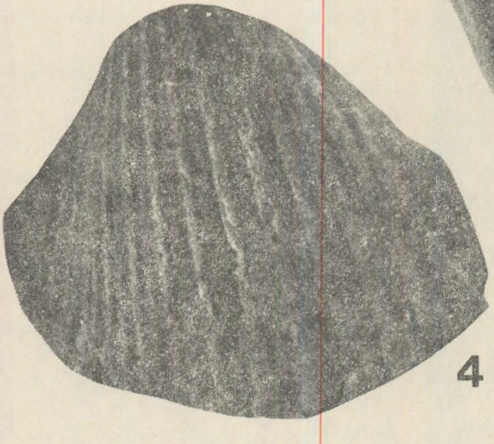
1



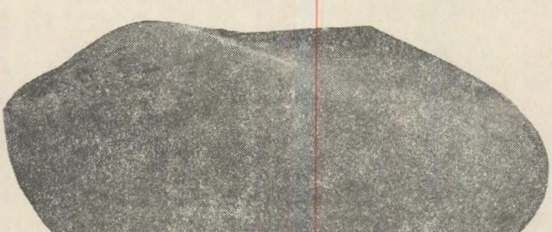
3



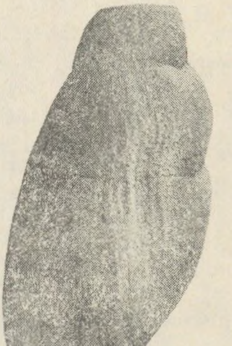
2



4



5



6

PLATE 1.

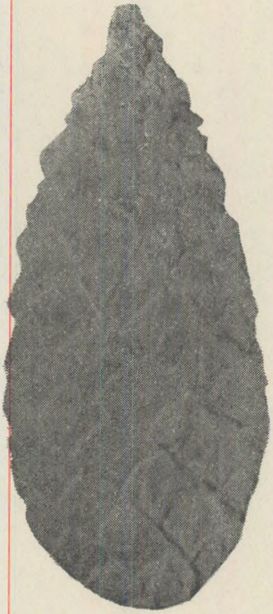
Figs. 1 – 2. *Congeria* sp.

Fig. 3. *Lymnocardium* cf. *majeri* (Hörnes). 1,5 x

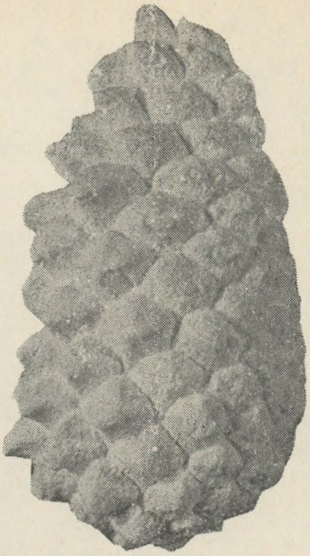
Fig. 4. *Lymnocardium* cf. *sopronienese* Vitális

Fig. 5. *Unio atavus* Hörnes

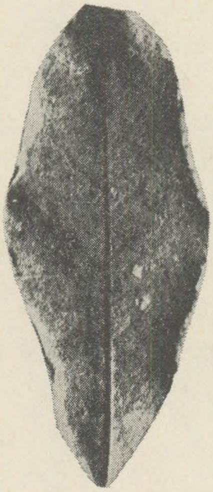
1



2

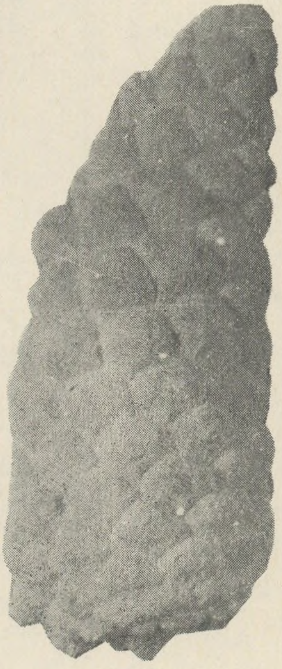


3



4

5



6

PLATE 2.

Figs. 1 – 2. *Pinus* cf. *rostrata* (MILLER)

Fig. 3. *Pinus* cf. *silvestris* LINNÉ

Fig. 4. *Myrica* sp.

Fig. 5. *Rhamnus alaternus* LINNÉ

Fig. 6. *Pinus halepensis* MILLER

MÜLLER P. – SZÓNOKY M. (in prep.): Faciostratotype Tihany-Fehérpart. – in: STEVANOVIC (red.): Chronostratigraphie und Neostratotypen 8. Pontien

PAPP A. (1953): Die Molluskenfauna des Pannon im Wiener Becken. – Mitt. österr. geol. Ges. 44 85 – 222.

PARTSCH P. (1835): Über die sogenannten versteinerten Ziegenklauen aus dem Plattensee in Ungarn. – Annales d. Wiener Mus. d. Naturg. Bd. I pp. 93 – 102.

STRAUSZ L. (1942/a): Das Pannon des mittleren Westungarns. – Annales hist.-nat. Mus. Nat. Hung. 35 pp. 1 – 102.

STRAUSZ L. (1942/b): Pannóniai fauna Dernáról és Tatarosról. – A m. kir. Földt. Int. 1941 évi jelentésének függeléke pp. 191 – 199. (In Hungarian)

SZATMÁRI P. (1971): A kvarchomokképződés feltételei és a magyarországi felső pannon. – in: A magyarországi pannonkori képződmények kutatásai pp. 233 – 252 Akadémiai Kiadó, Budapest (In Hungarian)

VITÁLIS I. (1911): Die Ziegenklauen der Balatongegend und ihre Fundorte. – in: Resultate der wissenschaftlichen Erforschung des Balatonsees 1/1/Pal. Anh. 4/3 pp. 1 – 215.

VITÁLIS I. (1934): Limnocardium soproniense n. sp. – Mathematischer und Naturwissenschaftlicher Anzeiger der Ungarische Akademie der Wissenschaften 51 pp. 705 – 716.

HYDROCARBON GEOLOGY OF THE EXPLORATION AREA SZEGHALOM (BÉKÉS, HUNGARY).

by

A. ABAKA ESSEL

(Abstract of doctoral thesis accepted by Eötvös University, Budapest)

The Szeghalom petroleum occurence found in Békés country in the eastern part of the country is one of the important fields in the Hungarian petroleum industry. The perspectivity of the drilling exploration was justified by the previous seismic measurements. On the basis of these data the area showed a significant increase in pre-Tertiary hydrocarbon formation in Hungary. 53 percent of the fields initial geological hydrocarbon wealth is found in metamorphic rock formations.

Surface geophysical measurement which was started in 1977 proved the presence of geological structure and gave precisely clear picture of the geology and structure of the area. As a result of the surface geophysical measurements and their geological interpretation, the wells located between Szeghalom and Füzesgyarmat communities, a significant oil and natural gas pool was found.

The data of the 48 exploratory wells was able to give a clear picture of the geological setting of the area. The Precambrian basement which is strongly deformed consist of brecciated metamorphic rocks (amphibolites, amphibole – gneisses and small amount of granites).

The Miocene strata is of trangressive character. It's strata begins chiefly with coarse – grained conglomerate, and sandstones which is overlained by calcareous pelites. (limestone, calcareous – marl, marl). The Pannonian strata begins usually with calcareous marls. The upper part of the Lower Pannonian complex is characterized by prograded bedding, sandstone, clay, marl, aleurlite, the Upper Pannonian consists of alternating succession of sandstone and clay beds. Dominantly the young sedimentary rock ends up with terrestrial deposits.

The oil and natural gas in Szeghalom fields is found between 1842 – 2095 meters. The pool consists of two oil fields with rich gascap. The thickness of the gascap in Halom – 1 field does not exceed 100 meters. That of the oil fields varies from 5 – 27 m. The oil-water boundary is tilted, it varies from 1980 – 2015 m below sea level. The gas-oil boundary is relatively uniform, it is about – 1975 m in field – 1 and – 1995 m field – 2. More than 100 drill stem test show that, from the relatively thin oil body it is difficult to gain a water free inflow.

The two fields have a common water body which is actively recharged. The trap is a statigraphic one, its caprock is Lower Pannonian calcareous marl.

70 percent of hydrocarbon bearing rockmass in Halom – 1 reservoir consist of brecciated, fissured metamorphic rock. In the development of the reservoir, an important role was played by the multi-phase regional metamorphism. The formation porosity and water saturation can be reliably determined from well logs. However, direct measurements from the core samples would give much lower porosity values and worse inflow. The same can be established in connection with permeability. Correct permeability values can be estimated from flow rate measurements. The Miocene clastic rocks forms the entire reservoir of the Halom – 2 field. On the grounds of more than 200 values measured on the core samples, the porosity and permeability relationship of the reservoir was well known.

