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THE OLDEST TRIASSIC PLATFORM MARGIN REEF FROM THE ALPINE – CARPATHIAN REGION (AGGTELEK, NE HUNGARY): PLATFORM EVOLUTION, REEFAL BIOTA AND BIOSTRATIGRAPHIC FRAMEWORK

FELICITÁSZ VELLEDITS[1], CSABA PÉRÓ[2], JOACHIM BLAU[3], BABA SENOWBARI-DARYAN[4],
†SÁNDOR KOVÁCS[2], OLGA PIROS[5], TAMÁS POCSAI[6], HAJNALKA SZÜGYI-SIMON[7],
PAULIAN DUMITRICĂ[8] & JÓZSEF PÁLFY[9]

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Abstract. The 1:10,000 scale mapping of the southern part of the Aggtelek Plateau (Western Carpathians, Silica Nappe, NE Hungary) and the study of five sections revealed two Middle Triassic reef bodies.

In the late Pelsonian the uniform Steinalm Platform was drowned and dissected due to the Reifling Event. A connection with the open sea was established, indicated by the appearance of gladigondolellid conodonts from the early Illyrian. Basins and highs were formed. In the NW part of the studied area lower – middle? Illyrian basinal carbonates were followed by a platform margin reef (early? - middle Illyrian; reef stage 1) developed on a morphological high. This is the oldest known Triassic platform margin reef within the Alpine-Carpathian region. The reef association is dominated by sphinctozoans and microproblematics. The fossils are characteristic of the Wetterstein – type reef communities.

Differently from this in the SE part of the studied region a basin existed from the late Pelsonian until the early Ladinian. During the late Illyrian – early Ladinian, the reef prograded to the SE, and reef stage 2 was established. Meanwhile, on the NW part of the platform a lagoon was formed behind the reef.

Based on our palaeontological study the stratigraphic range of *Colospongia catenulata, Follicatena cautica, Solenolmia manon manon, Vesicocaulis oenipontanus* must be extended down to the middle Illyrian.

Synsedimentary tectonics were detected in the 1. Binodosus Subzone, 2. Trinodosus Zone – the most part of the Reitzi Zone, 3. Avisianum Subzone.

Riassunto. In base al rilevamento alla scala 1: 10,000 e allo studio di 5 sezioni stratigrafiche nella parte meridionale del plateau di Aggtelek (Carpazi occidentali, Silica Nappe, NE Ungheria) si è messa in evidenza l'esistenza di due corpi di scogliera nel Triassico Medio.

Durante il tardo Pelsonico, la piattaforma omogenea della Formazione Steinalm annegò e fu smembrata in seguito al cosiddetto "Reifling Event". Si venne a formare un collegamento con il mare aperto, come viene indicato dalla comparsa delle gladigondolellidi tra i conodonti, a partire dall'Illirico inferiore. In seguito a questo evento si formarono depressioni e alti strutturali. Nel settore NO dell'area in studio, i carbonati bacinali di età Illirico inferiore e forse medio furono ricoperti da un margine di scogliera (*reef stage 1*), sviluppato a partire da un alto morfologico. Questo viene considerato il margine di piattaforma più antico conosciuto nella regione alpino-carpatica. L'associazione degli organismi di scogliera è dominata dagli sfinctozoi e dai microproblematici. Questi fossili sono caratteristici delle comunità di scogliera del Wetterstein.

Invece nella porzione SE della regione studiata, l'area bacinale persitette dal tardo Pelsonico sino alla fine dell'Illirico. Verso la fine dell'Illirico - inizio Ladinico la scogliera progradò verso SE, dando luogo al "*reef stage 2*" Contemporaneamente sulla parte NO della piattaforma si formava una laguna carbonatica al riparo del *reef*.

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[1] Limestone Bt., H-2120 Dunakeszi, Andrássy Gy. u. 6, Hungary. E-mail: fvelledits@freemail.hu
[2] MTA-ELTE Geological Research Group, H-1117 Budapest, Pázmány sétány 1/C, Hungary. E-mail: perocs@elte.hu
[3] Feldbergstrasse 5, D-61191 Rosbach-Rodheim, Germany. E-mail: joachim.blau@geolo.uni-giessen.de
[4] Institut für Paläontologie, Universität Erlangen, Loewenichstr. 28, D-91054 Erlangen, Germany. E-mail: basendar@pal.uni-erlangen.de
[5] MÁFI, H-1143 Budapest, Stefánia u. 14, Hungary. E-mail: piros@mafi.hu
[6] MOL, H-1117 Budapest, Októberhuszonharmadika utca 18, Hungary. E-mail: tpocsai@mol.hu
[7] Central Transdanubian Environmental and Water Authority, H-8000 Székesfehérvár, Balatoni u. 6, Hungary. E-mail: szusiha@vipmail.hu
[8] Dennigkofenweg 33, CH-3073 Gümligen, Switzerland. E-mail: Paulian.Dumitrica@unil.ch
[9] Hungarian Academy of Sciences-Hungarian Natural History Museum, Research Group for Palaeontology, POB 137, H-1431 Budapest, Hungary; Department of Physical and Applied Geology, Eötvös University (ELTE), H-1117 Budapest, Pázmány sétány 1/C, Hungary. E-mail: palfy@nhmus.hu

In base allo studio biostratigrafico, la comparsa di *Colospongia catenulata, Follicatena cautica, Solenolmia manon manon, Vesicocaulis oenipontanus* va anticipata all' Illirico medio.

Eventi di tettonica sinsedimentaria sono stati individuati in tempi corrispondenti a: 1. Sottozona a Binodosus, 2. dalla Zona a Trinodosus alla maggior parte della Zona a Reitzi, 3. Sottozona a Avisianum.

Introduction

In the literature we can find numerous definitions of reefs (e.g. Flügel 1982a; Scoffin 1987; Tucker & Wright 1990). The consistent theme in these definitions is that they all describe a wave-resistant biogenic structure, built up by a community of calcium-secreting organisms. According to James (1983) the numerous, large calcium carbonate-secreting organisms stand on the remains of their ancestors and are surrounded and often buried by the remains of the many small organisms that once lived on, beneath and between them. Unlike other sedimentary deposits, a reef is not solely the product of physical sedimentation but is almost entirely the physical expression of a community of organisms growing in one place for an extended period of time. Platform margin reefs are developed on platform edges (James 1983). They can range from almost continuous barriers to isolated patches along the margin where the reef is dissected by channels.

The end-Permian extinction event caused a sudden disappearance of metazoan reefs worldwide. The subsequent Triassic reef ecosystem underwent a three-step development (Flügel 2002). The process started with microbial reefs in the Early Triassic, and was followed by metazoan reefs. In the late Anisian-Carnian the metazoan reefs are represented in the Northern Calcareous Alps by the Wetterstein reefs and in the Norian-Rhaetian by the Dachstein reefs. Wetterstein reefs are characterised by the dominance of the segmented calcisponges (sphinctozoans). During the late Carnian-early Norian interval most of the fossils belonging to the Wetterstein reef community died out and new species belonging to the Dachstein reef community appeared. The Dachstein reefs are characterised by the dominance of corals (Riedel 1990; Flügel 2002; Velledits 2008).

In the studied area the transition between the underlying unit (Jenei Formation) and the Aggtelek reef (Wetterstein Formation) is revealed in the subsurface in the Baradla Cave and on the surface in a Road-cut section. Unfortunately the study of the transition is restricted by dropstones covering the cave wall and the rock is frequently recrystallised. Although well-preserved reef organisms can be observed on the weathered surface of the rock, but because of recrystallization the inner structure of the fossils can only rarely be observed. Continuous outcrops are also missing on the surface.

Despite these unfavourable conditions the reef has the great advantage that its exact age can be determined with the help of conodonts originating from the underlying and intercalating deeper water limestones.

The aims of this study are (1) to reconstruct the evolution of the Aggtelek platform during the Pelsonian-Ladinian where the oldest Triassic platform margin reef of the Alpine – Carpathian region came into existence, (2) to determine and describe the reef fossil assemblage and to compare it with other Anisian-Ladinian reefs, and (3) to determine the exact age of the Aggtelek reef.

During our work a detailed (1:10000) geological map was produced by Cs. Péró, T. Pocsai and H. Simon. This was complemented by sedimentological, palaeontological and geochemical investigations of five cross-sections.

Because reef-building organisms do not allow exact biostratigraphic age determination, emphasis was placed on dating the hemipelagic sequences with the help of conodonts, allowing the age determination of the underlying unit of the reef and the deep water limestone intercalated within it. This work was completed by the dating of the neptunian dykes that cross-cut the Aggtelek platform.

In this article the Anisian/Ladinian boundary is considered to be at the base of the Curionii Ammonite Zone in accordance with the latest ratification by the IUGS Executive Committee in 2005 (Brack et al. 2005).

Previous works

Pia (1940) was the first to mention Anisian dasycladaleans from the light-grey limestone at Silická Brezová and Balogh (1940) correlated this limestone with the brachiopod-bearing limestone near Aggtelek. Reference to the reef facies in Hungarian territory is first found in the works of Balogh (1948a, b).

Between the 1950s and 1970s, Czech and Slovak geologists (Bystrický 1972; Kochánová et al. 1975) identified the light-coloured limestone of Anisian age as the Steinalm Limestone. Bystrický (1986) established a dasycladalean zonation for the Middle – Upper Triassic limestones of lagoonal facies, which was also used by Hungarian geologists.

The first work which focused on the Aggtelek reef was written by Scholz (1972), who considered the reef limestone to be heteropic with the Pelsonian lagoonal Steinalm Limestone. Consequently, he misdated the reef as Pelsonian – middle Illyrian. Scholz's inaccurate age determination was cited in the literature many times e.g. Kovács (1978); Flügel (1982; 2002); Senowbari et al. (1993); Payne et al. (2006a, b).

Mihály (1981) studied the Middle Triassic echinoids of the Aggtelek Karst. According to him, the reef core comprises two biofacies: (1) “calcareous-sponge-hydrozoan-coral” and (2) “echinodermata-brachiopodal-molluscan” limestone. Based on the echinoids he considered the age of the reef to be Pelsonian – early Illyrian.

Borka (1982) mapped the NW part of the Aggtelek Plateau and studied the part of the Baradla Cave lying under this area. He discovered ammonoids (Piros et al. 1989a) and the tuffite intercalation below the reef in the cave. He was the first to discover the neptunian dykes dissecting the Steinalm Limestone. Based on *Diplopora annulatissima* found in the Baradla Cave 4400 m from the Aggtelek main entrance he stated that the reef-building took place in the late Illyrian and continued up until the Ladinian (Piros & Kovács 1993).

In the 1980s the area was mapped on a 1: 25,000 scale by the Hungarian Geological Survey (Less et al. 1988; Szentpétery & Less 2006). The deep water sequence between the Steinalm and Wetterstein Formations was not recognised.

Piros (2002) differentiated the Anisian (Steinalm) and Ladinian-Carnian (Wetterstein) limestones and subdivided the reef and the lagoonal facies of the Wetterstein Formation. She determined the age of the Steinalm and Wetterstein Formations on the basis of her own dasycladalean zonation.

Geological background

The Aggtelek-Rudabánya Hills in NE Hungary (Fig. 1a-c) are situated in the NE part of the large, composite Pelso Megaunit (Fülöp et al. 1987; Haas et al. 2001) or Pelsonia Composite Terrane (Kovács et al. 2000).

The investigated carbonate platform (lagoon, basin and successive reef) forms a 1-3 km wide belt striking NW/SE in the karstified Aggtelek Hills. It can be followed for 7 km between the villages of Aggtelek, Jósvafő and Égerszög (Fig. 1c). The Aggtelek Karst continues in Slovakia as Slovak Karst (Bystrický 1964; Mello et al. 1997).

The Triassic formations building up the Aggtelek Karst belong to the Silica Nappe (s.s.) which is the uppermost nappe of the Inner West Carpathians (Kozur & Mock 1973; Mello et al. 1997). According to its lithostratigraphic succession the Silica Nappe corresponds to the “Juvavicum” of the Northern Calcareous Alps (NCA) (Lein 1987; Tollmann 1987; Kozur 1991), recently considered to be the “Hallstatt mélange” (Gawlick et al. 1999). In the Middle – Late Triassic both the West Carpathians and the Northern Calcareous Alps were situated on the northern shelf of the northwestern end of the opening Neo-Tethys (Tollmann 1987; Kovács 1984, 1997; Haas et al. 2001; Schmid et al. 2008). The Triassic rifting had a profound influence

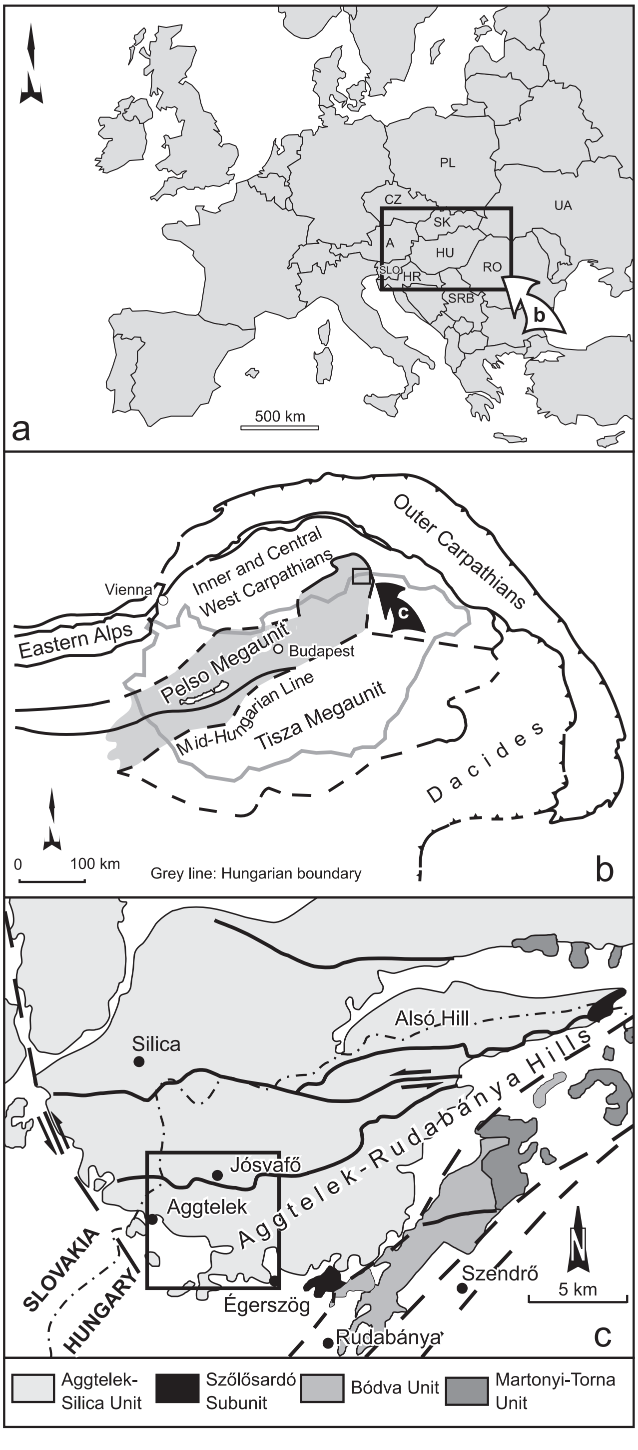


Fig. 1 - a) Location map of the Carpathian-Pannonian region. b) Main tectonic units in the wider surroundings of the Aggtelek-Rudabánya Hills. The quadrangle depicts the studied area. c) Tectonic units of the Aggtelek-Rudabánya Hills (modified after Kovács 1989). The quadrangle depicts studied area. Dashed line: Hungarian/Slovakian border.

on the evolution of the Silica Nappe and thus also on the evolution of the area under study.

In the Aggtelek-Rudabánya Hills sedimentation started in the Late Permian with sabkha facies of thick anhydrites and variegated shales (Perkupa Anhydrite). They were succeeded by siliciclastics in the Early Triassic (Bódvaszilas Sandstone, Szin Marl).

A homoclinal ramp existed from the Early Triassic through Pelsonian times (Hips 1998, 2001). By the beginning of the Middle Triassic, the siliciclastic input ceased and an euxinic lagoonal environment came into existence (Gutenstein ramp stage). From the upper part of the Gutenstein Formation, Hips (2007) described sponge-microbial mud-mound deposits of Pelsonian (?) age (*Glomospira densa*). Cyanobacteria, calcimicrobes and (?)*Tubiphytes* played the main roles in this biocoenosis. The Gutenstein Formation is overlain by the open lagoonal, thick-bedded, laminitic, dasycladalean and oncoidal Steinalm Limestone.

According to Kovács et al. (1989) three units (Aggtelek, Szőlősardó and Bódva) of the Silica Nappe formed a fairly uniform ramp until the late Pelsonian, when it was dissected due to rifting (Fig. 2). From that time onward, the evolution of the three units was different. The major part of the Aggtelek Unit survived as a platform up to the Tuvalian, while the Szőlősardó Unit represented the shelf-slope and the periplatform environment and the Bódva Unit corresponded to the pelagic basin bordering the opening ocean. The Silica – Aggtelek Unit shows a southward-deepening facies polarity from the platform towards the pelagic deep water facies of the Bódva Unit (Mello 1976; Kovács 1984, 1997; Kovács et al. 1989; Less 2000).

In this study only the Aggtelek Unit is discussed. In the Aggtelek Unit after the drowning of the Steinalm Platform deep water carbonates were deposited: Reifling Limestone and Schreyeralm Limestone. In the studied area the deep water carbonates were different from the Reifling and Schreyeralm Limestones. Despite its grey colour, it doesn't contain cherts at all and is rich in calcarenitic turbidites, justifying the introduction of the new name Jenei Limestone.

In the area of the Aggtelek Hills several reefs containing fossils typical of the Wetterstein reef community existed in the late Anisian – Carnian (Wetterstein Formation). Two of these reefs are dated: (1) that in the studied area (informally known as the Aggtelek reef) as Illyrian-Ladinian and (2) the Alsó Hill reef as Carnian (Piros & Kovács 1993). This study deals only with the Illyrian-Ladinian Aggtelek reef.

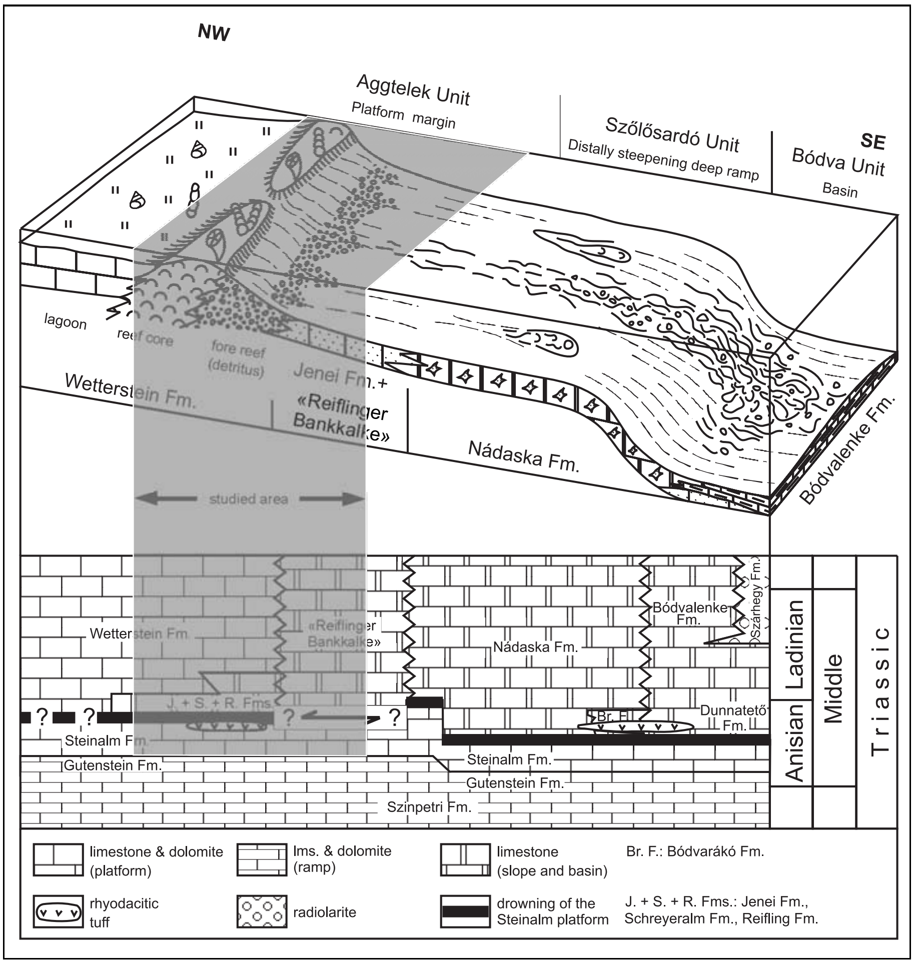


Fig. 2 - Middle Triassic facies model (modified after Kovács 1997). Light-grey shading indicates the studied area.

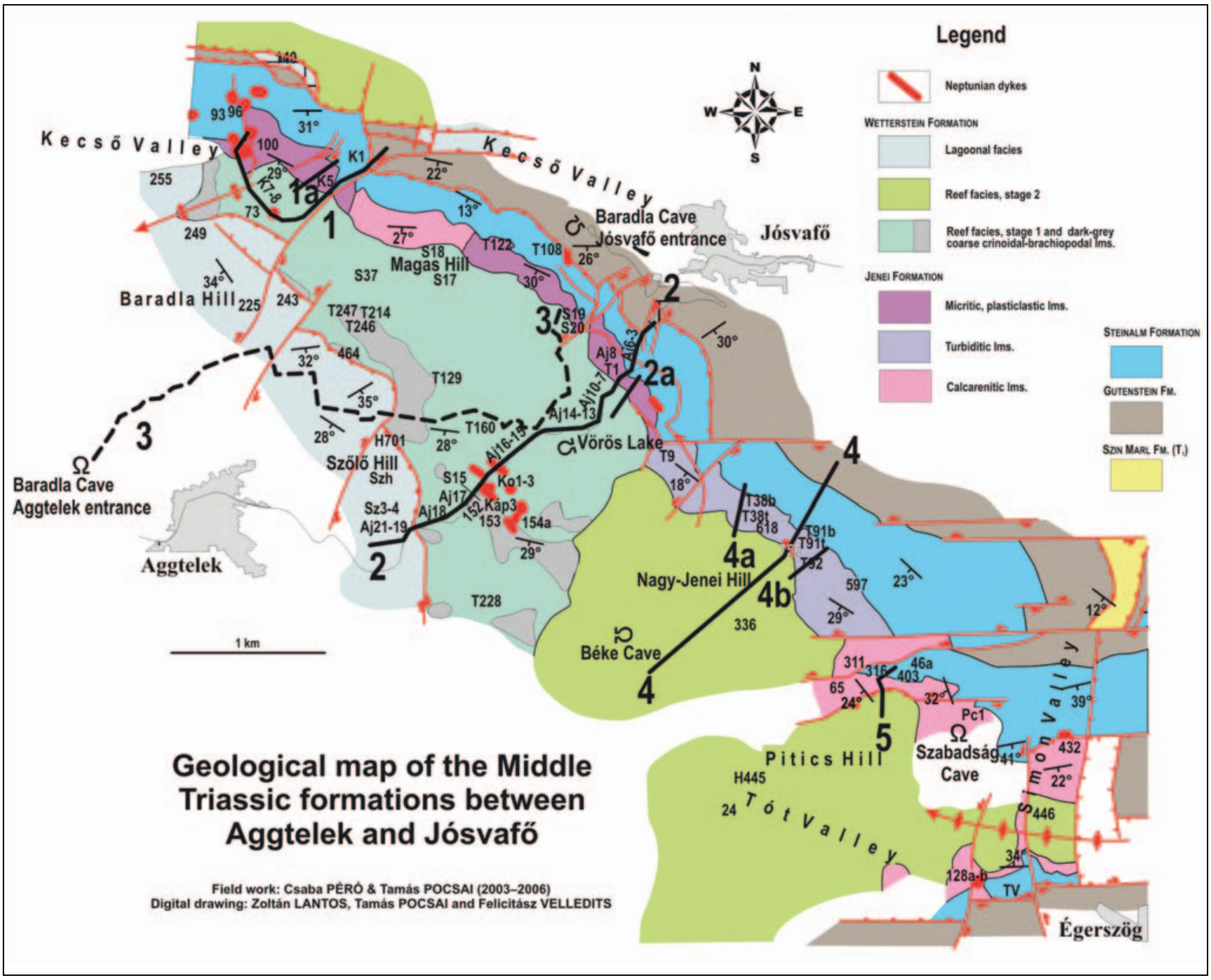


Fig. 3 - Geological map with the main fossil sampling points and the tracks of the investigated sections. Dashed line: Baradla Cave section. The numbers 1-5 refer to the studied sections.

Description of the lithostratigraphic units

In the area between Aggtelek, Jósvafő and Égerszög, the Pelsonian – Ladinian carbonate facies were mapped and five cross sections from NW to SE were examined (Fig. 3). Sections 1, 2 and 4 are composite sections.

1. The Kecső Valley section [Figs 3 (Sections 1, 1a), 4, 5, 6] was measured along the middle part of the Kecső Valley, to the west of the village of Jósvafő. This is the least accurate of the five sections, because the area was affected by strong tectonics. In Section 1 the Jenei Formation could not be observed because of faults. However, 200 m to the north, in an auxiliary section (Fig. 3: Section 1a), a complete sequence of the Jenei Formation could be investigated.

2. The Road-cut section [Figs 3 (Sections 2; 2a), 7] was measured along the main road between Jósvafő and Aggtelek. Because of bad outcrop conditions, the section was supplemented with an auxiliary one.

3. The Baradla Cave subsurface section [Figs 3 (Section 3), 8a-b, 9-10] was measured along the main branch (6.6 km) of the Cave, starting at the Jósvafő entrance and ending at the Aggtelek main entrance.

4. The Nagy-Jenei Hill composite section [Figs 3 (Sections 4, 4a, 4b), 11] was compiled from the profiles of three neighbouring sink-holes (T38, T91, T92), situated on the NE slope of Nagy-Jenei Hill.

5. The Pitics Hill northern section [Figs 3 (Section 5), 12] is situated on the northern slope of Pitics Hill to the NW of Égerszög village.

The five sections start at the boundary between the Gutenstein Fm. and the Steinalm Fm. The Steinalm Fm. is tectonically sheared from the Gutenstein Fm. along a rauwacke horizon.

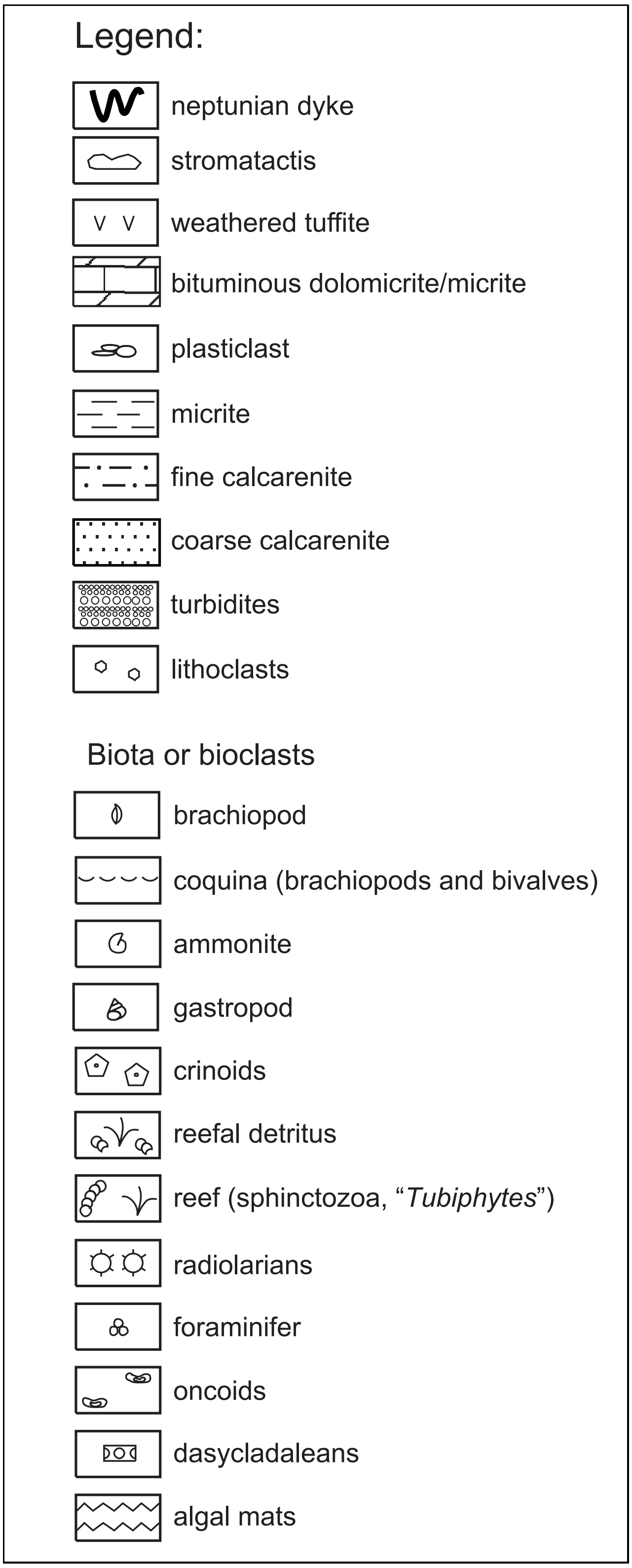


Fig. 4 - Legend for Figs 5, 7, 9-12 and 29.

