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Tuvalian sequences of the Balaton Highland and the Zsámbék Basin

Part I: Litho-, bio- and chronostratigraphic subdivision

Ferenc Góczán Anna Oravecz-Scheffer

The lithostratigraphic units which constitute the Carnian sequences of the outcrops and of boreholes drilled in the area of the Transdanubian Range, in the Balaton Highland, the Keszthely Mountains and the Zsámbék Basin, were studied from palynological and foraminifer-stratigraphic points of view.

We analyzed the Tuvalian microfauna (the age of which was verified *by Neomegalodon carinthiacus* (Hauer) and *Cornucardia hornigii hornigii* (Bittner)) as well as the sporomorph assemblages occurring with it. Knowledge of the entering and terminating taxa, as well as the changes in dominance of the taxa which form associations, made it possible to extend the evolutionary trend, known from the Cordevolian and Julian substages, of both micropalaentologic groups throughout the entire Carnian stage. Thus we were able to tag the Julian/Tuvalian substage boundary, characterize the Tuvalian foraminifer and sporomorph assemblages and correlate the studied sections.

By jointly evaluating the organic and inorganic microfacies, we were able to delineate the environmental conditions of the Upper Carnian formations between the Veszprém Marl Formation and the Main Dolomite Formation.

Key words: lithostratigraphy, biostratigraphy, chronostratigraphy, Carnian, Tuvalian, correlation, sporomorph, foraminifer, palaeoenvironment

1. Introduction

Palynologic and foraminifer investigations of Tuvalian formations of the Transdanubian Range form an integral continuation of our previous Triassic microbiostratigraphic research (Góczán et al. 1986; Loriga et al. 1990; Góczán et al. 1991; Góczán and Oravecz-Scheffer 1993).

In the present study, we give an account of the results of palynostratigraphic and foraminifer-stratigraphic investigations of the formations assigned to the Tuvalian substage, which were obtained during the study of the Triassic sequences of boreholes drilled in the area of the Balaton Highland, the Keszthely Mts, and the Zsámbék Basin, and of the classic surface exposures of the Triassic in the Balaton Highland (Fig. 1).

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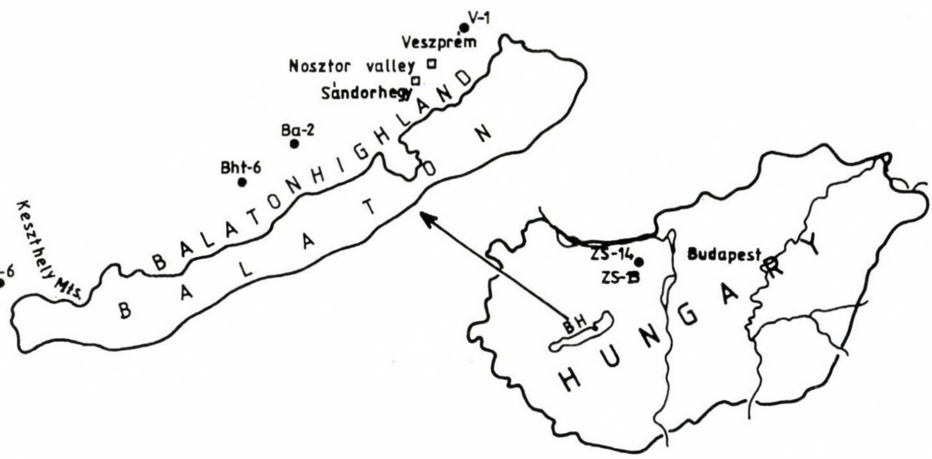


Fig. 1
Localities of Tuvalian sequences

In connection with the chronostratigraphic classification of the examined sections, it must be emphasized that we define the Tuvalian substage in the sense of Mojsisovics (1895, p. 1298), despite the fact that no ammonite fauna has been found in these formations. Indeed, the Tuvalian age of our surface sections is determined by megalodontid and foraminifer fauna, and that of our borehole sections by sporomorph and foraminifer assemblages.

Concerning Krystyn's biozonation of the substage (the described sequences contain no ammonite fauna) we cannot take a stand.

2. *Historic overview*

In this section, we will mention the studies of those authors who contributed most significantly to the stratigraphic and paleontological investigation of the Tuvalian formations of the Balaton Highland, the Southern Bakony Mts., the Veszprém Plateau, the Keszthely Mts., and the Zsámbék Basin.

Böck (1872) can be considered the author of the first monographic description. While investigating the Triassic formations of the Balaton Highland and Southern Bakony Mts, he was the first to determine the Upper Triassic age of the marl complex situated between the Füred Limestone and the Hauptdolomit. He called it "upper marl group" and correlated its upper formations with the Tor Beds ("Torer Schichten") of the Alps on the basis of their fauna (*Ostrea montis caprilis* Klipstein, *Pecten filosus* Hauer, *Corbis mellingi* Hauer, *Megalodus* sp. (small), *Waldheimia stopani* Suess). At the same time, he established the chronostratigraphic classification of these formations, since most of the Tor Beds are considered to belong to the Tuvalian substage (Tollmann 1976).

In his work entitled "Geological description of the town of Veszprém and its wider surroundings", Laczkó (1911) presented the Upper Triassic formations with detailed descriptions and illustrations of the sections of surface exposures. He called the Carnian formations beneath the Hauptdolomit Tor Beds, among other things on the basis of their fauna content; he pointed out their similarity to the Opponitz Beds of the Northern Alps.

Lóczy (1913), in his monograph on the geology of the Balaton Highland, subdivided the Carnian formations with an approach which would be considered up-to-date even today. He classified them lithostratigraphically as the "group of upper marls", "St. Cassian and Raibl layers", and biostratigraphically as the "*Protrachyceras aon, Trachyceras austriacum,* and *Physocardia hornigi*" zones.

The part of the Upper Carnian formations considered contemporaneous with the Tor Beds by Böck he named Sándorhegy Limestone.

In the detailed work performed in the Keszthely Mts, Szentes (1953) made some stratigraphic statements (still valid today) concerning the contemporaneous deposition of the Ederics Limestone and the Sándorhegy Limestone.

In "Geology of Hungary", Vadász (1960) reported – among the Upper Triassic formations of the Balaton Highland – on the upper part of upper marl group according to Böck (1872), Laczkó (1911), and Lóczy (1913).

Oravecz (1963), in his work on the stratigraphic and facies relations of Upper Triassic formations of the Transdanubian Range, pointed out those formations "contemporaneous with the Tor Beds" in the Pilis and Buda Mountains.

During the investigations of the Carnian formations in the surroundings of Veszprém, Badinszky (1973 a, b) compared the sections of Laczkó which were still to be found with the sequences of newer exposures. Among his well-documented sections, calcareous marl exposed at the Vasas sports ground and subdivided in detail, as well as the marl with *Cornucardia hornigii* outcropping in the pasture of Jutas and the overlying thin-layered dolomite characterized by *Megalodon triqueter pannonicus,* can be assigned to the Tuvalian substage.

During his mapping activity in the surroundings of Veszprém, Peregi (1979) undertook the detailed lithostratigraphic subdivision of the Carnian formations.

In his explanatory notes to the map of Veszprém and in the Lexique Stratigraphique, Szabó (1972–78) gave an account of the characteristics of the Sándorhegy Limestone according to Lóczy (1913). He determined that it belonged in the Tuvalian substage.

Bohn (1979), in his work on the geology of the Keszthely Mts, described the white biogenic limestone outcropping in the surroundings of Balatonederics as a lithostratigraphic unit of formation rank and proposed the name "Ederics Limestone Formation" for it.

In the correlation table of the Hungarian Triassic formations, among the Upper Triassic formations of the Balaton Highland and Keszthely Mts, Balogh (1981) indicated the Sándorhegy Limestone and Ederics Limestone as parts of the Veszprém Marl Formation in the *Tropites subbullatus* zone of the Tuvalian substage.

The report of the Hungarian working group on the Triassic within the framework of IGCP Project 4 (Balogh et al. 1983) gives an account of the microbiostratigraphic investigation of the Veszprém Marl Formation on the basis of the sequence of borehole Zsámbék-14. Based upon the foraminifer and palynologic knowledge of that time, the Upper Triassic sequence between the Budaörs Dolomite and Hauptdolomit was assigned to the Cordevolian and Julian substages. We show the results of their re-investigation in the present paper.

Góczán, Haas, Lőrincz, and Oravecz-Scheffer (1983) reported on the results of biostratigraphic and paleoenvironmental investigations of the 350.9 m thick Carnian sequence of borehole Hévíz-6 drilled in the Keszthely Mts. We also describe the results of the re-investigation of the sequence in this paper.

The geologic description of the type section of the Sándorhegy Limestone Formation was written by Oravecz in 1986. The surface exposure can be found in the Nosztori Valley near Csopak, at km 4.3 of the road. He assigned the entire sequence to the Tuvalian substage.

In their work "The stratigraphic position of the Hauptdolomit and its footwall formations in the eastern part of Keszthely Mts", Gyalog, Oravecz-Scheffer, Detre and Budai (1986) established that the marl layers with limestone intercalations, contemporaneous with the Ederics Limestone, belong to the uppermost part of the Carnian stage, and are contemporaneous with the Sándorhegy Limestone of the Balaton Highland on the basis of the microfauna and macrofauna investigations.

In her study "Foraminifera of the Triassic formations of Transdanubian Range", Oravecz-Scheffer (1987) dealt in detail with the boreholes which also penetrated the Tuvalian sequences. She verified the contemporaneity of the Ederics Limestone and Sándorhegy Limestone, and that they belong to the Tuvalian substage. On the basis of the foraminifer fauna, she believed that the sedimentation of the Ederics Limestone continued even into the Norian stage in some parts of its depositional area.

Végh-Neubrandt (1982), in her monograph "Triassische Megalodontaceae", assigns the uppermost layers of the Veszprém Marl Formation, and the carbonate formations contemporaneous with them, to the Tuvalian substage on the basis of their *Neomegalodon carinthiacus* (Hauer) and *Cornucardia hornigii hornigii* (Bittner) content.

In their report "Results to date of the mapping of the Keszthely Mts and the Balaton Highland", Császár et al. (1989) proposed a formation rank for the Sándorhegy Limestone.

In his doctoral dissertation "Geologic framework of the surroundings of Mencshely", Csillag (1991) suggested the introduction of the names Pécsely Member, Henye Dolomite Member, and Barnag Member, within the Sándorhegy Limestone Formation.

In the closing paragraph of their work dealing with the biostratigraphic characterization of Cordevolian and Julian formations of Csukrét Ravine at Balatoncsicsó, Góczán et al. (1991) also mention the boundary problems of Julian/Tuvalian substages.

Kristan-Tollmann et al. (1991) reported on the lithostratigraphic subdivision as well as the ostracod and conodont fauna of the Triassic formations of borehole Zsámbék-14.

In his paper "Carnian basin evolution in the Transdanubian Central Range, Hungary", Haas (1994) outlined the evolutionary history of the Carnian basin of the Transdanubian Range. He showed the geographic setting of Transdanubian Range, including the relation between the depositional areas of the Balaton Highland and the Northern Bakony Mts during the Middle Carnian, by comparing the individual facies zones using the paleogeographic reconstruction of the Northern Calcareous Alps and the Drauzug of Hagemeister et al. (1987).

Monostori (1994) described the Tuvalian ostracod fauna of the type locality of the Sándorhegy Limestone Formation exposed in the Nosztori Valley. In his paleoecologic evaluation, he described the periodically hypersaline conditions of formation of the lower, bituminous part of the sequence.

3. *Geologic characterization, lithostratigraphic and biostratigraphic subdivision and environmental analysis of the studied sections*

In our sections, the stratigraphic position of the Tuvalian formations we studied lies between the Veszprém Marl Formation and the Hauptdolomit Formation. Lithostratigraphically, they belong predominantly to the Sándorhegy Formation, more rarely to the Ederics Limestone Formation, and the youngest layers, sometimes, to the Hauptdolomit Formation.

The Sándorhegy Formation develops with continuous sedimentation from the Veszprém Marl Formation (constituting its footwall) and passes over without interruption into the Hauptdolomit Formation which constitutes its cover. The greater part of their sections is found by means of drilling, and the remainder in surface sections. In describing these sections, we put the main emphasis on the surface outcrop in the Nosztori Valley because:

– the sequence of this exposure was accepted by the Triassic Subcommission of the Hungarian Stratigraphic Committee as the surface type section of the Sándorhegy Formation,

– in this section, the characteristic features of the formation can be investigated from the base to the cover, and the bulk of bivalve and foraminifer faunas which prove that it belongs to the Tuvalian substage was found here,

– this exposure also played an important role in the work of the "classic" authors (Böck, Lóczy) who first described these formations.

3.1 Nosztori Valley exposure

The road cut beginning at the 4th km of Highway No. 73 between Csopak and Veszprém exposes a surface section of the Sándorhegy Formation in which both the Pécsely and Barnag Members of the formation can be well studied; it is approximately 90 m thick.

The Pécsely Member develops with continuous sedimentation from the Veszprém Marl Formation; it begins with thin-layered, bituminous limestones, and continues with platy limestones with marl, and calcareous marl intercalations. Above these beds, limestone layers with bivalve and Brachiopod fragments, and sometimes oncoidic biogenic limestones, are found. They form the closing layers of the member.

The Barnag Member consists of yellow-coloured, thick-bedded limestone beds with chert lenses, and in the upper part of the member, light pink-coloured, thick-bedded limestones. The *Neomegalodon carinthiacus* (Hauer), *Cornucardia hornigii hornigii* (Bittner) bivalve species (Oravecz 1986) and the Aulotortus-dominated foraminifer fauna (determined during their thin section re-investigation), which prove their position in the Tuvalian substage, were found in these layers.

By means of repeated collecting, we carried out the thin section microfauna investigation in the complete section of the formation, and palynologic maceration work in the marly intercalations and bituminous limestones. The latter proved to be barren.

The results of the microfacies and microfauna investigations can be summarized by groups of depositional beds as follows:

– platy, bituminous limestone layers are made up of homogeneous biomicrites and biomicrosparites with dark bituminous micrite shreds and pyrite nuclei (seen in thin section). Among their biogenic components, relatively well-preserved gastropod and bivalve sections, ostracod valves and fish-scales as well as filament fibres can be identified. Benthonic foraminifer fauna is very sparse. It consists of some Gsollbergella, Duostomina and Glomospira sections.

– the following biogenic limestone beds show pelletal and peloidal texture, with oolitic and oncoidic parts becoming more frequent upwards. They contain a remarkable amount of echinoderm fragments, Parafavrenia coproliths, brachiopod and mollusc fragments, on which encrustation by colonies of the sessile foraminifer *Tolypammina gregaria* Wendt is frequent. Among the vagile benthonic foraminifers – beside the *Gsollbergella spiroloculiformis* which continues to be present –, the following ones appear:

Aulotortus sinuosus Weynschenk
Aulotortus friedli (Kristan)
Aulotortus subsphaericus (Salaj)
Triadodiscus eomesozoicus (Oberhauser)
Glomospirella capellinii Ciarapica et Zaninetti
Nodosaria raibliana Gümbel
Endotriada izjumiana (Dain)
Dentalina subsiliqua Franke
Opthalmidium sp.
Vaginulinopsis sp.

Calcite spots, sometimes visible even to the naked eye on the fresh fracture surface of thick-bedded biogenic limestone layers, derive from the mass of recrystallized *Aulotortus* remnants. In the thin carbonate laminae of fine lime mud intercalated between them, a microfauna consisting, besides foraminifers, of sponge spicules and *Roveacrinidae brachialias* washed together, can also be observed.

– the microfacies picture of oncoidic lumachelle layers is very diversified. The greatest part of the bioclasts encrusted by sessile foraminifers and blue algae of rock-forming quantity is composed of bivalve and echinoderm fragments and a few gastropods. In the sparitized, dolomitized matrix with upward-mottling limonite, some dasycladaceans and *Aulotortus sinuosus* as well as *Tetrataxis* sp. have been preserved.

– the uppermost, pink-coloured limestone beds form a transition towards the Hauptdolomit Formation. Their thin section texture shows idiomorphic dolomite, rhombohedral micrite and microsparite with blue algae shreds, and very few recrystallized Aulotortus sections.

In the evolutionary history of the sequence, the following environmental changes can be distinguished:

– in the lower part of the formation, the depositional area represents a poorly ventilated, deeper water environment, reflecting anaerobic bottom conditions;

– in the middle part, it became a well-ventilated, shallower water environment, with a well-agitated bottom.

– in the upper part, it developed into an open lagoon, then into a proximal zone (reaching the tide mark), to finally become the carbonate sedimentary environment of the Hauptdolomit. The fauna determined in the exposure is listed in Fig. 2.

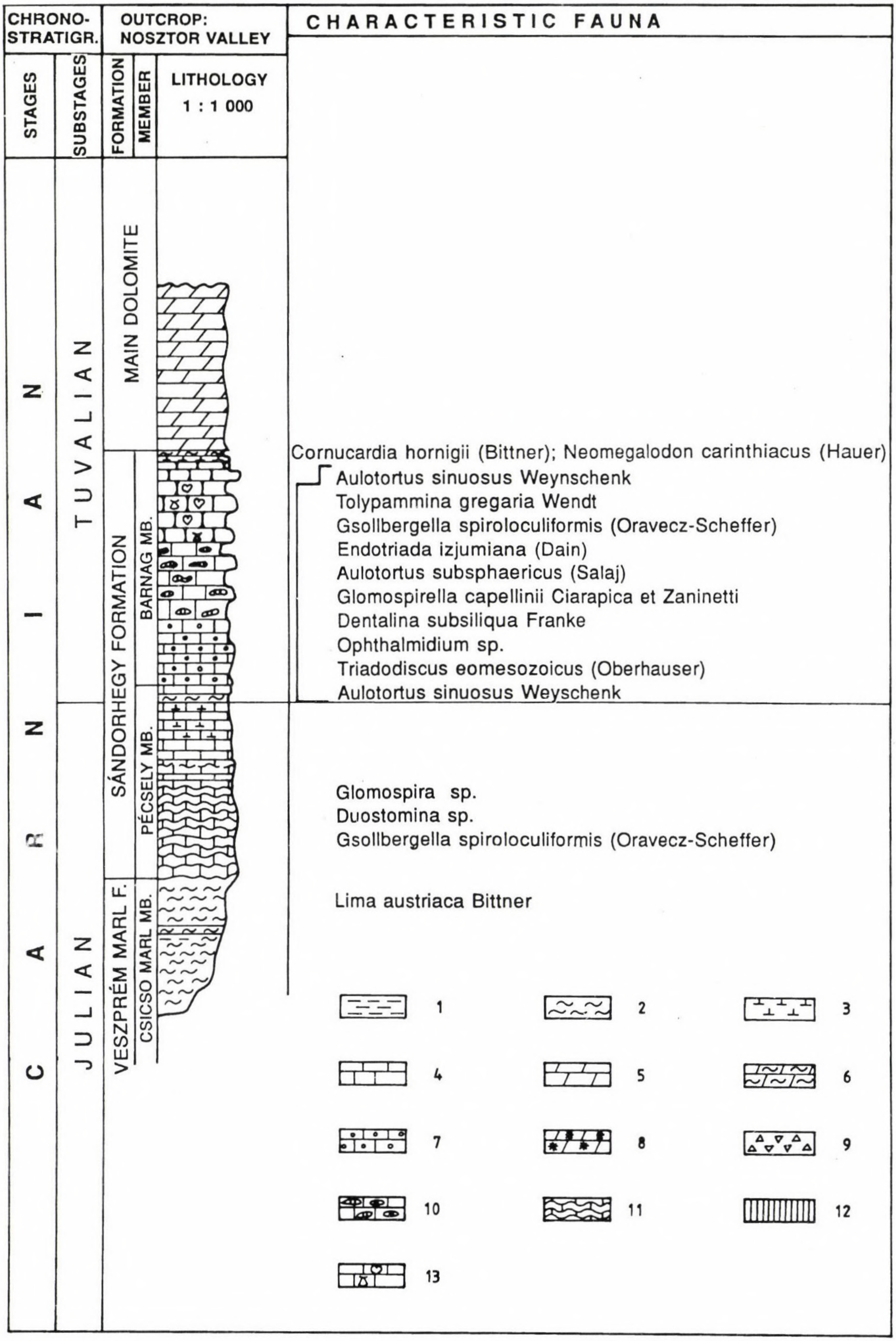
3.2 Sándorhegy surface exposure

Actually, the exposure of this name is situated not on the Sándor Hill, but at the end of the road leading from the Koloska Valley northwest to the Arács Ridge, as was pointed out by Csillag (1991). The locus tipicus of the Sándorhegy Limestone named in Lóczy's work (1913) is represented by this exposure.

Here, overlying the Csicsó Marl Member of the Veszprém Marl Formation, grey, slightly clayey limestone beds are deposited, the uppermost layer of which are formed by lighter grey biogenic limestone. On the basis of the investigation of the thin sections made from the layers of the exposure, it also appears here that a large part of the Pécsely Member and the uppermost layers of the Barnag Member are missing from the sequence known in the type section of the formation.

The microfauna of the two limestone beds of the exposure contains the following foraminifer taxa:

Glomospira cf. *kuthani* (Salaj)
Glomospirella cf. *capellinii* Ciarapica et Zaninetti
Agathammina iranica Zaninetti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J U L I A N
MAIN DOLOMITE
SÁNDORHEGY FORMATION
BARNAG MB.
PÉCSELY MB.
VESZPRÉM MARL F.
CSICSO MARL MB.
Cornucardia hornigii (Bittner); Neomegalodon carinthiacus (Hauer)
Aulotortus sinuosus Weynschenk
Tolypammina gregaria Wendt
Gsollbergella spiroloculiformis (Oravecz-Scheffer)
Endotriada izjumiana (Dain)
Aulotortus subsphaericus (Salaj)
Glomospirella capellinii Ciarapica et Zaninetti
Dentalina subsiliqua Franke
Ophthalmidium sp.
Triadodiscus eomesozoicus (Oberhauser)
Aulotortus sinuosus Weyschenk
Glomospira sp.
Duostomina sp.
Gsollbergella spiroloculiformis (Oravecz-Scheffer)
Lima austriaca Bittner
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"Paleonubecularia" floriformis Ciarapica et Zaninetti
Nodosaria raibliana Gümbel
Aulotortus praegaschei (Koehn-Zaninetti)
Aulotortus sinuosus Weynschenk

Beside these, there is a remarkable amount of encrusted echinoderm and mollusc fragments as well.

In the residue from washing the thin marl laminae intercalated between limestone beds, only a few specimens of *Nodosaridae* div. sp. and *Cornuspira pachygyra* Gümbel were found. However, holothurian (Theelia and Eocaudina) sclerites as well as tiny fragile ostracod valves and fish teeth are frequent. This formation also did not contain sporomorphs. The determined microfauna can be seen in Fig. 3.

This assemblage indicates periodically open marine environmental changes in the evolution of the depositional area.

The assigning of a Tuvalian age to these units, which were first described in the surface exposures, was possible in large measure thanks to subsurface sections obtained from the following boreholes:

3.3 Barnag, borehole Bat-2

According to Csillag (1991), its sequence is made up of the following lithostratigraphic units:

0.8–17.4 m: Hauptdolomit Formation
17.4–88.7 m: Sándorhegy Formation, Barnag Member
88.7–175.7 m: Sándorhegy Formation, Pécsely Member
175.7–200.0 m: Veszprém Marl Formation, Csicsó Marl Member

The sequence and its evolutionary history can be outlined as follows:

The series of predominantly calcareous marl layers of the Csicsó Marl Member and the Pécsely Member's lower microcrystalline portion (composed of limestone layers interbedded with thin marl laminae and extending up to 162.5 m) – which were formed in the medial zone of an open lagoon – are replaced by an alginite-banded bituminous limestone series. Initially, the deposition of these units began in a lagoon with a gradually sinking bottom, then continued in a rapidly deepening, poorly ventilated anoxic environment. In the sequence, this fact can be traced up to the depth of 143.2 m. On the basis of the rich organic microfacies of the rock layers, this part of the borehole can be described as of expressly alginitic facies. The already decreasing

← Fig. 2
Lithology and characteristic fauna of Outcrop Nosztor Valley. 1. clay; 2. marl; 3. calcareous marl; 4. limestone; 5. dolomite; 6. dolomitic marl; 7. oolitic limestone; 8. cherty dolomite; 9. lithoclasts; 10. cherty nodular limestone; 11. bituminous limestone; 12. gap; 13. limestone with molluscs

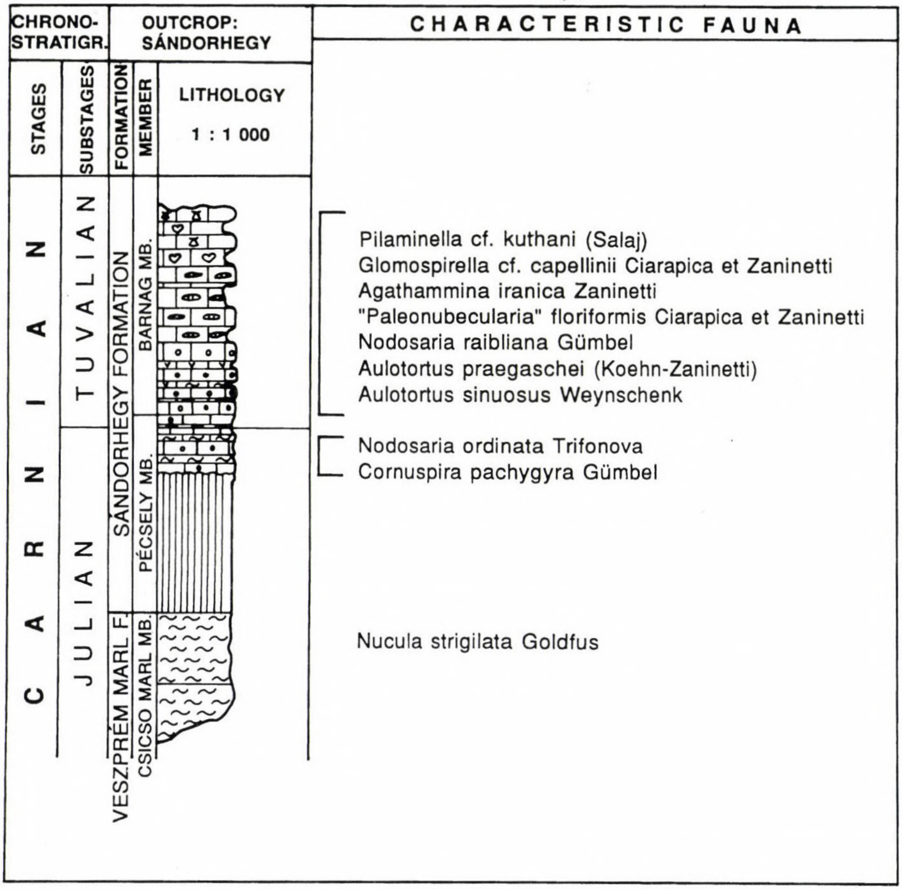

Fig. 3
Lithology and characteristic fauna of Outcrop Sándorhegy. For legend see Fig. 2

biodegradation in the organic microfacies of the sample taken at 143.8 m indicates the transition to the anoxic environment. A tiny fraction of common pollen making up about 90%, and coal grains (consisting almost exclusively of fibrous alga fragments) amounting to approximately 10% of the organic microfacies of the grey marl from 141.5 m, already unambiguously indicates a deeper water microenvironment of the distal zone of an open lagoon. These marl, clay marl and calcareous marl layers reflect a yet deeper-water lagoon environment, as well as reducing bottom conditions, and have preserved large amounts of pollen; they extend up to 91.5 m, practically to the upper part of the Pécsely Member, where a considerable environmental change can again be recognized. This event also resulted in changes in both the organic and inorganic microfacies, and in the sporomorph and foraminifer associations. All these indications together suggest a microbiostratigraphically reliable Julian–Tuvalian boundary determination in this sequence.

Rapidity of change in the former biotope is well characterized by the fact that the foraminifer fauna of the sample taken at 91.9 m is still characteristic of the Julian substage, while that deriving from 90.2 m already consists of the assemblage of the Tuvalian substage. This environmental change began with a rapid subsidence of the basement, which (due partly to the deepening of the depositional area, partly to the emergence of the erosional base in the coastal region) resulted in a fluvial influx of higher energy and water mass. As a consequence of this environmental change, cherty limestone layers penetrated between 88.7 and 74.3 m appeared in the sequence, representing the lower part of the Barnag Formation of the Sándorhegy Limestone. The texture of these rocks as seen in thin sections is characterized by dark pellets and micrite nodules. Among the microfauna remains, coproliths are frequent. Its foraminifer fauna is relatively rich. The most frequent forms are *Nodosaria ordinata* Trif., *Triadodiscus* sp., and *Gsollbergella spiroloculiformis*. The appearance of *Aulotortus sinuosus* is of substage indicator value. Among the elements of macrofauna, echinoid remnants as well as sponge spicules and bodies occurring more rarely, are well recognizable.

From this pelagic inner basin environment, a lagoon developed in the course of a slow transition, in which thick-bedded limestones with oncoidal intercalations were formed. From 52.5 m upwards, an open lagoon environment with a frequently oscillating bottom can be recognized, in which marl, calcareous marl, and thin limestone layers of various thickness were deposited. In the depth interval between 49 and 50 m, microfacies analysis outlines a deeper-water, protected microenvironment of a nearshore, proximal zone of the open lagoon. Here the rocks are originally of lime mud matrix, packstone and mud supported texture, and are slightly recrystallized. They have a rich, well-preserved microfauna of diversified composition. Plankton is constituted exclusively by roveacrinid test elements, and benthic elements by calcareous foraminifers and some ostracods. Some agglutinated specimens can be also observed. Among the encrusting organisms, *Tolypammina gregaria* is worth mentioning. In the composition of organic microfacies, already fragments of carbonized wood play a leading role. In the grain composition, the coarse fraction already tends toward medium, which is slightly rounded and not decomposed. The grains of the medium and fine fraction are well-rounded but not decomposed. Fibrous algae and marine microplankton with organic test (*Dictyotidium reticulatum* Schulz) occur frequently. Sporomorphs are of medium quantity and in relatively good preservation. Their colour varies still between dark yellow and light brown; however, bisaccate pine pollen with white air pockets also occur frequently.

This organic microfacies picture completely coincides with the evaluation of inorganic microfacies, i.e. it indicates a protected microenvironment of the proximal region of the open lagoon, beneath the wave base.

In the depth interval 27.8–29.6 m, a tendency of gradual emergence of the bottom resulted in an open lagoon/nearshore zone shallow water micro- environment, with an agitated bottom; it shows periodical oxidation effects, to which organic and inorganic microfacies bear unambiguous witness. According to the inorganic microfacies, the original matrix of lime mud is replaced here by coarse, translucent crystalline calcite sparite. Detrital material of biogenic origin occurs in massive quantity. Microfauna is composed of foraminifers with coarse, agglutinated tests, among which *Meandrospirella karnica* (Oravecz-Sch.), *M. planispira* (Oravecz-Sch.), *Glomospirella balatonica* nov. sp. as well as *Ammovertellina tuvalica* nov. sp. are worth mentioning.

In this location, the youngest, topmost layers of the member are formed by a 70 cm thick greyish-brown marl bed, in the lower 10 cm of which occur many bivalve shell fragments and few oncoids; also a few sporomorphs of glass-white exine and some thick-walled, dark-brown, about 100 μ-sized, fern spores (belonging to genera *Verrucosisporites* and *Converrucosisporites*) were found. The latter's influx, mainly through aereal erosion and fluvial transportation, as well as their organic microfacies (consisting of well-rounded coal grains belonging to fine, medium and coarse fractions) indicate the nearshore, but deeper water, microenvironment of an open lagoon. In the Tuvalian sequence of borehole Barnag-2, from 91.5 m up, the same evolutionary tendency can be observed in the evolution of the sporomorph assemblages as in borehole Balatonhenye-6, with the difference that in the latter, in the rich sporomorph assemblages of Upper Julian and Lower Tuvalian beds, gradual change is better reflected. For this reason, the boundary of the two substages can be proven more convincingly in borehole Barnag-2. Its typical sporomorph and foraminifer taxa are indicated in Fig. 4.

3.4 Balatonhenye, borehole Bht-6

According to Csillag (1991), its sequence is made up of the following lithostratigraphic units:

6.6–22.6 m: Hauptdolomit Formation
22.6–147.7 m: Sándorhegy Formation
  22.6–63.7 m: Barnag Member
  63.7–113.0 m: Henye Dolomite Member
  113.0–147.7 m: Pécsely Member
147.7–200.0 m: Veszprém Marl Formation, Csicsó Marl Member

Its biochronostratigraphic subdivision and the changes of its environmental conditions (in genetic order) are as follows:

Between 200.0–147.7 m, the well-encountered dolomitic marly layers in the upper part of the Csicsó Marl Member. All of this member, as well as the overlying Pécsely Member (consisting of limestone beds with dolomite and dolomitic marly intercalations) can be assigned to the Julian substage – with the exception of the top one and a half meters. Its classification is verified by the occurrence of a rich sporomorph assemblage, and also proven by the

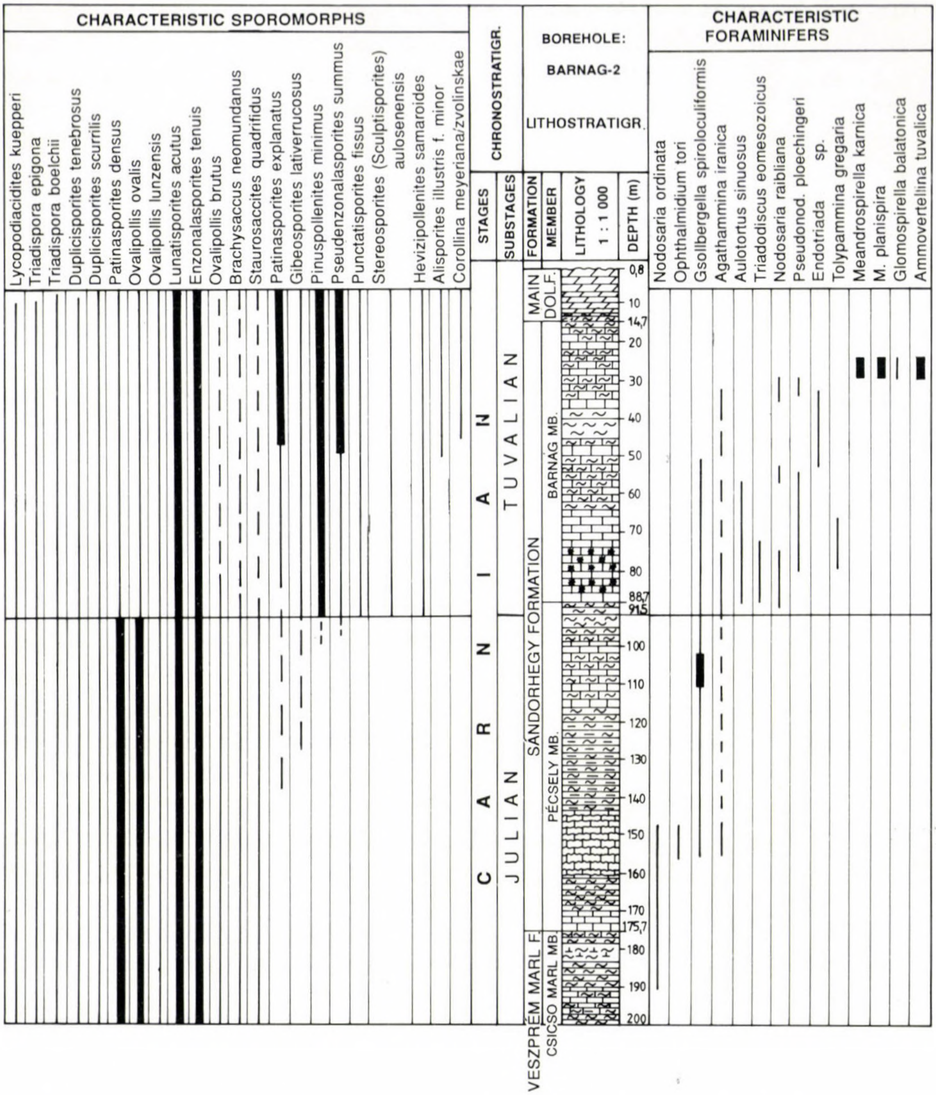

Fig. 4
Characteristic sporomorph and foraminifer taxa of Borehole Barnag-2 (Bat-2). For legend see Fig. 2

presence of the ammonite *Neoprotrachyceras baconicum* (Mojs.), found in the section of Csukrét Ravine (Góczán, et al. 1991). This assemblage, characterized by the species *Patinasporites densus, Sulcatisporites kraeuseli, Staurosaccites quadrifidus, Brachisaccus neomundanus, Ovalipollis brutus,* and *Duplicisporites maljavkinae,* can be traced from 200.0 m to 117.5 m without any notable changes.

The same applies to microfauna, the stratigraphic value of which is also confirmed in the section of Csukrét Ravine.

From the depth of 117.5 m upwards, a radical change in the environment of the sedimentary area of such magnitude began that it resulted in the deposition of the Henye Dolomite. These rocks did not favor the preservation of the sporomorph material any more.

In this sequence, the boundary of Julian and Tuvalian substages is marked by the appearance of *Aulotortus sinuosus* at 116.5 m, and is supported by radical changes in both the lithofacies and the preservation of sporomorph assemblages, as well as the composition of organic microfacies. The open lagoon environmental sequence, consisting predominantly of an alternation of limestone, calcareous marl, and marl (characteristic from the bottom of the borehole at 200 m up to 115.1 m), is replaced by the formation of dolomitic limestone and calcdolomite at 115.1 m, as a consequence of the change in environment which already began at 117.5 m. Above them, at 113.0 m, layers of the Henye Dolomite Member appear, which can be traced without any considerable change up to 63.7 m. Their thin section investigation shows a coarse, mosaic-like, sparitic texture. Neither microfauna nor macrofauna were found in the beds of this member. Even its organic microfacies is characterized by only a small amount of organic matter, made up exclusively of a composition of mainly thin, fibrous alga fragments of fine grain size and some colloid nodules with clay mineral contamination. This typical organic microfacies indicates an offshore carbonate plateau sedimentary environment, which (beginning from 64.0 m) developed into an open lagoon environment, according to the evidence of organic and inorganic microfacies. In its offshore region, fine lime mud sedimentation occurred, accompanied by slight oscillation.

From 63.7 m to 34.8 m, marly, dolomitic-marly, and calcareous-marly layers, which make up the greater part of the Barnag Member, were formed in this environment; among the microfauna of this unit, besides benthonic foraminifers, pelagic roveacrinids, holothurians (Theelia) and filaments played an important role. Foraminifers are represented by sessile *Tolypammina gregaria* as well as by *Gsollbergella spiroloculiformis*, species of *Triadodiscus* and *Nodosaria raibliana*.

Within the sporomorph associations, only a few specimens of the species *Staurosaccites quadrifidus*, *Brachysaccus neomundanus*, *Sulcatisporites kraeuseli*, and *Duplexisporites maljavkinae*, characteristic of the Julian, can be found already. In their stead, besides the Ovalipollis species, and *Lunatisporites acutus*, *Patinasporites densus*, *Enzonalasporites tenuis*, *Duplexisporites scurrilis*, *D. tenebrosus*, and *D. granulatus* extending through the whole of the Carnian stage, an increasingly important role is played by *Pinuspollenites minimus* and *Microcachryidites* div. sp., appearing at the end of the Julian among the bisaccates, *Gibeosporites lativerrucosus* among the spores, as well as the elements characteristic of the end of the Triassic (some specimens related to *Corollina zvolinskae*, *Cingulizonates rhaeticus*).

At 34.8 m, another considerable change can be observed in the sequence, which indicates that the open lagoon was being transformed into a shallower-water, highly agitated, euphotic, nearshore shelf lagoon, through a slight emergence of the bottom. In this environment, thick-walled agglutinated foraminifer species already occur very frequently, among which species of the genus *Meandrospirella* are the most characteristic: *M. karnica*, *M. planispira*, and *Glomospirella balatonica* nov. sp. The uppermost, calcareous-marly layers of the Barnag Member, containing thin-shelled bivalves and crinoid fragments, grade into the Hauptdolomit Formation, alternating with about 0.7 m thick dolomitic-marl layers.

A change in the sequence, beginning at 34.8 m, also leaves its mark on the organic microfacies. Because of the shallower water conditions of the basin on the one hand, and the possibility of increased oxidation in the fine lime mud (as a consequence of which less pollen can be fossilized) on the other, fern spores, considered as undergrowth of the longshore vegetation, attain a poorer relative frequency in the sporomorph assemblages, in terms of species and specimens. Nevertheless, among the grains of carbonized wood of microscopic size, coarse and medium fraction is frequent, and at the same time, fragments of colloid and fibrous algae decrease or disappear. The typical sporomorph and foraminifer taxa for the section are indicated in Fig. 5.

3.5 Veszprém, borehole V-1

The Carnian sequence of the borehole drilled in the Aranyos Valley near Veszprém shows the following lithostratigraphic subdivision:

29.0–140.3 m: Hauptdolomit Formation
140.3–232.0 m: Sándorhegy Formation
232.0–589.5 m: Veszprém Marl Formation
  232.0–360.0 m: Csicsó Marl Member
  360.0–488.0 m: Sédvölgy Dolomite Member
  488.0–589.2 m: Mencshely Marl Member
589.2–660.0 m: Kádárta Dolomite Formation

Its biostratigraphic subdivision is referred to in the work of Oravecz-Scheffer (1987), and its comparative geologic relations in the paper of Peregi (1979).

For the present study, we resampled the still accessible core material from the borehole, primarily in order to perform the previously unrealized palynostratigraphic examinations, but also to complete the microfaunal and microfacies investigations. As a result, we were able to undertake the chronostratigraphic classification of different lithostratigraphic units penetrated by boreholes in a more accurate fashion, and were also able to increase the foraminifer fauna from Tuvalian formations. According to the renewed investigations, the lower part of the sequence, the Kádárta Dolomite Formation (penetrated between 589.2–660.9 m), the whole of the Mencshely Marl Member (exposed between 488.0 and 589.2 m) and the lower part of the Sédvölgy

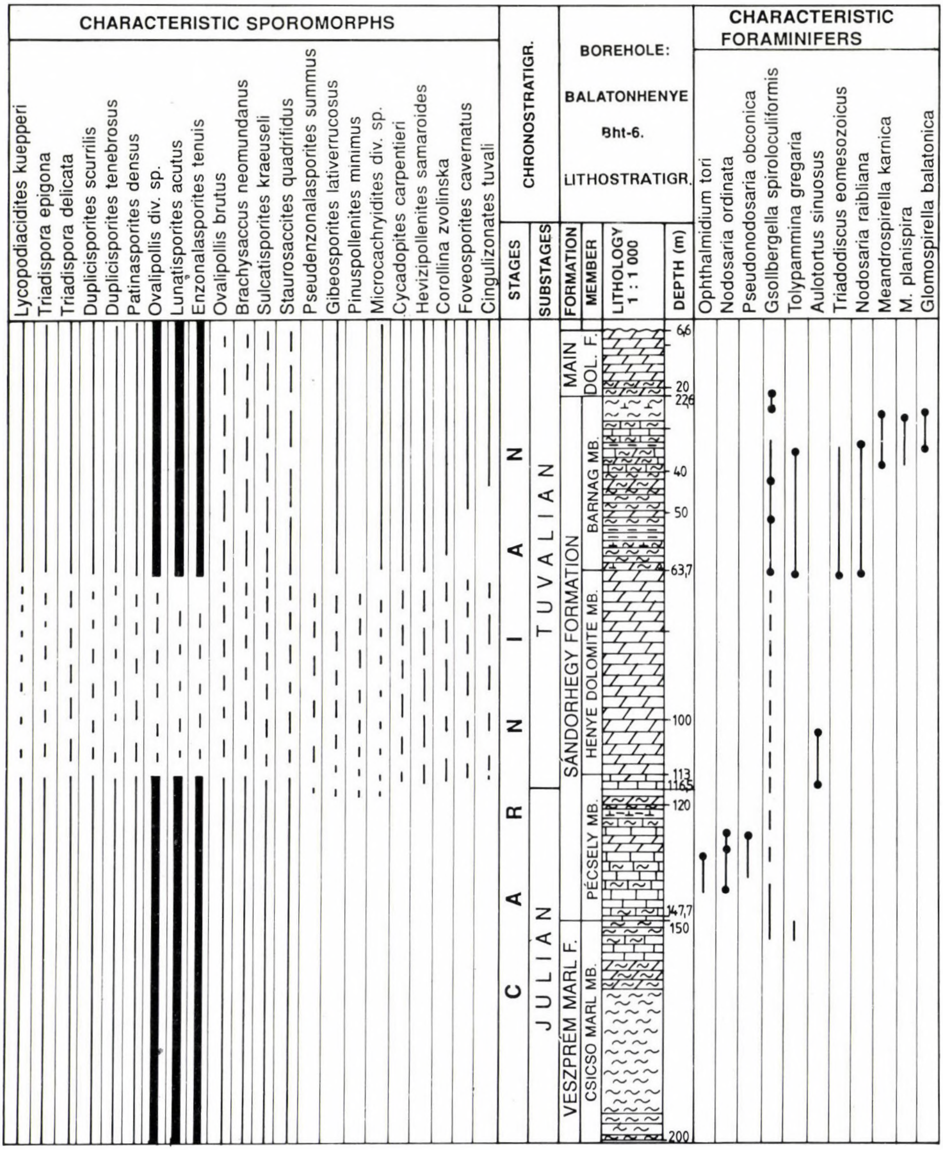

Fig. 5
Characteristic sporomorph and foraminifer taxa of Borehole Balatonhenye-6. For legend see Fig. 2

Dolomite Member (451–488 m) belong to the Cordevolian substage; this is verified by the Circumpolles-dominated sporomorph assemblages of the depth intervals 582.0–583.0 m, 553.0 m, 485.0–485.4 m, and 451.9 m. Cordevolian microfauna is represented by characteristic "Cassianian" assemblages, traceable from 595.0 up to 505.5 m. Assigning of the greater part of the Sédvölgy Dolomite Member (penetrated between 360.0 and 488.0 m) to the Julian substage is not only based upon its concordance with the stratigraphic position of the Nosztor Limestone Member, but also upon the foraminifer assemblage containing *Ophtalmidium tori, Triadodiscus* and *Austrocolomia* species traceable from 358.0 up to 338.0 m.

Marly layers encountered between 360.0–232.0 m represent the Csicsó Marl Member of the Veszprém Marl Formation, assigned to the Julian substage on the basis of (besides the above-listed foraminifer fauna) the rich, *Staurosaccites quadrifidus-, Sulcatisporites kraeuseli-,* and *Duplicisporites maljavkinae*-bearing sporomorph assemblages of the samples taken from 352.7 m and 326.0–327.0 m. Unfortunately, no sample from the upper part of the borehole, where no coring took place, remained. For this reason, the boundary of the Julian and Tuvalian substages can be emplaced only on the basis of analogies at 205.0 m, in the lower part of the Sándorhegy Formation penetrated in the depth interval 232.0–135.0 m.

Foraminifer fauna traceable from 163.5 to 143.0 m points to the Tuvalian substage. This fauna association is *Tolypammina gregaria*-dominated and also contains robust agglutinated *Glomospirella* and *Ammovertellina* species. Their appearance can be observed in microfacies with oncoids, blue algae, echinoderms, molluscs, and microbiosparites. In the well-bedded marly dolomite (143.0–151.0 m) of the uppermost part of the Sándorhegy Formation (already forming a transition to the Hauptdolomit Formation), there is also a remarkably great amount of shell fragments of echinoderms and molluscs. Among the foraminifers, however, rather than the encrusting sessile forms, members of the vagile benthos play a leading role: *Nodosaria raiblina, Nodosaria ordinata,* and *Gsollbergella spiroloculiformis.*

3.6 Hévíz, borehole Hv-6

This well (with a hydrogeologic objective) was drilled in 1978 in the Hévíz –Alsópáhok–Felsőpáhok triangle.

Beneath Quaternary and Tertiary formations, between 180.0 m and the bottom of the borehole at 530.9 m, Upper Triassic formations were penetrated. The results of a thorough examination of the Triassic layers were published in a common paper (Góczán et al. 1983). In this work, in addition to the biostratigraphic subdivision, foraminifer investigations, microfacies analyses (and their environmental interpretation) were discussed in detail.

Since then, on the basis of mapping activities and the results of investigations of newer borehole sequences, it has appeared reasonable to re-investigate the Triassic formations of the borehole. As a result, the sequence of the borehole shows the following lithostratigraphic subdivision:

180.0–247.2 m: Sándorhegy Formation, Barnag Member
247.2–408.0 m: Ederics Limestone Formation
408.0–539.0 m: Veszprém Marl Formation, Csicsó Marl Member

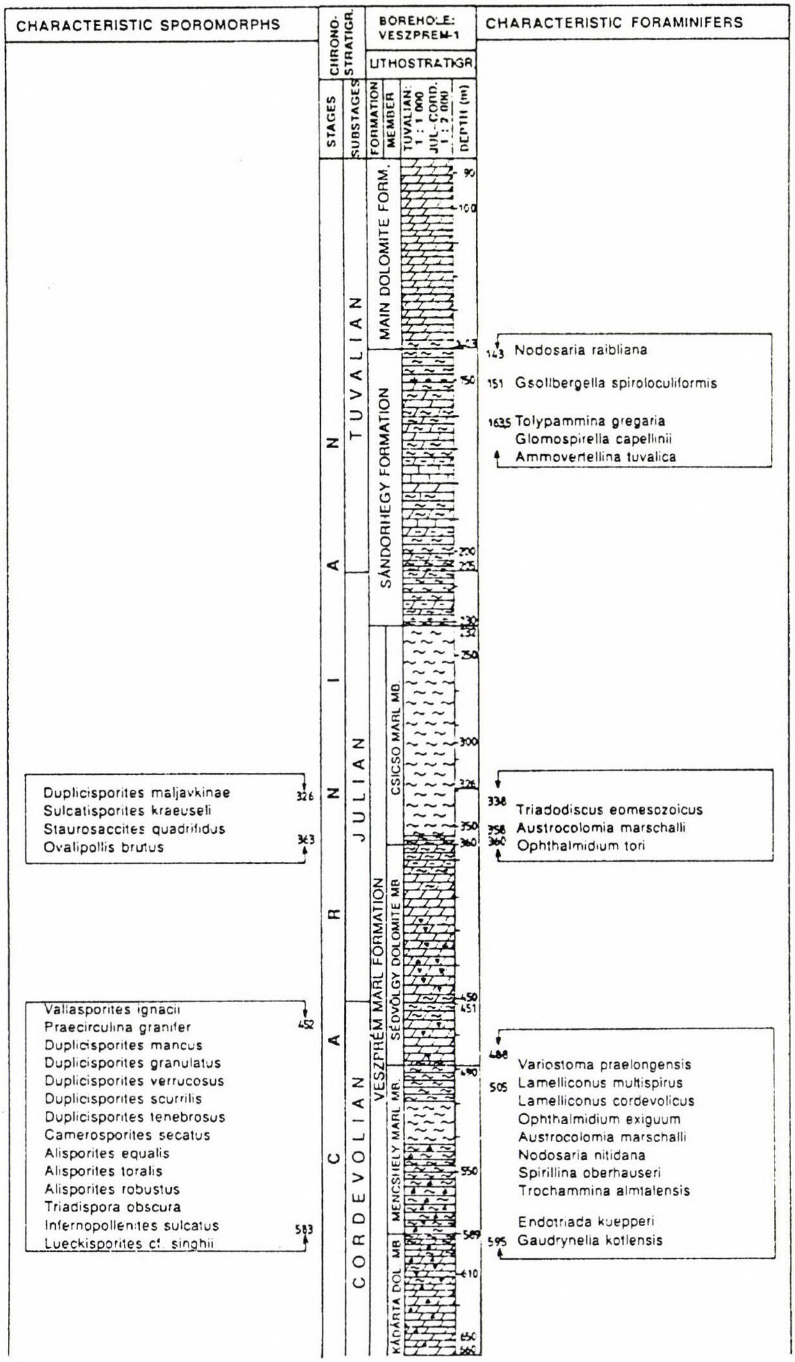

Fig. 6
Characteristic sporomorph and foraminifer taxa of Borehole Veszprém-1. For legend see Fig.2

The published microfacies analyses, environmental and evolutionary interpretations of these lithostratigraphic units are still acceptable today. Organic microfacies investigations had not been carried out previously; the ones performed now confirm the results of inorganic microfacies analyses and refine our environmental knowledge. Thus, in the evolutionary history of the former lagoon environment of the formations (penetrated from 530.1 to 411.0 m in the Csicsó Marl Member of the well), different microenvironments of proximal, medial, and distal zones of the lagoon and their rhythmic alternations could be demonstrated. Above this depth interval, from 411.0 m to 408.2 m, a gradual transition of the lagoon into a carbonate platform could be traced. In the uppermost part of the Triassic sequence, above a plateau environment extending from 408.8 m to 247.2 m, between 247.2 and 180.0 m, it was possible to determine medial and proximal microenvironments of a setting beginning with an open lagoon developed from the carbonate platform, and developing into a restricted lagoon.

In our biostratigraphic re-evaluation, besides the newer literature, it was mainly the sporomorph and foraminifer assemblages known from the sequences of the Carnian sections in Balatonfelvidék (Góczán et al. 1991) which supplied good material for comparison.

Nevertheless, the accuracy of the boundary between the Julian and Tuvalian substages is based on two points: on the one hand, on the presence of *Aulotortus sinuosus* appearing at 412.0 m and traceable up to 185.2 m, as well as of *Miliolipora cuvilieri*, and on the Julian and Tuvalian sporomorph assemblages of wells Barnag-2 and Balatonhenye-6 on the other. On the basis thereof, the biostratigraphic subdivision of the Triassic sequence of borehole Hévíz-6 (as compared to the published data) is modified as follows:

530.9–413.0 m: Upper Julian
413.0–180.0 m: Tuvalian

Accordingly, we propose to designate the Julian/Tuvalian substage boundary in the depth interval 412.0–413.0 m with the following explanation:

– Among the bisaccates of great size, the frequency of the taxa *Alisporites robustus* Nilsson 1958, *Ovalipollis brutus* Scheuring 1970, *Staurosaccites quadrifidus* Dolby 1976, *Sulcatisporites kraeuseli* Mädler 1964, and *Brachysaccus neomundanus* (Leschik 1956) Mädler 1964, characteristic of the entire Julian substage, decreases to accessory value in this depth interval.

– Contemporaneously, among the bisaccates of medium and small size, *Triadispora delicata* Orlowska-Zwolinska 1983, *Triadispora epigona* Klaus 1964, *Alisporites illustris* Leschik 1956, *Lunatisporites acutus* Leschik 1956, *Ovalipollis ovalis* Krutzsch 1955, *Ovalipollis minimus* Scheuring 1970 and bisaccates found in Rhaetian formations of Western Poland and identical with grains determined as *Pinuspollenites minimus* (Couper 1958) Kemp by Orlowska-Zwolinska in 1983 as well as *Hevizipollenites samaroides* nov. gen. et sp., gain an association-forming role.

– Accompanying the members of *Circumpolles* (*Duplicisporites granulatus* Leschik 1956, *D. scurrilis* (Scheuring 1970) 1978, *Duplicisporites maljavkinae* (Klaus 1960) Scheuring 1978, *D. tenebrosus* Scheuring 1978, *Enzonalasporites tenuis* Leschik 1956, and *Patinasporites densus* Leschik 1956) which extend throughout the Carnian, first specimens of *Pseudenzonalasporites summus* Scheuring 1970 and *Patinasporites explanatus* (Leschik 1956) nov. comb.,

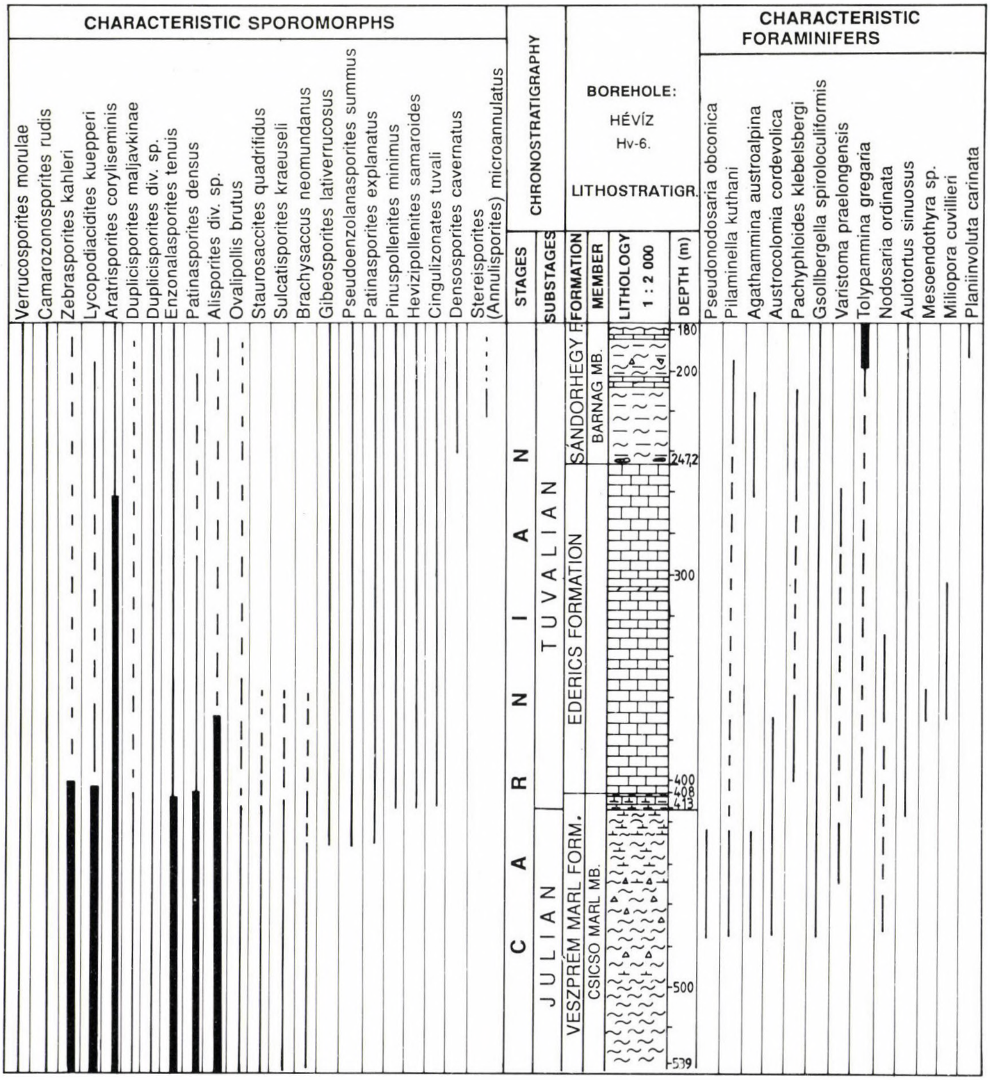

Fig. 7
Characteristic sporomorph and foraminifer taxa of Borehole Hévíz-6. For legend see Fig. 2

restricted to the Tuvalian substage according to Visscher et Brugman (1981), appear.

– Besides the pteridophyte spores (such as *Verrucosisporites morulae* Klaus 1960, *Camarozonosporites rudis* (Leschik 1956) Klaus 1960,' *Zebrasporites kahleri* Klaus 1960, *Lycopodiacidites kuepperi* Klaus 1960, *Tigrisporites hallensis* Klaus 1960, *Aratrisporites coryliseminis* Klaus 1960, and *Uvaesporites gadensis* Praehauser-Enzenberg 1970) which also occur throughout the entire Carnian, *Stereosporites (Annulisporites) microannulatus* (de Jersey 1962) Schulz 1970, which appears in the Upper Julian and already has a global extension prior to the Rhaetian stage, as well as the regionally occurring *Gibeosporites lativerrucosus* (Leschik 1956) 1959, appearing almost simultaneously, can be regarded as of consistent occurrence for the first time here.

In this location occurs the first appearance of *Densosporites cavernatus* Orlowska-Zwolinska 1966, described in the Rhaetian stage of the German Triassic, and *Cingulizonates tuvali* nov. sp., closely related to *Cingulizonates rhaeticus* (Reinhardt 1962) Schulz 1967, also only known in the Rhaetian so far.

The typical sporomorph and foraminifer taxa of this borehole are shown in Fig. 7.

3.7 Zsámbék, borehole Zs-14

Well Zs-14 was a structural test drilled in the southeast foreland of the Gerecse Mountains, in the Mány–Zsámbék Basin within the plateau, west of the village of Zsámbék in 1979. It encountered Carnian formations in a thickness of 500 m. Its detailed, section-by-section macroscopic elaboration and geologic evaluation were first carried out by Oravecz (in Haas et al., 1981). Results of the thorough examination were reported by Haas et al (1981) in "Final report on borehole Zsámbék-14". On the basis of this well, Balogh et al. (1983) also gave an account of the results of investigations of borehole Zs-14 in their report on the activity of the Hungarian Triassic working group, within the framework of IGCP programme.

A Triassic age was assigned to the following lithostratigraphic units by Oravecz:

280.0–317.0 m: Hauptdolomit Formation
317.0–765.0 m: Veszprém Marl Formation

within which he distinguished 5 members, naming them with the letters a-b-c-d-e. He emphasized that "the formation essentially differs from the described stratotype not only in its thickness observed here, but also in its lithology and subdivision".

765.0–881.0 m: Budaörs Dolomite Formation.

The lithostratigraphic subdivision of the sequence was proposed by Haas (in Kristan-Tollmann et al. 1991; also in 1994) as follows:

<table>
<tr><th colspan="2">J. Oravecz 1991</th><th colspan="2">J. Haas 1994</th><th colspan="2">F. Góczán and
A. Oravecz-Scheffer 1994</th></tr>
<tr><td colspan="6">Hauptdolomite Formation</td></tr>
<tr><td>e
member
395 m</td><td rowspan="5">veszprém marl formation</td><td colspan="2">Veszprém Marl Formation
Upper member
395 m</td><td>Barnag Member</td><td></td></tr>
<tr><td>d member
445.5 m</td><td>dolomite member
450 m</td><td rowspan="3">Mátyáshegy Formation</td><td>Henye Member
445.5 m</td><td></td></tr>
<tr><td>c
member
516 m</td><td rowspan="2">limestone member
684 m</td><td>516 m</td><td></td></tr>
<tr><td>b
member
684 m</td><td>Mátyáshegy Formation</td><td></td></tr>
<tr><td>a
member
767 m</td><td colspan="2">Veszprém Marl
Lower Member</td><td colspan="2">Veszprém Marl
Mencshely Marl Member</td></tr>
<tr><td colspan="6">Budaörs Dolomite Formation</td></tr>
</table>

280.0–315.0 m: Hauptdolomit Formation
315.0–395.0 m: Veszprém Marl Formation, upper member
395.0–450.0 m: Mátyáshegy Formation, dolomite member
450.0–684.0 m: Mátyáshegy Formation, limestone member
684.0–767.0 m: Veszprém Marl Formation, lower member
767.0–881.3 m: Budaörs Dolomite Formation.

On the basis of the knowledge of the Carnian sections we have worked upon, we see the possibility of lithostratigraphic and biostratigraphic correlation of the individual sections.

Accordingly, in borehole Zs-14, formations developed from the Budaörs Dolomite Formation by gradual transition and consisting of predominantly grey marls (penetrated between 684.0–765.0 m) correspond to the Mencshely Marl Member of the Veszprém Marl Formation. The overlying "limestone succession with chert layers and lenses" differs completely from the members of the Veszprém Marl Formation between 516.0–683.0 m. As far as the stratigraphic position is concerned, though its lower part (637.0–683.0 m), interbedded with clay marl layers and containing less chert, can be compared to the facies of the Nosztor Limestone Member which contains chert nodules (e.g. Csukrét Ravine exposure), its upper part, consisting of cherty limestone and cherty dolomite layers and extending from 616.0 m to 637.0 m, is more closely related to the Mátyáshegy Formation, known in the Buda Mts., with its layers of higher chert content.

The section extending from 516.0 m up to the Hauptdolomit Formation (315.0 m), which consists of limestone interbedded with marl layers at the base, in the middle of cherty dolomite, and grey marl layers in the upper part, is correlatable with the corresponding members of the Sándorhegy Formation.

The different interpretations of the lithostratigraphic subdivision of the Carnian formations penetrated between the Budaörs Dolomite Formation and the Hauptdolomit Formation in borehole Zs-14 are summarized in the Table below.

The lithostratigraphic character of the section between these two facies areas (that is, of the Carnian sequence of the borehole) may help to reconstruct the distance separating the environments of two sedimentary sub-basins from one another.

The previous biostratigraphic subdivision of the sequence has been modified as follows:

881.3–855.0 m: Longobardian (?)
855.0–683.0 m: Cordevolian
683.0–493.2 m: Julian
493.2–315.0 m: Tuvalian

This chronostratigraphic subdivision can be justified by the following facts:

– In the foraminifer fauna of the depth interval 855.0–805.0 m, no taxa restricted to the Ladinian stage occur; however, *Nodosaria ordinata* Trifonova and *Meandrospirella karnica* (Oravecz-Scheffer) are known only in Carnian formations so far. This is the reason why we assign this upper part of the Budaörs Dolomite Formation to the Cordevolian substage.

– Foraminifers appearing at 739.0 m indicate the appearance of the Carnian fauna. They are as follows:

Pilamminella kuthani (Salaj)
Gsollbergella spiroloculiformis (Oravecz-Scheffer)
Pachyphloides klebelsbergi (Oberhauser)
Aulotortus friedli (Kristan)

On the basis thereof, the Mencshely Marl Member can be also assigned to the Cordevolian substage.

In separating the Cordevolian and Julian substages, we could rely only on palynologic data, since no chronostratigraphically valuable foraminifers were found in this part of the borehole (at the beginning of the formation of the cherty units, ostracods and sponge colonies populated the basement of the restricted lagoon, rather than stenohaline organisms).

The first sporomorph assemblages of the Cordevolian substage can already be found in the upper, marly part of the Budaörs Dolomite Formation (783.0–783.3 m). As a consequence of the carbonate facies, the massive bisaccate and the few Circumpolles grains occur only as exine clasts. From this depth interval upward, the composition and quantitative change of the sporomorph associations can be well traced in average samples taken at 1 m intervals, but in strongly differing states of preservation. Well-determinable grains were first found between 749.2 and 750.2 m. The general characteristics of this Cordevolian assemblage are as follows:

– Bisaccates dominate over the Circumpolles group (62:34–65:32); although in most cases, medium and small-sized forms are prevalent among the bisaccates (47:2–40:9), the big-sized ones have an association-forming role. To the former group belong representatives of Ovalipollis, Triadispora, Schizosaccus, Riamesporites, Cuneatisporites, Parvisaccites, and Vitreisporites, and to the latter one, mainly the greater part of Alisporites species (*A. robustus, A. aequalis, A. toralis*), among the *Ovalipollis* genus only *O. brutus* as well as members of the genera *Brachysaccus* and *Infernopollenites*, can be assigned.

– Among the Circumpolles group, the genera *Duplicisporites, Camerosporites, Enzonalasporites*, and *Praecirculina* occur systematically.

– Pteridophyte spores are represented only by some trilet triangularis grains of 30–40 μ size (Cyathidites, Converrucosisporites, Leiotriletes).

– Sporomorph assemblages of Cordevolian formations from borehole Zs-14 are also characterized by organic-walled foraminifer chamber remnants occurring consistently, with several specimens (locally in great quantities) showing uniserial to botryoidal and planispiral structure, indicating the open marine character of the Cordevolian depositional environment.

The above-listed palynostratigraphic characteristics can be traced up to 683.0 m of the sequence.

Among the assemblages forming the Cordevolian sporomorph association, the following taxa were determined:

Cyathidites australis Couper 1953
Leiotriletes sp.
Converrucosisporites sp.
Praecirculina granifer (Leschik 1956) Kl. 1960
Praecirculina tenebrosa Scheuring 1970
Vallasporites ignacii Leschik 1956
Camerosporites secatus Leschik 1956
Enzonalasporites vigens Leschik 1956

Doubingerispora filamentosa Scheuring 1978
Triadispora aurea Scheuring 1978
Triadispora cf. *crassa* Kl. 1964
Alisporites aequalis Mädler 1964
Alisporites robustus Nilsson 1958
Alisporites toralis (Leschik 1955) Clarke 1965
Brachysaccus neomundanus (Leschik 1956) Mädler 1964
Schizosaccus keuperi Mädler 1964
Cuneatisporites radialis Leschik 1956
Rimaesporites potoniei Leschik 1956
Parvisaccites triassicus Scheuring 1978
Protodiploxipinus sp.

From 682.0–683.0 m upward, the composition and dominant character of the sporomorph associations change. On the basis of the degree of this change, the designation of the boundary of the Cordevolian/Julian substages seems to be justified here, based upon the following facts:

– in the associations where bisaccates still dominate, *Alisporites robustus, A. aequalis, A. toralis* of great size already play a subordinate role, while the percentage of medium and small-sized forms is as high as 80%;

– among subdominant Circumpolles, *Duplicisporites granulatus* Leschik occurs consistently, *Patinasporites densus* and *Pseudenzonalsporites summus* Scheuring first appear and reach already a share of 5% at the end of the Julian (494.2–495.2 m);

– among the pteridophyte spores, Cyclogranisporites appears first, then, some metres higher up, two coarsely ornamented species of Verrucosisporites (*V. thuringiacus* Mädler and *V. krempii* Mädler) are found, which are present all along the Julian sequence. Consistently occurring taxa of the Julian part of the sequence are as follows:

Leiotriletes sp.
Cyathidites australis Couper 1953
Paraconcavisporites sp.
Camarozosporites rudis (Leschik 1956) Kl. 1960
Cyclogranisporites arenosus Mädler 1964
Verrucosisporites krempi Mädler
Verrucosisporites thuringiacus Mädler
Verrucosisporites morulae Kl. 1960
Lycopodiacidites kuepperi Kl. 1960
Aratrisporites scabratus Kl. 1960
Praecirculina granifer (Leschik 1956) Kl. 1960
Paracirculina tenebrosa Scheuring 1987
Paracirculina scurrilis Scheuring 1970
Pseudenzonalasporites summus Scheuring 1970
Ovalipollis ovalis Krutzsch 1955
Ovalipollis ludens Scheuring 1970
Ovalipollis brutus Scheuring 1970
Doubingerispora filamentosa Scheuring 1978
Infernopollenites sulcatus (Pautsch 1958) Scheur. 1970
Duplicisporites granulatus Leshik 1956
Camerosporites secatus Leschik 1956

Enzonalasporites manifestus Leschik 1956
Patinasporites densus Leschik 1956
Ellipsovellatisporites toralis Kl. 1960
Cuneatisporites radialis Leschik 1956
Rimaesporites potoniei Leschik 1956
Chordasporites singulichorda Kl. 1960
Alisporites toralis (Leschik 1955) Clarce 1965
Schizosaccus keuperi Mädler 1964
Septasporites pectinatus Leschik 1956
Pytiosporites devolvens Leschik 1956
Brachysaccus neomundanus (Leschik) Mädler 1964
Podosporites amicus Scheuring 1970
Triadispora epigona Kl. 1960
Lunatisporites acutus Leschik 1956
Lunatisporites noviaulensis (Leschik 1956) Scheur.
Striatoabietites aytugii Visscher 1966

This sporomorph assemblage can be easily traced (depending on the lithofacies) in different states of preservation, strongly influenced by environmental factors, with larger or smaller fluctuations in composition and quantity, in the Pécsely Member of Sándorhegy Formation up to the interval 494.3–495.2 m. In the grey marl layers of this member, which were deposited in the more protected microenvironment of the distal zone of an open lagoon, evidence of the Julian vegetation of the surrounding land area were preserved in an excellent state, in varied composition and in great quantities.

The Julian substage is also marked by foraminifers appearing at 628.5 m with several specimens: *Ophtalmidium tori* Koehn-Zaninetti, *Tolypammina gregaria* Wendt, *Gsollbergella spiroloculiformis* (Oravecz-Scheffer), which also propagated locally, as well as *Nodosaria ordinata* Trifonova, the great density of which is also characteristic of the sometimes more open marine condition of the depositional area.

In separating the Julian and Tuvalian substages at 493.2 m, we primarily took into account the appearance of *Glomospirella capellinii* Ciarapica et Zaninetti, as well as the consistent occurrence of *Aulotortus sinuosus* Weynschenk. However, in characterizing the substage we also did not leave the presence of members of the *Eoguttulina* foraminifer genus from 368.0–315.0 m, or the changes in the slow evolutionary trend of the rich sporomorph material between 494.2 and 493.2 m, out of consideration. This change is manifested most remarkably in the abrupt quantitative increase of *Pseudenzonalasporites summus* Scheuring.

The percentage distribution in the sporomorph spectra of the sequence is as follows:

551.2–552.7 m: 0.71%
496.2–497.5 m: 4.40%
494.2–495.2 m: 5.50%
493.2–494.2 m: 20.0%
338.9–339.6 m: 17.0%

An abrupt increase in percentage value, rising gradually from 5.5% to 20.0% between 552.7 and 494.2 m, and its average not falling below 10% in the part investigable to 315.0 m, unambiguously indicates a significant biostratigraphic boundary in this depth interval. If we also take into account (beside these quantitative data) the observation of Visscher et Brugman (1981) concerning the biostratigraphic value of this taxon, according to which the occurrence of *Ps. summus* (supported also by ammonite data) is restricted to the Tuvalian substage in the Alpine region, the Julian/Tuvalian substage boundary designated at 493.2 m on the basis of the appearance of foraminifer species seems to be confirmed.

We also take into account, as part of the evidence of the biostratigraphic boundary drawable in this depth interval, the change in Circumpolles/bisaccate ratio which (in the sequence of this borehole) is as follows:

707.4–708.4 m: 34 : 62
494.2–495.2 m: 45 : 54
493.2–494.2 m: 52 : 48
338.9–339.2 m: 61 : 32

Beside these quantitative changes (similar to those in other investigated borehole sections), the *Densosporites* and *Cingulizonates* species which have now appeared are also regarded as an evidence of the Tuvalian substage here, equal or very closely related to those which so far are known only in the Norian and Rhaetian stages of the German Triassic.

From the Julian/Tuvalian boundary of well Zs-14, which can be emplaced in the depth interval 493.2–494.2 m, the following taxa were determined in the Tuvalian sporomorph associations, traceable up to 315.0–316.0 m:

Paraconcavisporites lunzensis Kl. 1960
Trilites tuberculiformis Couper 1947
Lycopodiacidites kuepperi Kl. 1960
Converrucosisporites sp.
Verrucosisporites morulae Kl. 1960
Verrucosisporites krempii Mädler 1983
Kyrtomisporites ervii Van Der Eems 1983
Uvaesporites reissingeri (Reinhardt 1964) Lund 1977
Uvaesporites gadensis Preh.–Enz. 1970
Uvaesporites argenteformis (Bolkh. 1953) Schulz 1967
Densosporites fissus (Reinhardt 1964) Schulz 1967
Cingulizonates cf. *rhaeticus* Schulz 1967
Vallasporites ignacii Leschik 1956
Praecirculina granifer (Leschik 1956) Kl. 1960
Duplicisporites granulatus Leschik 1956
Duplicisporites scurrilis (Scheuring 1970) 1978
Duplicisporites maljavkinae (Kl. 1960) Scheuring 1978
Duplicisporites quadruplicis (Scheuring 1970) 1978
Duplicisporites tenebrosus (Scheuring 1970) 1978
Duplicisporites novimundanus (Leschik 1956) Scheuring 1978
Camerosporites secatus Leschik 1955
Pseudenzonalasporites summus Scheuring 1970
Enzonalasporites tenuis Leschik 1956

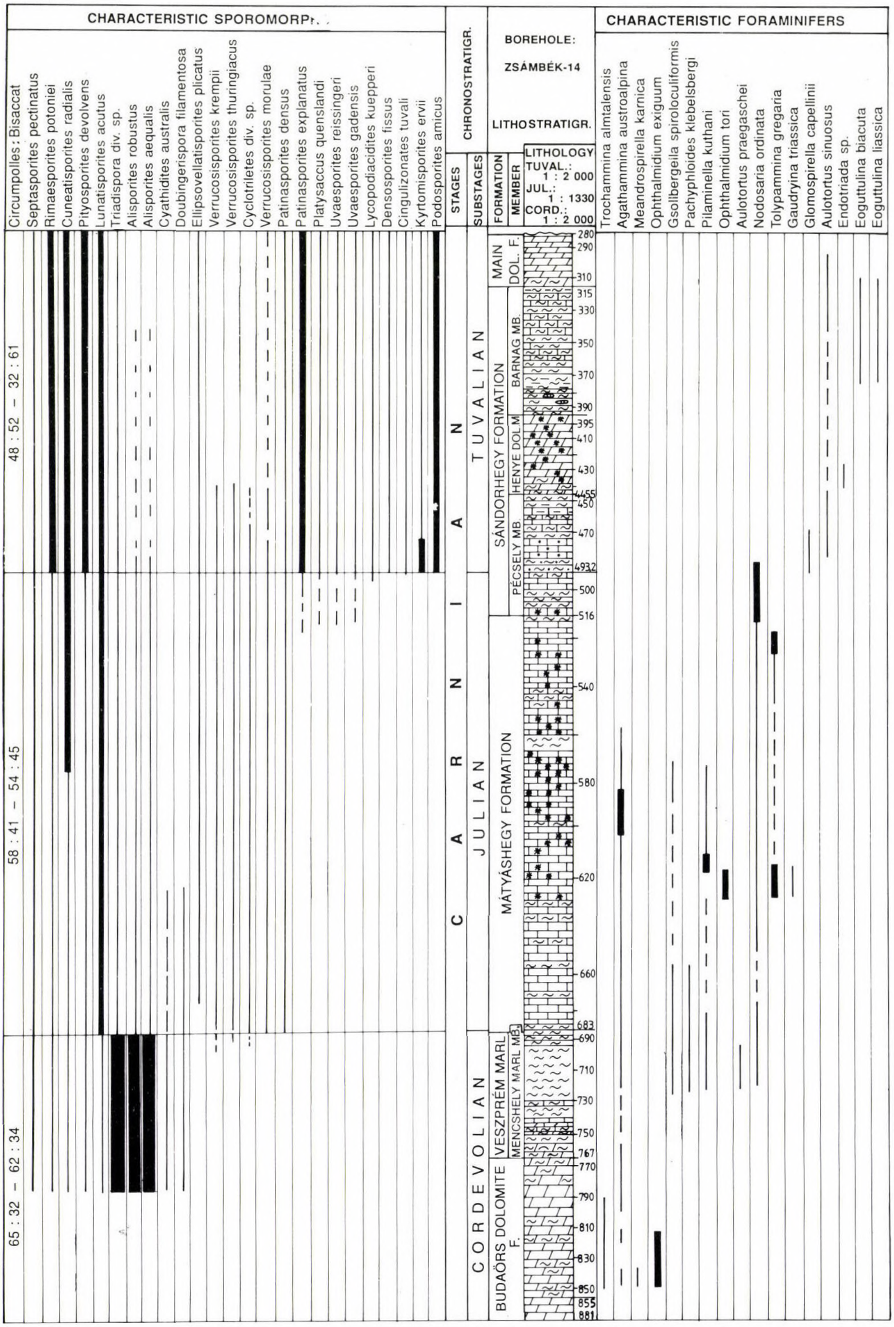

Fig. 8
Characteristic sporomorph and foraminifer taxa of Borehole Zsámbék-14. For legend see Fig. 2

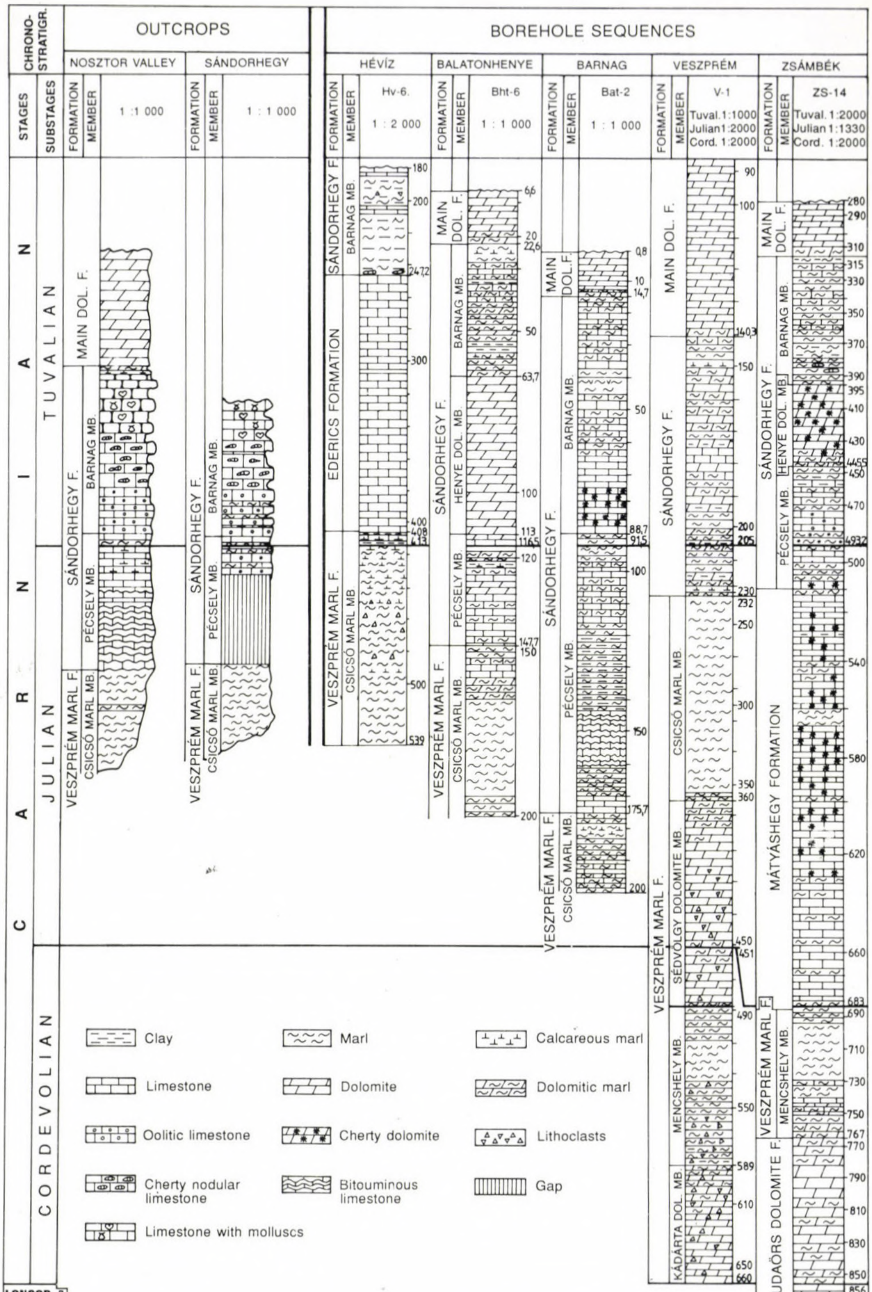

Fig. 9
The correlation of the Tuvalian formations of the investigated sections

Enzonalasporites vigens Leschik 1956
Patinasporites densus Leschik 1956
Patinasporites explanatus (Leschik 1956) nov. comb.
Ovalipolis ovalis Kr. 1955
Ovalipollis cultus Scheuring 1970
Ovalipollis minimus Scheuring 1970
Alisporites australis de Jersey 1962
Alisporites aequalis Mädler 1964
Rimaesporites potoniei Leschik 1956
Septasporites pectinatus Leschik 1956
Chordasporites singulichorda Kl. 1960
Schizosaccus keuperi Mädler 1964
Cuneatisporites radialis Leschik 1956
Pityosporites devolvens Leschik 1956
Ellipsovelatisporites plicatus Kl. 1960
Podosporis amicus Scheuring 1970
Lunatisporites acutus Leschik 1956

The typical sporomorph and foraminifer taxa are indicated in Fig. 8.

The correlation of the Tuvalian formations of the investigated sections is shown in Fig. 9.

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Tuvalian sequences of the Balaton Highland and the Zsámbék Basin

Part II: Characterization of sporomorph and foraminifer assemblages, biostratigraphic, palaeogeographic and geohistoric conclusions

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We analyzed the Tuvalian foraminifer and sporomorph assemblages occurring in the Carnian formations of outcrops and boreholes drilled in the Balaton Highland and the Zsámbék Basin, from biostratigraphic and palaeogeographic points of view. Having studied their dominance relations and their ranges, besides the taxa occurring throughout the Carnian and entering in the Julian, it was found that those which appear in the Tuvalian but reach their dominance at the end of the Triassic and in the Liassic, respectively, proved to be characteristic of the Tuvalian substage, as well as those which have been known only from Tuvalian formations so far.

Palynologic analyses from a palaeogeographic point of view resulted in the interpretation that the Carnian basins of the Balaton Highland and of Zsámbék had developed separately from each other, as parts of two terranes; the former close to the southern coastal region of Tethys, and the latter near the northern one, from the Julian to the beginning of the Middle-Upper Tuvalian, when they came into proximity of each other for the first time. During the sedimentation of the Main Dolomite, they occurred already as a single terrane.

Among the newly-found taxa, two sporomorphs and two foraminifera have been palaeontologically described, and the taxonomic position of two foraminifer species has been discussed.

Key words: foraminifer, sporomorph, Carnian, Tuvalian, biostratigraphy, palaeogeography, palynologic terrane analysis.

1. Introduction

In Part I of the present paper "Tuvalian sequences of the Balaton Highland and the Zsámbék Basin", the lithostratigraphic, biostratigraphic and chronostratigraphic subdivision and palaeoenvironmental conditions of the studied sections were described. Their stratigraphic correlation was shown in chart No. 2.

The present paper deals primarily with the characterization of Tuvalian sporomorph and foraminifer assemblages found to date, as well as with their

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biostratigraphic and palaeogeographic analysis. On the basis of the data obtained by comparing their occurrence in time and space, an attempt was made to outline the trend of evolution of the depositional area of the Balaton Highland and the Zsámbék Basin in the Carnian.

In the last part, the authors present the description of some new taxa, significant from both stratigraphic and palaeogeographic points of view.

Because of the abundance of the material, the authors could not aspire to completeness when compiling the plates of photos. However, one or more specimens of all the taxa occurring regularly in the Tuvalian formations and being preserved well enough to be photographed are presented, also demonstrating their variability.

2. *Characterization and biostratigraphic and palaeogeographic evaluation of foraminifer fauna*

The following foraminifer fauna was encountered in the studied Tuvalian formations:

Tolypammina gregaria Wendt
Ammovertellina tuvalica nov. sp.
Lituotuba cf. *canovicae* Urosevic
Glomospirella capellinii Ciarapica et Zan.
Glomospirella balatonica nov. sp.
Meandrospirella karnica (Oravecz-Scheffer)
Meandrospirella planispira (Oravecz-Scheffer)
Glomospirella shengi Ho
Pilaminella gemerica (Salaj)
Pilaminella kuthani (Salaj)
Trochammina alpina Kristan-Tollmann
Trochammina tabasensis Brönnimann et Zan.
Valvulina azzouzi Salaj
Tetrataxis inflata Kristan
Tetrataxis sp.
Endotriada izjumiana (Dain)
Endotriada austrotriadica (Oberhauser)
Endotriada gruenbachensis (Oberhauser)
Endotriada sp.
Agathammina austroalpina Kristan
Agathammina iranica Zaninetti et. al.
"*Paleonubecularia*" *floriformis* Ciarapica et Zan.
Ophthalmidium martanum (Farinacci)
Ophthalmidium leischneri (Kristan-Tollmann)
Opthalmidium tori Koehn-Zaninetti
Ophthalmidium sp.
Gsollbergella spiroloculiformis (Oravecz-Scheffer)
Glyphostomella triloculina Cushman et Waters
Miliolipora cuvillieri Brönnimann et Zaninetti
Ophthalmipora dolomitica Zaninetti et. Brönn.
Planiinvolua carinata Leischer
Nodosaria ordinata Trifonova
Nodosaria raibliana Gümbel
Dentalina subsiliqua Franke
Pseudonodosaria ploechingeri (Oberhauser)
Pseudonodosaria klebelsbergi (Oberhauser)
Austrocolomia sp.
Astacolus kanicus (Oberhauser)
Frondicularia woodwardi Howchin
Eoguttulina biacuta Kristan
Eoguttulina liassica Strickland
Eoguttulina liassica procera Kristan
Triadodiscus eomesozoicus (Oberhauser)
Aulotortus praegaschei (Koehn-Zaninetti)
Aulotortus sinuosus Weynschenk
Aulotortus friedli (Kristan)
Aulotortus subsphaericaus (Salaj)
Diplotremmina astrofimbriata Kristan
Duostomina sp.
Oberhauserellinidae div. sp.

The distribution of foraminifera is very uneven in the different sequences. Both in boreholes and outcrop profiles, they appear dispersedly, locally concentrated, sometimes in bulk between long, monotonous, microfauna-free sections. This can be explained by the following reasons:

– the thin section method of investigation, which can be regarded as point-sampling,

– strong facies control, originating from sessile and vagile benthonic lifestyles,

– subsequent recrystallization processes.

Accordingly, it is clear that successive evolutionary steps and lines cannot be shown. However, those typical associations can be identified, which may help to recognize the relations and similarities in time and space. In the studied sequences, the following assemblages can be distinguished:

– *Gsollbergella–Agathammina* association (borehole Barnag-2, lower and middle parts of Nosztor Valley outcrop),

– oncoidal *Tolypammina*-Cyanophyta association (borehole Veszprém-1, 157.0–163.0 m, upper part of Nosztor Valley outcrop, biogenic limestone bed of Sándorhegy outcrop, borehole Hévíz-6, 195.0 m),

– *Aulotortus–Glomospirella* association (uppermost layers of Nosztor Valley outcrop, uppermost bed of Sándorhegy outcrop, borehole Barnag-2, 55.0 m),

– *Ammovertellina–Meandrospirella* association (borehole Barnag-2, 29.5 m, borehole Balatonhenye-6, 31.0-34.3 m),

– *Eoguttulina*-Ostracoda association (borehole Zsámbék-14, 315.0-368.0 m).

The occurrence of these associations in the Sándorhegy Formation of the Balaton Highland indicates an approximate chronological succession. However, in the Ederics Limestone Formation, located beneath the Main Dolomite Formation in the Keszthely Mts., – obviously as a consequence of facies differences – the situation is not the same (see the foraminifer associations of boreholes Balatonederics-1 and Hévíz-6, in Oravecz-Scheffer, and Gyalog et al. 1986).

In turn, the appearance of the *Eoguttulina* association as well as the lack of *Tolypammina* and *Ammovertellina–Glomospirella balatonica–Meandrospirella karnica* associations, respectively, are characteristic of the upper part of the Triassic sequence of borehole Zsámbék-14.

Taking into account the ranges of foraminifer taxa determined in the Tuvalian formations of the Transdanubian Range, the following four groups of the taxa can be distinguished:

– taxa typical of the entire Carnian: *Pseudonodosaria klebelsbergi, Pseudonodosaria ploechingeri, Astacolus carnicus, Gsollbergella spiroloculiformis, Agathammina austroalpina, Triadodiscus eomesozoicus*

– taxa appearing in the Julian substage and being present to the end of the Tuvalian substage: *Ophthalmidium tori, Valvulina azzouzi, Pilaminella kuthani, Pilaminella gemerica, Tolypammina gregaria, Nodosaria raibliana*

– taxa appearing in the Tuvalian substage and occurring also in the younger levels of the Upper Triassic: *Glomospirella capellinii, Aulotortus sinuosus, Aulotortus subsphaericus, Ammovertellina tuvalica, Endotriada izjumiana, Glomospirella balatonica, Miliolipora cuvillieri*

– taxa known so far only in the Tuvalian substage: *Glomospirella capellinii, "Paleonubecularia" floriformis., Glomospirella balatonica, Ammovertellina tuvalica.*

Among them, *Glomospirella capellinii* was described by Ciarapica and Zaninetti (1984) in the Upper Carnian of the Coregna Dolomite Formation in the La Spezia outcrop (Ligurian Alps). Martini et al. (1989) considered it to be a characteristic species of the Upper Carnian of the Bruno Formation in South Toscana. In Hungary, it has been found so far at the depth of 394.2 m of borehole Zsámbék-14 (drilled in the Zsámbék Basin) as well as in the Sándorhegy outcrop and in Nosztor Valley section, in the latter location in limestone beds verified by Tuvalian macrofauna.

"*Paleonubecularia*" *floriformis* was also described in the Upper Carnian dolomites of the La Spezia section of the Ligurian Alps (Ciarapica and Zaninetti 1984). In Hungary, it was identified in the Sándorhegy section.

These significant Southern Alpine elements typical of the Tuvalian are joined by the new taxa described in the present paper enriching the number of foraminifer species restricted to the Tuvalian. They are as follows: *Ammovertellina tuvalica* nov. sp. *Meandrospirella carnica, M. planispira, Glomospirella balatonica.*

Though the species of the genera *Aulotortus* and *Miliolipora* already appear in the formations of the Tuvalian substage, they reach their acme in the Norian and Rhaetian stages.

In the studied Tuvalian foraminifer assemblages, the species of the genus *Eoguttulina* proved to be the youngest, as they are generally predominant in the Liassic foraminifer associations. However, they also play an important role in the Rhaetian Zlambach Marl of Fischerwiese (Kristan-Tollmann 1964).

In Hungary, they had previously also only been found in Rhaetian formations (Oravecz-Scheffer 1987). In borehole Zsámbék-14, however, they also appear in the Tuvalian formations. Between 315 and 360 m, their appearance is consistent, despite the small number of specimens. The oldest representative of the genus *Eoguttulina*, named "*Guttulina raiblina*" Gümbel 1869, was described in the Raibl beds containing "*Myophora*" *kefersteini* Münster.

This species is missing from the *Eoguttulina* association found in Tuvalian marls of borehole Zsámbék-14, whereas *Eoguttulina biacuta* Kristan-Tollmann, *Eoguttulina laissica liassica* (Strickland) and *Eoguttulina liassica procera* Kristan-Tollmann are consistently present.

Thus, their appearance in the Tuvalian of the Zsámbék Basin is their oldest occurrence known until now; this emphasizes the young character of the Tuvalian foraminifer associations as compared to the Julian ones.

Taking into account the important role played by the foraminifera in the different microfacies, we consider the following new observations and conclusions worth mentioning, which complement the already known features (e.g. the *Aulotortus* species restricted to backreef environment, or the requirement of fragile nodosarids, *Gsollbergella* and *Agathammina* species for a deeper, undisturbed, muddy environment, or the sessile and encrusting foraminifera preferring shallow water with an agitated environment):

In the upper part of the Barnag Member, in boreholes Barnag-2 and Balatonhenye-6, a special foraminifer association was found, consisting of a great quantity particularly robust specimens of *Ammovertellina, Meandrospirella,* and *Glomospirella*. This suddenly propagated population, of great variability but of very low diversity (it is almost monospecific), should have been produced in a very shallow hypersaline lagoon environment (see Pl. XXVI, XXVII) The overspecialization of the population might suggest a previous stage of extinction.

This hypersaline facies is very similar to the periodically evaporitic sedimentary environments of the Opponitz Limestone in the Northern Alps and to the different sections of Raibl and Tor beds in the Southern Alps (Lombardy, Carnian Alps, Tarvisiano, Western Dolomites).

In regard to the regional relations of the investigated Tuvalian foraminifer fauna, a great similarity to that of the "Tisovec Limestone" of the Western Carpathians can be observed. The fact that two-thirds of the species are the same proves not only a close relationship but coevality as well (see Bystricky and Jendrjekova 1977; Salaj et al. 1983).

A similar connection can be recognized with the microfauna of the type-area of the Opponitz Limestone in the surroundings of Lunz (Kristan-Tollmann and Hamedani 1973) and to the foraminifer fauna of the Opponitz Limestone in the Western Carpathians (Bucek, Jendrejakova and Papsova 1991).

Likewise, there are several taxa common with Upper Carnian microfaunas of some Southern Alpine localities: the Sella Dolomite Group of the Eastern Dolomites (Bosellini and Broglio Loriga 1966; the Drauzug (Kraus 1969); the Northern Karawanken (Kisten et al. 1990); the uppermost Raibl beds of Eberstein in Middle Carinthia (Dullo and Lein 1980); La Spezia in Ligurian Alps (Ciarapica and Zaninetti 1984); the Tamari Region in the Julian Alps (Ogorelec et al. 1984); the Trento Region in the Julian Alps (Jurkovsek et al. 1984).

It follows from the foregoing that Tuvalian microfaunas of the Transdanubian Range are in genetic relation with other microfaunas of the Western Region of Tethys belonging to the same fauna province.

However, the known Tuvalian foraminifer fauna is not suitable for establishing closer palaeogeographic connections. This can be explained by the following facts:

- strong facies control of the benthonic foraminifera,
- considerable mobility of vagile benthonic foraminifera,
- planktonic lifestyle during the larval stage.

Their diffusion depends to a high degree upon the sedimentary environments.

3. *Characterization and biostratigraphic evaluation of sporomorph assemblages*

The sporomorph taxa encountered in the studied Tuvalian formations is summarized in the following list:

Botriococcus brauni Kützig
Dictyotidium reticulatum Schulz 1963
Dictyiotidium tenuiornatus Eisenack 1955
Gibeosporites lativerrucosus (Leschik 1956) 1959
Stereisporites (Stereisporites) cf. *nochtenesis* (W.Krutzsch 1967) Schuurman 1977
Stereisporites (Annulispora) microannulata (De Jersey) Schulz 1970
Stereisporites (Annulispora) folliculosa (Rog. 1954) De Jersey 1959
Stereisporites (Sculptisporis) cf. *aulosenensis* (Schulz 1967) 1970
Anapiculatisporites telephorus (Pautsch 1958) Klaus 1960
Laevigatisporites robustus Leschik 1956
Deltoidosporites mesozoicus (Thiergart 1949) Schuurman 1977
Undulatisporites dilucidus Leschik 1956
Paraconcavisporites lunzensis Klaus 1960
Concavisporites toralis (Leschik 1956) Nilsson 1958
Conbaculatisporites mesozoicus Klaus 1960
Neoraistrickia taylori Playford et Dettmann 1965
Punctatisporites digestus Leschik 1956
Punctatisporites ambigus Leschik 1956
Punctatisporites fissus Leschik 1956
Foveosporites cavernatus Orlowska-Zwolinska 1966
Tigrisporites halleinis Klaus 1960
Lycopodiacidites kuepperi Klaus 1960
Reticulitriletes cf. *globosus* Mädler 1964a
Camarozonosporites rudis (Leschik 1956) Klaus 1960
Cyclotriletes cf. *margaritatus* Mädler 1964
Trilites tuberculiformis Cookson 1947
Uvaesporites gadensis Praehauser-Enzenberg 1970
Uvaesporites argenteformis (Bolkh. 1953) Schulz 1967
Concavisporites crassexinus Nilsson 1958
Porcellispora longdonensis (Clarke 1965) Scheuring 1970
Leschikisporites aductus (Leschik 1956) R.Potoniè 1958
Apiculatisporites parvispinosus (Leschik 1956) Schulz 1962
Verrucosisporites morules Klaus 1960
Verrucosisporites krempii Mädler 1964
Verrucosisporites thuringiacus Mädler 1966
Calamospora nathorstii (Halle 1908) Klaus 1960
Aulisporites astigmosus (leschik 1956) Klaus 1960
Kyrtomisporites ervii Van Der Eems 1983
Kraeuselisporites lituus (Leschik 1956) Scheuring 1974
Densosporites fissus (Reinhardt 1964) Schulz 1967
Densosporites cavernatus Orlowska-Zwolinska 1966
Cingulizonates cf. *rhaeticus* (Reinardt. 1962) Schulz 1967
Cingulizonates tuvali nov. sp.
Aratrisporites copyliseminis Klaus 1960
Aratrisporites palettae (Klaus 1960) Schulz 1967
Praecirculina granifer (Leschik 1956) Kl. 1960
Duplicisporites maljavkinae (Klaus 1960) Scheuring 1978
Duplicisporites scurrilis (Scheuring 1970) 1978

Duplicisporites tenebrosus (Scheuring 1970) 1978
Duplicisporites granulatus Leschik 1956 emend Scheuring 1978
Duplicisporites verrucosus Leschik 1956 emend Scheuring 1978
Duplicisporites novimundanus (Leschik 1956) Scheuring 1978
Pseudenzonalasporites summus Scheuring 1970
Enzonalasporites tenuis Leschik 1956
Patinasporites densus Leschik 1956
Patinasporites explanatus (Leschik 1956) nov. comb.
Corollina meyeriana (Kl. 1960) Venkatachala et. Góczán 1964
Corollina zvolinskae Lund 1977
Ovalipollis lunzenzis Klaus 1960
Ovalipollis septimus Scheuring 1970
Ovalipollis ovalis Krutzsch 1955
Ovalipollis cultus Scheuring 1970
Ovalipollis brutus Scheuring 1970
Ovalipollis minimus Scheuring 1970
Podosporis amicus Scheuring 1970
Sulcatisporites kraeuseli Mädler 1964
Staurosaccites quadrificus Dolby 1976
Schizosaccus keuperi Mädler 1964
Brachysaccus neomundanus (Leschik 1956) Mädler 1964
Enzonalasporites vigens Leschik 1956
Triadispora boelchii (Scheuring 1970) 1978
Triadispora epigona Scheuring 1970
Triadispora delicata Orlowska-Zwolinska 1983
Triadispora keuperiana Orlowska-Zwolinska 1983
Triadispora cf. *crassa* Klaus 1964
Alisporites aequalis Mädler 1964
Alisporites illustris (Leschik 1956) nov. comb.
Alisporites toralis (Leschik 1956) Clarke 1965
Pinuspollenites minimus (Couper 1958) Kemp 1970
Hevizipollenites samaroides nov. sp.
Cuneatisporites radialis Leschik 1956
Rimaesporites potoniei Leschik 1956
Septasporites pectinatus Leschik 1956
Pityosporites devolvens Leschik 1956
Ellipsovelatisporites plicatus Klaus 1960
Chordasporites singulichorda Klaus 1960
Infernopollenites sulcatus (Pautsch 1958) Scheuring 1970
Infernopollenites parvus Scheuring 1970
Lunatisporites acutus Leschik 1956
Lunatisporites noviaulensis mollis Scheuring 1970
Microcachryidites sp.

In order to determine the biostratigraphic value of the examined sporomorph association, the identities and differences of coeval sporomorph assemblages in the Alpine Region and the Germanic Basin must first be analysed.

For this comparison only a few published papers appear to be suitable, as the palynologic examinations of Carnian sequences scarcely concerned the Tuvalian formations. This is especially true for the Alpine Triassic area. The palynologic investigation of the Tuvalian formations of this area was published by Dunay and Fischer (1978) and Planderova (1989), containing valuable comparisons and analyses of different palynofloras.

Palynostratigraphers of the palynologic school led by Visscher in Utrecht published different palynofloras, either older (Visscher 1996: Brugman 1986a, b; Van der Eem 1983) or younger (Schuurman 1976, 1979; Besems 1982) than Tuvalian. In turn, the paper of Visscher and Krystyn (1978) presents a sporomorph association of the Tuvalian Monte Trione section in Sicily – dated by ammonites-belonging to the Sephardian Province. The authors made a global comparison of Triassic assemblages and presented some palynostratigraphic conclusions.

Dunay and Fischer (1978) reported on a sporomorph association from shale intercalations – assigned to the *Tropites subbulatus* Zone – of the Opponitz Limestone of the Lunz am See section, situated in the Northern Calcareous Alps. According to them, this occurrence of the Opponitz Limestone (lying between terrestrial sediments of Lunz beds and the Norian Main Dolomite) is a representative of the Tuvalian substage. They based their findings on Kuehn's work (1962), comparing the determined sporomorph assemblage with the known Alpine and Germanic Triassic palynofloras, and separated 15 significant taxa from the Opponitz Limestone as characteristic elements of the Tropites subbulatus Zone. Among them, *Brodiospora striata*, described by Clarke (1965) in the Upper Keuper of the Arden Sandstone (England) was considered as a characteristic species of the Tuvalian substage. In addition, this taxon was found in Tuvalian localities of the Cincle Formation and in the Dockum Group in the southwestern USA. Among the selected 15 taxa, 14 are unfortunately also frequent in the Julian substage. Material similarly important from the palynostratigraphic point of view was also published by Planderova (1989). She studied the sporomorph assemblage of the Lunz beds and of the overlying dark shales penetrated by boreholes in Slovakia. Referring to Kysela's work (1983), she assigned the series of dark shales partly to the Opponitz Limestone, partly to the Main Dolomite. These layers were penetrated by boreholes LNV-7 and Sastin-12. She indicated their age as Tuvalian and Lacian, and selected 16 characteristic taxa. Unfortunately, only *Camerosporites secatus* Leschik and *Ovalipollis ovalis* Krutzsch were common with the 15 key taxa of Dunay and Fischer (1978).

It is to be noted that Van der Eem (1983) designated the range of *C. secatus* from the middle part of the Fassanian to the middle of the Julian in the Alpine Region. In his work, he carried out the palynostratigraphic subdivision of the Alpine Triassic from the Anisian to the Middle Julian, separating 7 phases. This subdivision concerned different sequences, from the middle part of the "Buchenstein Group" through the whole of the "Wengen Group" as far as the middle part of the San Cassiano Formation. Among the seven phases, the *secatus* occurs as a predominant or subdominant phase-marker in three of them.

In the Balaton Highland, however, *C. secatus* appears in the lowermost dolomarl beds of the Anisian Megyehegy Dolomite Formation and can be followed as far as the basal layers of the Main Dolomite Formation. Thus, its range extends from the Anisian to the Upper Tuvalian.

The range of *Ovalipollis ovalis*, the other selected Tuvalian taxon of Planderova (1989), is from the Ladinian to the Liassic. It was first described from Liassic beds by Krutzsch (1955).

Planderova (op. cit.) found and documented with photos *Granulo-perculatipollis rudis* in the assemblage obtained at 2.301 m from borehole LNV-7, indicating the age of the layers as Tuvalian-Lacian.

Some palynostratigraphers consider this taxon as a zone or subzone marker of the Lower Rhaetian (Lund 1977). It was described from the "Kössen Marl" of the southern Zala Basin by Venkatachala and Góczán (1964). However, Orlowska-Zwolinska (1983) found it frequently together with *Corollina meyeriana* and *Corollina zwolinska* in the Upper Gypsum Member of the Keuper in Poland. If we accept Orlowska-Zwolinska's stratigraphic determination, according to which the Upper Gypsum Member already belongs to the upper part of the Tuvalian substage, then the appearance of *Corollina meyeriana/zwolinskai* specimens found at 41.8–45.0 m of borehole Barnag-2, as well as the *Cingulizonates* cf. *rhaeticus* specimens (also frequent in the Lower Rhaetian and determined at 42.5–43.5 m in borehole Balatonhenye-6), has a greater stratigraphic value for proving Tuvalian in the studied profiles than the presence of the 15 "key taxa" of the Subbulatus Zone selected by Dunay and Fischer.

It seems that *Duplicisporites malkjavkinae–Corollina meyeriana, Granulo-perculatipollis rudis* and *Classopollis torosus* form a well-recognizable evolutionary lineage from the Carnian to the Liassic. Our primitive *Corollina* specimen fits well into this lineage.

Consequently, as far as the sporomorph taxa proposed as characteristic for the Tuvalian in the Alpine Region so far is concerned, it can be stated that:

– among the 15 selected taxa of Dunay and Fischer, 14 also occur consistently in the Julian, and even their acme is nearly contemporaneous (with some exceptions). This is the reason why we do not consider them to be key taxa of the Tuvalian.

– from the 16 taxa listed by Planderova, 4-5 can already be regarded as Norian-Rhaetian elements rather than Carnian ones, as they have not been mentioned by other authors from the Carnian so far. Concerning the other 11–12 taxa, they do not allow a more precise biostratigraphic determination than Carnian.

The Keuper palynofloras of the Germanic Triassic Basin are extremely rich in taxa and specimens. They are well investigated by different authors. First of all, the Middle Keuper sporomorph assemblages of Neuwelt near Basel are worth mentioning because most of the Carnian type species were published from here (Leschik 1956). We found these species in sequences of former sedimentary basins situated close to each other in space and time. These sporomorph assemblages indicate well the spatial relations of sedimentary basins and the degree of temporal coincidences or differences. The evaluation of the biostratigraphic subdivision and palaeogeographic situation of the investigated profiles is based upon the palynologic data obtained from this basin.

The number of Upper Triassic sporomorph taxa was increased by Mädler (1964a). He described the spore and pollen taxa of the Röthian-Muschelkalk and Lower Keuper sediments from the Harz Mountains (Germany). We found these taxa primarily in borehole Zsámbék-14.

The Triassic sequences of the central part of the Germanic Basin were studied thoroughly and fully by Schultz (1967). He investigated the sequences from the Middle Keuper to the Upper Liassic and clarified the biostratigraphic status of 103 sporomorph taxa. In his palynostratigraphic chart, he evaluated the Rhaetian and Liassic taxa in accordance with the chronostratigraphic units of the Alpine Triassic. Similarly, Keuper sporomorph assemblages were studied from a tunnel section between Eptingen and Hägendorf (ca. 25 km SE of Basel) by Scheuring (1970) in his first monograph. His second monographic work (1978) dealt with palaeontologic descriptions and systematization of Ladinian and Carnian sporomorph taxa from the Alpine Region, documented with 219 pages and 95 photo tables.

These two valuable papers are indispensable for Triassic palynologic research. In the systematic part of our work, we also applied the classification of Scheuring (1970, 1978).

Orlowska-Zwolinska (1983, 1985) carried out the palynologic studies of the Germanic Triassic profiles of Poland. In her papers, she made an essential comparison between the published sporomorph assemblages of the Germanic and Alpine Regions. At the same time, she presented the palynozonation of the Keuper and Rhaetian as well as their correlation with the Alpine subdivision. She established that sporomorph associations corresponding to the entire Tuvalian microflora had not been found in the studied profiles of Poland until then, because the upper part of the Red Sandstone and the Upper Gypsum Member, forming the Tuvalian sequences, are barren. In the upper layers of the Upper Gypsum Member (in borehole Ksiaz IG-2), however, she found a sporomorph association with *Corollina meyeriana* and *Corollina zwolinskai*, which she considered to be Upper Tuvalian. This is the only known locality where *Corollina meyeriana* and *Corollina zwolinskai* appeared already at the end of the Carnian.

Although the work of Dolby and Balme (1976) reports sporomorph assemblages belonging to the Gondwana vegetation of the Carnarven Basin of West Australia, it is worth mentioning, because it concerns our investigations for the following reasons:

– *Staurosaccites quadrifidus* Dolby et Balme 1976 was described by them as an element of the Gondwana vegetation appearing in the Anisian and being traceable to the Tuvalian. Since then, this taxon has also been known as an important member of Laurasian vegetation. *Staurosaccites quadrifidus* is a characteristic element of the Julian sporomorph association of the Balaton Highland.

Staurosaccites quadrificus has a zone-marker value in the palynozonation of the Carnarven Basin. The lower boundary of the *Quadrifidus* Zone is drawn in the Middle Anisian, and the upper one in the Upper Carnian (Dolby and Balme 1976).

– Another important palynostratigraphic datum is the extension of *Samaropollenites speciosus* Goubin 1965. Dolby and Balme also considered this taxon as a zone-marker for the Upper Carnian. The *Speciosus* Zone follows the Quadrifidus Zone and it is "... equivalent to the upper part of the Carnian stage" in the opinion of the authors.

Though the zonation of Dolby and Balme cannot be completely applied to the Triassic sequences of the Balaton Highland, the stratigraphic and palaeogeographic importance of the *quadrifidus* must also be taken into account in the palynostratigraphy of our profiles. *Samaropollenites speciosus* has not been found in the Triassic of Hungary yet; however, it must be considered as a Tuvalian marker element of the Sephardian Province (see Visscher and Krystyn 1978; Doubinger in Sopena 1979; Doubinger in Martini et al. 1991; Cirilli and Eshet 1991).

Sporomorph taxa determined from the Tuvalian sequences of the studied profiles can be arranged on the basis of their palynostratigraphic value as follows:

- taxa occurring throughout the Carnian,
- taxa of the Julian,
- taxa known from the Norian–Rhaetian.

To the first group belong almost all of the members of *Circumpolles*, with the exception of *Duplicisporites malkjavkinae* (Klaus 1960) Scheuring 1978 and *Pseudenzonalasporites summus* Scheuring 1970. The former appears at the beginning of the Julian, and the latter at the end of it. To this group can be assigned the species *Enzonalasporites* and *Camerosporites*, as well as, among the bisaccats, mainly the representatives of *Ovalipollis* – if we accept the concept of Schuurman (1976). However, if we take into account the differing appearance and frequency of the extremely diversified forms of the genus, *Ovalipollis* can not be assigned to this group. For example, *Ovalipollis brutus* Scheuring 1970, described from the Gypsum Keuper in Switzerland, is known in the continuous Carnian sequences of the Balaton Highland only in the Julian and Tuvalian, but is totally absent from the Cordevolian.

The genus *Triadispora* must doubtlessly be assigned into this group, although the ranges of some of its form-species cannot be regarded as completely clear yet. *Lunatisporites acutus* (Leschik 1956) and *Infernopollenites sulcatus* (Pautsc 1958) Scheuring 1970 also belong to this group.

Among the taxa occurring in the Julian, the most important Bisaccats are as follows: *Patinasporites densus, Duplicisporites maljavkinae, Ovalipollis brutus, Taurosaccites quadrificus, Sulcatisporites kraeuseli, Brachysaccus neomundanus, Cuneatisporites radialis, Rimeasporites potoniei, Schizosáccus keuperi*

Of the pteridophyte spores appearing in the upper part of the Julian, the following are worth mentioning: *Gibeosporites lativerrucosus, Stereosporites (Annulisporites) folliculosus, Punctatisporites fissus, P. ambiguus, Anapiculatisporites telephorus, Conbaculatisporites mesozoicus, Aulisporites astigmosus, Leschikisporites aductus, Apiculatisporites parvispinosus, Pityosporites devolvens* Leschik 1956, *Pinuspollenites minimus* (Couper 1958) Kemp 1970.

Among the Norian–Rhaetian elements, the following taxa can be found in the studied Tuvalian formations: *Densosporites fissus* (Reinh. 1964) Schulz 1967, *Densosporites cavernatus* Orlowska-Zwolinska 1966, *Cingulizonates rhaeticus* (Reinh. 1962) Schulz 1967, *Concavisporites crassexinus* Nilsson 1958, *Foveosporites cavernatus* Orlowska-Zwolinska 1966, *Corollina meyeriana* (Kl. 1960) Venk. et Gócz. 1964, *Corollina zwolinskae* Lund 1977.

Summarizing the palynostratigraphic analysis of the sporomorph assemblages obtained from the studied profiles of the Transdanubian Range, we found the assemblage of the following taxa to be characteristic of the Tuvalian substage:

– spores: besides the above-listed Norian–Rhaetian elements, *Cingulizonates tuvali* sp. nov. described in the present paper;

– pollen: *Hevizipollenites samaroides* nov. gen et sp.

The specimen of the genus *Corollina* found in borehole Barnag-2, in the upper part of the Barnag Member, beneath the Upper Tuvalian Main Dolomite must be mentioned separately. Based on its structure and shape, it can be regarded as a primitive, transitional form of *Corollina meyeriana/zwolinskai*. In any case, it is the oldest representative of the genus *Corollina*.

4. Palaeogeographic and evolutionary conclusions

Having compared the sporomorph assemblages of the investigated sections first with each other, then with Alpine, Germanic, and Sephardian Triassic vegetation of the Tethyan region, the authors summarize their conclusions in the following paragraphs:

I. The sporomorph assemblages of the Carnian sections of the Veszprém / Balaton Highland/Keszthely Mountains Region (hereinafter: Balaton Highland) derive from a vegetation of the same habitat and – with the exception of the ubiquitous ones – differ sharply from the sporomorph assemblages of the same age of the Zsámbék Basin.

Reasoning behind this statement:

1) The percentage of the *Circumpolles* group shows a consistently decreasing tendency in the sporomorph assemblages of the Balaton Highland, and an increasing tendency in those of Zsámbék, from the Cordevolian to the end of the Tuvalian.

2) In the Carnian sections of the Balaton Highland, a bisaccat pollen of the Sephardian Triassic, *Staurosaccites quadrifidus* Dolby 1976, is considered a marker taxon of the Julian; it is absent from the Carnian at Zsámbék.

3) Up to the lower part of the Tuvalian, pteridophyte spores (*Verrucosisporites krempii* Mädler 1964, *V. thuringiacus* Mädler 1964, *Cyclotriletes* div. sp.), large and with coarse verrucated ornamentation, described in the Röt of the Germanic Triassic, which are missing from the Carnian of the Balaton Highland, occur systematically in the Julian at Zsámbék.

4) The bisaccat pine pollen taxa *Pinuspollenites minimus* (Couper 1948) Kemp 1970, *Samaropollenites concinnus* Fischer et Dunay 1984, and *Hevizipollenites samaroides* nov. gen. et sp., which are absent in the Tuvalian of Zsámbék, play a significant role in the Tuvalian formations of the Balaton Highland.

5) Transportation of Keuper elements, among them the dominant *Pityosporites devolvens*, becoming consummated in the Julian, was continued; at the same time, characteristic pteridophyte spores (*Lycopodiacidites kuepperi* Klaus 1960, *Paraconcavisporites lunzensis* Klaus 1960, *Verrucosisporites morulae* Klaus 1960), described in the Julian formations of the Eastern Alps, appear in the Tuvalian of Zsámbék. The first specimens of some of them already emerge at the end of the Julian.

II. The two basins, with different coastal vegetation, had been evolving independently and separately from each other from the Cordevolian to the lower part of the Tuvalian, and only came into contact with each other for the first time in the middle of the Tuvalian.

Reasoning:

1) From the Cordevolian to the Middle Tuvalian, sporomorph assemblages of both basins had preserved the characteristics which we have listed as evidence for the previous statement in paragraphs 1–5. Their evolutionary development appears to be unbroken until the Tuvalian.

2) In the coastal vegetation of both basins, pteridophyte spore species, known so far only from sediments of Rhaetian age of the Germanic Triassic, appear in the middle part of the Tuvalian: *Densosporites cavernatus* Orlowska-Zwolinska 1966, *Cingulizonates* cf. *rhaeticus* (Reinhardt 1962) Schulz 1967, and *Densosporites fissus* (Reinhardt 1964) Schulz 1967.

III. The Carnian basin of the Balaton Highland might have been located relatively close to southern coastal region of Tethys, in the neighbourhood of the Western Dolomites at the beginning of the Julian substage – as in the concept of Haas (1994, p. 1247, Fig. 10), but closer.

The justification for this assumption is based upon the following:

In the continuous sequences of the Carnian sections of the Balaton Highland, *Staurosaccites quadrifidus* Dolby 1976 appears at the beginning of the Julian substage, and can be regarded as of consistent occurrence up to the middle part of the Tuvalian.

Type locality of the taxon: Onslow No. 1 Well, core 7, 1,448.5; Mungaroo Beds, Carnarvon Basin, W-Australia. Here, in the Triassic sequence of the basin, it is a palynostratigraphic assemblage zone index species from the Middle Anisian to the middle part of the Carnian, but it is also a sporadic member of the assemblage of the subsequent *Samaropollenites speciosus* zone (Dolby and Balme 1976). Since its description, it has been found in both the Sephardian and the Alpine Triassic nearshore basins in the Tethyan region.

It seems, however, that its N–NW-ward migration from the type locality took "considerable" time: the age of its appearance in western Australia was Middle Anisian, Ladinian in the plateaux of the southern Alps (W-Dolomites – Van der Eem 1983), and in the Balaton Highland at the beginning of the Julian substage (Góczán, Oravecz-Scheffer and Csillag, 1991).

So far, it has not been encountered in the Germanic Triassic area, with the exception of southeastern Spain, where it was found in Ladinian–Carnian formations (Besems, 1981a, b).

Argumentation for this statement:

On the basis of the above-listed data, it can be reasonably supposed that the depositional area of the W-Dolomites first sufficiently approached the Sephardian vegetation area of the south coast of the western Tethys for pollen of the parent plant of *Staurosaccites quadrifidus* to be transported from the coastal pine-wood to its locality.

Since this event (according to the data of Van Der Eem, op. cit.) occurred during the Ladinian stage, and in the lifetime of the Carnian basin of the Balaton Highland at the beginning of the Julian substage, we feel justified in concluding that the Carnian basin of the Balaton Highland came into contact with the Western Dolomite Plateau of the Southern Alps from the north during the Julian substage.

IV. By the beginning of the Tuvalian substage, the Carnian basin of the Balaton Highland might have been shifted to the north of its position in the Julian substage.

This assumption is supported by the following knowledge:

Samaropollenites speciosus Goubin 1965, occurring in the "Onslow Microflora" of the Sephardian Triassic, plays a determinative role in the southern nearshore depositional areas of the western Tethys during the Upper Carnian. According to the interpretation of Visscher and Krystyn (1978), "in the western Tethyan area, *Camerosporites secatus–Samaropollenites speciosus* might prove to be indicative of a Tuvalian age". Then, immediately thereafter, they write: "in the western part of the Tethys realm, the southern element *Samaropollenites speciosus* may mark the Karnian–Norian transition."

In connection with the introduction of the sporomorph assemblages of a borehole in South Israel penetrating Lower Carnian formations, Cirilli and Eshet (1991) review the range of *Samaropollenites speciosus*, as a member of the Onslow Microflora, in Australia, India, Madagascar, the Middle East, North Africa and South Europe. They emphasize its biostratigraphic importance in the Upper Carnian. Referring to a personal communication of Visscher (1988), they report that, on the one hand, *Samaropollenites speciosus* was also found in Italy (unfortunately, the locality is not mentioned), on the other, that the sporomorph assemblage named "Onslow Microflora" was also found in the earliest Norian layers identified by ammonites in South Turkey. The Onslow Microflora is the name of the spore-pollen assemblage in which parts of Gondwanian and Laurasian elements occur together in a mixed form. In the Middle and Upper Triassic, it is represented most frequently by its two prominent forms, *Staurosaccites quadrifidus* and *Samaropollenites speciosus*, respectively.

In the Tuvalian sequence of the Balaton Highland, *Staurosaccites quadrifidus* still can be found sporadically (mainly in the lower part of the sequences); however, *Samaropollenites speciosus* has not been found so far. In turn, two morphospecies, *Samaropollenites concinnus* Fischer et Dunay 1984 and *Hevizipollenites samaroides* nov. gen. et sp., being very near *S. speciosus* both in morphology and structure, play a determinative role here.

Even if *Samaropollenites concinnus* described in the Petrified Forest Member of the Chinle Formation in Arizona cannot be regarded a member of the Onslow Microflora, as long as it is also found in the Sephardian Triassic, it can in any case be considered to be the closest relative of *S. speciosus*.

Following the above-listed data are the reasons for which we feel that assumption IV is correct:

1) If the Carnian basin of the Balaton Highland had remained in the place it occupied in the Julian during the Tuvalian substage as well, it should also have contained grains of *Samaropollenites speciosus* at the beginning of the Tuvalian – as in the Sephardian Triassic basins formed along the southern and western coastal region of Tethys.

2) If it had shifted to the west (which might be concluded on the basis of the occurrence of *S. concinnus*), this Tuvalian marker pollen should have arrived from the coastal dry land vegetation of the basins of the Iberian Cordilleras, since in the area of southern Spain, *S. speciosus* is **also** present in the Tuvalian sequence of the zone outside of both the Cordilleras and Betic Cordilleras (Doubinger in Ramos 1979; Bessems 1982).

3) If it had shifted to the east, it would have lost its connection with the (vegetational) dry land environment because of the increased distance from the coast at the beginning of the Tuvalian.

4) Displacement to the north is supported also by the fact that it also preserved (just like *Saturosaccites quadrifidus* coming from the south) the direction of transportation, and that grains assignable to *Hevizipollenites samaroides* can be encountered both in the Sicilian Tuvalian sporomorph assemblage (see Visscher

and Krystyn, 1978, Pl. IX, Fig. 5, determined as cf. *Klausipollenites* sp.) and among those found in the Libyan Upper Carnian formations. Although in this case the grain appears under the name of *Samaropollenites speciosus* (Adloff et al. 1985, Pl. IX, Fig. 6), on the basis of the illustration it can be established that the connecting strip of sacci is missing from this grain, in the same way as with the specimens of *Hevizipollenites*. These data suggest that the parent plants of *Hevizipollenites samaroides* may also have lived in the vegetational areas of the Sephardian Triassic, but playing a more subordinate role in the case of the two mentioned localities.

V. In the course of the northward migration of the Carnian basin of the Balaton Highland, from the Upper Julian to the upper part of the Lower Tuvalian, it approached the coastal vegetational area, from where also the characteristic pteridophyte spores were transported to the depositional area of the Eastern Alps during the Julian substage.

Grounds for this statement:

1) In the sporomorph association of the Carnian basin of the Balaton Highland, both in the Cordevolian and Julian substages, pollen grains originating from ancestral pines predominate unambiguously. They determine the aspect of the individual sporomorph assemblages. In our sections, spores of Lycopodiaceae, Selaginellaceae and Filicales, regarded as undergrowth, are encountered only sporadically – as opposed to the more nearshore basins of the Western Dolomites, from which a rich pteridophyte spore material (including many thick-walled, hardly transportable grains) – was published by Van Der Eem (1983).

Since these spores are transported primarily not by wind but by areal erosion and flowing water from their habitat to the locality of burial, the great number of their specimens in the basins suggests always the proximity of the coast. In the Carnian basin of the Balaton Highland, frequent and consistent occurrence of pteridophyte spores begins with the Upper Julian. Almost all of the encountered specimens belong to the taxa which were first described in the *Halobia rugosa* and *Cardita gümbeli*-bearing layers of the Eastern Alps (Klaus 1960; Kavary 1966, 1972).

2) The above-mentioned pteridophyte spores cannot be regarded as East Alpine flora elements exclusively, since in the Tethyal region their range is much wider; they can be found both in the Alpine and Germanic Triassic. In our case, however, they serveas evidence for connection with Julian vegetation of Eastern Alps, because only a few taxa among the spores which are more frequent in the Keuper, and of those occurring in the Lunz basins of Northern Alps only some of the ubiquitous forms, are common with the spores of the Balaton Highland. The Germanic Triassic pteridophyte spores (which are known only in the Rhaetian stage so far) appear in the higher part of the Tuvalian sequence. On the basis of this fact, however, another conclusion can be drawn.

VI. From the middle/upper part of the Tuvalian sequence, the Carnian depositional area of the Balaton Highland (together with the Carnian depositional area of the Zsámbék Basin evolving separately and independently until then) reached the immediate vicinity of the coastal vegetational area, from where the Upper Keuper–Rhaetian sporomorph assemblages of the Germanic Triassic are derived. This position might have been farther to the north than the previous one.

Reasoning behind this statement:

1) Data under II/2 unambiguously prove the connection of the two depositional areas with the new coastal vegetational area.

2) Their spatial position farther to the north can be concluded from the fact that the distribution in the Rhaetian stage of both *Densosporites cavernatus* Orlowska-Zwolinska 1966 and *Cingulizonates rhaeticus* (Reinhardt 1962) Schulz 1967 is of pronouncedly northern migrational direction in the facies areas of both the Alpine and the Germanic Triassic. This holds true particularly of *Cingulizonates rhaeticus*, which conquered (beginning from the former sedimentary area of the Northern Calcareous Alps) the entire Germanic Triassic, its fresh water, brackish water and marine basins from the Thuringian Mts. via Poland and England to the Norwegian Hopen Islands during the Rhaetian stage (Bjaerke and Manum 1977).

3) On the basis of the detailed elaboration of the Lower and Middle Keuper formations of the Germanic Triassic carried out so far, as well as of the equally thorough investigations of the Lunz layers of the Northern Calcareous Alps, it can be considered justified that the mentioned characteristic Rhaetian elements are not yet present in their Tuvalian sporomorph assemblages. For this reason, it can be concluded from their appearance in the Carnian basins of the Balaton Highland and Zsámbék that in the middle/upper part of the Tuvalian, only these basins were in connection with the dry land vegetational area, in which the parent plants of these pteridophyte spores appeared for the first time during the Tuvalian substage, and from where they started their conquering journey at the end of the Triassic.

VII. It can be proved that the Triassic depositional area of the Zsámbék Basin evolved undisturbed in connection with the Thuringian, Harz Mts. South Swiss Muschelkalk and Keuper depositional areas from the Cordevolian substage to the Tuvalian. At this time, it had no direct connection with the coastal vegetational areas of either the basins of the Balaton Highland or those of the Eastern and Northern Alps. For the first time, it approached the basin of the Balaton Highland at the beginning of the Tuvalian, then (from the middle of the Tuvalian) they showed a common evolution, which was continued even during the formation of the Main Dolomite platforms.

Two alternatives offer themselves for the geological interpretation of the evolutionary trend of the basins of both Zsámbék and the Balaton Highland outlined above.

In one case, the two basins should be regarded as two plate fragments, which had been parts of different terranes during the Carnian sedimentation, up to the middle part of the Tuvalian. The degree and direction of their mobility and migration worked out according to different power impulses. Whichever basin came closest to the coastal region of Tethys was the one which accumulated the most sporomorph material. From the varying sporomorph assemblages of different formations, exposed in their present locations in sequences deposited in different sedimentary environments and different facies zones of Tethys, it is possible to determine these movements and these phytogeographic connections.

In our case, it seems that the two plate fragments encountered each other in the middle part of the Tuvalian and they already had amalgamated, as one terrane, in the Upper Tuvalian, during the deposition and formation of the Main Dolomite.

According to the other interpretation, the western basin basement of Tethys was a single plate at this time, and the basins of Zsámbék and the Balaton Highland may have been separated from each other by a barrier or island series. In this case, the oscillation movement of the basement would have been responsible for the varying direction and distance from the coast of the different basins, and for the decrease or increase and joining or separation of vegetational areas during each sedimentary cycle.

The evolution of the Carnian basins of the Balaton Highland and Zsámbék can be outlined on the basis of both interpretations. Their evolution, traceable with palynologic data from the Cordevolian to the Upper Tuvalian, seems for us to be more understandable when supposing two terranes. This is mainly on the basis of the different appearance of the Sephardian and Sephardian-related, as well as the Keuper and Keuper-related elements, in the Carnian sequence of the two basins. However, it does not exclude the possibility of the second alternative. Ladinian–Carnian palaeogeographic analysis of the Southern Alps carried out by Brusca et al. (1981) shows our supposition to be well-founded. On the basis of their palaeogeographic sketch maps (p. 73, Fig. 3; p. 47, Fig. 4), it seems that the Carnian basin of the Balaton Highland came into the neighbourhood of the Western Dolomites by the beginning of the Julian - as a direct consequence of the considerable northward expansion of the dry land of the Southern Alps, which took place from the Upper Ladinian to the end of the Lower Carnian. By that time, the Sephardian bisaccat parent plant of *Staurosaccites quadrifidus* Dolby 1967 had already also conquered these dry lands, from where its pollen could easily make its way into the Julian basin of the Balaton Highland as well.

As to the lack of the marker pollen of the Sephardian Tuvalian (*Samaropollenites speciosus* Goubin 1965) in the Tuvalian sequence of the Balaton Highland, two explanations offer themselves on the basis of the palaeogeographic sketch maps and reconstruction sections (p. 76, Fig. 5) of Brusca et al.:

– at the beginning of the Tuvalian, this taxon had neither sufficient time for migration, nor the possibility (because of the separating sea branch) to appear in the vegetation of the Southern Alps.

– in this mobile zone, at the beginning of the Tuvalian, the basin of the Carnian in the Balaton Highland detached itself from the Western Dolomites and began its N-ward migration as an independent terrane.

It seems that palynologic investigation of the Tuvalian lagoon sediments located beneath the Main Dolomite in the Tarvisianian–Pontebranian section (shown in the 3rd column of the above-mentioned sections of Brusca et al., 1981) could be suitable not only for settling the question of the South Alpine occurrence of *Samaropollenites speciosus*, but also for explaining its absence in the Tuvalian sequence of Balaton Highland.

Our palaeogeographic conclusions outlined above are in conformity with those plate tectonic, palaeogeographic and terrane reconstruction notions (also concerning the Transdanubian Range) as described in the work of Kovács (1995), Haas (1994) and Haas et al. (1995).

5. *Palaeontologic descriptions and taxonomic remarks*

Below are descriptions of the new taxa found in our Tuvalian sequences.

Formagenus: **Cingulizonates** (Dybova et Jachowicz 1957) emend Butterwort, Jansonius, Smith et Staplin 1954

Cingulizonates tuvali sp. nov. (Góczán)

Plate VI, Figs 1–2.

Derivatio nominis: according to its occurrence in the Tuvalian sediments.
Locus typicus: borehole Balatonhenye Bht-6.
Stratum typicum: Bht-6: 42.4-45.5 m, dark grey marl, Barnag Mb. of the Sándorhegy Fm.
Holotype: specimen in slide No. 70887; co-ord. No. 2.7/104.5, Pl. VI, Figs. 1–2.

Diagnosis: middle and large sized, trilete, triangular zonate microspora with perforated cingulum. The proximal side of body is smooth or maculate, the distal one is verrucate.

Description: sides of spores are convex, triangular, with rounded corners in equatorial view. The body is surrounded by an uneven wavy zone and connected to it by a slightly undulating cingulum. Thickness of wall is 2–3 μm. The proximal surface is smooth or finely maculate. The distal surface is ornamented by dispersed verrucae. The height of verrucae and their breadth at the base is 3–5 μm.

The trilete mark does not reach the corners, but is longer than two-thirds of the radius. The breadth of the zone is 3–6 µm, with an irregular outline and pinnatifid border.

Thickness of cingulum is 0.5–0.6 µm, its breadth is 6–11 µm. Its outline is also irregular. In some places, it is connected to the zone with narrow, stiffening battens. The surface of the cingulum is perforated by rounded holes, 1 µm in diameter. The holes are more or less equidistant from each other, and are arranged in regular lines.

Dimensions of holotype: greatest diameter is 69 µm, breadth of zone alternates between 3 and 6 µm, while that of cingulum between 6 and 10 µm.

Differential diagnosis: Cingulizonates tuvali sp. nov. shows the greatest similarity to *Cingulizonates rhaeticus* (Reinhard 1962) Schulz 1967 in form and structure, but differs from it in sculpture. The significant differences between *C. tuvali* sp. nov. and *C. rhaeticus* are as follows:

Cingulizonates tuvali sp. nov. has a verrucate ornamentation on the distal surface of body, while *C. rhaeticus* shows a striated surface;

The cingulum of *Cingulizonates tuvali* sp. nov. is perforated, but that of *C. rhaeticus* is also striated.

Occurrence: middle part of the Tuvalian sequences of the Balaton Highland. Its appearance is rare but regular.

Remarks: the measurement ranges of the sporomorph specimens are as follows:

small – from 1 to 30 µm
medium – from 31 to 60 µm
large – above 61 µm

Formagenus: **Hevizipollenites** nov. gen. (Góczán)

Genotype: ***Hevizipollenites samaroides*** gen. et sp. nov.,

Plate XVIII, Figs 1–2.

Derivatio nominis: Hévíz, borehole Hv-6, Keszthely Mts., Hungary.

Genus diagnosis: medium-sized, alete, bisaccate haploxylonoid pollen grains. The contour of the body in lateral longitudinal view is triangular with rounded corners and convex sides. Cappa is up 7 to 2 µm thick and well-defined. Exine is infrapunctate. Sacci are of approximately half the corpus size, distally pendent and symmetric. Structure of the saccus is infrareticulate with radial elongated, lath-like elements.

There is no sulcus on the (sub)triangular corpus; however, distal thinning can be observed.

Differential diagnosis: *Hevizipollenites* nov. gen. can be distinguished from *Samaropollenites* Goubin, 1965 by the absence of a connecting strip of sacci. *Hevizipollenites* differs from *Microcachryidites* (Cookson 1947) ex Couper 1953 by its (sub)triangular body and by the structure of its sacci.

Hevizipollenites samaroides gen. et sp. nov. (Góczán)

Pl. XVII, Fig. 1, Pl. XVIII, Figs 1–4, 7

Derivatio nominis: its similarity to *Samaropollenites speciosus* Goubin 1965.
Locus typicus: Hévíz, borehole Hv-6, Keszthely Mts., Hungary.
Stratum typicum: borehole Hévíz, Hv-6, 243.9 m, grey marl, Barnag Mb. of the Sándorhegy Fm., Tuvalian
Holotype: specimen in slide No. 50291; co-ord. No. 11.7/109.0, Pl. XVIII, Figs. 1–2.

Description: medium-sized, alete, bisaccate haploxylonoid pollen grains. The contour of the body is triangular with rounded corners and convex sides in lateral longitudinal view. Cappa is 2.5–3.0 μm wide. The longitudinal axis is more or less equal to the transversal one, or is a bit longer. The surface of the body is infrapunctate. The sacci are semicircular, distally pendent; the insertion place is nearly symmetric. Between them, on the distal side, a more or less elliptic leptoma is visible. The structure of the saccus is infrareticulate. The reticulum is irregular with several radially elongated batten-like thickenings. It has neither monolete, nor trilete marks.

Measurement of holotype:
overall dimension: 64 x 37 μm
corpus: 38 x 37 μm
saccus: 36 x 20 μm
cappa: 2.8 x 3 μm

Differential diagnosis: *Hevizipollenites samaroides* gen. et sp. nov. shows a strong similarity to *Samaropollenites speciosus* Goubin 1965 in form and size, but on the specimens of *Hevizipollenites samaroides* the connecting strip of sacci is missing. This is the *differencia specifica* essentially distinguishing these two taxa from each other. Similarly, a great resemblance appears between the type specimens of *H. samaroides* (Pl. XVIII, Figs 1–4, 7–8) and those of *Protodiploxypinus triquetricorpus* Fischer et Dunay 1984 (p. 255, Pl. XI, Figs 7–8) both in the forms of body and sacci. But *Protodiploxypinus triquetricorpus* is larger and the leptoma or distal thinning is missing. The similarity is so striking that – disregarding the differences – one could consider them as belonging to the same taxon.

Remarks: we must mention our observations on the published photos of *Samaropollenites speciosus* Goubin 1965 and *Microcachryidites fastidioides* (Jansonius 1962) Klaus 1964. Some of them suggest that they are identical with *Hevizipollenites samaroides* gen. et sp. nov. These are the following: in Adloff et al. (1986), Pl. IX, Fig. 6, *Samaropollenites speciosus* Goubin 1965 from the Tuvalian in Libya; Doubinger in Sopena, 1979, p. 241, Pl. LXI, Fig. 11; *Microcachryidites fastidioides* (Jansonius 1962) Klaus 1964. Since these photos are not sufficient for identification, we cannot consider them as belonging to *Hevizipollenites samaroides* gen. et sp. nov.

Occurrence: in well-preserved state and with regular appearance in the clayey marl layers of the Tuvalian sequences of the Balaton Highland.

Superfamilia: **Ammodiscacea** Reus 1862

Familia: **Ammodiscidae** Reus 1862

Subfamilia: **Ammovertellinae** Saidova 1981

Genus: **Ammovertellina** Sulajmanov 1959

Ammovertellina tuvalica nov. sp. (Oravecz-Scheffer)

Pl. XXVII, Figs 1-4

1986. *Paleonubecularia* sp. Gyalog, Oravecz-Scheffer, Detre and Budai: Pl. III, Figs 3–4.

Derivatio nominis: the name of the species refers to its occurrence in the Tuvalian.
Locus typicus: borehole Barnag, Bdt-2, Balaton Highland, Hungary.
Stratum typicum: borehole Barnag, Bdt-2, sample from 29.5 m, marly limestone, Barnag Mb. of the Sándorhegy Fm., Tuvalian, Carnian.
Holotype: Pl. XXVII, Fig. 1.

Description: test free, robust, elongated form with distinct irregular prolongations or extensions. The small proloculus is followed by an undivided, streptospirally coiled tubular second chamber. Later, it becomes zigzag-like or irregularly wound.

Chamber lumen changes slightly in the early and middle stages, then it grows suddenly at least twofold in the last whorl. Number of whorls varies between 4 and 6. Aperture is not visible in our sections. Wall is agglutinated and very thick.

Dimensions: holotype: max. diameter 0.37 mm (including the last, irregular whorl).

min. diameter: 0.15 mm

diameter of proloculus: 0.009 mm

thickness of wall (in average): 0.02–0.03 mm

Material: several specimens in different planes in thin section.

Association: in the type locality, *Ammovertellina tuvalica* nov. sp. is associated with *Meandrospirella karnica* (Oravecz-Scheffer), *Meandrospirella planispira* (Oravecz-Scheffer) and *Glomospirella balatonica* nov. sp. In the Keszthely Mts., it is accompanied by *Ophthalmipora dolomitica* Koehn-Zaninetti, *Aulotortus sinuosus* Weynschenk, *Tolypammina gregaria* Wendt and *Valvulina azzouzi* Salaj.

Distribution: Balaton Highland and Keszthely Mts. (Transdanubian Range, Hungary).

Age: Tuvalian.

Remarks: In 1984, the author noticed this species in thin sections of Upper Carnian marly limestones of the Keszthely Mts. Temporarily, it was referred to *Paleonubecularia* sp. According to Loeblich and Tappan (1987), *Paleonubecularia* cannot be considered a valid genus. Based on the manner of coiling and the irregular growth of the final stage, assigning this new species to *Ammovertellina* seems to be justifiable.

Genus: **Glomospirella** Plummer 1945

Glomospirella balatonica nov. sp. (Oravecz-Scheffer)

Pl. XXVI, Figs 7, 9.

1983. "Grandes Glomospires-Glomospirelles" Ciarapica et Zaninetti, Pl. III, Figs 1–12.

Derivatio nominis: the name of the species refers to its occurrence in the Balaton Highland.
Locus typicus: borehole Barnag, Bdt-2, Balaton Highland, Hungary.
Stratum typicum: sample from 29.5 m, marly limestone, borehole Barnag, Bat-2, Sándorhegy Fm., Barnag Mb., Tuvalian, Upper Carnian.

Description: test free, discoidal form. Initially, the tubular, undivided deuteroloculus – following the spherical proloculus – is streptospirally coiled, as in *Glomospira*, later planispirally enrolled. Chamber lumen grows continuously. Aperture is not visible in our sections. Wall is agglutinated and very thick.

Dimensions: max. diameter of holotype: 0.45 mm
min. diameter of holotype: 0.18 mm
thickness of wall: 0.03 mm
max. chamber lumen: 0.05 mm

Material: several specimens in thin section.

Association: Ammovertellina tuvalica nov. sp., *Meandrospirella planispira* (Oravecz-Scheffer) in the Balaton Highland; *Agathammina* sp., *Planiinvoluta* sp., *Meandrospira*? sp., *Paleonubecularia*? sp, *Tolypammina gregaria* Wendt, *Ophthalmidium* sp. in the Apuan Alps, Italy.

Stratigraphic distribution: Tuvalian (type locality), Ladinian-Carnian in Italy.

Remarks: On the paratype (Pl. II, Fig. 9), some additional irregular chambers are visible upon the last planispiral whorl. As their walls are rather thin, they seem to be parts of an other sessile foraminifer specimen.

Taxonomic remarks

Concerning *Meandrospirella planispira* (Oravecz-Scheffer) and *Meandrospirella karnica* (Oravecz-Scheffer), we must take the following remarks:

These two taxa were described in the "Annual report of the Hungarian Geological Institute for 1968", published in 1971.

The species *Meandrospirella planispira* (Oravecz-Scheffer 1971) was assigned to the genus *Meandrospiranella* with a question mark, as this genus had no valid definition at that time. The name of genus Meandrospiranella was proposed by Salaj et al. in 1967; however, its valid diagnosis was also only given by him in 1971.

Based on the genus diagnosis of *Meandrospiranella* carried out by Salaj in 1971, it is obvious that – owing to the lack of the rectolinear part of the test –

the *Meandrospirella? planispira* found in borehole Bakonyszűcs-1 cannot be assigned to the genus *Meandrospiranella*.

This is the reason why we assigned in 1987 *Meandrospiranella? planispira* to *Glomospirella* Plummer.

Referring to the holotype and the diagnosis of *Meandrospiranella? planispira* Oravecz-Scheffer 1971, Salaj proposed a new genus name, Meandrospirella, in 1983, for the specimens described from borehole Bakonyszűcs-1 as *Meandrospiranella? planispira* and *Meandrospira karnica* in the following form: "*Meandrospirella* Oraveczné-Scheffer 1968, emend Salaj 1979".

"Type species: *Meandrospirella planispira* Oraveczné-Scheffer 1968".

We accept this proposition with the following corrections:

– the valid date of the quoted paper of Oravecz-Scheffer is 1971 (and not 1968);

– the author of the genus *Meandrospirella* is correctly Salaj, because Oravecz-Scheffer's diagnosis of *Meandrospirella planispira* concerned the species, not the genus, and *Meandrospiranella? planispira* was not monospecific in 1971;

– the valid date of *Meandrospirella* Salaj is 1983 (and not 1979), because his work of 1979 was a manuscript (see Salaj, 1983 in References).

Taking into account these corrections, the valid name of this genus is as follows: *Meandrospirella* Salaj 1983. Genotype: *Meandrospirella planispira* (Oravecz-Scheffer 1971).

Along the type species, *Meandrospirella karnica* (Oravecz-Scheffer 1971) was also assigned by Salaj to this genus.

Concerning this species, in 1987 we could observe that their wall material is calcareous, yellowish-white, compact, and definitely miliolid-like; however, "these cannot be assigned to any of the known miliolid genera, being probably the representatives of a new genus closely related to *Meandrospira*" (p. 114).

As *Meandrospira karnica* was assigned to the genus *Meandrospirella*, and, at the same time, the genus *Meandrospirella* to the family Fischerinidae (Millet 1898) by Salaj (1983), the taxonomic and systematic status of this taxon can also be regarded as clarified.

Based on the type species "*Meandrospira karnica* Oravecz-Scheffer 1971", however, Urosevic (1988) proposed a new genus named *Semimeandrospira*. In her diagnosis, she considered the wall of the new genus to be calcareous and also assigned it to Fischerinidae Millet 1898. It is obvious, however, that *Meandrospirella* Salaj 1983 has priority over Semimeandrospira Urosevic 1988.

Probably the above-mentioned problems of assignment derive from the uncertainty of different interpretations of the material and the structure of the wall. Taking into account the method of investigations using thin sections and the processes of recrystallization, this uncertainty is very understandable. Thus, the remark "agglutinated" in the diagnosis of *Meandrospirella* assigned to Fischerinidae presumably refers to the recrystallized coarse-grained, calcareous substance of the test without any generic diagnostic value.

Finally, we want to express our agreement with Salaj's concept of the evolutionary lineage of the Triassic *Meandrospira* group and with the supposition that the Carnian *Meandrospirella* genus forms the last link of this phylogenetic lineage.