Adequate pressure and temperature data was at our disposal to determine satisfactory physical parameters of the reservoir. The same applies to the determination of natural gas, distillate, petroleum and water characteristics in the reservoir.

I completed the reserves calculation on the basis of the isovol maps drawn from calculated porosity values, well logs, water saturation and effective thickness values.

The initial producable petroleum reserves in the metamorphic reservoir – because of the little knowledge aquired about the reservoir's characteristics – is small, 15 percent. For the Miocene reservoir I calculated 30 percent production.

I took the initial gas reserves production from the field's known analogy as 80 percent.

On the basis of the already known geological and organic geochemical data, it was established that the prospecting area's environments have hydrocarbon formation conditions. The surrounding depressions of the Miocene and the Lower Pannonian age pelitic strata were considered to be oil and gas hydrocarbon potential source rocks. The results of the genetic investigation shows that, the Szeghalom oil- and gas- hydrocarbon were originated from the catagenetic advance degree stage of the Békés deep depressions of the Miocene age source rocks.

The lateral migration of the hydrocarbon generated was made possible by the psammitic development of Pa$_1^{1b}$ lithogenetic unit.

Along the pitch out of Pa$_1^{1b}$ unit, the migration was ensured by the unconformity between the Miocene and the Precambrian basement and/or the coarse – grained Miocene strata.

The hydrocarbon accumulation were found in structure heights of Miocene and Old-Paleozoic reservoir rocks, under several hundred meter thick pelitic seal (Pa$_1^2$ -lithogenetic unit).

Futher hydrocarbon occurrence can be predicted, taking the facies analysis of the area into consideration. The recent outlook of the detailed surface geophysics work offer a proof. Considering the area's up to date hydrocarbon and geological results a further significant quantity – mainly natural gas – may be discovered.

STUDY OF A SPECIAL CASE OF IN SITU IRON AND MANGANESE ELIMINATION: THE VYREDOX AND THE SUBTERRA METHODS (WATERWORK GESZTELY – I)

by

I. ORSOVAI

Institute of Applied and Engineering Geology, Eötvös Loránd University, Budapest

(Received: 30th March, 1988)

Abstract

Due to a technical failure in the iron-manganese elimination experiment (Vyredox method) tried in a producing well, originally surrounded by three absorbing wells, had to be transformed into a so-called subterra system of alternating function in a single well.

The same hydrogeological and operating circumstances enabled us to make a comparison between the two methods. According by, both methods are suitable for iron-manganese elimination under the hydrogeological conditions given.

Calculations for the subterra method have shown the method just economical with a pertinent water quality still acceptable when keeping a ratio of 1 to 4 between water intake and production.

Introduction

The in situ iron-manganese elimination methods act basically in two different systems:

a) The water, enriched in oxygene, is recharched in three or more test wells around the producing well.

b) On single well serves alternatively for recharge and a production as well.

The efficiency of the two methods is approximately the same; it depends on technical and economical parameters which method is more suitable in a certain case.

Though both methods are well-known and widely studied, this is their first comparative examination made in Hungary. Both methods were applied to the same well at different time.

Geological and hydrogeological make up

The study area is situated on the gravel terrace of the river Hernád, which is considered to be Early Holocene – Late Pleistocene because it lies +110 – +112 m above the sea level (Fig. 1.).

According to the generalizable sequence of the study area, from the surface the A + B + C level of the soil is approximately 1 m thick, under which brown sandy clay about 15 m thick can be found.

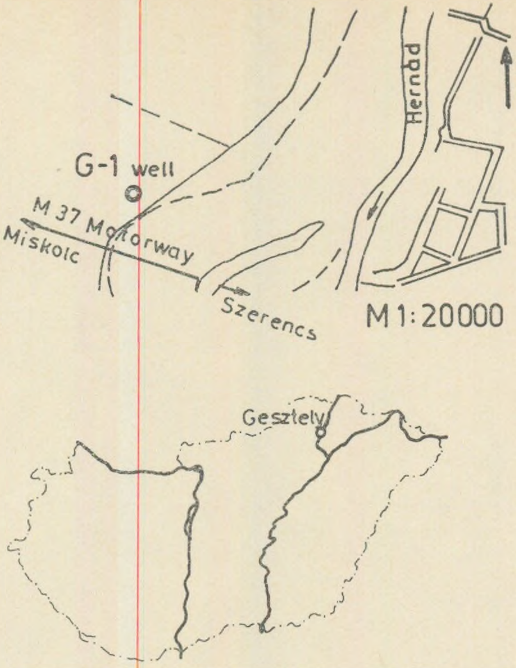


Fig.1. Locality of experiments

The waterbearing sandy gravel sequence is about a 20 m thick, yellow, red-brown, unconsolidated, somewhat silty, medium-and-coarse grained, with *sand* composed of grains of 0,1 – 2,0 mm, moderately rounded, with no mica.

Pebbles are of quartz, quartzite, generally with brown crust (iron coating) being as large as 2 – 5 mm in diameter. Because of the silt content the rock is compact when dried up.

Lime content is small, 0,3 – 3,0% with a weighted average of 0,8%, therefore incapable to adsorb the agressive CO_2 quantity.

The upper part of the underlying bed is a 0,2 m-thick clay the upper part of which is yellow, the lower one grey.

The sequence of test well G – 1 :

	Rock description
0,0 – 1,0 m	*Clay* Brown, strongly coherent, with no lime content, containing recent plant remains

1 –1,9 m	*Sand* Yellow-grey, loose, medium calcareous (+ +), medium grained: 0,2 – 0,5 mm in diameter, it contains quartz and mafic components, devoid of mica, and moderately rounded
1,9 – 19,8 m	*Gravelly sand* Yellow-grey, unconsolidated, medium-calcareous (+ +) sequence, the *sand* is approximately half medium and half coarse grained of 0,2 – 2,0 mm in diameter; with quartz and mafic components, without mica and moderately rounded; the *gravel* is multi-coloured, consisting of quartz and quartzite, 1 – 3 cm large in diameter and moderately rounded
19,8 – 22,0 m	*Sand* Yellow-grey, unconsolidated, medium-calcareous (+ +) 0,2 – 0,5 mm in diameter, with quartz and mafic components, devoid of mica and moderately rounded

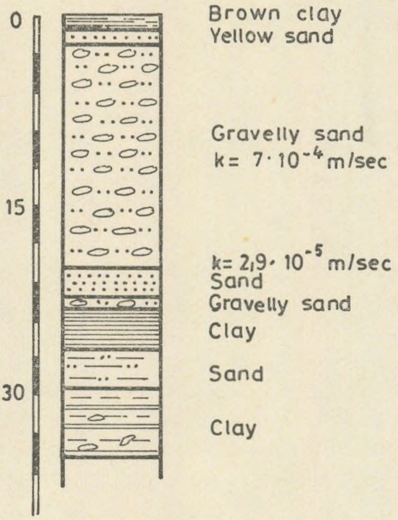


Fig. 2. Successive layers of G-1. well

22,0 – 23,0 m	*Gravelly sand* Yellow-grey, unconsolidated, medium-calcareous (+ +) approximately half of the sand is medium-grained and a half part of it coarse-grained (0,2 – 2,0 mm) with quartz and mafic components, without mica moderately rounded; the gravel (1 – 3 cm) multi-coloured, consist of quartz and quartzite, moderately rounded
23,0 – 26,0 m	*Clay* Yellow-grey, coherent medium-calcareous (+ +)
26,0 – 29,0 m	*Silty – sand* Yellow-grey, coherent, medium-calcareous (+ +), limonite-mottled, lime concretionary with high silt content (Fig. 2.)

Three drain-wells were installed at a distance of five metres around test well G – 1 at an angle of 120°. The core samples were subjected to mineralogical, petrological and chemical analyses. These examinations had two purposes: first of all we wanted to make clear the origin of the iron-manganese and to estimate the quantity of its future amount; on the other hand we wanted to examine the possible influence of the water-bearing rock on the iron-manganese elimination process.

The oldest formation examined was a material classified to belong to the lower part of the Upper Pannonian substage (Congeria ungula caprae level), it deposited under brackish water conditions. However, it can be found in situ only in the deep underlying bed. It has been observed that due to drenching the upper part of the clay became loose and local stream water erosion, removed it. Ostracod clasts testify to Pannonian origin but because they are of their being fragmental, a closer identification is not possible.