The general dipping of the bedded lagoonal and basinal limestones that under- and overlie the reef unit is SSW – SW (Fig. 3), so despite the development of normal or reverse faults, the younging-upwards sequence is preserved.

Steinalm Formation (145 – 155 m)

The succession and thickness of this formation is uniform in the whole area. The 50 m of the lower part of the formation records peritidal cycle sedimentation: dasycladalean-rich subtidal calcarenites alternate with pink, laminated inter-supratidal limestone beds with fenestral structures (bacterial-algal mats).

The upper sequence is characterized by algal calcarenites with abundant dasycladaleans and foraminifers, with intercalated oncoid-rich layers and, further up, oolithic-oncolithic limestones. The sections therefore record a deepening and opening up trend, from peritidal to open shoal conditions.

The samples K1; Aj3, Aj5-Aj6; 46a, 316, 403 yielded a dasycladalean association: *Physoporella pauciforata pauciforata*, *Ph. pauciforata undulata*, *Ph. pauciforata sulcata* and *Teutloporella peniculiformis* which assemblage zone indicates Pelsonian – middle Illyrian age. *Poncetella hexaster* (K1; Fj2, Fj7, Fj9), *Anisoporella anisica* (Fj7) together with *Meandrospira dinarica* (K2-K3; Fj2, Fj3/6, Fj7-9/1; Aj3-Aj6) and *Glomospirella semiplana* (Fj8-10) limit this lithostratigraphic interval to the Pelsonian.

Neptunian dykes in the Steinalm Formation. The Steinalm Fm. is dissected by numerous neptunian dykes for nearly its total thickness. They can reach 130 m depth, with maximum width of a few dm. At 5700 m from the Aggtelek entrance, sample Fj4 (see Fig. 8b) a dark-red block fallen from the cave's ceiling, proved to be rich in brachiopods and in an abundant conodont fauna *(Gondolella bulgarica, G. hanbulogi)* indicating a Pelsonian age. The brachiopods are represented by single valves and appear size-sorted, favouring predominantly small individuals. The observation suggests transport and resedimentation of the fossils. The assemblage is rich in small, smooth rhynchonellids (*Norella*, *Austriellula*?) that may reflect a relatively deep-water environment.

Neptunian dykes filled with bivalve filament-rich mud-wacke-packstones are not always distinguishable from the host rock due to bad outcrop conditions. In the micritic or pelmicritic matrix bivalve filaments occur frequently, and ostracods, radiolarians, foraminifers (lagenids) and sponge spicules are also found. This microfacies indicates an open marine, low energy, deep water environment. The conodont fauna of the neptunian dykes in the Steinalm Fm. proves the latest Pelsonian (*Neospathodus kockeli, Gondolella bulgarica, G. hanbulogi, G. bifurcata, G. preszaboi bystrickyi, G. presz. preszaboi*: Binodosus Subzone, samples Fj3/3, Fj3/4, Fj4, Fj9Nd) and early to middle Illyrian (*Gondolella constricta cornuta, G. szaboi, G. liebermani, Gladigondolella budurovi:* Trinodosus Zone up to the most part of the Reitzi Zone, samples Fj6, Fj9d) ages.

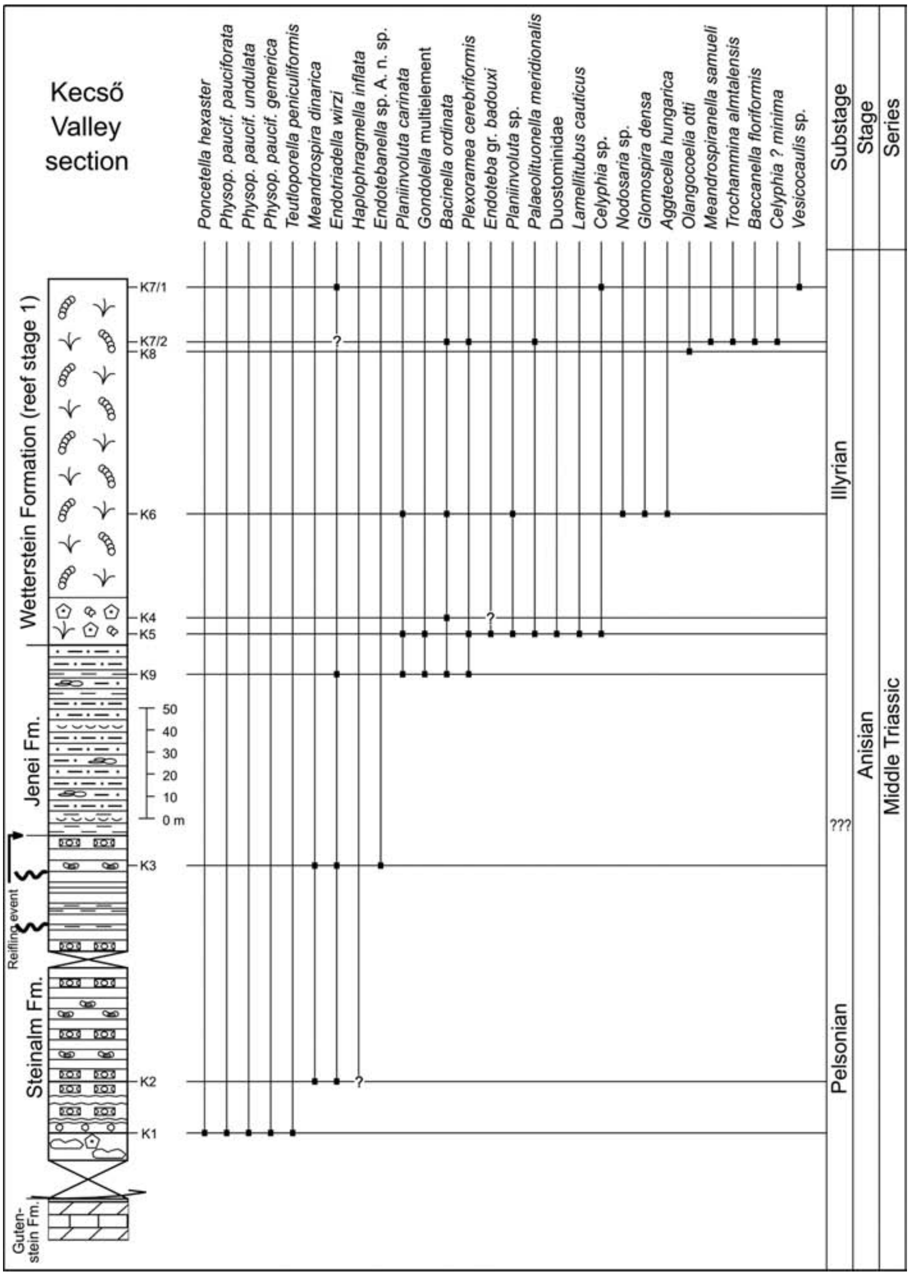


Fig. 5 - Kecső Valley composite section and fossils. Note: The Wetterstein Fm. represents reef facies, stage 1.

In the insoluble residue of some neptunian dykes (Fj3/3, Fj4, Fj9d), late Pelsonian (Binodosus Subzone) in age, heavy minerals including orthopyroxene, magnetite, ilmenite and limonite have been found (pers. comm. S. Józsa). Since orthopyroxene is difficult to transport over a long distance (Mange & Maurer 1992; Morton & Hallsworth 1999), these heavy minerals must have been derived from ultramafic-mafic-neutral magmatic rocks, probably as a product of a coeval volcanic activity.

Neptunian dykes are also frequent in the Steinalm Fm. in the southern part of the studied area. From sample 403c the mixed fauna (*Gondolella liebermani, G. szaboi, G. excelsa, G. constricta balcanica, G. trammeri*) proves Trinodosus – Reitzi Zones – Avisianum Subzone.

Jenei Formation in the North (40 – 80 m)

The evolution, age and thickness of the Jenei Fm. and Wetterstein Fm. is different in the NW (reef facies, stage 1) and in the SE (reef facies, stage 2) and thus they are described in separate chapters.

In the NW part of the area the unit begins with pinkish to reddish or greyish micritic limestones, with an ammonoid layer at the base. The microfacies is filament wackestone with radiolarians. The ammonoid layer is known only from the Baradla Cave section (Fj9, Fj9/base, Fj9/top; Fig. 10). It yielded two different conodont associations. In the lower part (Fj9/B, Fj9/base) representatives of the *G. bulgarica* group (*G. bulgarica, G. hanbulogi, G. bifurcata*), *Neospathodus kockeli* and the two subspecies of *G. praeszaboi* were found. This association indicates the upper part of the Pelso-

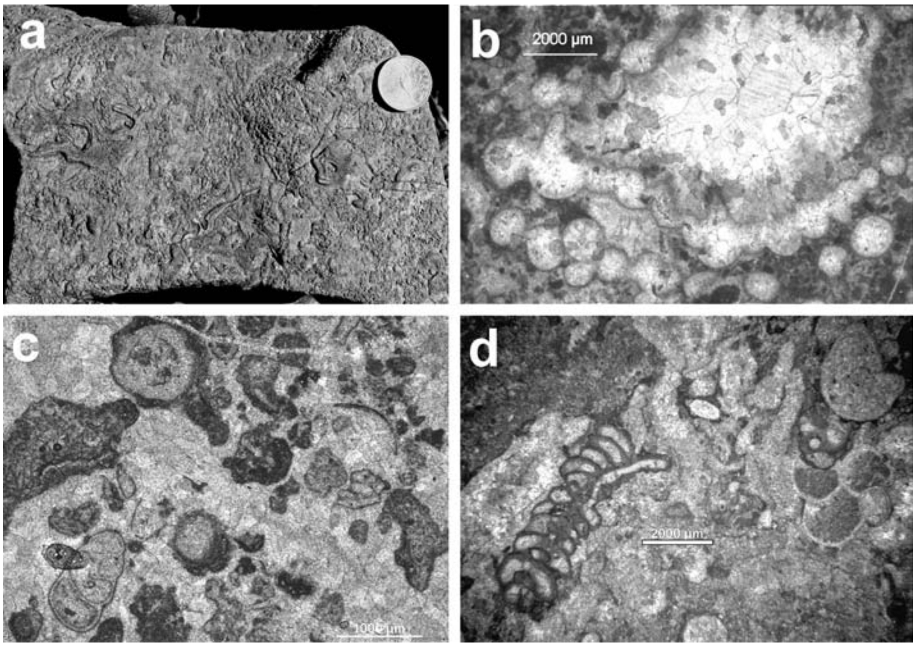


Fig. 6 - Microfacies types of the reefs. a) Microfacies type 1: On weathered rock surfaces well-preserved reefal organisms can be observed. Between the fossils sparry calcite cement is visible. This MF type is characteristic of the autochtonous reef. Sample K8. b) *Olangocoelia* sp. in pelmicritic matrix. Sample 336. c) Microfacies type 2: Fossil fragments (*Plexoramea cerebriformis* and gastropod) in sparry calcite matrix represent the detrital reef facies around the reef core. Sample K7/14. d) Microfacies type 1: *Vesicocaulis* sp. and a catenulate sphinctozoa in autochtonous position. The space between the sponges is partly filled with sparry calcite cement and partly with pelmicritic matrix. Sample K7/11.

nian (Binodosus Subzone). In the insoluble residue of the sample Fj9 / base (Binodosus Subzone), heavy minerals including orthopyroxene, magnetite and ilmenite have been found (pers. comm. S. Józsa).

The upper part of the ammonoid layer (Borka21, Fj9/top) contains species of the early-middle Illyrian, from the Trinodosus Zone up to the most part of the Reitzi Zone (*Gondolella liebermani, G. constricta cornuta, G. szaboi, G. excelsa*). The appearance of gladigondolelloids (*Gladigondolella tethydis, Gl. budurovi)* from the Binodosus/Trinodosus Subzone boundary onward indicates a connection with the open sea. The microfacies of the rock is filament wackestone containing ostracods as well.

Above the ammonoid layer grey limestones follow rich in brachiopod coquinas and resedimented intraclasts. The plasticlastic appearance of the rock refers to the fact that the intraclasts were soft when they were resedimented. Several beds are rich in crinoid remnants.

Thirty metres above the base of the ammonoid layer (sample Fj11), the first resedimented reef-building organisms, porostromate algae and microproblematica (*Baccinella ordinata, Ladinella porata, Plexoramea celebriformis,"Tubiphytes"* sp.), appear in a micritic filament-rich matrix. This level is dissected by numerous neptunian dykes (see below).

Sixty-five m above the base of the ammonoid layer, the conodonts *Gondolella liebermani, G. constricta cornuta, G. excelsa* and *Gl. tethydis* (Fj11/4, Fj12, Fj12/3) refer to the early-middle Illyrian: Trinodosus Zone and most part of the Reitzi Zone (= G. constricta cornuta Conodont Range Zone).

Approximately 70 m above the ammonoid layer, some undeterminable autochton (?) segmented sponges appear, which are encrusted by *Tubiphytes* sp. (sample Fj11), *Plexoramea cerebriformis* is also present. Because of the bad outcrop conditions it is uncertain whether the fossils are autochtonous or resedimented on the slope.

Thirty cm below the radiolarite – tuffite layers (see below), the microfacies of the limestone is again a filament wackestone with resedimented *Plexoramea cerebriformis* fragments. The change in the microfacies (from bafflestone to filament wackestone) might indicate a change in environmental conditions.

About 80 m above the ammonoid layer is a 15 cm thick level consisting of four radiolarite layers, each 2 cm thick. The fourth radiolarite layer is covered by a 3 cm thick acid tuffite layer. This is followed by a 2 cm thick limestone layer, on top of which a thin radiolarite layer appears again (Fj13/3 on Fig. 9). The radiolarian assemblage is Illyrian in age. From the same horizon (Fj12/o) *Gondolella liebermani* and *G. szaboi* also prove an early to middle Illyrian age (Trinodosus Zone up to the most part of the Reitzi Zone = G. constrica cornuta Conodont Range Zone). X-ray diffraction of the tuffite revealed that the original rock could be an acidic vulcanite (rhyolite-rhyodacite-dacite; pers. comm. of P. Kovács Pálffy), which originated either *in situ* through halmyrolysis or from continental erosion.

Immediately above the upper radiolarite layer the microfacies of the limestone is filament wackestone containing some *Tubiphytes* sp.

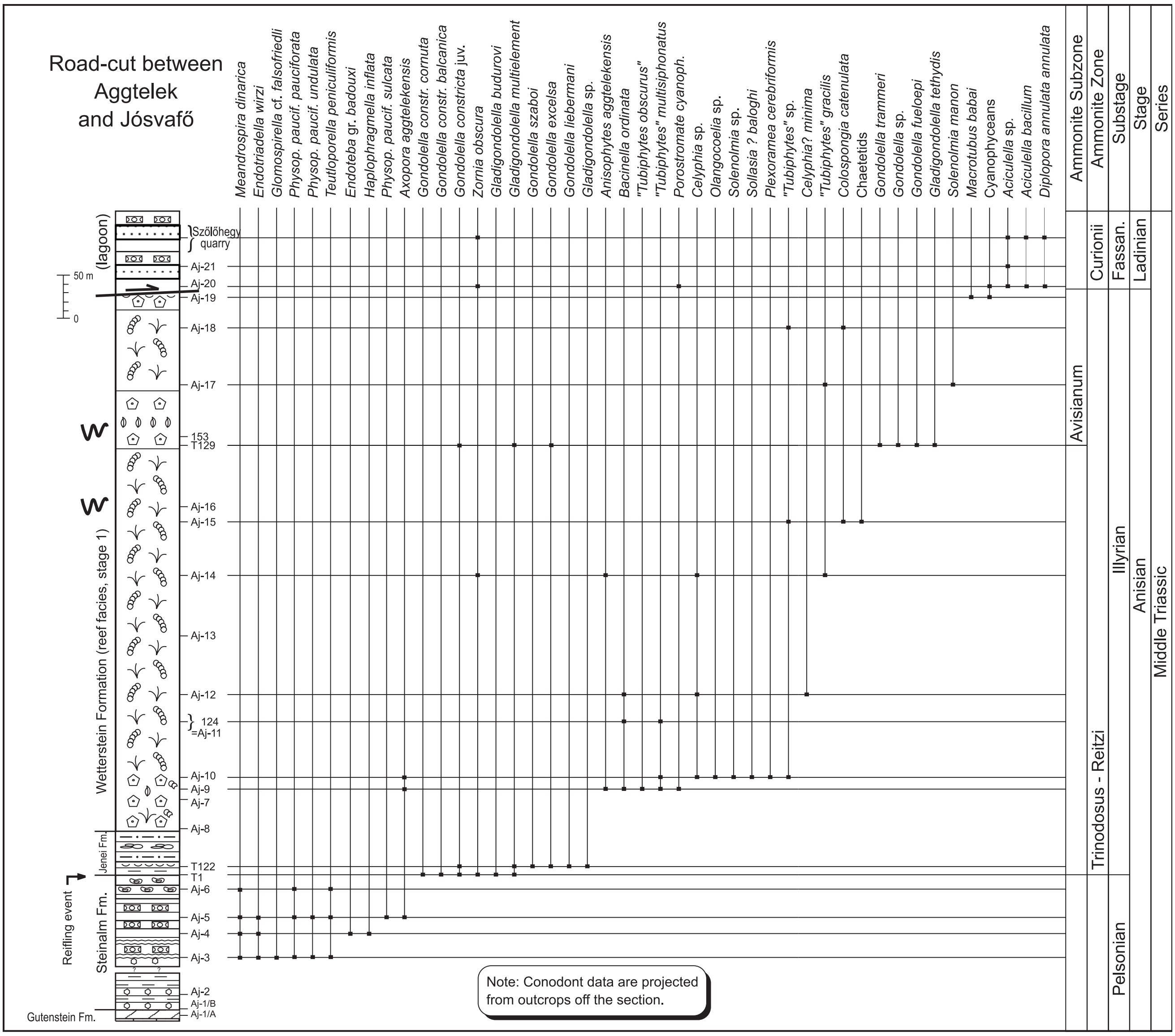


Fig. 7 - Road-cut composite section between Aggtelek and Jósvafő. Note: The Wetterstein Fm. (reef) represents reef facies, stage 1.

Neptunian dykes in the Jenei Formation in the North. From the sample A-30 m the conodonts (*G. excelsa, G. trammeri* and *G.* aff. *eotrammeri*) clearly indicate the middle Illyrian to early Fassanian age (Avisianum Subzone – lower Curionii Zone). In the insoluble residue of this sample a rich association of heavy minerals was found: zircon, magnetite, limonite, ilmenite, tourmaline and chlorite. The stratigraphic framework of this sample is uncertain because of the bad outcrop conditions. It can be interpreted most probably as a neptunian dyke.

Jenei Formation in the South (110 - 135 m)

Section 4. At the base of the section a few metres of pinkish micritic beds appear. The sample from the bottom of doline T91b, just above the Steinalm Fm. clearly shows a mixture of Pelsonian (*G.* gr. *bulgarica*) and Illyrian (e.g. *G. szaboi*) conodonts.

The sample T9/C (projected from NW) contains a rich mixed conodont fauna referring to the Pelsonian and Illyrian (Binodosus Subzone: *Gondolella praeszaboi bystrickyi*, *G. praeszaboi praeszaboi* and Trinodosus Zone up to the most part of the Reitzi Zone: *G. liebermani*, *G. constricta cornuta*, *G. szaboi* and *G. excelsa*).

The micritic beds at the base of the unit are followed by calcareous turbidites rich in brachiopod-coquinas. Soft intraclasts are also frequent. The average thickness of these beds is between 6-10 cm, with extremes of 2 to 30 cm. The lower part of the cycles contains graded bedded brachiopod coquinas, fading out upwards. The grey calcarenitic limestones turn to grey micritic limestones, and pink micritic limestones close the cyclothems. The Trinodosus Zone is documented by gladigondolellids indicating the Gondolella constricta cornuta Partial Range Zone. The conodont association

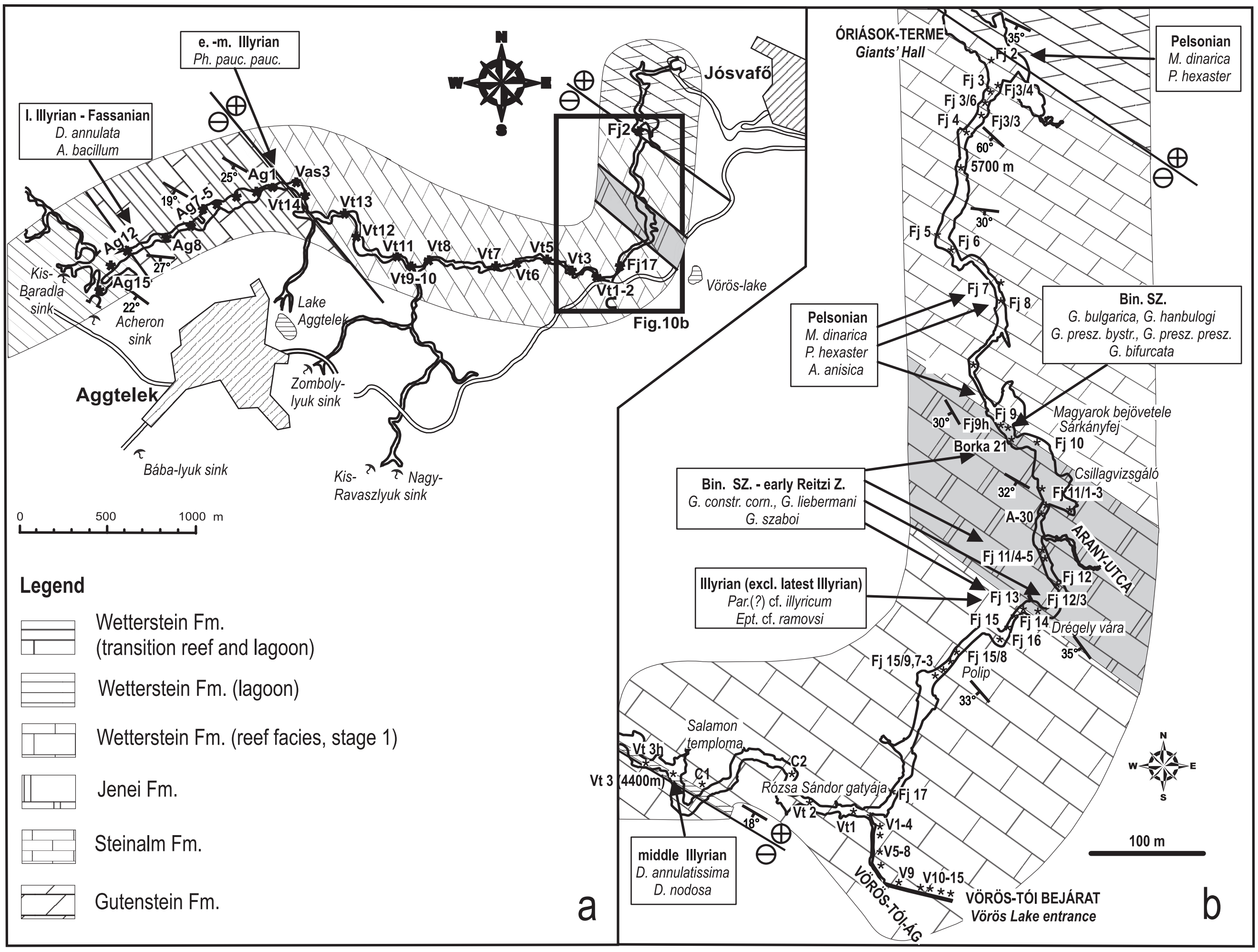


Fig. 8a, b - Baradla Cave map with the location of the most important samples.
Reef facies, stage 1 is above the Jenei Fm. (early Illyrian) and below the lagoonal facies of the Wetterstein Formation (late Illyrian). Note: The Wetterstein Fm. (reef) represents reef facies, stage 1.

from the higher part of the section (T91t) is dominated by *G. liebermani* and indicates also an early-middle Illyrian age (Trinodosus Zone – most part of the Reitzi Zone). A few juvenile specimens resembling those described by Krystyn (1983) from Epidaurus (Greece) could suggest that even the younger part of the Reitzi Subzone is found here.

The higher part of the section 4 is very poor in outcrops (45-93 m). The amount of calcarenitic (crinoidal) turbidites increases, but brachiopod-coquinas can still be found. From 93 m in the section the rocks became harder and crinoidal calcarenites are intercalated by grey to dark-grey silicious limestones yielding sponge spicules. Starting from 100 m in the crinoidal beds the first coarse resedimented fragments of reef building organisms appear.

The micritic beds become rarer and rarer and above the last brownish grey, pinkish spotted micritic limestone (131.5 m) the base of the reef appears at 135.5 m in section 4. Consequently, at least the upper 35.5 m portion of the Jenei Limestone can be interpreted as the slope facies of the prograding reef.

Auxiliary sections 4a and 4b. Because we don't have any conodont data from the upper part of section 4, the youngest conodont faunas were found in samples from auxiliary sections 4a and 4b. The sample (T38b) from the bottom of section 4a yielded a fauna referring to the uppermost middle Illyrian (Avisianum Subzone: *Gondolella fueloepi, G. trammeri*) and lacks younger morphotypes. The samples from the upper part of this section (T38t, 618) and auxiliary section 4b (T92) yielded *G. trammeri*, *G. transita*, *G. transita/pseudolonga* and much younger forms *Gondolella* gr. *bakalovi* (sensu Kovács 1994) indicating late Illyrian to Fassanian (upper Secedensis to Curionii Zones).