Plates

I–XXIV: Sporomorpha

Magnifications 1000x, exceptions are signed. Order of data: locality, mark of borehole, depth of sample in meter, number of slide, numbers of co-ordinate, number of photos

XXV–XXXIV: Foraminifers and microfacies

Order of data: locality, mark of borehole or outcrop, depth in meter, or number of sample, magnification

Plate I

1. *Dictyotidium tenuiornatum* Eis. 1955, Borehole Barnag-2, 58.8 m; 80078, 4.6–114.0, 2024/12–15
2. *Dictyotidium tenuiornatum* Eis. 1955, Borehole Barnag-2, 49.0–50.0 m; 80075, 10.9–112.6, 2025/33–38
3. *Dictyotidium reticulatum* Schulz 1965, Borehole Barnag-2, 58.5 m; 800078, 2024/7–9
4. *Dictyotidium reticulatum* Schulz 1965, Borehole Barnag-2, 50.5–52.5 m; 8077, 19.5–101.1, 2025/5
5. *Dictyotidium reticulatum* Schulz 1965, Borehole Barnag-2, 40.0 m; 80070, 5.2–102.1, 2025/18–19

6–7. *Dictyotidium reticulatum* Schulz 1965, Borehole Barnag-2, 91.0–91.20 m; 92079, 3.5–115.5, 2020/18–21

8. *Stereisporites (Annulisporites) folliculosus* (Rog. 1954) De Jersey 1959, Borehole Hévíz-6, 209.0 m; 50287, 14.4–109.1, 1322/11–13
9. *Stereisporites (Sculptisporis) aulosenensis* (Schulz 1967) Schulz 1970, Borehole Barnag-2, 41.8–45.0 m; 80071, 13.9–106.0, 1905/22–24
10. *Anapiculatisporites telephorus* (Pautsch 1958) Kl. 1960, Borehole Barnag-2, 41.8–45.0 m; 80060, 9.3–98.4, 2069/34–35

Plate II

1. *Laevigatisporites robustus* Leschik 1956, Borehole Barnag-2, 63.0–64.0 m; 8083, 7.0–99.9, 2005/24–26
2. *Laevigatisporites robustus* Leschik 1956, Borehole Barnag-2, 89.2 m; 80068, 4.8–105.0, 1973/3–5
3. *Deltoidospora mesozoica* (Thierg. 1949) Schuurman 1977, Borehole Barnag-2, 41.8–45.8 m; 80071, 16.3–103.9, 1905/18–21
4. *Todisporites* sp., Borehole Balatonhenye-6, 43.5–44.5 m 7088, 20.7–103.9, 2050/19–20
5. *Concavisporites toralis* (Leschik 1955) Nilsson 1958, Borehole Barnag-2, 49.0–50.0 m; 80075, 3.9–100.1, 2006/35–36
6. *Paraconcavisporites lunzensis* Kl. 1960, Borehole Barnag-2, 41.8–45.0 m; 800060, 16.2–96.7, 2060/16–19
7. *Paraconcavisporites lunzensis* Kl. 1960, Borehole Hévíz-6, 211.0 m; 50298, 14.0–104.2, 1322/4–7
8. *Concavisporites crassexinus* Nilsson 1958, Borehole Hévíz-6, 225.40 m; 50289, 13.8–110.0, 1326/1–4
9. *Undulatisporites dilucidus* Leschik 1956, Borehole Balatonhenye-6, 45.4–46.5 m; 70899, 4.5–106.7, 2039/1–5
10. *Neoraistrickia taylorii* Playford et Dettmann 1965, Borehole Hévíz-6, 225.40 m; 50289, 12.8–110.0, 1326/8–11
11. *Punctatisporites fissus* Leschik 1956, Borehole Barnag-2, 50.0–52.5 m; 80077, 9.2–11.4, 2024/18–21
12. *Praecirculina granifer* (Leschik 1956) Kl. 1960

Plate III

1–2. *Trilites tuberculiformis* Cookson 1947, Borehole Zsámbék-14, 455.4–456.4 m
3–4. *Lycopodiacidites kuepperi* Kl. 1960, Borehole Zsámbék-14, 339.6–340.4 m
5–6. *Lycopodiacidites kuepperi* Kl. 1960, Borehole Zsámbék-14, 341.9–343.3 m
7–8. *Lycopodiacidites* sp., Borehole Zsámbék-14, 332.4–333.3 m

Plate IV

1. *Verrucosisporites thuringiacus* Mädler 1964, Borehole Zsámbék-14, 571.4–572.3 m (Julian)
2. *Camerosporites secatus* Leschik 1955, Borehole Zsámbék-14, 335.3–336.3 m
3–6. *Kyrtomisporites ervii* Van Der Eem 1983, Borehole Zsámbék-14, 3–4: 338.9–339.6 m, 5–6: 354.0–355.3 m

Plate V

1–2. *Uvaesporites argenteformis* (Bolkh. 1953) Lund 1977, Borehole Zsámbék-14, 338.8–339.6 m
3. *Verrucosisporites krempii* Mädler 1964, Borehole Zsámbék-14, 492.1–493.2 m
4–5. *Uvaesporites reissingeri* (Reinh. 1961) Lund 1977, Borehole Zsámbék-14, 423.2–424.2 m

Plate VI

1–2. *Cingulizonates tuvali* nov. sp., Borehole Balatonhenye-6, 42.5–43.5 m; 70887, 2.7–104.5, 2071/33–34
3. *Densosporites cavernatus* Orlowska-Zvolinska 1966, Borehole Hévíz-6, 243.9 m; 50291
4. *Densosporites cavernatus* Orlowska-Zvolinska 1966, Borehole Hévíz-6, 209.0 m
5–7. *Reticulitriletes* cf. *globosus* Mädler 1964a, Borehole Hévíz-6, 243.9 m; 50291, 9.9–109.0, 2071/29–32

Plate VII

1. *Lycopodiacidites kuepperi* Kl. 1960, Borehole Barnag-2, 89.2 m; 80068, 22.2–108.7, 1974/21–22
2. *Gibeosporites lativerrucosus* (Leschik 1956) 1959, Borehole Barnag-2, 49.0–50.0 m; 80075, 18.5–103.8, 1914/28–30
3. *Foveosporites cavernatus* Orl.-Zw. 1966, Borehole Balatonhenye-6, 49.1–49.9 m; 70892, 4.1–109.8, 2055/9–13
4. *Verrucosisporites morulae* Kl. 1960, Borehole Barnag-2, 18.0–19.0 m; 80058, 7.7–100.1 V-5/35–36
5. *Cyclotriletes* cf. *margaritatus* Mädler 1964, Borehole Barnag-2, 89.2 m; 80068, 7.4–111.3, 1974/30–32
6. *Aratrisporites coryliseminis* Kl. 1960, Borehole Hévíz-6, 209.0 m; 50287, 9.8–115, 1322/19–21
7. *Uvaesporites gadensis* Praehauser-Enzenberg 1970, Borehole Barnag-2, 41.8–45.0 m; 80071, 4.5–103.6, 1905/12–13
8. *Aratrisporites palettae* (Kl. 1960) Schulz 1967, Borehole Hévíz-6, 404.0–410.0 m; 55083, 15.8–106.5, 1412/10–13
9. *Lycopodiacidites kuepperi* Kl. 1960, Borehole Barnag-2, 41.8–45.0 m; 80060, 11.1–100.4, 2029/12–13
10. *Kraeuselisporites lituus* (Leschik 1956) Scheuring 1974, Borehole Hévíz-6, 425.3–426.0 m; 55090, 7.4–109.3, 1322/1–3
11. *Punctatisporites* sp., Borehole Hévíz-6, 243.9 m; 50291, 19.7–114.6, 1323/26–28

Plate VIII

1–2. *Praecirculina granifer* (Leschik 1956) Kl. 1960, Borehole Zsámbék-14, 359.8–360.8 m
3–4. *Duplicisporites tenebrosus* (Scheuring 1970) 1978, Borehole Zsámbék-14, 315.0–316.0 m; 3: 5.8–98.3, 4: 18.8–98.2
5. *Duplicisporites tenebrosus* (Scheuring 1970) 1978, Borehole Barnag-2, 50.5–52.5 m
6. *Pseudenzonalasporites summus* Scheuring 1970, Borehole Zsámbék-14, 492.10–493.2 m
7. *Pseudenzonalasporites summus* Scheuring 1970, Borehole Barnag-2, 49.0–50.5 m
8–9. *Duplicisporites scurrilis* Scheuring 1970, Borehole Zsámbék-14, 372.2–373.2 m
10–11. *Duplicisporites scurrilis* Scheuring 1970, Borehole Zsámbék-14, 344.7–346.2 m
12. *Duplicisporites scurrilis* Scheuring 1970, Borehole Barnag-2, 91.6–91.2???
13–14. *Duplicisporites maljavkinae* (Kl. 1960) Scheuring 1970, Borehole Zsámbék-14, 373.2–374.2 m

Plate IX

1–2. *Partitisporites novimundanus* Leschik 1956, Borehole Zsámbék-14, 349.0–350.0 m
3–5. *Duplicisporites granulatus* (Leschik 1956) Scheuring 1970, Borehole Zsámbék-14, 349.0–350.4 m
6. *Duplicisporites quadruplicis* (Scheuring 1970) 1978, Borehole Zsámbék-14, 338.9–339.6 m
7–8. *Camerosporites secatus* Leschik 1955, Borehole Zsámbék-14, 493.2–494.2 m
9–13. *Enzonalasporites tenuis* Leschik 1955, Borehole Zsámbék-14, 9–10: 354.0–355.3 m, 11: 338.9–339.6 m, 12–13: 354.0–355.3 m
14. *Enzonalasporites* sp., Borehole Zsámbék-14, 335.8–336.3 m

Plate X

1. *Enzonalasporites tenuis* Leschik 1956, Borehole Balatonhenye-6, 54.6–55.7 m
2. *Enzonalasporites tenuis* Leschik 1956, Borehole Zsámbék-14, 338.9–339.6 m
3. *Vallasporites ignacii* Leschik 1956, Borehole Zsámbék-14, 338.9–339.6 m
4–5. *Enzonalasporites vigens* Leschik 1956, Borehole Zsámbék-14, 333.3–334.3 m
6. *Vallasporites ignacii* Leschik, 1956 Borehole Zsámbék-14, 338.9–339.6 m
7. *Enzonalasporites tenuis* Leschik 1956, Borehole Barnag-2, 50.5–52.2 m
8–10. *Patinasporites explanatus* (Leschik 1956) n. comb. 8: Borehole Zsámbék-14, 338.9–339.6 m, 9: Borehole Hévíz-6, 243.9 m, 10: Borehole Barnag-2, 61.8 m
11. *Patinasporites densus* Leschik 1956, Borehole Barnag-2, 41.8–45.0 m

Plate XI

1–3. *Corollina meyeriana* Kl. 1960, Borehole Hévíz-6, 243.0 m
4. *Duplicisporites granulatus* Leschik 1956, Borehole Hévíz-6, 243.0 m5–6.
5–8. *Lunatisporites acutus* Leschik 1956, Borehole Hévíz-6, 243.0 m, 5: 9.1–111.1; 6: 10.0–110.2, 7: 20.4–110.9, 8: 19.8–112.3
9–10. *Infernopollenites parvus* Scheuring 1970, Borehole Hévíz-6, 243.9 m

Plate XII

1–3. *Ovalipollis ovalis* Kr. 1955, Borehole Barnag-2, 1: 89.2 m; 80068, 19.9–109.5, 1973/21–23, 2: 50.5–52.5 m 80077, 11.7–100.6, 2024/30, 3: 89.2 m, 80068, 11.9–99.9, 1974/1–5
4. *Ovalipollis ovalis* Kr. 1955, Borehole Hévíz-6, 234.7–235.7 m; 55071, 14.9–115.2, 1327/22–24
5. *Ovalipollis lunzensis* Kl 1960, Borehole Barnag-2, 63.0–64.0 m; 80083, 10.3–97.7 2005/22–23
6. *Ovalipollis cultus* Scheuring 1970, Borehole Zsámbék-14, 314.0–315.0 m
7. *Ovalipollis ovalis* Kr. 1955, Borehole Barnag-2 51.0 m; 80076, 5.3–100.3, 1916/17–20
8. *Ovalipollis septimus* Scheuring 1970, Borehole Balatonhenye-6, 48.0–48.7 m; 70891, 18.9–98.6, 2049/8, 2058/1–13
9. *Ovalipollis minimus* Scheuring 1970, Borehole Hévíz-6, 225.4 m; 50290, 20.4–112.5, 1325/19–21

Plate XIII

1–3. *Cuneatisporites radialis* Leschik 1956, Borehole Zsámbék-14 357.8–358.8 m; , 1–2: 16.8–101.3, 3: 5.5–110.4
4. *Alisporites australis* De Jersey 1962, Borehole Zsámbék-14, 356.9–357.8 m
5–9. *Lunatisporites acutus* Leschik 1956, Borehole Zsámbék-14, 5–6: 372.2–373.2 m, 7–8: 346.2–347.6 m, 9: 315.0–316.0 m

Plate XIV

1–4. *Pityosporites devolvens* Leschik 1956, Borehole Zsámbék-14, 1: 338.9–339.6 m, 2: 340.4–341.0 m, 3: 357.9–358.0 m, 4: 491.0–492.1 m
5–6. *Podosporites amicus* Scheuring 1970, Borehole Zsámbék-14, 5: 357.8–358.8 m, 6. 338.9–339.6 m
7. *Lunatisporites acutus* Leschik 1956, Borehole Zsámbék-14, 340.4–344.0 m
8. *Ellipsovelatisporites plicatus* Kl. 1960, Borehole Zsámbék-14, 338.9–339.6 m

Plate XV

1. *Septasporites pectinatus* Leschik 1956, Borehole Zsámbék-14, 338.9–339.6 m
2. *Pityosporites devolvens* Leschik 1956, Borehole Zsámbék-14, 338.9–339.6 m
3. *Podosporis amicus* Scheuring 1970, Borehole Zsámbék-14, 338.9–339.6 m
4. *Rimaesporites potoniei* Leschik 1956, Borehole Zsámbék-14, 357.8–358.2 m

Plate XVI

1. *Alisporites aequalis* Mädler 1964, Borehole Zsámbék-14, 338.9–339.6 m
2. *Schizosaccus keuperi* Mädler 1964, Borehole Zsámbék-14, 338.9–339.6 m
3. *Chordasporites singulichorda* Kl. 1960, Borehole Zsámbék-14, 357.8–358.8 m

Plate XVII

1. *Hevizipollenites samaroides* nov. gen. et sp., Borehole Balatonhenye-6, 62.0–63.0 m; 70900, 2.7–95.6, 2053/1,3 6–8
2–8. *Pinuspollenites minimus* (Couper 1958) Kemp 1970, 2: Borehole Barnag-2, 90.8–91.0 m; 92078, 10.5–109.8, 2005/19–21, 3: Borehole Barnag-2, 57.4–57.8 m; 70896, 17.1–105.6, 2004/26–29, 4: Borehole Balatonhenye-6, 30.4–30.8 m; 70883, 12.9–106.8, 1999/3–5, 5–6, 8: Borehole Barnag-2, 91.0–91.2 m; 92079, 7.1–101.4, 20.8–117.1, 4.9–99.5, 2020/9–12, 2021/9–13, 2020/1–2, 7: Borehole Barnag-2, 61.8 m; 80081, 16.7–105.3, 2006/22–24
9–10. *Lunatisporites acutus* Leschik 1956, Borehole Hévíz-6, 243.9 m; 50291, 9: 16.3–109.0, 10: 13.6–109.7

Plate XVIII

1–4,
7. *Hevizipollenites samaroides* nov. gen. et sp., Borehole Hévíz-6, 243.9 m, 1-2: holotypes, 50291, 11.7–109.0, 3–4: 50291, 14.7–114.4, 7: 50291, 19.9–116.2

5–6. *Lunatisporites acutus* Leschik 1956, Borehole Hévíz-6, 243.9 m; 50291, 9.5–115.5

8. *Samaropollenites concinnus* Fischer et Dunay 1984, Borehole Hévíz-6, 243.9 m; 50291, 13.0–114.5

Plate XIX

1–4. *Samaropollenites concinnus* Fischer et Dunay 1984, Borehole Hévíz-6, 243.9 m; 50291, 1–2: 19.9–112.3, 3–4: 11.5–112.3

5–8. *Microcachryidites* sp., Borehole Hévíz-6, 243.9 m; 50291, 5: 5.5–115.5, 6–7: 7.0–111.4, 8: 16.5–105.4

9. *Lunatisporites acutus* Leschik 1956, Borehole Hévíz-6, 243.9 m; 50291, 9.7–113.8

Plate XX

1–5. *Lunatisporites acutus* Leschik 1956, 1–2, 4–5: Borehole Barnag-2, 61.0–63.0 m; 80082, 18.5–113.0, 13.9–103.5, 6.5–105.8, 7.3–102.8, 2006/7–, 19–21, 4–6, 1–3, 3: Borehole Hévíz-6 233.7–234.7 m; 55070, 1326/23–26

6. *Triadispora delicata* Orl.-Zw. 1983, Borehole Balatonhenye-6, 50.5–51.2 m; 70894, 4.4–110.5, 2055/15–19

7. *Triadispora boelchii* (Scheuring 1970) 1979, Borehole Barnag-2, 63.0–64.0 m; 80083, 12.6–112.5, 2005/31–32

8. *Triadispora delicata* Orl.-Zw. 1983, Borehole hévíz-6, 240.7–241.7 m; 51909, 6.4–113.5, 1327/16–18

Plate XXI

1, 4,
5, 7. *Triadispora epigona* Kl. 1960, 1: Borehole Balatonhenye-6, 57.4–57.8 m; 70896, 23.6–100.3, 2004/23–25, 4: Borehole Barnag-2, 61.0–63.0 m; 80082, 17.0–101.4, 2005/36–37, 5: Borehole Ny-1, 187.5–187.7 m; 55312, 1342/9–12, 7: Borehole Zsámbék-14, 319.3–320.4 m; 54361, 21.5–103.0, 1293/26–29

2–3. *Triadispora* cf. *crassa* Kl. 1964, Borehole Balatonhenye-6, 2: 48.0–48,7 m, 70891, 7.8–96.3, 2004/23–25, 3. 34.9 m; 92103, 16.1–103.0 , 2001/21–28

6. *Triadispora* sp., Borehole Barnag-2, 27.8–29.6; 80066, 15.2–100.4, 2007/19–22

Plate XXII

1. *Ovalipollis brutus* Scheuring 1970, Borehole Barnag-2, 42.5 m; 80072, 18.8–97.5, 1906/28–30, M= 403x
2. *Ovalipollis septimus* Scheuring 1970, Borehole Balatonhenye-6, 41.5–42.5 m 70886, 6.0–109.3, 2002/20–23
3. *Brachysaccus neomundanus* (Leschik 1956) Mädler 1964, forma minor Orl-Zw. 1983, Borehole Barnag-2. 41.8–45.0 m; 80071, 14.1–100.7, 1905/6–11
4. *Sulcatisporites kraeuseli* Mädler 1964, Borehole Hévíz-6, 233.7–234.7 m; 55070, 21.3–103.0, 1327/1–2
5. *Alisporites illustris* (Leschik 1956) nov. comb., Borehole Ny-1, 187.5–187.7 m; 55312, 1342/1–4

Plate XXIII

1–2. *Platysaccus quenslandi* De Jersey 1962, Borehole Zsámbék-14, 329.2–330.2 m
3–4. *Platysaccus quenslandi* De Jersey 1962, Borehole Zsámbék-14, 363.9–365.4 m
5. *Ovalipollis minimus* Scheuring 1970, Borehole Zsámbék-14, 496.2–497.55 m
6–7. *Ellipsovelatisporites plicatus* Kl. 1960, Borehole Zsámbék-14, 383.8–385.0 m
8–9. *Ovalipollis minimus* Scheuring 1970, Borehole Zsámbék-14, 357.8–358.8 m

Plate XXIV

1. *Alisporites illustris* (Leschik 1956) nov. comb., Borehole Barnag-2, 27.8–29.6 m; 80066, 3.7–111.2, 2007/29–30
2. *Staurosaccites quadrifidus* Dolby 1976, Borehole Barnag-2, 41.8–45.0 m; 80060, 3.5–96.4, 2069/21–24
3. *Samaropollenites concinnus* Fischer et Dunay 1984, Borehole Barnag-2, 41.8–45.0 m; 80060, 17.3–95.5, 2069/3–4
4. *Enzonalasporites tenuis* Leschik 1956, Borehole Barnag-2, 41.8–45.0 m; 80060, 17.3–95.5, 2069/3–4
5. *Lunatisporites acutus* Leschik 1956, Borehole Barnag-2, 41.8–45.0 m; 80060, 22.2–95.7, 2060/11–12
6. *Punctatisporites digestus* Leschik 1956, Borehole Barnag-2, 41.8–45.0 m; 80060, 4.0–96.4, 2069/19–20
7–8. *Duplicisporites maljavkinae* (Kl. 1960) Scheuring 1978, Borehole Balatonhenye-6, 54,6–55.7 m; 70895, 10.8–94.5, 2046/22–23
9. *Corollina* cf. *meyeriana* Kl 1960/zwolinskai Lund 1977, Borehole Barnag-2, 41.8–45.0 m; 80060, 13.7–95.5, 2069/5–6
10. *Cycadopites* sp., Borehole Balatonhenye-6, 63.7–64.7 m; 92558, 15.8–112.9, 2056/25–28
11. *Cycadopites carpenteri* (Delq. et Spr. 1956) Couper 1958, Borehole Balatonhenye-6, 62.0–63.0 m; 70900, 14.9–112.2, 2045/3–4, 6

Plate XXV

1–5. *Tolypammina gregaria* Wendt, 1–2: Borehole Hévíz-6, 195.0 m, 65x, 3: Borehole Öcs-24, 16.0 m, 50x, 4: Borehole Veszprém-1, 163.4 m, 65x, 5: Borehole Veszprém-1, 163.5 m, 65x,
6. *Planiinvoluta carinata* Leischer, Borehole Hévíz-6, 195.0 m, 65x
7. *Pilaminella kuthani* (Salaj), Borehole Hévíz-6, 195.0 m, 65x
8. *Lituotuba* cf. *canovicae* Urosevic, Borehole Hévíz-6, 195.0 m, 65x
9. *Ophthalmipora* sp., Borehole Veszprém-1, 163.5 m; 65x
10. *Pilaminella gemerica* (Salaj), Nosztori-Valley, Road-cut, sample 2, 65x

Plate XXVI

1–4. *Meandrospirella karnica* (Oravecz-Sch.), 1, 3–4: Borehole Balatonhenye-6, 34.0 m, 65x, 2: Nemesvita, sample 119, 110x
5, 6, 8. *Meandrospirella planispira* (Oravecz-Sch.) Borehole Balatonhenye-6, 34.0 m, 65x
7, 9. *Glomospirella balatonica* nov. sp., 7: Holotype, Borehole Barnag-2. 295 m, 110x

Plate XXVII

1–4. *Ammovertelina tuvalica* n. sp., 1: Holotype, Borehole Barnag-2, 29.5 m, 110x
5–6. *Endotriada* cf. *austrotriadica* (Oberhauser), 5: Nemesvita, sample 119, 110x, 6: Borehole Barnag-2, 72.4 m, 110x
7. *Endotriada izjumiana* (Dain), Nosztori Valley, Road-cut, sample 6, 65x
8. *Valvulina azzouzi* Salaj, Nemesvita, sample 119, 110x
9. *Tetrataxis inflata* Kristan, Nemesvita, sample 119, 110x

Plate XXVIII

1. *Endotriada* sp., Nosztori Valley, Road-cut, sample 2, 65x
2. *Glomospirella shengi* Ho, Nosztori Valley, Road-cut, sample 6, 130x

3–8. *Gsollbergella spiroloculiformis* (Oravecz-Sch.), 3–4, 5, 8: Outcrop near the Fountain Szent Miklós, 130x, 6–7: Borehole Hévíz-6, 6: 195.0 m, 65x, 7: 272.0 m, 65x

9. *Glyphostomella triloculina* (Cushman et Waters) Borehole Veszprémvarsány, Vvt-2, 28.0 m, 65x
10. *Glomospirella capellinii* Ciarapica et Zaninetti, Outcrop Sándorhegy, sample 1, 65x

11–12. *Ophthalmidium* cf. *martanum* (Farinacci), Veszprém Vasas sports ground, sample 1, 65

13. *Trochammina* cf. *alpina* Kristan-Tolman, Borehole Hévíz-6, 284.0 m, 55x
14. *Astacolus karnicus* (Oberhauser), Nosztori Valley, Road-cut, sample 5, 65x

15–17. *Glomospirella capellinii* Ciarapica et Zaninetti, Nosztori Valley, Road-cut, sample 2, 65x

Plate XXIX

1–5. *Pseudonodosaria ploechingeri* (Oberhauser), 1–3: Borehole Barnag-2, 1: 31.0 m, 110x, 2: 55.9 m, 110x, 3: 78.9 m, 110x, 4–5: Nosztori Valley, Road-cut, sample 2, 65x

6–8. *Nodosaria raibliana* Gümbel, Borehole Barnag-2, 6: 82.3 m, 110x, 7–8: 84.7 m, 110x

9. *Austrocolomia?* sp., Borehole Barnag-2, 72.4 m, 110x

10–12. *Nodosaria ordinata* Trifonova, 10: Borehole Balatonhenye-6, 34.0 m, 56x 11: Nosztori Valley, Road-cut, sample 2, 65x, 12: Nosztori Valley, Road-cut, sample 5, 65x

13–14. *Nodosaria* sp., Borehole Balatonhenye-6, 34,0 m. 65x

Plate XXX

1. *Aulotortus subsphaericus* (Salaj), Nosztori Valley, Road-cut, sample 6, 65x, 2–3.

2–3. *Triadodiscus eomesozoicus* (Oberhauser), Nosztori Valley, Road-cut, sample 6, 65x

4. *Aulotortus sinuosus* Weyn., Borehole Barnag-2, 55.0 m, 55x
5. *Aulotortus friedli* (Kristan), Nosztori Valley, Road-cut, sample 2, 65x
6. *Aulotortus praegaschei* (Koehn-Zan.),Outcrop Sándorhegy, sample 0, 65x
7. *Aulotortus* cf. *sinuosus* Weyn., Nosztori Valley, Road-cut, sample 2, 65x

Plate XXXI

Characteristic microbiofacies of Sándorhegy Formation

1–2. Oncoidal–Crinoidal biosparite, Borehole Hévíz-6, 195.0 m, 65x

Plate XXXII

Characteristic microbiofacies of Sándorhegy Formation

1–2. Oncosparite with Tolypammina, and "Sphaerocodium", Borehole Veszprém-1, 1: 157.5 m, 65x, 2: 163.5 m, 65x

Plate XXXIII

Characteristic microbiofacies of Sándorhegy Formation

1. Foraminiferal microbiosparite, Borehole Balatonhenye-6, 34.0 m, 65x
2. "Ostracodal lumachella" microbiosparite, Borehole Balatonhenye-6, 119.3 m, 65x

Plate XXXIV

Characteristic microbiofacies of Sándorhegy Formation

1. Intrabiosparite, Veszprém Vasas sports ground, sample 1, 65x
2. Foraminiferal microbiosparite, with Holothuroidea, Borehole Balatonhenye-6, 34.3, 65x

Plate I

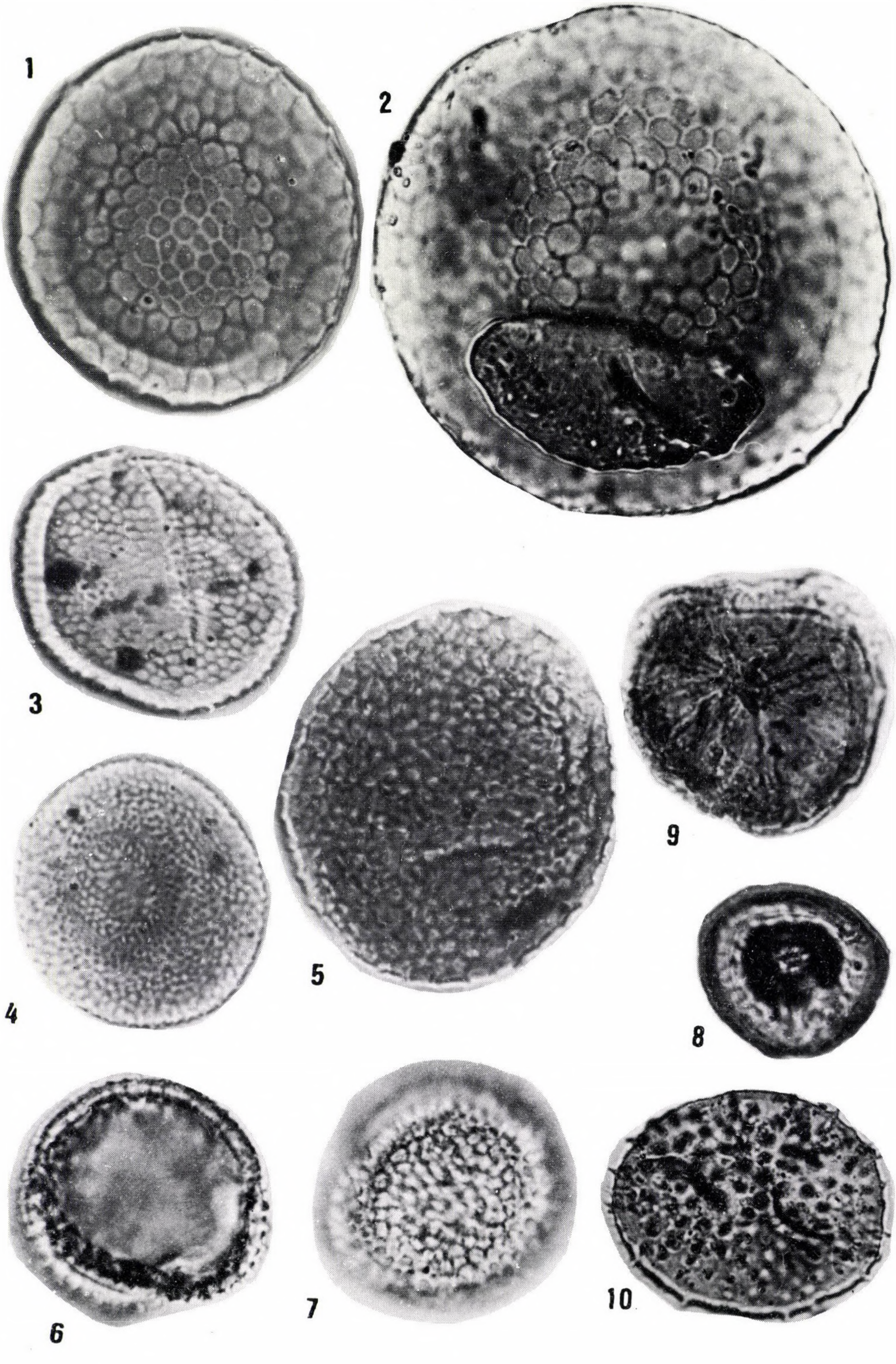


Plate II

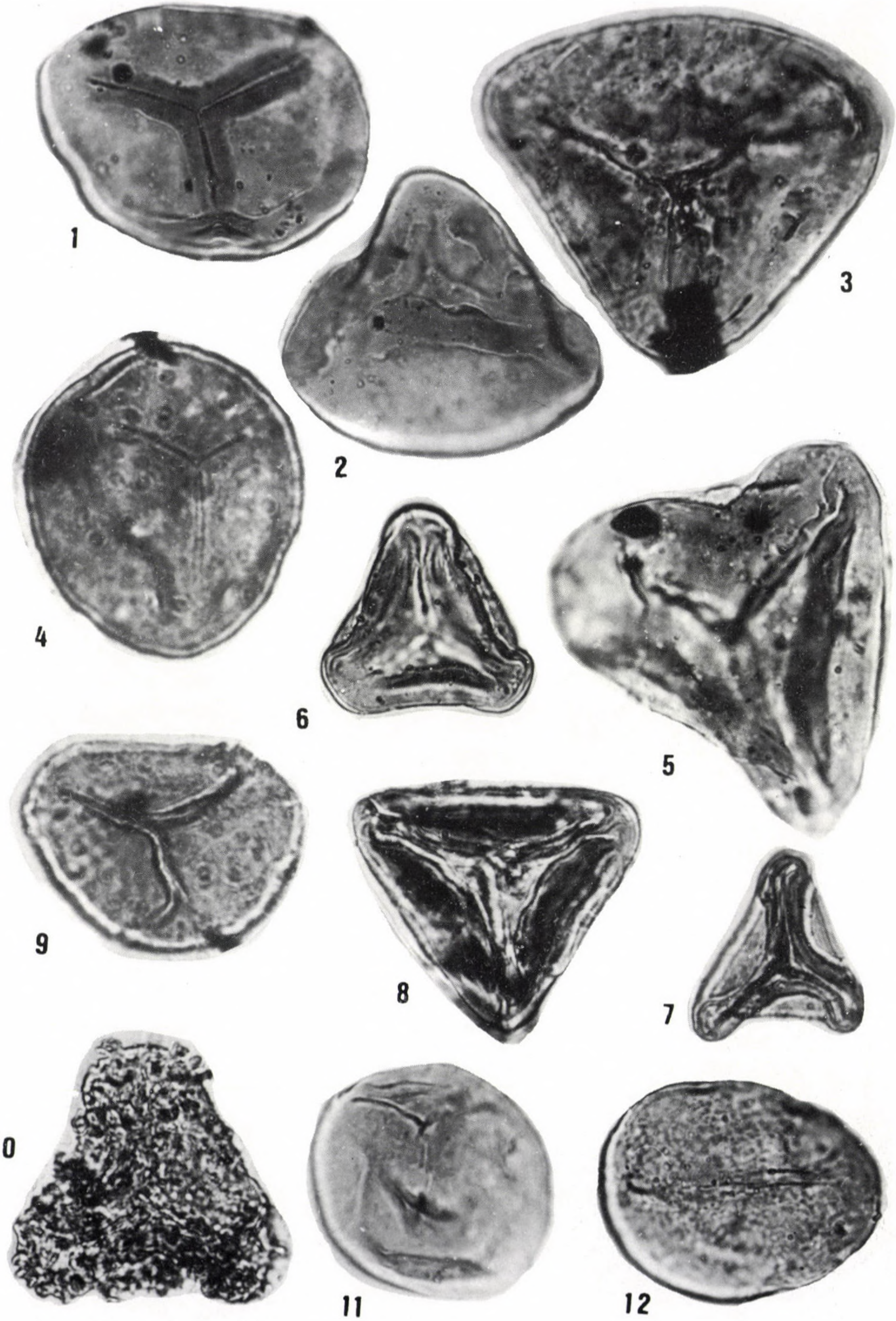


Plate III

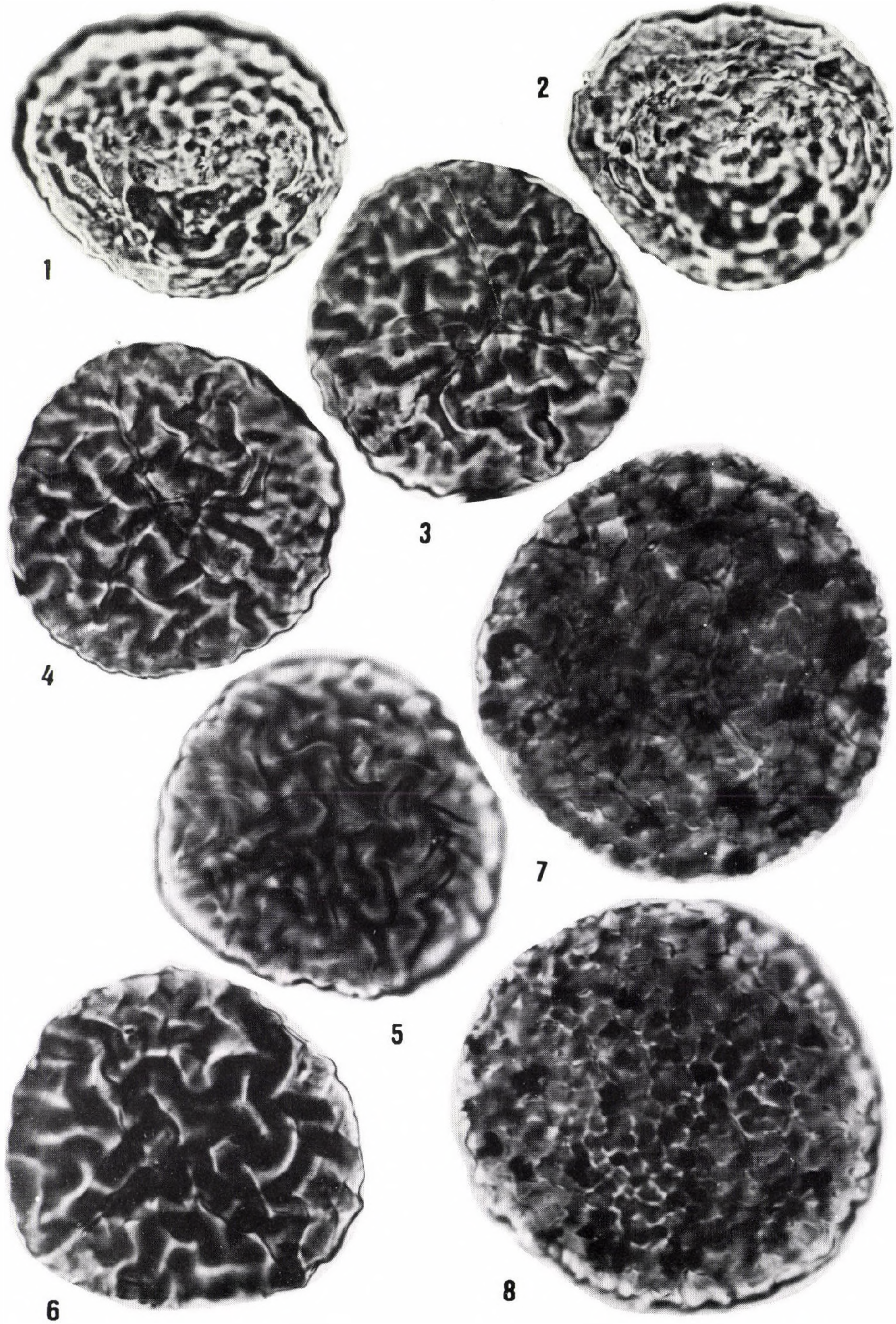


Plate IV

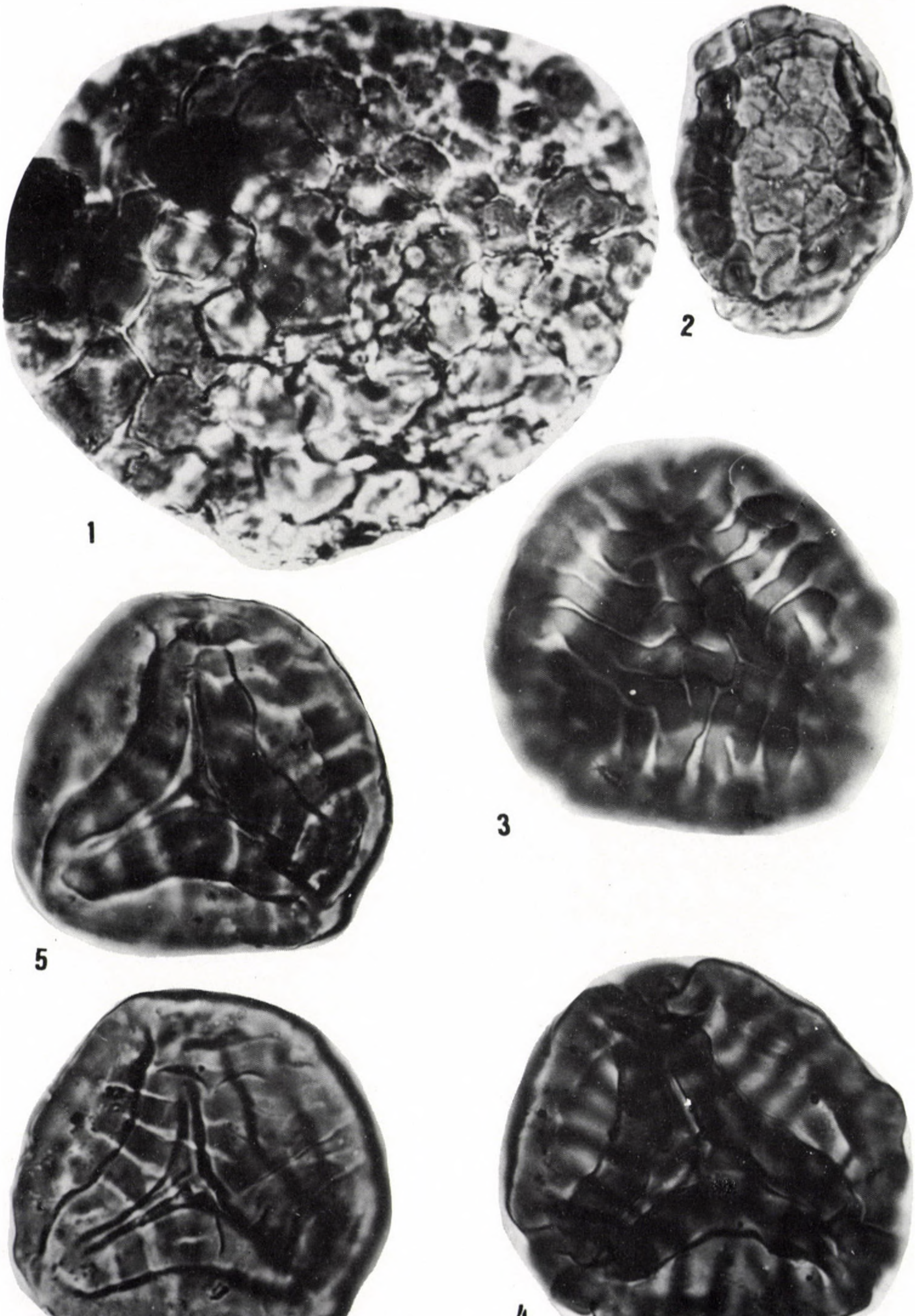


Plate V

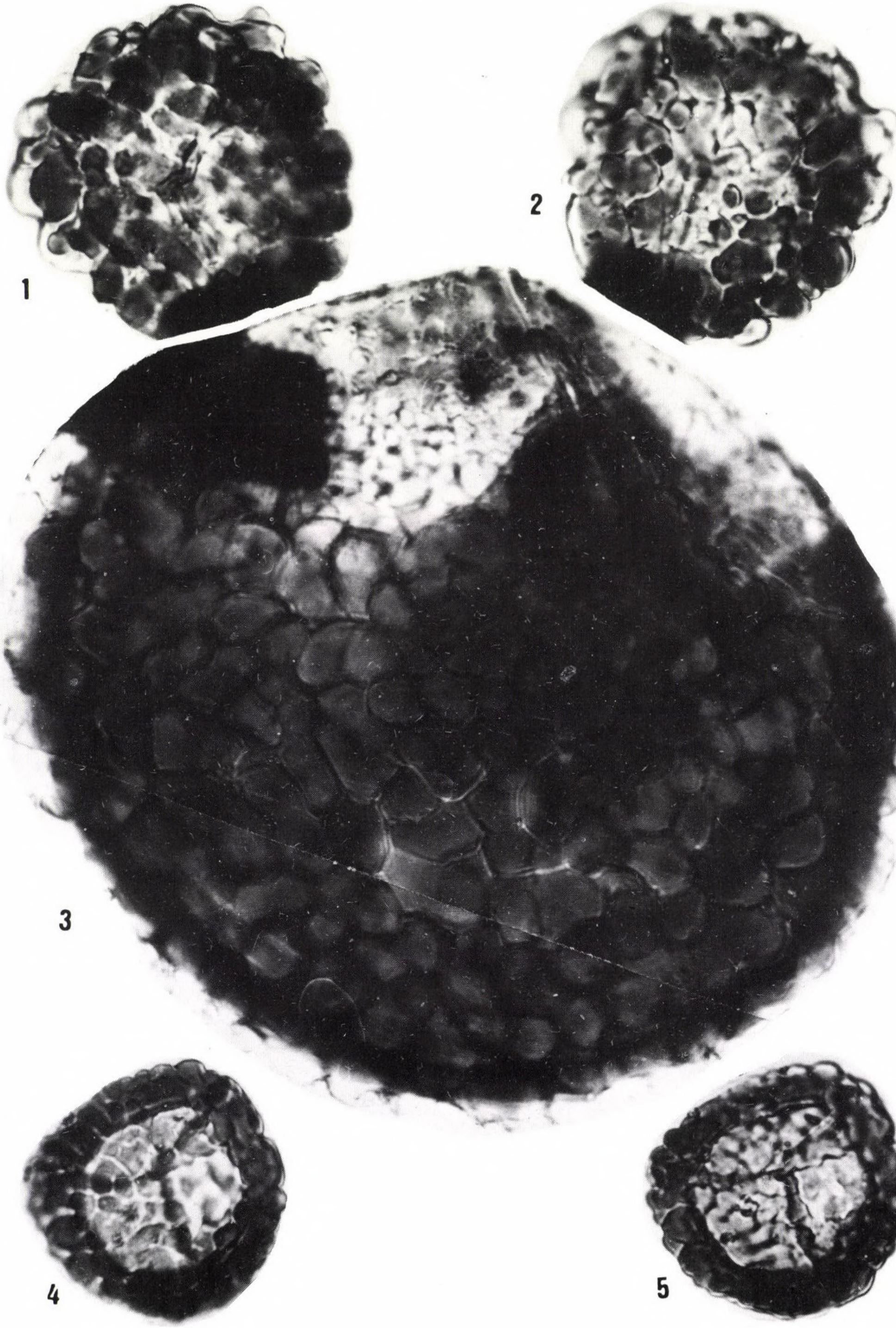


Plate VI

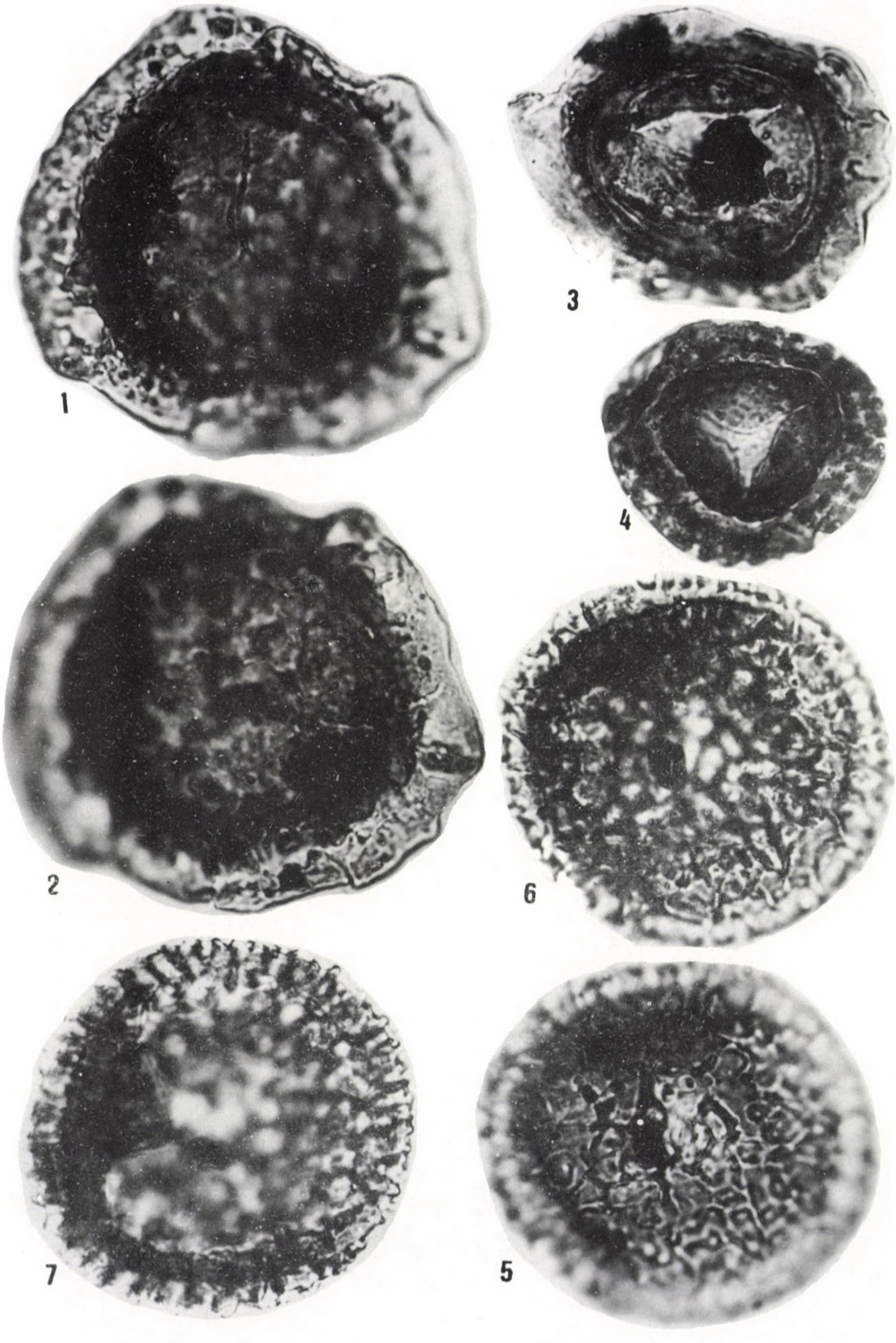


Plate VII

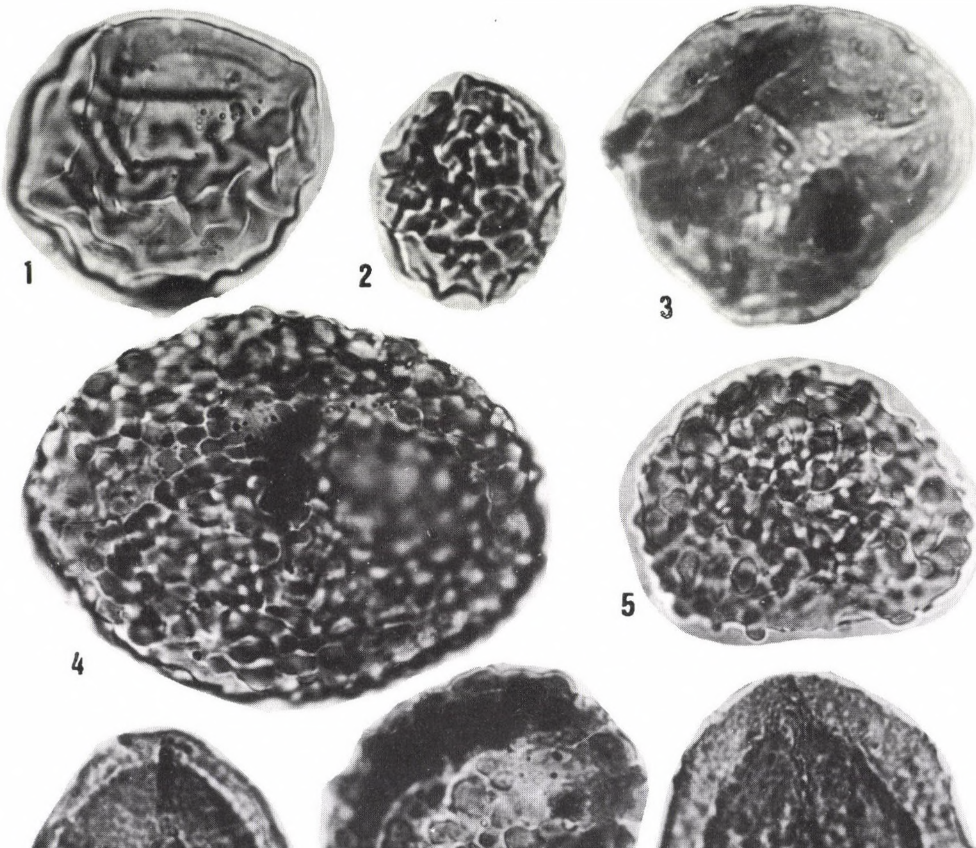


Plate VIII

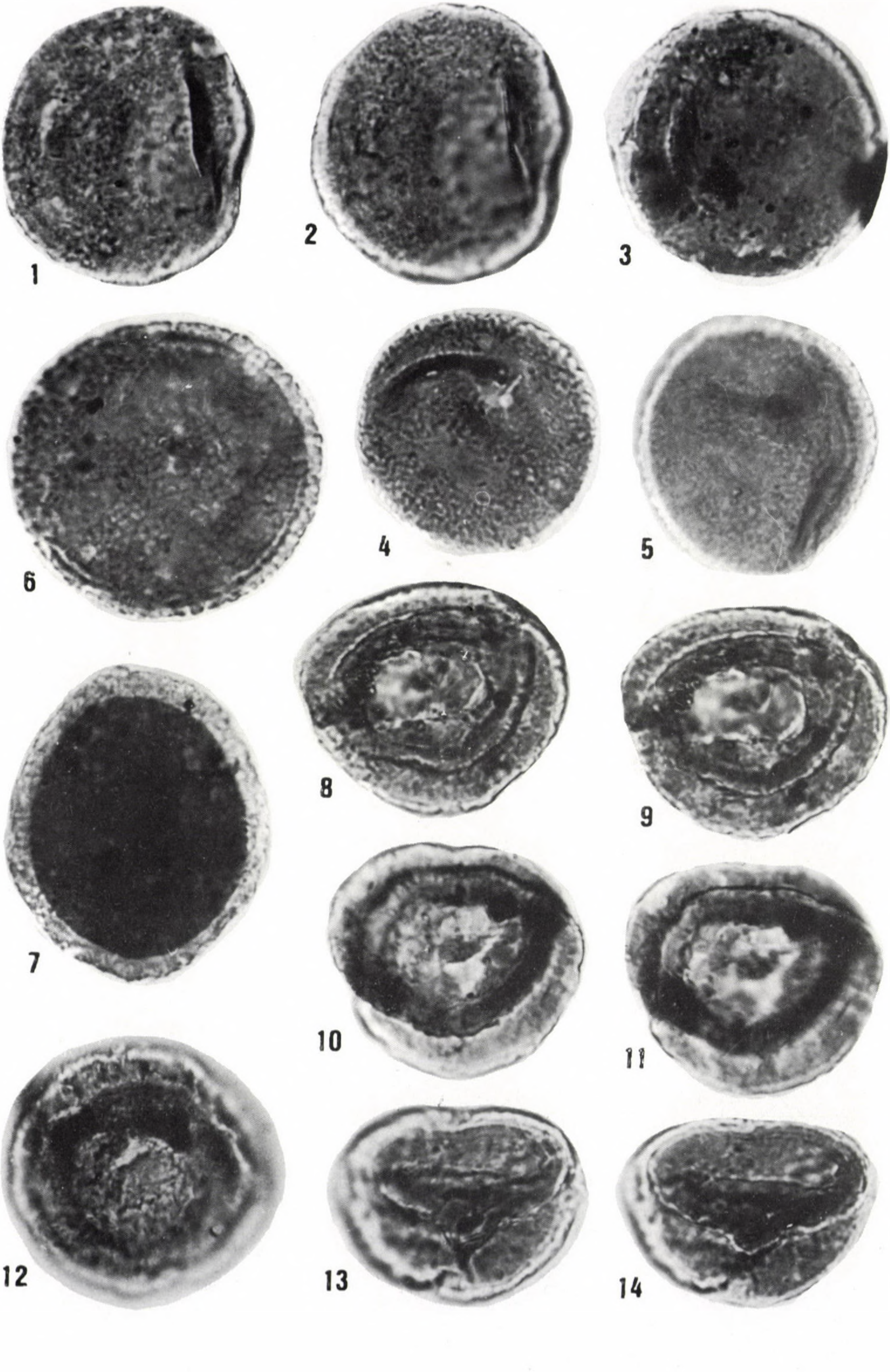
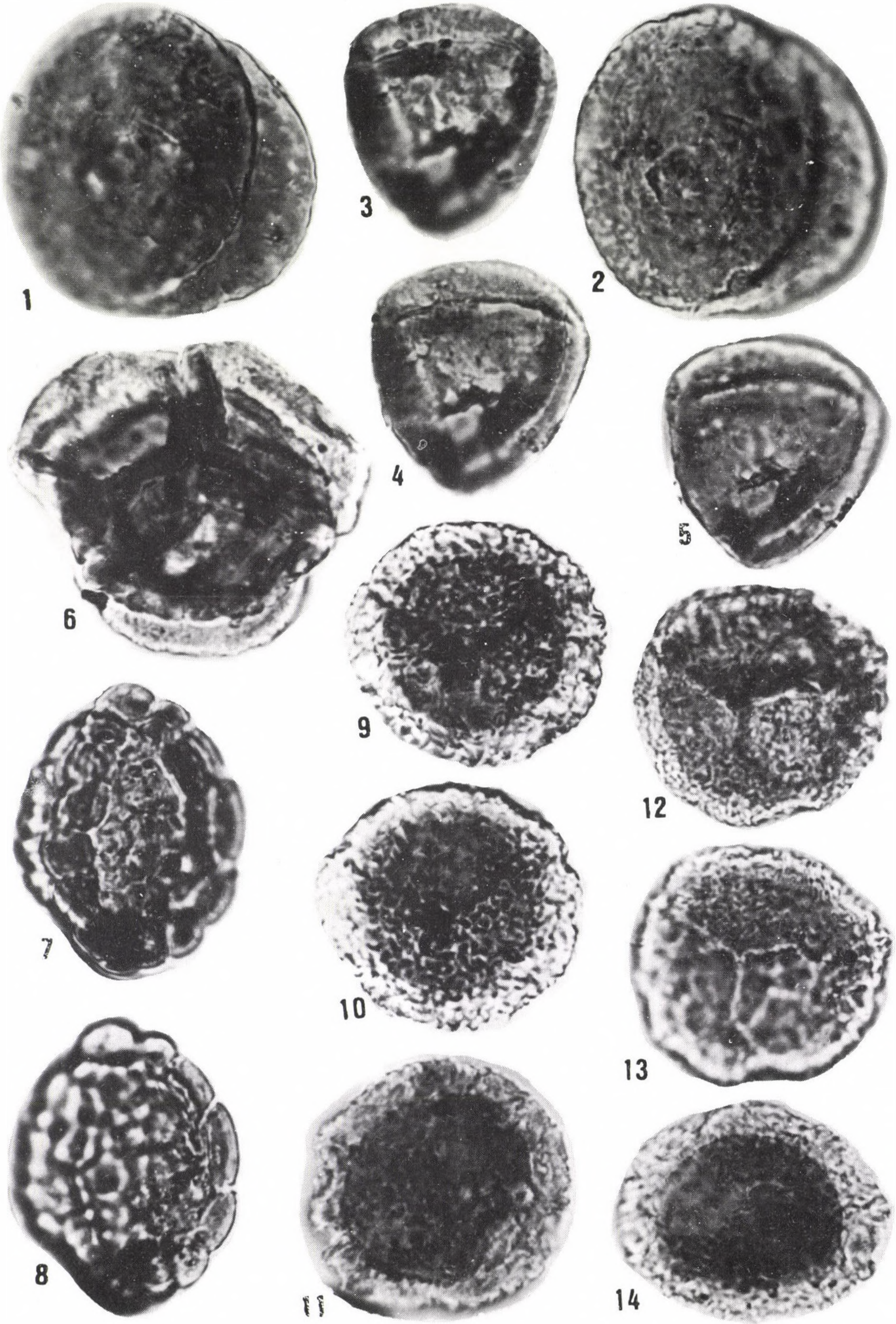


Plate IX



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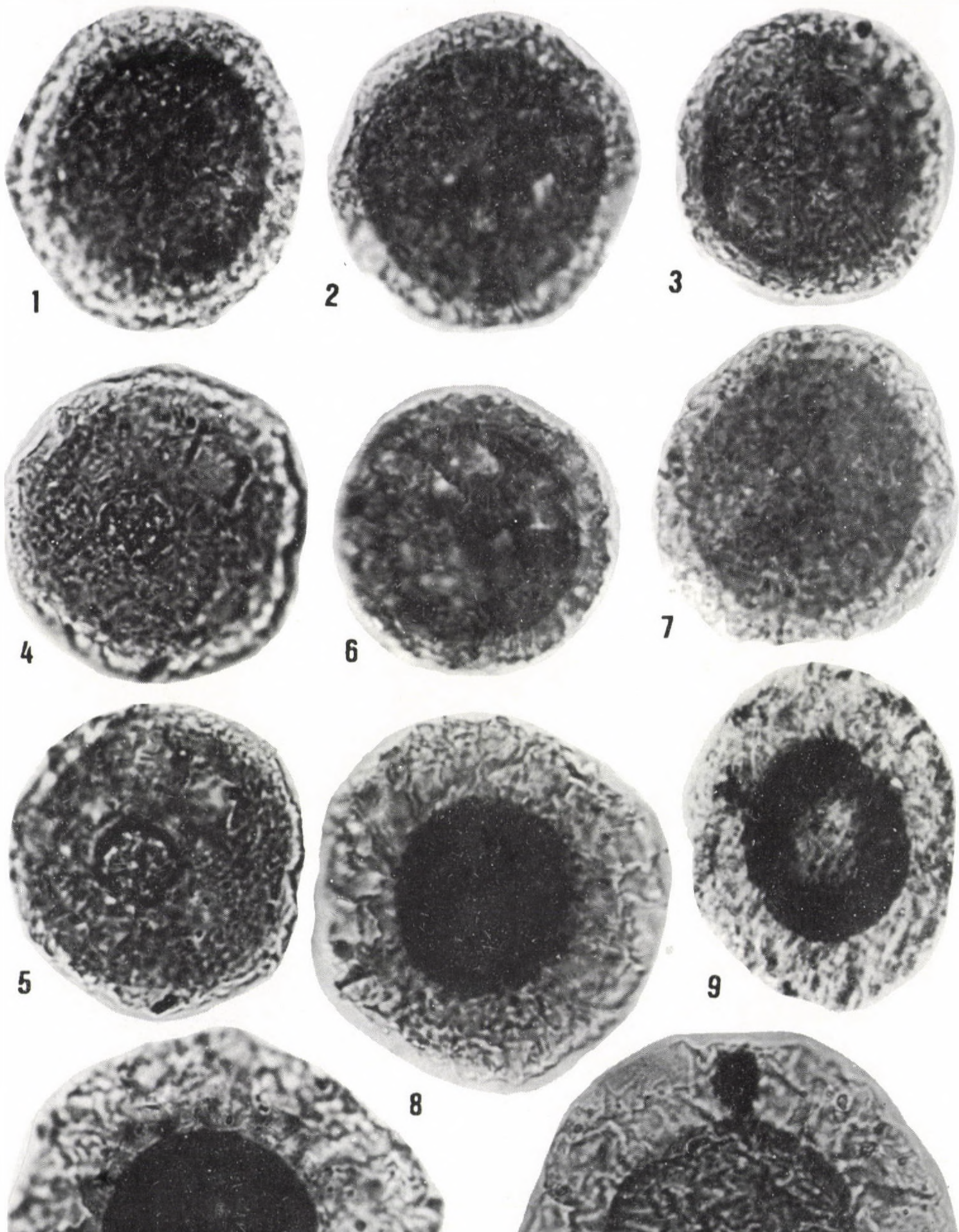

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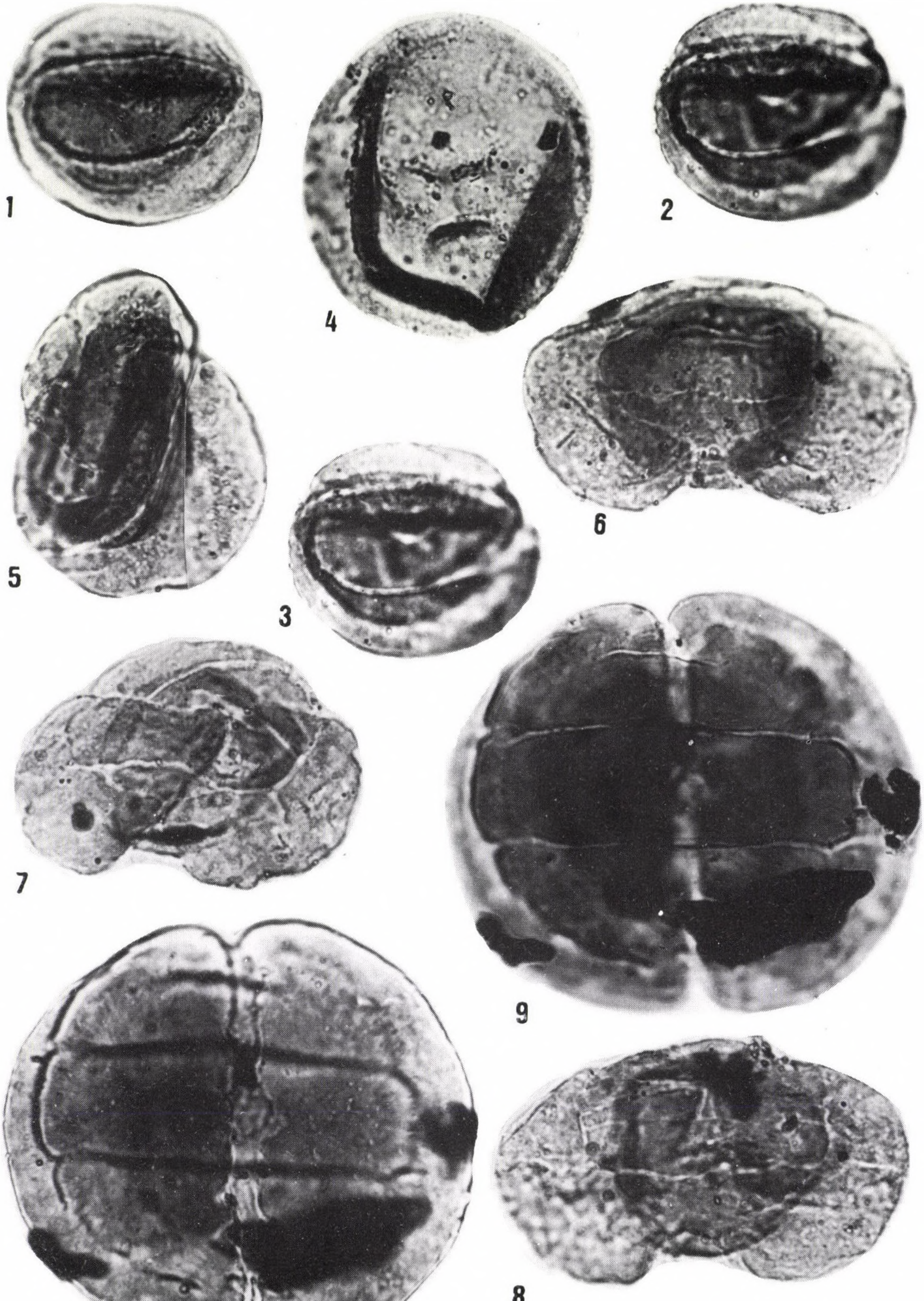

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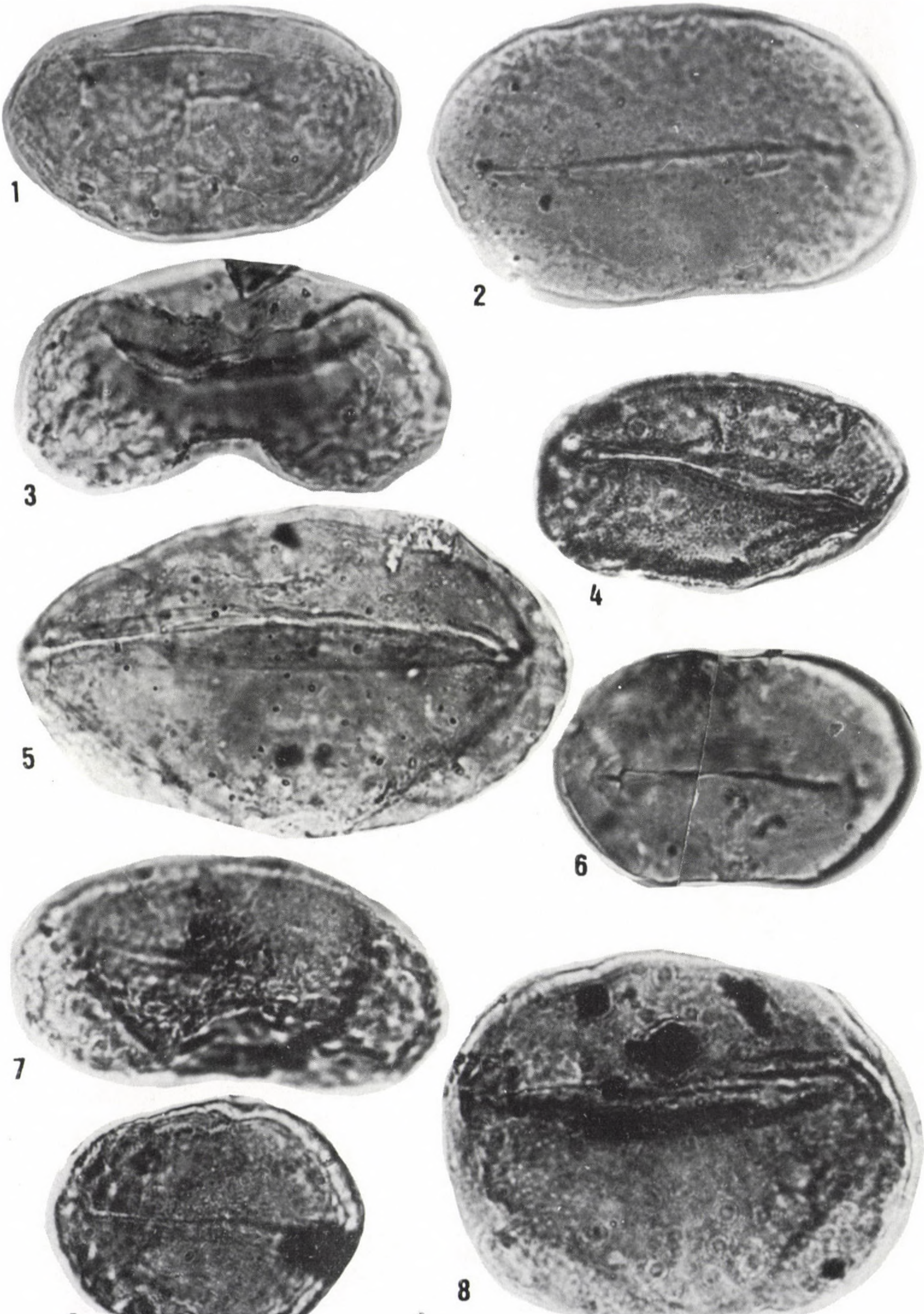

Plate XIII

Plate XIV


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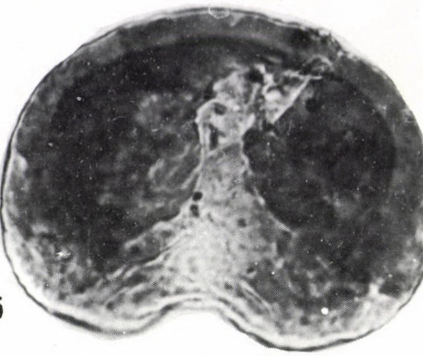
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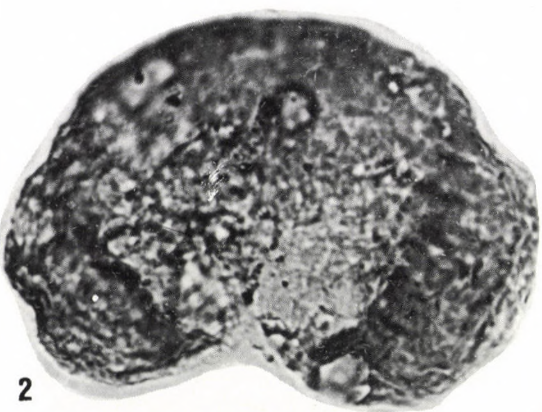
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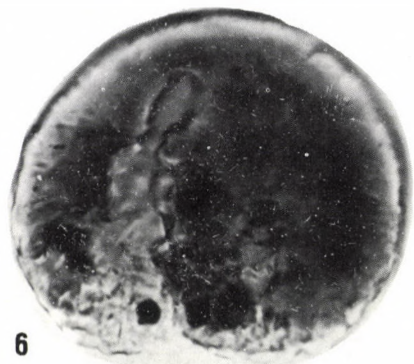
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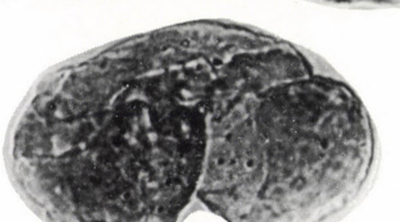
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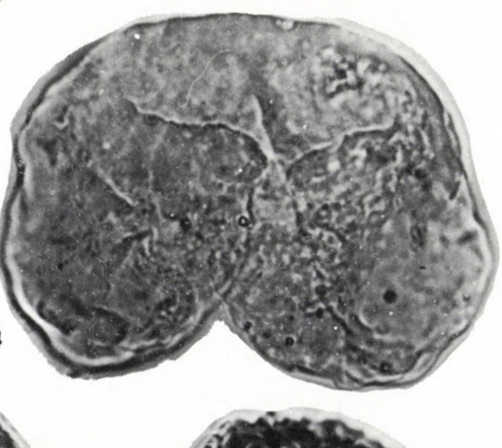
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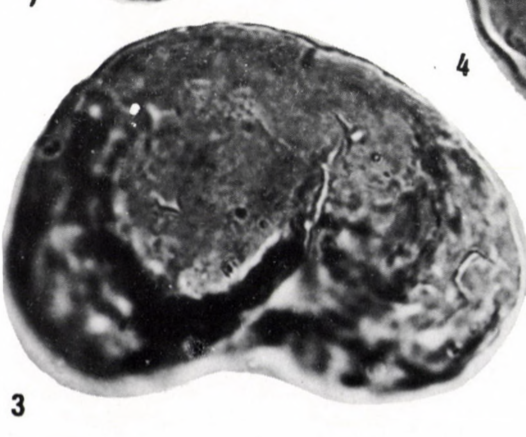
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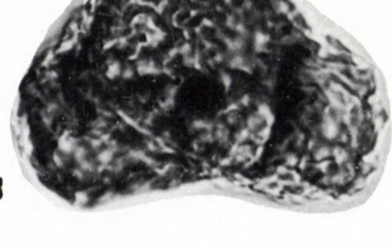
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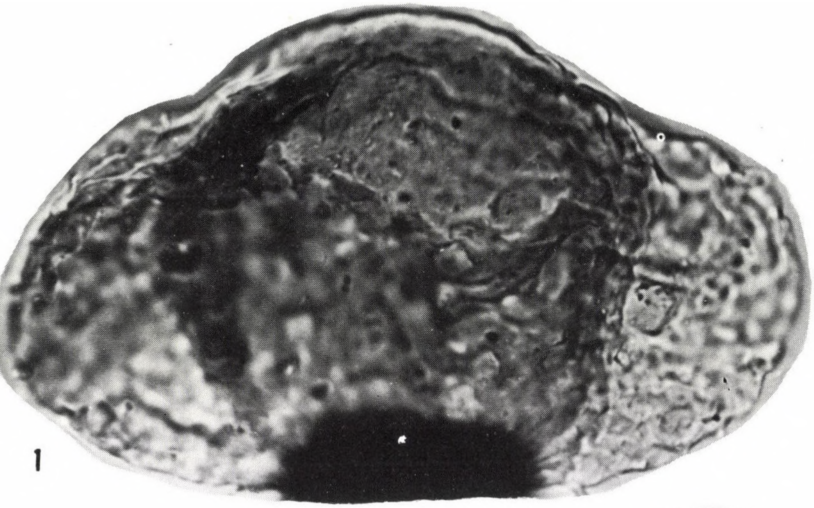

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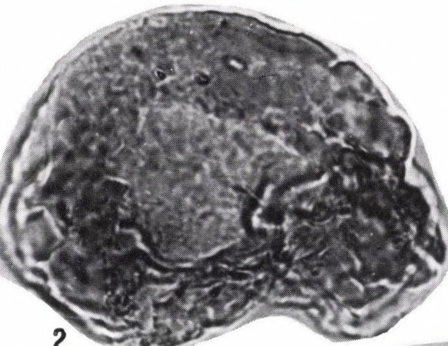

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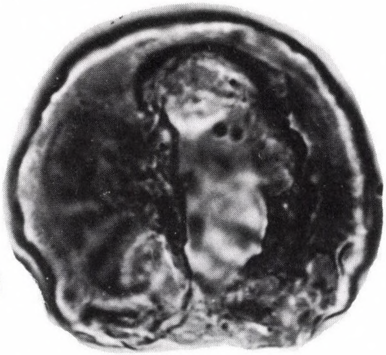

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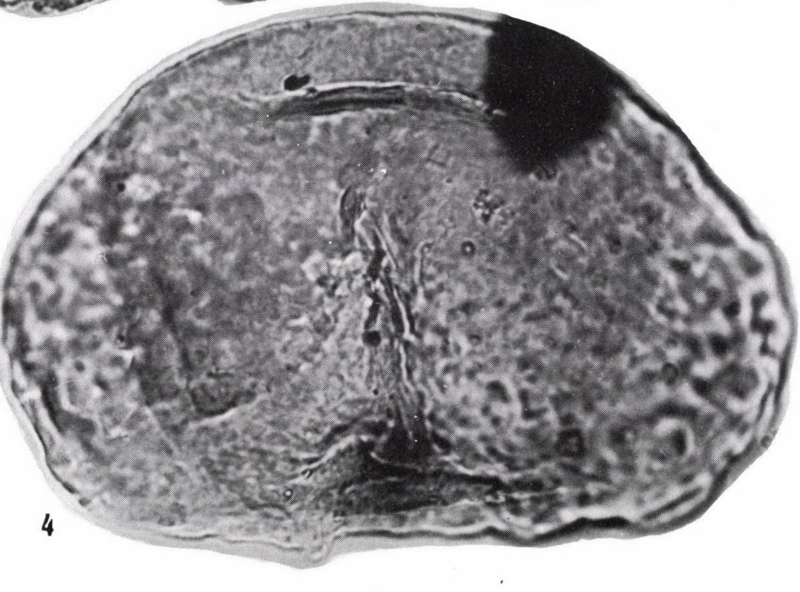

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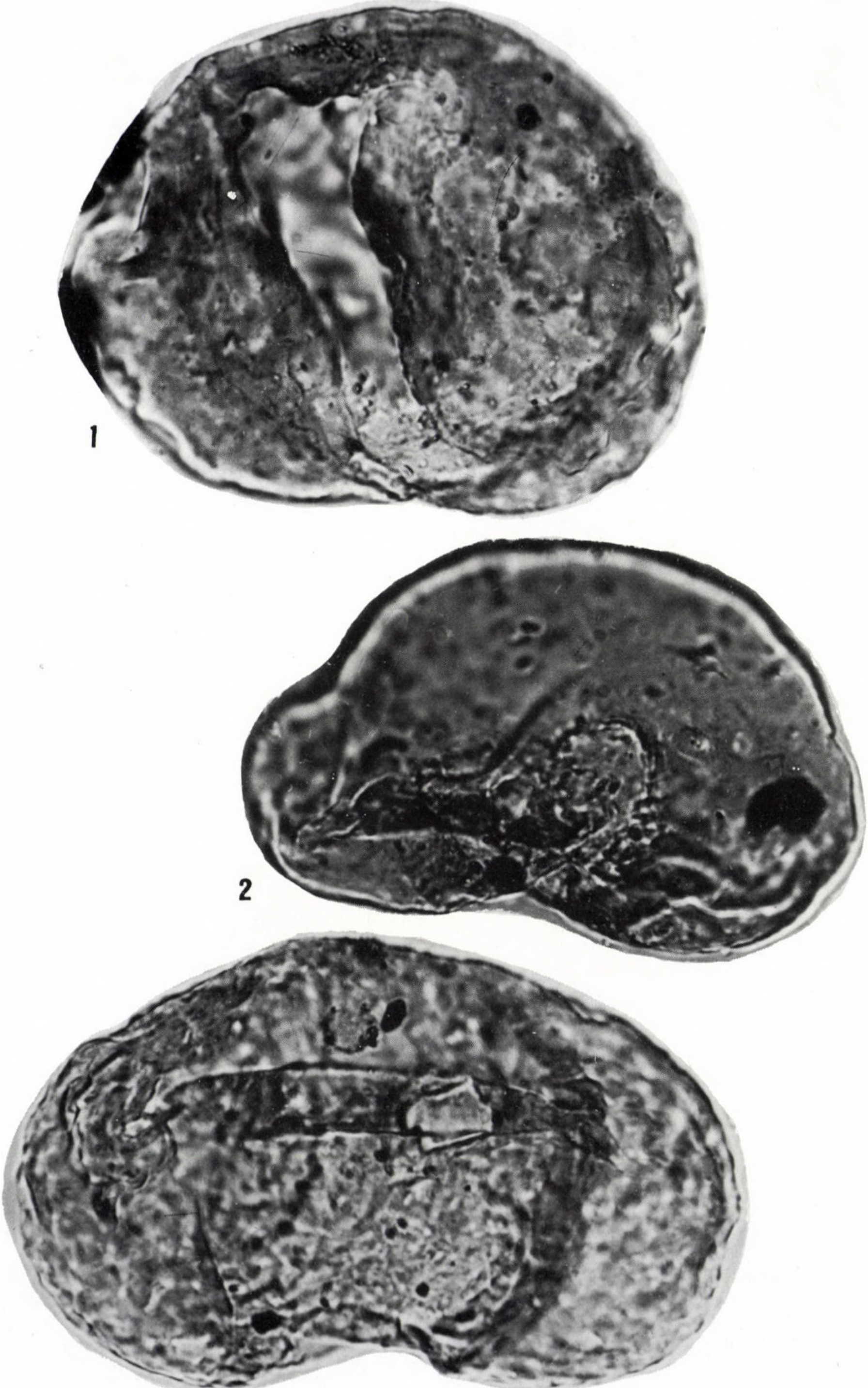

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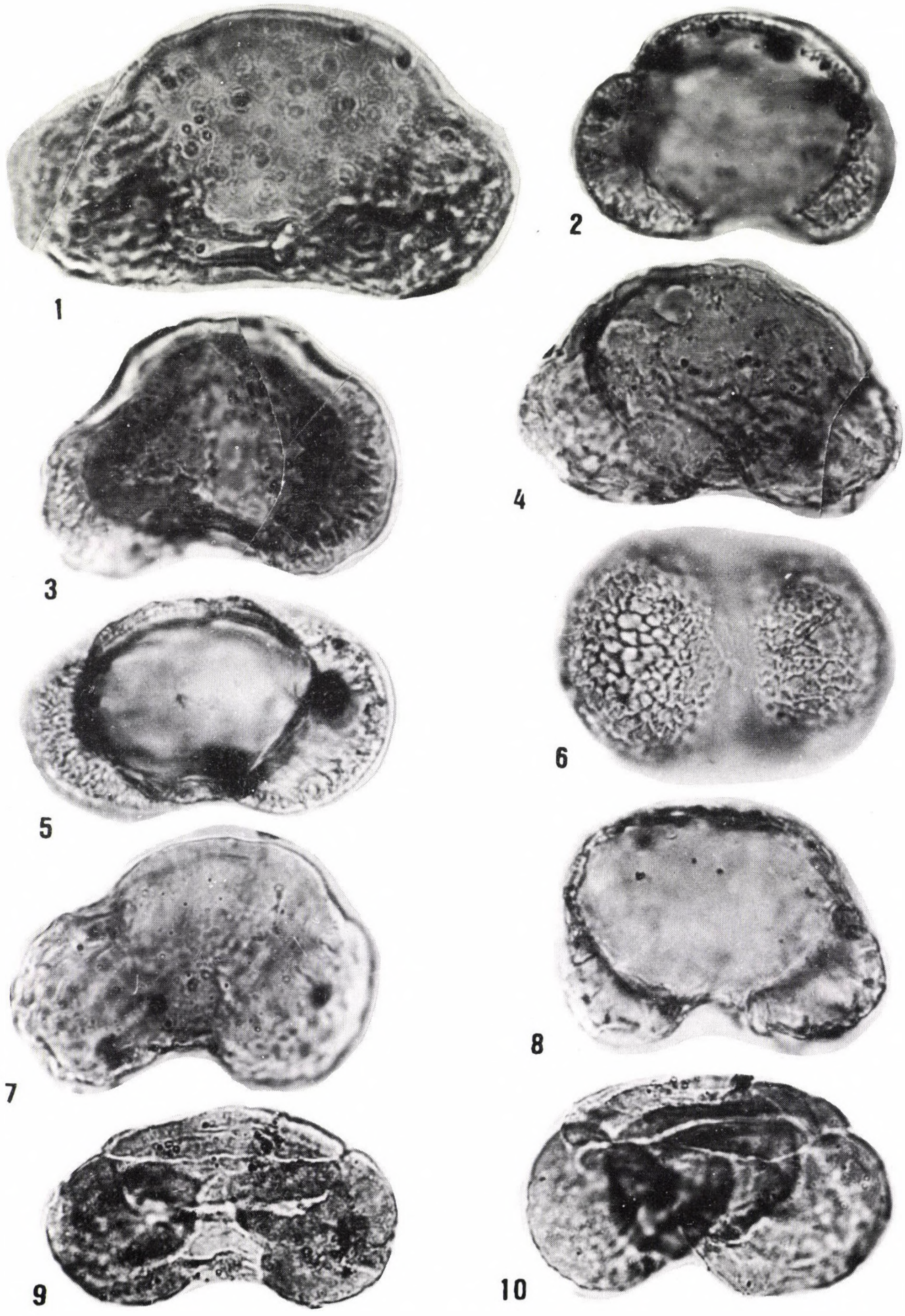

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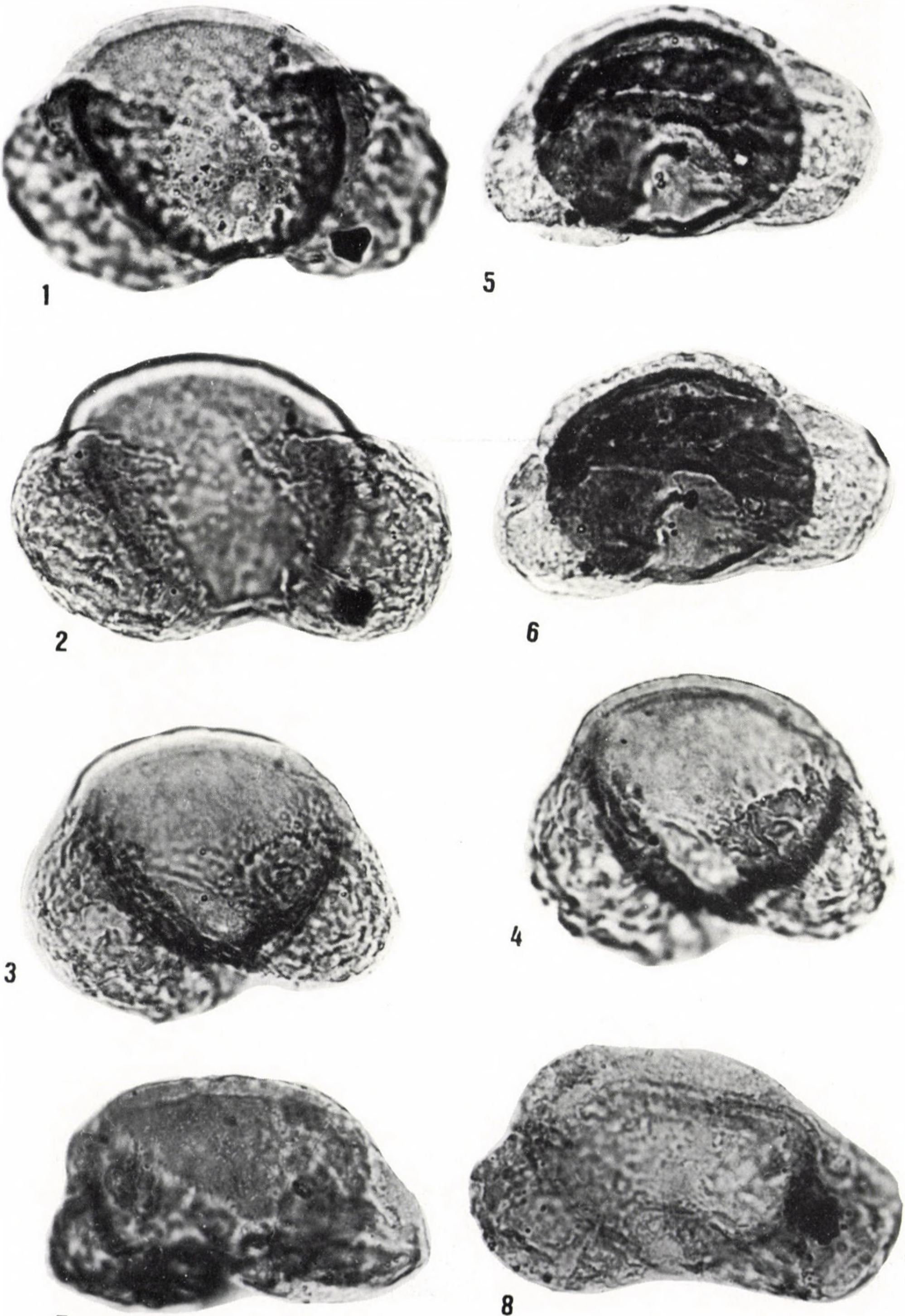

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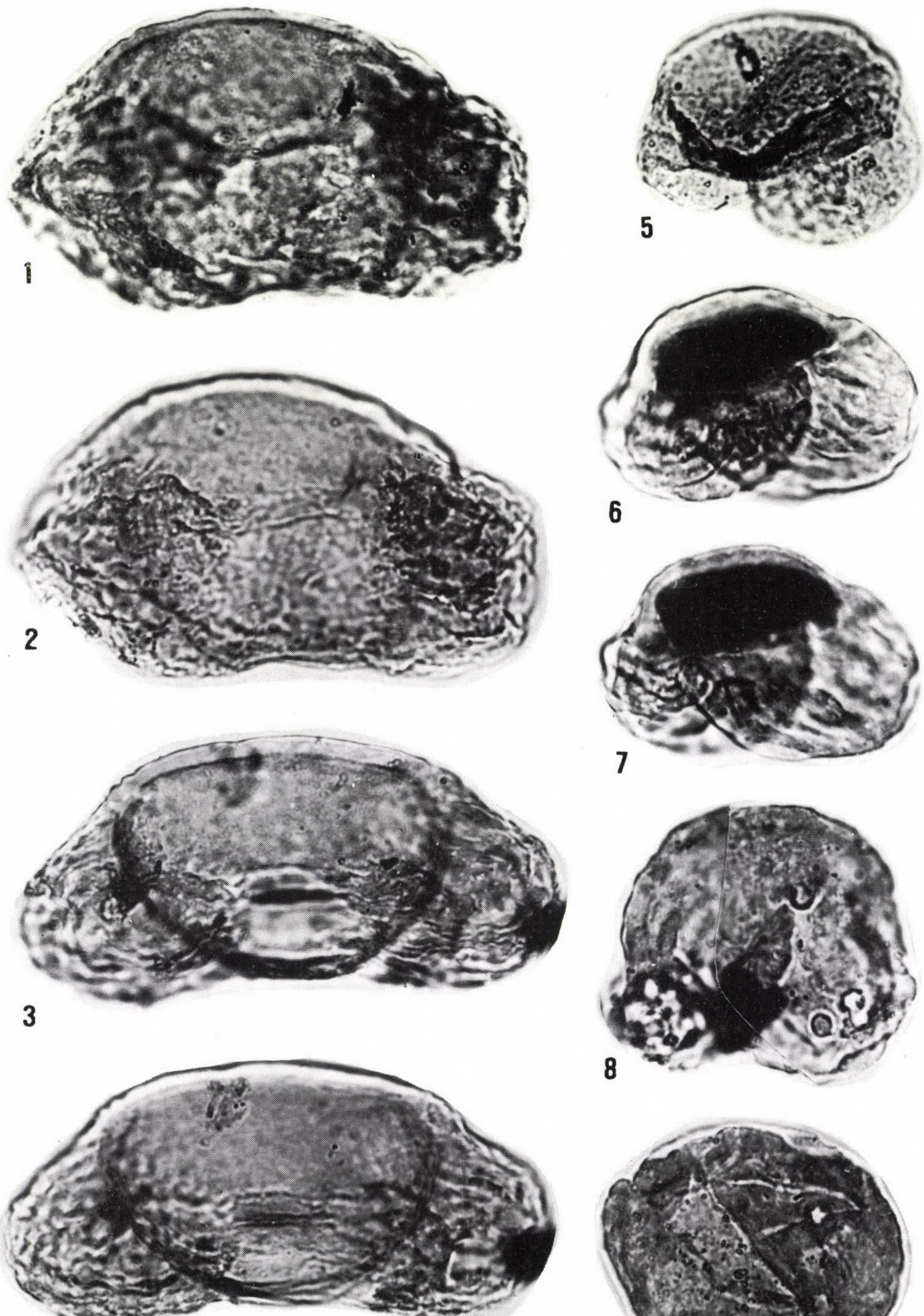

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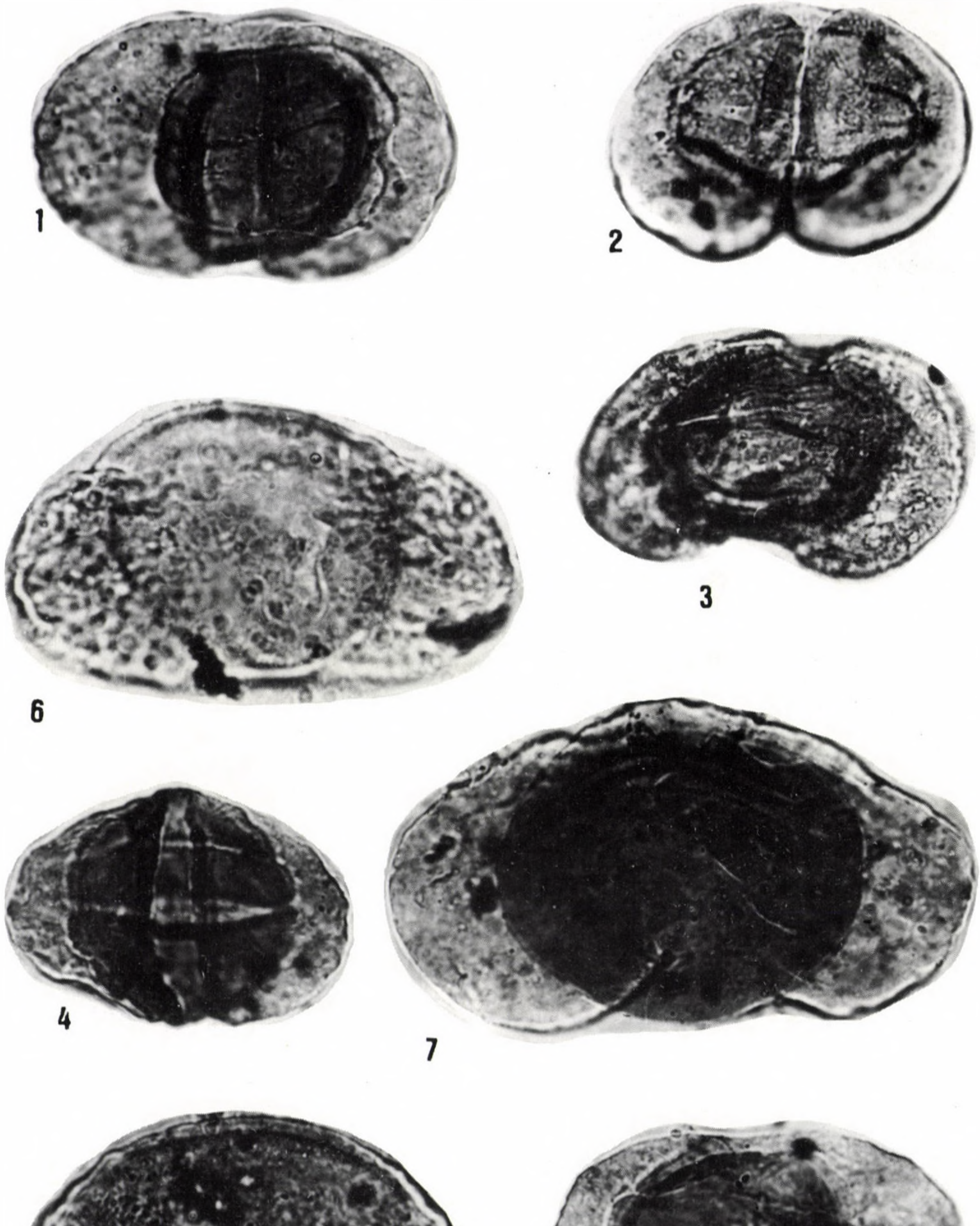

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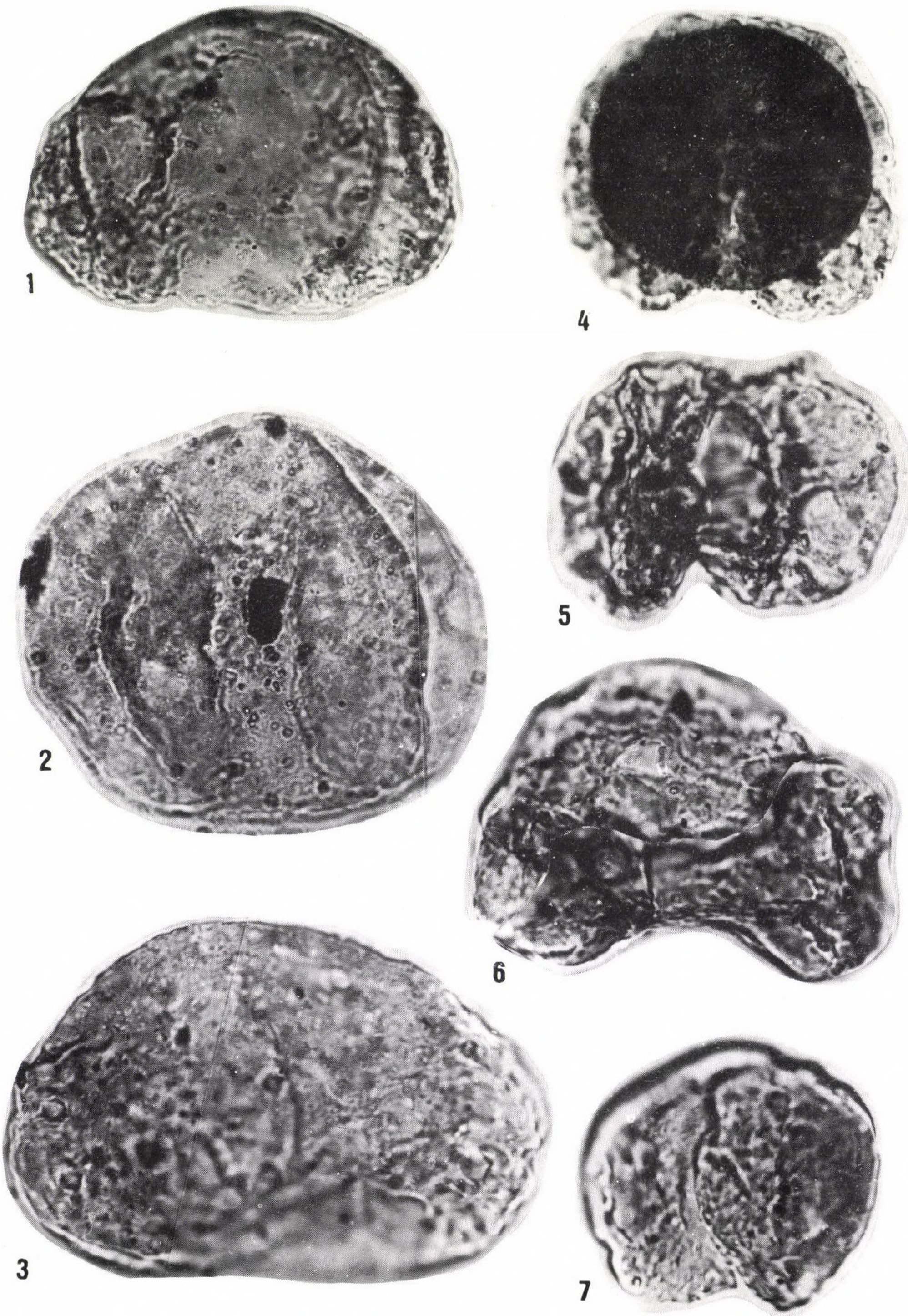

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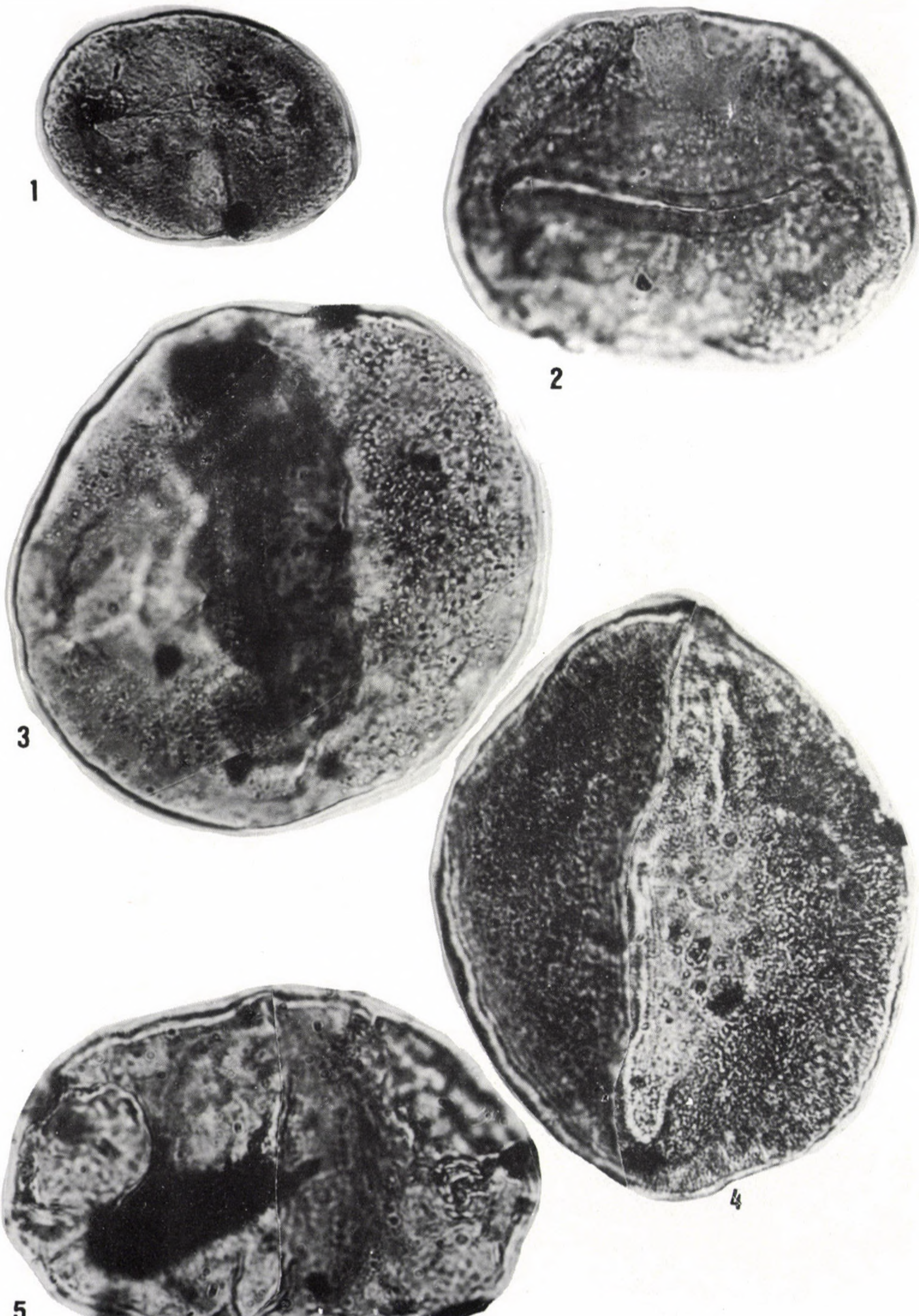

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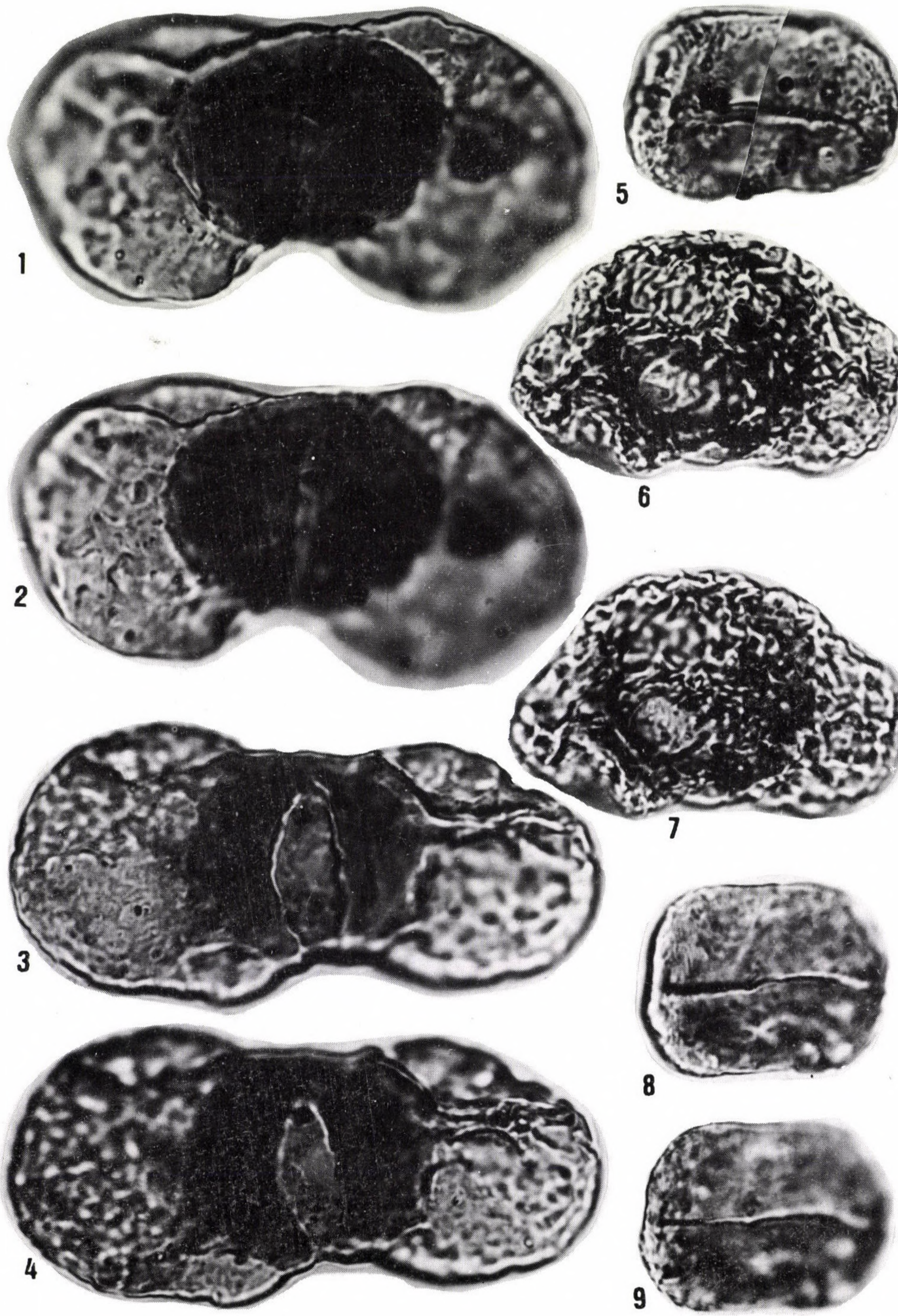

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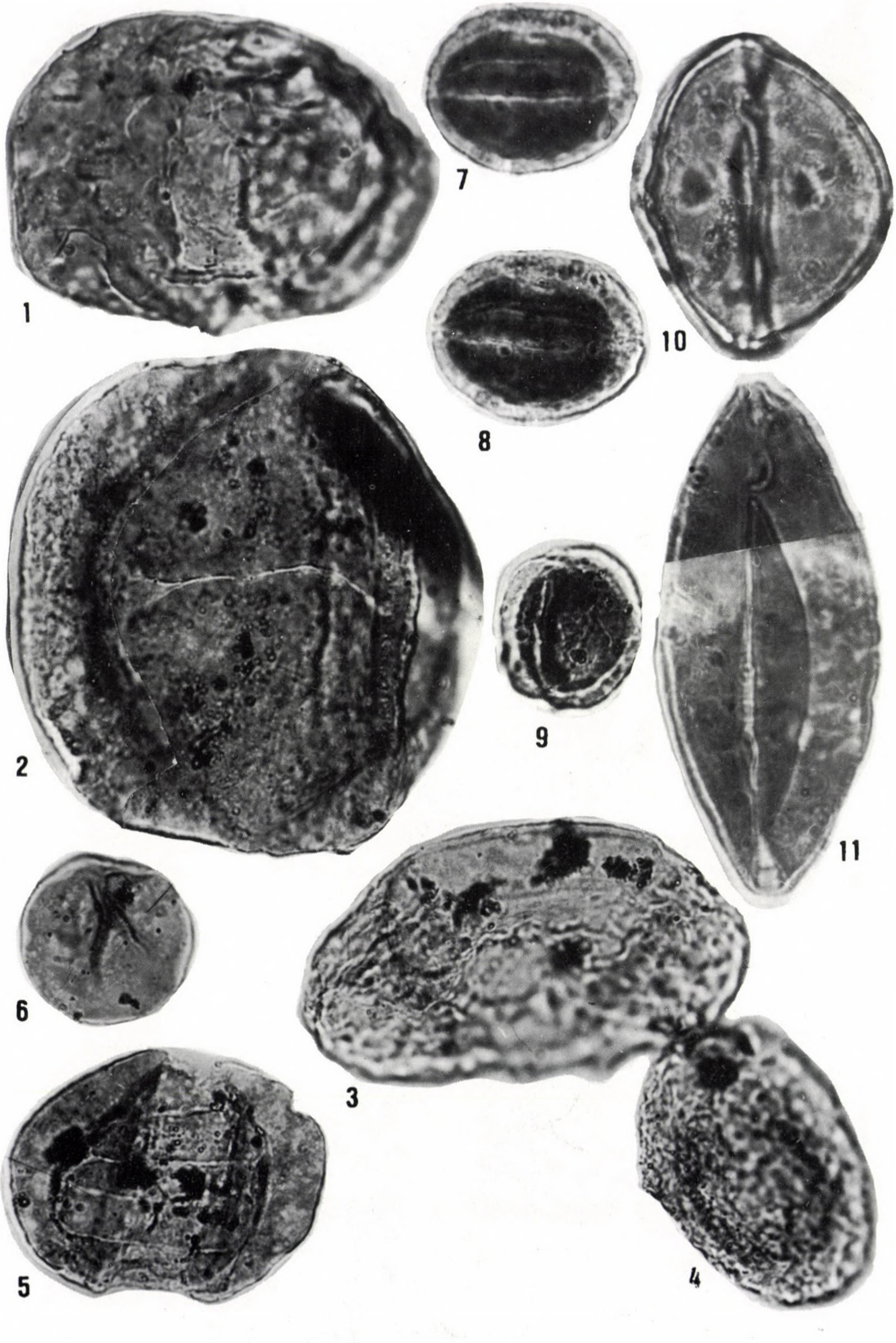

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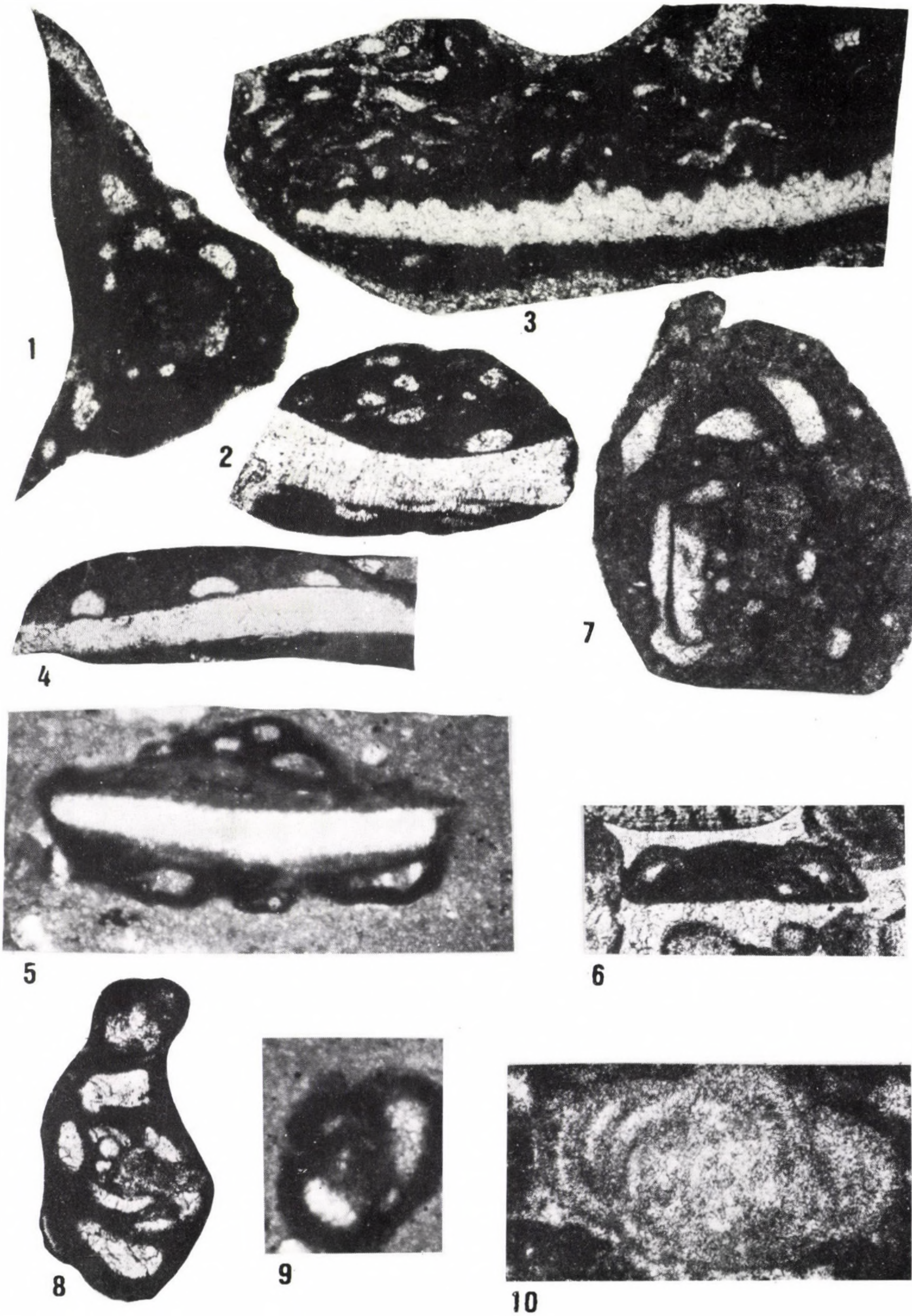

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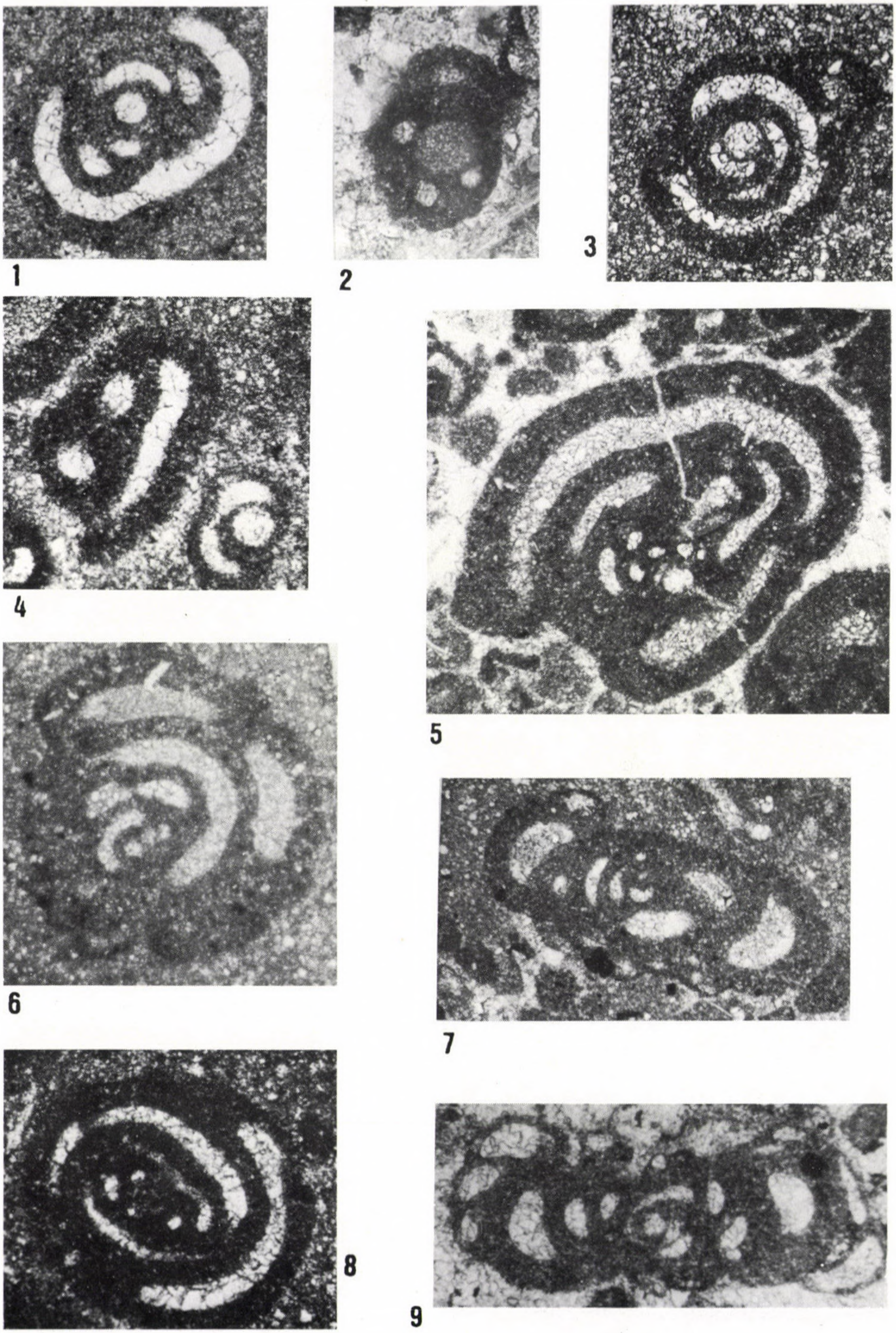

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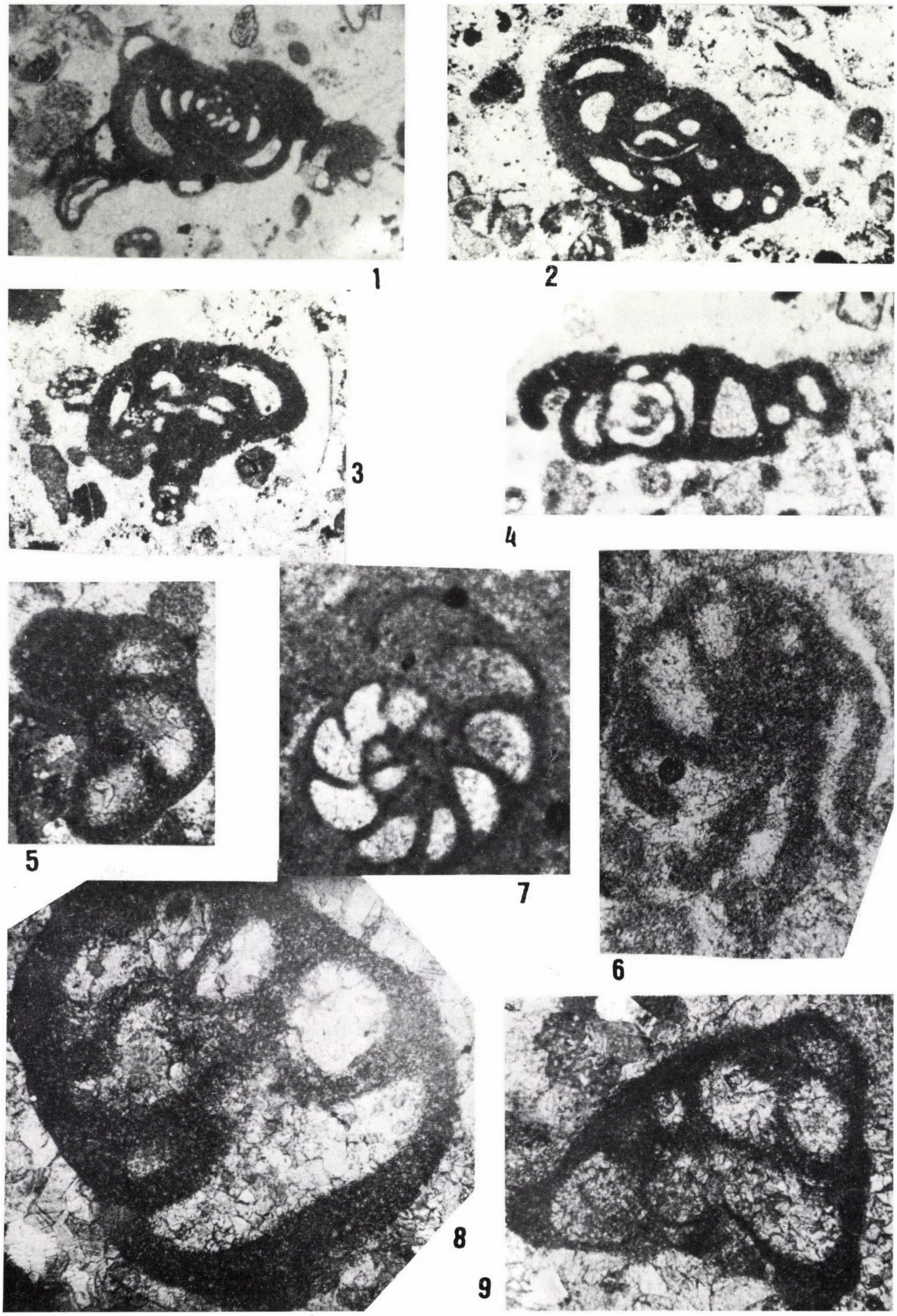

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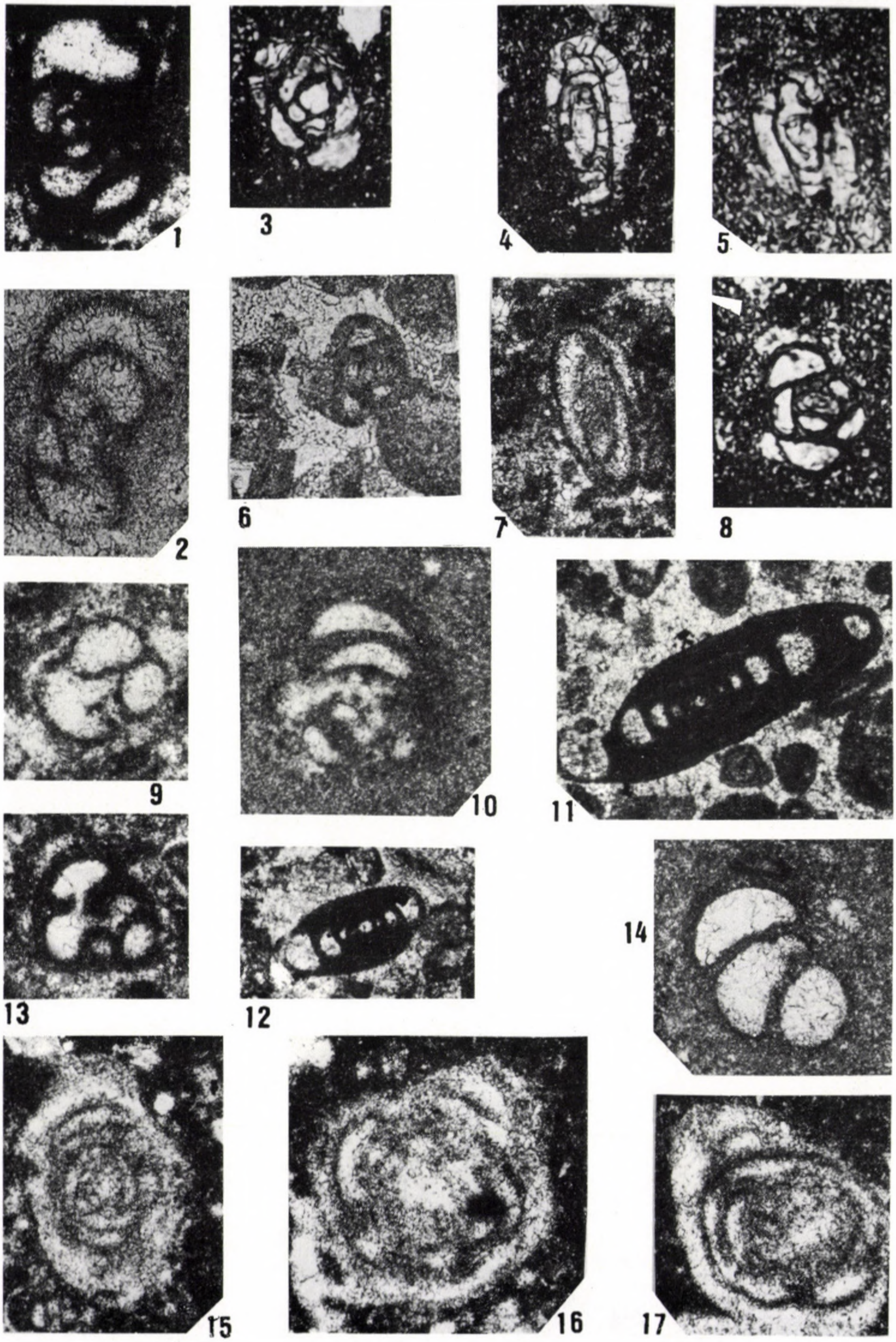

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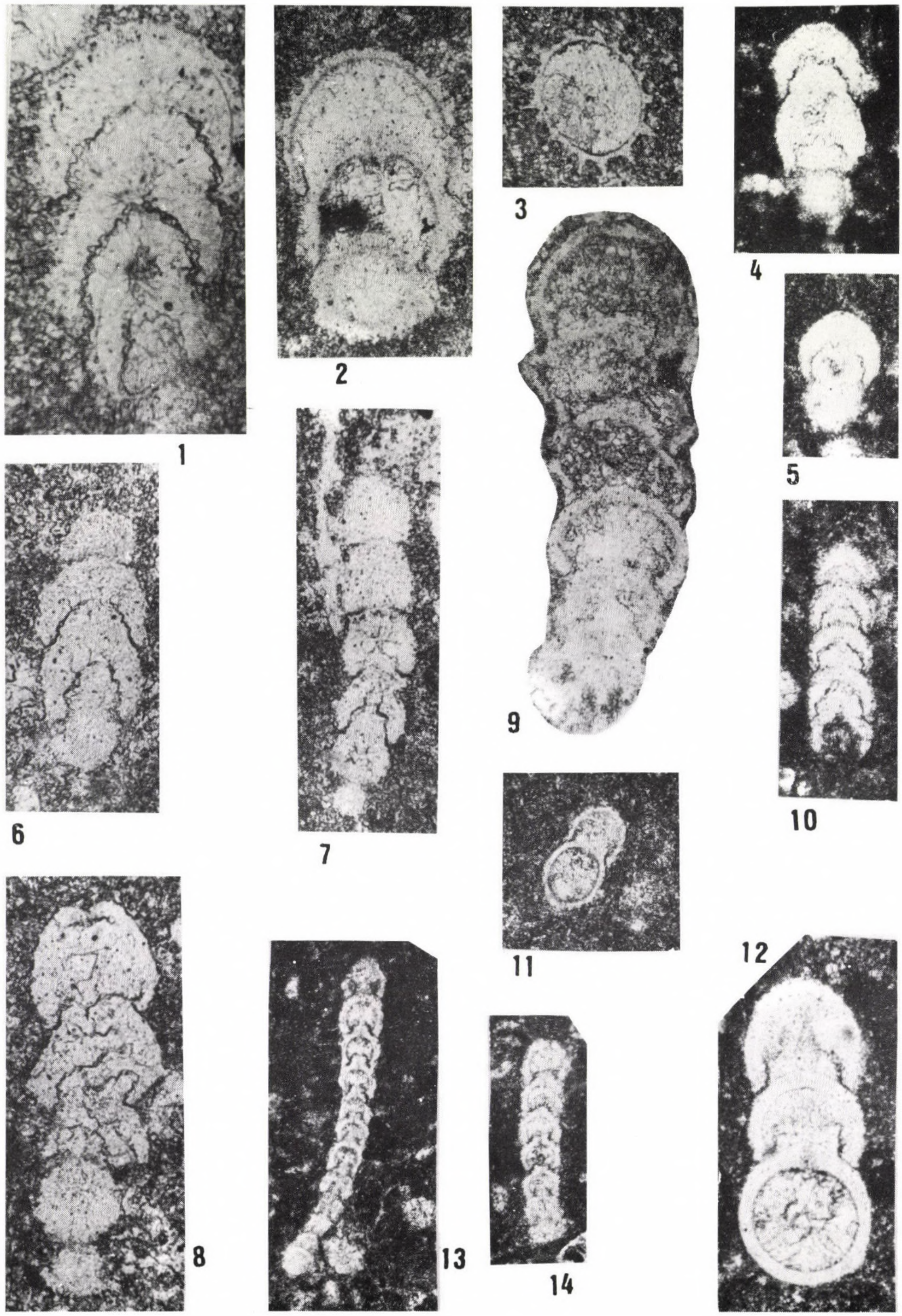

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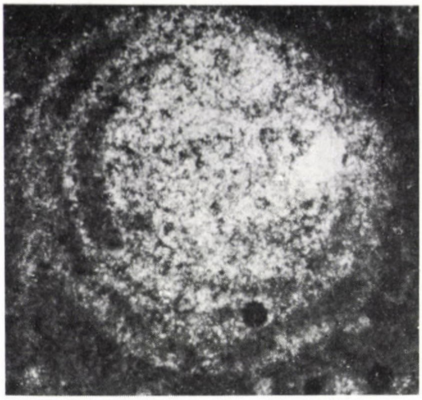

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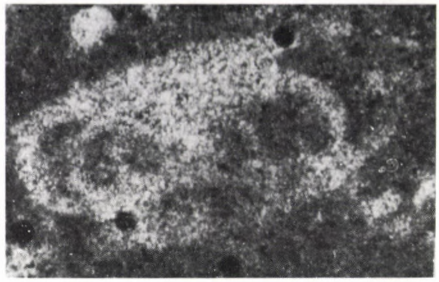

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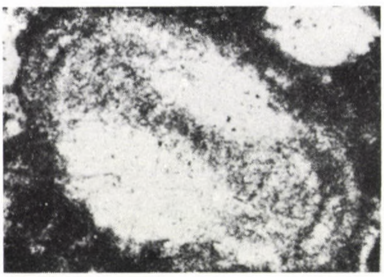

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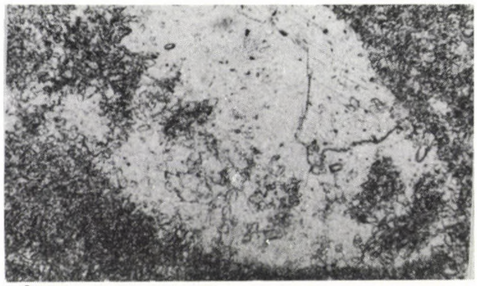

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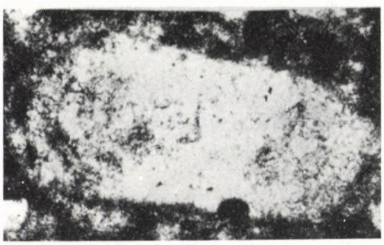

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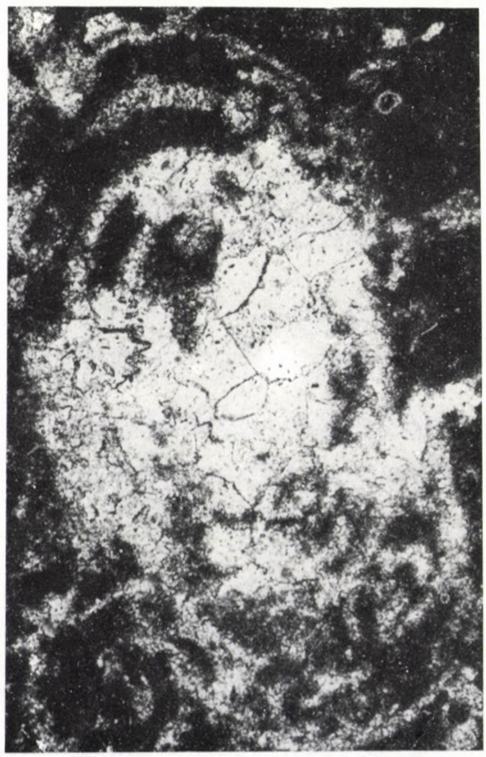

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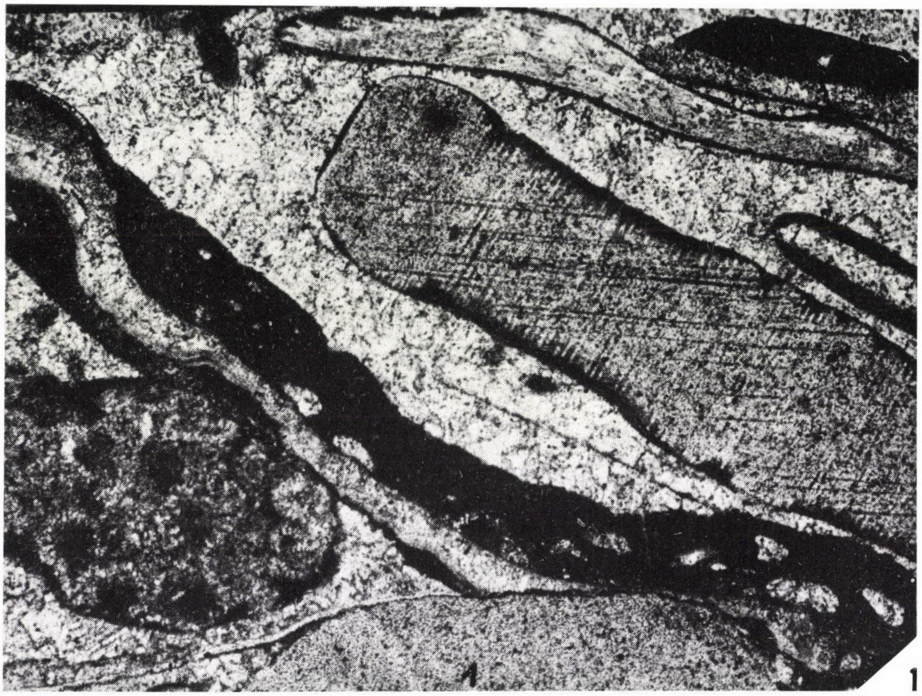

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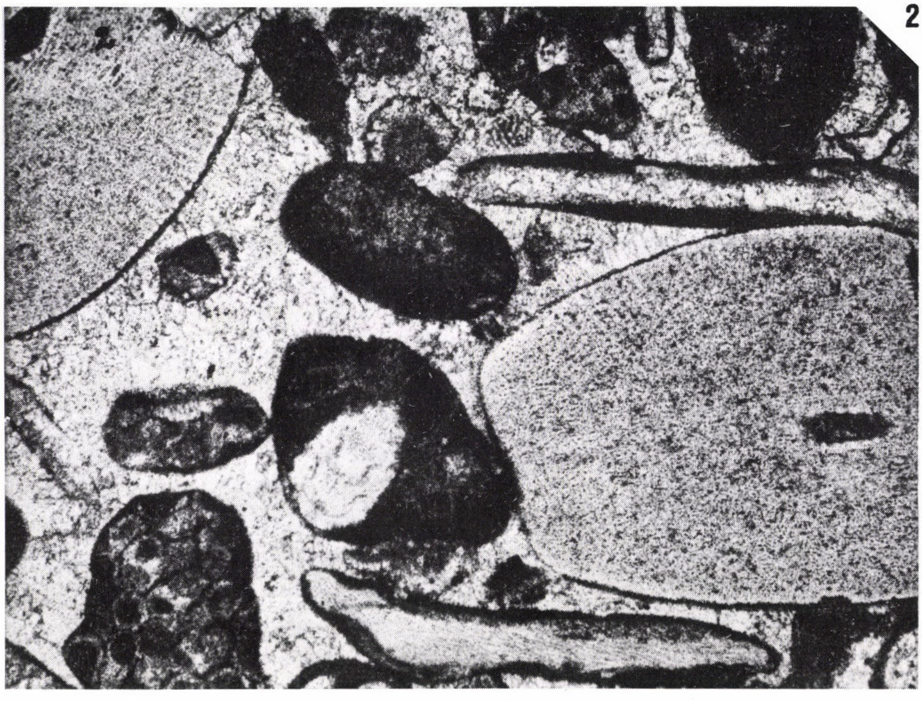

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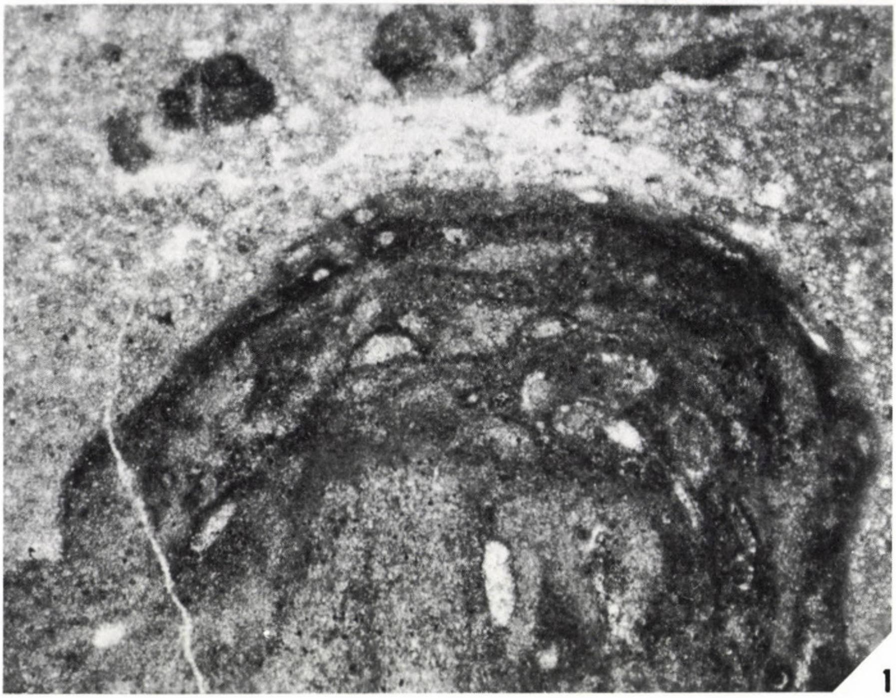

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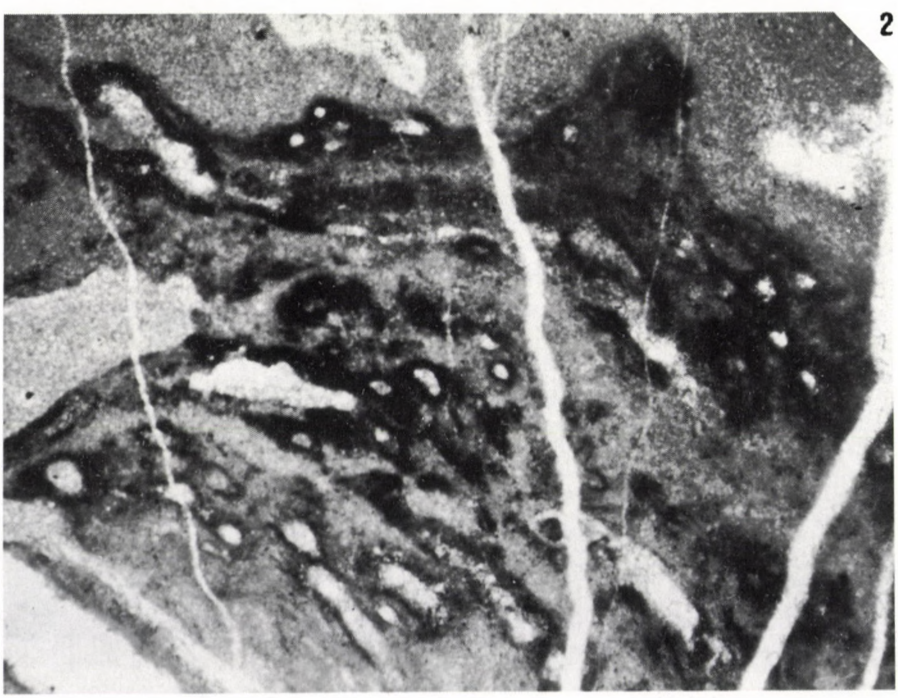

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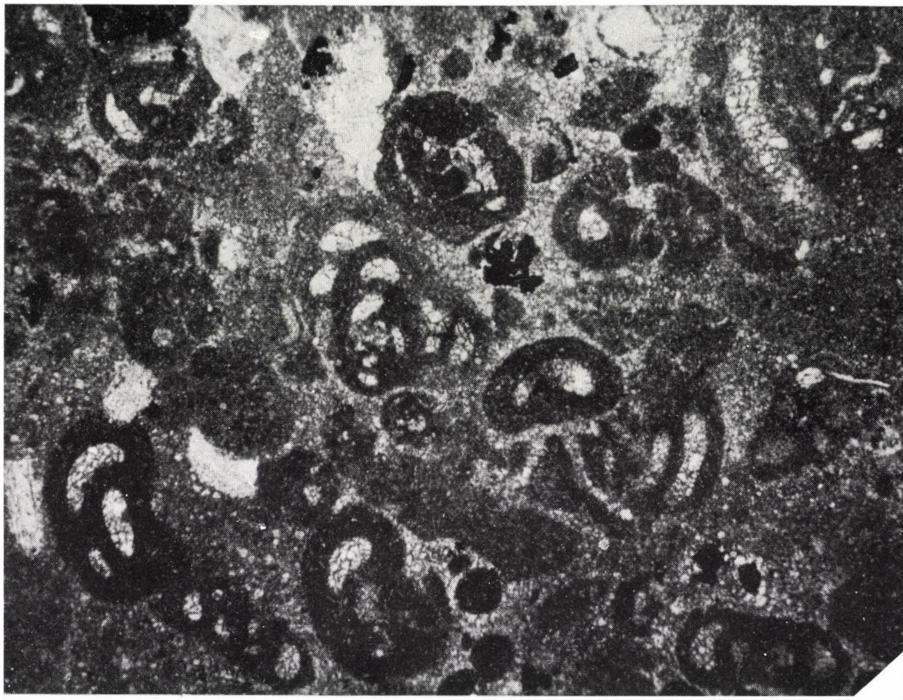

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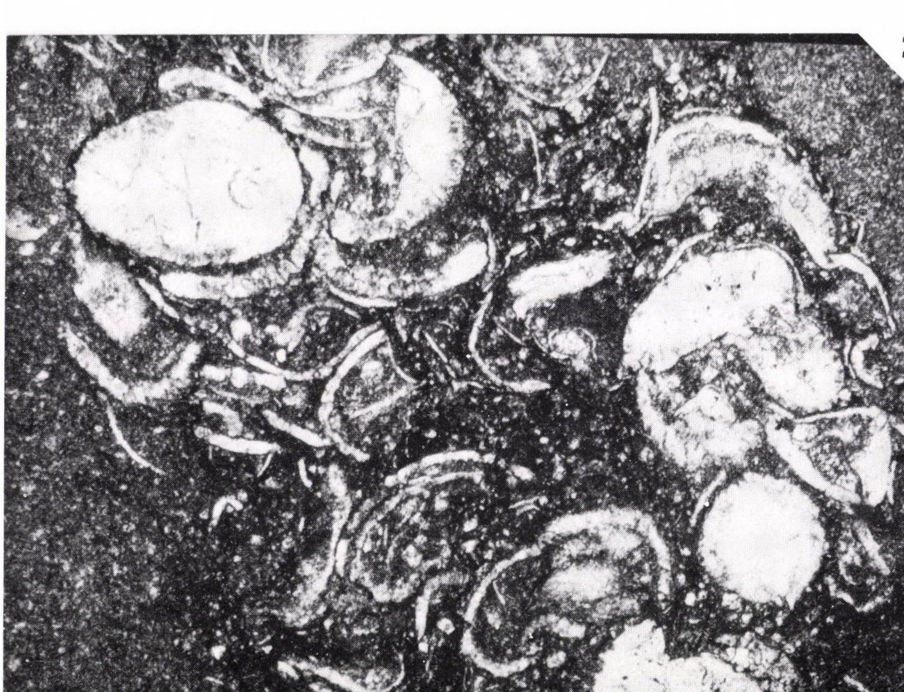

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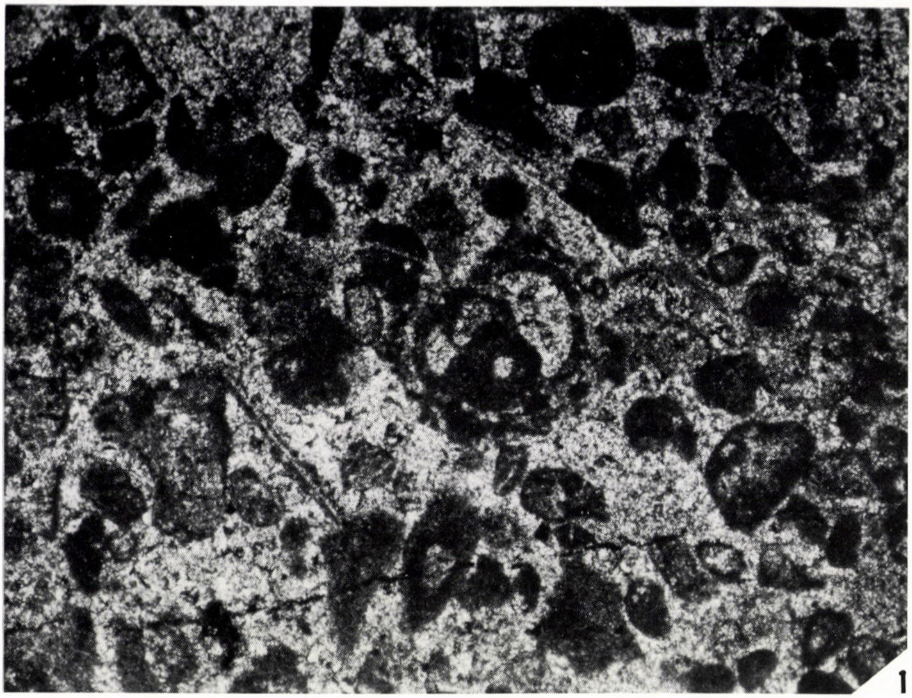

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New Middle Triassic conodonts of the *Gondolella szabói–G. trammeri* lineage from the West Carpathian Mts and from the Southern Alps

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New conodonts, *Gondolella praeszabói bystrickyi* n .ssp. and *Gondolella praeszabói praeszabói* n. ssp. have been recognized in the West Carpathian Mts of southeastern Slovakia and northeastern Hungary as well as in the Southern Alps of Northern Italy, which belong to the early stage of the evolutionary lineage leading to *Gondolella szabói* and *Gondolella trammeri*. They are characterized by extremely high carina and narrow platform, and represent transitional phylogenetic stages between *Gondolella bulgarica* and *Gondolella szabói* Kovács 1983. They occur in the uppermost Pelsonian (*Gondolella bulgarica* partial range-zone) and in part of the Illyrian (*Gondolella bifurcata bifurcata* partial range-zone and part of the *Gondolella constricta cornuta* partial range-zone). Representatives of this evolutionary lineage appear to have been characteristic especially of slope and swell environments, being frequent in crinoidal–brachiopodal packstones.

Key words: conodonts, Middle Triassic, micropaleontology, Hungary, Italy, Slovakia

Introduction

Thus far undescribed gondolelloids have been discovered in two localities located close to each other on the two sides of the Hungarian–Slovakian border (Figs 1–2), and in eight localities in Cadore and Carnia of the Southern Alps in Italy (Fig. 3). They can be classified as two subspecies of the same species, being bound by a wide field of morphological variations. These forms represent the earliest stage of the evolutionary lineage leading from *Gondolella bulgarica* (Budurov and Stefanov 1975) to *Gondolella szabói* Kovács 1983 and to *Gondolella trammeri* (Kozur, in Kozur and Mock 1972).

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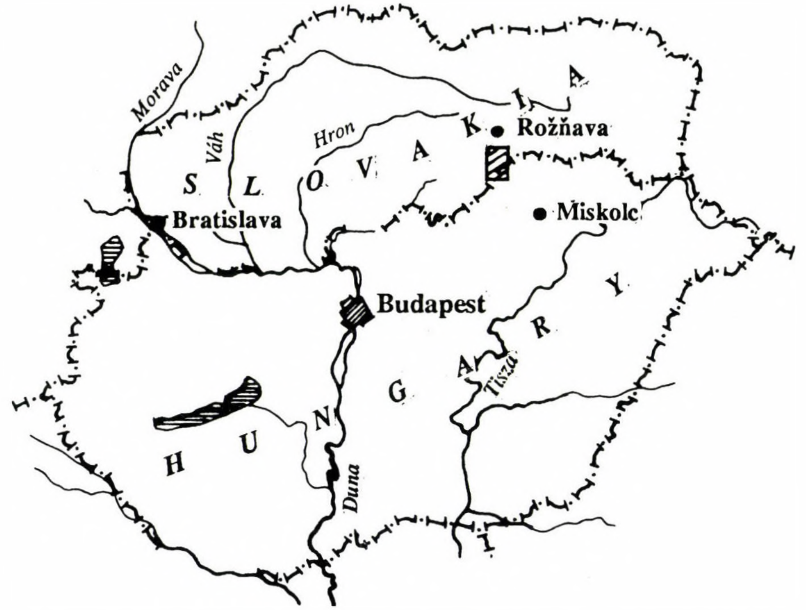

Fig. 1
Setting of the area (hatched) shown in Fig. 2, at the boundary of Hungary and Slovakia

The Hungarian locality is situated at a distance of 5700 m from the Aggtelek entrance of the Baradla Cave towards the Jósvafő exit (Fig. 2), where an about 0.5 m thick red micritic, brachiopodal limestone intercalation occurs within the Steinalm Limestone carbonate platform (Piros et al. 1989). The material available for investigation is a block fallen from the roof of the cave. It contains the following brachiopods (det. Detre, in Piros et al. 1989): *Coenothyris vulgaris* (Schloth.), *Koeveskallina koeveskaliensis* (Stur), *Mentzelia mentzeli* Dunk., *Tetractinella trigonella* (Schloth.).

The Slovakian locality lies on the Silická planina about 1.5 km NE of Silica, at Zákazané (Fig. 2). In the section a platform/basin transition can be seen, from the dasycladacean-bearing Steinalm Limestone through crinoidal limestone into gray, thick-bedded, then pink, nodular micritic limestone (Schreyeralm Limestone). (The lithology and biostratigraphy of the entire section will be published in a separate paper with Dr. J. Mello). The conodonts described here derive from sample Z–4, from the top part of the crinoidal limestone.

Both horizons yielded a fairly large number of conodonts (more than 200 specimens from both), consisting only of specimens of the two subspecies described below and a few ramiform elements of the Gondolella apparatus. In the Zákazané section the samples below (Z–1 to Z–3, all from the crinoidal limestone) yielded mainly *G. bifurcata hanbulogi, G. bifurcata bifurcata* and *G. bulgarica* (in order of frequency), but Gladigondolella elements and a few

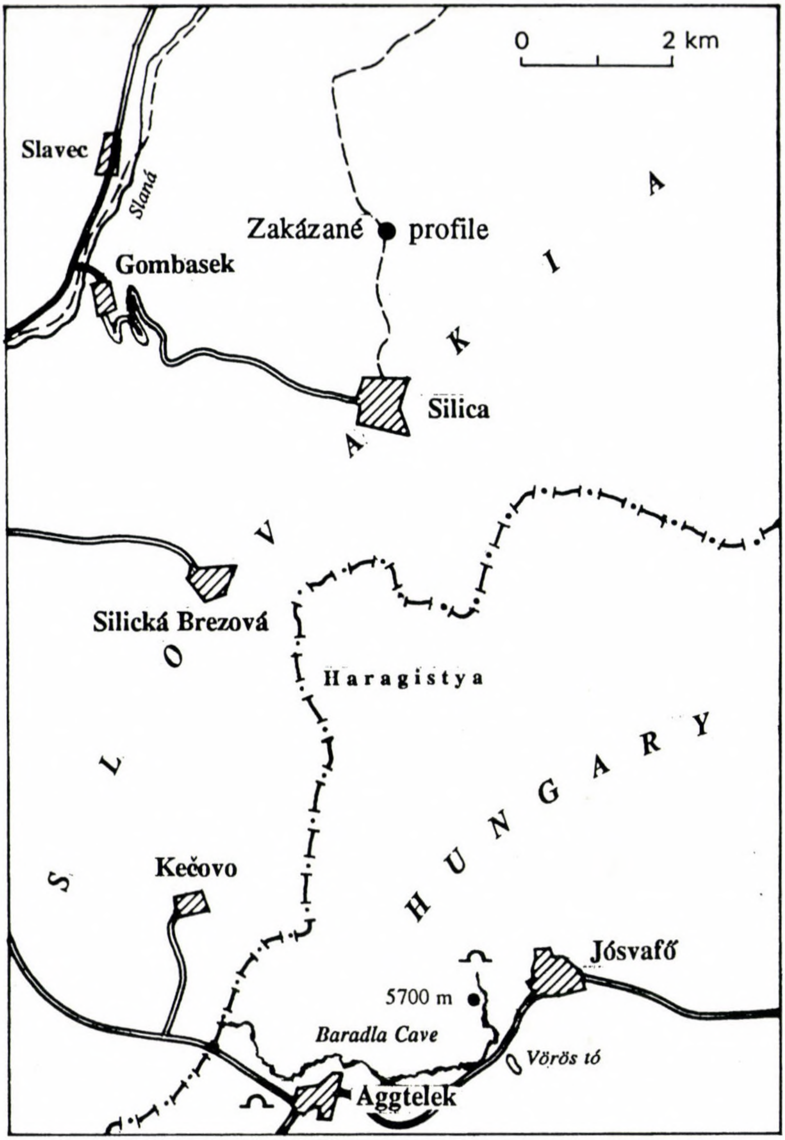

Fig. 2
Map of the Hungarian (Baradla Cave, at 5700 m) and the Slovakian (Zákazané, N of Silica) localites)

specimens of *Gondolella praeszabói bystrickyi* n.ssp (mostly transitional forms from *G. bulgarica)* were also found. The sample immediately above (Z–5/a, from the base of the micritic limestone) already belongs to the *G. constricta cornuta* partial range zone, but still yielded a few specimens of *G. praeszabói*

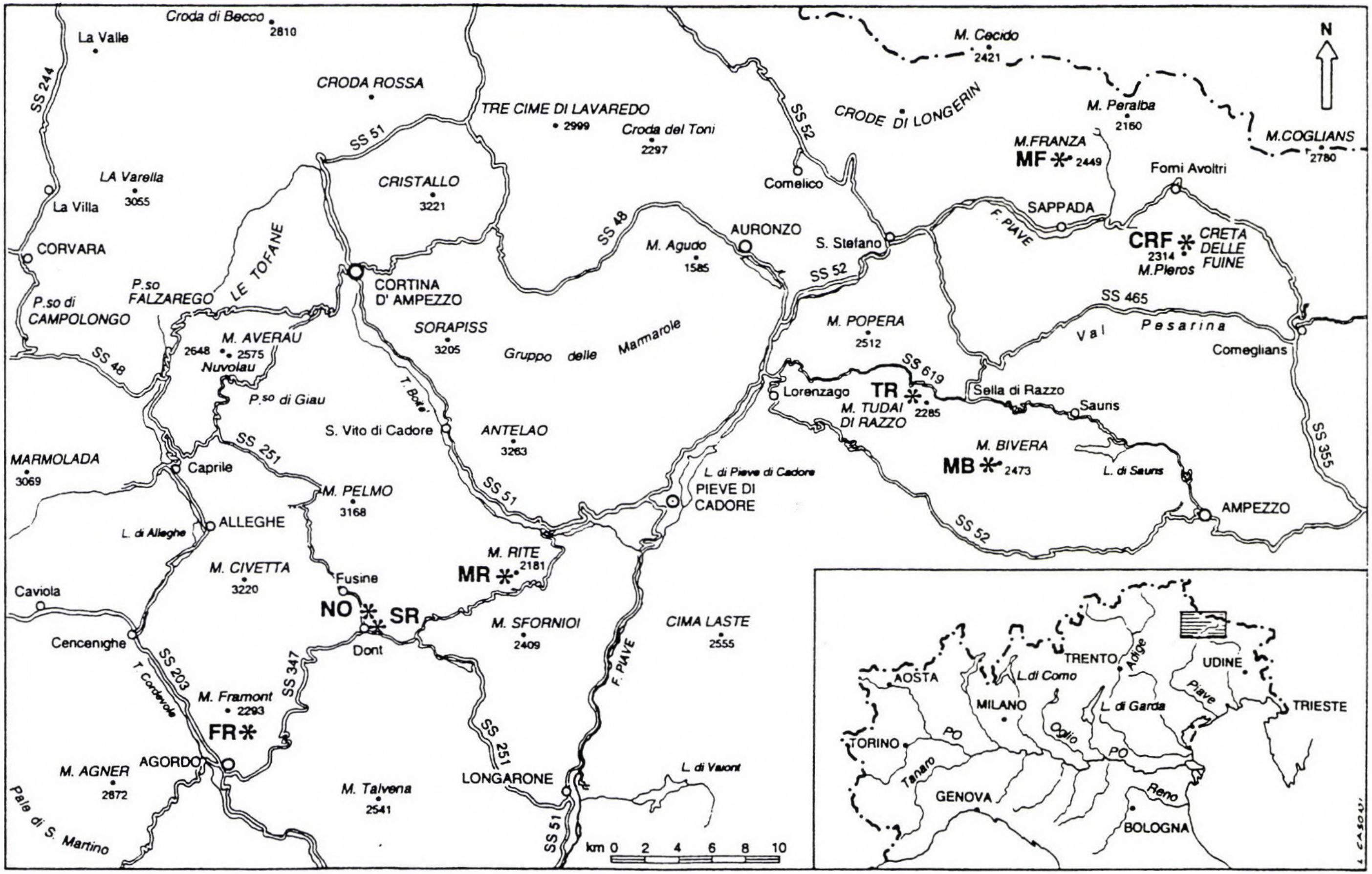

Fig. 3

Locality map of the sections from the Southern Alps in Italy. FR – Framont section; NO – Nosgieda section; SR – Sotto le Rive section; MR – Monte Rite section; TR – Tudai di Razzo section; MB – Monte Bivera section; MF – Monte Franza section; CRF – Creta delle Fuine section *praeszabói*. Higher up in the section the *G. szabói* lineage is represented only by rare (mostly juvenile) specimens of G. szabói. At the same time *Gladigondolella tethydis* (from Z–5/a), becomes quite characteristic, indicating full pelagic connections during deposition.

Forms representing transitional stages of the evolutionary lineage towards *G. szabói* and *G. trammeri* or related to this group, occur rarely also in Illyrian formations of the Szőlősardó and Bódva units of Aggtelek–Rudabánya Mts, NE Hungary (Kovács unpubl.).

The eight Italian localities are situated in the Southern Alps from Cadore to Carnia. They are, from West to East, the Framont creek (1) to the north of Agordo, two outcrops, named Nosgieda (2) and Sotto le Rive (3), near Dont, alongside state road n^{0} 251. The Rite Mt. (4) southwest of Pieve di Cadore, Tudai di Razzo (5) and Bivera Mt. 6) southwest, Franza Mt. (7) to the north and Creta delle Fuine (8) southeast of Sappada (Fig. 3). Some stratigraphic columns of the sections involved were already published, totally or in part (Pisa et al. 1980; Farabegoli and Levanti 1982; Farabegoli et al. 1984). In Farabegoli et al. (1984) only the conodont associations of the levels referred to the M. Bivera Formation were described. The Italian co-author of the present paper (together with Prof. E. Farabegoli) intends to publish the conodont fauna referred to the other lithostratigraphic units and all data from the unpublished Rio Framont section. In this last-named section about 17 m of Dont Formation, followed by 10 m of M. Bivera Formation and 7 m of Ambata Formation, were recognized.

G. praeszabói was found in 49 samples of the eight localities, mainly in the M. Rite and Nosgieda sections.

The predominant finding of the new species was in the Dont and M. Bivera Formations; nevertheless, some layers from the bottom of the Ambata Formation (Rio Framont and M. Rite) and of its heteropic Contrin Formation (Creta delle Fuine) yielded *G. praeszabói*.

The Dont, M. Bivera and Ambata Formations are lithostratigraphic units belonging to Braies Group. This group includes all the Upper Anisian terrigenous and terrigenous-carbonate formations of the Cadore and Carnia in the Southern Alps.

The Dont Fm is composed of gray and dark silty biomicrites, thin-bedded (5–10 cm), parallel to nodular, alternating with marls or gray-green silty to clayey marls. The unit is rich in radiolarians, foraminifers, ostracods, sponge spicules, bivalves, ammonites and conodonts.

The M. Bivera Fm. is made up of several lithofacies. The most widespread normal facies is composed of 1–10 cm thick, lateral, continuous, and discontinuously nodular limestones and marly limestones, alternating with silty-clayey marls. This normal facies was sampled for conodonts. The dominant colour is reddish to violet and subordinately green-gray. Thin layers (1–5 cm) of gray and greenish tuffites are interbedded locally. The carbonate component is characterized by bioturbated mudstones and bioturbated fossiliferous mudstones, and wackestones rich in radiolarians, foraminifers, ostracods, bivalves, gastropod fragments, crinoid ossicles and pellets. The unit also yields ammonites and conodonts.

The Ambata Fm is characterized by dark, parallel or nodular, thin-bedded, cherty limestones and dolostones alternating with silty marls. The biomicritic microfacies is rich in radiolarians, sponge spicules, bivalves and conodonts.

The Contrin Fm is represented by prevailing massive gray limestones and dolomicritic limestones. In the Creta gelle Fuine section the top five meters show a strong pelagic influence. The reddish-gray pelagic biomicrites yield radiolarians, crinoid ossicles, spicules of siliceous sponges, bivalves and conodonts.

More than 800 specimens of G. *praeszabói* of both subspecies were found in the Italian localities. Previously these forms were referred to G. *bulgarica* (*cf.* Pisa et al. 1980; Farabegoli et al. 1984) and to G. *trammeri* (cf. Farabegoli and Levanti 1982). The two subspecies have different vertical distribution, G. *praeszabói bystrickyi* being more limited.

In the lower layers both subspecies are present in association with G. *bifurcata bifurcata*, G. *bifurcata hanbulogi* and G. *bulgarica* (in order of frequency) (G. *bulgarica* partial range-zone). G. *praeszabói bystrickyi* is numerically prevailing over G. *praeszabói praeszabói*.

In the higher levels G. *bulgarica* disappears and the conodont fauna is represented by G. *p. bystrickyi* G. *p. praeszabói*, G. *b. bifurcata*, G. *b. hanbulogi*, G. *balkanica*, G. *excelsa* and Gladigondolella elements (G. *bifurcata bifurcata* partial range-zone). In these beds G. *p. praeszabói* becomes more abundant than the other subspecies.

Higher up, at about the first appearance of G. *constricta cornuta*, in the same or in the sample immediately following, G. *p. bistrickyi* disappears while G. *p. praeszabói* remains associated with G. *constricta cornuta*, G. *b. bifurcata*, G. *liebermani*, G. *excelsa*, and Gladigondolella elements (G. *constricta cornuta* partial range zone).

In the stratigraphically lower parts of some Italian sections there are transitional forms from G. *bulgarica* to G. *p. bystrickyi*, and in the higher ones transitional forms from G. *p. bystrickyi* to G. *p. praeszabói*, and from the latter to G. *szabói* and G. *trammeri*.

These findings bear witness to the early history (development from G. *bulgarica* during the late Pelsonian radiation) of the evolutionary lineage, the final events of which can be seen in the reitzi-zone s.s. of the Balaton Highland (appearance of G. *alpina s.s.* and G. *trammeri*), having a major importance in defining the Anisian/Ladinian boundary.

The figured specimens from the Hungarian locality are reposited at the Museum of the Hungarian Geological Survey (catalogue numbers: T–6468 to T–6479), from the Slovakian locality at the Slovak National Museum (catalogue numbers: SNM/Z 21 834 to 21 848) and from the Italian localities at the Department of Earth Sciences University of Bologna (catalogue numbers: IC 1561 to 1578).

Taxonomic part

Genus **Gondolella** Stauffer and Plummer 1932

Gondolella praeszabói n.sp.

Diagnosis: Representatives of the new species (both juvenile and adult forms) are characterized by very high carina and a narrow to very narrow platform. The carina is nearly of the same height in the anterior two-thirds and is composed of highly fused, densely spaced denticles, with prominent striae between them almost to their base. The number of denticles is usually 13–15. The narrow platform with nearly parallel margins tends to be reduced in the anterior third. The keel is strong, encompassing a posteriorly located small and narrow pit.

Relations: Gondolella praeszabói n. sp. represents a transitional evolutionary stage between *Gondolella bulgarica* (Budurov and Stefanov 1975; for some revision see Kovács and Papšová 1986), of Aegean to Pelsonian age and *Gondolella szabói* Kovács (1983), of Illyrian to Early Fassanian (=*Paraceratites trinodosus* and *Reitziites reitzi* s.s. zones) age. It is distinguished from the former primarily by its very narrow to narrow platform with subparallel margins and the consistently high carina (even in the posterior part and also in juvenile forms). The platform of the latter is much more compressed and upturned, and the unit is arched in lateral view.

G. praeszabói n. sp. is divided into two subspecies bound by a transitional series, making a definite separation between them difficult.

G. preszabói bystrickyi n. ssp. is still closely related to *G. bulgarica*, whereas *G. praeszabói praeszabói* n. ssp. represents a more evolved evolutionary stage in direction of *Gondolella szabói*. On most of the figured specimens of both subspecies, a duplication of the pit can be observed in lower view, e.g. two smaller pits can be seen in the posterior part of the basal groove, within the larger basal pit proper encircled by the loop. A similar feature can be seen on Ladinian to earliest Carnian metapolygnathoids. To clear up the phylogenetic significance of this morphological feature, however it will be necessary to study the whole evolutionary lineage

Gondolella praeszabói bystrickyi n. ssp.

Pl. I: Figs 1a–b, 2, 3a–b; Pl. II: Figs 1a–d, 2a–d, 3a–d, 4a–d; Pl. III: Figs. 1a–d, 2a–d, 4a–c; Pl. VII: Figs 1a–b, 2a–b, 3a–d, 4; Pl VIII: Figs 1a–c, 3a–d, 5a–c; Pl. X. Figs 4a–c, 6a–d; Pl. XI. Figs 2a–c

Pl. VI: Figs 2a–d [transitional form between *Gondolella bulgarica* (Budurov et Stefanov) and *Gondolella praeszabói* bystrickyi n. ssp.]

1980 *Neogondolella bulgarica* (Budurov et Stefanov) – Pisa, Perri and Veneri, Pl. 61: only Fig. 2

?1980 *Neogondolella bulgarica* (Budurov et Stefanov) – Pisa, Perri et Veneri, Pl. 61: only Figs 5a–b (transitional form between *G. praeszabói bystrickyi* and *G. praeszabói praeszabói*

1984 *"Gondolella" bulgarica* (Budurov et Stefanov) – Farabegoli, Levanti, Perri and Veneri, Fig. 4, a1–3, b1–3

Derivatio nominis: In honour of late Dr. Ján Bystricky, the great specialist of the West Carpathian Triassic.
Locus typicus: Aggtelek Karst (NE Hungary), Baradla Cave, 5700 m from the Aggtelek entrance toward the Jósvafő exit.
Stratum typicum: Red micritic brachiopodal limestone intercalation in the Steinalm Limestone Formation
Material: About 500 specimens.

Diagnosis: Representatives of the subspecies have an extremely high carina along the whole length of the unit, which is highest in the middle then abruptly decreases in height in the posterior third or quarter. The platform is narrow to very narrow, with slightly thickened, moderately upturned, mostly asymmetrically developed margins. A free blade can be present. The platform end is narrowly blunted, in juvenile forms pointed, fused with the last denticle, or a very small brim can be present.

Relations: Gondolella bulgarica is more arched in lateral view and its platform end is always pointed (see Kovács and Papšová 1986). Furthermore, its platform margins are smooth, never thickened and do not show upturning. Also, its juvenile forms, as opposed to those of the new subspecies described herein, have a considerably lower carina, without strong lateral striations. Usually the same is true for more advanced ontogenetic stages.

Representatives of the Lower Anisian *Gondolella regalis* Mosher may be very similar (especially the morphotypes presented by Nicora, 1977) to the transitional stages between *G. praeszabói bystrickyi* and *G. praeszabói praeszabói*. However, besides the difference in age, the upper edge of the carina of the new species (of both subspecies) is not as straight as in *G. regalis*.

Typical forms of *Gondolella excelsa* are distinguished by their regularly arched (nearly semicircular) upper edge of their carina, which is highest in the middle. Furthermore, the teeth are considerably wider and, with the exception of their tips, are completely fused. For this reason the surface of the carina lacks the striation which is characteristic of the new species (both subspecies). Certain morphotypes of *G. excelsa* may have a similarly reduced platform (both in juvenile and adult ontogenetic stages), but that is flat, and the margins are not thickened, respectively upturned. On the lower surface the keel is wider, with flaring pit and loop.

The carina of the other subspecies, *G. praeszabói praeszabói* n. ssp. is lower (but still considerably higher than in the case of most of the Triassic gondolelloids) and the declination of its upper edge in the posterior third is not as abrupt as in *G. praeszabói bystrickyi*. Furthermore, its platform extends along the entire length of the unit (leaving no free blade) and surrounds the posterior end of the carina, thus showing a definite brim behind the last denticle. Juvenile forms can also be distinguished by the shape of the carina: it is considerably higher in the case of *G. praeszabói bystrickyi*. However no sharp boundary between the taxa can be recognized in our material, and all transitional forms occur between the two typical morphotypes.