There are some proofs of reworking, as follows:

a) The stratification is different from that of the Pannonian (the basin facies of the Pannon inland lake had excellent conditions for deposition), the characteristic vertical parameter of the stratification is $10^{-1} - 10^{0}$ m: While in our case the stratification has a $10^{-3} - 10^{-2}$ m rhythmicity and on good core samples marks of cross bedding can be observed.

b) Mixing materials, characteristically coarse-grained, sandy gravel lenses showing lamellar stratification are present.

Since its material is the same as that of the Pannonian clays, it contains all the mineral and chemical components that are characteristic of the Pannonian clay.

The main component is the FeS_2, appearing as pyrite or marcasite as crystallinized, and colloidal melnikovite or hydrotroilite ($FeS_{1-2}x \cdot nH_2O$) in its hardly crystalline form. The FeS_2 is not stable under oxidizational circumstances; when becoming oxidized, it forms ferri-oxi-hydroxid and sulphuric acid.

A by-effect of the sulphate is given by the transformation of clay minerals. It is well-known from literature that in acidic environment (e.g. terrestrial weathering, acidic hydrothermal solution) kaolinite forms, and in alkaline environment (e. g. alkaline hydrothermal, marine halmirolitic decomposition) montmorillonite comes to existence. In permanently acidic environment this montmorillonite partially changes into kaolinite. This is what has happened in our case as well. Due to sulphuric acid the Pannonian clay, qualified to be halmirolitic (mainly montmorillonite and illite with less epygene kaolinite), transformed and the amount of kaolinite increased at the cost of the montmorillonite, whereas the amount of illite did not change. Thus the ion exchange capacity of the underlying bed grew less, approximately 27.4 mekv/loo g, While that of the primary Pannonian clay is 40 – 60 mekv/loo g.

The water bearing rock is a mixture of gravel and sand of various grain size where the clay fraction of the suspended load of the original sedimentary pool is also present.

The sandy gravel consists mainly of metamoprhic quartzite. Under different ground water chemical conditions only the surface coating of the quartzite emphasizes its importance. On a higher relief the congelational crust (see: congelational phenomenon) is characteristic, the limonite (FeO(OH)) and the pyrolusite (MnO_2) form a chemosorbtional surface.

The oxidizationally precipitated ferri-oxi hydroxid films are mainly in colloidal phase, the hardly mineralize at all, so they are inclined to be reversible and dissolve for reductional effects (usually as ferrohydrogene carbonates). Manganese does not form oxidizational files, the actual redox potential in the bank filtration well is smaller ($+150 - +450$ V) than the reduced normal redox potential of the manganese. The amount of the ferri-oxi-hydroxid coating depends on the extent of the coating; the bigger the specific surface – that is, the smaller then grain size – is, the bigger its extension will be. This is the primary role of the grain size distribution that influences the chemical properties of the water.

The most important chemical factor of the aquifer is the silt fraction. According to engineering-geological practice, it was separated by means of a sieve of 20 μm meshes (Fritsch Afnor NFX 11 – 501. No 14 standard sieve) by rinsing. We took also the 20 – 50 μm fraction under investigation in case it prooved to be active in a way.

The silt content of the sandy gravel can be of different origin. In the vicinity of the present river channel, recent kolmatation and in the vicinity of the fossil one fossil kolmatation can be observed.

The more or less equally distributed silt content of the aquifer is syngenetic and originates from the sedimentary pool of the gravelly sand, that is, from the suspended of the fossil stream.

This seems to contradict the law of sedimentation according to which the different fractions should separate (apart from silt, also gravel and sand).

However, according to our experiments this cannot be corroborated neither in the case of recent, nor in the case of fossil sediments. Probably this is covered by the dinamics of slurry movement.

The ion exchange capacity of the clay mineral can be estimated to be around the average, it cannot be measured precisely because it can hardly be separated from the components of the other fractions and even in the case of solid organic matters some surface activity, adsorbtion can be observed.

According to the X-ray analysis the composition of the clay minerals is varied, bot it is usually, on an average, of 50% montmorillonite, 20% kaolinite and 30% illite.

The organophilia of the montmorillonite cannot be measured since it cannot be separated by means of the available methods. Therefore our working hypothesis in the following was that the clay mineral and the detritus form separate adsorbtional systems (otherwise the two systems would adsorb each other thus disabling the adsorbtional capacity). Indirect measurements have made this working hypothesis plausible.

The surface activity of the suspended load has two effects: it helps some chemical processes (mainly reduction) and accumulates the transformed matters on its surface making bacterial functions possible at the same time.

The reason for this latter case can be found in the environmental conditions, for the optimal life functions of these bacteria do not meet the actual environmental conditions and bacteria can only make permanent

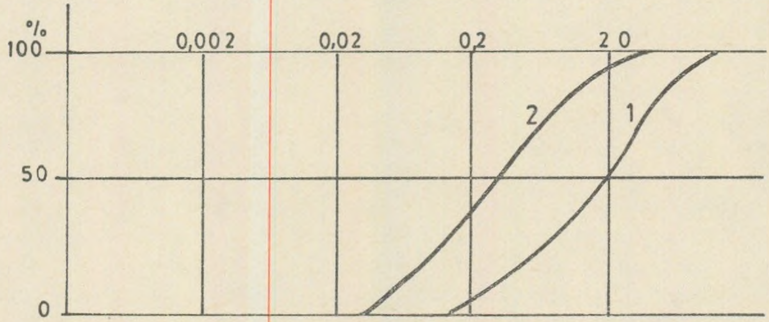


Fig. 3. Granulometry in G-1. producing well

1. 1,9 - 19,3 m gravelly sand
2. 19,3 - 22,0 m sand

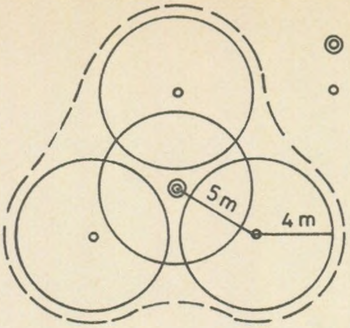


Fig. 4. **Plan of oxidation zone**

◎ producing well
○ drain wells
◌ extension of oxidation zone

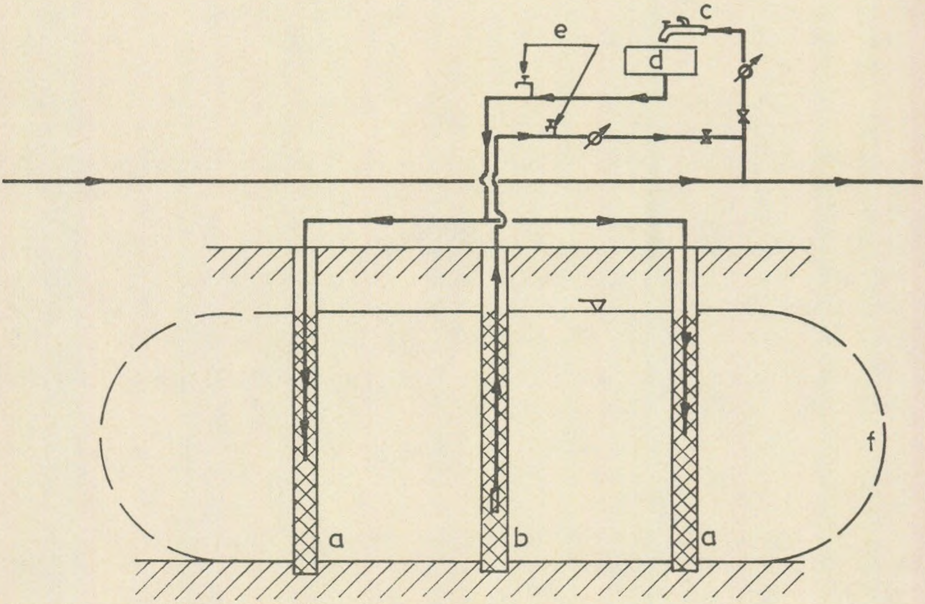


Fig. 5. **Functional plan of experimental method**

a drain well
b. producing well
c. oxygenator
d. degasing unit
e. sampler valves
f. oxidation zone

microconditions (pH, Eh) in muddy rocks, where due to the bad fluid permeability, the small speed of current and diffusion does not let the two different chemical environments to mix.

The hydraulical parameters of the aquifer were determined partly upon examination of rock samples taken from boreholes and partly upon data by test pumping (see Fig. 3.).

The porosity of the gravel sand at a depth of 1,9 – 19,3 m is 10,4 – 15,7 %, its transmissivity is on an average 7.10^{-4} m/sec, the porosity at a depth of 19,3 – 22,0 m is 8,5 – 13,2%, the transmissivity is $2{,}9.10^{-5}$ sec. The resultant transmissivity as counted from the data obtained by pumping test is $3{,}6 \cdot 10^{-4}$ m/sec.