Pitics Hill N section. Over the base of the Jenei Fm. (micritic and coquina beds) moving upward in the section, thick-bedded fine-grained grey calcarenites appear (at least 70 m thick, samples P1-P5). From sample

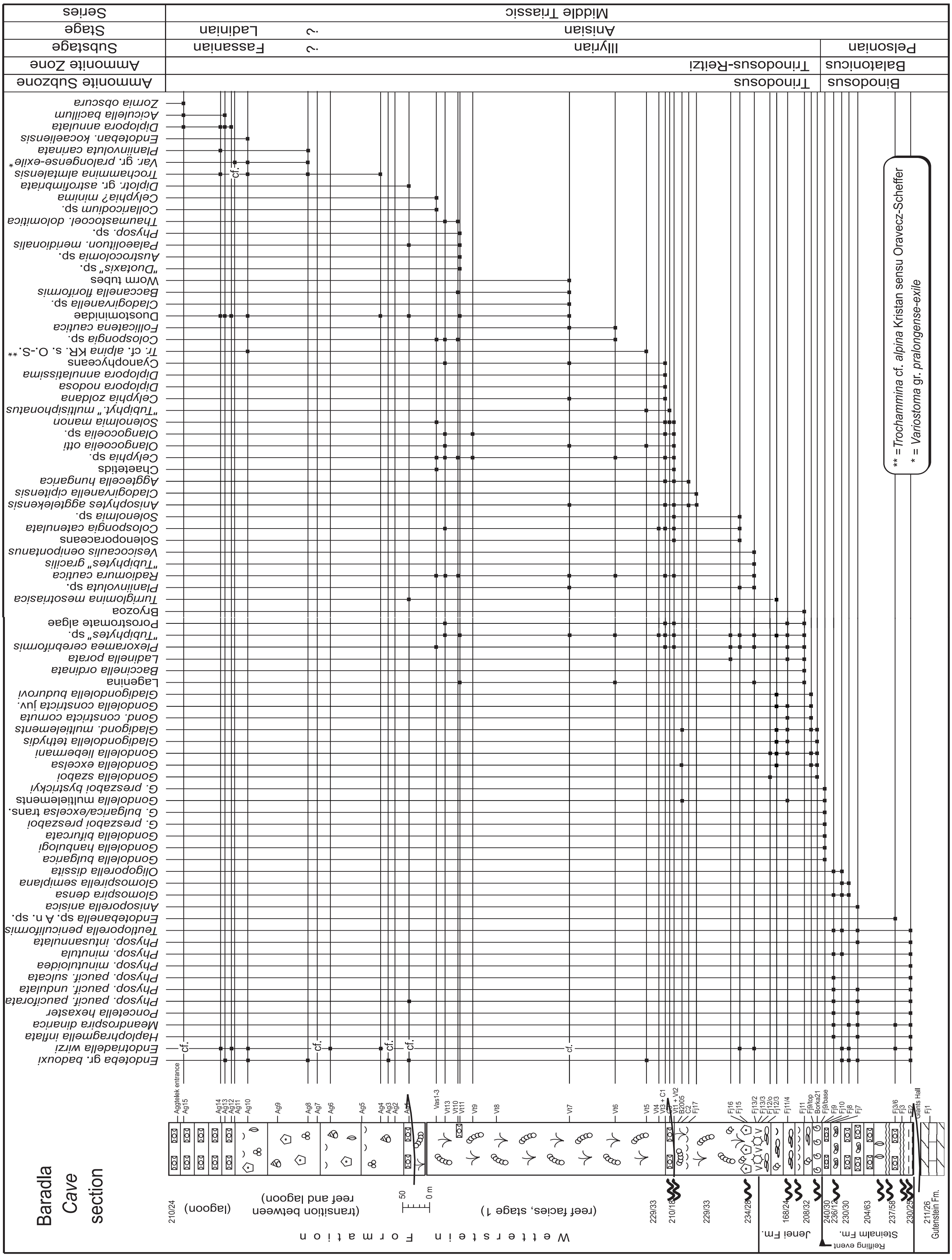


Fig. 9 - Baradla Cave section and fossils. For radiolarians (sample Fj13) see text and Fig. 20. Note: The Wetterstein Fm. (reef) represents reef facies, stage 1.

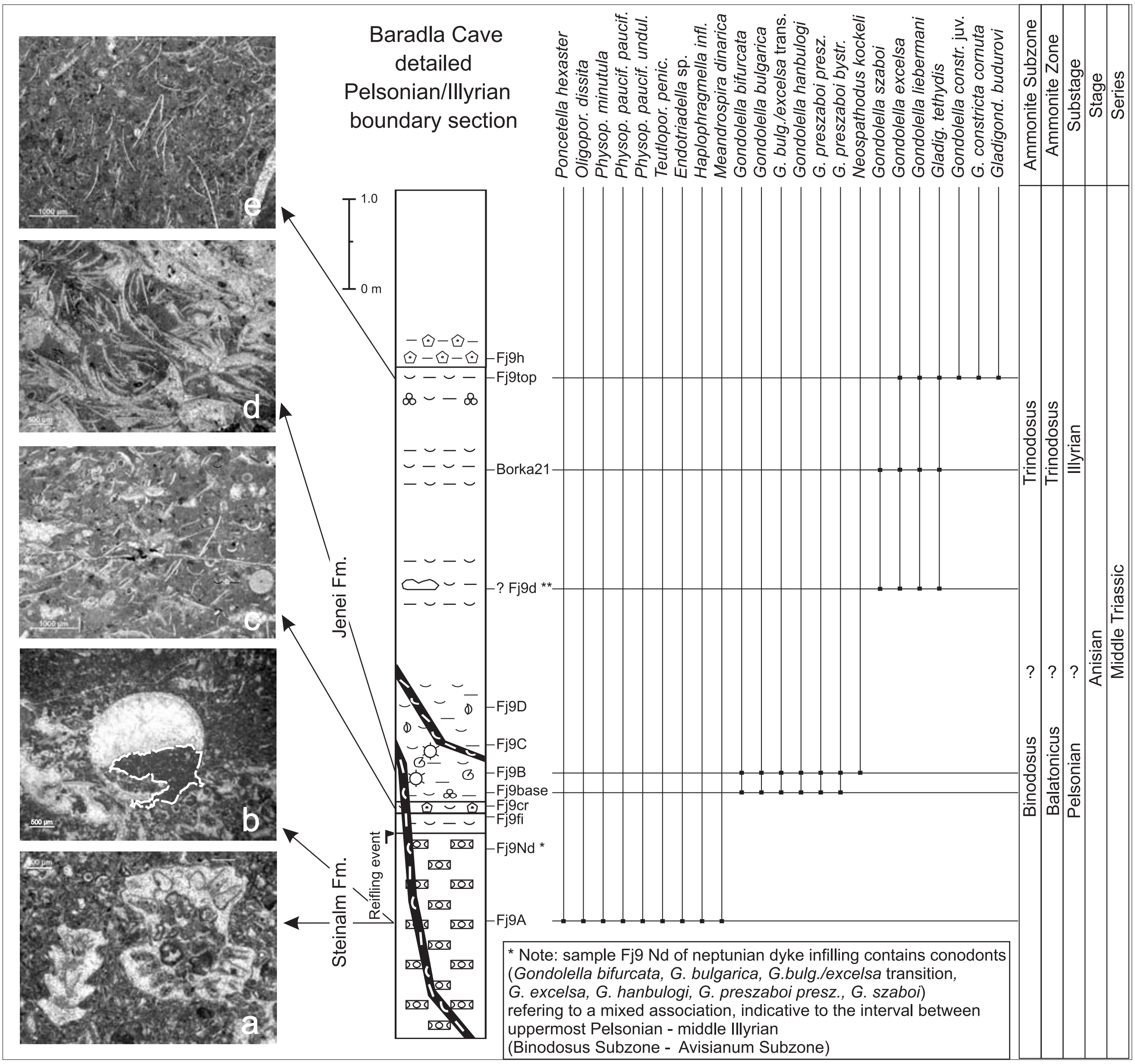


Fig. 10 - Baradla Cave, detailed Pelsonian/Illyrian boundary section. A significant change is visible in the sediments between the Steinalm Fm. (a-b) and the Jenei Fm. (c-e):
a) Two dasycladaleans from the Steinalm Fm.: *Physoporella pauciforata* var. *undulata* Pia 1935 to the right, and *Oligoporella minutula* [=*Physoporella minutula* (Gümbel 1872) Pia 1912] to the left. b) The original filling of the gastropod shows a geopetal structure (lower part micrite, upper part sparite). Later the micrites were partly dissolved and filled with brownish filament wackestone (surrounded by dashed white line), infiltrated from above. c) Filament-crinoidal packstone just below the base of the ammonoid layer. d) Filament packstone from the lower part of the ammonoid layer. e) Filament packstone with ostracods.
* Fj9Nd was taken from a neptunian dyke.
** Fj9d was collected from a fallen block originating from a higher level than Fj9D.

P5 upwards reef-building organisms become increasingly frequent, which indicates a reef slope approximately 30 m thick.

From the eastern foot of Pitics Hill, near the entrance of Szabadság Cave, sample Pc1 contained *G. transita* pointing to a late Illyrian/early Fassanian age (Secedensis/Curionii Zone).

Neptunian dykes in the Jenei Formation in the South. In the Jenei sections the upper part of the Jenei Fm. is cut by neptunian dykes filled by red micrites which yielded *Gondolella* cf. *fueloepi, G. trammeri* and *G. excelsa*. These fauna indicate a middle Illyrian or even younger (Avisianum Subzone or younger, T38g, 128b, 756) age for these.

Wetterstein Formation, reef facies, stage 1 in the North (650 – 700 m; in the Kecső section only 165 m)

Reef facies, stage 1 (or briefly reef stage 1) crops out only in the NW part of the studied area.

In the Baradla Cave section the tuffite/radiolarite level is overlain by crinoidal-dominated coarse-grained limestones, starting from Fj13. Well-preserved crinoid stems (1-1.5 cm in diameter) are frequent and whole chalices and autochtonous crinoids can be found between Fj13-Fj15 (Hagdorn & Velledits 2006). On the surface, in the Road-cut section (Aj8-Aj10) the crinoidal limestones contain a rich brachiopod fauna (13 taxa, Scholz 1972, 1973 and p. 248 in this paper.). The first determinable sponge *(Vesicocaulis oenipontanus)* together with *Radiomura cautica* and *"Tubiphytes" gracilis* appear already (Fj13/2) above the fourth radiolarite layer. About 25 m higher in the section, in sample Fj15, other sponges (*Colospongia catenulata, Solenolmia* sp.) and microproblematica were found. Neptunian dykes are very frequent in this level.

Higher up in the section, the reef-building organisms (*Colospongia catenulata, Solenolmia manon, Olangocoelia otti, Plexoramea cerebriformis, "Tubiphytes"* sp., *Radiomura cautica, Porostromata algae, Anisophytes aggtelekensis, Aggtecella hungarica*) become more abundant, while the crinoids disappear (Vt1). In the lower part of the reefal sequence, a level rich in *Diplopora nodosa* associated with *Diplopora annulatissima* (sample Vt3= 4400 m from the Aggtelek entrance) indicates a middle Illyrian age. Next to the dasycladaleans this level contains several sphinctozoans: *Colospongia catenulata, Solenolmia manon, Celyphia zoldana, Celyphia?* sp., and *Tubyphites* sp., *Aggtecella hungarica,* bryozoa, brachiopoda and ostracoda.

Well-preserved reef organisms can be observed on weathered surfaces, although the inner structure of the fossils cannot be always seen in thin sections due to recrystallization. The reef facies is characterised by two microfacies types. The first consists of bafflestone-bindstone with a micritic – pelmicritic matrix, in which reef-building organisms, sponges, microproblematicas, porostromata algae, bryozoans, gastropods and foraminifers can be found (Figs 6a-b, d). The reef-building organisms are sometimes coated by crusts of different origin. The stromatactis are filled by different generations of calcite cements.

The second microfacies type is characterised by a sparry calcite cement with fossils (*"Tubiphytes"*, *Plexoramea cerebriformis*, echinodermata fragments with micritic envelopes, gastropods, bivalves, foraminifers, ostracods, dasycladaleans and rarely by segmented sponges), fossil fragments and intraclasts (Fig. 6c).

The reef community consists mainly of segmented sponges (Sphinctozoans: *Celyphia? minima*, *C. zoldana*, *Colospongia catenulata, Follicatena cautica*, *Olangocoelia otti*, *Solenolmia manon manon*, *Sollasia*? *baloghi*, *Thaumastocoelia dolomitica*, *Vesicocaulis oenipontanus*), and microproblematica (*Baccanella floriformis*, *Bacinella ordinata, Ladinella porata, Plexoramea cerebriformis, Radiomura cautica, "Tubiphytes" gracilis, "T." multisiphonatus, Tubiphytes* sp.), porostromata algae, bryozoans, gastropods, and foraminifera.

In the Kecső Valley section from reef facies, stage 1, *Glomospira densa* (sample K6) and *Meandrospiranella samueli* (K7/2) indicate an age interval from Pelsonian to Illyrian. Sample 73 (Fig. 3) yielded *Celyphia? minima* together with *Physoporella pauciforata pauciforata.* The latter indicates a Pelsonian to early-middle Illyrian age.

In the Road-cut section in the upper part of the reef unit, two dark-grey crinoid-brachiopod-rich limestone units interfinger. The lower crinoidal-brachiopodal unit represents the first deep water intercalation. Situated near the top of the reef stage 1, it yielded conodonts (sample T129) indicative of the age Avisianum Subzone or younger (*Gondolella fueloepi* and *G. trammeri*). The brachiopod biostratigraphic data suggest that the Aggtelek reef facies, stage 1 is Pelsonian – Illyrian in age (see p. 250).

The second deep water intercalation (Fig. 7: Aj19) produced no fossils.

Neptunian dykes in the Wetterstein reef facies, stage 1. The basal portion of the lower crinoidal-brachiopodal unit is frequently cut by neptunian dykes, filled by red crinoidal limestones. They are at least some tens of metres deep and a maximum of one metre wide. The chaotically filled dykes often consist of breccia with reefal limestone clasts. The crinoidal wacke-packstone is characterized by a red micritic matrix with crinoidal fragments. The sediment in the dykes shows either internal bedding or a chaotic arrangement of fossils. In the first case, the internal sediments are fine-grained and direct gradation can be frequently observed. This type of sedimentation can be explained by currents circulating in the dyke system (Velledits & Blau 2003). The conodont faunas from the neptunian dykes (samples: Ko1-3; see Fig. 3) also prove an age Avisianum Subzone or younger: *Gondolella excelsa, G.* cf. *szaboi* and *G. trammeri*. We consider that the age of the dykes might be middle Illyrian (Avisianum Subzone), because the later stepping-in species like *Gondolella transita* or *G.* gr. *bakalovi* are missing.

The upper contact of the Wetterstein reef facies, stage 1 with the Wetterstein Formation lagoonal facies is tectonically discordant. The lagoonal limestone is overthrust by the reef and the reverse fault cuts different levels (both reefal and the dark grey crinoid-brachiopod basinal limestone) of the reef. In the Baradla Cave section this contact is tectonically discordant too, but a transitional sequence from reefal to lagoonal facies is observable.

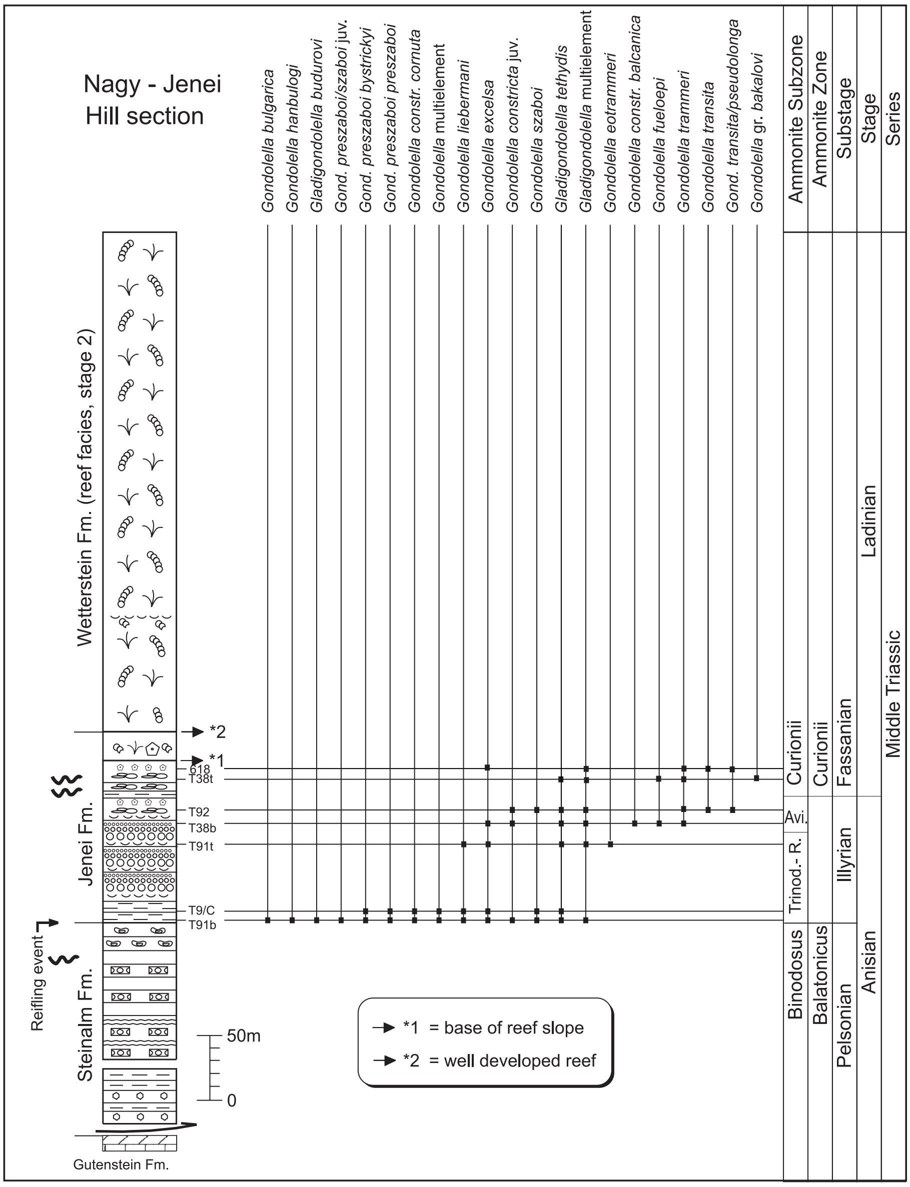


Fig. 11 - Nagy-Jenei Hill composite section and fossils. Note: The Wetterstein Fm. represents the reef facies, stage 2.

Wetterstein Formation; transitional sequence from reefal to lagoonal facies (300 m)

Grey or light-grey limestones occasionally containing birds-eyes follow, recording the transition from reef to lagoon facies. Porostromate algae, dasycladaleans, molluscs, brachiopods, crinoids, and foraminifers are present in a pelmicritic matrix, but real reef-builders are missing. In the lower portion of the unit, the porostromate algae are abundant but their quantity diminishes upwards in the section. Dasycladaleans abundance on the contrary records a sharp increase up-section. At the base of the transitional facies (Ag1), *Ph. pauciforata* var. *pauciforata* justifies a middle Illyrian age.

Wetterstein Formation; lagoonal facies (the investigated part is 90 - 120 m thick)

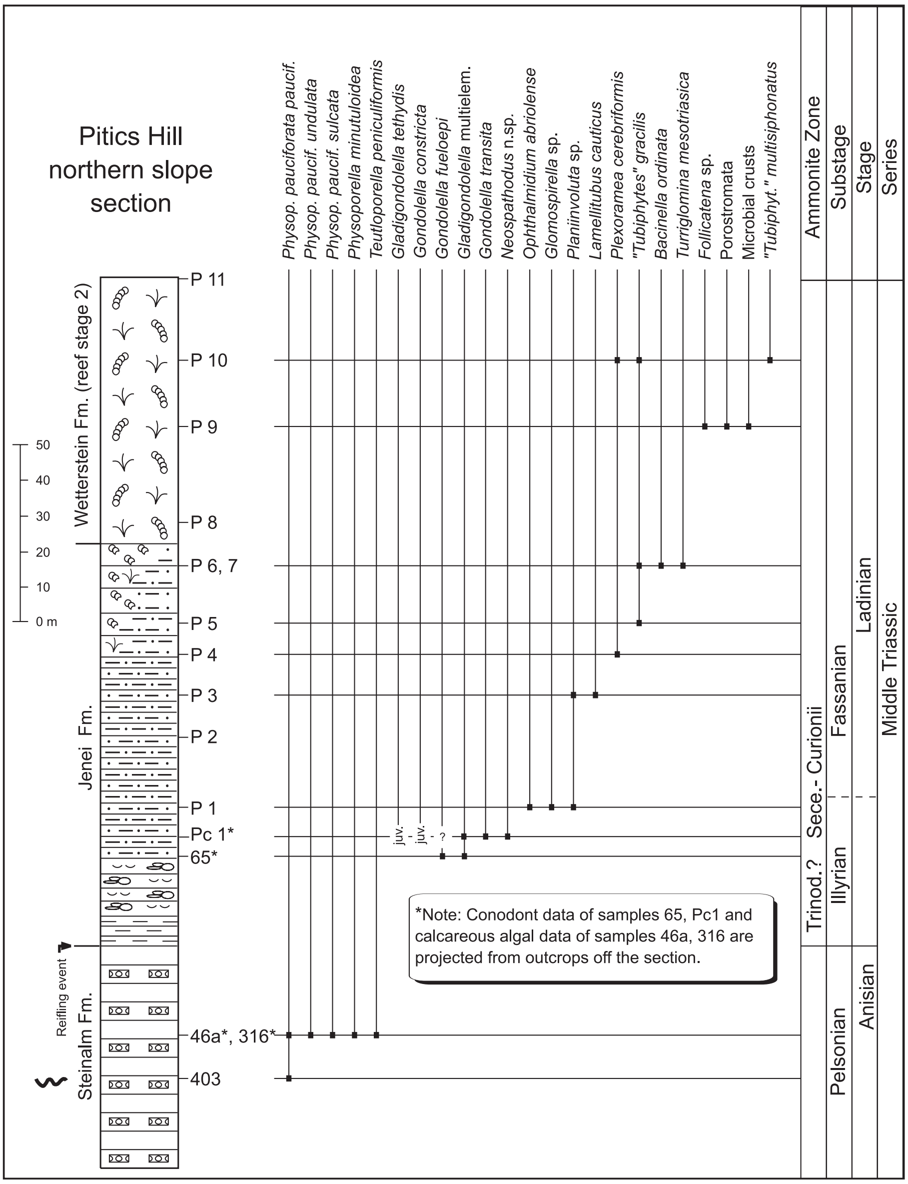
The light-grey to grey limestone is a typical coarse calcarenitic, dasycladaleans-dominated, lagoonal limestone (Ag11). In the topmost part of the section, *Diplopora annulata* (samples Ag12-15; Aj20) appears in large quantity, together with *Aciculella bacillum,* indicating a late Illyrian – Fassanian age. The absence of *D. annulatissima* may suggest the Fassanian substage (Granier & Grgasović 2000).

Wetterstein Formation, reefal facies, stage 2 (in the South, at least 550 - 590 m)

In contrast to reef facies, stage 1, the reef facies, stage 2 (briefly reef stage 2) crops out on the SE part of the studied area.

Above the top of the Jenei Fm., after an outcrop gap of 2 to 4 metres, light-grey or white sphinctozoan reef limestones appear. Compared to the previous reef facies, stage 1 sections (sections 1-3) the reef cores are much larger and densely packed with reef-building organisms. The thick, coarse crinoidal member, forming the base of the reef stage 1, is here absent.

Fig. 12 - Pitics Hill northern slope section and fossil ranges. Note: The Wetterstein Fm. represents the reef facies, stage 2.



On the weathered surface, catenulate chambers of segmented sponges are visible, coated by crusts of different origin, and associated with stromatactis. Under the microscope both microfacies types described in reef stage 1 occur. From the Pitics Hill section the following fossils were identified. Sphinctozoa: *Follicatena* sp., Microproblematica: *Bacinella ordinata, Lamellitubus cauticus, Plexoramea cerebriformis, "Tubiphytes" gracilis, "T." multisiphonatus,* Foraminifera: *Turriglomina mesotriassica,* porostromata algae and microbial crusts.

The neptunian dykes were not found in reef facies, stage 2.

Palaeontology

This section of the article describes the major fossil groups found in the Aggtelek platform (for detailed descriptions of echinoids see Mihály (1981) and for crinoids see Hagdorn & Velledits 2006). It is not the aim of this paper to provide detailed systematic descriptions for the fossil groups, although one exception was made for the conodonts: Appendix 1 deals with the evolution and the biostratigraphical approach of the conodonts in greater detail.

The different fossil groups have varying powers of stratigraphic resolution and/or may be dependent on facies. Pelagic fossils such as ammonoids and conodonts have a high stratigraphic resolution and therefore the Triassic biostratigraphic frame is based on ammonoids (Krystyn 1980, 1983; Brack & Rieber 1993; Kovács 1994; Mietto & Manfrin 1995; Nicora & Brack 1995; Pálfy & Vörös 1998).

Conodonts can be recovered even from limestones lacking ammonoids. Conodont species have longer distribution ranges than ammonoids, but due to the application of zonal concepts (e.g. different type of interval zones) the resulting chronological resolution is the second-best in the Triassic.

Platform carbonates are usually subdivided biostratigraphically by dasycladaleans and foraminifers. Unfortunately the biostratigraphic resolution power of these fossil groups is not as precise as that of the ammonoids and the conodonts. It can be improved if deep-water intercalations bearing biostratigraphically useful taxa are present.

Another problem is the chronostratigraphic correlation between the different taxonomic groups. Some attempts were made to find a correlation between dasycladaleans, ammonoids and conodonts by Piros et al. (2002) and Piros & Preto (2008), but a comprehensive correlation between the above-mentioned fossil groups has yet to be accomplished.

In Triassic metazoan reefs two different reef communities can be distinguished, those of (1) the Wetterstein reef (Pelsonian – late Carnian) and (2) the Dachstein reef (late Carnian – Rhaetian). Within these metazoan communities, no further stratigraphic resolution can be achieved.

The most important reef-builders of the investigated limestones are hypercalcified sponges, including sphinctozoans, inozoans and chaetetids, followed by the "*Tubiphytes*"-like group and comparable problematica. Among the sponges the sphinctozoids are very abundant whereas the inozoids and chaetetids are rare.

Cyanophycea

Cladogirvanella cipitensis is the most important representative of this group. *C. cipitensis* is described from several Ladinian-Carnian localities (Senowbari-Daryan & Bernecker 2009). SEM-photographs and the cell structures of individual branches are documented by Senowbari-Daryan & Flügel (1993).

Scholz (1972: pl. 4, fig. 4 and pl. 5, figs. 3-6) described a fossil called *Axopora aggtelekensis* and attributed it to the hydrozoans, but examination of the type material of *Axopora aggtelekensis* has shown that this fossil cannot be attributed to the hydrozoans. The tubes of *Axopora aggtelekensis* suggest a cyanobacterian nature. For *Axopora aggtelekensis* the new genus name *Anisophytes* was proposed by Senowbari-Daryan & Velledits (2007b).

Algae (Figs 13-14)

In the literature different opinions can be found concerning the stratigraphical range of the Anisian-Ladinian Dasycladaleas (Granier & Grgasović 2000; Granier & Deloffre 1994). In the recent paper the ranges are considered according to the results of Ott (1972); Bystrický (1964); Piros (2002). Ott (1972) investigated the Dasycladaleans from the Northern Calcareous Alps, Bystrický (1964) made careful research in the West Carpathians and Piros (2002) in the Aggtelek Hills. In the above mentioned papers the stratigraphical ranges of the Dasycladaleans were defined according to the classical Anisian/Ladinian boundary (i.e. the Nevadites/Secedensis zone). In this paper the Dasycladaleas ranges are adjusted to the recently accepted Anisian/Ladinian boundary (Brack et al. 2005).

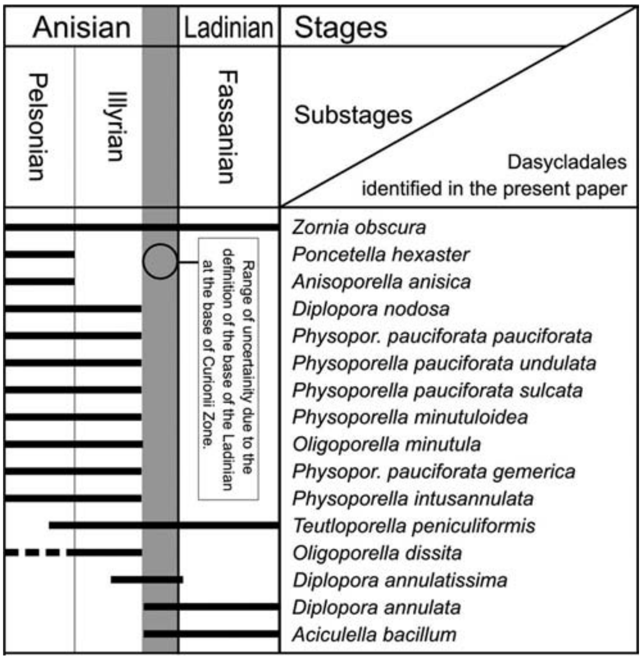


Fig. 13 - Compiled range chart of selected dasycladalean species. Based on described Dasycladales for the Alps (Ott 1972) and West Carpathians (Bystrický 1964) including Aggtelek Hills (Piros 2002).

The first mass-appearance of Dasycladaleans occurred in the Pelsonian, coevally with the formation of extended carbonate platforms. In the Pelsonian and early-middle Illyrian the genera *Physoporella* and *Oligoporella* prevail (Ott 1972; Bystrický 1986, Piros 2002). In addition, at the beginning of the Pelsonian *Poncetella hexaster* and *Favoporella annulata* appear, followed by *Teutloporella peniculiformis* in the late Pelsonian. There is no substantial change at the Pelsonian/Illyrian boundary. At the end of the middle Illyrian the majority of the *Physoporella* and *Oligoporella* species became extinct.

