From Late Triassic passive to Early Cretaceous active continental margin of dominantly carbonate sediments in the Transdanubian Range, Western Tethys

By

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With 120 figures

Field Trip Guide

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Content

Abstract

The Transdanubian Range is part of a huge carbonate platform until the earliest Early Jurassic. The first signal of the opening of the Penninic Ocean is the break of the carbonate platform system. The result of this process is the differentiation of the sedimentary environments into highs with comparatively thin, discontinuous and into deeper-water areas with condensed lithofacies, and thicker, continuous successions showing less condensation. Throughout the Liassic partly nodular, cherty limestones with interbedded Hierlatz Limestone, typical Ammonitico Rosso-type limestones and marls occur. Pelagic carbonate sedimentation continued up to the Middle Jurassic when it was replaced by cherty limestones and bedded radiolarites in the basin, while on submarine highs there was no sedimentation at all or just highly lacunose one. Due to a shallowing tendency in the North Bakony Mts., the deposition of Ammonitico Rosso-type limestones with white pelagic cherty limestones and marls were from the Late Jurassic to the Early Cretaceous in the South Bakony. In contrast, the Early Cretaceous strata in the Gerecse Mts. (northern part of the Transdanubian Range) represent a siliciclastic deep-water succession including marls, turbiditic sequences and conglomerates with ophiolithic detritus. This event caused by the partial closure of the

Neotethys Ocean. In the Late Jurassic, there is no clear evidence for a nappe structure in the Transdanubian Range but there are some hints for it to the north. Fundamental facies changes between the south-western and the north-eastern part caused by compressional deformation in the Early Berriasian. Later, a new sedimentary cycle began with the deposition of freshwater and brackish marlstones, locally with bauxite lenses at the base of the new succession. In the late Early Cretaceous these two basins were united again with the Urgonian Limestones deposition. The facies links of the south-western basin closely relates to the Southern Alps, while the north-eastern one show analogues to the Northern Calcareous Alps.

1. Topics and area of the Field Trip

- Lofer cyclic Upper Triassic platform with lagoonal oncoidic and ooidic dune limestones.
- Lowermost Lower Jurassic oncoidic limestone of lagoonal facies.
- Typical Tethyan Ammonitico Rosso-type Jurassic sublittoral, nodular and well bedded, condensed limestones and marls of basin facies variations reflecting the early phase of the extensional tectonic movement and the vicinity of the submarine highs.
- Giant neptunian dykes of varied types of Middle Jurassic limestones with different sizes of Jurassic and Upper Triassic fragments of limestones and dolomites.
- Middle Jurassic scarp or rockfall breccia with Triassic and Lower Jurassic limestone blocks.
- Middle and Upper Jurassic limestone and radiolarite formations of bathyal (mesopelagic) zone.
- Highly lacunose Middle and Upper Jurassic limy sediments on submarine highs within the Tethys.
- Upper Jurassic and Lower Cretaceous pelagic limestones of Maiolica facies.
- Foreland basin type Lower Cretaceous coarse-grained clastics with deep-see fan lobes, channels and reworked platform carbonate clasts.
- Middle to upper Lower Cretaceous fluvial, through lacustrine, Urgon type platform and shallow bathyal sequence.
- Some elements of the Upper Cretaceous sedimentary sequence.

The field trip area is restricted to the Transdanubian Ran-

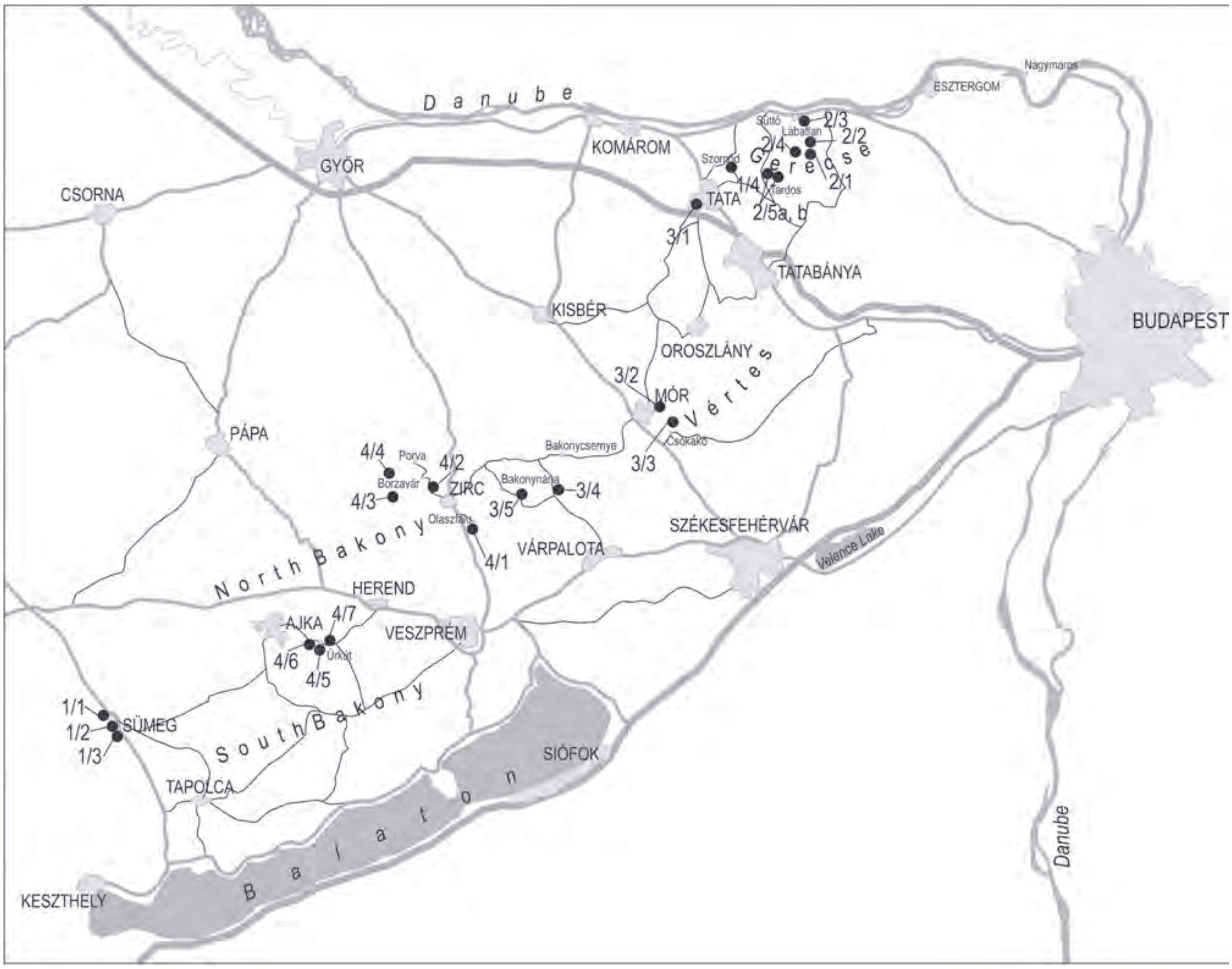


Fig. I: Simplified topographic map of the Transdanubian Range with indication of the visiting localities and sites by days (1/1-4/7).

ge, a unique tectonic unit comprising both the South Alpine and the North Alpine (Northern Calcareous Alps) developments within it. The change can be followed between the two palaeogeographic units in both time and space. The stops are indicated on a topographic map (Fig. I).

2. Introduction

Géza CSÁSZÁR

The Transdanubian Range (TR) is an isolated geographic unit (Fig. II) but geologically it is an integral part of the ALCAPA tectonic unit. Its western part (South Bakony) shows striking affinity with the Southern Alps while its easternmost part (Gerecse) with the Northern Calcareous Alps although the latter one shows also transitional character towards the internal Dinarides in the Early Cretaceous. Tectonically it is a syncline (Fig. II) developed during the Austrian tectonic phase in the Early Albian. The axis of the syncline is oriented in north-east - south-west direction equally with the orientation of the Transdanubian Range. Forming a narrow belt in the axis of the syncline Jurassic and Cretaceous formations are preserved as parts of the syncline and later in this inherited basin Upper Cretaceous, Middle to Upper Eocene and Lower Oligocene sedimentary successions were deposited. On the limbs of the syncline starting from the internal part Upper, Middle, and Lower Triassic, Permian and a few Carboniferous formations are known to occur. Large-scale overthrusts occur on both sides of the syncline.
The ALCAPA unit occupied its recent position in the Early Miocene only but the previous opening and closure of the varied Alpine oceanic branches strongly determined the actual sedimentary environments. The Transdanubian Range acted as a part of a huge carbonate platform until the early Early Jurassic time. The first signal of the start of the opening of the Penninic Ocean is the break of the carbonate platform system. It resulted in a differentiated subsidence when among submarine highs local basins begun forming with continuous but condensed sedimentation in the basin and with no or highly lacunose sedimentation on the highs. The deepening process slowed down or stopped at the end of the Middle Jurassic. It is followed with the shallowing tendency in the Late Jurassic.

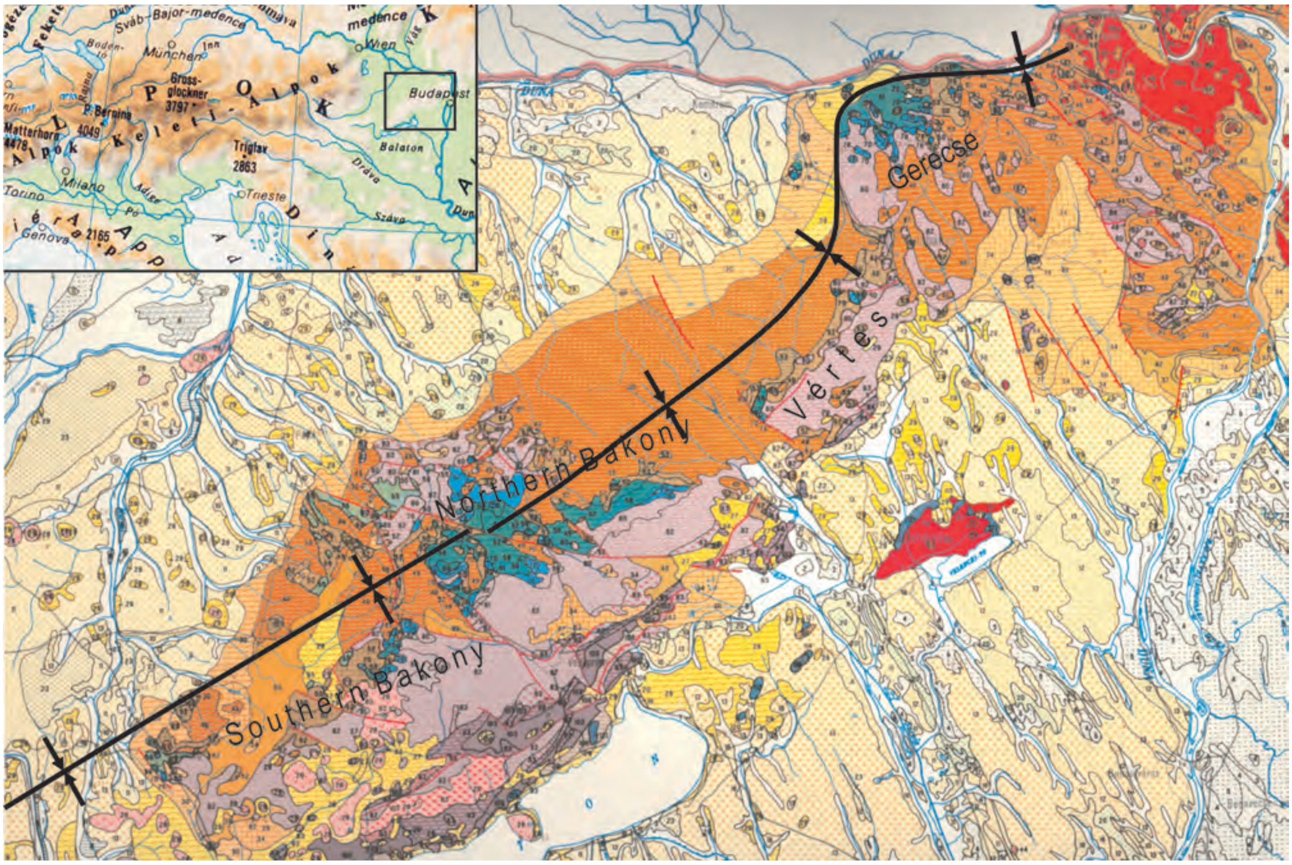


Fig. II: Geological map of the Transdanubian Range without Quaternary and Neogene formations on its central part. Note the axis of the syncline along which Jurassic and Cretaceous formations are preserved in the frame of the Triassic. Detail from the Geological map of Hungary by FÜLÖP (editor in chief) (1984).
Legend of the Mesozoic formations: Triassic is lighter and darker pinkish colour, Jurassic is blue and Cretaceous is green. The Cenozoic formations are represented by numbers as follows: Eocene (50-53), Oligocene (46-49) and Miocene (27-45). The small scale satellite geographic map in the upper left corner offers you a chance to compare how great differences are between the Eastern Alps and the Transdanubian Range from morphological point of view while the stratigraphic composition is very similar.