Therefore, we think that it is reasonable to consider them as subspecies of the same species.

Occurrences: Thus far known from the West Carpathian Mountains, in the Silica Nappe (Baradla Cave between Aggtelek and Jósvafő, and the Zákazané section at Silica) and the Choc Nappe (Zámoštie section, Michalík and Papšová, unpubl.). Furthermore, it also occurs in the Dont and M. Bivera Formations of five sections (Rio Framont, Nosgieda, Sotto le Rive, M. Rite and M. Bivera) of the Southern Alps (Pisa, Perri and Veneri 1980, Pl. 61, Figs 2, 5; Farabegoli et al. 1984, Fig. 4, a, b), assigned at that time to *G. bulgarica* (see the list of synonymy).

Age: Late Pelsonian (uppermost part of the *Gondolella bulgarica* partial range-zone) to Early Illyrian (*Gondolella bifurcata bifurcata* partial range-zone).

Gondolella praeszabói praeszabói n. ssp.

Pl. I: Figs 4a–b, 5a–d; Pl. IV: Figs 1a–d, 2a–d, 3a–d, 4a–d; Pl. VI: Figs 1a–e, 3a–d; Pl. VIII: Figs 2a–c, 4a–c, 6a–c; Pl. IX: Figs 2a–c, 3a–c, 4a–c, 5a–c, 6a–c; Pl. X: Figs 1a–c, 2a–c, 3a–c; Pl. XI: Figs 3a–d, 4a–c, 5a–c

Pl. III: Figs 3a–e; Pl. V: Figs 1a–e, 2a–d, 3a–e; Pl. IX: Figs 1a–c; Pl. X: Figs 5a–c; Pl. XI: Figs. 1a–c (transitional forms between *Gondolella praeszabói bystrickyi* n. ssp. and *G. praeszabói praeszabói* n ssp.)

1980 *Neogondolella bulgarica* (Budurov et Stefanov) – Pisa, Perri and Veneri, Pl. 61; only Figs 1, 6, 8
?1981 *Gondolella regalis* Mosher–Balogh and Kovács, p. 46, Fig. 2

Derivatio nominis: Because of its phylogenetic relationship (forerunner) to *Gondolella szabói* Kovács 1983.
Locus typicus: Zákazané (Tilalmas) E of Silica, Silická Planina, Slovak Karst (SE Slovakia).
Stratum typicum: Top part of light-gray crinoidal limestone occurring between Steinalm Limestone and Schreyeralm Limestone, sample Z–4.
Material: About 850 specimens.

Diagnosis: Representatives of the subspecies have a high carina, which is nearly of the same height in the anterior 2/3, then gradually decreases in height behind it. The narrow platform, tending to have parallel margins, extends along the entire length of the unit, leaving no free blade. Platform margins are more or less thickened, moderately upturned. The platform end surrounds the posterior end of the carina.

Relations: Gondolella szabói Kovács 1983 has a considerably more compressed platform with much more overturned margins.

Gondolella bifurcata hanbulogi (Sudar and Budurov 1979), also deriving from *G. bulgarica*, is morphologically very close to the new subspecies. However, characteristic forms of the latter have a more compressed platform, with upturned and thickened parallel margins. Furthermore, the carina is usually higher and the unit is less arched in lateral view. The wide field of transition between the characteristic forms of the two taxa, however, indicates that the boundary between them in fact, would also be only at subspecies rank (a case similar to *Gondolella foliata inclinata*, *G. foliata foliata*, and *G. tadpole*; see Kovács 1983).

Gondolella liebermani Kovács and Krystyn (in Kovács 1994) is distinguished by its thicker and flat (not upturned) platform margins. Furthermore, its platform end broadly surrounds the last denticle of the carina, and its basal pit is flaring (like in *G. excelsa*, however, in adult forms it can be considerably overgrown).

For differences with *G. praeszabói bystrickyi* n. ssp. see above.

Occurrences: So far known from the West Carpathian Mountains, from the Silica Nappe (Baradla Cave between Aggtelek and Jósvafő and Zákazané section at Silica) and from the Choc Nappe (Zámoštie section, Michalik and Papšová 1993). It also occurs in the Southern Alps from the Dont, M. Bivera, Ambata and Contrin Formations, in eight sections (Rio Framont, Nosgieda, Sotto le Rive, Tudai di Razzo, M. Bivera, M. Franza and Creta delle Fuine Pisa, Perri and Veneri 1980, Pl. 61, Figs 1,6,8) assigned at that time to G. bulgarica (see the list of synonymy).

Age: Illyrian: *Gondolella bifurcata bifurcata* partial range-zone and lowermost part of the *G. constricta cornuta* partial range-zone in the Zákazané section, SE Slovakia and in the Southern Alps.

Acknowledgements

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x Photos taken in Bratislava by SEM type TESLA
xx Photos taken in Budapest by SEM type JEOL 230

Plate I

1a–b *Gondolella praeszabói bystrickyi* n. ssp. Early juvenile ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 20/Kov., T-6468.
x 1a: lateral view, 145x; xx 1b: lower-lateral view, 200x

2 *Gondolella praeszabói bystrickyi* n. ssp. Juvenile ontogenetic stage. Zákazané, sample Z-4. Spec. N. 3/Paps., SNM/Z 21834, xx Lateral view, 200x

3a–b *Gondolella praeszabói bystrickyi* n. ssp. Early juvenile ontogenetic stage. Zákazané, sample Z-4. Spec. N. 4/Paps., SNM/Z 21835
x 3a: lateral view, 175x; xx 3b: lower-lateral view, 175x

4a–b *Gondolella praeszabói praeszabói* n. ssp. Juvenile ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 18/Kov., T-6469
x 4a: lateral view, 125x; xx 4b: lower-lateral view, 150x

5a–d *Gondolella praeszabói praeszabói* n. ssp. Juvenile ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 21/Kov., T-6470
xx 5a: lateral view, 130x ; xx 5b: upper-lateral view, 130x;
xx 5c: upper view, 130x; xx 5d: lower-lateral view, 130x.

Plate II

1a–d *Gondolella praeszabói bystrickyi* n. ssp. Subadult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 23/Kov., T-6471
x 1a: lateral view, 150x; xx 1b: upper-lateral view, 150x;
xx 1c: upper view, 150x; x 1d: lower view, 150x

2a–d *Gondolella praeszabói bystrickyi* n. ssp. Subadult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 22/Kov., T-6472
x 2a: lateral view, 150x; xx 2b: slightly oblique lateral view, 150x;
xx 2c: upper-lateral view, 150x; xx 2d: lower view, 150x

3a–d *Gondolella praeszabói bystryckyi* n. ssp. Subadult ontogenetic stage. Zákazan,é sample Z-4. Spec. N. 11/Kov./Bystr., SNM/Z 21836
x 3a: lateral view, 150x; xx 3b: upper-lateral view, 150x;
xx 3c: upper view, 150x; xx 3d: lower view, 150x

4a–c *Gondolella praeszabói bystrickyi* n. ssp. Subadult ontogenetic stage. Zákazané, sample Z-4. Spec. N. 10/Kov./Bystr. SNM/Z 21837
xx 4a: lateral view, 150x; xx 4b: upper-lateral view, 150x;
xx 4c: lower-lateral view, 150x

Plate III

1a–d *Gondolella praeszabói bystrickyi* n. ssp. *Holotype*. Subadult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 19/Kov., T-6473
xx 1a: lateral view, 150x; xx 1b: upper-lateral view, 150x;
xx 1c: lower-lateral view, 150x; xx 1d: lower view 150x

2a–d *Gondolella praeszabói bystrickyi* n. ssp. Subadult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 24/Kov., T-6474
x 2a: lateral view, 150x; xx 2b: upper-lateral view, 150x;
xx 2c: upper view, 150x; xx 2d: lower view 150x

3a–e Transitional form between *Gondolella praeszabói bystrickyi* n. ssp. and *G. praeszabói praeszabói* n.ssp. Subadult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 25/Kov., T-6475
xx 3a: lateral view, 150x; (Tips of denticles have been partly broken when changing the position.)
xx 3b: upper-lateral view, 150x; xx 3c: upper view, 150x;
xx 3d: lower-lateral view, 150x; xx 3e: lower view, 150x

4a–c *Gondolella praeszabói bystrickyi* n. ssp., with broken denticles in the posterior third of the unit. Medium ontogenetic stage. Zákazané, sample Z-4. Spec. N. 3/Kov./Bystr., SNM/Z 21838
x 4a: lateral view 180x, x 4b: lower view, 180x,
x 4c: upper view, 180x

Plate IV

1a–d *Gondolella praeszabói praeszabói* n. ssp. *Holotype*. Adult ontogenetic stage. Zákazané, sample Z-4. Spec. N. 4/93/Kov./Bystr., SNM/Z 21839
xx 1a: lateral view, 100x; xx 1b: upper-lateral view, 100x;
xx 1c: lateral-upper view, 100x;
xx 1d: lower view, 100x. (The specimen was partly damaged when it was sticked up in this view.)

2a–d *Gondolella praeszabói praeszabói* n. ssp. Subadult ontogenetic stage. Zákazané, sample Z-4. Spec. N. 2/93/Kov./Bystr., SNM/Z 21840
xx 2a: lateral view, 150x; xx 2b: upper-lateral view, 150x;
xx 2c: upper view, 150x; xx 2d: lower view, 150x

3a–d *Gondolella praeszabói praeszabói* n. ssp. Subadult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 14/Kov., T-6476
xx 3a: lateral view, 150x; xx 3b: upper-lateral view, 150x;
xx 3c: upper view, 150x; xx 3d: lower view, 150x

4a–d *Gondolella praeszabói praeszabói* n. ssp. Late juvenile ontogenetic stage. Zákazané, sample Z-4. Spec. N. 2/Paps., SNM/Z 21841
x 4a: lateral view, 200x; xx 4b: lateral-upper view, 200x;
xx 4c: upper view, 200x; xx 4d: lower view, 200x

Plate V

1a–e Transitional form between *Gondolella praeszabói bystrickyi* n. ssp. and *G. praeszabói praeszabói* n. ssp. Adult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 12/Kov., T-6477
xx 1a: lateral view, 100x; x 1b: upper-lateral view, 100x;
x 1c: upper view, 100x; xx 1d: lower-lateral view, 100x;
xx 1e: lower view, 100x

2a–d Transitional form between *Gondolella praeszabói bystrickyi* n. ssp. and *G. praeszabói* praeszabói n. ssp. Adult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 13/Kov., T-6478
x 2a: lateral view, 100x; x 2b: upper-lateral view, 100x;
x 2c: upper view, 100x; xx 2d: lower view, 100x

3a-e Transitional form between *Gondolella praeszabói bystrickyi* n. ssp. and *Gondolella praeszabói praeszabói* n .ssp. Subadult ontogenetic stage. Baradla Cave, 5700 m. Spec. N. 26/Kov., T-6479
xx 3a: lateral view 150x, xx 3b: upper-lateral view, 150x;
xx 3c: upper view, 150x; xx 3d: lower-lateral view, 150x;
xx 3e: lower view, 110x

Plate VI

1a–e *Gondolella praeszabói praeszabói* n. ssp. Hyperadult ontogenetic stage. Zákazané, sample Z-4. Spec. N. 1/93/Kov./Bystr., SNM/Z 21842
xx 1a: upper-lateral view, 100x; xx 1b: lateral view, 100x;
xx 1c: lower-lateral view, 100x; xx 1d: lateral-upper view, 100x;
xx 1e: upper view, 100x. (The specimen was broken before taking its photo in lower view.)

2a–d Transitional form between *Gondolella bulgarica* (Bud. et Stef.) and *G. praeszabói* n. ssp. Subadult ontogenetic stage. Zákazané, sample Z-4. Spec. N. 15/Kov./Bystr. SNM/Z 21843
xx 2a: slightly oblique lateral view, 150; x 2b: upper-lateral vie ,150x;
x 2c: upper view, 150x; xx 2d:lower view, 150x

3a–d *G. praeszabói praeszabói* n. ssp. Subadult ontogenetic stage. Zákazané, sample Z-4. Spec. N. 4/Kov./Bystr. SNM/Z 21844
x 3a: lateral view, 150x; x 3b: upper-lateral view, 150x;
x 3c: upper view, 160x; xx 3d: lower view, 165.

Plate VII

1a–b *Gondolella praeszabói bystrickyi* n. ssp. Juvenile ontogenetic stage. Zákazané, sample Z-4. Spec. N. 19/Paps., SNM/Z 21845
x 1a: lower-lateral view, 200x; x 1b: lower view, 200x

2a–b *Gondolella praeszabói bystrickyi* n. ssp. Juvenile ontogenetic stage. Zákazané, sample Z-4/ Spec. N. 1/Paps., SNM/Z 21846
xx 2a: lateral view, 200x; xx 2b: lower- lateral view, 200x

3a–c *Gondolella praeszabói bystrickyi* n. ssp. Subadult ontogenetic stage. Zákazané, sample Z-4. Spec. N. 17/Kov./Bystr. SNM/Z 21847
xx 3a: lateral view, 150x; xx 3b: lateral-upper view, 150x;
xx 3c: lower view, 50x

4 *Gondolella praeszabói bystrickyi* n. ssp. Subadult ontogenetic stage. Zákazané, sample Z-4. Spec. N. 2/Kov./Bystr. SNM/Z 21848
x lateral view, 150x

5 Wheathered surface of red, micritic, brachiopodal limestone from the locality at 5700 m of Baradla Cave. Cm-scale on lower left. (Courtesy of F. Szilágyi.)

Plate VIII

Photos taken in Bologna by SEM type JEOL 5400, all magnifications are 133x

1a–c *Gondolella praeszabói bystrickyi* n. ssp., medium ontogenetic stage. Dont Fm. Sample MR 7/3, 5106, IC 1556,
1a: lateral view, 1b: upper view,
1c: lower view

2a–c *Gondolella praeszabói praeszabói* n. ssp., subadult ontogenetic stage. Dont Fm. Sample No. 15, 6425, IC 1557,
2a: lateral view, 2b: upper view,
2c: lower view

3a–d *Gondolella praeszabói bystrickyi* subadult ontogenetic stage. Contrin Fm. Sample CRF 2, 5092, IC 1558,
3a and 3b: lateral views, 3c: upper view,
3d: lower view.

4a–c *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. M. Bivera Fm. Sample NO 20, 5101, IC 1559,
4a: lateral view, 4b: upper view,
4c: lower view

5a–c *G. praeszabói bystrickyi n.* ssp., juvenile ontogenetic stage. Dont Fm. Sample MR 7/3, 5079, IC 1560,
5a: lateral view, 5b: upper view,
5c: lower view

6a–c *G. praeszabói praeszabói* n. ssp., late juvenile ontogenetic stage. M. Bivera Fm. Sample SR 1, 5088, IC 1561,
6a: lateral view, 6b: upper view,
6c: lower view

Plate IX
All magnifications are x 133.

1a–c Transitional form between *G. praeszabói bystrickyi* n. ssp. and *G. praeszabói praeszabói* n. ssp., subadult ontogenetic stage. Dont Fm. Sample MR 7, 5105, IC 1562,
1a: lateral view, 1b: upper view,
1c: lower view

2a–c *G. praeszabói praeszabói* n. ssp., subadult ontogenetic stage. Dont Fm. Sample MR 7/3, 5084, IC 1563,
2a: lateral view, 2b: upper view,
2c: lower view

3a–c *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. Dont Fm. Sample MR 7/3, 5083, IC 1564,
3a: lateral view, 3b: upper view,
3c: lower view

4a–c *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. Dont Fm. Sample MR 7/3, 5082, IC 1565,
4a: lateral view, 4b: upper view,
4c: lower view

5a–c *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. Dont Fm. Sample MR 7/5, 6445, IC 1566,
5a: lateral view, 5b: upper view,
5c: lower view

6a–c *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. M. Bivera Fm. Sample MR 24, 6421, IC 1567,
6a: lateral view, 6b: upper view,
6c: lower view

Plate X
All magnifications are x 133.

1a–c *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. Dont Fm. Sample MR 7/3, 5081, IC 1568,
1a: lateral view, 1b: upper view,
1c: lower view

2a–c *G. praeszabói praeszabói* n. ssp., subadult ontogenetic stage. Dont Fm. Sample NO 9, 6426, IC 1569,
2a: lateral view, 2b: upper view,
2c: lower view

3a–c *G. praeszabói praeszabói* n. ssp., subadult ontogenetic stage. Dont Fm. Sample FR 2, 5093, IC 1570,
3a: lateral view, 3b: upper view,
3c: lower view

4a–c *G. praeszabói bystrickyi* n. ssp., subadult ontogenetic stage. Dont Fm. Sample NO 14, 5096, IC 1571,
4a: lateral view, 4b: upper view,
4c: lower view

5a–c Transitional form between *G. praeszabói bystrickyi* n. ssp. and *G. praeszabói praeszabói* n. ssp., subadult ontogenetic stage. M. Bivera Fm. Sample SR 1, 5090, IC 1572,
5a: lateral view, 5b: upper view,
5c: lower view

6a–d *G. praeszabói bystrickyi* n. ssp., subadult ontogenetic stage. Dont Fm. Sample MR 18, 5085, IC 1573,
6a and 6b: lateral views, 6c: upper view, 6d: lower view

Plate XI

All magnifications are x 133.

1a–c Transitional form between *G. praeszabói bystrickyi* n. ssp. and *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. Dont Fm. Sample MR 7/3, 5080, IC 1574,
1a: lateral view, 1b: upper view,
1c: lower view

2a–c *G. praeszabói bystrickyi* n. ssp., adult ontogenetic stage. M. Bivera Fm. Sample MB 15, 5095, IC 1575,
2a: lateral view, 2b: upper view,
2c: lower view

3a–d *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. Dont Fm. Sample MR 1/2, 5104, IC 1576,
3a and 3b: lateral views, 3c: upper view,
3d: lower view

4a–c *G. praeszabói praeszabói* n. ssp., subadult ontogenetic stage. Dont Fm. Sample MR 1/2, 5103, IC 1577,
4a: lateral view, 4b: upper view,
4c: lower view

5a–c *G. praeszabói praeszabói* n. ssp., adult ontogenetic stage. M. Bivera Fm. Sample MB 14, 5102, IC 1578,
5a: lateral view, 5b: upper view,
5c: lower view

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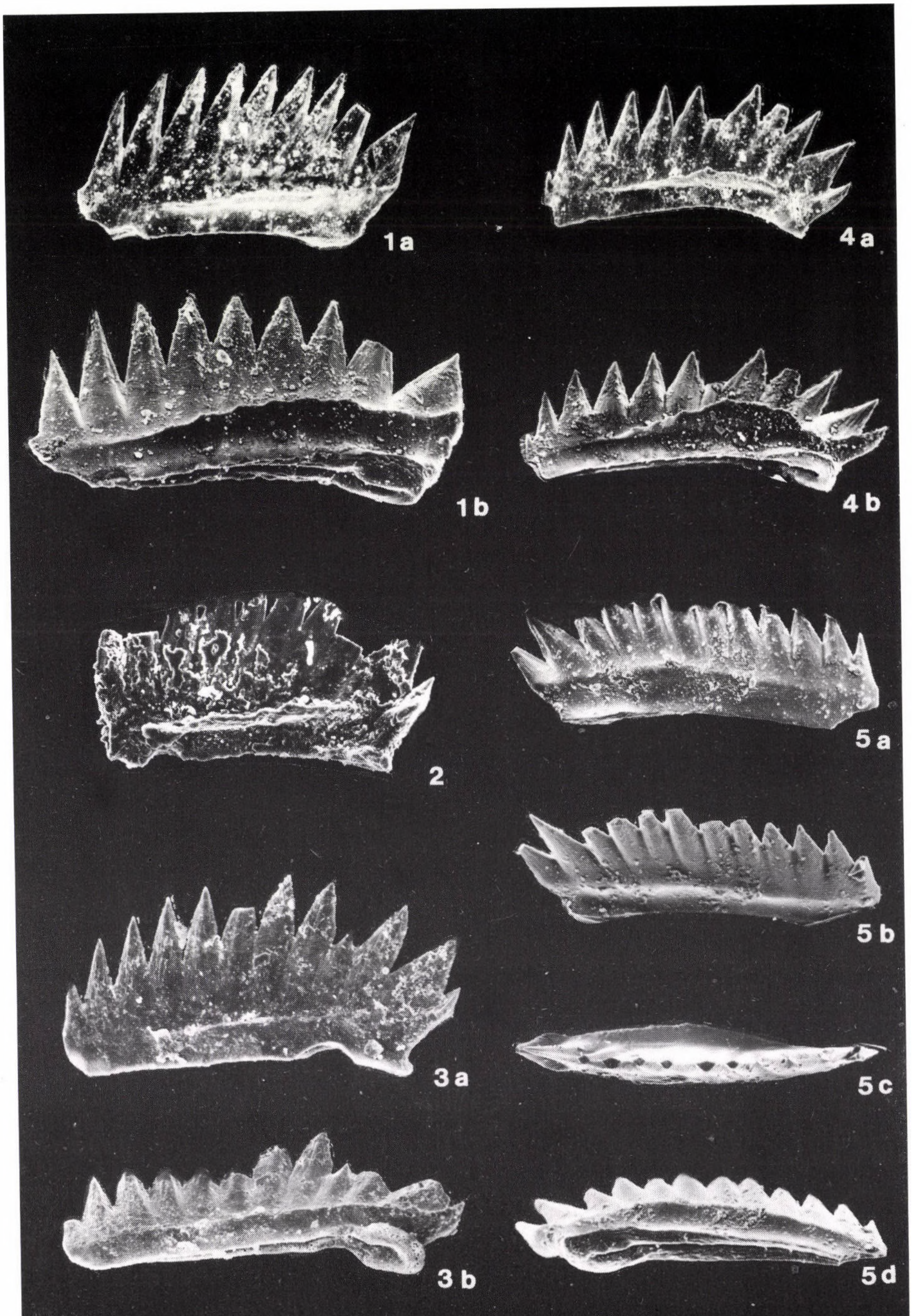
Plate I



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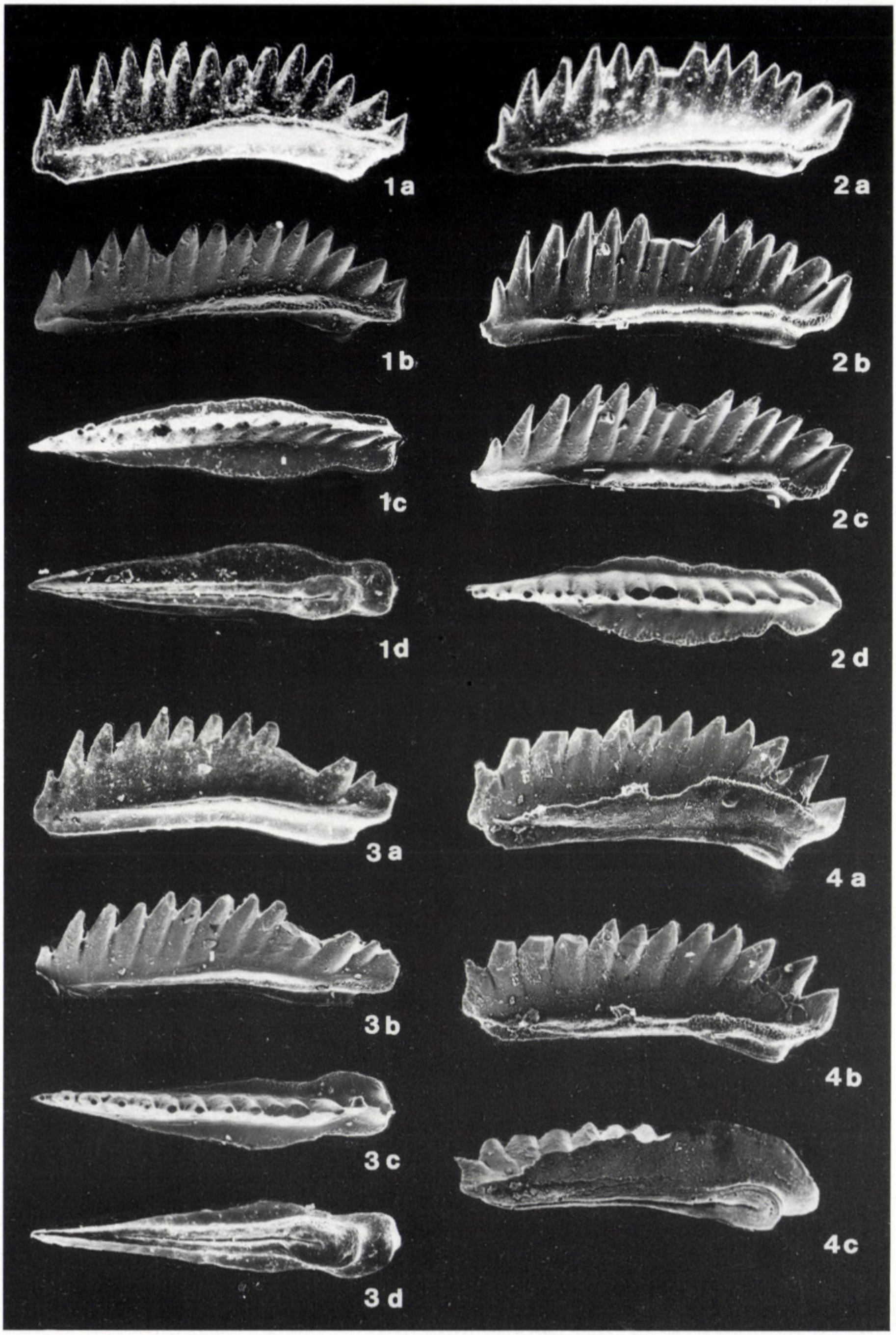

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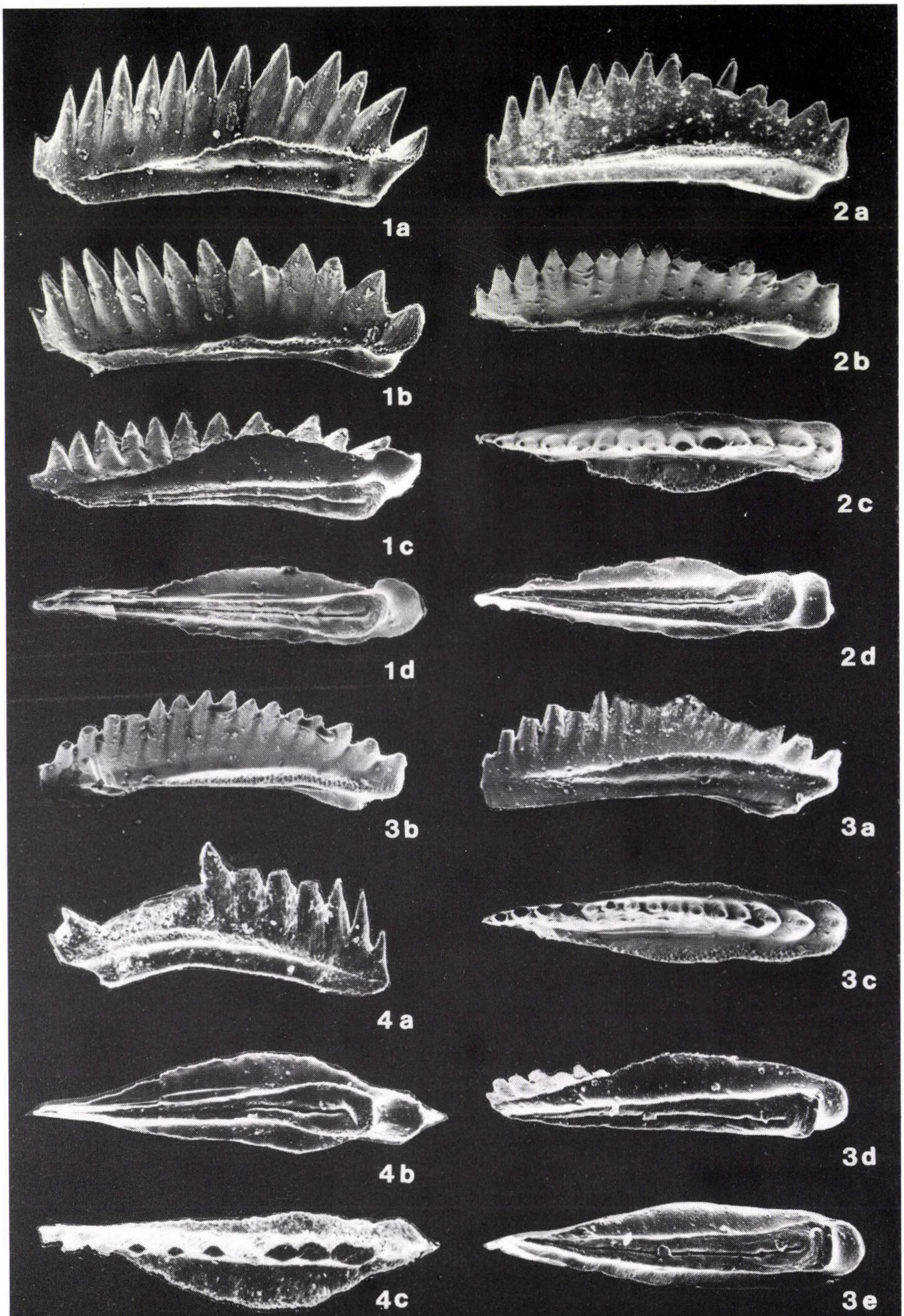

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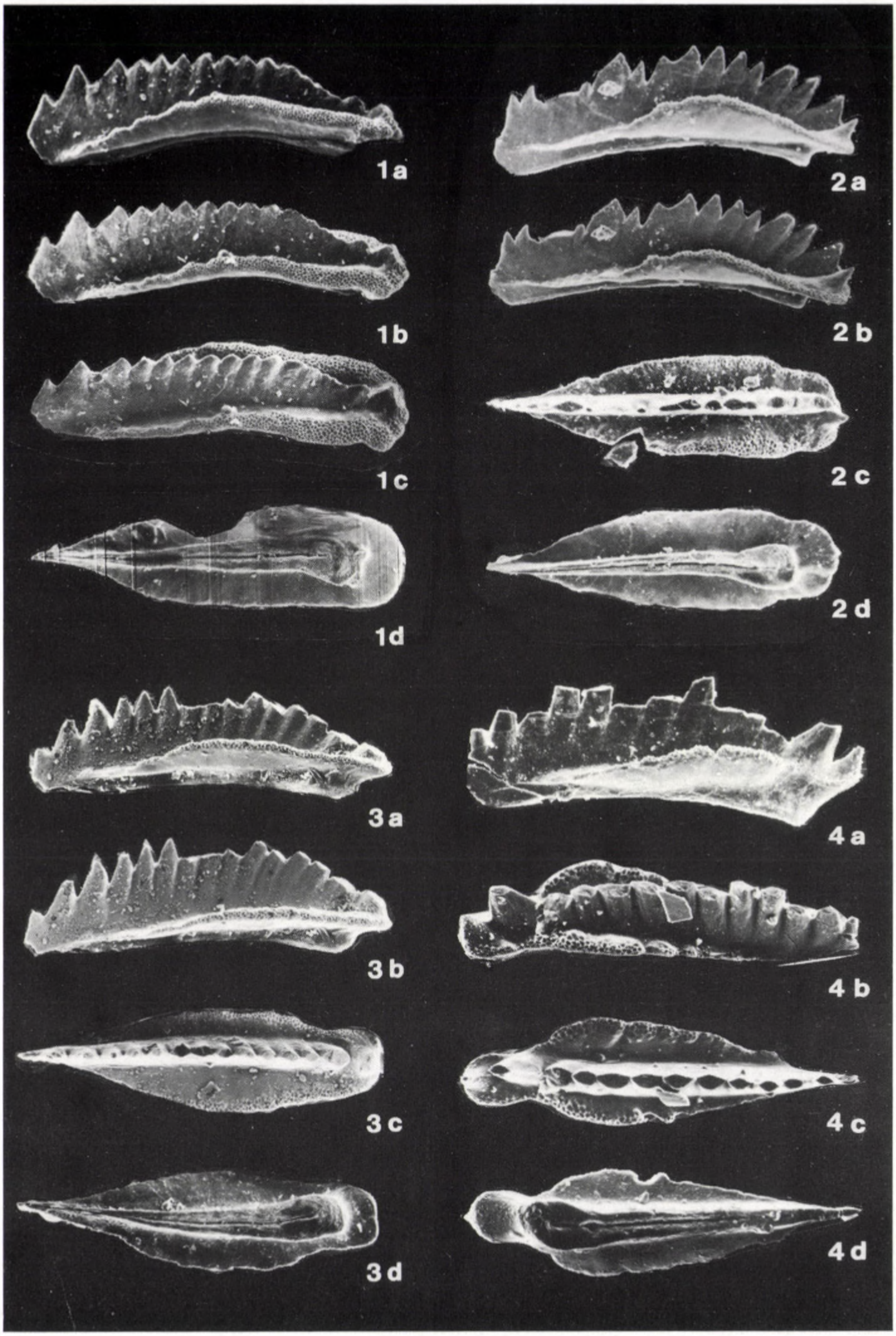

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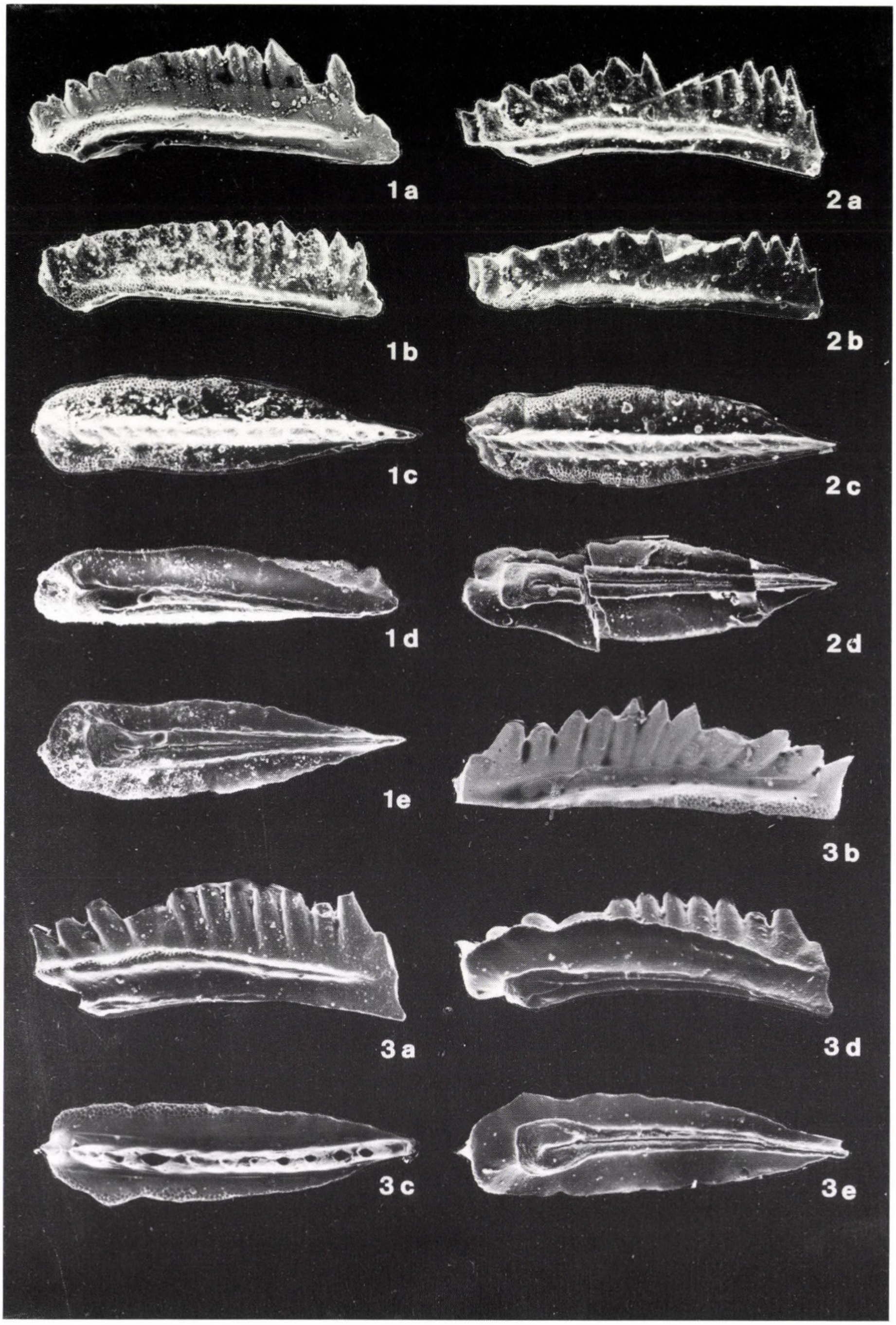

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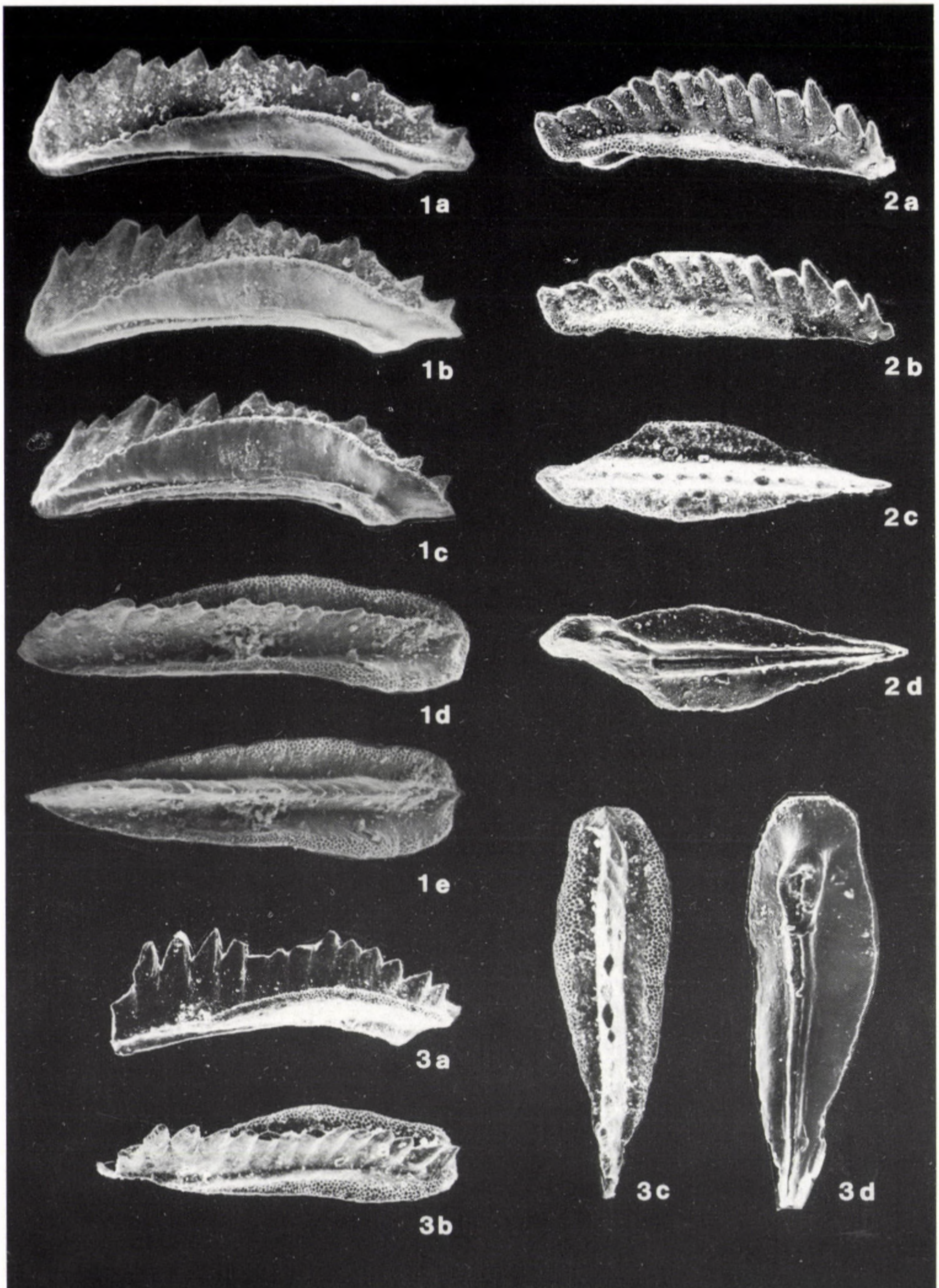

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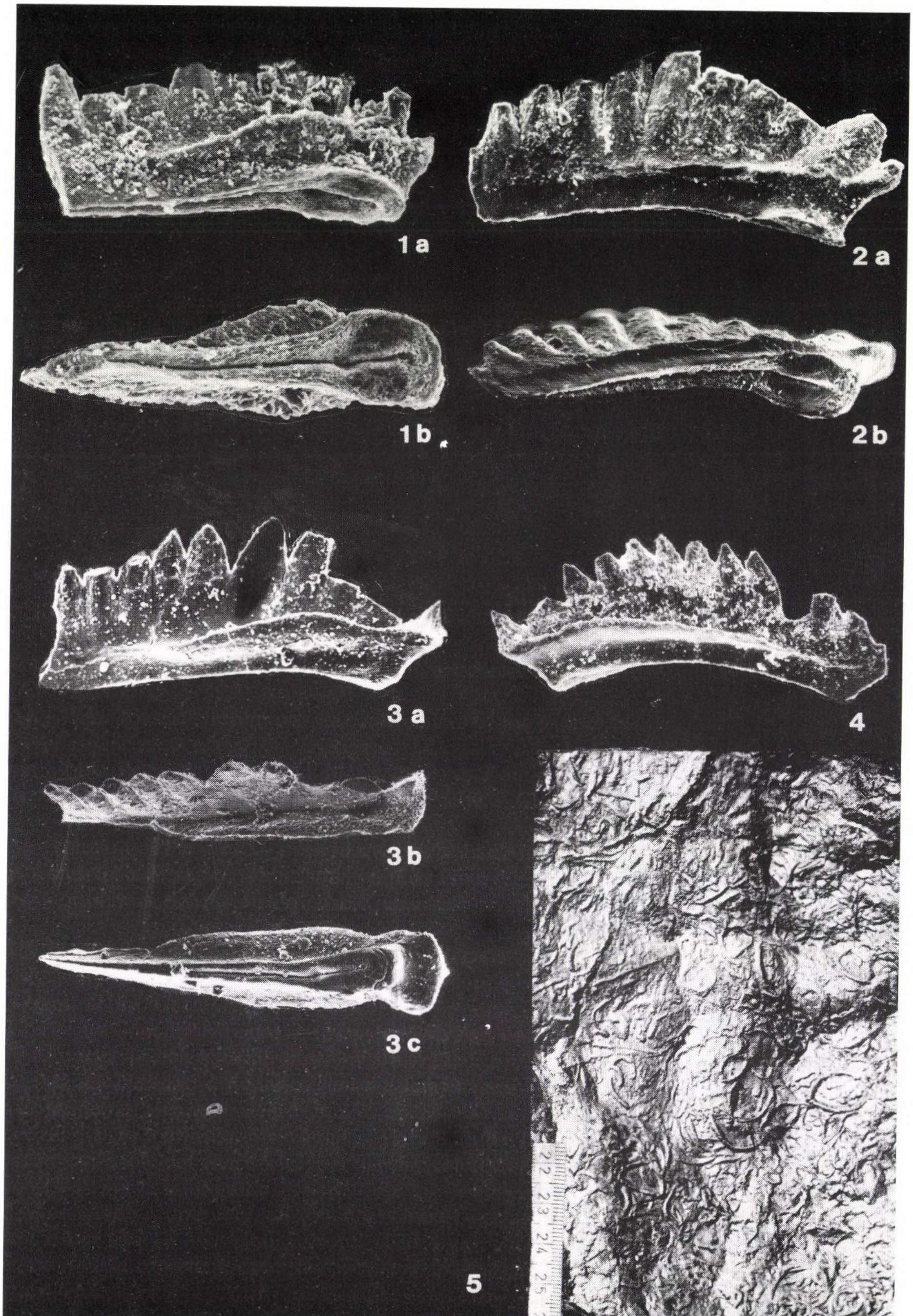

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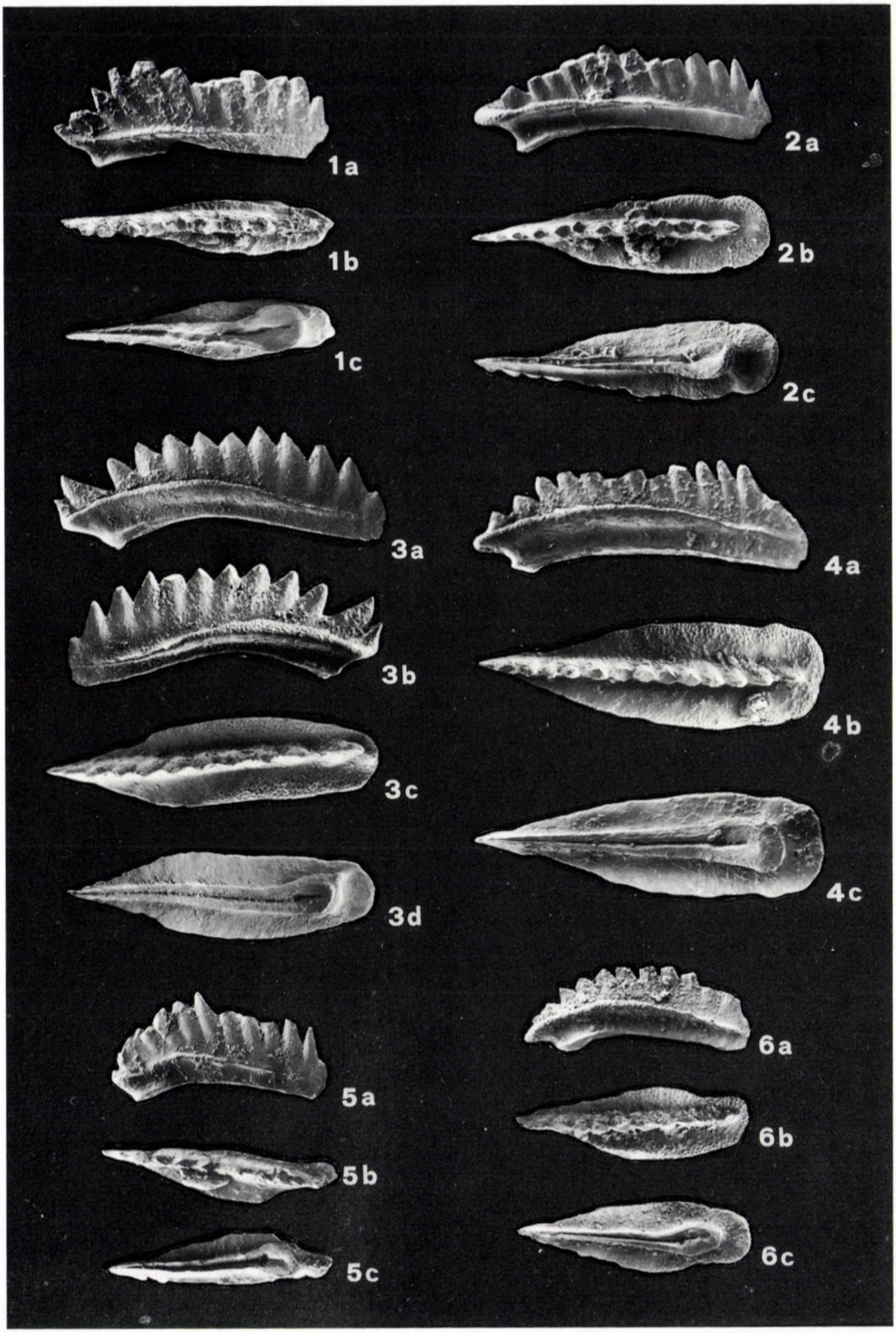

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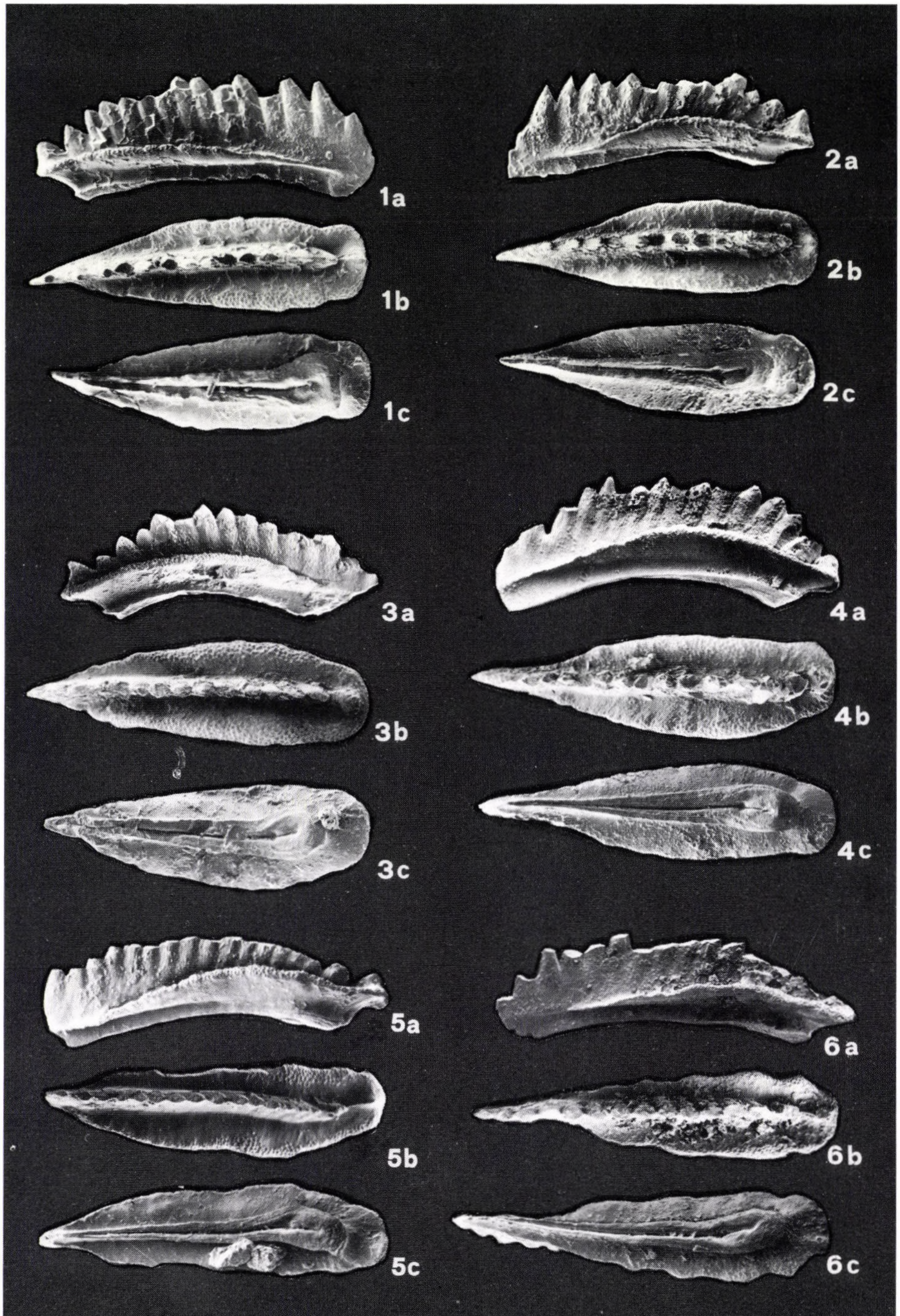

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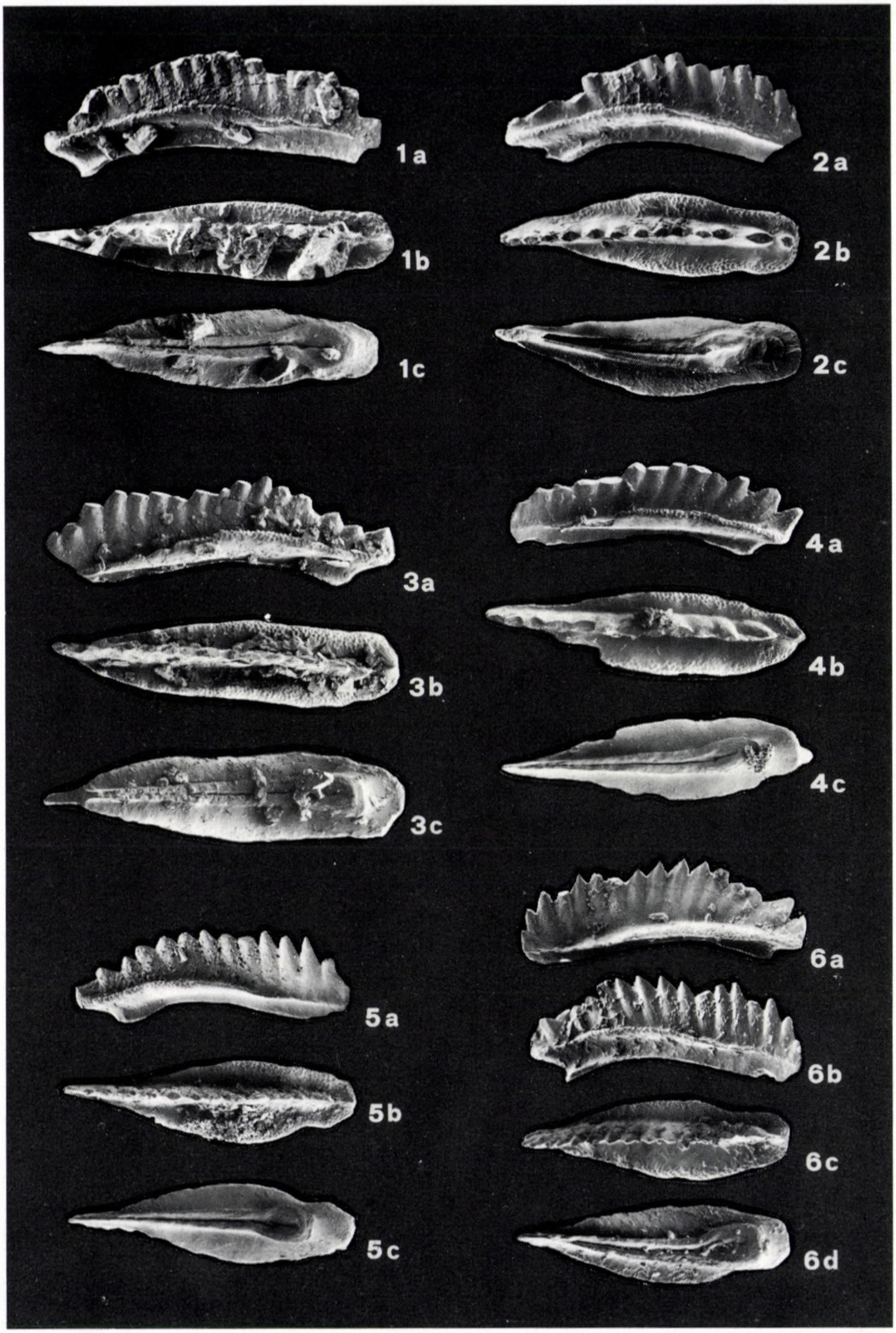
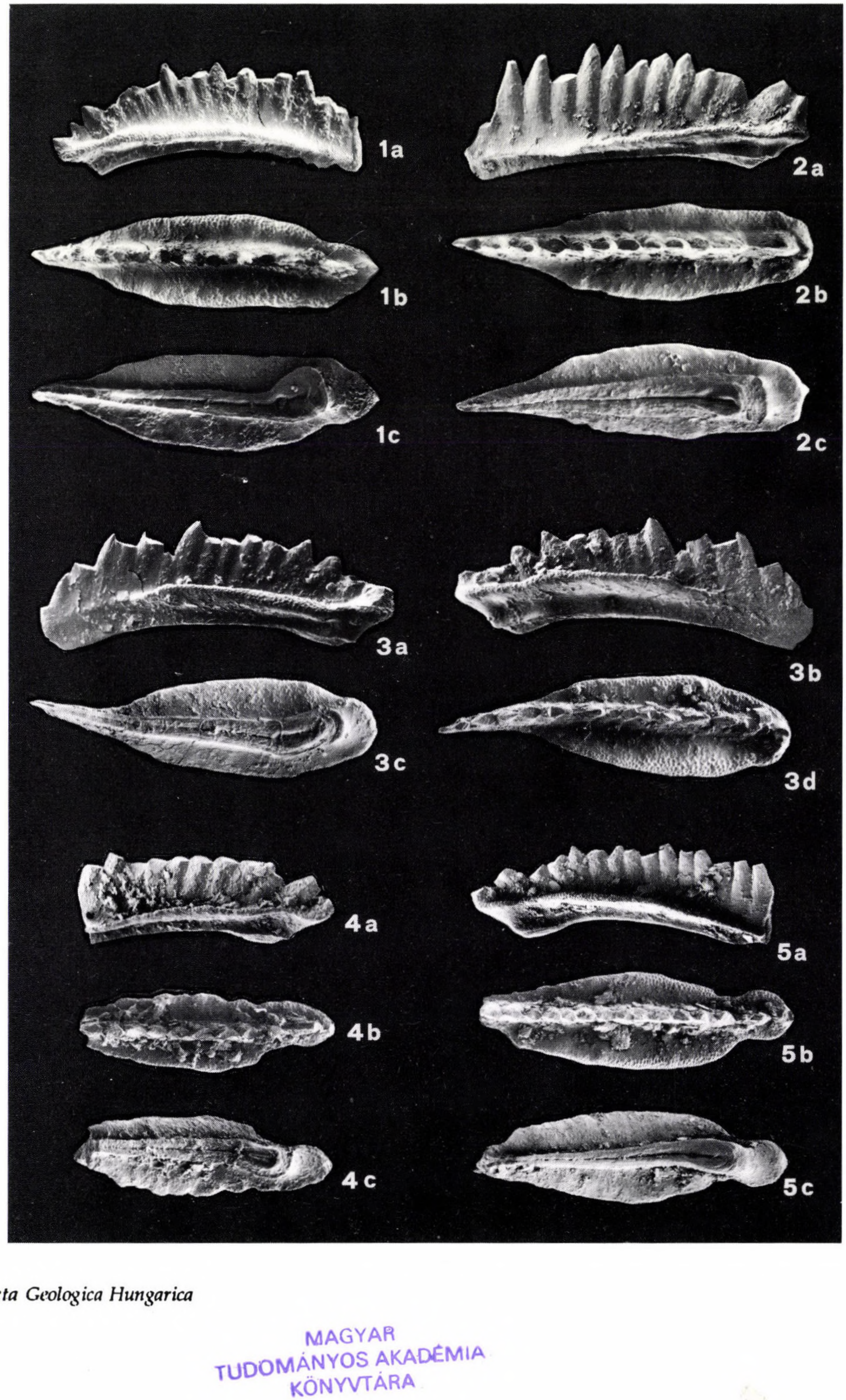


Plate XI



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High-resolution sedimentological and subsidence analysis of the Late Neogene, Pannonian Basin, Hungary

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Detailed sedimentological and paleontological analyses were carried out on more than 13,000 m of core from ten boreholes in the Late Neogene sediments of the Pannonian Basin, Hungary. These data provide the basis for determining the character of high-order depositional cycles and their stacking patterns. In the Late Neogene sediments of the Pannonian Basin there are two third-order sequences: the Late Miocene and the Pliocene ones.

The Miocene sequence shows a regressive, upward-coarsening trend. There are four distinguishable sedimentary units in this sequence: the basal transgressive, the lower aggradational, the progradational and the upper aggradational units. The Pliocene sequence is also of aggradational character.

The progradation does not coincide in time in the wells within the basin. The character of the relative water-level curves is similar throughout the basin but shows only very faint similarity to the sea-level curve. Therefore, it is unlikely that eustasy played any significant role in the pattern of basin filling. Rather, the dominant controls were the rapidly changing basin subsidence and high sedimentation rates, together with possible climatic factors.

Key words: basinanalysis, sequence stratigraphy, subsidence analysis, magnetostratigraphy, sedimentology, lacustrine environment, Neogene, Pannonian basin

Introduction

The Pannonian Basin, one of the type back-arc basins, was formed during Neogene time in central-eastern Europe, in response to plate tectonic events that also led to the formation of the Carpathian Mountains (Royden and Horváth 1988). The extension of the Pannonian Basin occurred along a system

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of strike-slip faults during the Early to Late Miocene. This was followed, about 13 Ma ago, by a phase of thermal subsidence. Both events were diachronous throughout the basin (Royden 1988).

An inland sea, located between the Eastern Alps, the Carpathian Mountains, and the Dinarid chain (Fig. 1), gradually evolved into a large brackish to freshwater lake named Pannonian Lake/Sea (Jámbor 1980; Kázmér 1990). The depocentre actually consists of several subbasins, some containing more than 5,000 m of Neogene sediment. The lacustrine basin fill was regarded by many (e.g. Roth 1879) as belonging to the Pannonian stage and generally considered to be restricted to the Pliocene. More recently, K–Ar dating of volcanic rocks, as well as magnetostratigraphic and biostratigraphic studies demonstrated that the Pannonian s.l. regional stage ranges from 12.0–2.4 Ma – i.e. Late Miocene and Pliocene (Jámbor 1987; Lantos et al. 1990 – see Fig. 2). They are overlain by Pleistocene and Holocene deposits up to 500 m thick.

The sequence stratigraphy of the Pannonian Basin has been studied by Pogácsás et al. (1988a, 1988b, 1993), using an extensive reflection seismic database. They recorded lake level drops in the Pannonian Lake (despite its isolation from the world oceans) between 7.9–7.6, 6.8–5.7 and 5.4–4.6 Ma. Comparing them to those of the eustatic sea level curve of Haq et al. (1987),

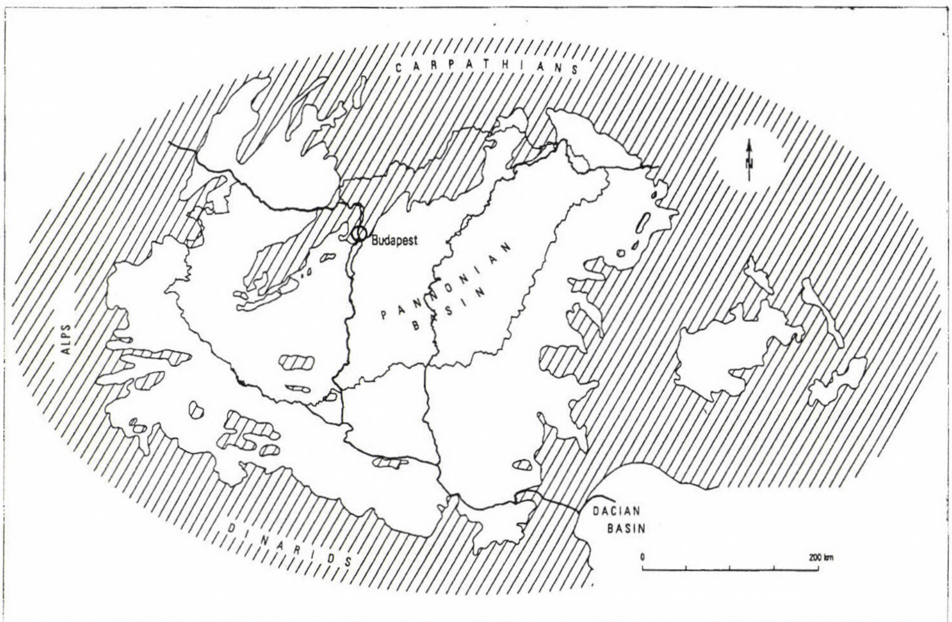


Fig. 1
Paleogeographic sketch of the Pannonian Basin during the Late Miocene (after Rögl and Steininger 1984)

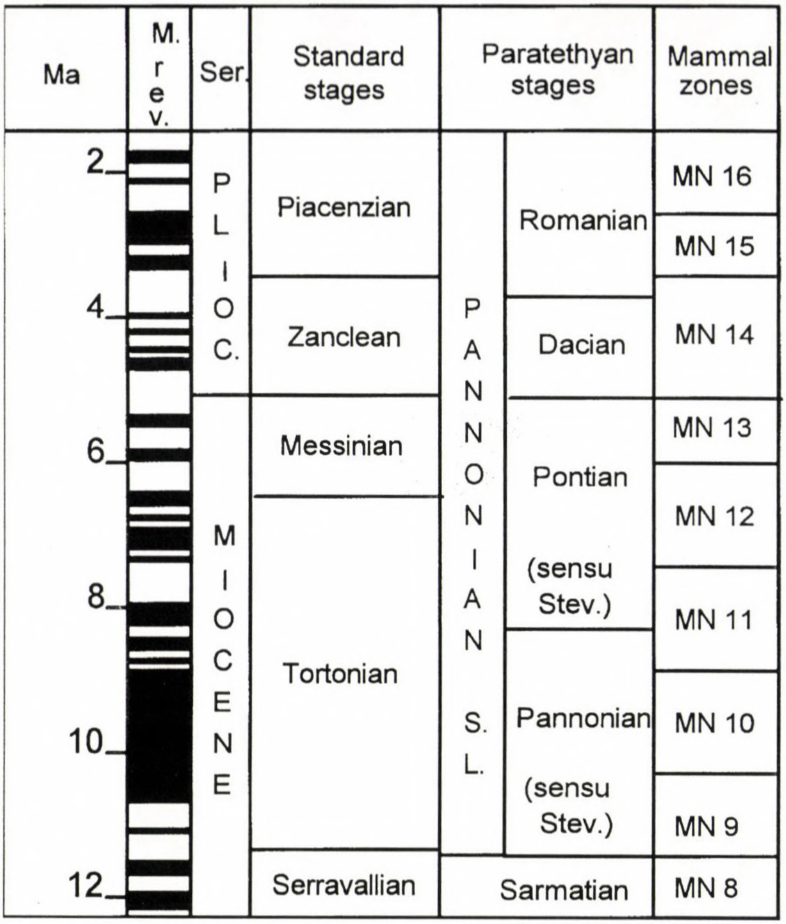


Fig. 2
Chronostratigraphic time scale for the Neogene in Central Paratethys completed by mammal and paleomag zones.

which shows significant sea level drops at approximately 7.8, 6.3 and 5.2 Ma, they concluded that the lake level rose and fell in phase with the global sea level (Pogácsás et al. 1988a, 1994). Müller and Magyar (1992a) argue that eustatic sea-level could not have affected the Pannonian stratigraphic architecture because of the endemic nature of the basin fauna, especially of the mollusc fauna. The fossil record shows no evidence of repeated connection with the marine system.

In this paper we attempt to shed some light on the Pannonian Basin evolution and the structure of the sedimentary build-up. Our studies have integrated sedimentological and stratigraphic methods (core and well-log evaluations, high-resolution stratigraphy, magnetostratigraphy and biostratigraphy) to investigate the following problems: 1. the identification of stratigraphic sequences in the Pannonian Basin; 2. examining evidence of lake-level changes that can be attributed to eustasy; 3. other possible causes of relative lake-level changes; and 4. problems of correlation of significant events in the basin.

Paleogeography

From Oligocene to Pliocene time the Paratethys extended from the northern Alpine molasse basins to the Aral sea. Faunal and paleogeographic evidence indicate repeated connections of Paratethys with the world ocean system, but its evolution shows an increasing trend toward isolation (Hámor 1988; Nagymarosy and Müller 1988). This process of isolation culminated in the early Late Miocene when the Pannonian "lake" was finally disconnected from its neighbouring basins (Jámbor 1987; Müller and Magyar 1992a).

Migration patterns of the aquatic molluscs and stable isotope data of their shells (Mátyás et al. in press) suggest that the lake had no outflow for the first few million years of its history. During the later half of the lake's history, intermittent outflow occurred toward the neighbouring Dacian Lake (south Romania and north Bulgaria – Müller and Magyar 1992b). At that time the catchment area of the Pannonian lake was much smaller than that of the modern Pannonian basin (Hámor 1988).

Chronostratigraphy

Early stratigraphic analyses of the Pannonian lake sediments were based on facies-dependent benthic molluscs, incorrectly assigned to the Pliocene (e.g. Bartha 1971; Pogácsás et al. 1993). Like other isolated or partly isolated basins around the world, the endemic fauna poses difficulties for extrabasinal correlations. Some relief is afforded from this dilemma by mammal biostratigraphic zonal schemes (Steininger et al. 1990), as well as other independent methods like radiometric dating and magnetostratigraphic ages (Kókay et al. 1991; Lantos et al. 1990; Pogácsás et al. 1988a). Reliable correlation is available from 12.6 Ma (Kókay et al. 1991) or 11.6 Ma (Steininger et al. 1990) to about 5.2 Ma in the Pannonian Lake, although the exact age of the stratigraphic boundaries is still uncertain with about a few hundred thousand years.

Intrabasinal stratigraphic correlation is also problematic, because of the occurrence of the mainly benthic, and therefore facies-dependent fossils (Korpás-Hódi 1983; Müller and Magyar 1992b). The only planctonic forms of the Pannonian succession are dinoflagellates, although benthic genera are also present (Fuchs and Sütő-Szentai 1991). Some measure of independence is gained by comparing biostratigraphically determined boundaries in different sedimentary facies with boundaries determined by seismic and depositional systems tracts (Pogácsás et al. 1993).

Methods

The sedimentological and lithological features, together with the paleontological records, were observed by means of the detailed logging of more than 17,000 m of core from 17 boreholes (Fig. 3), and then interpreted in terms of sedimentary facies. Following the genetic stratigraphical method of Homewood et al. (1992), first the genetic depositional units were identified. Each unit is characterised by its most distant and closest facies to the shoreline. Graphically, in the function of the shoreline shift, the figuring of the facies changes, from the deepest water (most distant facies) to the shallowest (closest facies), gives a triangle for each unit. The succession of the genetic units, the stacking pattern, plots the changes of the paleoenvironments (Fig. 4; see also Figs 7–9). Using paleomagnetic data, the stacking pattern diagrams for each borehole were reliably dated. The variation of the stacking pattern reflects the migration of the lake shoreline, i.e. the relative water-level changes at the site of the borehole.

First the tendency of the change was examined in each borehole; then their correlation was carried out well by well. Magnetostratigraphic dating (Elston et al. 1990; Lantos et al. 1992) provided the basis for the correlation. Due to the rapid depositional rates (400–2000 m/Ma), and detailed sampling (0.5 m intervals), the paleomagnetic records provide the highest resolution for dating the Late Miocene.

Sedimentary characteristics

Three unconformities are present within the Late Neogene sequence: between the pre-Neogene and/or older Miocene and the Pannonian s.l. (SB3), between the late Miocene and Pliocene rocks (SB2), and the third between the Pliocene and Pleistocene (SB1) (Fig. 5a, b). Between SB3 and SB2 an apparently continuous sequence developed with four main units: a basal transgressive, a lower aggradational, a middle progradational, and an upper aggradational units, which were also observed on seismic profiles (Pogácsás et al. 1988a, b).

Boundary 3

In the studied sections, Pannonian sediments unconformably overlie Miocene and pre-Neogene rocks. Magnetostratigraphic data suggest that the age of the basal strata of the Pannonian sedimentary cycle ranges from 8.9 Ma to 11.2 Ma. In the different subbasins Pannonian sediments cover the eroded surface of older formations: Upper Cretaceous schist in borehole Bácsalmás, Upper Badenian red algal limestone in borehole Iharosberény, Sarmatian sandstone in borehole Jánoshalma, calcareous silt, sandstone and conglomerate in borehole Szombathely; and Sarmatian mollusc-bearing, coarse-grained limestone in borehole Kaskantyú. The maximum hiatus between the Pannonian and the older Miocene rocks is estimated as 6 Ma. The estimated minimum hiatus between the Sarmatian and Pannonian is 0.0 Ma to 2 Ma (see Fig. 5a, b, wells

Fig. 3
Isopach map of the Neogene basin fill of Hungary with the location of the studied boreholes.

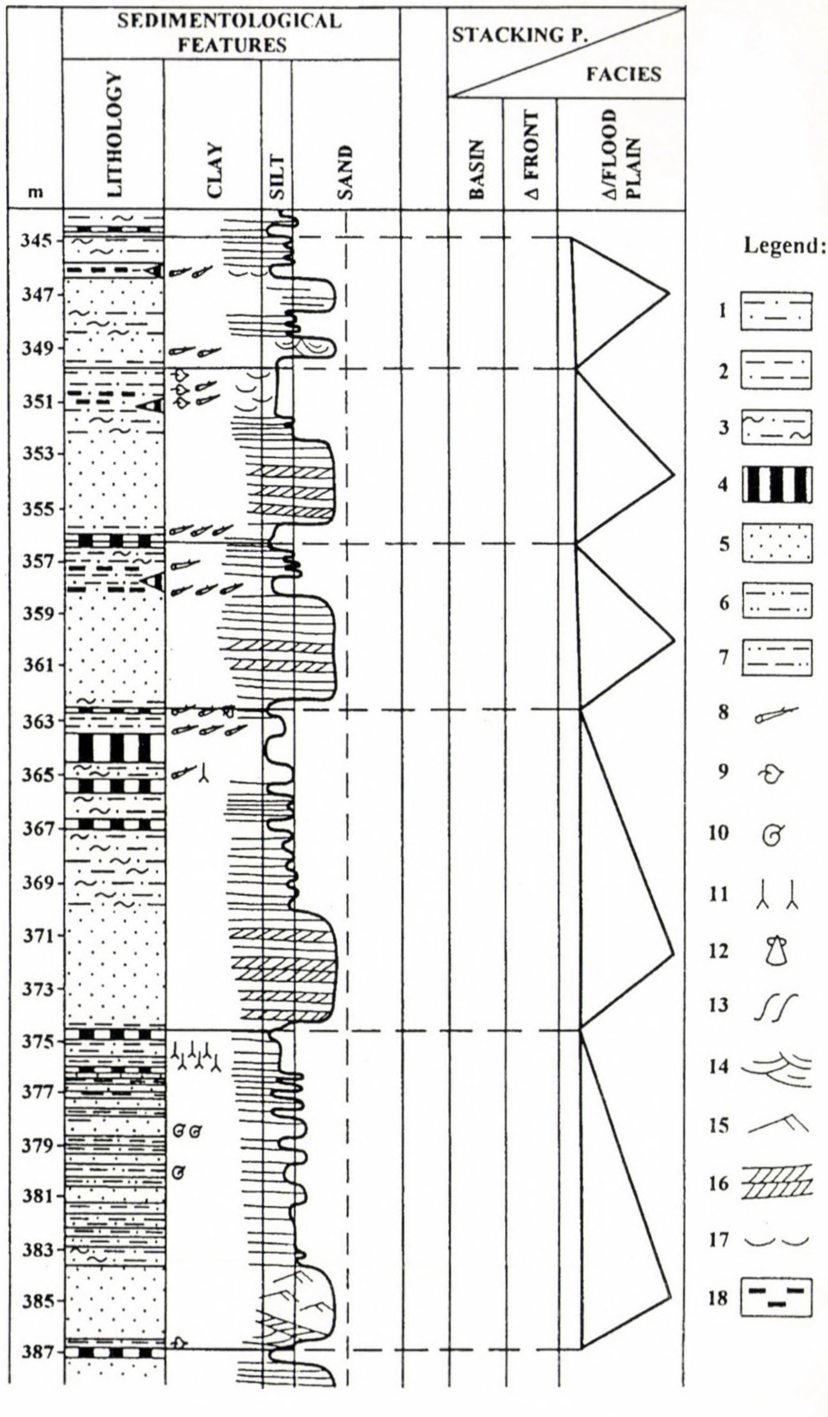
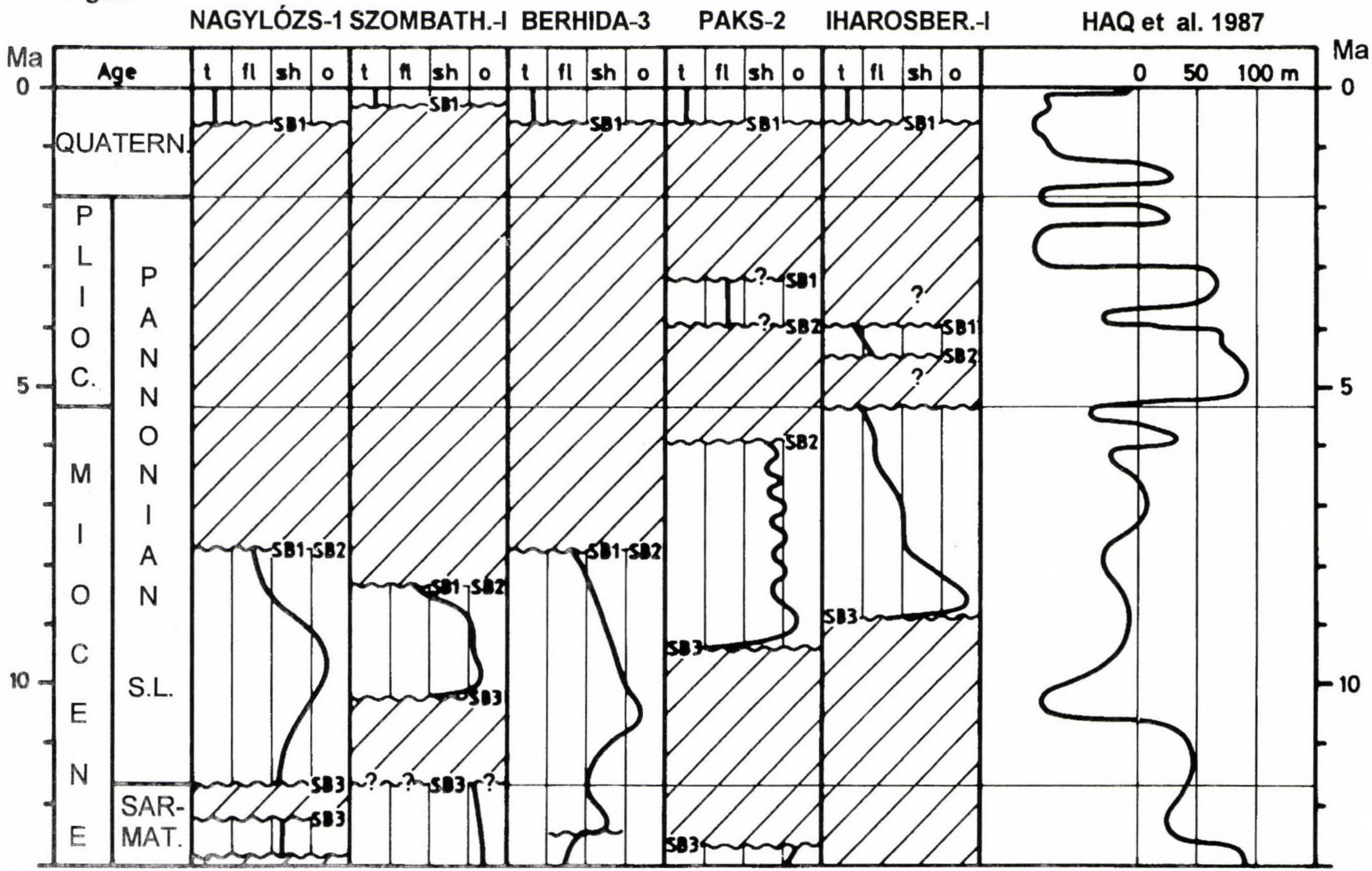


Fig. 4
Lithological and sedimentological features, the stacking pattern of the genetic units and the facies in borehole Iharosberény (Ib-1). The genetic units, whose thickness ranges from 12 m to 5 m, were formed in a delta plain environment with a clear aggradational stacking pattern. Note the decrease of thickness of genetic units and the relative increase of sand compared to other lithologies up-section. 1. silt; 2. silty clay; 3. marly silt; 4. lignite; 5. sand; 6 sandy silt; 7. sandy clay; 8. wood pieces in horizontal position; 9. leaves in horizontal position; 10. gastropods; 11. roots; 12. bivalves; 13. bioturbation; 14. tough cross beds; 15. ripple marks; 16. large scale cross beds; 17. conchoidal cracks; 18. organic rich silt/clay

Fig.5a


NAGYLÓZS-1
SZOMBATH.-I
BERHIDA-3
PAKS-2
IHAROSBER.-I
HAQ et al. 1987
Ma
Age
t
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0
50
100 m
5
10
QUATERN.
PLIOC.
MIOCENE
PANNONIAN S.L.
SAR-MAT.
SB1
SB2
SB3
SB1-SB2
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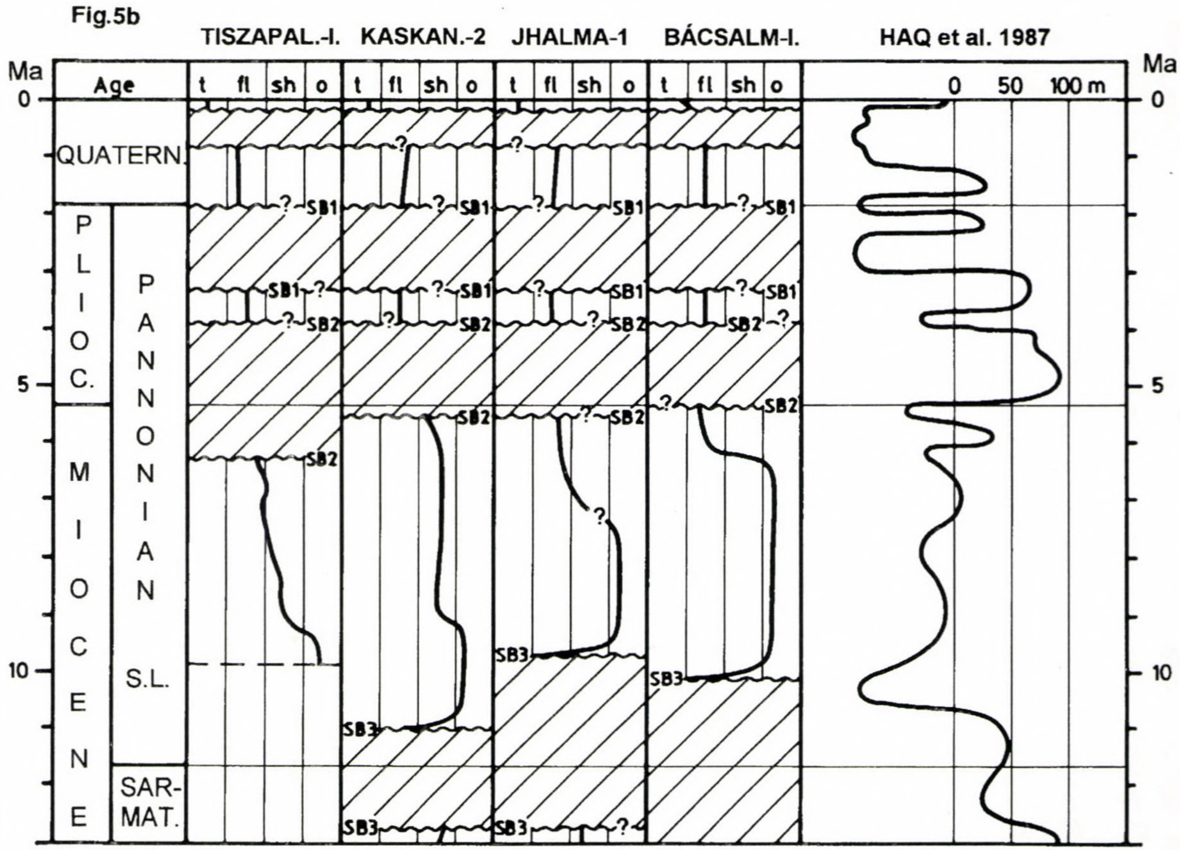


Fig. 5
Changes of the paleoenvironment *vs.* time in the studied borehole sections. a) ansdanubian sections; b) Great Hungarian Plain sections. SB1-3 – sequence boundaries; t – terrestrial; fl – fluvial; sh – shallow marine; o – open marine

Berhida, Nagylózs and Kaskantyú). In Berhida section the sedimentation between the Sarmatian and Pannonian seems to be continuous, based on sedimentological characteristics, and biostratigraphic data do not contradict this assumption (Fig. 5a). In most of the investigated cases, there is an angular unconformity between the Pannonian strata and the underlying rocks. The basal Pannonian layers contain reworked clasts of bedrock.

Boundary 2

A significant regional unconformity is observed between the Miocene and Pliocene sediments in the sections. In all cases, flood plain fine sand, silt and clay contain paleosols. At the top of the Pannonian succession, yellow and white mottles, calcareous nodules, and abundant root casts indicate subaerial exposure (Fig. 6). The thickness of the altered zone below the unconformity ranges from 1 to 10 m.

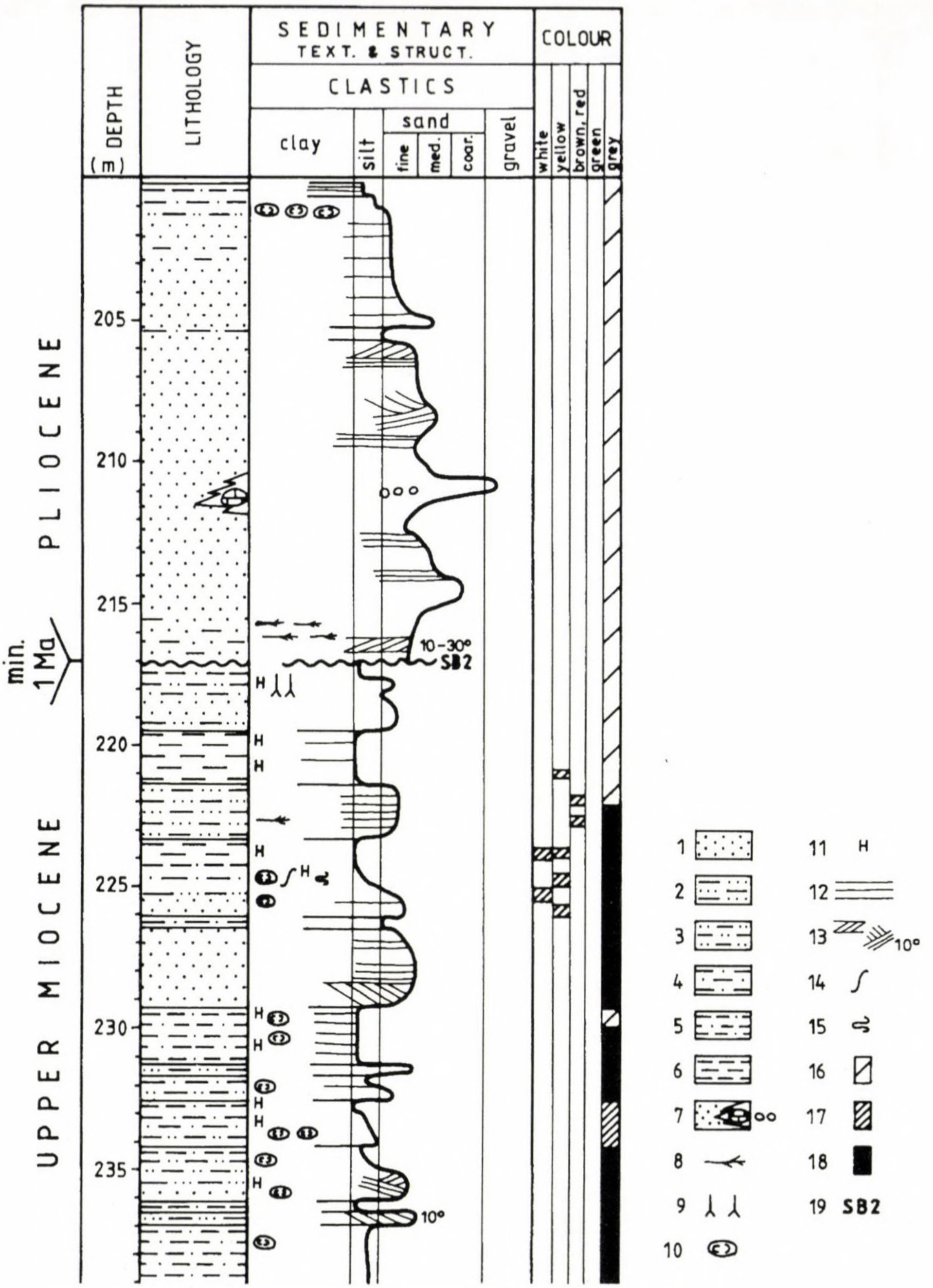
The Pliocene sequence starts with coarse channel sand and flood plain marl facies. There is a definite difference in colour and grain-roundness between the Pannonian and the Pliocene flood plain sediments: the Pannonian layers are grey, while the Pliocene ones are multicoloured, brown, red, grey and green. The grains of the Pannonian sand are very well and well rounded, and those of the Pliocene are subangular. In the Transdanubian part of the basin (see Fig. 5a) the Pliocene is poorly preserved compared to that of the Great Hungarian Plain (see Fig. 5b). In the Iharosberény well the Pliocene is only 21 m, whereas in the boreholes of the Great Hungarian Plain it can be few hundred metres thick.

Between the Pannonian and the Pliocene sequences magnetostratigraphic data indicate a 1.5–2.0 Ma hiatus.

Boundary 1

A subaerial erosional unconformity is present between the Pliocene and Pleistocene sediments. A 1–2 m thick Pleistocene soil occurs on the top of the Pliocene. In the Great Hungarian Plain (see Fig. 5b) the Pleistocene layers can be several hundred metres thick.

Fig. 6 →
Unconformity, representing about a 1 Ma gap between the Upper Miocene and Pliocene strata. Concretions made of calcium carbonate, root casts and mottled structure indicating subaerial conditions along SB2.: 1. sand; 2. sand with silt; 3. silty sand; 4. silt; 5. clayey silt; 6. clay; 7. rip-up dolomite clasts in sand; 8. coalified plant debris on bedding plain; 9. root casts, 10. calcium carbonate concretions; 11. huminite; 12. planar bedding or lamination; 13. crossbedding with the angle of cross strata; 14. bioturbation; 15. burrows along bedding plane; 16. pale tone of colour; 17. medium tone of colour; 18. dark tone of colour; 19. sequence boundary


SEDIMENTARY TEXT. & STRUCT.
CLASTICS
COLOUR
DEPTH (m)
LITHOLOGY
clay
silt
sand
fine
med.
coar.
gravel
white
yellow
brown, red
green
grey
PLIOCENE
UPPER MIOCENE
min. 1 Ma
205
210
215
220
225
230
235
10-30°
SB2
10°
1
2
3
4
5
6
7
8
9
10
11 H
12
13 10°
14
15
16
17
18
19 SB2

Sedimentological cycles

Between SB3 and SB2 an apparently continuous sequence was developed including four units with distinct stacking pattern:

Transgressive unit

In most of the studied boreholes, the base of the Pannonian sequence contains a thin (0–10, exceptionally 23 m), poorly sorted sandstone and conglomerate (Fig. 7). The most common types of clast (Badenian and Cretaceous limestone, quartzite and schist) were derived from the underlying Middle and Lower Miocene or pre-Neogene rocks, but rip-up clasts of mud or marl are also present.

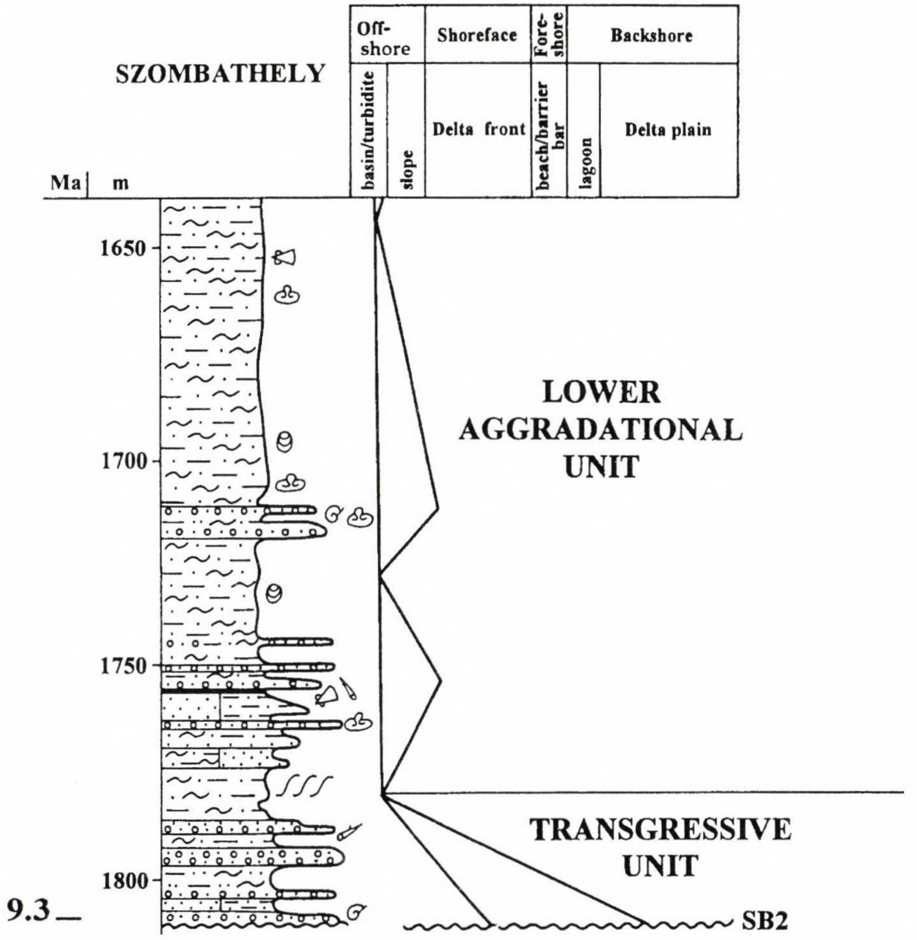


Fig. 7
Transgressive and lower aggradational stacking pattern of genetic units (parasequences) from borehole section Szombathely-I

The maximum diameter of the usually rounded clasts is 4 cm. Only subtle stratification can be observed in the conglomerate layers. They are capped by well laminated marl which contains molluscs, most commonly Congeria and Paradacna.

Lower aggradational unit

The lower aggradational unit overlies the transgressive layers. Most of the dark grey marl, calcareous marl, clayey silt and silt beds are structureless, but locally are laminated and bioturbated. Sporadically, shells and shell fragments of brackish water molluscs occur. The thickness of the basin (offshore) marl varies from 200–649 m in the boreholes. In each borehole the marls are interbedded with 10–15 cm thick, graded sand beds, which have irregular but sharp bases. The aggradational unit is made up of 1–6 smaller-scale cycles, each cycle containing facies which oscillate within the offshore, or between the offshore and shoreface. The thickness of the individual cycles range from 40 m to 210 m. The overall stacking pattern of the strata is aggradational (Fig. 8).

Progradational unit

Transitional units with a thickness of 70–200 m (Fig. 8) occur in the middle part of the sequence. They are made up of claystone, abundant coarse siltstone and fine sandstone. Strata dip as much as 7°. Graded bedding, alternation of siltstone and sandstone laminae, small-scale crossbedding, rip-up clasts in the base of sandstone beds and bioturbation are the most characteristic sedimentary features observed in these layers.

The transitional unit contains 1–4 smaller-scale cycles. Individual cycles range from 10 to 150 m in thickness. The environment of deposition changed from offshore to shoreface or to delta plain, showing a strong progradational stacking pattern (Fig. 8). The paleomagnetic data give approximately a 0.3–0.4 Ma time interval for the deposition of the transitional unit.

Upper aggradational unit

In the upper part of the Pannonian sequence (Late Miocene) flood plain facies sediments occur with an aggradational stacking pattern (Fig. 9). These deposits represent a variety of paleo-environments, including channels, lakes, ponds, marshes and flood plains. Large and small-scale crossbedding in the upward-fining sandstone, planar lamination or strong bioturbation of siltstone, shells or shell fragments, lignite beds, mottled clay and siltstone, calcareous nodules and root structures representing paleosols are the most characteristic sedimentary features in this unit.

The thickness of the upper aggradational unit varies from 30 to 1,280 m. The thickness of the smaller-scale upward-fining cycles ranges from 3 to 22 m. In most cases, the sediment is of delta plain or flood plain facies, but in the case

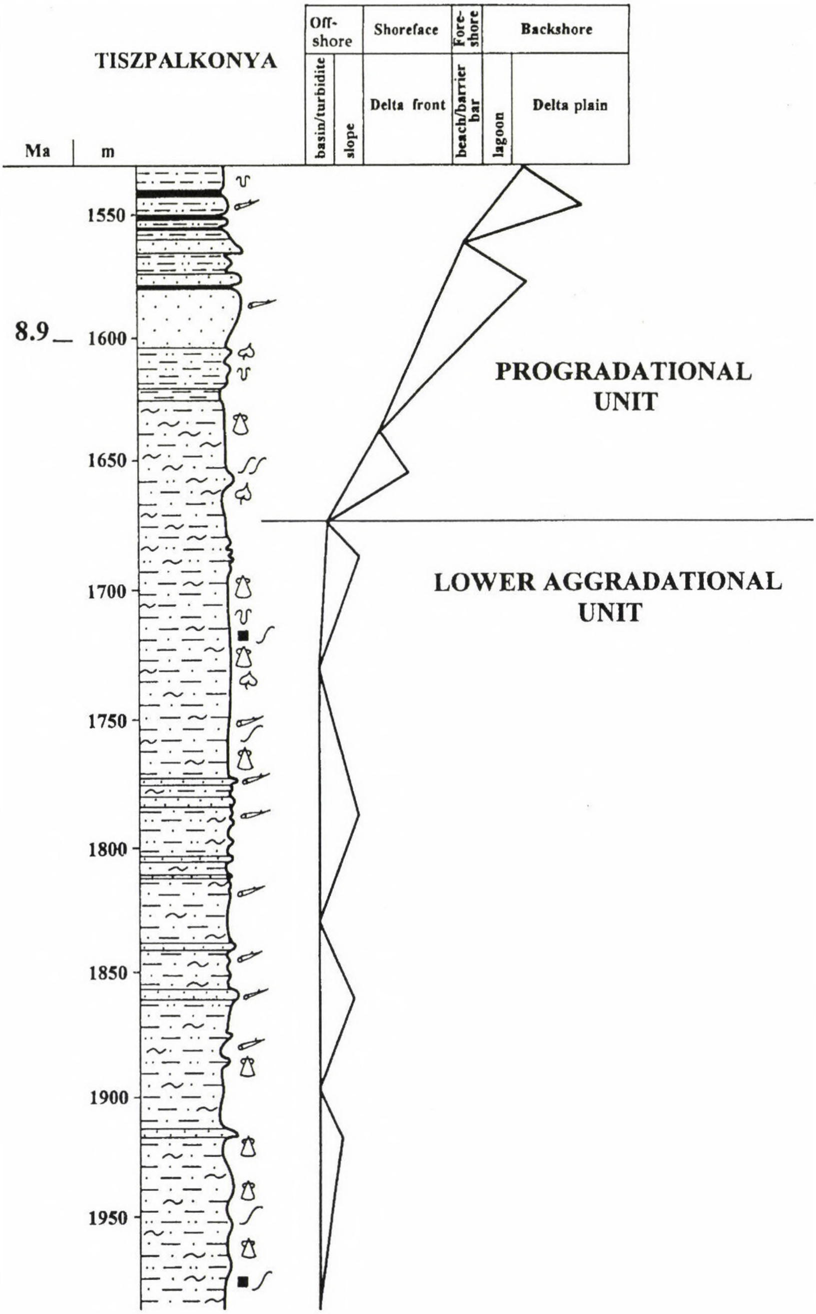


Fig. 8
Aggradational (lower) and progradational (upper) stacking pattern of genetic units (parasequences) from borehole section Tiszapalkonya-1

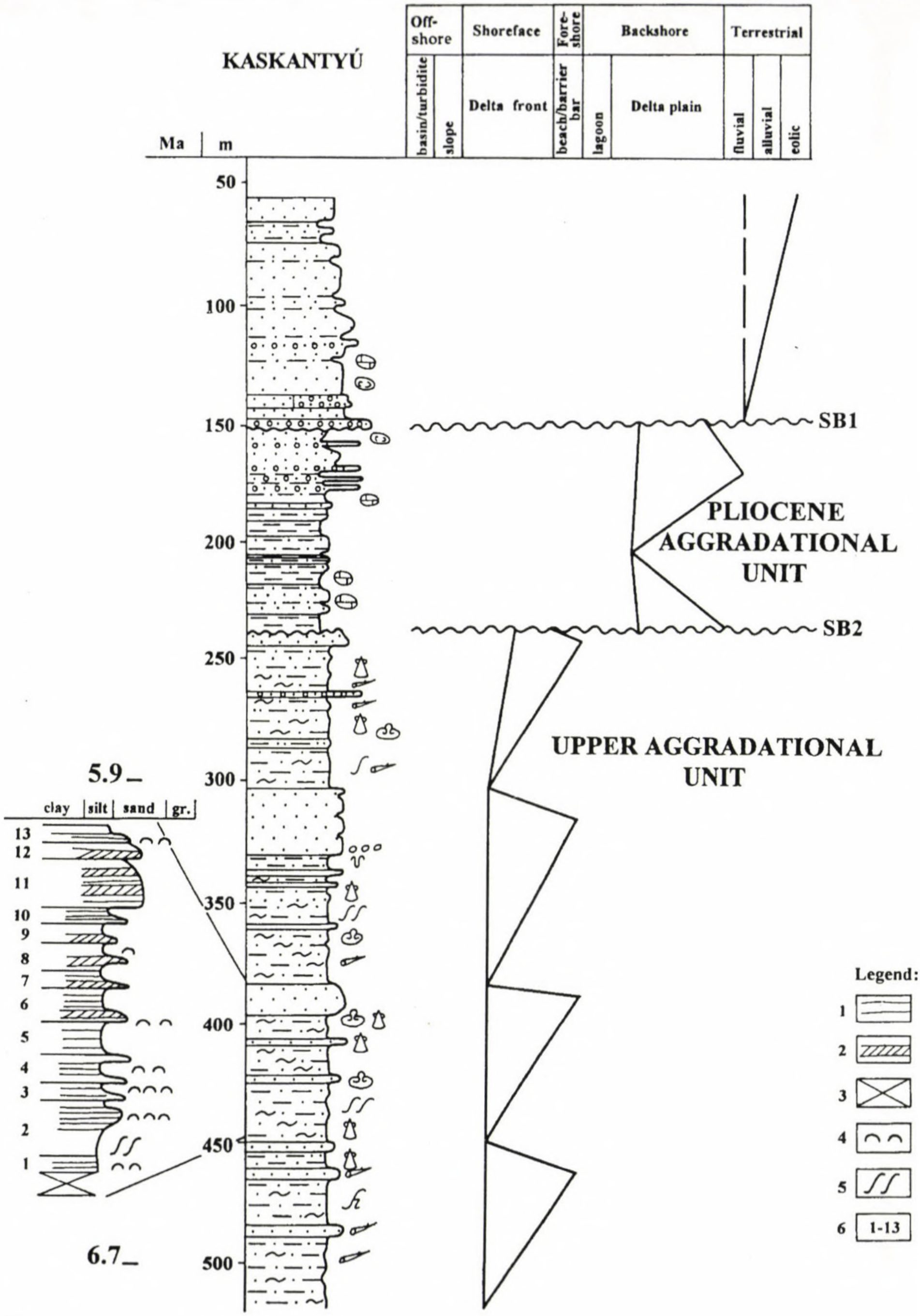


Fig. 9
The upper aggradational set of genetic units with elementary cycles from borehole section Kaskantyú-2, together with the Pliocene sequence. 1. bedded, laminated silt; 2. large-scale crossbedding; 3. lost section; 4. shell fragments; 5. bioturbation; 6. cycle number

of the basinal areas (Kaskantyú, Iharosberény boreholes) shoreface facies also are present. The stacking pattern of the cycles is aggradational with slight progradation, i.e. the thickness of the sand layers increases upward (Fig. 9).

The Pliocene sequence

An additional aggradational unit is present between sequence boundaries SB2 and SB3 (see Fig. 5a, b). Its thickness varies from 20 m to 140 m. It consists predominantly of coarse, fining-upward channel sand with large-scale cross-stratification, and subordinate finer grained sediment with calcareous nodules, and a fluvial and terrestrial fauna (Viviparus, Helicidae). The entire unit contains 1–5 smaller-scale cycles with a maximum cycle thickness of 50 m. The facies oscillates within the fluvial regime in the marginal areas, while in the basinal areas the environment varies between the delta plain and fluvial facies (Fig. 9).

Basin subsidence

Thermal subsidence, beginning about 13 Ma ago, followed an earlier phase of rifting, was diachronous throughout the basin (Royden 1988). Pronounced differential subsidence also resulted in several sub-basins, some containing more than 5,000 m of sediment. Although chronostratigraphic control is poor for these deeper sub-basins, deposition probably spanned a similar period to those boreholes studied here, attesting to very high subsidence and sedimentation rates in different parts of the Pannonian Basin. The subsidence analysis shown here therefore represent only the "shallower" parts of the basin.

In subsidence analysis, backstripping a column of sediment separates the isostatic effects of sediment and water load, from the effects of tectonic subsidence (Steckler and Watts 1978). The data used to calculate tectonic subsidence, according to the techniques outlined by Sclater and Christie (1980), and Bond and Kominz (1984) are: 1) Time-stratigraphic data, which for the Pannonian basin are derived primarily from magnetostratigraphy (Lantos et al. 1992), and a few K–Ar age dates; 2) Thickness and lithology, obtained directly from the borehole core; 3) Porosity–depth data, used to correct for changes in compaction and cementation, are not directly available in the boreholes – the standard exponential porosity–depth relations and material parameters of Sclater and Christie (1980) were used; 4) Paleobathymetry, perhaps the least controlled factor in any basin analysis, is difficult in the Pannonian Basin because of the highly endemic molluscan fauna. In this analysis we have tended towards conservative paleowater depths. They range from zero where subaerial exposure is indicated, 0–10 m for shoreface deposits, up to 50 m for shelf like deposits, to a maximum of 200 m, or in some very deep sub-basins more, for slope and "deep basin" facies.

Backstripping of four of the boreholes (Fig. 10) indicates two patterns of subsidence, again illustrating the differential nature of the basin dynamics. All four wells show initial rapid subsidence between 11 and 9 Ma, corresponding to the basal transgressive, and subsequent deep-water deposits of the succeeding highstand (above SB3, see Fig. 5a, b); however, there are significant differences between the Bácsalmás–Jánoshalma and the Kaskantyú–Tiszapalkonya boreholes. The actual amount of accommodation space created in the latter two boreholes during this time period (tracked by the basement curve), is almost double that of the Bácsalmás–Jánoshalma holes. Furthermore, the uplift recorded in the Bácsalmás–Jánoshalma boreholes between 9 and 5 Ma is not observed in the other two holes. Here, the basement and tectonic curves are markedly divergent, suggesting an additional component of accommodation space to that formed by thermal–isostatic subsidence.

Discussion

The subsidence and infilling of the Pannonian basin occurred principally during the Late Miocene and Pliocene. The studied boreholes, with full core recovery, are sufficiently scattered over the area of the basin to depict a general picture of its evolution. Sequence stratigraphical remarks are summarized on Fig. 5a, b. On the figure the generalised depositional environments are pictured as a function of time for each section. The curves illustrate the shoreline shifts, which give information for the relative lake level changes. The major subaerial unconformities and the sequences between them are presented as well. For comparison, the eustatic sea level curve is added (Haq et al. 1987).

Unconformities

Magnetostratigraphic data of Lantos et al. (1992) were applied to the borehole sections. At SB3 the basal Pannonian sediments have a magnetostratigraphic signature that corresponds to an age of 12.0 and 8.8 Ma; the unconformity represents a significant gap (0.5–7.0 Ma). The Berhida section is exceptional in this respect, since the sedimentation seems to be continuous between the Sarmatian and the Pannonian.

In the studied boreholes, the youngest magnetostratigraphic dates are 5.9 Ma at 300 m in the Kaskantyú and 6.4 Ma at 400 m depth in the Tiszapalkonya boreholes. Due to the unsuitable physical state of the oxidised, loose sediments, it was not possible to correlate the uppermost strata to the global polarity scale (Lantos et al. 1992).

The three unconformities (SB1, SB2, SB3) identified in the basin fill represent significant erosion and a minimum 0.5 Ma and maximum 7 Ma gap. They are interpreted as regional or single (SB3), and super or composite unconformities (SB2 and SB1). In terms of sequence stratigraphy they bound 3rd order

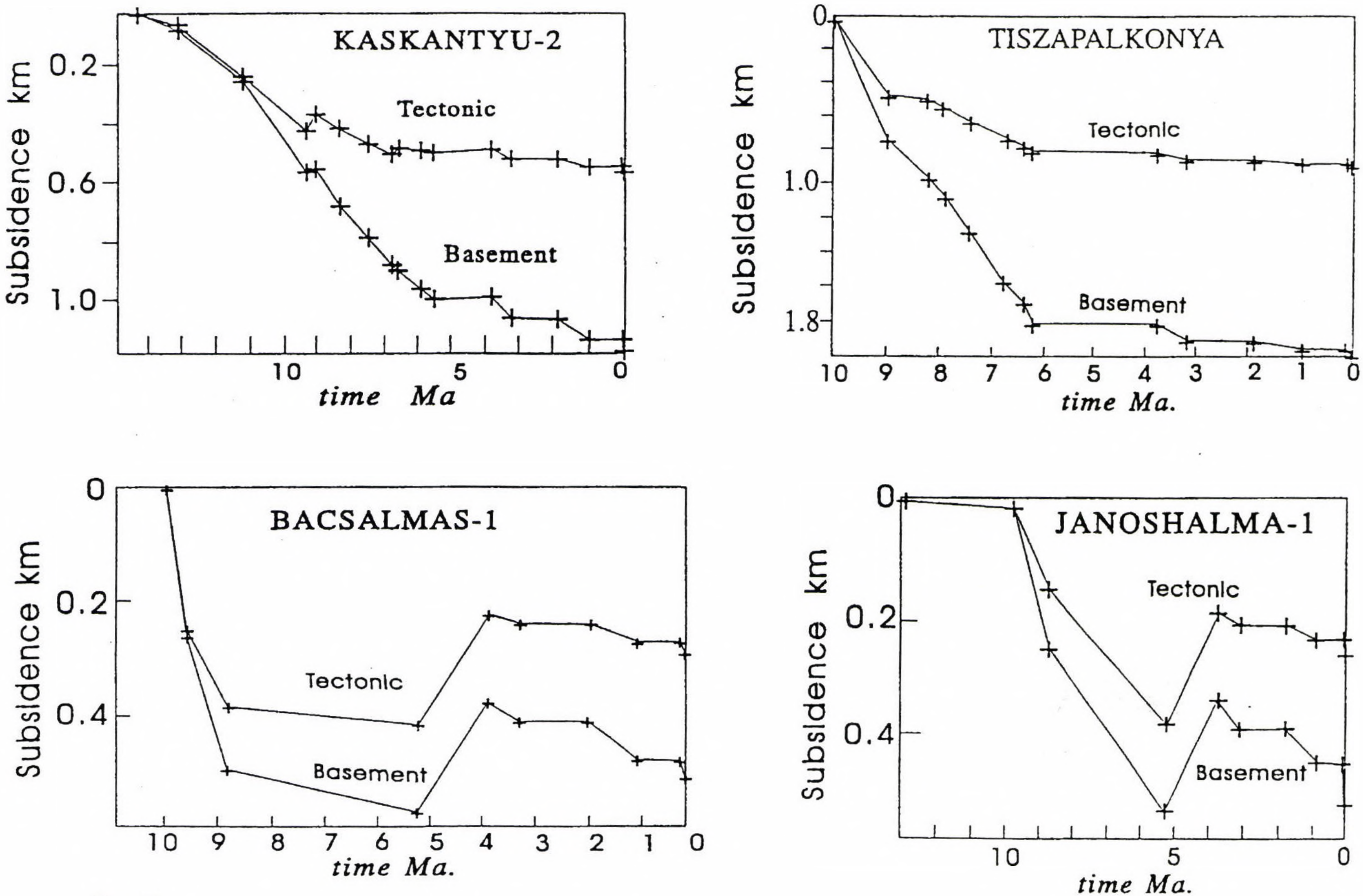


Fig. 10
Subsidence curves of some Great Hungarian Plain sections

sequences (see Fig. 5a, b). Therefore two third-order sequences are present in the studied boreholes: Late Miocene and Pliocene sequences.

The unconformity at the Miocene/Pliocene boundary (SB2) seems to correlate well with the Messinian salinity crisis recognised by Hsü (1978).

Sedimentary units

The succession of the changing sedimentary environments record the relative water level changes in the Pannonian lake. Between SB3 and SB2 an apparently continuous sequence was developed, including four units with a distinct stacking pattern: a basal transgressive, a lower aggradational, a middle progradational, and an upper aggradational unit. An idealised profile of the Pannonian basin fill (Fig. 11) shows the main sedimentological features, the facies distribution, the stacking pattern with the observed thickness conditions, the time control, derived from the *in situ* magnetostratigraphic measurements, the bounding major unconformities, and the relative lake-level changes based on the genetic stratigraphic analysis.

Above SB3 a relatively rapid transgression is expressed by the landward shift of facies. Subsequently, deep-water environments were established and a distinctive aggradational unit accumulated. The striking basinward shift of the facies, i.e. a drop in relative water level, is a characteristic part of each lake level curve. The upper aggradational unit, up to the Miocene/Pliocene boundary (SB2), records an equilibrium between sedimentation rate and basin subsidence (i.e. there were no major changes in the accommodation potential).

The Pliocene sequence occurs between the Miocene/Pliocene (SB2) and Pliocene/Pleistocene (SB3) unconformities. The predominantly fluvial character is strikingly different to the upper part of the Late Miocene sequence.

Correlation

Nine boreholes (Fig. 5a, b) were used for the intrabasinal correlation. Most of them were dated by magnetostratigraphic measurements (Lantos et al. 1992), using biostratigraphical and radiometric tie-points, enabling a good estimation of the age of the sedimentary cycles. For the upper Miocene deposits of the Jánoshalma-1, Bácsalmás-I and Paks-2 boreholes the magnetostratigraphic dating was extended with reasonable accuracy using seismic reflector tracking, and by biostratigraphic correlation. In the case of the Pliocene and Quaternary deposits, the time span of deposition was estimated mostly by biostratigraphical correlation.

The recognised facies changes of the genetic units were assembled into four main facies groups: terrestrial, fluvial, shoreface and offshore sediments. The temporal change of environment at the studied sites was plotted against time in the diagrams (Fig. 5a, b). The diagram illustrates also the global (eustatic) sea level changes as proposed by Haq et al. (1987).

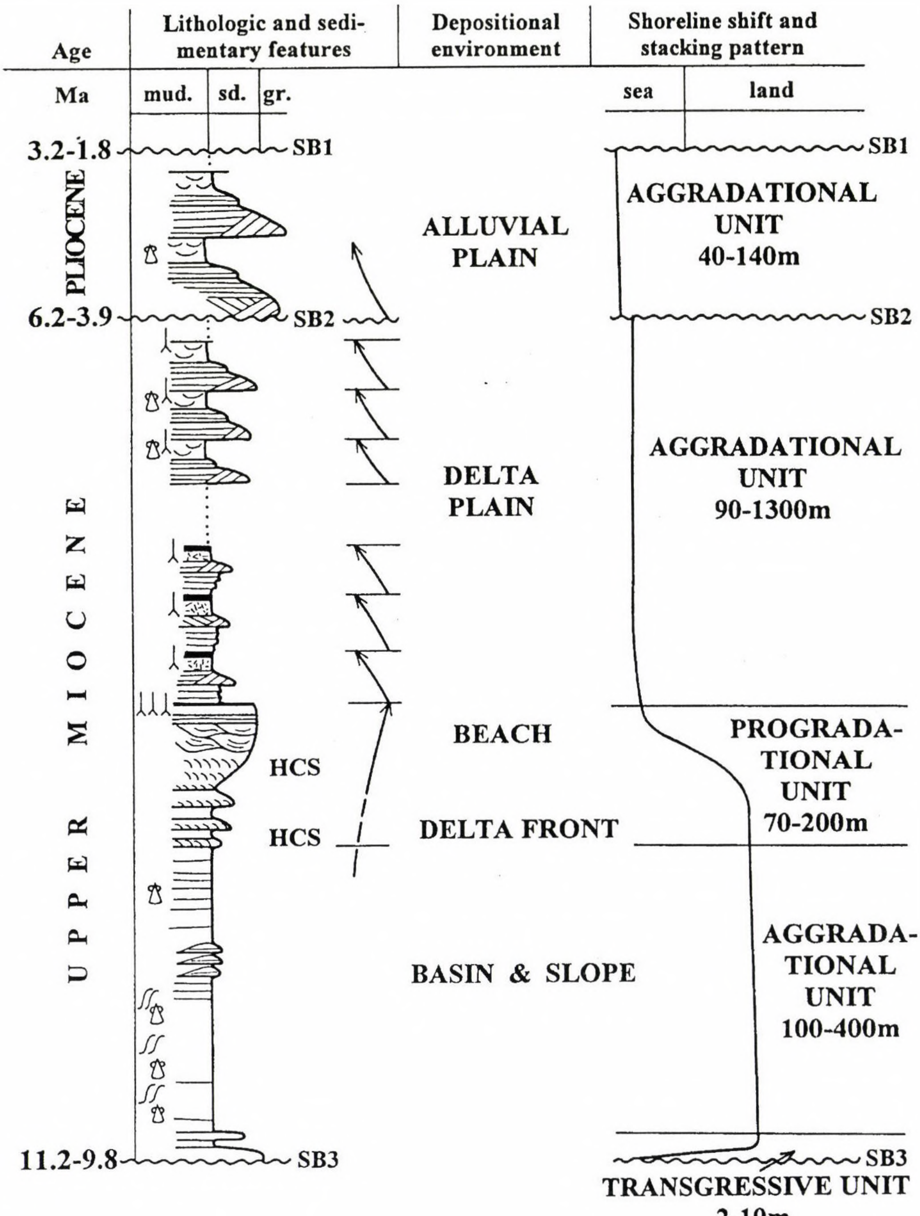


Fig. 11
Complex presentation of the stratigraphic, lithologic, sedimentologic and facies characteristics of the Pannonian basin fill. The cycle analysis was carried out on the Upper Miocene sequence (except for the basin and slope facies sediments). The upper part of the Upper Miocene sequence is cyclic; however, the cycle thickness and cycle stratigraphy can be variable. The stacking pattern of the genetic units and the shoreline shift indicate two dramatic changes in the life of the Pannonian Lake: right above SB3 a rapid and intense transgression, which gave rise to the lake, and the progradational unit with a distinct shoreline shift towards the sea. The ages of the sequence boundaries were determined by magnetostratigraphic measurements. The lithologic and sedimentologic features were identified on the continuous cores of the studied boreholes

These diagrams may be regarded as a rough estimation of relative lake level variations in the former surroundings of the studied boreholes. The stacking pattern of each borehole shows a general regressive, upward-coarsening trend. The shift of the site of deposition from terrestrial to offshore, then from offshore to shoreline, or terrestrial facies groups, is time-transgressive in the basin. This is especially clear in the case of the four boreholes of the Great Hungarian Plain (Fig. 5b), which are arranged in the sense of the progradational infilling of the basin. Thus, the shift from offshore to shoreface (or even to fluvial and to terrestrial) facies groups reflects the prograding delta- and interdelta infilling process. Taking the magnetostratigraphic data into account, it is evident that the progradational components in each well do not coincide in time within the basin. Therefore, the dominant controls of the progradational process were probably the changing basin subsidence and the very high sed- imentation rate, but not the lake level drop.

Most probably the signals of low-frequency lake level changes were overprinted by the high sediment influx. Very faint records of low-frequency lake level changes were detected only in few cases (Juhász et al. in press). Only slight if any correlation can be observed between the water level changes of the Pannonian Lake and the oceans (see Fig. 5a, b).

Conclusions

1. Basin subsidence curves indicate the different subsidence history of the sub-basins. The break in the subsidence (locally the uplift of the basement around 9 million years ago) cannot be explained with the change of the paleo-water depth exclusively.

2. On the basis of the detailed sedimentological studies three regional unconformities were detected in the Late Neogene Pannonian basin fill, which can correspond to 3rd order sequence boundaries. Consequently two third-order sequences form the Late Neogene Pannonian basin fill: a Late Miocene and a Pliocene one.

Based on paleomagnetic data it is obvious that neither the transgression, nor the progradation, recorded in the Late Miocene sequence, coincide in time within the basin. The dominant controls of the latter process were probably the changing basin subsidence and the very high sedimentation rate. The slow, trend-like increase in frequency of silt and sand beds along the sections would fit with the idea that the Pannonian Lake was infilled by the basinward migration of the marginal facies.

3. There are only slight similarities between the sea-level curve (Haq et al. 1987) and that of the Pannonian lake level in 3rd order scale, suggesting that the sea level fluctuations had no direct influence on the lake level.

4. The SB2 boundary, at the top of the Late Miocene sequence, seems to reflect a major global or Mediterranean event. It may be correlated in time, and

probably causally, to the Messinian salinity crisis, and the Lago Mare event as well. A similar conclusion was drawn by I. Csató (1993).

5. The Pliocene fluvial sequence, between SB1 and SB2, is also of an aggradational character. The abundance of calcretes points to a semiarid climate. This sequence is absent in most of Transdanubia (West Hungary).

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Geochemistry and stable isotope ratio of modern carbonates in natron lakes of the Danube–Tisza Interfluve, Hungary

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In the Danube-Tisza Interfluve region of Hungary, there are some one hundred lakes of different sizes. During the Holocene calcite, dolomite, and sometimes magnesite, were precipitated in these lakes.

In order to determine the sedimentary environments, and aiming at a comparison with various other lacustrine sediments, the chemical and isotope characteristics of these sediments were studied.

Three types of lakes were distinguished in the studied area. The salinity of "A" type lakes is low and the water level changes, but they seldom dry up. The carbonate precipitated is calcite; its formation is a result of the carbon dioxide consumption of aquatic plants, and, partly, of evaporation. The lakes of type "B" are only a few dm deep, recharged primarily by rain, snowfall and ground water. Intensive evaporation results in the precipitation of dolomite, in major changes of lake surface, and high salinity. Type "C", similarly to the type "B" lakes, are ephemeral, and their carbonate content is also similar. They are, however, recharged from waters remaining after Danube floods; thus the $\delta^{18}O$ values of their carbonate sediments are more negative than those of the previously mentioned lake types.

Additionally, there are carbonate sediments designated as "D". These are deposits of "A" type lakes, which have been diagenetically modified. Consequently, their chemical and isotope characteristics vary over a wide range.

The chemical properties and isotope ratios of the carbonate deposits of the Danube-Tisza Interfluve differ from those of other regions, indicating a special sedimentary environment here.

Key words: Carbonate sedimentology, geochemistry, isotope geochemistry, lake environments analysis

Introduction

The Danube–Tisza Interfluve area is situated in central Hungary, and is 180 km long by 120 km wide. The Danube (Duna) valley proper is tectonic and erosional in origin. Its elevation is 90 to 100 m above sea level. It is filled with gravel and coarse sand; the surface is covered with silt and, locally, with peat. Before the present-day water management works and dam constructions, it was an active floodplain, of a width of 5 to 15 km.

There is a slightly elevated divide east of the Danube valley. Its elevation is about 100–150 m, and its width 70–80 km; it is covered with wind-blown sands

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and loess. The sands were arranged in NW–SE oriented dune rows by the prevailing Holocene winds. The dune crests are some 10 to 20 m higher than the interdune depressions.

The Tisza valley is situated to the east of the loess and sand-covered divide; its width is about 10 to 15 km, and its elevation about 80 m. It is filled with fluvial sands and silts.

In the interdune depressions and in the Danube valley there are about 100 lesser or greater lakes. Their width is about 100 to 200 m, their length 5 to 6 km, and their depth a few dm. Even during wet periods the greatest depth of the lakes in the area never exceeds 1 or 2 m. During the drought of the last ten years most of the lakes dried up. The Holocene lacustrine deposits, however, indicate the position and number of former lakes.

Summer air temperatures on the Danube–Tisza Interfluve often exceed 30 °C. The water temperature of shallow lakes may reach 30 °C as well. The groundwater level was formerly situated at 1–5 m beneath the surface, but in depressions it often was located above ground level. During the latest dry period it sank to below 3–8 m. Often several weeks are totally rainless. Evaporation rates of lake water is high, and at the end of August most lakes have dried up, even during wet periods.

The salinity of groundwaters is high in the vicinity of these lakes, generally between 500–2000 mg/l, but sometimes in excess of 4000 mg/l. Evaporating interdune lakes are mainly recharged from the groundwater; thus, their salt content is between 8000–70000 mg/l. Among ions in lake waters Na^+ dominates, but Ca^{2+} and Mg^{2+}, as well as HCO_3, may reach high values. The summer value range of lake water pH is 9–11.

Most interdune lakes lack surface in and outflow. The lakes on the Danube floodplain obtained their water from annual floods prior to the regulation of the river.

It has been demonstrated (Molnár 1980, 1991; Molnár et al. 1980) that calcite, dolomite, and sometimes magnesite mud was precipitated from these lake waters.

The substratum of interdune lacustrine deposits is latest Pleistocene loess or aeolian sand. In the case of the Danube valley lakes it is generally Holocene fluvial (Danube) sand. There are two types of lacustrine sediments, namely dolomite mud (Fig. 1) and peaty carbonate mud, predominantly calcite. Due to a fall of groundwater level some lakes dried up in the early Holocene; thus, the evolution of lacustrine systems ended there. In such cases a lithification (mainly cementation) of carbonate mud began in the zone between the highstand and lowstand of the groundwater level (Fig. 2). In some instances the carbonate mud was covered by late Holocene wind-blown sands (Fig. 3).

The differences between the genesis of lacustrine carbonates of interdune and Danube valley lakes has remained unclear. Stable isotope and chemical analyses were carried out to solve these problems.

Fig. 1
Section of dolomite mud of lake Kisréti

Sampling and analytical methods

175 sediment samples were taken along 17 vertical profiles from 10 sites within 10 lakes in the Danube–Tisza region (Fig. 4). The samples were selected in order to cover all known lithologies as they have been previously described by Molnár (1980, 1985, 1990, and 1991).

Bulk sediments were oven dried at 60 °C and then homogenised by grinding. The mineralogy was identified by X-ray diffraction (Philips PW 1710 diffractometer, Cu Kα radiation). The relative amounts of calcite and dolomite were estimated using the peak heights of the strongest reflection of both minerals (Tennant and Berger 1957).

After leaching the bulk samples in hot concentrated HCl the element concentrations of Fe, Mn, Ca, Mg, and Sr were measured by atomic absorption spectroscopy (Perkin-Elmer flame-AAS).

The inorganic and organic carbon contents of the samples were measured by combustion of total carbon to CO_2 using a Ströhlein coulomat 702; after the inorganic carbon was dissolved only the organic carbon was measured.

For carbonate isotope analysis ($\delta^{13}C$, $\delta^{18}O$), 30 to 100 mg (depending on the carbonate content) of the bulk sample material was allowed to react with 100% phosphoric acid at 25 °C (McCrea 1950), and the produced CO_2 was analysed in a stable isotope mass spectrometer (MAT 250). The results are reported in the common notation relative to the PDB-standard.

Chemical analyses

Figure 5 depicts the main types of the studied carbonate sequences. At the bottom of this figure are presented the results of the chemical analysis

Fig. 2
Partly cemented hard carbonate in the Csólyospálos section. a. red iron precipitate hard carbonate; b. light grey hard carbonate; c. uncemented dolomite mud

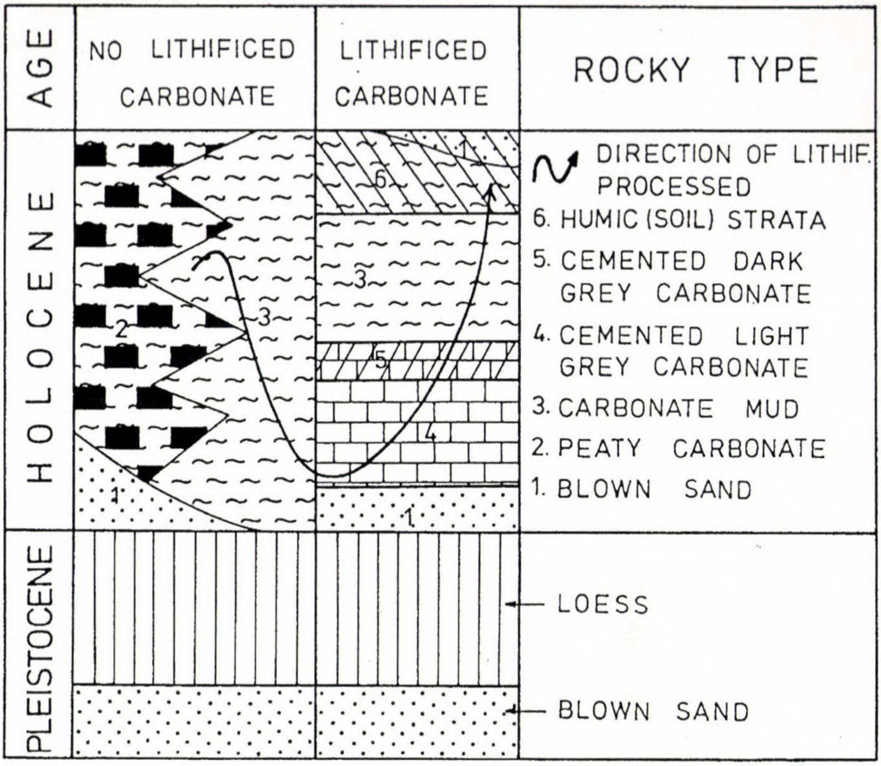


Fig. 3
Idealised sequence of lacustrine carbonates and their substrata

performed on loess and aeolian sand samples from the well Szappanosszék-12, regarded as typical for the Danube–Tisza Interfluve sediments. In this area these sediments constitute the substratum of the lakes and lacustrine deposits. Thus the effects of lacustrine sedimentation upon these layers could be investigated.

The subsequent section on Fig. 5 is that of Lake Kolon, representing the peaty-carbonate sediment type. The examples of lake Ródliszék in the divide area and lake Kisréti in the Danube valley represent the lacustrine carbonate sediment sequences. The section of the Csólyospálos sequence is typical for lithified carbonates. In this last mentioned case the lacustrine regime ended earlier. Carbonates dissolved in the groundwater cemented the mud in the zone of seasonal variations of the groundwater level, resulting in a hard rock (Molnár et al. 1980).

Based on the individual sections, the following characteristic variations in geochemical properties can be demonstrated:

a) The iron content of the loess substratum of the lakes is about 0.8–1.2%. In wind-blown sand this value is about 0.3%. Manganese content displays a similar trend: in loess it is 300 to 400 ppm, and in sand about 100–200 ppm. The amount of iron and manganese in the sections was determined but will not be dealt with in detail in this paper.

The calcium, and, particularly, the magnesium content is low if compared to lacustrine deposits, except for the peat-carbonate sediments. The calcium content of loess is 5–9%, and of wind-blown sands 4–5%. The magnesium content of loess is 1.5–2.3%, and of sand 0.6–1.0%.

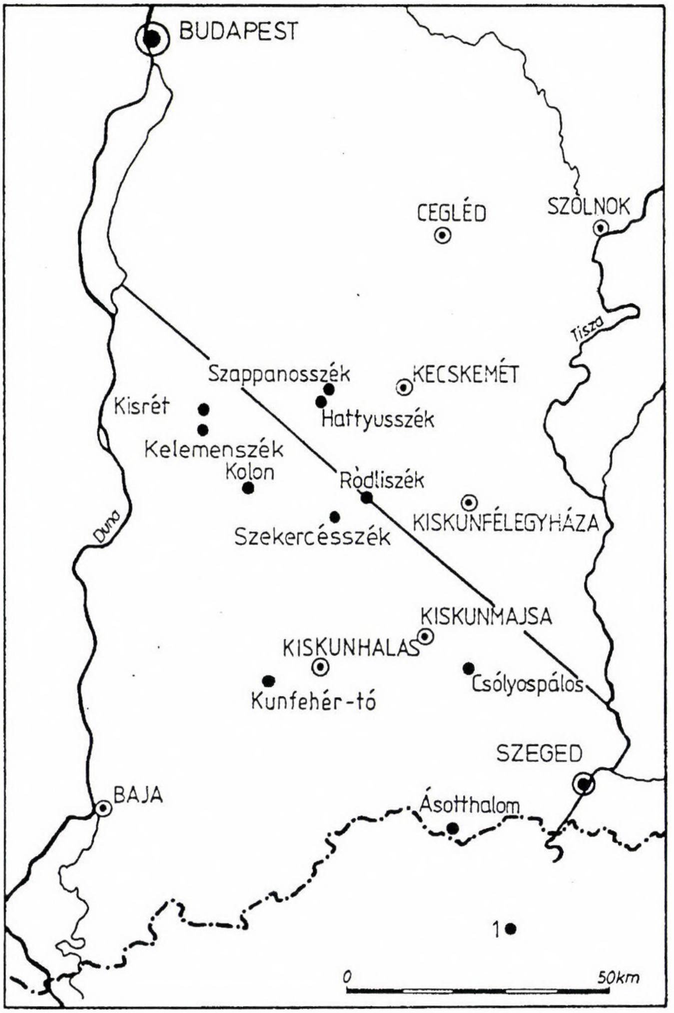


Fig. 4
Location of geochemically studied lacustrine deposit sections with the reference line of the section on Fig. 9, used as model for geological and geomorphologic settings. 1. sites of sections

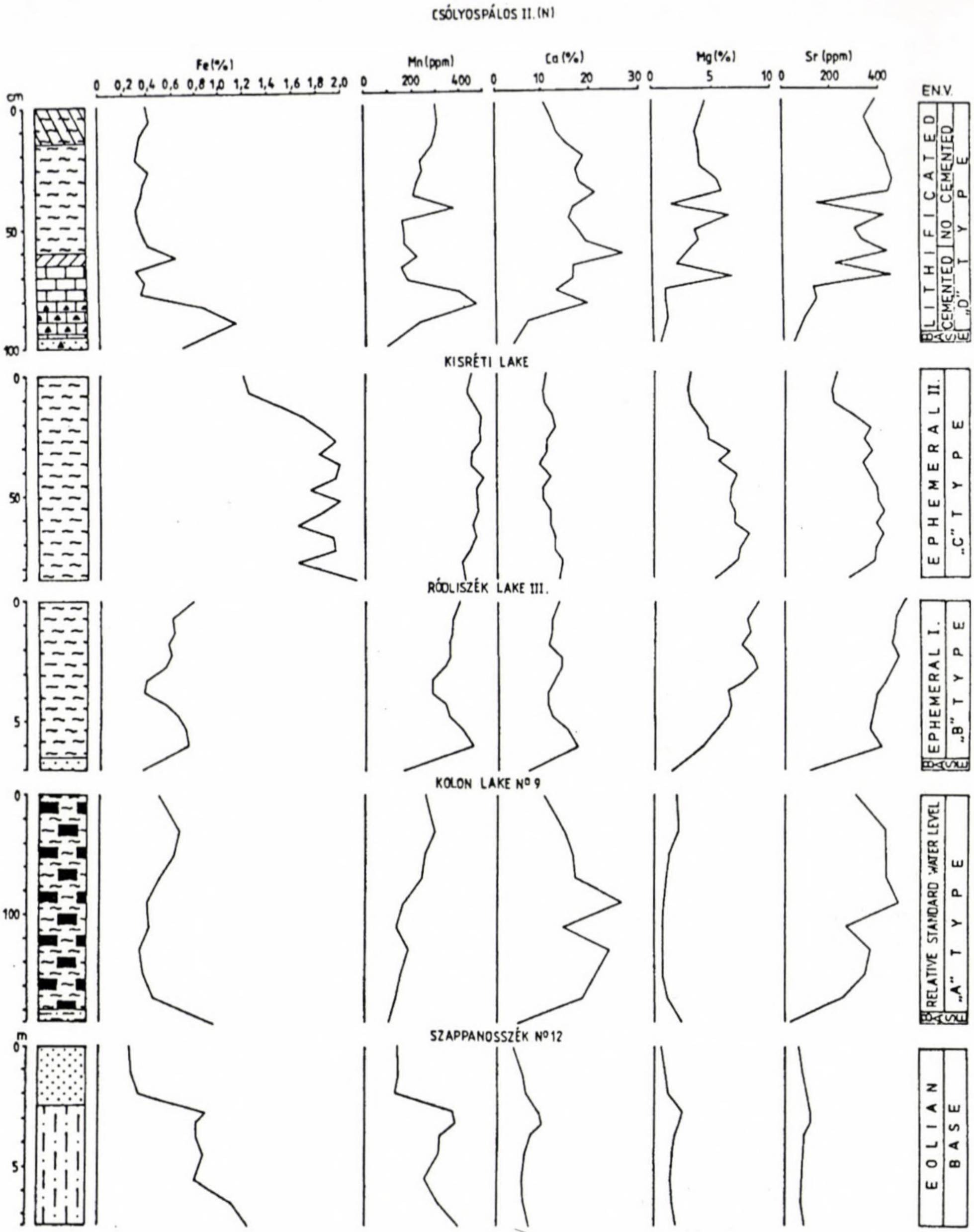


Fig. 5
Results of chemical analyses of lacustrine carbonate section types in the Danube–Tisza Interfluve (marks refer to Fig. 6)

Strontium content is very low, about 100 to 200 ppm, equally in aeolian sands and loess.

b) In the lower part of the Lake Kolon section the iron content of the wind-blown sand is 0.9%. The lacustrine carbonate capping the sand contains only 0.4%, due to a sudden change at the boundary. Upsection the value increases; at 20–40 cm depth it reaches 0.6%. The manganese content also increases upward, from 100 ppm to 300 ppm.

The peaty carbonate section at Ásotthalom contains more iron and manganese than the lake Kolon section; the values increase upwards here, too.

The percentage of calcium content, since the section is of carbonate type, is higher than at the base, and may reach a value of 4–26%. The magnesium content is similar to the previous ones, just about 0.5–1.0%. It will be shown that this is caused by the calcitic nature of carbonates in this sequence. In other sections, however, dolomite may dominate or at least occur in significant quantity.

The strontium value in the wind blown-sand at the basement is merely 50 ppm, increasing upward, reaching a value of 300–400 ppm.

c) In the Ródliszék section the chemical composition of the wind-blown sand at the base is similar to that of the Szappanosszék one. However, the magnesium values differ significantly from those observed in the lake Kolon section, increasing upwards from 3 to 8%. The strontium content increases upsection as well, from 398 ppm to 492 ppm. The quantity of iron dramatically increases in the carbonate above the boundary, at 0.7%. Similarly the manganese has a value above 400 ppm. At 40–45 cm, where the maximum value of dolomite is encountered, these quantities decrease to 0.5% and 338 ppm. Upward from here they increase again; close to the surface they are 0.8% and 400 ppm, respectively. These data refer to the section at the centre of the lake. At its margins, close to the shore, the sections show somewhat lower values for iron (4–5%). The higher value at the centre is due to the more prolonged inundation there, resulting in a higher accumulation of salts, iron, and magnesium. Lakes of this type are characterised by the predominance of dolomite in the carbonate sediment, which means a higher value of magnesium content. The high strontium value is attributable to an increased evaporation, connected with the dolomite formation.

d) The carbonate sequence of Lake Kisrét does not extend to the substratum. Iron and manganese show the highest values here, with 1.6–2.1% and 400–500 ppm, respectively, due to a special sedimentary environment, as will be discussed later.

Calcium and magnesium values are close to those of the Ródliszék section. the calcite/dolomite ratio increases upward; accordingly, the magnesium value decreases from 5–6% to 3%, and that of strontium from 400 to 200 ppm. Lake Kelemenszék also belongs to this type; the observed trends in its sequence are identical to those of the Kisréti section.

e) Chemical data of the Csólyospályos sequence are more variable than those of the previously mentioned carbonate sections. In its lower part there is a hard cemented carbonate rock instead of a mud, due to diagenetic processes. The sequence was influenced by results of geological processes not observed in the previous sections, which is reflected in the diverse chemical values.

Aeolian sand at the base of this section shows values identical to the previous ones. The hard carbonate is variegated with iron-containing patches, there the iron content is 1.2%, and that of manganese 450 ppm, although in lower parts of similar sections these values may be as high as 6.2% and 1100 ppm, respectively. The groundwater level is situated in this depth; its seasonal changes and migration of ions is the cause of these accumulations. Calcium content is 10–20%, and that of magnesium 2–7%, changing significantly. The intergranular cement between the grains of the original dolomite mud is calcite, since it was precipitated from the groundwater, which has a lower Mg/Ca ratio than the lake water (Molnár et al. 1980).

X-ray diffractogram and stable isotope studies

Figure 6 depicts the amounts of calcite, dolomite, and total carbonates determined from the X-ray diffractograms, as well as the organic carbon and stable isotope values for the carbonate section types demonstrated on Fig. 5. The following statements can be made for the lake types and sections:

a) Well Szappanosszék-12 showed a carbonate content of 8–16% for the loess and wind-blown sand substrate. The proportion of dolomite in the bulk carbonate is about 60–75% in the loess, and 40% in the sand. The high concentration of dolomite is a very important factor, as was demonstrated earlier. The magnesium content of ground water around existing lakes is recharged from this source, later on gets into the lakes. Subsequent evaporation results in a high magnesium/calcium ratio of the lake water and, together with other factors, causes precipitation of dolomite (Molnár 1980, 1991).

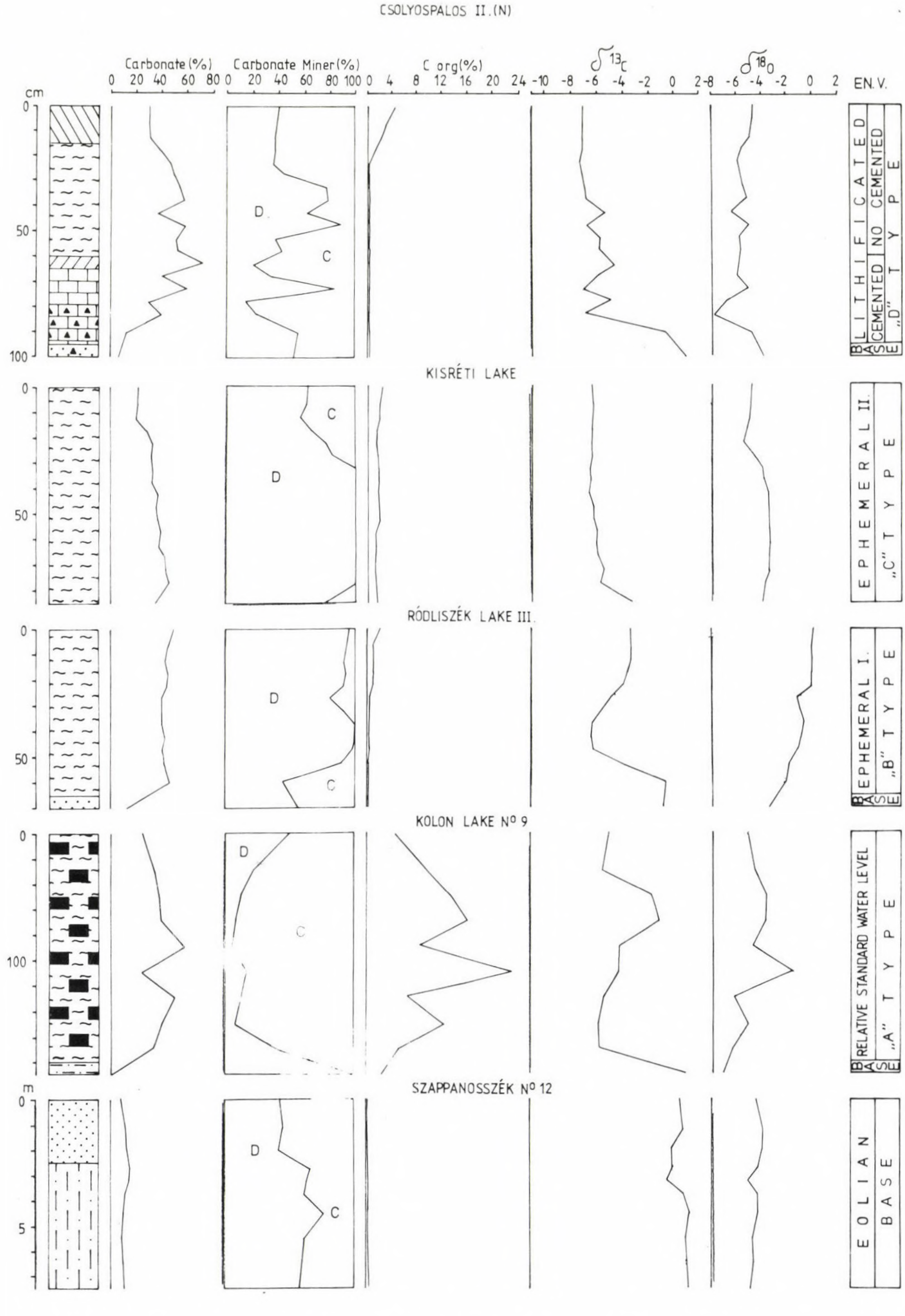
The organic carbon content is low, below 1%. $\delta^{13}C$ varies between 0.07–1.29 ‰. $\delta^{18}O$ is about–4.0 to –5.0‰.

b) The values of the lake Kolon section differ significantly from the previously mentioned ones, except for the sand at its base. Carbonate content is highly variable (20–60%), which is characteristic for peaty carbonates. The proportion of dolomite is low (5–50%, but mostly 10–20%). In the middle part of the Kolon section there is a slight increase in the dolomite amount, probably due to a drier climate and increased evaporation. A similar increase was observed at the Ásotthalom section, which is similar to the Kolon one.

The organic carbon content is highest in sections of this type. At Lake Kolon it is occurs between 5 and 24%, strongly varying.

The $\delta^{13}C$ values of the wind-blown sand at the base are similar to those of the Szappanosszék section, about +1‰. Upsection it decreases dramatically, to –6‰, indicating a lacustrine sedimentary environment. In the Ásotthalom section this value is even lower: –10‰.

$\delta^{18}O$ values unevenly increase upwards, from –7‰ to –3.5‰ at 40–60 cm. Above this level it decreases again; at the surface it is –5‰. A similar trend



CSOLYOSPALOS II.(N)
Carbonate (%)
Carbonate Miner (%)
C org (%)
$\delta^{13}C$
$\delta^{18}O$
EN.V.
cm
KISRÉTI LAKE
RÓDLISZÉK LAKE III.
KOLON LAKE Nº 9
SZAPPANOSSZÉK Nº 12
m
D
C
LITHIFICATED
CEMENTED
NO CEMENTED
„D" TYPE
EPHEMERAL II.
„C" TYPE
EPHEMERAL I.
„B" TYPE
RELATIVE STANDARD WATER LEVEL
„A" TYPE
EOLIAN
BASE
10 D C
11 EN.V.

was observed at lake Ásotthalom, where the values were around –6 to –8‰. The highest $\delta^{18}O$ value, observed in midsection, coincides with the dolomite peak, due to the same effect mentioned previously.

c) The carbonate content in the Ródliszék section is about 40%, except for the sand at the base. The dolomite ratio in the bulk carbonate is 100% at midsection; generally it is higher than 90% in the rest of the sequence. Close to the shores this value is slightly lower (70 to 80%). The organic carbon content is extremely low, compared to the lake Kolon section (between 0.3 and 2.2%). Close to the surface it is slightly higher.

$\delta^{18}O$ values vary between –2.8 and 0.0‰, increasing gradually upward. In sections close to the lake shore this trend is similar, reflecting an increasing evaporation.

d) The Kisrét section shows up a slightly decreasing bulk carbonate content upsection, with about 40%. At the centre of the section the dolomite proportion is 100%, lower near the base and especially lower at the top part of the sequence. The organic carbon value is about 1.5–2.0%, slightly higher than in the Ródliszék section.

Except for the lowermost sample, taken just at the base sand boundary, the $\delta^{13}C$ values are between –6.0 and –6.5‰, slightly decreasing upward until the level of maximum dolomite value, and then increasing again toward the top. This trend is even more clear in the case of Lake Kelemenszék, which belongs to the same type.

$\delta^{18}O$ varies between –3.5 and –5.6‰. Where the dolomite proportion is 100 %, the $\delta^{18}O$ value is higher than elsewhere, by –0.5 to –0.8‰, very similar to the situation at the Kelemenszék section. Thus, the dolomite maxima and highest negative $\delta^{18}O$ values coincide.

e) In the diagenetically altered Csólyospályos sequence the bulk carbonate value above the sand substratum is about 30–74%. The dolomite/calcite ratio strongly varies in the hard, cemented carbonate. This results from the calcitic nature of the cements precipitated from the pore water, in contrast to the more dolomitic early diagenetic matter. The cement/grain ratio strongly varies; thus, in the X-ray diffractograms, either the cement or the grains dominate.

Close to the surface the soil forming processes may cause de-dolomitisation. Soilification is evident from the increasing organic carbon values as well. These values are about 1% in deeper parts of the section, and may attain 4.6% close to the surface.

$\delta^{13}C$ is about 1‰ in the wind-blown sands. In the carbonates it varies between 6.0 and 7.3‰.

← Fig. 6
Results of X-ray and isotope-geochemical analyses of lacustrine carbonate section types on the Danube–Tisza Interfluve. 1. loess; 2. aeolian sand; 3. coarse silt; 4. peaty-carbonate; 5. carbonate mud; 6. cemented, hard, light grey carbonate; 7. cemented, hard, dark grey carbonate; 8. iron precipitate; 9. humic layer; 10. dolomite and calcite; 11. depositional environment

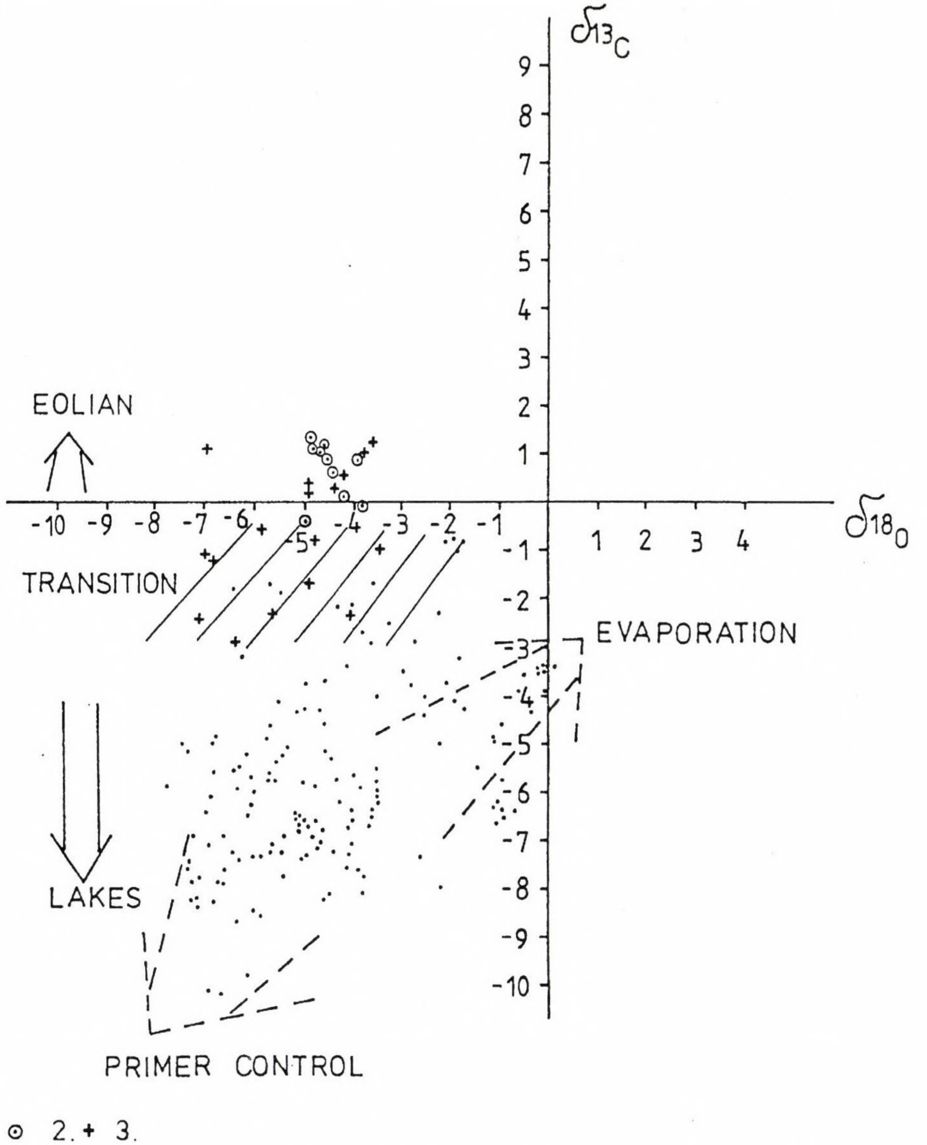


Fig. 7
Diagrammatic representation of $\delta^{13}C$ and $\delta^{18}O$ values. 1. loess and wind blown sand underlying carbonate deposits (data from well Szappanosszék-12); 2. data of samples taken from the substratum deposits; 3. data of lacustrine deposits

$\delta^{18}O$ is between –4.8 and –7.3‰, except for the aeolian sands at the base. The Csólyospálos section and some other sections were densely sampled, at 5 cm intervals. Stable isotope values are more variable in such densely sampled sections than in others (Fig. 4).

Evaluation of the sedimentary environments of the studied lacustrine sections

Plotting the $\delta^{13}C$ against the $\delta^{18}O$ values on a diagram, well-delimited groups appear, reflecting the sedimentary and early diagenetic environments (Fig. 7).

Plots of the *wind blown sediments* beneath the lacustrine deposits (loess and wind-blown sands) appear at the left upper corner. $\delta^{13}C$ ratios are close to zero or have a low positive value, while the $\delta^{18}O$ values are about –4.0 or –5.0‰.

In the left lower part are located the plots of the *peaty carbonate* sediments. Both the $\delta^{13}C$ (–7.0 to –10.0‰) and $\delta^{18}O$ (–5.0 to –7.5‰) values are negative. There is a *transitional* zone between them characteristic for the uppermost part of the sandy substratum. For these small negative (0.0 to –2.5‰) $\delta^{13}C$ values, negative $\delta^{18}O$ ones are characteristic.

Exclusively *carbonate* (dolomitic) lacustrine deposits show rather small negative $\delta^{13}C$ and small $\delta^{18}O$ values.

Figure 7 clearly demonstrates that *wind-blown* and *lacustrine* sediments are well separated from each other. Within the lacustrine group two clusters are delimited, the peaty-calcitic and the dolomitic (due to effects of high evaporation) ones.

Chemical data of loess and wind-blown sand in the substratum of the Szappanosszék-12 well are characteristic for the environment of interdune lakes. Data of lacustrine sediments, representing a lacustrine environment, differ from these. Different chemistry of different lacustrine sections reflect variations in the lacustrine regimes.

Comparing these data the following main definitions are clear: iron content is highest in loess samples and in the Kisrét-type lacustrine sediments. A high iron value recorded in the lower part of the Csólyospálos section is due to changes of groundwater level. Changes in manganese content display similar trends.

The percentage of calcium is highest in the calcitic peaty carbonates, which were moderately influenced by evaporation (lake Kolon, lake Ásotthalmi), as well as in those Csólyospálos sections which are strongly lithified. Magnesium content is highest in sections dominantly containing dolomite, which reflects the influence of strong evaporation, belonging to the Ródliszék and Kisrét types (Kelemenszék, Szappanosszék, Hattyússzék, Szekercésszék, and Kunfehértó). Bulk carbonate values of these lacustrine carbonates are much higher than those of the loess and aeolian sand in the Szappanosszék-12 well.

As has been shown above, strontium is more concentrated in the lacustrine sediments than in the loess and sand substrata. Its values often display a trend similar to the $\delta^{18}O$‰ ones, but sometimes behave differently. Calcite/dolomite ratio is about 50–50% in loess and aeolian sand layers in the substratum. In the peaty carbonate sections calcite dominates, in the other lacustrine sequences dolomite prevails, except for the Csólyospálos one. In this last-mentioned sequence the mainly calcitic cement often modified the original mineralogical ratio, resulting in a calcite domination.

Organic carbon is rare in the substrata. Obviously its value is high in the peaty carbonates. Close to the surface its slightly higher values reflect the start of the soil formation process.

Values of $\delta^{13}C$ are highest in loess and wind-blown sands, and generally contain less lacustrine carbonates. It has been established that salinity is rather low in lakes depositing peat (Molnár et al. 1979). Consequently, the magnesium/calcium ratio is also low, so calcite is precipitated instead of dolomite (Müller et al. 1972). Carbon dioxide is consumed by their lush aquatic vegetation, promoting carbonate precipitation. Thus the isotope content varies highly in such lakes, and $\delta^{13}C$ values may be as high as –10‰.

$\delta^{13}C$ varied between –3.83 and –5.01‰ in the loess and sand of the Szappanosszék-12 section.

Carbonates of Lake Kolon have $\delta^{13}C$ values between –1.54 and –6.30‰. In the Ásotthalom section similar carbonates have rather uniform values between –6.11 to –6.83‰. These are close to values of Hungarian rainfalls (Deák et al. 1992).

Complex geochemical processes occurred at lakes of this type. Carbonate precipitation was caused by carbon dioxide depletion by vegetation, but also, in some cases, by evaporation as well.

The section in the central part of Lake Ródliszék III displays much lower $\delta^{18}O$ negative values than the preceding ones, varying between –2.03 and –0.1‰, with negative values decreasing upward. $\delta^{18}O$ values for different sections are as follows:

- At the shore of Lake Ródliszék:–1.4 to 0.0‰,
- lake Szappanosszék:–3.68 to –1.62‰,
- Lake Hattyússzék, –3.96 to –1.8‰,
- Lake Szekercésszék:–2.19 to –0.34‰,
- Kunfehértó: –1.57 to 0.95‰.

This trend reflects an increasing role of evaporation in the evolution of lakes.

The lake Kisréti section gave $\delta^{18}O$ values between –5.6 to –3.5‰. The similar lake Kelemenszék in the Danube valley produced results of –6.11 to –4.3‰, without any trend of upsection increasing, or any slight changes in between.

In section II (N) at lake Csólyospálos the carbonate was cemented, $\delta^{18}O$ values were between –4.63 and –6.73‰, and the numbers decreased upward, with slight deviations. In section I (S) at Lake Csólyospálos the upsection decrease of negative values is even more pronounced. Sections III, IV and V displayed similar upward-decreasing trends, with slight deviations. Extreme values were sometimes similar to the above ones, and sometimes deviating from them.