Planning the in situ iron-manganese elimination process in Vyredox system

Three absorbing wells were installed around the test well G – 1, at a distance of five metres and at an angle of 120° from it (Fig. 4.).

Counting with a porosity of 10% the pore volume of the oxidizational zone, considered to be 4 metres in radius, is 5.026 m^3/lm. Counting with an active filter length of 20 meters that is approximately 100 m^3/well, and taking the environment of the three wells and the space between them also into consideration it is 350 – 400 m^3. The diagram of function can be seen in Fig. 5.

By means of bacteria the water, enriched in oxygen oxidizes the iron and manganese thus becoming solid, according to the well-known process. The aim of the experiments was to determine the optimal technical and economical parameters of the process and to predict the expectable kolmatation of the aquifer.

Unfortunately the 9 – 11 mg/l iron content of the feed water precipitated after the oxygen enrichment and the $Fe(OH)_3$ precipitation partly kolmatated the filter of the drain-well, therefore we reorganized the system, thus solving the primary elimination of iron from the feedwater.

Three examination periods could be terminated, each lasted for three weeks. The operational conditions were the following:

– Efficiency of the oxygenator was 80 – 100%, meaning that there were approximately 9 – 11 mg/l oxygen in solution in the water at a temperatura of 10 – 12 °C;

– Enrichment took ten hours, the amount of feed-water was 400 – 500 m^3), the uplifting lasted ten hours and 500 m^3 water was obtained during the steady uplift.

The ion content of the recharged water fluctuated between 0,05 and 0,3 mg/l, its manganese content was about 1,2 – 2,1 mg/l (manganese could not be eliminated by means of airing, applied previously for iron elimination), the aggressive CO_2 content was 0,0 – 6,5 mg/l, the O_2 in solution was 8,3 – 11,0 mg/l in average, COD was 0,6 – 1,8 mg/l, the pH was 7,4 – 7,7.

The quality of the uplifted water can be seen in Figs. 6 and 7.

Though the decrease of the iron and manganese content shows a positive tendency, its value is high above the permissible limit, therefore it would have been reasonable to continue the examinations, however, due to kolmatation at the beginning of the experiment it was made impossible.

Apart from this technical failure we judge the Vyredox method to be applicable to an economical and reliable in situ iron – manganese elimination in the given hydrogeological situation.

Planning the in situ iron – manganese elimination process in Subterra system

After the kolmatation of the absorbing wells the producing well had to be operated in an alternative operational mode; that means ten hours of recharge, four hours reaction time and ten hours producing in three-week cycles.

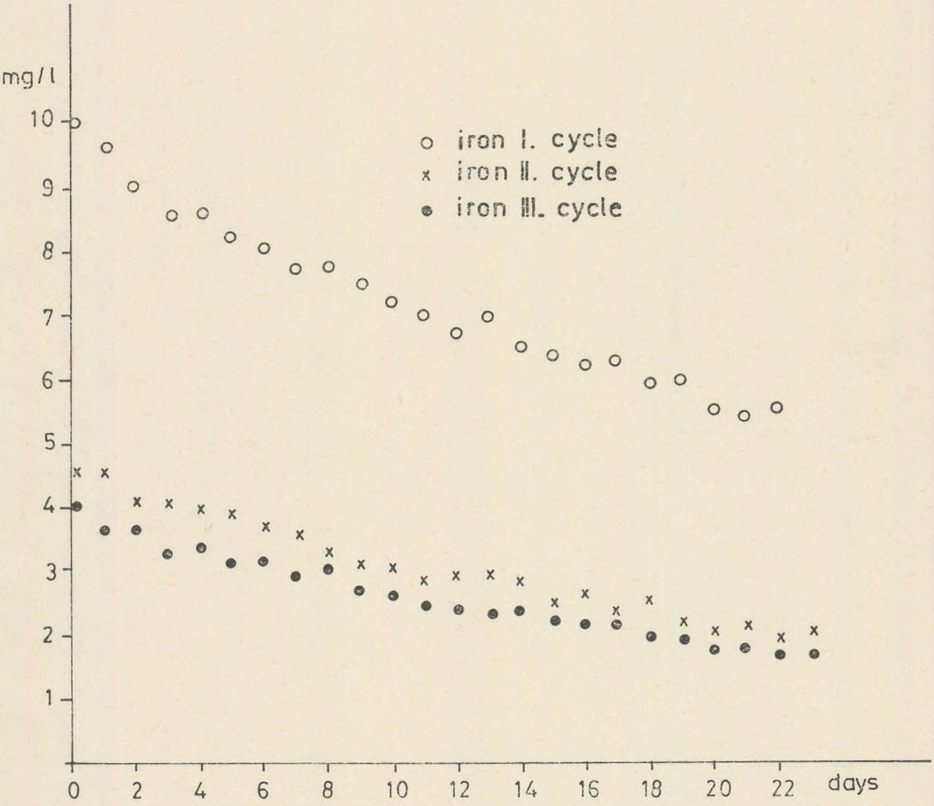


Fig 6. Change of iron concentration in produced water (Vyredox - method)

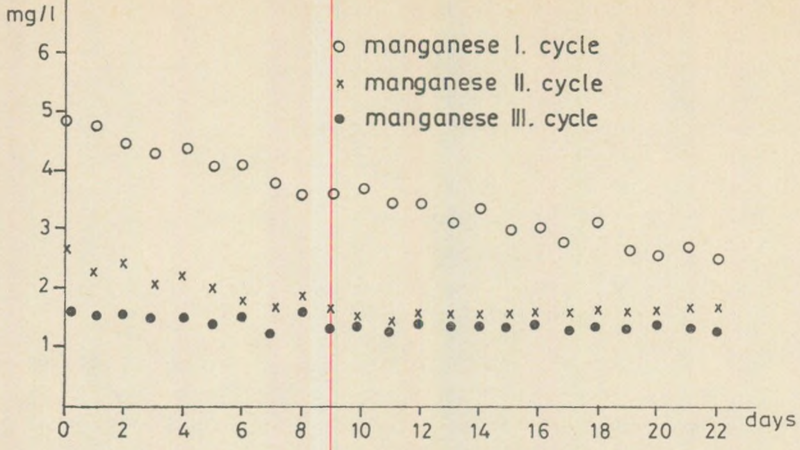


Fig. 7. Change of manganese concentration in produced water (Vyredox-method)

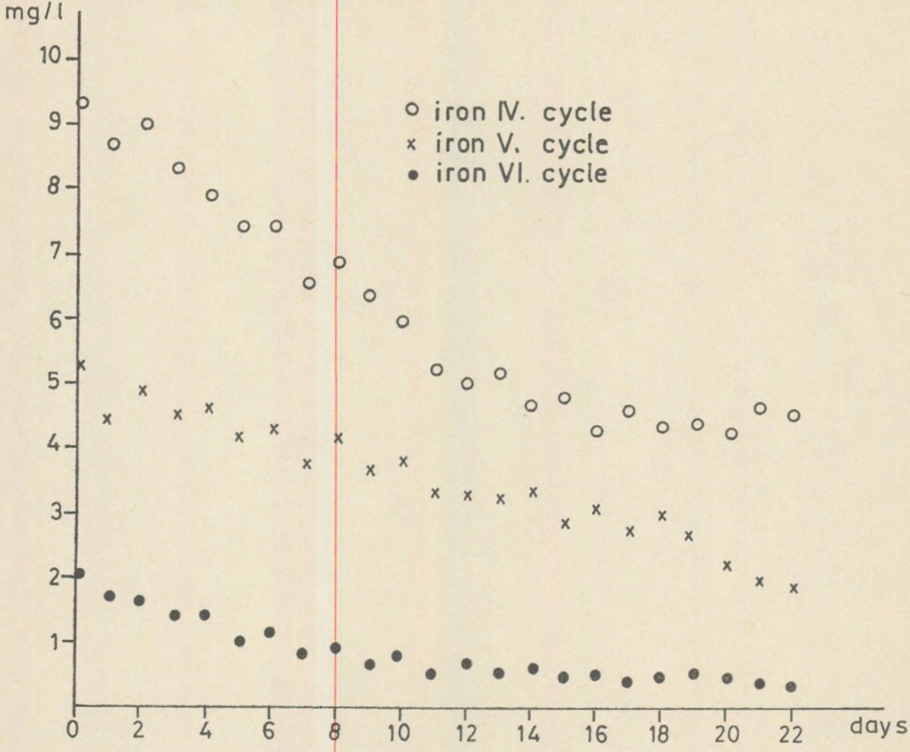


Fig. 8. Change of iron concentration in produced water (SUBTERRA-METHOD)