These events caused by the closure of a branch of the Neotethys Ocean. There is no evidence for the nappe stacking in the Transdanubian Range at this time but there are some hints for it to the north.
There are fundamental changes between the south-western and the north-eastern part of the range, caused by an upwarping in the middle part of the range in the Early Berriasian. Then the evolution of the south-western sub-basin got close relationships to that of the Southern Alps while the north-easterly one to the Northern Calcareous Alps. These two sub-basins united again in the late Early Cretaceous and then stopped again in the Late Cretaceous epoch because of the renewed tectonic activity. In addition to the attractions of a great variety of sedimentary environments determined by the change of extensional and compressional type tectonic movements you will have a chance to see the touristic landscape of the environs of the Danube Bend where the Danube cut into the Miocene volcanic build up and the Balaton Upland to the north of Lake Balaton, the largest lake in Central Europe.

3. Speciality of the Transdanubian Range

Géza Császár

Contrary to the other elements of the ALCAPA unit such as the Eastern and Southern Alps or the Western Carpathians the Transdanubian Range morphologically look like a hilly area with the highest point of 756 m. In spite of this morphologic difference the successions are the same or at least similar to those of Alpine areas. What is unique then in the Transdanubian Range? As it is well known, there is a great difference in facies, in sedimentary environment and in tectonic structure and - as a consequence - in lithology compared with the Northern Calcareous Alps and the Southern Alps. Within the stratigraphic interval involved in the title of the excursion the most characteristic differences are developed in the Upper Jurassic and the Lower Cretaceous. The Northern Calcareous Alps are characterised by the coexistence of the carbonate platform and its foreland basin with varied clastic and carbonate development which became more pregnant in the Rossfeld clastic succession. The most significant nature of the Southern Alps is the Maiolica facies of the Uppermost Jurassic to Lower Cretaceous.
The Transdanubian Range can be subdivided into three subunits which bear a relation to both the East Alpine and the South Alpine facies development.

3.1. The Gerecse Mountains

In the Cenozoic basement the two parts of the subunit are forming a uniform tectono-sedimentary system, albeit no younger than early Early Jurassic formations are preserved in its eastern part (Danube Left Side Block) which is separated by Neogene volcanic and volcano-sedimentary successions. The thickness of the Upper Triassic Lofer cyclic Dachstein Limestone exceeds the 1200 m in the Gerecse, and towards the east it became highly oncoidic in the Buda Mountains and Danube Left Side Blocks between them with basinal formation, and at Csövár-Nézsa environs reef facies developments are forming the margin of the carbonate platform. In addition to the lagoonal and reef facies of the Dachstein Limestone Fm. slope breccia has also developed forming a transition towards the Upper Triassic to Lower Jurassic well-bedded Csövár Limestone Formation of basin facies (Pálfy et al. 2007). The age of these formations is controlled by ammonites (*Choristoceras* and *Nevadaphillites, Psiloceras* respectively).
There is no continuation known to occur into the Jurassic from the Dachstein Limestone. After subaerial erosion the marine sedimentations continued since the Late Hettagian in the Gerecse Mountains. The Triassic carbonate platform started to break into highs and basins already in the early Early Jurassic but this process culminated in the Toarcian and early Middle Jurassic. The outgrowth is a continuous but condensed succession in the basins and highly lacunose sedimentation on the highs (Császár et al. 1998). The fist signal of change in sedimentation is known to have occurred in the Oxfordian (“Oxfordian Breccia“) but a fundamental change passed off in the Berriasian when the carbonate sedimentation started to be replaced by siliciclastic sedimentation. This facies change coincided with the formation of the similar Rossfeld-type succession in the Northern Calcareous Alps.

3.2. North Bakony and Vértes Foreland subunit

The thickness of the Lofer cyclic Dachstein Limestone is rapidly decreasing towards the south-west in the Vértes Foreland and the North Bakony. The easternmost occurrence of the Hettangian oncoidic Kardosrét Limestone is found at Tés-Bakonycsernye environ of the Eastern Bakony. It is also formed under carbonate platform conditions but below the sea-level fluctuation soon after a short break in sedimentation, at the Rhaetian/Hettangian boundary. It lasted longer from the Vértes eastwards. The primary fragmentation of the carbonate platform eventuated in the Sinemurian to Pliensbachian which has generated a facies diversification of the Ammonitico Rosso-type formation between the just developed submarine highs and the slowly deepening basins. This diversification speeded up in the Toarcian and Early Middle Jurassic. The separation of the Gerecse and the South Bakony Basin speeded up in the Late Jurassic when an upwarping occurred in the North Bakony and Vértes area. The Vértes foreland was flooded in Late Aptian to Middle Albian, when the terrestrial sediments, including bauxite and then the Urgonian limestones developed. The transgression was finished at the Late Albian time thanks to the global (?) sea-level rise of about 150 m within a short time interval.

3.3. South Bakony subunit

This subunit is characterized by the thinning of the Upper Triassic Dachstein Limestone which is continuously replaced by the Kössen Formation south-westwards. The Dachstein Limestone is replaced by the oncoidic Kardosrét

Limestone in the Hettangian. The moderate fragmentation of the platform is resulted in formation of a great variety of Ammonitico Rosso-type limestones in the basins, on the submarine highs and above the transitional interval between them (VÖRÖS & GALÁCZ 1998). The submarine highs started to become lacunose from the middle Early Jurassic. In the Early Toarcian thanks to the deep-seated faults manganese ore were formed in some basins. The basins around submarine highs became deeper here in the Middle Jurassic than elsewhere in the Transdanubian Range represented by thick radiolarite and cherty limestone. The same conditions were preserved for the Late Jurassic, but close to its end the Ammonitico Rosso facies was replaced by the Maiolica/Biancone facies typical in the basins of the Southern Alps. This radiolaria-bearing Maiolica limestone was substituted by grey marl (a Scaglia-type sediment) in the western part of the South Bakony while both of them pinched out in the Zirc Basin. The Gerecse and the South Bakony Basins started to be united in the Late Aptian in connection with the Austrian tectonic phase but it was realized in the Late Albian only. A new tectonic phase provoked another overall elevation and regression in the early Late Cretaceous which was followed by westwards tilting and north-eastward transgression.

3.4. The importance of successions from applied point of view

Various types of sedimentary rocks were used during the centuries since the Palaeolithicum and several of them have special economic value also nowadays. The recent ones will be listed hereinafter:

a) A huge mass of the Upper Triassic Dachstein Limestone and the Lower Cretaceous Bersek Marl is used in the lime and cement industry (Stops 1 and 2, Second day).
b) Several types of massive limestone are used as building stone but there are large quarries producing decorative stone, especially in the Gerecse (Pisznice Limestone and Törökbükk Limestone - Stop 1, Third day).
c) The Lower Toarcian oxidic manganese ore are under exploitation at Úrkút (last stop, Fourth day).
d) Bauxite is very common in Transdanubian Range in three levels two of them are Cretaceous. The karstic cavities are developed on Triassic carbonates, including Dachstein Limestone, the cover is either the lacustrine Albian Tés Clay or varied Upper Cretaceous, mainly non-marine sediments. They are opencast and subsurface mines. Unfortunately, none of them will be visited.
e) The Upper Cretaceous Ajka Coal Formation of freshwater to brackish-water peat-bog facies origin contains more than 100 coal seams. A few of them were mined for several decades close to Ajka. Unfortunately, there is no operating open pit mine anymore although dumps are still available.
f) The Upper Cretaceous rudistid Ugod Limestone in the Zala Basin (western continuation of the Transdanubian Range) acts as a hydrocarbon reservoir.

4. The Field Trip

4.1. First day: Jurassic to Cretaceous of the South Bakony and Gerecse western foreland

Today's program

- The geology of Sümeg environs is in the focus of the today's program. Introduction to the geology of the area - including those having no surface outcrops - will be given on the top of the Castle Hill built up of Aptian crinoidal limestone of shallow marine origin.
- At the Mogyorós-domb folded Middle Jurassic deep-water radiolarite, thin Upper Jurassic pelagic limestone and a deepening Lower Cretaceous (Neocomian) succession of Maiolica-type limestone will be seen in a long artificial trench.
- In an abandoned quarry the steeply dipping Aptian Tata Limestone and its covering, flat-lying Upper Cretaceous limestone and marl gave evidences about the intensive tectonic movements passed off meanwhile.
- Last stop of the day is situated in the western foreland of the Gerecse Mts. where the following formations crop out: a) almost complete but condensed Jurassic to Hauterivian pelagic limestone with at least two carbonate breccia intercalations, b) siliciclastic sandstone of Barremian age. This succession itself gave clear evidence that this area from the palaeogeographical point of view represent another subunit than the Sümeg area.

Stop 1: Vár-hegy (Castle Hill) Sümeg
Upper part of the Lower Cretaceous
János HAAS

Sümeg is a nice town at the south-western end of the South Bakony Mts. The medieval castle sitting on the top of a horst made up of Cretaceous limestones is the main attraction of the local tourism (Fig. 1/1). There is an excellent panoramic view from the top of the walls of the fortress providing an exceptional opportunity to introduce the geology of the surrounding area. A NW-SE trending range is visible north-east of the Vár-hegy. It is made up

Fig. 1/1: The steep eastern slope of the Castle Hill with cliffs of the Aptian Tata Limestone.

of Upper Triassic Hauptdolomite that is discordantly overlain by Upper Cretaceous formations and above another major unconformity by a Middle Eocene succession. The so-called urban terrace where the town is situated was trimmed to a subhorizontal face by the abrasion of the Pannonian Lake during the Late Miocene. Under a thin Neogen cover Mesozoic formations occur. Senonian beds crop out locally north of the Vár-hegy and on the Köves Hill south of the settlement. Exposures of Lower Cretaceous, Jurassic and Triassic rocks occur further southwards on the Mogyorós Hill, both of which are targets of the field trip. Bounding the urban terrace westwards, there is a Miocene fault system representing the western tectonic ending of the Bakony separated by the Várvölgy Basin from the Keszthely Mountains. To the north the lowland of the Little Hungarian Plane is visible.