Diplopora annulatissima appeared in the middle Illyrian and is used in some areas as a separate zone marker (Bystrický 1986; Piros 2002). *Diplopora annulata* appeared at the beginning of the late Illyrian. *Diplopora annulatissima* and *Diplopora annulata* occur together (assemblage-zone) from the beginning of the base of the late Illyrian (Fig. 13). In the late Illyrian – Longobardian *Diplopora annulata* prevails and in addition *Macroporella beneckei*, *Zornia obscura,* and *Aciculella bacillum* appear. Although Bucur et al. (1994) de-

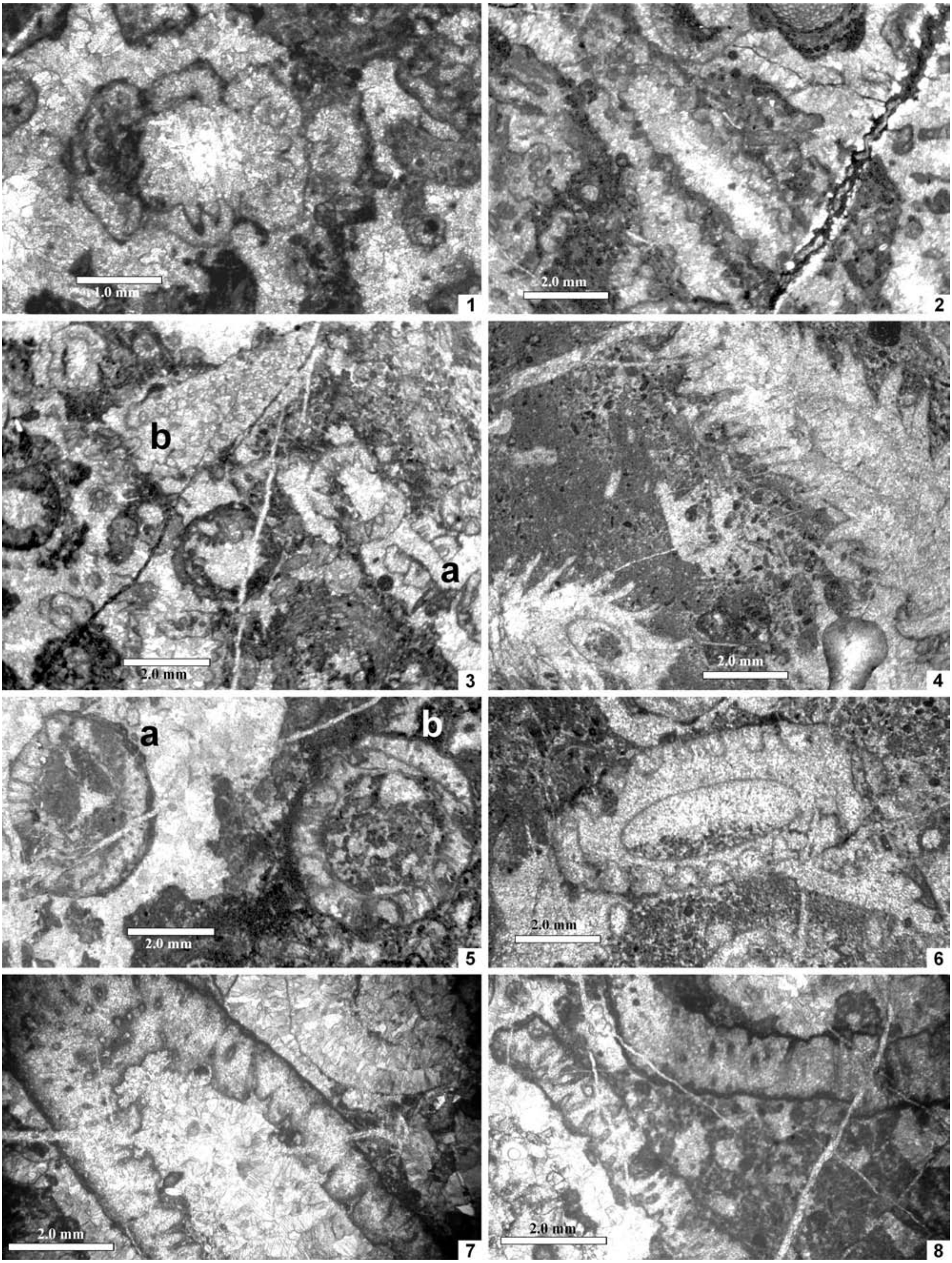


Fig. 14 - Dasycladales.
1) *Oligoporella dissita* [= *Physoporella dissita* (Gümbel, 1872) Pia, 1912]. Aj3. 2) *Physoporella pauciforata* var. *pauciforata* Pia ex. Bystrický, 1964. Aj3. 3) (a) *Oligoporella dissita* [= *Physoporella dissita* (Gümbel, 1872) Pia, 1912], (b) *Ph. pauciforata* var. *undulata,* Pia. Aj3. 4) *Diplopora nodosa* Schafhäutl 1863, emend. De Castro, 1979. TV (Tót Valley). 5) (a) *Diplopora annulata annulata* Schafhäutl, 1863, (b) *Diplopora annulatissima,* Pia 1920. 255. 6) *Diplopora annulatissima* Schafhäutl, 1863. Vt3 (= 4400 m, Baradla Cave). 7) *Diplopora annulata annulata* Schafhäutl, 1863. Ag13. 8) *Diplopora annulata annulata* Schafhäutl, 1863. Ag13.

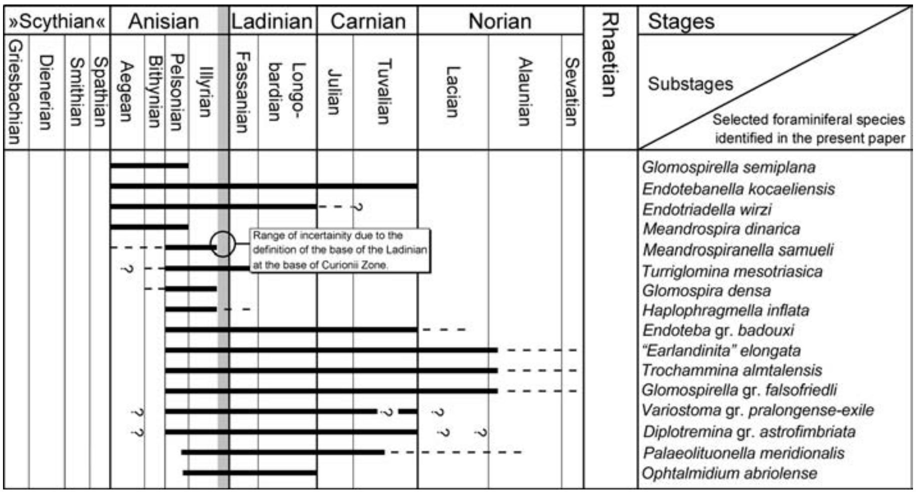


Fig. 15 - Compiled range charts of selected foraminifera species. For the compilation the papers of Koehn-Zaninetti (1969); Oravecz-Scheffer (1987); Rettori (1995); Salaj et al. (1983); Zaninetti (1976) and own data were used.

scribed *A. bacillum* from the Southern Carpathians from the Pelsonian-Illyrian, based on Bystrický (1975) and Piros (2002) in the Western Carpathians it appears only at the base late Illyrian.

In the Aggtelek platform the following Dasycladaleans appeared in different formations.

Dasycladales in the Steinalm lagoonal facies (Pelsonian). In the Pelsonian the sea floor was undifferentiated and lagoonal conditions prevailed over the whole area (Steinalm lagoon). These rocks crop out in a NW-SE striking direction in a strip 7 km long and 200-300 m wide ranging from the Slovakian/Hungarian border (Kecső Valley) to the Simon Valley (see Fig. 3 on the surface: 46a, 140, 93, K1, Aj3, Aj5, Aj6, T1, TV, 403, 316; and from the Baradla Cave Fj2-Fj9; see Figs 3, 8b, 9). Several levels yielded a rich dasycladalean flora (e.g. *Physoporella pauciforata* var. *undulata*, *Ph. pauciforata* var. *sulcata*, *Ph. pauciforata* var. *pauciforata, Oligoporella dissita, Ph. minutuloidea*, *Ph. intusannulata*, *O. minutula*, *Anisoporella anisica*, *Teutloporella peniculiformis*, *Poncetella hexaster* (Figs 13, 14/1-4). During the end-Pelsonian due to the Reifling drowning event the lagoonal sediments were succeeded by deep water carbonates, making the environmental conditions unfavourable for dasycladaleans.

A few dasycladales appeared sporadically between the reef building organisms when reef stage 1 (early? – middle Illyrian) was formed. In the Baradla Cave section sample Vt3 yields an association of *Diplopora nodosa* and *D. annulatissima* (Fig. 14/6). This association indicates a middle Illyrian (Fig. 13) age for the lower part of reef stage 1, 160 m above the base of the reef (Figs. 8b, 9, 14/6). In the uppermost part of reef stage 1 (sample 73: Fig. 3) immediately below the lagoonal facies of the Wetterstein Formation *Ph. pauciforata* var. *pauciforata* indicates a Pelsonian-middle Illyrian age.

Dasycladales from the Wetterstein lagoon (late Illyrian-Fassanian). In the NW part of the studied area, the deposits of reef stage 1 were overlain by lagoonal facies of the Wetterstein Formation which is heteropic with reef stage 2.

In these lagoonal deposits *Diplopora annulata annulata*, *Aciculella bacillum*, and *Zornia obscura* appear (on the surface: 249, 225, 243, Aj20, Aj21, in the Baradla Cave: Ag12, Ag13, Ag14, Ag15). *D. annulata annulata* confirms a late Illyrian – Fassanian age (Figs. 3, 8a, 9, 14/7-8). *D. annulatissima* and *D. annulata* are in association in sample 255 indicating a late Illyrian – very base of the Fassanian age (Figs. 3, 14/5a-b).

Foraminifera (Figs 15-18)

Figure 15 shows a compilation of the known stratigraphic ranges of selected foraminifers identified in the studied material. Some forms, such as *Trochammina* cf. *alpina* Kristan sensu Oravecz-Scheffer (Figs. 18/16-17), have been omitted because their documentation in the literature is scarce.

Some foraminiferal species have very long ranges such as *Planiinvoluta carinata* (Figs 17/26, 18/8-9), a species known from the Triassic up to the Jurassic (e.g., Leischner 1961; Wernli 1971; Blau & Grün 1994; Piuz 2004) or *Hoyenella* gr. *sinensis* (Fig. 16/7) which seems to persist from the Lower to the Upper Triassic.

In the Middle Triassic there are only a few foraminiferal species with a more or less short range in terms of stratigraphical ranges. Nevertheless, these ranges are long in comparison to those of ammonites and conodonts. Additionally since the classical paper of Resch (1979) it is known that some foraminiferal species are obviously bound to distinct facies.

According to Rettori (1995, fig. 6) *Glomospirella semiplana* (Fig. 16/6) ranges from the lower Anisian (Aegean) up to the Pelsonian. Rettori (l. c.) indicates the same range for *Meandrospira dinarica* (Figs 16/8, 18-22). We note that the last local occurrence of *Mean-*

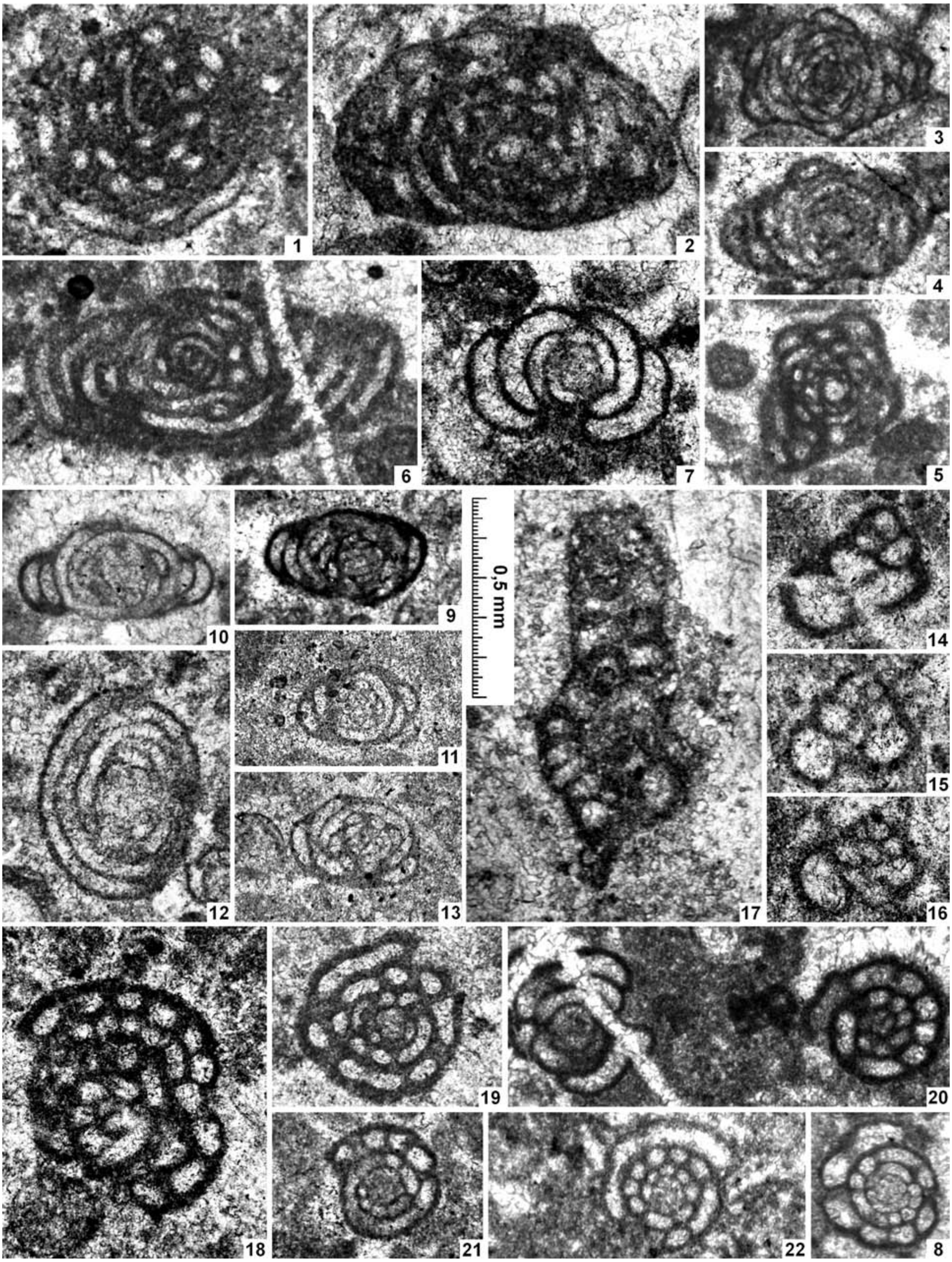


Fig. 16 - Foraminifera 1

1-5) *Glomospira densa* (Pantić, 1965). 1: Fj9; 2, 3: Fj10, 4: Fj9(=AmoA); 5: Fj8/3.

6) *Glomospirella semiplana* (Kochansky-Devidé & Pantić, 1966). Fj8/3. 7) *Hoyenella* gr. *sinensis* (Ho, 1959). Fj8. 8) *Meandrospira dinarica* Kochansky-Devidé & Pantić, 1965. K2. 9-13) *Glomospirella* cf. *falsofriedli* (Salaj, Borza & Samuel, 1983). 9, 10: Fj3b; 11, 13: Aj3; 12: Fj2. 14-16) *Trochammina almtalensis* Koehn-Zaninetti, 1968. 14, 15: Fj3b; 16: Fj2. 17) *Meandrospiranella samueli* Salaj *in* Salaj, Bielý & Bystrický, 1967. K7/2. 18-22) *Meandrospira dinarica* Kochansky-Devidé & Pantić, 1965. 20: K2; 18, 19: Fj2; 21: Fj3b; 22: Aj6.

The scale is suitable for all specimens.

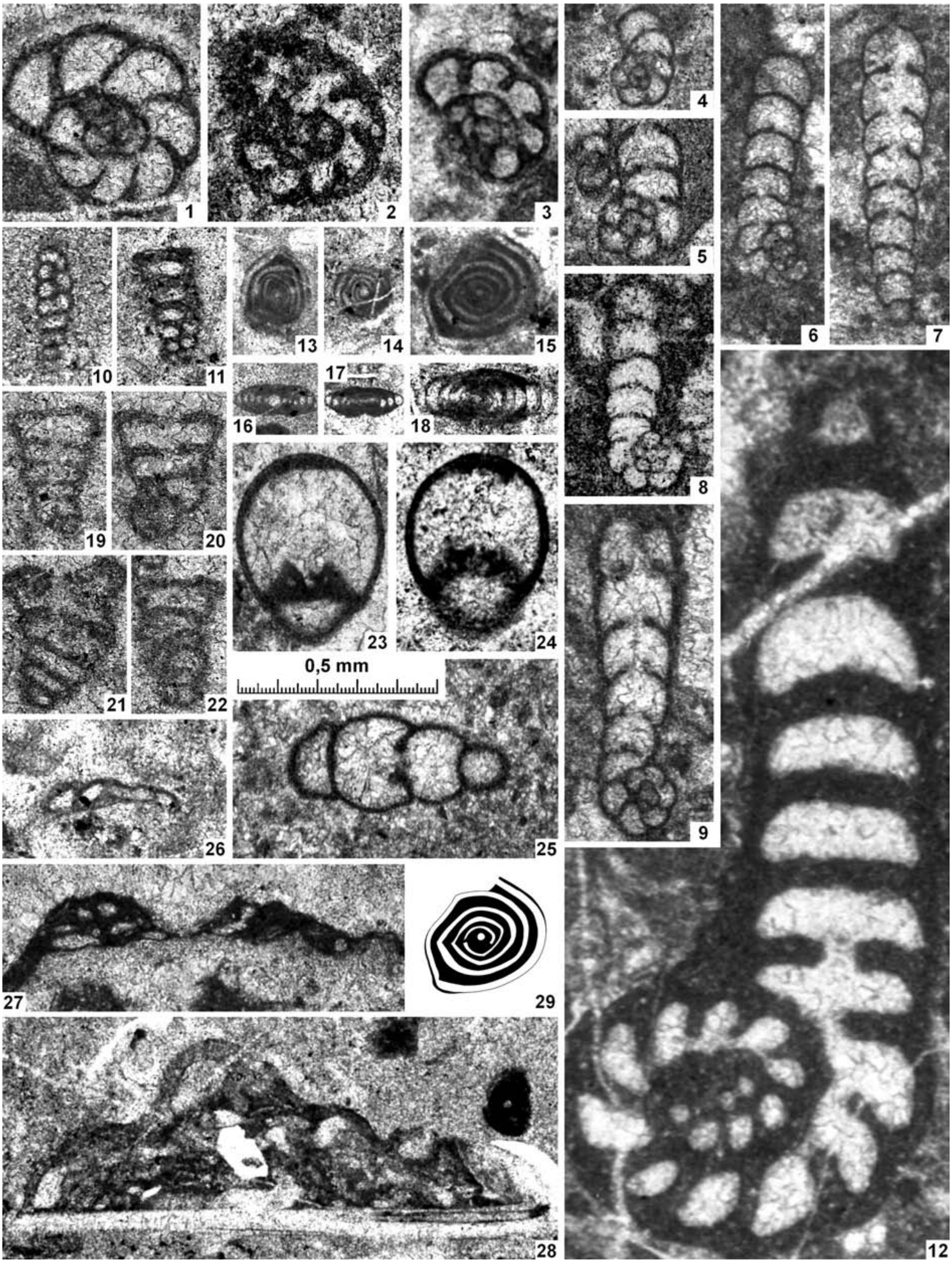


Fig. 17 - Foraminifera 2

1-3) *Endoteba* gr. *badouxi* (Zaninetti & Brönnimann in Zaninetti, Brönnimann & Baud, 1972). 1: Ag2; 2: Fj2; 3: Fj10. 4-9) *Endotriadella wirzi* (Koehn-Zaninetti, 1969) emend. Vachard et al. 1994. 4: Fj3b; 5, 8: Fj2; 6, 7: K2; 9: Aj4. 10-11) *Turriglomina mesotriasica* (Koehn-Zaninetti, 1969). 10: Fj12/3; 11: AmoC (= Fj9). 12) *Endotebanella* sp. A sp. nov. K3. 13-18, 29) *Ophthalmidium abriolense* (Luperto, 1965). Fig. 17/29 is a line drawing of the specimen to Fig. 17/15. 13-14, 16-18: Fj9 (=AmoC); 15, 29: Fj12. 19-22) *Palaeolituonella meridionalis* (Luperto, 1965). 19: K5(7); 20: K7; 21-22: K5(9). 23-25) *Haplophragmella inflata* Zaninetti & Brönnimann *in* Brönnimann, Cadet & Zaninetti, 1973. 23: Fj8; 24: AmoA; 25: Aj4. 26) *Planiinvoluta carinata* Leischner, 1961. Fj9 (=AmoC). 27-28) *Planiinvoluta* sp. or *Tolypammina* sp. 27: Fj11; 28: Fj9(=AmoC)

The scale is suitable for all specimens.

drospira dinarica in our sections always precede facies changes in the stratigraphic column (see Figs 7, 9, 11).

Glomospira densa (Figs 16/1-5) and *Haplophragmella inflata* (Figs 17/23-25) also have short ranges (see Fig. 15). Based on the latter four species the Pelsonian/Illyrian boundary has been drawn in the Baradla Cave section (see Fig. 9). Foraminiferal data are in accordance with conodont data.

The stratigraphic range of *Diplotremina* gr. *astrofimbriata* (Figs 18/10-14) is not well understood. The holotype is from the Upper Cassian beds of the Southern Alps (Pralongiá) and rarely occurs also in the "tuffitic" layer separating Lower and Upper Cassian beds (see Kristan-Tollmann 1960: 48, 64). According to Salaj et al. (1983: 152) this species has a long range from the Ladinian up to the Norian. This is comparable to *Variostoma* gr. *pralongense-exile* (Figs 18/1-4). The holotypes are from the same locality (see Kristan-Tollmann 1960: 48, 57-58) as the holotype of *Diplotremina astrofimbriata* and therefore are "most probably Carnian" (pers. comm. M. Gaetani, 2011) in age. According to Salaj et al. (1983: 155) this species covers a time interval from the Ladinian up to the Carnian. Nevertheless, this group has already been described from the Anisian of Hungary (see Oravecz-Scheffer 1987: 108-109).

Trochammina almtalensis (Figs 16/14-16) has a long range. The holotype is from the upper Anisian (Pelsonian-Illyrian, see Koehn-Zaninetti, 1969: 21-22) Reifling Limestone Fm. of the Northern Calcareous Alps (Koehn-Zaninetti 1969: 38). Later, Zaninetti (1976) provided a range from the Illyrian to ?Ladinan. According to Salaj et al. (1983: 77) the species occurs in the Western Carpathians "most frequently in the Carnian-Rhaetian".

Also according to Salaj et al. (1983: 81) "*Earlandinita*" *elongata* (Fig. 18/15) occurs from the Anisian up to the Carnian in dasycladalean-rich facies.

Ophthalmidium abriolense (Figs 17/13-18) has a long range from Anisian (Pelsonian) up to the Ladinan (Rettori 1995, fig. 6). In our samples it is very often found in a micritic matrix and is also present in neptunian dyke infillings.

Endotriadella wirzi (Figs 17/4-9) is of Anisian (Aegean)-Ladinian, ? Carnian age whereas *Endoteba* gr. *badouxi* (Figs 17/1-3) has a range from Anisian (Pelsonian) up to the ? Norian. *Palaeolituonella meridionalis* (Figs 17/19-22) ranges from the Anisian (Pelsonian) up to the Carnian or even to the Norian (Rettori 1995, fig. 6).

Turriglomina mesotriassica (Figs 17/10-11) occurs from the ? base of the Anisian up to the Ladinan (Rettori 1995, fig. 6). We detected this species in reefal facies (reef stage 1). This adds new data to the environmental interpretation in Rettori (1995, fig. 11) suggesting that the species is restricted to basinal environments.

Radiolaria (Figs 19-20)

The sample Fj13/3 from the Baradla Cave (Figs 8b, 9) contains numerous radiolarians, but only very few are suitable for taxonomic determination. In most cases the shell is covered by siliceous spherules obscuring the cortical skeleton (Fig. 20). In many other cases the initial skeleton was dissolved and only the outer mould of the skeletal elements (bars and spines) is preserved.

The radiolarian assemblage contains very few species. The most frequent specimens belong to globular forms which cannot be identified with certainty. Such a low diversity may suggest a stressed environment in terms of radiolarian ecology.

In the annotations given below the ages of the determined species are provided (Fig. 19). It is noteworthy that most of the radiolarian species of the studied assemblage are known from the Illyrian (Trinodosus Zone), late Illyrian or late Illyrian-Fassanian, with very few from the Pelsonian and only a single species (*Cenosphaera andoi*) from the Spathian. It is also noteworthy that the latest Illyrian and Fassanian species of the oertlispongid genera *Pseudoertlispongus*, *Oertlispongus* and *Baumgartneria*, almost ubiquitous at these stratigraphic levels, are completely lacking here. Consequently, it can be concluded that the radiolarian assemblage of sample Fj13/3 is Illyrian in age. At the present state of knowledge and due to the poverty of the assemblage it is difficult to establish precisely which interval of the Illyrian it represents, but the absence of oertlispongid radiolarians excludes the latest Illyrian.

Anisicyrtis sp. 1 (Fig. 20/23): this specimen seems to be morphologically closer to the Fassanian species *Anisicyrtis foremanae* than to the Illyrian species *A. hungarica*, *A. conica* or *A. mocki* described and discussed by Kozur & Mostler (1994).

Anisicyrtis sp. 2 (Fig. 20/22): the simple cephalis and the shape of the test allow this species to be placed in the genus *Anisicyrtis* Kozur & Mostler, but the exact determination of the species is impossible.

Annulotriassocampe campanilis (Fig. 20/20): although only a fragment of this type was found, its shape and the presence of a single row of pores on each segment suggest an assignation to this species. According to Kozur & Mostler (1994) this species ranges between the Illyrian (*Paraceratites trinodosus* zone) and Middle Fassanian.

Cenosphaera gr. *andoi* (Figs. 20/1, 5): the recovered specimens resemble rather well the holotype and the paratype of this species as described by Sugiyama (1992) from the *Parentactinia nakatsugawaensis* assemblage of Japan which also contains conodonts of the *Neospathodus homeri* assemblage and is considered to be Spathian in age (Sugiyama 1992).