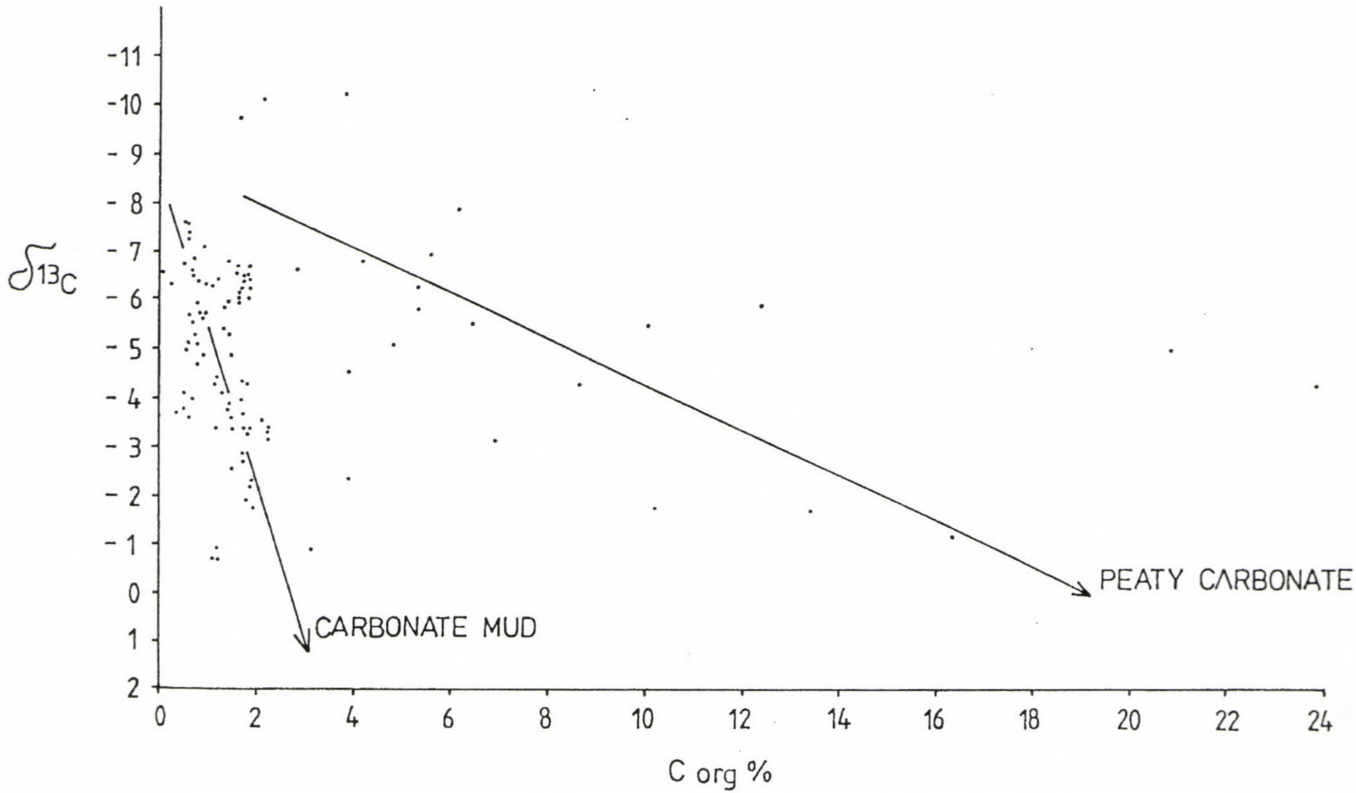


Fig. 8
Relationship between organic carbon content and $\delta^{13}C$ values in carbonate mud and peaty carbonate mud

Three different types of lake evolution can be discerned, based on the above data.

Type "A" lakes are peaty carbonate lakes with moderately changing water level and with continuous inundation. Changing, but relatively high negative values of $\delta^{13}C$, and high organic carbon content, is characteristic (Figs 6, 8 and 11). Their carbonate is calcitic, its precipitation partly caused by CO_2 depletion by aquatic plants, and partly by evaporation. In this paper Lake Kolon and Lake Ásotthalmi were studied by this group of authors, but Kerekszék and lake Zsombói, at Bugac, which were investigated earlier, were added. These lakes are situated in the highest parts of the Danube–Tisza Interfluve region (Fig. 9).

The *type "B"* lakes are shallow and ephemeral, displaying effects of intense evaporation; their extent varies seasonally due to evaporation. By late summertime most of them dry up. Precipitated carbonate is dolomitic; in the case of some formerly studied lakes we also found magnesite. The higher percentage of dolomite is accompanied by a smaller negative value of $\delta^{18}O$ and a higher strontium content, proving an increased rate of evaporation (Figs 10, 11). The majority of the investigated lakes belong to this group. Most of them are situated on the eastern slope of the divide.

Lakes belonging to *type "C"* are similar to those of group "B" in terms of their ephemeral nature, of their seasonally changing surface area and of the nature of their carbonate sediment. In precipitation of carbonates evaporation is the prevailing process. Values of $\delta^{18}O$ are higher by –3.0 to –3.5 than those of the previous group. This value does not change upsection.

As has been mentioned, these lakes have a low geomorphologic setting in the Danube valley (Fig. 9). Thus, their water is supplied from Danube floods rather than from rainwater or groundwater. It is well known that precipitation falling on higher altitudes or under lower temperature has a lower $\delta^{18}O$ value. 85% of the Danube water in the Hungarian course is recharged from Alpine melt water and precipitation.

The mean $\delta^{18}O_{SMOW}$ value at Vienna is –11.7‰ (Rank in Deák et al. 1992). On the other hand, the weighted mean annual value for Hungarian precipitation is only –9.5‰, according to Deák et al. (1992). The difference, expressed in $\delta^{18}O_{PBB}$, is –2.53‰.

Thus the difference in the $\delta^{18}O$ values between the dolomites of the lakes of type "B" and "C" is mainly due to this variation. Part of it, –0.5 to –1.0‰, is attributable to the flow of precipitation and groundwater on the divide area toward the Danube.

This type included Lakes Kisrét and Kelemenszék (Fig. 9).

Carbonate sequences of type "D" reflect postsedimentary changes in the lacustrine sediments rather than the sedimentary environments. The lower parts of the sections underwent the first stage of diagenesis, and are lithified and cemented. iron and manganese accumulated in the zone of groundwater level fluctuation (Fig. 2). Accordingly, chemical data and isotope ratio deviate

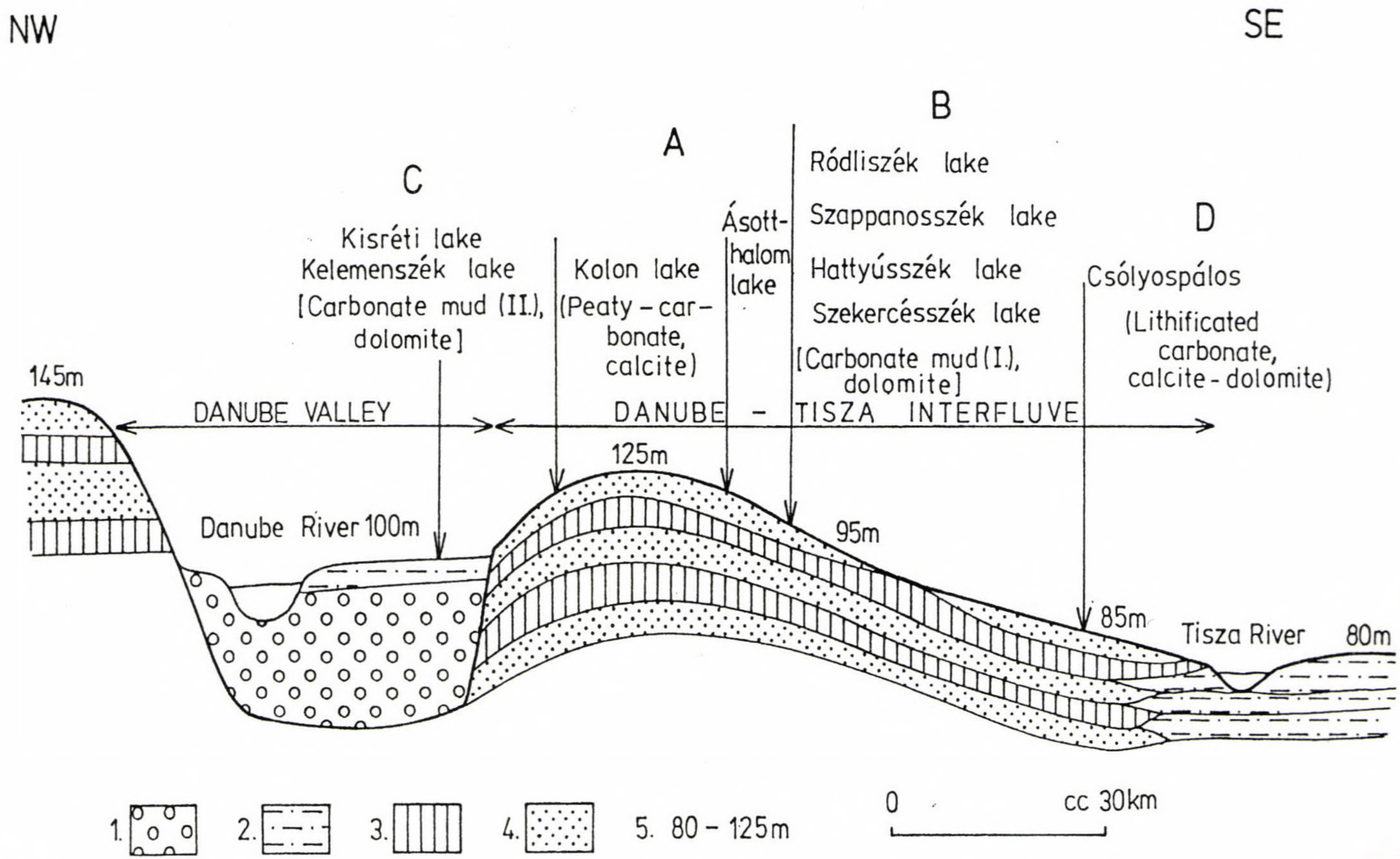


Fig. 9
Type geologic section of the Danube-Tisza Interfluve, showing the location of lake types, i.e. carbonate section types. 1. gravel; 2. silt; 3. loess; 4. aeolian (wind blown) sand; 5. elevation above sea level in metres

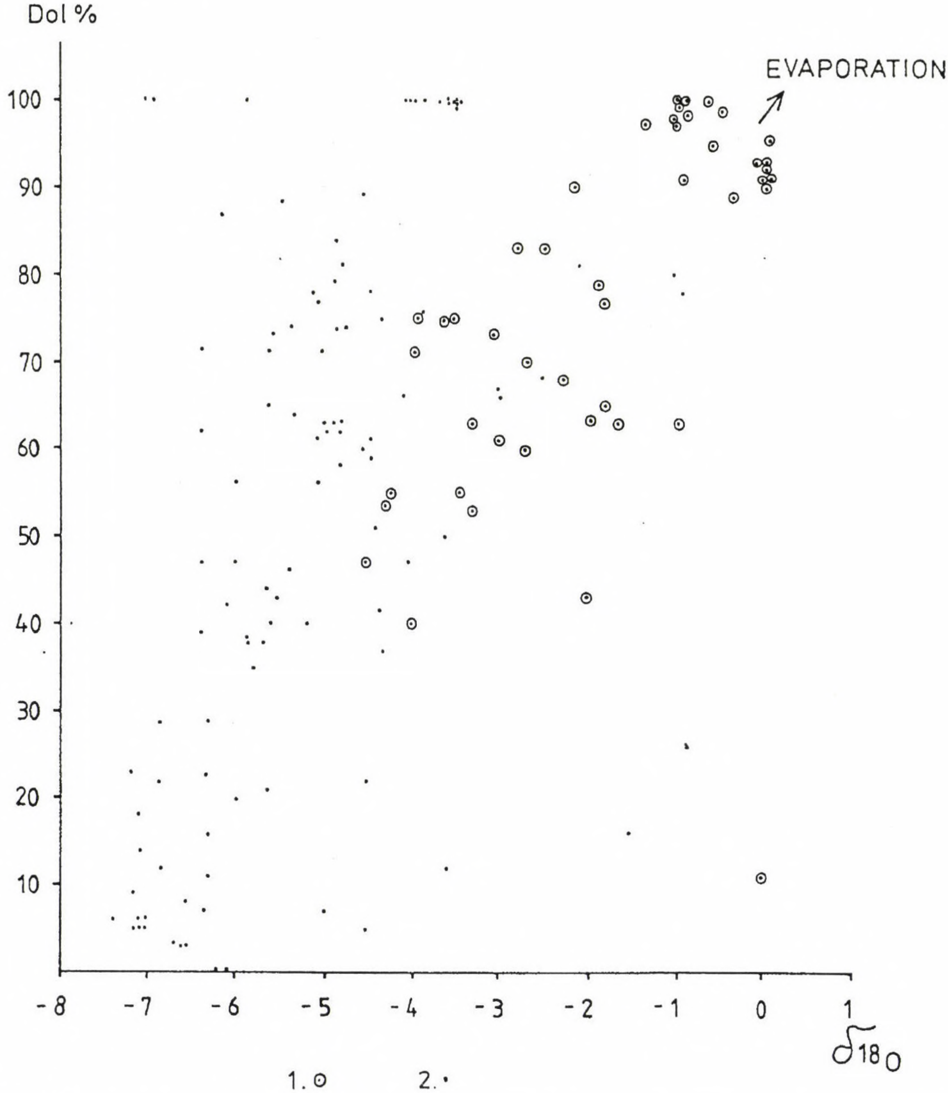


Fig. 10
Relationship between $\delta^{18}O$ values and dolomite contents of lake deposit sections. 1. plots of carbonates precipitated in Lakes Ródliszék, Szappanosszék, Hattyússzék, Szekercésszék, and Kunfehértó; 2. plots of carbonate contents of other lacustrine sequences investigated by us

strongly. They are mainly situated on the Tisza flank of the Danube–Tisza Interfluve, at low elevation, where there is a south-easterly groundwater flow (Fig. 9). These sections are regarded as diagenetically altered "B" type sequences.

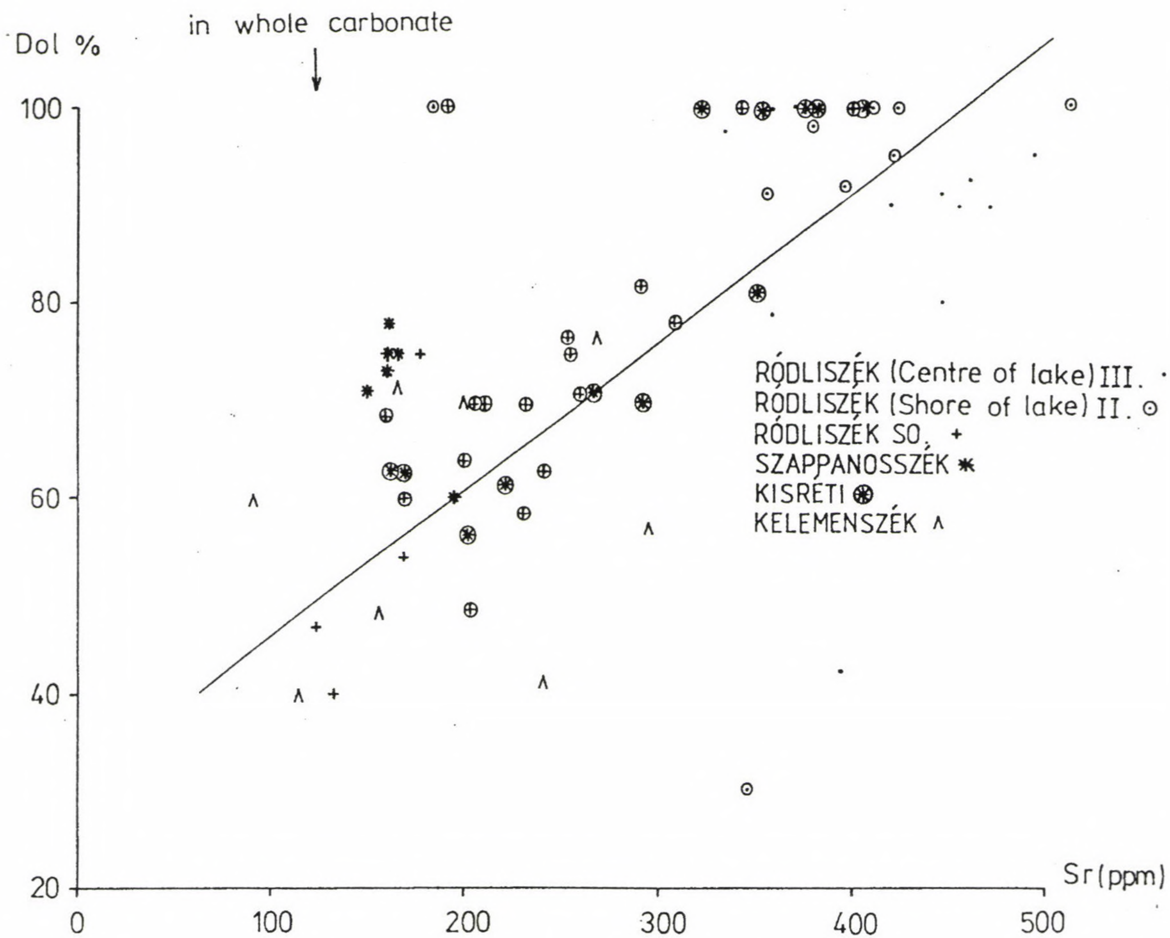


Fig. 11
Correlation between strontium and dolomite content

Comparison of lacustrine carbonates of the Danube–Tisza Interfluve with those of other regions

It is a well-established fact that primary dolomites are rich in heavy oxygen, in strontium and sodium, but are depleted in iron and manganese. The dolomites of type "B" interdune lakes (Ródliszék) correspond best to these features. "C" type lakes in the Danube valley are somewhat less rich in heavy oxygen due to the water originating from the river. Their iron and manganese content is slightly higher, which might be the consequence of locally frequently changing conditions of sedimentation.

Stable isotopic ratios of modern lake waters were frequently studied, but those of lacustrine carbonates were seldom dealt with (Gonfiantini 1986); marine carbonates were the preferred subject.

Carbonates of the Balaton area (Hungary) were studied by Müller and Wagner (1980). They found that maximum content of $MgCO_3$, strontium, sodium and lithium in the calcite crystal lattice point to lowstands of lake water. During such events evaporation causes an increase in $\delta^{18}O$ values of carbonates. The history of lake Balaton includes three dolomite peaks, corresponding to three major periods of dry climate and high evaporation.

The data of lacustrine carbonates of the Danube–Tisza Interfluve differ from those of Balaton. Even the type "A" calcitic deposits of lake Kolon contain a high amount of strontium, and $\delta^{18}O$ and $\delta^{13}C$ values fluctuate between wide limits. The dolomites are also unlike those of the Balaton deposits, due to more frequent and rapid changes in water chemistry.

Carbon- and oxygen isotopic ratios of the south Australian Coroong lagoon carbonates were studied by Botz and Von der Borch (1984). They distinguished a fine grained, isotopically light ($\delta^{13}C$= –1 to –2‰ and $\delta^{18}O$ =+3 to +5‰) dolomite which was precipitated from a water originating from the mainland by evaporation. The other type was coarser-grained and less depleted in heavy isotopes ($\delta^{13}C$= +3 to +4‰ and $\delta^{18}O$ =+5 to + 6‰), and calcium dominated over magnesium. This probably originated by dolomitisation of an aragonite in equilibrium with the atmospheric CO_2 in a closed lagoon. In the case of the central east African lake Kivu, the isotopes of the primary aragonite were in equilibrium with the dissolved CO_2, the isotope ratio of which was close to the atmospheric one. At the southern part of the lake the Bukavu basin is isolated from the lake during lowstands, when precipitating aragonites are richer in $\delta^{13}C$, due to a chemically stratified water (Botz et al. 1988).

The heavy carbon and oxygen isotope ratios of lake Kivu are also much higher than those of the Danube–Tisza Interfluve lacustrine deposits, due to a tropical climate and to different sedimentary environments.

Talbot (1992) gave a detailed account about carbon and oxygen isotope ratios of primary lacustrine carbonates, as well as on their dependence on palaeo-hydrological conditions. He emphasised that such dependencies are present in closed, endorheic lacustrine basins. The Hungarian data differ from those of

Talbot, which refer to large, endorheic lake systems. In his study both $\delta^{18}O$ and $\delta^{13}C$ values are positive.

The Hungarian "A" type calcitic carbonates are probably the closest to the freshwater limestones described by Milliman (1974).

Szöőr and his co-workers (Szöőr et al. 1992) presented some isotope data for late Miocene (Pannonian) deposits of "a normal salinity and temperature lacustrine basin" as follows: $\delta^{13}C= -8.1$ to $-6.27‰$ and $\delta^{18}O=-7.01$ to $-5.12‰$ (samples 13, 19, 25, and 32). It is not clear whether these ratios refer to "limnic basin" dolomites or calcites. These values, however, are close to those of the "A" and "D" type sections of the present study.

It can be stated that chemical properties and isotope ratios of calcites and dolomites precipitated from high-salinity lakes of the Danube–Tisza Interfluve vary within a wide range. This proves the role of the variable geochemical processes in the precipitation of carbonates. These processes depend highly upon the geomorphology of the immediate environment, the salinity of the lakes, the magnesium/calcium ratio and the nature of the recharge of the lakes.

Acknowledgements

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Foraminifera of the Triassic formations of Alsó Hill (Northern Hungary)

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In the Hungarian portion of Alsó Hill, extending in a length of some 15 km along the Hungarian–Slovakian border, a rich foraminifer assemblage has been found in Triassic formations. The richest foraminifer association characterizes the platform carbonates (Steinalm Limestone Formation, Wetterstein Limestone Formation). The poor foraminifer fauna of the basinal facies (Nádaska Limestone Formation, Reifling Limestone Formation, Derenk Limestone Formation, Hallstatt Limestone Formation, and Pötschen Limestone Formation), with some exceptions, is not suitable for drawing stratigraphic conclusions.

In the foraminifer assemblage of the formations of the lagoonal facies of the Anisian (Upper Pelsonian–Illyrian) Steinalm Limestone Formation, *Pilammina densa* Pantic, *Meandrospira dinarica* Kochansky-Devidé et Pantic as well as species of the genus *Earlandinita* are predominant.

Key words: Triassic, biostratigraphy, foraminifera, Northern Hungary

Introduction

In the several hundred thin sections of the Alsó Hill samples examined on behalf of the North Hungary Department of the Hungarian Geological Institute at the end of the 70s and in the 80s, a rich Middle and Upper Triassic foraminifer fauna was found. The thin sections were made from material collected by Kálmán Balogh and Sándor Kovács. I would like to express my thanks to Sándor Kovács for making the thin sections for foraminifer investigation available to me.

The Hungarian part of Alsó Hill (Fig. 1) belongs to the extended karst plateau of the Gemer-Torna Karst. It extends over a length of some 15 km along the Hungarian–Slovakian border (Kovács 1979), and is one of the type areas of the Triassic formations of the Southern Gemer (Kovács 1992a, b; Kovács et al. 1988, 1989).

A rich foraminifer assemblage of local biostratigraphic importance was encountered both in platform carbonates and basinal facies (Fig. 2).

The richest foraminifer association characterizes the platform carbonates (Steinalm Limestone Formation, Wetterstein Limestone Formation).

The foraminifer assemblage found in the well-oxygenated, open marine formations of lagoonal facies of the Anisian (Pelsonian–Illyrian) Steinalm Limestone Formation can be well correlated with formations of similar age and facies known in the area of Tethys. Among the taxa bound to facies, the

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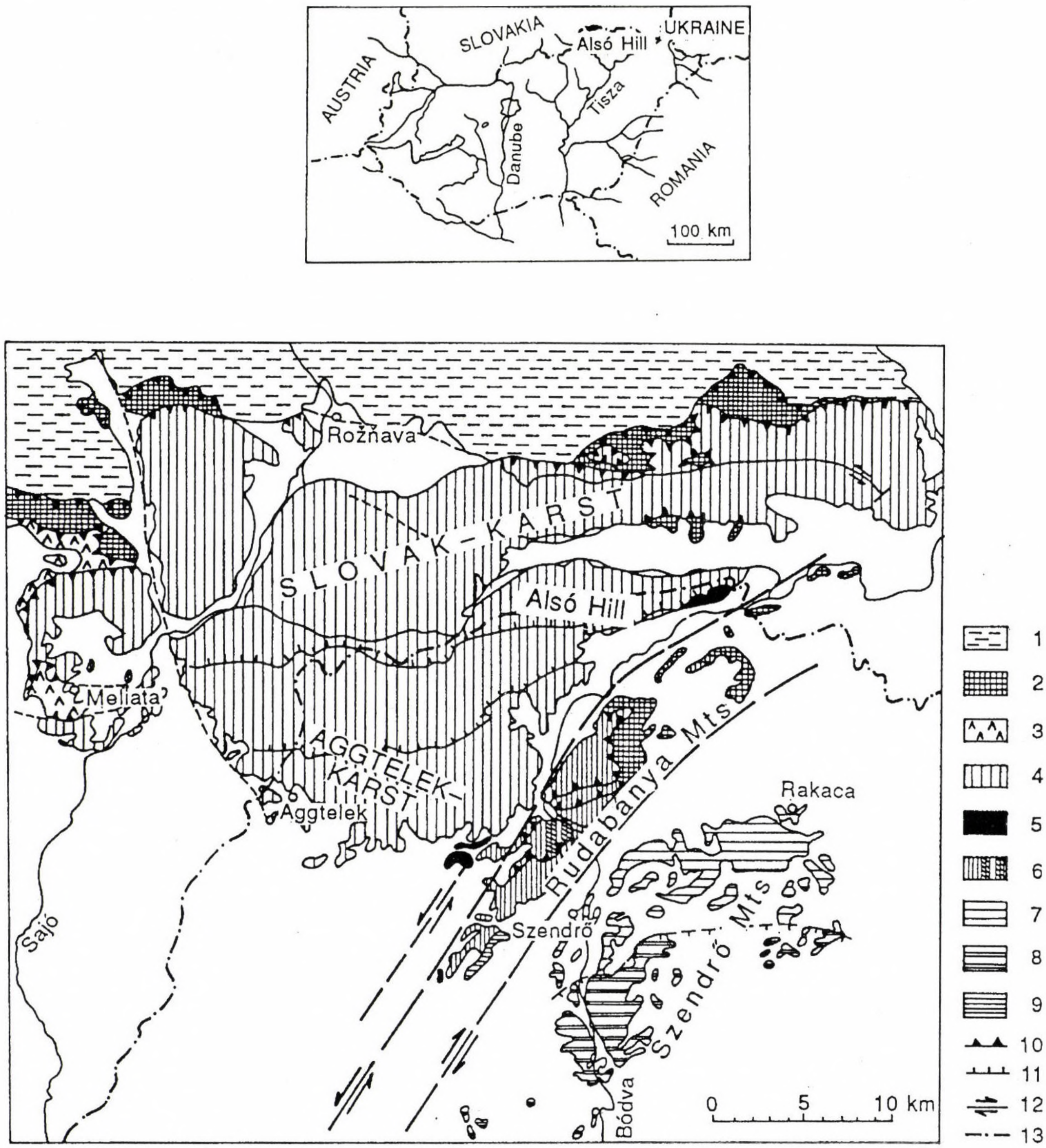


Fig. 1
Geographical setting of Alsó Hill within the tectofacies system of the Aggtelek-Rudabánya Mountains (after Kovács et al. 1993). 1. Gemer Palaeozoic; 2. Tornaicum; 3. Meliaticum; 4–6. Silicicum: 4. Silice Nappe s.s.; 5. Szőlősardó Unit; 6. Bódva Nappe; 7–8. Szendrő Palaeozoic; 9. Uppony-type Palaeozoic; 10. nappe boundary; 11. sliver boundary; 12. horizontal displacement; 13. national boundary

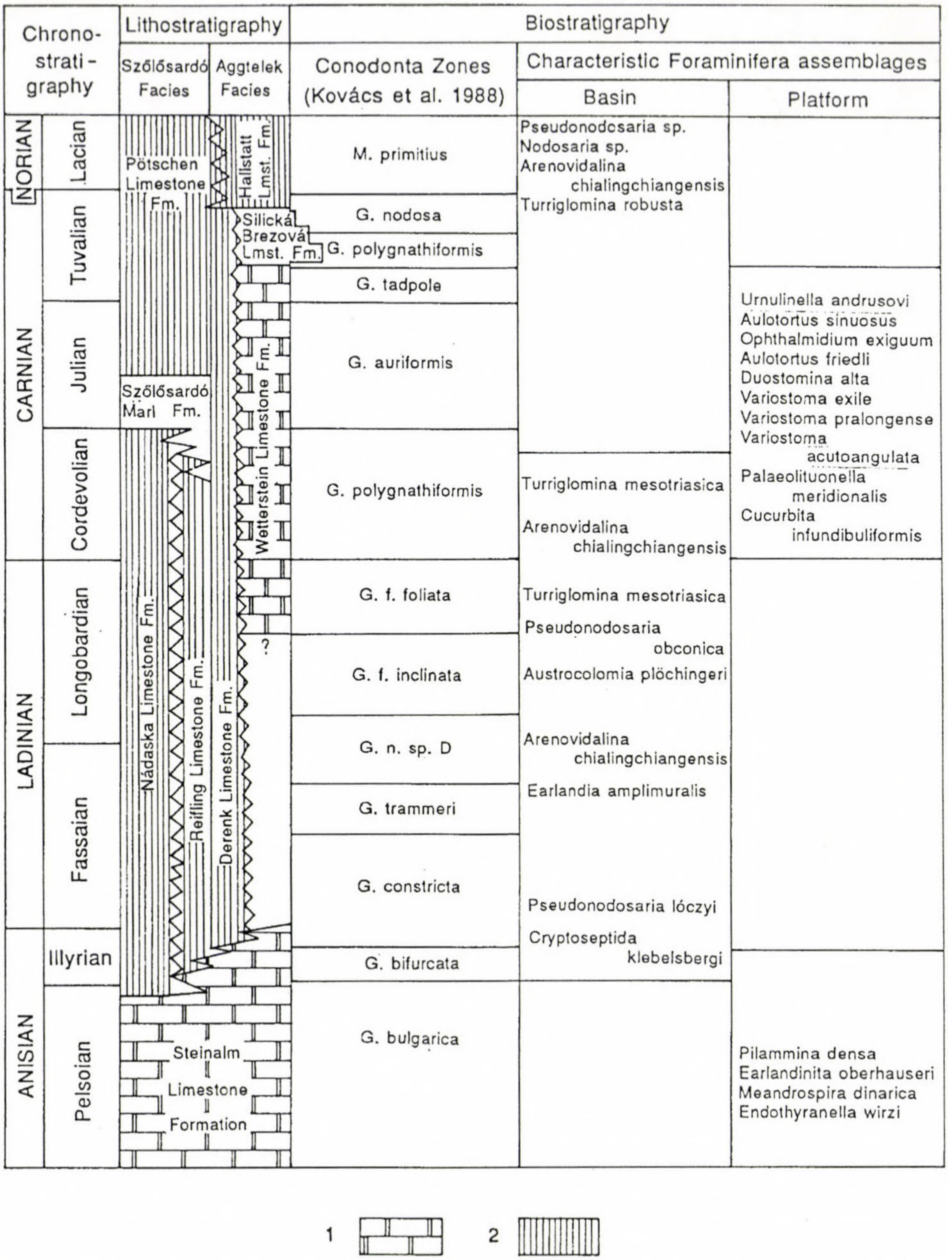


Fig. 2

Characteristic foraminifer horizons of the Triassic formations of Alsó Hill. 1. platform carbonates; 2. basin facies

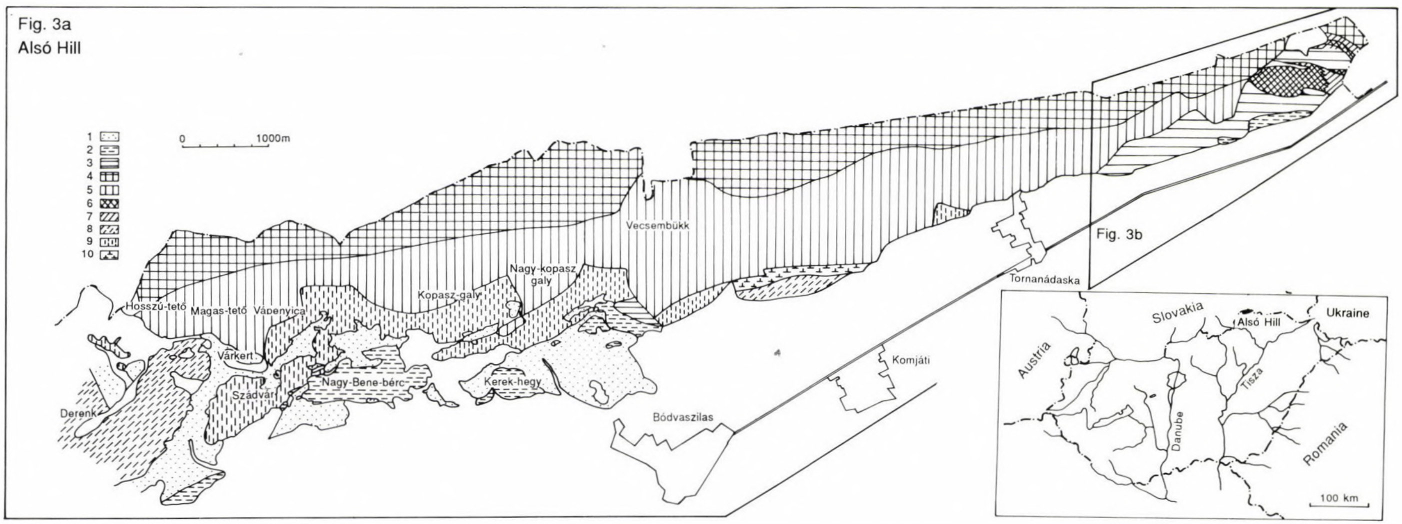


Fig. 3a, b

Locality map of the studied Steinalm Limestone samples of Alsó Hill (after Kovács, S. 1977). 1. Lower Triassic; 2. Gutenstein Formation; 3. Steinalm Limestone Formation; 4. lagoon facies of the Wetterstein Limestone Formation; 5. reef facies of the Wetterstein Limestone Formation; 6. Nádaska Limestone Formation; 7. Reifling Limestone Formation; 8. Derenk Limestone Formation; 9. Hallstatt Limestone Formation; 10. Pötschen Limestone Formation

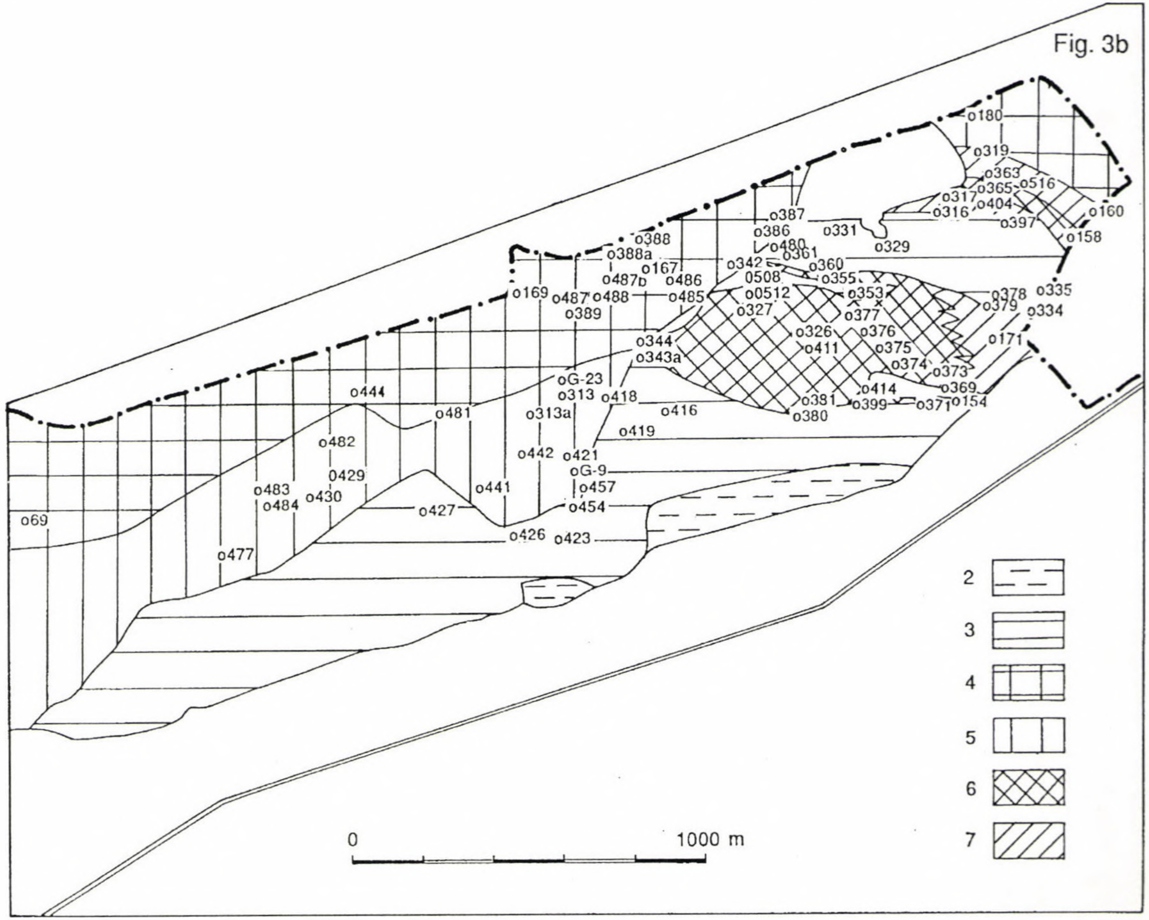


Fig. 3b
o180
o319
o363
o365
o516
o317
o404
o316
o397
o160
o158
o387
o386
o331
o329
o388
o388a
o480
o361
o167
o342
o360
o508
o355
o487b
o486
o485
o169
o487
o488
o389
o0512
o353
o378
o335
o379
o334
o327
o377
o344
o326
o376
o171
o343a
o411
o375
o374
o373
oG-23
o313
o418
o414
o369
o444
o481
o313a
o416
o381
o399
o371
o154
o380
o419
o482
o442
o421
oG-9
o429
o457
o483
o484
o430
o441
o427
o454
o69
o426
o423
o477
2
3
4
5
6
7
0
1000 m

frequency of *Pilammina densa* Pantic, *Meandrospira dinarica* Kochansky-Devidé et Pantic as well as of species of the genus *Earlandinita* is remarkable.

On the basis of the rich foraminifer fauna, formations of reefal and lagoonal facies of the Wetterstein Limestone Formation, constituting the main part of Alsó Hill, can be well distinguished, also permitting a chronostratigraphic classification. The foraminifer association is unambiguously of Carnian age, on the basis of the presence and frequency of species of the genera *Variostoma, Urnulinella, Cucurbita* and *Aulotortus*. In the reefal facies, the frequency of the species *Aulotortus sinuosus* Weynschenk, *Urnulinella andrusovi* (Borza et Samuel), *Miliolipora cuvillieri* Brönn. et Zan., and *Palaeolituonella meridionalis* (Luperto) is determinative from the point of view of age and facies classification. The lagoonal facies is unambiguous taking into account the great number of specimens of species of the genus *Earlandinita*. Furthermore, the mass occurrence of *Aulotortus friedli* (Kristan-Tollmann) specimens, of species of the genera *Glomospira* and *Duostomina* as well as of calcareous algae is characteristic.

As far as the foraminifer fauna of the basinal facies (Nádaska Limestone Formation, Reifling Limestone Formation, Derenk Limestone Formation, Hallstatt Limestone Formation, and Pötschen Limestone Formation) is concerned, it can be generally stated that they are reliable facies indicators; however, they do not provide information concerning the geologic age, with some exceptions.

The Nádaska Limestone Formation, extending from the Middle Anisian (Upper Pelsonian) to the Middle Carnian (Julian), consists of open marine slope sediments. In its foraminifer fauna, Nodosariidae (indicating basinal facies) as well as specimens of species belonging to the genera *Lenticulina* and *Ophthalmidium* are frequent. The poor foraminifer fauna of the Reifling Limestone Formation of pelagic basinal facies is biostratigraphically undistinctive. The scattered foraminifera fauna (*Nodosaria, Agathammina*) found in the syndiagenetically brecciated limestone with microfilaments of the Derenk Limestone Formation is not suitable for drawing stratigraphic conclusions, apart from the species of the genus *Turriglomina* (Bérczi-Makk 1993).

The scattered foraminifer fauna of Upper Triassic pelagic basinal facies and Carnian–Norian age (Hallstatt Limestone Formation, Pötschen Limestone Formation) unambiguously indicates basinal facies, but offers no possibility to draw stratigraphic conclusions.

Hereinafter, foraminifer fauna of elaborated platform carbonates and basinal facies of Alsó Hill will be discussed in detail with the following subdivision:

I. foraminifer assemblage of the Steinalm Limestone Formation (this paper),

II. foraminifer assemblage of the Wetterstein Limestone Formation (Acta Geol. Hung., 39/3, 1996, in press),

III. foraminifer assemblage of basin facies (Acta Geol. Hung., 39/4, 1996, in press).

I. Foraminifer assemblage of the Steinalm Limestone Formation

Introduction

The Steinalm Limestone Formation is a carbonate platform formation consisting of limestones and dolomites. Its lithology, microfacies and biofacies correspond to the lagoonal facies of the Wetterstein Limestone Formation. In the slivers of the eastern end of Alsó Hill, its main mass is formed by light grey, thick-bedded limestones with late diagenetic dolomite intercalations. Among the tidal facies, homogeneous loferites and pellet loferites are characteristic. Subtidal formations are represented mainly by bioclastic limestones, more rarely by oncolites. It is a pelagic lagoonal facies of well-oxygenated water.

Its calcareous algae assemblage is characterized by the frequency of the species *Diplopora hexaster* Pia, *Macroporella alpina* Pia, *Oligoporella pilosa* Pia, *Physoporella pauciforata pauciforata* (Gümbel), *Physoporella pauciforata gemerica* Bystricky, *Physoporella pauciforata sulcata* Bystricky, *Physoporella pauciforata undulata* Bystricky, *Physoporella dissita* (Gümbel) (Kovács 1979).

The foraminifer fauna from the thin sections of the investigated 34 samples (Fig. 3) is characterized by poverty in species and richness in specimens. The frequency of the species *Pilammina densa* Pantic and *Meandrospira dinarica* Kochansky-Devidé et Pantic as well as the great number of specimens belonging to the genera *Ammobaculites*, *Earlandinita* and *Endothyra* are remarkable. Forms of agglutinated shells represent the majority of the number of both species and specimens. In general, thick-shelled specimens predominate; thus they can resist stronger mechanical impacts caused by water motion.

Biostratigraphic evaluation

From a biostratigraphic point of view, the foraminifer assemblage of Alsó Hill can be well correlated with the microfauna of the Anisian sediments of similar facies known from the area of Tethys (from the Alps to Turkey). On the basis of the data in literature, the species in question existed in the Pelsonian and Illyrian substages:

Pilammina densa Pantic
Paulbronnimannella whittakeri Rettori
Glomospira sp.
Glomospirella sp.
Reophax asper Cushman et Waters
Ammobaculites elongatus (Salaj)
Ammobaculites sp.2.
Ammobaculites sp.3.
Trochammina cf. *alpina* Kristan-Tollmann
Trochammina aff. *almtalensis* Koehn-Zaninetti
Trochammina sp.
Gaudryinella sp.
Earlandinita grandis Salaj
Earlandinita ladinica Salaj

Earlandinita oberhauseri Salaj
Earlandinita soussi Salaj
Endothyra badouxi Zaninetti et Brönnimann
Endothyra cf. *küpperi* Oberhauser
Endothyra malayensis Gazdzicki
Endothyra sp.1.
Endothyra sp.
Endoteba sp. cf. *Neoendothyra* reicheli Reitlinger
Endothyranella wirzi (Koehn-Zaninetti)
Endothyranella bicamerata Salaj
Endothyranella sp.
Haplophragmella inflata Zaninetti et Brönnimann
Meandrospira dinarica Kochansky-Devidé et Pantic
Arenovidalina chialingchiangensis He
Nodosaria sp.
Dentalina sp.
Aulotortus sinuosus Weynschenk
Diplotremina astrofimbriata Kristan-Tollmann
Diplotremina sp.

Pilammina densa Pantic is a species bound strongly to facies. Its optimal biotope is the shelf slope (Rálisch-Felgenhauer et al. 1993). It can be found in the transitional facies between clastic facies and carbonate platform (Farabegoli et al. 1976). In such facies, it suddenly appears en masse. In the samples taken in Alsó Hill, it is distinguished by its even distribution and by always accompanying *Meandrospira dinarica* Kochansky-Devidé et Pantic. In general, only robust specimens are known, which can be explained by the living conditions optimal for the species.

In the investigated samples, species of the genus *Earlandinita* are generally distributed and represented by a great number of specimens. Taking into account the foraminifer faunas of the reefal and lagoonal facies of the Wetterstein Limestone and the Steinalm Limestone of Alsó Hill, it seems that the *Earlandinita* species show facies susceptibility. They are characteristic forms of lagoonal facies of the platform margin. Their optimal living conditions were in the typical lagoonal facies (see the lagoonal facies of the Wetterstein Limestone Formation of Alsó Hill).

Meandrospira dinarica Kochansky-Devidé et Pantic is a strongly facies-susceptible foraminifer which lived in clear-water, shallow marine carbonate platform zones. Farabegoli et al. (1976) dealt with the Triassic species of the genus *Meandrospira* in detail. In their work, they assigned the specimens with a diameter ranging from 0.16 to 0.29 mm to the taxon *Meandrospira dinarica*. It is a species of even distribution and is represented by a great number of specimens in the samples of the Steinalm Limestone Formation of Alsó Hill. The diameters of all the specimens are above 0.2 mm. The most frequent sizes vary between 0.3 and 0.4 mm; however, diameters above 0.4 mm are not rare. The largest specimens might be the most developed forms of the Triassic Meandrospira lineage (Oravecz-Scheffer 1978). As a matter of curiosity, it is worth mentioning that the large size is not in direct proportion to the number of whorls in the case of the specimens of Alsó Hill (Fig. 5). In general, the

Sample	Foraminifers																																				Other Organic remnants			
	Pilammina densa	Glomospira sp.	Glomospirella sp.	Rheopax sp.	Ammobaculites sp2	Ammobaculites sp3	Trochammina cf. alpina	Trochammina aff. almtalensis	Trochammina sp.	Gaudrinella sp.	Earlandinita grandis	Earlandinita ladinica	Earlandinita oberhauseri	Earlandinita soussi	Ammobaculites elongatus	Tetrataxis sp.	Endothyra badouxi	Endothyra cf. küpperi	Endothyra malayensis	Endothyra sp1	Endothyra sp	Endoteba sp.	Endothyranella wirzi	Endothyranella bicamerata	Endothyranella sp.	Haplophragmella inflata	Meandrospira dinarica	Arenovidalina chialingchian.	Nodosaria sp.	Dentalina sp.	Aulotortus sinuosus	Diplotremina astrofimbriata	Diplotremina sp.	Duostomina sp.	Duostomina biconvexa	Aulotortus friedli	Echinoidea fragment	Mollusc fragment	Gastropoda	Ostracoda fragment
b/1971/BK	•																	•			•							■						•						
T-329		•			•												•	•			•	•					+		•	•									•	
T-331																											+													
T-342	•	•													•						•							•		•										
T-343	+	•											•														+					•					•	•		
T-353																	•										+													
T-360																					•																			
T-361		•			•	•															•																			
T-369																											•													
T-371		•			•	•							+									•					+					•	•							
T-380													+				•						•				■													•
T-384/7			•					•					•														+		•											
T-386/9													•								+	•																		•
T-397			•						•	•				•							•				•				•				•		■	•				
T-399		•																		•	•																			
T-404		•	•								•				•										•		+													
T-416						•		•	•																															
T-417																			•								■													
T-419	+				•	•																					+													
T-423																			•						•		+													
T-426			•		•	•	•																		•															+
T-427																																	•							
T-431	+	•					•				+	■									•	•					+				•	+		•						
T-448	•																		•		•						•					•								
T-449	•	•				•							•				•				•												•	•						
T-454						•															•																			
T-490					■					•			+		+						•						•													
T-491		•				•															•					•	+						•							
T-513													•								•																			
Ah-I/2		•			+									+									•				+		•								•			
Ah-VIII/1	■	•																																						
Ah-VIII/2	■	•		+				•								•											■					•	•							
Ah-VIII/3	+							•	•																		+		•								+			
Ah-VIII/4				•																					•		+										+			

Fig. 4

Distribution and frequency of the foraminifer fauna of the Steinalm Limestone Formation of Alsó Hill on the basis of the samples. • scattered; + frequent; ■ en mass

largest specimens have the smallest number of whorls (see Plate IV, Figs 6, 9; Plate V, Fig. 4; Plate VII, Figs 2, 3). Clarification and interpretation of this question require further investigations.

According to Piller (1978), the facies-indicating indicating role of the species *Aulotortus sinuosus* (Weynschenk) is great; however, it has no stratigraphic (bio- and chronostratigraphic) value. It is most widespread in the near-reef calcareous sands, but is also frequent in the lagoonal facies. In the latter facies, it can be found from the Anisian to the end of the Triassic. In sample No. T-431 of the Steinalm Limestone Formation of Alsó Hill, it is accompanied by *Pilammina densa* Pantic, *Meandrospira dinarica* Kochansky-Devidé et Pantic, and *Trochammina almtalensis* Koehn-Zaninetti (Plate VII, Fig. 1).

Diplotremina astrofimbriata Kristan-Tollmann is one of the few foraminifer species which are not facies-susceptible; it first appears in the lowermost horizon of the Pelsonian substage (Oravecz-Scheffer 1978). It can be found in oolitic or bioclastic limestones of the carbonate platform, both in the facies of the platform margin and the strongly terrigenous lagoonal facies. In the samples taken in Alsó Hill, it is an evenly distributed species represented by a small number of specimens.

The foraminifer fauna of sample No. T-397 differs from the foraminifer assemblage of the Anisian Steinalm Limestone Formation. On the basis of the frequency of *Duostomina biconvexa* Kristan-Tollmann as well as the presence of *Aulotortus friedli* (Kristan-Tollmann) and a specimen belonging to the genus *Palaeolituonella*, it is unlikely that this sample is older than uppermost Anisian or, more likely, Ladinian. This is also confirmed by the presence of *Diplopora annulatissima* Pia (Kovács 1977). The fossil association of the lagoonal facies tends more toward the lagoonal facies of the Wetterstein Limestone Formation than toward the formations of the Steinalm Limestone Formation.

In the slivers of the eastern end of Alsó Hill, besides the scattered samples, Steinalm Limestone was also exposed in two sections (Bérczi-Makk, in press) with a relatively rich Anisian foraminifer fauna (Figs 6, 7).

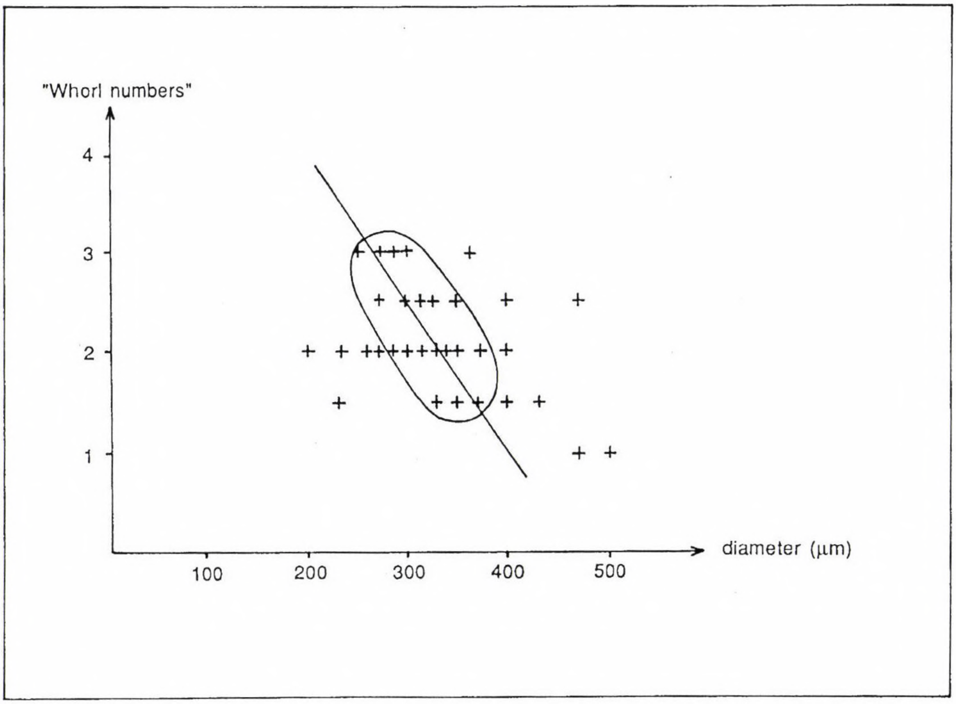


Fig. 5
Connection between the diameter and the number of "whorls" at the species *Meandrospira dinarica*

In section No. 1 of Alsó Hill (Fig. 6), the younger (Illyrian) Steinalm Limestone layers were encountered with a poor foraminifer assemblage (Plate VIII):

Ammobaculites sp.
Endothyra sp.
Endothyranella sp.
Pilammina densa Pantic
Paulbronnimannella whittakeri Rettori
Meandrospira dinarica Kochansky-Devidé et Pantic
Earlandinita soussi Salaj
Earlandinita sp.

In section No. 8 of Alsó Hill (Fig. 7), the older (Pelsonian) Steinalm Limestone is exposed (Kovács 1981) which contains a foraminifer fauna poor in species but rich in specimens (Plate IX):

Reophax asper Cushman et Waters
Glomospira sp.
Pilammina densa Pantic
Trochammina almtalensis Koehn-Zaninetti
Endothyranella pentacamerata Salaj
Meandrospira pusilla (He)
Meandrospira dinarica Kochansky-Devidé et Pantic
Diplotremina astrofimbriata Kristan-Tollmann

Conclusions

– The foraminifer assemblage found in the well-oxygenated, open marine formations of the lagoonal facies of the Anisian (Pelsonian–Illyrian) Steinalm Limestone Formation can be well correlated with the formations of similar age and facies known in the area of Tethys;

– The foraminifer fauna is characterized by poverty in species and richness in specimens, as well as by a predominance of forms with agglutinated shells;

– Among the taxa bound to facies, *Pilammina densa* Pantic, *Meandrospira dinarica* Kochansky-Devidé et Pantic as well as species of the genus *Earlandinita* are frequent;

– The presence of *Aulotortus sinuosus* (Weynschenk) in the foraminifer association of the Steinalm Limestone supports the facies-indicating role and lack of stratigraphic value of the species.

Palaeontology

In this part only the Triassic Foraminifera of biostratigraphic significance are described. A portion of them is of chronostratigraphic significance; the other group is characteristic of a facies, while the third one comprises all species of "incertae sedis".

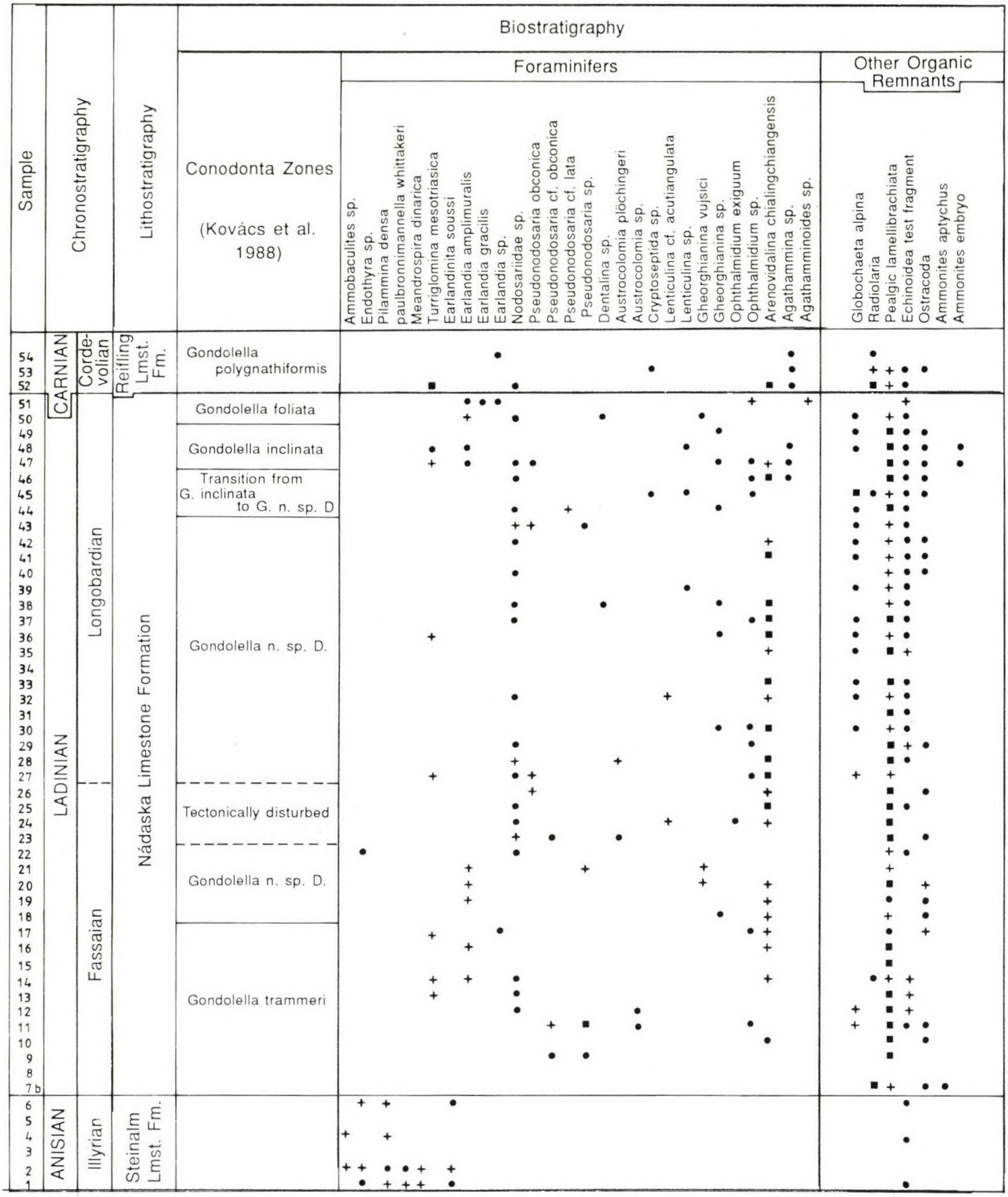


Fig. 6
Distribution and frequency of the foraminifer fauna of the section Alsó Hill-1 on the basis of the samples. • scattered; + frequent; ■ en mass

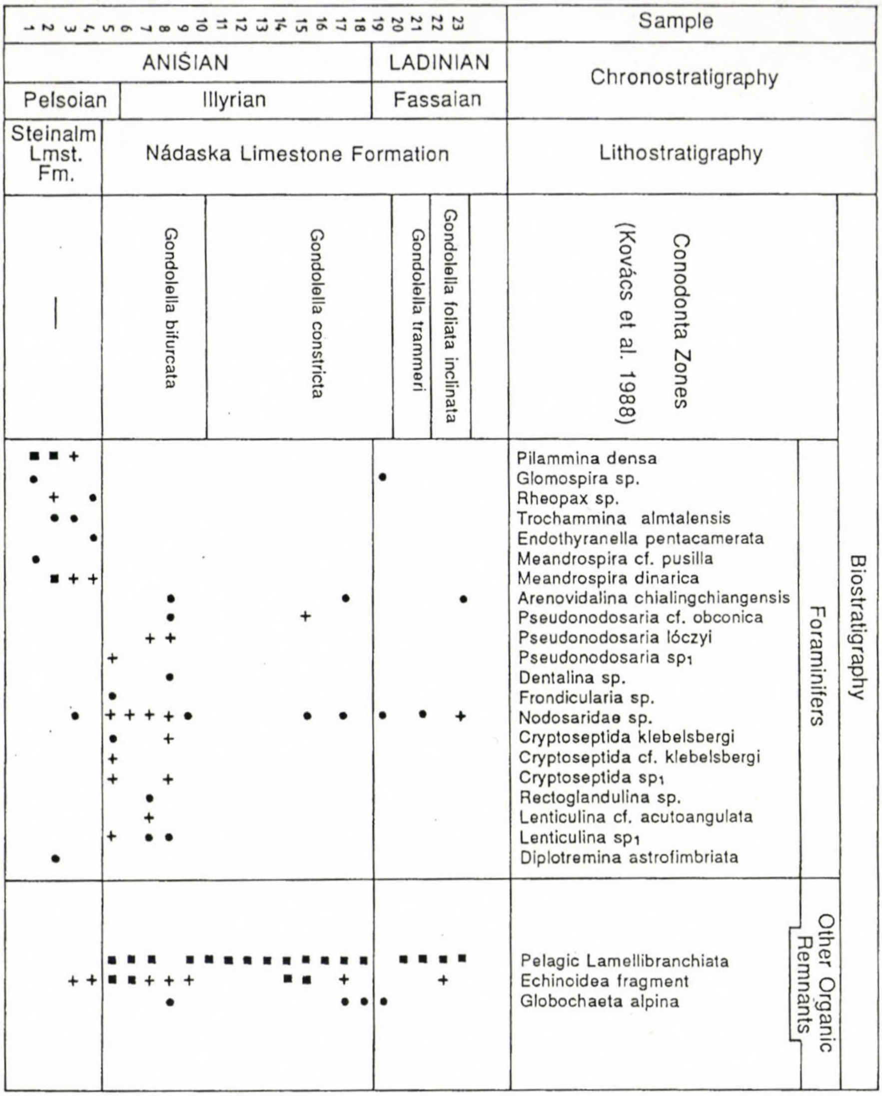


Fig. 7
Distribution and frequency of the foraminifer fauna of the section Alsó Hill-8 on the basis of the samples. • scattered; + frequent; ■ en mass

The taxonomic classification is that of Loeblich and Tappan (1988). The short descriptions of the genera are based on those in the monograph of Loeblich and Tappan (1988) and/or the original ones have been taken into consideration.

The references of the taxonomic part can be found in the monograph "Foraminiferal genera and their classification" by Loeblich and Tappan (1988).

ORDER: FORAMINIFERIDA Eichwald, 1830
I. suborder: TEXTULARIINA Delage et Hérouard, 1896
superfamily: AMMODISCACEA Reuss, 1862
family: Ammodiscidae Reuss, 1862
subfamily: Ammovertellininae Sajdova, 1981
genus: Pilammina Pantic, 1965 *Pilammina densa* Pantic, 1965
Pilammina negevi (Benjamini, 1984)

genus: Pilamminella Salaj, 1977
Pilamminella semiplana (Kochansky-Devidé et Pantic, 1966)

subfamily: Paulbronnimanninae Rettori et Zaninetti, 1993
genus: Paulbronnimannella Rettori, 1994
Paulbronnimannella whittakeri Rettori in: Zaninetti, Rettori et Martini, 1994

superfamily: HORMOSINACEA Haeckel, 1894
family: Hormosinidae Haeckel, 1894
subfamily: Reophacinae Cushman, 1910
genus: Reophax de Montfort, 1808
Reophax asper (Ziegler, 1964)

superfamily: TROCHAMMINACEA Schwager, 1877
family: Trochamminidae Schwager, 1877
subfamily: Trochammininae Schwager, 1877
genus: Trochammina Jones et Parker, 1859
Trochammina almtalensis Koehn-Zaninetti, 1969
Trochammina alpina Kristan-Tollmann, 1964

superfamily: LITUOLACEA de Blainville, 1827
family: Lituolidae de Blainville, 1827
subfamily: Lituolinae de Blainville, 1827
genus: Ammobaculites Cushman, 1910
Ammobaculites elongatus (Salaj in: Salaj, Biely et Bystricky, 1967)

II. suborder: FUSULININA Wedekind, 1937
superfamily: NODOSINELLACEA Rhumbler, 1895
family: Earlandinitidae Loeblich et Tappan, 1984
genus: Earlandinita Cummings, 1955
Earlandinita grandis Salaj, 1977
Earlandinita ladinica Salaj, 1977
Earlandinita oberhauseri Salaj in: Salaj, Biely et Bystricky, 1967
Earlandinita soussi Salaj, 1978

superfamily: ENDOTHYRACEA Brady, 1884
family: Endothyridae Brady, 1884
subfamily: Haplophragmellinae Reitlinger, 1959
genus: Haplophragmella Rauzer-Chernuseva et Reitlinger, 1959

Haplophragmella inflata Zaninetti et Brönnimann in: Brönnimann, Cadet et Zaninetti, 1973

subfamily: Endothyrinae Brady, 1884
genus: Endothyra Phyllips, 1846
Endothyra badouxi Zaninetti et Brönnimann in: Zaninetti, Brönnimann et Baud, 1972
Endothyra küpperi Oberhauser, 1960
Endothyra malayensis Gazdzicki, 1977

subfamily: Endothyranopsinae Reytlinger, 1958
genus: Endothyranella Galloway et Harlton, 1930
Endothyranella bicamerata Salaj in: Salaj, Biely et Bystricky, 1967
Endothyranella pentacamerata Salaj in: Salaj, Biely et Bystricky, 1967
Endothyranella wirzi (Koehn-Zaninetti, 1968)

family: Endotebidae Vachard, Martini, Rettori et Zaninetti, 1994
genus: Endoteba Vachard et Razgallah, 1988
Endoteba sp. (*Neoendothyra reicheli* Reitlinger)

III. suborder: INVOLUTININA Hohenegger et Piller, 1977
family: Involutinidae Bütschli, 1880
subfamily: Aulotortinae Zaninetti, 1984
genus: Aulotortus Weynschenk, 1956
Aulotortus sinuosus Weynschenk, 1956

IV. suborder: MILIOLINA Delage et Hérouard, 1896
superfamily: CORNUSPIRACEA Schultze, 1854
family: Arenovidalinidae Zaninetti et Rettori in: Zaninetti, Rettori, He et Martini, 1991
subfamily: Arenovidalininae Zaninetti et Rettori in: Zaninetti, Rettori, He et Martini, 1991
genus: Arenovidalina Ho, 1959
Arenovidalina chialingchiangensis Ho, 1959

family: Meandrospiridae Sajdova, 1981
subfamily: Meandrospirinae Sajdova, 1981
genus: Meandrospira Loeblich et Tappan, 1946
Meandrospira dinarica Kochansky-Devidé et Pantic, 1966
Meandrospira pusilla He, 1959

V. suborder: ROBERTININA Loeblich et Tappan, 1984
superfamily: DUOSTOMINACEA Brotzen, 1963
family: Duostominidae Brotzen, 1963
genus: Diplotremina Kristan-Tollmann, 1960
Diplotremina astrofimbriata Kristan-Tollmann, 1960

genus: *Pilammina* Pantic, 1965: "The shell is free, large, spherical. It is made of a sphaerical initial chamber and an elongated, tubular and undivided one.

The coiling of the tubular chamber around the proloculum is glomerated, the coiling of whorls having taken place by pressing one whorl to another, while the angle of coils is changing gradually relative to preceding ones. The theca made of limestone, imperforate, including slight amounts of foreign admixtures."

Pilammina densa Pantic, 1965

Pl. I, Figs: 3–4, IX, Figs: 2–3, 5–6

Type reference:

1965.	*Pilammina densa*	– Pantic, S. p. 191. pl. 1, Figs 1–2., pl. 2, Figs 1–9.

Synonyms:

1966.	*Pilammina densa*	– Kochansky-Devidé, V. et Pantic, S. (not illustrated)
1966/67a.	*Pilammina densa*	– Pantic, S. pl. 1, Fig. 1.
1966/67b.	*Pilammina densa*	– Pantic, S. (not illustrated)
1967.	*Pilammina densa*	– Pantic, S. pl. 1, Fig. 2.
1967a.	*Pilammina densa*	– Salaj, J., Biely, A. et Bystricky, J. pl. 1, Fig. 7.
1967a.	*Pilammina* sp.	– Salaj, J., Biely, A. et Bystricky, J. pl. 1, Fig. 6.
1967b.	*Pilammina densa*	– Salaj, J., Biely, A. et Bystricky, J. pl. 1, Fig. 2.
1968.	*Glomospira* cf. *densa*	– Koehn-Zaninetti, L. (not illustrated)
1968.	*Pilammina densa*	– Dimitrijevic, M., Pantic, S., Radoicic, R. et Stefanovska, D. pl. 2, Fig. E., pl. 8, Fig. 5.
1968.	*Pilammina densa*	– Pantic, S. (not illustrated)
1969.	*Glomospira* cf. *densa*	– Koehn-Zaninetti, L. p. 27. pl. 4, Figs A-C.
1969.	*Glomospirella friedli*	– Koehn-Zaninetti, L., Brönnimann, P. et Gall, J.C. (not illustrated)
1969.	*Pilammina* ex. gr. *densa*	– Gaetani, M. pl. 32, Figs 3–4., pl. 33, Fig. 1.
1969a.	*Pilammina densa*	– Salaj, J. pl. 2, Fig. 1.
1969c.	*Pilammina densa*	– Salaj, J. (not illustrated)
1970.	*Glomospira densa*	– Bechstädt, T. et Brandner, R. pl. 2, Fig. 4.
1970.	*Glomospira densa*	– Borza, K. p. 180. Figs 2, 3, 5–8.
1970.	*Pilammina densa*	– Ganeva, M., Stefanov, S. et Chatalov, G. (not illustrated)
1970.	*Glomospira densa*	– Pantic, S. pl. 4, Fig. 8.
1970.	*Glomospira* sp.	– Pantic, S. pl. 4, Fig. 9.
1970.	*Pilammina* ex. gr. *densa*	– Gaetani, M., Premoli-Silva, I. et Zanin Buri, C. (not illustrated)
1970a, b.	*Pilammina densa*	– Mirkovic, M. (not illustrated)
1970.	*Pilammina densa*	– Roksandic, M. et Canovic, M. pl. 8, Fig. 3.
1971.	*Glomospira densa*	– Baud, A., Zaninetti, L. et Brönnimann, P. p. 80. pl. 1, Figs 1–4.
1971.	*Glomospira densa*	– Urosevic, D. pl. 2, Figs 1, 12.
1971.	*Pilammina densa*	– Pantic, S. (not illustrated)
1971.	*Pilammina densa*	– Premoli-Silva, I. p. 325. pl. 2, Figs 1–3., pl. 22, Figs 3–4.
1972.	*Glomospira densa*	– Brönnimann, P. et Zaninetti, L. (not illustrated)
1972.	*Glomospira densa*	– Brönnimann, P., Zaninetti, L. et Baud, A. (not illustrated)
1972.	*Glomospira densa*	– Canovic, M. et Kemenci, R. pl. 1, Fig. 4.
1972.	*Glomospira* cf. *densa*	– Christodoulou, G. et Tsaila-Monopolis, S. pl. 26, Figs 1–2., pl. 29, Fig. 5.
1972.	*Glomospira densa*	– Christodoulou, G. et Tsaila-Monopolis, S. pl. 29, Fig. 4.
1972.	*Glomospira densa*	– Pantic, S. et Rampnoux, J.P. pl. 1, Fig. 3.

1972.	*Pilammina (Glomospira) densa*	– Bystricky, J. (not illustrated)
1972.	*Glomospira* aff. *densa*	– Ramovs, A. (not illustrated)
1972b.	*Pilammina densa*	– Trifonova, E. (not illustrated)
1972.	*Glomospira densa*	– Jendrejáková, O. (not illustrated)
1972a.	*Glomospira densa*	– Zaninetti, L., Brönnimann, P. et Baud, A. (not illustrated)
1973.	*Glomospira articulosa*	– Glazek, J., Trammer, J. et Zawidzka, K. pl. 2, Fig. 5a.
1973.	*Glomospira densa*	– Glazek, J., Trammer, J. et Zawidzka, K. p. 470. pl. 1, Figs 1, 3a, 5, 6a, 7a., pl. 2, Figs 8–9., pl. 3, Figs 1–6., pl. 4, Figs 5–6.
1973.	*Glomospira densa*	– Glazek, J., Trammer, J. et Zawidzka, K.pl. 2, Fig. 5b., pl. 4, Fig. 4.
1973.	*Glomospira densa*	– Jendrejáková, O. (not illustrated)
1973.	?*Glomospira* cf. *densa*	– Lys, M. et Marin, Ph. (not illustrated)
1973.	?*Glomospira densa*	– Popa, E. et Dragastan, O. pl. 1, Fig. 4.
1973.	?*Glomospira regularis*	– Glazek, J., Trammer, J. et Zawidzka, K. pl. 2, Fig. 4.
1973.	*Glomospira densa* (not illustrated)	– Brönnimann, P., Zaninetti, L., Moshtaghian, A. et Huber, H.
1973a.	*Glomospira densa*	– Brönnimann, P., Cadet, J.P. et Zaninetti, L. p. 307. pl. 21, Figs 1–7, 10–11.
1973b.	*Glomospira densa*	– Brönnimann, P., Cadet, J.P. et Zaninetti, L. p. 466. pl. 47, Figs 3–4.
1973.	*Glomospira densa*	– Rampnoux, J.P. (not illustrated)
1973/74.	*Glomospira densa*	– Gheorghian, D. p. 54. pl. 1, Figs 1–3.
1974b.	*Glomospira densa*	– Pantic, S. (not illustrated)
1974c.	*Glomospira densa*	– Pantic, S. pl. 1, Fig. 7.
1974.	*Glomospira densa*	– Druckman, Y. (not illustrated)
1974.	?*Pilammina densa*	– Efimova, N.A. pl. 1, Fig. 8.
1974.	*Glomospira densa*	– Kollárová-Andrusovová, V. et Bystricky, J. (not illustrated)
1974.	*Glomospira densa*	– Budurov, K. et Trifonova, E. (not illustrated)
1975.	*Glomospira* cf. *densa*	– Christodoulou, G. et Tsaila-Monopolis, S. pl. 4, Fig. 2, pl. 8, Figs 1–2.
1975.	*Glomospira densa*	– Gazdzicki, A., Trammer, J. et Zawidzka, K. pl. 2, Figs 5–9.
1975.	*Glomospira densa*	– Baltres, A. pl. 2, Figs 9–10.
1975.	*Glomospira densa*	– Pantic-Prodanovic, S. pl. 24, Figs 1–2.
1975.	*Glomospira densa*	– Triofonova, E. et Chatalov, G.V. pl. 2, Figs 7–8, pl. 3, Figs 1–3.
1975.	*Glomospira densa*	– Ramovs, A. textfig. 3.
1976.	*Glomospira densa*	– Zaninetti, L. p. 89. pl. 2, Fig. 17, 21.
1976.	*Pilammina densa*	– Tollmann, A. textfig. 27.
1976.	*Glomospira* cf. *densa*	– Belka, Z. et Gazdzicki, A. pl. 1, Figs 10–11.
1976.	*Glomospira densa*	– Belka, Z. et Gazdzicki, A. pl. 1, Figs 15–16.
1976.	*Glomospira densa*	– Urosevic, D. et Dumurdanov, N. pl. 2, Fig. 4.
1976.	*Glomospira densa*	– Mostler, H. (not illustrated)
1976.	*Glomospira densa*	– Farabegoli, E., Pisa, G. et Ott, E. (not illustrated)
1977a.	*Glomospira densa*	– Trifonova, E. p. 51. pl. 1, Fig. 10.
1977.	*Glomospira densa*	– Sudar, M. pl. 3, Fig. 1.
1977.	*Glomospira densa*	– Urosevic, D. pl. 2, Figs 6–7.
1977.	*Glomospira densa*	– Gazdzicki, A. et Smit, O.E. pl. 3, Figs 4–9.
1977.	*Glomospira densa*	– Pantic-Prodanovic, S. et Radosevic, B. pl. 4, Figs 5–8.
1977.	*Pilammina densa*	– Salaj, J. pl. 1, Figs 6–7.
1977.	*Glomospira densa*	– Zaninetti, L. (not illustrated)
1978.	*Pilammina densa*	– Salaj, J. et Polák, M. (not illustrated)
1978.	*Glomospira densa*	– Zaninetti, L. et Dager, Z. (not illustrated)
1978a.	*Glomospira densa*	– Trifonova, Ek. pl. 2, Fig. 3.
1978b.	*Glomospira densa*	– Dager, Z. p. 49. pl. 1, Fig. 2.

1978a. *Glomospira densa* – Dager, Z. (not illustrated)
1978b. *Glomospira densa* – Trifonova, E. (not illustrated)
1979. *Glomospira densa* – Resch, W. (not illustrated)
1979. *Glomospira densa* – Sokac, B. et Velic, I. (not illustrated)
1979. *Glomospira densa* – Chatalov, G. et Trifonova, E. pl. 2, Figs 5–6.
1980. *Glomospira densa* – Trifonova, Ek. (not illustrated)
1981. *Glomospira densa* – Dragastan, O. (not illustrated)
1982. *Glomospira densa* – Gerolymatos, E.; Dornisepen, U. et Trifonova, E. (not illustrated)
1982. *Glomospirella densa* – Trifonova, E. et Vaptsarova, A. (not illustrated)
1982. *Glomospira densa* – Dragastan, O.; Diaconu, M.; Popa, E. et Damian, R. pl. 4, Fig. 3.
1982. *Glomospira densa* – Kristan-Tollmann, E. et Tollmann, A. (not illustrated)
1983. *Pilammina densa* – Salaj, J.; Borza, K. et Samuel, O. p. 66.; pl. 9, Figs 1–4.
1983. *Glomospira densa* – Trifonova, Ek. (not illustrated)
1983. *Glomospira densa* – Kristan-Tollmann, E. et Tollmann, A. pl. 12, Figs 1–2.
1984. *Pilammina densa* – Salaj, J. et Jendrejáková, O. (not illustrated)
1984. *Glomospira densa* – Benjamini, C. (not illustrated)
1984. *Glomospira densa* – He, Y. p. 422., pl. 1, Figs 1–7.
1985. *Glomospira densa* – Chatalov, G. et Trifonova, E. pl. 1, Fig. 7.
1986. *Pilammina densa* – Sudar, M. pl. 17, Figs 1–4.
1987. *Glomospira densa* – Pirdeni, A. pl. 2, Figs 6–9.
1988. *Pilammina densa* – AGIP p. 43 (textfig.)
1988. *Glomospiora densa* – Pirdeni, A. pl. 1, Figs 8–9.
1988. *Pilammina densa* – Salaj, J., Trifonova, E., Gheorghian, D. (not illustrated)
1988. *Pilammina densa* – Canovic, M. et Kemenci, R. pl. 4, Fig. 2.
1988. *Glomospira densa* – Kuss, J. (not illustrated)
1988. *Pilammina densa* – Urosevic, D. (not illustrated)
1988. *Glomospira* cf. *densa* – Kovács, S., Less, Gy., Piros, O. et Róth, L. (not illustrated)
1989. *Pilammina densa* – Gaetani, M. et Gorza, M. pl. 10, Fig. 8.
1989. *Glomospira* cf. *densa* – Kovács, S., Less, Gy., Piros, O., Réti, Zs. et Róth, L. (not illustrated)
1990. *Glomospira densa* – Herak, M., Jamicic, D., Simunic, A. et Bukovac, J. (not illustrated)
1991. *Glomospira sygmoidalis* – He, Y. et Cai, L.Q. p. 219. pl. 1, Figs 3–4.
1992. *Pilammina densa* – Simunic, A. et Simunic, A. (not illustrated)
1992. *Pilammina densa* – Urosevic, D. (not illustrated)
1992. *Pilammina densa* – Angiolini, L., Dragonetti, L., Muttoni, G., Nicora, A. (not illustrated)
1992. *Pilammina densa* – Trifonova, E. p. 20. pl. 2, Figs 10–11, pl. 6, Fig. 15.
1993. *Glomospira densa* – He, Y. p. 180. pl. 1, Figs 17–18.
1993. *Glomospira (Pilammina) densa* – Senowbari-Daryan, B., Zülhke, R., Bechstädt, T. et Flügel, E. pl. 65, Figs 3–4, 8.
1993. *Glomospira* cf. *densa* – Kovács, S., Less, Gy., Piros, O., Réti, Zs. et Róth, L. (not illustrated)
1993. *Glomospira densa* – Rálisch-Felgenhauer, E., Török, Á., Barabás-Stuhl, Á. et Nagy, E. (not illustrated)
1993. *Glomospira densa* – Góczán, F. et Oravecz-Scheffer, A. pl. 17, Fig. 12.
1994. *Pilammina densa* – Flügel, E., Ramovs, A. et Bucur, I.I. pl. 5, Figs 7–8.
1994. *Pilammina* cf. *densa* – Flügel, E., Ramovs, A. et Bucur, I.I. pl. 5, Figs 5–6.
1994. *Pilammina densa* – Bucur, I.I., Strutinski, C., Pop-Stratila, D. pl. 14, Fig. 11.
1994. *Pilammina densa* – Piros, O., Mandl, G.W., Leion, R., Pavlik, W, Bérczi-Makk, A., Siblik, M. et Lobitzer, H. (not illustrated)
1994. *Pilammina densa* – Muttoni, G. et Rettori, P. pl. 2, Fig. 4.
1994. *Pilammina densa* – Zaninetti, L., Rettori, R., Martini, R. pl. 2, Figs 15–16.

Size: Diameter of the test: 0.45–0.53 mm
Remark: The test is large in size and consists of a globular proloculus followed by a tubular, planispiral second chamber with dense coiling. The cross-section of the test is normally circular, but elliptical and/or quadrangular sections are also frequent. The breadth of the second, extraordinarily long chamber increases gradually. As a consequence of the heavily recrystallized texture, the number of the whorls can be determined with difficulty, if at all. This species is one of the rare ones with chronostratigraphic significance.
Occurrence in Alsó Hill: This species can be detected very consistently and in large number in the Steinalm Limestone (Locations: T-342, -343, -419, -431, -448, -449 and sampling points 1, 2, 3 in section Alsó-Hill-8).

Pilammina negevi (Benjamini, 1984)

Pl. I, Figs 1–2

Type reference:

1984.	*Glomospira negevi*	– Benjamini, Ch. p. 37. pl. 1, Figs 1–5.

Synonyms:

1975.	*Glomospira* sp.	– Zaninetti, L. et Brönnimann, P. pl. 36, Figs 7–8.
1975.	*Glomospirella* aff. *densa*	– Zaninetti, L. et Brönnimann, P. pl. 36, Fig. 2.

Size: Diameter of the test: 0.15–0.20 mm
Remark: The style of coiling is similar that of the species *Pilammina densa*, but the size of the test is much smaller in the case of Pilammina negevi. Unlike the earlier authors, the latest Taxonomy of the Foraminifers (Loeblich and Tappan 1988) pigeon-holes this species in the genus of *Pilammina* and not that of *Glomospira*. It can be easily distinguished from the latter by its smaller test, the very long streptospirally coiled second chamber and the imperforate, micro-granular calcareous wall. At the same time, another explanation cannot be neglected: the smaller test may indicate younger individuals of the species *Pilammina densa*. In order to draw a final conclusion, i.e to consider *Pilammina negevi* as young individuals of *Pilammina densa*, additional investigations are required.
Occurrence in Alsó Hill: Several individuals have been recovered from two locations of the Steinalm Limestone (Locations: b/1971/BK, T-342).

genus: **Ammobaculites** Cushman, 1910 (after Loeblich, Tappan, 1988):

"Test free, elongate, early portion close coiled, later uncoiling and rectilinear, rounded in section, wall coarsely agglutinated, interior simple, aperture terminal, rounded. Cosmopolitan."

Ammobaculites elongatus (Salaj in: Salaj, Biely et Bystricky 1967)

Pl. II, Fig. 4

Type reference:

1967a. *Earlandinita elongata* – Salaj, J., Biely, A. et Bystricky, J. p. 120. pl. 1, Fig. 4.

Synonyms:

1970b.	*Earlandinita elongata*	– Mirkovic, M. (not illustrated)
1972.	*Earlandinita elongata*	– Pantic, S. et Rampnoux, J.P. pl. 1, Fig. 8.
1973.	*Earlandinita elongata*	– Jendrejáková, O. (not illustrated)
1976.	*Earlandinita elongata* (*Ammobaculites radstadtensis*)	– Zaninetti, L. (not illustrated)
1977.	*Ammobaculites? elongatus*	– Hohenegger, J. et Lein, R. p. 234. pl. 16, Figs 3–4, pl. 18, Fig. 1.
1983.	*Earlandinita elongata*	– Salaj, J., Borza, K. et Samuel, O. p. 81. pl. 30, Fig. 6, pl. 31, Figs 1–2. pl. 32, Figs 2, 5., pl. 42, Figs 2–4.
1991/92.	*Ammobaculites elongatus*	– Flügel, E., Velledits, F., Senowbari-daryan, B. et Riedel, P. (not illustrated)
1994.	*Earlandinita elongata*	– Flügel, E., Ramovs, A. et Bucur, I.I. pl. 2, Fig. 10.
1994.	*Earlandinita elongata*	– Bucur, I. I., Strutinski, C. et Pop-Stratila, D. pl. 14, Fig. 1.

Size:: Length of the test: 1.2 mm, maximum breadth of the test: 0.25 mm
Remark: This species was originally considered to belong to the genus *Earlandinita*. On the basis of its initial, coiled part as shown in the illustration of the holotype and of its agglutinated shell, it may well belong to the genus *Ammobaculites* (The description of the holotype does not have any reference to its original condition). This modification was – but due to the inadequate description only conditionally – performed by Hohenegger et Lein, (1977). Zaninetti (1976) proposed to classify it among the species *Ammobaculites radstadtensis*.
Occurrence in Alsó Hill: Several examples from three locations (Locations: T-342, -404, -490) in the Steinalm Limestone

genus: **Earlandinita** Cummings, 1955: "Test free, small, straight or slightly curved, cylindrical or tapering, slender, circular in cross section, consisting of a sphaerical proloculum and varying number of small, cylindrical, well-defined chambers, which increase gradually in size as added well-developed septa, with septal openings, separating chambers and marked externally by thin, distinct, depressed sutures, lateral margins slightly lobulate, surface smooth, wall composed of small, equidimensional granules of calcite bound by calcareous cement, aperture terminal, central, simple, circular, on apex of slightly domed apertrural face. In thin section this genus is characteristed by the wall-structure and the well-developed septation."

Earlandinita grandis Salaj, 1977

Pl. I, Fig. 8, Pl. II, Fig. 3

Type reference:

1977.	*Earlandinita grandis*	– Salaj, J. p. 108. pl. 3, Figs 2, 4.

Synonyms:

1983.	*Earlandinita grandis*	– Salaj, J., Borza, K. et Samuel, O. p. 81. pl. 30, Fig. 6., pl. 31, Figs 1–2., pl. 32, Figs 2, 5, pl. 42, Figs 2, 4.
1987.	*Earlandinita* sp. aff. *E. grandis*	– Pirdeni, A. pl. 3, Fig. 5.
1992.	*Earlandinita grandis*	– Trifonova, E. p. 41. pl. 5, Fig. 1.

Size:: Length of the test: 1.00–1.07 mm, breadth of the test: 0.50 mm
Remark: Relatively broad, uniserial test. The spherical proloculus is followed by four slightly flattened chambers with rounded up rims. The wall is heavily recrystallized.
Occurrence in Alsó Hill: A couple of individuals have been recovered from the lagoonal part of the Steinalm Limestone. (Locations: T-404, -431)

Earlandinita ladinica Salaj, 1977

Pl. II, Figs 9–10

Type reference:

1977.	*Earlandinita ladinica*	– Salaj, J. p. 1096. pl. 2, Fig. 8.

Synonyms:

1973b.	*Endothyranella?* sp.	– Brönnimann, P., Cadet, J.P. et Zaninetti, L. pl. 48, Figs 11–13.
1983.	*Earlandinita ladinica*	– Salaj, J., Borza, K. et Samuel, O. p. 82. pl.31, Figs 3–6., pl. 47, Figs 7, 10.
1988.	*Earlandinita ladinica*	– Haas, J., Rálisch-Felgenhauer, E., Oravecz-Scheffer, A., Nagy, E. et Bérczi-Makk, A. (not illustrated)
1991/92.	*Earlandinita* cf. *E. ladinica*	– Flügel, E., Velledits, F., Senowbari-Daryan, B. et Riedel, P. (not illustrated)

Size:: Length of the test: 1.5 mm, breadth of the test: 0.40–0.46 mm
Remark: Large uniserial test consisting of 6–8 chambers of identical size. The proloculus of the recovered fragmented individuals is not known. Due to the large test and identical chamber size, these individuals have been identified as specimens of the species *Earlandinita ladinica*. The tests recovered at Alsó Hill are broader than that of the holotype recovered/described from the Western-Carpathians by Salaj.
Occurrence in Alsó Hill: Recovered from a single location (T-431) in the Steinalm Limestone.

Earlandinita oberhauseri Salaj in: Salaj, Biely et Bystricky, 1967

Pl. II, Figs 2, 5–6, 11b, Pl. V, Fig. 8b

Type reference:

1967b. *Earlandinita oberhauseri* – Salaj, J., Biely, A. et Bystricky, J. p. 120. pl. 1, Fig. 4.

Synonyms:

1970.	*Earlandinita* sp.	– Pantic, S. pl. 3, Fig. 3.
1976.	*Earlandinita oberhauseri*	– Zaninetti, L. p. 121. (not illustrated)
1977.	*Earlandinita* sp.	– Gazdzicki, A. et Smit, O.E. pl. 7, Fig. 9.
1978.	*Earlandinita oberhauseri*	– Oravecz-Scheffer, A. pl. 3, Figs 1–4.
1983.	*Earlandinita oberhauseri*	– Salaj, J., Borza, K. et Samuel, O. p. 82. pl. 33, Figs 1–2., pl. 143, Fig. 1.
1983.	*Earlandinita oberhauseri*	– Bystricky, J. et Jendrejáková, O. (not illustrated)
1983.	*Earlandinita oberhauseri*	– Oravecz-Scheffer, A. (not illustrated)
1987.	*Earlandinita oberhauseri*	– Oravecz-Scheffer, A. pl. 20, Fig. 12.
1988.	*Earlandinita oberhauseri*	– Haas, J.; Rálisch-Felgenhauer, E.; Oravecz-Scheffer, A.; Nagy, E. et Bérczi-Makk, A. (not illustrated)
1989a.	*Earlandinita oberhauseri*	– Bérczi-Makk, A. (not illustrated)
1989b.	*Earlandinita oberhauseri*	– Bérczi-Makk, A. (not illustrated)
1993.	*Earlandinita oberhauseri*	– Góczán, F. et Oravecz-Scheffer, A. pl. 39, Fig.2.
1994	*Earlandinita oberhauseri*	– Piros, O., Mandl, G.W., Lein, R., Pavlik, W., Bérczi-Makk, A., Siblik, M. et Lobitzer, H. (not illustrated)

Size: Length of the test: 0.60–0.70 mm, breadth (max.) of the test: 0.21–0.35 mm
Remark: The most populous species of the genus *Earlandinita* in the lagoonal facies. The large globular proloculus is followed by 3-4 chambers of identical breadth and size. They are rounded adjacent to the rim. More than 4 chambers are extremely rare.
Occurrence in Alsó Hill: This species is more frequent in the lagoonal part of the Steinalm Limestone (Locations: T-343, -371, -380, -384, -386, -449, -490, -513) than in those of the Wetterstein Limestone (Locations: T-167, -174, -444, -524).

genus: **Haplophragmella** Rauzer-Chernuseva et Reitlinger in: Rauzer-Chernuseva, Beljaev et Reitlinger, 1936 (after Loeblich and Tappan, 1988): "Test large, streptospirally enrolled in the early stage, with few chambers per whorl, later chambers uncoiled and rectilinear, wall coming terminal and cribrate, with large openings."

Haplophragmella inflata **Zaninetti et Brönnimann**
in: Brönnimann, Cadet et Zaninetti, 1973

Pl. VI, Fig. 7

Type references:

1973a.	*Haplophragmella inflata*	– Brönnimann, P., Cadet, J.P. et Zaninetti, L. (nomen nudum)
1973b.	*Haplophragmella inflata*	– Brönnimann, P., Cadet, J.P. et Zaninetti, L. p. 468. pl. 46, Figs 1–9, 10?

Synonyms:

1971.	*Ammobaculites wirzi*	– Premoli-Silva, I. pl. 25, Fig. 3.
1976.	*Haplophragmella inflata*	– Zaninetti, L. p. 130. pl. 4, Figs 13–15.
1977.	*?Haplophraghmella inflata*	– Sudar, M. pl. 3, Fig. 6.
1978.	*Haplophragmella inflata*	– Oravecz-Scheffer, A. pl. 4, Figs 2–3.
1987.	*Haplophragmella? inflata*	– Oravecz-Scheffer, A. p. 69. pl. 21, Fig. 3?
1987.	*Haplophragmella inflata*	– Pirdeni, A. pl. 3, Figs 9–10.
1988.	*Haplophragmella inflata*	– Pirdeni, A. pl. 1, Fig. 16.
1988.	*Haplophragmella inflata*	– Kovács, S., Less, Gy., Piros, O. et Róth, L. (not illustrated)
1989.	*Haplophragmella inflata*	– Gaetani, M. et Gorza, M. pl. 12, Fig. 4.
1989.	*Haplophragmella inflata*	– Bérczi-Makk, A. (not illustrated)
1989.	*Haplophragmella inflata*	– Kovács, S., Less, Gy., Piros, O., Réti, Zs. et Róth, L. (not illustrated)
1993.	*Haplophragmella inflata*	– Kovács, S., Less, Gy., Piros, O., Réti, Zs. et Róth, L. (not illustrated)
1993.	*Haplophragmella* cf. *inflata*	– Trifonova, E. p. 23. pl. 2, Fig. 7.
1994.	*Haplophragmella inflata*	– Piros, O., Mandl, G.W., Lein, R., Pavlik, W., Bérczi-Makk, A., Siblik, M. et Lobitzer, H. (not illustrated)

Size:: Length of the test: 0.95 mm
Remark: The coiled proloculum cannot be detected in the oblique sections. The uncoiled uniserial part is composed of 3–4 inflated globular chambers. The slot is a series of pores in terminal position on the chambers of the uniserial part. Due to the strong recrystallization the pores may be merged.
Occurrence in Alsó Hill: This species is known from one sample (Location: T-491) of the Steinalm Limestone.

genus: **Meandrospira** Loeblich et Tappan, 1946: "Test free, composed of proloculum followed by a tubular second chamber, which spirals about the proloculum in short zizag bends, so that a side view shows numerous loops reaching toward the umbilicus, the loops being formed by the tubular chamber swinging back upon itself frequently, wall calcareous, imperforate, aperture simple, terminal."

Meandrospira dinarica Kochansky-Devidé et Pantic, 1966

Pl. II, Fig. 11a, Pl. IV, Figs 1–10, Pl. V, Figs 1–8, Pl. VIII, Fig. 4, Pl. IX, Figs 4a, 9–11

Type reference:

1966. Meandrospira dinarica – Kochansky-Devidé, V. et Pantic, S. p. 21. pl. 3, Figs 9–11., pl. 4, Figs 1–10.

Synonyms:

1966/67a.	*Meandrospira dinarica*	– Pantic, S. pl. 1, Figs 2–4.
1967a.	*Meandrospira dinarica*	– Salaj, J., Biely, A. et Bystricky, J. pl. 1, Figs 13, 19.
1967b.	*Meandrospira dinarica*	– Salaj, J., Biely, A. et Bystricky, J. (not illustrated)
1967.	*Meandrospira dinarica*	– Pantic, S. pl. 1, Fig. 3.
1968.	*Meandrospira dinarica*	– Pantic, S. et Mojsilovic, S. (not illustrated)

1968.	*Meandrospira dinarica*	– Dimitrijevic, E., Pantic, S., Radoicic, R. et Stefanovska, D. pl. 1, Fig. d, pl. 5, Fig. 1.
1968.	*Meandrospira dinarica*	– Pantic, S. (not illustrated)
1969.	*Citaella? dinarica*	– Gaetani, M. pl. 33, Fig. 2.
1969a.	*Meandrospira dinarica*	– Salaj, J. (not illustrated)
1969c.	*Meandrospira dinarica*	– Salaj, J. (not illustrated)
1970.	*Meandrospira dinarica*	– Roksandic, M. et Canovic, M. pl. 7, Figs 1–2.
1970.	*Meandrospira dinarica*	– Pantic, S. pl. 4, Fig. 1-2.
1970.	*Meandrospira dinarica*	– Papp, A. et Turnovsky, K. pl. 22, Figs 3–5.
1970.	*Meandrospira* aff. *dinarica*	– Turculet, I. (not illustrated)
1970a, b.	*Meandrospira dinarica*	– Mirkovic, M. (not illustrated)
1970.	*Citaella? dfinarica*	– Gaetani, M., Premoli-Silva, I. et Zanin Butzi, C. (not illustrated)
1971.	*Citaella dinarica*	– Premoli-Silva, I. p. 324. pl. 20, Figs 2, 4–8.
1971.	*?Meandrospira dinarica*	– Urosevic, D. pl. 2, Figs 10–11, pl. 4, Figs 2–5.
1971.	*Meandrospira dinarica*	– Baud, A., Zaninetti, L. et Brönnimann, P. p. 88. textfig. 3a, pl. 2, Fig 1–4.
1971.	*Meandrospira dinarica*	– Scholtz, G. (not illustrated)
1971.	*Meandrospira dinarica*	– Pantic, S. (not illustrated)
1972a.	*Meandrospira dinarica*	– Zaninetti, L., Brönnimann, P. et Baud, A. (not illustrated)
1972b.	*Meandrospira dinarica*	– Zaninetti, L., Brönnimann, P. et Baud, A. p. 479. pl. 7, Figs 1–3., pl. 9, Figs 19, 23–25., pl. 10, Figs 9–11, 15.
1972b.	*Meandrospira dinarica*	– Trifonova, E. (not illustrated)
1972.	*Meandrospira dinarica*	– Scholtz, G. pl. 1, Figs 1, 3.
1972.	*Citaella dinarica*	– Bystricky, J. (not illustrated)
1972.	*Meandrospira dinarica*	– Brönnimann, P., Zaninetti, L. et Baud, A. (not illustrated)
1972.	*Meandrospira dinarica*	– Oravecz-Scheffer, A. (not illustrated)
1972.	*Meandrospira dinarica*	– Urosevic, D. et Radovanovic, Z. pl. 1, Figs 1–2.
1972.	*Meandrospira dinarica*	– Pantic, S. et Grubic, A. (not illustrated)
1972.	*Meandrospira dinarica*	– Canovic, M. et Kemenci, R. (not illustrated))
1972.	*Meandrospira dinarica*	– Samuel, O., Borza, K. et Köhler, E. pl. 18, Figs 1–2.
1972.	*Meandrospira dinarica*	– Pantic, S. pl. 2, Figs 1–2.
1972.	*Meandrospira dinarica*	– Christodoulou, G. et Tsaila-Monopolis, S. pl. 31, Fig. 7.
1972.	*Meandrospira dinarica*	– Brönnimann, P. et Zaninetti, L. (not illustrated)
1973.	*Meandrospira dinarica*	– Pantic, S. (not illustrated)
1973a.	*Meandrospira dinarica*	– Brönnimann, P., Cadet, J.P. et Zaninetti, L. p. 313. pl. 20, Fig. 8, 11–12.
1973b.	*Meandrospira dinarica*	– Brönnimann, P., Cadet, J.P. et Zaninetti, L. p. 469. pl. 46, Figs 11, 15., pl. 47, Fig. 10.
1973.	*Meandrospira dinarica*	– Glazek, J., Trammer, J. et Zawidzka, K. pl. 4, Figs 1–2.
1973.	*Meandrospira dinarica*	– Jendrejáková, O. (not illustrated)
1973.	*Citaella dinarica*	– Bystricky, J. (not illustrated)
1973.	*Arenovidalina chialingchiangensis*	– Courel, L. pl. 8, Figs 1–2.
1973.	*Meandrospira dinarica*	– Popa, E. et Dragastan, O. pl. 1, Fig. 4.
1973.	*Meandrospira dinarica*	– Rampnoux, J.P. (not illustrated)
1973/74.	*Meandrospira dinarica*	– Gheorghian, D. p. 63. pl. 2, Figs 1–2.
1974.	*Citaella dinarica*	– Kollarova-Andrusova, V. et Bystricky, J . (not illustrated)
1974.	*Meandrospira dinarica*	– Ramovs, A. (not illustrated)
1974.	*Meandrospira dinarica*	– Efimova, N.A. pl. 3, Figs 15–17.
1974c.	*Meandrospira dinarica*	– Pantic, S. pl. 1, Fig. 10.
1974.	*Meandrospira dinarica*	– Trifonova, E. (not illustrated)
1975.	*Meandrospira dinarica*	– Gazdzicki, A., Trammer, J. et Zawidzka, K. pl. 9, Figs 5–9.
1975.	*Meandrospira dinarica*	– Ramovs, A. textfig. 4.
1975.	*Meandrospira dinarica*	– Christodoulou, G. et Tsaila-Monopolis, S. pl. 7, Fig. 8.

1975. *Meandrospira dinarica* – Trifonova, E. et Chatalov, G. pl. 3, Figs 6–7.
1975. *Meandrospira dinarica* – Pantic-Prodanovic, S. pl. 14, Fig. 1.
1976. *Meandrospira dinarica* – Zaninetti, L. p. 133. pl. 1, Figs 12–14.
1976. *Meandrospira dinarica* – Tollmann, A. textfig. 31, 32.
1976. *Meandrospira dinarica* – Farabegoli, E., Pisa, G. et Ott, E. textfig. 6/b–o.
1976. *Meandrospira dinarica* – Urosevic, D. et Dumurdanov, N. pl. 2, Figs 1–2.
1976 *Meandrospira* cf. *dinarica* – Nagy, E. et Nagy, I. pl. 15, Fig. 11.
1977. *Meandrospira dinarica* – Salaj, J. pl. 1, Fig. 3.
1977. *Meandrospira dinarica* – Sudar, M. pl. 3, Fig. 2, pl. 4, Fig. 3.
1977. ?*Meandrospira dinarica* – Gazdzicki, A. et Smit, O.E. pl. 4, Fig. 7.
1977. *Meandrospira dinarica* – Gazdzicki, A. et Smit, O.E. pl. 4, Figs 8–9.
1977. *Meandrospira dinarica* – Misik, M., Mock, R. et Sykora, M. (not illustrated)
1977. *Meandrospira dinarica* – Pantic-Prodanovic, S. et Radosevic, B. pl. 4, Figs 1–2.
1977. *Meandrospira dinarica* – Zaninetti, L. (not illustrated)
1978. *Meandrospira dinarica* – Bérczi-Makk, A. pl. 1, Fig. 3.
1978. *Meandrospira dinarica* – Zaninetti, L. et Dager, Z. (not illustrated)
1978. *Meandrospira dinarica* – Salaj, J. et Polak, M. (not illustrated)
1978. *Meandrospira dinarica* – Pisa, G., Farabegoli, E. et Ott, E. (not illustrated)
1978a. *Meandrospira dinarica* – Dager, Z. (not illustrated)
1978b. *Meandrospira dinarica* – Dager, Z. p. 54. pl. 2, Fig. 6.
1978. *Meandrospira dinarica* – Oravecz-Scheffer, A. pl. 1, Figs 1–18.
1978a. *Meandrospira dinarica* – Trifonova, E. pl. 2, Fig. 7.
1979. *Citaella dinarica* – Jadoul, F. et Nikora, A. textfig. 2/c.
1979. *Meandrospira dinarica* – Jadoul, F. et Nikora, A. (not illustrated)
1979. *Meandrospira dinarica* – Resch, W. (not illustrated)
1979. *Meandrospira dinarica* – Sokac, B. et Velic, I. (not illustrated)
1979. *Meandrospira dinarica* – Chatalov, G. et Trifonova, E. p. 52. pl. 4, Fig. 11.
1980. *Meandrospira dinarica* – Trifonova, E. (not illustrated)
1981. *Meandrospira dinarica* – Dragastan, O. (not illustrated)
1982. *Meandrospira dinarica* – Kaya, O. et Lys, M. (not illustrated)
1982. *Meandrospira dinarica* – Dragastan, D., Diaconu, M., Popa, E. et Damian, R. pl. 4, Figs 1–2.
1982. *Meandrospira dinarica* – Kristan-Tollmann, E. et Tollmann, A. (not illustrated)
1983. *Meandrospira insolita* – Salaj, J., Borza, K. et Samuel, O. p. 100. pl.54, Figs 7–9., pl. 55, Fig. 19b.
1983. *Meandrospira dinarica* – Bystricky, J. et Jendrejáková, O. (not illustrated)
1983. *Meandrospira dinarica* – Kristan-Tollmann, E. et Tollmann, A. pl. 11, Figs 6–8.
1983. *Meandrospira dinarica* – Salaj, J., Borza, K. et Samuel, O. p. 99. pl. 47, Fig. 4., pl. 51, Figs 1–8., pl. 52, Figs 1–8.
1983. *Meandrospira dinarica* – Trifonova, E. (not illustrated)
1983. *Meandrospira dinarica* – Oravecz-Scheffer, A. (not illustrated)
1983. *Meandrospira dinarica* – Balogh, K., Dobosi, K., Góczán, F., Haas, J., Oravecz, J., Oravecz-Scheffer, A., Szabó, I. et Végh-Neubrandt, E. (not illustrated)
1984. *Meandrospira dinarica* – Salaj, J. et Jendrejáková, O. (not illustrated)
1984. *Meandrospira dinarica* – He, Y. p. 427. pl. 3, Figs 4–9.
1985. *Meandrospira dinarica* – Chatalov, G. et Trifonova, E. pl. 1, Fig. 13.
1986. *Meandrospira dinarica* – Sudar, M. pl. 19, Figs 1–5., pl. 28, Fig. 4.
1987. *Meandrospira dinarica* – Ramovs, A. pl. 3, Figs 1–2.
1987. *Meandrospira dinarica* – Zaninetti, L., Ciarapica, G., Martini, R., Salvini-Bonnard, G. et Rettori, R. (not illustrated)
1987. *Meandrospira dinarica* – Oravecz-Scheffer, A. pl. 19, Figs 1–11, 14
1987. *Meandrospira dinarica* – Pirdeni, A. pl. 2, Figs 1–5.
1988. *Meandrospira dinarica* – AGIP p. 43 (textfig.)

1988.	*Meandrospira immatura*	– He, Y. p. 92. pl. 1, Figs 13–14.
1988.	*Meandrospira dinarica*	– Pirdeni, A. pl. l, Fig. 7.
1988.	*Meandrospira dinarica*	– Salaj, J.; Trifonova, E. et Gheorghian, D. (not illustrated)
1988.	*Meandrospira dinarica*	– Tsaila-Monopolis, S. (not illustrated)
1988.	*Meandrospira dinarica*	– Haas, J., Rálisch-Felgenhauer, E., Nagy, E. et Bérczi-Makk, A. pl. 6, Fig. 8.
1989.	*Meandrospira dinarica*	– Gaetani, M. et Gorza, M. pl. 12, Fig. 5.
1989.	*Meandrospira dinarica*	– Bérczi-Makk, A. (not illustrated)
1990.	*Meandrospira dinarica*	– Baroz, F., Martini, R. et Zaninetti, L. pl. 5, Figs 4–9.
1990.	*Meandrospira dinarica*	– Ciarapica, G., Cirill, S.; Panzanelli-Fratoni, R., Passeri, L. et Zaninetti, L. (not illustrated)
1990.	*Meandrospira dinarica*	– Herak, M., Jamicic, D., Simunic, A. et Bukovac, J. (not illustrated)
1991.	*Meandrospira dinarica*	– Frechengues, M. et Peybernés, B. (not illustrated)
1992.	*Meandrospira dinarica*	– Angiolini, L., Dragonetti L., Muttoni G., Nicora A. (not illustrated)
1992.	*Meandrospira dinarica*	– Simunic, A. et Simunic, A. (not illustrated)
1992.	*Meandrospira dinarica*	– Urosevic, D. (not illustrated)
1993.	*Meandrospira dinarica*	– Trifonova, E. p. 40. pl. 5, Figs 10–11.
1993.	*Meandrospira dinarica*	– Budai, T., Csillag, G., Haas, J., Koloszár, L., Szabó, I. et Tóth-Makk. Á. (not illustrated)
1993.	*Meandrospira dinarica*	– Pelikán, P., Csontos, L., Less, Gy., Hives-Velledits, F., Dosztály, L., Szabó, Cs. et Szoldán, Zs. (not illustrated)
1993.	*Meandrospira dinarica*	– He, Y. pl. 4, Fig. 21.
1993.	*Meandrospira immatura*	– He, Y. p. 182. pl. 4, Figs 22–24.
1993.	*Meandrospira dinarica*	– Senowbari-Daryan, B., Zühlke, R., Bechstädt, T. et Flügel, E. pl. 65, Figs 7, 11–12, 17.
1993.	*Meandrospira dinarica* (not illustrated)	– Peybernés, B., Kamoun, F., Ben-Youssef, M., Fréchengues, M.
1993.	*Meandrospira dinarica*	– Budai, T., Lelkes, Gy. et Piros, O. (not illustrated)
1993.	*Meandrospira dinarica*	– Góczán, F. et Oravecz-Scheffer, A. pl. 16, Fig. 1-2.
1994.	*Meandrospira dinarica*	– Kamoun, F., Peybernes, B.; Montacer, M., Ben-Youssef, M., Trigui, A. et Ghanmi, M. (not illustrated)
1994.	*Meandrospira dinarica*	– Flügel, E., Ramovs, A. et Bucur, I.I. pl. 3, Figs 12–15, pl. 6, Fig. 8.
1994.	*Meandrospira* aff. *dinarica*	– Flügel, E., Ramovs, A. et Bucur, I.I. pl. 3, Fig. 16-17; pl. 4, Figs 1–2.
1994.	*Meandrospira dinarica*	– Bucur, I.I., Strutinsk, I.C. et Pop- Stratila, D. pl. 14, Figs 12–15.
1994.	*Meandrospira dinarica*	– Piros, O., Mandl, G., Lein, R., Pavlik, W., Bérczi-Makk, A., Siblik, M. et Lobitzer, H. (not illustrated)
1994.	*Meandrospira dinarica*	– Muttoni, G. et Rettori, R. pl. l, Figs 8–9.
1994.	*Meandrospira dinarica*	– Zaninetti, L., Rettori, R., Martini, R. pl. 2, Fig. 14.

Size: Diameter of the test: 0.20–0.50 mm

Remark: It is the largest-size species of the genus *Meandrospira*. It consists of a proloculus (invisible in thin section) and of a second, tubular chamber with variable length and breadth, coiling in a zigzagging manner. The diameter of the test is not linearly proportional to the number of the whorls (Fig. 3). It is of biostratigraphic significance, since this species is widely distributed in the Anisian formations of lagoonal facies in Hungary. As such, it is a species for stratigraphic correlation.

Occurrence in Alsó Hill: This species is widely distributed in the Steinalm Limestone (Locations: T-329, -331, -343, -353, -368, -371, -380, -384, -404, -417, -419, -423, -431,

-448, -490, -491, sampling points 2, 6 in section Alsó Hill-1., sampling points 2, 3, 4 in section Alsó Hill-8). This is the most populous (100) Foraminifera species in this formation.

Plate I

1. *Pilammina negevi* (Benjamini), b/1971/B, 90x
2. *Pilammina negevi* (Benjamini), T-342, 90x
3. *Pilammina densa* Pantic, T-343/c, 90x
4. *Pilammina densa* Pantic, T-448, 70x
5. *Trochammina* aff. *almtalensis* Koehn-Zaninetti, T-384/7, 110x
6. *Gaudryinella* sp., T-490, 100x
7. *Endothyranella bicamerata* Salaj, T-380, 50x
8. *Earlandinita grandis* Salaj, T-432, 50x
9. *Ammobaculites* sp_2, T-329, 70x
10. *Ammobaculites* sp_2, T-490, 50x

Plate II

1. *Earlandinita* sp_1, T-342, 50x
2. *Earlandinita* cf. *oberhauseri* Salaj, T-371, 100x
3. *Earlandinita grandis* Salaj, T-404, 50x
4. *Ammobaculites elongatus* (Salaj), T-490, 50x
5. *Earlandinita oberhauseri* Salaj, T-490, 50x
6. *Earlandinita oberhauseri* Salaj, T-384/7, 50x
7. *Dentalina* sp., T-329, 100x
8. *Dentalina* sp., T-342, 100x
9. *Earlandinita ladinica* Salaj, T-431, 50x
10. *Earlandinita ladinica* Salaj, T-431, 50x
11. a) *Meandrospira dinarica* Kochansky-Devidé et Pantic T-371, 50x
    b) *Earlandinita oberhauseri* Salaj, T-371, 50x

Plate III

1. *Endoteba* sp. *Neoendothyra? reicheli* Reitlinger, T-386/9, 100x
2. *Endoteba* sp. *Neoendothyra? reicheli* Reitlinger, T-386/9, 100x
3. *Endoteba* sp. *Endothyra badouxi* Zan. et. Brönn., T-329, 50x
4. *Neoendothyra? reicheli* Reitlinger, T-4319, 100x
5. *Endothyra* sp., b/1971/B.K., 100x
6. *Endothyra* sp., T-448, 70x
7. *Endothyra malayensis* Gazdzicki, T-417, 100x
8. *Endothyra* cf. *küpperi* Oberhauser, b/1971/B, 100x

Plate IV

1–10. *Meandrospira dinarica* Kochansky-Devidé et Pantic
1. T-364/7, 100x
2. T-423B, 100x
3. T-431, 100x
4. T-431, 100x
5. T-353, 100x
6. T-331, 100x
7. T-417, 100x
8. T-417, 50x
9. T-380, 50x
10. T-380, 50x

Plate V

1–6,
8a. *Meandrospira dinarica* Kochansky-Devidé et Pantic
1. T-371, 50x
2. T-404, 50x
3. T-448, 50x
4. T-423, 50x
5. T-490, 50x
6. T-419, 50x
8a. T-371, 50x
7. *Aulotortus sinuosus* Weyschenk, T-431, 50x
8b. *Earlandinita oberhauseri* Salaj, T-371, 50x

Plate VI

1. *Endothyranella* cf. *wirzi* (Koehn-Zaninetti), T-371, 100x
2. *Duostominidae* sp., T-371, 100x
3. *Duostominidae* sp., T-449, 100x
4. *Ammobaculites radstadtensis* Kristan-Tollmann, T-449, 50x
5. *Diplotremina astrofimbriata* Kristan-Tollmann, T-431, 100x
6. *Diplotremina astrofimbriata* Kristan-Tollmann, T-343, 100x
7. *Haplophragmella inflata* Zaninetti et Brönnimann, T-491, 50x
8. *Duostominidae* sp., T-431, 50x
9. *Trochammina* cf. *alpina* Kristan-Tollmann, T-431, 50x

Plate VII

1. *Gaudryina* sp., T-397, 60x
2. *Textularia* sp., T-416, 100x
3. *Earlandinita soussi* Salaj, T-397/2, 50x
4. *Nodosariidae* sp., T-397, 60x
5. *Earlandinita*? sp., T-416, 50x
6. *Duostomina* cf. *biconvexa* Kristan-Tollmann, T-397, 50x

Plate VIII

Alsó Hill–I section

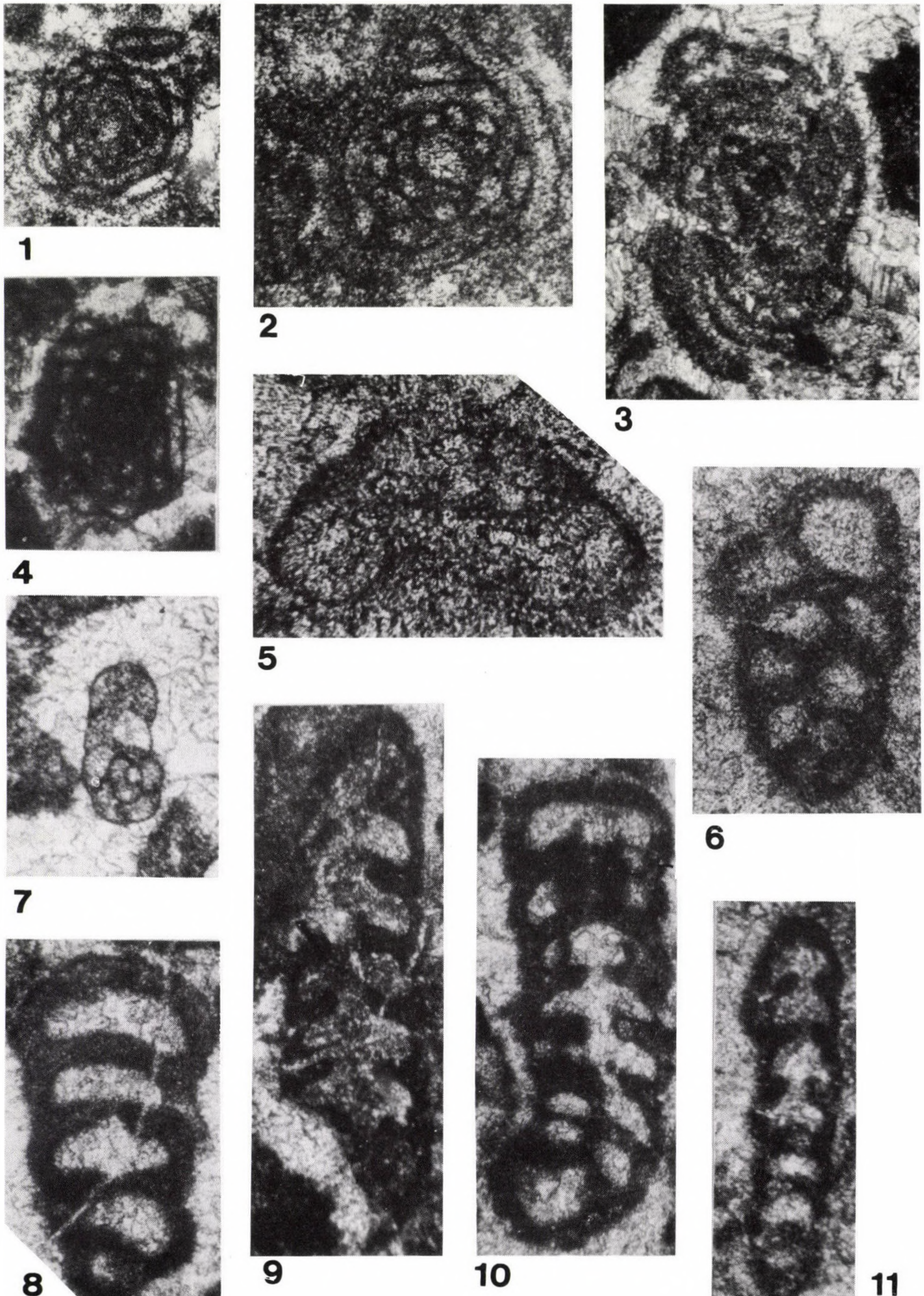
1. *Pilamminella semiplana* (Kochansky-Devidé et Pantic), Ah-1/1, 50x
2. *Pilamminella semiplana* (Kochansky-Devidé et Pantic), Ah-1/6b, 50x
3. *Meandrospira dinarica* (Kochansky-Devidé et Pantic), Ah-1/6b, 50x
4. *Meandrospira dinarica* Kochansky-Devidé et Pantic), Ah–1, 7a, 50x
5. *Endoteba* sp., Ah-1/4c, 50x
6. *Endoteba* sp., Ah-1/6b, 50x
7. *Endothyra badouxi* Zaninetti et Brönnimann, Ah-1/7a, 50x
8. *Ammobaculites* sp., Ah-1/6b, 40x
9. *Ammobaculites* sp., Ah-1/2, 40x
10. *Earlandinita soussi* Salaj, Ah-1/6b, 40x

Plate IX

Alsó Hill–8 section

1. *Meandrospira* cf. *pusilla* Ho, Ah-8/1, 120x
2. *Pilammina densa* Pantic, Ah-8/1, 150x
3. *Pilammina densa* Pantic, Ah-8/2, 100x
4. a) *Meandrospira dinarica* Kochansky-Devidé et Pantic, 50x
   b) *Trochammina almtalensis* Koehn-Zaninetti, Ah-8/2
5. *Pilammina densa* Pantic, Ah-8/2, 100x
6. *Pilammina densa* Pantic, Ah-8/2, 100x
7. *Diplotremina* cf. *astrofimbriata* Kristan-Tollmann, Ah-8/2, 100x
8. *Endothyranella pentacamerata* Salaj, Ah-8/4, 50x
9. *Meandrospira dinarica* Kochansky-Devidé et Pantic, Ah-8/4, 100x
10. *Meandrospira dinarica* Kochansky-Devidé et Pantic, Ah-8/2, 100x
11. *Meandrospira dinarica* Kochansky-Devidé et Pantic, Ah-8/4, 100x
12. *Rheopax asper* Cushman et Waters, Ah–8/4, 50x

Plate I



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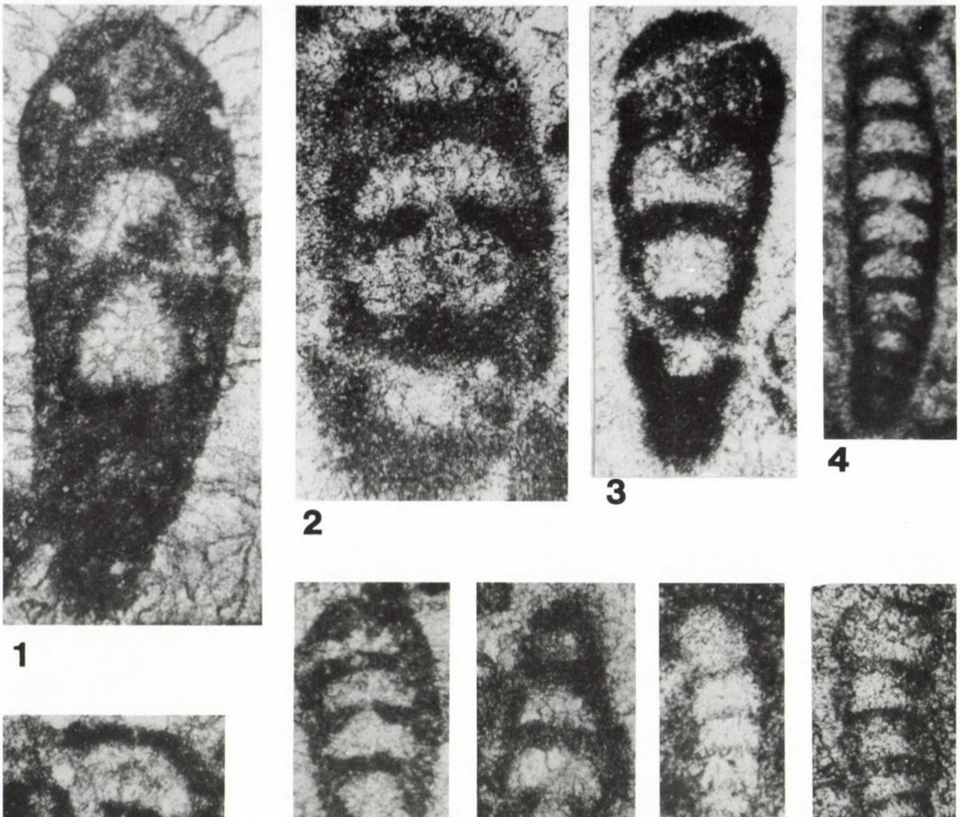

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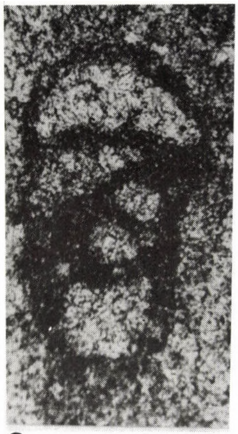

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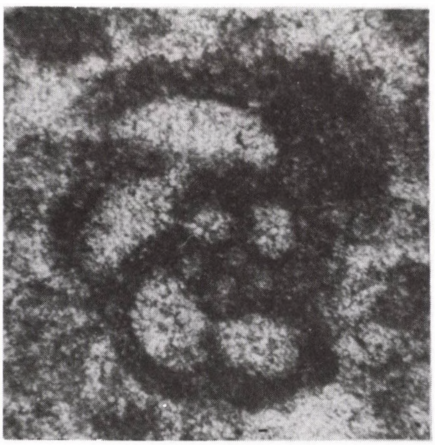

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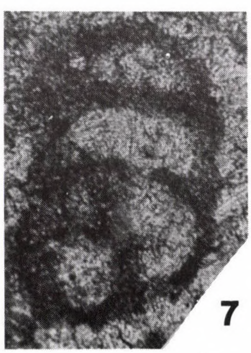

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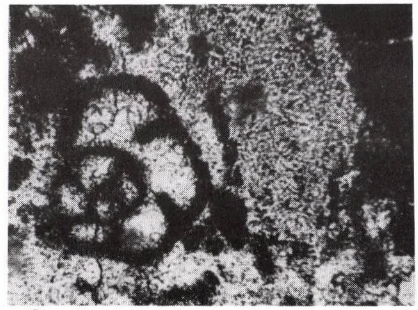

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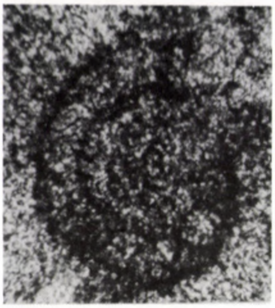

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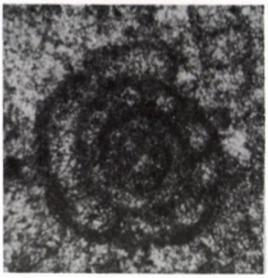

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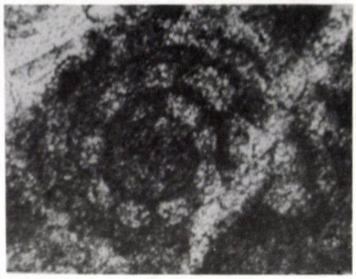

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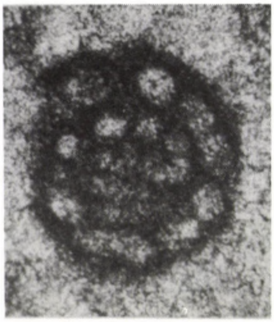

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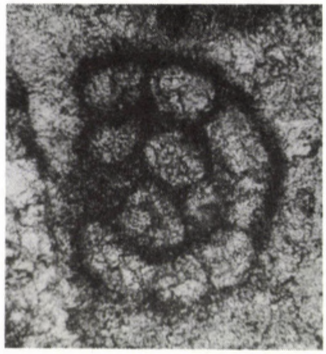

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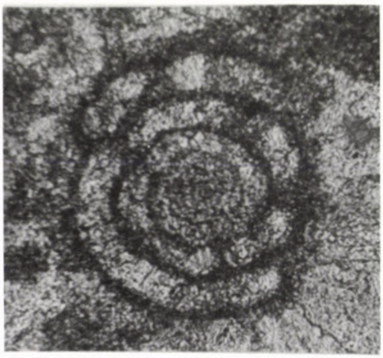

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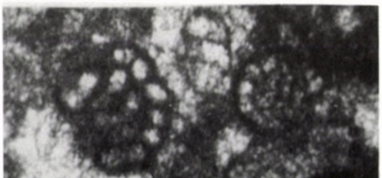

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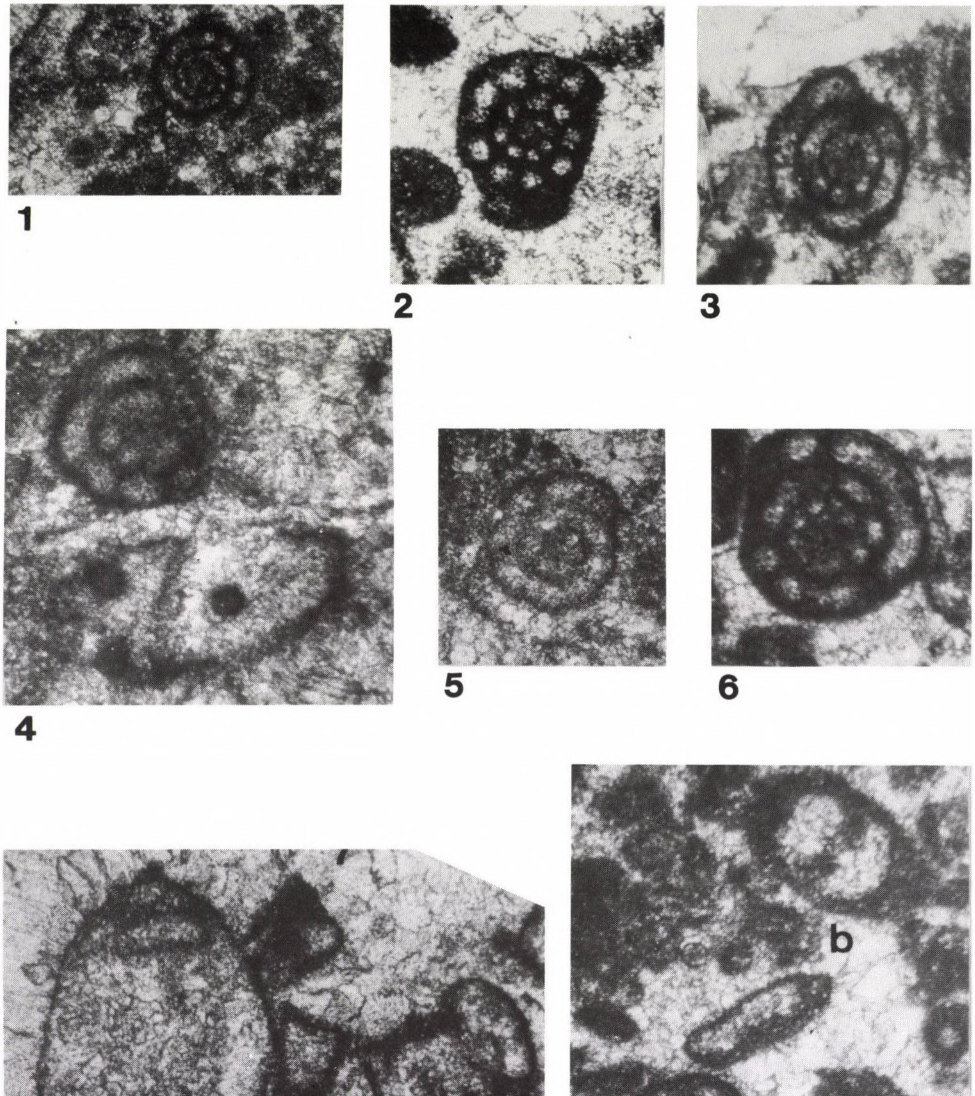

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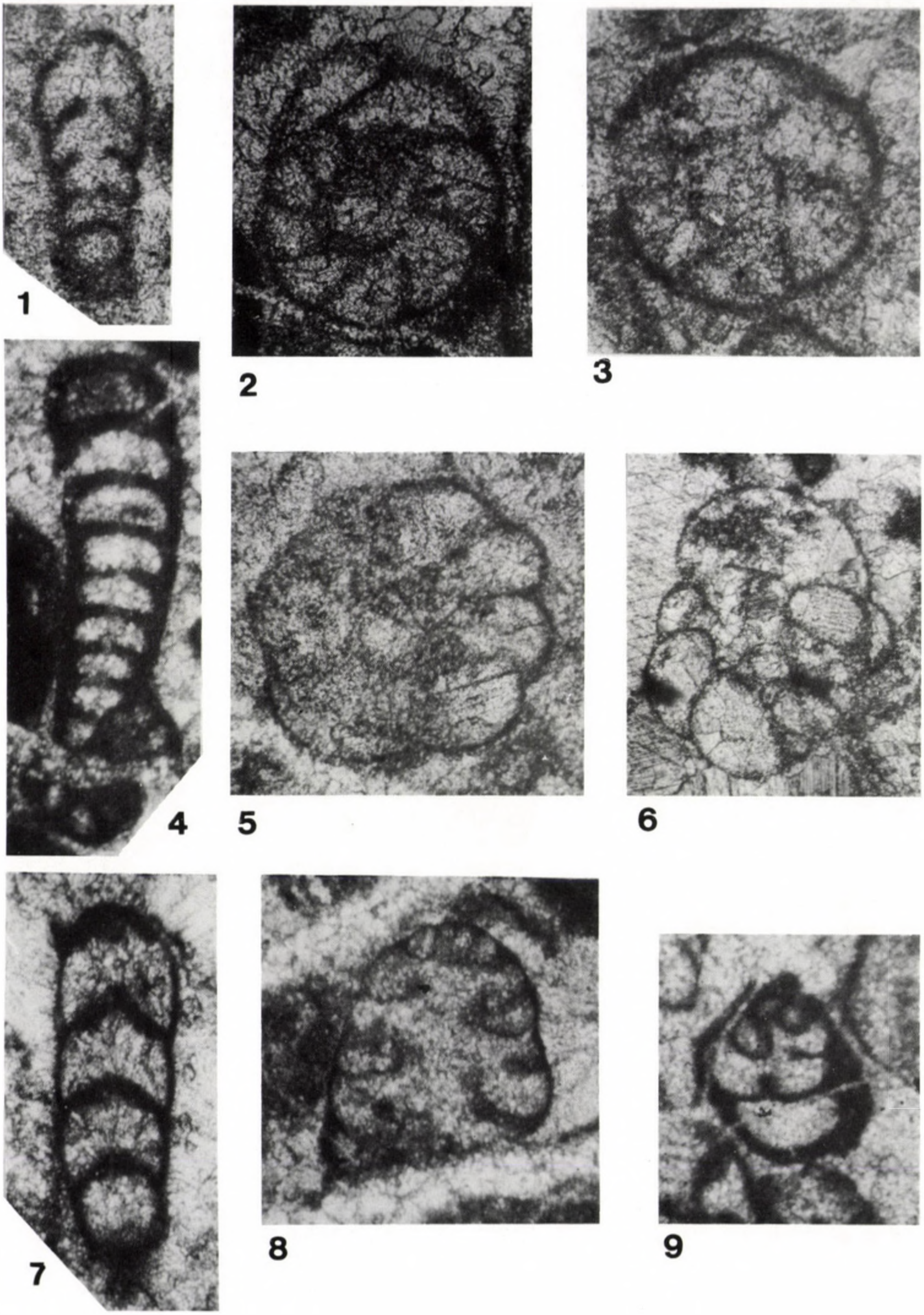
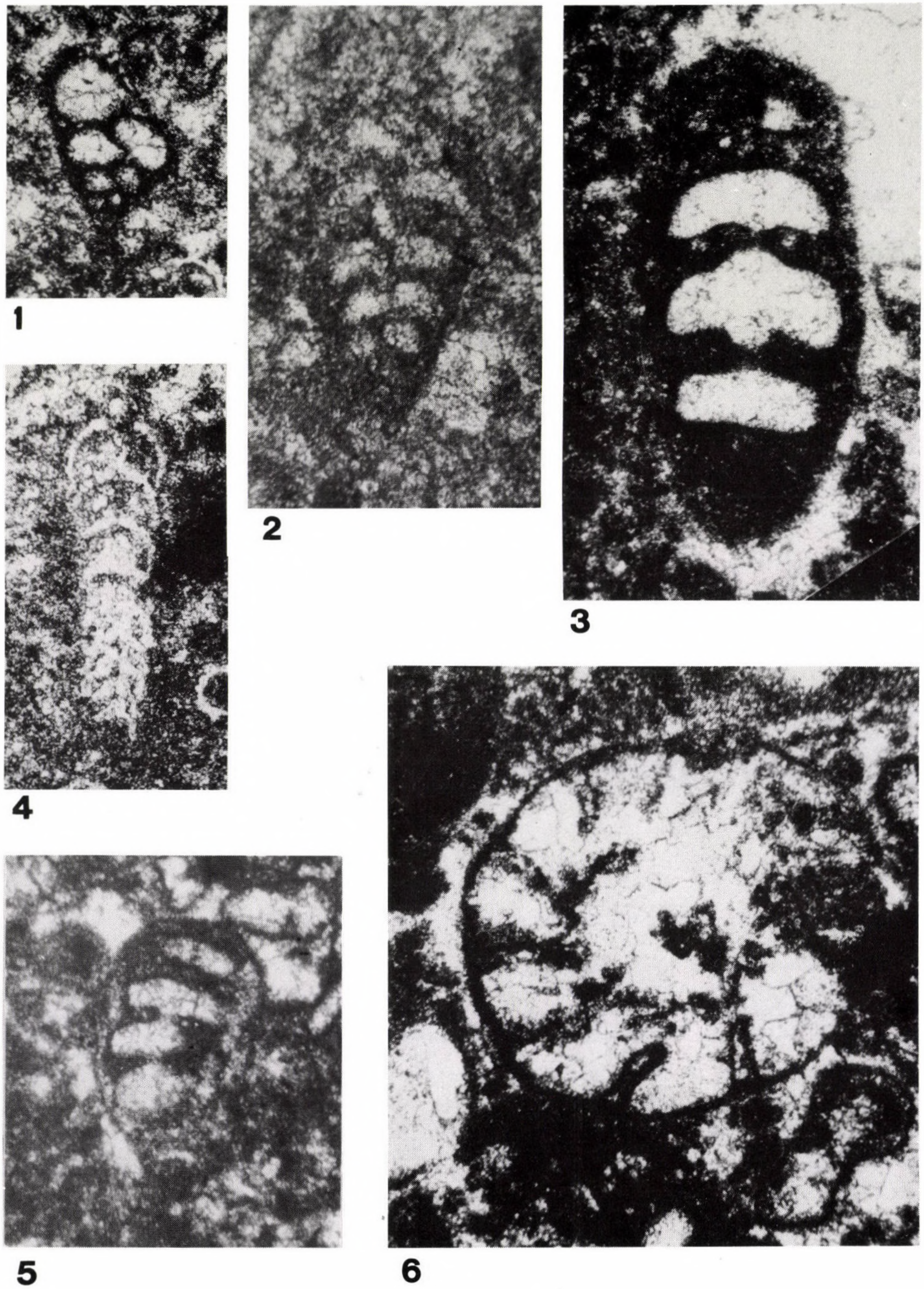


Plate VII



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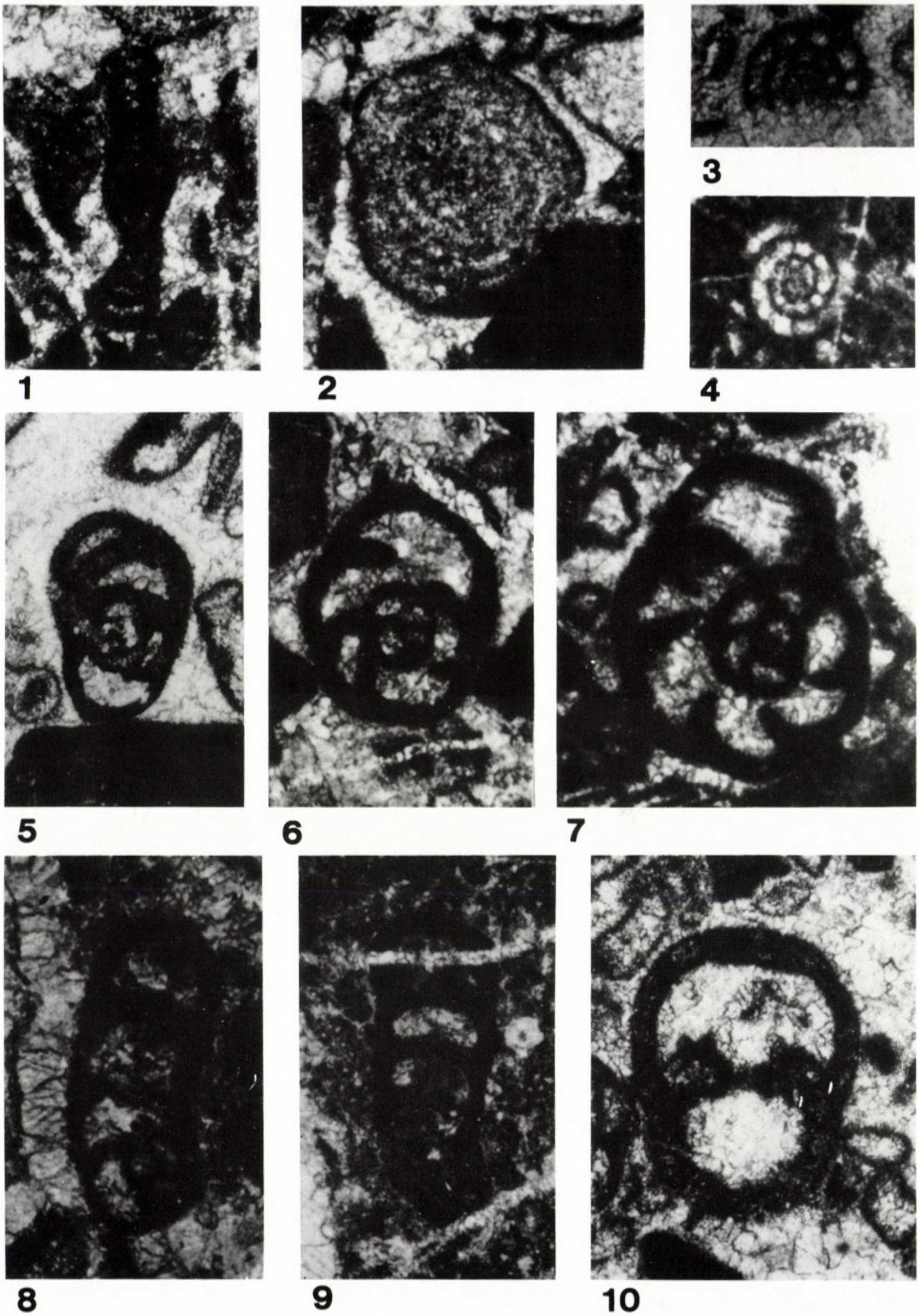
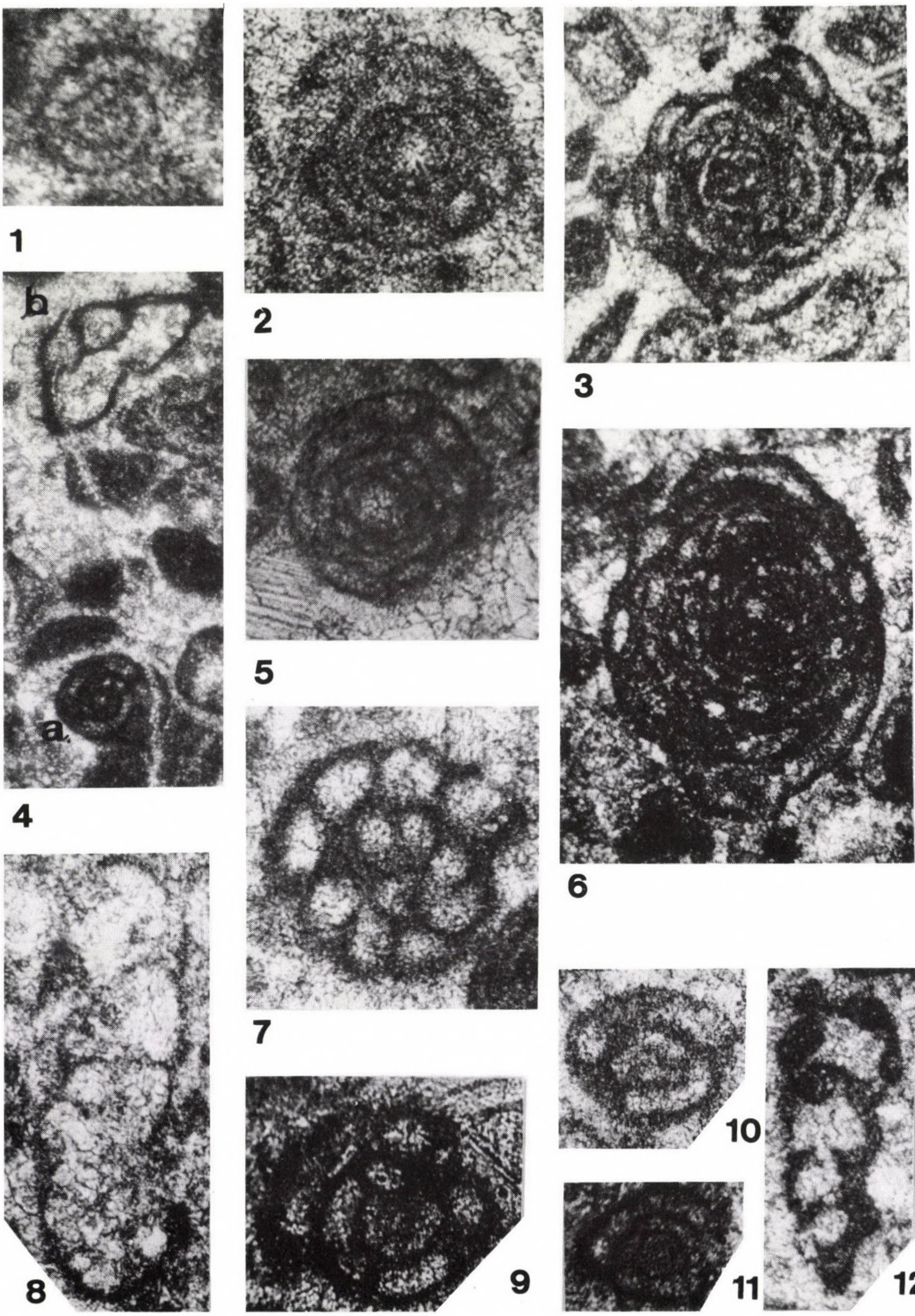


Plate IX



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Foraminifera of the Triassic formations of Alsó Hill (Northern Hungary). Part 2: Foraminifer assemblage of the Wetterstein Limestone Formation

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Reefal and lagoonal facies of the Wetterstein Limestone Formation, constituting the main mass of Alsó Hill extends along the Hungarian-Slovakian border, contain a rich foraminifer assemblage of Carnian age.

In the species- and specimen-rich foraminifer fauna of the reefal facies, species *Gsollbergella spiroloculiformis* (Oravecz-Scheffer), *Aulotortus sinuosus* Weynschenk, *Urnulinella andrusovi* (Borza et Samuel), *Cucurbita infundibuliformis* Jablonsky, *Miliolipora cuvillieri* Brönnimann et Zaninetti, *Palaeolituonella meridionalis* (Luperto) are frequent.

The lagoonal facies is characterized by the great number of specimens of the genus Earlandinita, the mass occurrence of *Aulotortus friedli* (Kristan-Tollmann) and the even distribution of the taxon Variostoma.

A new species, *Endothyranella inflata* nov. sp., is described. Its representatives can be found in the Wetterstein Limestone of both the lagoon and the back reef on Alsó Hill, Northern Hungary.

Key words: Triassic, biostratigraphy, foraminifera, Northern Hungary

Introduction

In the Hungarian part of the Alsó Hill, which extends in a length of some 15 km along the Hungarian–Slovakian border, a rich foraminifer assemblage has been found in Triassic platform carbonates.

After presenting the foraminifer fauna (poor in species and rich in specimens) of the open lagoon formations of the Steinalm Limestone Formation (Bérczi-Makk in press), the foraminifer assemblage of the Wetterstein Limestone Formation is discussed in the present paper.

Formations of reefal and lagoonal facies of the Wetterstein Limestone Formation (Fig. 1a–d), constitut the main mass of Alsó Hill, can be easily distinguished on the basis of the rich foraminifer fauna. In the reefal facies, frequency of species *Gsollbergella spiroloculiformis* (Oravecz-Scheffer), *Aulotortus sinuosus* Weynschenk, *Urnulinella andrusovi* (Borza et Samuel), *Cucurbita infundibuliformis* Jablonsky, *Miliolipora cuvillieri* Brönnimann et Zaninetti, *Palaeolituonella meridionalis* (Luperto) is decisive as to the age and facies determination.

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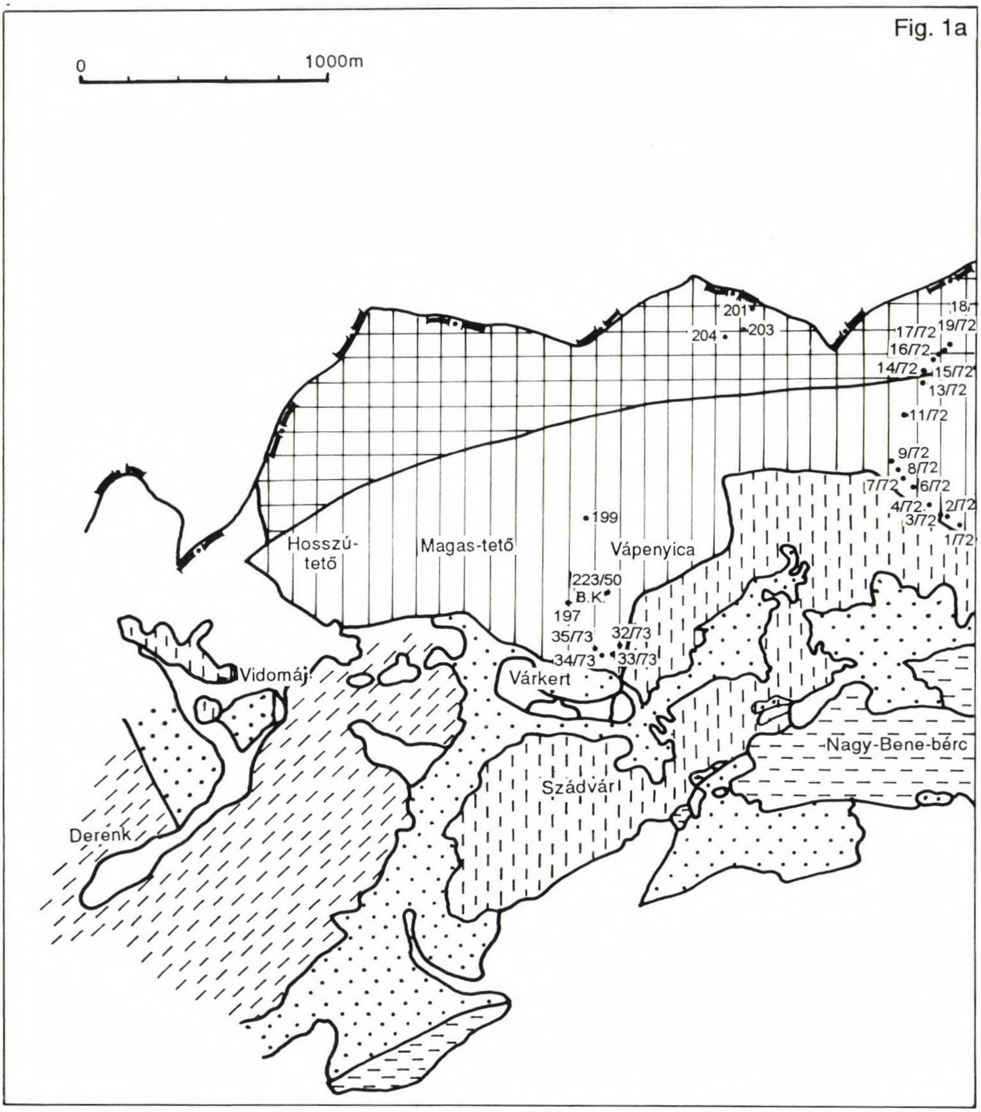
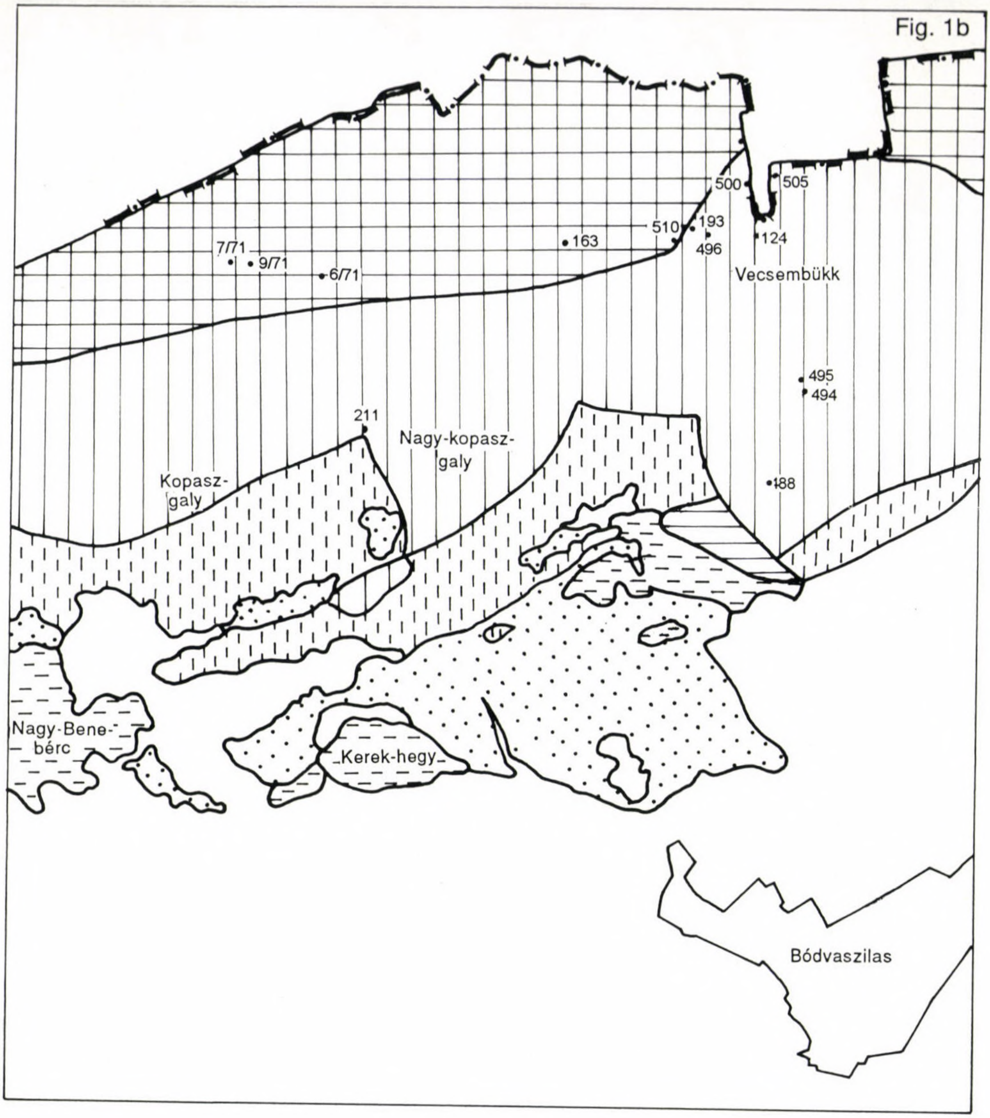
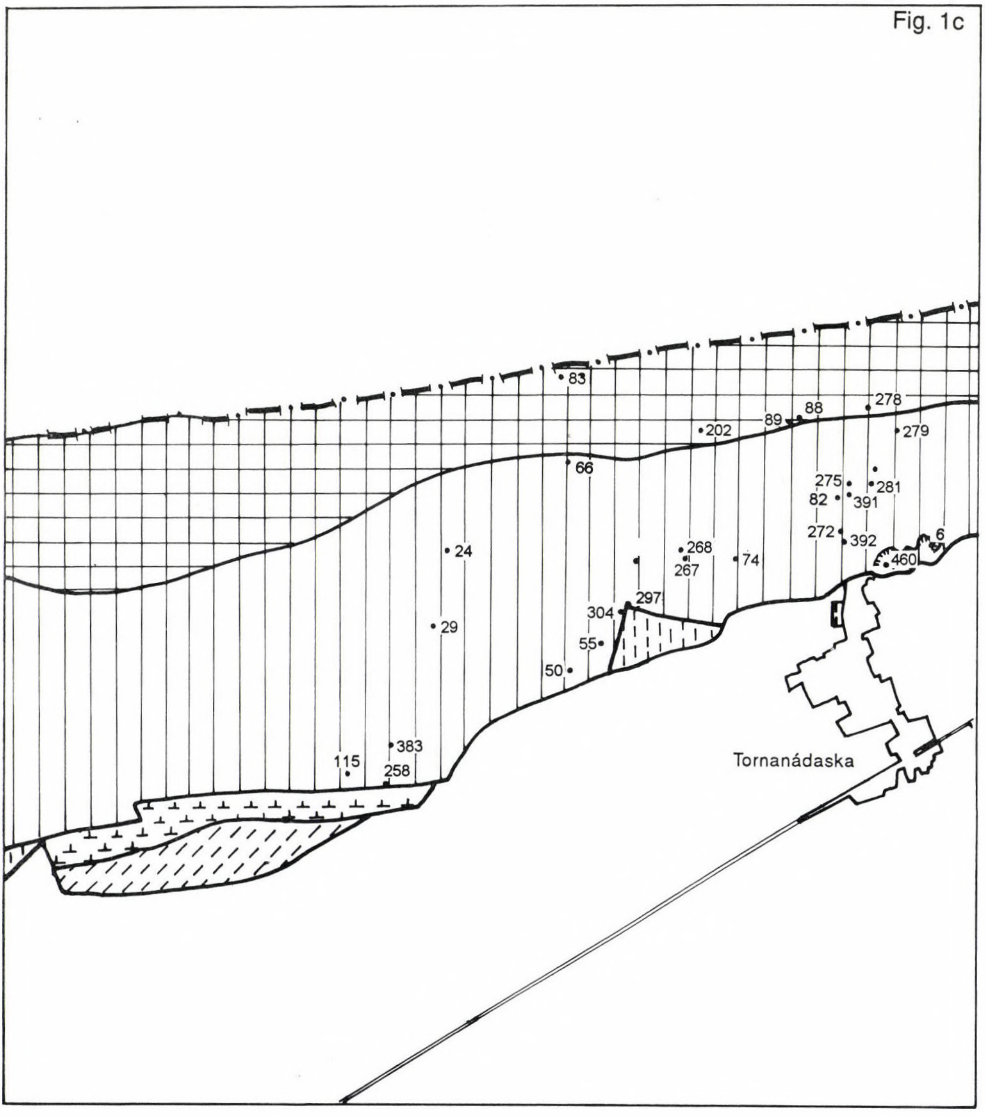


The lagoonal facies is characterized by the great number of specimens of the genus Earlandinita, the mass occurrence of *Aulotortus friedli* specimens (Kristan-Tollmann) specimens and the even distribution of the taxa Variostoma.

The foraminifer associations of the Wetterstein Limestone Formation are unambiguously of Carnian age on the basis of the presence and frequency of the taxa Variostoma, Urnulinella, Cucurbita, Palaeolituonella, Gsollbergella and the species *Aulotortus friedli* (Kristan-Tollmann) (Fig. 2).



The foraminifer fauna of the Carnian Wetterstein Limestone of Alsó Hill can be well correlated with the foraminifer assemblage of the Tisovec Limestone, also of Carnian age in Silicicum, Slovakia (Jendrejáková in: Bystricky 1973). These light grey unbedded limestones, showing the same facies as the Wetterstein Limestone (Borza and Samuel 1977a; Bystricky 1964, 1967, 1972; Misik and Borza 1976) and containing Carnian fossil assemblage, were described by Bystricky (1959) as a separate lithostratigraphic unit in the Western



Carpathians. Previously (Csiskó 1942; Pouba 1951), these limestones of Carnian age had been described as Upper Wetterstein Limestones.