The Vár-hegy is made up of the Aptian Tata Limestone Formation. Core Sümeg Süt-17, drilled at the north-eastern foot of the hill exposed the underlying Lower Cretaceous and Jurassic succession reaching the Upper Triassic Kössen Formation. The stratigraphic column is shown in Fig. 1/2. The Triassic rocks are directly overlain by the Kimmeridgian Pálihálás Formation suggesting uplifted setting of this area during the Early, Middle and early Late Jurassic. It is overlain by the deep marine cherty carbonates of the Mogyorósdomb Formation grading upward into a pelagic marl and siltstone unite (Sümeg Marl Formation) of Hauterivian to Early Aptian age. This is an upward shallowing succession; its upper member is sandy limestone that progresses upward into the crinoidal facies of the Tata

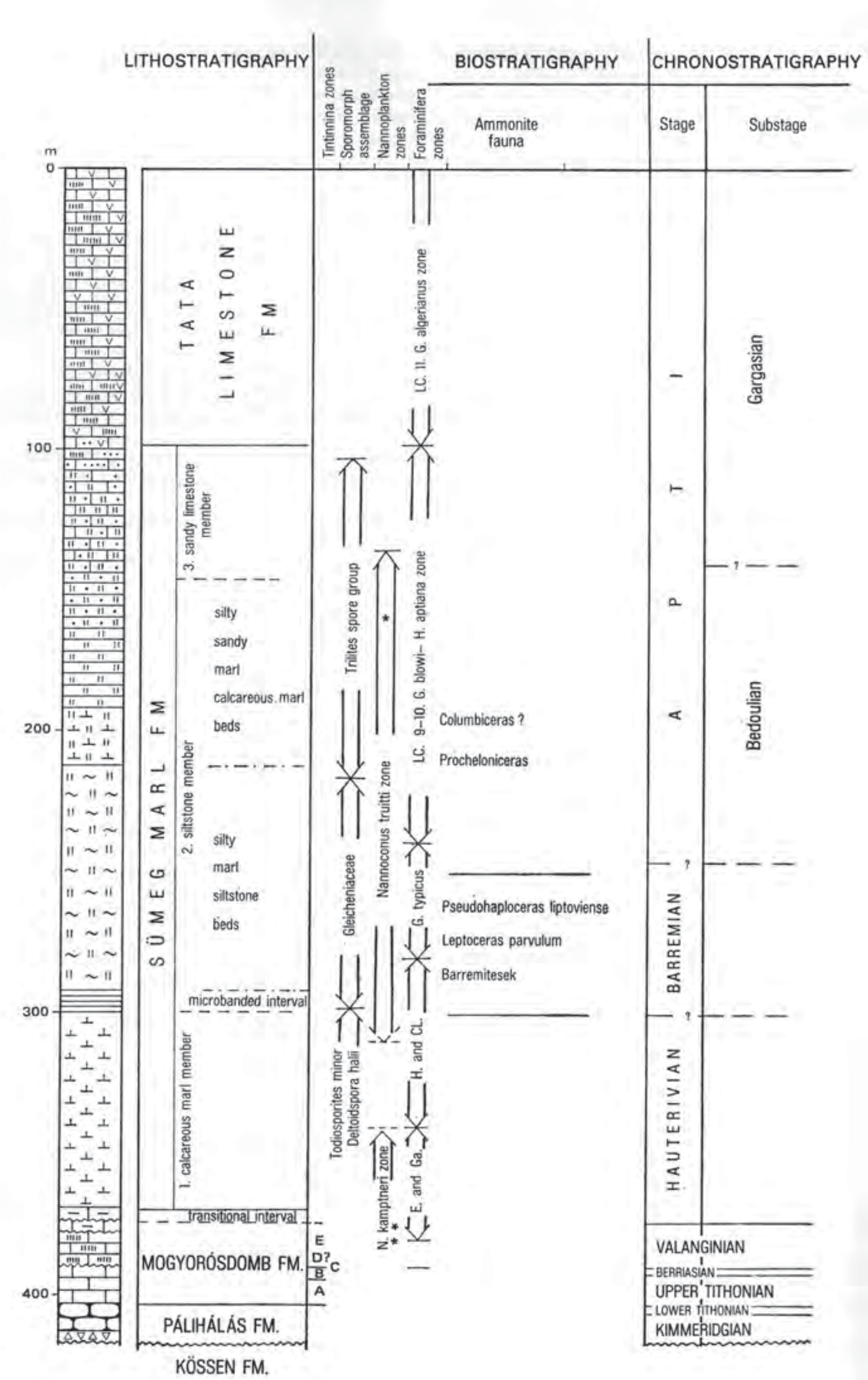


Fig. 1/2: Lithological column and stratigraphic subdivision of core Sümeg Süt-14.

Fig. 1/3: Crinoidal limestone with chert nodules along the road toward the gate of the castle.

Limestone.

Core Sümeg Süt-14 exposed the Tata Limestone in a thickness of nearly 100 m. The rather monotonous yellowish grey limestone consists predominantly of crinoid ossicles 0.1-3.0 mm in size. Foraminifera both planktonic (*Hedbergella*, *Globigerinelloides*, *Ticinella*) and benthic (mostly arenaceous; Orbitolinids also occur) are common. Abraded fragments of corals, bivalves, gastropods, brachiopods and ostracodes were also encountered. Chert nodules, lenses and chertified intervals were commonly found in the upper part of the core section. The cherts are probably of sponge-spicules origin but usually they could not be recognised under microscope. The sand-sized extraclasts are also important components of the limestone; among which the carbonate grains are predominant. Along with the most common fossil-free micritic clasts there are *Calpionella*, and *Bositra* limestone clasts and oolitic grains. Quartz, chert and quartzite grains also occur in a small quantity. The appearance of the carbonate extraclasts indicates the onset of the mid-Cretaceous mountain-

Fig. 1/4: Exposure of the Tata Limestone Fm. in the lower yard of the castle. A large erosional channel is visible that is filled by crinoidal grainstone beds pinching out on the limbs of the channel.

building processes already during the deposition of the Tata Limestone although the main deformation phase took place subsequent to its deposition and consolidation.

Along the road to the castle cherty limestones (Fig. 1/3) akin to those exposed in the core section are visible. Crinoid ossicles and extraclast grains are easily recognisable on the weathered rock surfaces.

The most spectacular exposures are visible within the external wall of the castle in the lower yard of the fortress providing examples of various sedimentary structures developed in the high-energy depositional environment. Just behind the entrance of the castle a large but shallow erosional channel is exposed (Fig. 1/4). It was formed in the high-energy inner ramp probably by a storm-enhanced rip current. Step by step the filling of the channel can also be observed.

Stop 2: Mogyorós Hill, Sümeg

Middle Jurassic to Lower Cretaceous

János Haas

The Mogyorós Hill is located south of the town. On the hill an artificial trench exposes a continuous section from Middle Jurassic radiolarites, through Upper Jurassic Ammonitico Rosso-type limestones to the Upper Tithonian to Hauterivian Mogyorósdomb Formation (Fig. 1/5). The limb of a large scale synclinal structure is exposed that is why the layers are in a nearly vertical position (Fig. 1/6). Harmonic folding could be observed in the section north to the fence of the protected archaeological pits. The unearthed prehistoric chert pits in the Berriasian part of the section provide the best exposure of the Maiolica-type cherty limestones.

At the SE end of the trench black radiolaritic chert layers, representing the topmost part of the Lókút Radiolarite Formation are exposed (Fig. 1/6). Based on a borehole drilled near this place the stratigraphic thickness of the Lókút Formation is about 30 m and it is underlain by *Bositra* limestone of the Eplény Formation. The age of the radiolarite formation is probably Bathonian to Oxfordian but there is no biostratigraphic evidence for this at this locality. It is overlain by light grey marl of 2.5 m in thickness that is assigned to the Oxfordian but it is not proved either.

The next 10 m thick interval is a red nodular limestone, rich in moulds of Ammonites (Pálihálás Limestone Formation) (Fig. 1/6). The limestone is abundant in fragments of *Saccocoma*. Based on Ammonites this formation can be assigned to the Kimmeridgian to Lower Tithonian (Vígh 1984).

It is overlain by the Mogyorósdomb Limestone Formation that is made up of greyish-white cherty limestone. This trench is the stratotype section of this formation. There is a gradual transition between the two formations. Calpionellids (Fig. 1/7) appear in a great number about 1 m above the formation boundary together with the appearence of the chert nodules. Based on Calpionellids the Jurassic-Cretaceous boundary could be recognized about 2.5 m above the formation boundary (Fülöp 1964, Haas et al. 1985). The Berriasian part of the formation is

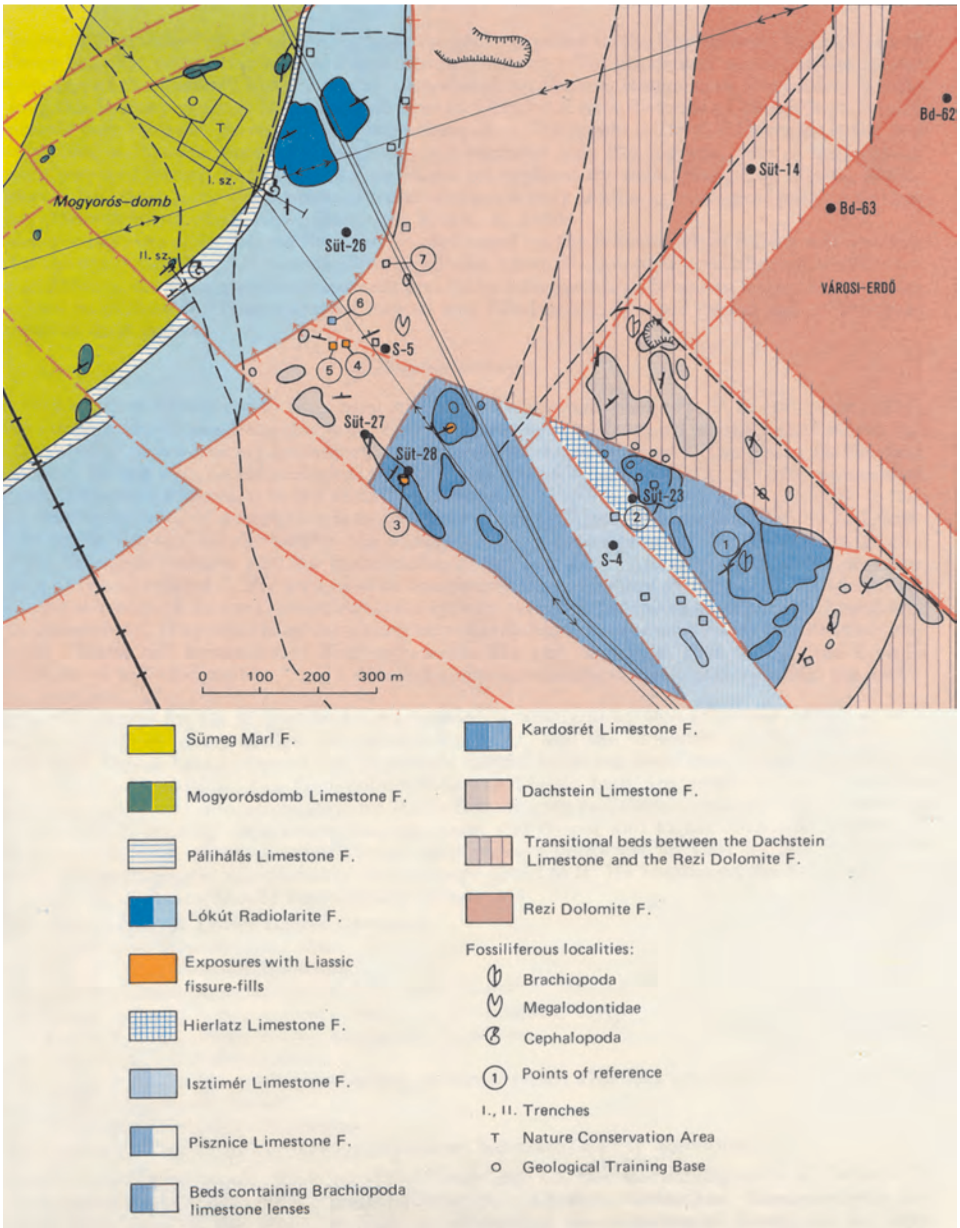


Fig. 1/5: Pre-Cenozoic geological map of the Mogyorósdomb area.