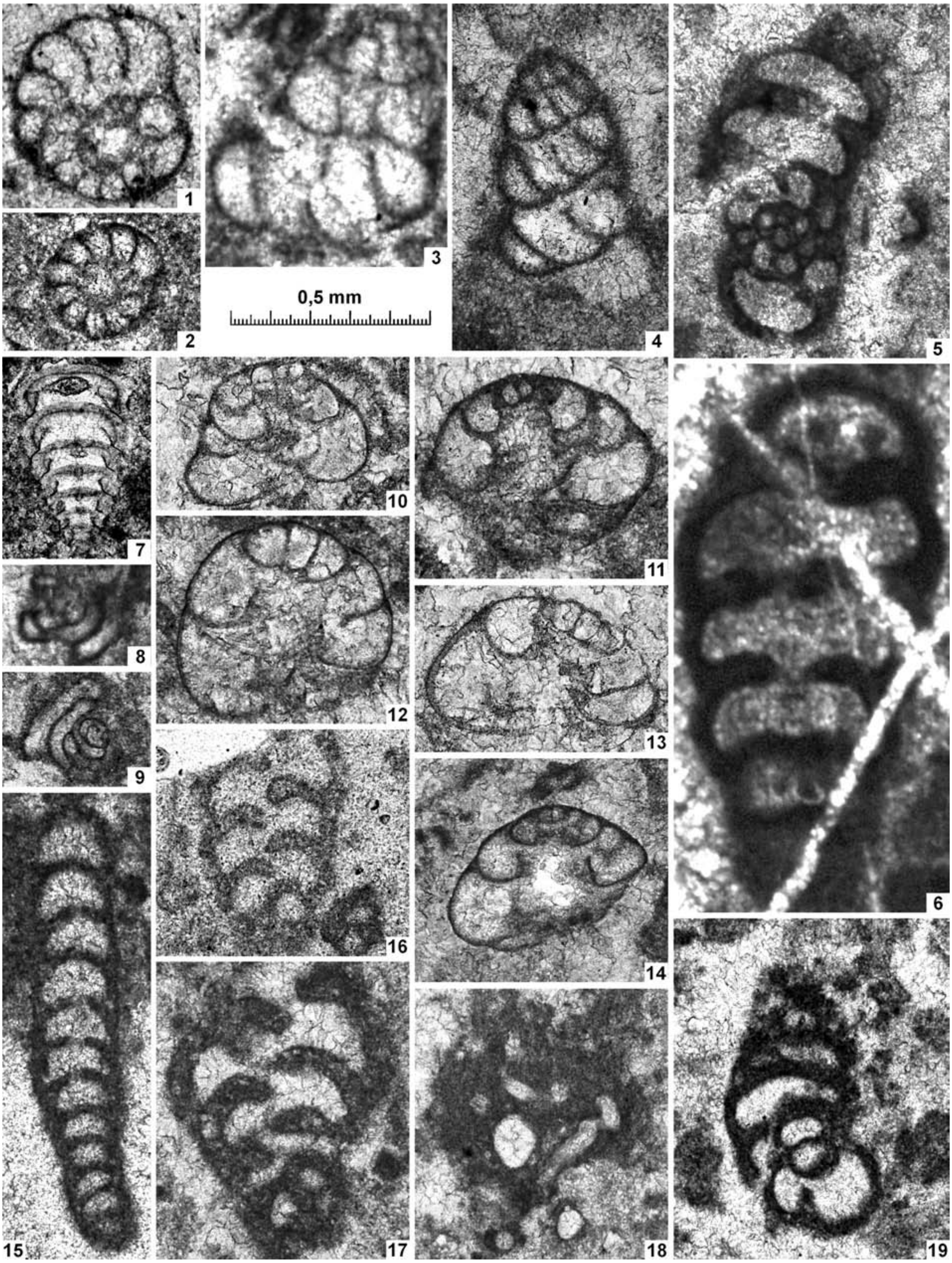


Fig. 18 - Foraminifera 3

1-4) *Variostoma* gr. *pralongense-exile* Kristan-Tollmann, 1960. 1: K5; 2: 96, 3: Ag11; 4: Ag10. 5-6) *Endotebanella* sp. A sp. nov. 5-6: Fj3/6. 7)? *Austrocolomia* sp. Vt13.

8-9) *Planiinvoluta carinata* Leischner, 1961. 8-9: Ag14. 10-14) *Diplotremina* gr. *astrofimbriata* Kristan-Tollmann, 1960. 10, 13: Sz3 (=Szőlőhegy3); 11: Sz4 (=Szőlőhegy4); 12: Ag14; 14: Ag1. 15) "*Earlandinita*" *elongata* Salaj, 1967. 46E2.

16-17) *Trochammina* cf. *alpina* Kristan sensu Oravecz-Scheffer 1987. 16: Ag10; 17: Vt5. 18) sessile miliolid, gen. et sp. ind. Ag14. 19) *Endotebanella kocaeliensis* Dager, 1978. Ag10.

The scale is suitable for all specimens.

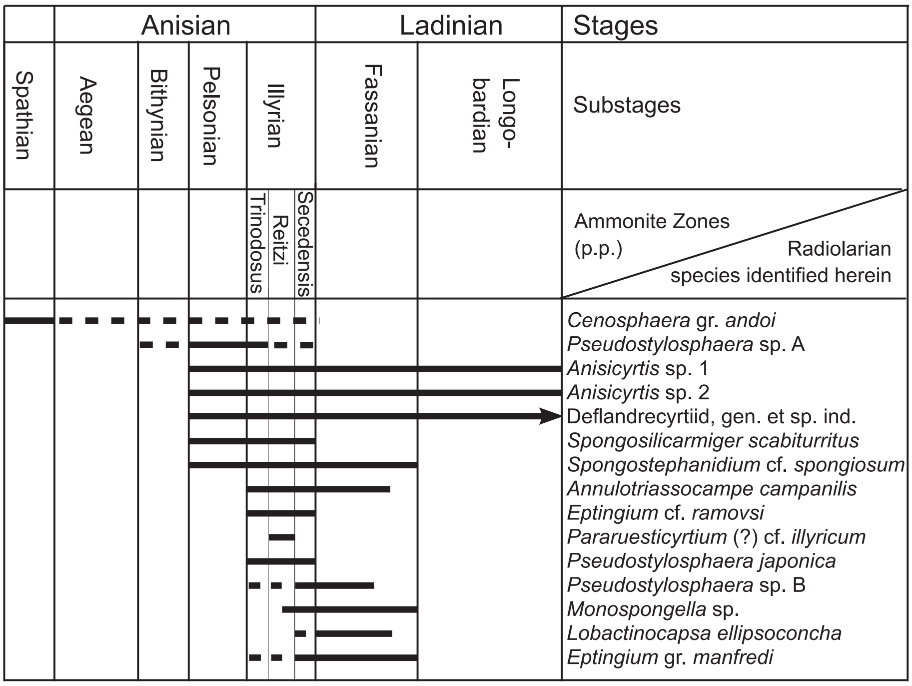


Fig. 19 - Compiled range charts of selected radiolarian species identified in the context of the present paper. For compilation the papers of Sugiyama (1992); Kozur & Mostler (1994); Ramovš & Goričan (1995); Kozur et al. (1996) and own data were used.

Deflandrecyrtiidae gen. et sp. indet. (Fig. 20/16): the strong dorso-ventral asymmetry of this species suggests that it belongs to the family Deflandrecyrtiidae Kozur & Mostler as amended by Dumitrică (in De Wever et al. 2001). The absence of the apical horn, common in this family, is probably due to poor preservation. This Triassic family is known to range between middle Anisian and Norian.

Eptingium gr. *manfredi* (Figs 20/3, 8-9, 11): among the species of this genus, *E. manfredi* is the most frequent. Although the known stratigraphic range of the species is late Illyrian to Fassanian, the appearance of secondary furrows probably took place in the early Illyrian.

Eptingium cf. *ramovsi* (Fig. 20/7): our specimens differ from *E. ramovsi* in having shorter spines and very thick blades of spines on the external margin. *E. ramovsi* is recorded in the Illyrian of Japan, Slovenia, Austria and Hungary.

Lobactinocapsa cf. *ellipsoconcha* (Fig. 20/13): this species was known from the Fassanian of the Vicentinian Alps (N Italy). It has not yet been reported from the Illyrian but unpublished data seem to show that the genus had already occurred in the Pelsonian of Eastern Carpathians.

Pararuesticyrtium (?) cf. *illyricum* (Fig. 20/19): the illustrated fragments may be also compared to *Pararuesticyrtium*? sp. illustrated by Ramovš & Goričan (1995) from the late Illyrian (*Neogondolella mesotriassica* conodont Zone).

Pararuesticyrtium? sp. (Fig. 20/21): although very poorly preserved, the specimen seems to have some characteristics of the primitive species of the genus *Pararuesticyrtium* such as a cephalothorax, trapezoidal segments and a difference between the distal segment and the postabdominal segments. The range of the genus seems to be early Fassanian – Carnian (Kozur & Mostler 1994).

Pseudostylosphaera japonica (Fig. 20/12): this specimen may be well compared with the type specimens of *Pseudostylosphaera japonica* and with *P. coccoctyla acrior* sensu Kozur et al. (1996) (= *P. japonica*), which is common in the Illyrian.

Pseudostylosphaera sp. A (Fig. 20/10): the specimens collected have a spherical test and relatively long, acute spines, and they resembled perfectly *Pseudostylosphaera* sp. A of Sugiyama (1992). He found this species in the *Triassocampe coronata* (Tc) assemblage that ranges from the middle Anisian to the lower part of the Illyrian, co-occurring with conodonts of the *Neogondolella bulgarica* assemblage recognized by Koike (1981). The species is common in the Pelsonian of Romania and has a range from the middle Anisian (Bithynian or Pelsonian) to the early Illyrian. It is known from Japan, Romania, and Hungary.

Pseudostylosphaera sp. B (Fig. 20/14): this ellipsoidal morphology was recorded in the late Illyrian from Slovenia where Ramovš & Goričan (1995) determined it as *Pseudostylosphaera coccostyla*. It is also characteristic of many other Ladinian species. Its occurrence may indicate a post-Pelsonian age.

Spongosilicarmiger scabiturritus (Fig. 20/17): Sugiyama (1992) found this species in the *Triassocampe coronata* (Tc) assemblage which ranges from the middle

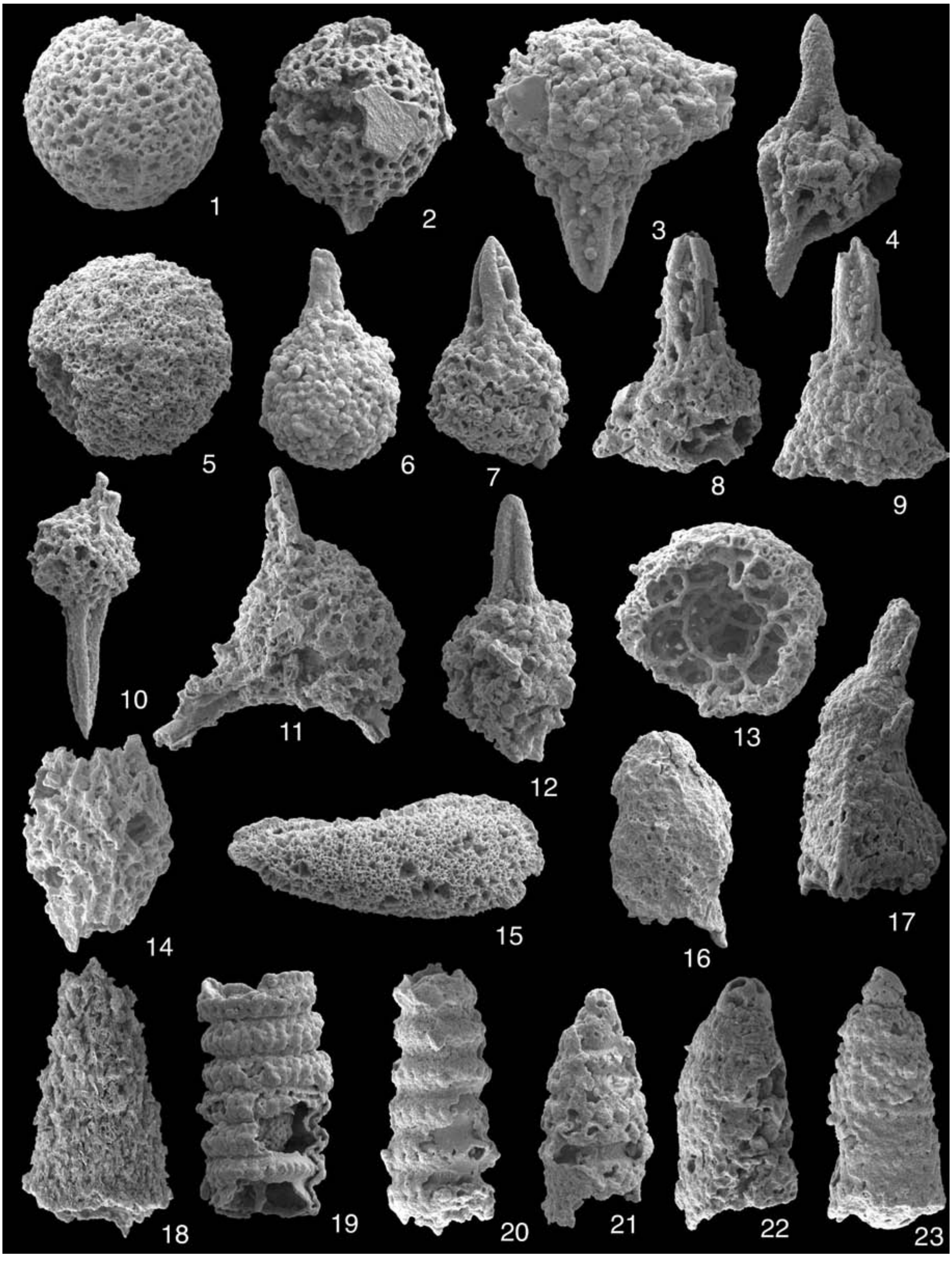


Fig. 20 - Radiolaria and Ostracoda; sample Fj13/3.

1) *Cenosphaera* gr. *andoi* Sugiyama, 1992, x185. 2) Spumellarian, gen. et sp. indet., x185. 3) *Eptingium* gr. *manfredi* Dumitrică, 1978, x275. 4) *Spongostephanidium* cf. *spongiosum* Dumitrică, 1978, x275. 5) *Cenosphaera* gr. *andoi* Sugiyama, 1992, x125.

6) *Monospongella* sp., x275. 7) *Eptingium* cf. *ramovsi* Kozur, Krainer & Mostler, 1996, x185. 8) *Eptingium* gr. *manfredi* Dumitrică, 1978, x185. 9) *Eptingium* gr. *manfredi* Dumitrică, 1978, x185. 10) *Pseudostylosphaera* sp. A, x275. 11) *Eptingium* gr. *manfredi* Dumitrică, 1978, x185. 12) *Pseudostylosphaera japonica* (Nakaseko & Nishimura, 1979), x185. 13) *Lobactinocapsa* cf. *ellipsoconcha* Dumitrică, 1978, x185.

14) *Pseudostylosphaera* sp. B, x185. 15) Ostracod, gen. et sp. ind., x185. 16) *Deflandrecyrtiid,* gen. et sp. ind., x185. 17) *Spongosilicarmiger scabiturritus* Sugiyama, 1992, x185. 18) Nassellarian, gen et sp. ind., x154. 19) *Pararuesticyrtium* (?) cf. *illyricum* (Kozur & Mostler, 1981), x185. 20) *Annulotriassocampe campanilis* Kozur & Mostler, 1994, x275. 21) *Pararuesticyrtium* ? sp., x275. 22) *Anisicyrtis* sp. 2, x275. 23) *Anisicyrtis* sp. 1, x185.

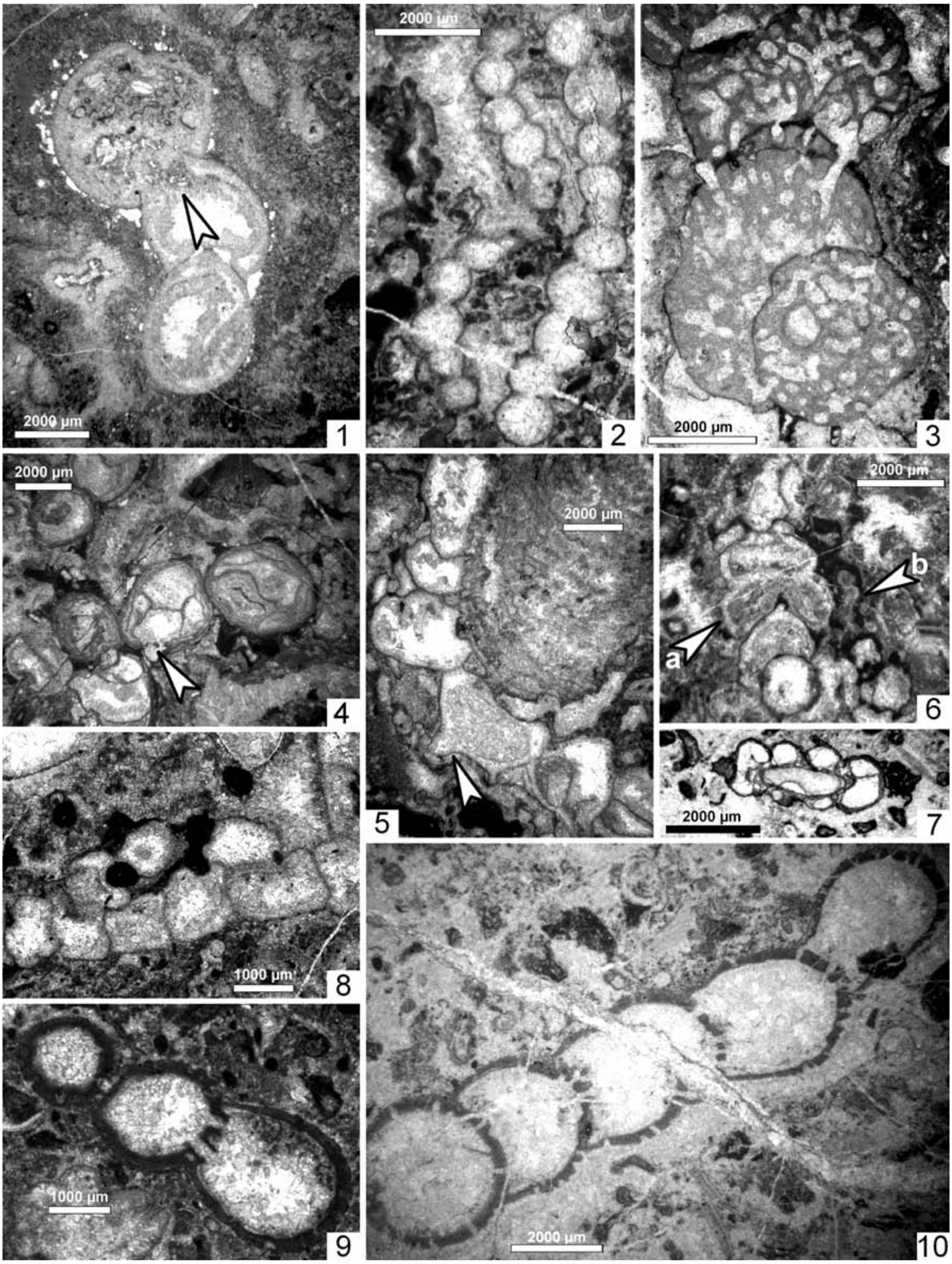


Fig. 21 - Porifera.

1) *Celyphia*? *minima* Senowbari-Daryan, Zühlke, Bechstädt & Flügel, 1993. Section through three chambers. Arrow shows the osculum at the top of the middle chamber. Vas3. 2) *Olangocoelia otti* Bechstädt & Brandner, 1970. Chains through numerous spherical chambers. 333 (= H502). 3) *Solenolmia manon manon* (Münster, 1841). Section through several chambers showing the coarse internal filling structure. T160 (= H516). 4) *Follicatena cautica* Ott, 1967. Specimen exhibits vesicular filling skeleton within the chamber interiors. A sieve-like opening (cribribullum) is cut in the wall of the middle chamber (arrow). Vt7. 5) *Celyphia*? sp. Arrow indicates the rimmed osculum cut in one chamber. Vt10. 6) *Celyphia zoldana* (arrow a) Ott, Pisa & Farabegoli, 1980 is colonized by a specimen of *Colospongia* sp. (arrow b). Vt3E. 7) *Vesicocaulis oenipontanus* (Ott, 1967). Fj13/2. This is the earliest sponge and occurs immediately above the radiolarite layer. 8) *Celyphia zoldana* Ott, Pisa & Farabegoli, 1980. The dark circles with a white point in the center are specimens of *Anisophytes aggtelekensis* Senowbari-Daryan & Velledits, 2007. Vt7. 9) *Colospongia catenulata catenulata* Ott, 1967. Perforation of the chamber walls is well recognizable at the tops of the chambers. 163 (=H133). 10) *Colospongia catenulata catenulata* Ott, 1967. Section through six chambers exhibiting the well-perforated chamber walls. Vas1.

to the late Anisian, when it co-occurs with conodonts of the *Neogondolella bulgarica* assemblage of Koike (1981). In Slovenia (Ramovš & Goričan 1995) this species was recorded in the Illyrian.

Monospongella sp. (Fig. 20/6): this so far undescribed species is rather frequent in the latest Illyrian and Fassanian of the Vicentinian Alps and in other Fassanian radiolarian assemblages. So far no specimens of this species have been found in the Pelsonian.

Porifera (Fig. 21)

Sponges from the investigated units are represented by hypercalcified sphinctozoans and inozoans. Hexactinellid sponges with spicular tatics were found at the base of the reef stage 2. Sphinctozoans are abundant, instead inozoans are extremely rare and strongly recrystallized.

Follicatena cautica (Fig. 21/4) is the most abundant species among sphinctozoans. This aporate sponge is composed of several chambers with a moniliform arrangement. All characteristics of the specimens from the Aggtelek reef facies, stage 1 correspond to the original description. *F. cautica* was described originally from the Ladinian part of the Wetterstein Formation of the Kaiser-Gebirge, Austria, by Ott (1967) and is also known from numerous Ladinian-Carnian localities in the western Tethyan region (Senowbari-Daryan 1990; Rüffer & Zamparelli 1997). Up to now, *F. cautica* has not been reported from the Anisian. The Aggtelek reef facies, stage 1 therefore provides the first Anisian (Illyrian) occurrence of this taxon.

Colospongia catenulata catenulata (Figs 21/9-10) is almost as frequent as *Follicatena cautica*. This moniliform thalamid sponge is composed of numerous spherical to hemispherical chambers with perforated chamber walls. Vesiculae may – albeit rarely – occur within the chamber. *C. catenulata* was also formerly known from Ladinian-Carnian localities with the same distribution as *Follicatena cautica*. With the findings in the Aggtelek reef stage 1 their biostratigraphic range can be extended down to the Illyrian. Scholz (1972) described a subspecies as *C. catenulata macrocatenulata* from the Aggtelek locality. However, the biometric dimensions of this subspecies are within the variation range of *C. catenulata catenulata* Ott, therefore *C. catenulata macrocatenulata* seems to be synonymous with C. *catenulata catenulata*.

Solenolmia manon manon (Fig. 21/3) is the third most frequent sphinctozoan sponge from the Aggtelek platform. Like the preceding species, this sponge is also known from numerous Ladinian-Carnian localities of the world, particularly in the Alpine-Mediterranean region (Senowbari-Daryan 1990; Senowbari-Daryan & Garcia-Bellido 2002). With the findings in the Anisian part of the Aggtelek reef (reef stage 1) the biostratigraphic range of the species can be extended down to the Illyrian.

Olangocoelia otti (Fig. 21/2), which is possibly a sphinctozoan sponge, is composed of numerous small spherical chambers, less than 1 mm in diameter, which surround irregularly-formed cavities, ranging from mm to cm in diameter. A detailed description of this organism is found in Bechstädt & Brandner (1970) and Senowbari-Daryan et al. (1993). *O. otti* is an abundant organism in the Anisian reefs of the Dolomites, Italy (Senowbari-Daryan et al. 1993). It also occurs in the Anisian reef limestones of Carinthia (Schafhauser 1997). It was reported from the Carnic Alps, Austria (Pfeiffer 1988) as Ladinian (Fassanian), but, according to the new definition of the Anisian-Ladinian boundary (Brack et al. 2005) the age is latest Anisian.

Celyphia zoldana (Figs 21/6, 8) is a small sphinctozoan sponge forming chains that are composed of small chambers with aporate chamber walls. The sponge was described originally from Anisian limestones, but also occurs in Ladinian reefs (see: http: //paleodb.org/cgi-bin/bridge.pl?action=displayCollectionDetailsand-collection no=49937).

Celyphia? minima (Fig. 21/1) was found in the upper part of reef stage 1 (Vas3). It was previously considered (Senowbari et al. 1993; Emmerich et al. 2005) Anisian, and the appearance in the Ladinian is questionable.

Thaumastocoelia dolomitica is another sphinctozoan sponge that was described originally from the Anisian reef limestones of the Dolomites. A comparable age was provided by Emmerich et al. (2005) from the Anisian part of the Latemar platform of the Dolomites. In the studied material *T. dolomitica* was found in the Illyrian reef stage 1.

Vesicocaulis oenipontanus (Fig. 21/7) is a sphinctozoid sponge which up to now has been known only from the Ladinian reef limestones of the Northern Calcareous Alps (Ott 1967). With the findings in the Aggtelek reef its biostratigraphic range can be extended down to the Illyrian.

In addition to the above mentioned sphinctozoan sponges, rare fragments of *Colospongia* sp., *Celyphia?* sp. (Fig. 21/5) and *Sollasia? baloghi* occur within the investigated reef limestones. The latter species is known only from Hungary.

No determinable inozoan sponge was found in the investigated material.

As conclusive comment, the reef association contains considerably fewer species than the classical late Ladinian – Carnian Wetterstein reefs. For a detailed description of the Wetterstein reef biota we refer to Riedel (1990) and Flügel (2002). Several typical Wetterstein sphinctozoan taxa (cf. Ott 1967: *Alpinothalamia bavarica, Uvanella irregularis, Stylothalamia dehmi,*

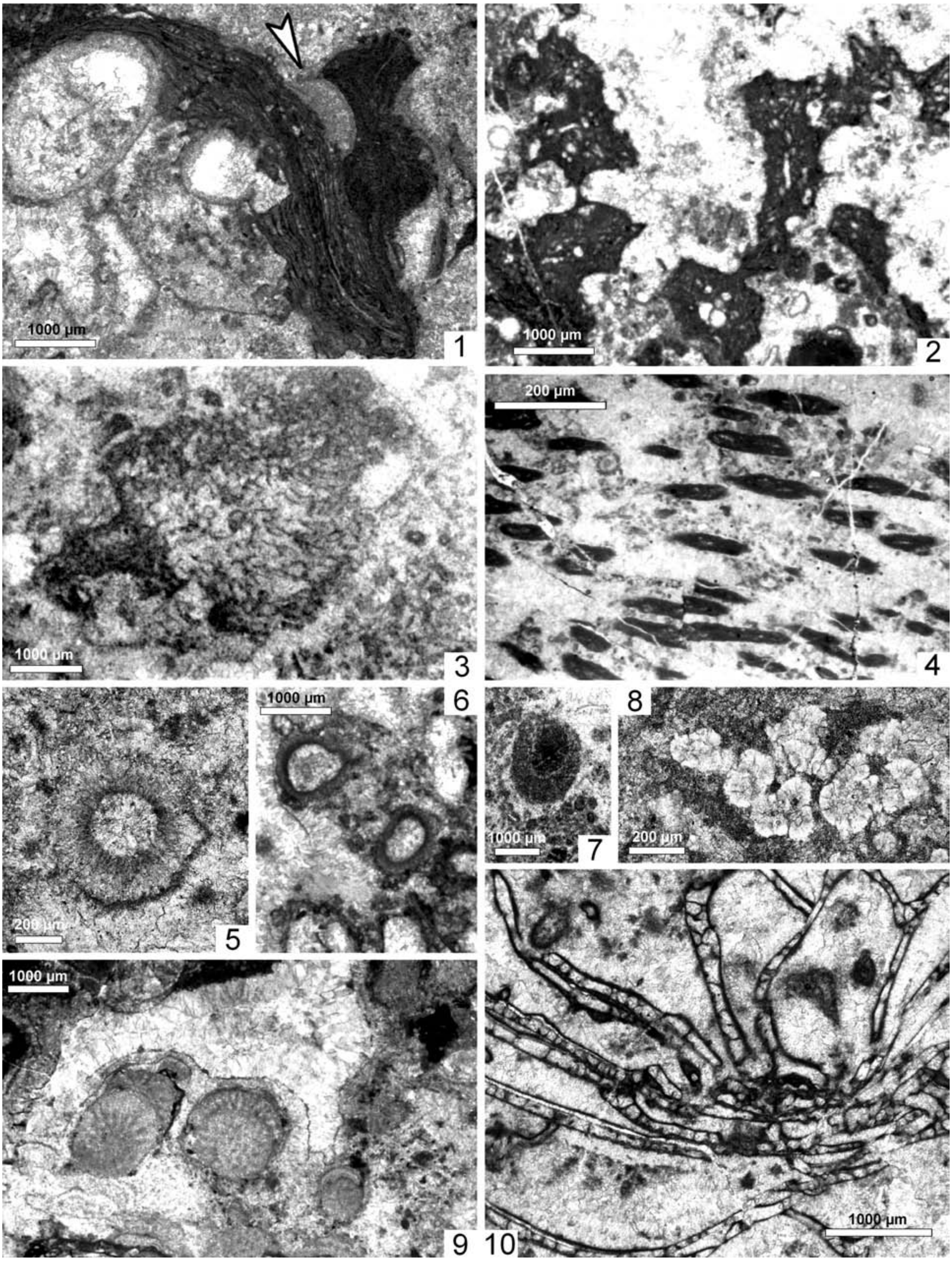


Fig. 22 - Microproblematica, Cyanophycea, Rhodophyta

1) Sponge encrusted by *Aggtecella hungarica* Senowbari-Daryan & Velledits, 2007. Arrow indicates an undetermined organism which colonized *Aggtecella* and is overgrown by *A. hungarica*. V12. 2) "*Tubiphytes*" *multisiphonatus* Schäfer & Senowbari-Daryan, 1983. Cross-sections through several "thalli" that are laterally connected. Vt5. 3) *Plexoramea cerebriformis* Mello, 1977. An abundant problematic organism in Ladinian-Carnian reefs. H445. 4) *Cladogirvanella cipitensis* Ott, 1966. Oblique section through numerous thalli with smooth outer surfaces. Aj13 (=H304). 5) *Radiomura cautica* Senowbari-Daryan & Schäfer, 1979. Vt1. 6) *Radiomura cautica* Senowbari-Daryan & Schäfer, 1979. Vt6. 7) "*Tubiphytes*" sp. 24 (=H141/3). 8) *Baccanella floriformis* Pantić, 1971. Vas1. 9) *Ladinella porata* Ott, 1968. Section through three specimens. 154a (=H311/1). 10) *Bacinella ordinata* Pantić, 1972. P7.