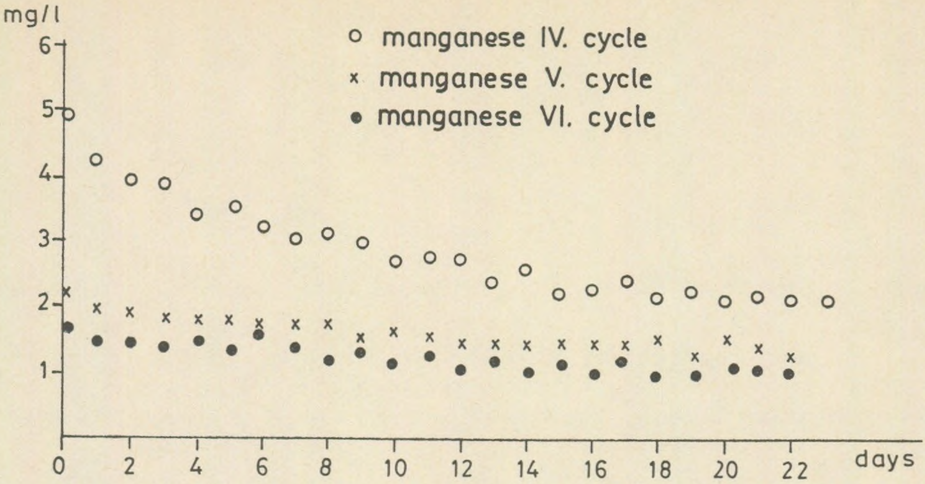


Fig. 9. Change of manganese concentration in produced water (Subterra-method)

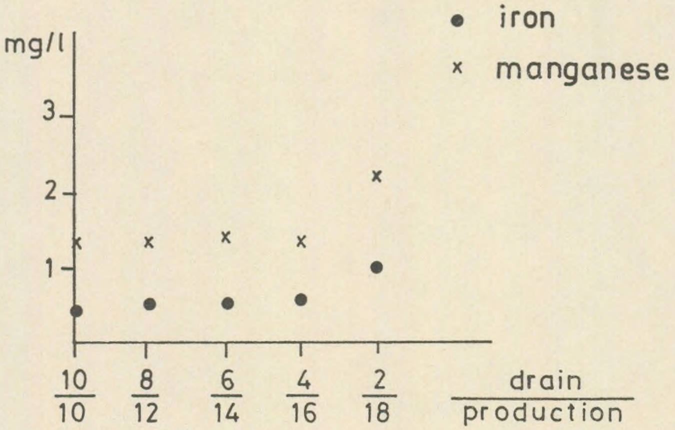


Fig. 10. Change of iron and manganese concentration as a function of rate drain/production

We mention that the consequence of the previous Subterra experiment (adsorbtional catalythic and chemosorbtional coating on the rock grains) were stopped by a one-year production thus the Subterra cycle started according to the original condition.

The quality of the recharged water was the same and at the preliminary surface iron elimination the concentration of the manganese did not decrease.

Experiences at other waterworks confirmed that if we employ more wells alternatively the increasing quality of the produced water will also mean the increasing quality of the recharged water which leads to a self-improving process.

The decrease of the iron and manganese content of the produced water is shown in Figs. 8 and 9. By the end of the sixth cycle, that is, after 60 days the iron content decreased permanently to 0,5 mg/l which can be considered to be a satisfactory result, but, due to the high manganese content of the recharged water the manganese did not decrease to the desired level.

The cycles IV – V – VI. proved the utility of the Subterra method under the given hydrogeological conditions. Further examinations were needed to decide the economical operational time ratio, that is, the proportion of the phases in a 24-hour-period had to be varied.

Since the maximum intensity of both the recharge and the producing was fixed by the small ($K = 3{,}6 \cdot 10^{-4}$ m/sec) transmissivity, the problem was solved by the change of the time ratio. Leaving the four hours reaction time unchanged the ratio of recharging and producing changed as seen below:

recharging	producing
10 hours	10 hours
8 hours	12 hours
6 hours	14 hours
4 hours	16 hours
2 hours	18 hours

It can be seen in Fig. 10, that there is no significant change in the concentration at the end of a period till the ratio is 4:6, but then the values increase abruptly to ratio of 2:18.

This coincides with our experiences that in aquifers where the grain-size frequency distribution is badly sorted, the in situ iron and manganese elimination, due to the small pore size, is on the bounds of economic rentability.

REFERENCES

FILLIS, J. – MOLOF, A. H. (1972): Effect of benthal deposits on oxygen and nutrient economy of flowing waters – J. WPCF 44. 4 pp. 644 – 62.

FLICK, G. (1968): Versuche zur Entmanganung eines Wassers auf adsorptiv-katalytischem Entmanganungsmaterial Neue Deliwa Zeitschrift H. 3.

GONDOS, GY. (1970): Relationship between the dissolved iron and manganese compounds in water and the mineralogical composition of the aquifer 2nd Conference on Water Quality and Technology Budapest.

HÄSSELBARTH, U. – LÜDEMANN, D. (1967): Die biologische Verockerung von Brunnen durch Massenentwicklung von Eisen und Manganbakterien. Bohrtechnik – Brunnenbau – Rohrleitungsbau, Berlin 10 – 11. sz.

ROTT, U. – BOOCHS, P. W. – BAROVIC, G. (1978): Unterirdische Grundwasser-aufbereitung durch Einleitung von sauerstoffhaltigem Wasser in den Boden – Wasser und Boden 8.

SEYFRIED, C. F. – ROTT, U. (1975): Verfahren zur Reinigung von Grundwasser von Mangan oder anderen löslichen Substanzen im Untergrund. BDPa.

SEYFRIED, C. F. – ROTT, U. (1977): Grenzen und Möglichkeiten der subterrestrischen Wasseraufbereitung. Mitteilung der Subterra Methoden.

INVESTIGATION OF THE OPERATIONAL PARAMETERS OF THE SUBTERRA METHOD FOR IN SITU IRON-MANGANESE ELIMINATION (WATERWORK HALÁSZTELEK)

by

I. ORSOVAI

Institute of Applied and Engineering Geology, Eötvös Loránd University, Budapest

(Received: 30th March, 1987)

Abstract

Upon the execution and evaluation of programmed tests in a series of driven wells under operation it has been clarified the efficiency of iron-manganese elimination under given hydrogeological conditions.

The characteristic data of the aquifer are:

- Transmissivity: $(2,5-5,0)\cdot 10^{-3}$ m/sec,
- Porosity: 27,85 – 28,37%
- Seepage speed: from the direction of the Danube: $1,6-1,8\cdot 10^{-5}$ m/sec,
  - : from the direction of the background: $7,7-9,8\cdot 10^{-5}$ m/sec,
- Distribution of the clay minerals: 50% montmorillonite, 20% kaolinite, 30% illite,
- Ion-exchange capacity: 40 – 60 mekv/100 g,
- The extent ot the oxidational zone, on the basis of the measurement of the O_2 in solution: 9,0 – 9,5 m
- Maintainability of oxidational zone: 0,05 mg/l iron after 60 hours, 0,5 mg/l iron after 96 hours.

The extension of the depressed are is different in the two profiles: in Well – 8 it is $R = 3-6$ m, and in Well – 22 it extends as far as the Danube.

The iron-manganese content of the water arriving from the Danube and from the background differs very little, but water from the Danube has higher concentration.

Due to oversizing (it is approximately twenty fold at the given time-program) it is hard to tell the efficiency numerically, however, according to complementary experiments it is satisfactory.

Introduction

The Subterra method for in situ iron-manganese elimination of a driven-well was first introduced for operational conditions between May 1985 – October 1986 in the middle part of the Danube valley. Previously, half-operational experiments were carried out in this territory, operating the two neighbouring wells alternatively. The introduction at an operational level started after a series of successful experiments had been done.

To determine the operational parameters the following questions had to be answered:

a) The extent of the oxidational zone and the temporal change of the chemical parameters,

b) The range of maintaining,

c) The extension of the area of water-table lowering by single wells and the well-line,

d) Space/time changes in iron-manganese content of the Danube and from the background,

e) The efficiency of the process.

Experimental apparatus and procedure

The operational program (Fig. 1.) was determined by the Subterra method and also the wells had to be installed according to that.

Taking the environments of the wells separately, the plan of the experiments was the following:

The geometrical data had to be determined from the theoretical profile seen in Fig. 3., with the help of the observation wells seen in Fig. 4. It could already be foreseen, and was also confirmed later, that the distance between the observation wells is much too big as compared to the extent of the oxidational zone.