visible within the fenced area. Here limestone, cherty limestone and chert layers alternate. The limestone layers are typified by wackestone textures, although the micritic matrix is made up mostly of Nannoconus. Calpionellids and Cadosinas are also abundant in some of the layers, whereas the others are rich in calcified radiolarians. The radiolaria-bearing beds are usually chertified and contain chert nodules. However, *Calpionella*-rich layers may also be chertified due to diagenetic mobilization of SiO_2. Abundances of radiolarians and calpionellids show rhythmic changes (Fig. 1/8). Statistical analysis of these variations in abundance reveals a composite cyclicity (Fig. 1/9). The alternation of calpionellidae-rich and radiolaria-rich layers may reflect periodically changing surface fertility (the proliferation of radiolarians reflect high fertility conditions - Baumgartner 1987) that was controlled by orbitally induced climatic changes (eccentricity cycles - Haas et al. 1994). A record of productivity cycles is clearest in the Berriasian part of the section where neither facies change nor evolutionary trend of calpionellids masks the ecological effect (Haas et al. 1994).

Based on calpionellids the Valanginian stage was clearly evidenced for the higher part of the succession exposed north of the fence of the archaeological sites. Prints of Hauterivian ammonites were reported by Fülöp (1964) from the more argillaceous topmost part of the section.

The Mogyorósdomb Limestone Formation represents a typical deep pelagic basin facies deposited under the ACD. It is constrained by lack of ammonites, while aptychi occur. However, the depth of ACD in the Early Cretaceous is unknown.

The chert pits were made by prehistoric people 4000 to 6000 years ago during the Neolithic and Copper Ages. They excavated the chert for tool and weapon making. They developed narrow pits along the strike of the beds following the best quality chert occurrences and used stag-horn mining tools.

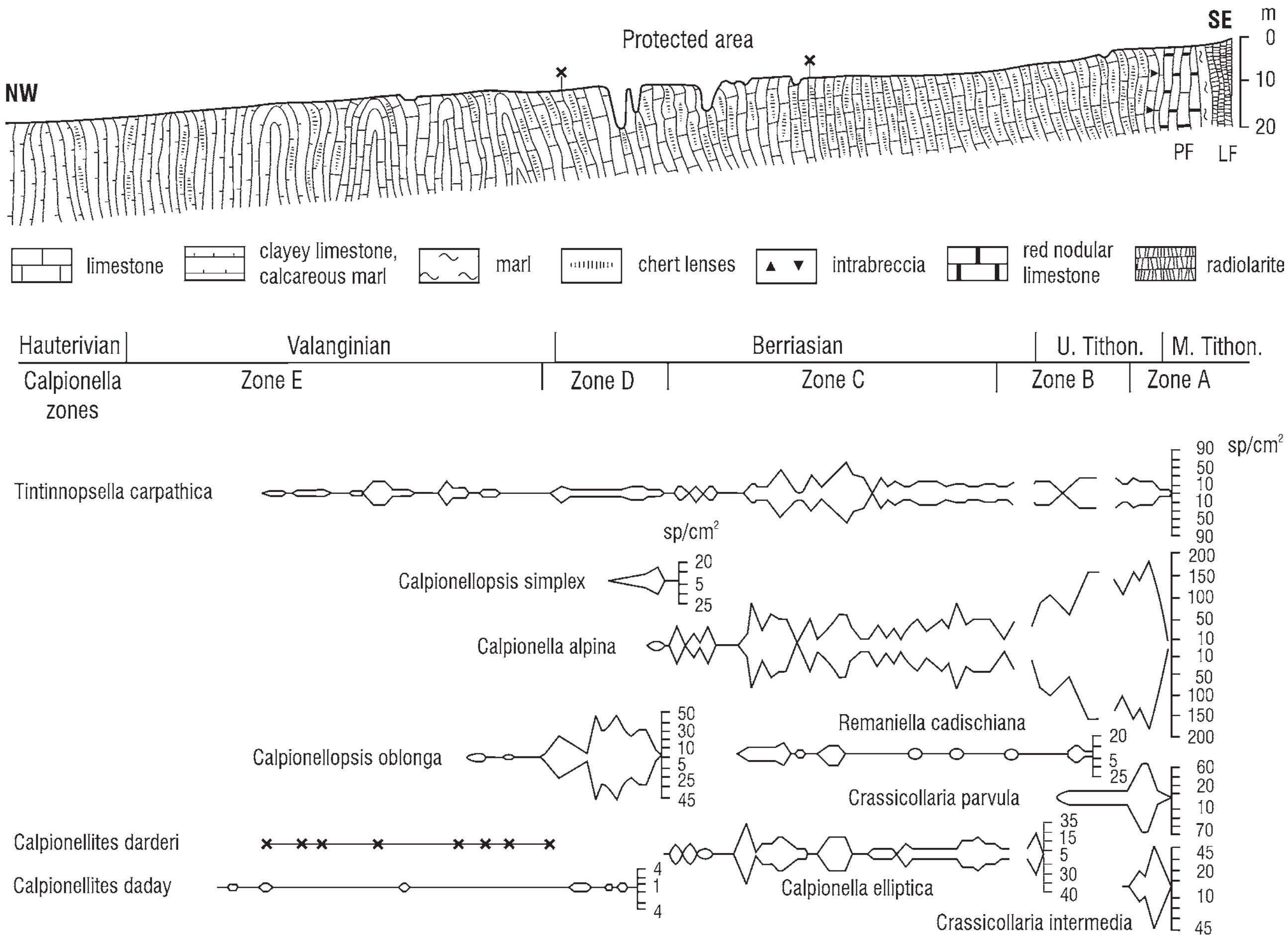


Fig. 1/6: The key-section of the Mogyorósdomb Limestone Formation.
Abbreviations: LF - Lókút Radiolarite Formation; PF - Pálihálás Limestone Formation.

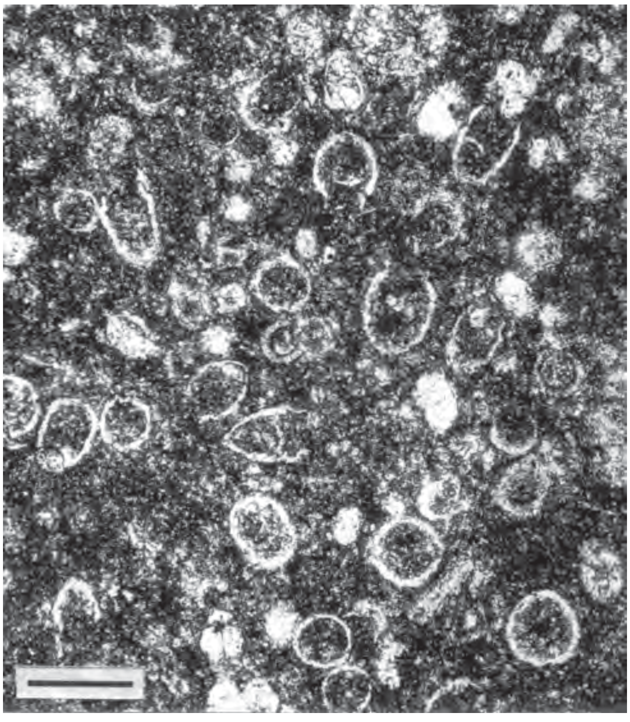


Fig. 1/7: *Calpionella*-wackestone - a typical microfacies of the Mogyorósdomb Limestone. Scale bar: 0.1 mm.

Stop 3: Sintérlap quarry, Sümeg

Upper part of the Lower Cretaceous and Upper Cretaceous

János Haas

The abandoned quarry is located on Köves-domb, in the south-western part of the town (Figs. 1/10, 1/11). At present it is a protected geological trail. Steeply dipping beds of the Lower Cretaceous Tata Limestone are exposed in the western wall of the quarry. In the eastern wall, the angular and erosional disconformity between the Tata Limestone and the Campanian succession is well visible (Fig. 1/12). There is a conglomerate unit at the base of the Campanian sequence that is overlain by rudistid limestone beds containing a very rich and spectacular fauna. In the northern wall of the quarry the rudistid limestone is covered by pelagic limestone layers. The whole quarry records a peculiar local palaeogeographic setting prevailed in the Campanian.

Slightly folded Tata Limestone having a dip of 40-45° is visible in the western wall of the quarry. The rock is composed mostly of crinoid ossicles and other biogenic components (benthonic and planktonic foraminifera, mollusc shell fragments, bryozoans, red algal detritus etc.) and a remarkable amount of sand-sized extraclasts deriving from the deeper part of the Mesozoic succession. The extraclasts deriving from the Kimmeridgian to Barremian

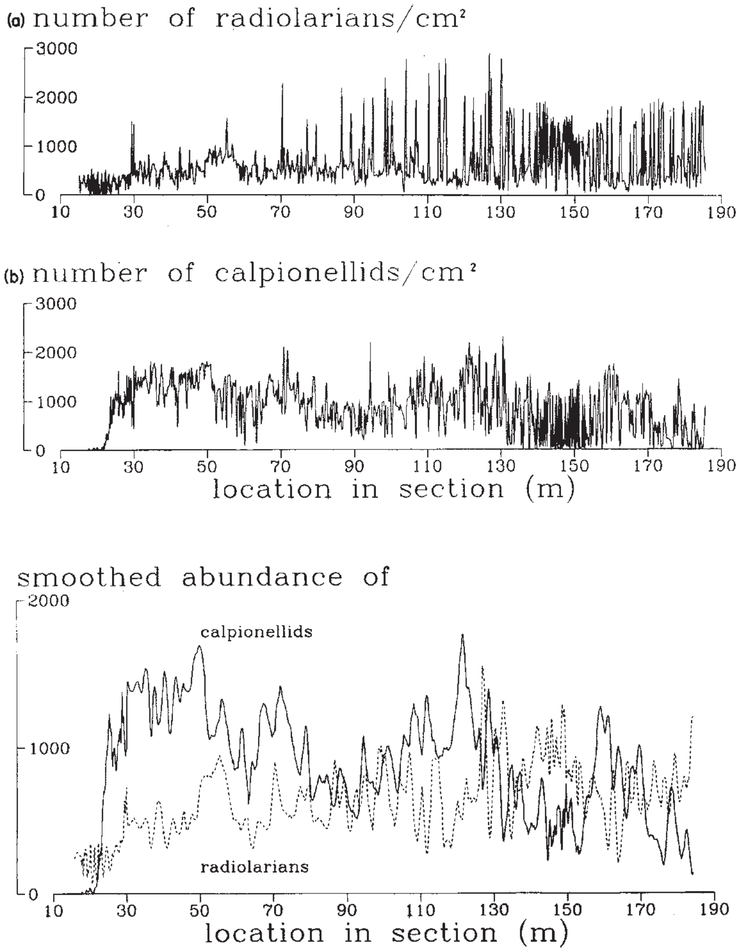


Fig. 1/8: Variation curves of the abundance of radiolarians (a) and calpionellids (b) along the section; smoothed abundance curves of the two microfossil groups.