Well-distinguishable, foraminifer-bearing microbiofacies of the reefal and lagoonal developments of the Wetterstein Limestone of Alsó Hill will be separately presented below.

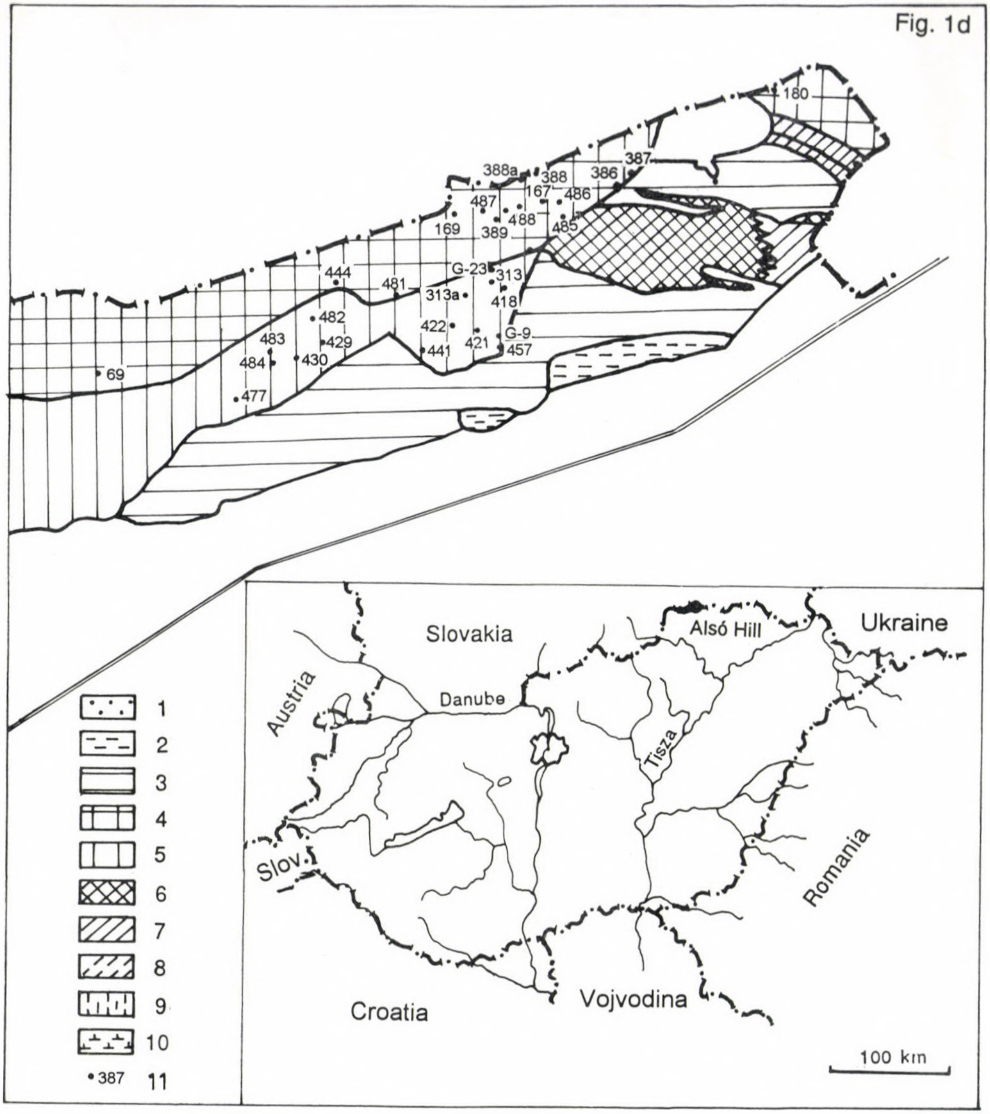


Fig. 1a–d
Locality map of the studied Wetterstein Limestone Formation samples of Alsó Hill (after Kovács 1977). 1. Lower Triassic; 2. Gutenstein Limestone Formation; 3. Steinalm Limestone Formation; 4. Wetterstein Limestone Formation lagoonal facies; 5. Wetterstein Limestone Formation reefal facies; 6. Nádaska Limestone Formation; 7. Reifling Limestone Formation; 8. Derenk Limestone Formation; 9. Hallstatt Limestone Formation; 10. Pötschen Limestone Formation; 11. sample No.

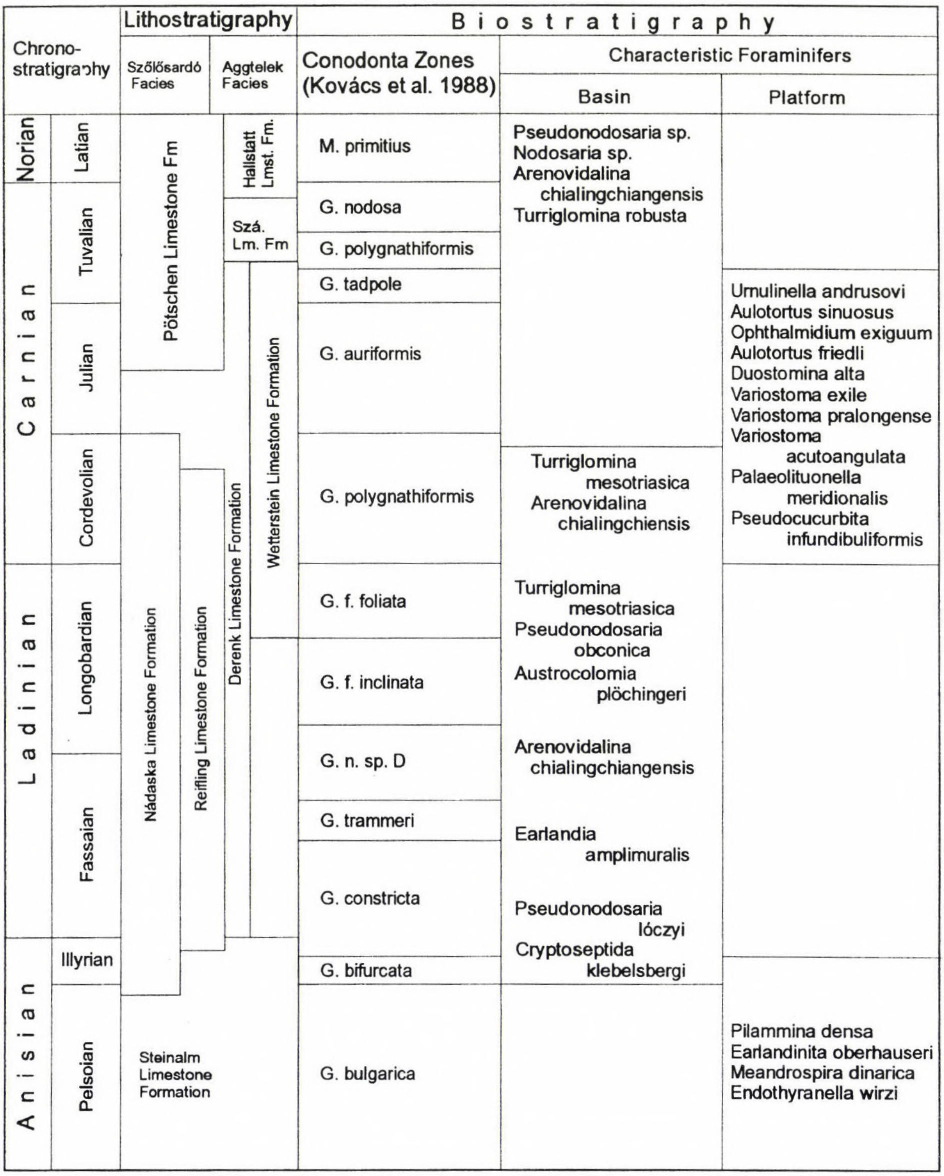


Fig. 2
Characteristic foraminifer horizons of the Triassic formations of Alsó Hill. Szá. Lm.F.– Szádvárborsa Limestone Formation; Szől. M.F. – Szőlősardó Marl Formation

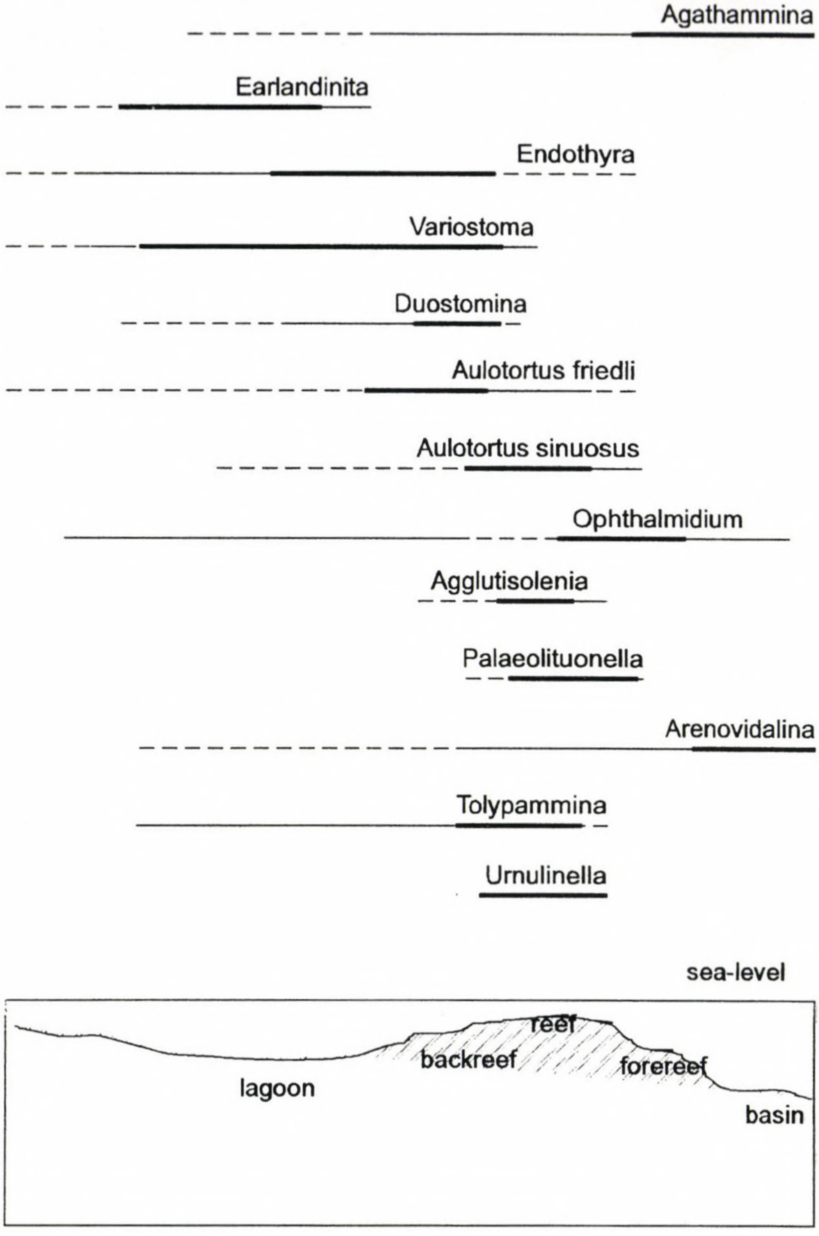


Fig. 3
Distribution of the most frequent foraminifer taxa of the Wetterstein Limestone Formation of Alsó Hill on the basis of the facies

Reefal facies (Plates I–XXIII)

The Wetterstein Reef Limestone, of massive occurrence and light grey colour, forms the southern slope of Alsó Hill and the southern margin of the plateau. Within the reefal limestone, grainstone reef detritus, crushed by wave action, prevails. Framestone and boundstone-type reef core facies is subordinate.

On the weathered rock surfaces, reef-building calcareous sponges (Inozoa: *Leiospongia* sp., *Peronidella* aff. *loretzi* (Zittel), *Peronidella* cf. *subcaespitosa* (Münster); Sphinctozoa: *Colospongia catenulata* Ott, *Cryptocoelia zitteli* Steinmann, *Dictyocoelia manon* (Münster), *Follicatena cautica* Ott, *Paravesicocaulis concentricus* Kovács, *Uvanella irregularis* Ott, *Verticillites triassicus* Kovács, *Vesicocaulis carinthiacus* Ott, and *Vesicocaulis multisiphonatus* Kovács) as well as colonial and ahermatypic corals have been weathered out in equally large amounts (Balogh and Kovács 1976; Kovács 1978, 1979).

Among the reef dwellers, bivalves, gastropods, brachiopods, crinoids, and bryozoans occur in smaller quantity than the reef-building organisms.

Microproblematica, characteristic of the reef facies of the Wetterstein Limestone, are also frequent: *Tubiphytes obscurus* Maslov, *Ladinella porata* Ott, *Microtubus communis* Flügel, *Baccanella floriformis* Pantic, and *Muranella sphaerica* Borza.

The foraminifer fauna (rich in species and specimens) is a good indicator of the reefal facies. In the 170 studied samples, 70 foraminifer species have been found (Fig. 4). On the basis of presence and frequency of the taxa Urnulinella, Cucurbita, Gsollbergella, Aulotortus, and Palaeolituonella, the main body of the Wetterstein Reef Limestone of Alsó Hill is of Upper Triassic (Carnian) age. Three microbiofacies types can be distinguished:

- Urnulinella–Cucurbita microbiofacies,
- Palaeolituonella microbiofacies,
- Aulotortus–Variostoma microbiofacies.

Urnulinella–Cucurbita microbiofacies

The youngest (Upper Carnian) reef formation can be found in the central part of the Alsó Hill reef body, on the western margin in Bába Valley (samples No. 1/1972, 2/1972, 9/1972, 15/1972), southwest of Mt. Vápenyica (samples No. 35/1973, T-197) and on the eastern end of Alsó Hill (samples No. T-6, -66, -258, -279, -430, -505) (Fig. 1).

The central part of the reef body is distinguished not only by the presence but also the richness in specimens of species of the genera Urnulinella, Cucurbita, Ophthalmidium, Palaeolituonella and Tolypammina. Among the sessile foraminifera, the species Urnulinella, Cucurbita and Ophthalmidium are predominant in the central part of the reef (Brönnimann et al. 1973; Hohenegger and Piller 1975a; Piller 1978). Representatives of the genera Variostoma and Duostomina are totally missing.

T–505	T–430	T–279	T–258	T–187	T–66	T–6	35/1973	15/1972	9/1972	2/1972	1/1972	SAMPLE No.
CARNIAN												CHRONOSTRATIGRAPHY
WETTERSTEIN LIMESTONE FORMATION												LITHOSTRATIGRAPHY
Urnulinella–Cucurbita												microbiofacies
•			•	•			+	■		•		Glomospira sp
			•	+			+		+	+	+	Tolypammina gregaria
										•	•	Palaeotextularia sp.
			•	•			+	+				Trochammina alpina
						•						Trochammina jaunensis
						+				•	•	Varneuilinoides sp.
						•						Pseudobolivina globosa
					+			■	+			Palaeolituonella meridionalis
			•									Tetrataxis sp.
							+					Agglutisolenia conica
	+							•				Endothyra obturata
				•			•					Endothyranella pentacamerata
				•						•		Ophthalmidium exiguum
				•								Ophthalmidium sp. cf. O. carinatum
•	•		•					•				Ophthalmidium sp.
+	•	+	+				•	•		•		Arenovidalina chialingchiangensis
				•	•					•	•	Agathammina sp_1
	•					+	+					Gsolbergella spiroloculiformis
				•						•		Pseudonodosaria sp.
•	•		•	•	•	•	■		+	+	+	Urnulinella andrusovi
•												Galeanella sp.
•			•	•		•	•		•	•	•	Cucurbita infundibuliformis
		•										Miliopora cuvillieri
		+	+	■	•		+		•	+		Triadodiscus eomesoicus
			•	■				+			■	Aulotortus sinuosus
				•			•	•				Aulotortus friedli
	•		•			•						Aulotortus? sp.
•			•		•							Diplotremina sp.

Fig. 4
The foraminifer fauna of the Urnulinella–Cucurbita microfacies of the reefal facies of the Wetterstein Limestone Formation of Alsó Hill. • scattered; + frequent; ■ en mass

Samples No. 15/1972, deriving from the northern end of Bába Valley, in which – besides the taxon Urnulinella – some Variostoma specimens have also already been found, are worth mentioning. They already indicate the transition towards the lagoon and the back reef exposed to strong wave action.

The foraminifer assemblage of the reefal limestone indicating the central part of the reef body (the Urnulinella–Cucurbita microbiofacies) is as follows (Fig. 4):

Glomospira sp.
Tolypammina gregaria Wendt
Trochammina alpina Kristan-Tollmann
Trochammina jaunensis Brönnimann et Page
Verneuilinoides sp.
Pseudobolivina globosa Kristan-Tollmann
Palaeolituonella meridionalis (Luperto)
Agglutisolenia conica Senowbary-Daryan
Tetrataxis sp.
Endothyra sp.
Endothyranella sp.
Endothyranella pentacamerata Salaj
Ophthalmidium exiguum Koehn-Zaninetti
Ophthalmidium sp. cf. *O. carinata* (Leischner)
Arenovidalina chialingchiangensis He
Gsollbergella spiroloculiformis (Oravecz-Scheffer)
Pseudonodosaria sp.
Urnulinella andrusovi Borza et Samuel
Cucurbita infundibuliformis Jablonsky
Miliolipora cuvillieri Brönnimann et Zaninetti
Triadodiscus eomesozoicus (Oberhauser)
Aulotortus sinuosus Weynschenk
Aulotortus sp.
Agathammina sp.

Palaeolituonella microbiofacies

Species of the genera Palaeolituonella and Agglutisolenia show a nearly similar distribution as the Urnulinella–Cucurbita microbiofacies. They can be found in samples deriving from the western part of the Alsó Hill reef body in Bába Valley (samples No. 3/1972, 4/1972, 7/1972, 8/1972, 11/1972, 19/1972), south of Mt. Vápenyica (samples No. 223/1950 BK, 35/1973), from the southern margin (samples No. T-188, -211) and the eastern end (samples No. G-9/1974, G-23/1974, T-421, -477, -484) of the reef body (Fig. 1). In addition to their presence in the central part of the reef body, species of the genus Palaeolituonella occur also in the near-reef sand facies (Bérczi-Makk 1981). They are sessile foraminifera, resisting well the strong wave action of the back-reef.

In the Palaeolituonella microbiofacies, species of Variostoma and Duostomina already appear, supporting a Carnian age of the Alsó Hill reefal limestone. On the basis of the Palaeolituonella remnants (Bérczi-Makk 1981; Senowbari-Daryan 1984), however, a younger than Lower Carnian age of a part of the Alsó Hill reef body cannot be excluded.

The foraminifer association found in the Palaeolituonella microbiofacies is rich in species and specimens (Fig. 5):

Glomospira sp.
Pilamminella kuthani (Salaj)
Tolypammina gregaria Wendt
Textularia sp.
Palaeospiroplectammina sp.
Trochammina alpina Kristan-Tollmann
Palaeolituonella meridionalis (Luperto)
Earlandia tintinniformis (Misik)
Endothyra cf. *obturata* Brönnimann et Zaninetti
Endothyra sp. aff. *Endoteba* sp.
Endothyra sp$_1$
Endothyra sp.
Endothyranella cf. *pentacamerata* Salaj
Endothyranella sp$_1$
Arenovidalina chialingchiangensis He
Agathammina sp$_1$
Gsollbergella spiroloculiformis (Oravecz-Scheffer)
Frondicularia woodwardi Howchin
Lenticulina sp.
Gaudryina sp.
Pseudonodosaria sp.
Triadodiscus eomesozoicus (Oberhauser)
Aulotortus sinuosus Weynschenk
Aulotortus friedli (Kristan-Tollmann)
Diplotremina astrofimbriata Kristan-Tollmann
Duostomina alta Kristan-Tollmann
Duostomina cf. *biconvexa* Kristan-Tollmann
Duostomina turboidea Kristan-Tollmann

Ophthalmidium exiguum Koehn-Zaninetti
Ophthalmidium sp_1
Variostoma acutoangulata Kristan-Tollmann
Variostoma pralongense Kristan-Tollmann

Aulotortus–Variostoma microbiofacies

The foraminifer assemblage found in sporadic samples of the Alsó Hill reefal limestone (Fig. 1: 8/1971, 5/1972, 6/1972, 10/1972, 13/1972, 14/1972, 16/1972,

T–484	T–477	T–421	T–211	T–188	6–23/1974	6–9/1974	19/1972	11/1972	8/1972	7/1972	4/1972	3/1972	223/508K	SAMPLE No.
CARNIAN														CHRONOSTRATIGRAPHY
WETTERSTEIN LIMESTONE FORMATION														LITHOSTRATIGRAPHY
Palaeolituonella														microbiofacies
		•	•						•		•			Glomospira sp
													•	Pilamminella kuthani
•			•		+			•	•	•	•	•		Tolypammina gregaria
		•												Palaeospiroplectammina sp.
•					•								•	Trochammina alpina
•	+	+	•	+	+	+	•	+		•	+	•	•	Palaeolituonella meridionalis
										•				Endothyra cf. obturata
				•							•			Ophthalmidium exiguum
			•	•	•	•		•	•	•				Ophthalmidium sp.
		+		•	•	•		•	•	•	•			Arenovidalina chialingchiangensis
									•					Agathammina sp_1
		•									•		•	Gsollbergella spiroloculiformis
									•					Pseudonodosaria sp.
+		■	■	+		+		•		•	•			Triadodiscus eomesozoicus
		+			■		•		•	•	•		■	Aulotortus sinuosus
		•			•	•					•		+	Aulotortus friedli
				•										Diplotremina astrofimbriata
					•						•			Diplotremina sp.
		+												Duostomina turboidea
		•												Duostomina cf. biconvexa
		+												Duostomina alta
			•		+				•				•	Variostoma acutoangulata
					•									Variostoma pralongense
									•					Earlandia tintinniformis
		•										•		Frondicularia woodwardi
			•				•							Lenticulina sp.
		•											•	Glomospirella sp.
					•							•	•	Gaudryna sp.
									•		•		•	Endothyra sp. aff. Endoteba sp.
					•									Endothyra sp_1
		•												Endothyranella cf. pentacamerata
•						•								Endothyranella sp_1

Fig. 5
The foraminifer fauna of the plaeolituonella microfacies of the reefal facies of the Wetterstein Limestone Formation of Alsó Hill. • scattered; + frequent; ■ en mass

17/1972, 18/1972, 25/1973, 27/1973, 30/1973, 32/1973, 33/1973, 34/1973, 7/1974, G-20/1974, G-22/1974, T-24, -29, -50, -55, -74, -83, -124, -193, -199, -267, -268, -272, -275, -279, -280, -291, -303, -304, -313, -383, -391, -392, -418, -422, -429, -441, -457, -460, -482, -483, -494, -495, -496, -500) indicates a forereef environment exposed to strong wave agitation. Species of Urnulinella and Palaeolituonella are totally absent from these samples. The taxa Glomospira, Glomospirella, Reophax, Endothyra, Endothyranella, and Variostoma show even distribution. Specimens of the robust Aulotortus species are present in great frequency. The predominance of *Aulotortus sinuosus* Weynschenk is especially remarkable (Fig. 6):

Glomospira sp.
Glomospirella minima Michalik; Jendrejáková et Borza
Glomospirella aff. *gemerica* (Salaj)
Pilamminella kuthani (Salaj)
Tolypammina gregaria Wendt
Calcitornella sp.
Reophax asper Cushman et Waters
Ammobaculites sp.
Trochammina almtalensis Koehn-Zaninetti
Trochammina alpina Kristan-Tollmann
Trochammina sp.
Verneuilinoides sp.
Textulariidae sp.
Palaeotextularia sp.
Endothyra badouxi Zaninetti et Brönnimann
Endothyra sp1
Endothyra sp. aff. *Endoteba* sp.
Endothyranella inflata nov. sp.
Endothyranella cf. *pentacamerata* Salaj
Endothyranella sp. aff. *E. kocaeliensis* Dager
Endothyranella sp1
Endothyranella sp2
Ophthalmidium exiguum Koehn-Zaninetti
Ophthalmidium lucidum Trifonova
Ophthalmidium sp1
Agathammina sp1
Agathammina sp2
Gsollbergella spiroloculiformis (Oravecz-Scheffer)
Miliolipora cuvillieri Brönnimann et Zaninetti
Spiroloculina sp.
Pseudonodosaria sp.
Frondicularia woodwardi Howchin
Lenticulina sp.
Triadodiscus eomesozoicus (Oberhauser)
Aulotortus friedli (Kristan-Tollmann)
Aulotortus sinuosus Weynschenk
Aulotortus sp1
Diplotremina astrofimbriata Kristan-Tollmann
Diplotreminidae sp.
Duostomina cf. *biconvexa* Kristan-Tollmann
Duostomina sp. cf. *D. magna* Trifonova
Variostoma acutoangulata Kristan-Tollmann
Variostoma exile Kristan-Tollmann
Variostoma cf. *pralongense* Kristan-Tollmann

Lagoonal facies (Plates XXIV–XL)

On the plateau of Alsó Hill (T-69, -89, -169, -174, -180, -202, -278, -344, -388, -389, -444, -450, -451, -481, -485, -486, -487, -488, -497, -499, -522, -524) and in its western continuation (T-163, -167, -201, -203, -204, -489, -510, 6/1971, 7/1971, 9/1971), light grey (in certain horizons dark grey), thick-bedded Wetterstein Limestone of lagoonal facies occurs over a great extension. Its fossil assemblage is characterized by rich green (Dasycladacea, Codiacea) and red algae (Solenoporacea) flora, as well as bryozoan and foraminifer fauna, and – more rarely – gastropod, bivalve and echinoderm skeletal components.

Its lithological characters correspond to those of the Steinalm Limestone Formation. It is built up by tidal and subtidal facies similar to the lagoonal facies of the Steinalm Limestone. Its microfacies types are also the same (Kovács et al. 1988).

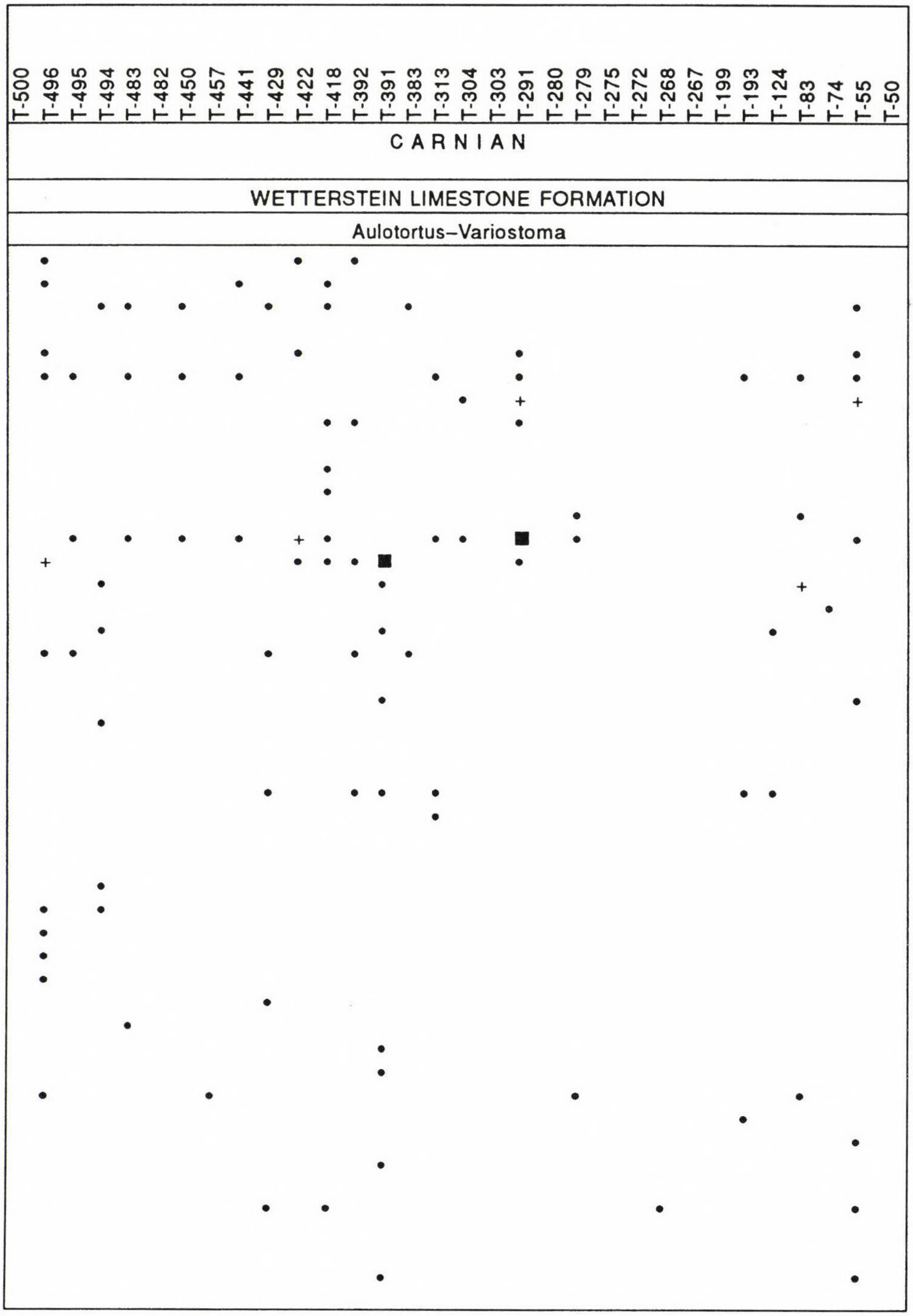
Facies – indicating foraminifer taxa (e.g. Earlandinita) can be found in both formations; however, on the basis of presence and absence, respectively, of species of biostratigraphical significance (*Meandrospira dinarica, Variostoma acutoangulata, Variostoma exile, Variostoma pralongense*), the formations of the lagoonal facies of the Steinalm and Wetterstein Limestones can be easily separated by means of the foraminifer association.

Among the green algae, Dasycladacea are represented – besides *Poikiloporella duplicata* (Pia) and *Teutloporella herculea* Stoppani, occurring en masse – by the species *Macroporella spectabilis* Bystricky, *Physoporella lotharingica* (Benecke), *Poikiloporella brezovica* (Bystricky), and *Uragiella* cf. *supratriassica* Bystricky (Kovács 1979), which is the reason for assigning the formations of the reefal and lagoonal facies to the Carnian stage.

The foraminifer fauna of the 131 thin sections made from samples of the formations of lagoonal facies of the Wetterstein Limestone is characterized by richness in species and specimens (Fig. 7). In summary, the foraminifer assemblage renders a well-oxygenated, photic biotope of high energy and slightly increased salinity probable. Agglutinated, thick-shelled forms prevail. The frequency of species of the genera Trochammina and Earlandinita, as well as the mass occurrence of specimens of *Aulotortus sinuosus* Weynschenk and *Aulotortus friedli* (Kristan-Tollmann) are characteristic. The even distribution of taxa belonging to the family Variostomatidae is remarkable – but not surprising – and also supports the Carnian age of the Alsó Hill Wetterstein Limestone of lagoonal facies.

The foraminifer fauna found in the Alsó Hill Wetterstein Limestone Formation of lagoonal facies is as follows:

Pilamminella kuthani (Salaj)
Glomospira sp.
Glomospirella sp.
Textularia sp1
Textularia sp2
Trochammina almtalensis Koehn-Zaninetti
Trochammina alpina Kristan-Tollmann
Trochammina sp.
Gaudryina sp.
Earlandinita libera (Trifonova)
Earlandinita oberhauseri Salaj
Earlandinita soussi Salaj
Earlandinita sp.
Earlandia tintinniformis (Misik)
Earlandia sp.
Tetrataxis humilis Kristan
Endothyranella inflata nov. sp.
Endothyranella pentacamerata Salaj
Endothyranella sp.
Endothyra obturata Brönnimann et Zaninetti
Ophthalmidium lucidum (Trifonova)
Ophthalmidium sp.
Agathammina sp.
Gsollbergella spiroloculiformis (Oravecz-Scheffer)
Nodosaria cf. *ordinata* Trifonova
Nodosariidae sp.
Aulotortus sinuosus Weynschenk
Aulotortus friedli (Kristan-Tollmann)
Aulotortus sp.
Involutinidae sp. (*Triasina*? sp.)
Diplotremina astrofimbriata Kristan-Tollmann
Diplotremina subangulata Kristan-Tollmann
Diplotremina sp.
Duostomina cf. *alta* Kristan-Tollmann
Duostomina sp.
Variostoma acutoangulata Kristan-Tollmann
Variostoma exile Kristan-Tollmann
Variostoma pralongense Kristan-Tollmann
Variostoma sp.
Endothyra sp.


T-500
T-496
T-495
T-494
T-483
T-482
T-450
T-457
T-441
T-429
T-422
T-418
T-392
T-391
T-383
T-313
T-304
T-303
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T-280
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T-272
T-268
T-267
T-199
T-193
T-124
T-83
T-74
T-55
T-50
CARNIAN
WETTERSTEIN LIMESTONE FORMATION
Aulotortus–Variostoma

SAMPLE No.	T-29	T-24	G-22/1974	G-20/1974	1/1974	34/1973	33/1973	32/1973	30/1973	27/1973	25/1973	18/1972	17/1972	16/1972	14/1972	13/1972	10/1972	6-1972	5-1972	8-1971
CHRONOSTRATIGRAPHY	CARNIAN																			
LITHOSTRATIGRAPHY	WETTERSTEIN LIMESTONE FORMATION																			
microbiofacies	Aulotortus–Variostoma																			
Glomospira sp.						•														
Tolypammina gregaria						•					•						•			
Trochammina alpina		•		•				•						•						•
Verneuilinoides sp.								•										•		
Ophthalmidium exiguum										•										
Ophthalmidium sp.					•	•														•
Arenovidalina chialingchiangensis																				
Agathammina sp_1					•	•						•								
Gsolbergella spiroloculiformis																				•
Pseudonodosaria sp.										•										
Tignumparina zeissi																				
Miliolipora cuvillieri																				
Triadodiscus eomesozoicus					■	+				•	•		•	•						
Aulotortus sinuosus					•	•						•	■	•		•				
Aulotortus friedli								•				•	+			•		•		
Aulotortus? sp.																				
Diplotremina astrofimbriata													+	•						
Diplotremina sp.												•	•	•			•			
Duostomina sp. cf. D. magna												•								
Variostoma acutoangulata		•				•							•	•	•	•		•		
Variostoma pralongense																				
Variostoma exile																		•		
Earlandia tintinniformis																		•		
Ammobaculites sp.																				
Frondicularia woodwardi						•														
Lenticulina sp.										•										
Glomospirella minima																				
Pilamminella gemerica																				
Glomospirella sp.					•															
Pilamminella kuthani																				
Calcitornella sp.																				
Rheopax asper																				
Rheopax sp.																				
Gaudryina sp.					•															
Endothyra badouxi						•														
Endothyra sp. aff. Endoteba sp.								•										•		
Endothyra sp_1			•					•								•				
Endothyranella inflata																				
Endothyranella cf. pentacamerata																				
Endothyranella sp. aff. E. kocaeliensis																				
Endothyranella sp.																				
Ophthalmidium nov. sp_1			•																	
Spiroloculina sp.					•															
Trochammina almtalensis								•												
Nodosaria ex. gr. ordinata																				

Fig. 6
The foraminifer fauna of the Aulotortus–Variostoma microbiofacies of the reefal facies of the Wetterstein Limestone Formation of Alsó Hill. • scattered; + frequent; ■ en mass

UPPER TRIASSIC																													CHRONOSTRATIGRAPHY
CARNIAN																													
WETTERSTEIN LIMESTONE FORMATION																													LITHOSTRATIGRAPHY
9/1971	T–524	T–522	T–510	T–499	T–497	T–489	T–488	T–487	T–486	T–485	T–481	T–451	T–450	T–444	T–389	T–388	T–344	T–278	T–203	T–202	T–201	T–180	T–174	T–169	T–167	T–163	T– 89	T– 69	SAMPLE No.
						•												•					•	•	+	+	•	•	Ammobaculites sp.
																											+		Pilamminella kuthani
•					•			•	•	•		•											•	•		•	+	•	Glomospira sp.
									•									•											Glomospirella sp.
																									•				Textularia sp_1
																											+		Textularia sp_2
																							•		•				Trochammina almtalensis
•				•						•														•	•	•			Trochammina alpina
	•		•																										Trochammina sp.
			•			•															•				+	•			Gaudryina sp.
																		•											Earlandinita libera
		•	•																				•						Earlandinita soussi
	•													•									•		•				Earlandinita oberhauseri
														•															Earlandinita sp.
					•				•										•				•		•	•			Earlandia tintinniformis
									•																				Earlandia gracilis
																									•				Tetrataxis nana
																							•						Tetrataxis humilis
•			•																		•			•		•			Endothyranella bicamerata
																				•			•	•	•				Endothyranella pentacamerata
•																								•					Endothyranella inflata
														•															Endothyra obturata
	•		•			•			•	•			•	•		•					•		•		•	•			Endothyra sp.
															•														Ophthalmidium lucidum
	•		+	•											•		•	•				•		+			•		Agathammina sp.
				•					•																				Gsollbergella spiroloculiformis
			•	•				•																	•	•			Agathamminoides sp.
																										•			Nodosaria cf. ordinata
	•																						•			•	•		Nodosaridae sp.
			■	•		+	•						•	+	■	+	+	+			•				■				Aulotortus sinuosus
			■	•		•	•		•		•		+	•	■	+	•							•	■				Aulotortus friedli
			•															•											Angulodiscus commonuis
			•															•								•			Spirillina sp.
			•																										Diplotremina astrofimbriata
									•																				Diplotremina subangulata
														•									•		•				Diplotremina sp.
			•																				•						Duostomina cf. alta
						•																			•				Variostoma exile
																						•			•		•		Variostoma acutoangulata
						•																•							Variostoma pralongense
•			•																						•				Variostoma sp.

Fig. 7

The foraminifer fauna of the lagoonal facies of the Wetterstein Limestone Foramtion of Alsó Hill. • scattered; + frequent; ■ en mass

Species of the genus Trochammina have a great ecological adaptability. This could be the explanation for the fact that its specimens can be found both in the reefal and lagoonal facies of the Alsó Hill Wetterstein Limestone Formation. It is to be noted that the biostratigraphic value of the species *Trochammina almtalensis* Koehn-Zaninetti and *Trochammina alpina* Kristan-Tollmann is not as significant as had been thought previously. This is supported by the presence of both species in the lagoonal facies. It also cannot be excluded that the two species are taxonomically one and the same.

Species of genus Earlandinita are generally distributed in the lagoon facies. Taking into account the microfauna of the Alsó Hill Triassic formations, it seems that the Earlandinita species are facies dependent. They are typical forms of the platform margin, back reef, near-reef biogenetic sandy facies. They occur together with the specimens of the families Variostomatidae, Miliolidae and other agglutinated foraminifera. Their characteristic feature is the robust, thick-walled shell, which points to a relatively strong wave activity.

Out of the Miliolinidae, genera Agathammina, Ophthalmidium are present. According to Hohenegger and Piller (1975a), distribution of Miliolina taxa in the Triassic shows a strong dependence on change in salinity.

Specimens *Aulotortus sinuosus* Weynschenk and *Aulotortus friedli* (Kristan-Tollmann) show a mass occurrence. Piller (1978) mentions the exclusive occurrence of Aulotortus species in the platform facies, emphasizing that in the near reef sandy facies, *Aulotortus sinuosus* Weynschenk is the most widespread species, while *Aulotortus friedli* (Kristan-Tollmann) plays a more subordinate role. Robust specimens of species *Aulotortus sinuosus* Weynschenk with a long range (Anisian-Rhaetian), being present en mass in the Alsó Hill Wetterstein Limestone, can be found in both the reef and lagoon facies. Acme of *Aulotortus friedli* (Kristan-Tollmann) falls on the Julian-Tuvalian Substage (Oravecz-Scheffer 1987), thus it supports, with its frequency, the Carnian age of the Alsó Hill Wetterstein Limestone Formation

Conclusions

– Reef and lagoon facies of the Wetterstein Limestone Formation, constituting the main mass of Alsó Hill (Northern Hungary) extending along the Hungarian-Slovakian border, contain a rich foraminifer assemblage of Carnian age.

– In the species- and specimen-rich foraminifer fauna of the reef facies, species *Gsollbergella spiroloculiformis* (Oravecz-Scheffer), *Urnulinella andrusovi* (Borza et Samuel), *Cucurbita infundibuliformis* Jablonsky, *Aulotortus sinuosus* Weynschenk, *Miliolipora cuvillieri* Brönnimann et Zaninetti, *Palaeolituonella meridionalis* (Luperto) predominate.

– In the reef limestone, three microbiofacies types can be distinguished (Fig. 4):
- Urnulinella, Cucurbita microbiofacies in the youngest, central part of the reef body,

- Palaeolituonella microbiofacies, beyond the central part of the reef body, also in the near-reef facies with foraminifera, well-resisting the strong wave action of the back reef,
- Aulotortus, Variostoma microbiofacies, representing the characteristic foraminifer assemblage of the forereef.

– In the foraminifer assemblage of the lagoon facies, species of genera Trochammina, Earlandinita, specimens of *Aulotortus friedli* (Kristan-Tollmann) and *Aulotortus sinuosus* Weynschenk, as well as Variostoma species, having biostratigraphic significance, predominate.

– Foraminifer fauna of the Wetterstein Limestone of Carnian age, elaborated in the Hungarian part of Alsó Hill, can be well identified with the foraminifer assemblage of the Tisovec Limestone of Carnian age in Silicicum, Slovakia.

Palaeontology

Since 1964 the taxonomy of the Foraminifera had been based on the monography "Foraminiferida" by Loeblich, A. R. et Tappan, H. In the 3 decades passed since that time have witnessed to a significant accumulation of knowledge about chemical composition, micro-structure, and morphology of the tests of Triassic Foraminifera. Thus, it became inevitably urgent to hammer out and introduce a new taxonomic synthesis. This happened in 1984 and/or 1988 when a comprehensively new taxonomy "Suprageneric classification of Foraminifera (Protozoa)" and/or monograph "Foraminiferal genera and their classification" were published, respectively.

In classifying the Foraminifera from the Wetterstein Limestone taxonomically the above mentioned new principles and some recently published taxonomic studies (Ciarapica and Zaninetti 1985; Decrouez 1989; Vachard et al. 1994; Zaninetti et al. 1987; Zaninetti 1984) have equally been taken into consideration.

References of the taxonomic part can be found in monography of Loeblich and Tappan (1988).

ORDER: FORAMINIFERIDA EICHWALD, 1830

I. suborder: TEXTULARIINA Delage et Hérouard, 1896

superfamily: AMMODISCACEA Reuss, 1862
family: Ammodiscidae Reuss, 1862
subfamily: Tolypammininae Cushman, 1928
genus: Tolypammina Rhumbler, 1895
Tolypammina gregaria Wendt, 1895

subfamily: Glomospirellinae Ciarapica et Zaninetti, 1985
genus: Glomospirella Plummer, 1945
Glomospirella minima Michalik, Jendrejáková, Borza, 1979

genus: Pilammina Pantic, 1965
Pilammina semiplana Kochansky-Devidé et Pantic, 1966

genus: Pilamminella Salaj, 1978
Pilamminella kuthani (Salaj in: Salaj, Biely, Bystricky, 1967)
Pilamminella gemerica (Salaj, 1969)

superfamily: HORMOSINACEA Haeckel, 1894
family: Hormosinidae Haeckel, 1894
subfamily: Reophacinae Cushman, 1910
genus: Reophax de Montfort, 1808
Reophax asper (Ziegler, 1964)

superfamily: TROCHAMMINACEA Schwager, 1877
family: Trochamminidae Schwager, 1877
subfamily: Trochammininae Schwager, 1877
genus: Trochammina Jones et Parker, 1859
Trochammina almtalensis Koehn-Zaninetti, 1969
Trochammina alpina Kristan-Tollmann, 1964
Trochammina jaunensis Brönnimann et Page, 1966

superfamily: VERNEUILINACEA Cushman, 1911
family: Verneuilinidae Cushman, 1911
subfamily: Verneuilinoidinae Suleymanov, 1973
Verneuilinoidinae sp.

subfamily: Verneuilininae Cushman, 1911
genus: Gaudryina d'Orbigny, 1839
Gaudryina sp.

superfamily ATAXOPHRAGMACEA Schwager, 1877
family: Ataxophragmiidae Schwager, 1877
subfamily: Pernerininae Loeblich-Tappan, 1984
genus: Agglutisolenia Senowbari-Daryan, 1984
Agglutisolenia conica Senowbari-Daryan, 1984

genus: Palaeolituonella Bérczi-Makk, 1981
Palaeolituonella meridionalis (Luperto, 1965)

II. suborder: FUSULININA Wedekind, 1937

superfamily: EARLANDIACEA Cummings, 1955
family: Earlandiidae Cummings, 1955
genus: Earlandia Plummer, 1930
Earlandia gracilis (Pantic, 1972)
Earlandia tintinniformis (Misik, 1971)

superfamily: NODOSINELLACEA Rhumbler, 1895
family: Earlandinitidae Loeblich et Tappan, 1984

genus: Earlandinita Cummings, 1955
Earlandinita libera (Trifonova, 1967)
Earlandinita oberhauseri Salaj in: Salaj, Biely, Bystricky, 1967
Earlandinita soussi Salaj, 1978

superfamily: ENDOTHYRACEA Brady, 1884
family: Endothyridae Brady, 1884
subfamily: Endothyrinae Brady, 1884
genus: Endothyra Phyllips, 1846
Endothyra badouxi Zaninetti et Brönnimann, 1972
Endothyra obturata Brönnimann et Zaninetti, 1972

subfamily: Endothyranopsinae Reytlinger, 1958
genus: Endothyranella Galloway et Harlton, 1930
Endothyranella bicamerata Salaj in: Salaj, Biely, Bystricky, 1967
Endothyranella inflata nov. sp.
Endothyranella kocaeliensis Dager, 1978
Endothyranella pentacamerata Salaj in: Salaj, Biely, Bystricky, 1967

family: Endotebidae Vachard, Martini, Rettori et Zaninetti, 1994
genus: Endoteba Vachard et Razgallah, 1988
Endoteba sp.

superfamily: TETRATAXACEA Galloway, 1933
family: Tetrataxidae Galloway, 1933
genus: Tetrataxis Ehrenberg, 1854
Tetrataxis humilis Kristan, 1957

III. suborder: INVOLUTININA Hohenegger et Piller, 1977

family: Involutinidae Bütschli, 1880
subfamily: Triadodiscinae Zaninetti, 1984
genus: Triadodiscus Piller, 1983
Triadodiscus eomesozoicus (Oberhauser, 1951)

subfamily: Aulotortinae Zaninetti, 1984
genus: Aulotortus Weynschenk, 1956
Aulotortus friedli (Kristan-Tollmann, 1962)
Aulotortus sinuosus Weynschenk, 1956

IV. suborder: MILIOLINA Delage et Hérouard, 1896

superfamily: CORNUSPIRACEA Schultze, 1854
family: Arenovidalinidae Zaninetti et Rettori in: Zaninetti, Rettori, He et Martini, 1991
subfamily: Arenovidalininae Zaninetti et Rettori, in: Zaninetti, Rettori, He e Martini, 1991

genus: Arenovidalina Ho, 1959
Arenovidalina chialingchiangensis Ho, 1959

family: Ophthalmidiidae Wiesner, 1920
genus: Gsollbergella Zaninetti, 1979
Gsollbergella spiroloculiformis (Oravecz-Scheffer, 1970)

genus: Ophthalmidium Kübler et Zwingli, 1870
Ophthalmidium carinatum (Leischner, 1961)
Ophthalmidium exiguum Koehn-Zaninetti, 1968
Ophthalmidium lucidum (Trifonova, 1961)

superfamily: MILIOLIPORACEA Brönnimann et Zaninetti in: Brönnimann, Zaninetti, Bozorgnia, Dashti et Moshtahian 1971
family: Pseudocucurbitidae Senowbary-Daryan et Zaninetti, 1986
subfamily: Pseudocucurbitinae Zaninetti, Altiner, Dager et Ducret, 1982
genus: Cucurbita Jablonsky, 1973
Cucurbita infundibuliformis Jablonsky, 1973

genus: Tignumparina Senowbari-Daryan, 1993
Tignumparina zeissi Senowbari-Daryan, 1993

genus: Urnulinella Borza et Samuel, 1977
Urnulinella andrusovi Borza et Samuel, 1977

family: Milioliporidae Brönnimann et Zaninetti, 1971
subfamily: Milioliporinae Brönnimann et Zaninetti, 1971
genus: Miliolipora Brönnimann et Zaninetti in: Brönnimann, Zaninetti, Bozorgnia, Dashti et Moshtaghian 1971
Miliolipora cuvillieri Brönnimann et Zaninetti in: Brönnimann, Zaninetti, Bozorgnia, Dashti et Moshtaghian, 1971

V. suborder: LAGENINA Delage et Herouard, 1896

superfamily: ROBULOIDACEA Reiss, 1963
family: Ichthyolariidae Loeblich et Tappan, 1986
genus: Austrocolomia Oberhauser, 1960
Austrocolomia cordevolica Oberhauser, 1967

superfamily: NODOSARIACEA Ehrenberg, 1838
family: Nodosariidae Ehrenberg, 1838
subfamily: Nodosariinae Ehrenberg, 1838
genus: Nodosaria Lamarck, 1812
Nodosaria ordinata Trifonova, 1965

VI. suborder: ROBERTININA Loeblich et Tappan, 1984

superfamily: DUOSTOMINACEA Brotzen, 1963
family: Duostominidae Brotzen, 1963

genus: Diplotremina Kristan-Tollmann, 1960
Diplotremina astrofimbriata Kristan-Tollmann, 1960
Diplotremina subangulata Kristan-Tollmann, 1960

genus: Duostomina Kristan-Tollmann, 1960
Duostomina alta Kristan-Tollmann, 1960
Duostomina biconvexa Kristan-Tollmann, 1960
Duostomina magna Trifonova, 1974
Duostomina turboidea Kristan-Tollmann, 1960

genus: Variostoma Kristan-Tollmann, 1960
Variostoma acutoangulata Kristan-Tollmann, 1973
Variostoma exile Kristan-Tollmann, 1960
Variostoma pralongense Kristan-Tollmann, 1960

In this part the Foraminifera of biostratigraphic and/or chronostratigraphic significance are described only.

genus: **Pilamminella** Salaj, 1978: "Test libre, petit, composé du proloculus et d'une chambre tubulaire (deutéroloculus) non divisée. La premiére partie du deuteroloculus esttypiquement arrangée selon plusieurs tours comme chez le genre pilammina Pantic. Aprés ce stade d'enroulement, le deutéroloculus change de direction á 90^{0} et forme pendant 2 á 3 tours un stade oscillant, suivi finalement par un stade planispiré. La paroi du test est agglutinante, l'ouverture simple et probablement ronde."

After Loeblich, Tappan, 1988: "Test small to moderate in size, up to about 1 mm in diameter, spherical proloculus followed by tubular undivided second chamber, with early coiling as in pilammina, then with 90^{o} change in plane of coiling, followed by two to three oscillating coils, and then with planispiral stage of two to five whorls with tubular chamber becoming broad and low, wall agglutinated, aperture rounded, simple, at the open end of the tube."

Pilamminella kuthani (Salaj in: Salaj, Biely, Bystricky 1967)

Pl. I. Figs 5, 7; Pl. XIII. Figs 4–5; Pl. XXXIV. Figs 1–2

Type reference:

1967a. *Pilammina kuthani*	– Salaj, J., Biely, A. et Bystricky, J. p. 124. pl. 3, figs 5–6.

Synonyms:

1969a. *Pilammina kuthani*	– Salaj, J. pl. 3, fig. 1
1969b. *Pilammina kuthani*	– Salaj, J. (not illustrated)
1970. *Glomospirella kuthani*	– Jendrejáková, O. pl. 1, fig. 6
1972. *Glomospira kuthani*	– Bystricky, J. (not illustrated)
1972b. *Pilammina kuthani*	– Trifonova, Ek. (not illustrated)
1973. *Glomospira kuthani*	– Jendrejáková, O. (not illustrated)
1976. *Glomospira kuthani*	– Zaninetti, L. p. 91. pl. 2, figs 22–23
1976. *Glomospira* sp.	– Misik, M. et Borza, K. pl. 7, figs7–6
1976. *Pilamminella kuthani*	– Salaj, J. (not illustrated)

1977. *Pilamminella kuthani*	– Salaj, J. pl. 2, fig. 4; pl. 5, fig. 6
1978. *Glomospira kuthani*	– Schaefer, P. et Senowbari-Daryan, B pl. 3, fig. 7
1981. *Glomospira kuthani*	– Sadati, S.M. pl. 62, fig. 13. p
1983. *Pilamminella kuthani*	– Salaj, J., Borza, K. et Samuel, O. p. 69. pl. 13, figs 1–4., pl. 14, figs 1–4, pl. 47, fig. 3b
1983. *Glomospira* cf. *kuthani*	– Balogh, K:, Dobosi, K., Oravecz-Scheffer, A., Szabó, I. et Végh-Neubrandt, E. (not illustrated)
1984. *Pilamminella kuthani*	– Ogorelec, B., Jurkovsek, B., Sribar, L., Jelen, B., Stojanovic, B. et Misic, M. pl. 7, figs 2–3; pl. 9, fig. 1
1986. Pilamminella kuthani	– Adloff, M.C., Doubinger, J., Massa, D et Vachard, D. (not illustrated)
1986. *Glomospira* aff. *kuthani*	– Gyalog, L., Oravecz-Scheffer, A., Detre, Cs. et Budai, T. pl. 1, fig. 6; pl. 2, figs 2, 4, 9
1987. *Glomospira kuthani*	– Oravecz-Scheffer, A. pl. 45, figs 7–8.
1988. *Glomospirella kuthani*	– Benjamini, C. p. 133. pl. 1, figs 4–5.
1988. *Pilamminella kuthani*	– Alaj, J., Trifonova, Ek. et Gheorghian, D. (not illustrated)
1988. *Pilamminella cuthani*	– Canovic, M. et Kemenci, R. pl. 10, fig. 1
1988. Pilamminella kuthani	– Salaj, J., Trifonova, Ek., Gheorghian, D., Coroneou, V. pl. 9, fig. 9
1989. *Pilamminella kuthani*	– Góczán, F. et Oravecz-Scheffer, A. (not illustrated)
1991. *Glomospira kuthani*	– He, Y., et Norling, E. pl. 1, figs 1, 5
1992. *Pilamminella kuthani*	– Trifonova, E. p. 21. pl. 3, fig. 15

Size: diameter of the streptospirally coiled part: 0.46–0.53 mm
Remark: The streptospirally coiled part is followed by 2–3 planispiral whorls. Its wall is calcareous, inperforata. It can be distinguished from the genus Pilammina by its planispiral part. Typically of Carnian age.
Occurrence in Alsó Hill: This species has been equally discovered in the lagoonal and reef part of the Wetterstein Limestone (locations: T-89, T-496, 223/50 BK)

genus: **Palaeolituonella** Bérczi-Makk, 1981: "The shell is free, elongated forming a slightly flattened cone. In its initial stage it consist of 4-5 chambers coiled up in a trochospiral way. During its grow, the shell suddenly changes into a linear form. The chambers spread and form a low reversed truncated cone, which, however, grows during its development. Inside the chambers hardly perceptible rudiments of septa can be observed. The one layer wall is thick, agglutinated. The apertura is not known."

Palaeolituonella meridionalis (Luperto, 1965)

Pl. II. Figs 4–11; Pl. III. 1–2

Type reference:

1965. *Textularia meridionalis*	– Luperto, E. p. 177. pl. 10, figs 6–7

Synonyms:

1966/67. *Lituolida*	– Pantic, S. pl. 3, fig. 7
1971. *Ammobaculites* sp.	– Hohenegger, J. et Lobitzer, H. pl. 2, fig. 6

1971/72. *Lituolidae* sp.	– Pantic, S. pl. 1, fig. 6, pl. 3, fig. 1; pl. 8, fig. 6; pl. 9, fig. 3; pl.12, fig. 4
1978. "*Lituosepta*" sp.	– Schäfer, P. et Senowbari-Daryan, B. pl. 2, fig. 7
1978a. *Duotaxis* sp.	– Trifonova, Ek. pl. 3, fig. 3
1979. "*Lituosepta*" sp. indet.	– Schaäfer, P. pl. 19, fig. 13
1980. "*Lituosepta*" sp.	– Senowbari-Daryan, B. p. 115. pl. 19, fig. 6
1981. Foraminifera genus indet 1	– Altiner, D. et Zaninetti, L. pl. 88, fig. 1
1981. Foraminiféra genus indet 2	– Altiner, D. et Zaninetti, L. pl. 88, fig. 2
1981. *Ammobaculites* sp.	– Bradner, R. et Resch, W. fig. 22/D
1981. *Palaeolituonella majzoni*	– Bérczi-Makk, A. p. 391. pl. 1, figs 1–8
1982 *Bigenerina* sp.	– Wurm, D. p. 223. pl. 32, fig. 13
1982b. *Palaeolituonella majzoni*	– Zaninetti, L., Altiner, D., Dager, Z. et Ducret, B. (not illustrated)
1982. *Lituolidae* (gen et sp. indet)	– Trifonova, Ek. et Vaptsarova, A. (not illustrated)
1984. *Pseudolituonella?* sp.	– He, Y. p. 425. pl. 3, figs 18–20
1984. *Palaeolituonella majzoni*	– Senowbari-Daryan, B. p. 84
1984. *Palaeolituonella majzoni*	– Senowbari-Daryan, B. p. 84. pl. 1, fig. 8; pl. 2, fig. 7
1985. *Palaeolituonella majzoni*	– Trifonova, Ek. et Vaptsarova, A. pl. 1, fig. 8
1986. *Palaeolituonella meridionalis*	– Zaninetti, L., Ciarapica, G. et Martini, R. pl. 1, figs 1–4
1987. *Palaeolituonella meridionalis*	– Zaninetti, L., Ciarapica, G., Martini, R., Salvini-Bonnard, G. et Rettori, R. (not illustrated)
1987. *Palaeolituonella majzoni*	– Oravecz-Scheffer, A. p. 68. pl. 86, fig. 5
1987. *Palaeoltuonella majzoni*	– Dullo, W.Ch., Flügel, E., Lein, R., Riedel, P. et Senowbari-Daryan, B. pl. 4, figs 4–6
1990. ?*Palaeolituonella majzoni*	– Riedel, P. pl. 4, fig. 6
1990. *Palaeolituonella meridionalis*	– Ciarapica, G., Cirilli, S., Martini ,r., Rettori, R., Zaninetti, L. et Salvini-Bonnard, G. textfig. 4A.
1991/92. *Palaeolituonella meridionalis*	– Flügel, E., Velledits, F., Senowbari-Daryan, B. et Riedel, P. pl.. 5, fig. 8, pl.. 6, fig. 6
1991. *Palaeolituonella meridionalis*	– HE, Y., et Norling, E. (not illustrated)
1991. *Palaeolituonella reclinata*	– He, Y. et Cai, L.Q. p. 228. pl. 1, figs 16–19
1991. *Palaeolituonella majzoni*	– Kristan-Tollmann, E. pl. 3, figs 3–4
1992. *Palaeolituonella meridionalis*	– Trifonova, E. p. 37. pl. 4, figs 21–22
1994. *Palaeolituonella majzoni*	– Piros, O., Mandl, G.W., Lein, R., Pavlik, W., Bérczi-Makk, A., Siblik, M. et Lobitzer, H. (not illustrated)

Size: Length of the test: 0.50–0.80 mm; diameter of the coiled part: 0.26–0.33 mm
Remark: In its early age the elongated test forming a slightly compressed cone consists o 4–5 trochospirally wound chambers. After this coiled interval the test suddenly turns to be uniserial. The chambers flatten out forming a low reversed truncated cone. Inside the chambers rudaments of pillars are not consistently visible. Agglutinated walls.
Occurrence in Alsó Hill: Very aboundant in the upper, younger part of the Wetterstein Reefal limestone (locations: T-66, T-188, T-241; G-23, 8/1972, 9/1972, 35/1973).

genus: **Earlandinita** Cummings, 1955: "Test free, small, straight or slightly curved, cylindrical or tapering, slender, circular in cross section, consisting of a sphaerical proloculum and varying number of small, cylindrical, well-defined chambers, which increase gradually in size as added well-developed septa, with septal openings, separating chambers and marked externally by thin, distinct, depressed sutures, lateral margins slightly lobulate, surface smooth, wall composed of small, equidimensional granules of calcite bound by calcareous cement, aperture terminal, central, simple, circular, on apex of slightly domed apertrural face. In thin section this genus is characteristed by the wall-structure and the well-developed septation."

Earlandinita soussi Salaj, 1977

Pl. XXXVII. Fig. 1; Pl. XXXVIII. Fig. 9

Type reference:

1977. *Earlandinita soussi*	– Salaj, J. p. 109. pl. 3, fig. 3

Synonyms:

1977. *Earlandinita* cf. *soussi*	– Gazdzicki, A. et Smit, O.E. pl. 7, fig. 7
1983. *Earlandinita soussi*	– Salaj, J., Borza, K. et Samuel, O. p. 82. pl. 32, fig. 6, pl. 42, fig. 3
1986. *Earlandinita soussi*	– Gyalog, L., Oravecz-Scheffer, A., Detre, Cs. et Budai, T. pl. 1, fig. 10
1987. *Earlandinita* cf. *soussi*	– Velledits, F. et Péró, Cs. pl. 10, fig. 3
1993. *Earlandinita* cf. *soussi*	– Góczán, F. et Oravecz-Scheffer, A. pl. 39, fig. 1

Size: Length of the test: 0.80–1.30 mm, breadth of the test: 0.45–0.60 mm
Remark: Large, uniserial test, with 3–4 chambers increasing in size. On the basis of the form and size of their chambers, the exemplars discovered have been assigned to the species *Earlandinita soussi*.
Occurrence in Alsó Hill: Recovered from the Steinalm Limestone (locations: T-397, sample point 2 in section Alsó Hill 1) and from the lagoonal facies of the Wetterstein Limestone (locations: T-174, T-510, T-522)

genus: **Endothyranella** Galloway et Harlton 1930 in Galloway and Ryniker 1930 (after Loeblich, Tappan 1988): "Test enroled in the early stage, later uncoiling, early whorls slightly streptospiral, later planispiral and evolute, chambers slightly inflated and wedgelike, sutures depressed, septa thickened, especially in the apertural region of the rectilinear chambers, where they may be up to four times the thickeness of the outer wall, wall calcareous, thin, and undifferentiated, granular, fibrous,and perforate, aperture simple and basal in the enrolled stage, later areal and rounded, terminal in the rectilinear stage."

Endothyranella inflata nov. sp.

Pl. IV. Fig. 3; Pl. XXIV. Fig. 8

Synonyms:

1987. *Haplophragmium?* sp.	– Oravecz-Scheffer, A. pl. 84, fig. 12
1993. *Endothyranella wirzi*	– Fréchengues, M., Peybernés, B., Martini, R. et Zaninetti, L. pl. 2, fig. 21

Derivatio nominis: form of the inflated chambers
Locus typicus: Alsó Hill (NE-Hungary, Silica Nappe) sample number 9/1971/B
Stratum typicum: Wetterstein Limestone, Carnian
Holotype: In the micropalaeontolocial collection of the Hungarian Geological Institute
Material: 6 exemplars from the lagoonal (locations: 9/1971; T-169) and reefal facies of the Wetterstein Limestone
Description: Free test. Wound, evolute initial part consisting of 5 inflated chambers. Approaches to more linear form with stronly enlarged chambers. Wall calcareauos, heavily recrystallized.
Size: Diameter of the wound part: 0.33 mm, length of the test: 0.50–0.60 mm
Differential diagnosis: The heavily inflated, rounded chambers with their characteristic form are very distinct from any other species of the genus Endothyranella. From the species *Endothyranella wirzi* (Koehn-Zaninetti) it can be distinguished by its double size and by the different form of the chamber.
Occurrence in Alsó Hill: Recovered from the reefal and lagoonal facies of the Wetterstein Limestone (locations T-193 and 9/1971B, respectively) of Carnian age, Silica Nappe, NE-Hungary.
Other fossils: Ammobaculites sp., *Glomospira* sp., *Trochammina alpina* Kristan-Tollmann, *Endothyranella bicamerata* Salaj, *Endothyranella pentacamerata* Salaj, *Agathammina* sp., *Ophthalmidium* sp., *Aulotortus friedli* (Kristan-Tollmann), *Variostoma* sp.

genus: **Gsollbergella** Zaninetti, 1979 (after Loeblich, Tappan, 1988): "Test fusiform, globular proloculus followed by cornuspirine undivided second chamber of one whorl and then by chambers one-half coil in length in a quinqueloculine arrangement, individual chambers separeted only by slight thickenings of the wall rather than by distinct septa, wall calcareous, imperforate, porcelaneous, aperture simple, terminal."

Gsollbergella spiroloculiformis (Oravecz-Scheffer, 1968)

Pl. VI. Figs 6–7, 10, 13; Pl. VII. Fig. 8; Pl. XXXII. Figs 1, 6; Pl. XXXIII. Fig. 3

Type reference:

1968. *Agathammina spiroloculiformis*	– Oravecz-Scheffer, A. p. 102. pl. 2, figs 1–5

Synonyms:

1968. *Agathammina austroalpina*	– Koehn-Zaninetti, L. (not illustrated)
1969. *Agathammina austroalpina*	– Koehn-Zaninetti, L. p. 57. pl. 8,fig. A–D, textfig. 11.
1969. *Agathamminoides gsollbergensis*	– Zaninetti, L. p. 699. textfig. 1.
1969. *Agathamminoides gsollbergensis*	– Zaninetti, L., Brönnimann, P. textfig. 1(C), 5(12), 6(A, B)
1969. *Agathamminoides* sp.	– Zaninetti, L. et Brönnimann, P. textfig. 1 (A, B, D, E)

1976.	*Agathamminoides spiroloculiformis*	– Zaninetti, L. p. 147. pl. 5, figs 10–14, pl. 7, figs 1–2
1979.	*Gsollbergella spiroloculiformis*	– Zaninetti, L. (not illustrated)
1980.	*Agathamminoides spiroloculiformis*	– Dullo, W.Ch. et Lein, R. (not illustrated)
1983.	*Gsollbergella spiroloculiformis*	– Oravecz-Scheffer, A. (not illustrated)
1983.	*Agathamminoides spiroloculiformis*	– Salaj, J., Borza, K. et Samuel, O. p. 113. pl. 8, fig. 5a, pl. 72, figs 7–10
1983.	*Agathamminoides* cf. *spiroloculiformis*	– Balogh, K., Dobosi, K., Góczán, F., Haas, J., Oravecz-Scheffer, A., Szabó, I. et Végh-Neubrandt, E. (not illustrated)
1986.	*Gsollbergella spiroloculiformis*	– Gyalog, L., Oravecz-Scheffer, A., Detre, Cs. et Budai, T. pl. 7, figs 2, 4–6
1987.	*Gsollbergella spiroloculiformis*	– Oravecz-Scheffer, A. p. 71. pl. 32, figs 1–4, 10; pl. 39, figs 1–10; pl. 42, figs 6–9; pl. 45, fig. 6; pl. 51, fig. 4; pl. 52, figs 1–4
1987.	*Gsollbergella spiroloculiformis*	– Velledits, F. et Péró, Cs. pl. 10, fig. 1
1988.	*Gsollbergella spiroloculiformis*	– Benjamini, Ch. p. 135. pl. 2, fig. 20
1988.	*Agathamminoides* aff. *spiroloculiformis*	– Kuss, J. (not illustrated)
1988.	*Agathamminoides spiroloculiformis*	– Pantic-Prodanovic, S. (not illustrated)
1989.	*Gsollbergella spiroloculiformis*	– Góczán, F. et Oravecz-Scheffer, A. (not illustrated)
1991.	*Gsollbergella spiroloculiformis*	– He, Y., et Norling, E. p. 30. pl. 1, fig. 8
1991.	*Gsollbergella spiroloculiformis*	– Urosevic, D. et Sudar, M. (not illustrated)
1993.	*Gsollbergella spiroloculiformis*	– Budai, T., Csillag, G., Haas, J., Koloszár, L., Szabó, I. et Tóth-Makk, Á. (not illustrated)
1993.	*Gsolbergella spiroloculiformis*	– Trifonova, E. p. 52. pl. 8, figs 23–25
1994.	*Gsollbergella spiroloculiformis*	– Piros, O., Mandl, G.W., Lein, R., Pavlik, W., Bérczi-Makk, A., Siblik, M. et Lobitzer, H. (not illustrated)

Size: Diameter of proloculus: 0.018–0.020 mm, length of the test: 0.500–0.600 mm, breadth of the test: 0.200–0.330 mm
Remark: Test elongated, cornuspirine. Globular proloculus surrounded by a tubular second chamber of consistent diameter. The plain of the winding is variable. Agglutinated wall.
Occurrence in Alsó Hill: Very aboundant in the reefal facies of the Carnian Wetterstein Limestone (locations: 35/1973, T-6, T-430, 223/50 BK, 4/1972, T-421, 8/1971, T-483) while sparse in the lagoonal facies of the same formation (locations: 35/1973, T-6, T-430, 223/50 BK, 4/1972, T-421, 8/1971, T-483).

genus: **Cucurbita** Jablonsky, 1973: "Kolébenförmiges Calcitgehaeuse, mit einem trichterförmigen Saum an der Oralseite."

After Loeblich, Tappan, 1988: "Elongate campanulate, flasklike, or amphora-shaped chambers forming a rectilinear to arcuate series, each rounded to apiculate at the base, then may be somewhat constricted, and finally flaring broadly into a wide recurved collar around the aperture, wall porcelaneous, commonly recrystallized as micritic calcite , may be coarsely perforate, aperture large, terminal, rounded, bordered by a broad collar, flange, or lip that may be recurved at the outer edge."

Cucurbita infundibuliformis Jablonsky, 1973

Pl. II. Fig. 3

Type reference:

1973. *Cucurbita infundibuliforme*	– Jablonsky, E. p. 420. pl. 2, figs 1–4, pl. 3, figs 1–6

Synonyms:

1977a. *Amphorella subsphaerica*	– Borza, K. et Samuel, O. p. 108. pl. 2, figs 10–14
1977a. *Amphorella bicamerata bicamerata*	– Borza, K. et Samuel, O. p. 100. pl. 1, figs 1–8
1977b. *Paratintinnina tulipaformis*	– Borza, K. et Samuel, O. p. 144. pl. 70, figs 2–4
1978. *Galeanella? infundibuliforme*	– Gazdzicki, A., Kozur, H., Mock, R. et Trammer, J. pl. 42, figs 1–4
1978. *Pseudocucurbita globosa*	– Borza, K. et Samuel, O. p. 69. pl. 1, figs 1–2
1978. *Pseudocucurbita subglobosa*	– Borza, K. et Samuel, O. p. 70. pl. 1, figs 3–6
1978. *Pseudocucurbita campanulaformis*	– Borza, K. et Samuel, O. p. 72. pl. 1, figs 7–8; pl. 2, figs 1–3
1978. *Pseudocucurbita fusani*	– Borza, K. et Samuel, O. p. 74. pl. 2, figs 4–6
1981. *Cucurbita infundibuliformis*	– Zaninetti, L. et Altiner, D. (not illustrated)
1981. *Cucurbita infundibuliformis*	– Zaninetti, L. et Altiner, D. (not illustrated)
1981. *?Galeanella infundibuliformis*	– Senowbari-Daryan, B. pl. 10, figs 4–5
1981. *Pseudocucurbita fusani*	– Samuel, O. et Borza, K. textfig. 4/2a–c, pl. 21, fig. 1
1981. *Pseudocucurbita subglobosa*	– Samuel, O et Borza, K. textfig. 4/4a–b, pl. 21, fig. 2
1981. *Pseudocucurbita campanulaformis*	– Samuel, O. et Borza, K. textfig. 4/1a–c
1981. *Pseudocucurbita globosa*	– Samuel, O. et Borza, K. textfig. 4/3a–c
1981. *Pseudocucurbita subsphaerica*	– Samuel, O. et Borza, K. textfig. 5/1
1982a. *Pseudocucurbita subsphaerica*	– Zaninetti, L., Altiner, D., Dager, Z. et Ducret, B. p. 98. textfig. 1/F–K, pl. 1, figs 1–6, 8–9
1982b. *Pseudocucurbita subsphaerica*	– Zaninetti, L., Altiner, D., Dager, Z. et Ducret, B. p. 114 (not illustrated)
1982b. *Pseudocucurbita subsphaerica*	– Zaninetti, L., Altiner, D., Dager, Z. et Ducret, B. p. 114 (not illustrated)
1983. *Pseudocucurbita infundibuliformis*	– Miconnet, P., Ciarapica, G. et Zaninetti, L. (not illustrated)
1983. *Cucurbita infundibuliforme*	– Salaj, J., Borza, K. et Samuel, O. p. 156. pl. 157, figs 7–8
1983. *Pseudocucurbita infundibuliformis*	– Senowbari-Daryan, B. p. 194. textfigs 6–7, pl. 12, figs 1–8, pl. 13, figs 1–11, pl. 23, fig. 11
1983. *Paratintinnina tulipaformis*	– Salaj, J., Borza, K., Samuel, O. p. 156. pl. 147, figs 8–10
1983. *Pseudocucurbita campanulaformis*	– Salaj, J., Borza, K., Samuel, O. p. 156. pl. 156, figs 7–8, pl. 157, figs 1–3
1983. *Pseudocucurbita fusani*	– Salaj, J., Borza, K., Samuel, O. p. 157. pl. 157, figs 4–6
1983. *Pseudocucurbita globosa*	– Salaj, J., Borza, K., Samuel, O. p. 157. pl. 156, figs 1–2
1983. *Pseudocucurbita subglobosa*	– Salaj, J., Borza, K., Samuel, O. p. 158. pl. 156, figs 3–6
1983. *Amphorella bicamerata bicamerata*	– Salaj, J., Borza, K., Samuel, O. p. 158. pl. 148, fig. 8
1983. *Amphorella? subsphaerica*	– Salaj, J., Borza, K., Samuel, O. p. 160. pl. 149, figs 10, 12, 14
1983. *Pseudocucurbita subsphaerica*	– Zaninetti, L. et Altiner, D. pl. 1, fig. 4
1986. *Cucurbita infundibuliformis*	– Senowbari-Daryan, B. et Zaninetti, L. (not illustrated)
1986. *Pseudocucurbita globosa*	– Senowbari-Daryan, B. et Zaninetti, L. (not illustrated)
1986. *Pseudocucurbita infundibuliformis*	– Senowbari-Daryan, B. pl. 1, figs 2–4, 7, 9–10, pl. 2, fig. 3
1986. *Pseudocucurbita infundibuliformis?*	– Senowbari-Daryan, B. et Abate, B. pl. 10, fig. 1
1986. *Cucurbita infundibuliformis*	– Senowbari-Daryan, B. et Zaninetti, L. (not illustrated)
1987. *Pseudocucurbita infundibuliformis*	– Senowbari-Daryan, B. p. 257. pl. 1, figs 4–8
1988. *Cucurbita infundibuliformis*	– Loeblich, A. R., Tappan, H. p. 367. pl. 387, figs 11–13, pl. 388, figs 1–5

1990. *Pseudocucurbita infundibuliformis*	– Riedel, P. pl. 4, figs 6, 10–12
1991. *Pseudocucurbita* cf. *infundibuliformis*	– Martini, R., Zaninetti, L., Abate, B., Renda, P., Doubinger, J., Rauscher, R. et Vrielynck, B. pl. 15, figs 1–8
1992. *Cucurbita infundibuliformis*	– Zaninetti, L. et Martini, R. p. 29. pl. 1, figs 1–6, pl. 2, figs 1–6, pl. 3, figs 1–5, pl. 4, figs 1–5, textfig. 1/A–F, textfig. 2/A–J, 3/B

Size: max. breadth of the test: 0.150 mm, length of a chamber: 0.200 mm
Remark: One-chamber sections predominate. These chambers are of flasklike form. Rounded bottom, then gets narrow and forms a broad collar. Calcareous, heavily recrystallized. Terminal aperture.
Occurrence in Alsó Hill: Very aboundant in the central (i.e. latest) part of the Wetterstein Reef (locations: 1/1972, 2/1972, 9/1972, 35/1973, T-6, T-197, T-258, T-430, T-505).

genus: **Urnulinella** Borza et Samuel, 1977: "A belly-shaped test, multicameral, with broad terminal aperture and a fine collar. The test wall is composed of micrite calcite."

After Loeblich, Tappan 1988: "Test robust, up to 0.8 mm in length, large proloculus followed by up to four, rapidly enlarging, globular to flasklike chambers, rectilinear to somewhat irregularly uniserial, wall calcareous, of micritic calcite, probably originally porcelaneous, aperture terminal, wide, with distinctly recurved flangelike collar."

Urnulinella andrusovi Borza et Samuel, 1977

Pl. VII. Figs 1–2, 4–7

Type reference:

1977a. *Urnulinella andrusovi*	– Borza, K. et Samuel, O. p. 118. pl. 7, figs 1–6

Synonyms:

1977. *Galeanella panticae*	– Zaninetti, L. pl. 1, figs 22–26
1977a. *Spiriamphorella irregularis*	– Borza, K. et Samuel, O. p. 116. pl. 6, figs 1–2
1978. *Urnulinella andrusovi*	– Borza, K. et Samuel, O. (not illustrated)
1978. *Spiriamphorella irregularis*	– Borza, K. et Samuel, O. (not illustrated)
1981. *Urnulinella andrusovi*	– Samuel, O. et Borza, K. pl. 21, fig. 4
1982a. *Galeanella irregularis*	– Zaninetti, L., Altiner, D., Dager, Z. et Ducret, B. p. 97. textfig. 1/A–E, pl. 2, figs 1–8
1982b. *Galeanella irregularis*	– Zaninetti, L., Altiner, D., Dager, Z. et Ducret, B. p. 112
1982. *Galeanella irregularis*	– Zaninetti, L. et Altiner, D. (not illustrated)
1983. *Urnulinella andrusovi*	– Senowbari-Daryan, B. p. 203. textfig. 9, pl. 18, figs 1–3, pl. 23, figs 1–3
1983. *Urnulinella andrusovi*	– Salaj, J., Borza, K. et Samuel, O. p. 162. pl. 154, figs 1–6, pl. 155, figs 1–6
1983. *Urnulinella? irregularis*	– Salaj, J., Borza, K. et Samuel, O. p. 162. pl. 153, figs 1–8
1983. *Amphorella? subsphaerica*	– Salaj, J., Borza, K. et Samuel, O. p. 160, pl. 149, figs 11, 13
1983. *Galeanella irregularis*	– Al-Shaibani, S.K., Carter, J.D. et Zaninetti, L. (not illustrated)

1983. *Galeanella irregularis*	– Zaninetti, L. et Altiner, D. pl. 1, figs 3, 5–7
1984. *Galeanella irregularis*	– Al-Shaibani, S.K., Carter, J.D. et Zaninetti, L. (not illustrated)
1985. *Galeanella irregularis*	– Dragastan, D., Papanikos, D. et Papanikos, P. pl. 1, figs 4, 7
1987. *Urnulinella* sp. aff. *U. andrusovi*	– Pirdeni, A. pl. 7, figs 1–16
1987. *Urnulinella andrusovi*	– Senowbari-Daryan, B. p. 257. pl. 1, figs 1–3, 9–10
1988. *Urnulinella?* sp.	– Pirdeni, A. pl. 2, figs 5–6
1988. *Urnulinella andrusovi*	– Loeblich, R.A. et Tappan, H. pl. 388, figs 6–9
1992. *Urnulinella andrusovi*	– Zaninetti, L. et Martini, R. p. 32. textfig. 2/K; 3/A, pl. 4, fig. 6

Size: broadest chamber: 0.300–0.450 mm; height of a chamber: 0.400 mm
Remark: Scattered chamber sections. Two chamber individuals are very sparse and always in oblique section. One chamber is heavily inflated forming an almost perfect sphere, scarcely bulb. Wall thick, calcareous, heavily recrystallized. Aperture terminal, with recurved flangelike collar.
Occurrence in Alsó Hill: Very characteristic member of the foraminifera association in the central (i.e. latest) part of the Wetterstein Reef (locations: 1/1972, 2/1972, 9/1972, 35/1973, T-6, T-66, T-197, T-258, T-279, T-430, T-505).

genus: **Variostoma** Kristan-Tollmann, 1960 (after Loeblich, Tappan, 1988): "Test trochospiral, moderate to high spired, all chambers visible on the spiral side, opposite side involute and deeply umbilicate, umbilical margin lobulate, wall calcareous, finely microgranular with an organic matrix, sporadically and finely perforate, nonlamellar, primary aperture simple, rounded to oval, or with fimbriate margin, separated from the umbilicus by a flap."

Variostoma acutoangulata Kristan-Tollmann, 1973

P. X. Fig. 5; Pl. XVI. Figs 1–7; Pl. XVII. Figs 1, 5, 8–9; Pl. XXVIII. Fig. 2a; Pl. XXXIV. Fig. 6; Pl. XXXIX. Fig. 1b

Type reference:

1973. *Variostoma acutoangulata*	– Kristan-Tollmann, E. p. 424. textfig. 2/2; 4/1–2

Synonyms:

1976. *Variostoma acutoangulata*	– Zaninetti, L. p. 189. pl. 17, fig. 8
1982. *Variostoma acutoangulata*	– Kristan-Tollmann, E. et Tollmann, A. (not illustrated)
1983. *Variostoma acutoangulata*	– Kristan-Tollmann, E. et Tollmann, A. (not illustrated)
1983. *Variostoma acutoangulata*	– Salaj, J., Borza, K. et Samuel, O. p. 154. pl. 133, figs 4, 7

Size: diameter: 0.400–0.800 mm; height: 0.500 mm
Remark: The most flattened test within the group of the large Variostoma species. Sligthly elevetad spiral side and sharp edge characteristic. The large whols carries a number of small chambers. They are almost identical in size, diameter grows

very slowly. Slightly incised sutures between the chambers. Calcareous test. No visible aperture in thin sections.
Occurrence in Alsó Hill: Very common and aboundant in the reefal facies of the Wetterstein limestone (locations: 223/50BK, 8/1972, G-23/1974, 10/1972, 13/1972, 14/1972, 16/1972, 17/1972, 34/1972, T-24, T-35, T-383). Less frequent, but exists in the lagoonal facies too (locations: T-89, T-163, T-74).

Variostoma exile Kristan-Tollmann, 1960

Pl. XXVIII. Fig. 2b.

Type reference:

1960. *Variostoma exile*	– Kristan-Tollmann, E. p. 58. pl. 8, fig. 5, pl. 9, figs 4–8

Synonyms:

1963. *Variostoma exile*	– Kristan-Tollmann, E. pl. 9.
1967. *Variostoma exile*	– Salaj, J . et Jendrejáková, O. pl. 19, fig. 1/6
1967b. *Variostoma exile*	– Salaj, J., Biely, A. et Bystricky, J. (not illustrated)
1972. *Variostoma exile*	– Turculet, I. pl. 1, figs 4–5
1974b. *Variostoma exile*	– Pantic, S. (not illustrated)
1974c. *Variostoma exile*	– Pantic, S. pl. 4, fig. 3
1975a. *Variostoma exile*	– Fuchs, W. textfig. 1–3, pl. 1, figs 1–4, pl. 2, fig. 1 pl. 3, figs 1–4
1976. *Variostoma exile*	– Zaninetti, L. p. 190. pl. 16, fig. 7
1976. *Variostoma exile*	– Tollmann, A. textfig. 58/3–4
1979. *Variostoma exile*	– Resch, W. pl. 5, fig. 30
1983. *Variostoma exile*	– Bystricky, J. et Jendrejáková, O. (not illustrated)
1983. *Variostoma exile*	– Oravecz-Scheffer, A. (not illustrated)
1993. *Variostoma exile*	– Budai, T., Csillag, G., Haas, J., Koloszár, L., Szabó, I. et Tóth-Makk, Á. (not illustrated)

Size: diameter: 0.500–0.700 mm; height: 1.000–1.300 mm
Remark: Very high spiral side forming a slim, high cone with a sharp apex and convex base. Breadth of the whols increases systematically from the spiky initial part. Size of the ligtly inflated chambers increases slowly. Edge of the chambers is rounded. Thick, calcareous wall. Individuals recovered/described from Alsó-hegy are larger than the holotype from the Cassian Beds of the Dolomites.
Occurrence in Alsó- Hill: Several exemplares recovered from the reefal (location: 6/1972) and lagoonal (location: T-167) beds of the Wetterstein Limestone.

Variostoma pralongense Kristan-Tollmann, 1960

Pl. XV. Fig. 8, Pl. XXIII. Fig. 5, Pl. XXVII. Fig. 1a, Pl. XXXV. Fig. 4

Type reference:

1960. *Variostoma pralongense*	– Kristan-Tollmann, E. p. 57. pl. 8, figs 2–4, pl. 9, figs 1–3

Synonyms:

1963. *Variostoma pralongense*	– Kristan-Tollmann, E. pl. 9
1967a. *Variostoma pralongense*	– Salaj, J., Biely, A . et Bystricky, J. (not illustrated)
1967b. *Variostoma* cf. *pralongense*	– Salaj, J., Biely, A. et Bystricky, J. pl. 2, fig. 1c
1967. *Variostoma pralongense*	– Salaj, J. et Jendrejáková, O. (not illustrated)
1972. *Variostoma* aff. *pralongense*	– Turculet, I. pl. 2, fig. 4
1973. *Variostoma pralongense*	– Jendrejáková, O. (not illustrated)
1975a. *Variostoma pralongense*	– Fuchs, W. pl. 1, figs 5–6
1975c. *Variostoma pralongense*	– Hohenegger, J. et Piller, W. pl. 5, figs 1, 3–4
1976. *Variostoma pralongense*	– Zaninetti, L. p. 190. pl. 16, fig. 6
1976. *Variostoma pralongense*	– Tollmann, A. textfig. 58/1–2
1977. *Variostoma* aff. *pralongense*	– Misik, M., Mock, R. et Sykora, M. (not illustrated)
1977. *Variostoma pralongense*	– Salaj, J. pl. 2, fig. 7
1979. *Variostoma pralongense*	– Oravecz-Scheffer, A. (not illustrated)
1983. *Variostoma* aff. *pralongense*	– Bystricky, J. et Jendrejáková, O. (not illustrated)
1983. *Variostoma pralongense*	– Góczán, F., Haas, J., Lőrincz, H. et Oravecz-Scheffer, A. (not illustrated)
1983. *Variostoma pralongense*	– Oravecz-Scheffer, A. (not illustrated)
1983. *Variostoma pralongense*	– Salaj, J., Borza, K. et Samuel, O. p. 155. pl. 138, fig. 4, pl. 139, fig. 3–4
1985. *Variostoma pralongense*	– Trifonova, Ek. et Vaptsarova, A. pl. 3, fig. 5
1987. *Variostoma pralongense*	– Oravecz-Scheffer, A. pl. 44, fig. 6, pl. 45, fig. 9, pl. 54, fig. 2
1988. *Variostoma pralongense*	– Pantic-Prodanovic, S. (not illustrated)
1991 *Variostoma pralongense*	– He, Y., et Norling, E. p. 34. pl. 1, fig. 9
1991. *Diplotremina stenocamera*	– He, Y., Cia, L.Q. pl. 4, figs 15–17
1993. *Variostoma pralongense*	– Budai, T., Csillag, G., Haas, J., Szabó, I. et Tóth-Makk, Á. (not illustrated)

Size: diameter: 0.400 –0.600 mm; height: 0.530–1.000 mm
Remark: Spiral side conical, high, wound with spiky apex and slightly inflated, fast growing chambers. Convex umbilical side. Exemplars in oblique longitudinal section only. Calcareous, perforated wall. Exemplars recovered in Alsó-hegy are of larger size than the holotype.
Occurrence in Alsó Hill: Few individuals from the reefal (locations: G-23/1972, T-494) and lagoonal facies (locations: T-180, T-489) of the Wetterstein Limestone.

Plate I

1. *Earlandia tintinniformis* (Misik) 8/1972. 53x
2. *Earlandia* sp. 6/1972/A. 54x
3. Mikroproblematicum 2/1972/B. 90x
4. Mikroproblematicum 4/1972/C. 90x
5. *Pilamminella kuthani* (Salaj) T-496/J. 55x
6. *Baccanella floriformis* Pantic T-279. 60x
7. *Pilamminella kuthani* (Salaj) T-496/1. 55x
8. *Glomospirella* sp. T-496/B. 94x
9. *Tignumparina zeissi* Senowbari-Daryan T-418/E. 50x
10. *Calcitornella?* sp. T-496/C. 60x
11. *Glomospira* sp. 2/1972/A. 150x
12. *Tolypammina* cf. *gregaria* Wendt T-496/C. 60x

Plate II

1. *Verneuilinoides* sp. T-6/1972. 50x
2. *Verneuilinoides* sp. 32/1973. 50x
3. *Pseudobolivina globosa* Kristan-Tollmann T-6. 90x
4. *Palaeolituonella meridionalis* (Luperto) 9/1972. 100x
5. *Palaeolituonella meridionalis* (Luperto) T-421. 90x
6. *Palaeolituonella meridionalis* (Luperto) T-66/F. 100x
7. *Palaeolituonella meridionalis* (Luperto) 8/1972/12. 55x
8. *Palaeolituonella meridionalis* (Luperto) T-421. 70x
9. *Palaeolituonella meridionalis* (Luperto) G-23. 100x
10. *Palaeolituonella meridionalis* (Luperto) T-66/A. 75x
11. *Palaeolituonella meridionalis* (Luperto) 22/1972. 80x

Plate III

1. *Palaeolituonella meridionalis* (Luperto) 35/1973/M. 100x
2. *Palaeolituonella meridionalis* (Luperto) 35/1973/M. 100x
3. *Agglutisolenia conica* Senowbari-Daryan 35/1973/E. 60x
4. *Reophax asper* Cushman et Waters T-429/A. 60x
5. Foram. indet. sp. T-211. 60x
6. *Trochammina almtalensis* Koehn-Zaninetti T-55/B. 95x
7. *Trochammina jaunensis* Brönnimann et Page T-6. 95x
8. *Trochammina* cf. *alpina* Kristan-Tollmann 15/1972/C. 65x
9. *Trochammina* cf. *almtalensis* Koehn-Zaninetti 32/1973. 60x

Plate IV

1. *Endothyra* sp. aff. *Endoteba* sp. 6/1972. 80x
2. *Ammobaculites* sp. T-392. 60x
3. *Endothyranella inflata* nov. sp. T-193. 100x
4. *Endothyranella* sp1 T-55. 90x
5. *Endothyranella* sp2 T-268. 100x
6. *Endothyranella* sp3 T-197/B. 100x
7. *Endothyranella* cf. *pentacamerata* Salaj 35/1973/F 60x
8. *Ammobaculites* sp. T-421. 110x

Plate V

1. *Endothyra* sp1 G-23/1974. 40x
2. *Endothyra badouxi* Zaninetti et Brönnimann T-496/I. 50x
3. *Endothyra badouxi* Zaninetti et Brönnimann 34/1973/D. 50x
4. *Endothyra* cf. *obturata* Brönnimann et Zaninetti 7/1972. 60x
5. *Endothyra* cf. *obturata* Brönnimann et Zaninetti T-430/A. 95x
6. *Endothyra* cf. *obturata* Brönnimann et Zaninetti T-430/A. 85x
7. *Endothyra* sp. aff. *Endoteba* sp. 32/1973. 45x
8. *Endothyra* sp1 T-496/H. 100x

Plate VI

1. *Ophthalmidium* sp. cf. *O. carinatum* (Leischner) T-197/5. 90x
2. *Ophthalmidium* sp. 7/1974. 90x
3. *Ophthalmidium* sp. T-211. 100x
4. *Ophthalmidium exiguum* Koehn-Zaninetti T-291. 90x
5. *Ophthalmidium exiguum* Koehn-Zaninetti T-197/5. 90x
6. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) 8/1971/B. 90x
7. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) T-6. 90x
8. *Agathammina* sp. T-418/E. 95x
9. *Ophthalmidium exiguum* Koehn-Zaninetti T-55/B. 90x
10. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) T-6. 95x
11. *Miliolipora cuvillieri* Brönnimann et Zaninetti T-279. 100x
12. *Agathammina?* sp. T-66/B. 90x
13. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) T-421. 95x
14. *Spiroloculina* sp. 7/1974. 90x
15. *Agathammina* sp. 2/1972/E. 110x
16. *Agathammina* sp. T-418/E. 90x

Plate VII

1. *Urnulinella andrusovi* Borza et Samuel 35/1973/E. 85x
2. *Urnulinella andrusovi* Borza et Samuel 2/1972/A. 50x
3. *Cucurbita infundibuliformis* Jablonsky T-197/B5. 100x
4. *Urnulinella andrusovi* Borza et Samuel 35/1973/L. 90x
5. *Urnulinella andrusovi* Borza et Samuel 35/1973/F. 100x
6. *Urnulinella andrusovi* Borza et Samuel 35/1973/M. 90x
7. *Urnulinella andrusovi* Borza et Samuel 2/1972/F. 50x
8. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) 223/5 BK. 90x

Plate VIII

1. *Pseudonodosaria* sp. 27/1973/B. 90x
2. *Pseudonodosaria* sp. 8/1972/12. 90x
3. *Pseudonodosaria* sp. T-197/5. 90x
4. *Nodosaria* sp. 2/1972/K. 90x
5. *Nodosaria* ex. gr. *ordinata* Trifonova T-418/A. 90x
6. *Nodosariidae* sp. 35/1973/G. 90x
7. *Nodosariidae* sp. 4/1972/B. 90x
8. *Gaudryina* sp. G-23/1974. 60x
9. *Gaudryina* sp. 223/50 BK. 90x
10. *Lenticulina* sp. T-211. 60x
11. *Lenticulina* sp. 27/1973/B. 60x
12. *Lenticulina* sp. 19/1972/H. 50x

Plate IX

1. *Arenovidalina chialingchiangensis* He T-279. 85x
2. *Arenovidalina chialingchiangensis* He T-421. 75x
3. *Arenovidalina chialingchiangensis* He T-291. 100x
4. *Arenovidalina chialingchiangensis* He T-55/B. 90x
5. *Arenovidalina chialingchiangensis* He T-291. 90x
6. *Triadodiscus eomesozoicus* (Oberhauser) 2/1972/A. 90x
7. *Triadodiscus eomesozoicus* (Oberhauser) T-291. 90x
8. *Triadodiscus eomesozoicus* (Oberhauser) T-291. 90x
9. *Triadodiscus eomesozoicus* (Oberhauser) 34/1973/D. 110x
10. *Triadodiscus eomesozoicus* (Oberhauser) T-188. 95x
11. *Triadodiscus eomesozoicus* (Oberhauser) T-484/A. 90x
12. *Agathammina* sp. 7/1974. 80x
13. *Agathammina* sp. T-66/F. 95x
14. *Agathammina* sp. T-291. 95x
15. *Triadodiscus eomesozoicus* (Oberhauser) T-441. 95x
16. *Agathammina* sp. 7/1974. 80x

Plate X

1. *Triadodiscus eomesozoicus* (Oberhauser) T-291. 50x
2. *Triadodiscus eomesozoicus* (Oberhauser) T-291. 90x
3. *Aulotortus?* sp. 6/1972. 90x
4. *Aulotortus?* sp. T-55/B. 90x
5. *Arenovidalina chialingchiangensis* He 4/1972/B. 90x
6. *Arenovidalina chialingchiangensis* He T-304/9. 90x
7. *Arenovidalina chialingchiangensis* He T-505/A. 100x
8. *Agathammina* sp. 7/1974. 60x
9. *Ophthalmidium?* sp. 7/1974. 80x
10. *Ophthalmidium?* sp. 34/1973/D. 100x

Plate XI

1. *Aulotortus sinuosus* Weynschenk T-197/5. 90x
2. *Aulotortus sinuosus* Weynschenk T-496/D. 50x
3. *Aulotortus sinuosus* Weynschenk 16/1972/B. 50x
4. *Aulotortus sinuosus* Weynschenk 17/1972/B. 50x
5. *Aulotortus sinuosus* Weynschenk T-496/L. 45x
6. *Aulotortus sinuosus* Weynschenk 17/1972/B. 90x
7. *Aulotortus sinuosus* Weynschenk T-421. 55x
8. *Aulotortus sinuosus* Weynschenk 17/1972/E. 50x
9. *Aulotortus sinuosus* Weynschenk 8/1972/12. 55x

Plate XII

1. *Aulotortus sinuosus* Weynschenk T-421. 50x
2. *Aulotortus sinuosus* Weynschenk G-23. 50x
3. *Aulotortus friedli* (Kristan-Tollmann) 19/1973/E. 90x
4. *Aulotortus friedli* (Kristan-Tollmann) 15/1972/B. 90x
5. *Aulotortus friedli* (Kristan-Tollmann) 13/1972/B. 45x
6. *Aulotortus friedli* (Kristan-Tollmann) 17/1972/C. 50x
7. *Aulotortus friedli* (Kristan-Tollmann) 17/1972/E. 50x

Plate XIII

1. *Aulotortus sinuosus* Weynschenk G-23/1974. 55x
2. *Aulotortus sinuosus* Weynschenk G-23/1974. 55x
3. *Aulotortus sinuosus* Weynschenk 15/1972/A. 80x
4. *Pilamminella kuthani* (Salaj) 223/50 BK. 50x
5. *Pilamminella kuthani* (Salaj) 223/50 BK. 50x
6. *Aulotortus sinuosus* Weynschenk 223/50 BK. 50x

Plate XIV

1. *Involutinidae* sp. T-188. 80x
2. *Diplotremina astrofimbriata* Kristan-Tollmann T-496/B. 80x
3. *Diplotremina astrofimbriata* Kristan-Tollmann 17/1972/D. 50x
4. *Diplotremina* sp. 18/1972/F. 100x
5. *Diplotremina* sp. T-496/B. 95x
6. *Diplotremina astrofimbriata* Kristan-Tollmann 16/1972/C. 120x
7. *Diplotremina* sp2 16/1972/B. 95x
8. *Diplotremina* sp1 T-258/B1. 90x

Plate XV

1. *Duostomina turboidea* Kristan-Tollmann T-421. 85x
2. *Duostomina turboidea* Kristan-Tollmann T-421. 85x
3. *Duostomina turboidea* Kristan-Tollmann T-421. 90x
4. *Duostomina biconvexa* Kristan-Tollmann 1971. Béke-bg. 100x
5. *Duostomina* sp. cf. *D. magna* Trifonova 18/1972/E. 50x
6. *Diplotreminidae* sp. 17/1972/E. 50x
7. *Miliolidae* sp. T-115. 100x
8. *Variostoma* cf. *pralongense* Kristan-Tollmann G-23/1974. 50x
9. *Variostomatidae* sp. 15/1972/A. 110x

Plate XVI

1. *Variostoma acutoangulata* Kristan-Tollmann 17/1972/E. 50x
2. *Variostoma acutoangulata* Kristan-Tollmann 34/1973/B. 50x
3. *Variostoma acutoangulata* Kristan-Tollmann T-55. 50x
4. *Variostoma acutoangulata* Kristan-Tollmann T-24. 90x
5. *Variostoma acutoangulata* Kristan-Tollmann G-23/1974. 90x
6. *Variostoma acutoangulata* Kristan-Tollmann 13/1972/B. 80x
7. *Variostoma acutoangulata* Kristan-Tollmann 14/1972/A. 70x

Plate XVII

1. *Variostoma* cf. *acutoangulata* Kristan-Tollmann 6/1972/A. 60x
2. *Frondicularia woodwardi* Howchin 3/1972/A. 65x
3. *Gaudryina* sp. 3/1972/A. 55x
4. *Palaeotextularia* sp. 1/1972/E. 65x
5. *Variostoma acutoangulata* Kristan-Tollmann 223/50 BK. 95x
6. *Diplotreminidae?* sp. 10/1972/A. 100x
7. *Variostoma exile* Kristan-Tollmann 6/1972/A. 50x
8. *Variostoma acutoangulata* Kristan-Tollmann 8/1972. 100x
9. *Variostoma* cf. *acutoangulata* Kristan-Tollmann G-23. 50x

Plate XVIII

1. *Tetrataxis* sp. T-258/A. 120x
2. *Galeanella* sp. T-258/B. 100x
3. *Endothyra* sp. 15/1972/A. 100x
4. *Galeanella* sp. T-505/A. 100x
5. *Arenovidalina chialingchiangensis* He T-291. 100x
6. *Arenovidalina chialingchiangensis* He T-291. 100x
7. *Arenovidalina chialingchiangensis* He T-258/B. 110
8. *Arenovidalina chialingchiangensis* He 2/1972/E. 50x

Plate XIX

1. *Aulotortus friedli* (Kristan-Tollmann) T-83. 100x
2. *Aulotortus friedli* (Kristan-Tollmann) T-83. 100x
3. *Ophthalmidium lucidum* Trifonova T-83. 100x
4. *Miliolipora cuvillieri* Brönnimann et Zaninetti T-83. 100x
5. *Endothyra* sp. T-83. 100x
6. *Diplotremina astrofimbriata* Kristan-Tollmann T-83. 100x

Plate XX

1. *Reophax* sp. T-391. 50x
2. *Endothyranella* sp. aff. *E. kocaeliensis* Dager T-391. 60x
3. *Trochammina almtalensis* Koehn-Zaninetti T-391. 100x
4. *Gaudryina?* sp. T-391. 50x
5. *Variostoma acutoangulata* Kristan-Tollmann T-391. 50x
6. *Diplotremina astrofimbriata* Kristan-Tollmann T-391. 50x

Plate XXI

1. *Aulotortus sinuosus* Weynschenk (=*Angulodiscus communis* Kristan) T-391. 50x
2. *Aulotortus sinuosus* Weynschenk T-391. 60x
3. a) *Triadodiscus eomesozoicus* (Oberhauser),
   b) *Aulotortus sinuosus* Weynschenk T-391. 50x
4. *Aulotortus sinuosus* Weynschenk T-391. 60x

Plate XXII

1. *Ophthalmidium lucidum* Trifonova T-494. 100x
2. *Pilamminella gemerica* (Salaj) T-494. 100x
3. *"Glomospirella" minima* Michalik, Jendrejáková, Borza T-494. 100x
4. *Aulotortus friedli* (Kristan-Tollmann) T-494. 100x
5. *Aulotortus friedli* (Kristan-Tollmann) T-494. 100x

Plate XXIII

1. *Trochammina* cf. *alpina* Kristan-Tollmann T-494. 100x
2. *Trochammina* cf. *alpina* Kristan-Tollmann T-494. 100x
3. *Trochammina alpina* Kristan-Tollmann T-494. 100x
4. *Triadodiscus eomesozoicus* (Oberhauser) T-494. 100x
5. *Variostoma pralongense* Kristan-Tollmann T-494. 90x

Plate XXIV

1. *Trochammina alpina* Kristan-Tollmann T-485. 100x
2. *Foraminiferida* sp. T-444. 40x
3. *Earlandinita oberhauseri* Salaj T-522. 90x
4. *Endothyra* sp2 T-524. 100x
5. *Endothyra obturata* Brönnimann et Zaninetti T-444. 60x
6. *Endothyranella pentacamerata* Salaj T-202. 50x
7. *Endothyranella bicamerata* Salaj T-169. 100x
8. *Endothyranella inflata* nov. sp. 9/1971/B. 90x

Plate XXV

1. *Ophthalmidium lucidum* (Trifonova) T-485. 100x
2. Foram. indet sp. cf. *Gaudryina* sp. 9/1971/B. 90x
3. Foram. indet sp. cf. *Gaudryina* sp. T-180. 90x
4. *Aulotortus sinuosus* Weynschenk T-488. 100x
5. *Aulotortus sinuosus* Weynschenk T-388. 40x
6. *Aulotortus sinuosus* Weynschenk (=Involutina muranica Jendrejáková) T-201. 50x
7. *Aulotortus sinuosus* Weynschenk T-488. 50x
8. *Aulotortus sinuosus* Weynschenk T-444. 50x

Plate XXVI

1. *Aulotortus friedli* (Kristan-Tollmann) T-167/A. 100x
2. *Aulotortus friedli* (Kristan-Tollmann) T-167/B. 50x
3. *Aulotortus friedli* (Kristan-Tollmann) T-167. 50x
4. *Textularia* sp1 T-167. 100x
5. Foram. indet sp. T-167. 50x

Plate XXVII

1. a) *Variostoma pralongense* Kristan-Tollmann,
   b) *Aulotortus friedli* (Kristan-Tollmann) T-167/B. 50x
2. *Variostomatidae* sp. T-167/B. 50x
3. *Endothyra* sp2 T-167/B. 50x
4. *Trochammina almtalensis* Koehn-Zaninetti T-167/C. 90x
5. a) *Aulotortus sinuosus* Weynschenk,
   b) *Aulotortus friedli* (Kristan-Tollmann) T-167/A. 40x

Plate XXVIII

1. *Aulotortus microbiofacies* T-167/A. 30x
2. a) *Variostoma acutoangulata* Kristan-Tollmann,
   b) *Variostoma exile* Kristan-Tollmann T-167/C. 50x
3. *Earlandinita oberhauseri* Salaj T-167/A. 50x

Plate XXIX

1. a) *Aulotortus sinuosus* Weynschenk,
   b) *Earlandinita libera* Salaj T-278. 40x
2. *Aulotortus sinuosus* Weynschenk T-278. 40x
3. *Aulotortus sinuosus* Weynschenk T-278. 50x
4. *Involutinidae* sp. T-278. 40x

Plate XXX

1. *Aulotortus friedli* (Kristan-Tollmann) T-389. 50x
2. *Diplotremina* sp. T-389/13. 45x
3. *Aulotortus friedli* (Kristan-Tollmann) T-389/13. 50x
4. *Aulotortus friedli* (Kristan-Tollmann) T-389. 45x
5. *Aulotortus sinuosus* Weynschenk T-389/13. 80x
6. *Aulotortus friedli* (Kristan-Tollmann) T-389/13. 60x

Plate XXXI

1. *Aulotortus sinuosus* Weynschenk T-389. 50x
2. *Ophthalmidium lucidum* (Trifonova) T-389. 50x
3. *Aulotortus sinuosus* Weynschenk T-389. 50x
4. *Aulotortus friedli* (Kristan-Tollmann) T-389. 50x

Plate XXXII

1. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) T-486. 100x
2. a) *Ammobaculites* sp.,
   b) *Agathammina* sp. T-486. 50x
3. *Earlandia* sp. T-486. 50x
4. *Diplotremina subangulata* Kristan-Tollmann T-486. 80x
5. *Glomospirella* sp. T-486. 100x
6. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) T-486. 100x

Plate XXXIII

1. *Aulotortus* cf. *sinuosus* Weynschenk T-499. 100x
2. *Aulotortus friedli* (Kristan-Tollmann) T-499. 60x
3. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) T-499. 100x
4. *Aulotortus friedli* (Kristan-Tollmann) T-499. 70x

Plate XXXIV

1. *Pilamminella kuthani* (Salaj) T-89/2. 65x
2. *Pilamminella kuthani* (Salaj) T-89/1. 50x
3. *Textularia* sp2 T-89/2. 100x
4. *Geinitzina?* sp. T-89/2. 100x
5. *Textularia* sp2 T-89/2. 100x
6. *Variostoma acutoangulata* Kristan-Tollmann T-89/3. 50x

Plate XXXV

1. *Gaudryina* sp. T-489. 70x
2. *Variostoma pralongense* Kristan-Tollmann T-489. 50x
3. *Ammobaculites* sp. T-489. 50x
4. *Aulotortus sinuosus* Weynschenk (=*Angulodiscus communis* Kristan) T-489. 50x

Plate XXXVI

1. *Nodosaria* cf. *ordinata* Trifonova T-163. 100x
2. *Nodosaria* sp. T-163. 50x
3. *Earlandinita oberhauseri* Salaj T-163. 85x
4. *Spirillina* sp. T-163. 100x

5. *Earlandinita oberhauseri* Salaj T-163. 90x
6. *Trochammina* cf. *alpina* Kristan-Tollmann T-163. 80x

Plate XXXVII

1. *Earlandinita soussi* Salaj T-174. 50x
2. *Trochammina almtalensis* Koehn-Zaninetti T-174. 100x
3. *Earlandinita oberhauseri* Salaj T-174. 50x
4. *Earlandia tintinniformis* (Misik) T-174. 80x
5. *Tetrataxis humilis* Kristan T-174. 100x
6. *Nodosariidae* sp. T-174. 100x
7. *Duostomina* cf. *alta* Kristan-Tollmann T-174. 100x

Plate XXXVIII

1. *Textularia* sp. 510/5. 50x
2. *Agathamminoides* sp. 510/5. 50x
3. *Agathamminoides* sp. 510/14. 100x
4. *Agathamminoides* sp. 510/32. 100x
5. *Agathamminoides* sp. 510/11. 100x
6. *Agathamminoides* sp. 510/31. 100x
7. *Duostomina* cf. *alta* Kristan-Tollmann 510/5. 50x
8. *Trochammina?* sp. 510/5. 100x
9. Earlandinita soussi Salaj 510/11. 50x
10. *Diplotremina astrofimbriata* Kristan-Tollmann 510/2. 50x
11. a) *Aulotortus sinuosus* Weynschenk,
    b) *Variostomatidae* sp. 510/A. 50x
12. Diplotremina, Aulotortus microbifacieses 510/A. 30x
13. *Endothyra* sp. 510/A. 50x

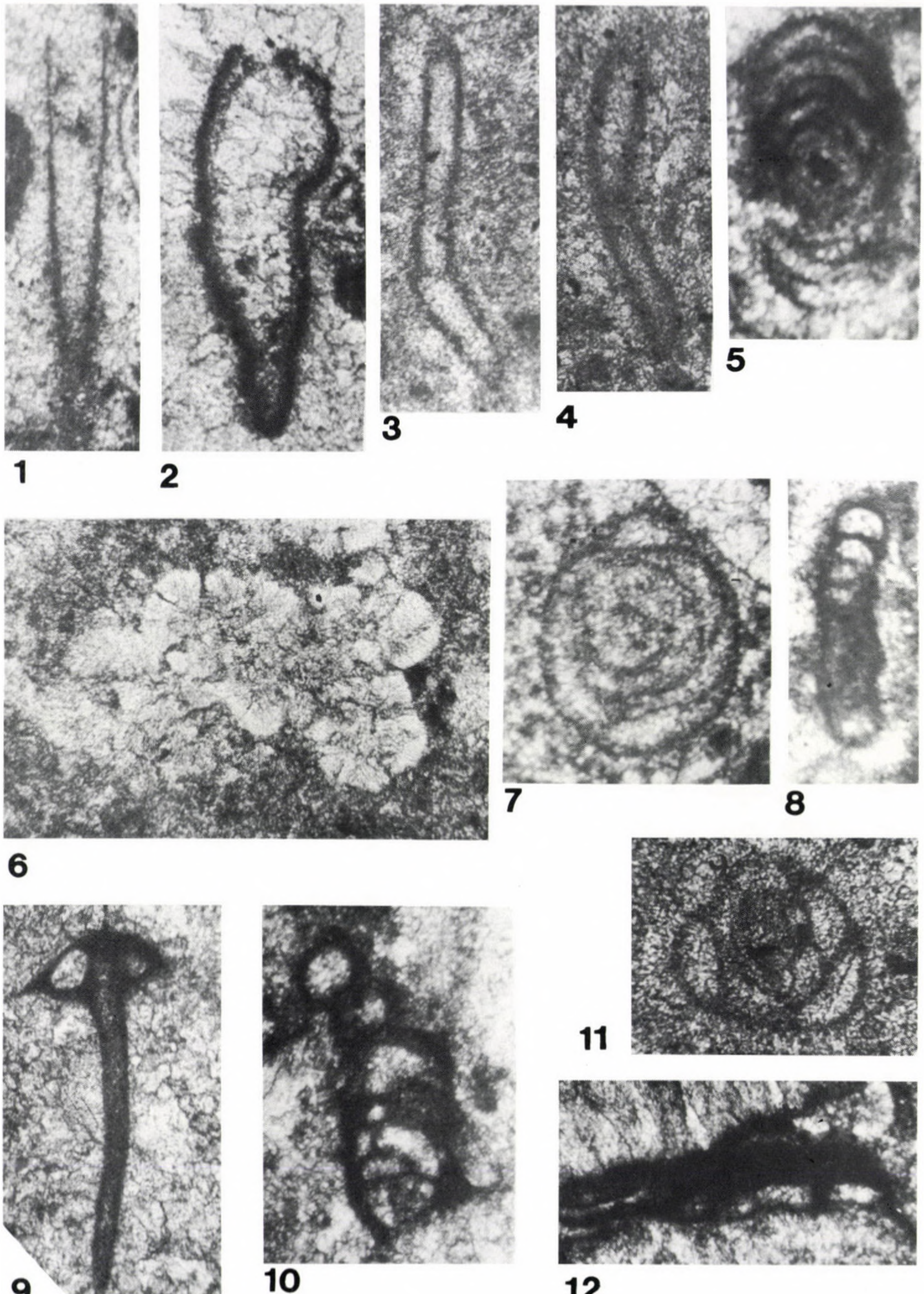
Plate XXXIX

1. a) *Aulotortus sinuosus* Weynschenk,
   b) *Variostoma acutoangulata* Kristan-Tollmann 510/2. 50x
2. *Triadodiscus eomesozoicus* (Oberhauser) 510/5. 50x
3. *Aulotortus sinuosus* Weynschenk 510/2. 100x
4. a) *Aulotortus sinuosus* Weynschenk,
   b) *Aulotortus friedli* Kristan-Tollmann 510/A. 50x
5. *Austrocolomia* sp. 510/5. 50 x
6. *Aulotortus friedli* Kristan-Tollmann 510/11. 50x
7. *Aulotortus friedli* Kristan-Tollmann 510/11. 50x
8. *Aulotortus friedli* Kristan-Tollmann 510/A. 50x
9. *Spirillina* sp. 510/2. 50x
10. *Aulotortus friedli* Kristan-Tollmann 510/5. 50x

Plate XL

1. *Aulotortus sinuosus* Weynschenk 510/A. 50x
2. *Aulotortus sinuosus* Weynschenk 510/2. 50x
3. *Aulotortus sinuosus* Weynschenk 510/3. 50x
4. *Aulotortus sinuosus* Weynschenk 510/A. 50x
5. *Aulotortus sinuosus* Weynschenk 510/11. 50x
6. *Aulotortus sinuosus* Weynschenk 510/5. 50x
7. *Aulotortus sinuosus* Weynschenk 510/33.2. 50x

Plate I



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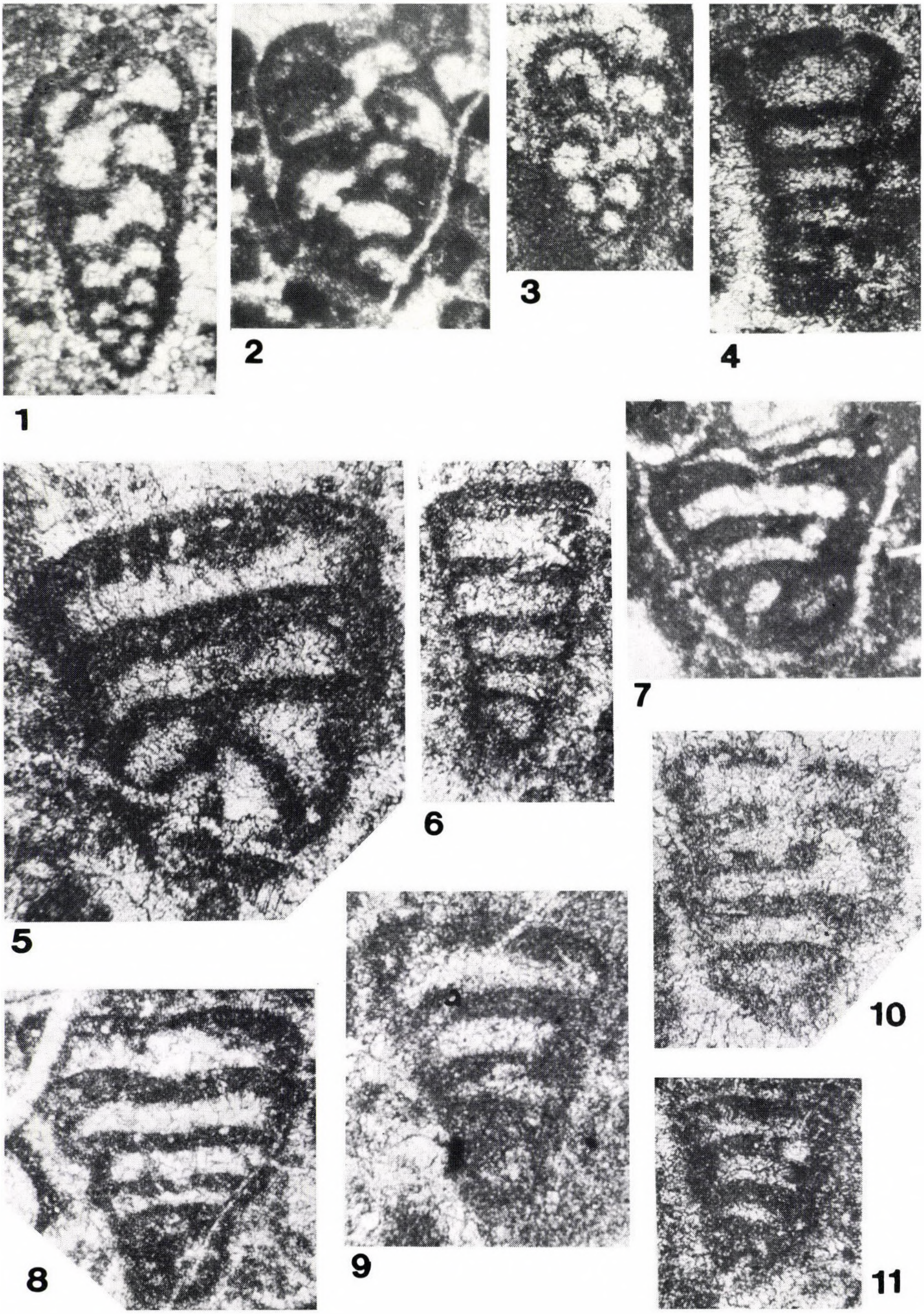

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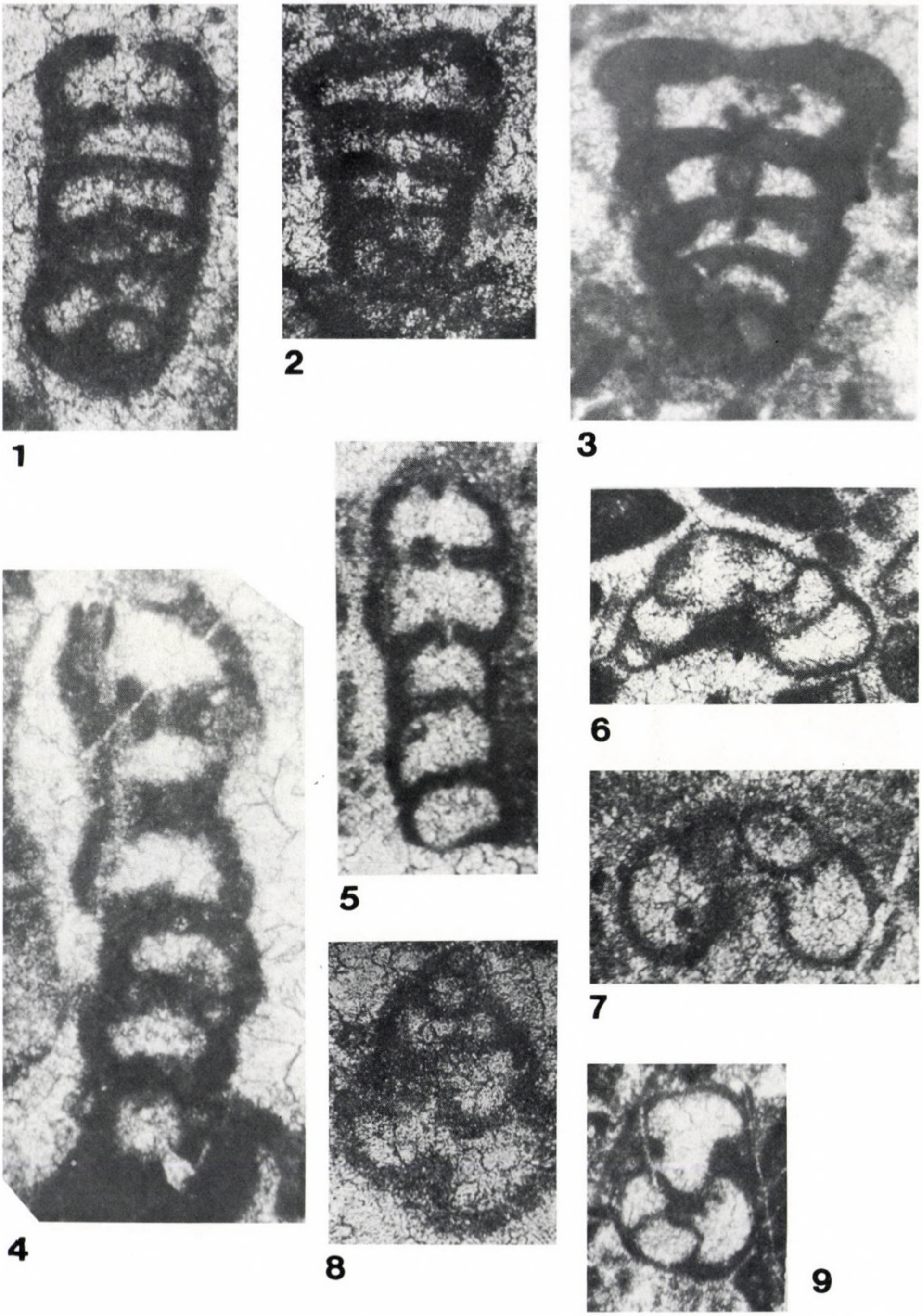

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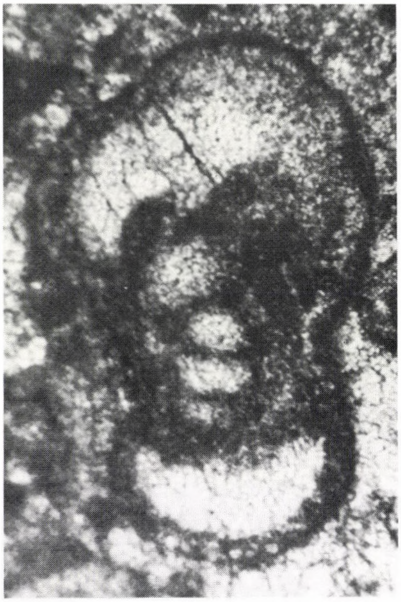

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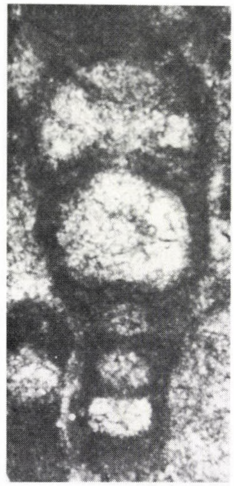

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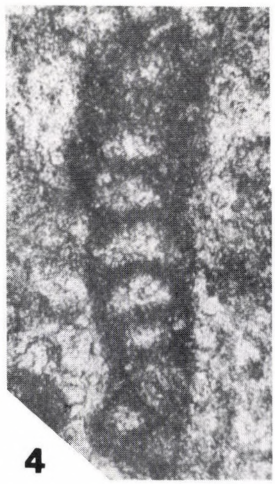

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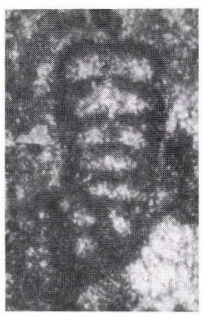

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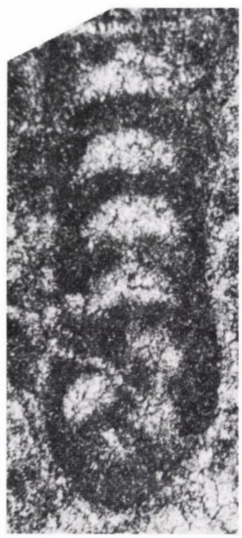

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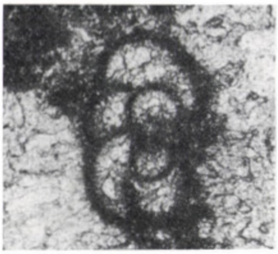

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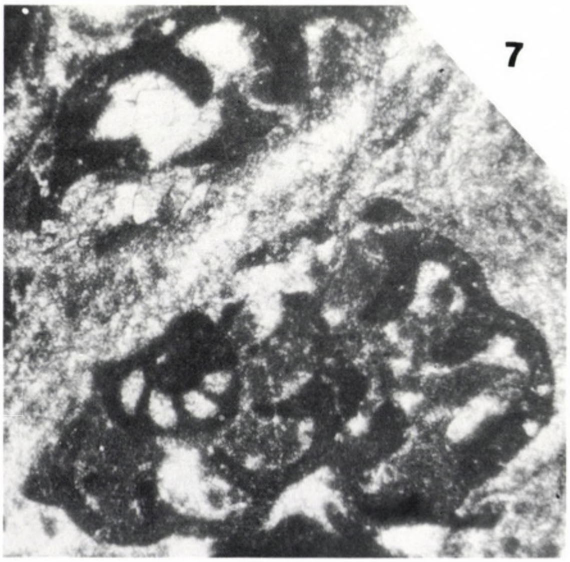

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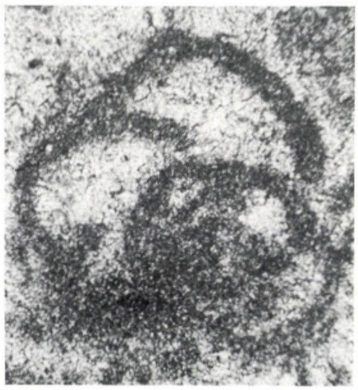

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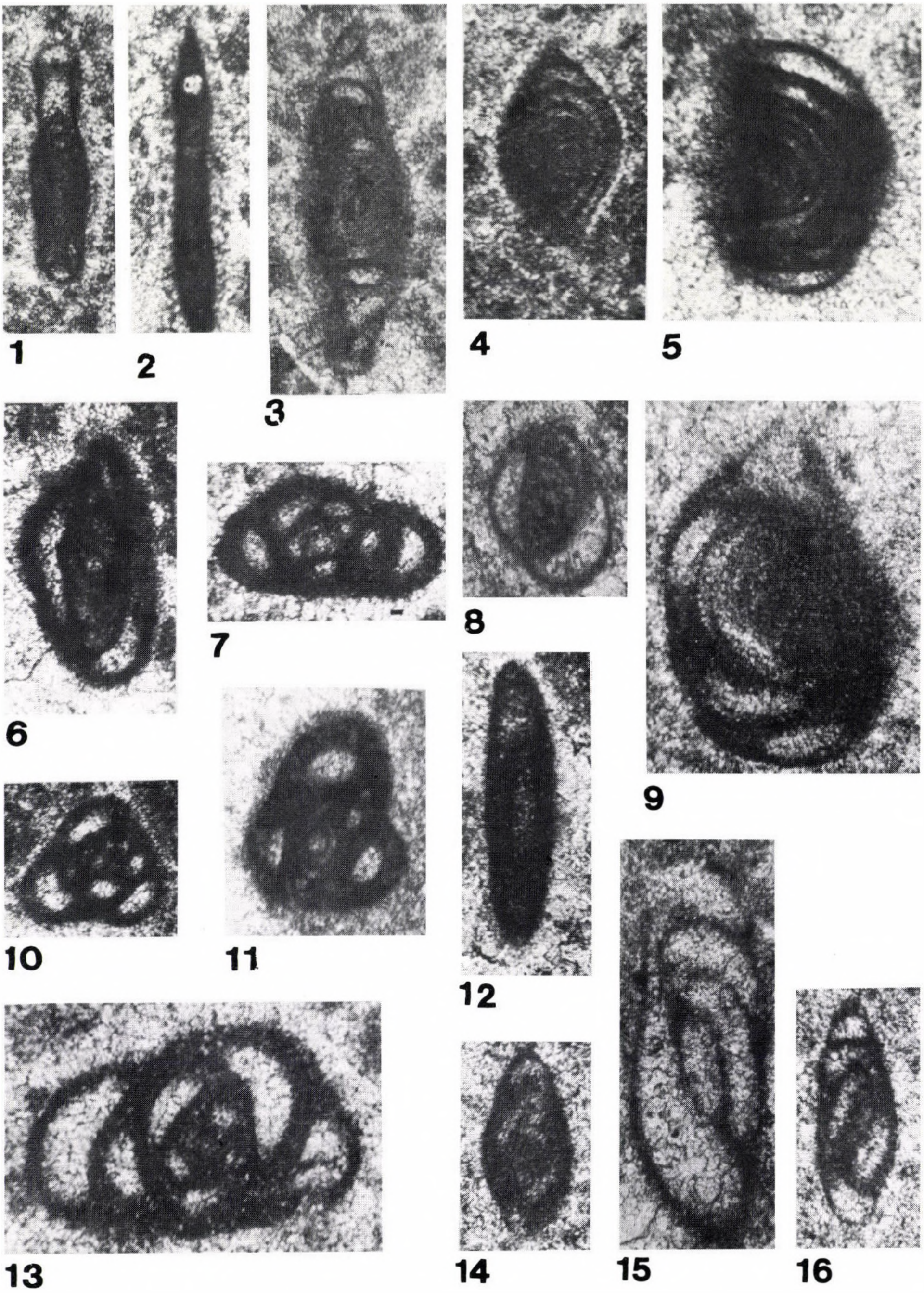

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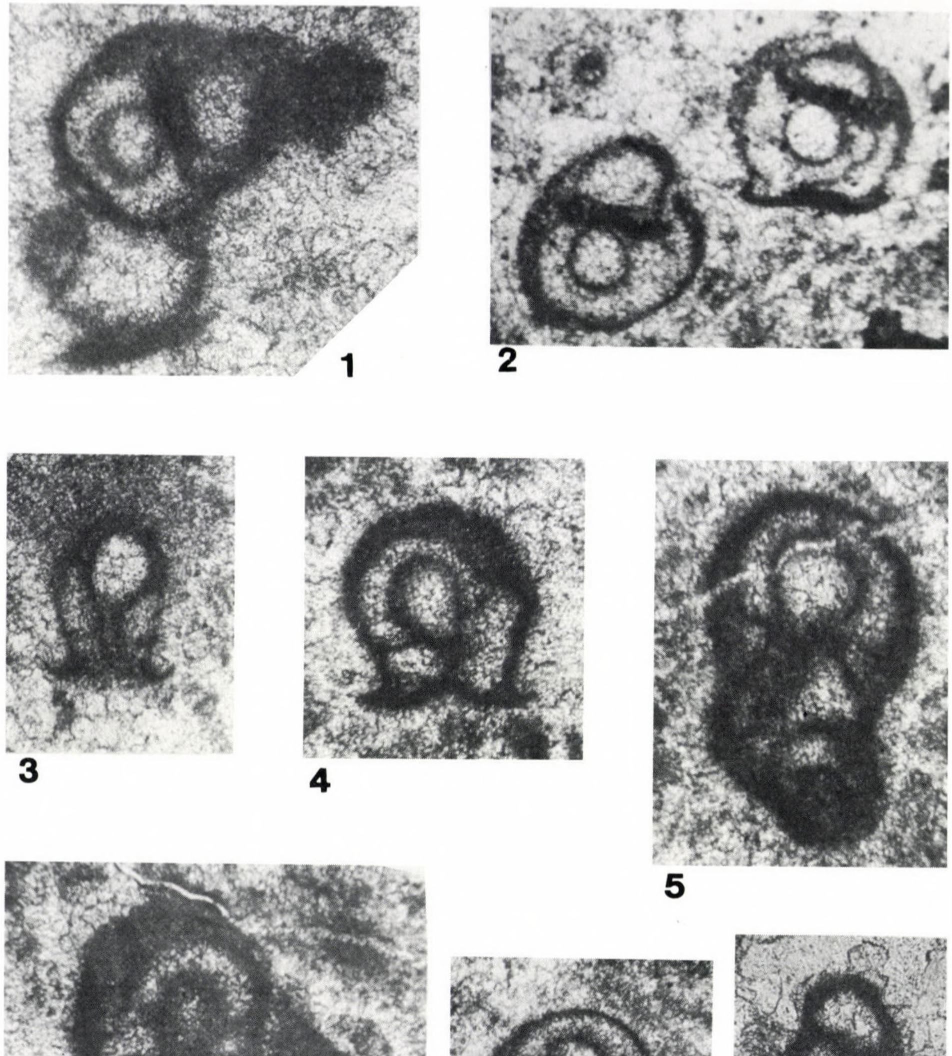

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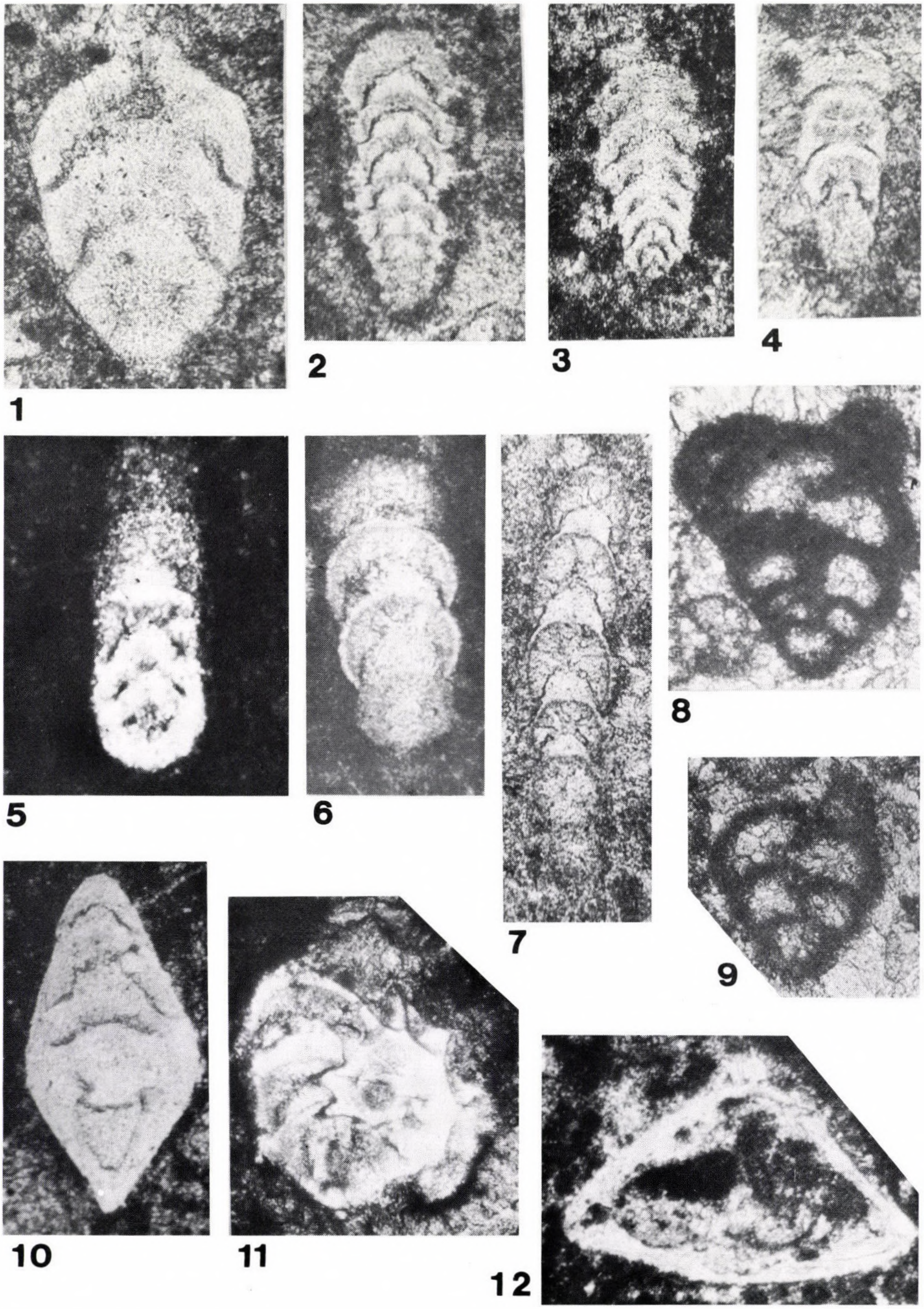

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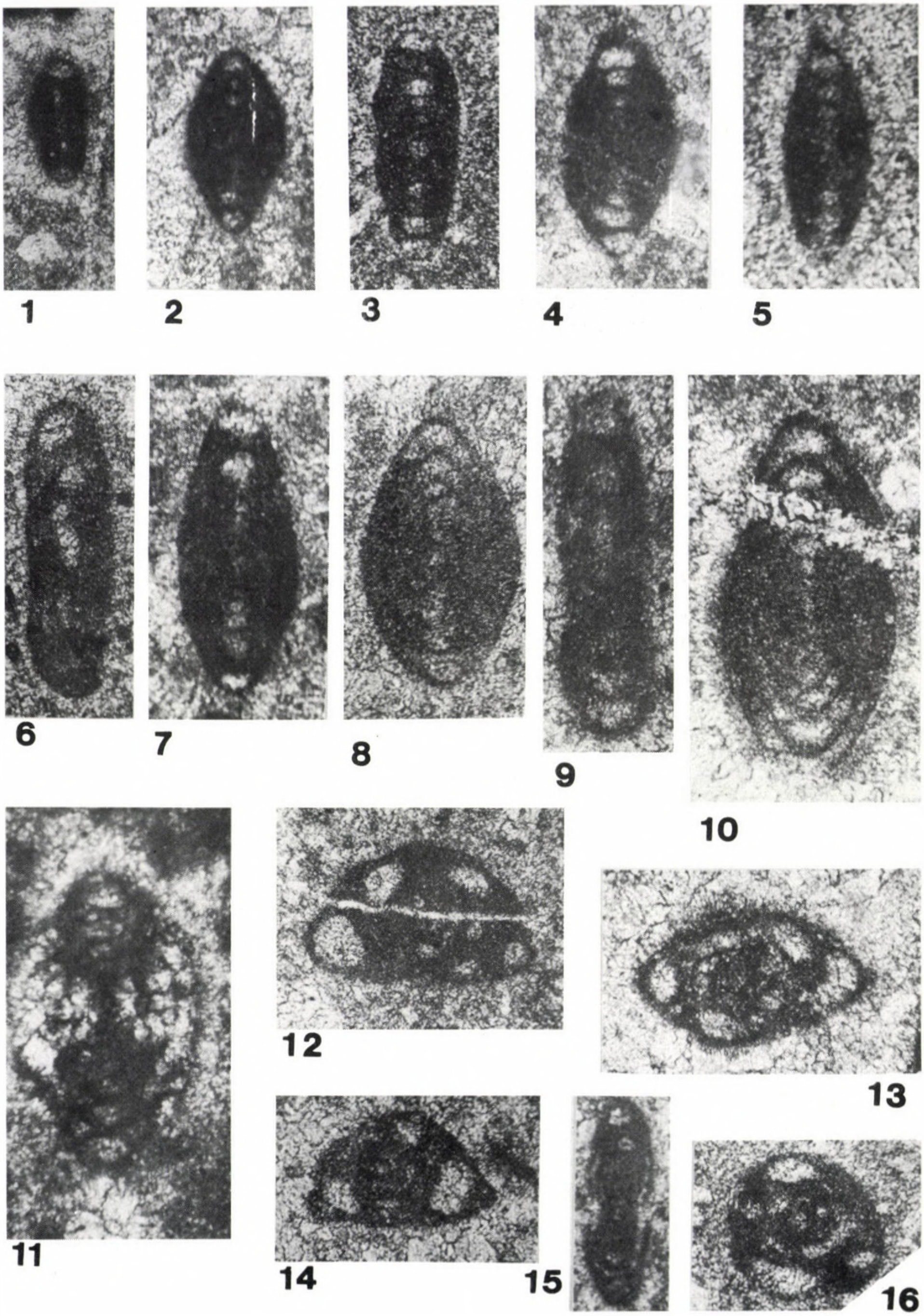

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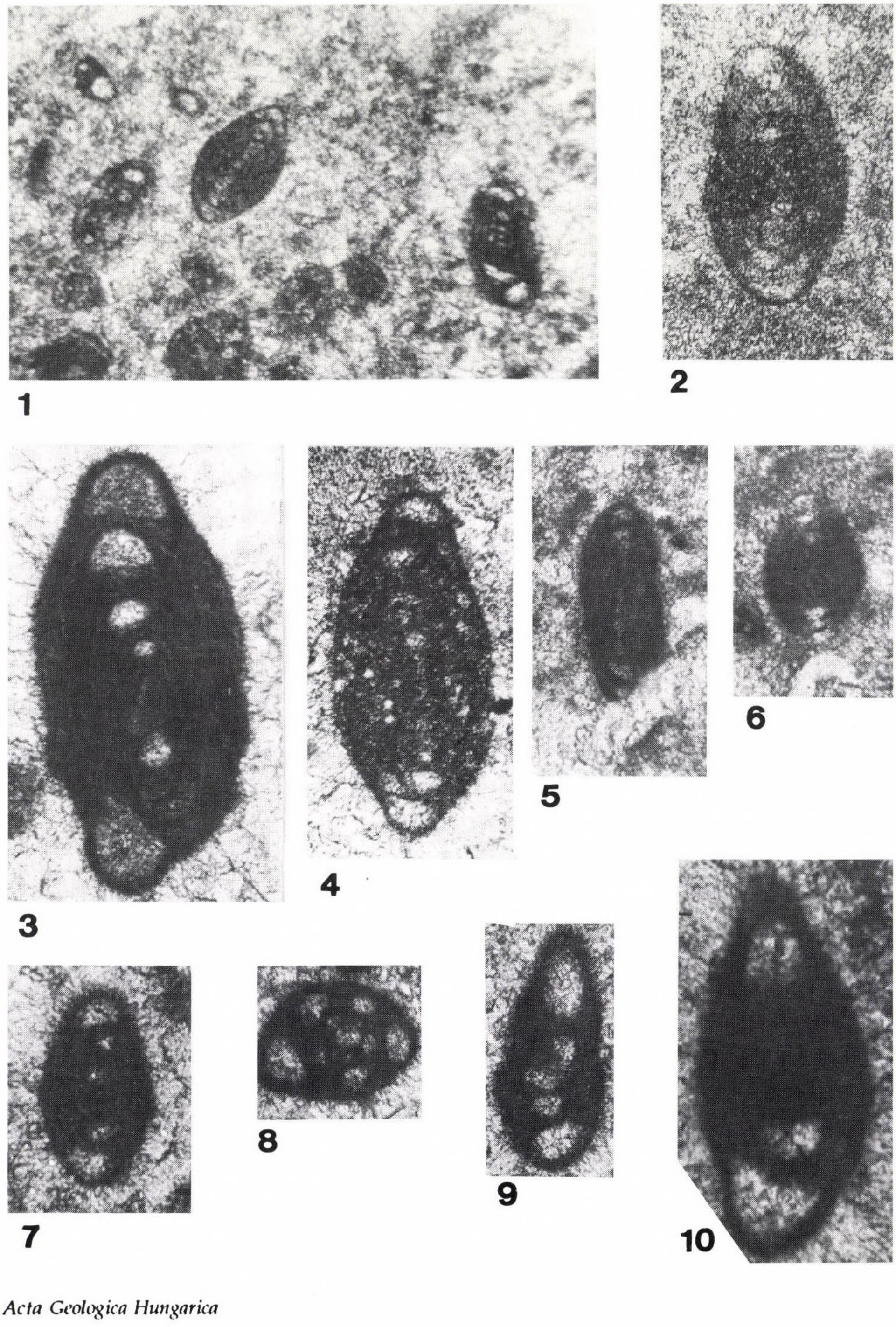

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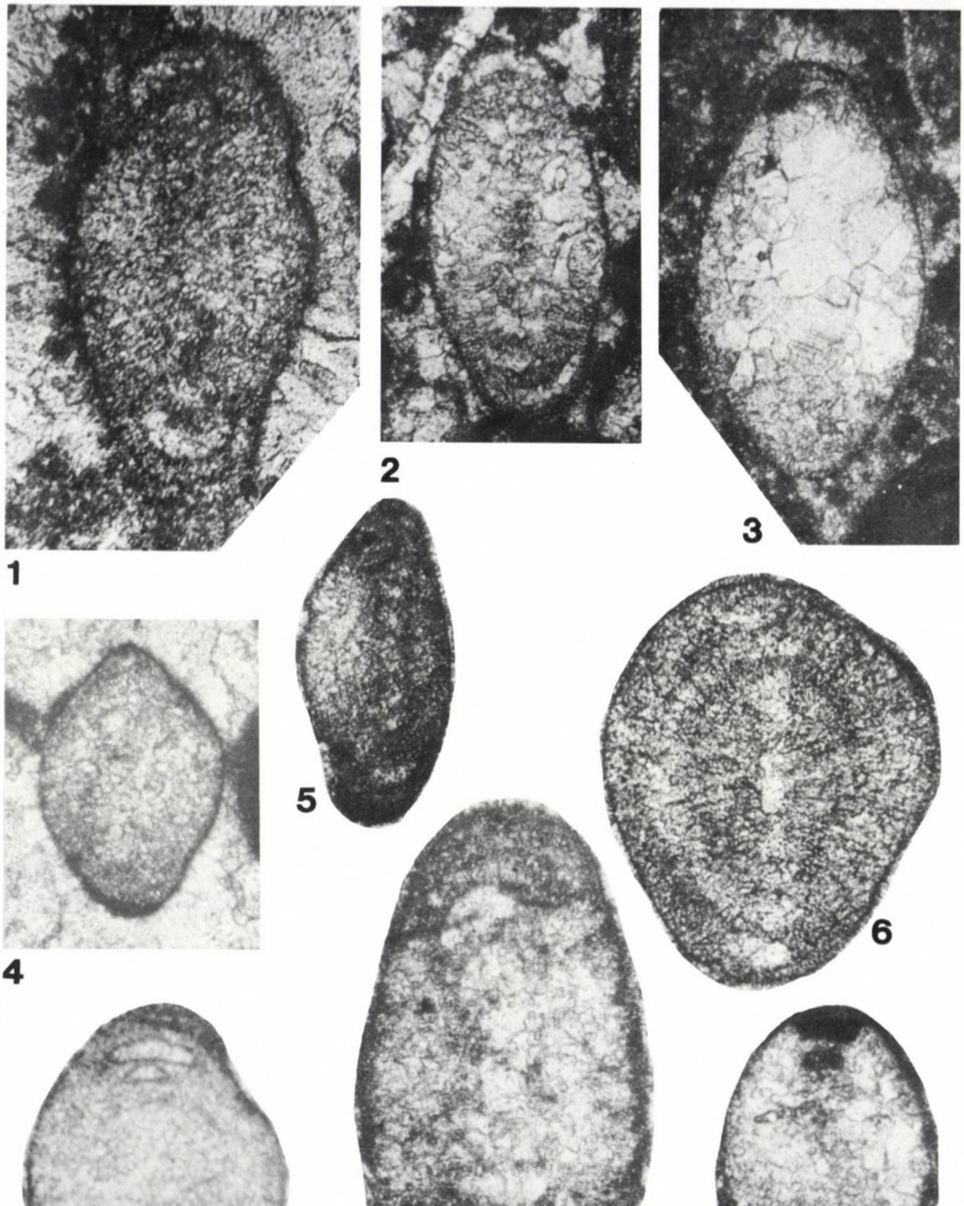

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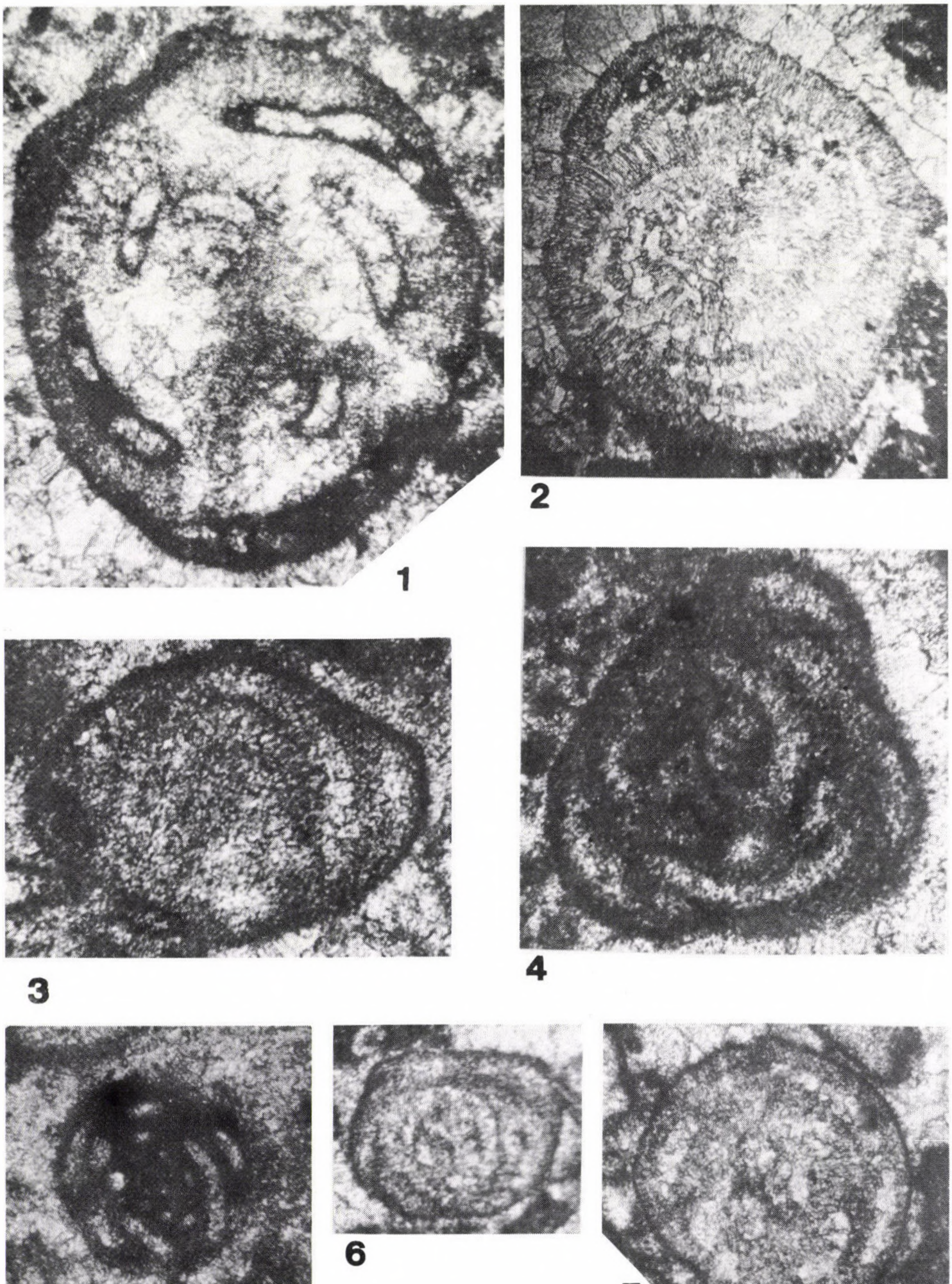

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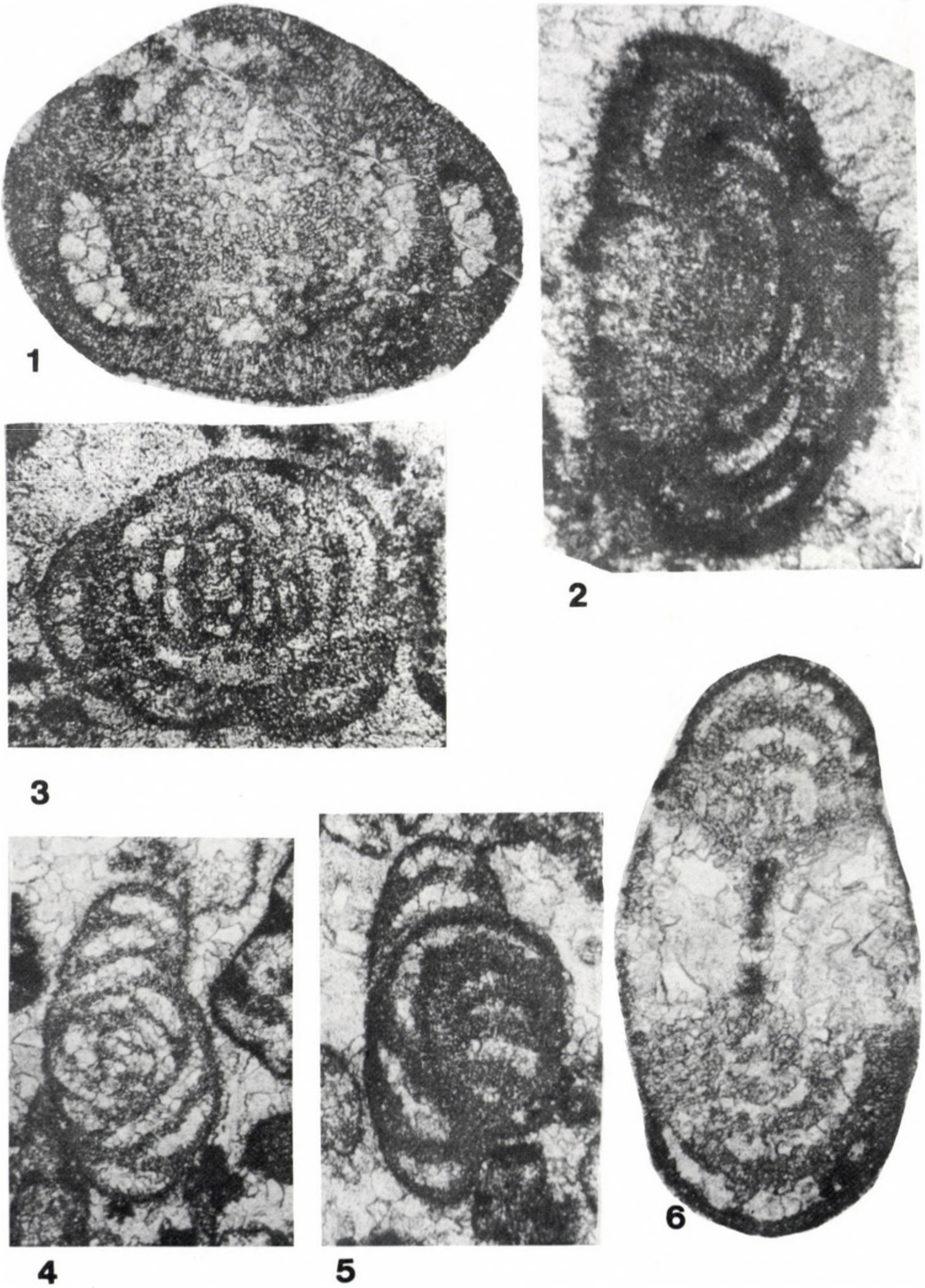

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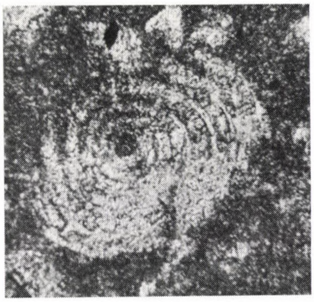

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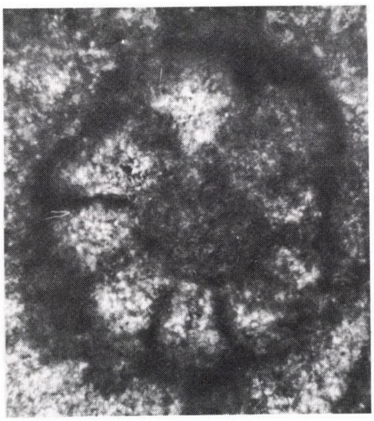

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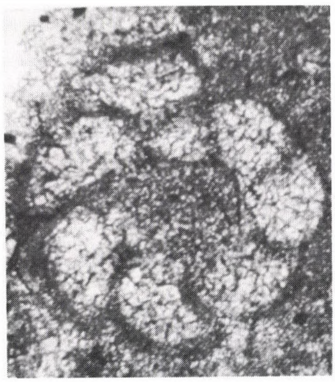

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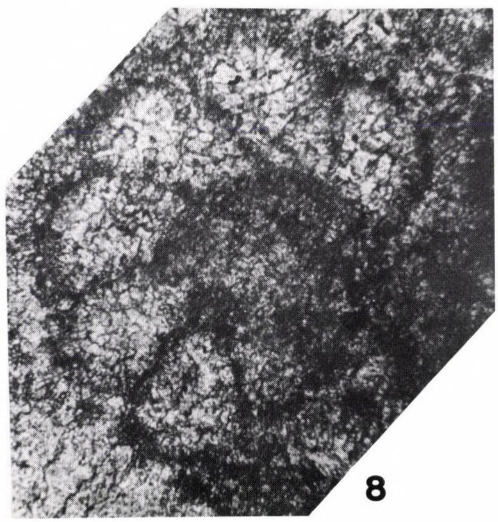

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Plate XV

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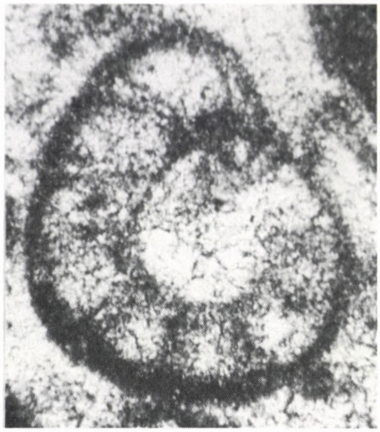

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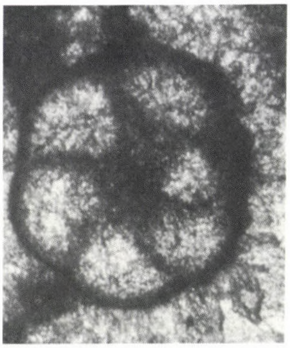

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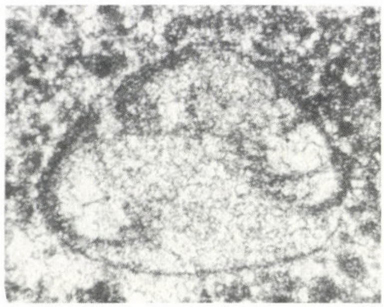