Nevertheless, because of the water mechanical works (collector cable, electric ground cable) the observation wells could not be installed closer to each other than three metres.

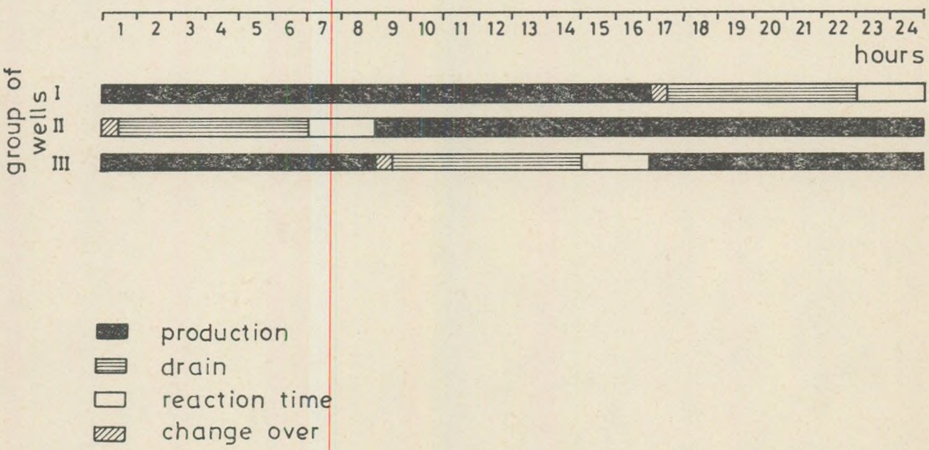


Fig. 1. Daily programme of consolidated process

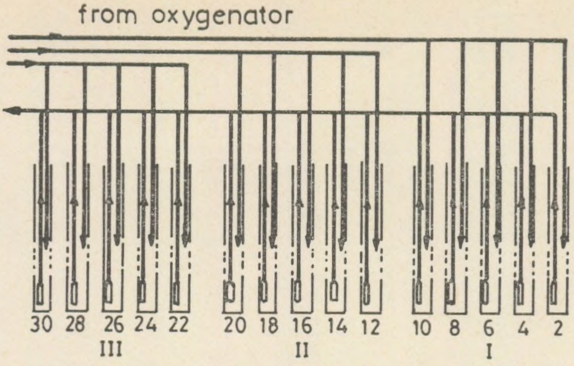


Fig. 2. Functional plan of experiment

↑ (produced) pump

↓ drain

2 - 30 wells

I-II-III collaborated group of wells

A rough outline of the geological and hydrogeological properties of the aquifer used for iron-manganese elimination process

The impermeable underlying bed is an Upper Pannonian, clayey, sandy, micaceous formation. Its water chemical role is important.

The actual site of the iron-manganese elimination process is a gravelly, sandy, somewhat silty clastic formation, which is strati graphically the same as the Late Pleistocene – Early Holocene II/a terrace of the Danube. Its fraction above 2 mm of grain-size contains mainly quartzite, various amounts of andesite and an insignificant amount of carbonate rocks (more dolomite with less limestone).

Its transmissivity and pore volume depends on the grain distribution and sorting determining its hydraulical importance too.

Practically it has no direct hydrochemical role, the surface of the grains is inactive. Hydrochemically the grains under 2 mm are most important. These could be examined thoroughly because the whole amount of the material that was brought up from under the water table by drilling, was elutriated, so the loss of the small grain fraction was minimal (Fig. 5.).

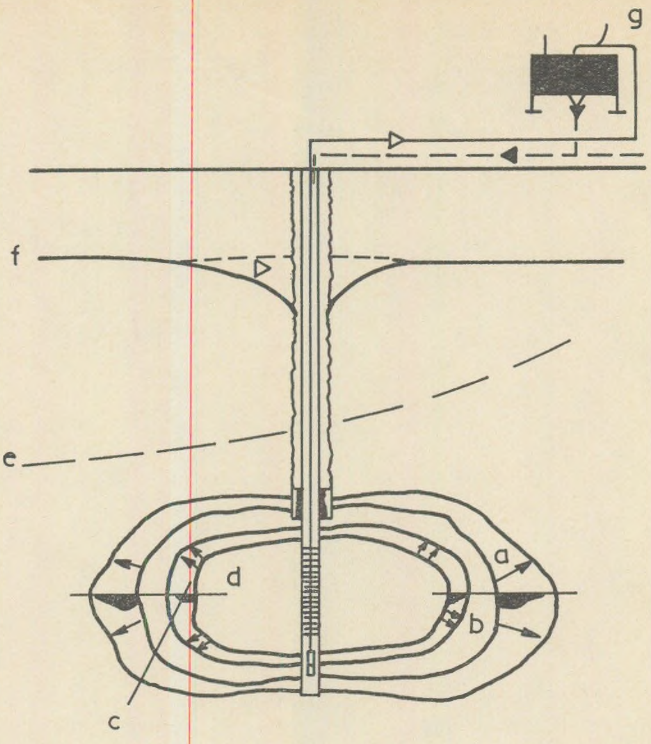


Fig. 3. Plan of oxidation zone

a. accumulation of iron
b. zone free from iron
c. accumulation of manganese
d. zone free from iron and manganese
e. limit of O_2 content
f. water-table
g. oxygenator

Chemically the silt fraction is most typical of the aquifer. It was separated by means of a sieve of 20 μm meshes (Fritsch afnor NFX 11 – 501. No. 14.) by rinsing, according to engineering geological practice. The fraction between 20 – 50 μm was also taken under examination if it proved to be active in a way.

The silt content of the sandy gravel can be syngenetic (grains of different distributions settle from the turbulating current) and epigenetic

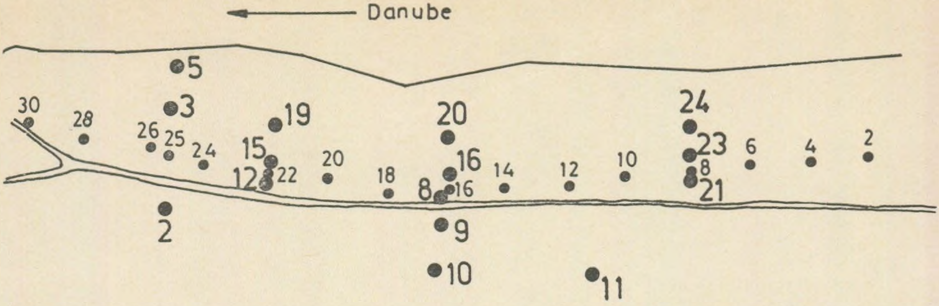


Fig. 4. Locality of experiments 1·5000

- ● 2 - 30 producing and drain wells
- ● 15-19 test wells

through fossil and recent kolmatation. In our case syngenetic sedimentation is typical of the aquifer while recent kolmatation characterizes the river channel, so two different silt types had to be taken into account, differing both genetically and in composition.

The floating fraction of the core samples and the floating matter content of the Danube water are very similar in composition, The difference is the result of diagenesis. The material of the kolmatated channel bottom is substantially different.

	1.	2.	3.
SiO_2	8,8%	25,2%	15,7%
Al_2O_3	4,9	5,2	3,1
Fe_2O_3	0,4	14,6	4,3
MnO_2	—	3,4	1,1
CaO	14,3	12,1	3,7
MgO	2,9	2,6	3,5
Na_2O	9,8	4,7	7,6
K_2O	2,1	3,1	2,7
Cl^-	6,4	6,2	3,1
SO_4^-	12,3	13,5	1,8
CO_2	13,0	11,0	19,6
C_{org}	25,0	8,2	37,0
	99,9%	99,8%	100,2%

1. The floating matter of the Danube
2. The fraction above 20 μm in diameter of the aquifer
3. Recent Danube channel kolmatating material