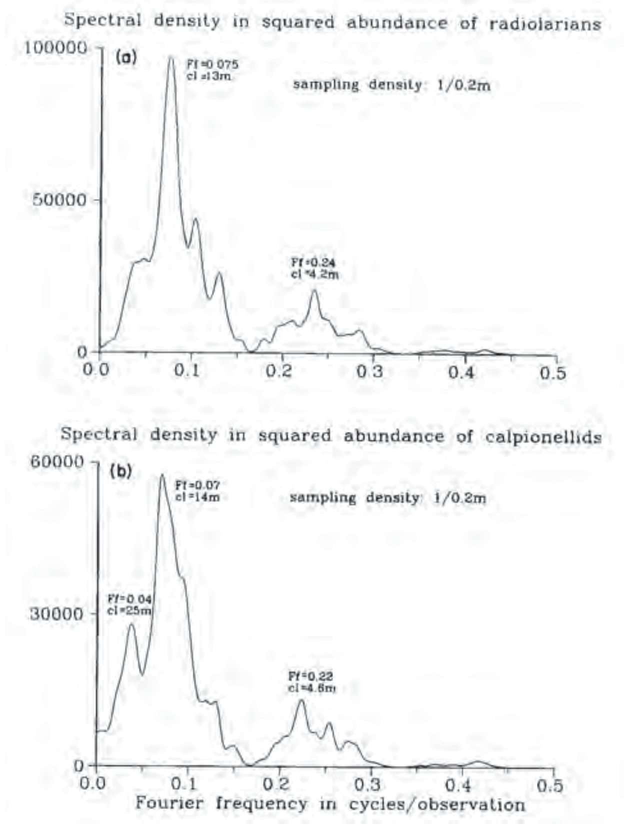


Fig. 1/9: Spectral density in squared abundance of (a) radiolarians and (b).

interval are prevailing. Bioclastic or bioextraclastic grainstones are the typical texture.

Based on core data, the Tata Limestone gradually progresses from the Barremian to Aptian Sümeg Marl of pelagic basin facies in the environs of Sümeg (Haas et al. 1985). Occurrence of *Globigerinelloides algerianus* in these beds indicates Late Aptian age of the formation. The deposition took place in a high energy inner ramp environment. The appearance of Jurassic to Lower Cretaceous clasts in the Aptian deposits suggests onset of intense tectonic movements, coeval with the deposition. The main folding stage, however, took place subsequent to the deposition and consolidation of the Tata Limestone and led to the folding of the whole Jurassic to Lower Cretaceous succession.

The folding was followed by an extensional tectonic phase still prior to the Campanian transgression which resulted in the formation of red calcite-filled fissures, which can be observed at several parts of the quarry.

Pre-Senonian tectonics and connected erosion created an articulated topography that controlled the Senonian sediment deposition for a long time both on regional and local scale (Fig. 1/13). The NW part of the Sümeg area which was located in the axial zone of the synform of the Transdanubian Range was in a relatively deep position. This depression was surrounded SE-ward by a relatively elevated dolomite plateau and a slope linking the two

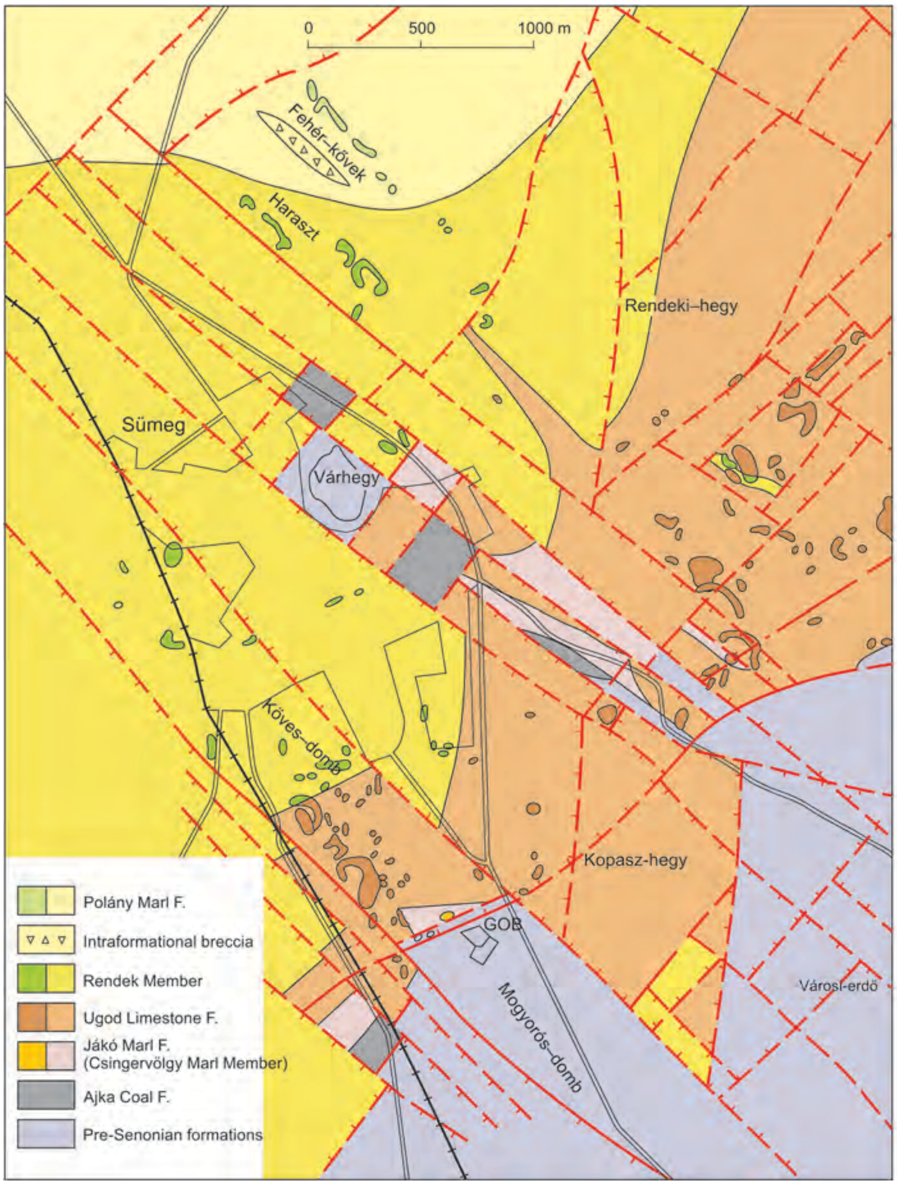


Fig. 1/10: Pre-Cenozoic geological map of the Sümeg area showing the extension of the Upper Cretaceous formations.

morphological units. The Late Santonian transgression started in the depression with the deposition of coal-bearing sequences and extended onto the slope gradually, reaching the dolomite plateau during the Campanian and gave rise to the formation of extended rudist platforms (Fig. 1/14) (Haas 1979).

Palaeogeographically the area of the Sintérlap quarry was located on a gentle slope between the basin and the high. However, at this place a local fault bounded basement elevation developed, which modified the general pattern. Along the southern slope of this small basement block a breccia apron was formed, containing gravel-sized fragments of the Tata Limestone and also the fissure-filling red calcite in Campanian limestone matrix. On the top of the high, the rough surface of the Tata Limestone is directly overlain by the rudist-bearing Ugod Limestone. Northward the rudistid limestone body pinches out interfingering with deeper water argillaceous deposits.

In the south-eastern part of the quarry limestone breccias containing pebble-sized fragments (Fig. 1/15) of the underlying formation and large gastropods (*Trochacteon*) and rudists are visible directly above the Tata Limestone. These basal beds are overlain by argillaceous limestones and marls containing large amount of complete and fragmented rudists (Fig. 1/16). The upper part of the succession exposed in the eastern wall of the quarry is made up of calcarenite-calcirudite with large rudist valves (Fig. 1/17). In the uppermost bed rudist bioherms occur, containing clusters of rudists embedded in life position.

In the northern wall, the Tata Limestone is directly overlain by rudist limestone beds, whereas in the topmost part of the exposed sequence these beds are covered by thin-bedded argillaceous limestones containing pelagic microfossils (calcisphaerulids and planktonic foraminifera) and ammonites (*Pachydiscus* cf. *levyi, Scaphites hippocrepis* - Szives, 2007) that can be assigned to the Polány Marl Formation (Fig. 1/11).

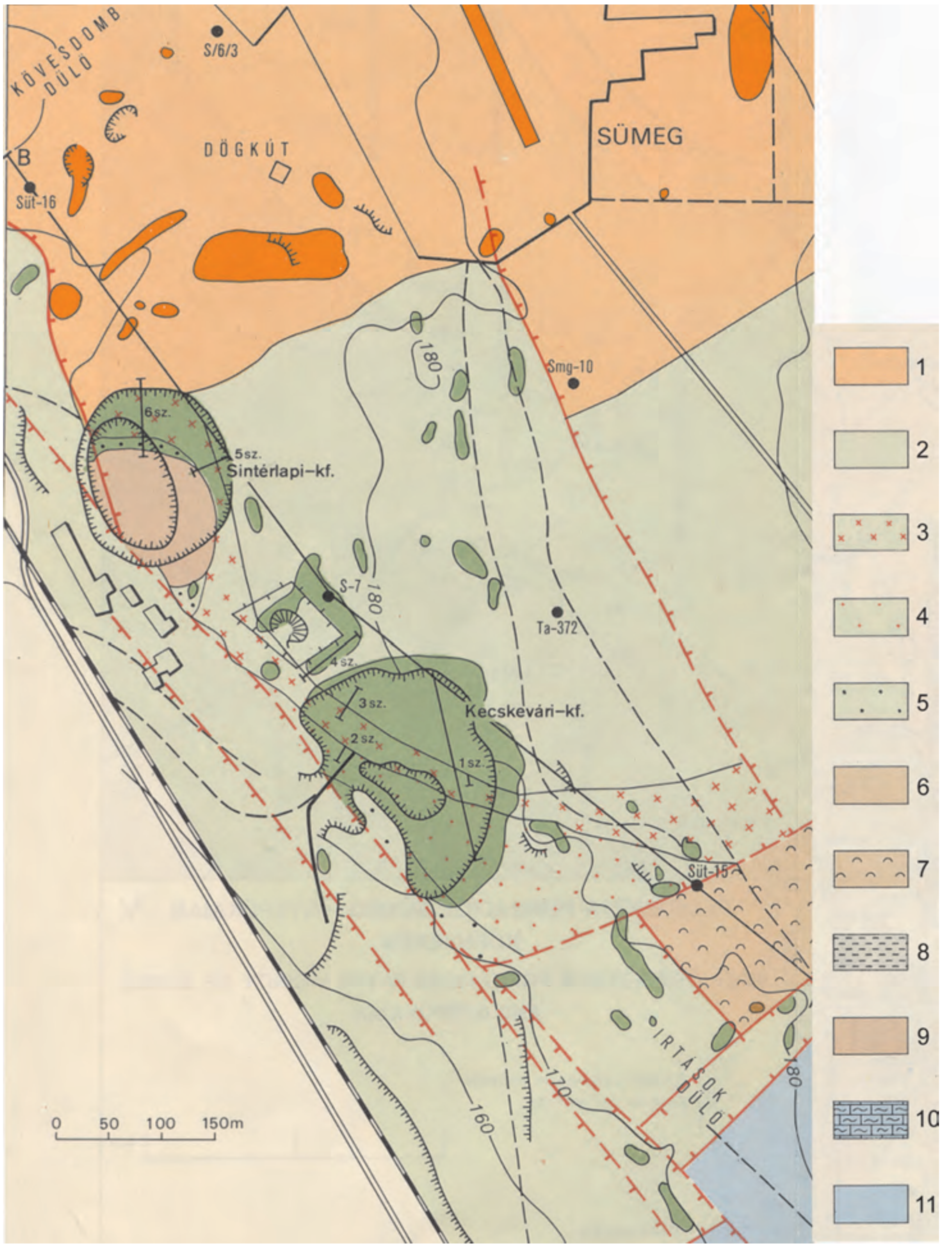


Fig. 1/11: Geological map of the Köves Hill area showing the position of the Sintérlap quarry.
Legend: 1 - Polány Marl Fm., Rendek Mb.; 2-5 - Ugod Limestone Fm., 2 - *Hippurites*-bearing bioclastic limestone, 3 - red and light-grey, bioclastic limestone, 4 - aphaneritic limestone, 5 - extraclastic limestone; 6-7 - Jákó Marl Fm., 7 - Csingervölgy Mb., 8 - Ajka Coal Fm., 9 - Tata Limestone Fm, 10 - Sümeg Marl Fm., 11 - Mogyrósdomb Limestone Fm.