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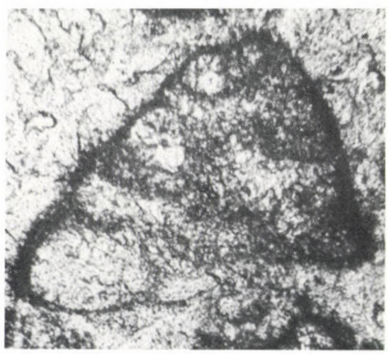

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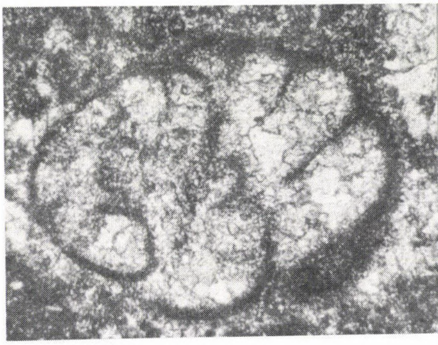

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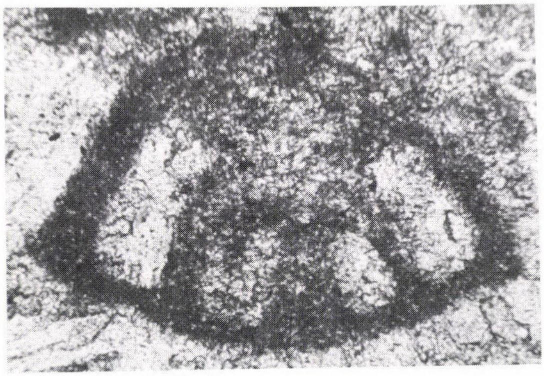

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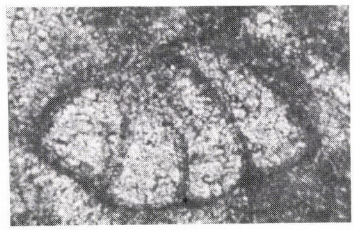

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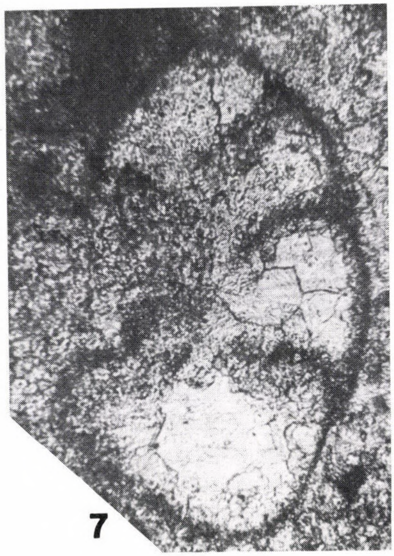

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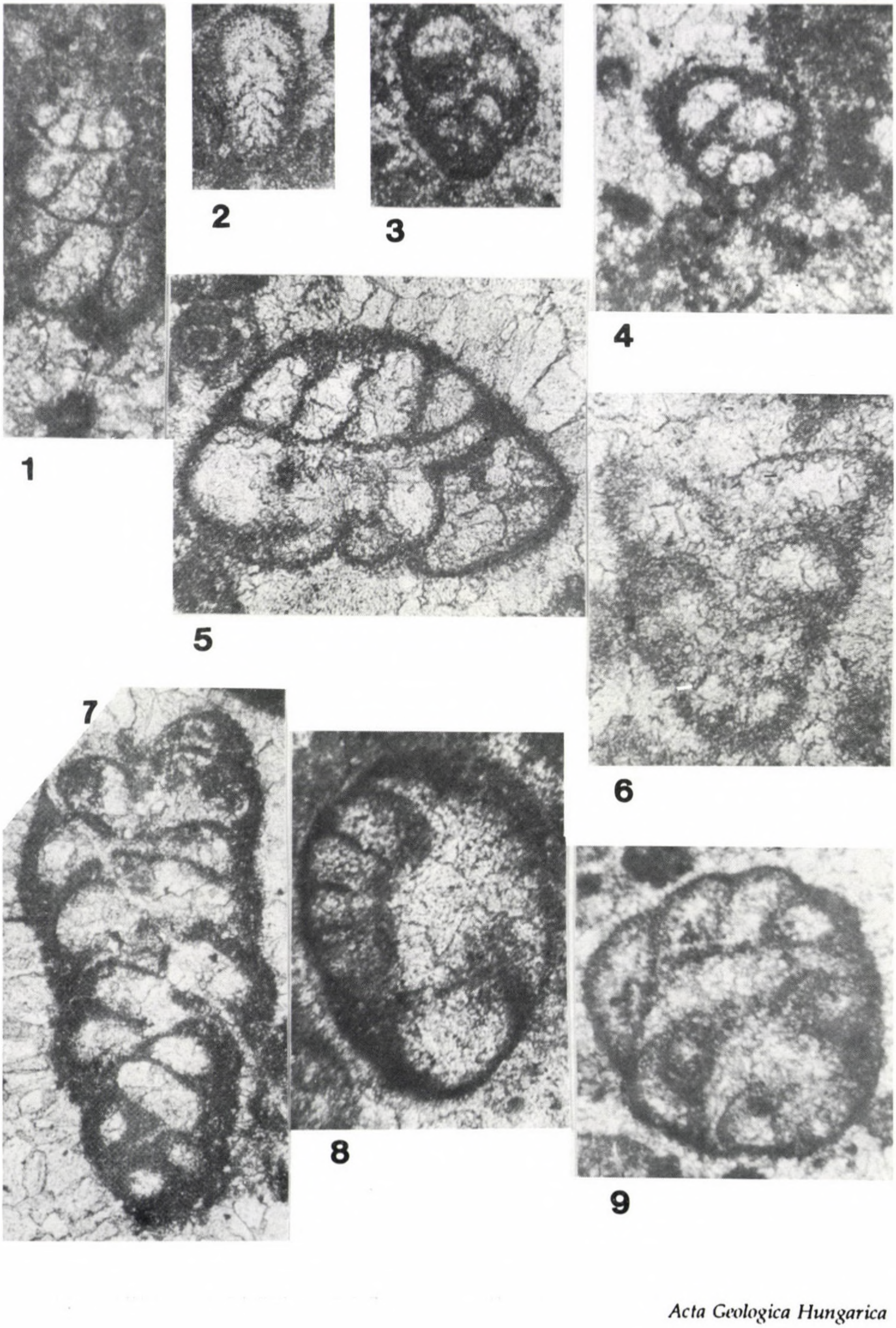

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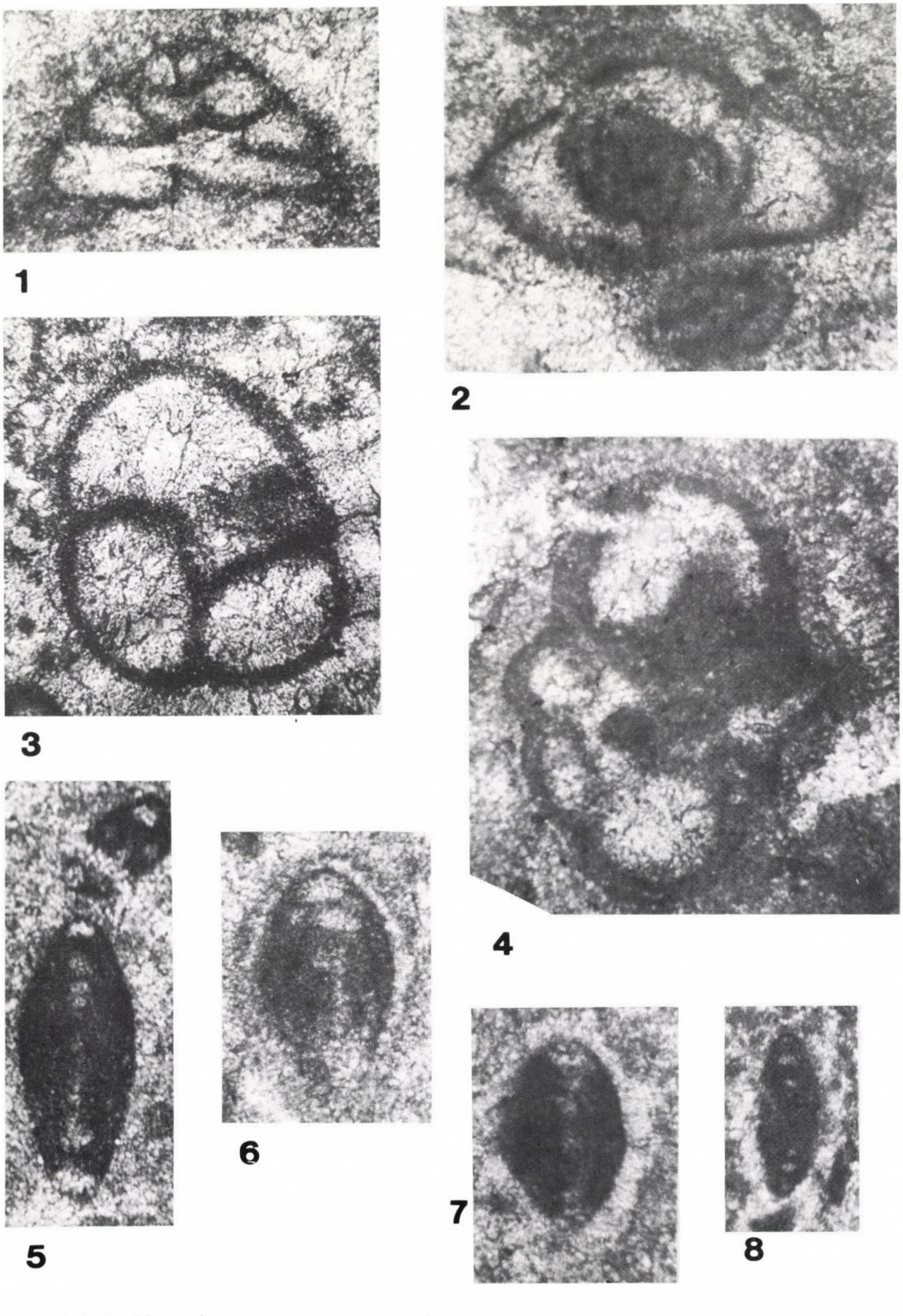

Plate XIX

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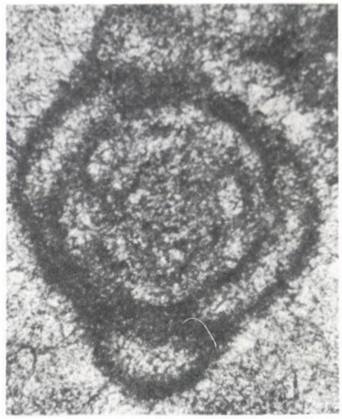

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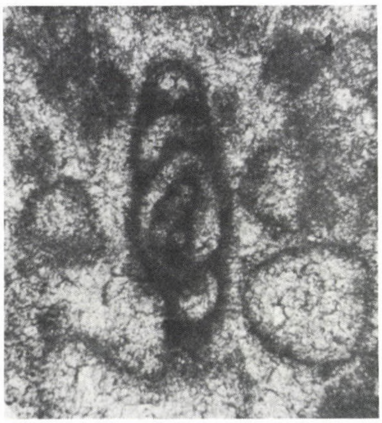

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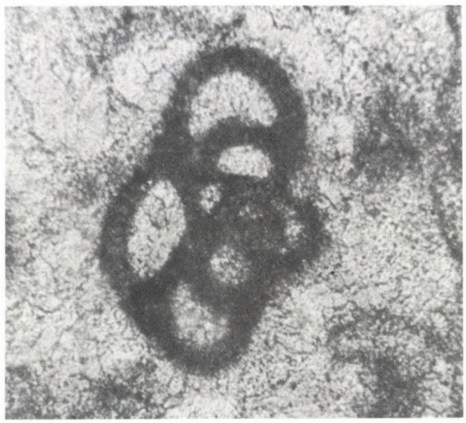

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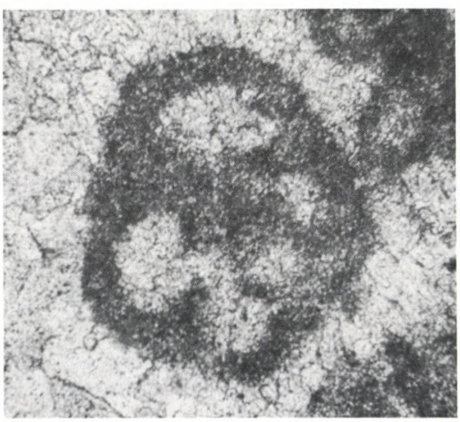

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Plate XX

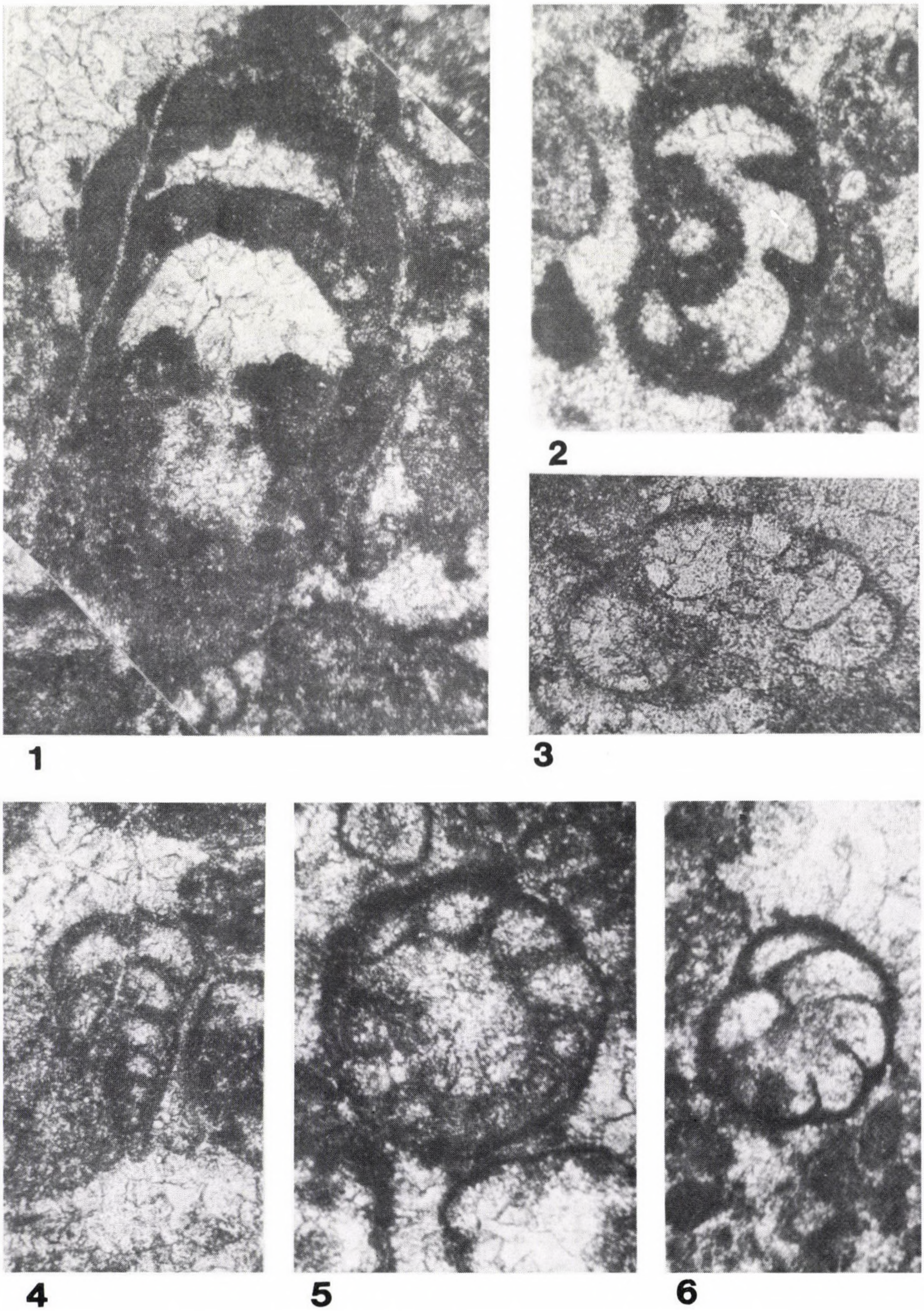

Plate XXI

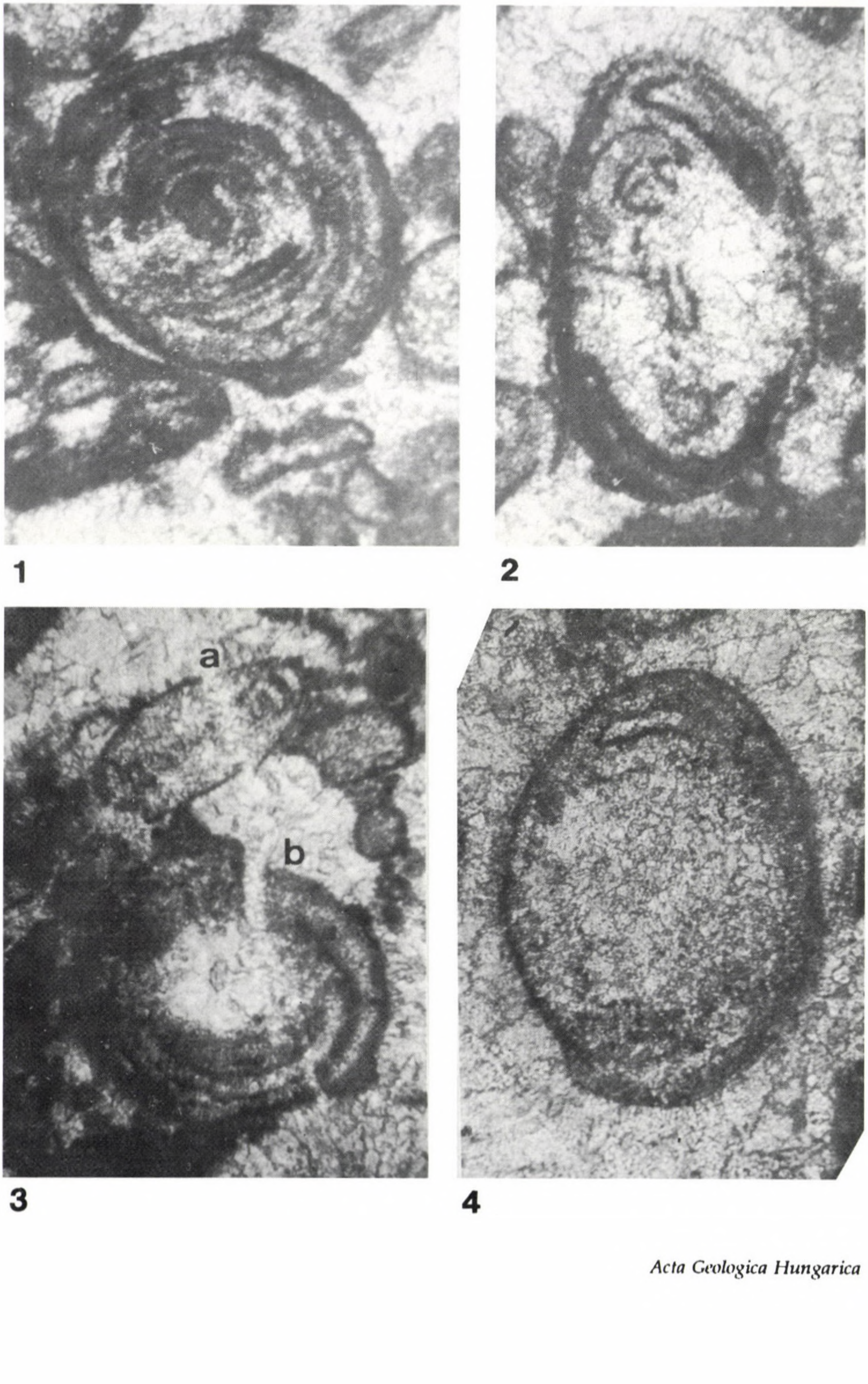

Plate XXII

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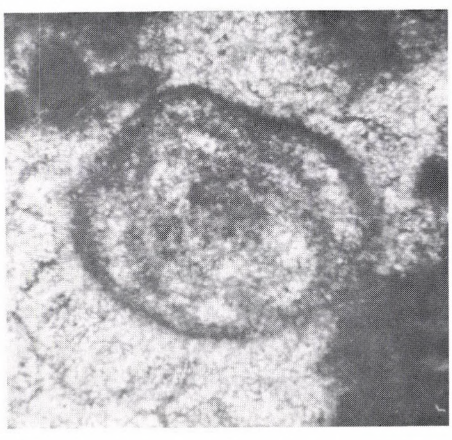

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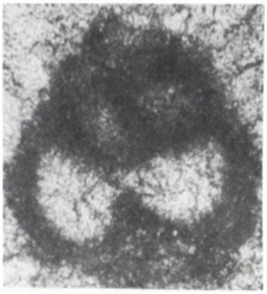
Plate XXIII



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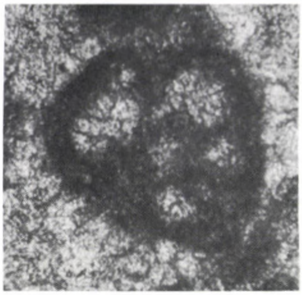

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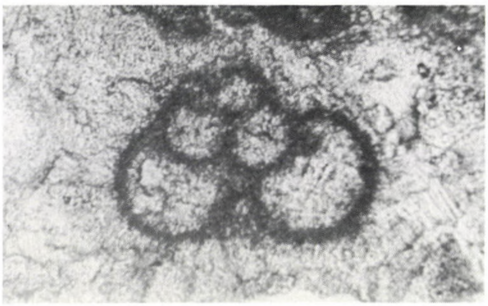

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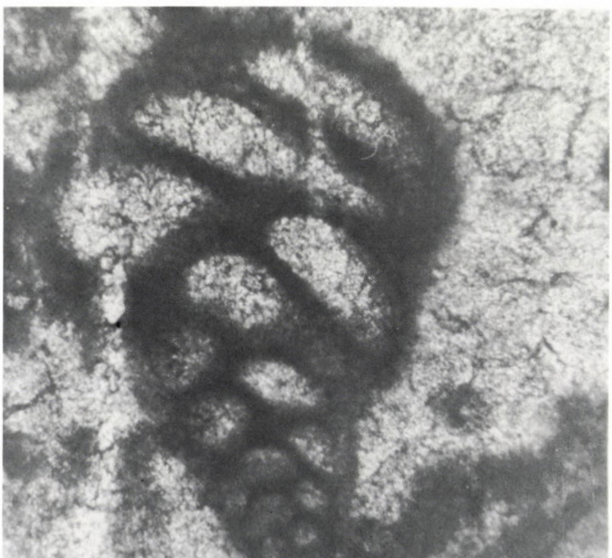

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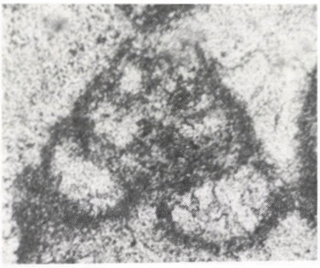
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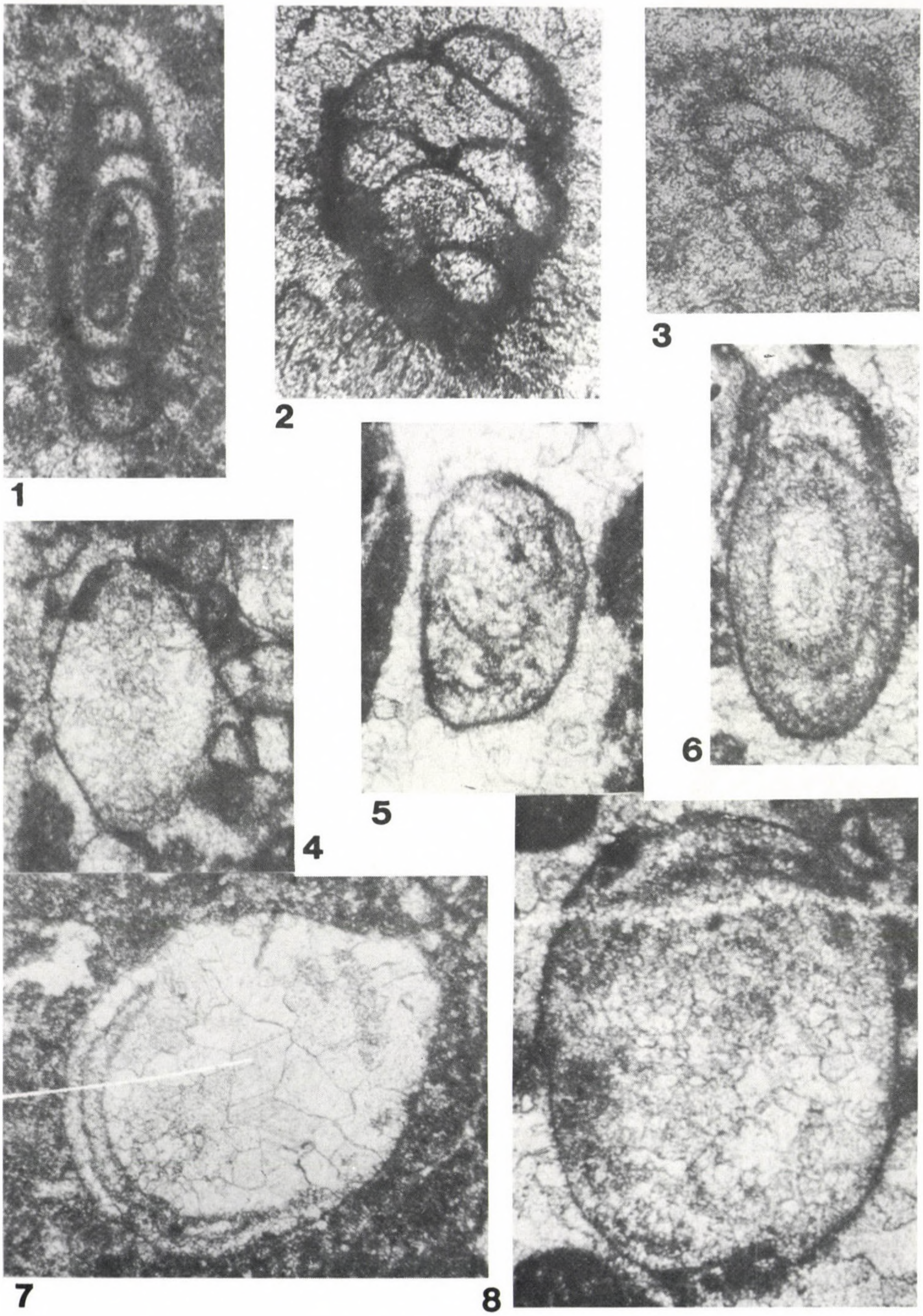
Plate XXV



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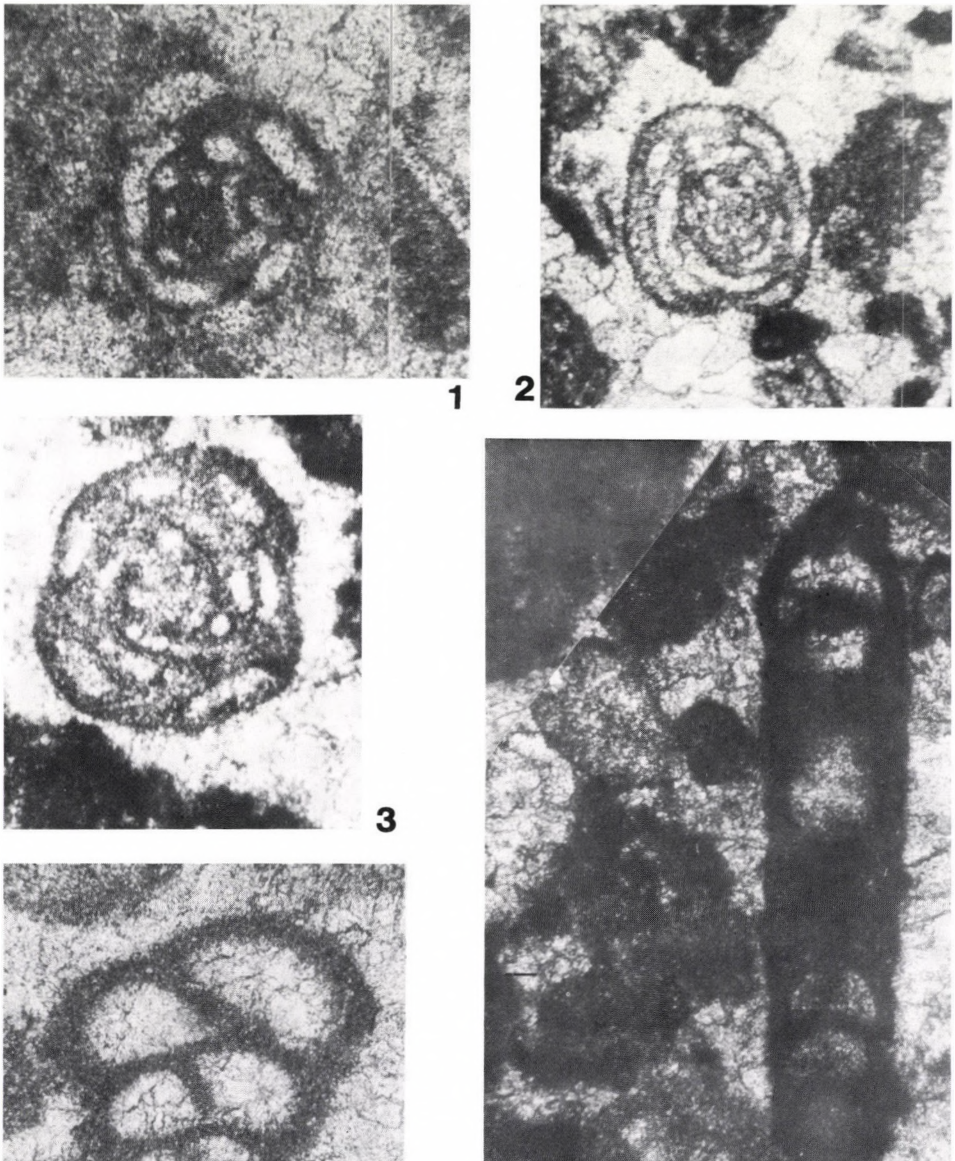

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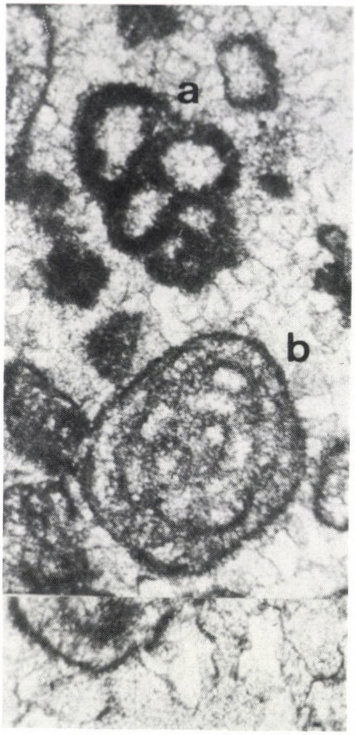
Plate XXVII



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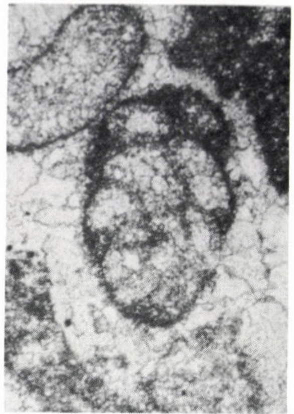

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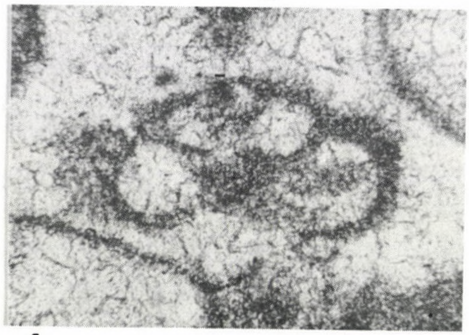

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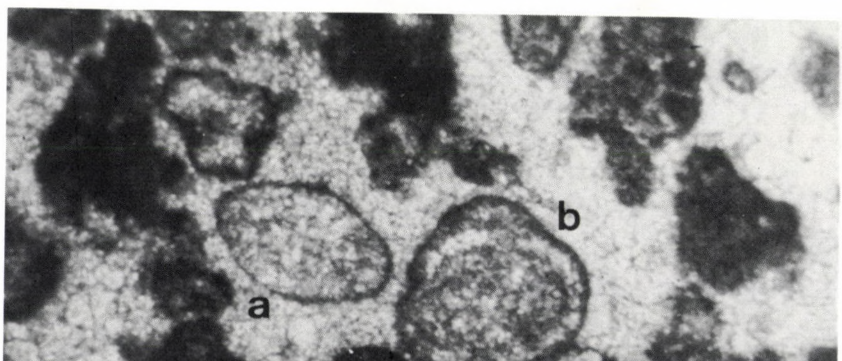

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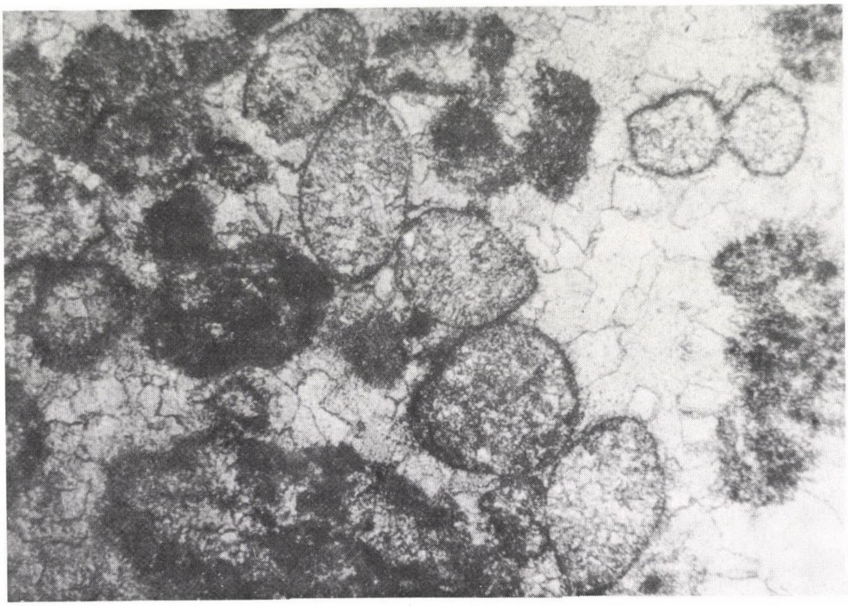
Plate XXVIII



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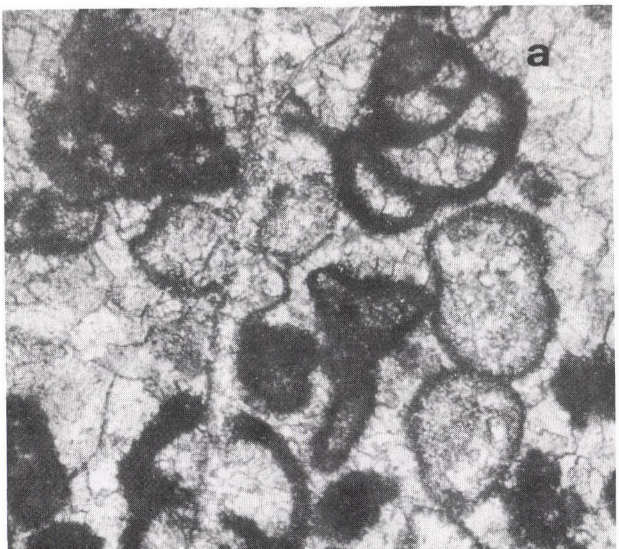

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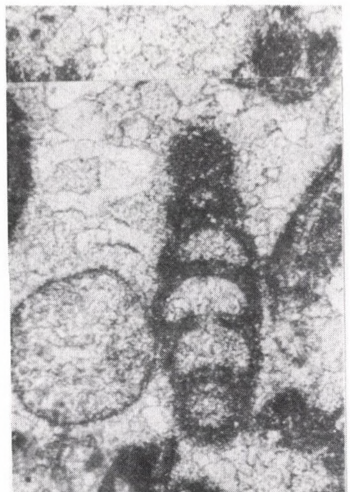

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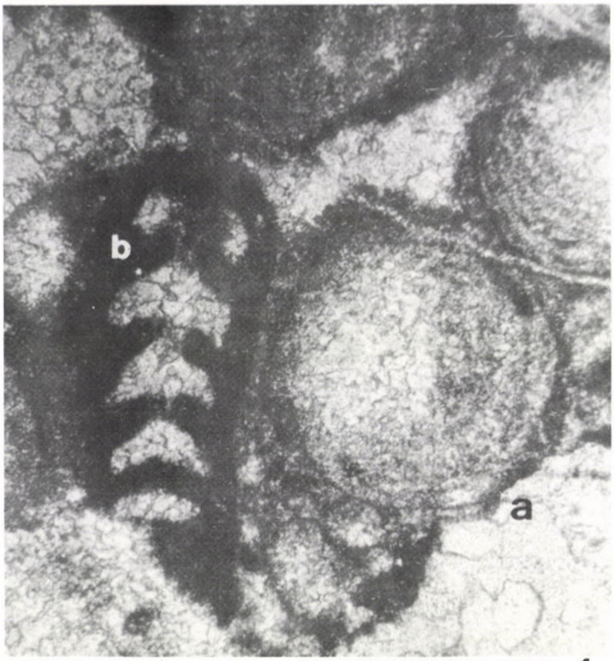
Plate XXIX



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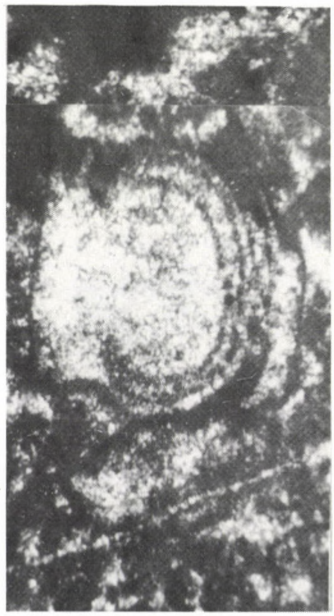

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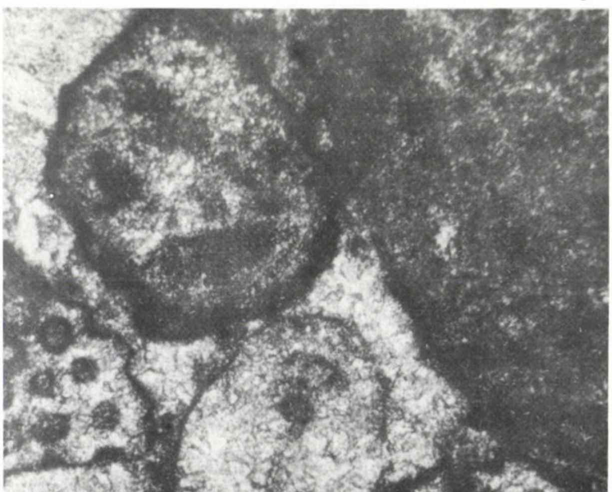

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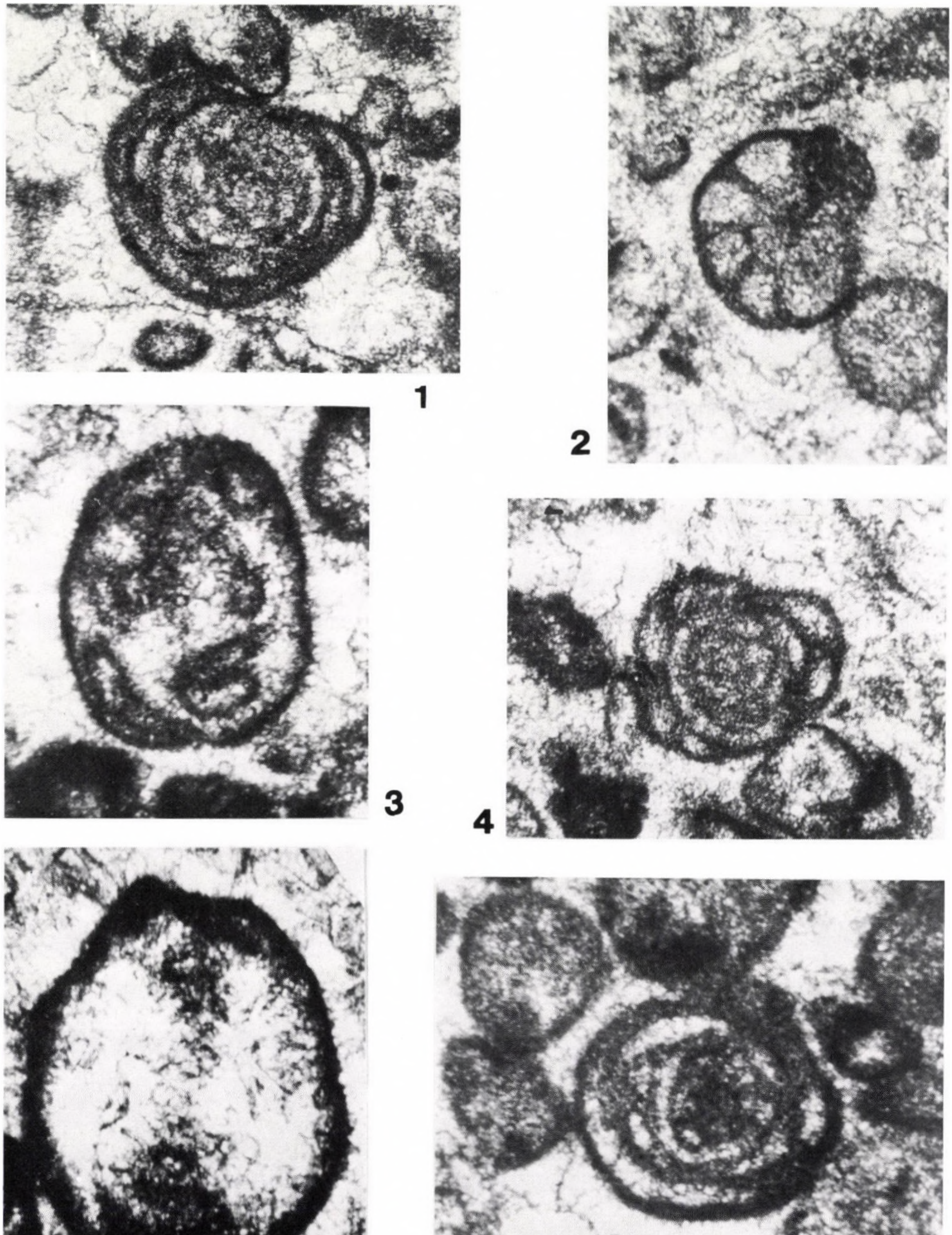

Plate XXXI

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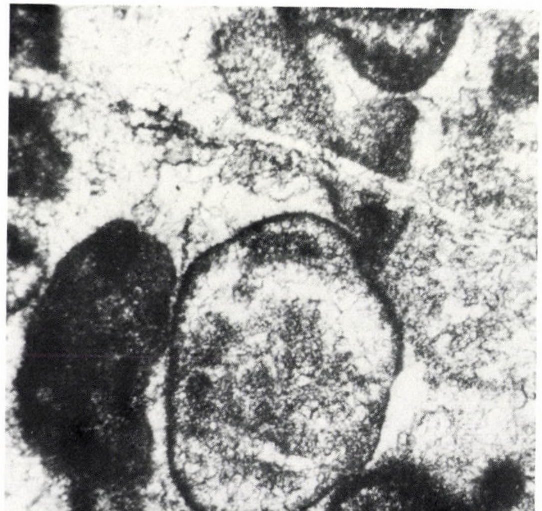

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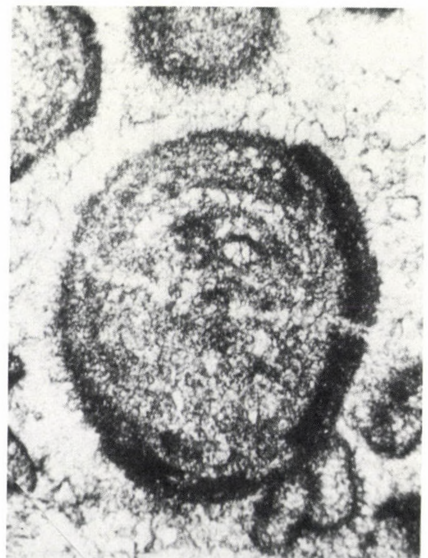

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Plate XXXII

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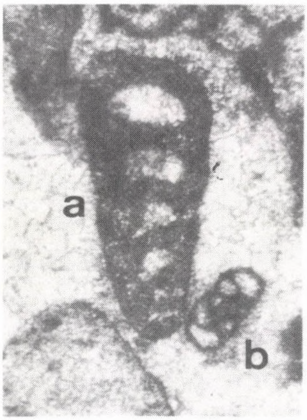

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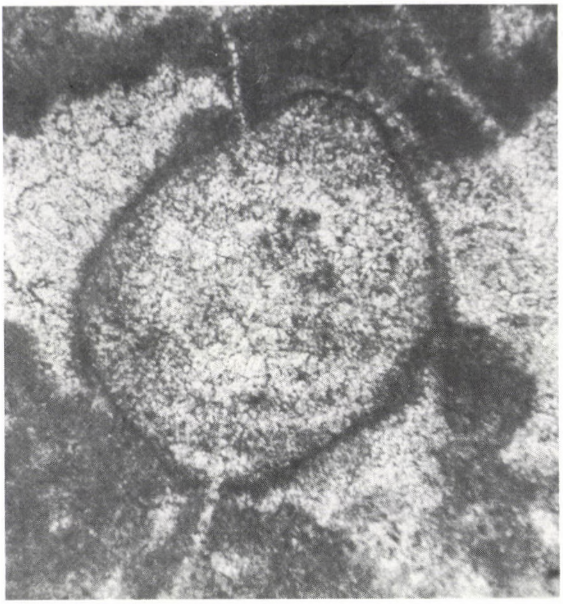
Plate XXXIII



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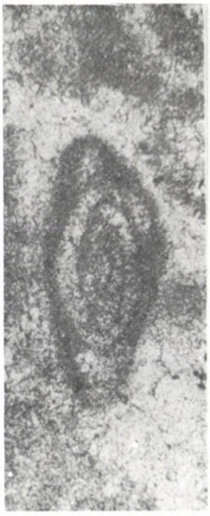

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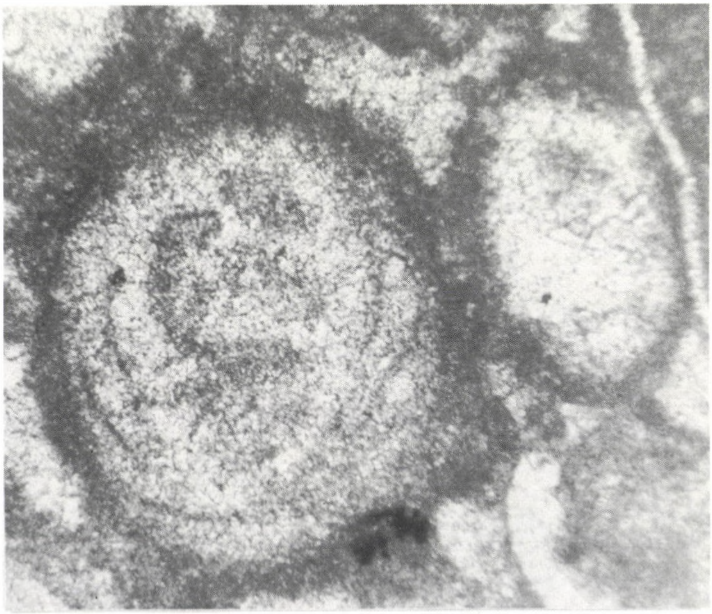

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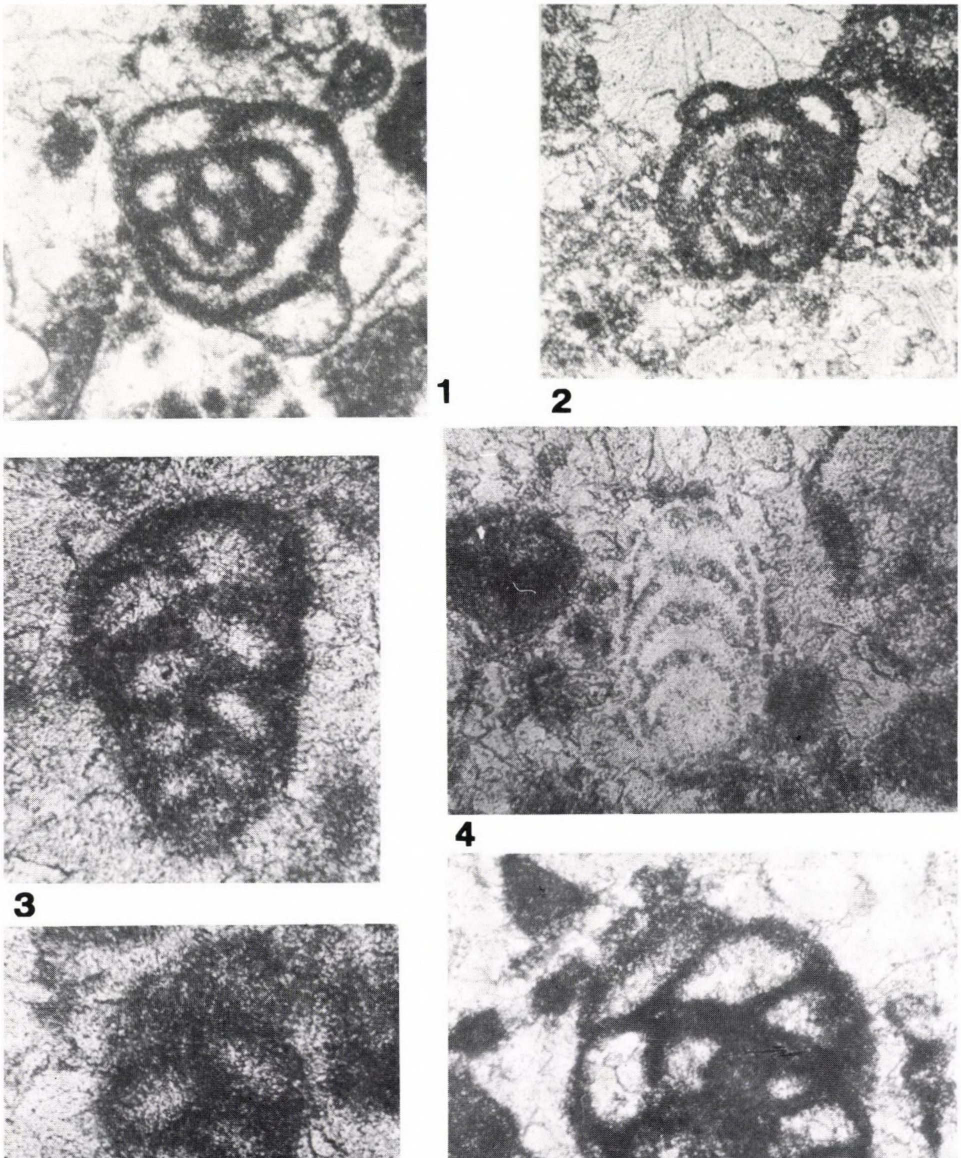
Plate XXXIV



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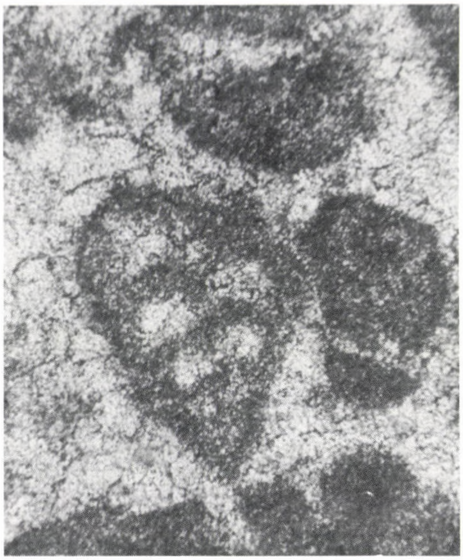

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Plate XXXVI

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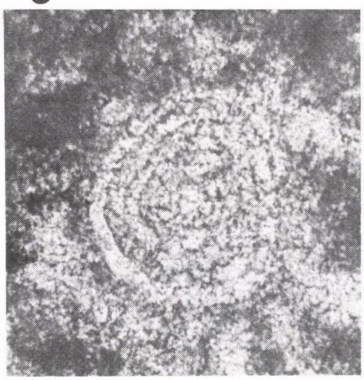

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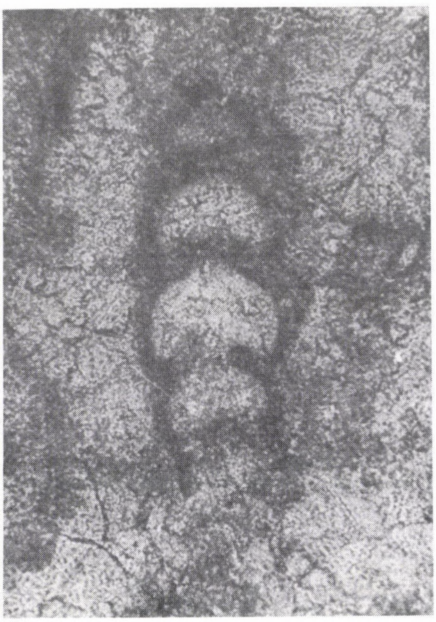

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Plate XXXVII

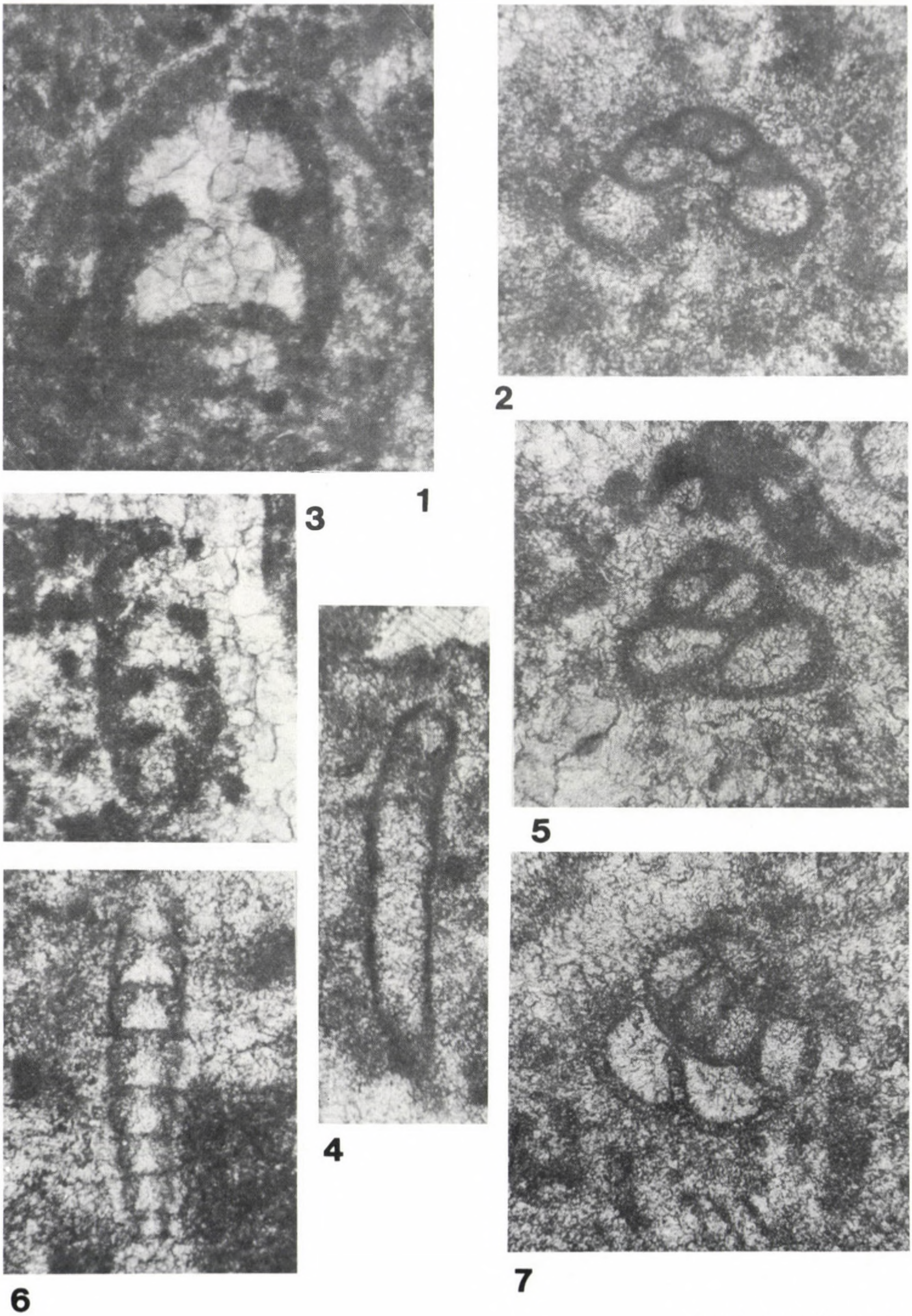


Plate XXXVIII

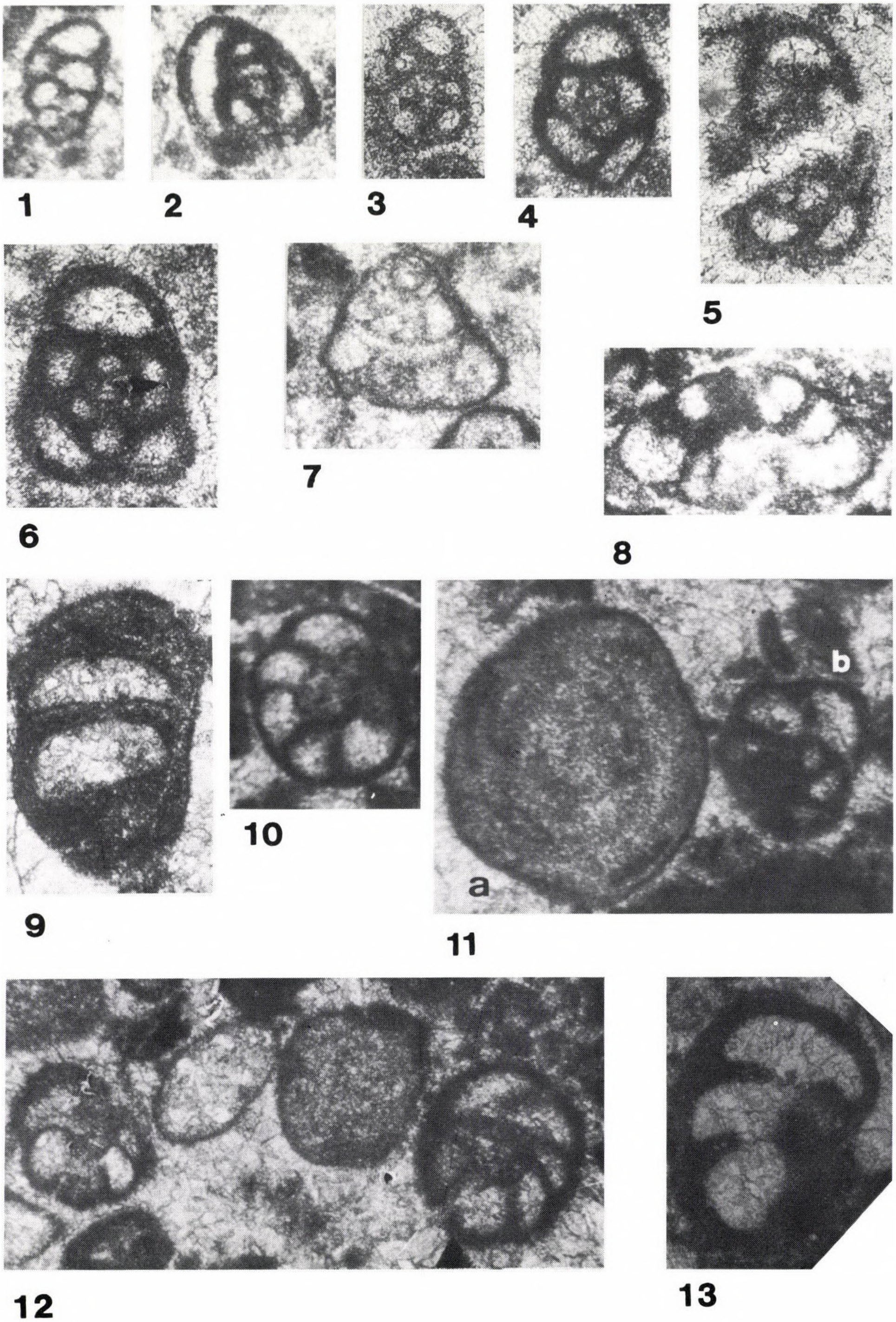


Plate XXXIX

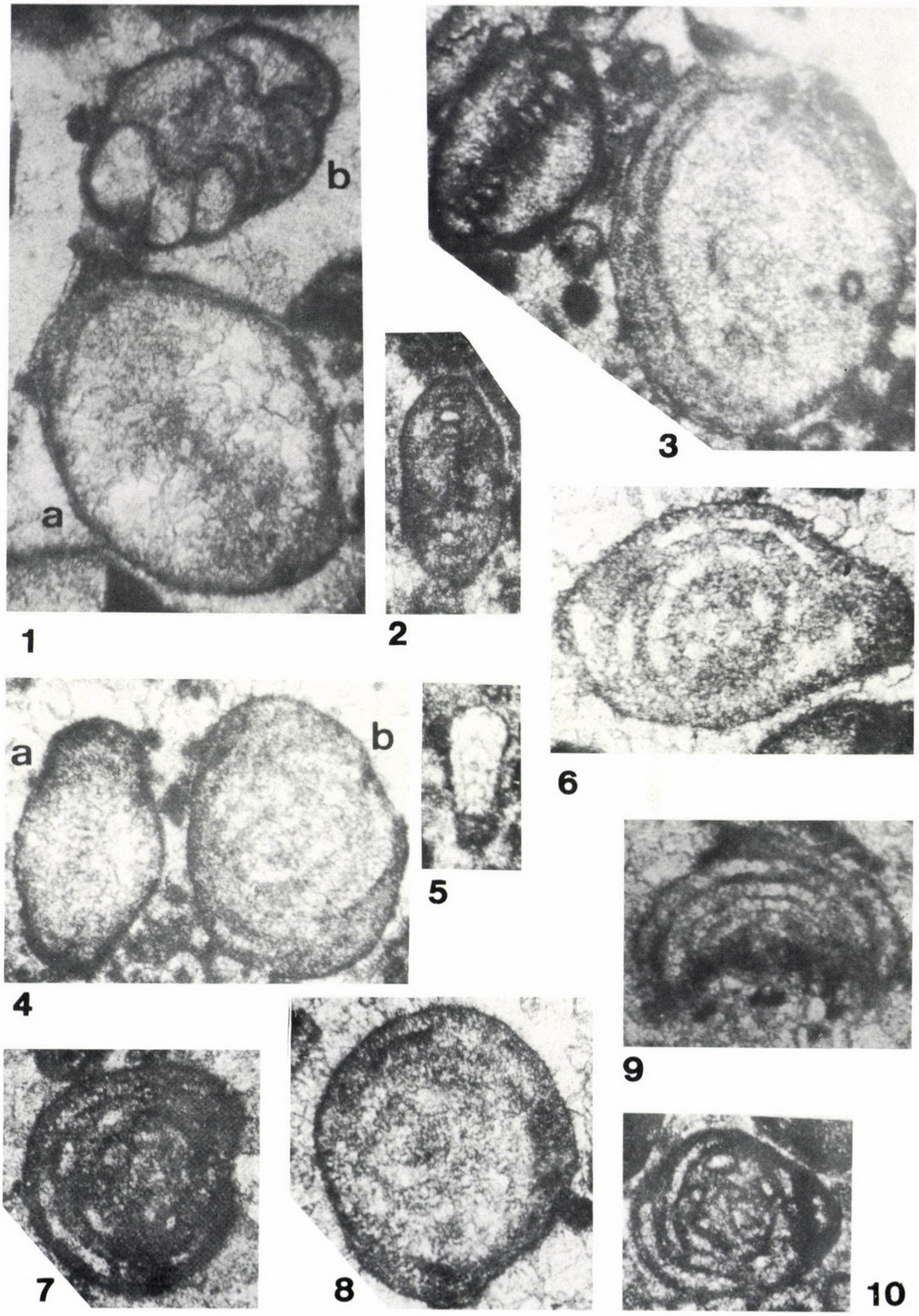
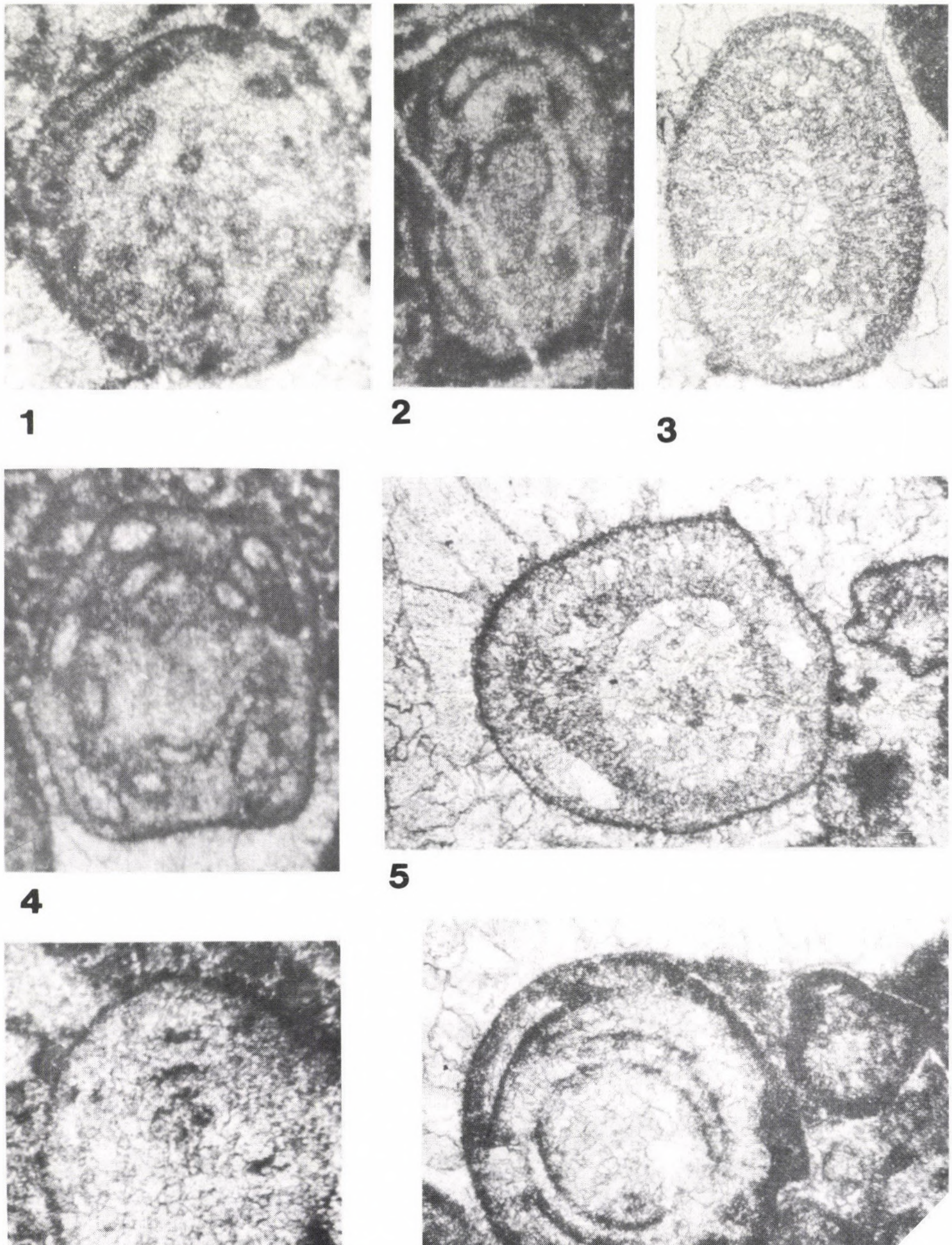


Plate XL



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Ostracods and charophytes from the Triassic Kantavár Formation, Mecsek Mts, Hungary

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The lower part of the Kantavár Formation, defined on the basis of macrofossils as of Upper Ladinian-Lower Carnian age, contains large numbers of ostracods and, in some beds, many charophytes. The charophytes belong to the genus *Altochara*, confirming the Upper Ladinian age of these beds. One to two million *Darwinulas* per kg of rock were found, certifying the freshwater origin of this limestone and marl. The entire ostracod material consists of two species: *D. liassica* Jones, 1894 (sensu lato) and *D. globosa* (Jones 1862).

Key words: Triassic, Ostracoda, Charophyta, paleoecology

Introduction

The rich occurrence of ostracods in the Kantavár Limestone of the Mecsek Mts has been known since the publication of the works of Stur (1874) and Böckh (1876). These ostracods were originally described as *Bairdia*.

The new sampling and the preparation of the material were financially supported by OTKA project N T 2671 (J. Haas).

Geology and sampling

The lower part of this formation in the Kantavár limestone quarry consists of dark-grey to black limestone and marl (Fig. 1); the underlying and overlying beds are not accessible in the quarry. Between the thick beds of limestone thin laminated marl layers are intercalated.

Eleven samples were collected from the limestone and marl beds. Further samples were chosen on the basis of the perceptibly high mass of ostracods or macrofauna. The preparation of the material was carried out using concentrated acetic acid. All beds contain ostracods; in the laminated marls up to 1–2 million per kg of rock, in the limestone beds only about a few thousand.

In the laminated marl the microfossils are usually collapsed due to the high compaction of the rock. The surfaces of the laminae are densely covered by ostracods. In spite of the millions of specimens it is sometimes difficult to pick a complete and determinable carapace. In the limestones the specimens are even more damaged.

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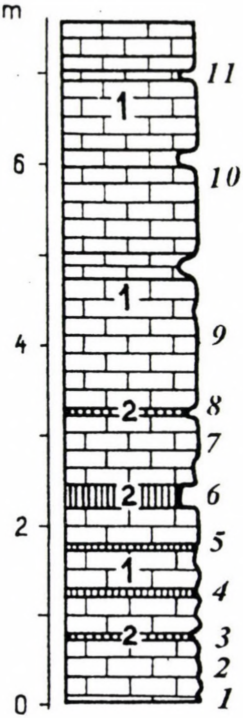

Fig. 1
Samples of the Kantavár section. Lithological section after Nagy (1968). 1. argillaceous limestone; 2. marl. The samples are numbered on the right side of the section.

The complete lithological data concerning the section are to be found in the paper of Nagy (1968, pp. 64–65.).

In the upper part of the quarry section (samples 9–11), charophyte oogonia are frequent, with a preservation similar to that of the ostracods. There is a list of macrofauna determined from the section in the paper of Nagy (1968, pp. 83–84, as fossils in the lower member). The preservation of the mollusks is very poor and it is necessary to carry out a careful revision of the material to obtain correct ecological data.

Charophyta

Three samples (9–11) in the upper part of section with charophyte oogonia were encountered, and only few ostracods as compared to other samples. The specimen number is up to several thousands per kg of rock. The specimens are usually broken or compressed, and the surface damaged or rounded off.

The majority of the gyrogonites belong to a form with broadly oval or globular shape, with slightly convex spiraling cells running nearly at right angles to the axis and with more or less obtuse apical and basal ends bearing stellate and pentagonal opening. 8–9 spirals are visible in lateral view.

These characters belong to the genus Altochara Sajdakovsky 1968 and indicate a new species. All the described species of Altochara are from the Lower and Middle Triassic of Russia and are mentioned by the same author from the Lower Triassic of Germany and Bulgaria.

A new sampling will be necessary to obtain material suitable for correct species determination and description of the charophytes.

The dominance of Altochara appears to be a confirmation of the Ladinian age of the lower part of Kantavár formation (Nagy 1968; Rálisch-Felgenhauer and Török 1993).

Ostracoda

Remarks: In the early geological works the innumerable ostracods are listed as *Bairdia* sp. (Stur 1874), Ostracoda indet. (Böckh 1876), *Bairdia pirus* Seeb. (Vadász 1935), and there has been no revision in the later ones. *Darwinula* is the only genus confirmed in the new material.

Genus Darwinula Brady et Robertson, 1885

Darwinula liassica Jones, 1894 s. l.

Pl. 1. Figs 1–6

1894.	*Darwinula liassica* (Brodie)	– Jones, pp. 162–163, Pl. 9, figs 1a, C
1894	*Darwinula liassica* var. *major* n. sp.	– Jones, p. 163, Pl. 9, f. 2
1956.	*Darwinula fragilis* Schneider, 1948	– Lubimova, pp. 538–539, Pl. I. f. 8
1963.	*Darwinula liassica* (Brodie, 1843)	– Beutler et Gründel, pp. 67–68, Pl. VI, figs 9–11, Pl. VII, figs 1–3, Pl. IX, figs 7–10
1964.	*Darwinula liassica* Jones	– Anderson, pp. 136–137, Pl. 13, figs 81–82
1964.	*Darwinula major* Jones, 1894	– Anderson, p. 137, Pl. XV, figs 115–117
1966.	*Darwinula liassica* Jones, 1894	– Urlichs, pp. 15–16, Pl. 2, figs 2, 4, 6, figs 5c, 4
1966.	*Darwinula major* Jones, 1894	– Urlichs, pp. 14–15, Pl. 2, figs 3, 5; Textfig. 5d
1969.	*Darwinula liassica* (Brodie, 1843)	– Will, pp. 54–55
1978.	*Darwinula major* Jones, 1894	– Bate, p. 180, Pl. 1, figs 5, 7, 13
1979.	*Darwinula* cf. *major* Jones, 1894	– Uroševic, Pl. figs 1–10
1979.	*Darwinula liassica* (Brodie, 1843)	– Styk, p. 113, Pl. XXV, fig. 1.
1982.	*Darwinula liassica* (Brodie, 1843)	– Styk, pp. 42–43, Pl. XIV, figs 6, 7

Remarks: In the German and Polish material there are intermediate forms (in terms of dimensions) between *liassica* and *major* in Anderson (1964). Being of similar shape there is no reason to separate these forms.

The species is very variable, as mentioned by Bate (1978) in referring to "*major*", not only in time (from Anisian to Rhaetian in his material) but also within the same sample. In the Kantavár material the elongate form, which becomes only moderately narrow anteriorly, is less frequent than the form with narrow anterior and large posterior ends. The dorsal outline of the latter is somewhat more arcuate as that of the type-form.

The overlap problem is interesting. According to Anderson (1964) the left valve is the larger one in "*major*", and the "*liassica*" has an opposite overlap.

In Bate's material ("*major*" - 1978) the specimens in figs 7 and 13 appear to show opposite types of overlap. Other forms described as "*liassica*" or "*major*" have a larger left valve. It is possible that the overlap is variable in this species. In the Kantavár material the left valve is larger.

The Lower Triassic (?) form from Ukraine, Russia and Kazakhstan described as *D. fragilis* Schneider (1948) in Ljubimova (1956) possibly belongs to this species.

The form illustrated by Uroševic (1979) from the Rhaetian of Yugoslavia is very close to my material, and Uroševic and Kristič believe it to be a new species (Uroševic 1979). Considering the continuous presentation of the transitional forms in the same sample I have decided to leave the Kantavár form within *D. liassica* "sensu lato".

Dimensions: L = 1.00–1.10 mm, H = 0.49–0.58 mm, L/H = 1.90–2.04.

Material: several thousand specimens.

Darwinula globosa (Jones, 1862)

Pl. 1, figs 7–8

1862. *Candona? globosa* (Duff)	– Jones, pp. 126–127, Pl. 5, figs 23–24
1894. *Darwinula globosa* (Duff)	– Jones, pp. 163–164, Pl. 9, figs 3, 4
1964. *Darwinula globosa* (Jones, 1862)	– Anderson, pp. 135–136, Pl. XV, fig. 128
1969. *Darwinula globosa* (Duff, 1842)	– Will, pp. 55–56
1979. *Darwinula globosa* (Duff, 1842)	– Styk, p. 11, Pl. XXII, fig. 6
1982. *Darwinula globosa* (Duff, 1842)	– Styk, p. 41, Pl. XIII, figs 8–10, Pl. XIV, figs 1–2

Remarks: A wider and more stubby form, the anterior end is variable in its asymmetry. The dorsal and ventral outlines are usually parallel, sometimes converging anteriorly. The posterior end is nearly symmetrically rounded. The dimensions are variable. The Kantavár forms are larger, and the Polish material is smaller, than the type material.

Dimensions: L = 1.02–1.09 mm, H = 0.55–0.60 mm, L/H = 1.77–1.90.

Material: about 100 specimens.

Conclusions

The extensive ostracod material provides no usable data for stratigraphy, as these *Darwinula* lived throughout the entire Triassic. The dominance of *Altochara* among the charophytes appears to support the Ladinian age of the lower part of the Kantavár Formation (Nagy 1968; Rálisch-Felgenhauer and Török 1993).

According to the above-mentioned authors the formation originated as a regressive succession, mainly in a lagoonal environment, based on the macrofauna and lithology. The large number of *Darwinula* and, occasionally, of charophytes, without any other ostracods, obviously indicate fresh water: the recent forms are similarly abundant in shallow, calm lake waters (Carbonel et al. 1988). The very poorly preserved gastropods and bivalves did not indicate any marine influence. According to the microfauna the sediments were deposited in a shallow, freshwater basin with plenty of plant debris. There is a large amount of organic matter in these black limestones and marls, with carbonaceous intercalations marking the former terrestrial plant material deposition necessary to the mass appearance of *Darwinula*. Similar lake environments existed for darwinulids during the Carboniferous, Permian and Lower Triassic in Russia and Kazakhstan (Carbonel et al. 1988).

The abundance of charophytes is in negative correlation with that of *Darwinula*, because the charophytes possibly lived in places with stronger currents. The sediments of the true lagoonal environment are in the Csukma Formation (underlying the Kantavár Formation).

Having a very wide stratigraphical and geographical distribution, these *Darwinula* species do not permit the determination of paleogeographic connections.

Plate I

All forms are derived from the Kantavár quarry, Kantavár Formation, Triassic, ?Upper Ladinian

1–6. *Darwinula liassica* Jones, 1894.
1. Left valve. Sample 1. M = 59x.
2. Left valve. Sample 4. M = 55x.
3. Right valve. Sample 11. M = 58x.
4. Right valve. Sample 4. M = 60x.
5. Right valve. Sample 1. M = 59x.
6. Left valve. Sample 8. M = 50x.

7–8. *Darwinula globosa* (Jones, 1862)
Left valves. Sample 3. M = 65x.

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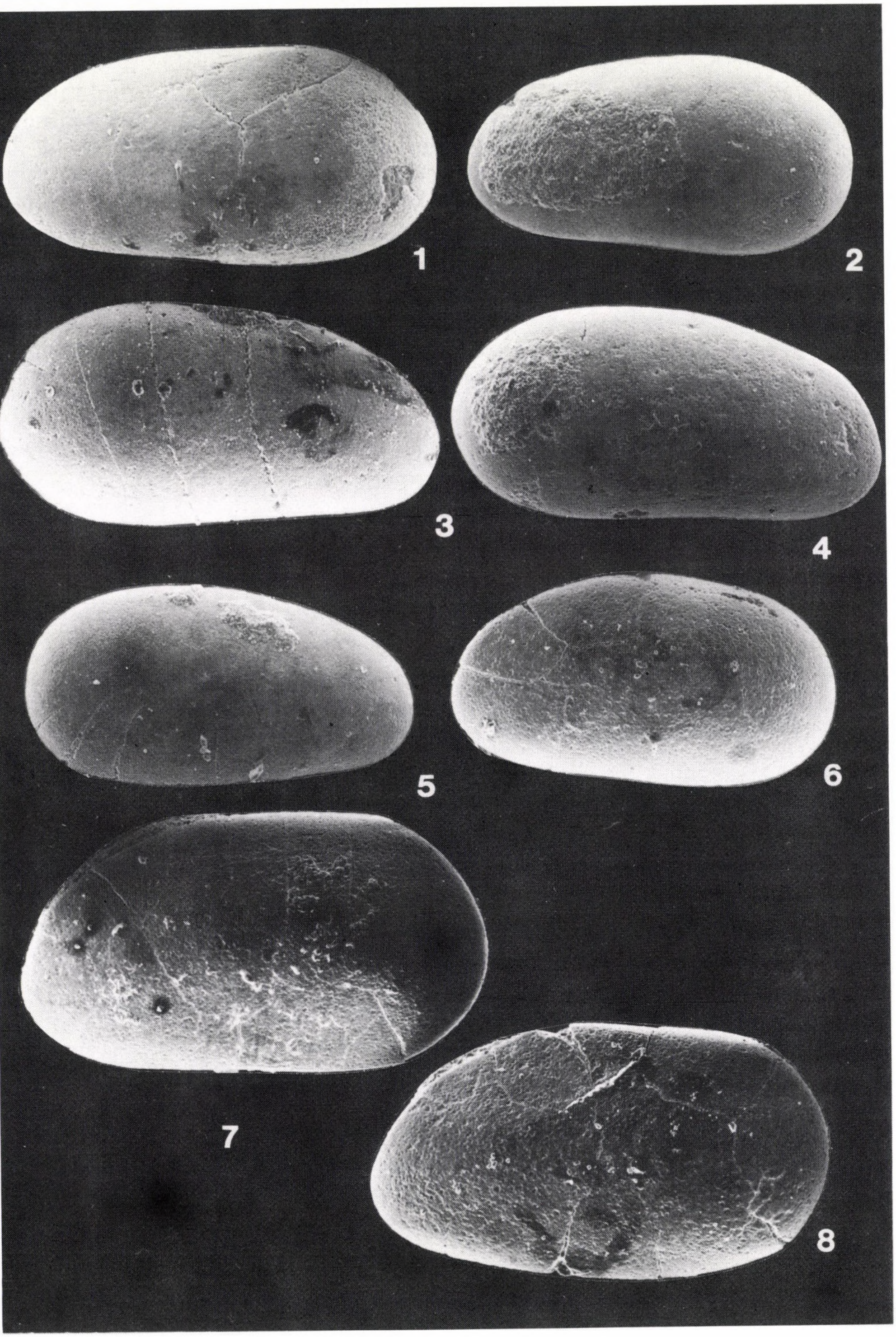
Plate I



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Errata

to M. Monostori: Environmental significance of the Anisian Ostracoda fauna from the Forrás Hill near Felsőörs (Balaton Highland, Transdanubia, Hungary) Acta Geologica Hungarica, Vol. 39/1 (1995)

p. 40: "*Hungarella*" *felsooersensis* (Kozur, 1970)
correctly: Plate I, Figs 2–4
p. 41: "*Hungarella*" *reniformis* (Méhes, 1911)
correctly: Plate I, Fig. 6
"*Hungarella*" *anisica* (Kozur, 1970)
correctly: Plate I, Fig. 5
p. 42: *Bairdia balatonica* Méhes, 1911
correctly: Plate II, Figs 1–3
Bairdia cassiana rotundidorsata n.ssp.
correctly: Plate II, Figs 4–5

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Hydrogeochemical properties and activity of the fluids in the Pomurje Region of the Pannonian Sedimentary Basin

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Thermal waters with high hydrogen carbonate mineralization (up to 7500 ppm) were examined. The origin and transport of gaseous CO_2 are the main questions in evaluating the evolution of the Radenci water system. The investigated district of Radenci (24 km^2), within the larger influenced Pomurje region of about 300 km^2, lies in the western part of the Pannonian basin. There, a great amount of clastic material of highly variable mineralogical composition had been deposited over a paleo-relief of Paleozoic metamorphic schists (phyllites) and Triassic dolomites after the Middle Miocene. Thermal gradients are very high and vary between 45 and 80 °C/1000m depth. The isotope composition of CO2 shows the range of d13C from –2.21 to –10.77‰(PDB) and of d18O from –7.0 to –18.3‰(SMOW). The waters' d18O varies from –4.68 to –12.45‰ (up to +0.85‰(SMOW) of the deep strata Miocene formation water in the wider area of influence).

Additionally $\delta^{13}C$ of gaseous and dissolved carbonate species as well as organic compounds have been measured. According to obtained data, using thermodynamic calculations (including geothermometry and rock-fluid equilibrium balances), and by considering hydrogeologic possibilities of transport through the system, we found that most carbonate species are derived from the decomposition of dolomite in interactions between dolomite – quartz – clay minerals in the temperature range from 80 to 160 °C. Some CO_2 may be derived from sulfate reduction as well as from the maturation of organic matter. Less probable is mantle origin of CO_2 because of the highly metamorphosed crystalline base which is quite impermeable and contains only calcite marbles as carbonate constituents. However, even if the latter occurs, concentrations are negligible compared to total dissolved and gaseous carbonate species. Considering thermal conditions and the amount of available dolomite, we have concluded that the system is still active, with continued CO_2 production.

Key words: stable isotopes, oxygen, carbon, hydrogen, mineral water, thermal water, fluids, hydrogeochemistry, sedimentary basin

Introduction

The aim of research in Radenci is to define the isotopic properties of water, its contents, gases, and minerals in the water system of Pomurje. By anticipating the physico-chemical mechanisms of the isotopic fractionation of light elements, we hope to contribute to the knowledge of the sedimentary basin, specifically regarding its fluid characteristics.

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1. Hydrogeologic properties

1.1. Geography and economic potentials

Pomurje is located in northeastern Slovenia. With its geographic position and geologic configuration, Pomurje forms the western part of the Pannonian basin. The investigated district in which mineral waters emerge, comprises an area of about 24 km^2 , lying within the wider region of influence of Pomurje, which itself covers an areal extent of approximately 300 km^2. This is the flat plain which lies at the frontier between the Pannonian plain and the fringes of the eastern Alps. The river Mura flows through the Pannonian basin which is surrounded by the hilly areas of Slovenske Gorice in the southeast and Goricko to the north. The elevation of the plain is approximately 180 m and the highest hills rise about 350 m above sea level.

Due to confirmed and potential locations of oil fields, mineral and thermal waters, recently discovered coal deposits, and planned construction of a hydroelectric plant on the River Mura, the entire basin has been thoroughly investigated, using hydrogeologic, geochemical as well as geophysical methods in boreholes up to 4000 m deep.

1.2. Geologic history

Prior to the Tertiary, the area of the present-day Pannonian basin underwent a long period of erosion beginning in the Triassic. This period was accompanied by tectonic movements, shaping the land by the end of the Oligocene (about 50 million years ago). The subcrop of the Tertiary sediments consists of Paleozoic metamorphic rocks, such as those of the Eastern Alps (e.g. phyllites, amphibolites, mica and biotite schist, gneiss, aplite, quartzite, eclogite, and marble). Today, in the Ljutomer and Radgona depression, there are indications of dolomite strata, most probably of Triassic age. The Tertiary clastic sedimentation in the Pomurje region began not earlier than at the beginning of the Neogene (about 24 million years ago). From the Oligocene to the Miocene, the climate cooled from tropical to subtropical, and during the Badenian seawater covered the entire Pomurje area except for the elevated Sobota massif, which formed an island. The marine basin, Paratethys, was then filled in by river deposits and thus became shallow and less saline.

The last euhaline period ended in the Badenian, about 17 million years ago. The basin was separated from the open sea because of progressive Alpine orogenesis, giving rise to the Alps, Dinarides, and Carpathian mountains. Following the withdrawal of saline waters in the Paratethys basin in the late Mid-Miocene (Sarmatian, about 12 million years ago), a new intensive inflow of freshwater formed a brackish environment in the Pannonian lake. Subsequently, river sediments completely filled the entire basin, also covering the Sobota massif.

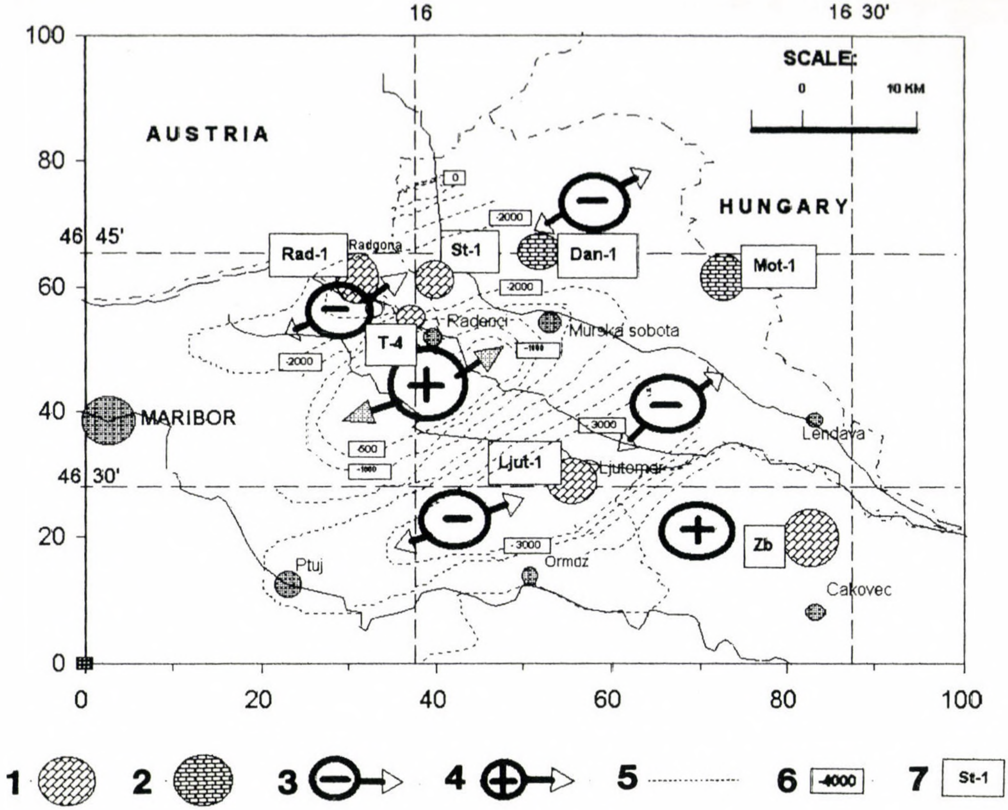

Fig. 1
Schematic map of Pomurje with topography of Paleozoic Basement and Triassic carbonate types. 1. dolomite in Tertiary basement; 2. limestone; 3. depressions; 4. horsts; 5. isolines of paleorelief; 5. depth in m; 7. borehole

During the beginning of the Pliocene (about 7.5 million years ago), the sedimentary basin was filled with water again – this time with fresh water derived from relatively high-energy inflow of rivers. Thus was formed a shallow fresh water lake where deposition of clastic sediments was intensive. Subsequently, the lake's water found its way to the open sea through an opening in the Carpathian Mountains.

During the Pleistocene and Quaternary (or Alluvial – less than 1 million years ago), rapid, high-energetic sedimentation continued and clastic river material of varying grain size covered the area.

Throughout the entire Tertiary, occasional volcanic activities occurred (mainly in Middle Miocene and Pliocene) in the wider Pannonian basin but did not directly influence the Pomurje region. Frequent erosion periods were characteristic during different stages throughout the Pannonian basin.

1.3. Hydrogeologic conditions

In the Tertiary layers, coarse-grained and fine-grained sediments were deposited successively. The heterogeneous aquifers have permeabilities between 10^{-3} cm s^{-1} and 10^{-6} cm s^{-1}, and porosities between 25 and 45%. Fine-grained zones have an effective porosity no greater than 6%, while in the zones with larger grains, porosity is around 16%. Furthermore, because of the varied nature of rock compositions, the waters in these aquifers have differing mineral contents with respect to concentration and specification. These waters emerge in Radenci with high levels of gas (mainly CO_2). The large temperature gradient with respect to depth is also partly responsible for the varying chemical compositions of water which emerge (Žlebnik 1978).

The aquifers and accompanying layers decline towards the southeast and are cut by several fractures. The fractured zones, in general, enable (but sometimes block) fluid flow between microtectonic formations. Hydrogeologically, the most important microtectonic formations in the Radenska mineral water area are Melovska, Šratovska, Radenska and Turjanska (Žižek 1982).

2. *Database and procedures*

In determining the genesis and dynamics of mineral waters in Pomurje, a wide range of chemical data was used: measurements of the isotopic composition of the water (δD and $\delta^{18}O$), dissolved carbonate concentration, CO_2 gas, and the isotopes $\delta^{13}C$ and $\delta^{18}O$ from carbonate cement and organic compounds, as well as the detailed chemical analyses of dissolved species. The data was utilized as input for various computer simulation models to obtain chemical speciation under various conditions. On the basis of a comparative interpretation of isotopic measurements, geochemical parameters, equilibrium and mass balance calculations, and by including the paleo and actual hydrogeologic conditions in the basin, we have attempted to explain the basic characteristics of the genesis and dynamics of the fluid system in the Radenci area (Pezdič 1991).

2.1. The carbonate system: CO_2 and HCO_3^-

Carbon dioxide is the most important component influencing the composition of thermo-mineral waters. As is seen from Fig. 2 the isotope composition of carbon, $\delta^{13}C$, in CO_2 is between −10.7 and −2.2‰ in the wider basin and between −6.1 and −2.2‰ in the area around Radenci. These are not values characteristic of known processes of CO_2 origin (Hoefs 1987; Fritz and Fontes 1980). Therefore, different sources of CO_2 must be present in the wider area. Correspondingly, pathways of fluid migration towards the Radenci area must exist.

Equilibrium principles between gaseous CO_2 and aqueous HCO_3^- under various thermodynamic conditions were utilized. Comparisons with the content of other gaseous components such as methane, argon, and helium (Pezdič 1991; Deak et al. 1987), as well as past studies in stratigraphy, tectonics, mineralogy and thermal characteristics of the surveyed area form the basis of the argumentation (Nosan 1973; Žižek 1982; Žlebnik 1978; Ravnik 1991).

2.2. Chemical composition

The concentration of dissolved species in Radenci's waters depends principally on the presence of CO_2. Carbon dioxide causes and accelerates a number of chemical reactions with the parent rock. Initial concentrations of the fluid solution relative to the solubilities of minerals from the rock determine the final chemical composition of the water. The data indicates that the reactions are relatively rapid and that the system, at constant temperature and pressure, does not undergo extreme changes in particular any aquifer layer. The changes are caused by water flow through host rocks of varying mineral composition. After mixing of differently mineralized waters, the final chemical concentration (equilibrium state) of the mixture depends upon the chemical activity (rate of reaction) and saturation index of particular ions. The resulting concentrations are also not easy to model as in an equilibrium state (mass and charge balance).

2.3. Water isotopes

The characteristics and origin of the water can be successfully determined with isotopic composition of $\delta^{18}O$ and δD of water.

2.3.1. Rainfall

For the determination of young groundwaters, the isotopic composition of recent precipitation is very important. However, for the Pomurje region we do not have such data. Therefore, we had to use the average isotopic composition of precipitation in Zagreb, $\delta^{18}O$ is –9.1‰ (Horvatincic et al. 1986). Zagreb lies only about 50 km from the investigated area and has a very similar topography and altitude to the Pomurje area. The isotopic properties of some of the shallow and less mineralized waters in the Radenci region includes values of $\delta^{18}O$ between –8.7 and –9.7‰, with an average of –9.1‰. We can thus, with fair probability, accept the median isotopic composition -9.1± 0.5‰ for oxygen and -63 ± 4‰ for hydrogen as a representative isotopic composition of precipitation in Pomurje for the last several years.

2.3.2 Mineral waters

The geochemical investigations of the isotopic composition of the mineral waters in the vicinity of Radenci began more than twenty years ago. The first analysis, performed between 1970 and 1972, shows that the waters have a relatively wide spectrum of $\delta^{18}O$ and δD. More extensive research between 1978 and 1980 at almost all the active boreholes and wells in Radenci gave a

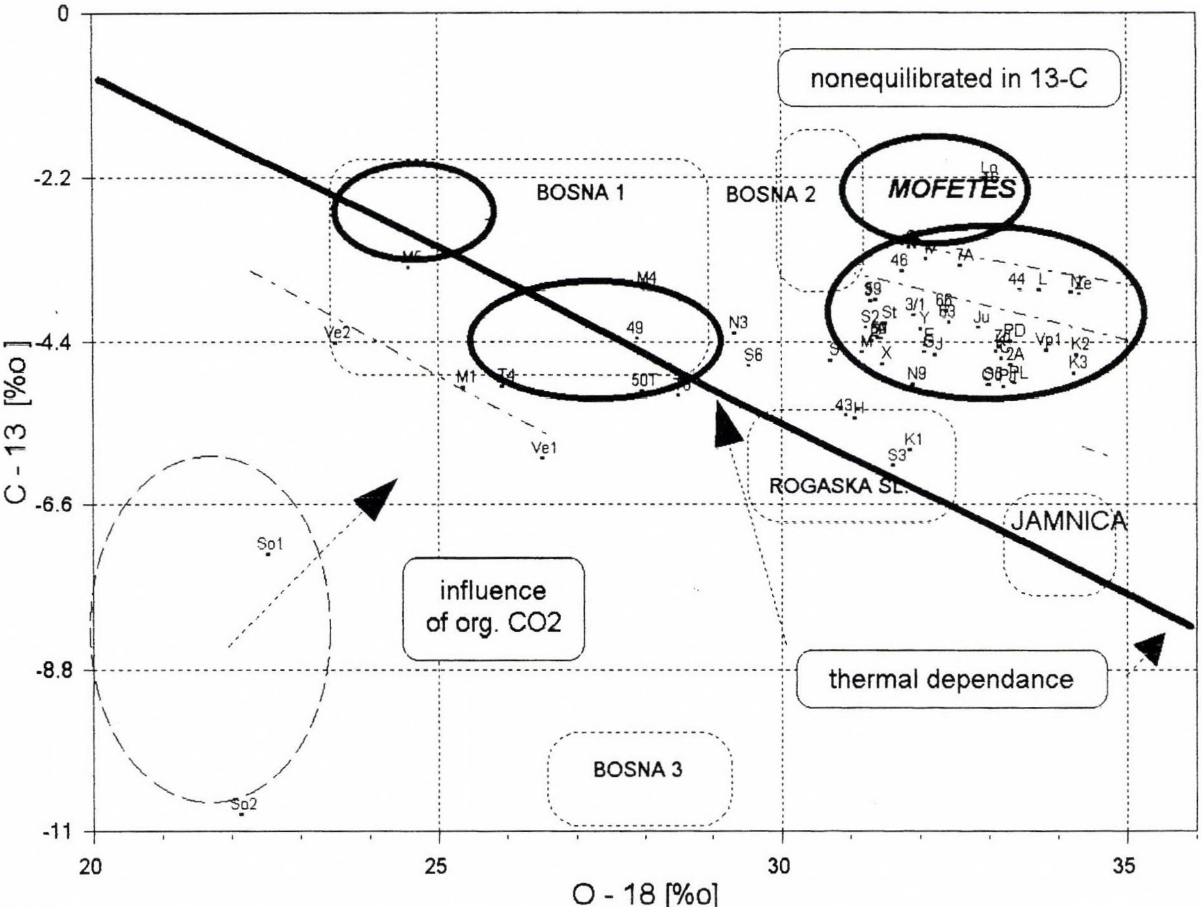

Fig. 2
The ratio of isotopic composition between $\delta^{18}O$ and $\delta^{13}C$ show different sources of CO_2, temperature dependence of equilibrium, non-steady state isotopic conditions for the Mura region and areas at the southwest border between the Pannonian basin and Alpine to Dinaric mountains

range of isotopic composition between –9.2 and –12.3‰ for oxygen, and between –70 and –88‰ for hydrogen.

The data from this period, supplemented by the data from wells analyzed in the latest period (1987–1990) are shown in Fig. 2. We have determined four basic groups of water origins in the Radenci region according to their median values of isotopic composition of oxygen and hydrogen ($\delta^{18}O$ (δD)):

[1] = A = –9.6 (–65) ± 0.4(4)‰,
[2] = M = –10.6 (–74) ± 0.4(6)‰,
[3] = B_1 = –11.3 (–78) ± 0.3(5)‰,
[4] = B_2 = –12.3 (–85) ± 0.4(3)‰.

Investigations of water from deep wells in the wider area of northeastern Slovenia indicate a wider spectrum of isotopic composition and chemical composition than in the Radenci area. However, the salt contents increase toward the east in the direction of the deep boreholes in Dankovci, Petišovci and Lendava. This is also visible in the isotopic composition of oxygen from water samples.

Data from the 2800 m deep borehole, in the Mid-Miocene layers near Petišovci, where $\delta^{18}O$ is +0.85‰, indicates water similar to that of a medium evaporative sea such as the current Adriatic. The decreasing values of $\delta^{18}O$ in the other deep wells are evidence that this formation water is mixing with old meteoric waters penetrating from the northwest.

The Radenci region is characterized by three basic types of water: young meteoric waters (A), old ground waters of meteoric origin (B) and formation water (M) (see Figs 3 and 5). Water types A, B, and M have the following primary locations and properties:

- Type M: Diluted brine waters with properties of remanent ancient sea-water, which appear in the deep layers eastward from the examined area; oil and natural gas fields are also found in this region.
- Type A: Old ground-waters, which are by their isotopic composition meteoric from past, colder epochs (Ferronsky 1983), perhaps including the Pleistocene; this water type appears mainly in the northwest area of the basin.
- Type B: Young meteoric waters, which recharge quickly particularly in the shallow aquifers where they are intensively pumped.

Table 1
Isotopic composition from boreholes in the Radenci Area

	Depth (m)	$\delta^{18}O$ (‰)
Mt-1		-9.46
Ve-1	1100	-9.33
Ve-2	1400	-8.19
Mt-4		-7.36
Dankovci	1190	-6.54
Dankovci	1230	-4.68
Petišovci	1700	-2.12

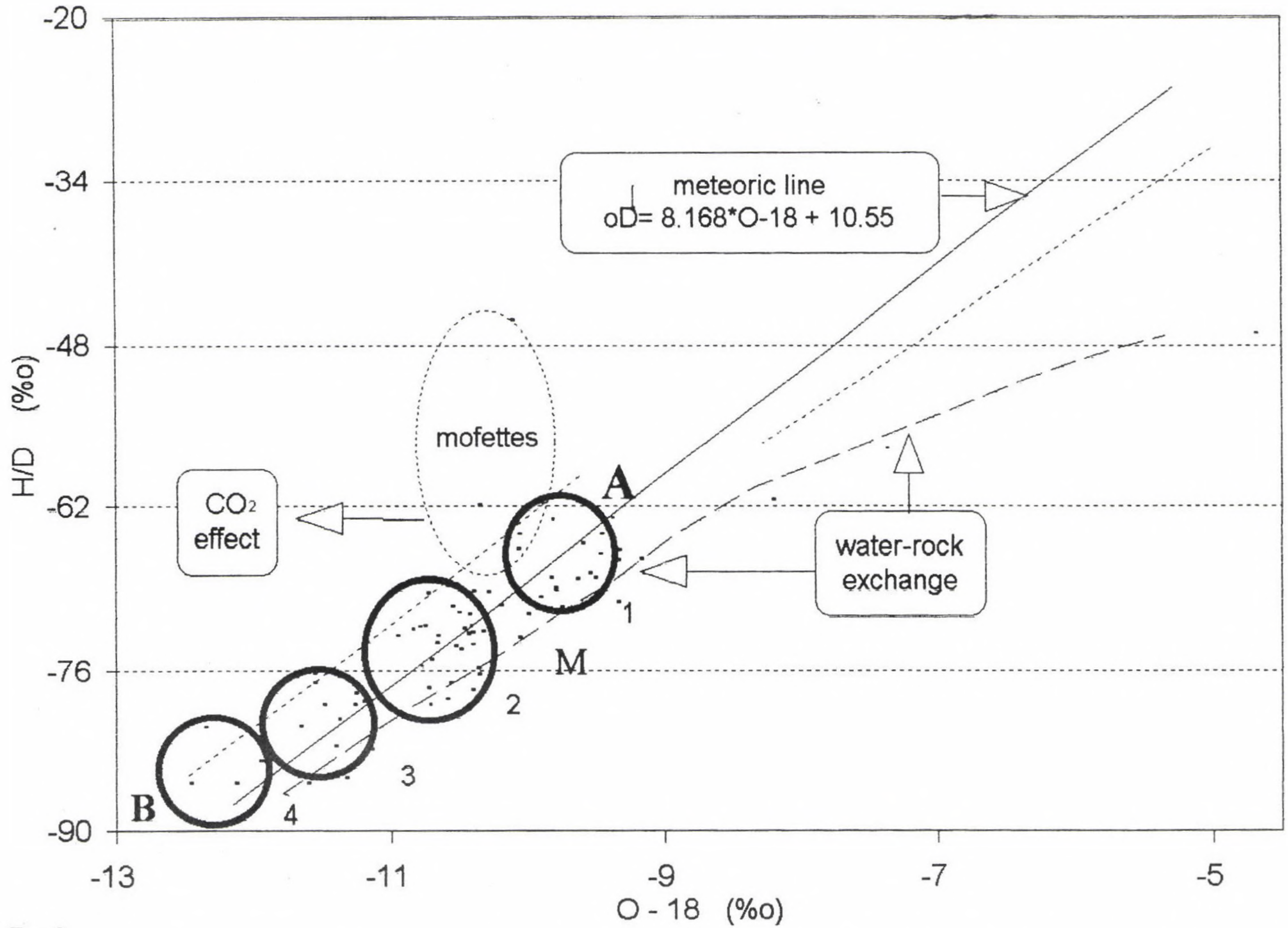

Fig. 3
Characteristic types of water in Pomurje expressed as the ratio of isotopic composition of the waters' oxygen and hydrogen

The range of water types was made by the mixing of these three main sources. This permits classification of the basin. Additionally, mixing of specific types of water from the zone's border provides the possibility to determine dynamic properties of the fluid flow.

3. *Creation of the water reservoir, retention time, and circulation of fluids*

The Pannonian sedimentation basin underwent characteristic stages of development. In order to assess the current hydrogeologic condition, various sources of data were used: successive sedimentation, mineral content, lithological changes, and different hydrogeologic characteristics. Further considerations of chemical and isotopic data allow a more detailed description of the present state of the basin and the influence of past eras. Discussion of the genesis of the water reservoir, retention, and flow of individual types of waters in the system includes basic hydraulic and mechanical processes and mechanisms used to define sedimentation.

3.1. Hypothetical sedimentation basin

Fyfe et al. (1978) studied the evolution of the hypothetical sedimentation basin, which was later refined by J. Pezdič (1991), who has mainly researched the fluid phases.

Combining quantitative studies and the above model, the following conclusions are arrived at:

The hypothetical basin, with an average porosity of 15%, contains 150 m of water column per 1000 m of depth. Due to compaction by increas- ing lithostatic pressure, porosity decreases from above 40% at the surface to 5% at a depth of 3000 m. The sediments contain up to 350 m of water column per 1 km of depth. Consolidation of the sediments has resulted in the formation of concave layers, with the largest depression in the center of the basin. At the edges of the basin, with lower depth and lithostatic pressure, compression is lower and the decrease in porosity less apparent.

Throughout the heterogeneous sediments, water rises up through permeable layers. In addition to lithostatic pressure, pressure is further increased by the geothermal gradient in the water system and by the partial pressure of the gaseous component (mainly CO_2). The system has a tendency towards equilibrium, determined by the interaction between the fluids and the rock. In general, solubility of mineral phases is higher at higher temperatures and the mass of the solid phase decreases. Due to intensive dissolution of minerals,

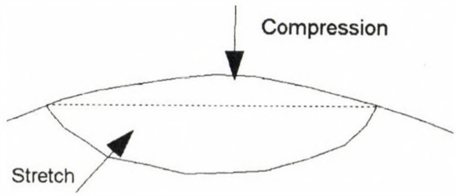

Fig. 4
Hypothetical Sedimentation Basin (Pezdic 1991 after Fyfe et al. 1978).

caused mostly by CO_2 species, highly permeable channels are formed in the first step and the system is released. However, they are then largely cemented by new oversaturated solutions as the partial pressure of CO_2 decreases.

During the upward flow of fluids to a cooler zone with lower pressure, the solutions become oversaturated and individual components precipitate. Due to these new cements, the channels are often completely closed. In this case high pressure is created, which then either re-opens the barrier or, more often, breaks mechanically less resistant and formerly impermeable layers such as clays. In these unconsolidated materials temporary cleavages open but close immediately after the pressure drops. In consolidated layers, permanent hydraulic cleavages are formed and create new conditions for fluid movement and for the further precipitation of different cements. This creates pulsating drainage of the basin. The frequency and force of the pulses depends on the intensity of the drainage and the mechanical properties of the barriers.

3.2. Formation of clastic porous aquifers around Radenci

All the mentioned characteristics of the hypothetical basin can be found in Pomurje, which forms a part of the Pannonian sedimentation basin. These characteristics can be described in more detail utilizing previous sedimentation studies. In the early Miocene, the Pomurje area was markedly marine, later on brackish, and then filled with fresh water before the beginning of the Pliocene. At that time the Sobota massif divided the basin in the Radenci area into two sub-basins known as Radgona and Ljutomer depressions.

During the erosional periods in the Miocene and Pliocene, the concave shapes were formed (Nosan 1973). After last erosion period, deposition of Pontian and younger Pliocene sediments in the unified basin took place. As the basin was filled with clastic material the edges moved towards the east. The outcrops of the Miocene layers can be seen today in the northwest area of Radenci. Eastward of these outcrops, along the dividing line from the hamlets Ihova to Crešnjevci to Cankova, are overlying layers of Pleistocene and Quaternary sediments. Above the Paleozoic Sobota massif the Tertiary sedimentary layers are broken into several blocks, which are divided by fractures, probably appearing as a result of subsidence of the sediments near the massif.

Applying the model of the hypothetical basin (Fyfe et al. 1978) to the real system would mean subsequent emission of fluids due to compaction. However, erosion created conditions which allowed infiltration of surface water. After the erosional periods and the end of the glacial periods, intensive glaciofluvial depositing of large quantities of clastic materials ensued. The mass of these sediments caused additional lithostatic pressure where the system is still in compression and fluids are released.

3.3. Geothermal conditions

The summary of thermomineral investigations in Slovenia was given by Ravnik (1991). He found that the northeast region of Slovenia (the Pannonian basin) characteristically has high thermal gradients, between 45 and 80^0 C/km. This is caused by intensive heat flow (q=100–145 mW/m^2 ; see Fig. 5). In the Pannonian region these flows may be connected with Mid-Miocene or Upper Pliocene volcanic activity, or with the thinning of the Earth's core. Ravnik related high heat flow and consequent thermal gradients to the thinning of the Earth's core with convection in the upper mantle, which produces subcrustal erosion, thermal diapirism (or passive lifted astenosphere). The majority of total heat flow may also be produced by radioactive elements which are present in high concentrations in Pannonian sediments. It was found that the radiogenic heat of Miocene clastites is 1.4 mW/m^3.

Temperature gradients can be defined directly from measured temperatures in boreholes or by calculating the highest temperature of organic matter with the vitrinite reflectance method. Hamrla (1989) reported the thermal gradient to be around 60° C/km for the Badenian and 52° C/km for the period between the Sarmatian and Mid-Pliocene. The local increase of thermal gradients may also be caused by the upward flow of warmer fluids (in Turjanci, approx. 100°C/km and in Boraecvo, approx. 70° C/km).

3.4. Sources of water in various aquifers around Radenci

Collected geochemical and isotopic data from the western Pannonian plain and considerations of sedimentation and hydraulic conditions, correspond to those of the hypothetical basin. There is little doubt that shallow aquifers predominantly receive direct infiltration of young meteoric waters (type B). Furthermore, it is clear that the hydraulic pressure from the northwest is great enough to cause the old meteoric waters (type A) to flow into the Radenci area (Fig. 6). Because of the compression of sediments at the eastern part of the basin, waters similar to sea-water (type M) drain from the deep subsided strata and mix with younger meteoric waters. For the Radenci area the mixing of the three basic types of water is most characteristic.

From Fig. 7, where the relation between $\delta^{18}O_{(H2O)}$ and chlorine is shown, we have managed to isolate particular types of waters which can be compared with the above-mentioned isotopic ratio, $\delta^{18}O$: δD (Fig. 3). The basic water types, A and B, are meteoric and contain almost no chlorine. However, in the east, near Radenci, Plio-Miocene sediments contain type M waters with characteristic values of $\delta^{18}O$ = –10.5‰ and about 450 mg/l of chlorine. This chlorine concentration probably originates as a result of additional intrusion of old meteoric waters from Plio-Miocene layers into the aquifers westward of the Verzej region (e.g. borehole Ve-1 has $\delta^{18}O$ = –9‰ and Cl^- = 750 mg/l). We have further defined subtypes "C" and "D", where both meteoric waters mix and there is almost no chlorine content.

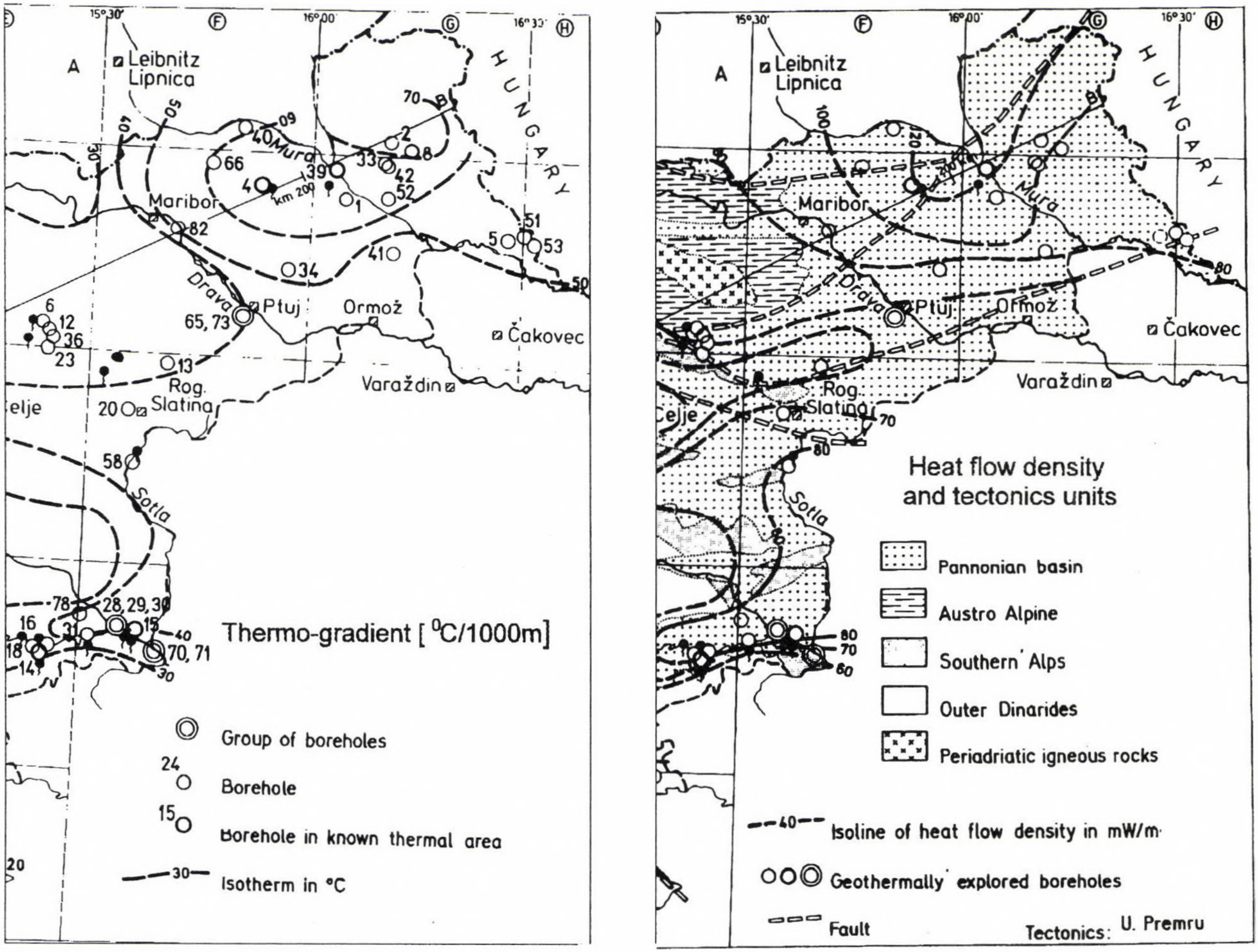

Fig. 5
Thermal gradients and heat flow in Eastern Slovenia (modified from Ravnik 1991)

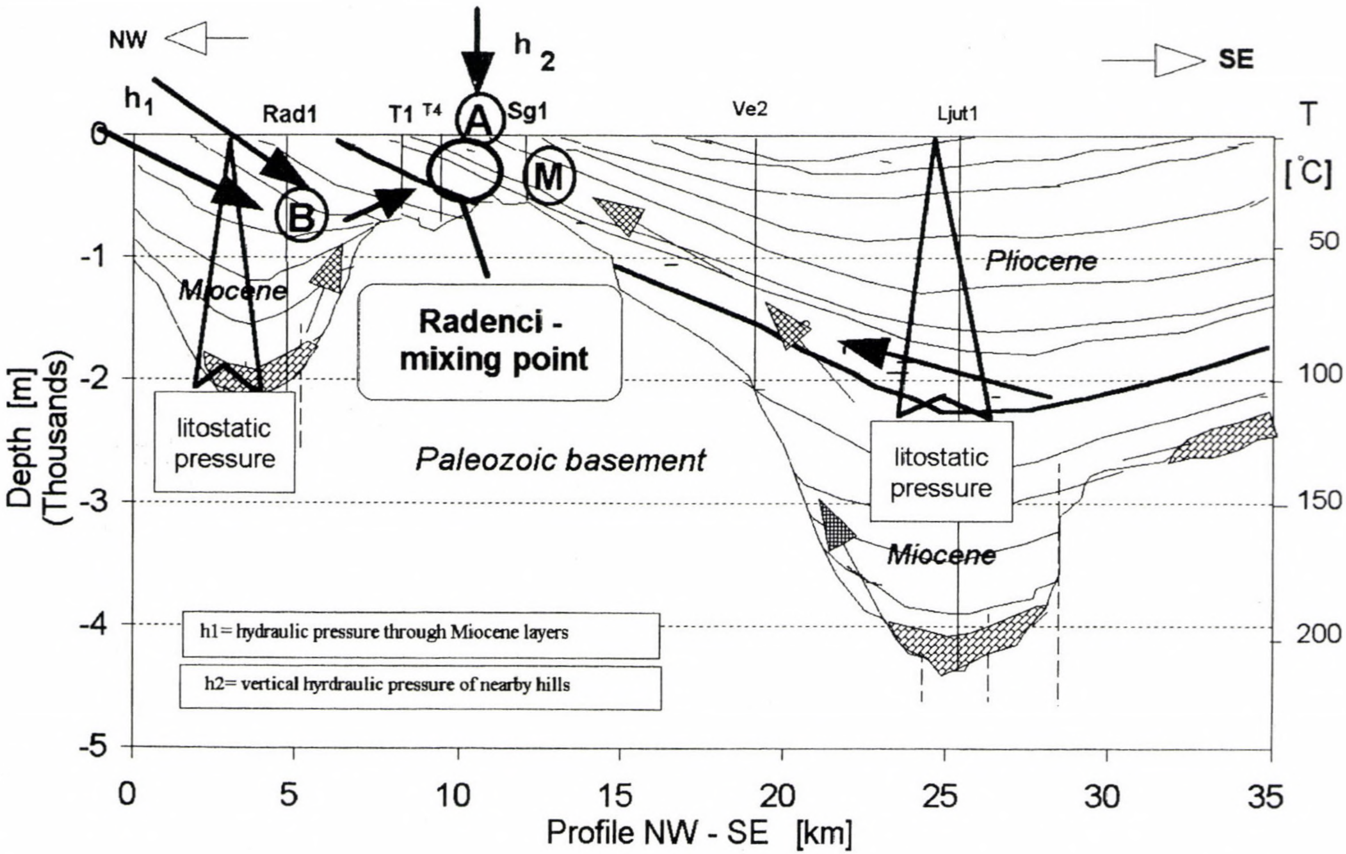

Fig. 6
Simplified model profile of Pomurje with lithostatic, hydraulic, and gas uplift conditions

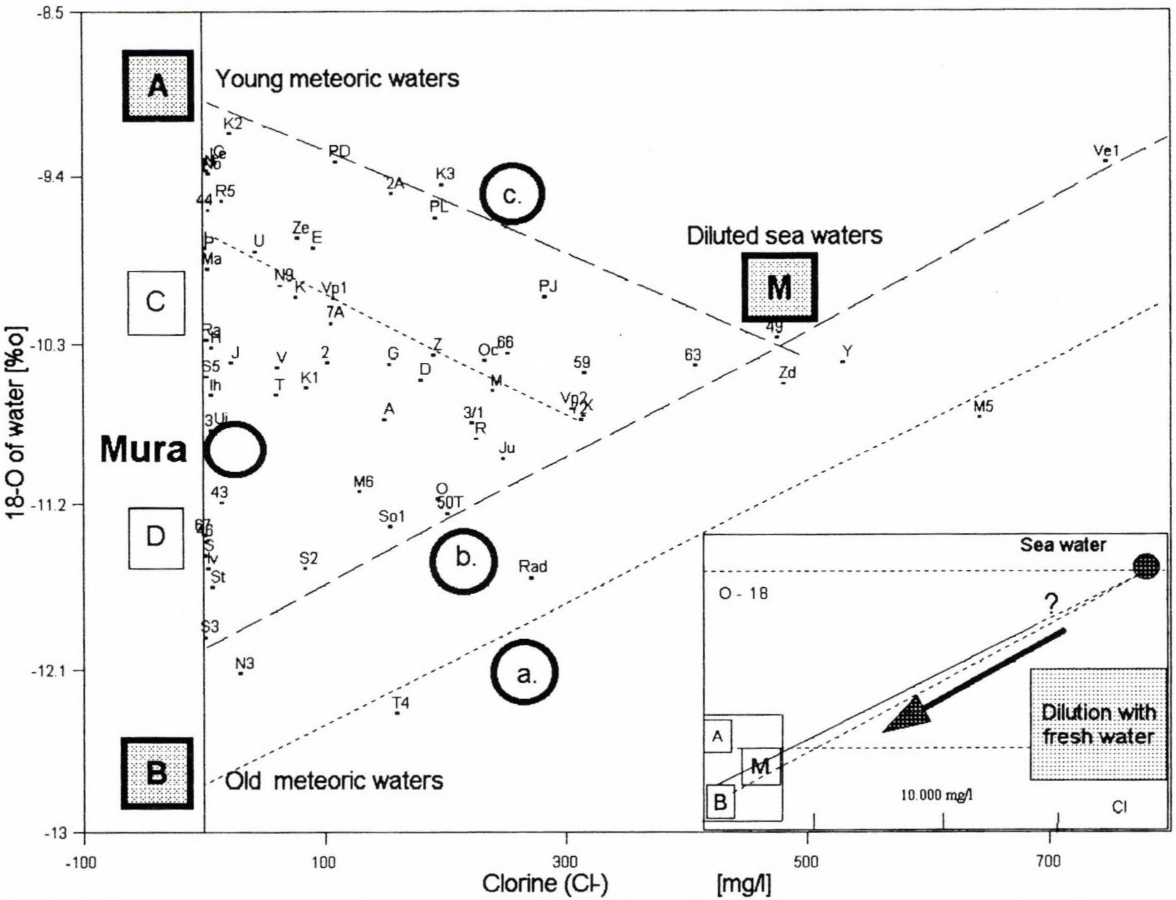

Fig. 7
Isotopic composition and chlorine concentration are independent parameters yet reflect the mixing of waters in various aquifers

Mixed waters similar to sea-water show a good relation of isotopic and chemical data with the age or type of the aquifers. Line (a) shows mixing in Miocene aquifers and line (b) in Pliocene aquifers. Meteoric waters (type A) mix along line (c) with saline (or type M) waters. In the space between, which involves a large range of different waters in Radenci, all three types of water mix. Similarly, relationships were found for other ions in solution: Na^+, Br^-, SO_4^{2-} and isotope composition of carbon in HCO_3^-, and in the southwestern area of Radenci and in the valley of Ščavnica, Ca^{2+}, Mg^{2+} – hydrogen-carbonate waters emerge. High sodium concentrations are characteristic for aquifers in the eastern part of the Radenci area.

The river Mura, with an average $\delta^{18}O$ value of about –10.8‰, may partially influence shallow aquifers. However, their isotope composition shows no conclusive evidence of strong river infiltration. In fact, during flood water periods, when the infiltration is most probable, these aquifers do not show changes of isotopic composition of light elements, of chlorine, nor of other dissolved species concentrations characteristic of the river's water.

Modeling of the aquifer system

The Pomurje area can be represented by a schematic model which consists of three basic water types with particular directions of flow, mixing, and sedimentation properties. The model is based upon previous hydrogeologic studies, the possibilities of fluid transport, assumed aquifer compaction, isotope measurements, and species concentrations (such as Cl^- and HCO_3^-). Various equilibrium conditions may be found in the basin which depend on temperature, rate of mixing, mineral composition of the rocks, and permeability of the aquifer.

The main processes of mineral water origin take place near the surface at the Boracevo fault (a fractured zone) in the Radenci area and Šcavnica valley. The faults show active gas exhalation and also partially contribute to the migration of waters towards the surface. Mobility is also enhanced by porous zones of Miocene to Pliocene layers which slope upward to the surface in this area, and along the boundary between Paleozoic metamorphic rock of the Sobota massif and Tertiary sediments.

The capacity of the water flow in the system depends on the hydraulic gradient and the porosity of the stratigraphic layers. The reservoirs' large volume and the frequently low permeability of sediments limits fluid circulation. The dynamics of mixing can be seen in various isotope compositions, chemical species, and pressure conditions in connected aquifers. The proposed hydraulic pressures and possible directions of flow, characteristic of the Radenci region, are shown in Fig. 8. The final composition of water and dissolved species is expressed as the mixing ratio between the three basic water types (A, B, and M). These mixing ratios permit the prediction of some facts about flow rate, namely that over a ten year period, isotopic data of oxygen in water shows that old meteoric waters (type B) are drained intensively to the pumped area, with a velocity of around 6.3×10^{-6} m/s.

The controlling factor of mobility and mineralization in the system are carbonate species. The majority of gaseous CO_2 and aqueous HCO_3^- in both Radenci and the wider area was created by the decarbonization of dolomite in the presence of quartz (as metasilicic acid H_4SiO_4) and silicates (mainly clay minerals), at a temperature range between 80 and 150 °C (also see Shanmugam 1985, who found that minor CO_2 production from dolomite can occur already at atmospheric conditions). The sediments contain a sufficiently large quantity of ancient dolomite – about 20% (Ogorelec et al. 1988). In contact with clastic sediments, the dolomite rapidly degrades at the existing thermal conditions.

Thermodynamic calculations using the computer simulation PHREEQE (Parkhurst 1987–1993) shows that a great amount of CO_2 can be produced at relatively low temperatures:

$$5\ \text{Dol} + 8\ SiO_2 + H_2O \Rightarrow \text{tremolite} + 3\ CaCO_3 + 7\ CO_2$$
$$5\ \text{Dol} + 4\ SiO_2 + H_2O + \text{kaolinite} \Rightarrow \text{chlorite} + 5\ CaCO_3 + 5\ CO_2$$
$$5\ \text{Dol} + 8\ SiO_2 + H_2O \Rightarrow \text{talc} + 3\ CaCO_3 + 3\ CO_2$$

In a closed system, the partial pressure of CO_2 (1 bar) is attained in the temperature range of 70 to 120 °C (Fig. 9). These conditions are particular to the formation of clay minerals such as:

tremolite:	$Ca_2Mg_5(SiO_{11})_2(OH)_2$,
chlorite:	$(Mg,Fe)_5Al(AlSi_3)O_{10}$,
talc:	$Mg_3Si_4O_{10}(OH)_2$

In the presence of marine-like water or a higher concentration of iron in dolomite (ankerite), the reactions are more rapid, or a lower temperature is required. The production of CO_2 where the subcrop of Tertiary sediments is composed of metamorphic rocks and contain only marbles, is less probable, since marbles can only be thermally decomposed at temperatures of over 700 °C (Fyfe et al. 1978). This is not the case in the Radenci aquifers system .

Carbon isotope fractionation in carbonate species shows the origin of CO_2 to be from the dissolution of dolomite in the temperature range of 80 to 170 °C (Pezdic 1991; see Fig. 10). Specifically, this is seen in the intersection of $\Delta\delta^{13}C$ calculated curves and the measured range of $\delta^{13}C$ of CO_2 in Radenci.

Furthermore, some gaseous CO_2 is created by the processes of sulfate reduction and the maturation of organic matter (kerogen). Both processes are related to the presence of organic matter in sediment layers. The isotopic composition of the carbon of methane (Pezdic 1991) and vitrinite reflectance (Hamrla 1989) prove the intensity of production, step of maturation, and exchange with CO_2, which contains $\delta^{13}C$ down to –12‰ in the deep, organic-rich layers; see Fig. 2).

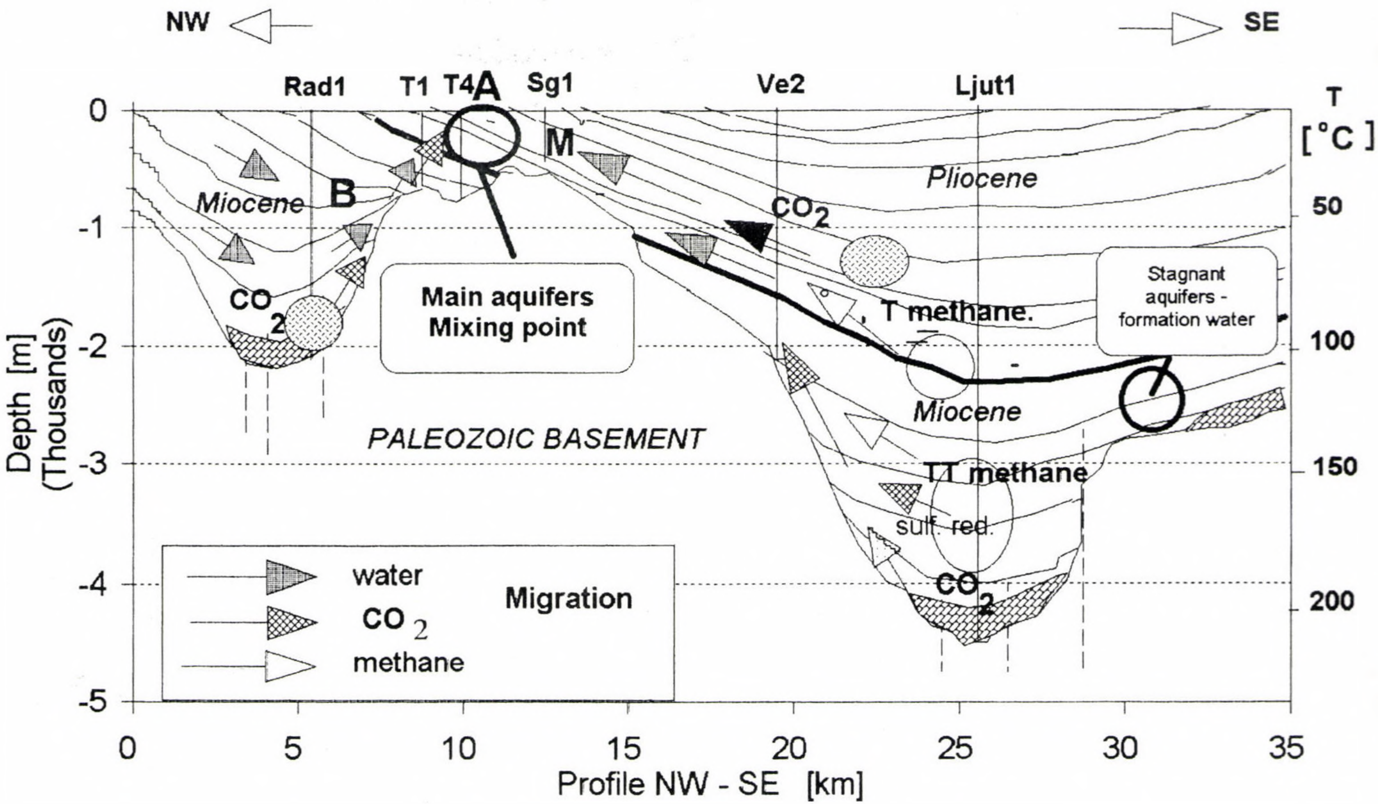

Fig. 8
Fluid transport through Tertiary sediments around the Sobota massif

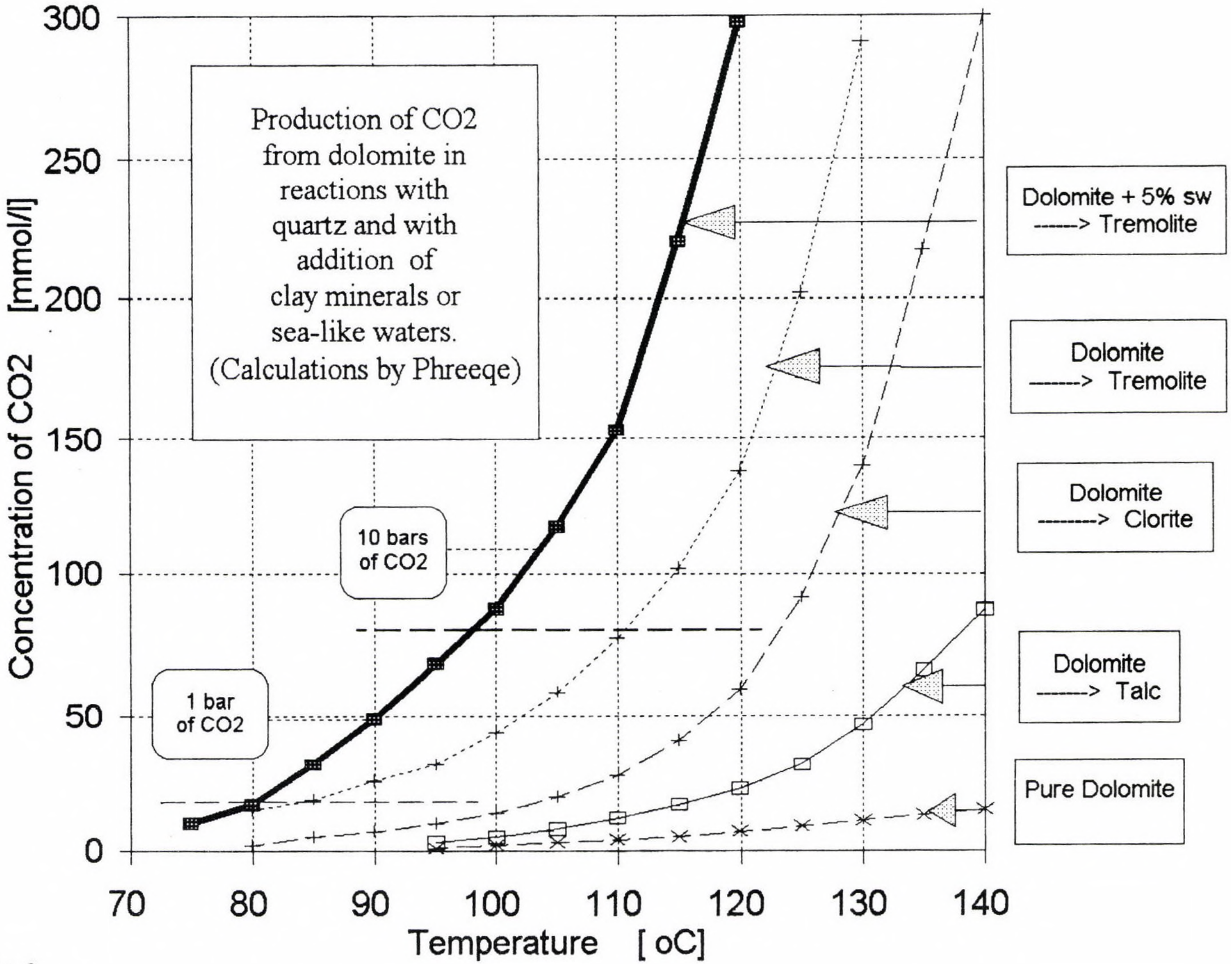

Fig. 9
Thermal properties of CO_2 production in different mixtures of dolomite and other species

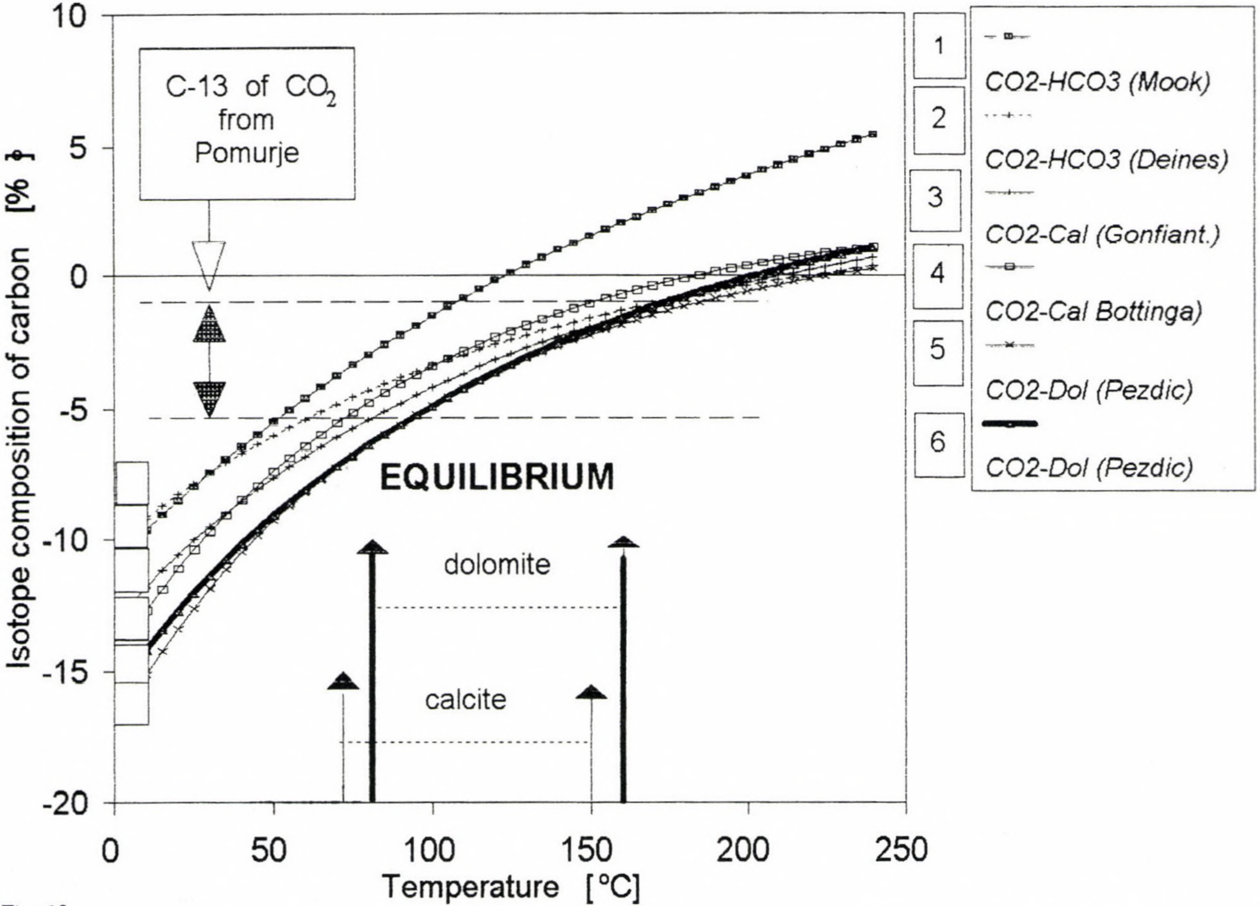

Fig. 10

Carbon isotope fractionation and dolomite dissolution is dependent upon the carbonate species where $\delta^{13}C$ data for the Radenci area corresponds to 80 to 160 °C

Miocene and mainly Pliocene post-volcanic influence is possible and $\delta^{13}C(_{CO_2})$ does not negate this. However, considering other parameters, physical and chemical characteristics of the system, the quantity of CO_2 from this source is marginal. Additionally, the origin of CO_2 from the mantle is not probable. This assumption may be checked by measuring the isotopic composition of helium which was found in some fluids, but only in minimal quantities.

The gas flow through the surveyed system is expected to be more rapid than that of water, since the areas where CO_2 is produced are several kilometers away from the locations of interest. Non-equilibrium states are observed in the carbonate species and their isotopic composition differs between phases. The exchange of oxygen isotopes between water and carbon dioxide is quickly established, within a few hours (see Fig. 2). The fractured zones and coarse-grained clastic sediments, whose porosities can reach up to 20% and permeabilities up to 10^{-3} cm/s, would permit such a flow.

Conclusions

The goal of the current work is to define the characteristics of the stable isotope composition of water, of the types dissolved in the system, gases, and surrounding rocks of the thermo-mineral waters area of Radenci, as well as the larger influenced region of Pomurje. The evaluation of aquifers in the Tertiary clastic sedimentary basin is described by the isotopic characteristics and fractionation of light elements (H, C, O), and on the basis of available geologic, hydrological and chemical data. The study draws conclusions concerning the properties of the sedimentation basin (particularly its fluid parts), the possible sources of its components, the mixing processes of various types of waters, and their interactions with the host rocks.

1) On the basis of the isotopic characteristics of oxygen in water three basic types of waters in the Radenci area were distinguished: young (type A) and old (type B) meteoric waters, as well as some percent admixture of Miocene formation water (sea water-like type M) with later infiltrated meteoric water. Most of water samples from individual aquifers in Radenci show mixtures of these types.

2) Based on previous studies, possible thermodynamically favorable reactions, isotopic composition, and chemical analysis, the principal source of carbon dioxide is attributed to reactions of dolomite with quartz and clay minerals at a temperature range between 80 and 160°C. A smaller portion of carbon dioxide originates from the maturation of organic matter in certain strata and from reduction of sulfates, while exhalations of carbon dioxide from the mantle play a subordinate role.

3) The established sedimentation and hydraulic model of the basin, supported by known hydrogeochemical characteristics, allowed us to draw conclusions on the likelihood of fluid transport towards Radenci. In addition, proportions of mixing of fluids (water and gas) of various origins were demonstrated.

4) Thermal gradients and heat flow contribute to the origin and transport of large quantities of CO_2 from dolomite decomposition. Temperatures over 100 °C is reached at the depth of 2000 m where sediments contain up to 20% of dolomite clastites and in depressions around the Sobota massif where dolomite relicts exist.

Consideration of additional parameters is necessary to complete the investigation of the Mura region. Specifically, chemical reactions have been theoretically defined although expected products have not been found yet. The aforementioned conclusions present the introduction of research methods with which it will be possible to determine new quantitative facts.

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Geochemical investigations of detrital chrome spinels as a tool to detect an ophiolitic source area (Gerecse Mountains, Hungary)

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The chemical composition of detrital chrome spinel grains of a Berriasian to Lower Albian(?) clastic succession in the Gerecse Mountains, which is located within the Transdanubian Range unit, was examined by electron microprobe. The majority of spinel grains is Cr-rich, derived from harzburgite and can be related to Type II and Type III alpine-type peridotites and ophiolites in the sense of Dick and Bullen (1984). The predominance of chrome spinels in the heavy mineral assemblages and the large amount of ultrabasic and basic rock fragments reflects an ophiolitic source area.

The chemical similarity of the detrital Cr-rich spinels with the supposed analogous sequence of the Eastern Alps (Rossfeld Formation) provides new petrologic evidence of a suture zone that was probably the source area for the Gerecse Mountains (situated to the south) and for the Northern Calcareous Alps (situated to the north).

The source rocks for the detritus of the Gerecse Mountains may have been the harzburgite-subprovince of the Tethys–Vardar suture zone, which is part of the Dinaridic ophiolite belt.

Key words: detrital spinel chemistry, heavy minerals, Lower Cretaceous flysch sequence, Gerecse Mountains, Rossfeld Formation, Northern Calcareous Alps, Tethys–Vardar ocean

Introduction

Chrome spinel (Mg, Fe^{2+})(Cr, Al, Fe^{3+})$_2O_4$ is a very important accessory phase in basalts and peridotites because of the different chemical variations of its main constituents during partial melting and fractional crystallization (e.g. Irvine 1967; Thayer 1970; Evans and Frost 1975; Hill and Roeder 1974; Fisk and Bence 1980; Murck and Campbell 1986; Allan et al. 1988; Ozawa 1989; Sack and Ghiorso 1991; Arai 1992). The most characteristic chemical variation is the large reciprocal range of Cr^{3+} and Al^{3+}, with increasing Cr# [Cr# = Cr/(Cr+Al)] reflecting an increasing degree of partial melting in the mantle, as well as the strong correlation between Cr# [Cr# = Cr(Cr+Al)] and Mg# [Mg# = Mg/(Mg+Fe^{2+})].

Spinels in basaltic rocks may prove as informative about the earliest stage of magmatic crystallization. Spinels are very sensitive to subsolidus reequilibration; thus spinel chemical compositions have to be interpreted with caution due to the possibility of reaction between early-formed spinel and

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residual melt. Generally, Cr^{3+} and Mg^{2+} are strongly partitioned into the solid, while Al^{3+} is partitioned into the melt. Partitioning of Mg^{2+} and Fe^{2+} between spinel and silicate melts is strongly temperature-dependent and the ratio of Fe^{2+} to Fe^{3+} is sensitive to variations in oxygen fugacity.

It is well known that chrome spinel could be in equilibrium with co-existing olivine during partial melting and fractional crystallization, showing the equilibrium temperature in the olivine-bearing rocks (e.g. Irvine 1967; Evans and Frost 1975; Fabriés 1979; Roeder et al. 1979; Lehmann 1983). Chrome spinel in peridotites could be a good indicator of the oxygen fugacity of the upper mantle (e.g. Mattioli and Wood 1986, 1988; Wood 1990; Ballhaus et al. 1990; Wood 1991). Consequently, it plays a special petrologic indicator role for the parent rocks.

Dick and Bullen (1984) demonstrated that chrome spinel chemistry is an important key for discovering the origin and tectonic settings of alpine-type peridotites and ophiolites.

It is also well documented that detrital chrome spinel is a diagnostic component of sedimentary rocks, especially of sandstones, deposited within an orogenic belt, e.g. remnant ocean basins (Zimmerle 1984). Detrital spinel, therefore, is a key mineral to palaeogeographic reconstructions and a reliable indicator of basic to ultrabasic source areas, especially of ophiolites.

The first detrital spinel occurrences from the Cretaceous clastic sequence of the Gerecse Mountains were published by Vaskó-Dávid (1989, 1991). She determined the spinel composition between Cr-picotite and hercinite by X-ray analysis.

Facies similarities between the Gerecse flysch sequence in the Transdanubian Central Range (=TCR) and the Rossfeld Formation in the Northern Calcareous Alps (=NCA) have been known for along time (Hantken 1868; Fülöp 1958) based on the lithology and ammonite assemblage. Detailed petrographic and petrologic studies have not yet been published.

This paper is dedicated to the geochemistry of detrital spinel grains from the Gerecse Mountains and the Vértes Foreland and the comparison of these data with those derived from the analogous sequences, and to their palaeogeographic implications.

Regional occurrence of detrital chrome spinels

The occurrence of detrital chrome spinel grains of the Alpine–Carpathian–Dinaridic region is connected to the main tectonic events from the Late Jurassic/Early Cretaceous to the Tertiary. Figure 1 shows the occurrences of detrital spinel grains in the Berriasian to Albian sediments within the region, which probably derived from the Tethys–Vardar suture zone. The appearance of detrital spinel grains was described from the Eastern Alps (e.g. Woletz 1963; Müller 1973; Dietrich and Franz 1976; Faupl 1977; Faupl and Tollmann 1978; Hagn 1982; Decker et al. 1987; Pober and Faupl 1988; Faupl and Wagreich 1992;

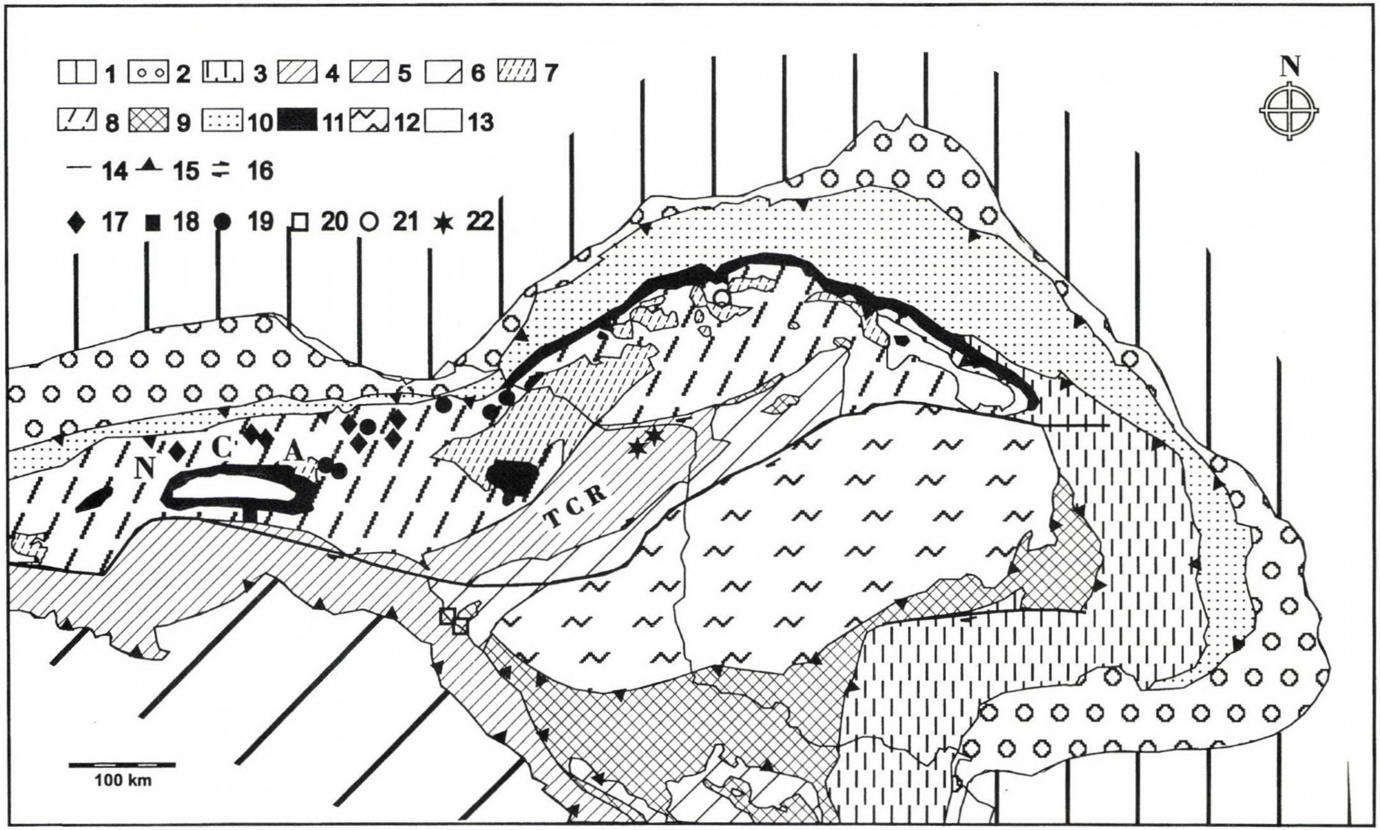
Wagreich et al. 1995), from the Dinarids (Zupanič et al. 1981) as well as from the West Carpathians (Mišík et al. 1980; Jablonský 1992).

Based on sedimentological and geodynamic evidence, as well as on spinel chemistry, the ophiolitic detritus of the clastic sediments of the Eastern Alps (Northern Calcareous Alps, Lienz Dolomites, Central Alpine Gosau, Lower Austroalpine Series, Penninic Series in Dogger to Upper Eocene age; see in Pober and Faupl 1988) were derived from two different ophiolitic areas: from the accretionary margin of the South Penninic ocean situated to the north of the Austroalpine realm, and from the suture zone of the Tethys–Vardar ocean (Pober and Faupl 1988). In this study, I concentrate only upon the latter source, which was situated to the south of the NCA. According to the palaeogeographic implications of Pober and Faupl (1988), this huge ophiolitic complex provided the detritus for the Rossfeld Formation and for certain parts of the Lower and Upper Gosau Subgroup in the NCA, as well as for the Lavant Formation in the Drauzug unit (see Fig. 1).

The Cr-rich spinels of the Valanginian to Aptian Rossfeld Formation came from the harzburgite sub-province of the Tethys–Vardar ocean. The Al-rich spinels of the Aptian to Albian Lavant Formation and of the Upper Cretaceous Gosau Group (southern provenance) probably correspond to the lherzolite sub-province of the suture zone (Pober and Faupl 1988). In the heavy mineral distributions of the Rossfeld Formation detrital chrome spinels are associated with a few types of metamorphic and stable minerals (Faupl and Tollmann 1978; Decker et al. 1987) (Fig. 2). Actinolitic amphiboles, kaersutite and glaucophanitic amphiboles, derived from the local source area, are also present in minor quantity. Serpentinite and basic rock fragments eroded from the Tethys–Vardar suture zone have not been published from the NCA. In contrast, metabasalts, serpentinites, ophicalcites, gabbroic rock fragments, derived from the Penninic oceanic crust, were reported from the clastic Gosau deposits of the Santonian in the NCA (Dietrich and Franz 1976).

In the heavy mineral assemblages of the supposed analogous sequence of the Hauterivian to Albian flysch sediments of the Ivanščica Mountains (Oštrc Formation) in Croatia (Zupanič et al. 1981) the chrome spinels predominate (on average over 85% of the translucent minerals, see Fig. 2). Serpentinites and basic rock fragments with subophitic textures are the most important lithic fragments in the Oštrc Formation, similar to those of the Gerecse Mountains. Microprobe analyses of detrital spinels have not been published yet. According to Blanchet et al. (1969) and Zupanič et al. (1981), in spite of the rare heavy minerals and the few petrologic data, a palaeogeographic connection may be supposed between the Ivanščica Mountains and the Vranduk flysch in Bosnia, probably throughout the Banija region. The Lower Cretaceous beds of the Banija region also contain spilite fragments and detrital chrome spinels (Šparica et al. 1974; Šimunić et al. 1976).

Detrital spinel grains are also recorded from Barremian–Aptian limestone pebbles and from Albian–Cenomanian sandstones from the Pieniny Klippen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Belt (Tatric unit) and from the Krížna nappe of the Fatric unit (Mišík et al. 1980; Aubrecht et al. 1992). The arithmetical mean spinel content in the heavy mineral distributions of the Oravice Formation is 14%, excluding opaque and chlorite grains (Fig. 2). According to the published microprobe analysis (Mišík et al. 1980) the spinels are Al-rich, showing a similar chemical composition to the spinels from lherzolite xenoliths (see Fig. 5a). The sources of detrital spinel grains from serpentinite rock fragments might have been the "Pieninic Exotic Ridge", the "Ultratatric Ridge" and probably the Ultra-Krížna areas, that have disappeared as a result of tectonic movements (Mišík et al. 1980). Based on the newest sedimentological and petrologic studies the Oravice Formation in the High Tatra Mountains can be compared to the turbiditic intercalations within the Aptychus limestone of the Schrambach Formation in the NCA (Jablonský 1992).

In the heavy mineral distribution of the Berriasian to Lower Albian(?) clastic sediments of the Gerecse Mountains in the TCR chrome spinels are also predominant (Fig. 2) (Árgyelán 1992, 1995b; Császár and Árgyelán 1994). Based upon the detailed petrographic analysis of the detrital framework of the Gerecse Mountains (Árgyelán 1995a) the studied formations contain serpentinite, dolerite, chloritite and volcanic glass rock fragments similar to the Oštrc Formation in the Ivanščica Mountains and to the some formations of Fatric and Tatric units (Aubrecht et al. 1992).

Geologic setting

The biostratigraphical (Sztanó and Báldi-Beke 1991; Félegyházy and Nagymarosy 1991) and sedimentological investigations of the last couple of years (Fogarasi 1995) significantly modified the previous (Fülöp 1958) stratigraphic subdivision and interpretation of the Cretaceous succession of the Gerecse Mountains and Vértes Foreland (see in Császár and Árgyelán 1994).