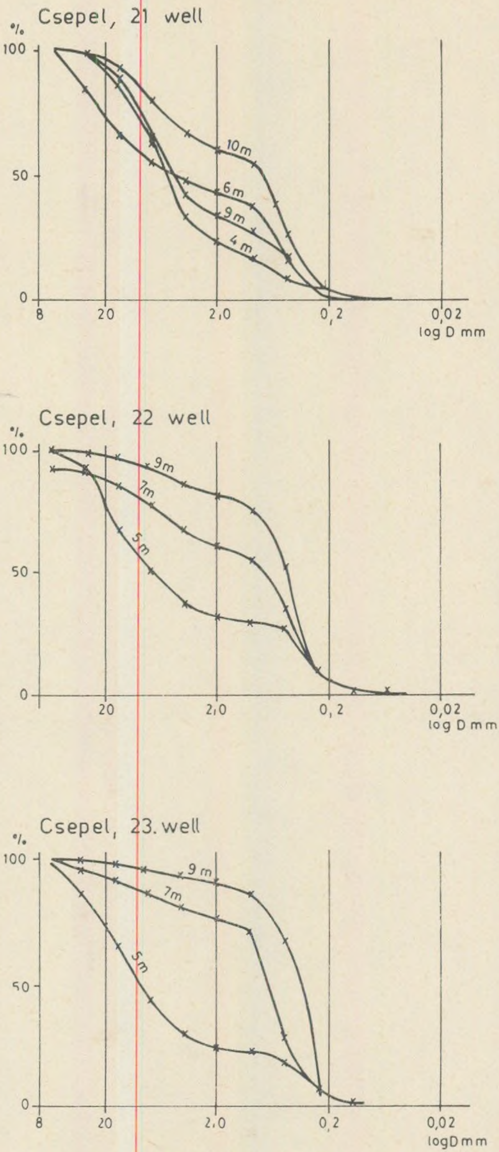


Fig. 5 Characteristic granulometry in tested aquifer

The ion-exchange capacity of the clay minerals is moderate; 40 – 60 mekv/100 g and difficult to measure because it can hardly be separated from the other components of the fraction; even the effective agents of the C_{org} have surface activity (adsorbtion).

According to X-ray analysis the composition of the clay minerals is varied, 50% montmorillonite, 20% kaolinite and 30% illite is typical of them on an average.

On the basis of the examinations it could be firmly concluded that the silt fraction is decisive regarding the iron-manganese transport (stabilization and mobilization or, in a proper sense, restabilization and remobilization). This is not merely the result of the small specific surface which is attributable to the small grain-size and which advances surface-dependent processes (chemosorbtion), because the surface activity has much more importance than the specific surface (e. g. ion-exchange, adsorbtional catalysis, etc.).

Due to similar causes (small amount and difficulties in separation) the organophilia of montmorillonite could not be measured, therefore our working hypothesis was the following:

The clay mineral and the detritus form separate adsorbtional systems, otherwise the two systems would adsorb each other thus desabling the adsorbtional capacity.

Indirect measurements made this working hypothesis plausible.

The surface activity of the floating matter has double chemical effects:

a) It promotes some (mainly reductional) chemical processes (chemosorbtion, adsorbtional catalysis) and accumulates the transformed matters on the surface of the grains,

b) It produces favourable conditions for bacterial functions.

This latter effect is based on the fact that the environmental conditions, needed for the optimum lifefunction of these bacteria, does not meet the actual emvironmental conditions, and the bacteria can only make permanent micro-conditions (pH, Eh) in the silty rocks, where due to the bad permeability, the small speed of seepage and diffusion does not let the two different chemical environments to mix.

We determined the free pore volume by means of the core samples (28,37% on an average) and also by means of a pumping test, according to the Bindemann – method (27,85%) therefore we calculated with a rounded porosity value of approximately 30% in preliminary planning. This time we measured the seepage also in the directions of the Danube and of the background. Comparing these data with the data obtained in 1981 we got the following results:

place	direction	1981 speed, V_{eff} (m/sec)	1981 speed, v_{eff} (m/sec)
observation	from the Danube	$1{,}4 \cdot 10^{-4}$	$1{,}6 \cdot 10^{-4}$
wells 13 – 12.	from the background	$1{,}8 \cdot 10^{-4}$	$9{,}8 \cdot 10^{-5}$
wells 15 – 14.	from the Danube	$1{,}8 \cdot 10^{-4}$	$1{,}9 \cdot 10^{-4}$
wells	from the background	$7{,}0 \cdot 10^{-5}$	$7{,}7 \cdot 10^{-5}$
wells 21 – 24.	from the Danube	–	$1{,}8 \cdot 10^{-4}$
	from the background	–	$8{,}0 \cdot 10^{-5}$

When the measurements were carried out the water level of the Danube was approximately 200 cm in both cases.

Former data for transmissivity in 1981:

producing well – 20.: $K = (4{,}13 - 4{,}18) \cdot 10^{-3}$ m/sec
producing well – 22.: $K = (2{,}50 - 2{,}64) \cdot 10^{-3}$ m/sec

The Extent of the Oxidational Zone and variations in space of the chemical parameters

The oxidational zone was considered to be $R_o = 5$ m at the preliminary planning, the neccessary amount of water to the enriching was 471,2 m^3/6 hours, the amount of the actually dessicated water was 430 – 470 m^3/6 hours so they correspond very well.

The results of the measurements of the O_2 in solution:

producing well – 8 (in recharged water): 8,6 mg/l
observation well – 22. (3 m from well – 8.): 3,4 mg/l
observation well – 23. (6 m from well – 8.): 1,2 mg/l
observation well – 24. (bank filtration groundwater): 0,25 mg/l

By means of extrapolation we estimated that the O_2 in solution dropped to a value of 0,25 mg/l in the vicinity of well – 8. which is approximately 9,0 – 9,5 m (Fig. 6.).

The spatial variations of the chemical parameters show partly the theoretically probable tendencies, but partly the results have a rendom deviation (the values are the average of the five examinations made between 13 November 1985 – 4. September 1986).

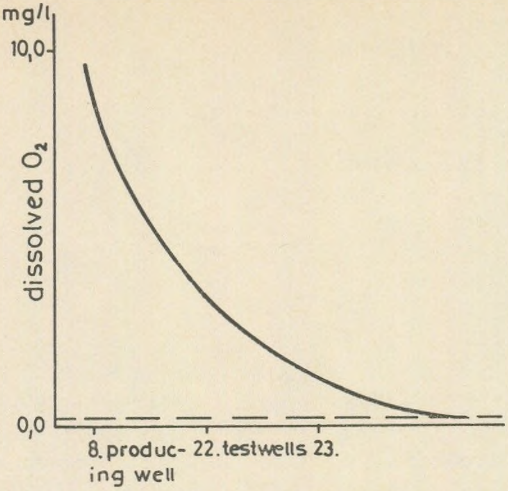


Fig. 6. Change of dissolved oxygen as a function of distance from 8. producing well

observation well	alkalinity	chloride	Ca	Mg	Fe	Mn
12.	4,4	38,0	42,0	9,12	0,05	0
15.	3,8	36,4	34,07	7,9	0,02	0
19.	3,6	31,5	36,07	7,6	0,01	0
21.	4,0	24,2	31,00	7,3	0,01	0
22.	3,9	37,1	34,07	8,5	0,01	0
23.	3,5	25,0	38,08	9,1	0,01	0
24.	3,2	28,6	40,08	9,8	0,01	0

Maintainability of the oxidizing zone

The program of the Subterra method did not make possible the direct examination of the time of maintainability of the oxidizing zone, therefore we had to apply a complementary method.

We made the examinations at shutdowns, caused by technical problems, by means of pumping (432 m^3/24 hours) in the observation wells which were at 3 metres from each other. As a simplification we agreed that the common depressed zone of the observation wells 21 and 22 is approximately equal to the zone of water-level depression by producing well 8, and the amount of water, produced in a day, is approximately equal to the fivefold amount of the recharged water for one period, in one single well.

Making the chemical analysis continuously it could be concluded that the value of iron is 0,05 mg/l after approximately 60 hours and 0,5 mg/l after some 96 hours which means that the ratio of the feed water and the produced water was 1:12 in the former case and 1:20 in the latter.

Investigation of the extension of the area of water-table lowering in line with water production

The extension of the depressed area could be examined right angles to the Danube and to the producing well-line in two profiles, both of which gave different results.

In profiles 21 – 8 – 22 – 23 of the Danube (see Fig. 4) the cone of depression is charecteric of rocks with bad transmissivity; R is small, S_0 is big. In profiles 12 – 22 – 15 – 19 the depressional cone is typical of the terrace with good transmissivity (Fig. 7). The difference is caused by the inhomogenity of the aquifer if only it is not due to water mechanical causes.

Analysing five time profiles of water level changes and 15 profiles showing the former changes in space through the producing wells we arrived at a conclusion that the area of depression of the producing wells 2 – 4 – 6 – 8 and 18 are similar to each other; the area of depression is approximately 3 – 6 m of radius. Producing wells 10 and 30 (except for well 18) have different values, practically the depressional area extends as far as the Danube.

INVESTIGATION OF THE IRON-MANGANESE CONTENT OF THE WATER ARRIVING FROM THE DANUBE AND FROM THE BACKGROUND

The chemical parameters of the water arriving from the background are well known. However, due to the lack of a tendency in the spatial and temporal variations in the standard deviation we can only calculate with end values and average values.