Stop 4: Szomód, Tüzkö Hill
Jurassic and Lower Cretaceous
Géza Császár

The Tüzkö Hill is located at the foot of the western slope of the Gorba High and represented by an almost complete albeit condensed Jurassic succession (Császár et al 1998) with several specialities. The Triassic/Jurassic contact is unknown. The lowermost 3.1 m thick interval of the Jurassic beds are characterized by red colour and prevailingly by sporadic crinoid ossicles, and subordinately (in the upper 20 cm) by crinoidal limestone of Pliensbachian age (Fig. 18A). It is called Törökbükk Limestone Formation. In its lower, wackstone type limestone there is a 20 cm tick glauconite-rich intercalation which is very curious in the Ammonitico Rosso-type Transdanubian Jurassic. The other curiosity of this formation is the high relative frequency of clinopyroxene in its lower bed (B. Árgyelán & Császár 1998).

The Törökbükk Limestone is followed by a 40 cm thick red, clayey, nodular limestone with mudstone to wackestone texture. It may represent a transition towards the Kisgerecse Marl Fm but this interval is covered by scree.
Above the covered part of the sequence another unusual type of rock occur approximately in 5 m thickness (Fig. 18B). It is a thick-bedded light red limestone with plenty of relatively large size of *Bositra* shells oriented parallel to the bedding plane. This type of occurrence is an indication of a currentless environment where in the micritic matrix almost no other micro- and macrofossils can be recognised. The curiosity of this unit is that its lower part is the richest in chrome spinel - its relative frequency is 25%. In spite of the thick-bedded and matrix-rich character this limestone is correlated with the Eplény Limestone typical in the Bakony Mts. It is capped by red,

Fig. 1/12: Steeply dipping beds of the Aptian Tata Limestone disconformably overlain by subhorizontal beds of the Campanian Ugod Limestone.

Bositra-bearing, clayey and nodular limestone of 1 m thickness, with 1-2 cm size of phosphatic nodules impregnated by manganese. It is called Tölgyhát Limestone Fm.

As a result of tectonic disturbance the contact between the nodular limestone above and its overlying radiolarite beds (Lókút Radiolarite Fm.) does not crop out, just its upper 70 cm thick part can be studied (Fig. 18C). This reddish-greyish radiolarite contains a 15 cm thick, breccia-bearing limestone bed in its upper part which can correspond to the “Oxfordian Breccia“. This is a clear indication of the change in the sedimentary environment as the subsidence gave place to elevation. The following 3.0 m thick red limestone is characterized by varied lithology, size, and colour of limestone fragments and many ammonites of varied orientation. It means that the majority of beds are the products of slumps. That is why it requires a lot of effort to determine their ages. The *Saccocoma*-bearing Pálihálás Limestone and the *Calpionella*-bearing Szentivánhegy Limestone occur together. The large part of these rock fragments and in part the matrix too derive from the margin of the Gorba High to the East. In its continuation of the section the size and frequency of the limestone and fossil fragments are decreasing and became obvious that these beds belong to the Berriasian (Fig. 18D). It contains a 10 cm thick breccia bed which is the westernmost occurrence of the Felsövadács Breccia Member that cuts the facies boundary between the Szentivánhegy Limestone and the Bersek Marl as it is also proved in the abandoned small Szél Hill quarry. According to the preliminary results of the ongoing joint study with the team of Hans-Jürgen Gawlick (Austria) this breccia is an excellent marker in the Eastern Alps, the Western Carpathian and the Transdanubian Range. In the breccia in addition to the planktonic fossils Dasycladales can also be found.

Based on the great number of ammonites of the Szentivánhegy Limestone deriving from the Tüzkö Hill outcrop, Fözy (1993) certified the presence of the following Lower Tithonian zones: Semiforme, Fallauxi and Ponti and Berriasian age as well. Knauer (in: Fözy 1993) detected the presence of the following calpionellid zones: A, B, C, D_1, D_2, D_3. In the lower part of the limestone sequence deposited above the Lókút Radiolarite in the matrix and also in the rock fragments of the slump beds, namely appreciably below the Felsövadács Breccia horizon alike can be found remnants of the *Clypeina jurassica* and other green algae. These data denote that not far from the Tüzkö Hill elevated blocks must have been situated in the photic Zone in the Tithonian (C). This idea is supported by the presence of *Lithocodium* and *Bacinella*.

In the uppermost part of the Jurassic to Lower Cretaceous limestone succession (Fig. 19) 1 m above the breccia bed a 30-40 cm thick brownish-red marl with limestone lenses intercalate. This *Calpionella*-bearing pelagic limestone is

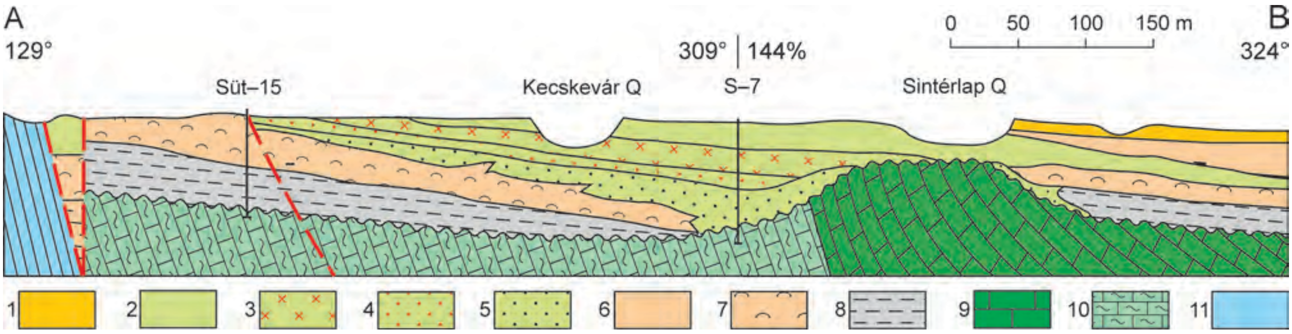


Fig. 1/13: Geological cross section of the Köves Hill area. For setting of the section see Figure 1/11.
Legend: 1 - Polány Marl; 2-5 - Ugod Limestone Fm.: 2 - Hippurites limestone, 3 - red and pale-grey bioclastic limestone, 4 - aphaneritic limestone, 5 - extraclastic limestone; 6-7 - Jákó Marl Fm., 7 - Csingervölgy Marl Mb.; 8 - Ajka Coal Fm., 9 - Tata Limestone Fm., 10 - Sümeg Marl Fm., 11 - Mogyorósdomb Limestone Fm.

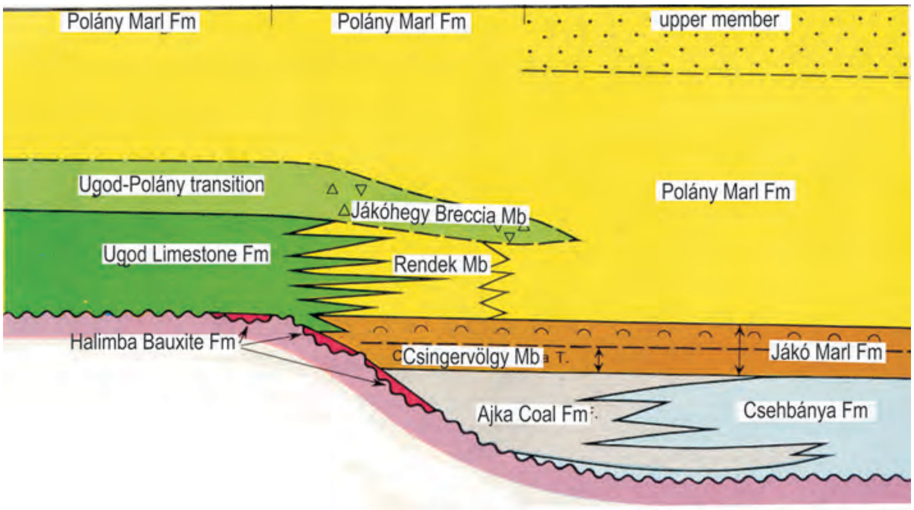


Fig. 1/14: Conceptual cross-section displaying the relationships of the Senonian formation in the Bakony region.

capped by the flysch-like Lábatlan Sandstone Formation.

Looking at the rich shallow marine microfossil association I feel inclined to partly modify the former idea (Császár et al. 1998) about the sources of these fossils. We were convinced that the only source of them was an island arc existed to the north of the Gerecse area. This is the case for the formation of the Felsövadács Breccia in the Late Berriasian/Early Valangian, but the Tithonian limestone was the only type of rock fragments which must have derived from nearer sources. This time the nekton and microplankton association all around the basin areas bears witness to the bathyal zone. The shallowing tendency in the North Bakony and the Vértes area is even more obvious while in the South Bakony (south-westward of the Zirc Basin) the bathyal depth increased.

Fig. 1/15: Basal breccia of the Ugod Limestone containing fragments of the underlying Tata Limestone.

Fig. 1/16: Typical development of the Ugod Limestone - skeletal calcarenite with rudite-sized fragment of rudists.

Fig. 1/17: Rudist bioherm from the uppermost bed of the succession exposed in the eastern wall of the quarry.