← Fig. 1

Occurrences of detrital spinel grains in the Alpine–Carpathian–Dinaridic region which were probably derived from the Tethys–Vardar suture zone. Tectonic units based on Balla 1984; Dercourt et al. 1986; Csontos et al. 1992; chrome spinel occurrences after Mišík et al. 1980; Zupanič et al. 1981; Pober and Faupl 1988; Faupl and Pober 1991; Aubrecht et al. 1992. *European continent 1–3:* 1. Foreland; 2. Molasse Foredeep; 3. Dacides. *African continent 4–8: (tectonic zones):* 4. Outer Dinaric, South Alpine, Transdanubian and Drauzug units; 5. Inner Dinaric, Bükk unit; 6. Inner and Outer Adriatic units; 7. Lower Austroalpine and Tatric unit; 8. Middle and Upper Austroalpine unit. *Tethyan ocean 9:* 9. Ophiolite nappes and related units, Vardar, Meliata, Mures, Olt oceanic nappes. *Other tectonic units 10–13:* 10. Alpine and Carpathian flysch nappes; 11. South-Penninic, Pieniny oceanic and Mesozoic flysch units; 12. Tisza unit; 13. Hochstegen, Vepor, Zemplén, Danubian domain; 14. Geographic contour; 15. Major thrust faults; 16. Strike-slip and normal faults; chrome spinel occurrences: 17. Rossfeld Formation NCA; 18. Lavant Formation Drauzug unit; 19. Lower Gosau and Upper Gosau Complex of southern provenance; 20. Oštrc Formation Ivanščica Mts. and Banija region; 21. Oravice Formation High Tatra Mts.; 22. Lower Cretaceous flysch sediments in Gerecse Mts; NCA – Northern Calcareous Alps; TCR – Transdanubian Central Range

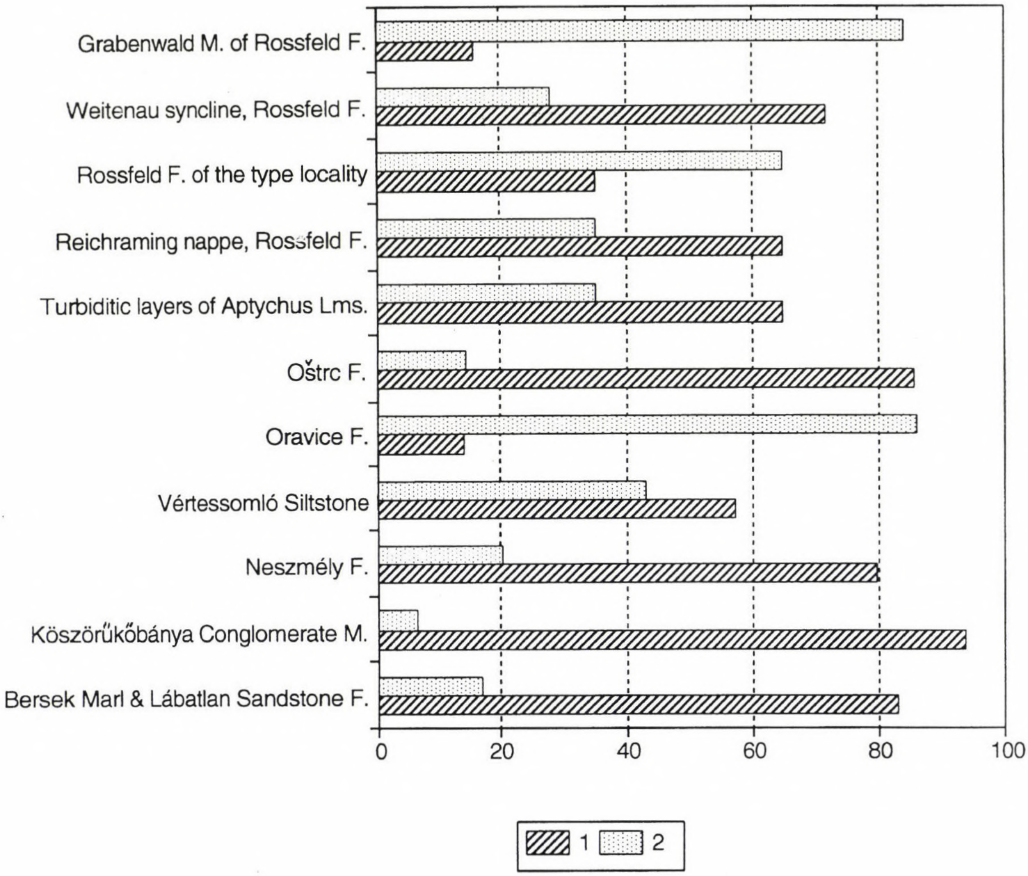


Fig. 2
Distributions of detrital spinel grains vs. other translucent minerals in the heavy mineral assemblages of the Gerecse Mountains and Vértes Foreland (Árgyelán 1989; Császár and Árgyelán 1994) compared to the several localities of Rossfeld Form. (Decker et al. 1987), Oštrc Form. (Zupanič et al. 1981) and Oravice Form. (Aubrecht et al. 1992; Mišík et al. 1980) indicated in Fig. 1. 1. percentage of detrital spinel grains; 2. percentage of other translucent minerals e.g. amphibole, pyroxene, garnet, staurolite, apatite, epidote-group, rutile, tourmaline, zircon

Figure 3 shows the geographic extension of the Cretaceous clastic sediments of the Gerecse Mountains and Vértes Foreland, while Fig. 4 represents the stratigraphic relations between the Gerecse Mountains and Vértes Foreland through the Tatabánya Basin from NE to SW.

The Triassic–Jurassic calcareous sedimentation was replaced by a siliciclastic one in Berriasian to Valanginian times (Fig. 4). This significant change in the sedimentation pattern was accompanied by deposition of conglomerates (Felsővadács Breccia Member). The conglomerate-beds overlie the Upper

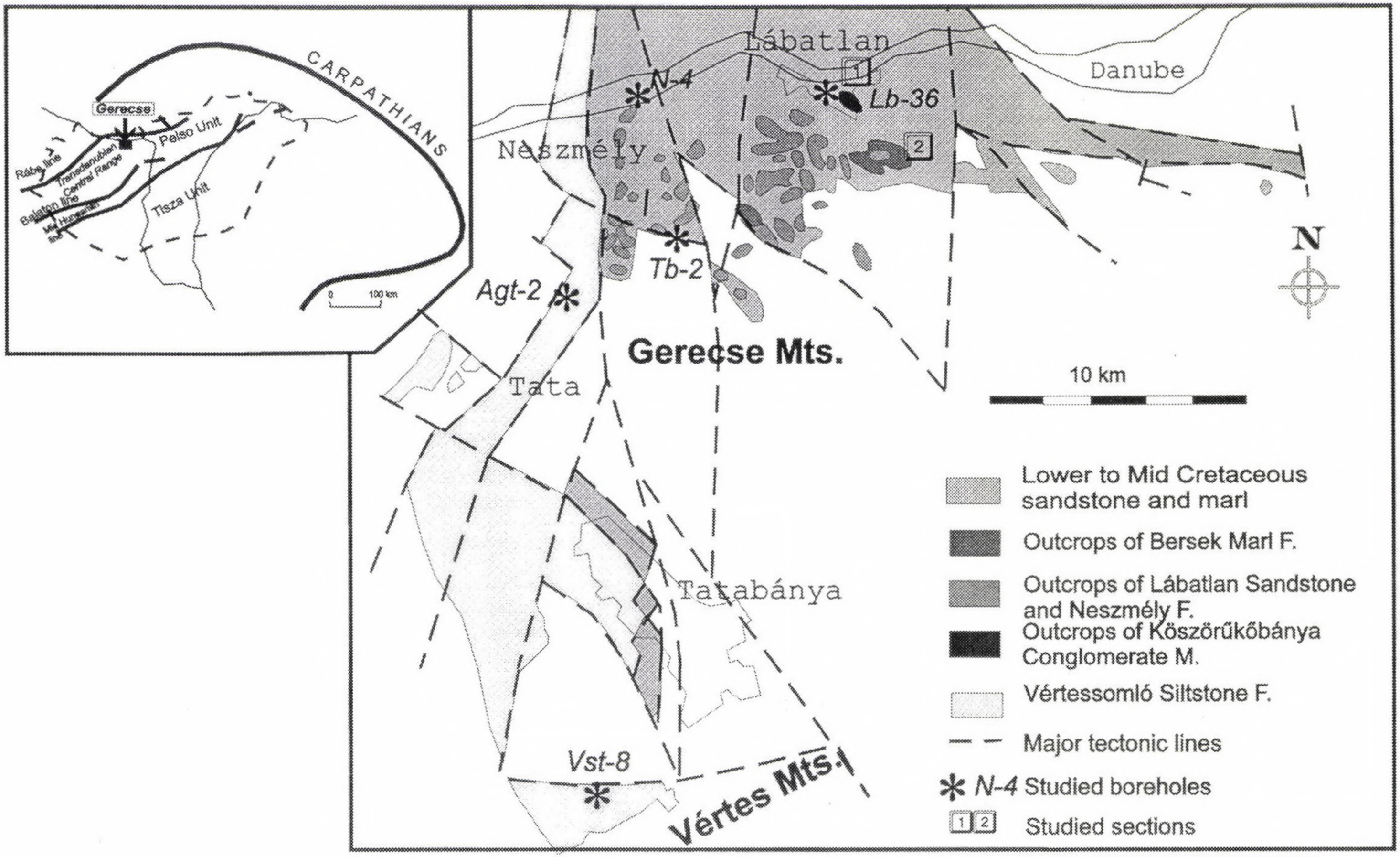
Tithonian to Lower Berriasian calpionellid limestones (Szentivánhegy Limestone Formation), or are embedded in it (Császár and Árgyelán 1994).

In the eastern part of the Gerecse Mountains (Fig. 4) a coarsening and thickening upward sequence was deposited on a prograding mud and silt-dominated submarine slope (Fogarasi 1995). According to Fogarasi, two different transport directions can be proved during the Early Cretaceous, which produced different types of materials from distinct source areas (see also Árgyelán, 1995a). The best outcrops of this series occur in a large quarry in Bersek Hill. Its lower part, the Bersek Marl Formation, consists of gray and red marl and mudstone, with thin turbiditic sandstone intercalations. It is followed by graded, moderately thick, medium to coarse-grained sandstone beds of the Lábatlan Sandstone Formation, showing the typical features of gravity flow sediments such as turbidites, debris flow deposits and slumps (Császár and Haas 1984; Fogarasi 1995). The sequence is capped by the fan-channel sequence of the Köszörűkőbánya Conglomerate Member (Kázmér 1987; Sztanó 1990) containing chert clasts and limestone fragments from Urgonian platform carbonates. The carbonate platforms may have been situated to the north of the sedimentary basin (Schlagintweit 1990). The measured transport direction of the Köszörűkőbánya Conglomerate is from NE to SW, according to the present-day co-ordinates (Sztanó 1990; Márton and Márton 1985). Based on the rich ammonite fauna, the siliciclastic sequence of the Eastern Gerecse was emplaced within the Berriasian–Barremian interval (Fülöp 1958). Re-examination of the ammonites from Bersek Quarry and from borehole Lábatlan Lb-36 supported the Early Hauterivian to Early Barremian age of the Lábatlan Sandstone (Főzy 1995). In contrast, nannofossil investigations of the mudstone intercalations of the Köszörűkőbánya Conglomerate (Sztanó and Báldi-Beke 1991) and the Lábatlan Lb-36 borehole (which exposed the upper part of the Lábatlan Sandstone and the lower part of the Köszörűkőbánya Conglomerate) suggested a Late Aptian to Middle Albian age.

In the western part of the Gerecse Mountains (Fig. 4) sedimentation began in the Late Hauterivian–Early Barremian and the coarse-grained Neszmély Formation was deposited contemporaneously with the sedimentation of the Bersek Marl and the Lábatlan Sandstone in the Eastern Gerecse (Császár and Árgyelán 1994). Dominantly fine to coarse-grained sandstones are interbedded with mudstones, siltstones and matrix-supported conglomerates deposited by turbidity currents (Árgyelán, 1989). They pass upwards into Albian hemipelagic siltstones, marls and muddy marls of the Vértessomló Siltstone Formation (Császár and Árgyelán 1994).

Classification of chrome spinels and their geochemistry

The major compositional features of chrome spinels can be illustrated in a triangular diagram, a scheme that was first used by Stevens (1944) and Thayer (1946). In practice, two projections are established from this triangular prism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Vst-8
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Lower to Mid Cretaceous sandstone and marl
Outcrops of Bersek Marl F.
Outcrops of Lábatlan Sandstone and Neszmély F.
Outcrops of Köszörűkőbánya Conglomerate M.
Vértessomló Siltstone F.
Major tectonic lines
N-4 Studied boreholes
1 2 Studied sections

← Fig. 3
Geological sketch map of the studied Cretaceous formations of the Gerecse Mts. and Vértes Foreland showing the location of the studied boreholes and outcrops. Boreholes: Neszmély-4 N-4, Lábatlan-36 Lb-36,Tardosbánya-2 Tb-2; Agostyán-2 Agt-2; Vértessomló-8 Vst-8; Pusztavám-980 Pv-980, because of its geographic position, is not indicated in the map. Outcrops: 1. Köszörűkőbánya quarry, Lábatlan; 2. Bersek quarry, Lábatlan. Modified after Császár and Árgyelán (1994)

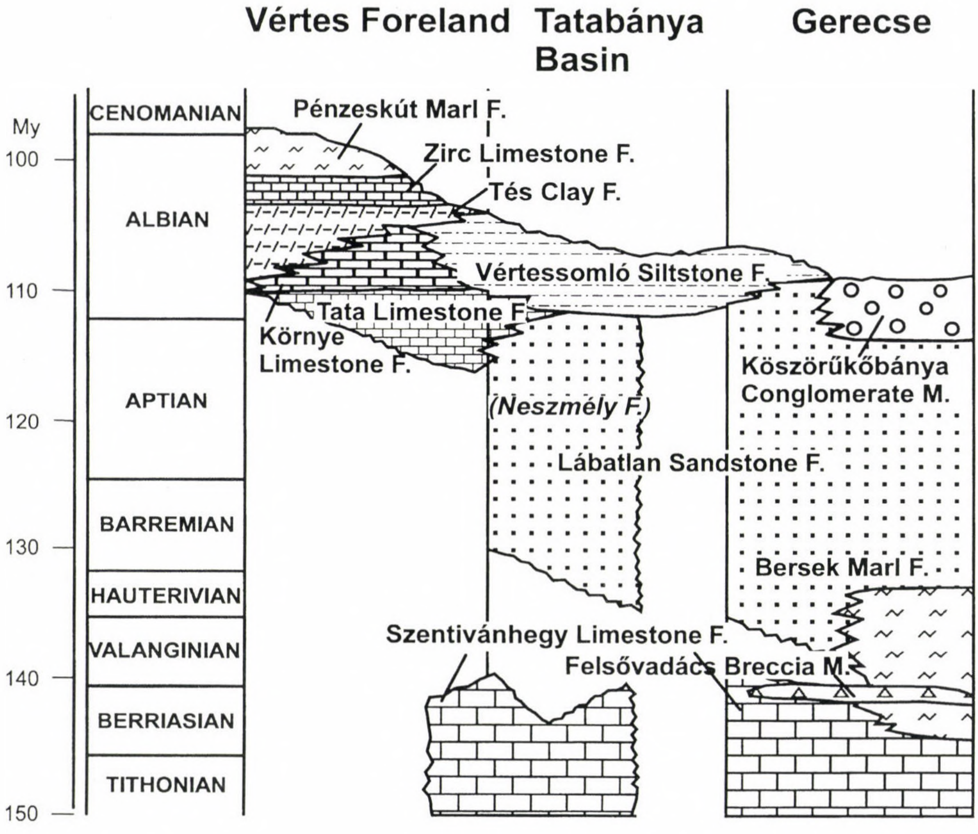

Fig. 4
Stratigraphic relations of Cretaceous formations of the Gerecse Mountains and Vértes Foreland after Császár (1995). According to the newest stratigraphic, paleontologic, petrologic results explanation in the text the Neszmély Formation in the western part of the Gerecse Mountains belongs to the Lábatlan Sandstone Formation

by plotting $Cr/(Cr+Al)$ against $Mg/(Mg+Fe^{2+})$, and $Fe^{3+}/(Cr+Al+Fe^{3+})$ against $Mg/(Mg+Fe^{2+})$.

Pober and Faupl (1988) postulated new compositional fields for the upper mantle-derived peridotites based on the Cr# vs. Mg# of their spinel grains, which slightly differ from the earlier ones (Stevens 1944; Dick and Bullen 1984). They separated the less-depleted lherzolite from the harzburgite in terms of Cr# vs. Mg# variations of spinel (Fig. 5a). The upper Cr# limit of lherzolite spinels is 0.5 to 0.55, while 0.3 is often the lower limit of harzburgite spinels. However, there is an overlap between the two compositional fields. The greatest populations of spinel data sets from the upper mantle-derived rocks are equivalent to the transitional field of Dick and Bullen (1984), the field of Type II alpine peridotites and ophiolites (Fig. 5b). In lherzolites and harzburgites, the Cr# of spinel depends mainly on the degree of partial melting and the initial composition of the melting material, while in the ultramafic cumulates (dunite, wehrlite) it depends on the chemistry of the magma.

Using the spinel composition, the alpine-type peridotites and ophiolites can be divided into three groups (Dick and Bullen 1984 Fig. 5b). Type I alpine-type peridotites and ophiolites, the spinels of which have Cr# values of less than 0.60, represent the oceanic lithosphere formed at the mid-ocean ridge. Type III alpine-type peridotites and associated volcanic rocks, those with spinel Cr# values greater than 0.60, are related to the earliest stage of arc formation on oceanic crust. Its intensely tectonized materials can be found in the forearc regions of many modern island arcs. Type II alpine-type peridotites and ophiolites, with spinel Cr# values spanning the ranges of the former two types, are composite in nature, representing the complex multistage melting history of the source area over a relatively short distance. Such petrogeneses may include areas where the young island arc was generated on the older oceanic crust, or sections across the transitions from arc to oceanic lithosphere. Dick and Bullen (1984) found that Type I alpine-type peridotites with alumina-rich spinel compositions are mostly lherzolites, and Type III alpine-type peridotites, those at high-chrome end of the Type III range, include many harzburgites.

Chrome spinels from abyssal spinel-peridotites (Dick and Bullen 1984), and from tectonites (e.g. Hebert 1982; Talkington and Malpas 1984) usually have low TiO_2 contents, lower than 0.2 wt%. During partial melting TiO_2 was concentrated in the residual liquid, depending upon the degree of partial melting (Dick and Bullen 1984; Talkington and Malpas 1984). Cumulus spinels are richer in TiO_2 and Fe_2O_3, than those from tectonites (Hebert 1982; Pallister and Hopson 1981; Auge and Roberts 1982; Economou 1984). Spinels in alpine dunites have a broader range of Mg# values for a given Cr#, and also have higher TiO_2 and Fe_2O_3 contents, than spinels in the associated peridotite tectonites (Dick 1977; Dick and Bullen 1984; Pober and Faupl 1988).

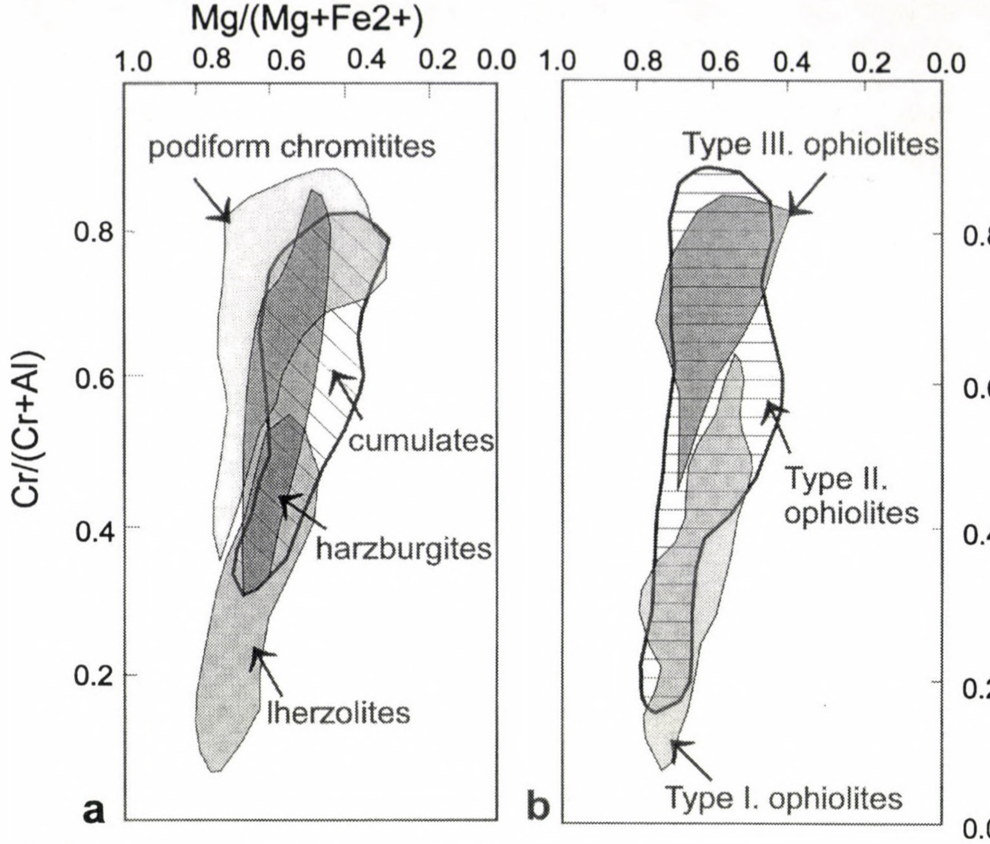

Fig. 5
Spinel chemistry from mantle rocks, cumulates rocks after Pober and Faupl (1988), Fig. 5a and from alpine type peridotites and ophiolites after Dick and Bullen (1984), Fig. 5b in a Cr# vs. Mg# diagram

Method

Sandstone samples were prepared analogous to heavy mineral separation: crushing, dissolving of carbonate cement and separating of 0.063–0.250 mm sieve fraction by tetrabromethane. All the heavy mineral fractions were embedded in epoxy-resin and polished for microprobe analysis. The spinel analyses were carried out by ARL-SEMQ WDS microprobe for minor elements (Ti, Mn) and EDS microprobe for major elements (Cr, Al, Mg, Fe) with 15 kV acceleration potential and standard correction procedure (ZAF) at the Institute of Petrology of the University of Vienna, Austria. Six elements were analysed in all cases (Al, Cr, Fe, Mg, Ti, Mn). Fe^{3+} was calculated by Droop's equation (Droop 1987).

Spinel geochemistry of the Lower Cretaceous clastic succession of the Gerecse Mountains

Detrital spinel grains of 26 samples from six different formations were analysed (Table 1). The most characteristic features of spinel chemistry are the large reciprocal variation of Cr# and Mg# and the petrologic importance of TiO_2 content (see Chapter 4). Therefore, geochemical compositions of spinels are represented in terms of Cr# vs. Mg# and Cr# vs. TiO_2 wt% diagrams (Figs 6–11). Generally, in the detrital spinel grains of the studied formations the Cr# ranges from 0.3 to 0.85 and the Mg# from 0.4 to 0.75. Fe_2O_3 and TiO_2 contents are consequently very low. The Fe^{3+}# [$Fe^{3+}/(Cr+Al+Fe^{3+})$] ratios of the analysed samples are always lower than 0.05, which is a characteristic feature of spinels from mantle-derived rocks. The TiO_2 wt% ranges from 0.00 to 0.65; in many instances the TiO_2 wt% are zero, but in few cases they are higher than the empirical upper TiO_2 wt% limit (0.2 wt%) of lherzolites and harzburgites (see Chapter 4). Zonal detrital spinel grain was not found. Representative microprobe analyses are given in Table 2.

Table 1
List of the formations studied and the number of samples and analyses

Formation	Localities	No. of samples	No. of analyses
Bersek Marl F.	Bersek quarry (Lábatlan)	5	114
Lábatlan Sandstone F.	Bersek quarry (Lábatlan)	5	72
Köszörűkőbánya Conglomerate M.	Köszörűkőbánya quarry (Lábatlan)	2	37
	Hole Lábatlan-36 (Lb-36)	3	37
Neszmély F.	Hole Neszmély-4 (N-4)	4	76
	Hole Tardosbánya-2 (Tb-2)	4	79
Vértessomló Siltstone F.	Hole Agostyán-2 (Agt-2)	1	20
	Hole Vértesomló-8 (Vst-8)	1	15
Tés Clay F.	Hole Pusztavám-980 (Pv-980)	1	19

Bersek Marl Formation

The Bersek Marl is the lower part of the Lower Cretaceous clastic sequence in the Gerecse Mountains. Detrital spinel compositions of the turbiditic sandstone intercalations show the largest variety all of the samples in Cr# and Mg#, ranging from 0.3 to 0.85 and from 0.4 to 0.75, respectively (Fig. 6a). Only 1% of the data set fall below the critical Cr# value of the harzburgite field (0.4) determined by Pober and Faupl (1988). A greater part of the analyses is within the harzburgite field, whereas the remaining data points plot within the lherzolite field. Exceptionally high TiO_2 and Fe_2O_3 wt% are found in this formation (0.65 wt% and 2.21 wt%, respectively, Fig. 6a, Table 2). Based on its higher TiO_2 value it shows a transition towards cumulus spinels, which was also supported by the wide range in the Cr/Al ratio. The Mg# variation is greatest of all in the data sets (0.4–0.75) probably reflecting the complex melting history of the provenance area (Dick and Bullen 1984).

According to the classification of Dick and Bullen (1984) the spinel association of the Bersek Marl Formation can be described as Type II alpine peridotites and ophiolites, indicating a multistage melting history of the source area. The detrital spinel grains probably came from the harzburgitic rocks on the one hand, and from the ultramafic cumulates (dunite) on the other hand.

Lábatlan Sandstone Formation

In the overlying Lábatlan Sandstone Cr/Al ratios and Mg# ranges are in a narrower domain than in the Bersek Marl Formation; the lower Cr# limit is 0.4 and the upper Cr# limit is 0.8. Most data are concentrated between 0.45–0.7, whereas the Mg# ranges are in a narrow compositional field (0.5–0.7), falling into the harzburgite field (Figs 6b, 7b). With regard to the classification of Dick and Bullen (1984) the Lábatlan Sandstone can be defined as Type II alpine peridotites and ophiolites.

Köszörűkőbánya Conglomerate Member

This is the terminating member of the Cretaceous clastic sedimentary cycle in the Gerecse Mountains. Upwards in the flysch sequence the Cr# values and TiO_2wt% show a slight shift in their variation; they range in a narrower domain than those of Bersek Marl and Lábatlan Sandstone. The majority of data fall between 0.45 as lower Cr# limit and 0.75 as upper limit (Fig. 6c). There is no data larger than 0.2 of TiO_2 wt% (Fig. 7c), which is the boundary between the field of ultramafic cumulates and lherzolite-harzburgite as described Pober and Faupl (1988). Consequently, the Cr-rich spinels of the Köszörűkőbánya Conglomerate are harzburgitic in composition and can be classified as Type III alpine peridotites and ophiolites based on their higher Cr# values and lower TiO_2 wt%, which is related to the earliest stage of island arc formation developed on oceanic crust.

Table 2

Representative microprobe analyses of the detrital spinel grains: oxide compositions, cation numbers. FeO = sum Fe. Cation numbers based on 32 oxygens. Fe^{3+} were calculated by Droop's equation (Droop 1987). Computer program made by Sz. Harangi (Eötvös University, Budapest)

	1	2	3	4	5	6
TiO2	0.65	0.00	0.04	0.12	0.00	0.05
Al2O3	21.16	31.62	39.48	23.36	19.82	32.97
Cr2O3	46.56	37.31	28.50	46.80	49.67	37.14
FeO	19.86	17.69	15.67	14.83	18.75	12.58
MnO	0.34	0.27	0.15	0.20	0.35	0.08
MgO	11.74	13.02	15.38	14.54	11.37	16.44
Sum.:	100.31	99.91	99.22	99.85	99.96	99.26
Fe2O3:	2.21	0.89	1.35	1.56	1.39	0.77
FeO:	17.87	16.89	14.46	13.43	17.50	11.89
newSum:	100.53	100.00	99.36	100.01	100.10	99.34
Cation numbers based on 32 oxygens						
Ti	0.1208	-	0.0056	0.0208	-	0.0072
Al	6.1936	8.8384	10.6104	6.6832	5.8664	9.0240
Cr	9.1424	6.9960	5.1376	8.9816	9.8640	6.8192
Fe2	3.7112	3.3488	2.7560	2.7256	3.6744	2.3080
Mn	0.0704	0.0528	0.0280	0.0400	0.0736	0.0144
Mg	4.3456	4.6024	5.2272	5.2608	4.2568	5.6904
cal Fe3	0.4128	0.1592	0.2312	0.2840	0.2632	0.1336
mg#:	0.54	0.58	0.65	0.66	0.54	0.71
cr#:	0.60	0.44	0.33	0.57	0.63	0.43
CAT#:	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000

The chemical compositions of chrome spinels of the above-mentioned three formations show a very close similarity to those of the Rossfeld Formation of the Northern Calcareous Alps (Pober and Faupl 1988; Faupl and Pober 1991).

Neszmély Formation

In the western part of the Gerecse Mountains, this clastic formation was deposited in a submarine fan contemporaneously with the sequence of the East Gerecse Mountains. In the case of the Neszmély Sandstone a slight shift can be recognized toward higher Cr# values, which range from 0.45 to 0.8 (Fig. 8a, b). In contrast to the spinel composition of the East Gerecse Mountains, 10% of the data are above the 0.7 Cr# value, implying that the Neszmély Sandstone

Table 2 (cont.)
Samples: 1–4. Bersek Marl Formation, Bersek quarry; 5–8. Lábatlan Sandstone Formation, Bersek quarry; 9. Köszörűkőbánya Conglomerate Member, Köszörűkőbánya quarry; 10–11. Neszmély Formation, Neszmély-4 borehole; 12–13 Neszmély Formation, Tardosbánya-2 borehole

7	8	9	10	11	12	13
0.09	0.00	0.00	0.21	0.04	0.13	0.09
29.63	35.75	26.03	19.30	31.39	30.09	22.44
38.30	32.68	43.47	50.62	38.58	37.67	45.45
16.50	15.90	17.13	16.41	16.51	18.34	18.28
0.21	0.16	0.22	0.33	0.21	0.22	0.28
13.73	15.09	12.27	12.77	13.90	14.05	13.00
98.46	99.58	99.12	99.64	100.63	100.50	99.54
1.47	1.69	0.22	1.15	0.76	3.21	3.13
15.18	14.38	16.93	15.37	15.83	15.45	15.46
98.61	99.75	99.14	99.76	100.71	100.82	99.85
0.0152	-	-	0.0384	0.0056	0.0224	0.0160
8.4056	9.7336	7.5248	5.6880	8.6856	8.3600	6.5200
7.2888	5.9680	8.4296	10.0096	7.1608	7.0208	8.8592
3.0552	2.7784	3.4728	3.2152	3.1064	3.0464	3.1872
0.0416	0.0304	0.0448	0.0688	0.0408	0.0432	0.0576
4.9256	5.1952	4.4856	4.7600	4.8640	4.9360	4.7768
0.2648	0.2928	0.0400	0.2168	0.1336	0.5680	0.5808
0.62	0.65	0.56	0.60	0.61	0.62	0.60
0.46	0.38	0.53	0.64	0.45	0.46	0.58
24.0000	24.0000	24.0000	24.0000	24.0000	24.0000	24.0000

can be described as Type III alpine peridotites and ophiolites. However, based on the greater range of TiO_2 wt% (Fig. 9b), the samples of the Neszmély-4 borehole may reflect the transition toward cumulus spinels. In the Tardosbánya-2 (Tb-2) borehole spinel grains have lower Mg# values than those of borehole Neszmély-4 (N-4); therefore, they can be described as Type II alpine peridotites and ophiolites rather than Type III.

Vértessomló Siltstone Formation

The data sets of the hemipelagic Vértessomló Siltstone of the Late Aptian to Early Albian resemble those of the Neszmély Formation. Geochemical compositions of spinels from the two studied boreholes differ slightly from

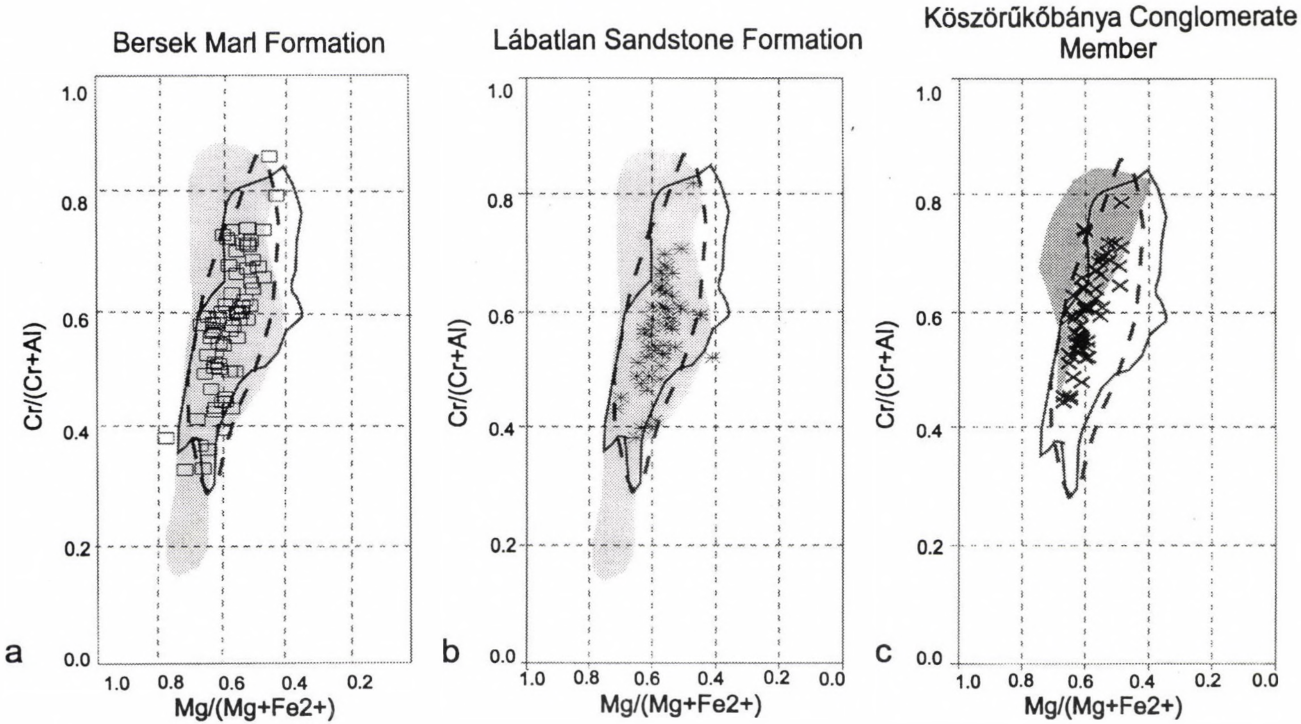

Fig. 6
Geochemical composition of detrital spinel grains of the a. Bersek Marl Formation turbiditic sandstone intercalations, b. Lábatlan Sandstone Formation Bersek quarry, and c. Köszörűkőbánya Conglomerate Member of Lábatlan Sandstone Formation Köszörűkőbánya quarry, Borehole Lábatlan-36 plotted into the Cr# vs. Mg# diagrams. Solid line: compositional field of spinels from Rossfeld Formation of the Eastern Alps (Pober and Faupl 1988). Dashed line: compositional field of harzburgites (Pober and Faupl 1988). Lighter area: compositional range of Type II alpine peridotites and ophiolites, darker area: compositional range of Type III alpine peridotites and ophiolites (Dick and Bullen 1984)

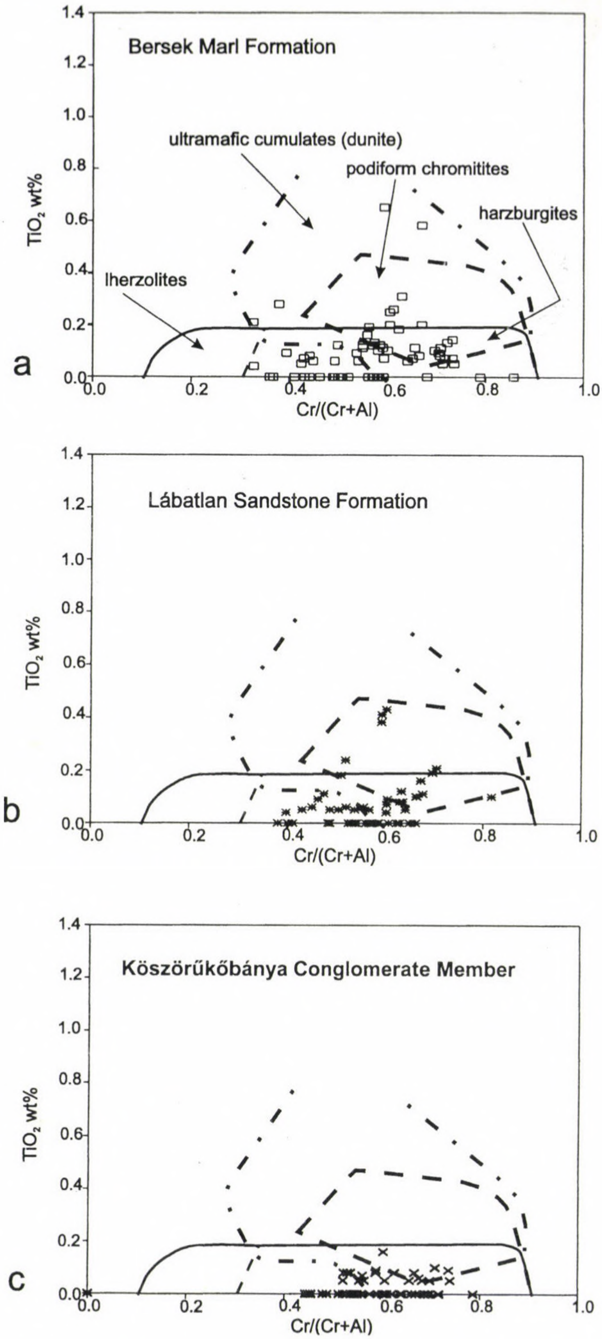

Fig. 7
Comparison of spinel compositions of the a. Bersek Marl Formation turbiditic sandstone intercalations, b. Lábatlan Sandstone Formation Bersek quarry, and c. Köszörűkőbánya Conglomerate Member of Lábatlan Sandstone Formation Köszörűkőbánya quarry, Borehole Lábatlan-36 in the TiO_2 wt% vs. Cr# diagram. Compositional range of lherzolites, harzburgites, podiform chromitites, ultramafic cumulates dunites indicated after Pober and Faupl (1988)

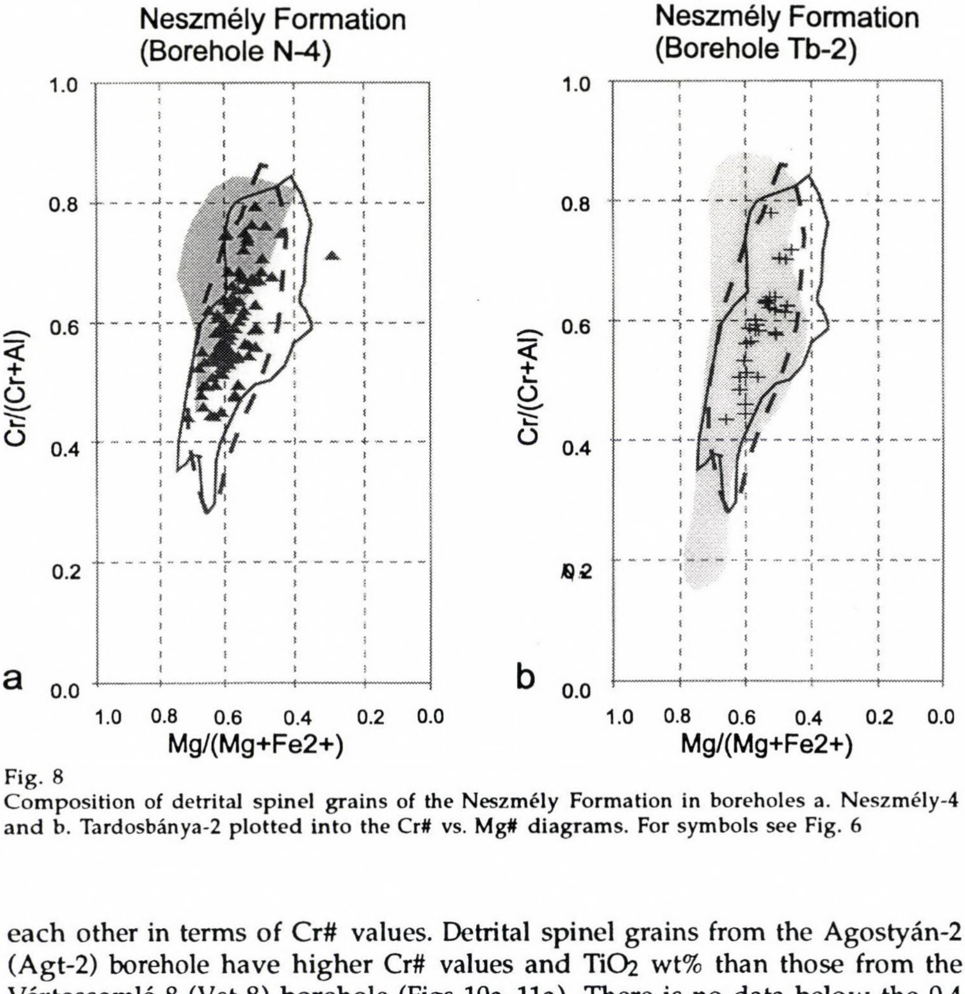

Fig. 8
Composition of detrital spinel grains of the Neszmély Formation in boreholes a. Neszmély-4 and b. Tardosbánya-2 plotted into the Cr# vs. Mg# diagrams. For symbols see Fig. 6

each other in terms of Cr# values. Detrital spinel grains from the Agostyán-2 (Agt-2) borehole have higher Cr# values and TiO_2 wt% than those from the Vértessomló-8 (Vst-8) borehole (Figs 10a–11a). There is no data below the 0.4 Cr#-value, which is the lower limit of the harzburgite field (Fig. 10a). Based on the different Cr# range of the studied boreholes, the Vértessomló Siltstone Formation can be classified either as Type II or Type III alpine peridotites and ophiolites.

Tés Clay Formation

Contemporaneously with the deposition of the hemipelagic Vértessomló Siltstone Formation, dark gray, muddy marl was deposited in brackish water conditions in the Vértes and Bakony Mountains (Császár and Árgyelán 1994). It is noteworthy that the Tés Clay Formation contains the last occurrences of detrital chrome spinel grains in the Vértes and Bakony Mountains. Cr# and

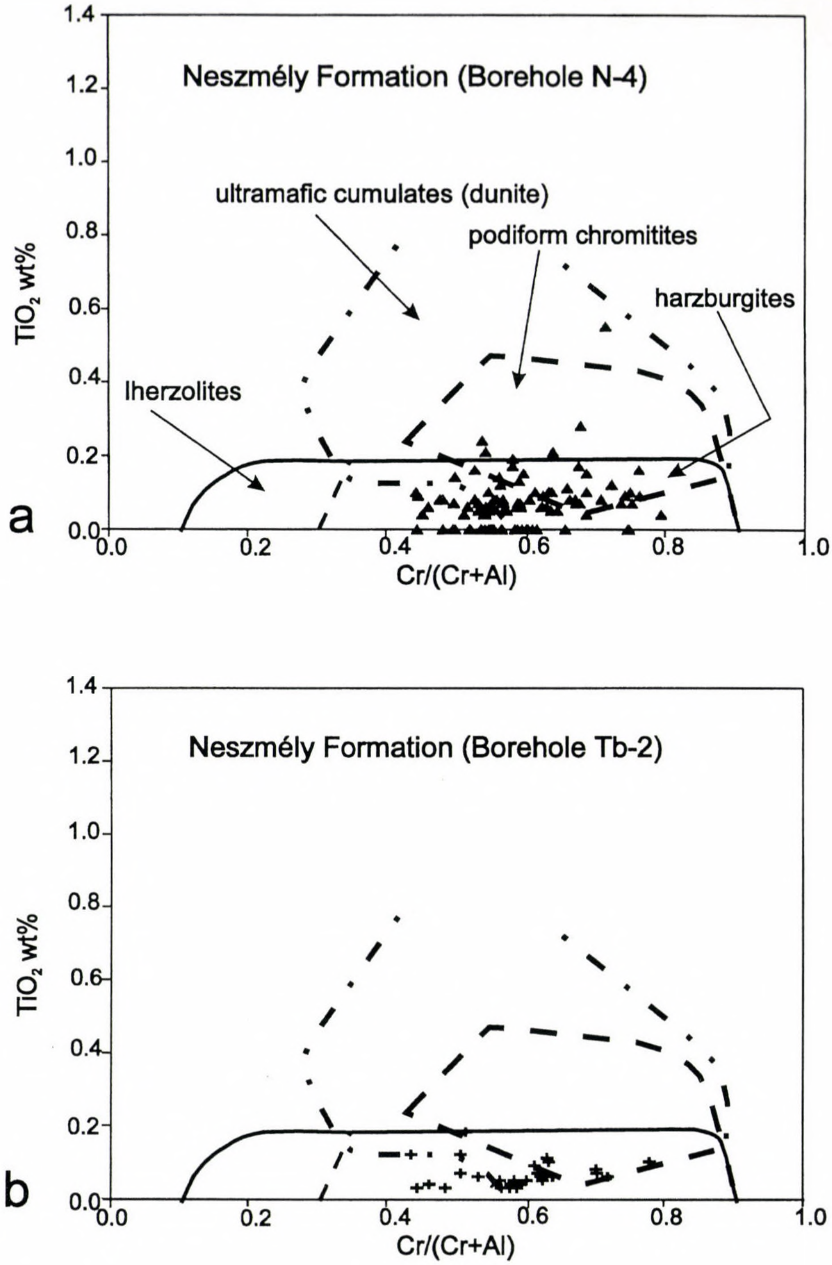

Fig. 9
Spinel composition of the Neszmély Formation in boreholes. a. Neszmély-4 and b. Tardosbánya-2 in terms of Cr# and TiO_2 wt%

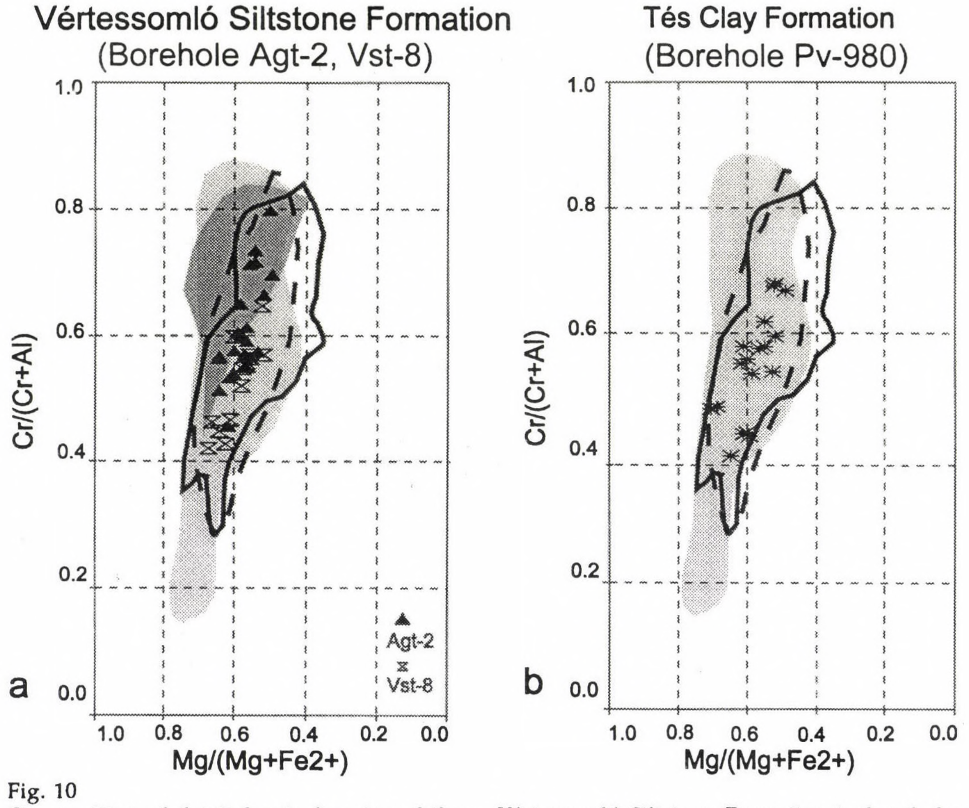

Fig. 10
Composition of detrital spinel grains of the a. Vértessomló Siltstone Formation in boreholes Agostyán-2 and Vértessomló-8, and the b. Tés Clay Formation in borehole Pusztavám-980, plotted on the Cr# vs. Mg# diagram. For symbols see Fig. 6

Mg# values fall within the harzburgite field, similar to those of Gerecse Mountains.

In summary, most detrital spinels are rich in chromium, falling into the harzburgite field of Pober and Faupl (1988) and can be described as Type II or/and Type III alpine peridotites and ophiolites (Dick and Bullen 1984). The higher TiO_2 wt% (>0.2) and the wide ranges of Mg# and Cr# suggest a transition toward cumulus spinels and reflect the complex melting history of the source area, whereas the high Cr# (>0.4) indicates the formation of a volcanic arc on oceanic crust. Al-rich spinel assemblages from lherzolite have not been found in the Gerecse Mountains and Vértes Foreland.

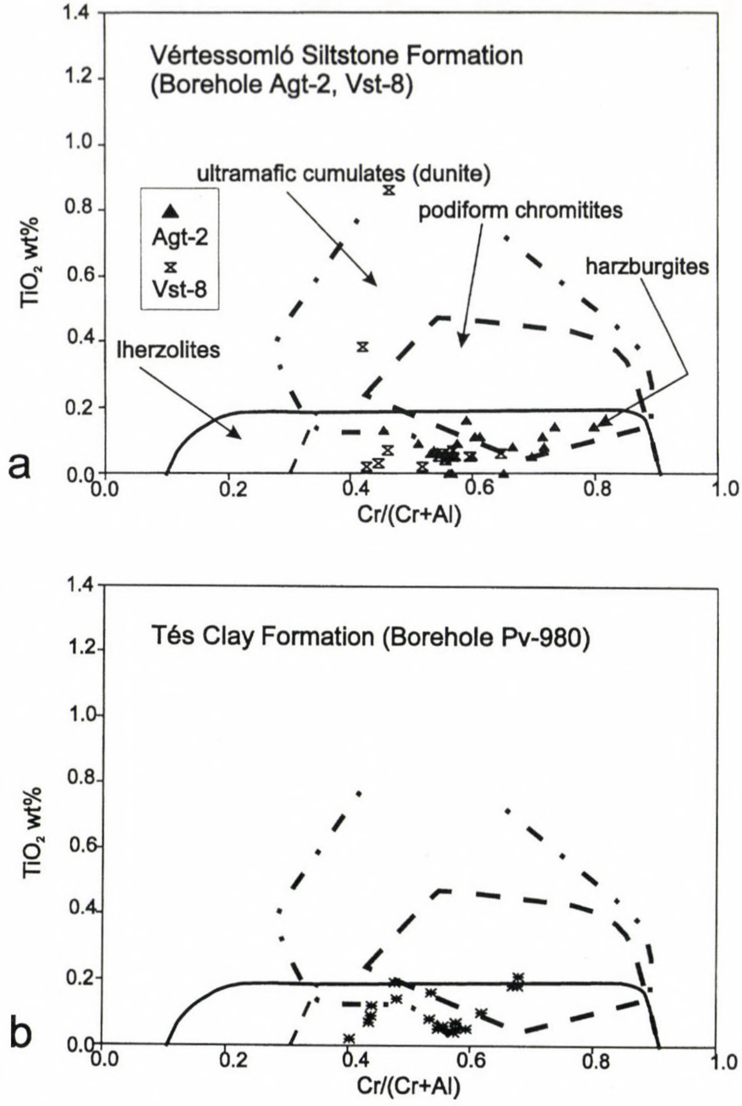

Fig. 11
TiO_2 wt% content of the spinel grains of the Vértessomló Siltstone Formation and the Tés Clay Formation

Palaeogeographic relations

Close facies similarities between the Lower Cretaceous clastic succession of the Gerecse Mountains of the Transdanubian Central Range and the Rossfeld beds of the Northern Calcareous Alps have been known for a long time (Hantken 1868; Fülöp 1958). The first palaeogeographic studies were based mainly on lithology (marl, sandstone and conglomerate facies) and the ammonite assemblage. According to the earlier palaeogeographic reconstructions of the Alpine–Carpathian–Dinaridic region the TCR could have been situated between the Southern and Eastern Alps on the southern side of the Tethys–Vardar ocean (Kovács 1982; Kázmér and Kovács 1985; Császár and Haas 1984; Faupl and Wagreich 1992; Csontos 1992) from the Triassic to the Jurassic.

In the axial part of the Alpine–Mediterranean chains two main oceanic suture zones (Tethys–Vardar ocean and Ligurian–Piemontais (=South Penninic) ocean) were formed, which distributed their clastic contents into the Eastern Alps and the Dinaridic unit. These ophiolite complexes have different geochemical characteristics and histories (Beccaluva et al. 1980; Weissert and Bernoulli 1985; Knipper et al. 1986). The fragments of the South Penninic oceanic crust constitute the detrital fraction of the Losenstein Formation and the Lower Gosau Subgroup of the NCA as well as of the Lower Austroalpine Unit and South Penninic mid-Cretaceous sediments (Pober and Faupl 1988).

The Vardar ophiolites are found along the internal chain of the Dinarids, showing rapid changes from one outcrop to another. They consist of tectonites (mainly harzburgites), cumulates covered by MORB and calc-alkaline volcanics (Knipper et al. 1986; Ricou et al. 1986). The roles of amphibolite-facies metamorphism can be recognized in cumulates. During the Jurassic oceanic lithosphere was created at a spreading centre and then involved in intraoceanic subduction, generating an island arc on the oceanic crust. The next major tectogenesis was the collision of the Austroalpine and Dinaridic continent by the obduction of this island arc onto the Dinaridic realm (Ricou et al. 1986; Csontos 1992). The first tectonic event might have formed the harzburgite subprovince characterized by Cr-rich spinels and the second one probably generated the lherzolite subprovince with Al-rich spinels (Dercourt et al. 1986; Knipper et al. 1986; Ricou et al. 1986). Maksimović and Majer (1981) have distinguished two main ultramafic zones in the Dinarids; the Inner zone (harzburgite) in the east and the Central zone (lherzolite) in the west. In spite of this, according to Pamić (1983), there is a continuous transition between them.

As a result of the Early Cretaceous tectonic movements the Tethys–Vardar ocean basin was closed, and its detritus (chrome spinels and volcanic rock fragments) could have been eroded and transported to the sedimentary basins surrounded the obduction zone from the earliest Cretaceous. In the NCA, the chrome spinels of the Rossfeld Formation of Valanginian to Aptian age came from the harzburgite subprovince of the Tethys–Vardar ocean, while the aluminious spinels of the Aptian-Albian Lavant Formation in the Drauzug unit and the Upper Cretaceous Gosau Group (southern provenance) probably corresponds to the lherzolite subprovince of the suture zone (Pober and Faupl 1988).

This multistage tectonic evolution of the ophiolite complex is also reflected by the detrital spinel composition of the Gerecse Mountains (e.g. large variation in Cr# and occasionally in Mg#, as well as in high TiO_2 wt% — higher than 0.2). Close similarities of chrome spinel chemistry in the Gerecse Mountains of the TCR and in the Rossfeld Formation of the NCA suggest that the main provenance area was the same. Thus, the detrital chrome spinels of the studied Lower Cretaceous clastic sediments could have been come from the harzburgite subprovince of the Tethys–Vardar suture zone, as in the case of the Rossfeld Formation (Árgyelán 1992, 1995a, 1995b).

However, there are a few dissimilarities in the detrital framework (e.g., presence of serpentinites, dolerites and other basic rock fragments up to 2 mm in size; see section 2), indicating that the Gerecse Mountains must have been located closer to the suture zone than the Rossfeld Formation. Probably the longer transport distance may have been the cause for the absence of similar lithic fragments in the NCA.

Another interesting point is that the Al-rich spinels (sourced from the supposed lherzolite subprovince of the suture zone) are absent in the Gerecse Mountains. In the region studied the first appearance of Al-rich spinel has been reported from the Aptian to Albian Lavant Formation in the Drauzug unit, whilst the last chrome spinel occurrence was found in the Upper Aptian to Lower Albian hemipelagic siltstone (Vértessomló Siltstone Formation) in the Gerecse Mountains and Vértes Foreland, and in the Albian brackish-water clay (Tés Clay Formation) in the Vértes Foreland. Therefore, the obducted oceanic crust, harzburgitic in composition, should have been exposed at the surface until the deposition of Tés Clay Formation.

The overly wide occurrences of detrital chrome spinel and aluminous spinels in the Cretaceous sediments of the Tethys belt (Fig. 1) suggest that the obducted and uplifted crust of the Tethys–Vardar ocean might have been the general source area of the sediments deposited from the Berriasian/Early Valanginian until the Late Cretaceous. Either no lherzolitic rocks were obducted in the Gerecse sector, or the tectonic movements of the Austroalpine unit, which started in Albian time, caused the absence of aluminous spinels in the Gerecse Mountains.

Unfortunately, no analytical data of detrital chrome spinel have been published until now from the analogous areas (Oštrc Formation in the Dinarids, Oravice Formation in the W. Carpathians, see Fig. 1), so that we must rely only on the earlier sedimentological, paleontological and geodynamic reconstruction.

Conclusions

The chemistry of detrital chrome spinel grains from the Lower Cretaceous sequences of the Gerecse Mountains and the Vértes Foreland were examined by electron microprobe analysis. The main conclusions are as follows:

1. Compositional populations of spinels from the Gerecse Mountains fall into the harzburgite field of Pober and Faupl (1988), consequently showing close similarities to those of the Rossfeld Formation of the Eastern Alps.

2. The majority of data sets can be described as Type II and Type III alpine-type peridotites and ophiolites. The former has a large variation in Cr# and TiO_2 wt%, reflecting a complex multistage melting history of the source area. The latter is typically harzburgitic in composition, indicating the formation of an island arc on oceanic crust based on the peridotite types of Dick and Bullen (1984). Therefore, the proposed geodynamic evolution of the Tethys–Vardar ocean can be traced by the geochemistry of detrital chrome spinel from the Gerecse Mountains.

3. The source rocks for the detrital sequence of the Gerecse Mountains may have been the harzburgite subprovince of the Tethys–Vardar suture zone, similar to that of the Rossfeld Formation. The detritus of the lherzolite subprovince has not been found in the Gerecse Mountains.

4. The heavy mineral assemblages and the detrital spinel chemistry support earlier palaeogeographic concepts suggesting that the TCR was probably situated in the S–SW part of the Tethys–Vardar ocean at least from the Triassic until the Early Cretaceous. The Tethys-Vardar ocean was partially closed by the effect of Late Jurassic–Early Cretaceous tectonic movements, and its detritus (chrome spinels, ophiolitic rock fragments) were transported to the surrounding sedimentary basins forming the sequences of the Rossfeld Formation, Gerecse Mountains and the Oštrc Formation.

5. The geochemical investigations of detrital chrome spinels provided fresh evidence for the palaeogeographic connection of the sedimentary basins of the Gerecse Mountains and the Rossfeld Formation during the Early Cretaceous.

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Stratigraphic and facies evaluation of the Lower Triassic formations in the Aggtelek–Rudabánya Mountains, NE Hungary

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Thanks to a complex examination of the Lower Triassic formations of the Aggtelek-Rudabánya Mountains, the lithostratigraphic sub-division, outlined previously only in a general way, could be performed more accurately. In the uppermost part of the Bódvaszilas Sandstone Formation, a characteristic limestone horizon was distinguished, while within the Szin Marl Formation, seven lithologic units could be separated.

During the Scythian sediments were deposited on a homoclinal ramp. Sedimentation had proceeded over a wide area from the supratidal zone of the inner shelf, through the lagoon, the zones of washover fans, shoals, and mid-ramp storm sheets, to the outer ramp. On the basis of the water depth changes during the Scythian, four third-order relative sea-level change cycles could be detected within the sequence. They are well correlatable with cycles of Scythian sequences in other areas.

The entire Scythian sequence could be divided into five biozones. These are as follows: *Claraia clarai*, *Claraia aurita*, *"Eumorphotis"*, *Tirolites cassianus*, and *Tirolites carniolicus* Zones. With the help of the biozones, the age of the formations and their members could be determined more accurately. It was found that the Perkupa Evaporite Formation reaches up to the Upper Griesbachian. The Bódvaszilas Sandstone Formation extends from the Upper Griesbachian to the end of the Smithian, while the Szin Marl and the Szinpetri Limestone Formations correspond to the Spathian. Due to the poor fossil content of the formations, the Permian/Triassic and Scythian/Anisian boundaries cannot be drawn unambiguously.

Key words: Lower Triassic, Aggtelek–Rudabánya Mts, Hungary, ramp sequence, facies, lithostratigraphy, biostratigraphy, chronostratigraphy, palaeogeography

Introduction

The Aggtelek–Rudabánya Mts (NE Hungary) are the southernmost, Hungarian part of the Mesozoic range of the South Gemer Unit. They are made up of the Silicicum, Meliaticum, and Tornaicum tectonic units. Their formations can be traced through the Slovakian Karst to the southern boundary of the Gemer Paleozoic, the Roznava Line (Fig. 1).

On the Hungarian side, Lower Triassic formations are known only in the Silicicum (Less et al. 1988; Kovács et al. 1989); however, they are present in all its three tectofacies units – Aggtelek, Bódva, and Szőlősardó (in the Szőlősardó tectofacies, the extension of the tectonically reduced formations is very limited)

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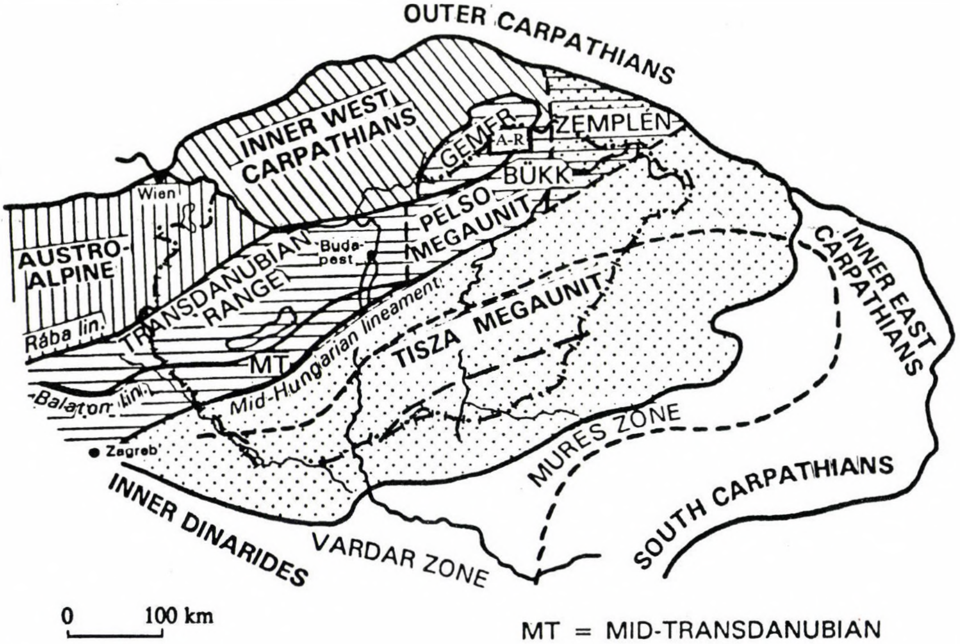

Fig. 1
Position of the Aggtelek-Rudabánya Unit (A–R) in the system of megatectonic units making up the basement of the Pannonian Basin, after Haas et al. (1995)

(Fig. 2). On the Slovakian side they are present in the Tornaicum as well. The pre-rift Lower Triassic formations, and also the Gutenstein and Steinalm Formations, deposited prior to the oceanic rifting which began in the Pelsonian, are still of uniform facies in the three units, apart from small differences.

By mapping some parts of the area in which Lower Triassic formations are found, the lithostratigraphic subdivision previously established by Kovács et al. (1989) and Róth (1993a, b, c) could be presented more accurately: within certain formations, additional lithologic units could be distinguished. Consequently, the redefinition of the units has also become necessary.

On the basis of the sedimentologic and facies examination of the units, I established a general facies model of the formations. Analysing the vertical successions of the facies and taking into account the relative amount of terrigeneous grains transported onto the shelf, I interpreted the water depth changes and transgressive–regressive processes which took place during the Scythian.

In the case of certain fossils, important from the point of view of biostratigraphic and chronostratigraphic evaluation (e.g. *Cyclogyra? mahajeri* (Brönn., Zan., Boz.), *Rectocornuspira kalhori* (Brönn., Zan., Boz.), *Eumorphotis hinnitidea* (Bitt.), and *Tirolites* species), the clarification and more exact

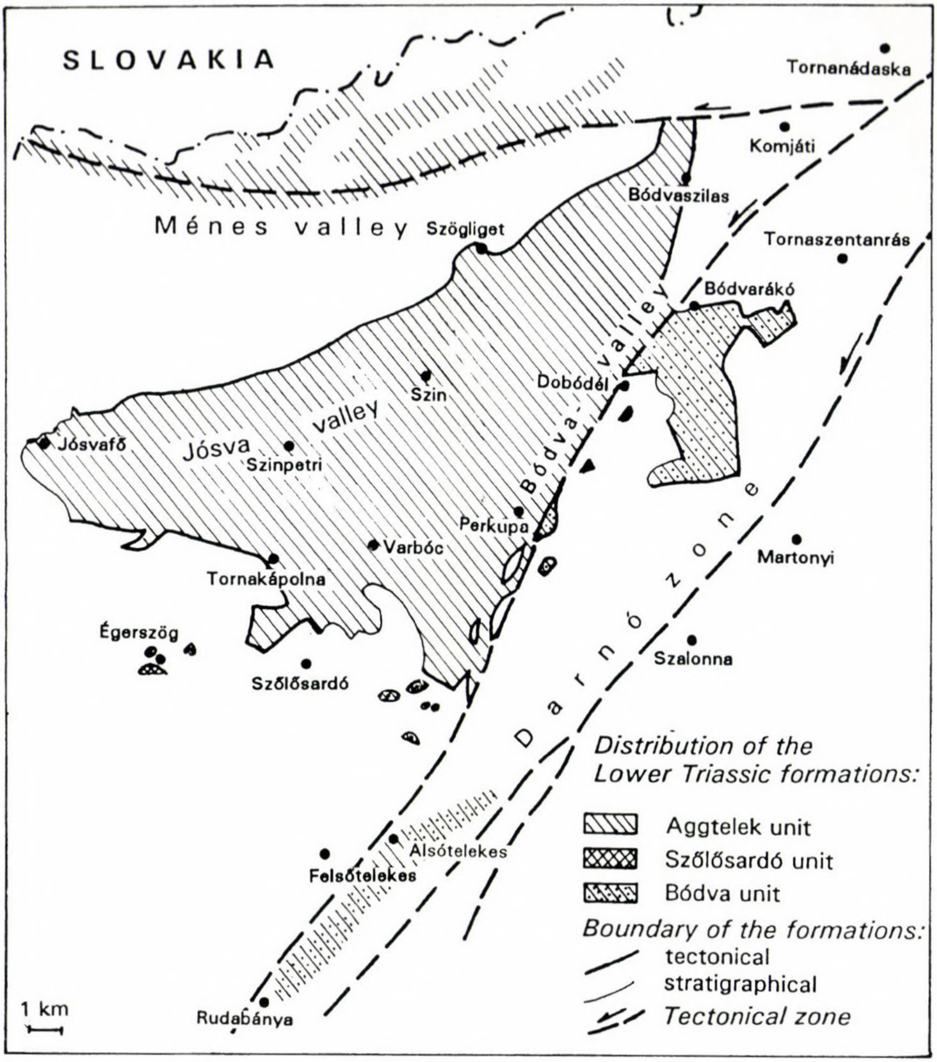

Fig. 2
Sketch map of the surficial distribution of the Lower Triassic formations

determination of their occurrence within the sequence were of prime importance. Fossils deriving from former collections required taxonomic revision. On the basis of these specimens and the newly found ones, the uniform and overall biostratigraphic subdivision of Lower Triassic formations of the Aggtelek-Rudabánya Mts became possible the first time. Thanks to this, I was able to make a more precise chronostratigraphic classification of the formations and their members.

Finally, the sequence of the Aggtelek-Rudabánya Mts is fitted into the paleogeographic model of the western termination of Tethys.

Review of the history of geologic knowledge

Geologic mapping at 1:25,000 scale, completed by the Hungarian Royal Geological Institute in 1907 over two areas, partly in the territory of present-day Slovakia (Böckh 1909; Vitális 1909), resulted in the discovery of several fossil-bearing locations. By means of fossils, sediments of the Lower Triassic were divided into two parts, the Seisian and Campilian beds (Fig. 3), in compliance with the practice developed generally in the Alpine–Carpathian–Dinaric facies areas.

In the 1940s, maps by Balogh (1945, 1948, 1950, 1953b) provided newer knowledge about the Lower Triassic formations. He connected the "coarse breccia containing red feldspar grains" with the "Seisian" sandstone NW of Bódvaszilas (Balogh 1953a), and subdivided the "Campilian" stage, providing the basis of the present-day subdivision (Fig. 3).

As a result of geological mapping at 1:10,000 completed in 1985 by the Hungarian Geological Institute, which aimed at a revision of previous work, rock units were assigned to formations (and partly to members) according to modern stratigraphic requirements (Grill et al. 1984; Kovács 1984; Róth 1987, 1988; Less et al. 1988; Kovács et al. 1989; Róth 1993a, b, c) (Fig. 3). Accordingly, the Bódvaszilas Sandstone Formation corresponds to the former "Seisian" and the Szin Marl Formation and Szinpetri Limestone Formation to the lower and upper parts of the unit formerly known as "Campilian".

VITÁLIS 1909	BALOGH 1953 a, b	KOVÁCS ET AL. 1989	
Campilian	bluish grey platty or thin bedded limestones	Szinperti Limestone F.	Jósvafő Limestone M.
	shales and marls yellowish and brown limestones		Szinpetri Limestone s. str.
	dark grey platty limestones alternation of purplish beige or grey limestones and shales redish brown sandstones	Szin Marl Formation	
			Véghegy Sandst. M
	brownish, greenish shales purple-brown ooidic limestones yellowish brown sandstones		
			Miklóshegy Limest. M
Seisian	Seisian sandstones and breccias	Bódvaszilas Sandstone Formation	

Fig. 3
Main lithostratigraphic subdivisions of the Lower Triassic formations

Sedimentologic characterisation of lithostratigraphic units

In the following section, I will deal with the accurate definition and lithologic division established for individual units, together with sedimentological and facies features (Fig. 4).

Bódvaszilas Sandstone Formation

Definition

Alternation of purplish-red, possibly greenish-grey sandstones, siltstones and shales. In the uppermost part of the formation, red ooilitic limestones also appear (Fig. 5).

Despite the prevalence of rocks of finer grain size in the lower part of the sequence, and of coarser grain size in the upper one, markedly different members cannot be distinguished within the formation. It is worth mentioning that the faunas of the two parts differ. The lower part is characterised by the presence of *Claraia* species and the upper one by that of *Eumorphotis* sp. (sensu Broglio Loriga and Mirabella 1986) and *E. hinnitidea* (Bitt.). However, a characteristic oolitic limestones horizon in the uppermost part of the formation can be traced throughout the entire area of distribution.

The thickness of the formation is 200–300 m. It is underlain by the Perkupa Evaporite Formation and overlain by the Szin Marl Formation. In both cases, the boundary of the formations is conformable; however, the lithologic change is rather sharp.

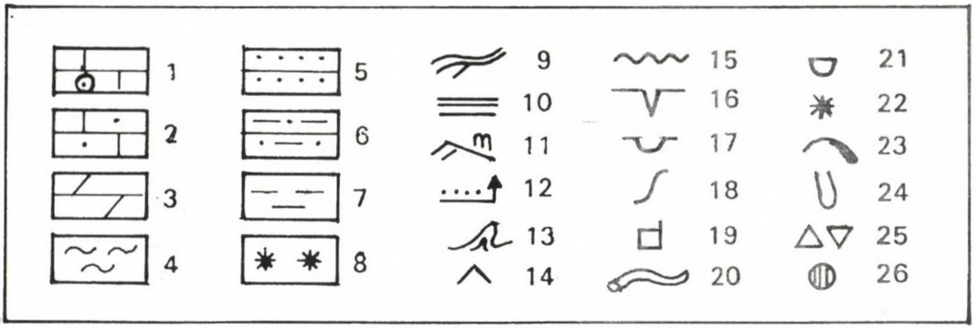

Fig. 4
Legend of the lithologic columns. 1. limestones oolites; 2. sandy limestones; 3. dolomites; 4. marls; 5. sandstones; 6. siltstones; 7. shales; 8. evaporites; 9. hummocky cross-stratification; 10. parallel-lamination; 11. micro-scale cross-lamination; 12. graded beds; 13. slumps; 14. ripple marks; 15. erosional surface; 16. desiccation cracks; 17. ball-and-pillow structures; 18. bioturbation; 19 pyrite; 20. trace fossils; 21 gutter casts; 22. evaporite-aggregates; 23 lumachelle; 24. U-shaped burrows; 25. intraclasts; 26. crinoids

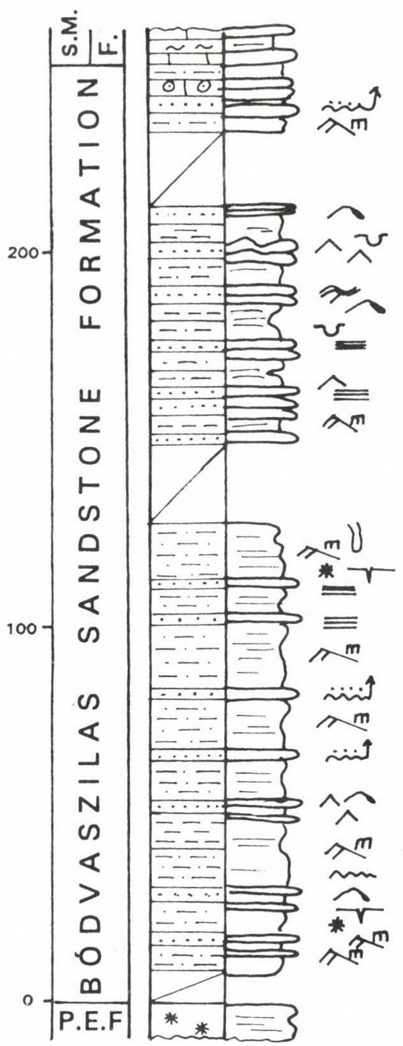

Fig. 5
Sequence of the Bódvaszilas Sandstone Formation. P.E.F. – Perkupa Evaporite Formation; S.M.F. – Szin Marl Formation

Lithology and sedimentological features

In the lower part of the formation the predominant lithofacies is made up of an alternation of red or green, parallel-laminated or micro-scale cross-laminated sand-streaked siltstones, with parallel-laminated silt-streaked shales and homogenous siltstone. Subordinately, flat, or cross-laminated as well as fine-grained sandstones occur in intercalations and in thinner packages, respectively. It is characteristic that the thicker the sandstone layers are, the thinner the siltstone and shale layers intercalated between them. The base of the sandstone layers is generally erosional. The thinner layers show a fining upward trend or planar cross-bedding. Thicker ones are constituted as follows: the bottom part as massive, homogenous and coarser- grained sand-stones, often with shell-coquinas, followed by finer-grained, siltstone-laminated, silty sandstones.

In red shales, mm-sized calcite, as pseudomorphs after evaporite-aggregates and on the bedding surface of the shales desiccation polygons can be found (Fig. 6). Wrinkle marks cover the bedding surface of the siltstones; furthermore, ripple marks and/or shell lumachelle are frequent on sandstone surfaces (Fig. 7). In certain horizons, sandstone layers composed of 3–25 cm thick, rusty brown, mica-rich, pulverised shells are characteristic.

Sediments were deposited in a shallow lagoon and on the related tidal flat. Sediments from the sand bars were reworked as washover fans into the open lagoon by major storms. On the tidal mud-flat, the subaerial exposure of the sediments over a shorter or longer period of time is reflected by surfaces with desiccation cracks and wrinkle marks (presumably the adhesion ripples are the recent analogy of later ones). The tiny evaporite-aggregates were formed during strong evaporation in the supratidal

Fig. 6
Desiccation cracks on the surface of reddish-brown shales. Bódvaszilas Sandstone Fm., Perkupa

Fig. 7
Bedding surfaces of fine sandstones with ripple marks and lumachelle, Bódvaszilas Sandstone Formation, Perkupa

mud. Coquinas were accumulated in the breaker zone. The zones which were more sheltered from currents and waves were populated by burrowing benthic organisms.

In the upper part of the formation the prevailing lithofacies is an alternation of thin or thick-bedded (1–25 cm), reddish-brown, fine-grained sandstones, siltstones and shales (Fig. 8). Small ball-and-pillow structures can be observed in the sandstone layers.

Deposition occurred in the well-circulated zone of the inner ramp. Load structures indicate the transportation and deposition of sediments of greater amount at a time, their formation can be connected to early diagenetic water escape processes (Lowe 1975).

In the uppermost part of the formation thin and thick-bedded (5–20 cm), stylolitic through cross-laminated red oolitic limestones and oolites with shell-coquinas form a characteristic horizon. In certain beds, fining-upward gradation can be observed: oolitic limestones turn into fine-grained sandstones. Between the layers there are mica-rich siltstone laminae.

Ooids were formed in an environment of permanently agitated water, probably in outer parts of narrow sand bars. Since the oolitic limestones are

Fig. 8
Thin sandstone layers alternate with siltstones and shales in the upper half of the Bódvaszilas Sandstone Formation, Perkupa

deposits in relatively thin horizons, where larger cross-bedded structures cannot be observed, it can be presumed that oolitic sandy material was reworked from its source area by storm currents and created washover fans. Finer-grained material was deposited from the suspension after the storms.

Facies model

Sedimentation proceeded in a storm- and wave-dominated, microtidal, inner ramp – lagoon environment restricted by sand bars, and in the related tidal flat environment, where a large amount of siliciclastic terrigenous sediments was transported into and reworked mainly by means of storms (Fig. 9).

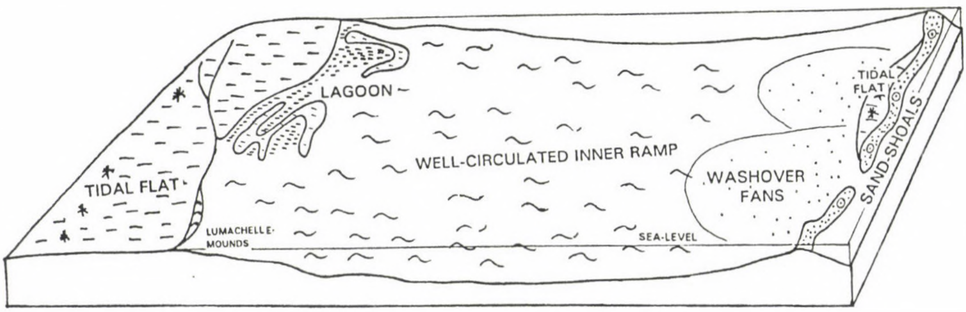

Fig. 9
Facies model of the Bódvaszilas Sandstone Formation

Under the oxidative conditions of the tidal flat and well-circulated inner ramp, the terrigenous grains deposited within and originally also in an oxidized state, could not be reduced. This is indicated by the red colour of the sediments. In the rocks of lagoonal facies, an alternation of laminae of red and green colours, formed mainly during the early diagenetic phase, reflects the original oxidative and reductive (richer in organic matter and partly restricted) conditions.

Cross-bedded sediments of tidal inlets have not been detected in the sequence. Similarly, no in-situ deposited sediments of narrow sand bars were found. This can be explained by the fact that their material (sand and ooids) was totally washed away from the primary place of accumulation and reworked by the intense storms.

Problem of the conglomerate – sandstone layer group formerly assigned to the formation

On the basis of my observations, the previously held assumption that lenses of Kavicsos Hill Conglomerate at Bódvaszilas are tidal channel fillings (Kovács et al. 1989) belonging to the formation (Balogh 1953a) must be modified. Earlier, Vitális (1909) mentioned the conglomerate and he considered it to be "a boundary layer of the Paleozoic or underlying of Triassic sediments".

Within the nearly 0.5 m thick beds of the red, unsorted, polymict conglomerates, stratification cannot be detected. The varicoloured conglomerate is composed of black radiolarite, pale red and light grey quartzite and greyish-red sandstone pebbles coated with red varnish. In the radiolarite pebbles Paleozoic radiolarians were found (Dosztály pers. comm. 1994). In a borehole sequence, sandstones related to the conglomerates are red, immature, feldsparic and do not contain plant fragments. Their grain size ranges from fine to coarse.

The coarse, detrital layers can be interpreted as fanglomerate, in an environment of a proximal fan established under an arid climate. This is indicated by the very poor sorting and red, varnish-like coating of the pebbles of extrabasinal origin as well as the almost total lack of structures caused by currents. The lack of inner stratification of the beds points to a sudden redeposition of the sediments in large amounts. The facies of the sandstones linked to the conglomerates is interpreted as arid alluvial plain.

The conclusion to be drawn from the above is that the rocks and their depositional environment differ considerably from the shallow marine sediments of the Bódvaszilas Sandstone Formation. Thus it should be separated from the Bódvaszilas Sandstone Formation as an independent lithostratigraphic unit. Presumably, it must belong to the underlying lithological unit of the Upper Permian–Lower Triassic Perkupa Evaporite Formation. Similar developments of red conglomerates and sandstones are characteristic of the underlying beds of the evaporite in Slovakia (Vozárová pers. com. on a field trip 1994).

Szin Marl Formation

Definition

It consists dominantly of alternating layers of brownish-grey, finely siliciclastic limestones and beige marls and clay marls. Subordinately, reddish-brown or varicoloured oolite, grey crinoidite and siliciclastic layers (fine sandstones, siltstones and shales) also appear (Fig. 10).

Seven lithological units can be distinguished (A–G) in the formation (Fig. 10). These cannot be defined as separate members because of lack of well-defined boundary between them, and sometimes their identification is hardly possible in the field. The two members defined previously by Kovács et al. (1989) are exceptions. The total thickness of the formation is about 350–370 m in the Aggtelek tectofacies unit, and somewhat more (about 400 m) in the Bódva tectofacies unit. The Szinpetri Limestone Formation covers it in both units; while the transition between the two formations is continuous in the Aggtelek tectofacies unit, the change is abrupt in the Bódva one.

Lithology and sedimentological features

The formation can be divided into the following units:

Lithological unit A makes up the lowermost part of the formation, from its base to the occurrence of thick-bedded oolites. Its thickness is about 35 m.

The characteristic litho-type of the unit is composed of grey, stylolitic oolites (grainstone), which are thickly bedded (10–70 cm) and show a thickening-upward trend. Thick-bedded bioclastic limestones (packstone/wackestone), thin-bedded, finely crystalline limestones (wackestone/ mudstone), which are dark grey and pyritic in one level, and thin, platy marl intercalations punctuate the oolite beds. The marly bedding surfaces are often full of trace fossils. Variegated dolomitic siltstones and laminated, brecciated, silty dolomites alternate with green shales and thin layers of red, fine sand-streaked siltstones, the bedding planes of which are covered by shrinkage cracks or ripples.

The ooids were formed in the subtidal surge zone on the edge of the inner ramp. Presumably only smaller shoals were built up by ooids. The ooids were redeposited by storms, forming amalgamated lobes, so that in the sequence they cannot found as in-situ depositions. The intercalating layers formed on a well-circulated inner ramp and in a low-energy, restricted lagoon.

Lithological unit B develops as a continuous transition while the thick-bedded grey oolites disappear. The characteristic red oolite intercalations form its upper boundary. Its thickness is about 120 m.

The following litho-types alternate:

1) Thick-bedded hummocky cross-stratified (grainstone) beds (Fig. 11) of which bases

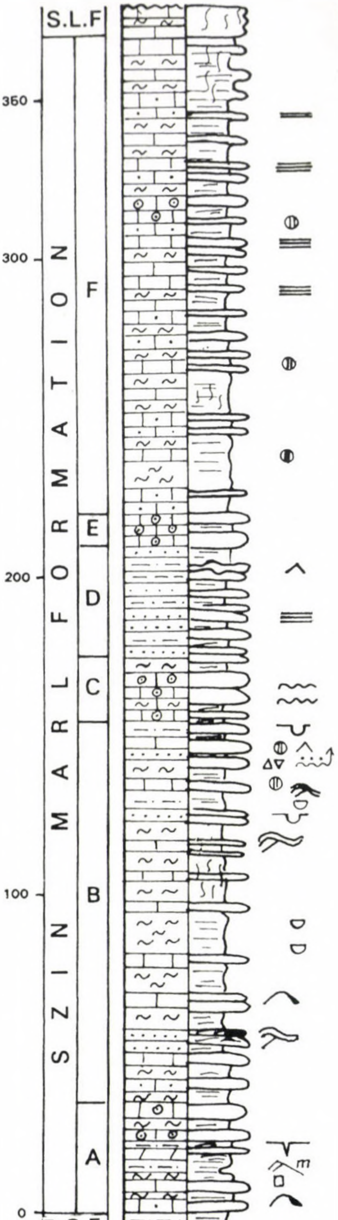

Fig. 10
Sequence of the Szin Marl Formation, in the Aggtelek tectofacies unit. B.S.F. – Bódvaszilas Sandstone Formation; S.L.F. – Szinpetri Limestone Formation

are eroded; the uppermost part thereof is often cross-laminated, and the bedding surfaces display ripples. In the beds, fining-upward gradation can be observed with the concentration of the intraclasts near their base.

2) Glauconitic, fining-upward crinoidal limestones (packstone/wackestone). Gutter casts, on the base of the layers or as limestone lenses (Plate II, Fig. 2) in the marls, are frequent in some levels.

3) Thickly bedded (6–30 cm) beige, brown, parallel-laminated or hummocky and swaley cross-stratified lime-cemented, fine, quartz sandstones (Fig. 12). Their layers were deposited with sharp bases, where loading structures occasionally occur, and bedding planes are covered by micas. The fine sandstone beds form thick ball-and-pillow structured levels in the upper part of the unit.

4) Alternation of grey, finely crystalline limestones (mudstone) and marlstones in thin layers. The bedding surfaces are often full of trace fossils and the marls laminated or bioturbated.

5) Intercalations of laminated or bioturbated siltstones (Fig. 13) and marlstones. Ammonites were found in some horizons.

The coarser-grained, sandy sediments were deposited in the proximal zone of the mid-ramp, above the storm wave base, where they were piled up as hummocks, or formed veneers. Benthic organisms could not live in this high-energy environment because of the frequent and strong storms. The finer-grained sandy sediments were formed in the distal zone of the mid-ramp. Between storms, mud settled out of suspension and benthic fauna restocked the uppermost part of the sediments. The thin, finely crystalline limestones, which were formed in the outer ramp zone, intercalated in marls as distal storm layers. Gutter casts represent distal scour-and-fill marks of the storms. The strong bioturbation and the appearance of glauconite indicate a slow sedimentation rate in the low-energy zone, below the storm wave base.

Lithological unit C, the most characteristic part of the formation, begins with the first occurrence of red oolites and ends with thicker, red, siliciclastic beds, and simultaneously at this level the oolites disappear entirely. Its thickness is about 20 m. It corresponds to the previously-defined Miklóshegy Limestone Member[1] (Kovács et al. 1989).

Fig. 11 →
Thick-bedded coarse-grained crinoidal limestones with thin marl intercalations in the unit B of Szin Marl Formation, Perkupa

Fig. 12 →
Thickening-upward swaley- and hummocky cross-stratified fine sandstone beds in the unit B of Szin Marl Formation, Perkupa

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1 The original definition must be corrected in that the member composes not the base but the middle unit of the formation.

Fig. 13
Bedding surface of marls with trace fossils, unit B of Szin Marl Formation, Perkupa

The main litho-type of the unit is made up of red, thick-bedded and banked oolites (grainstone – Fig. 14) with blackened lumachelle. All the shells represent shallow water benthic specimens. The shelter pores beneath the shells are partly filled with calcite. The layers often overlie eroded surfaces with sharp bases. The uppermost part of the thinner beds is strongly bioturbated. The presence of light-grey, thick-bedded, coarse-grained crinoidites (grainstone) in the sequence is closely connected to the oolite beds. The oolite and crinoidite layers are interrupted by marl intercalations.

The oolites and crinoidites are considered to be proximal storm sheets redeposited onto the proximal zone of the mid-ramp from the shoals formed in high-energy shallow water, on the edge of the inner ramp.

Lithological unit D extends from the appearance of thicker, brownish-red siliciclastic layers up to the reappearance of red and grey oolites. Its thickness can only be estimated, but could be around 30–40 m. Although this is a characteristic unit, it is not easy to identify it in the field; microfacies studies are the only way

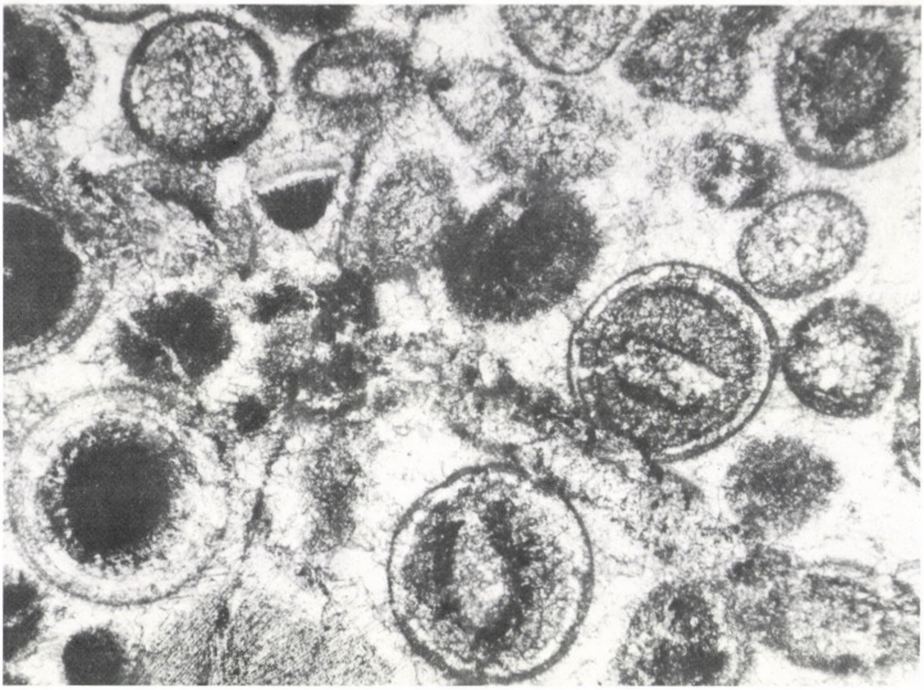

Fig. 14
Microfacies of the oolites (grainstone–bio-oopatite), unit C of Szin Marl Formation, Perkupa

to unambiguously distinguish it from similar rocks of the Bódvaszilas Sandstone Formation. It corresponds to the previously-defined Véghegy Sandstone Member[2] (Kovács et al. 1989).

Brownish-red, laminated sandstones, red, subordinately green, micro-scale cross-laminated, sand-streaked siltstones and silt-streaked shales alternate in thin to thick beds. It may occur that the beds are bioturbated or that the bedding surfaces are vermiculated.

The dominantly red siliciclastic layers were deposited on the inner ramp.

Lithological unit E extends from the appearance of the red and grey oolites up to their disappearance. Its thickness is about 5–10 m.

Variegated, red and grey oolites represent the characteristic lithotype, which is also similar in its development and facies to the oolites of the C lithological unit, the main difference being the lack of the blackened lumachelle. In addition, sandy limestones and limy sandstones can be found in the unit.

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2 With the correction that the lower boundary of the member is sharp, and does not develop by bed alternation.

Lithological unit F makes up the uppermost part of the formation in the Aggtelek tectofacies unit, and continuously passes over into the Szinpetri Limestone Formation. Its thickness is about 150 m.

It is made up of alternations of grey, finely crystalline or crinoidal limestones and marlstones. The lithological development in the lower part is similar to that in the lithological unit B, but in this case the fine-grained types dominate. The brownish-red and grey oolites, probably forming lens-like bodies, are quite similar to the type which occurs in the lithological unit E. In the upper part of the unit F bioturbated marls alternate with finely crinoidal or finely crystalline limestones.

The facies of the rocks in the lower part are also the same as in the above- mentioned unit B, namely the mid-ramp and outer ramp, while the inner ramp was the depositional environment of the sediments in the upper half of the unit.

Lithological unit G a variation of the uppermost part of the formation, can be found in the Bódva tectofacies unit. Its thickness is around 150–200 m.

Thin-bedded, grey, crinoidal limestones (wackestone), finely crystalline limestones (mudstone) and beige marlstones are the main lithotypes. Gutter casts at the base of limestone layers, or as lenses in marls, are frequent.

These sediments were deposited on the outer ramp and in the distal zone of the mid-ramp.

Facies model

The scenario of the arrangement of the depositional environments on the ramp was most likely as follows (Fig. 15). On the edge of the inner ramp, in the breaker-surf zone of the shallow subtidal zone, moving ooid sand shoals were built up as a result of strong, continuous wave agitation. Migration of the shoals may have taken place during storms, resulting in redeposition of ooids onto the proximal mid-ramp.

The well-circulated, moderate-energy, inner ramp with water of normal salinity, and behind it a low-energy, restricted lagoon, were separated by shoals. The water salinity in the lagoon differed from normal sea water, and the bottom water could be occasionally dysaerobic and depleted in oxygen. From shoals, washover fans spread out onto the inner ramp during major storms.

On the mid-ramp crinoidic, proximal storm sheets or hummocks bordered the outer flank of the ooidic shoals. In the direction of the distal zone, still above the storm wave base, siliciclastic and lime sands formed flat storm sheets of decreasing size. The outer ramp was the deepest depositional environment, where fine-grained sediments were deposited below the storm wave base. The adjoining facies zones continuously passed over into each other.

The supply of terrigenous siliciclastics, besides the carbonate accumulation, greatly influenced the sedimentation on the Aggtelek-Rudabánya ramp, which is why it differs from the typical carbonate ramps. The mixed (siliciclastic and

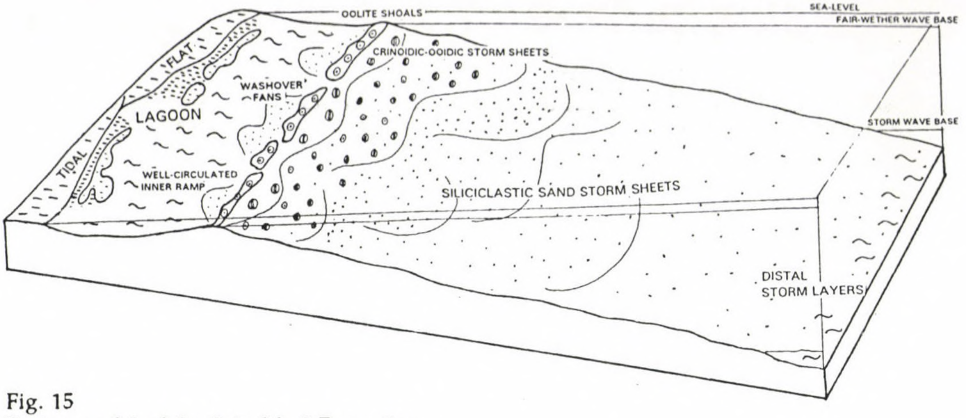


Fig. 15
Facies model of the Szin Marl Formation

carbonate) ramp is regarded as a homoclinal one, as a type of "ramp-ooid-barrier complex" in the classification of Read (1985).

Szinpetri Limestone Formation

Definition

The formation is composed of dominantly dark-grey, typically vermicular, limestones. In its lower half marl and clay marl intercalations can be found subordinately, while in the upper half vermicular limestones alternate with laminated ones (Fig. 16).

It can be divided into two characteristic members already defined previously: the lower Szinpetri Limestone s. str. and the upper Jósvafő Limestone Member (Kovács et al. 1989). However, a redefinition of their original facies interpretation is essential.

Its thickness in the Aggtelek tectofacies unit is about 150–200 m. In the Bódva tectofacies unit the formation is reduced, and it overlies in small thickness the lithological unit G of the Szin Marl Formation. Its development shows a transition between the Jósvafő Limestone Member and the Gutenstein Formation. The Gutenstein Formation covers it in both tectofacies units.

Lithology and sedimentological features

The easily distinguished two lithofacies correspond to the two members of the formation.

The *Szinpetri Limestone s. str.* is composed of typical vermiculated limestones: platy, thin-bedded (1–4 cm), dark or bluish-grey limestones (mudstone/wackestone) punctuated by clay marl flasers. The beds are entirely bioturbated, which gives them a nodular appearance (Fig. 17). The strong bioturbation masks almost every original sedimentary structure. Rarely, however, low-angle cross-stratification is recorded in the erosional based crinodal limestone layers. Occasionally, pelecypod lumachelle cover the bedding planes, and more or less parallel gutter casts run along the base of the other beds. Ostracods are found in large amounts in some beds in the lower part of the unit.

In the low-energy lagoon, where the sediments were deposited, the frequency of the storms and their influence on sedimentation were insignificant. The salinity of the lagoon water must have been different from that of normal marine water, judging by the euryhaline fauna. Partial restriction, in the form of a dysaerobic environment, is indicated by the dark colour of the rocks, the poor fossil content (benthic fauna of low diversity), and the strong bioturbation.

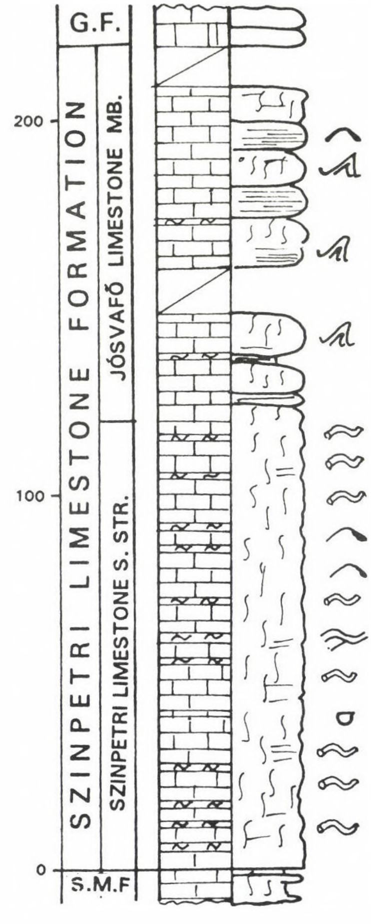


Fig. 16
Sequence of the Szinpetri Limestone Formation in the Aggtelek tectofacies unit. S.M.F. – Szin Marl Formation; G.F. – Gutenstein Formation

The *Jósvafő Limestone Member* is made up of an alternation (in sections) of two types of dark-grey, slightly bituminous limestones (mudstone). One of them is thick-bedded and laminated (Fig. 18). The lamination is expressed in an alternation of lighter and darker streaks. Thin marl films separate the limestone beds. Fining-upward gradation in the thicker beds is quite rare. In the upper part of the member, the pelecypods have accumulated as lumachelle on top of the beds. The other type is mottled and bioturbated. Slump structures are common in both types.

The sediments were deposited in a gradationally restricted lagoon. The facies of the bioturbated types is the same as described above for the lower member. The laminated beds were formed in the lagoon, where the bottom water of which became anaerobic. The lamination indicates the changing amount of organic matter. It is well preserved because of the lack of benthic organisms, which is due to the anoxic environment.

Fig. 17
Characteristic dark-grey vermicular limestones, Szinpetri Limestone Formation, Szinpetri Limestone s. str., Szinpetri

Fig. 18
Laminated part of the Jósvafő Limestone Member, Jósvafő

Facies model

On the widespread shallow inner ramp – in the lagoonal environment – water-circulation was limited (Fig. 19). Distant shoals may have partly contributed to the restriction of the lagoon, although in the study area, their sediments occur only as redeposited lobes in the sequence of the formation. Weak circulation led to density layering of the probably hypersaline lagoonal water followed by development and establishment of stagnant bottom water. The transition from the dysaerobic environment into the anaerobic one occurred gradually. Presumably the hypersalinity and oxygen depletion caused the faunal poverty.

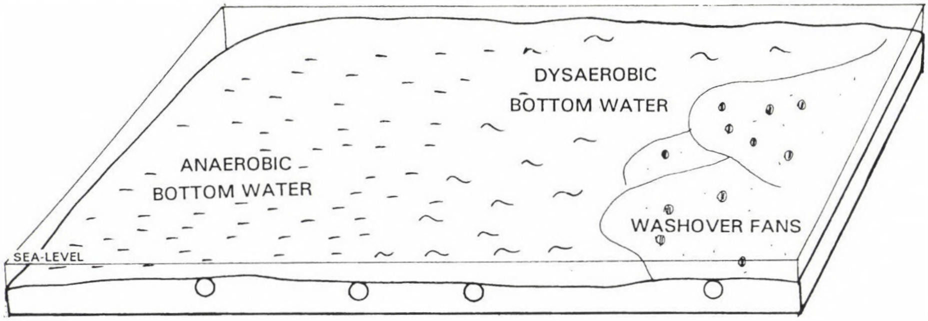


Fig. 19
Facies model of the Szinpetri Limestone Formation

Influences of sea-level changes on sedimentation

In the light of the vertical facies changes of sedimentary rocks (Fig. 20) changes in water depth may be assumed to have occurred during the Scythian. Considering the changes in intensity of terrigenous influx onto the ramp (Fig. 20) and on the basis of the changes in water depth, four significant transgression–regression cycles can be defined in the sequence. On a homoclinal ramp the stacking pattern reflects the relative sea-level changes (cf. Burchette and Wright 1992). A direct correlation can thus be presumed between the defined transgression–regression cycles and the relative sea-level changes. Therefore, the defined four cycles probably reflect third-order sea-level cycles (Fig. 21) as estimated by their duration based on biostratigraphic results. The cycles show good correlation with the relative sea-level cycles of other Scythian sequences, in the German Basin (Aigner and Bachmann 1992) and in the Dolomites (De Zanche et al. 1993) (Fig. 21).

Especially in the transgressive phases of third-order cycles, backstepping, meter-scale, shallowing-upward cycles (fourth- and/or fifth-order cycles) are well developed in the mid-ramp sequences. During sea-level highstand, less

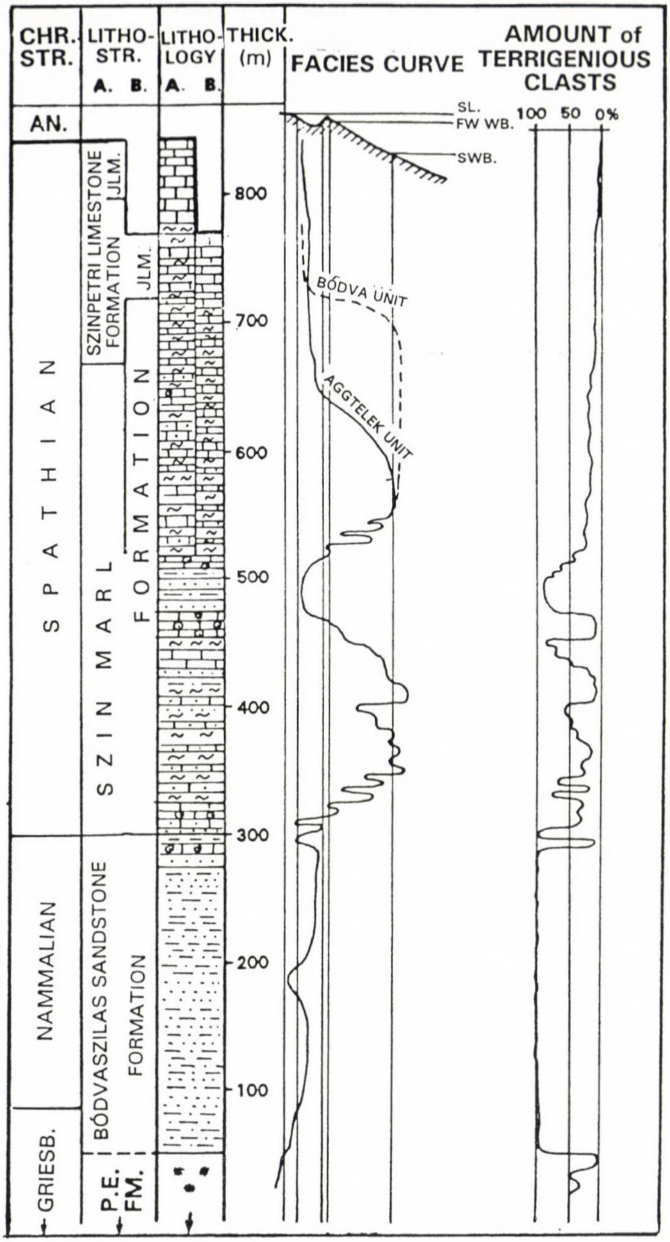


Fig. 20
Facies changes and relative content of the terrigenous component of the Lower Triassic formations. A. – Aggtelek tectofacies; B. – Bódva tectofacies; AN. – Anisian; SL. – sea-level; FWWB. – fair weather wave base; SWB. – storm wave base; JLM. – Jósvafő Limestone Member; P.E.FM. – Perkupa Evaporite Formation

clearly-defined, stacked, upward-shallowing, coarsening and thickening-upwards, fourth- and/or fifth-order sequences are developed. On the outer ramp the high-frequency sea-level changes influenced the position of the storm wave base.

Biostratigraphic subdivision

The Lower Triassic biozonation established for the Aggtelek-Rudabánya Mountains is based on ammonites (mainly on the basis of newly collected specimens) and – in the absence of ammonites – benthonic bivalves, respectively. Alpine ammonite zonation (Krystyn 1974; Posenato 1992) and the benthonic bivalve parastratigraphy elaborated in the Dolomites (Broglio Loriga et al. 1983, 1990, Broglio Loriga and Posenato 1986; Broglio Loriga and Mirabella 1986) (Fig. 23) proved to be partly applicable for our area as well.

Five biozones could be distinguished in the Lower Triassic of the Aggtelek-Rudabánya Mountains: the *Claraia clarai, C. aurita, "Eumorphotis", Tirolites cassianus* and *Tirolites carniolicus* Zones (Fig. 22). Fossils found in certain formations so far are displayed in Fig. 24 and among them some characteristic species in Plates I and II, respectively.

In the studied area, the lower boundary of the *Claraia clarai* Local Range Zone can be defined by the appearance of the index species, and the upper one by the appearance of *C. aurita* (Hauer). The *Claraia* genus first appears at the base of the Bódvaszilas Sandstone Formation, represented by *C. clarai* (Emmr.). This zone is represented by the lowermost part of the formation, since appearance of *C. clarai* in the sequence is soon followed by that of *C. aurita*.

The *C. aurita* Local Range Zone is defined by the vertical distribution of the index species. It represents the lower half of the Bódvaszilas Sandstone Formation, with the exception of the lowermost part of the formation.

In the Aggtelek-Rudabánya Mountains, the *"Eumorphotis"* Local interval zone can be defined by the disappearance of *C. aurita* and the appearance of the *Tirolites* genus, respectively, unlike its definition in the Dolomites and Transdanubian Central Range (Broglio Loriga et al. 1983, 1990), which is justified by the richer ammonite fauna in the Aggtelek-Rudabánya Mountains. In the Dolomites, the upper boundary of the zone was drawn at the appearance of *Costatoria costata* (Zenk.) and the zone was divided into four subzones. In the Aggtelek-Rudabánya Mountains, this zone embraces only the two lower subzones of the Dolomites, while the two upper ones can already be correlated with the ammonite zones of the Aggtelek-Rudabánya Mountains.

Within the sequence, the exact designation of the lower boundary of the "Eumorphotis" Zone – in the absence of a continuous section – is problematic. It can be stated only tentatively that the zone is represented roughly by the upper part of the Bódvaszilas Sandstone Formation. The zone is indicated by the species *Eumorphotis multiformis* (Bitt.), *E. hinnitidea* (Bitt.) and *Eumorphotis* sp. (sensu Broglio Loriga and Mirabella 1986).

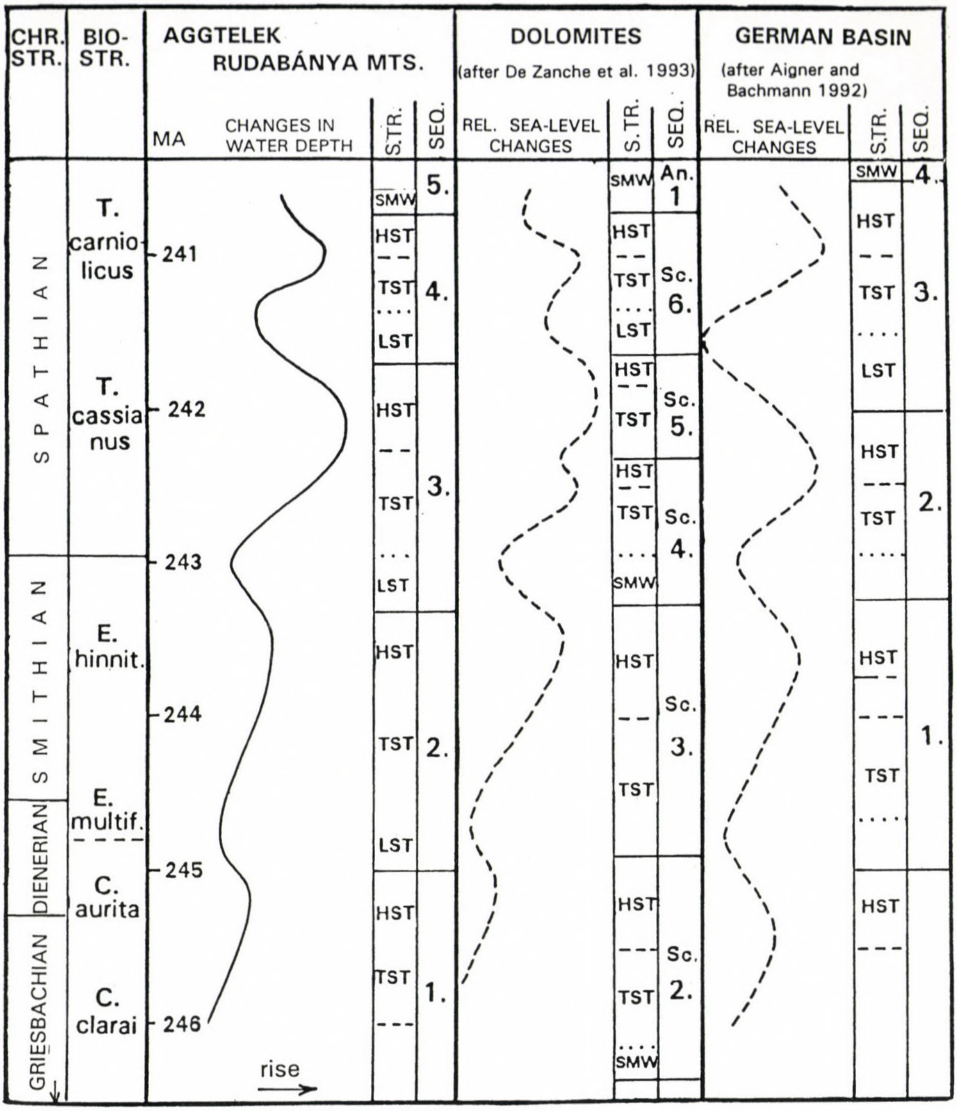


Fig. 21
Third-order relative sea-level cycles on the basis of the formations of the Aggtelek–Rudabánya Mountains, the Dolomites, the German Basin

The *Tirolites cassianus* Zone is represented – even taking into account, in a narrow sense, the subdivision of Posenato (1992, Fig. 23) – by the lower part of the Szin Marl Formation: from the appearance of the *Tirolites* genus (at the base of the Szin Marl Formation) to the appearance of *Diaplococeras liccanum*

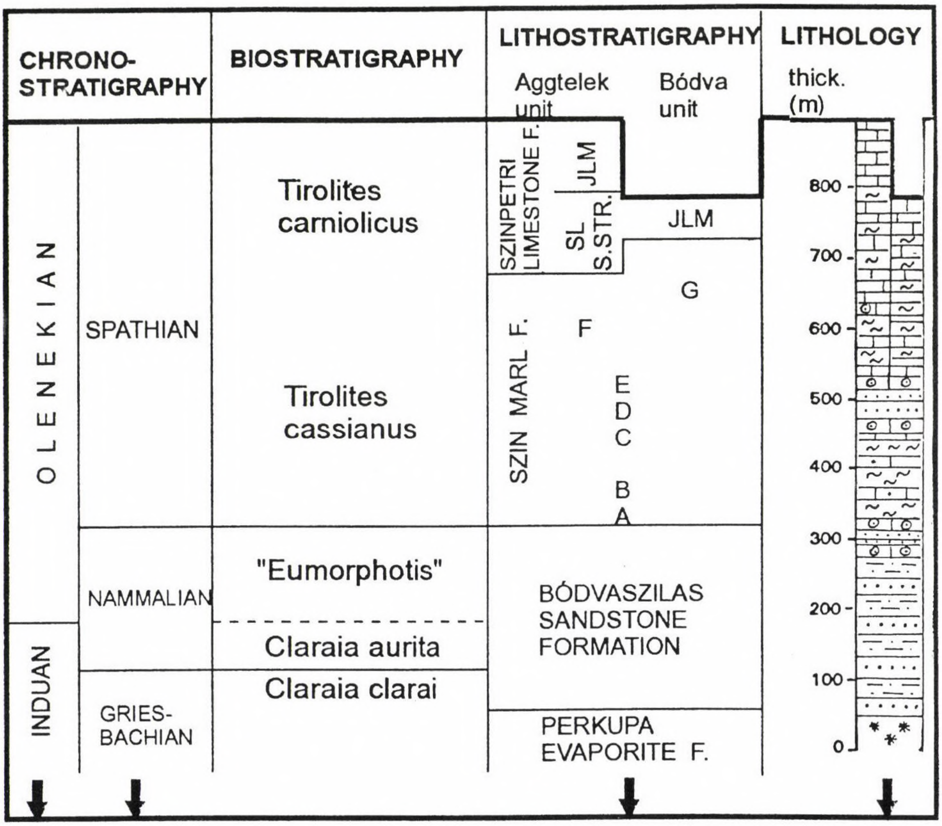


Fig. 22
Chronostratigraphic, biostratigraphic and lithostratigraphic subdivision of the Lower Triassic formations of the Aggtelek–Rudabánya Mountains. SL S.STR. – Szinpetri Limestone s. str.; JLM – Jósvafő Limestone Member

(Hauer) (in lithologic unit B of the Szin Marl Formation). It may be, however, that the lower part of the zone is missing (Posenato pers. comm. 1993).

On the basis of the occurrence of the *Tirolites carniolius* Mojs., the zonal index fossil, the lithologic unit G of the Szin Marl Formation in the Bódva tectofacies unit, and, on the basis of the occurrence of the *Stacheites* cf. *floweri* Kumm. (from the same genus, *S.* cf. *prionoides* Kittl and *S.* cf. *concavus* Shevyrev occur together with the zonal index ammonite in the Muc section – Herak et al. 1983), the lower part of the Szinpetri Limestone Formation in the Aggtelek tectofacies unit, can both be assigned to the *Tirolites carniolicus* Zone. The biostratigraphic classification of a significant part of the Szin Marl Formation – from the *Diaplococeras liccanum*-bearing layers (mid-level of lithologic unit B) up to lithologic unit F – is uncertain, since according to the subdivision of Krystyn (1974, Fig. 23) the boundary of the two *Tirolites* zones remains undefined.

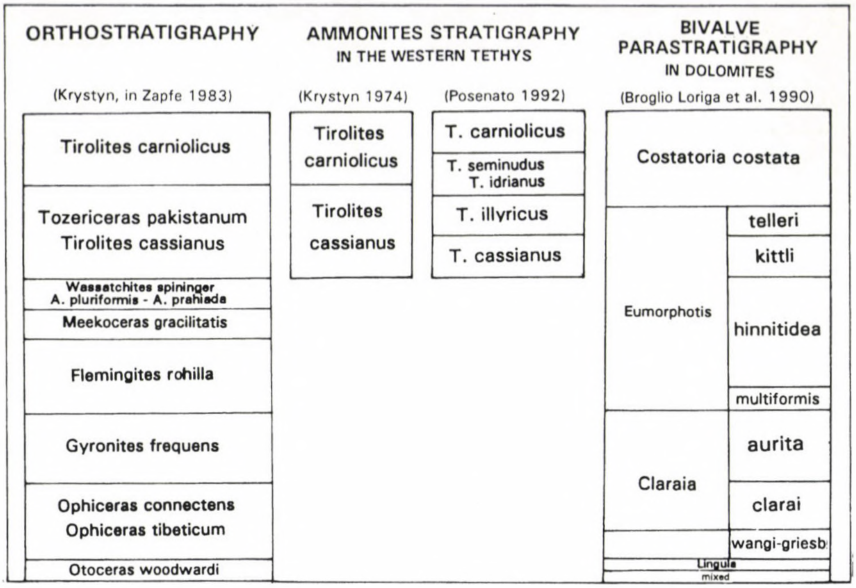
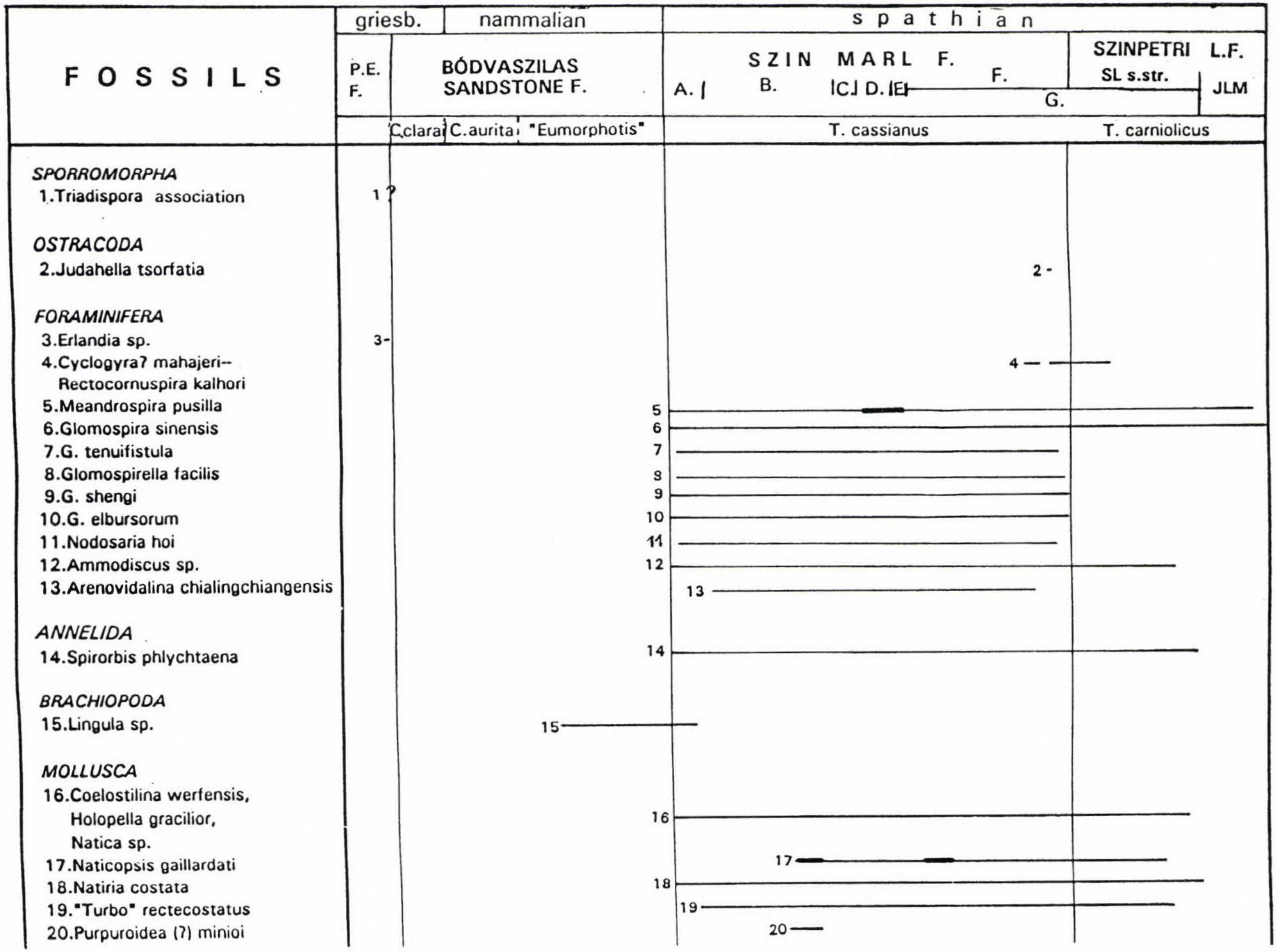


Fig. 23
Biostratigraphic zonations of the Lower Triassic

Taking other ammonite taxa into account, we can conditionally attempt the correlation with the zonation proposed by Posenato (1992) (Fig. 24). Thus, the *T. illyricus* zone following the *T. cassianus* zone is identified in the upper part of lithologic unit B of the Szin Marl Formation (from the appearance of *Diaplococeras liccanum* (Hauer)), by the common occurrence of *Dalmatites morlaccus* Kittl and *Dinarites dalmatinus* (Hauer), besides the index fossil. Furthermore, this zone is represented by the lower part of lithologic unit D of the formation, in which the index fossil occurs. In this case lithologic unit C between them also represents the *T. illyricus* Zone, on the basis of the appearance of *Costatoria costata* (Zenk.). Based on a single occurrence of *Dinarites dalmatinus* (Hauer), lithologic unit F of the Szin Marl Formation can be conditionally assigned to the *T. seminudus–T. idrianus* Zone. In the absence of ammonites, the biostratigraphic classification of lithologic unit E is uncertain.

For the sake of completeness, it is worth mentioning that the earliest appearance of *E. kittli* (Bitt.) is known from the base of the Szin Marl Formation, that of *E. telleri* (Bitt.) from the upper part of lithologic unit B, and that of *C. costata* (Zenk.) from lithologic unit C of the Szin Marl Formation.

Foraminifer zonation (Oravecz-Scheffer 1987; Broglio Loriga et al. 1990) cannot be applied in the Aggtelek-Rudabánya Mountains. Here, *Meandrospira pusilla* (Ho) appears in the lowermost part of the Szin Marl Formation, together with *E. kittli* (Bitt.) and *Tirolites cassianus* (Quens.), still before the occurrence of *Diaplococeras liccanum* (Hauer); and reaches up to the Jósvafő Limestone


FOSSILS
griesb.
nammalian
spathian
P.E. F.
BÓDVASZILAS SANDSTONE F.
SZIN MARL F.
A.
B.
C.
D.
E.
F.
G.
SZINPETRI L.F.
SL s.str.
JLM
C.clarai
C.aurita
"Eumorphotis"
T. cassianus
T. carniolicus
SPORROMORPHA
1.Triadispora association
OSTRACODA
2.Judahella tsorfatia
FORAMINIFERA
3.Erlandia sp.
4.Cyclogyra? mahajeri--
Rectocornuspira kalhori
5.Meandrospira pusilla
6.Glomospira sinensis
7.G. tenuifistula
8.Glomospirella facilis
9.G. shengi
10.G. elbursorum
11.Nodosaria hoi
12.Ammodiscus sp.
13.Arenovidalina chialingchiangensis
ANNELIDA
14.Spirorbis phlychtaena
BRACHIOPODA
15.Lingula sp.
MOLLUSCA
16.Coelostilina werfensis,
Holopella gracilior,
Natica sp.
17.Naticopsis gaillardati
18.Natiria costata
19."Turbo" rectecostatus
20.Purpuroidea (?) minioi

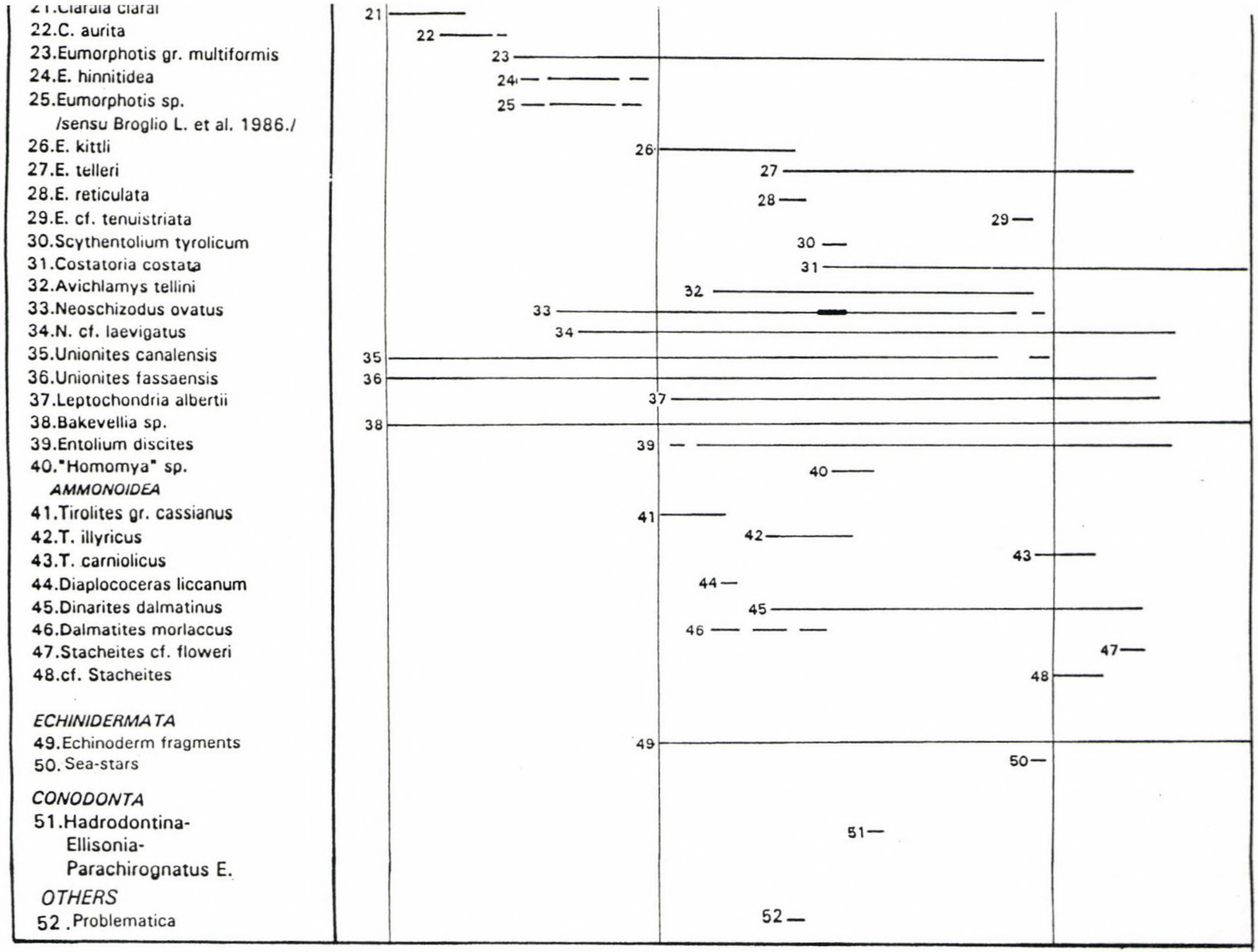


Fig. 24
Occurrences of fossils in the lithostratigraphic units of the Aggtelek–Rudabánya Mountains. P.E.F. – Perkupa Evaporite Formation; SL s.str. – Szinpetri Limestone s.str; JLM. – Jósvafő Limstone Member

Member. Also, *Cyclogyra? mahajeri* Brönn., Zan., Boz. does not appear with certainty together with *Claraia*; however, it certainly occurs together with *Costatoria costata* (Zenk.) – in lithological unit F of the Szin Marl and the Szinpetri Limestone Formations. Accordingly, the vertical distribution of the mentioned foraminifera is much greater than that observed in the Dolomites and the Balaton Highland (Oravecz-Scheffer 1987; Broglio Loriga et al. 1990; Posenato 1992). In summary, from the foraminifer investigations it can be concluded that foraminifera indicate facies rather than age; thus, they are not a suitable tool for age determination (Hips 1996).

The few conodont apparatuses found in lithologic unit F of the Szin Marl Formation represents the *Hadrodontina-Ellisonia-Parachirognathus* biofacies. Here, a contradiction must be pointed out: the above-mentioned biofacies detected in the unit of the Szin Marl Formation above the level of occurrence of *Tirolites cassianus* (Quens.), is of Smithian age according to the literature (Paull 1983; Budurov et al. 1983; Kolar-Jurkovsek 1990). However, Perri and Andraghetti (1987) have shown in the Dolomites that the *Hadrodontina–Ellisonia* assemblage occurs in the Val Badia and Cencenighe Members which – on the basis of other index fossils – represent the Spathian. *Hadrodontina anceps* Staesche is mentioned by Staesche (1964) and Perri and Andraghetti (1987) as a species running through the entire Scythian. *Parachirognathus* was also described by Sudar (1986) in the Muc Limestone (Spathian). On the basis of these arguments, the biostratigraphic and chronostratigraphic value of the above-mentioned compound conodonts is debatable.

Chronostratigraphic subdivision

The last Lower Triassic stage subdivision was accepted by the International Geological Congress in 1992, in Kyoto. Now, the valid stages of the Lower Triassic are Induan and Olenekian. The previously used other subdivisions were rejected, even as substages. In the Aggtelek-Rudabánya Mountains – just as it has already been shown from the Dolomites and the Balaton Highland (Broglio Loriga et al. 1990) –, the Induan/Olenekian boundary cannot be determined due to the lack of the fossils. Thus, the sequence of the Aggtelek-Rudabánya Mountains could not be subdivided at all. A more detailed subdivision of the Lower Triassic formations of the Aggtelek-Rudabánya Mountains can be made only on the basis of the three-fold division, invalid at present (Fig. 22).

The drawing of the Permian/Triassic boundary is a question still open today in this area.

In Slovakia, in black schist interfingering with a formation presumably equivalent to the Perkupa Evaporite Formation (a more detailed description of this formation is beyond the scope of the present paper), sporomorphs of Permian age are known (Ilavská 1965). Based on the lithologic development of the Perkupa Evaporite Formation and the correlation with the above-mentioned Slovakian counterpart, the formation was assigned to the Permian

(Kovács et al. 1989). Previously, however, the possibility of its extending over to the lower part of the Lower Triassic (Mészáros 1961) had been brought up, but without palaeontologic evidence it had been purely an assumption.

According to our present-day knowledge, it is more probable that the boundary is located in the upper part of the Perkupa Evaporite Formation, in contradiction to the widely-held view that the Permian/Triassic boundary should be drawn between the two formations, i.e. the Perkupa Evaporite and the Bódvaszilas Sandstone Formation. This is supported by the indirect argument that in the lowermost part of the Scythian sequence, fossils of the *Lingula* Zone and *Claraia wangi–griesbachi* Subzone defined in the Dolomites, are unknown in the Aggtelek-Rudabánya sequence. These zones presumably represent the uppermost part of the Perkupa Evaporite Formation, which is poorish in fossils. Thus, the formation may reach up to the Upper Griesbachian.

Upper Griesbachian, represented by the *C. clarai* Zone, is present in the lowermost part of the Bódvaszilas Sandstone Formation.

Since the Griesbachian/Nammalian boundary was defined by ammonite zones, in the absence of ammonites it cannot be precisely located in the study area. In an Iranian section, *C. aurita* (Hauer) appears in the *Gyronites* Zone (Nakazawa 1977), that is in the Dienerian. Accordingly, a boundary can be drawn between the *C. clarai* and *C. aurita* Zones as the boundary of the Griesbachian and Dienerian. Thus, the boundary falls into the lower part of the Bódvaszilas Sandstone Formation, and – from the appearance of *C. aurita* (Hauer) – the remaining parts of the formation can be assigned to the Nammalian.

Therefore, the upper half of the Bódvaszilas Sandstone Formation, represented by the *"Eumorphotis"* Zone following the *C. aurita* Zone, can also be considered to belong to the Nammalian.

The Nammalian/Spathian boundary can be defined in the Alpine facies areas by the appearance of *T. cassianus* (Quens.) as index species (Krystyn 1974; Herak et al. 1983). Completing it with the results of biostratigraphic investigations carried out in the Dolomites, according to which *E. kittli* subzone represents the Lower Spathian (Broglio Loriga et al. 1990), it can be established that this boundary is located between the Bódvaszilas Sandstone Formation and the Szin Marl Formation in the Aggtelek-Rudabánya Mountains.

On the basis of the *T. cassianus* Zone and the following *T. carniolicus* Zone, the Spathian is represented by the Szin Marl and Szinpetri Limestone Formations.

In attempting to draw the Scythian/Anisian boundary, we face the same problem as in the case of the lower boundary of the Scythian. On the basis of palaeontologic data, there is no doubt that in the Aggtelek tectofacies unit the Szinpetri Limestone Formation (with the exception of the Jósvafő Limestone Member), and in the Bódva tectofacies unit the Szin Marl Formation, are Scythian, and the Steinalm Formation is of Anisian age. The Jósvafő Limestone Member and the Gutenstein Formation, representing the intermediate interval, are very poor in fossils. Thus, in the absence of ammonites and other suitable fossils, their age can be determined neither an orthostratigraphic or a parastratigraphic basis. As a compromise, we must accept the lithostratigraphic boundary between the Szinpetri Limestone and the Gutenstein Formation as a chronostratigraphic boundary as well. Accordingly, the Gutenstein Formation already forms the lower part of the Anisian. It is my opinion, however, that for the moment a grounded opinion on the Scythian/Anisian boundary can hardly be formed due to the significant poverty in fossils of the above-mentioned formations.

Fitting of the sequence into the regional palaeogeographic framework

In the western end of Tethys, the Alpine sedimentary cycle was initiated by Late Permian transgression. As a result, the sea also reached the depositional areas of the Western Dolomites and the Transdanubian Central Range by the end of the Permian. In the units of the Bükk, Carnian Alps, Southern Karawanken, Julian Alps, Dinarides and Hellenides to the E–SSE of it, sediments were already deposited in a marine environment during the Upper Permian. In turn, the Mesoeuropean (Variscan) dry land north of the Vindelician Swell was flooded by the sea only at the beginning of the Middle Triassic.

The Late Permian shallow sea (area of deposition of the "Bellerophon Limestone") transgressing on red continental molasse was bordered by an evaporitic sabkha zone. Its formations of the latter are the "Facies Fiamazza" in the Southern Alps, the "Tabajd Evaporite Formation" in the Transdanubian Central Range, the "Haselgebirge" in the Northern Calcareous Alps and the "Perkupa Evaporite Formation" in the Silicicum of the Inner West Carpathians (Kovács 1992). This situation in the Late Permian is shown by the palaeogeographic model of the NW end of Tethys (Fig. 25a).

During the subsequent Scythian transgressional phases, a branch of Tethys gradually advanced over a levelled-off, flat surface in a N–NW direction. This step-by-step flooding of the Permian continent, and the scenario of how marine influence increased to the south, is shown by the zonal arrangement of the facies (Fig. 25).

On the basis of the time of the first occurrence of marine sediments deposited on continental formations, this gradual advance of the sea branch can be traced. In the Early Scythian (Griesbachian – Fig. 25b), the zones of the Dolomites and the Transdanubian Central Range – still partly terrestrial during the Upper Permian – were also flooded by the sea. Its formations are fine terrigenous clastic carbonate sediments; the "Tessero Oolite", the "Mazzin Member" and the "Alcsútdoboz Limestone", "Arács Marl", "Köveskál Dolomite Formations", respectively (Broglio Loriga et al. 1983, 1990). The coastal zone shifted as far as Lombardy; its formation is the "Praso Limestone" unit of the "Servino Formation" of tidal flat facies (Neri 1986). More south-easterly zones of the Northern Calcareous Alps were reached by the sea; its clastic sediments are

Fig. 25a

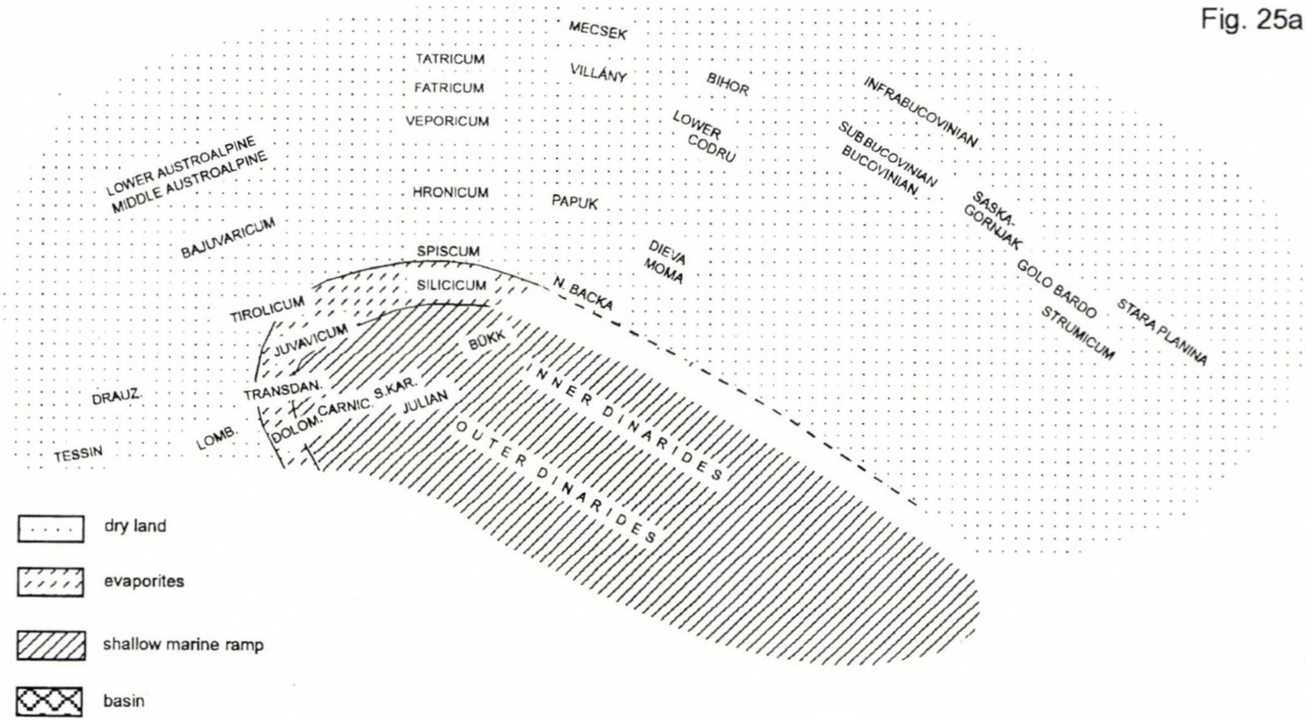


Fig. 25
Paleogeographic model of the western end of Tethys. Situation at Late Permian (a), at the beginning of the Scythian, Griesbachian (b), in the Spathian (c), at the Lowermost Anisian (d)

Fig. 25b

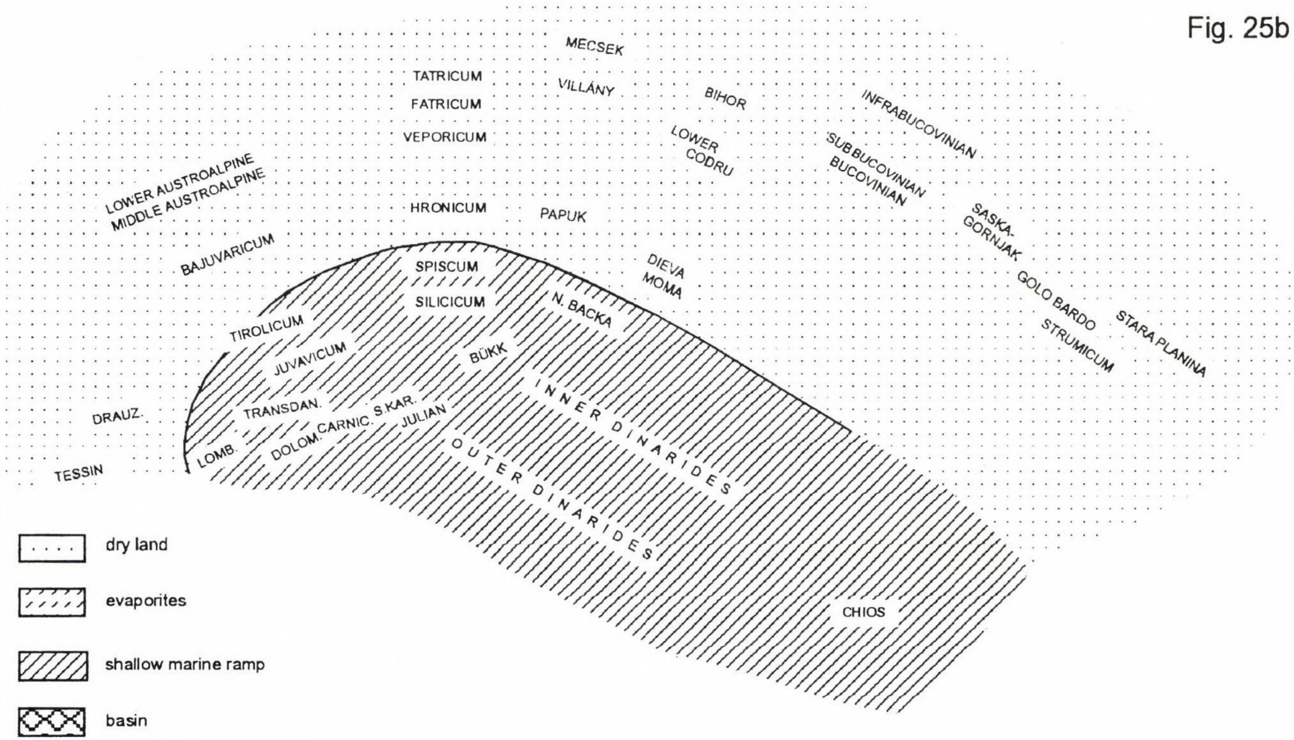

MECSEK
TATRICUM
VILLÁNY
BIHOR
INFRABUCOVINIAN
FATRICUM
VEPORICUM
LOWER CODRU
SUBBUCOVINIAN
BUCOVINIAN
LOWER AUSTROALPINE
MIDDLE AUSTROALPINE
HRONICUM
PAPUK
SASKA-GORNJAK
BAJUVARICUM
SPISCUM
DIEVA
MOMA
SILICICUM
N. BACKA
GOLO BARDO
STARA PLANINA
TIROLICUM
STRUMICUM
JUVAVICUM
BÜKK
INNER DINARIDES
TRANSDAN.
S.KAR.
CARNIC.
JULIAN
DRAUZ.
DOLOM.
LOMB.
OUTER DINARIDES
TESSIN
CHIOS
dry land
evaporites
shallow marine ramp
basin

Fig. 25c

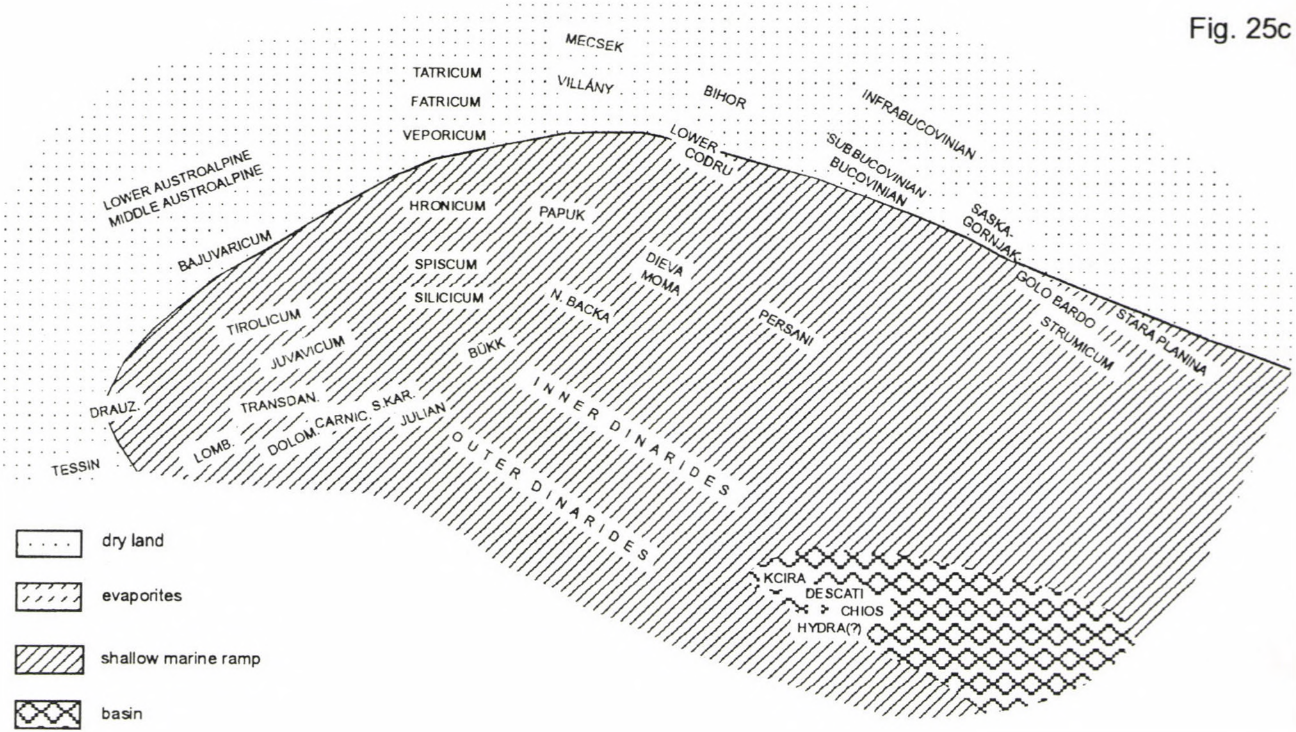
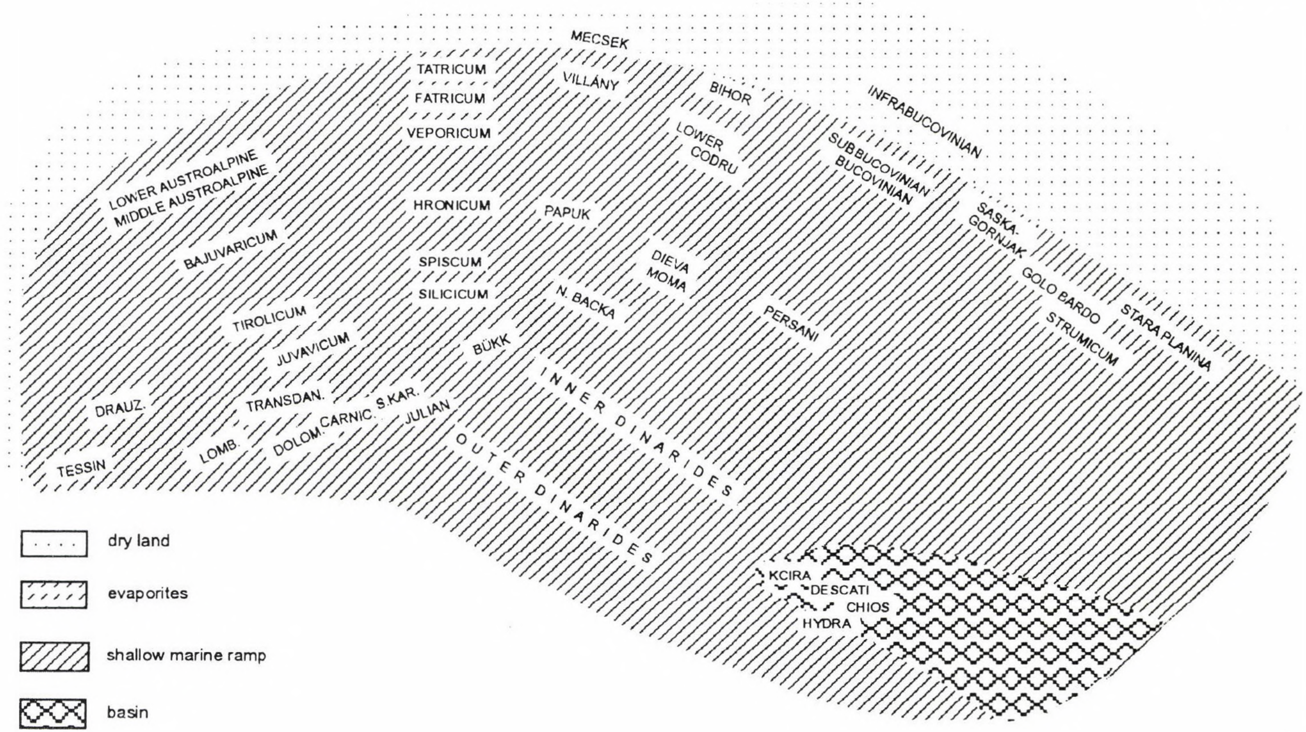

MECSEK
TATRICUM
VILLÁNY
FATRICUM
BIHOR
INFRABUCOVINIAN
VEPORICUM
LOWER CODRU
SUBBUCOVINIAN
BUCOVINIAN
LOWER AUSTROALPINE
MIDDLE AUSTROALPINE
HRONICUM
PAPUK
SASKA-GORNJAK
BAJUVARICUM
SPISCUM
DIEVA
MOMA
SILICICUM
GOLO BARDO
N. BACKA
STARA PLANINA
TIROLICUM
PERSANI
STRUMICUM
JUVAVICUM
BÜKK
INNER DINARIDES
TRANSDAN.
S.KAR.
DRAUZ.
CARNIC.
JULIAN
OUTER DINARIDES
LOMB.
DOLOM.
TESSIN
KCIRA
DESCATI
CHIOS
HYDRA(?)
dry land
evaporites
shallow marine ramp
basin

Fig. 25d


MECSEK
TATRICUM
FATRICUM
VEPORICUM
VILLÁNY
BIHOR
INFRABUCOVINIAN
LOWER CODRU
SUBBUCOVINIAN
BUCOVINIAN
LOWER AUSTROALPINE
MIDDLE AUSTROALPINE
HRONICUM
PAPUK
SASKA-GORNJAK
BAJUVARICUM
SPISCUM
DIEVA MOMA
SILICICUM
N. BACKA
GOLO BARDO
STARA PLANINA
PERSANI
STRUMICUM
TIROLICUM
JUVAVICUM
BÜKK
INNER DINARIDES
DRAUZ.
TRANSDAN.
S.KAR.
CARNIC.
JULIAN
DOLOM.
LOMB.
TESSIN
OUTER DINARIDES
KCIRA
DESCATI
CHIOS
HYDRA
dry land
evaporites
shallow marine ramp
basin

assigned to the "Werfen Schist" (Tollmann 1976). In the Silicicum, the formation of evaporite of sabkha facies continued further on ("Perkupa Evaporite Formation"). At the end of the Griesbachian, however, it was replaced by clastic sediments ("Bódvaszilas Sandstone Formation"). In certain areas of Spišcum, the accumulation of evaporites also began (Bystrický, 1973). In Northern Bačka the first marine clastic formation is the "Palić series", the deposition of which was accompanied by the formation of evaporite, the "Crna Bara series" (Bleahu et al. 1994; Kemenci and Čanović, in press). In the outer units, sedimentation still occurred in a fluvial environment. The generally used name for these formations is "Alpine Buntsandstein" or "Werfen Quartzite".

In the Dienerian, a zone of the western part of the Tirolicum unit of the Northern Calcareous Alps was flooded by the sea (Gwinner 1971; Mostler and Roβner 1984).

During the Smithian, in a marine environment, the "Campilian event", as an intensified influx of terrigenous detritus, can be traced in several units. Its formations, the red sandstones, siltstones and shales are assigned to the unit of the "Servino Formation" in Lombardy (Neri 1986), to the "Campil Member" in the Dolomites, Carnian Alps, and Southern Karawanken (Pisa 1974; Broglio Loriga et al. 1990), and to the "Hidegkút Formation" in the Transdanubian Central Range (Haas et al. 1988; Broglio Loriga et al. 1990). In the Silicicum, it is represented by the upper lithologic unit of the "Bódvaszilas Sandstone Formation".

In the Spathian (Fig. 25c), the sea branch advanced further in a N–NW direction and reached the area of the Hronicum (Bystrický 1967, 1973) and the internal belt of the Tisza Unit (Papuk, Dieva and Moma Nappes – Bleahu et al. 1994). In the Persani Series, there is tectonic contact between the Spathian marls and limestones and the underlying unit (Patrulius et al. 1971, 1979). While these are the first known marine sediments in the Scythian of the Persani Series, presumably, based on the facies development of the "Werfen Formation", the sea flooded this depositional area earlier.

At the end of the Spathian, at the Spathian/Anisian boundary, the sea branch reached the depositional area of the Drauzug (Bauer 1980; Krainer 1985), and the Lower Codru Nappes: the Corbeşti outlier, the Şeasa Nappe, the Finiş Nappe (s. str.) and moreover the Vălani Nappe and the Bihor Unit in the Pădurea Craiului. Its formations are assigned into the "Werfen Schist" (Bleahu et al. 1994). In Golo Bardo and Strumicum, the first clastic, dolomite and limestone formations of marine facies also appeared at this time in the sequence (Budurov et al. 1995).

The first deep-sea sediments in the wider West Tethyan region appeared in the Late Spathian, where they are represented by red nodular limestones. Such deep-sea sediments are known from the Hellenides, from the Deskati section in the western part of the Almopia Geotectonic Unit (Pelagonian Nappe System) (Papanikolaou 1995), in the Chios section in the lower part of the "Marmarotrapeza Formation" (Gaetani et al. 1992) and in the Vlichos section of Hydra in the upper part of the lower lithologic unit of the "Eros Limestone" (Angiolini et al. 1992). Its northernmost occurrence is known from the Kcira section of Korabi Unit (Albania – Krystyn 1974).

At the Early Anisian, further zones were flooded by the sea (Fig. 25d); the Tessin Alps (Pisa 1974), the Bajuvaricum of the Northern Calcareous Alps and the units of the Middle and Lower Austroalpine, (Gwinner 1971; Mostler and Roβner 1984), the Veporicum, Fatricum, Tatricum (Bystrický 1967, 1973), and in the Tisza Megaunit: the Vălani Nappe in Western Bihor Mts (Lower Codru Nappes) and Villány Mts and Bihor Unit in Bihor Mts (Villány–Bihor Zone) (Bleahu et al. 1994), the Bucovinian and Subbucovinian Units (Patrilius et al. 1979), and the narrow Saska-Gornjak Nappe running along the eastern front of the Serbo-Macedonian Megaunit (Năstăseanu et al. 1981). Later, but still in the Anisian, the Mecsek Zone was also reached by the sea (Bleahu et al. 1994).

Comparing the sequences of the different megaunits, several similar features can be shown in the formation of the sequences belonging to the same facies zone. Despite the similarities, however, one can only speak about a relationship in terms of the geologic features of development but not of total evolutionary and facies identity. In the western end of Tethys, the similarity of the sediments deposited on the ramp is explained by the fact that climatic and eustatic sea-level fluctuation events may have encompassed the entire region. Thus, similar geologic sequences could be deposited in areas relatively far from each other (Haas et al. 1988).

Summary of evolutionary history

In the Lower Triassic sequence of the Aggtelek-Rudabánya Mountains, the Perkupa Evaporite Formation is the oldest unit. Deposition of the sediments on the coastal tidal flat and sabkha already began in the Upper Permian and continued in the Upper Griesbachian. Because of its poverty in fossils, its age can be determined only in an indirect way. The *Claraia wangi-griesbachi* biozone demonstrated in other Lower Triassic sequences, is not proved by fossils here due to extreme environmental conditions. The Permian/Triassic boundary can be drawn in the upper part of the formation.

From the Upper Griesbachian, a larger amount of terrigenous clasts was deposited in the sedimentary system of the microtidal inner ramp – lagoon and the connected tidal flat. In the various environments, sedimentation was determined by intense evaporation, wave motion and storm processes of high energy. Red and subordinately green shales, siltstones and fine-grained sandstones were formed which may already be assigned to the Bódvaszilas Sandstone Formation. Presumably, the passing of the climate to humid may have caused the intensification of terrigenous supply.

In the lower part of the Bódvaszilas Sandstone Formation sediments were deposited dominantly in the supra- and intertidal zones of the tidal flat as well as partly in the subtidal zone of the lagoon. Among the marine fauna composed of eurytopic species living under extreme environmental conditions, *Claraia clarai* (Emmr.) and *Claraia aurita* (Hauer) have stratigraphic value.

From the middle of the Nammalian, in the upper half of the formation a new transgressional phase began, resulting in sedimentation in a well-oxygenated environment behind the shoals. Finer-grained sediments settled under fair-weather conditions, whereas washover fans were formed during storms. By the end of the Nammalian – simultaneously with a decrease in water depth – the inner ramp gradually became a restricted lagoon. Its characteristic faunal elements are *Eumorphotis hinnitidea* (Bittn.), *E. multiformis* (Bittn.) and *Eumorphotis* sp. (sensu Broglio Loriga and Mirabella 1986).

At the beginning of the Spathian, the Szin Marl Formation was deposited after a sudden lithologic change. In this formation, the colour of the rocks is predominantly grey. Carbonates and rocks of mixed lithology (limestones, silty limestones, fine sandy limestones, marls) prevail over siliciclastics (shales, siltstones, fine-grained sandstones).

Sediments were deposited on a homoclinal, storm-dominated, high-energy ramp, from the inner ramp through the mid-ramp to the outer ramp, depending on the relative sea-level changes. On the mid-ramp higher frequency, fourth- and/or fifth-order relative sea-level changes in the transgressional phase of the third-order cycles, caused well-detectable changes in the sedimentation.

Thus, at the beginning of the Spathian, during the transgression resulting from the rapid relative sea-level rise, inner ramp environments were replaced by mid-ramp, then outer ramp environments. At the beginning of the transgression, first hemipelagic fauna elements appeared at the base of the formation: ammonites, such as *Tirolites* and crinoids. Subsequently, newer and newer ammonite species appeared in the Spathian.

Maximum transgression is marked by glauconitic marls as well as an alternation of thin layers or lamina of marls and limestones deposited on the outer ramp. Subsequently in the highstand phase, sediments of the inner ramp prograded intensively onto the open shelf formations. In this way, the amount of coarser-grained sediments reworked onto the mid-ramp increased significantly. This was the time when *Costatoria costata* (Zenk.) and *Scythentolium tyrolicum* (Witt.) appeared among the shallow marine benthic fauna. In the middle of the Spathian, as a consequence of the fall in the relative sea-level, red siliciclastic sediments of inner ramp facies were deposited on top of the fine-grained sediments of the outer ramp facies. The increasing intensity of terrigenous influx may reflect a fall of the base level.

In the second half of the Spathian, a new cycle began to take shape, similar to the previous one. As a consequence of the rise in relative sea level, facies zones shifted landward. During maximum flooding, dark-coloured vermicular limestones and marls were deposited below the storm wave base. In the phase of high sea level, progradation of the mid-ramp and inner ramp facies zones was again characteristic.

Subsequently – still in the period of high water level – during the latest Spathian, in the *Tirolites carniolicus* Zone, the inner ramp was gradually restricted in the area of the Aggtelek tectofacies unit. Quiet environmental conditions favoured the burrowing activity of the benthic organisms in the mud. Characteristic dark-grey bioturbated vermicular limestone and marl layers, formed in a dysaerobic environment, are already assigned into the Szinpetri Limestone Formation. In the area of the Bódva tectofacies unit, the focus of sedimentation (during the formation of lithologic unit G of the Szin Marl Formation) remained on the outer ramp for a rather long time. In the uppermost Spathian, with a fall of the revative sea-level, the trend of restriction continued in the Aggtelek unit, and a restricted lagoon also came into being in the area of the Bódva tectofacies unit.

In the lagoonal environment superposition of small cycles onto the trend of the third-order relative sea-level fall can be easily detected: sediments deposited in dysaerobic (bioturbated limestones) and anaerobic (dark-grey platy limestones) bottom conditions alternate. This series, representing a transition between the dysaerobic and anaerobic facies, was distinguished as a member within the formation (Jósvafő Limestone Member). In the area of the Bódva tectofacies unit, only this member represents the formation.

In the absence of fossils, the drawing of the Scythian/Anisian boundary is uncertain. Based on lithology, it can be emplaced between the Szinpetri Limestone Formation and the Gutenstein Formation.