	1985			1986		
	12. June	5. Sept.	13. Nov.	30. April	14. Aug.	29. Oct.
Iron (mg/l) observational well – 2.	0,18	1,14	0,12	0,17	0,18	0,13
– 6.	0,29	0,16	0,12	0,21	0,23	0,17
– 9.	0,40	0,32	0,29	0,33	0,25	0,27
– 10.	0,12	0,21	0,17	0,13	0,22	0,20
– 11.	0,31	0,28	0,34	0,19	0,24	0,22

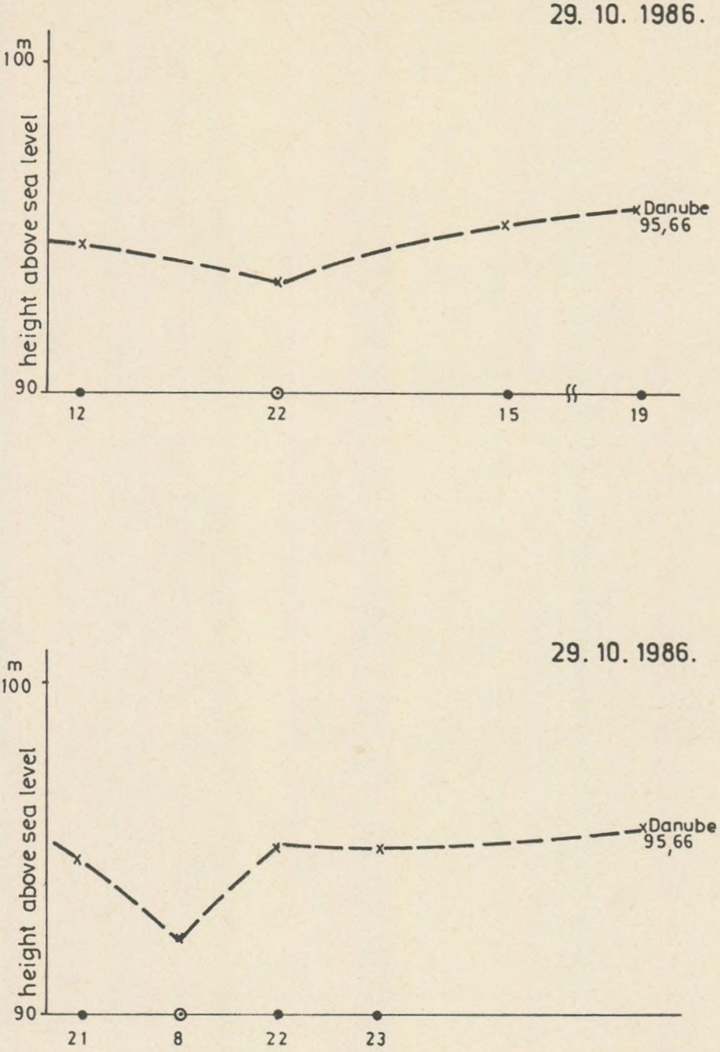


Fig. 7. Characteristic profils at 22. and 8. producing wells

⊙ 22., 8. producing wells

● 12., 15., 19., 21., 22., 23. testwells

Manganese (mg/l)						
observational						
well – 2.	0,11	0,18	0,21	0,17	0,19	0,14
– 6.	0,18	0,07	0,11	0,09	0,13	0,13
– 9.	0,12	0,11	0,12	0,14	0,11	0,12
–10.	0,16	0,14	0,19	0,08	0,11	0,09
–11.	0,11	0,13	0,13	0,18	0,08	0,10

End values: 0,12 – 0,40 mg/l iron
0,07 – 0,21 mg/l manganese

Average: 0,22 mg/l iron
0,13 mg/l manganese

The iron-manganese content of the water arriving from the Danube could be measured permanently in observation wells 19 add 24. In the vicinity of the producing wells the observation wells fall within the zone of the iron-manganese elimination, thus showing a smaller value.

	1985			1986		
	12. June	5. Sept.	13. Nov.	30. April	14. Aug.	29. Oct.
Iron (mg/l)						
Observation						
well –19.	0,31	0,38	0,35	0,44	0,41	0,40
–24.	0,28	0,48	0,43	0,41	0,44	0,37
Manganese (mg/l)						
Observation						
well –19.	0,22	0,20	0,24	0,20	0,28	0,23
–24.	0,24	0,29	0,25	0,24	0,26	0,22

End values: 0,28 – 0,48 mg/l iron
0,20 – 0,29 mg/l manganese

Average: 0,39 mg/l iron
0,24 mg/l manganese

Hence, a somewhat bigger amount of iron and manganese comes to the producing wells from the Danube than from the background. Though the difference is not big it is despite important because 80% of the water output comes from the Danube.

INVESTIGATION OF THE EFFICIENCY OF THE IN SITU IRON-MANGANESE ELIMINATION

Under operational conditions the oxygenator gives minimum 8 mg/l O_2 in solution to the recharge water, equivalent to 0,001 normality, which means that it can oxidize approximately 56 mg of iron or 274 mg of manganese in the same amount of water (1 1).

Of course, the O_2 in solution satisfies also the chemical oxygen demand, oxidizes organic compounds and also other elements of changing valency but in the method under discussion its main function is the oxidation of iron and manganese.

The 8 mg/l O_2 solution dessicates with 1400 m^3 enriching water a day. The total production of water is 3200–4600 m^3/day. Subtracting the amount of the recharge water from that the net water output is 1800 – 3200 m^3/day.

In respect of our objective it makes no difference whether we compare the amount of the recharge water to the gross or net amount of water, oversizing could easily be observed.

Disregarding the difference, due to the redox potentials which determines the order of succession of the oxidational process in this case (iron would be the first, manganese the second and later, at indefinite intervals the other effective agents of COD), the call for oxygen for 0,5 mg/l iron and 0,3 mg/l manganese is 0,115 mg/l O_2.

Multiplying that by the rate of dilution the call for O_2 in solution for the oxidation of iron and manganese is maximum 0,378 mg/l at the present Subterra program and water amount, which means that the oversizing is more than twentyfold. We emphasize that the COD calls for O_2 in solution which diminishes this ratio but there are abviously adsorbtional catalysis and bacterial functions going on beside the direct oxidation, increasing this ratio. However the values of the latter one cannot be determined numerically.

Summary

The in situ iron-manganese elimination process under discussion was accomplished in a technical sense; the iron and manganese content of the produced water decreased to an immeasurable value. Certain parts and parameters of the process were defined and it became clear that the applied Subterra time program is very far from beeing economical. By the increasing of the ratio of the produced/enriches water with an experimental value the economic index can presumably be multiplied as well.

REFERENCES

Fillis, J. – Molof, A. H. (1972): Effect of benthal deposits on oxygen and nutrient economy of flowing waters – J. WPCF 44.4 pp. 644 – 62.

Flick, G. (1968): Versuche zur Entmanganung eines Wassers auf adsorptiv-katalytischem Entmanganungsmaterial Neue Deliwa Zeitschrift H. 3.

Hässelbarth, U. – Lüdemann, D. (1967): Die biologische Verockerung von Brunnen durch Massenentwicklung von Eisen und Manganbakterien. Bohrtechnik – Brunnenbau – – Rohrleitungsbau, Berlin 10 – 11. sz.

Rott, U. (1976): Physikalische Grundlagen beim Transport von Schwermetallen im Grundwasser-Technische Univ. Hannover Sfb. 79. pp. 1 – 45.

Rott, U. – Boochs, P. W. – Barovic, G. (1978): Unterirdische Grundwasser-aufbereitung durch Einleitung von sauerstoffhaltigem Wasser in den Boden – Wasser und Boden 8.

Seyfried, C. F. – Rott, U. (1975): Verfahren zur Reinigung von Grundwasser von Mangan oder anderen löslichen Substanzen im Untergrund. BDPa.

Seyfried, C. F. – Rott, U. (1977): Grenzen und Möglichkeiten der subterrestrischen Wasseraufbereitung. Mitteilung der Subterra Methoden

INDEX

ISSN 0365–0634

A kiadásért felelős az Eötvös Loránd Tudományegyetem rektora
A kézirat nyomdába érkezett: 1988. január – Megjelent: 1988. október
Terjedelem: 21,28 A/5 ív. – Példányszám: 800
Készült monószedéssel, íves magasnyomással
az MSZ 5601–59 és az MSZ 5602–55 szabvány szerint
88.166., Állami Nyomda, Budapest
Felelős vezető: Mihalek Sándor igazgató