4.2. Second day: Upper Triassic platform carbonate, Jurassic basins and highs, Lower Cretaceous clastics, Gerecse Mts.

Today's program

- Lofer-cyclic Dachstein Limestone of Late Triassic age occurs in an active quarry with well preserved cliff.
- Mosaics of the Early Cretaceous foreland basin succession: Berriasian to Hauterivian marls, pelagic limestones and turbidite sandstones (Bersek Marl) as

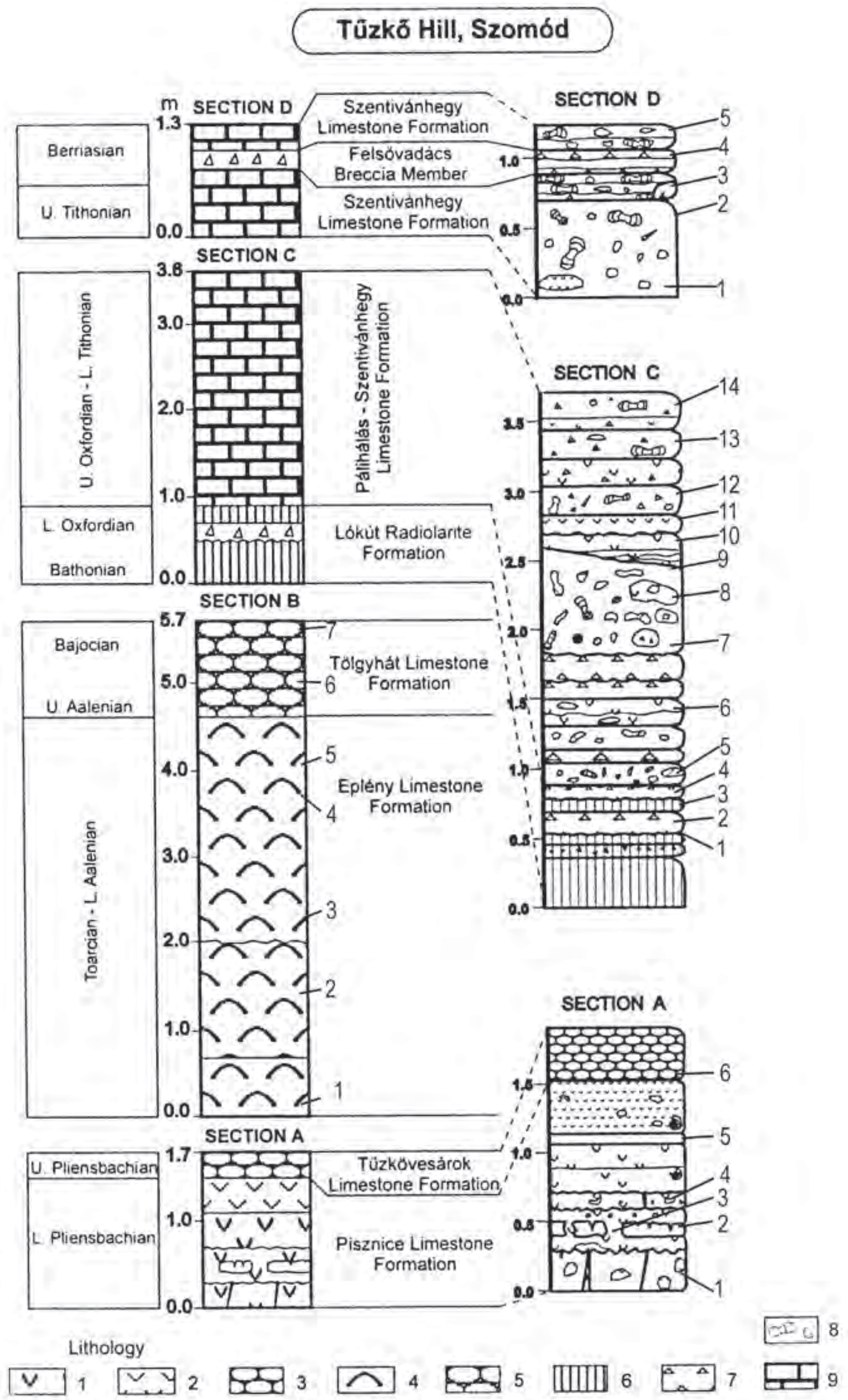


Fig. 1/18: Lithologic columns of the Tüzkö Hill section, Szomód.
Legend: 1 - limestone sporadically with crinoid fragments, 2 - crinoidal limestone, 3 - thin-bedded, red clayey nodular limestone with red clay streams, 4 - *Bositra* limestone, 5 - red nodular limestone, 6 - radiolarite, 7 - breccia, 8 - limestone, 9 - slump with blocks and detritus of various lithological and fossil content.
A) Upper crinoidal and glauconitic part of the Törökbükk Limestone Fm. and its upper transitional bed Tüzkö Hill,
B) Moderate to thick-bedded Middle Jurassic limestone with well preserved, large sized *Bositra* shells and its overlying nodular Tölgyhát Limestone Fm.
C) The upper beds of Middle to Upper Jurassic Lókút Radiolarite Fm. with limestone fragments as intercalation of the "Oxfordian Breccia" and the slump type succession of the Upper Jurassic Pálihálás-Szentivánhegy Fm. of varied size and type of limestone fragments,
D) Ammonite rich beds with decreasing number and size of the rock fragments within the Szentivánhegy Fm. In its upper part of the beds the ammonites are lying parallel to the bedding plane where the Felsövadács Breccia intercalates with its 10 cm thickness.

bathyal slope deposits and overlaying Barremian-Aptian Lábatlan Sandstone of deep-sea fan lobe origin.

- The uppermost deposit of the foreland basin is the Köszörüköbánya Conglomerate, which is a suit of channel-fill conglomerates and sandstones of the mid fan with large rip-up boulders and large fragments of the Early Albian Urgonian limestone derived from the coeval platform margin.
- In a shaft and trench a Kimmeridgian to Berriasian succession is exposed in the form of pelagic limestone and marl. In the latter one conglobreccia beds intercalate as gravitational mass-flow deposit.
- Close to the Gorba High in the Tithonian pelagic limestone a lenticular body of Hierlatz-type limestone is found while a few hundreds of metres away Felsövadács Breccia is preserved within the Berriasian pelagic limestone.

Stop 1: Kecskekö quarry, Lábatlan village
Upper Triassic
János HAAS

In the Gerecse Mts. the best exposure of the Rhaetian upper

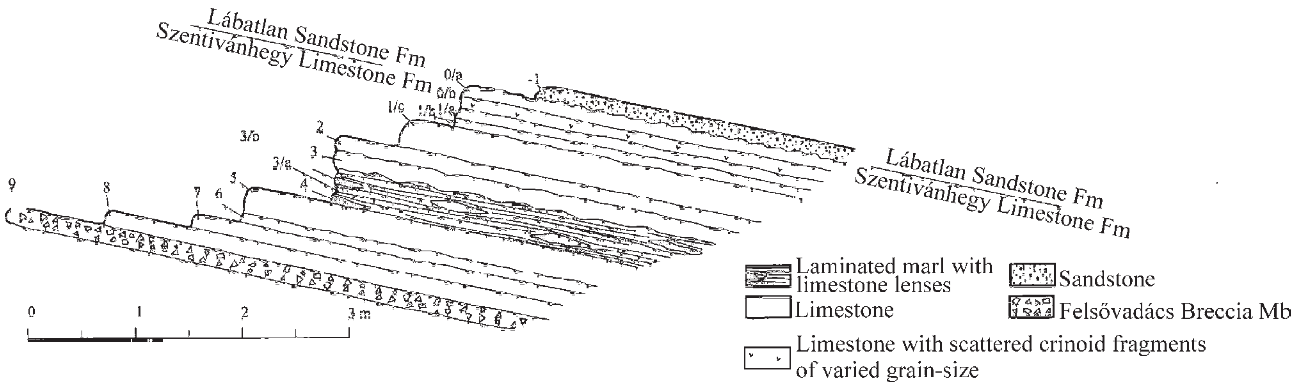


Fig. 1/19: The section showing uppermost beds of the former quarry from the Felsövadács Breccia bed of the Szentivánhegy Fm. with red clay-marl intercalations. The succession is capped by the Lower Cretaceous Lábatlan Sandstone Fm.

part of the Dachstein Limestone (Fig. 2/1) can be found in the Kecskekö quarry. The large exposure made it possible to study the characteristics of the metre-scale peritidal-lagoonal cycles (Lofer cycles) and the features of the cycle-bounding disconformity surfaces and related paleosols in detail.

The quarry is located south-east of Lábatlan in a distance of about 3 km. It exposes an approx. 60 m thick interval of the nearly 1000 m thick Dachstein Limestone. Rhaetian age of the succession is constrained by massive occurrence of the foraminifera *Triasina hantkeni* MAJZON and the rich Megalodontacea fauna (*Rhaetomegalodon incises*, *Conchodon infraliassicus*, *Neomegalodon boeckhi* - VÉGH-NEUBRANDT 1982). Taking also into account the results of the cycle-correlation with proximal sequences of the Jurassic cover (HAAS 1987) the exposed beds can be assigned to the Upper Rhaetian.

In the lower quarry yard the slightly tilted succession is continuously exposed in a length of 300 m without any significant tectonic disturbance (Fig. 2/2). These conditions offer excellent opportunity for the detailed observation of the vertical facies changes and for the study of the lateral variability of the facies characteristics.

The most spectacular feature of the exposed succession is the metre-scale cyclicity (Fig. 2/3). A slightly uneven erosional surface (disconformity) is visible at the base of the cycles as a rule. Traces of karstic solution are common on this surface and there are small cavities in the uppermost (few cm to -dm thick) part of the underlying bed which are filled by reddish or greenish clayey carbonate of the overlying layer. In some places several metre wide erosional channels filled by poorly sorted and commonly blackened

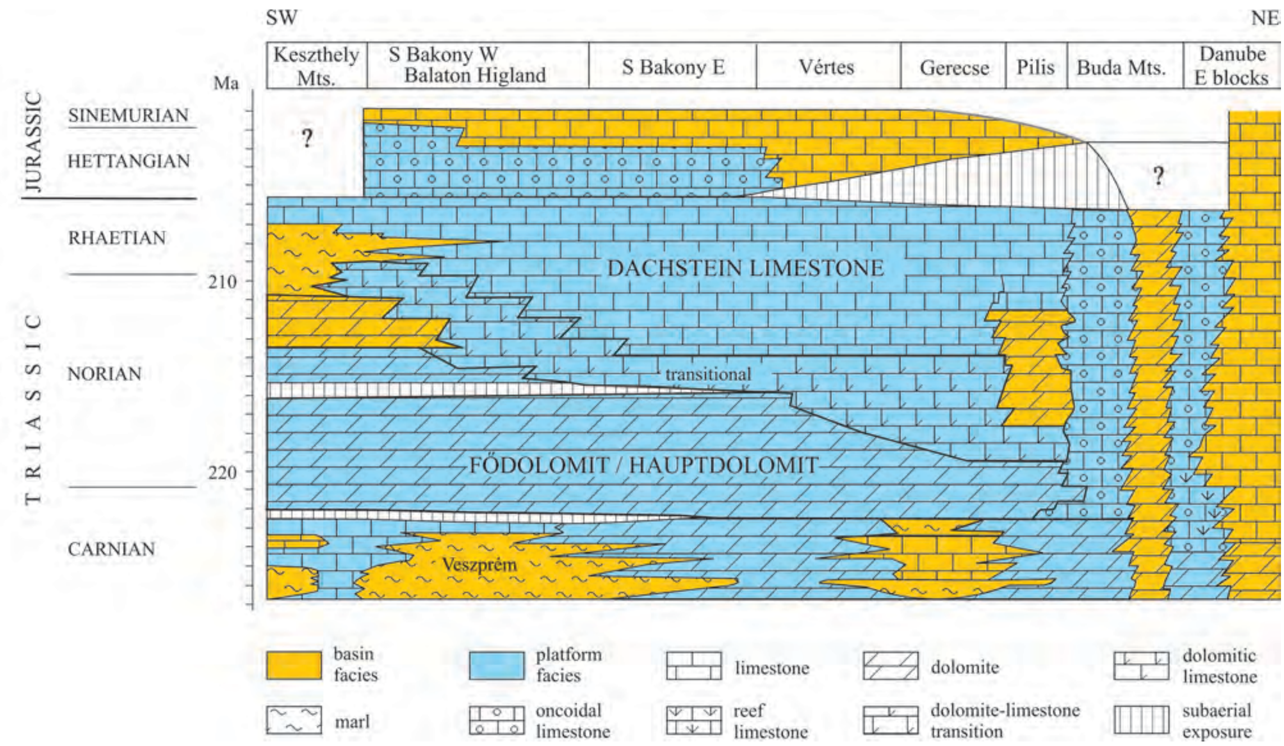


Fig. 2/1: Stratigraphic chart along the Transdanubian Range showing the relationships of the Upper Triassic to earliest Jurassic formations.