	Neptunian dykes in the Steinalm Formation		Jenei Lms.	Wetterstein Fm. reef facies, stage 1				
	T108	Fj4 Baradla Cave 5700 m	100	T214	T247	T246	152	TOTAL
RHYNCHONELLIDA								
Decurtella decurtata				1	2			3
Costirhynchopsis cf. *mentzeli*		1						1
Piarorhynchella trinodosi		2						2
Homoeorhynchia? sp.							1	1
Volirhynchia cf. *vivida*		1						1
Norella sp.		2						2
Austriellula? sp.		5						5
Holcorhynchella? sp.		1						1
ATHYRIDIDA								
Tetractinella trigonella							2	2
Schwagerispira cf. *mojsisovicsi*		4						4
Schwagerispira sp.		1						1
Spirigerellina? sp. A				37	27		1	65
Spirigerellina? sp. B				1	7			8
SPIRIFERIDA								
Mentzelia mentzeli		8	4	1	2			11
Koeveskallina koeveskalyensis				2	1			3
Dinarispira dinarica				7				7
Costispiriferina sp.			1					0
Punctospirella fragilis				1				1
TEREBRATULIDA								
„Aulacothyris"? sp.	4					2		2
Coenothyris vulgaris			3		1			1
Coenothyris? sp.						5	1	6
NUMBER OF SPECIES	**1**	**9**	**3**	**7**	**6**	**2**	**4**	**21**
NUMBER OF IDENTIFIED SPECIMENS	**4**	**25**	**8**	**50**	**40**	**7**	**5**	**127**

Fig. 23 - The brachiopod fauna from and around the Aggtelek reef. Brachiopods were found in reef facies, stage 1, from neptunian dykes in the Steinalm Fm. and in the Jenei Fm.

Cryptocoelia zitteli, and all species of *Vesicocaulis* except for *V. oenipontanus*) have not been found in the studied association; instead *Olangocoelia otti, Olangocoelia* sp. (Fig. 6b), *Celyphia zoldana* and *Celyphia*? *minima* are missing in the "classical" Wetterstein reefs.

Microproblematica (incertae sedis, Fig. 22)

For a detailed description of Ladinian-Carnian microproblematica with their stratigraphic distribution we refer to the recent contribution by Senowbari-Daryan & Bernecker (2009). In the studied limestones "*Tubiphytes*" and similar fossils are the most abundant group among the problematic organisms in the investigated limestones. According to their morphological appearance, several types of "*Tubiphytes*" may be differentiated: *Tubiphytes* cf. *obscurus*, "*T.*" *multisiphonatus* (Fig. 22/2), and "*T.*" *gracilis*. The fragments of the small and multibranched species "*Tubiphytes*" *gracilis*, originally described from the Carnian reefs of Hydra Island (Greece), are the most abundant biogenic components apart from sponges.

Other problematic organisms, such as *Plexoramea cerebriformis* (Fig. 22/3), *Lamellitubus cauticus*, *Baccanella floriformis* (Fig. 22/8), *Bacinella ordinata* (Fig. 22/10), *Ladinella porata* (Fig. 22/9), *Radiomura cautica* (Figs. 22/5-6) and *Macrotubus babai* are relatively abundant.

The "typical" Ladinian-Carnian microbial crusts around the reef organisms should also be mentioned (Flügel et al. 1992).

Brachiopoda (Figs 23-24)

Brachiopods are common and well-studied elements of the Middle Triassic shallow marine benthic faunas of the western Tethys (e.g. Pálfy 1992). Diverse brachiopod assemblages have been found in the vicinity of Wetterstein-type reefs, carbonate platforms and related environments (Siblík 1994).

Brachiopods from the Aggtelek area were first studied in detail by Scholz (1972, 1973) who listed the occurrence of 14 species. Among his 6 spot localities, the most diverse assemblage was reported from the southern flank of reef stage 1, near the Aggtelek-Jósvafő road, where 13 species were identified. The age of the brachiopod faunas was determined as Pelsonian-Illyrian. Siblík (1971, 1972) described the coeval brachiopod faunas from the Slovak Karst, only a few km north of the Aggtelek Karst. Twenty-one species were identified from six localities of the Silica and Plešivec plateaux. The assemblages also indicated the Pelsonian and/or the Illyrian substage.

During the detailed geological mapping of the Aggtelek reef complex, new brachiopod collections were acquired from 7 localities. Four were collected from reef stage 1, one from the Jenei Formation and

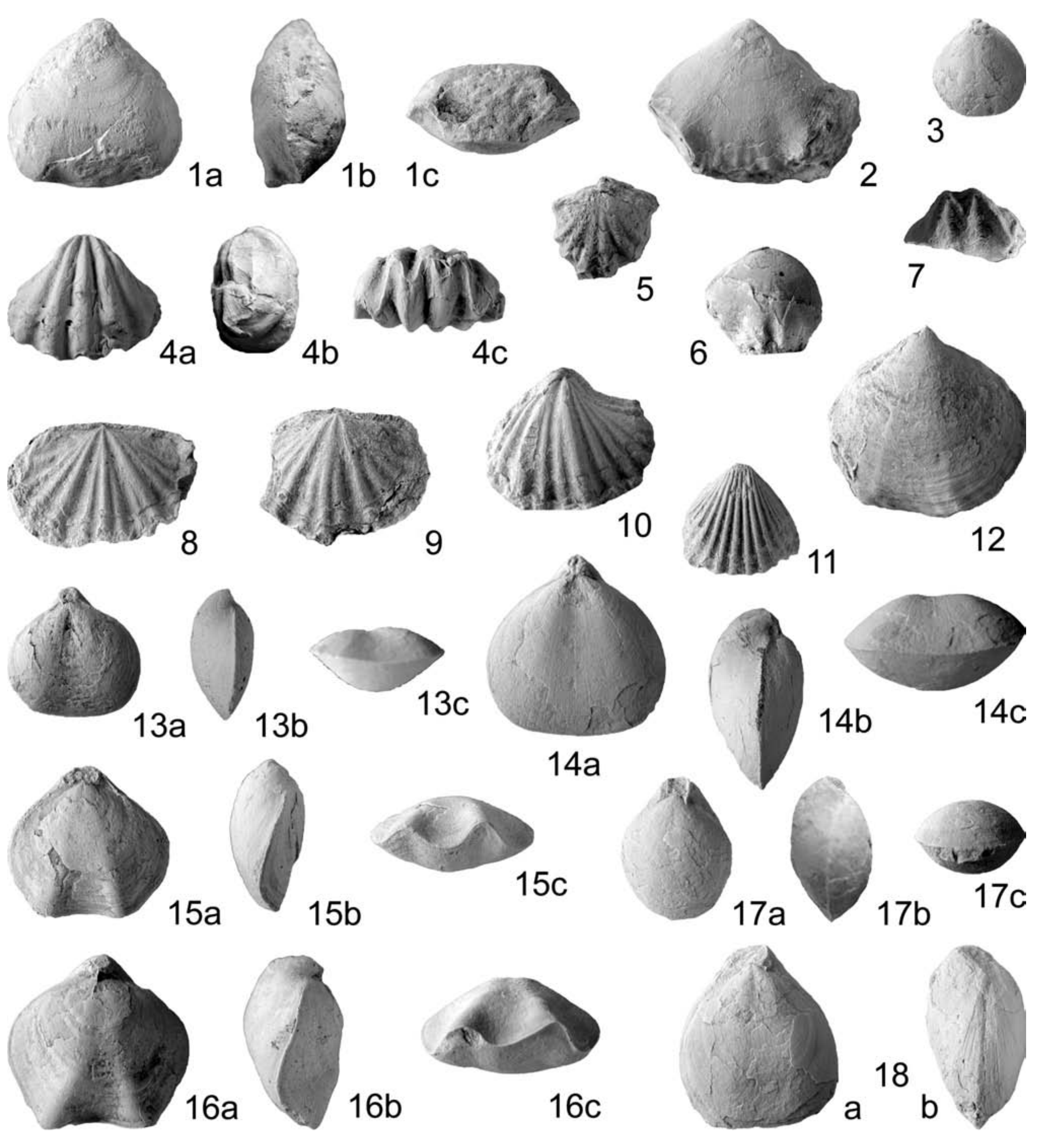


Fig. 24 - Brachiopoda

Brachiopods from and around the Aggtelek reef facies, stage 1. All figures are printed at natural size. Specimens are deposited in the collection of the Department of Palaeontology and Geology, Hungarian Natural History Museum. Where multiple views of the same specimen are provided, 'a' denotes the dorsal, 'b' the lateral and 'c' the anterior view respectively.

1-2) *Norella* sp. Baradla Cave 5700 m. 3) *Holcorhynchella* ? sp. Baradla Cave 5700 m.

4) *Decurtella decurtata* (Girard, 1843). T247. 5) *Volirhynchia* cf. *vivida* (Bittner, 1890). Baradla Cave 5700 m. 6-7) *Piarorhynchella trinodosi* (Bittner, 1890). Dorsal valve (6) and anterior view (7) of two fragmentary specimens. Baradla Cave 5700 m.

8-10) *Dinarispira dinarica* (Bittner, 1890). Dorsal valves (8, 9) and ventral valves of three specimens. T214. 11) *Schwagerispira* cf. *mojsisovicsi* (Böckh, 1872), dorsal valve. Baradla Cave 5700 m. 12) *Mentzelia mentzeli* (Dunker, 1851). Ventral valve. Baradla Cave 5700 m. 13-14) *Spirigerellina*? sp. A. 13: T247; 14: T214. 15-16) *Spirigerellina*? sp. B. 15: T214; 16: T247. 17-18) *Coenothyris* cf. *vulgaris* (Schlotheim, 1820). 17: 100; 18: T247.

two from neptunian dykes in the Steinalm Fm. The distribution of the 129 identified specimens from 21 taxa is listed in Fig. 23. Scholz's original material was re-examined in the Geological Museum of the Hungarian Geological Institute.

Two localities occur in a NW-SE trending belt, at the base of the Wetterstein Fm. (reef stage 1). Outcrop 100 (Fig. 3) represents the grey, crinoidal-brachiopodal facies within the Jenei Formation, which underlies the reefal member of the Wetterstein Fm. Sample T108 and Fj4 (Figs 3, 8b, 23) are neptunian dyke fillings in the Steinalm Fm., containing only juvenile and unidentifiable brachiopods. Scholz's localities S17-S20 and S37 (Fig. 3) belong to the lower part of the reef stage 1. This assemblage is of low diversity and our collection confirms only 3 of the 8 species reported by Scholz (1972).

The other four localities (T214, T246, T247, 152; see Fig. 3) occur in the lower deep-water intercalation in the upper part of the reef stage 1. One of these localities (152) is the same as Scholz's locality S15, beside the Aggtelek-Jósvafő road. The grey, slightly recrystallized, crinoidal-brachiopodal limestone is richly fossiliferous. Brachiopods are abundant and diverse in this assemblage, being represented by 10 taxa in the collection made for this study, and 12 taxa were reported by Scholz (1972). Two closely-spaced localities appear to represent palaeocommunities dominated by two athyridid species (*Spirigerellina*? sp. A and B, see Figs 24/13-16). Their abundance within the assemblage and articulated preservation suggest a lack of transport, possibly in a peri-reefal habitat.

A collection was also made in the Baradla Cave, from blocks fallen from the roof of the Cave, at a distance of ~5700 m from the Aggtelek entrance (Fig. 8b). This assemblage of four species was first mentioned by Piros et al. (1989b), and its age was determined by conodonts as late Pelsonian (Kovács et al. 1996). Recent conodont investigations have confined its age to the Binodosus Subzone (see p. 226 in this paper). The brachiopods are commonly represented by single valves and appear size-sorted, favouring predominantly small individuals. The observations suggest transport and resedimentation, possibly representing a neptunian dyke filling. The assemblage is rich in small, smooth rhynchonellids [*Norella* (Figs 24/1-2), *Austriellula*?] that may characterize a relatively deep-water environment.

The Aggtelek brachiopod assemblage shares many common species with other well-known localities from the western Tethyan shelf, some enjoying a reasonable calibration with ammonoid and/or conodont zonation, e.g. the Balaton Highland (Pálfy 1986, 1988, 2003), Southern Alps (Torti & Angiolini 1997), Romania (Apuseni Mts., Iordan 1993) and Bulgaria (Stara Planina, Benatov 2001). Age diagnostic taxa for middle – late Anisian (Balatonicus to Trinodosus ammonoid Zones) include *Decurtella decurtata* (Fig. 24/4) and *Dinarispira dinarica* (Figs 24/8-10). Some other species that first appear in the Trinodosus Zone but are known to range into the earliest Ladinian Curionii Zone include *Volirhynchia vivida* (Fig. 24/5) and *Piarorhynchella trinodosi* (Figs. 24/6-7). None of these species is restricted to the Ladinian, leading to the conclusion that the most likely age of the Aggtelek brachiopod assemblage is late Anisian, in agreement with Scholz (1972). One of the most widely distributed Middle Triassic terebratulids, *Coenothyris* cf. *vulgaris* (Figs. 24/17-18), occurs only sporadically at Aggtelek. Lacking information of its internal morphology, the identification carries some uncertainty as forms externally indistinguishable from typical *C. vulgaris* may belong to different taxa if their internal structure is known and properly considered (Pálfy & Török 1992).

Brachiopod assemblages from reefal facies of the Wetterstein Formation in the Raxalpe, Austria (Siblík 1994) and Slovak Karst (Siblík 1981) are significantly different in composition, dominated by species (e.g. *Tetractinella dyactis, Stolzenburgiella baloghi*) that are unknown from the Aggtelek reef. The age of the Wetterstein reef at Raxalpe is regarded as Longobardian-“Cordevolian” (late Ladinian – early Carnian) supported by conodonts from deep water intercalations (Siblík 1994). A somewhat older, lower Ladinian fossiliferous Wetterstein Formation is known from the Little Carpathians (Malé Karpaty Mts., Slovakia). Its brachiopod fauna shares many species with the Aggtelek assemblage but are dominated by species of *Cruratula* (Kochánová & Pevný 1982). The assemblage reported from the Silica Plateau of the Slovak Karst (Siblík 1971, 1972) is closest to the Aggtelek fauna, both geographically and biostratigraphically.

To summarize, brachiopod biostratigraphic data suggest that the Aggtelek reef facies, stage 1 is Pelsonian – Illyrian in age and therefore older than most other known Wetterstein-type reefs.

Although the brachiopod-bearing strata occur both below and in the upper part of reef stage 1, there is no biostratigraphic distinction between these two levels on the basis of the brachiopod faunas (Fig. 23). Therefore the main reef body of reef stage 1 unit most likely accumulated within a relatively short interval in the late Anisian.

Tectonic control on the evolution of the Aggtelek platform: the effect of the Reifling drowning event

Schlager & Schöllnberger (1974) were the first to describe the dramatic change in the sedimentation at the end Pelsonian – early Illyrian and named it Reifling Event. In that time platform carbonates were succeeded

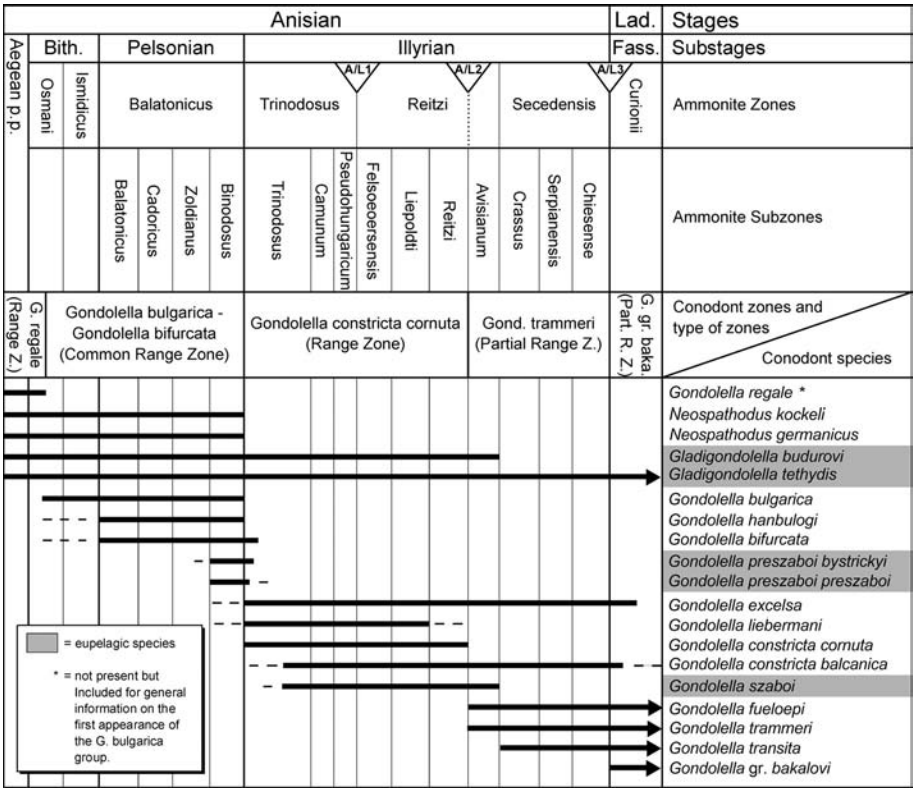


Fig. 25 - Compiled range chart of selected conodont species. For compilation the papers of Kozur (1972); Budurov & Stefanov (1975); Trammer (1975); Sudar (1982); Krystyn (1983); Kovács (1994); Kovács et al. (1994); Nicora & Brack (1995); Germani (2000), and own data were used. A/L1: Traditional Anisian/Ladinian boundary in Hungary (Vörös 1993). A/L2: Anisian/Ladinian boundary proposed by Mietto et al. (2003). A/L3: The Anisian/Ladinian boundary voted by the IUGS Subcomission of Triassic Stratigraphy

by deep water ones. The effect of this drowning event can be followed through the entire Northern Calcareous Alps.

This abrupt change in the sedimentation was reported in many localities from the Western Carpathians (Mello et al. 1997; Kochánová & Michalík 1986), the Transdanubian Range (Budai & Vörös 2006), the Northern Calcareous Alps (Gallet et al. 1998; Krystyn et al. 2008), the Southern Alps in Giudicarie (Gaetani 1969; Monnet et al. 2008) and Friuli (Metzeltin 1973), the Dinarids (Sudar 1982) and Nevada (Monnet & Bucher 2006). In some cases a considerable gap was reported between the Steinalm and Reifling Limestones (Gallet et al. 1998; Budai & Vörös 2006; Krystyn et al. 2008). Because the authors often use different ammonoid biostratigraphy subdivisions it is an open question whether the drowning of the Pelsonian platform was an isochronous event or different parts of the platforms drowned at different times.

Lein (1987) pointed out that this "Late Anisian" event was triggered by the disruption of the continental crust and constitutes the climax of a continuous opening of the Neo-Tethys Ocean. Mandl (2000) emphasises the role of the block-faulting which produced a differentiated sea floor relief with shallow carbonate platforms and basins.

In the present article the term "Reifling Event" refers to the tectonic-influenced drowning event at the end of the Pelsonian (Binodosus Subzone).

The Reifling Event also had a striking effect on the conodont evolution. Immediately after the drowning of the Steinalm Platform, the typical Pelsonian conodont species (*Gondolella bulgarica, G. hanbulogi* and *G. bifurcata*) still appear but a few metres above two out of the three species die out (*G. bulgarica* and *G. hanbulogi)* and new species appear (*Gondolella liebermani, G. szaboi, G. excelsa;* Figs 25-27).

In the Aggtelek area our investigation revealed only one drowning event in the latest Pelsonian (Binodosus Subzone). A considerable gap in the sedimentation (evidenced by hardground etc.) after the drowning of the Steinalm Platform could not be detected, probably due to an unfavourable outcrop situation. Nevertheless, the uppermost part of the Steinalm Fm. was affected by late diagenetic dissolution and the molds were filled with filament wackestone (see Fig. 10b). The Reifling event drowned and disrupted the former Steinalm Platform and triggered the starting up of the Aggtelek reef evolution by creating a large bathymetric gradient. As Scoffin (1987) pointed out, barrier reefs were formed in many cases on platform margins in the vicinity of steep slopes. In most cases these steep slopes are tectonically controlled.

The faunal turnover of the conodonts was also detected in the Baradla Cave section. The top of the Steinalm Fm. is followed by the ammonoid layer, the base of which (sample Fj9 base) contains the typical Pelsonian conodont species (*Gondolella bulgarica, G. hanbulogi* and *G. bifurcata*). A few metres above they

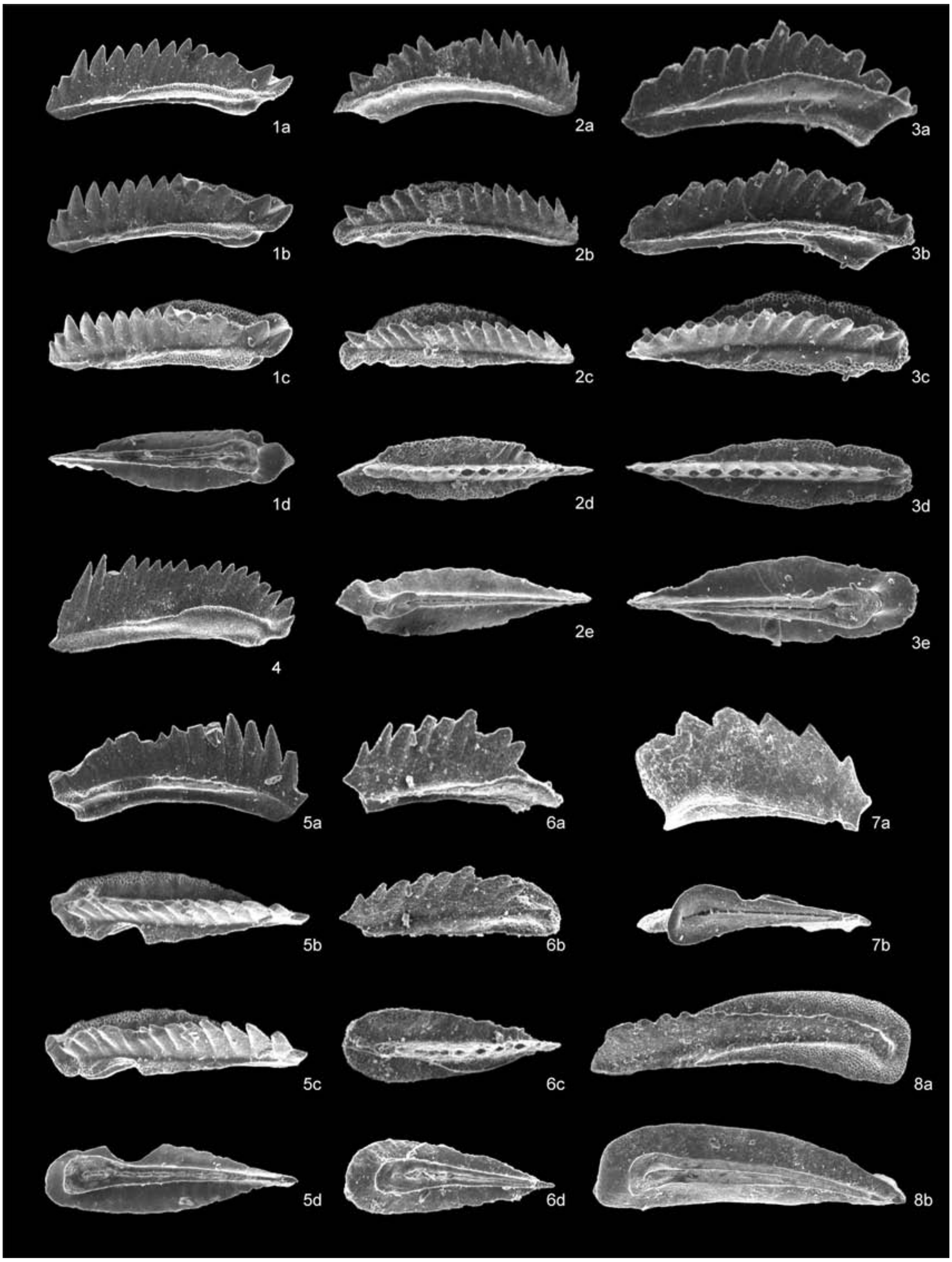


Fig. 26 - Conodonts 1

1a-d) *Gondolella bulgarica* (Budurov & Stefanov, 1975). Sub-adult ontogenetic stage. Fj9 (ammonoid bed). a) lateral view, b) upper-lateral view, c) lateral-upper view, d) lower view. All 60x.

2a-e) *Gondolella praeszaboi* Kovács, Papšová & Perri, 1996. Medium ontogenetic stage. T108. a) lateral view, b) upper-lateral view, c) lateral-upper view, d) upper view, e) lower view. All 60x.

3a-e) *Gondolella szaboi* Kovács, 1983. Medium ontogenetic stage. T91b (base). a) slightly lower-lateral view, b) slightly upper-lateral view, c) lateral-upper view, d): upper view, e) lower view. All 95x.

4) *Gondolella bystrickyi* Kovács, Papšová & Perri, 1996. Adult ontogenetic stage. Fj9 (ammonoid bed). Lateral view. 45x.

5a-d) *Gondolella bystrickyi* Kovács, Papšová & Perri, 1996. Medium ontogenetic stage. Fj9 (ammonoid bed). a) lateral view, b) slightly lateral-upper view, c) lateral-upper view, d) lower view. All 60x.

6a-d) *Gondolella excelsa* (Mosher, 1968). Medium ontogenetic stage. 128b. a) lateral view, b) lateral-upper view, c) upper view, d) lower view. All 60x.

7a-b) *Gondolella excelsa* (Mosher, 1968). Platformless growth stage, large form. Ko1. a) lateral view, b) lower view. Both 60x.

8a-b) *Gondolella bifurcata* (Budurov & Stefanov, 1972). Sub-adult ontogenetic stage. Fj9 (ammonite layer) a) lateral-upper view, b) lateral-lower view. Both 45x disappear and a new conodont association appears (*Gondolella liebermani, G. szaboi, G. excelsa* sample Borka 21; Figs 9-10 and 25-27). The high percentage of gondolelloid forms representing medium and adult ontogenetic stages in samples from the Binodosus Subzone points to favourable ecological conditions for conodonts in the Aggtelek area. However, the absence of the eupelagic gladigondolelloids during the Pelsonian indicates that the post-Steinalm basin was not fully connected to the open seas at the beginning, unlike the coeval deposits of the now-nearby Bódva and Szőlősardó Units of the Rudabánya Hills.

The appearance of gladigondolelloids just above the Pelsonian/Illyrian (Binodosus/Trinodosus Subzones) boundary in the Aggtelek area indicates that the full connection to the open sea had been established (Figs 10, 25). This event in the Alps, however, seems to have been connected to a significant sea-level rise at the base of the Avisianum Subzone (Muttoni et al. 2004; Manfrin et al. 2005; Haq & Schutter 2008).

In the Aggtelek Unit during the Illyrian (Trinodosus Subzone) – Fassanian (Curionii Zone) juvenile conodont forms predominate, indicating that conditions were less favourable for conodonts, as in the late Pelsonian (Binodosus Zone).

Evolution of the Aggtelek platform from the Middle Anisian to the Ladinian

The evolution of the studied area is uniform until the early Illyrian. From that time onward the sea floor was differentiated. Two areas were characterised by different successions: (1) on the NW the reef developed in the early? – middle Illyrian (reef stage 1), whereas (2) on the SE the reef developed only in the early Ladinian (reef stage 2).