In the Late Griesbachian and in the Nammalian, terrigenous influx was significant; however, from the beginning of the Spathian it decreased gradually, and it became completely insignificant by the end of the Spathian. The trends may indicate increasing aridity throughout the Scythian.

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Plate I

1. *Tirolites cassianus* (Quens.) (2x), lithologic unit A of the Szin Marl Formation, Csemer-berki creek
2. *Dinarites dalmatinus* (Hauer) (2x), lithologic unit F of the Szin Marl Formation, Varbóc, road cut
3. *Dalmatites morlaccus* Kittl (2x), lithologic unit B of the Szin Marl Formation, Perkupa, Vizes-vég valley
4. *Tirolites* gr. *carniolicus* Mojs. (2x), lithologic unit G of the Szin Marl Formation, Dobódél, Sivák

Plate II

1. *Claraia clarai* (Emmr.) (2x), Bódvaszilas Sandstone Formation, Perkupa, Tömedék quarry
2. *Eumorphotis hinnitidea* (Bittn.) (2x), Bódvaszilas Sandstone Formation, Perkupa, Cemetery
3. *Costatoria costata* (Zenk.) (2x), lithologic unit F of the Szin Marl Formation, Varbóc, road cut
4. *"Turbo" rectecostatus* Hauer (2x), lithologic unit B of the Szin Marl Formation, Szin, road cut
5. *Natiria costata* (Münst.) (2x), lithologic unit B of the Szin Marl Formation, Szinpetri, road cut
6. Sea star (2x), lithologic unit F of the Szin Marl Formation, Varbóc, road cut

Plate I

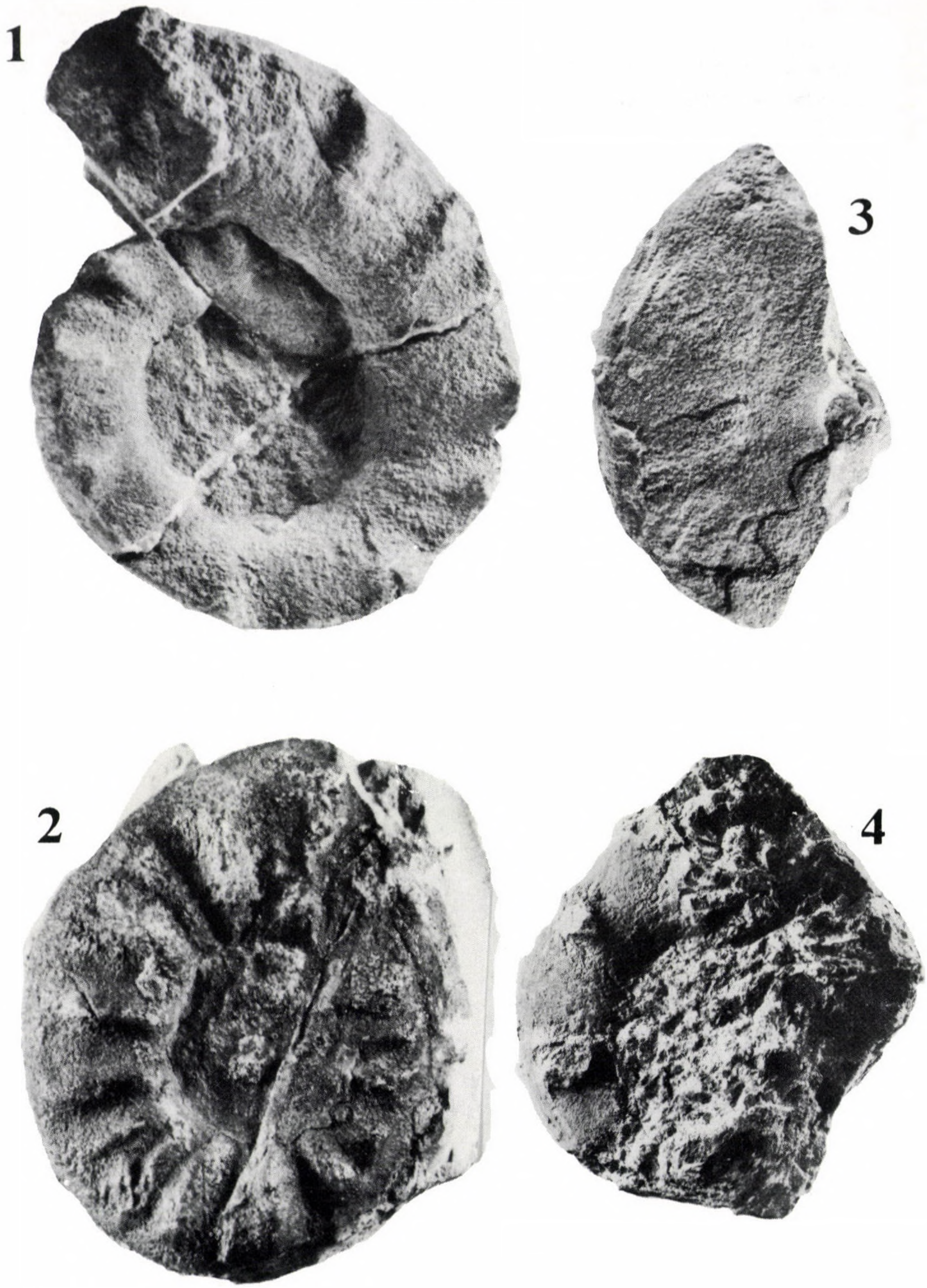
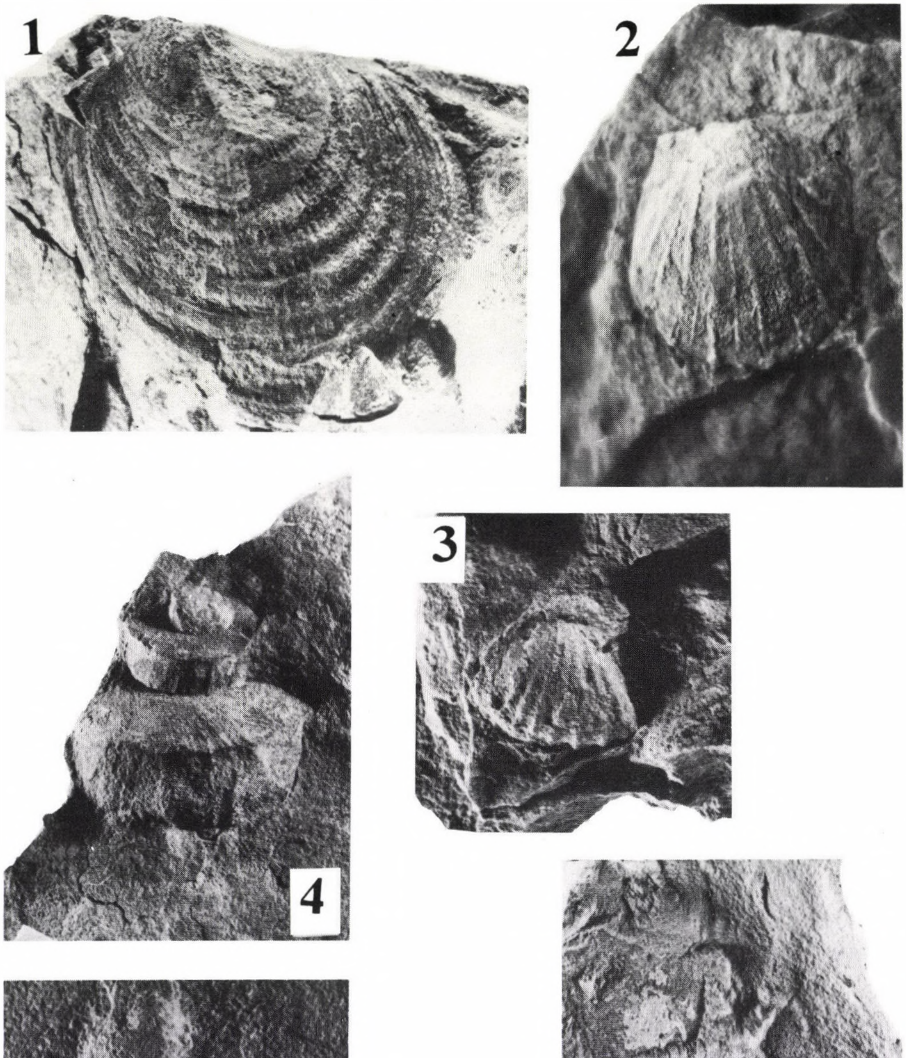


Plate I



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Foraminifera of the Triassic formations of Alsó Hill (Northern Hungary). Part 3: Foraminifer assemblage of the basinal facies

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In the poorish foraminifer fauna of the basinal facies which are exposed at the southern margin and NE end of the Triassic platform carbonates constituting the main mass of Alsó Hill (extending along the Hungarian–Slovakian border), the taxa Nodosariidae and Ichthyolariidae predominate and specimens of species belonging to the genera *Lenticulina, Arenovidalina, Ophthalmidium* and *Turriglomina* are frequent.

The richest foraminifer assemblage was found in the open marine slope sediments of the Nádaska Limestone Formation. In its foraminifer association, the species *Turriglomina mesotriasica* (Koehn-Zaninetti), *Arenovidalina chialingchiangensis* Ho, and *Ophthalmidium exiguum* Koehn-Zaninetti predominate and species of the genera *Pseudonodosaria* and *Lenticulina* are frequent.

The foraminifer assemblage of the pelagic basinal facies of the Reifling Limestone Formation is characterised by richness in specimens of the species *Turriglomina mesotriasica* Koehn-Zaninetti and *Arenovidalina chialingchiangensis* Ho.

Those associations of the open marine, pelagic radiolarian facies with microfilaments (Pötschen Limestone Formation, Derenk Limestone Formation, Hallstatt Limestone Formation) are the poorest ones.

Practically, the foraminifer assemblage is composed of *Turriglomina mesotriasica* (Koehn-Zaninetti), *Turriglomina robusta* Bérczi-Makk, and *Arenovidalina chialingchiangensis* Ho specimens.

Key words: Triassic, biostratigraphy, foraminifera, Northern Hungary

Introduction

At the southern margin and NE end (Fig. 1a–d) of the Triassic platform carbonates (Bérczi-Makk 1996a, 1996b) which constitute the main mass of the Hungarian part of Alsó Hill (extending in a length of some 15 km along the Hungarian–Slovakian border), basinal sediments, (which were tectonically ruptured several times during lithification – Derenk Limestone Formation), open marine slope sediments (Nádaska Limestone Formation) and formations of pelagic basinal facies (Reifling Limestone Formation, Pötschen Limestone Formation, and Hallstatt Limestone Formation) are known.

The foraminifer fauna of the basinal sediments of Alsó Hill can be characterised by associations poor in species and generally poor in specimens. In the assemblages, Nodosariidae – indicators of the basinal facies – predominate, and specimens of species belonging to the genera *Lenticulina,*

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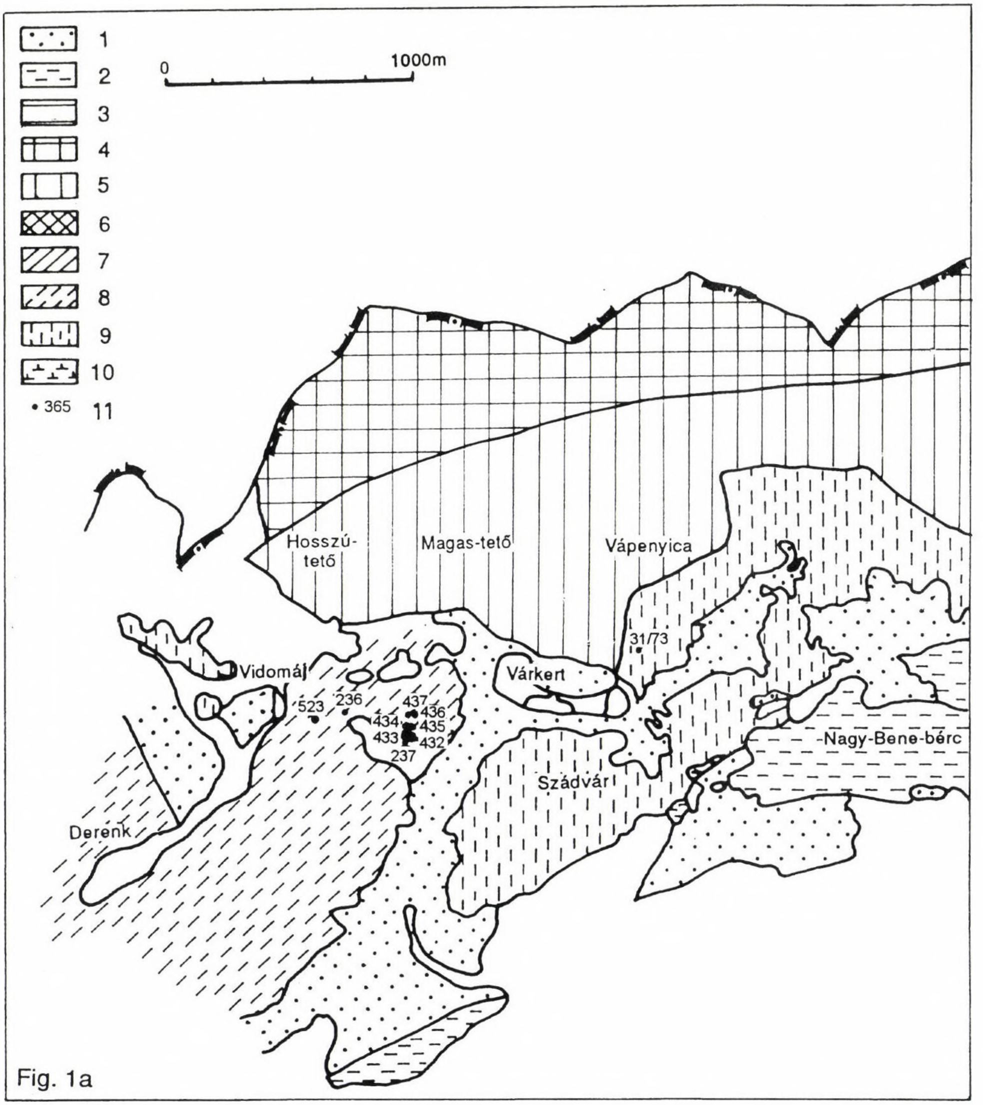


Fig. 1a–d
Locality map of the studied Alsó Hill samples of basinal facies (after Kovacs, 1977). 1. Lower Triassic; 2. Gutenstein Formation; 3. Steinalm Limestone Formation; 4. lagoonal facies of the Wetterstein Limestone Formation; 5. reefal facies of the Wetterstein Limestone Formation; 6. Nádaska Limestone Formation; 7. Reifling Limestone Formation; 8. Derenk Limestone Formation; 9. Hallstatt Limestone Formation; 10. Pötschen Limestone Formation; 11. sampling site

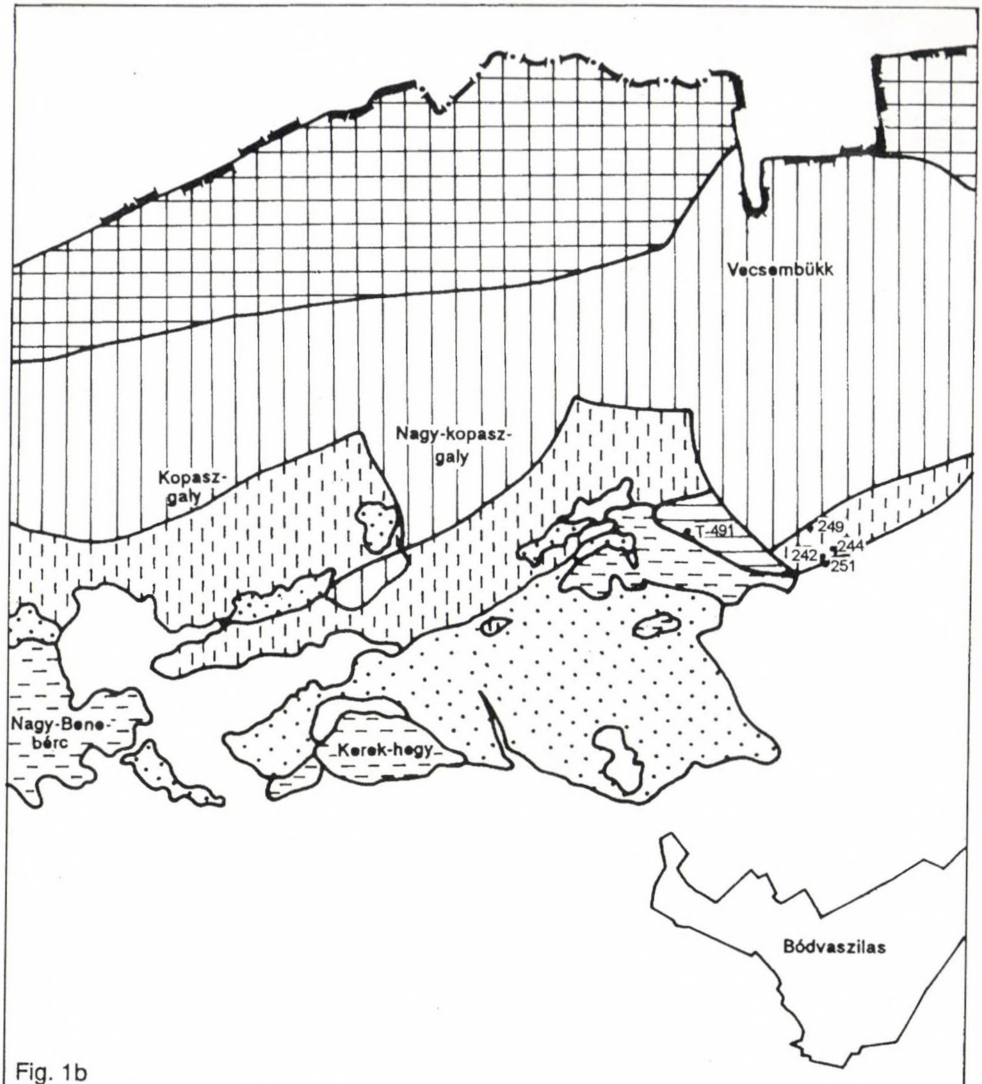


Fig. 1b

Arenovidalina, and *Ophthalmidium* are frequent. *Turriglomina* taxa are present in great frequency and diversity in the basinal facies.

The richest foraminifer assemblage was found in the open marine slope sediments of the Nádaska Limestone Formation (Figs 3–6). In this association, the predominance of the species *Ophthalmidium exiguum* Koehn-Zaninetti, *Arenovidalina chialingchiangensis* Ho, and *Turriglomina mesotriasica* (Koehn- Zaninetti) and a frequency of species of the genera *Pseudonodosaria* and *Lenticulina* are characteristic.

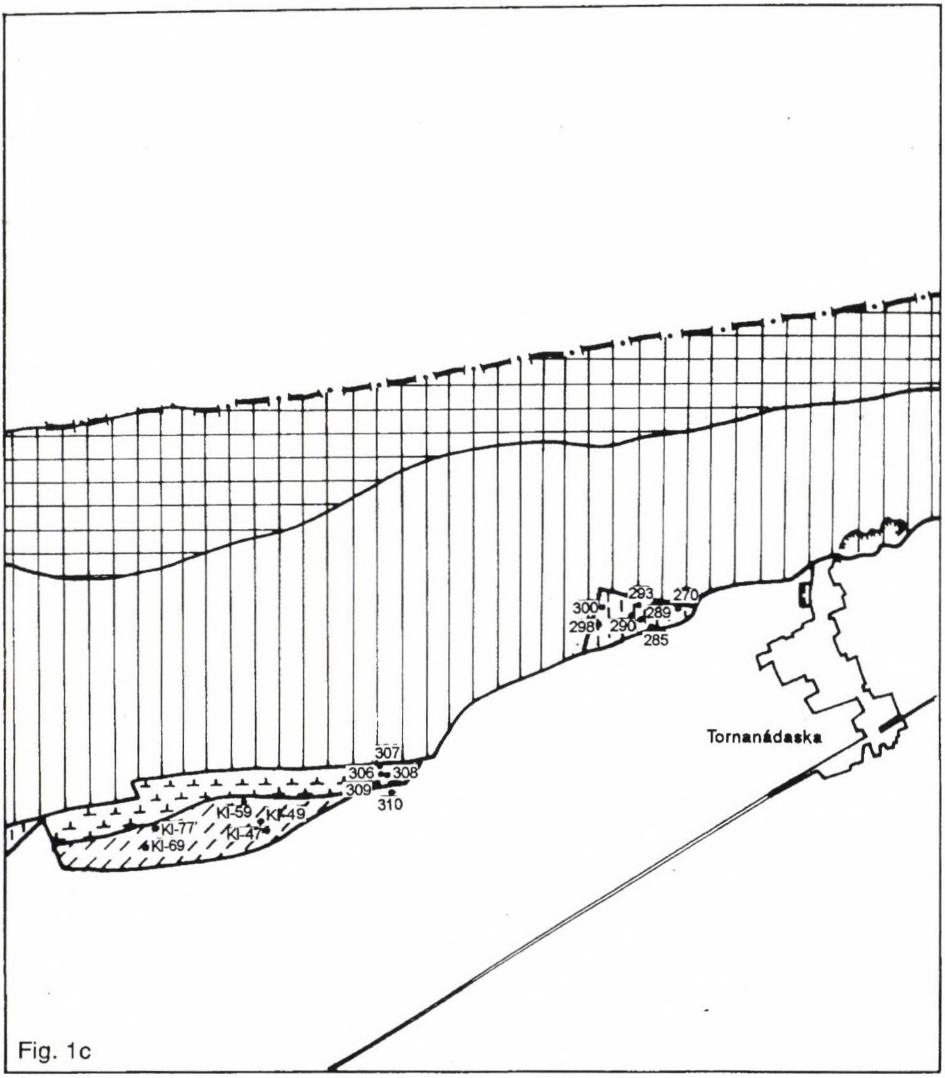


Fig. 1c

The foraminifer fauna of the pelagic basinal facies (Reifling Limestone Formation, Derenk Limestone Formation, Pötschen Limestone Formation, and Hallstatt Limestone Formation) is the poorest. The assemblage is dominated by species of the genus *Turriglomina* (Bérczi-Makk, 1993).

The foraminifer fauna of the basinal facies of Alsó Hill is a good facies indicator; however, it is not generally suitable for drawing chronostratigraphic conclusions.

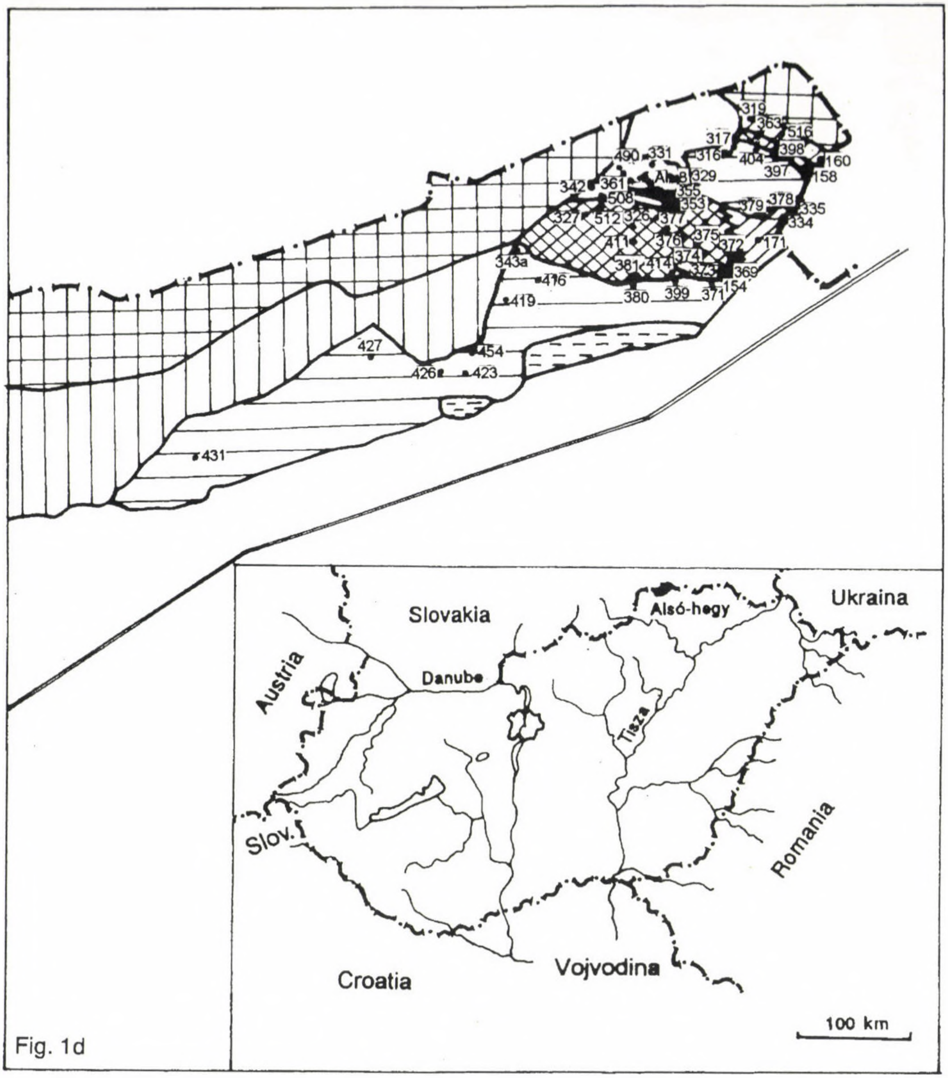


Fig. 1d

Stratigraphic evaluation

In the Aggtelek-Rudabánya Mountains, which constitute the Hungarian part of the complicated South Gemeric nappe system, significantly different Triassic formations are known. Differentiation of the Triassic began during the Anisian stage, with the appearance of pelagic formations of basinal facies related to rifting. At present, three facies units (Tornaicum, Meliaticum, Silicicum) can be distinguished among the "tectofacies" related to rifting (Kovács et al. 1988, 1993).

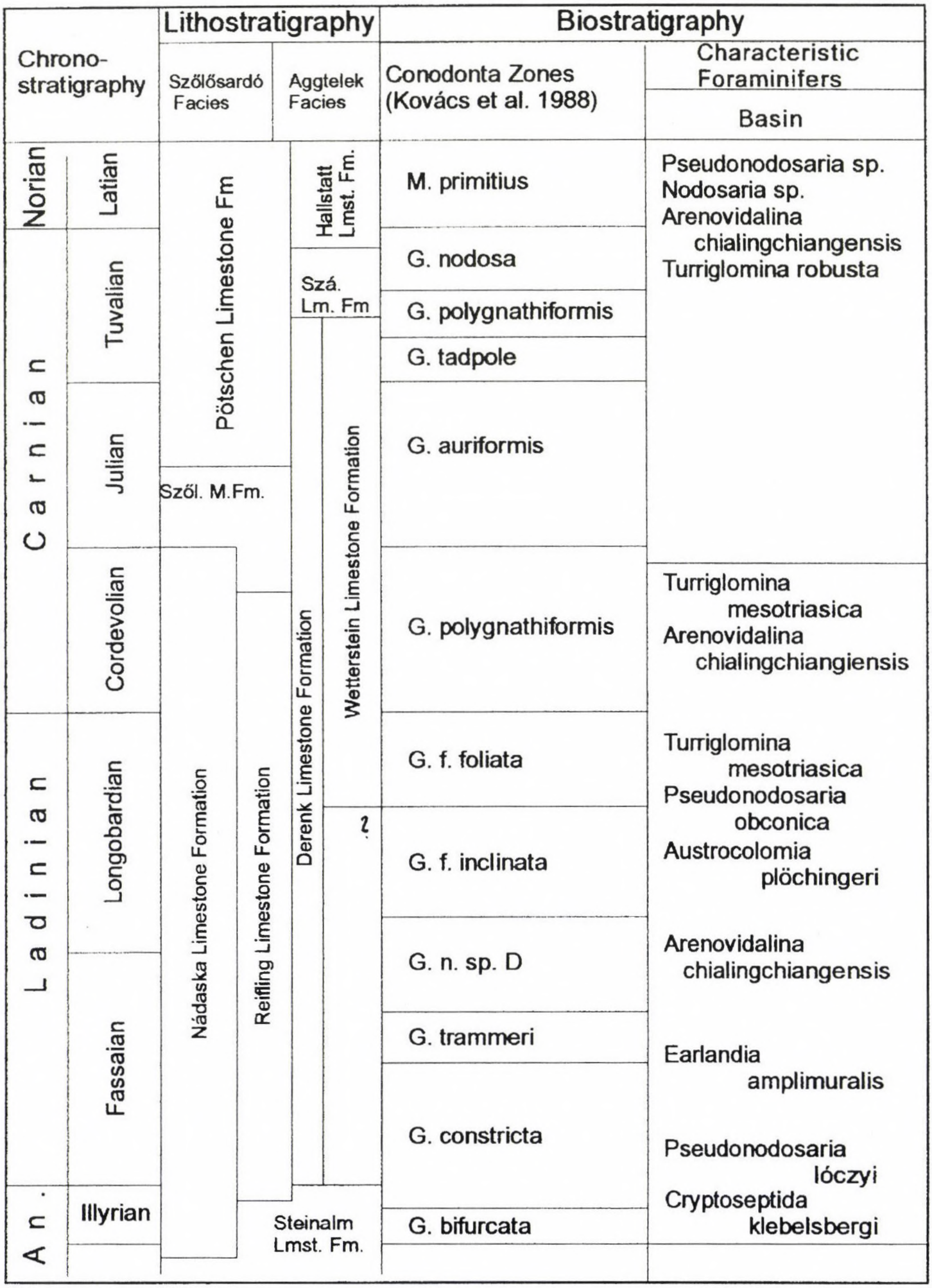


Fig. 2
Characteristic foraminifer horizons of the Triassic formations of Alsó Hill. Szá. Lm. Fm. – Szádvárborsa Limestone Formation, Szől. M. Fm. – Szőlősardó Marl Formation

A review of the rich Triassic foraminifer assemblage of Alsó Hill began with the representation of the characteristic foraminifer association of the Anisian Steinalm Limestone Formation of open marine lagoonal facies from the Alsó Hill pre-rift formations (Bérczi-Makk 1996a).

Syn-rift formations (Wetterstein Limestone Formation, Derenk Limestone Formation, Hallstatt Limestone Formation, Nádaska Limestone Formation, Reifling Limestone Formation, Pötschen Limestone Formation) of different facies (Aggtelek facies, Szőlősardó facies) form the Hungarian part of the Silicicum (Kovács et al. 1993). The rich foraminifer fauna of the Wetterstein Limestone Formation was dealt with in previous studies (Bérczi-Makk 1981, 1996b). The present study describes the scarce foraminifer fauna of basinal sediments which were tectonically ruptured during lithification (Derenk Limestone Formation), open marine slope sediments (Nádaska Limestone Formation) and formations of pelagic basinal facies (Reifling Limestone Formation, Pötschen Limestone Formation, and Hallstatt Limestone Formation).

The foraminifer fauna of the basinal sediments of Alsó Hill can be characterised by associations poor in species and – in most cases – poor in specimens, with from some exceptions, a poorish foraminifer fauna is not suitable for drawing stratigraphic conclusions. In the assemblage, Nodosariidae, indicating the basinal facies, predominate and specimens of species belonging to the genera *Lenticulina*, *Arenovidalina*, and *Ophthalmidium* are frequent. Species of the genus *Turriglomina* were found in great frequency and diversity in both the Ladinian and Carnian basinal facies (Bérczi-Makk 1993).

Szőlősardó tectofacies

On the southern front of the Silice Nappe, the Szőlősardó tectofacies is represented by slope facies of small extension, often with resedimentation phenomena (Kovács et al. 1988, 1993). Its characteristic formation is the open marine slope sediment of the Nádaska Limestone Formation. The Nádaska Limestone occurs in two slivers of the eastern end of Alsó Hill, often interfingered with the Reifling Limestone Formation of basinal facies. Atypical Pötschen Limestone Formation of pelagic basinal facies is known from the southern foot of Alsó Hill, in the neighbourhood to the north of Komjáti.

Nádaska Limestone Formation (Plates I–IX)

The characteristic facies of the Szőlősardó tectofacies, the Nádaska Limestone Formation, occurs in two slivers of the eastern end of Alsó Hill (Fig. 1d).

Rocks of the Nádaska Limestone Formation are varicoloured (shades from red to grey) and bedded. The red varieties are nodular. Its important distinguishing mark is the proto-intraclastic structure, due to which patches of different colours and microfacies can be seen within one bed. Essentially, it is a transitional basinal facies between the Schreyeralm and Reifling Limestones (Kovács 1979; Kovács et al. 1988) as an open marine, slope sediment.

The Nádaska Limestone contains a rich conodont fauna, on the basis of which its age is Pelsonian–Langobardian (Middle Anisian–Ladinian). On Alsó Hill, characteristic conodont species of the interval zones *Gondolella bulgarica, Gondolella bifurcata, Gondolella constricta, Gondolella trammeri,* and *Gondolella foliata* have been encountered (Kovács et al. 1988).

Because of the differentiated subsidence of the Steinalm carbonate platform, the basinal facies appear at in different times in the individual sections (Kovács 1981). Thus, in section Alsó Hill No. 1 (stratotype of the Nádaska Limestone Formation), the Nádaska Limestone appears near the Anisian–Ladinian boundary, and in section Alsó Hill No. 8 at the Pelsonian–Illyrian boundary.

In both sections, facies change is well indicated by the foraminifer fauna. Consequently, the occurrence of *Turriglomina* taxa as well as the frequency of forms belonging to the families Nodosariidae and Lagenidae are characteristic. Among them, species of the genera *Pseudonodosaria* and *Lenticulina* are the most typical. The richness in specimens of the species *Arenovidalina chialingchiangensis* Ho, enduring the changes in environmental conditions, is remarkable.

In samples Nos 7–51 of section Alsó Hill No. 1 (Fig. 3), *Turriglomina mesotriasica* (Koehn-Zaninetti) is one of the most frequent species. The foraminifer assemblage indicates an open marine environment:

Turriglomina mesotriasica Koehn-Zaninetti
Earlandia amplimuralis (Pantic)
Earlandia gracilis (Pantic)
Earlandia sp.
Nodosariidae sp.
Pseudonodosaria obconica (Reuss)
Pseudonodosaria cf. *obconica* (Reuss)
Pseudonodosaria cf. *lata* (Tappan)
Pseudonodosaria sp
Dentalina sp.
Austrocolomia plöchingeri (Oberhauser)
Austrocolomia sp.
Cryptoseptida sp. (=*Pachyphloides* sp.)
Lenticulina cf. *acutiangulata* (Terquem)
Lenticulina sp.
Gheorghianina vujisici (Urosevic et Gazdzicki)
Ophthalmidium exiguum Koehn-Zaninetti
Ophthalmidium sp.
Arenovidalina chialingchiangensis Ho
Agathammina sp.
Agathamminoides sp.

In samples No. 5–8 of section Alsó Hill No. 8 (Fig. 4), forms belonging to the family Nodosariidae are the most frequent. Among them, *Cryptoseptida klebelsbergi* (Oberhauser), represented by few specimens, is characteristic. It is known from several Ladinian formations of the Alpine area. Furthermore, some *Pseudonodosaria obconica* (Reuss) and *Pseudonodosaria loczyi* Oravecz-Scheffer were found. The conodont fauna unambiguously proves the Illyrian (Anisian) age of the Nádaska Limestone in this section (Kovács 1981). Thus, facies-susceptible foraminifera of section Alsó Hill No. 8 must be analysed taking into account that the above Nodosariidae species already appear in red pelagic basinal facies in the Illyrian (Fig. 4). The conclusion can be drawn that species of the Nodosariidae family are bound to basinal facies and not to geologic time. This also confirms the significance of the facies – indicating role of foraminifera:

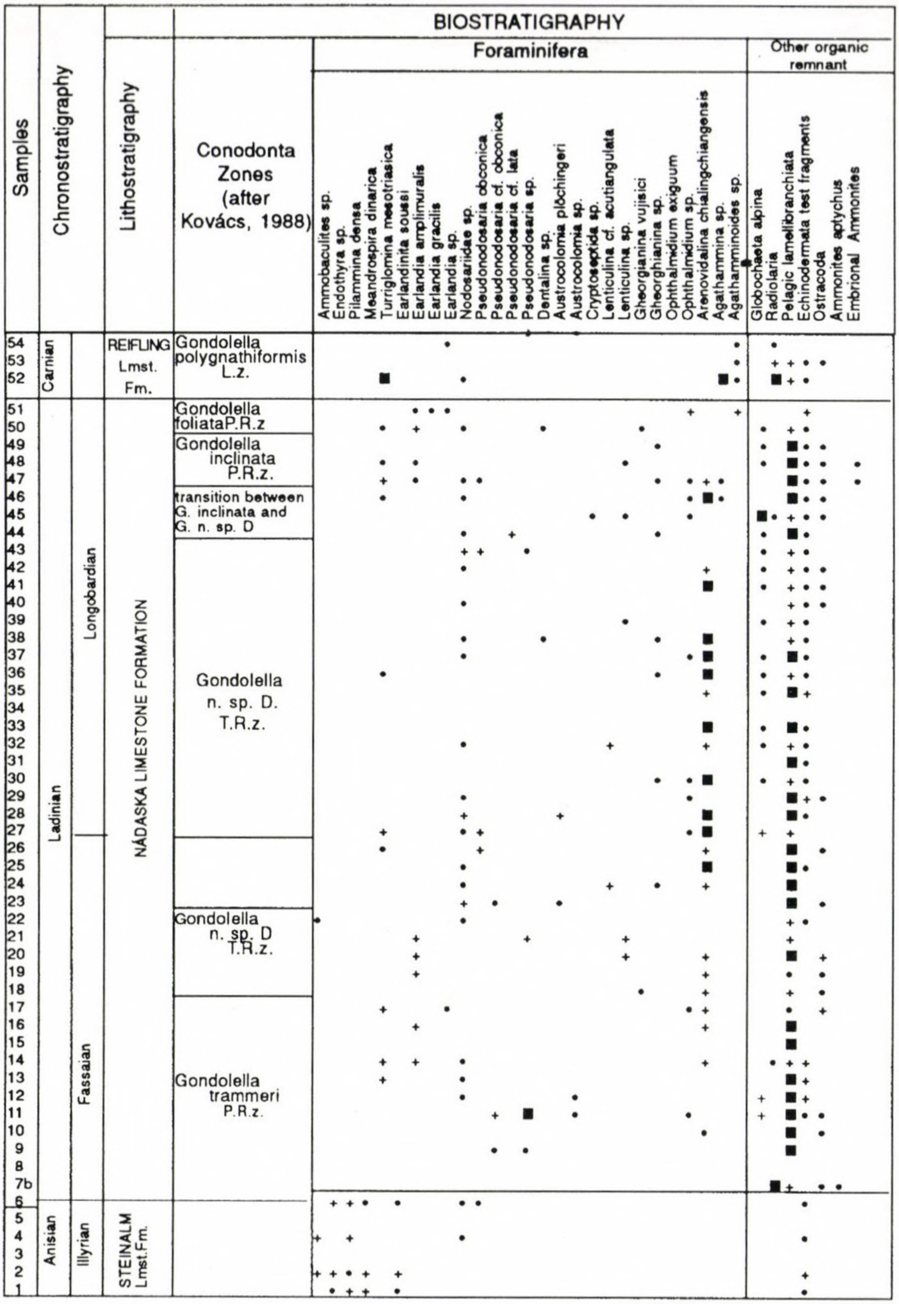


Fig. 3
Distribution by samples and frequency of the foraminifer fauna of the section Alsó Hill No. 1.
• – few; + – frequent; ■ – massive

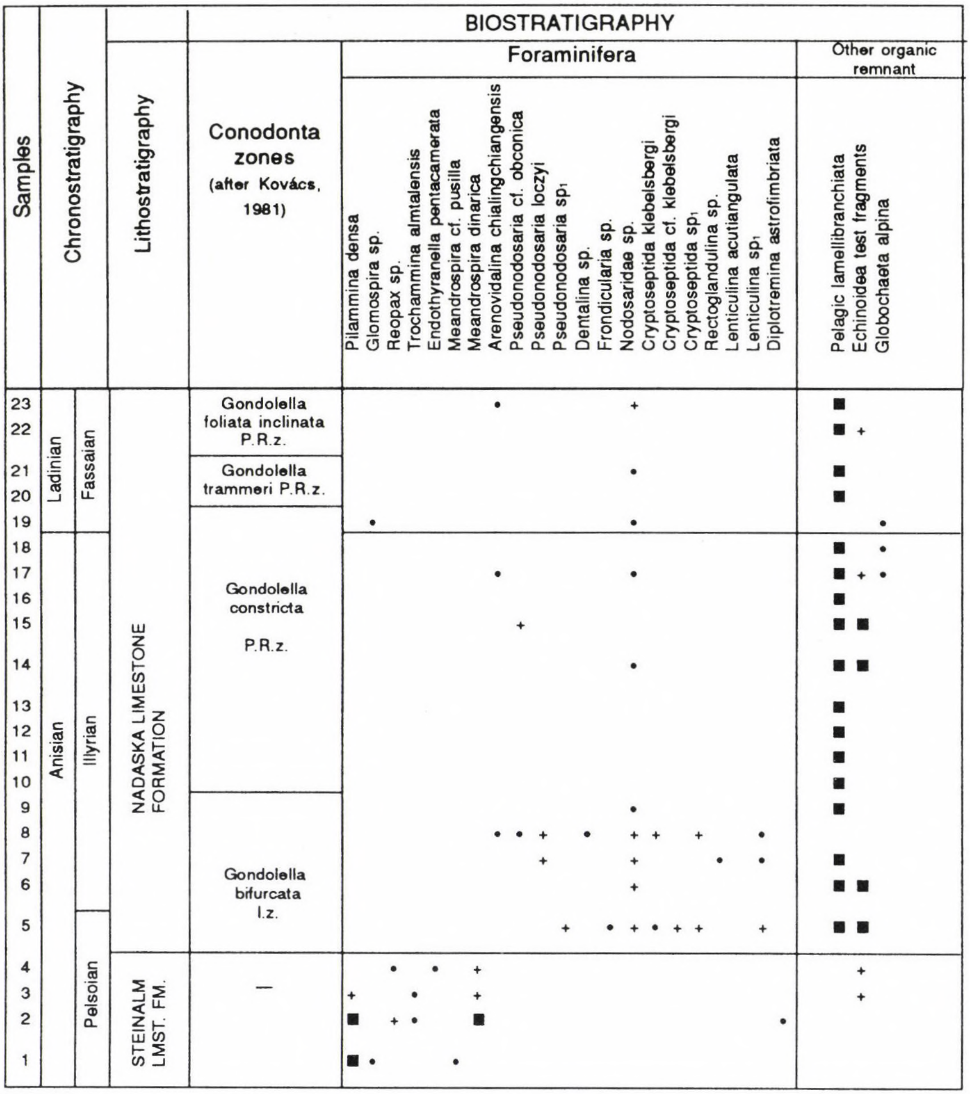


Fig. 4
Distribution by samples and frequency of the foraminifer fauna of the section Alsó Hill No. 8.
• – few; + – frequent; ■ – massive

Arenovidalina chialingchiangensis Ho

Pseudonodosaria cf. *obconica* (Reuss)

Pseudonodosaria loczyi Oravecz-Scheffer

Cryptoseptida (=*Pachyphloides*) *klebelsbergi* (Oberhauser)

Cryptoseptida (=*Pachyphloides*) cf. *klebelsbergi* (Oberhauser)

Cryptoseptida sp.

Pseudonodosaria sp$_1$
Dentalina sp.
Frondicularia sp.
Nodosariidae sp.
Rectoglandulina sp.
Lenticulina acutiangulata (Terquem)
Lenticulina sp$_1$

Compared to the foraminifer fauna of the Nádaska Limestone of sections Alsó Hill No. 1 and 8, the assemblage from scattered samples (T-158, -325, -332, -334, -335, -344, -358, -366, -372, -378, -379, -398) is extremely poor (Fig. 6). Frequency of taxa of the Nodosariidae family and species of the *Ophthalmidium* genus, the presence of *Turriglomina mesotriasica* (Koehn-Zaninetti) in some samples, as well as the general distribution of pelagic bivalves in the accompanying fossil assemblage make the basinal facies of the samples unambiguous. An exact age classification cannot be given on the basis of the foraminifer fauna:

Turriglomina mesotriasica (Koehn-Zaninetti)
Arenovidalina chialingchiangensis Ho
Glomospirella sp.
Trochammina sp.
Ophthalmidium exiguum Koehn-Zaninetti
Ophthalmidium sp.
Agathammina sp.
Nodosariidae sp.

Classification according to conodont interval zones is possible only by means of those samples containing conodont fauna (T-154, -321, -326, -327, -337, -354, -355, -355a, -359, -364, -365, -373, -374, -375, -376, -377, -381, -385, -410, -411, -413, -414, -508, -509, -511, -512 – Fig. 5). In these samples, the following foraminifer assemblage was found:

Arenovidalina chialingchiangensis Ho
Glomospira sp.
Glomospirella sp.
Trochammina sp.
Turriglomina mesotriasica (Koehn-Zaninetti)
Ophthalmidium exiguum Koehn-Zaninetti
Ophthalmidium sp.
Agathammina sp.
Endothyra sp.
Earlandia tintinniformis (Misik)
Pseudonodosaria obconica (Reuss)
Austrocolomia sp.
Nodosariidae sp.
Lenticulina sp.
Diplotremina astrofimbriata Kristan-Tollmann.

Reifling Limestone Formation (Plate X)

It is known from two slivers of the eastern end of Alsó Hill (Fig. 1), in facies with and without chert (Kovács et al. 1988).

The medium and dark-grey coloured, well-bedded Reifling Limestone of pelagic basinal facies with cherts is deposited over the Nádaska Limestone in the upper sliver. On the basis of the poorish conodont fauna (*Gondolella polygnathiformis* Bud. et Stef.), its age is Lower Carnian. Scattered samples (T-160, -216, -319, -516) are entirely free of foraminifera. In section Alsó Hill No. 1 (Fig. 3), the assemblage of samples No. 52-54 consists exclusively of *Turriglomina mesotriasica* (Koehn-Zaninetti) and *Arenovidalina chialingchiangensis* Ho, apart from some *Agathammina* specimens. The diversity of the species

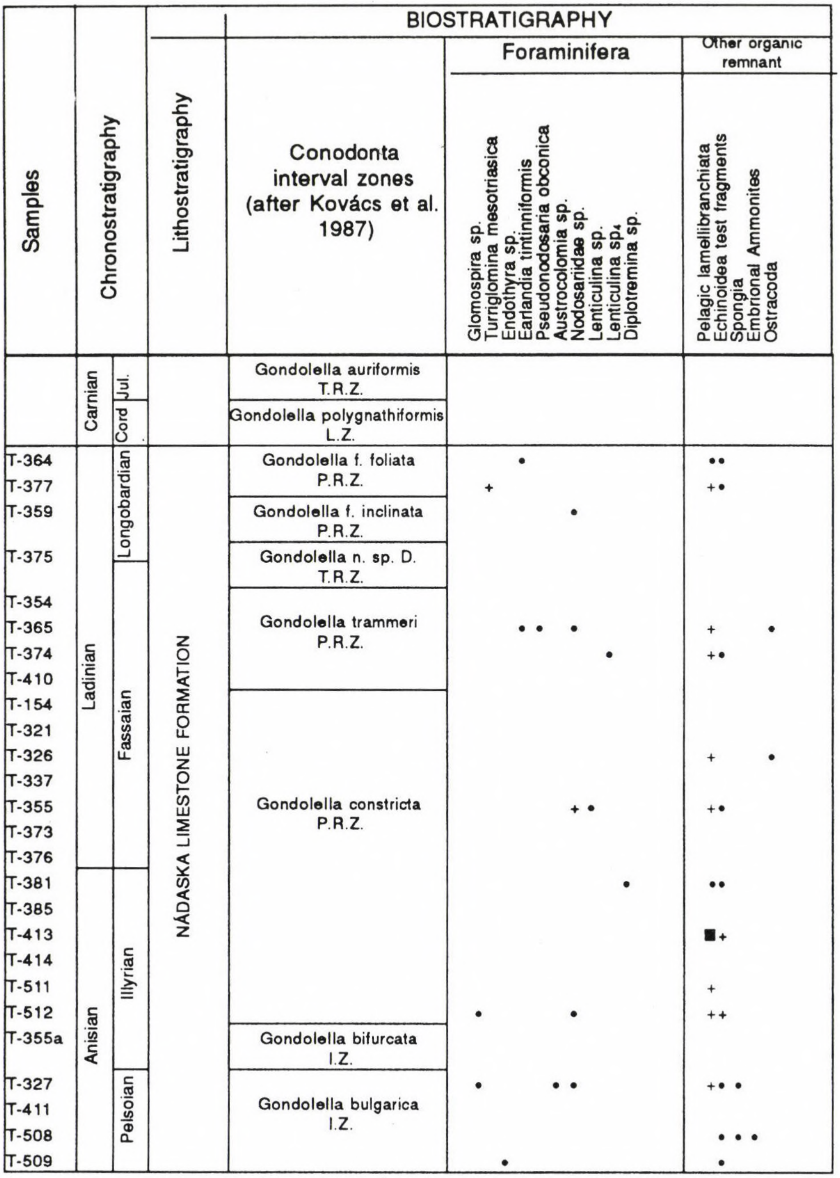


Fig. 5
Distribution by samples and frequency of the foraminifer fauna of the Alsó Hill Nádaska Limestone Formation. Legend: • – few; + – frequent; ■ – massive

Turriglomina mesotriasica (Koehn-Zaninetti) can be well studied in the formations of different facies and age, which are exposed at the eastern end of Alsó Hill (Bérczi-Makk 1993).

The dark-grey coloured, bedded Reifling Limestone of near-platform basinal facies without chert is interfingered with the Nádaska Limestone, mainly in the lower sliver (sample No. T-171). On the basis of its stratigraphic position and the conodont fauna (*Neospathodus tatricus* Zawidzka, *Gondolella polygnathiformis* Bud. et Stef.), its age is Upper Ladinian–Lower Carnian. The poorish, biostratigraphically undistinctive foraminifer fauna is represented by some not more exactly determinable specimens of the Nodosariidae family, good indicators of the basinal facies. At the eastern end of Alsó Hill, *Turriglomina mesotriasica* (Koehn-Zaninetti) specimens were found in some samples (collected by Gy. Less) of the chert – free Hidvégardó Reifling Limestone.

Samples	Chronostratigraphy	Lithostratigraphy	BIOSTRATIGRAPHY									
			Foraminifera							Other organic remnant		
			Glomospirella sp.	Trochammina sp.	Ophthalmidium exiguum	Ophthalmidium sp.	Arenovidalina chialingchiangensis	Agathammina sp.	Nodosariidae sp.	Pelagic lamellibranchiata	Echinoidea test fragments	Spongia
T-158	Ladinian	NÁDASKA LMST. FM.							•	•		•
T-325												
T-332			•						•	•		•
T-334				•			+					
T-335							•			•		
T-358												
T-366			•		•	•	+		•	+		
T-327												
T-378												
T-379								•			•	
T-398										■	•	

Fig. 6
Foraminifer fauna of the scattered samples of the Alsó Hill Nádaska Limestone Formation. • – few; + – frequent; ■ – massive

Pötschen Limestone Formation (Plate XI)

At the southern foot of Alsó Hill, above Komjáti (T-259, -306, -307, -308, -309, -310), a somewhat atypical variety of this formation can be found (Fig. 1). Stratified or thin-bedded, chert-free varieties of the limestone of predominantly grey colour as well as such with dark-grey chert nodules are known (Kovács et al. 1988).

On the basis of the conodont fauna of the *Gondolella tadpole* and *Metapolygnathus posterus* interval zones, its age is Upper Carnian–Lower Norian.

Kovács recognised pelagic crinoidea (*Osteocrinus* sp.) remnants in the uppermost Tuvalian layers (Oravecz-Scheffer 1979).

The foraminifer fauna belonging predominantly to the Nodosariidae family and found in a fossil association of radiolarian, microfilamented, characteristically basinal facies is only indicative of the facies, but gives no information concerning the age (Fig. 7):

Glomospira sp.
Ophthalmidium sp.
Nodosaria sp4
Pseudonodosaria sp1
Pseudonodosaria sp2
Nodosariidae sp.

Samples	Chronostratigraphy	Lithostratigraphy	BIOSTRATIGRAPHY: Foraminifera						Other organic remnant			
			Glomospira sp.	Ophthalmidium sp.	Nodosariidae sp.	Nodosaria sp_4	Pseudonodosaria sp_1	Pseudonodosaria sp_2	Microfilaments	Spongia	Globochaeta alpina	Embrional Ammonites
T-259	U. Carn.–L. Norian	Pötschen Lmst. Fm.	•	•	•			•	•	•		
T-306									•	•	•	
T-307									•			•
T-308										•		
T-309												
T-310			•		•	•	•					

Fig. 7
Foraminifer fauna of the scattered samples of the Alsó Hill Pötschen Limestone Formation. • – few; + – frequent; ■ – massive

Aggtelek tectofacies

Accretion of the platform carbonates (Wetterstein Limestone Formation), constituting the main mass of Alsó Hill, continued until the later part of the Carnian. Basin sediment ruptured repeatedly ("syndiagenetically brecciated"; Kovács 1977, 1979) during several generations, and is attributed to the subsidence of the Wetterstein carbonate platform in the Upper Carnian (Derenk Limestone Formation). In the Norian, pelagic Hallstatt limestone (Hallstatt Limestone Formation) was deposited on the Wetterstein platform (Kovács et al. 1988).

Wetterstein Limestone Formation

The rich foraminifer fauna of the formations of the reefal and lagoonal facies of the Wetterstein Limestone Formation was reviewed in a previous paper (Bérczi-Makk 1996b).

Derenk Limestone Formation (Plate XII)

In the southern foreland of the carbonate platform mass of Alsó Hill, the Derenk Limestone extends from Derenk to the neighbourhood north of Komjáti (Fig. 1). It is a thick-bedded or unstratified, syndiagenetically brecciated mottled basinal limestone, described by Kovács et al. (1988) as an atypical Hallstatt Limestone, originally consisting of varicoloured micrite but broken ("tectonically ruptured") by several generations of fissures filled with grey, drusic calcite,the amount of which often exceeds that of the original sediment.

On the basis of the conodont fauna of the *Gondolella trammeri* and *Gondolella polygnathiformis* interval zones, its age is Lower Ladinian–Lower Upper Carnian.

In the few samples (T-236, -237, -432, -433, -434, -435, -436, -437) deriving from the southern margin of the unnamed elevation in the north-western neighbourhood of Szádvár, as well as from the microfilamented limestone of sample No. Kl-69 deriving from north of Komjáti, a poorish foraminifer fauna was found (Fig. 8). *Nodosaria* taxa indicating basinal facies give no information about the age of the formation. The monotony of the scarce foraminifer fauna is broken by the appearance of species of the morphologically characteristic *Turriglomina* genus (Bérczi-Makk 1993). In the studied samples, the species

Turriglomina robusta Bérczi-Makk shows a general distribution. In one locality (sample Kl-69), specimens of *Turriglomina conica* He were also found:

Turriglomina robusta Bérczi-Makk
Turriglomina mesotriasica (Koehn-Zaninetti)
Turriglomina conica He
Agathammina sp.
Nodosariidae sp.
Nodosaria sp4

Hallstatt Limestone Formation
(Plates XIII–XIV)

The "Hallstatt variegated facies" of Carnian–Norian age can be found in the range of pelagic basinal facies broken off repeatedly along the southern foot of Alsó Hill (Kovács 1979; Kovács et al. 1988). The Hall\statt Limestone Formation built up by different members (lower "Massiger Hellkalk" A and B, "Hangendrothkalk", upper "Massiger Hellkalk") consists of brownish-grey, pink, purplish-pink or reddish-pink, and dark-red, thick-bedded limestones, respectively.

On the basis of the Alsó Hill conodont fauna consisting of *Gondolella nodosa* and the *Metapolygnathus primitius* taxon range zones (Kovács et al. 1988), and of the holothurian sclerites, its age is Upper Carnian–Norian.

Samples	Chronostratigraphy	Lithostratigraphy	BIOSTRATIGRAPHY: Foraminifera						BIOSTRATIGRAPHY: Other organic remnant		
			Turriglomina mesotriasica	Turriglomina robusta	Turriglomina conica	Agathammina sp.	Nodosariidae sp.	Nodosaria sp4	Microfilaments	Radiolaria	Spongia
T-236	Ladinian–Carnian	DERENK LMST. FM.									
T-237									•		
T-432									+		
T-433									•		
T-434			•	+					+	•	•
T-435			•			•		•	•		
T-436							•				•
T-437				•						•	•
KI-69					•				•		

Fig. 8
Foraminifer fauna of the scattered samples of the Alsó Hill Derenk Limestone Formation. • – few; + – frequent; ■ – massive

Its microfauna association indicates the basinal facies based on the frequency of radiolarians, sponge spicules and foraminifera belonging to the Nodosariidae family. For all practical purposes, the foraminifera give no information concerning the age.

Species belonging to the Nodosariidae family are known in a great number of specimens from the Alsó Hill Hallstatt Limestone. They are predominantly thin-walled forms, which are not able to resist strong water agitation, and thus do not appear in the areas of higher turbulence; they also keep away from hard substrate. Their distribution is restricted to the pellet-mud and mud facies (Hohenegger and Piller 1975).

The foraminifer fauna of the studied Hallstatt Limestone samples (T-88, -159, -241, -242, -243, -244, -245, -246, -247, -248, -249, -251, -276, -285, -287, -288, -289,

Samples	Chronostratigraphy	Lithostratigraphy	BIOSTRATIGRAPHY: Foraminifera																	Other organic remnant				
			Trochammina sp.	Ammobaculites sp.	"Turriglomina" carnica	Turriglomina robusta	Arenovidalina	chialingchiangensis	Ophthalmidium sp.	Paraopthalmidium sp.	Agathammina sp.	Agathammin sp₂	Lenticulina sp.	Dentalina sp2	Nodosariidae sp.	Nodosaida sp1	Nodosaria sp₃	Nodosaria sp₄	Pseudonodosaria sp.	Microfilaments	Radiolaria	Spongia	Globochaeta alpina	Ostracoda
T-88	Carnian– Norian	HALLSTATT LIMESTONE FORMATION																						
T-159															•					•		•		
T-241			•																					
T-242																								
T-243																				•		•		
T-244														•						■			•	
T-245								•												■		•	•	
T-246																				+	•	+		
T-247												•	•	•						+	+	•	•	
T-248																•				•	•	•	•	
T-249																		•		+			•	
T-251														•										
T-276																								
T-285			•					•	•		•			•										
T-287					+																			
T-288					•						•													
T-289					•																			
T-290																		•						
T-293														•						•		•		
T-298				•			■	•	•											•				
T-299																				•				
T-300																				•				
T-347										•							•					•		
T-357																								

Fig. 9

Foraminifer fauna of the scattered samples of the Alsó Hill Hallstatt Limestone Formation. • – few; + – frequent; ■ – massive

-290, -293, -298, -299, -300, -347, -357, section Szádvár No. 3, Szv-26.) of Alsó Hill is as follows (Fig. 9):

Trochammina sp.
Ammobaculites delicatus Trifonova
Turriglomina mesotriasica (Koehn-Zaninetti)
Turriglomina robusta Bérczi-Makk
Arenovidalina chialingchiangensis Ho
Ophthalmidium sp.
Paraophthalmidium sp.
Agathammina sp.
Agathammina sp2
Lenticulina sp.
Dentalina sp2
Nodosariidae sp.
Nodosaria sp2
Nodosaria sp3
Nodosaria sp4

Conclusions

– In the foraminifer assemblage of the basinal facies, the taxa Nodosariidae and Ichthyolariidae predominate and specimens of species belonging to the genera *Lenticulina, Arenovidalina, Ophthalmidium,* and *Turriglomina* are frequent.

– The richest foraminifer assemblage was found in the open marine slope sediments of the Nádaska Limestone Formation. In it, the species *Turriglomina mesotriasica* (Koehn-Zaninetti), *Arenovidalina chialingchiangensis* Ho, and *Ophthalmidium exiguum* Koehn-Zaninetti predominate and species of the genera *Pseudonodosaria* and *Lenticulina* are frequent.

– Apart from some *Agathammina* specimens, the foraminifer assemblage of the near-platform pelagic basinal facies of the Reifling Limestone Formation is characterised exclusively by the richness in specimens of the species *Turriglomina mesotriasica* Koehn-Zaninetti and *Arenovidalina chialingchiangensis* Ho.

– Poorish foraminifer fauna belonging to the Nodosariidae family, from samples of the rather atypical Pötschen Limestone Formation, indicates the basinal facies but gives no chronostratigraphic information.

– Poorish foraminifer fauna of the microfilamented limestone of the Derenk Limestone Formation is dominated by *Turriglomina robusta* Bérczi-Makk specimens.

– The poorest foraminifer association was found in the samples of the Hallstatt Limestone Formation, in which specimens of *Turriglomina mesotriasica* (Koehn-Zaninetti), *Turriglomina robusta* Bérczi-Makk, and *Arenovidalina chialingchiangensis* Ho have a determinative role.

Moving away from the shelf region towards the basin, the frequency and diversity of the *Turriglomina* taxa increase simultaneously with the decrease of other accompanying benthic foraminifera.

Palaeontology

Below only those foraminiferal species are listed which are relatively abundant in the impoverished associations of the basinal formations. The prevailing genus within the deposits of basinal facies is *Turriglomina*; a detailed description of its species was given earlier (Bérczi-Makk 1993).

The systematic order below follows the system of Loeblich, Tappan (1988), but for certain species the most recently published data (Rettori 1995; Zaninetti et al. 1991) were also taken into account.

The references for the systematic part can be found in the monograph of Loeblich and Tappan (1988).

The foraminiferal species from the basinal formations in systematic order are:

ORDER: FORAMINIFERIDA EICHWALD, 1830

I. suborder: TEXTULARIINA Delage et Hérouard, 1896

superfamily: Lituolacea de Blainville, 1827
family: Lituolidae de Blainville, 1827
subfamily: Lituolinae de Blainville, 1827
genus: *Ammobaculites* Cushman, 1910

***Ammobaculites delicatus* Trifonova, 1967**

II. suborder: FUSULININA Wedekind, 1937

superfamily: Earlandiacea Cummings, 1955
family: Earlandiidae Cummings, 1955
genus: *Earlandia* Plummer, 1930

***Earlandia amplimuralis* (Pantic)**

***Earlandia gracilis* (Pantic)**

***Earlandia tintinniformis* (Misik)**

III. suborder: MILIOLINA Delage et Hérouard, 1896

superfamily: Cornuspiracea Schultze, 1854
family: Arenovidalinidae Zaninetti et Rettori in: Zaninetti, Rettori, He et Martini, 1991
subfamily: Arenovidalininae Zaninetti et Rettori in: Zaninetti, Rettori, He et Martini, 1991
genus: *Arenovidalina* Ho, 1959

***Arenovidalina chialingchiangensis* Ho, 1959**

family: Meandrospiridae Sajdova, 1981
subfamily: Turriglomininae Zaninetti in: Limongi, Panzanelli-Fratoni, Ciarapica, Cirilli, Martini, Salvini-Bonnard, Zaninetti, 1987
genus: *Turriglomina* Zaninetti in: Limongi, Panzanelli-Fratoni, Ciarapica, Cirilli, Martini, Salvini-Bonnard, Zaninetti, 1987

***Turriglomina conica* (He, 1984)**

***Turriglomina mesotriasica* (Koehn-Zaninetti, 1968)**

***Turriglomina robusta* Bérczi-Makk, 1993**

family: Nubeculariidae Jones, 1875
subfamily: Nodophthalmidiinae Cushman, 1940
genus: *Gheorghianina* Loeblich et Tappan, 1986

***Gheorghianina vujisici* (Urosevic et Gazdzicki, 1977)**

family: Ophthalmidiidae Wiesner, 1920
genus: *Gsollbergella* Zaninetti, 1979

***Gsollbergella spiroloculiformis* (Oravecz-Scheffer, 1970)**

genus: *Ophthalmidium* Kübler et Zwingli, 1870

***Ophthalmidium exiguum* Koehn-Zaninetti, 1968**

IV. suborder: Lagenina Delage et Hérouard, 1896

superfamily: Robuloidacea Reiss, 1963
family: Ichtyolariidae Loeblich et Tappan, 1986
genus: *Austrocolomia* Oberhauser, 1960

***Austrocolomia cordevolica* Oberhauser, 1967**

***Austrocolomia plöchingeri* Oberhauser, 1960**

genus: *Cryptoseptida* Sellier de Civrieux et Dessauvagie, 1965

***Cryptoseptida (=Pachyphloides) klebelsbergi* (Oberhauser, 1960)**

superfamily: Nodosariacea Ehrenberg, 1838
family: Nodosariidae Ehrenberg, 1838
subfamily: Nodosariinae Ehrenberg, 1838
genus: *Pseudonodosaria* Boomgaart, 1949

***Pseudonodosaria lata* (Tappan, 1951)**

***Pseudonodosaria loczyi* Oravecz-Scheffer, 1980 in: Szabó, Kovács, Lelkes, Oravecz-Scheffer, 1980**

***Pseudonodosaria obconica* (Reuss, 1868)**

family: Vaginulinidae Reuss, 1860
subfamily: Lenticulininae Chapman, Parr et Collins, 1934
genus: *Lenticulina* Lamarck, 1804

***Lenticulina acutoangulata* (Terquem, 1864)**

genus: *ARENOVIDALINA* Ho, 1959: "Test minute, lenticular in shape, formed by two chambers, wall agglutinated, consisted of calcareous particles bound by calcareous cement, proloculus sphaeroidal, second chamber tubular, involute, wound in a plane, increasing gradually in size as added, central region thickened and gradually decreasing in thickness towards the periphery, aperture simple, formed by the open end of the tubular chamber."

Arenovidalina chialingchiangensis Ho, 1959

Pl. II, Figs 1b, 2–7, 9–10, Pl. VII, Fig. 6, Pl. VIII, Fig. 2, Pl. IX, Figs 2–3

Type reference:

1959. *Arenovidalina chialingchiangensis* – Ho, Y. p. 414. pl. 6, figs 9–28

Synonyms:

1959. *Arenovidalina chialingchiangensis* var. *rhombea* – Ho, Y. P. 415. pl. 7, figs 4–9
1959. *Arenovidalina chialingchiangensis* var. *major* – Ho, Y. P. 415. pl. 7, figs 1–3
1964. *Aulotortus chialingchiangensis* – Loeblich, A., H. Tappan textfig. 606 (4–5)
1965. *Arenovidalina chialingchiangensis* – Michailova-Jowtcheva, P., E. Trifonova (not illustrated)
1969. *Hemigordius? chialingchiangensis* – Zaninetti, L., P. Brönnimann textfig. 5/2
1972. *Hemigordius? chialingchiangensis* – Canovic, M., R. Kemenci. pl. 2, fig. 5, pl. 3, fig. 1
1972. *Hemigordius? chialingchiangensis* – Christodoulou, G., S. Tsaila-Monopolis pl. 30, fig. 1, pl. 31, fig. 3
1972a. *Arenovidalina chialingchiangensis* – Trifonova, E. p. 508. pl. 2, fig. 9
1972b. *Arenovidalina chialingchiangensis* – Trifonova, E. (not illustrated)
1973. *Arenovidalina chialingchiangensis* – Courel, L. textfig. 30/2–3. pl. 8, fig. 10
1973. *Hemigordius? chialingchiangensis* – Gazdzicki, A., K. Zawidzka pl. 1, figs 1–2
1974. *Arenovidalina? chialingchiangensis* – Efimova, E. p. 70. pl. 4, figs 6–8
1975. *Hemigordius? chialingchiangensis* – Gazdzicki, A., J. Trammer, K. Zawidzka (not illustrated)
1975. *Hemigordius chialingchiangensis* – Trifonova, E., G. Chatalov pl. 2, figs 1–6
1975. *Vidalina martana* – Pantic-Prodanovic, S. pl. 21, fig. 2, pl. 39, fig. 1
1975. *Vidalina* cf. *martana* – Pantic-Prodanovic, S. pl. 38, fig. 2
1976. *Ophthalmidium? chialingchiangensis* – Zaninetti, L. p. 142. pl. 3, figs 6–10
1976. *Hemigordius? chialingchiangensis* – Misik, M., K. Borza pl. 4, fig. 1
1976. *Arenovidalina chialingchiangensis* – Salaj, J. (not illustrated)
1977. *Arenovidalina chialingchiangensis* – Courel, L. (not illustrated)
1977. *Arenovidalina chialingchiangensis* – Salaj, J. pl. 1, fig. 1a
1978. *Ophthalmidium? chialingchiangensis* – Oravecz-Scheffer, A. pl. 9, figs 9–12
1978a. *Hemigordius chialingchiangensis* – Trifonova, E. pl. 1, fig. 2
1978. *Ophthalmidium? chialingchiangensis* – Zaninetti, L., Z. Dager (not illustrated)
1978b. *Ophthalmidium? chialingchiangensis* – Dager, Z. pl. 2, fig. 12
1980. *Hemigordius chialingchiangensis* – Trifonova, E. (not illustrated)
1980. *?Hemigordius chialingchiangensis* – Zaninetti, L., J. Whittaker pl. 2, fig. 11
1981. *Ophthalmidium? chialingchiangensis* – Altiner, D., L. Zaninetti pl. 82, figs 10, 14–16, 20–21, 26?
1981. *Ophthalmidium? chialingchiangensis* – Samuel, O., K. Borza p. 71. pl. 20, fig. 4
1982b. *Paraophthalmidium carpathicum* – Zaninetti, L., D. Altiner, Z. Dager, B. Ducret p. 110. pl. 6, figs 4–5
1983. *"Arenovidalina" chialingchiangensis* – Kristan-Tollmann, E. p. 296. textfig. 1/10–12
1983. *Hemigordius? chialingchiangensis* – Oravecz-Scheffer, A. (not illustrated)
1983. *Arenovidalina chialingchiangensis* – Salaj, J., K. Borza, O. Samuel p. 107. pl. 65, figs 1–20, pl. 72, fig. 6c
1983. *Arenovidalina chialingchiangensis* – Trifonova, E. (not illustrated)
1985. *Hemigordius chialingchiangensis* – Chatalov, G., E. Trifonova pl. 1, figs 6, 9
1985. *Hemigordius chialingchiangensis* – Trifonova, E., A. Vaptzarova pl. 2, fig. 4
1986. *Ophthalmidium tricki* – Sudar, M. pl. 20, figs 4–6
1987. *Hemigordius? chialingchiangensis* – Oravecz-Scheffer, A. p. 69. (not illustrated)
1988. *Hemigordius chialingchiangensis* – Vaptzarova, A. pl. 1, fig. 3

1988.	*Ophthalmidium chialingchiangensis*	– Benjamini, Ch. p. 135. pl. 2, figs 21–22, 24
1988.	*Arenovidalina chialingchiangensis*	– Tsaila-Monopolis, S. (not illustrated)
1988.	*Arenovidalina chialingchiangensis*	– Canovic, M., R. Kemenci (not illustrated)
1988.	*Arenovidalina chialingchiangensis*	– Salaj, J., E. Trifonova, D. Gheorghian, V. Coroneou pl. 9, fig. 15.
1991.	*Arenovidalina chialingchiangensis*	– Urosevic, D., M. Sudar (not illustrated)
1992.	*Ophthalmidium? chialingchiangensis*	– Angiolini, L., L. Dragonetti, G. Muttoni, A. Nicora (not illustrated)
1992.		
1993.	*Arenovidalina chialingchiangensis*	– Trifonova, E. p. 33. pl. 4, figs 10–12, 17
1993.	*Ophthalmidium (=Arenovidalina) chialingchiangensis*	– Senowbari-Daryan, B., R. Zühlke, T. Bechstaedt, E. Flügel pl. 65, fig. 10
1993.	*Hemigordius chialingchiangensis*	– Góczán, F., A. Oravecz-Scheffer pl. 17, fig. 5
1993.	*Arenovidalina chialingchiangensis*	– He, Y. p. 181. pl. 3, figs 12–18
1995.	*Arenovidalina chialingchiangensis*	– Rettori, R. p. 95. pl. 15, figs 4–12, pl. 16 figs 9–13

Size: Diameter of the test: 0.200–0.360 mm; diameter of the proloculus: 0.020–0.030 mm; breadth of the test: 0.090–0.150 mm

Remark: This species is widespread in the different facies of the Alsó Hill Triassic. It is most abundant in the basinal formations. Its taxonomic position has been debated for a long time.

He (= Ho, Y.) (1959) originally assigned the genus *Arenovidalina* into the family Ammodiscidae Reuss, 1862. It agglutinated calcite grains into the calcareous matrix of the test wall, its second chamber is coiled in a plane, and it is involute.

Loeblich and Tappan (1964), however, assigned this form to the genus *Aulotortus* Weynschenk 1956, of the family Involutinidae Bütschli 1880. The test wall was strongly recrystallised, and probably was calcareous and granular. Oravecz-Scheffer (1978) also conditionally assigned this species to the genus *Aulotortus*, family Involutinidae.

Other authors regarded *Arenovidalina* as a synonym of the genus *Hemigordius* Schubert, 1908 (Zaninetti and Brönnimann 1969; Canovic and Kemenci 1972; Christodoulou and Tsaila-Monopolis 1972; Gazdzicki and Zawidzka 1973; Gazdzicki et al. 1975; Trifonova and Chatalov 1975; Misik and Borza 1976; Trifonova 1978, 1980; Zaninetti and Whittaker 1980; Oravecz-Scheffer 1983, 1987; Chatalov and Trifonova 1985) or as one of *Ophthalmidium* Kübler and Zwingli 1870 (Oravecz-Scheffer 1978; Zaninetti and Dager 1981; Samuel and Borza 1981; Benjamini 1988). The difference in test material along with the planispiral coiling of the second, tubular chamber definitely excludes the possibility of its inclusion to either *Hemigordius* or *Ophthalmidium*.

Loeblich and Tappan (1988) recognised the validity of the genus *Arenovidalina* Ho, 1959 in their recent systematics of the foraminifera. They assigned it to the subfamily Aulotortinae Zaninetti 1984, because they observed a lamellar structure at the umbilicus, on both sides of the test.

According to Zaninetti et Rettori (in: Zaninetti et al. 1991), the genus *Arenovidalina* is the Triassic isomorph counterpart of the Palaeozoic genus *Hemigordius*. The introduction of the new family Arenovidalinidae Zaninetti and Rettori may settle the several decade – long debate over the genus *Arenovidalina* within the systematics of the foraminifera.

Occurrence in Alsó Hill: It is abundant in nearly all samples of the Upper Anisian–Ladinian open marine slope sediments of the Nádaska Limestone. A great number of specimens are found in the Lower Carnian layers of the Reifling Limestone (sampling point 52 in section Alsó Hill Nr. 1). Only a few specimens are known from the Hallstatt Limestone (locations: T-285, -298).

genus: ***TURRIGLOMINA*** Zaninetti in: Limongi, Panzanelli-Fratoni, Ciarapica, Cirilli, Martini, Salvini-Bonnard, Zaninetti, 1987: "Test libre, trés allongé, fait d'un proloculus sphérique et d'un deutéroloculus tubulaire, non divisé, de section circulaire, stade initial glomospiroide (méandrospiroide?), suivi d'un long stade hélicoidal serré, décrivant de nombreuses spires, tours jointifs, déterminant un axe columellaire central, dimorphisme á préciser, s'exprimant au niveau de la dimension du stade glomospiroide (plus volumineux chez la forme B que chez la forme A) et peut-étre de la hauteur totale de la trochospire, paroi simple, de texture microgranulaire, ouverture simple, terminale."

Remark: The variability and distribution of the *Turriglomina* species (*T. mesotriasica*, *T. conica*, and *T. robusta*) in the Alsó Hill section (northern Hungary) were discussed in a previous study (Bérczi-Makk 1993).

Moving basinward from the carbonate platform, the frequency and variability of the Turriglomina taxa increases, while the number of the accompanying benthic foraminifera decreases.

Turriglomina mesotriasica (Koehn-Zaninetti) is the most common and most variable species of the genus *Turriglomina* in both the Ladinian open marine slope sediments (Nádaska Limestone Formation) and the Lower Carnian pelagic basinal deposits (Reifling Limestone Formation). Its small-sized specimens are characteristic of the open marine slope sediments (Nádaska Limestone Formation) in the association dominated by forms belonging to the family Nodosariidae and the genera *Ophthalmidium* and *Arenovidalina*. In the periplatform basinal facies (Reifling Limestone Formation), dominated by the mass occurrence of *Arenovidalina chialingchiangensis* Ho, *Turriglomina mesotriasica* is also common and variable, but in the Carnian pelagic Hallstatt Limestone it is scarce. *Turriglomina mesotriasica* is geographically widely distributed in the Triassic Tethyan basins from the Alpine–Carpathian realm, through the Dinarides and Middle East, to China (Zaninetti 1976; Kristan-Tollmann 1983; Canovic and Kemenci 1988; Urosevic 1977; Dager 1978; He 1980, 1984; He and Yue 1987, etc.).

Occurrence in Alsó Hill: In the syndiagenetically brecciated Ladinian–Carnian open marine slope deposits of Alsó Hill (Derenk Limestone Formation), the frequency of *Turriglomina robusta* Bérczi-Makk, a large-sized, thick-walled species of wide columella, is conspicuous. In the fossil assemblage of the microfilamental radiolarian limestones it is the most characteristic foraminiferal species, accompanied by several specimens of *Turriglomina conica* (He).

genus: ***GHEORGHIANINA*** Loeblich et Tappan, 1986: "Test elongate, narrow, proloculus followed by tubular second chamber that is planispirally enrolled for about 1 whorl, then uncoils and extends for a distance about equal the diameter of the coil, later with as many as 4 elongate pyriform rectilinear chambers, tapering to an apertural neck, wall calcareous, imperforate, porcelaneous, but commonly silicified in limestones, surface smooth to ornamented with a few high elongate costae, aperture terminal, rounded, at end of tapering neck and bordered by phialine lip. Middle Triassic (Anisian–Ladinian boundary) to Upper Triassic (Carnian)."

Gheorghianina vujisici (Urosevic et Gazdzicki, 1977)

Pl. I, Figs 6–7

Type reference:

1977. *Nodobacularia vujisici*	– Urosevic, D., A. Gazdzicki p. 97. pl. 1, figs 1–6

Synonyms:

1975. *Hormosina* sp.	– Brönnimann, P., J. E. Whittaker, L. Zaninetti pl. 3, fig. 5
1975. *Nodobacularia* sp.	– Gusic, I. pl. 14, figs 9–11
1976. *Nodophthalmidium* sp.	– Patrulius, D., D.Gheorghian, E. Mirauta, p. 128. pl. 1, fig. 1
1980. *Nodophthalmidium elenae*	– Gheorghian, D. p. 38. pl. 1, figs 1–11, pl. 2, figs 1–6, pl. 3, figs 1–2
1983. *Nodophthalmidium vujisici*	– Salaj, J., K. Borza, O. Samuel p. 113. pl. 141, figs 1–2
1983. *Nodobacularia vujisici*	– Oravecz-Scheffer, A. (not illustrated)
1984. *Nodophthalmidium vujisici*	– Kristan-Tollmann, E. p. 285. pl. 8, fig. 9, pl. 11, figs 1–9, textfig. 8/1–7
1987. *Nodophthalmidium vujisici*	– Oravecz-Scheffer, A. pl. 31, fig. 4
1988. *Nodophthalmidium vujisici*	– Salaj, J., E. Trifonova, D. Gheorghian, V. Coroneou pl. 3, figs 25–26, 34
1991. *Nodobacularia vujisici*	– Urosevic, D., M. Sudar (not illustrated)
1993. *Gheorghianina vujisici*	– Trifonova, E. p. 50. pl. 8, figs 1–2

Size: Length of chamber: 0.300 mm, breadth of chamber: 0.070 mm
Remark: I found that the species *Nodophthalmidium elenae*, described by Gheorghian (1980) from Ladinian beds in Romania, is a synonym for *Nodobacularia vujisici*, described by Urosevic and Gazdzicki (1977) from Ladinian beds in Serbia. The two taxa, described under different names, are entirely identical morphologically. According to the rules of priority, the valid name is *vujisici*.

On the basis of their generic features, both forms belong to the genus Gheorghianina. The pear-shaped chamber of the genus Gheorghianina has a long, tapered neck. This neck is absent in both *Nodobacularia* and *Nodophthalmidium*.

The planispirally coiled part of *Gheorghianina* forms an entire whorl, but that of *Nodophthalmidium* generally forms half a whorl only.

In *Gheorghianina*, the diameter of the pear-shaped part is more or less the same as that of the planispirally coiled one. In contrast, the diameter of the planispirally coiled part in *Nodobacularia* and *Nodophthalmidium* is usually significantly greater than that of the pear-shaped chambers forming the straight part.

Occurrence in Alsó Hill: It is known from a single Lower Ladinian (Fassanian) sample from the open marine slope deposits of the Nádaska Limestone (sampling point 20 in section Alsó Hill Nr. 1).

genus: *PSEUDONODOSARIA* Boomgaart, 1949 (after Loeblich and Tappan 1988): "Test elongate, cylindrical, base tapering or broadly rounded, early chambers strongly overlapping and increasing rapidly in diameter, later ones enlarging more slowly and less closely appressed, final chamber may be somewhat inflated, sutures straight, horizontal, flush, wall calcareous, surface smooth, aperture terminal, radiate, or may be rounded with numerous radiating slits. Cosmopolitan."

Pseudonodosaria loczyi **Oravecz-Scheffer, 1980 in: Szabó, Kovács, Lelkes, Oravecz-Scheffer, 1980**

Pl. VI, Fig. 9a, Pl. VII, Fig. 4

Type reference:

1979. *Pseudonodosaria loczyi*	– Szabó, I., S. Kovács, Gy. Lelkes, A. Oravecz-Scheffer p. 798. textfig. 3. pl. 59, figs 1–3

Synonyms:

1983. *Pseudonodosaria loczyi*	– Oravecz-Scheffer, A. (not illustrated)
1989. *Pseudonodosaria loczyi*	– Oravecz-Scheffer, A. (not illustrated)
1993. *Pseudonodosaria loczyi*	– Góczán, F., A. Oravecz-Scheffer pl. 38, figs 1–3

Size: Length of test: 0.400–0.660 mm; breadth of test: 0.150–0.250 mm; wall thickness: 0.036–0.040 mm

Remark: The test is relatively large, with uniserial chambers. The subsphaerical proloculus is followed by 4 or 5 chambers, gradually increasing in diameter. The individual chambers are flat and very wide. The sutures are nearly horizontal. The wall of the test is thick, calcareous, and strongly recrystallised.

Occurrence in Alsó Hill: Several specimens from the Upper Anisian of Nádaska Limestone (sampling points 5, 7, 8 in section Alsó Hill Nr. 8).

Pseudonodosaria obconica (Reuss, 1868)

Pl. III, Figs 3, 6–7, 9, 13, Pl. VII, Figs 3a, 5, Pl. VIII, Fig. 4

Type reference:

1868. *Glandulina obconica* – Reuss, A. p. 104. pl. 1, fig. 7

Synonyms:

1975. *Pseudonodosaria obconica*	– Styk, O. p. 523. pl. 37, fig. 4
1977a. *Pseudonodosaria obconica*	– Trifonova, E. p. 61. pl. 3, fig. 8
1978. *Pseudonodosaria* cf. *obconica*	– Oravecz-Scheffer, A. pl. 7, figs 3, 12, 14
1979. *Pseudonodosaria obconica*	– Oravecz-Scheffer, A. (not illustrated)
1983. *Pseudonodosaria obconica*	– Trifonova, E., Chatalov, G. pl. 2, fig. 9
1985. *Pseudonodosaria obconica*	– Bérczi-Makk, A. pl. 2, fig. 6
1987. *Pseudonodosaria* cf. *obconica*	– Oravecz-Scheffer, A. pl. 16, fig. 14
1987. *Pseudonodosaria obconica*	– Oravecz-Scheffer, A. pl. 34, fig. 9
1989. *Pseudonodosaria obconica*	– Dosztály, L., S. Kovács, T. Budai (not illustrated)
1993. *Pseudonodosaria obconica*	– Góczán, F., A. Oravecz-Scheffer (not illustrated)
1994. *Pseudonodosaria obconica*	– Piros, O., G. W. Mandl, R. Lein, W. Pavlik, A. Bérczi-Makk, M. Siblik, H. Lobitzer (not illustrated)

Size: Maximum breadth of test: 0.20–0.30 mm; diameter of proloculus: 0.14–0.20 mm; wall thickness: 0.03–0.05 mm; height of the chamber: 0.09–0.12 mm

Remark: The large, sphaeroidal proloculus is followed by 4 or 5 trapezoidal chambers rapidly increasing in width. The wall of the test is thick and calcareous. The aperture is terminal and rounded, with a slightly elevated neck.

Occurrence in Alsó Hill: It is conspicuously common in the open marine slope deposits of the Nádaska Limestone (sampling points 9, 11, 23, 26, 27, 43, and 47 in section Alsó Hill Nr. 1, sampling points 8 and 15 in section Alsó Hill Nr. 8, location: T-365).

Plate I

Nádaska Limestone Formation

1. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/14. 100x
2. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/47. 150x
3. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/26. 120x
4. *Alpinophragmium* sp. Ah-1/31. 60x
5. *Earlandia amplimuralis* (Pantic) Ah-1/47. 120x
6. *Gheorghianina vujisici* (Urosevic et Gazdzicki) Ah-1/20. 35x
7. *Gheorghianina vujisici* (Urosevic et Gazdzicki) Ah-1/20. 85x
8. *Earlandia amplimuralis* (Pantic) Ah-1/48. 100x
9. *Earlandia amplimuralis* (Pantic) Ah-1/50. 100x
10. *Earlandia amplimuralis* (Pantic) Ah-1/20. 85x
11. *Earlandia amplimuralis* (Pantic) Ah-1/19. 90x

Plate II

Nádaska Limestone Formation

1. a) *Ophthalmidium exiguum* Koehn-Zaninetti
   b) *Arenovidalina chialingchiangensis* Ho Ah-1/24. 95x
2. *Arenovidalina chialingchiangensis* Ho Ah-1/33. 80x
3. *Arenovidalina chialingchiangensis* Ho Ah-1/18. 80x
4. *Arenovidalina chialingchiangensis* Ho Ah-1/33. 90x
5. *Arenovidalina chialingchiangensis* Ho Ah-1/28. 85x
6. *Arenovidalina chialingchiangensis* Ho Ah-1/27. 85x
7. *Arenovidalina chialingchiangensis* Ho Ah-1/17. 80x
8. *Ophthalmidium*? sp. Ah-1/14. 100x
9. *Arenovidalina chialingchiangensis* Ho Ah-1/28. 85x
10. *Arenovidalina chialingchiangensis* Ho Ah-1/46. 80x
11. *Ophthalmidium* sp. Ah-1/27. 85x

Plate III

Nádaska Limestone Formation

1. *Pseudonodosaria* sp. Ah-1/26. 50x
2. *Pseudonodosaria* sp. Ah-1/11. 45x
3. *Pseudonodosaria obconica* (Reuss) Ah-1/47. 40x
4. *Austrocolomia* sp. Ah-1/11. 90x
5. *Pseudonodosaria* cf. *lata* (Tappan) Ah-1/44. 40x
6. *Pseudonodosaria* cf. *obconica* (Reuss) Ah-1/23. 45x
7. *Pseudonodosaria obconica* (Reuss) Ah-1/43. 45x
8. *Austrocolomia plöchingeri* (Oberhauser) Ah-1/23. 90x
9. *Pseudonodosaria obconica* (Reuss) Ah-1/9. 30x
10. *Austrocolomia plöchingeri* (Oberhauser) Ah-1/28. 55x
11. *Pseudonodosaria* sp. Ah-1/43. 75x
12. *Austrocolomia* sp. Ah-1/12. 80x
13. *Pseudonodosaria obconica* (Reuss) Ah-1/27. 90x

Plate IV

Nádaska Limestone Formation

1. *Nodosaria* sp. Ah-1/43. 90x
2. *Nodosaria* sp. Ah-1/43. 90x
3. *Dentalina* sp. Ah-1/38. 80x
4. *Nodosariidae* sp. Ah-1/44. 75x
5. *Nodosariidae* sp. Ah-1/27. 40x
6. *Dentalina* sp. Ah-1/50. 45x
7. *Cryptoseptida* sp. (=*Pachyphloides* sp.) Ah-1/45. 80x
8. *Lenticulina* sp. Ah-1/13. 45x
9. *Lenticulina* cf. *acutiangulata* (Terquem) Ah-1/39. 80x
10. *Lenticulina* cf. *acutiangulata* (Terquem) Ah-1/32. 85x
11. *Lenticulina* cf. *acutiangulata* (Terquem) Ah-1/24. 100x
12. *Cryptoseptida* sp. (=*Pachyphloides* sp.) Ah-1/45. 90x
13. a) *Lenticulina* sp.
    b) Echinoidea fragments Ah-1/48. 50x
14. *Globochaeta alpina* Lombard Ah-1/45. 70x

Plate V

Nádaska Limestone Formation

1. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) Ah-1/51. 80x
2. *Agathammina* sp. Ah-1/51a. 60x
3. *Ophthalmidium?* sp. Ah-1/51. 85x
4. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) Ah-1/51a. 80x
5. *Agathammina* sp. Ah-1/51a. 90x
6. *Earlandia gracilis* (Pantic) Ah-1/51. 40x
7. *Earlandia gracilis* (Pantic) Ah-1/51b. 80x

Plate VI

Nádaska Limestone Formation

1. *Lenticulina* sp. Ah-8/5a. 50x
2. *Lenticulina* sp. Ah-8/5a. 100x
3. *Cryptoseptida (=Pachyphloides) klebelsbergi* (Oberhauser) Ah-8./5a. 50x
4. *Pseudonodosaria* sp. Ah-8/5a. 80x
5. a) *Frondicularia* sp.
   b) *Lenticulina* sp. Ah-8/5b. 50x
6. *Nodosariidae* sp. Ah-8/5b. 80x
7. *Pseudonodosaria* sp. Ah-8/5a. 100x
8. *Cryptoseptida (=Pachyphloides)* sp. Ah-8/5b. 80x
9. a) *Pseudonodosaria lóczyi* Oravecz-Scheffer
   b) *Rectoglandulina* sp. Ah-8/7. 110x
10. *Lenticulina* cf. *acutiangulata* (Terquem) Ah-8/7. 110x

Plate VII

Nádaska Limestone Formation

1. a) *Dentalina* sp.
   b) *Nodosariidae* sp.
   c) *Cryptoseptida (=Pachyphloides) klebelsbergi* (Oberhauser) Ah-8/8. 80x
2. Cryptoseptida (=Pachyphloides) sp. Ah-8/8. 80x
3. a) *Pseudonodosaria obconica* (Reuss)
   b) *Cryptoseptida (=Pachyphloides)* sp. Ah-8/8. 80x
4. *Pseudonodosaria lóczyi* Oravecz-Scheffer Ah-8/8. 80x
5. *Pseudonodosaria obconica* (Reuss) Ah-8/15. 100x
6. *Arenovidalina chialingchiangensis* Ho Ah-8/17. 120x

Plate VIII

Nádaska Limestone Formation

1. *Ophthalmidium?* sp. T-334. 100x
2. *Arenovidalina chialingchiangensis* Ho T-335. 100x
3. *Trochammina* sp. T-334. 100x
4. *Pseudonodosaria obconica* (Reuss) T-365. 100x
5. *Turriglomina mesotriasica* (Koehn-Zaninetti) T-377. 100x
6. *Turriglomina mesotrisasica* (Koehn-Zaninetti) T-377. 100x
7. *Lenticulina* sp. T-374. 80x
8. *Nodosariidae* sp. T-327. 100x
9. Microfilament microbiofacies T-413. 50x

Plate IX

Nádaska Limestone Formation

1. *Ophthalmidium?* sp. T-366. 100x
2. *Arenovidalina chialingchiangensis* Ho T-366. 100x
3. *Arenovidalina chialingchiangensis* Ho T-366. 100x
4. Ophthalmidium, Microfilament microbiofacies T-366. 50x
5. *Nodosariidae* sp. T-359. 100x

Plate X

Reifling Limestone Formation

1. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 100x
2. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 100x
3. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 100x
4. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 150x
5. *Miliolidae* sp. Ah-1/52. 100x
6. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 150x
7. *Turriglomina mesotriasica* (Koehn-Zaninetti) Hidvégardó sample 80027, sampled by Less Gy. 100x
8. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 150x
9. *Turriglomina* sp. Hidvégardó, Csemetekert sample 80033, sampled by Less Gy. 100x
10. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 100x
11. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 100x
12. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 100x
13. *Turriglomina mesotriasica* (Koehn-Zaninetti) Ah-1/52. 150x
14. *Turriglomina* sp. Hidvégardó sample 80027, sampled by Less Gy. 100x

Plate XI

Pötschen Limestone Formation

1. *Nodosariidae* sp. T-310. 100x
2. *Pseudonodosaria* sp. T-310. 100x
3. *Nodosaria* sp. T-310. 60x
4. *Pseudonodosaria* sp. T-259. 100x
5. picule, Radiolarian microbiofacies. T-306. 120x

Plate XII

Derenk Limestone Formation

1. *Endothyranella* sp. Kl-47. 50x
2. *Turriglomina conica* (He) Kl-69. 100x
3. *Triadodiscus eomesozoicus* (Oberhauser) Kl-59. 100x
4. *Agathammina?* sp. Kl-69. 100x
5. *Nodosaria* sp. Kl-69. 50x
6. *Nodosaria* sp. Kl-49. 100x
7. *Nodosariidae* sp. Kl-69. 100x
8. *Nodosaria* sp. Kl-77. 50x
9. *Turriglomina robusta* Bérczi-Makk T-434. 100x
10. *Turriglomina robusta* Bérczi-Makk T-434. 60x

Plate XIII

Hallstatt Limestone Formation

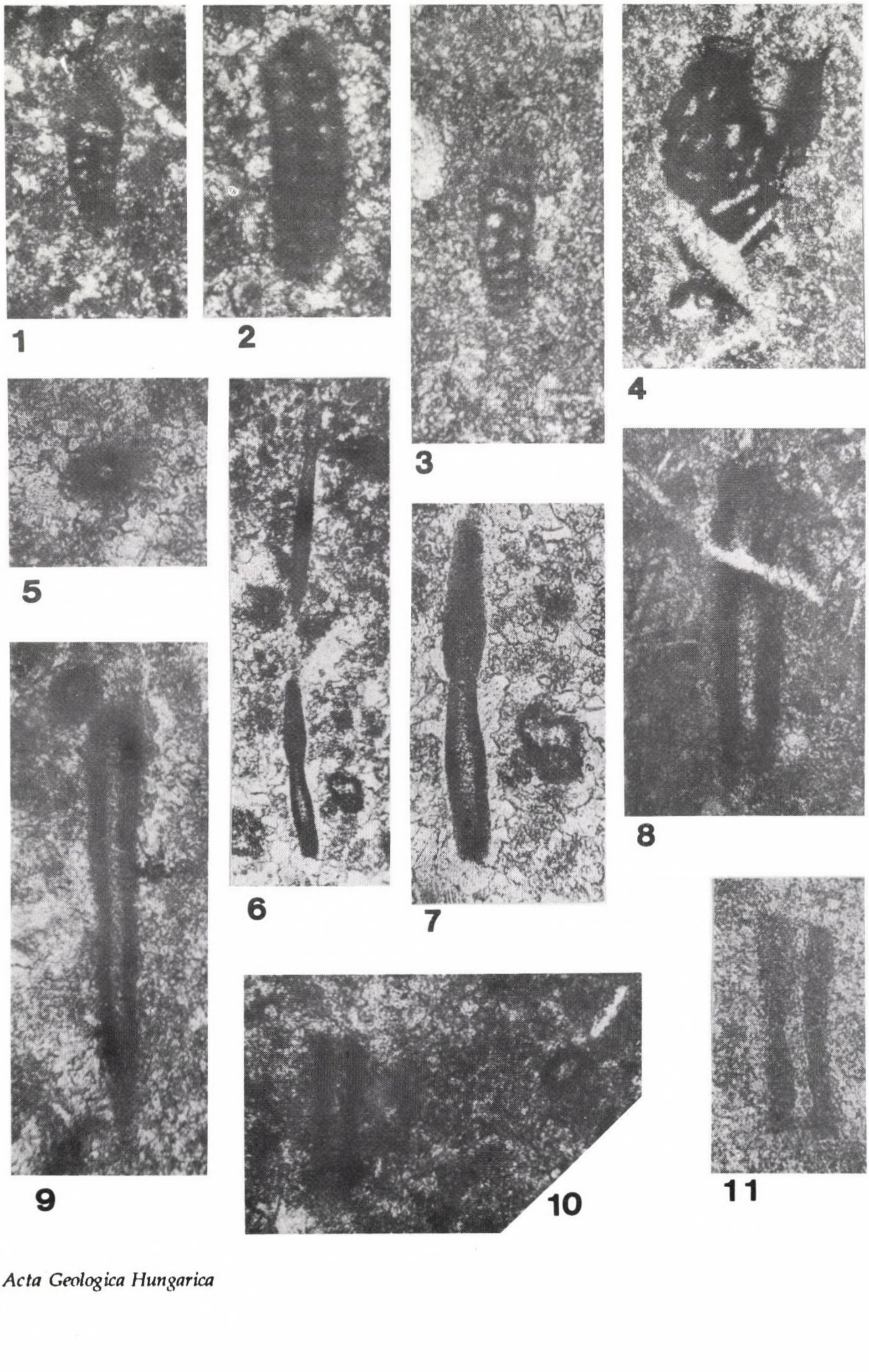
1. *Trochammina* sp. T-285. 100x
2. *Duostomina?* sp. T-241/a. 100x
3. *Agathammina* sp. T-285. 100x
4. *Agathammina* sp. T-285. 100x
5. *Gsollbergella spiroloculiformis* (Oravecz-Scheffer) T-288. 100x
6. *Agathammina* sp. T-347. 100x
7. *Nodosaria* sp. T-347. 50x
8. *Ophthalmidium* sp. T-245/b. 100x
9. *Ammobaculites* sp. aff. *A. delicatus* Trifonova T-298. 50x
10. *Turriglomina mesotriasica* (Koehn-Zaninetti) T-287. 140x
11. *Dentalina* sp. T-247/d. 100x

Plate XIV

Hallstatt Limestone Formation

1. Spicule microbiofacies. T-246/c. 50x
2. *Pseudonodosaria* sp. T-290. 100x
3. Spicule, Radiolarian microbiofacies. T-247/b. 50x
4. *Pseudonodosaria* sp. T-249/a. 100x

Plate I



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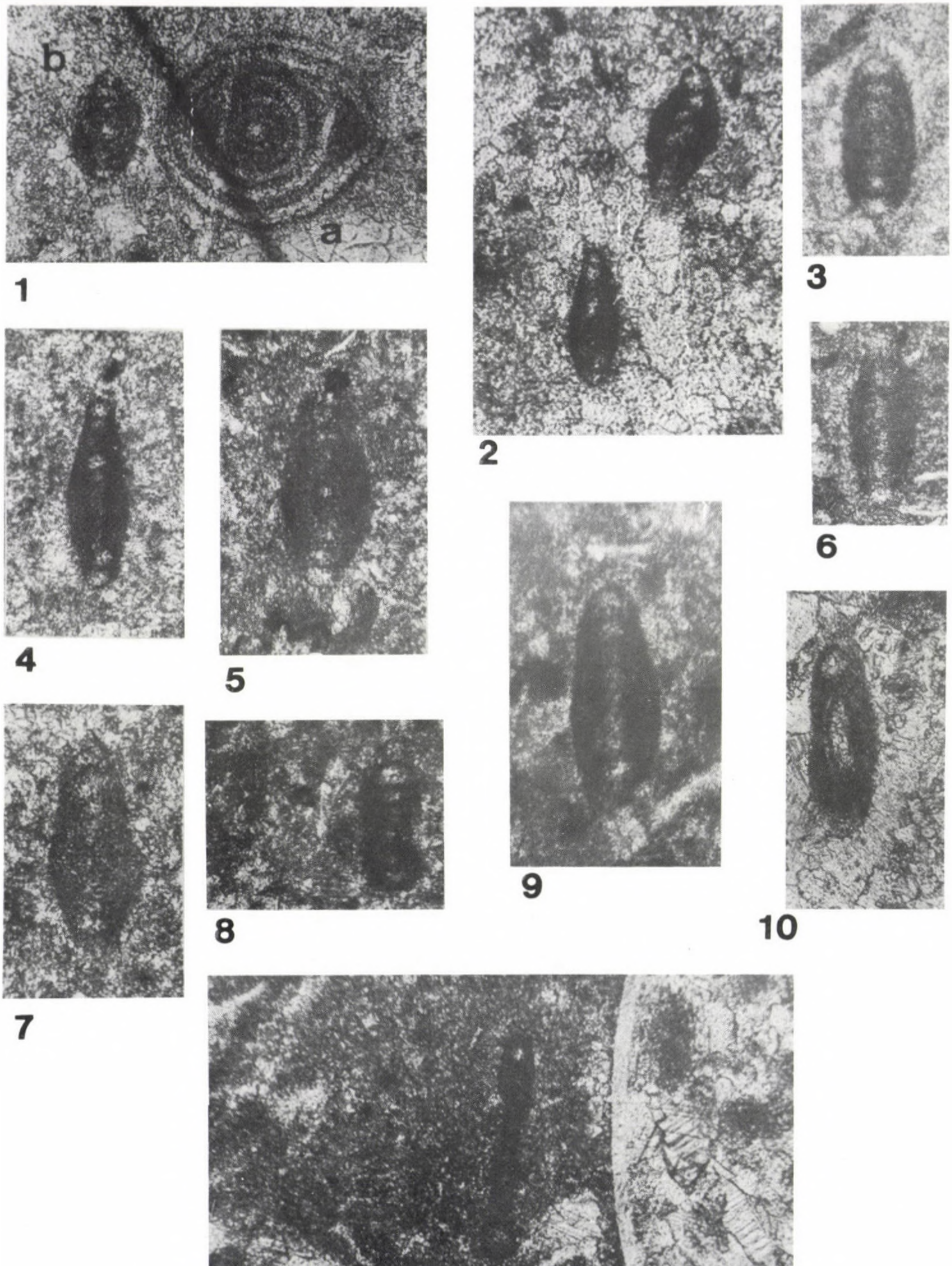

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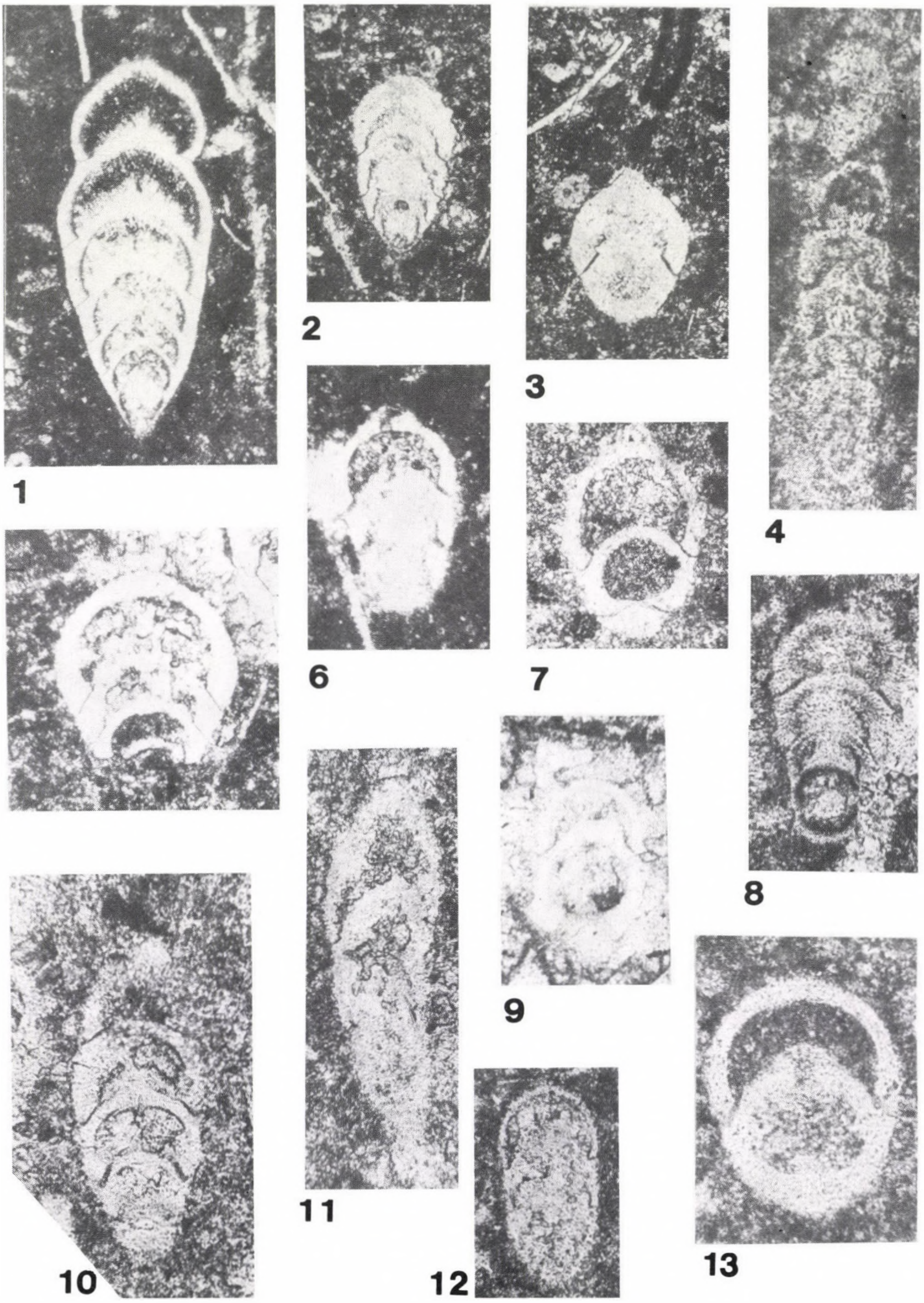

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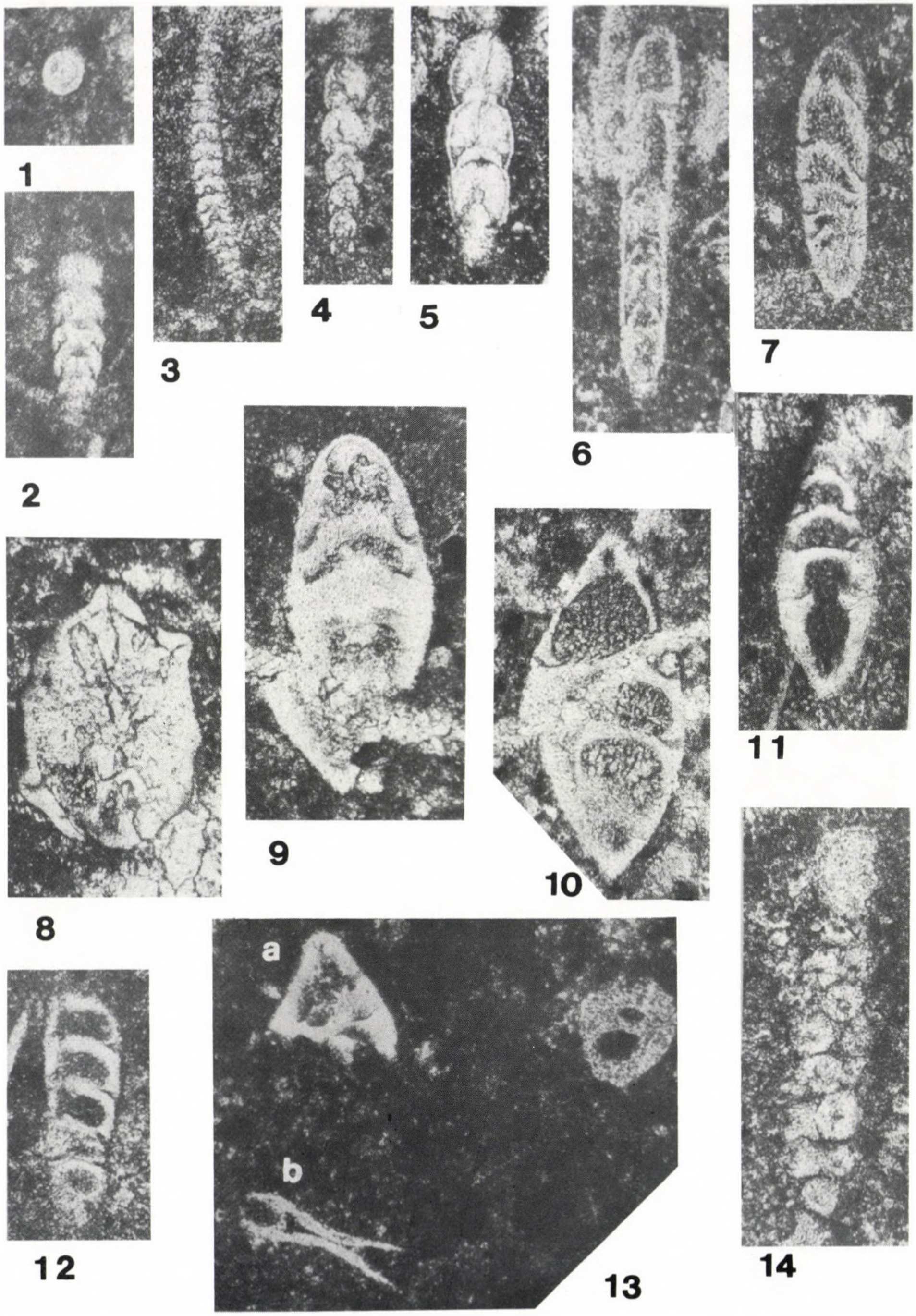

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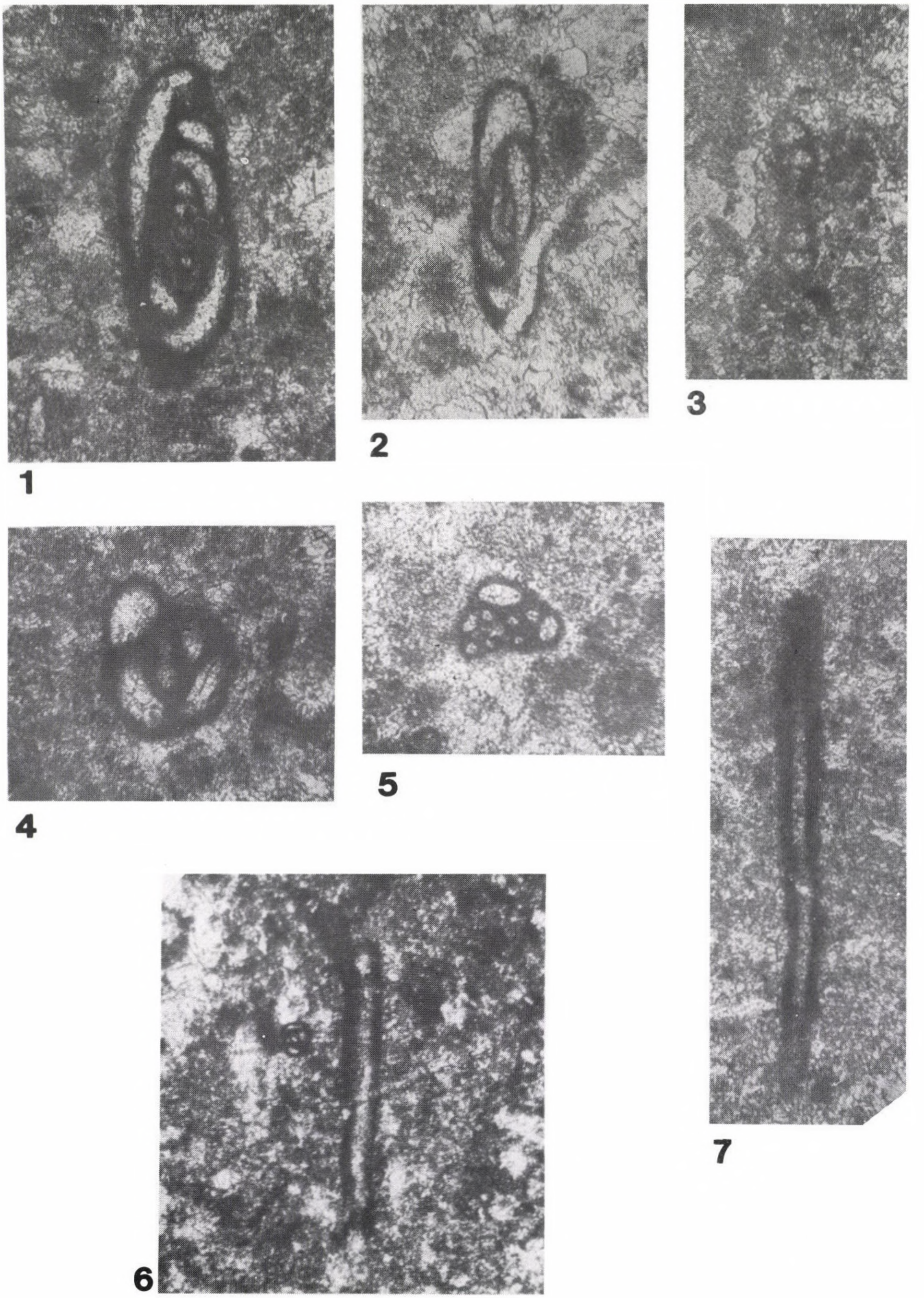
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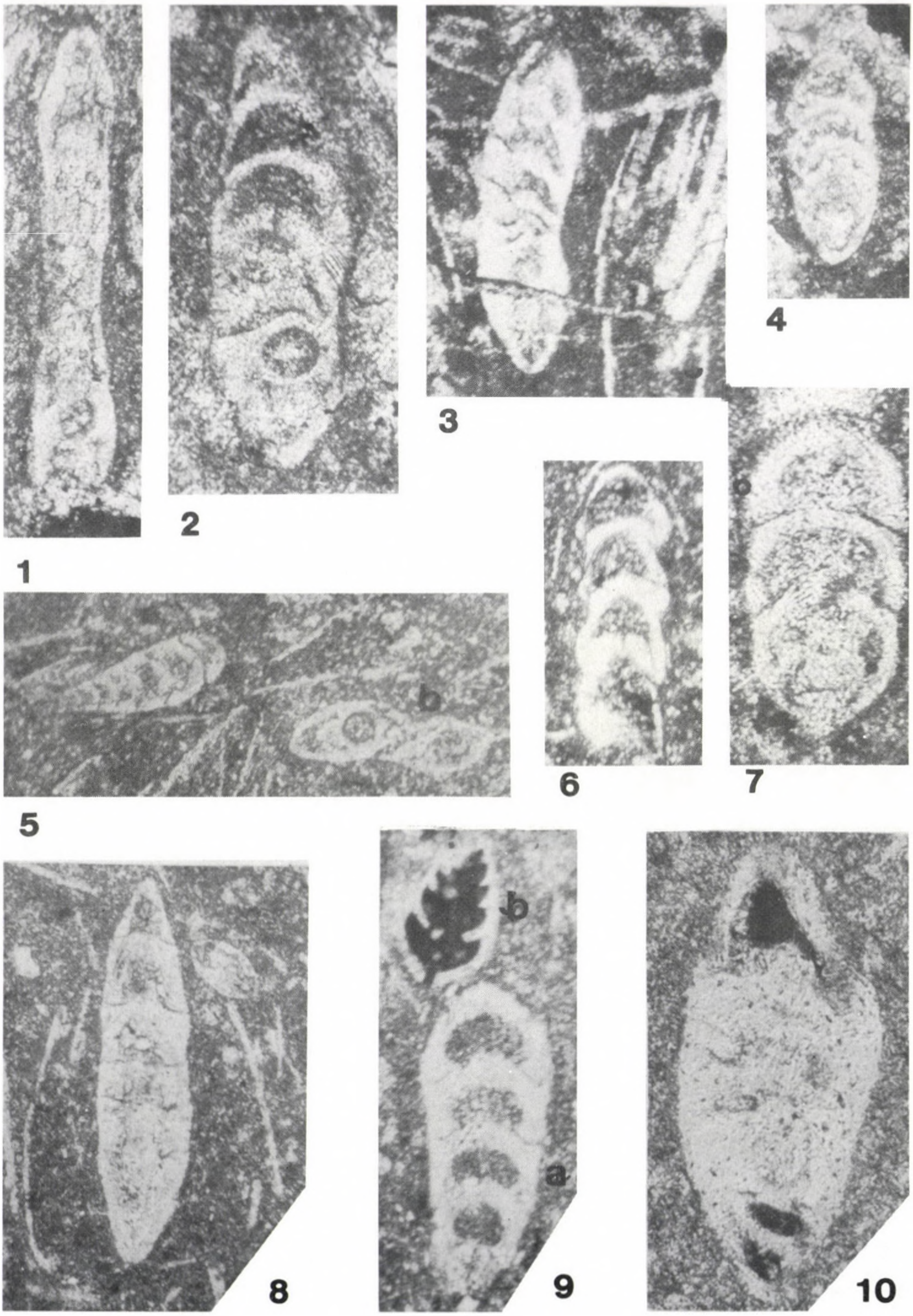

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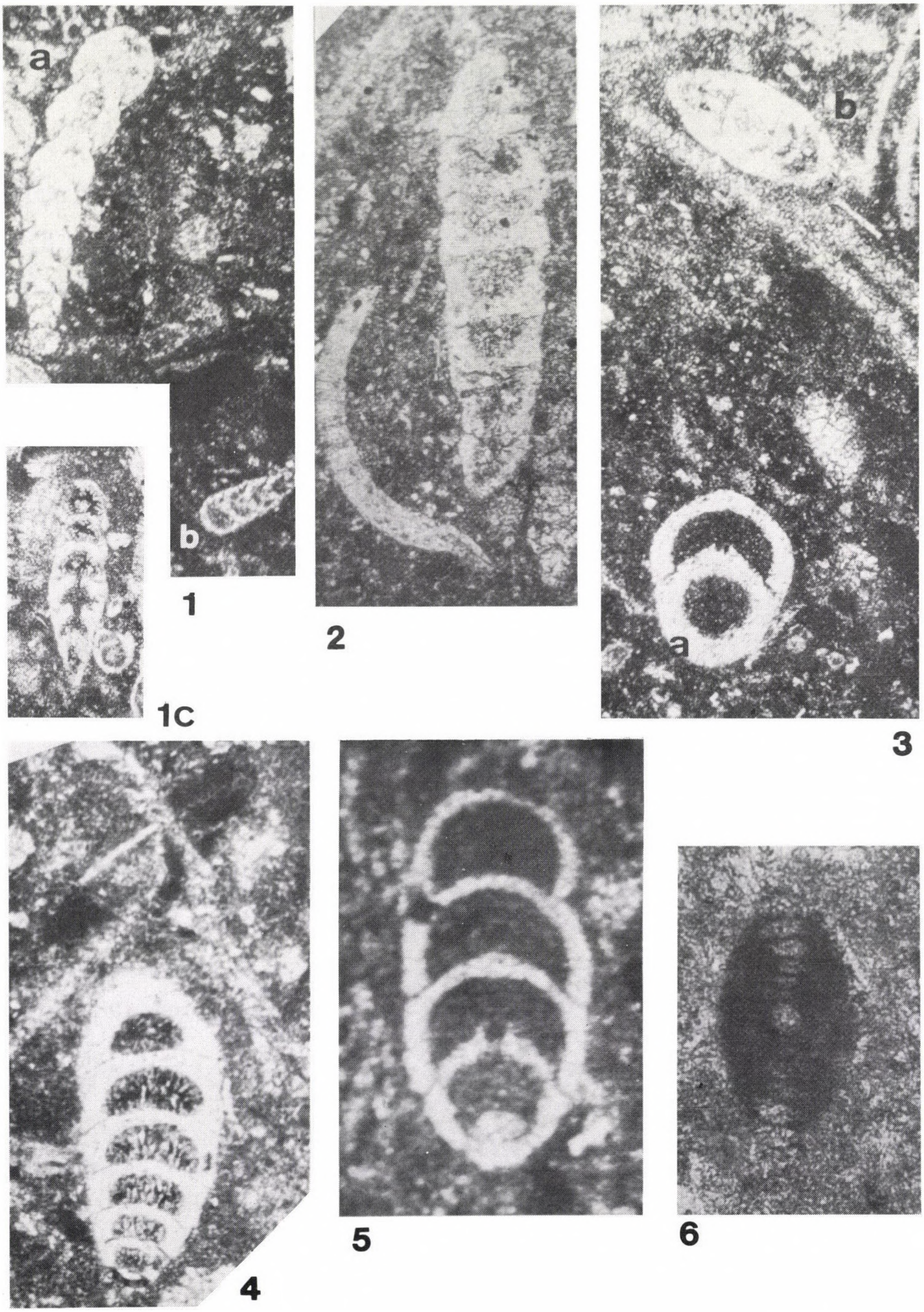

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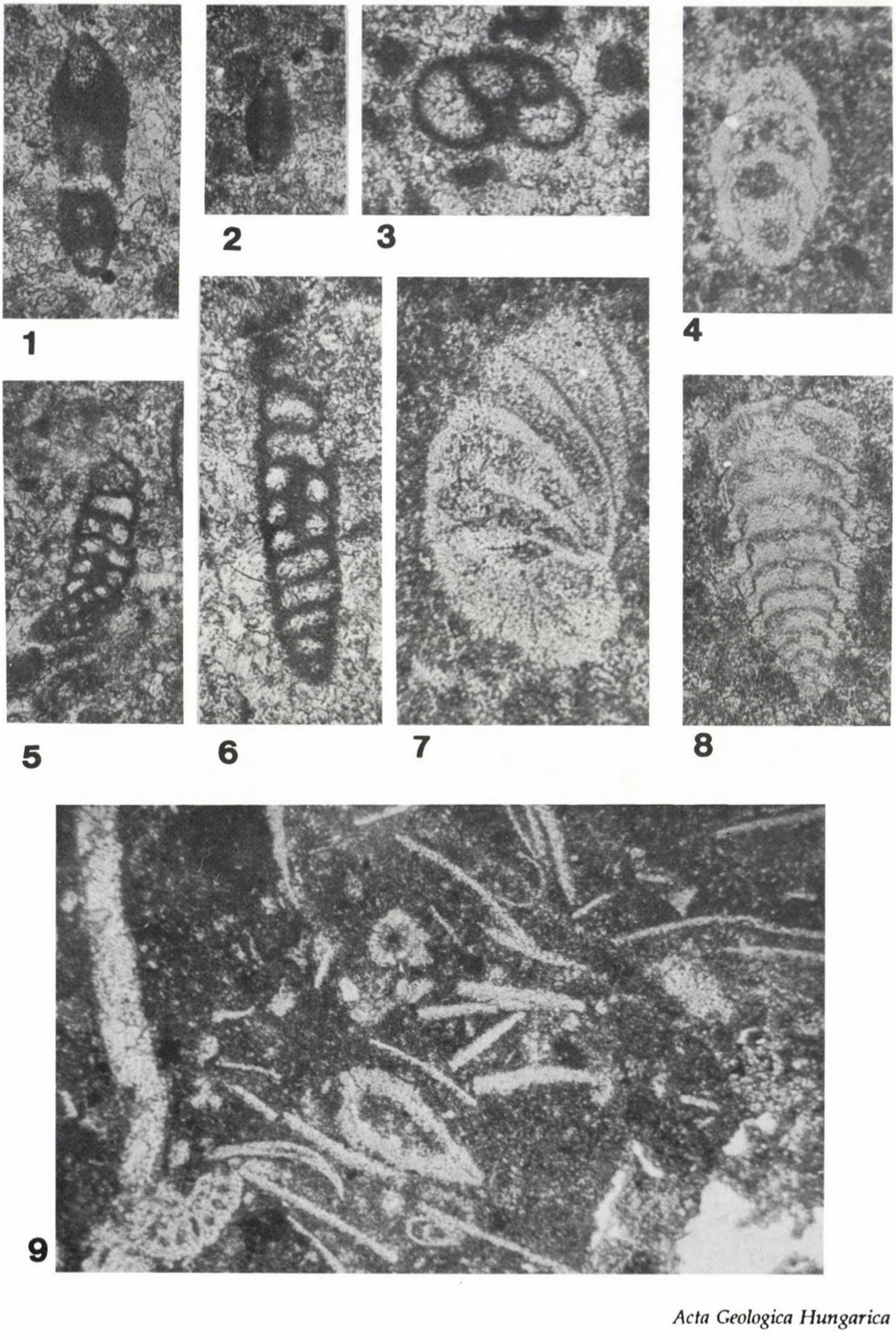

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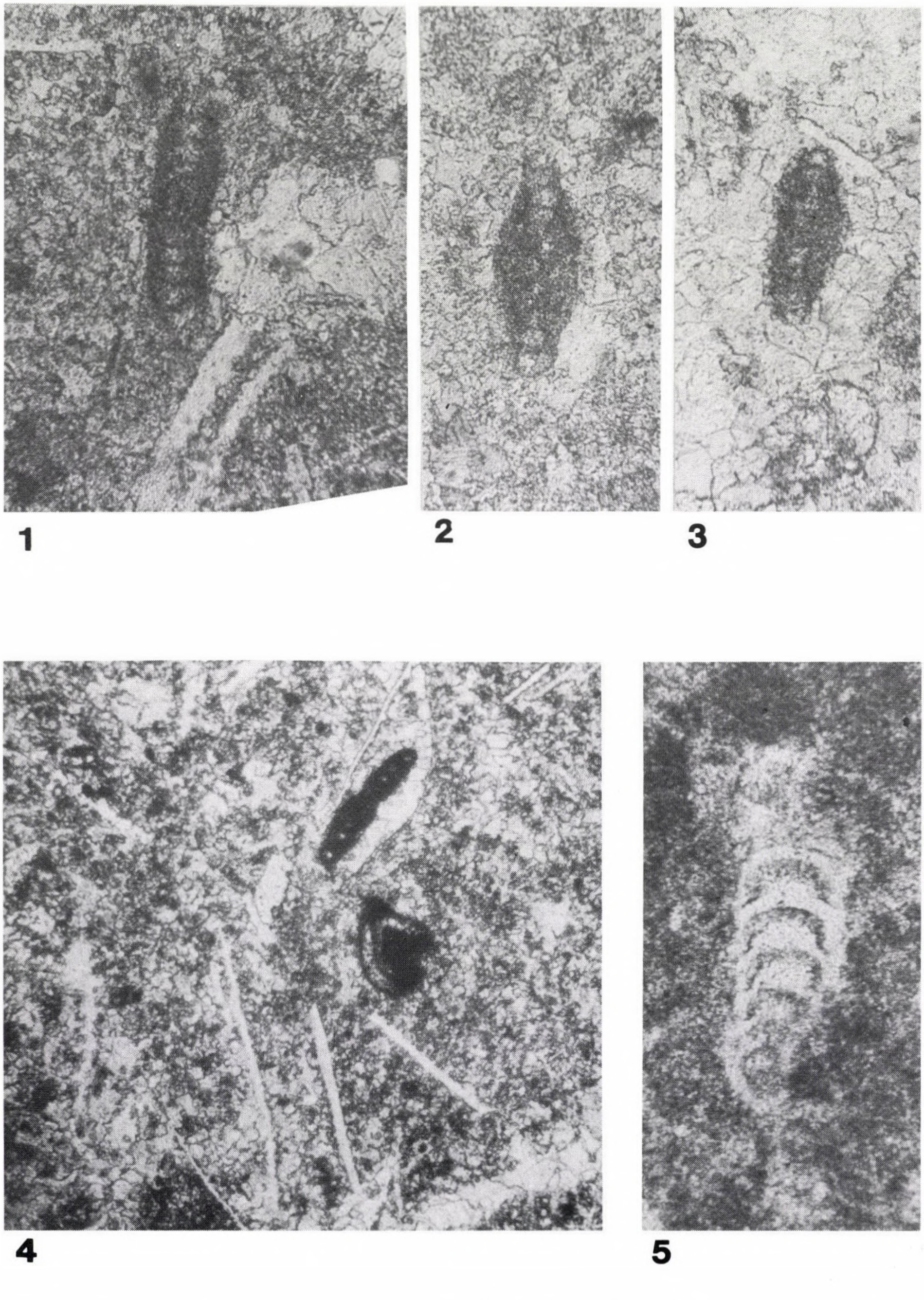

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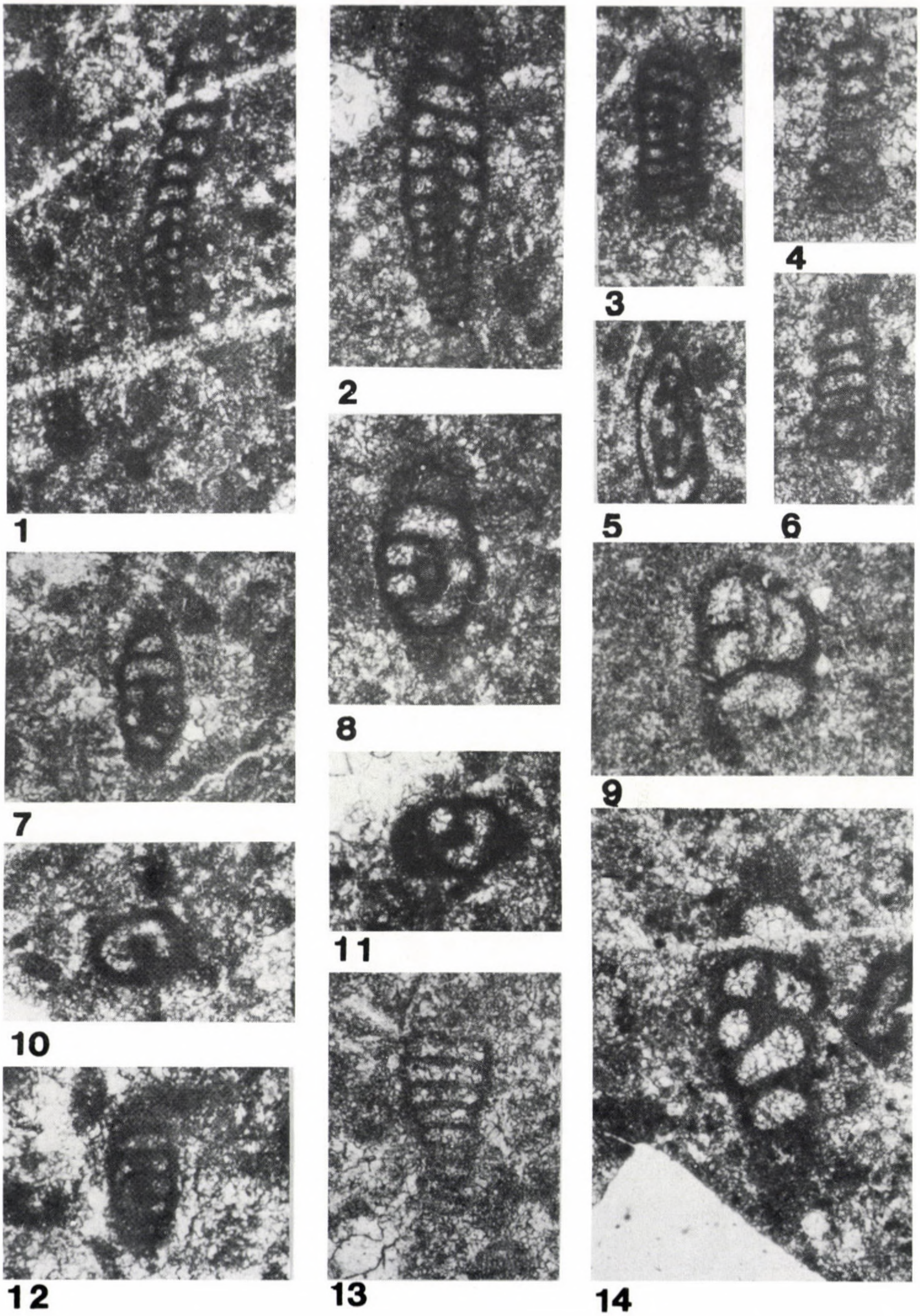
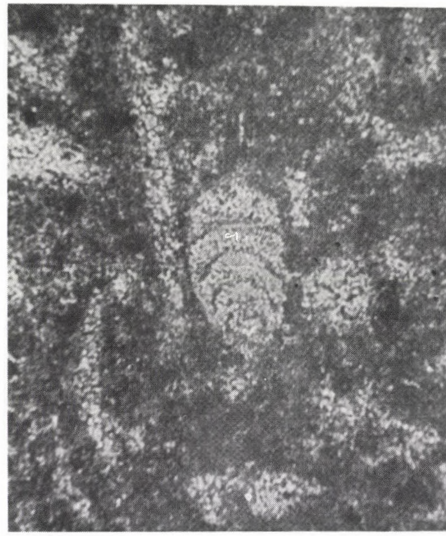


Plate XI

1



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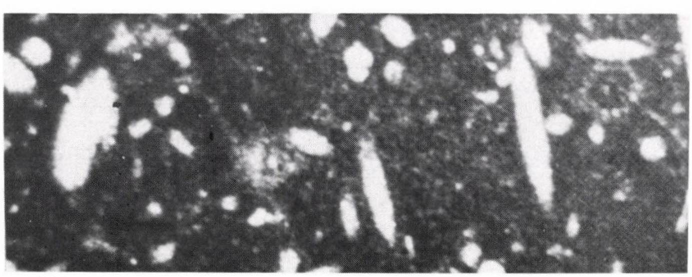

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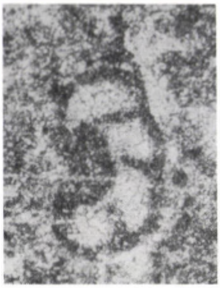
Plate XII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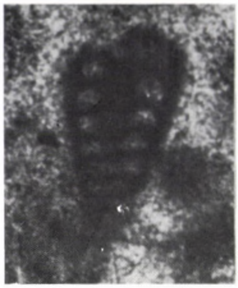
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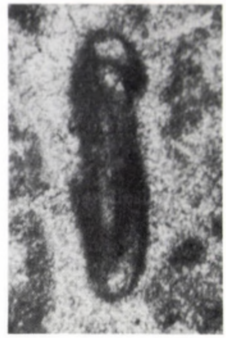
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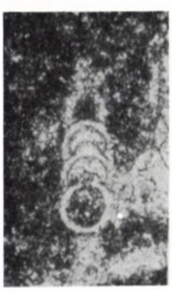
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Plate XIII

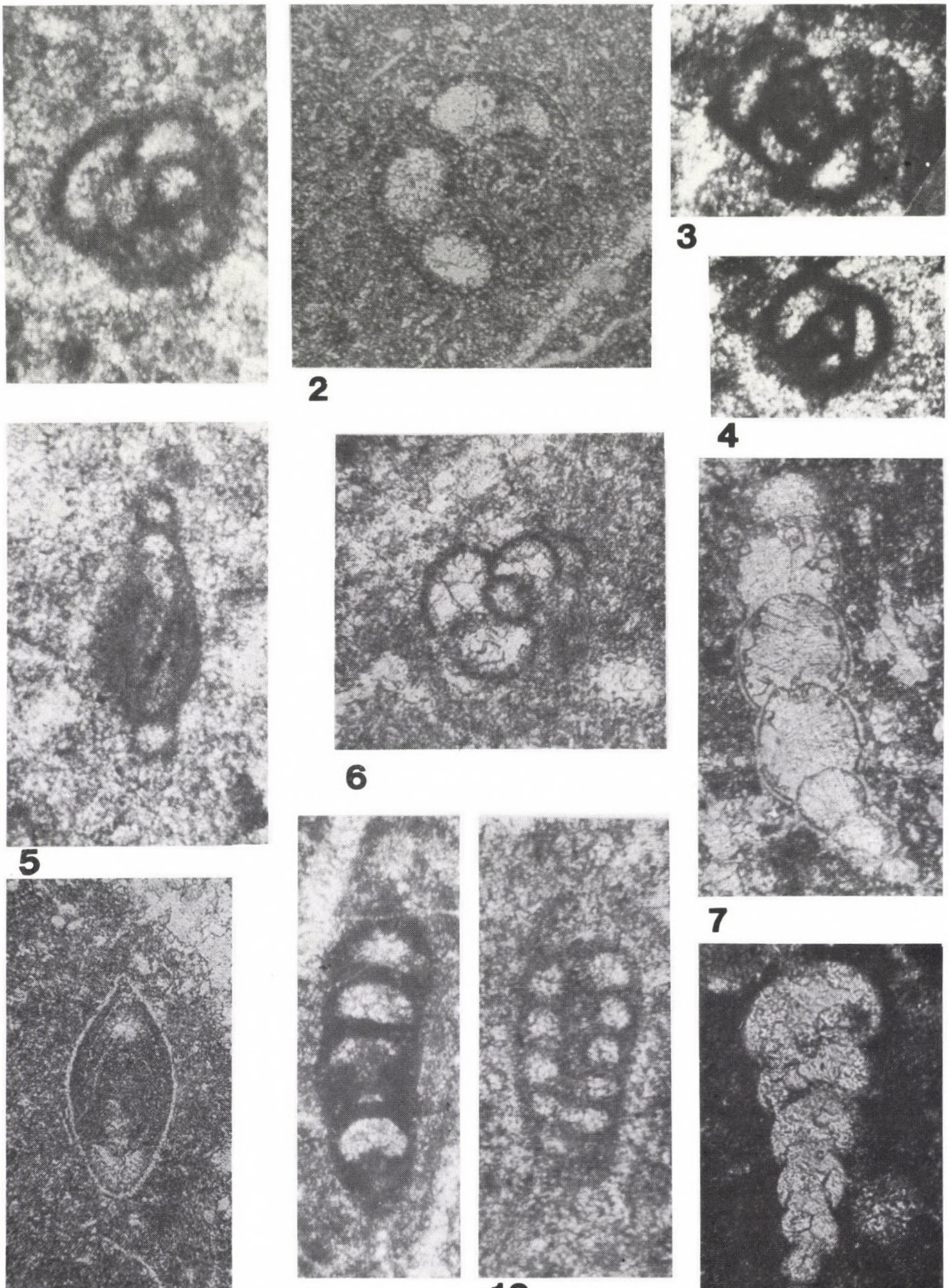
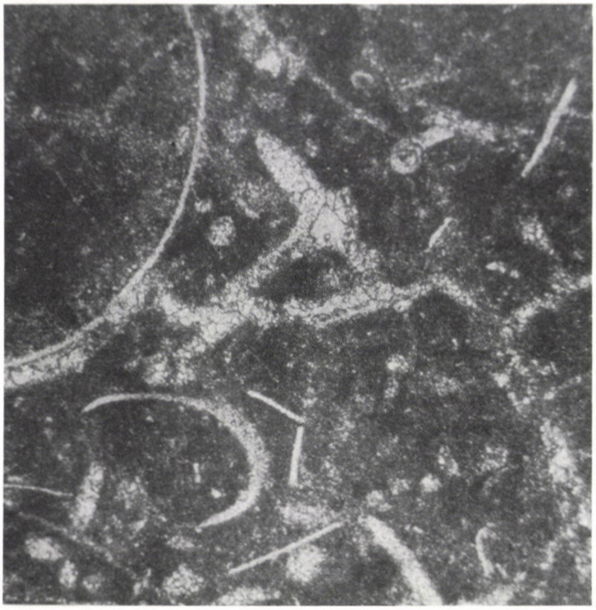


Plate XIV



1

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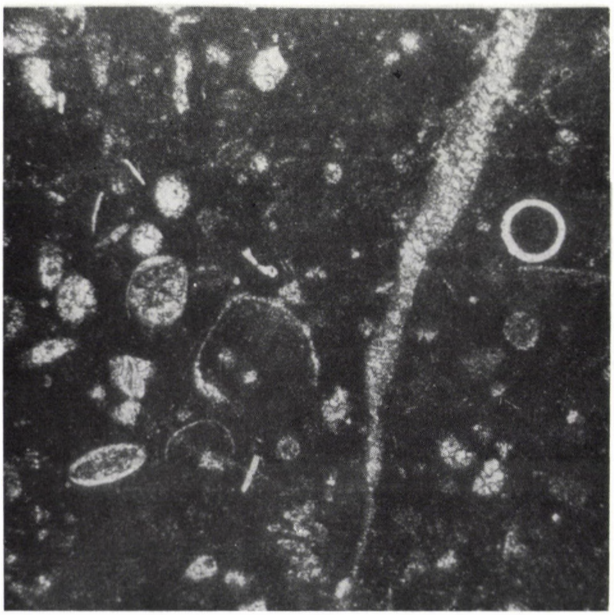

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4

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Obituaries

In Memory of Kálmán Balogh (1915–1995)

Kálmán Balogh, the geologist, university professor, and beloved and respected doyen of our profession died on 5 April 1995, at the age of 80, under tragic circumstances. During his long professional walk of life, with the exception of a few years, he was always linked with the one organization of Hungarian geology of greatest importance, the Hungarian Geological Institute. Here he served as assistant, head of department, director and finally also as scientific adviser.

During the last 50 years of the Institute, his professional personality has been one of the main determinative factors of the evolution and results of Hungarian geology, but he also took part in the activity of the Hungarian Geological Society, and of the Hungarian Academy of Sciences, and in university teaching.

The death of Kálmán Balogh leaves a great void for all of us, who were at some time his subordinates, colleagues, apprentices or merely co-workers without regular direct connection. We cannot discuss our professional problems with him any more, nor can we request from him advice for our work or other questions of our life. On the basis of his huge professional experience, unbounded selflessness, moral humanity, he could always somehow help those who turned to him.

Therefore, his memory remains in our hearts, and is also kept alive by his works, books, maps, and professional articles, which will be used effectively by geologists for many decades in the future. However, Kálmán Balogh erected for himself an even more imperishable, though hidden, memorial, by forming the consciousness of his colleagues through his university teaching activity,

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through professional exchanges of views as well as by proof-reading the manuscripts of hundreds of reports, professional articles and maps and providing in detail his expert opinion to the authors.

Kálmán Balogh was not an easy boss, not even an easy colleague, because he set a very high standard from the points of view of profession, diligence and morality. In turn, he always required the most from himself, both in the field and in the office, despite the fact that his physique could have released him from having to give an example. By means of his extraordinary will-power, he was able to overcome his physical disabilities because he clearly saw that an excellent geologist could only be one who gets to know the geologic formations in the field and who works with unflagging diligence.

Sizing up the earthly existence of Kálmán Balogh, it can be stated for certain that all in all he lived a very hard but complete life.

He was born on 19 October 1915 in Kolozsvár. His father was a professor of high school there.

In 1933, immediately after his high-school maturity examination, he was admitted to the Faculty of Arts of the Tisza István University of Sciences of Debrecen, where he studied to be a teacher of the natural history – geography branch of studies, following in his father's footsteps. In 1938, he received his teacher's diploma with the grade of excellent. In 1938–39, he worked as a teacher, paid per lesson, in the teacher's training school of the Presbyterian College. Between September 1935 and April 1939, he was on probation, then, from 1 May 1939 to 30 April 1940, an assistant at the Mineralogical–Geological Institute of the Tisza István University of Sciences.

Here in the university, he met the master who decisively influenced the whole of his later path of life, one of the most outstanding personalities of our profession, Professor Károly Telegdi Roth, through whose encouragement he chose the profession of geologist, instead of going in for teaching.

In 1940, he defended with the "summa cum laude" qualification his geological doctoral dissertation, on the study of the Triassic of the South Gemer area ("Contributions to the geologic setting of the environs of Pelsőcardó") in the subjects of geology, paleontology and mineralogy–petrology.

At the beginning of May 1940, on the proposal of Professor Károly Telegdi Roth, he went to Budapest, where he worked as a probationer in the Geological and Mineral Department of the Natural History Museum, from 1 May 1940 to 14 July 1941; however, even that time he received his salary from the Geological Institute.

From 15 July 1941 to 31 July 1966, he worked continuously for the Geological Institute.

Though organizationally a research worker of three different institutions, he carried out the geological mapping of the Gemer-Torna Karst Mountains at a scale of 1:25,000 between 1939 and 1944. In 1942 and 1943, for some months he conducted surveys in the gas fields of the temporarily reannexed Mezőség in Transylvania.

In the second half of 1944, he was also influenced by the world war, when he was called up to the Cartographical Institute and was immediately sent – together with the whole institute – to Germany. Here, at the beginning of 1945, he was taken prisoner of war by American troops, together with his entire unit. He, however, taking advantage of the very first opportunity, returned to Hungary before the summer of 1945, and resumed his activity in the Geological Institute.

First, he was sent to the Tokaj Mountains to map, then he was charged with leading the Hydrogeological Department.

In 1947-48, he carried out the geologic mapping of a portion of the Miocene Borsod Basin between Sajó and Bódva at a scale of 1:25,000, in order to evaluate the possibilities of exploring for Sarmatian and Helvetian lignite seams there.

Between 1948 and 1952, he prepared – in co-operation with Gábor Pantó – the geologic map of the Rudabánya Mountains at a scale of 1:25.000, in order to develop iron ore mining. In the meantime, he discovered the Perkupa gypsum–anhydrite deposit of Upper Permian age in this territory.

His surveying activity over many decades resulted in the clarification of the stratigraphical, facies, evolutionary and economic geologic questions of the Triassic formations of the Aggtelek-Rudabánya Mountains, as well as the Neogene formations of the Borsod Basin.

On the basis of his results in the stratigraphy of the Triassic formations, he already tried to resolve the contradictions of the stratigraphy of the Bükk Mountains in 1950. And he succeeded! In the course of the detailed mapping of the environs of Hámor, he recognized the overthrusted character of the Triassic complex of the Northern Bükk Mountains, and by means of some extremely lucky fossil finds, he not only clarified the correct order of the Triassic formations there, but also their age classification – reliable essentially even today, after the introduction of conodont investigations –, emphasizing at the same time the similarities and differences of the Triassic formations of the Aggtelek, Rudabánya and Bükk Mountains.

Appreciating his professional successes, he was appointed as leader of the Mapping Department of the Geological Institute in 1952, and on 31 December 1952, he was qualified as a candidate in earth sciences by the Hungarian Academy of Sciences. On 15 January 1953, he was appointed director of the Institute, but, just like his predecessors, quickly relieved of their duties, he also could not meet the political requirements (which seem today totally unjustified) of that time. Thus, he was also replaced, on 15 July 1953. After this short detour, he returned to mapping activity with pleasure.

Though by inclination he would have liked to continue his work in the Bükk Mountains, he was charged with the detailed mapping of the Liassic coking high-volatile bituminous coal range of the Mecsek Mountains, because the development of heavy industry was held to be more important.

Understanding the situation of the geologic surveying of the country and the economic demands, he initiated the compilation of unified geological maps of the mountainous and hilly areas in 1953. The work began and later these sheets served as a basis for the national geologic maps at a scale of 1:300.000, 1:200.000 and partly even those at 1:500.000.

Between 1955 and 1959, he was provided with an opportunity to continue his mapping activity in the Bükk Mountains. Setting an extremely quick pace both in the field and evaluating work, he finished his dissertation "Geological conditions of the Bükk Mountains" at the end of 1959, and defended it in 1961. On the basis of it, he was qualified as a doctor of earth sciences by the Hungarian Academy of Sciences.

The dissertation was published in the form of a monograph in 1964, and was the basic source-material on the geology of the Bükk Mountains till the end of the '80-ies. Besides elaborating the new Paleozoic–Triassic stratigraphy of the Northern Bükk Mountains in a way mostly acceptable even today, he proved the Dinaric character of the Bükk Mountains by means of very thorough comparative work.

Simultaneously, he began to compile the geologic maps of the country on a scale of 1:200.000 and the attached explanatory notes. Between 1 April 1964 and 31 July 1966, he was the leader of the Mapping Department of the Institute. On the basis of his initiating, pioneering and directing activity, he deserves credit for preparing the geological map series of the country at a scale of 1:200.000.

Beside all this activities, he also played an active role in the Hungarian Geological Society. From 1948 to 1995, he was a member of the committee, while between 1963 and 1966 he was the Vice-Chairman of the Society.

From 1950, as a member of the Geological Scientific Committee of the Hungarian Academy of Sciences, he also took part in influencing the politics of science. Between 1960 and 1963, he was Secretary of the International Mesozoic Committee, and in the academic year 1962–63, he instructed geology and paleontology in the Eötvös Loránd University of Sciences, as an external lecturer.

On 31 July 1966, he resigned his job in the Geological Institute and until 31 October 1977 was the professor and head of the Geological and Paleontological Department of the József Attila University of Sciences of Szeged. Here, beside his exemplary teaching activity which provided breadth of outlook for the students, he also participated in environmental geological research in a broad sense. However, he did not content himself with the investigation of the near-surface layers; he included in the scope of interest and investigation by the members of the Department the entire Cainozoic basin infill of the Pannonian Basin and its Paleozoic–Mesozoic basement, under the leadership of the leading geologists of the oil industry. Here, he introduced conodont investigations, bringing resounding success to Paleo–Mesozoic stratigraphy.

Between 1968 and 1977, as Chairman of the Great Plain Department of the Geological Society, he organized the presentation of new research results from the Great Plain of Hungary for the first time. On two occasions, he initiated and made possible, respectively, the discussion of Hungarian sedimentological results in a public forum.

In addition to all this activity, he began to collect the material for a Hungarian sedimentological book, relying on his former mapping experience, on core material from hydrocarbon exploration wells and from international specialist literature.

Despite being recognized for carrying out successful work at the Department, at his request, on 31 October 1977, he retired at the height of his creative power.

The loving support of his family and assistance from several kind former colleagues at the Geological Institute made it possible for him to overcome the difficulties. The Institution employed him as a retired scientific advisor, for token payment, beginning on 1 November 1977. Here, he took on two main tasks: on the one hand he helped the surveying, processing and synthetizing work of the Northern Hungarian Department; on the other, he continued and completed (with enormous energy-drawing into the accomplishment 18 of his colleagues) his activity on compiling the Hungarian sedimentological book.

In spite of the great number of participants, he bore the brunt of preparing this huge work of three volumes. Most of the chapters he wrote himself. Final editing of the texts of the co-authors, selection and formatting of the tables, figures, photos, fair copying, typographical editing, correcting of the material, were all carried out by him. It was also he who had to obtain the money for publishing the volumes.

Beside his professional activity in a stricter sense, he took on the duty of the Chairman of the Geological Committee of the Hungarian Academy of Sciences between 1977 and 1983. Under his guidance, high-level reports were made on almost every branch of Hungarian geologic research activities, among others the bauxite, coal, hydrocarbon and general geologic research, and certain questions of teaching, as well. Decisions and conclusions reached on the basis of the exchanges of views in the Committee successfully solved the problems of the Hungarian research activities.

In the meantime, he was unanimously elected by the General Assembly of the Hungarian Geological Society as an honorary member in 1986, and rewarded with "Eötvös Wreath" by the Presidency of the Hungarian Academy of Sciences in recognition of his high-level teaching activity in September 1993.

In the framework of the activity of the Tectonic Committee of the Carpatho-Balkan Geological Association, he prepared – together with László Kőrössy – the chapter "Hungarian Median Massif ..." of the explanatory notes to the Carpatho-Balkan tectonic map (Ed.: Mahel, M. 1974) – still based upon the traditional approach. Essentially simultaneously (1972) – already at the dawn of the new mobilistic approach -, he published his work "Historical review of conceptions referring to the Pannonian Median Mass", which indicates the closing of the epoch of the study of the basement of the Pannonian Basin before the advent of plate tectonic theory.

Professor Kálmán Balogh acted as a corresponding, then ordinary member of the IUGS Subcommission on Triassic stratigraphy from 1972 to 1982 and, contemporaneously, as Chairman of the Triassic Subcommission of the Hungarian Stratigraphic Committee from its establishment in 1972 till 1983. He worked untiringly to acquaint international professional circles with the Triassic of Hungary: after several preliminary versions, his synthetic work "Correlation of the Triassic of Hungary" was published in English in the Acta Geologica Hungarica in 1981. He took part actively in the improvement of the Hungarian – and especially Northern Hungarian – Triassic lithostratigraphic system, after his retirement also together with his younger colleagues.

In the middle of July 1993, during a field trip in the Bükk Mountains, when making a smaller physical effort to climb a steep hillside, he suffered a heart attack. After a few months of resting, physical and spiritual rehabilitation, he was – probably only seemingly – quite his old self again. He again visited the Institute frequently, continued to arrange the family relics, maintained connections with his friends and colleagues, and took part in the organization of the celebrations to commemorate the 125th anniversary of the foundation of the Geological Institute. At this time, he was awarded the Golden Plaquette of the Hungarian Geological Institute.

On 10 March 1995, he was notified by the Office of the President of the Republic that he would be awarded the highest scientific prize of Hungary, the "Széchenyi Prize", for his outstanding work "Sedimentology", and he was asked to be present on 15 March 1995 in Parliament in order to receive the prize.

He complied with the honouring invitation, and while waiting for receive the prize, he suffered a second heart attack. The doctors brought him back from a state of clinical death on the spot, and in the hospital again, but in the end they could not save him. Without regaining consciousness, he died on 5 April 1995.

I bow to his memory with respect and gratitude.

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Conference reports

Isotope Workshop III and the European Society for Isotope Research.

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A group of Polish isotope researchers initiated a new series of meetings in 1992 in Lublin, Poland, called Isotope Workshops, with the aim of providing a forum for presentations of scientific achievements and for discussions of future collaborations. Soon after the Isotope Workshop I, a new society named International Isotope Society (IIS) was established in Poland, consisting of members from 10 countries (Demény and Jedrysek, 1994). The next Isotope Workshop was organized in Ksiaz castle near Wroclaw (Poland), where the participants decided on the venue of the next meeting. The Isotope Workshop III meeting, which is the subject of the present report, took place in the Laboratory for Geochemical Research of the Hungarian Academy of Sciences from 24 to 28 June, 1996. The chairman and the secretary/ treasurer of the International Isotope Society in charge of organizing the Workshop were Attila Demény and István Fórizs, respectively. The Laboratory for Geochemical Research placed its 150-seat conference room at the participants' disposal and provided room for poster presentations, exhibitions and open discussions. The Isotope Workshop III received additional financial support from the Hungarian Academy of Sciences and the Laborexport Kft. of Budapest, which was used to cover part of the organizational expenses and to provide grants for the participants. In addition to the financial support, the Hungarian Academy of Sciences invited two well-known scientists (A. Longinelli, Italy and R. Vaikmäe, Estonia) and also supported two colleagues from Ukraine.

The Workshop was attended by 57 participants from 16 countries (Austria 1, Brazil 2, Canada 1, Croatia 2, Estonia 2, Germany 8, Hungary 11, Italy 1, Lithuania 1, Poland 12, Romania 4, Slovakia 3, Slovenia 1, Spain 2, Switzerland 2, Ukraine 2) who delivered 39 scientific talks and made 26 poster presentations dealing with a wide range of isotope research subjects, from air pollution problems to models of garnet growth during contact metamorphism. The papers were organized in 6 sessions:

Isotopes and the human environment (chairman: I. Cornides)

Recent technical developments (chairman and invited speaker: Z.D. Sharp)

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Paleoclimatology and isotope hydrology I. (chairman and invited speaker: R. Vaikmäe), II. (chairman: A. Gaweda)

Paleoenvironmental indicators (chairman and invited speaker: A. Longinelli)

High-temperature geological processes I, II (chairmen: M.O. Jedrysek and T.W. Vennemann)

Isotope geochemistry of sediments I, II (chairmen: A. Longinelli and T.W. Vennemann).

In accordance with the present trends in isotope research, the presentations were dominated by studies of environmental problems (25), whereas the other papers were distributed almost evenly among the sessions on sedimentary rocks (15), technical developments (13) and high-temperature processes (12). The abstracts were published as short papers in a supplement volume of Acta Geologica Hungarica (Demény and Fórizs 1996).

The Laboratory for Geochemical Research also hosted the meeting of the International Isotope Society where the members present discussed the future of the Society and decided on important changes. The first issue to be dealt with was the name of the society. It was discovered in 1994 that another group of isotope scientists had established a society with the same name in 1982, giving them the priority. After discussions on arguments concerning the international character and the aim of the society and a set of new name proposals, the participating members voted and decided to rename the society as the EUROPEAN SOCIETY FOR ISOTOPE RESEARCH (ESIR), the main aim of which is to bring European isotope researchers together and improve the scientific co-operation among them and with other scientists all over the world. The ESIR will be open to members from any country, for a membership fee of 10 USD/2 years. However, the ESIR meetings (Isotope Workshops) will be held in Europe, preferentially in Central-Eastern Europe, in order to minimize participation costs. The ESIR will be led by a President, two Vice Presidents and a Past President. They will be assisted by an Advisory Board consisting of the above leadership and former past chairmen and secretaries of the IIS. The members of the leadership elected for the period 1996–1998 are J. Pezdic (Slovenia, President), R. Vaikmäe (Estonia, Vice President), Z.D. Sharp (Switzerland, Vice President), A. Demény (Hungary, Past President) with S. Halas (Poland), M. O. Jedrysek (Poland) and I. Fórizs (Hungary) in the Advisory Board. The participating members also agreed upon the venue of Isotope Workshop IV, which will be organized by J. Pezdic in Ljubljana (Slovenia) in 1998. Two proposals for Isotope Workshop V were made by R. Vaikmäe (Tallinn, Estonia) and D. Axente (Cluj-Napoca, Romania); the final decision will be made in Ljubljana.

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GUIDELINES FOR AUTHORS

Acta Geologica Hungarica is an English-language quarterly publishing papers on geological topics. Besides papers on outstanding scientific achievements, on the main lines of geological research in Hungary, and on the geology of the Alpine–Carpathian–Dinaric region, reports on workshops of geological research, on major scientific meetings, and on contributions to international research projects will be accepted.
Only original papers will be published and a copy of the Publishing Agreement will be sent to the authors of papers accepted for publication. Manuscripts will be processed only after receiving the signed copy of the agreement.
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Form of manuscripts

The paper complete with abstract, figures, tables, and bibliography should not exceed 25 pages (25 double-spaced lines with 3 cm margins on both sides).
The first page should include:

- the title of the paper (with minuscule letters)
- the full name of the author
- the name of the institution and city where the work was prepared
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- a list of five to ten key words
- a footnote with the postal address of the author

The SI (System International) should be used for all units of measurements.

References

In text citations the author's name and the year of publication between brackets should be given. The reference list should contain the family name, a comma, the abbreviation of the first name, the year of publication, and a colon. This is followed by the title of the paper. Paper titles are followed – after a long hyphen – by periodical title, volume number, and inclusive page numbers. For books the title (English version), the name of the publisher, the place of publication, and the number of pages should be given.

Figures and tables

Figures and tables should be referred to in the text. Figures are expected in the size of the final type-area of the quarterly (12.6 x 18.6) or proportionally magnified 20–25% camera ready quality. Figures should be clear line drawings or good quality black-and-white photographic prints. Colour photographs will also be accepted, but the extra cost of reproduction in colour must be borne by the authors (in 1995 US$ 260 per page). The author's name and figure number should be indicated on the back of each figure. Tables should be typed on separate sheets with a number.

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