Evolution of the NW part of the studied area

On the NW the Kecső Valley, the Baradla Cave and the Road-cut sections record similar depositional development (Figs 3, 28, 29).

Above the Gutenstein ramp lagoonal sediments of the Steinalm Fm. follow. The lagoonal sedimentation was terminated by the Reifling drowning event represented by the base of the ammonite layer (filament wackestone with radiolarians) of the Jenei Fm. (Binodosus Subzone). Its base was used as a correlation level between the studied sections (see Fig. 29). The thickness of the Jenei Fm. ranges here between 40 and 80 m.

From the upper part of the ammonoid layer up to the radiolarite horizon (Fj13, Fig. 9) the sediments were deposited on a slope. This is justified by the plasticlastic structure of the limestone (soft lithoclasts were resedimented) and by the resedimented microproblematica fragments. The conodonts refer to an early-middle Illyrian (Trinodosus Zone up to the most part of the Reitzi Zone) age. This part of the section is strongly dissected by neptunian dykes.

The sedimentation was interrupted by a volcanic event nearby. It is represented by the appearance of heavy minerals and by a tuffitic layer between the radiolarite layers (Baradla Cave). Radiolarians yielded an Illyrian, but not latest Illyrian age.

Above the deep-water carbonates a 700 m thick reef limestone (reef stage 1) accumulated. The unbroken reef development starts with a crinoidal member less than 80 m thick, which corresponds to the stabilisation stage (sensu James 1983) of the reef evolution. In this case crinoids colonised the surface, and with their roots and holdfast bound and stabilised the substrate, preparing the ground for the reef-building organisms.

The lower 150 m of the reef stage 1 is dissected by neptunian dykes. Consequently the birth of the reef took place during a tectonically active period, but the real flourishing of the reef occured in a tectonically quiet period.

The reef building organisms are characteristic to the Wetterstein type reefs, although several typical Wetterstein sphinctozoan taxa (cf. Ott 1967: *Alpinothalamia bavarica, Uvanella irregularis, Stylothalamia dehmi* and *Cryptocoelia zitteli*, all species of *Vesicocaulis* except for *V. oenipontanus*, etc.) are absent in the studied association.

The reef stage 1 can be followed on the edge of the platform in the neighbourhood of the basin over a distance of 3.5 km (Fig. 3). Thus we can conclude that it was a platform margin reef.

The reef development was twice interrupted by deeper water events resulting in dark-grey crinoidal-brachiopodal limestones. The common range of conodonts and brachiopods from the lower intercalation indicates an age interval between the Avisianum Subzone and the end of the Illyrian. After the first deep water event the reef recovered for a short time until it was finally terminated by a second deep-water horizon, the age of which is unknown. It is overlain by upper Illyrian – Fassanian lagoonal limestone.

Evolution of the SE part of the studied area

In contrast to the NW part, in the SE part of the studied area, after the drowning of the Steinalm Platform deep-water facies persisted from the latest Pelsonian to the Fassanian (Binodosus Subzone up to the Curionii Zone). During this period calcareous turbidites were deposited in the proximal part of the Jenei Basin while in the distal areas mainly fine calcarenites were sedimented.

According to the conodont data the lower deep-water intercalation in reef facies, stage 1 (Road-cut sec-

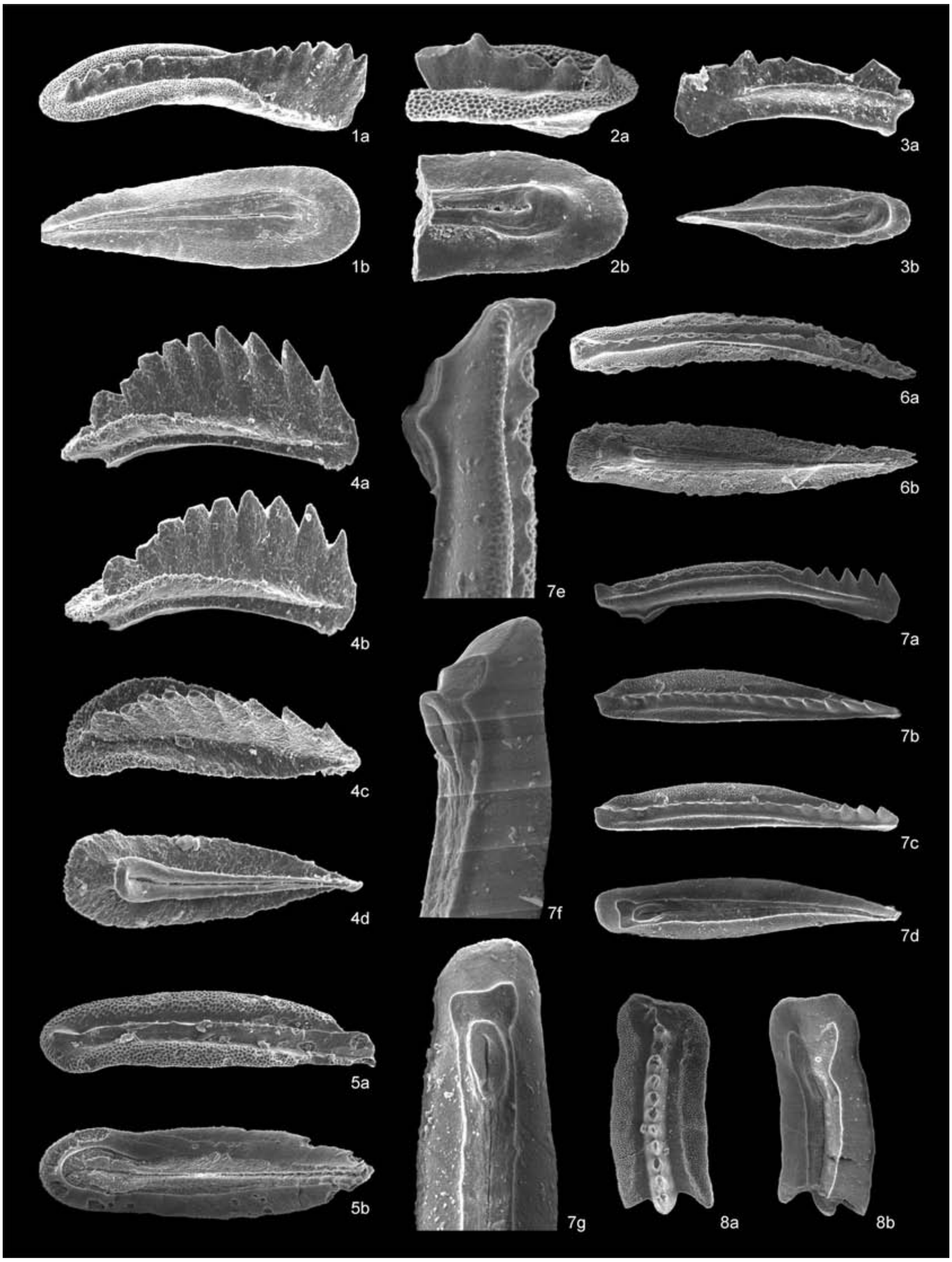


Fig. 27 - Conodonts 2

1a-b) *Gondolella fueloepi* Kovács, 1994. Adult ontogenetic stage. 128b. a) upper-lateral view, b) lower view. Both 40x.

2a-b) *Gondolella* cf. *szaboi* Kovács, 1983. Medium ontogenetic stage, broken form. Ko1. a) upper-lateral view, b) lower view. Both 90x.

3a-b) *Gondolella trammeri* Kozur, 1972. Medium ontogenetic stage. Ko1. a) lateral view, b) lower view. Both 60x.

4a-d) Transitional form between *Gondolella excelsa* (Mosher, 1968) and *G. fueloepi* Kovács 1994. Medium ontogenetic stage. T129. a) lateral view, b) upper-lateral view, c) lateral-upper view, d) lower view. All 90x.

5a-b) *Gondolella constricta balkanica* (Budurov, 1975). Adult ontogenetic stage. 432.
a) lateral-upper view, b) lower view. Both 60x.

6a-b) *Gondolella* ex gr. *bakalovi* (Budurov & Stefanov, 1975). Adult ontogenetic stage. T38t (top). a) upper-lateral view, b) lower view. Both 40x.

7a-g) *Gondolella* ex gr. *bakalovi* (Budurov & Stefanov, 1975). Sub-adult ontogenetic stage. T38t (top). a) upper-lateral view, b) upper view, c) lateral-upper view, d) lower view. All 45x. e-g) posterior end of unit: e) lateral view, 150x, f) lower-lateral view, 115x, g) lower view. f-g 115x. (Note the significantly forward-shifted basal pit with strongly protruding margins and the long loop behind it.).

8a-b) *Gondolella transita* Kozur & Mostler, 1971. Adult ontogenetic stage. Pc1.
a) upper view; b) lower view. Both 60x.

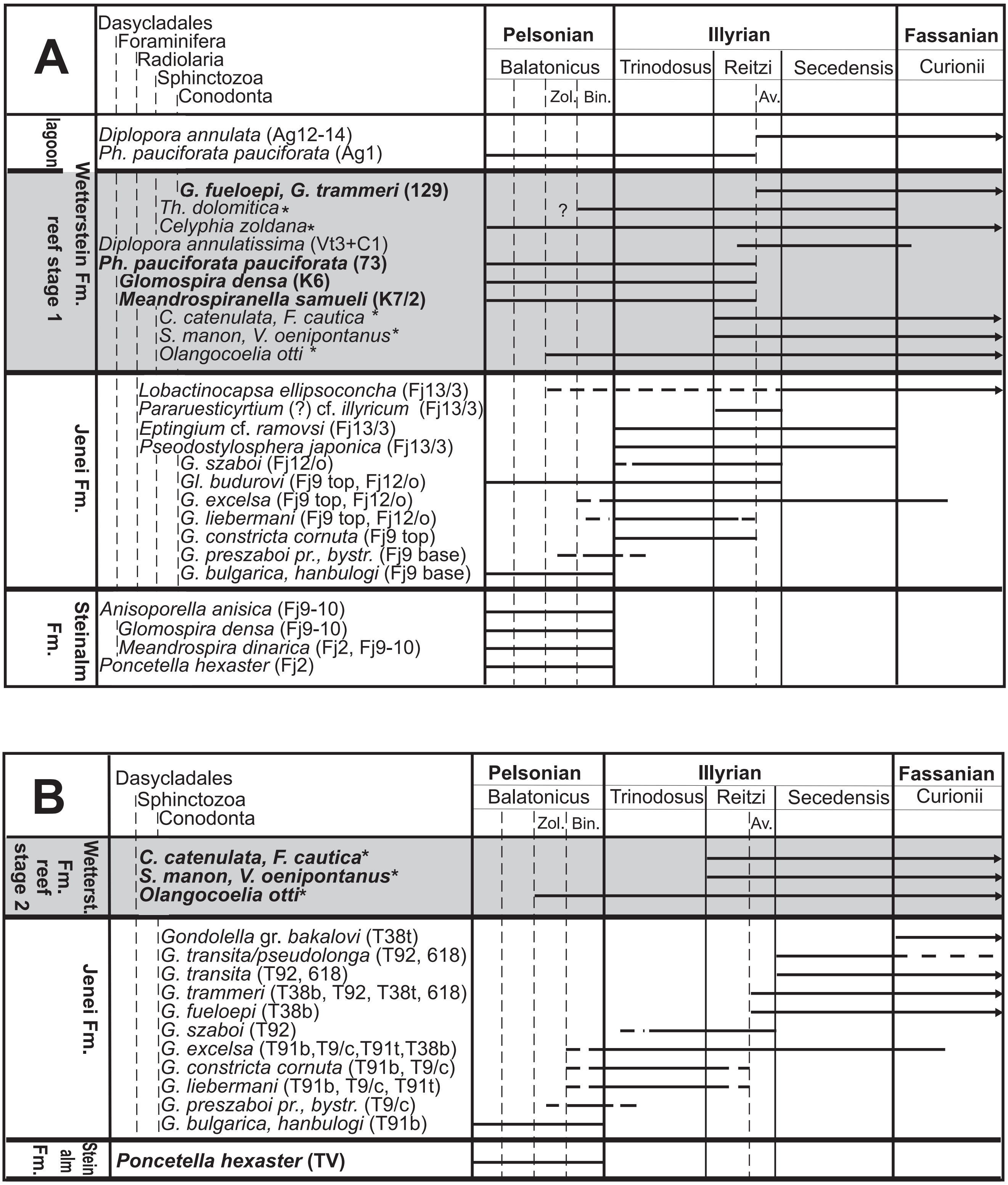


Fig. 28 - The most important fossils from different formations of the studied area and their stratigraphic range: (A) NW part of the area based on the Baradla Cave section. Note: fossil names in bold are projected from the Kecső valley (samples K6, K7/2) and the Road-cut (sample T129) sections. (B) SE part of the studied area, based on the Jenei Hill section. Note: fossil names in bold are projected from the Pitics Hill section.
Asterisk indicates fossils occurring in several samples.

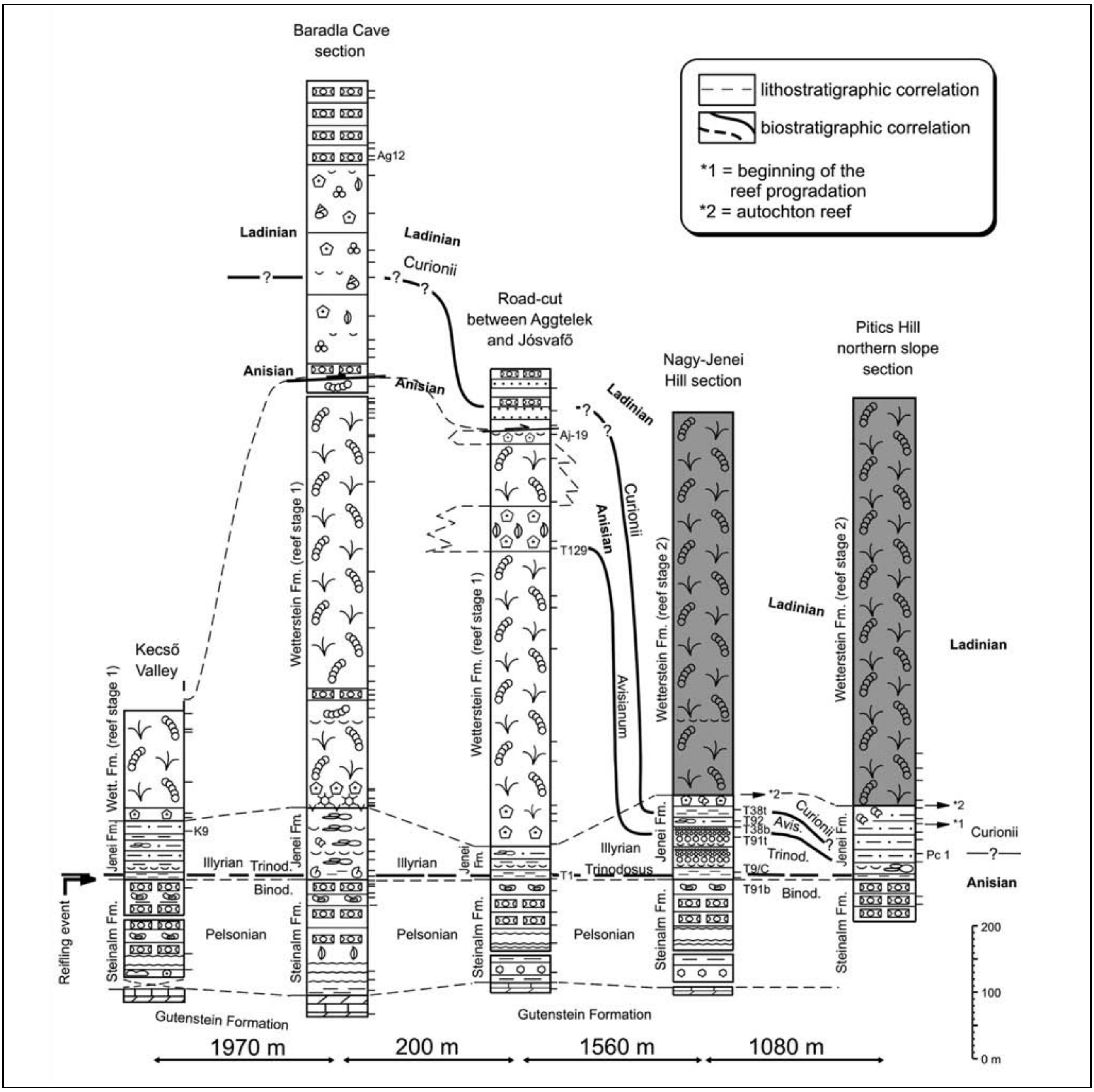


Fig. 29 - Bio- and lithostratigraphic correlation of the studied sections.
The uniform shallow marine shelf (Steinalm Platform) drowned and was dissected in the late Pelsonian due to the Reifling drowning event. On the top of the basinal sediments of the Jenei Formation on the NW (Kecső Valley, Baradla Cave, Road-cut sections) on the edge of a morphological high a platform margin reef (reef facies, stage 1) developed during the late Illyrian. In contrast to this in the SE (Nagy Jenei Hill, Pitics Hill sections) the basin survived until the early Ladinian. During the late Illyrian - early Ladinian the reef prograded to the SE (reef facies, stage 2). Meanwhile, on the NW part of the platform a lagoon was formed behind the reef.
Note: the raster indicates reef facies, stage 2.
The horizontal distances are not to scale.

tion, NW part of the area) and the higher turbiditic layers of the Nagy-Jenei Hill section (SE part of the area, Fig. 29) can be correlated and referred to the Avisianum Subzone. These data clearly demonstrate that a basin developed in the SE, while coevally in the NW part of the studied area reef growth took place.

In the early Ladinian (Curionii Zone or somewhat later) the reef prograded into the SE situated basin (reef stage 2). Coevally with reef stage 2 on the SE part, a heteropic lagoon existed in the NW part of the area (Fig. 30). The southward progradation of the Aggtelek reef conforms to the progradation of the Wetterstein reef of the Silica platform. This progradation trend can be clearly concluded from the well documented successions of the Silica platform (South Slovakia; Fig. 1c, Mello et al. 1997: fig. 6).

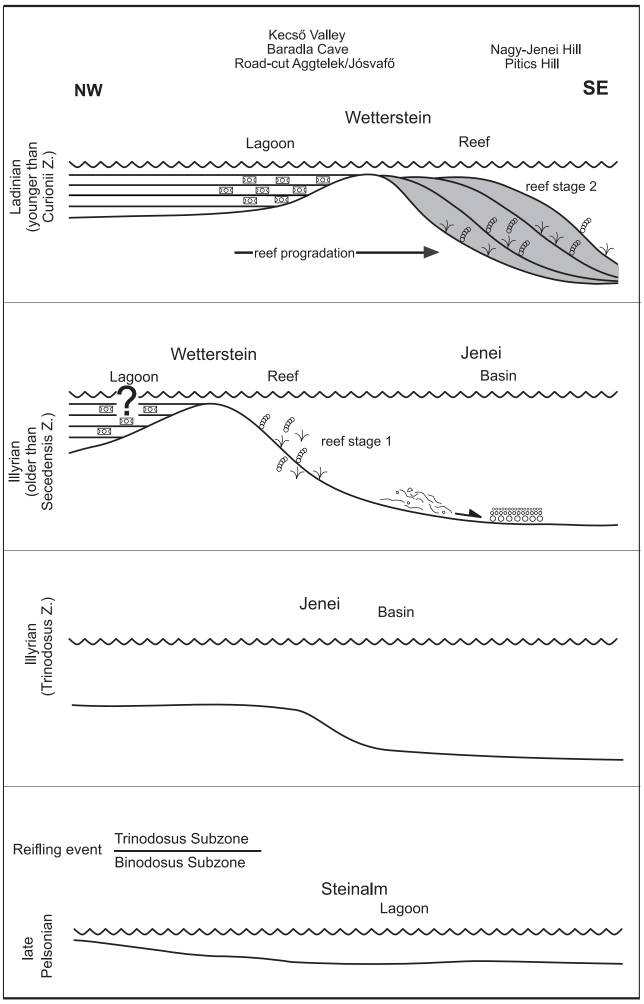


Fig. 30 - Schematic sketch of the evolution of the Aggtelek platform in the middle Anisian – early Ladinian. In the late Pelsonian the Steinalm Platform drowned and the see-floor was differentiated. In the studied area a basin and a topographic high originated. Later in the middle Illyrian to the NW on the edge of a morphological high a platform margin reef (reef facies, stage 1) developed. During the late Illyrian – early Ladinian the reef prograded into the Jenei Basin forming reef facies, stage 2. Meanwhile on the NW part of the platform behind reef facies, stage 2 a lagoon was formed. Note: the question mark in the Illyrian paleogeographic reconstruction indicates a facies (Wetterstein lagoon) which is not present in the studied area.

The cessation time of the reef stage 2 is not known due to the lack of index fossils in the reef and because of the huge stratigraphical discordance above the reef.

Comparison between reef stage 1 and reef stage 2

1. There is no considerable difference between the sponge genera and species, and the microproblematica are also the same.

2. Both reef associations represent an early Wetterstein-type reef. They are not as rich as those of the Ladinian-middle Carnian Wetterstein reef (Flügel 2002). Although they contain several sphinctozoans and microproblematicas which belong to the Wetterstein reef community, several typical taxa (cf. Ott 1967: *Alpinothalamia bavarica, Uvanella irregularis, Stylothalamia dehmi* and *Cryptocoelia zitteli,* all species of *Vesicocaulis* except for *V. oenipontanus*, etc.) are absent.

3. Dasycladaleans are present only in reef stage 1. *Physoporella pauciforata sulcata* (H219), and *Ph. pauciforata pauciforata* (73) indicate a Pelsonian- middle Illyrian age (chapter 5.1), whereas *Diplopora annulatissima* (Vt3) indicates middle Illyrian – base of Ladinian.

4. The base of reef stage 1 consists of a thick crinoidal sequence of not more than 80 m with coarse crinoid fragments and autochthon crinoids. This sequence is rich in brachiopods too. Contrary to this, below the base of reef stage 2 a roughly 30 m thick level appears consisting of the alternation of micritic and fine calcarenitic crinoidal beds with resedimented fragments of reef building organisms. This level represents the reef progradation. Brachiopods are absent.

5. Deep water intercalations with brachiopods appear only in the higher part of reef stage 1, which is dated to the interval between the Avisianum Subzone and the end Illyrian.

6. Neptunian dykes were found only through reef stage 1.

Comparison with other Early – Middle Triassic reefs

Early – Middle Triassic reef recovery

The aim of this chapter is twofolds: (1) to give a brief summary about the Early-Middle Triassic reef recovery and to highlight the place of the Aggtelek reef within this process. (2) To show the close connection between the tectonic processes and the reef recovery. Based on literature data were collected with regards to well documented Early Triassic – Early Ladinian reefs. For a comprehensive listing of Early and Middle Triassic reefs we refer to (Flügel 2002).

Small reefs: patch reefs, biostromes, reef/mud mounds (Fig. 31). In the Pelsonian – early Illyrian small patch reefs are known (Flügel 2002) and from the southern shelf of the north-western end of the Neo-Tethys Ocean. The diameter of these small reefs is between 20 cm and some 10 metres on average, but never exceeds 100 metres (e.g. Fois & Gaetani 1984; Senowbari-Daryan et al. 1993). The basement on which these small reefs were formed was never differentiated to any significant extent. They were mainly formed on the middle-lower part of the ramp. The lifetime of these small reefs was short, only episodic in geological terms.

Carbonate platforms (Early-Middle Anisian) which are several km wide and several hundred metres thick were formed in Lombardy (Gaetani & Gorza 1989; Berra et al. 2005) and Friuli (Metzeltin 1973) but these huge platforms were not colonised by a real reef community. The sea floor of these areas was not differentiated considerably (Berra et al. 2005).

Huge platform margin reefs (Late Olenekian – Early Ladinian) are known from the Paleo-Tethys and Neo-Tethys regions. The oldest known platform margin reef can be found on the shore of the Palaeo-Tethys in SW China (Payne et al. 2006a, b). It was formed on the isolated Late Permian – Late Triassic carbonate platform in the Nanpanjiang Basin.

From the Neo-Tethys region extended platform margin reefs are known from the Western Carpathians (WCA) including Aggtelek (present contribution), from the Northern Calcareous Alps (NCA) (Rüffer & Zamparelli 1997; Nittel 2006; Piller et al. 2004), from the Dolomites (Fois & Gaetani 1980; Fois 1981; Gaetani et al. 1981; Blendinger et al. 1984; Brandner et al. 1991; Bosellini 1991; Harris 1993, 1994; Russo et al. 1998; Emmerich et al. 2005). Similar platforms are present in Lombardy (Landra et al. 2000; Gaetani 2010). All these reefs were formed on platform margins, in the neighbourhood of deep basins. According to Payne et al. (2006a, b) in South China there was a 400 m vertical distance between the reef complex and the adjacent ba-

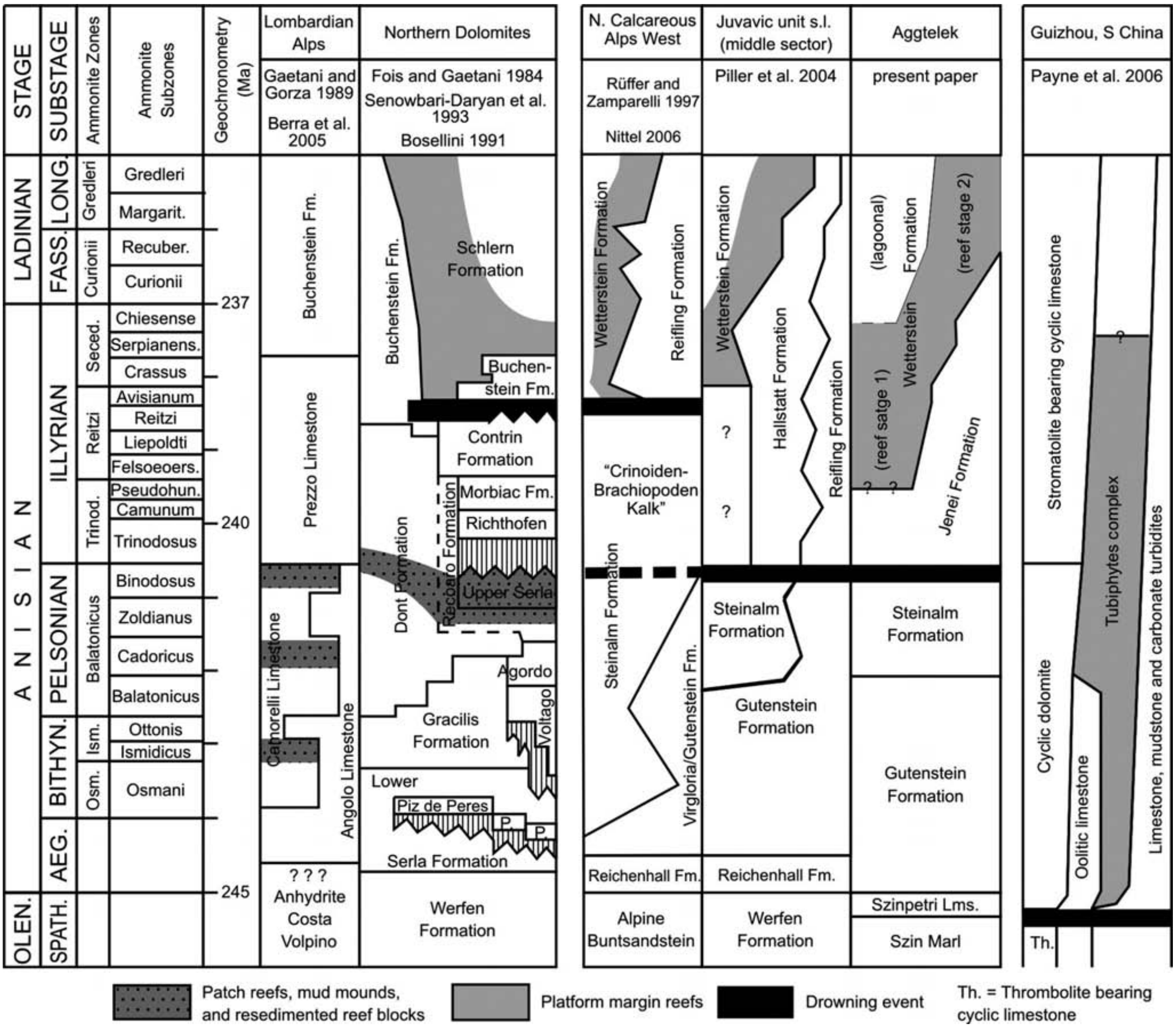


Fig. 31 - Well known selected reefs which appeared after the P/T extinction event.
Correlation chart of the Olenekian – early Ladinian formations from different parts of the Neo-Tethys Ocean. Dark grey shading with dots indicates small patch reefs, mud mounds and biostromes. Light grey shading indicates the platform margin reefs. A black line indicates the tectonic events preceding the formation of the extensive platform margin reefs while other parts of the former ramps subsided. This way vertical differences were created between platforms and basins, which were favourable for the formation of platform margin reefs.

sin. Bosellini (1991) gives a 700-800 m maximum depth for basins where the Buchenstein Fm. was deposited. These reefs existed over longer periods – i.e. for several millions of years.

The differentiation of the sea-floor obviously preceded the formation of the platform margin reefs. (1) In China this happened in the latest Olenekian (Payne et al. 2006a,b), in the (2) Western Carpathians and in the Eastern and Middle sectors of the Northern Calcareous Alps (NCA) in late Pelsonian; late Binodosus Subzone; Reifling Event as discussed in this article and in Piller et al. (2004). (3) In the western sector of the NCA and in the Dolomites in the middle Illyrian (Reitzi Subzone: Brack & Muttoni 2000; or Avisianum Subzone: Rüffer & Zamparelli 1997). According to our present knowledge in the western end of the Neo-Tethys the reef in the Aggtelek area (described in this paper) is the oldest platform margin reef.

Already Flügel (2002) stated that there was a connection between the Lower – Middle Triassic reef recovery and the opening of the Neo-Tethys Ocean. Platform margin reefs appeared only after a considerable differentiation of the sea-floor. The undifferentiated sea floor can be a credible explanation why in the Pelsonian only small patch reefs were formed on the middle – lower part of the ramp in the Dolomites and why the extended platforms in Lombardy were not colonised by a real reef community.

If we consider the time of the appearance of the big platform margin reefs on the northern shelf of the Neo-Tethys Ocean the statement of Fügel (op. cit.) seems to be true. On the Northern shelf of the opening Neo-Tethys the big platform margin reefs appeared earlier on the East than on the West (Fig. 31). This is most probably due to the successive opening of the Neo-Tethys Ocean which also propagated from east to west.

Differences in the Middle Triassic platform geometry between the Northern and Southern Neotethyan shelves

Striking differences can be seen in the geometry of the middle Illyrian-Ladinian carbonate platforms and reefs of the two opposite shelves of the opening Neo-Tethys Ocean (Velledits 2009 fig. 3a-b). On the northern shelf the platforms and the reefs have long, elongated shapes. The Aggtelek reef presently shows a length of 7 kms. The Ladinian-Cordevolian Wetterstein platform from the Inner Western Carpathians (from Koniar Plateau to Jasov Plateau) is today 48 km long with a maximum width of 8 km, its boundaries are partly tectonic (Mello et al. 1996, 1997). Reefs and lagoons are lying parallel to each other. Both have elongated shape. They never have roundish form. East of the Silica Plateau the Pelsonian-Illyrian basinal carbonates crop out only in several small restricted areas because of the strong successive tectonics and erosion. In this area these carbonates constitute the underlying strata of the Wetterstein platforms. In the Silica Plateau and West of it the Pelsonian – Ladinian basinal successions appear in narrow elongated belts parallel to the heteropic platform carbonates to the North and South respectively. Basinal carbonates cover much smaller area than platform carbonates.

In contrast to this on the southern shelf (Dolomites) platforms have curved outlines (Bosellini 1991, Gaetani 2010). Reefs grew at shelf platform margins (e.g. Sass da Putia, Sciliar/Schlern, Catinaccio/Rosengarten), other at the margins of isolated round platforms (Marmolata, Latemar; Flügel 2002). The latter are small (4-25 km in diameter), round, island platforms (Bosellini 1991), with lagoonal carbonates in the middle. Carbonate platforms are surrounded by pelagic interplatform basins. Basins cover much bigger area than platforms.

Results

Reef facies, stage 1 and reef facies, stage 2

On the southern part of the Aggtelek Plateau, two Middle Triassic reef bodies (reef stage 1: early? – middle Illyrian, reef stage 2: late Illyrian – Ladinian) were found, which differ from each other in age, in geographical setting and slightly in fossil content. Based on the age and reef community of both reefs they belong to the early Wetterstein-type reefs. The reef associations are not as rich as those of the Ladinian-middle Carnian Wetterstein reefs, as *Alpinothalamia bavarica, Uvanella irregularis, Stylothalamia dehmi* and *Cryptocoelia zitteli,* all species of *Vesicocaulis* except for *V. oenipontanus*, etc. are absent.

Both reef bodies are interpreted as platform margin reefs. From the middle Illyrian until the early Ladinian an heteropic basin can be traced in front of reef stage 1, while in the Ladinian a lagoon existed behind reef stage 2 (Figs 29, 30).

Sphinctozoa stratigraphical ranges

Based on our conodont, dasycladalean and foraminiferal age data the stratigraphic range of four typical Wetterstein sphinctozoan species (*Colospongia catenulata, Follicatena cautica, Solenolmia manon manon, Vesicocaulis oenipontanus*) must be extended down into the middle Illyrian.

The Reifling drowning event

The effect of the Reifling event on the evolution of the Aggtelek platform is threefold: (1) it caused the drowning of the Steinalm Platform in the late Pelsonian (Binodosus Subzone); (2) it opened a connection to the open sea as indicated by the appearance of gladigondolelloids from the boundary of the Binodosus/Trinodosus Subzone onward; (3) it differentiated the sea floor creating suitable morphology for the development of platform margin reefs.

The Avisianum flooding event

A flooding event was proved from the upper part of reef stage 1 (the lower crinoidal-brachiopodal deep water intercalation with conodont and brachiopoda fauna). The age of this level (Avisianum Subzone – end of Illyrian) most probably correlates with the flooding event reported from many localities of the Alpine region (Haq et al. 1988; Rüffer & Zühlke 1995; Gianolla et al. 1998).

Syndepositional tectonics

Based on conodonts from the neptunian dykes dissecting the platform, the three main periods of tectonic activity are (1) latest Pelsonian (Binodosus Subzone), (2) early-middle Illyrian (Trinodosus Zone – most part of Reitzi Zone), and (3) uppermost middle Illyrian (Avisianum Subzone).

Volcanic activity

Coeval volcanic activity is documented in two stratigraphic levels.

(1) In the Binodosus Subzone: heavy minerals of volcanic origin were found in the base of the ammonoid layer and within the neptunian dykes.

(2) In the middle Illyrian: a 3 cm thick tuffitic layer is found below the radiolarite layers.

Progradation trend

The southward progradation of the Aggtelek reef conforms to the well-documented one of the Wetterstein reef of the Silica platform (South Slovakia; Fig. 1b).

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Appendix 1

Note of the Editor. This Appendix was written by S. Kovács a few months before his sudden death. Even if it has a scope larger than the matter discussed in the present paper, it is considered important to publish his last contribution to the knowledge of Triassic conodonts.

General evolutionary events of the conodonts

The evolutionary events of the gondolelloid-stock in the Middle to Late Triassic provide a biostratigraphic tool practically equivalent in the resolution of ammonoid chronology.

The Bithynian-Pelsonian species *Gondolella bulgarica* (Budurov & Stefanov) appears to be the ancestor of all subsequent Triassic gondolelloid and metapolygnathoid species, having an evolutionary link to. *G. hanbulogi* (Sudar & Stefanov) and *G. bifurcata* (Budurov & Stefanov), proved by a wide variety of morphological transitions between the three species (cf. Germani 2000; Kovács 2003 and Kovács & Rálisch-Felgenhauer 2005, for the latest reviews). This phylogenetic relationship enabled an older *G. bulgarica* and a younger *G. bifurcata* Zone to be distinguished (cf. Budurov & Stefanov 1975; Budurov 1980). However, all the three taxa occur in the type locality of the Bythinian sub – stage from the middle part of the Osmani Zone (Germani, op.-cit.), therefore a palaeoenvironmental control on their distribution is obvious. Consequently, these two zones can be considered only as facies-determined "dominance zones" (see Kovács 2003).

A comparable situation exists in neospathoids: an older *N. germanicus* and a younger *N. kockeli* Zone are distinguishable in the German Basins and in some Alpine units (cf. Kozur 1972; Trammer 1975 and subsequent literature). However, in the Pelsonian-type area (Felsőörs, Balaton Highland, Hungary) their joint occurrence in the Binodosus Subzone is documented (Kovács 2003), therefore a palaeo-environmental control on their distribution is also obvious.

In Bithynian-Pelsonian eupelagic environments gladigondolelloids (the more primitive *Gl. budurovi* and the more "evolved" *Gl. tethyds*) are also common constituents of the conodont faunas (Sudar 1982; Germani 2000).

Contrary to the later period of the Triassic, conodonts have little resolution value in distinguishing different zones of the Bythinian and Pelsonian substages. In the later Pelsonian a prominent radiation event took place in the *G. bulgarica* group, resulting in transitional morphotypes in many directions.

The boundary of the Binodosus/Trinodosus Subzones is marked by a very rapid evolutionary event, with the rapid extinction of the *G. bulgarica* group (*G. bifurcata* surviving a bit longer) and the rise of the *G. constricta* (characterised by a "neogondolelloid" pit), *G. szaboi-trammeri* and *G. excelsa* (characterised by a "paragondolelloid" pit) lineages. This evolution event is well-documented in several South Alpine sections (Farabegoli & Perri 1998a, b; Balini & Nicora 1998). This event really represents a "stage level" change in the evolution of Middle Triassic conodonts (Fig. 25). Whereas the distinction of the "neogondolelloid" *G. constricta* and the "paragondolelloid" *G. excelsa* groups from the *G. bulgarica* group is quite easy (reflecting a sudden morphological change during phylogenetic evolution), the distinction of *G. szaboi* (Figs. 26/3a-e) from its ancestor, *G. praeszaboi* is quite difficult: it is only possible due to the more upturned and compressed platform margins of the latter (Figs. 26/2a-e).

After this sudden evolutionary event, gondolelloid and gladigondolelloid conodonts practically did not change throughout the Trinodosus Zone. On the one hand the *G. constricta* lineage was represented by the dominant *G. constricta cornuta* (Budurov & Stefanov) and the subordinate *G. constricta balcanica* (Budurov & Stefanov) (Figs. 27/5a-b); on the other hand, the *G. excelsa* lineage was represented by *G. excelsa* (Mosher) (Figs. 26/6a-d, 7a-b) itself and *G. liebermani* Kovács & Krystyn. The *G. szaboi-G. trammeri* lineage was represented in eupelagic facies by *G. szaboi* (Kovács 1987; Haas et al. 2005). Whereas gladigondolelloids were further represented by *Gl. budurovi* and *Gl. tethydis* in eupelagic facies by contrast Pelsonian representatives of neospathoids (*N. germanicus, N. kockeli*) became extinct at the boundary of the Binodosus and Trinodosus Subzones. However other representatives of neospathoids may have survived in certain restricted basin environments replacing the gondolelloid platform element in conodont apparatuses and repeatedly occuring again in more restricted environments throughout the rest of the Triassic.

A less significant event can be recognized at the base of the Reitzi Zone, e.g. in the Felsoeoersensis Subzone, on the constricta lineage *G. constricta postcornuta* developed from *G. constricta cornuta,* although with a rather slow evolutionary trend (Kovács 1994). The other lineages (i.e. *excelsa, szaboi-trammeri*) do not reflect any evolutionary event at this interval. However, detailed correlation of ammonoid and conodont zonation in non-condensed eupelagic (Tethyan) sections is still not available for the time interval between the base of the Camunum Subzone to the upper boundary of Reitzi Subzone (Fig. 25).

A very significant evolutionary event can be recognised on all gondolelloid evolutionary lineages in the Avisianum Subzone (which in current ammonoid zonation can be considered to be the highest subzone of the Reitzi Zone of Vörös et al. 2003a, b; Brack & Rieber 2003; Brack et al. 2005). On the eupelagic *G. szaboi-G. trammeri* lineage the typical late Illyrian-Ladinian form is *G. trammeri*, as well as *G. alpina*, whereas on the *excelsa* lineage *G. fueloepi* occurs first, with a less significant event represented by the extinction of *G. constricta cornuta* (Figs. 27/1a-b, 2a-b, 3a-b).

Somewhat higher above the Avisianum Subzone (Secedensis Zone or even later) in the Felsőörs section the rare *G. transita* Kozur occurs (Kovács 1994) (Figs. 27/8a-b). The base of the Curionii Zone is not marked by any conodont evolutionary event: in the Bagolino GSSP section the FAD (First Appearance Date) of *G. praehungarica* Kovács – the ancestor of Ladinian metapolygnathoids – somewhat precedes this boundary (Nicora & Brack 1995; Brack et al. 2005). The FAD of true Ladinian metapolygnathoids (*M. hungaricus* Kozur & Végh) occured either in the higher part of the Curionii Zone (Krystyn 1983) or even in the following Gredleri Zone (Brack et al. 2005). An important evolutionary event on the *G. constricta* lineage can be recognized in the Felsőörs section of the Balaton Highlands. This also has some importance in the Aggtelek area. From bed no. 10/86 upwards in the upper section of Felsőörs, long, elongated forms occur, which are assigned by Kovács (1994) as "*G. bakalovi* group". After publication of his monograph in 1998, Vörös (pers. comm.) found an *Eoprotrachyceras* sp. specimen in bed No. 9/86 in the Felsőörs section. Therefore this bioevent had already taken place during the Curionii Zone. Similar, elongated forms occur also in the Aggtelek area, representing the youngest conodont fauna found during this study (Fig. 25, 27/5a-b, 6a-b, 7a-g).

Appendix 2

Fossil list

For a detailed description of echinoids see Mihály (1981), crinoids see Hagdorn & Velledits (2006); for *Aggtecella hungarica* see Senowbari-Daryan & Velledits (2007a); and for *Anisophytes aggtelekensis* see Senowbari-Daryan & Velledits (2007b).

Legend:

St: Steinalm Formation, R1: reef facies, stage 1, R2: reef facies, stage 2, W_{lag}: Wetterstein Formation lagoonal facies, J: Jenei Fm., Nd: neptunian dyke, St_{Nd}: neptunian dyke within the Steinalm Fm., $R1_{Nd}$: neptunian dyke in reef stage 1, J_{Nd}: neptunian dyke within the Jenei Formation.

Cyanophycea

Cladogirvanella cipitensis Ott, 1966 (Fig. 22/4) R1

Anisophytes aggtelekensis (Scholz, 1972) (see Senowbari-Daryan & Velledits 2007b; plate 1-3) St, R1

Rhodophyta

Aggtecella hungarica Senowbari-Daryan & Velledits, 2007 (Fig. 22/1 and see Senowbari & Velledits 2007a, figs. 2-3) R1

Solenopora sp.

Dasycladales

Aciculella bacillum Pia, 1930 W_{lag}

Aciculella sp. W_{lag}, R2

Anisoporella anisica Ott 1972 (Zanin Buri, 1965) Hurka, 1969) St

Diplopora annulata annulata Schafhäutl, 1863. (Figs 14/5, 7-8) W_{lag}

Diplopora annulatissima Pia, 1920 (Fig. 14/6) R1, W_{lag}

Diplopora nodosa Schafhäutl, 1863 emend. De Castro, 1979 (Fig. 14/4) St, R1

Favoporella annulata Sokać, 1968 R1

Oligoporella dissita [=*Physoporella dissita* (Gümbel, 1872) Pia, 1912 (Figs 14/1, 3)] St

Oligoporella minutula [=*Physoporella minutula* (Gümbel, 1872) Pia, 1912] (Fig. 10a) St

Physoporella intusannulata Hurka, 1967 St

Physoporella minutuloidea Herak, 1967 St

Physoporella pauciforata gemerica Bystrický, 1962 St

Physoporella pauciforata var. *pauciforata* Pia ex. Bystrický, 1964 (Fig. 14/2) St, R1

Physoporella pauciforata var. *sulcata* Bystrický, 1962 St, R1

Physoporella pauciforata var. *undulata* Pia, 1935 (Figs 10a, 14/3) St

Physoporella sp. R1

Poncetella hexaster (Pia, 1912) Güvenç, 1979 St

Teutloporella peniculiformis Ott, 1963 St

Zornia obscura Senowbari-Daryan & Di Stefano, 2001 St, R1, W_{lag}

Microbial crusts R2

Foraminifera

?Austrocolomia sp. (Fig. 18/7) R1

Diplotremina gr. *astrofimbriata* Kristan-Tollmann, 1960 (Figs 18/10-14) R1, W_{lag}

"Duotaxis" sp. R1

"Earlandinita" elongata Salaj, 1967 (Fig. 18/15) St, J, W_{lag}

Endoteba gr. *badouxi* (Zaninetti & Brönnimann in Zaninetti, Brönnimann & Baud,1972) (Figs. 17/1-3) St, R1, W_{lag}

Endotebanella kocaeliensis Dager, 1978 (Fig. 18/19) R1

Endotebanella sp. A n. sp. (Fig. 17/12, Figs. 18/5-6) St

Endotriadella wirzi (Koehn-Zaninetti, 1969) emend. Vachard et al., 1994 (Figs. 17/4-9) St, R1, W_{lag}, $Nd_{Binodosus\ SZ}$

Glomospira densa (Pantić, 1965) (Figs. 16/1-5) St

Glomospirella cf. *falsofriedli* (Salaj, Borza & Samuel, 1983) (Figs. 16/9-13) St, J, R1,

Glomospirella semiplana (Kochansky-Devidé & Pantić, 1966) (Fig. 16/6) St

Glomospirella sp. J

Haplophragmella inflata Zaninetti & Brönnimann in Brönnimann, Cadet & Zaninetti, 1973 (Figs. 17/23-25) St

Meandrospira dinarica Kochansky-Devidé & Pantić, 1965 (Figs. 16/8, 18-22) St

Meandrospiranella samueli Salaj in Salaj, Biely & Bystrický, 1967 (Fig. 16/17) R1

Nodosaria sp. R1, $Nd_{Binososus\ SZ,\ Trinodosus\ Z}$

Ophthalmidium abriolense (Luperto, 1965) (Figs. 17/13-18, 29) St, J, R1, W_{lag}, $Nd_{Avisianum\ SZ}$

Palaeolituonella meridionalis Luperto, 1965) (Figs. 17/19-22) R1, R2

Planiinvoluta carinata Leischner, 1961 (Figs. 17/26, 18/8-9) J, R1, W_{lag}

Planiinvoluta sp. or *Tolypammina* sp. (Figs. 17/27-28) J, $Nd_{Trinosodus\ Zone,\ R1}$

Trochammina almtalensis Koehn-Zaninetti, 1968 (Figs. 16/14-16) St, J, R1, W_{lag}

Trochammina cf. *alpina* Kristan sensu Oravecz-Scheffer 1987 (Figs. 18/16-17) R1

Turriglomina mesotriasica (Koehn-Zaninetti, 1969) (Figs. 17/10-11) J, R1, R2

Variostoma gr. *pralongense-exile* Kristan-Tollmann, 1960 (Figs. 18/1-4) R1, W_{lag}

Radiolaria (all species originates from sample Fj13/3, top of J)

Anisicyrtis sp. 1 (Fig. 20/23)

Anisicyrtis sp. 2 (Fig. 20/22)

Annulotriassocampe campanilis Kozur & Mostler, 1994 (Fig. 20/20)

Cenosphaera gr. *andoi* Sugiyama, 1992 (Figs. 20/1, 5)

Deflandrecyrtiid, gen. et sp. indet. (Fig. 20/16)

Eptingium gr. *manfredi* Dumitrică, 1978a (Figs. 20/3, 8-9, 11)
Eptingium cf. *ramovsi* Kozur, Krainer & Mostler, 1996 (Fig. 20/7)
Lobactinocapsa cf. *ellipsoconcha* Dumitrică, 1978b (Fig. 20/13)
Monospongella sp. (Fig. 20/6)
Nassellarian, gen et sp. ind. (Fig. 20/18)
Pararuesticyrtium? cf. *illyricum* (Kozur & Mostler, 1981) (Fig. 20/19)
Pararuesticyrtium ? sp. (Fig. 20/21)
Pseudostylosphaera japonica (Nakaseko & Nishimura, 1979) (Fig. 20/12)
Pseudostylosphaera sp. A (Fig. 20/10)
Pseudostylosphaera sp. B (Fig. 20/14)
Spongosilicarmiger scabiturritus Sugiyama, 1992 (Fig. 20/17)
Spongostephanidium cf. *spongiosum* Dumitrică, 1978 (Fig. 20/4)
Spumellarian, n. gen., n. sp. (Fig. 20/2)

Inozoa R1, R2
Sphinctozoa
Celyphia? minima Senowbari-Daryan, Zühlke, Bechstädt & Flügel, 1993 (Fig. 21/1) R1
Celyphia zoldana Ott, Pisa & Farabegoli, 1980 (Figs. 21/6, 8) R1
Celyphia? sp. (Fig. 21/5) R1, R2
Colospongia catenulata catenulata Ott, 1967 (Figs. 21/9, 10) R1, R2
Colospongia sp. R1
Follicatena cautica Ott, 1967 (Fig. 21/4) R1
Follicatena sp. R2
Olangocoelia otti Bechstädt & Brandner, 1970 (Fig. 21/2) R1, R2
Olangocoelia sp. R1 (Fig. 6b)
Solenolmia manon manon (Münster, 1841) (Fig. 21/3) R1, R2
Solenolmia sp. R1
Sollasia? *baloghi* Kovács, 1978 R1
Thaumastocoelia dolomitica Senowbari-Daryan, Zühlke, Bechstädt & Flügel, 1993 R1
Vesicocaulis oenipontanus (Ott, 1967) (Fig. 21/7) R1, R2
Vesicocaulis sp. R1, R2 (Fig. 6d)

Hexactinellida J, R1, R2.
Chaetetida R1
Anthozoa R1, R2
Worm tubes R1
Ostracoda
Ostracoda, gen. et sp. ind., (Fig. 20/15) J

Bryozoa J, R1, R2
Brachiopoda
"Aulacothyris"? sp. St$_{Nd}$, R1
Austriellula? sp. St$_{Nd}$,
Coenothyris cf. *vulgaris* (Schlotheim, 1820) (Figs. 24/17-18) J, R1
Coenothyris? sp. R1, R1$_{Nd}$
Costirhynchopsis cf. *mentzeli* (Buch, 1843) St$_{Nd}$
Costispiriferina sp. J
Decurtella decurtata (Girare, 1843) (Fig. 24/4) R1
Dinarispira dinarica (Bittner, 1890) (Figs. 24/8-10) St$_{Nd}$, R1
Holcorhynchella? sp. (Fig. 24/3) R1$_{Nd}$
Homoeorhynchia? sp. St$_{Nd}$,
Koeveskallina koeveskalyensis (Stur, 1865) St$_{Nd}$, R1
Mentzelia mentzeli (Dunker, 1851) (Fig. 24/12) St$_{Nd}$, J, R1
Norella sp. (Figs. 24/1-2) St$_{Nd}$,
Piarorhynchella trinodosi (Bittner, 1890) (Figs. 24/6-7) St$_{Nd}$,
Punctospirella fragilis (Schlotheim, 1814) R1
Schwagerispira cf. *mojsisovicsi* (Böckh, 1872) (Fig. 24/11) St$_{Nd}$,
Schwagerispira sp. St$_{Nd}$,
Spirigerellina? sp. A (Figs. 24/13-14) R1, R1$_{Nd}$
Spirigerellina? sp. B (Figs. 24/15-16) R1
Tetractinella trigonella (Schlotheim, 1820) R1$_{Nd}$
Volirhynchia cf. *vivida* (Bitter, 1890) (Fig. 24/5) St$_{Nd}$,

Crinoidea
Encrinidae gen. et sp. indet. 1 (see Hagdorn & Velledits 2006; figs. 6a-d) R1
Encrinidae gen. et sp. indet. 2 (see Hagdorn & Velledits 2006; figs. 6e-g) R1
Encrinidae gen. et sp. indet. 3 (see Hagdorn & Velledits 2006; figs. 6c; 7i) R1
Silesiacrinus (?) *cancellistriatus* (Bather, 1909) (see Hagdorn & Velledits 2006; figs. 7a-h) St$_{Nd}$, R1
? *Tollmannicrinus quinqueradiatus* (Bather, 1909) (see Hagdorn & Velledits 2006; figs. 4 a-e) St$_{Nd}$
Isocrinidae gen. et sp. indet. (see Hagdorn & Velledits 2006; figs. 8a-g) R1

Conodonta
Gondolella ex gr. *bakalovi* (Budurov & Stefanov, 1975) (Figs. 27/6a-b, 7a-g) J
Gondolella bifurcata (Budurov & Stefanov, 1972) (Figs. 26/8a-b) J, J$_{Nd}$
Gondolella bulgarica Budurov & Stefanov, 1975 (Figs. 26/1a-d) J, J$_{Nd}$
Gondolella bulgarica/excelsa transitional forms J, J$_{Nd}$, R1
Gondolella bystrickyi Kovács, Papšová & Perri, 1996 (Fig. 26/4, 5a-d) J, J$_{Nd}$,
Gondolella constricta balkanica (Budurov & Stefanov, 1975), (Figs. 27/5a-b) J, J$_{Nd}$
Gondolella constricta cornuta (Budurov & Stefanov, 1972) J, J$_{Nd}$
Gondolella aff. *eotrammeri* Krystyn, 1983 J$_{Nd}$
Gondolella excelsa (Mosher, 1968), (Figs. 26/6a-d, 7a-b) J, J$_{Nd}$, R1, R1$_{Nd}$
Gondolella excelsa/fueloepi transitional form (Fig. 27/4a-d) R1
Gondolella fueloepi Kovács, 1994 (Figs. 27/1a-b) J, J$_{Nd}$, R1
Gondolella hanbulogi (Sudar & Budurov, 1979) J, J$_{Nd}$,
Gondolella liebermani Kovács & Krystyn, 1994 J, J$_{Nd}$,
Gondolella praeszaboi Kovács, Papšová & Perri, 1996 (Fig. 26/2a-e) J, J$_{Nd}$,
Gondolella pseudolonga Kovács, Kozur & Mietto, 1980 J
Gondolella szaboi Kovács, 1983 (Figs. 26/3a-e) J, J$_{Nd}$,
Gondolella cf. *szaboi* Kovács, 1983 (Figs. 27/2a-b) R1$_{Nd}$
Gondolella trammeri Kozur, 1972 (Figs. 27/3a-b) J, J$_{Nd}$, R1, R1$_{Nd}$
Gondolella transita Kozur & Mostler, 1971 (Figs. 27/8a-b) J
Gondolella transita/pseudolonga transitional form J
Gondolella sp. R1 R1$_{Nd}$
Gondolella ME J, J$_{Nd}$, R1
Gladigondolella budurovi Kovács & Kozur, 1980 J, J$_{Nd}$
Gladigondolella tethydis (Huckriede, 1958) J, J$_{Nd}$, R1
Gladigondolella sp. J
Gladigondolella ME J, J$_{Nd}$, R1, R1$_{Nd}$
Neosphathodus kockeli (Tatge, 1956) St$_{Nd}$
Neospathodus n. sp J

Microproblematica
Baccanella floriformis Pantić, 1971 (Fig. 22/8) R1
Bacinella ordinata Pantić, 1972 (Fig. 22/10) J, R1, R2
Ladinella porata Ott, 1968 (Fig. 22/9) J, R1, R2
Lamellitubus cauticus Ott, 1968 J, R1, R2
Macrotubus babai Fois, in Fois & Gaetani 1981 R1
Plexoramea cerebriformis Mello, 1977 (Figs. 6c, 22/3) J, R1, R2
Radiomura cautica Senowbari-Daryan & Schäfer, 1979 (Figs. 22/5-6) R1
"Tubiphytes" gracilis Schäfer & Senowbari-Daryan, 1983 J, R1, R2
"Tubiphytes" multisiphonatus Schäfer & Senowbari-Daryan, 1983 (Fig. 22/2) R1, R2
Tubiphytes cf. *obscurus* Maslov, 1956 R1
Tubiphytes sp. (Fig. 22/7) J, R1