Fig. 2/2: The lower yard of the Kecskekö quarry exposes the Rhaetian Dachstein Limestone in a remarkable thickness.

Fig. 2/3: Features of the Lofer-cyclic succession are well visible on the western wall of the quarry. The lighter beds are usually stromatolites (member B), the darker thick beds are megalodont-bearing subtidal beds (member C).

carbonate clasts were encountered (Haas 1995).

The disconformity surfaces are overlain by a pale red or greenish grey clayey marl, marl, calcareous marl, clayey limestone, or limestone layer, in a thickness from a few cm to several dm (Fig. 2/4). These are usually pedogenically altered sediments which were formed on the supratidal belt of the tidal flat during the low sea-level episodes (Member A). Cumulate paleosol beds that may represent longer (higher order) lowstand periods were also encountered. The thickness of one of those exposed in the lower quarry yard is 1.5 m (Fig. 2/5).

Detailed studies of paleosols were carried out by Mindszenty & Deák (1999). Based on macro- and micro-petrographic features they distinguished the following groups:

- Simple greenish clay; it lacks any pedo-features and does not contain clasts.
- Simple calcrete; it is characterised by well-developed root-moulds and minor to moderate microkarst features, with or without thin clay intercalations.
- Simple clayey calcrete with cm-sized carbonate clasts, black pebbles, root-moulds.
- Composite calcrete; a thin clay layer occurs at the base that is overlain by laminated, brecciated or massive calcrete punctuated by erosional surfaces.
- Composite calcrete with intraclasts, abundant root-moulds and microkarstic pores with pendant cement. Ostracode-bearing micritic mudstone layers alternate with 3 to 10 cm thick calcrete horizons.
- Cumulate (amalgamated) paleosol consisting of stacked thin layers of micronodular to wispy clay, mudstone of supratidal pond facies and pedogenicly altered microbial mats. Root-cast and rhizo-brecciation are common.

Detailed section of the cumulate paleosol is presented in Fig. 2/5. Rip-up clasts are visible in the topmost part of the underlying subtidal bed suggesting upward shallowing trend. It is overlain by a light grey carbonate interval with mm-sized calcite filled root-casts that is punctuated by thin

Fig. 2/4: The basal part of a Lofer-cycle is represented by a greenish, argillaceous layer with black pebbles (Member A) above an uneven disconformity surface. This layer is directly overlain by a light-grey subtidal bed (Member C).

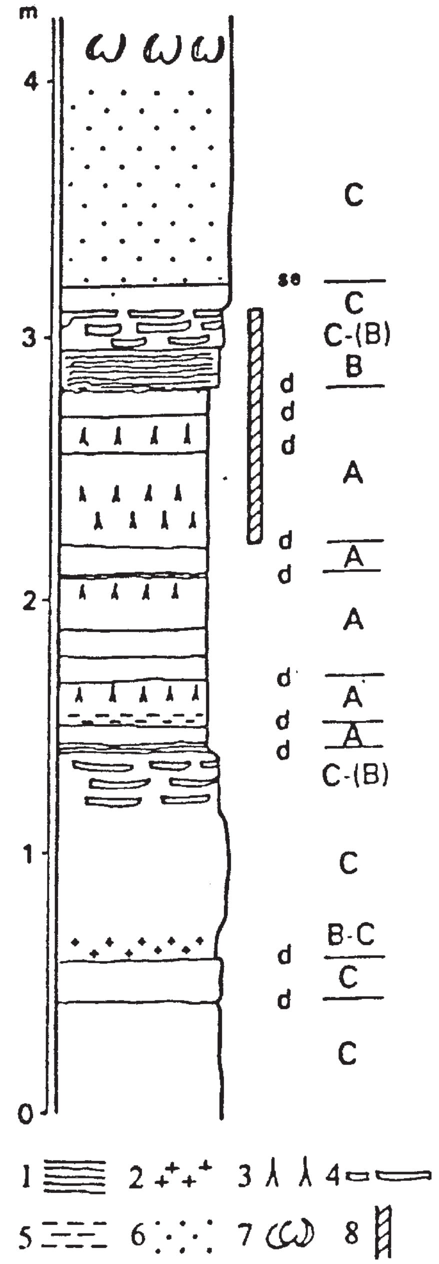


Fig. 2/5: Composite peritidal interval in the lower part of the western wall of the quarry.
Legend: 1 - laminate; 2 - fenestral pores; 3 - calcite-filled rootcasts; 4 - rip-up clasts; 5 - clayey; 6 - calcite speckled; 7 - Megalodontaceans; 8 - pink interval.
Abbreviations d - disconformity surface; se - submarine ravinement surface; A - supratidal facies; B - intertidal facies; C - subtidal facies.

laminar calcrete horizons. The upper part of this grey interval is partially dolomitized (dolomite content is 13%). The upper part of the cumulate paleosol bed is pinkish and also abundant in root-casts. It is overlain by calcretized stromatolite, also of pinkish colour.

Stromatolitic (fenestral laminated) beds or rip-up breccias of stromatolite origin which are typical facies-types of the cyclic Dachstein Limestone (Member B) also occur in some cycles above Member A, but they are commonly missing or they are thin (1-2 dm). However, in one cycle the thickness of Member B riches 60 cm. Pedogenically altered stromatolites are common.

The dark grey subtidal beds are the predominant components of the succession (Member C). They are 1 to 4 m in thickness. Megalodontaceans (fragments or whole specimens) usually occur, in some cases in rock forming quantity and they are in-situ embedded. Mm to cm-sized oncoids are also common in several beds. The most typical microfacies-types are as follows: Biomicrite wackestone or packstone with foraminifera and fragments of bivalves and gastropods, ostracodal or foraminiferal biopelmicrite wackestone and packstone, pelbiosparite grainstone, oosparite grainstone reflecting different hydrodynamical conditions.

The cycles are truncated as a rule. It means that the regressive peritidal members which are usually preserved in the lower (Norian) part of the Dachstein Limestone are missing in the section of the Kecskekö quarry; they probably eroded during the subaerial exposure episodes prior to the onset of the next marine inundation.

According to a number of studies the cyclicity of the Dachstein Limestone is controlled by orbitally forced climatic and related sea-level changes and the metre-scale basic cycles (Lofer cycles) are related to the ~20 kyr precessional cycles (Schwarzacher 1948, Fischer 1964, Schwarzacher & Haas 1986, Haas 1991, Balog et al. 1997). In the Kecskekö quarry (lower and upper yards) 30 Lofer-cycles have been documented (Haas 1987). It means that the exposed interval probably represent a 600 kyr period as minimum. The cumulate calcrete beds may have formed during a time-range of several cycles. They can be interpreted as boundaries of higher order cycles when the sea-level did not reach the level of the platform or only very low accommodation space was created even during the highest levels of the high-frequency cycles.

Introduction to Cretaceous clastics of the Gerecse Mts.
Orsolya Sztanó

By the end of the Jurassic the controlling structural style changed from extensional to compressional (Gawlick et al. 1999, Csontos et al. 2005). The Lower Cretaceous succession was deposited in an under-filled, i.e. flysch-type foreland basin, controlled by south-verging thrusts to the north (in present sense of directions; Császár & Haas 1984). The markable change in depositional style is announced by an important, yet very thin conglobreccia series, product of debris flows carrying clasts of Upper Jurassic limestones, cherts and volcanics into the pelagic basin (Bárány 2004, Császár et al. 2008). The overlying thick series of marls with slump scars, small rotational blocks and very thin turbidite sandstones were deposited on a submarine slope, revealing very slow accumulation and/or bypass (Fogarasi 1995a). Rate of sediment input increased when deposition of turbidite sandstones to conglomerates was initiated, and deep-sea fan lobes with channels had been formed (Sztanó 1990). Siliciclastics derived from obducting and colliding plate fragments, as revealed by ophiolite-derived clasts, metamorphics of a mixed-provenance orogenic belt and coeval reef-debris

(CSÁSZÁR & ÁRGYELÁN 1994, ÁRGYELÁN 1996). The aim of the following stops is to see the clayey slope deposits and the deep-sea fan conglomerates in which fragments of Lower Cretaceous reef and platform limestones also appear in abundance (CSÁSZÁR 2002).

Stop 2: Bersek Hill, Lábatlan
Valanginian-Barremian
Orsolya SZTANÓ

Overview of the main units: In the huge quarry the Bersek Marl and the lower part of the overlying Lábatlan Sandstone is cropping out. The marl can be divided into the lower grey and the upper purple units, which differ not only in colour, but also in lithology, i.e. the grey marl contains cm thick sandstone beds, but these are missing from the purple marl. The most remarkable difference is, however, that the grey marl is deformed: erosional surfaces, large packages of different dip angle and syn-sedimentary faults are present, while beds of the purple marl are laterally persistent, and are not affected by the above mentioned syn-sedimentary faults (Fig. 2/6).

Facies: Both in the grey and purple marls carbonate content varies significantly as reflected by alternations of argillaceous and calcareous marl layers. Occasionally the carbonate content is so high, that some beds can be regarded as "clean" pelagic limestones. Oxygen and carbon isotope signal confirms the variation of the carbonate content as well. The two types of marls make couplets, which based on varying thickness, are organized into larger bundles of about 4-5 and 16-17 pairs (FOGARASI 1995b).
In the marl aptychi and internal moulds of ammonites and belemnites can be collected. The rich, but poorly preserved ammonite assemblage contains forms of *Spitidiscus, Neocomites, Barremites, Phylloceras, Lytoceras, Neocomites and Anahamulina,* providing a firm base of age determinations (FÕZY 1995, FÕZY & JANSSEN 2009). Other macrofossils are not common. Trace fossils are, however, also frequent, particularly in the purple marl comprising a *Zoophycos*-type ichnofacies (*Fucoidea, Zoophycos, Chondrites, Palaeodyction,* etc.).
Sandstone occurs in the lower part of the succession in the grey marl as cm-thick fine- to medium-grained interbeds. In contrary in the upper part of the succession, i.e. in the Lábatlan Sandstone, they form 10-40 cm thick beds where they alternate with fair amount of purple to green silty marl. In both cases sandstones are sharp-based, often poorly graded, various elements of incomplete Bouma-sequences (Ta, Tab, Tabc and Tac) can be observed. Sole marks, like flute and prod marks are also common indicating transport most likely from E to W. The greenish grey sandstone beds comprise thickening upwards units of a few metres (FOGARASI 1995a).

Age: Based on the ammonite, belemnite and nannoplankton biostratigraphy the age of the grey marl is Valanginian, the fossil-rich purple marl is Hauterivian and the sandstone is of Barremian (FÕZY & FOGARASI 2002, FÕZY & JANSSEN 2009).
Synsedimentary deformational structures and their interpretation: In the grey marl the cm-thick sandstone layers commonly contain a set of small, parallel faults, which cannot be followed to the next sandstone bed (Fig. 2/7). The extensional character is clear, and deformation developed when the sandstone beds were partly consolidated (cemented), but the marls were still in plastic state. These small rotated blocks are always found in the vicinity of low-angle erosional surfaces. These surfaces are overlain either by a set of strata parallel with the surface itself or by a set of dipping beds. These beds are also seemingly unconformably overlain by beds parallel to the lower undeformed strata (Fig. 2/8 and 2/9). The low-ang-

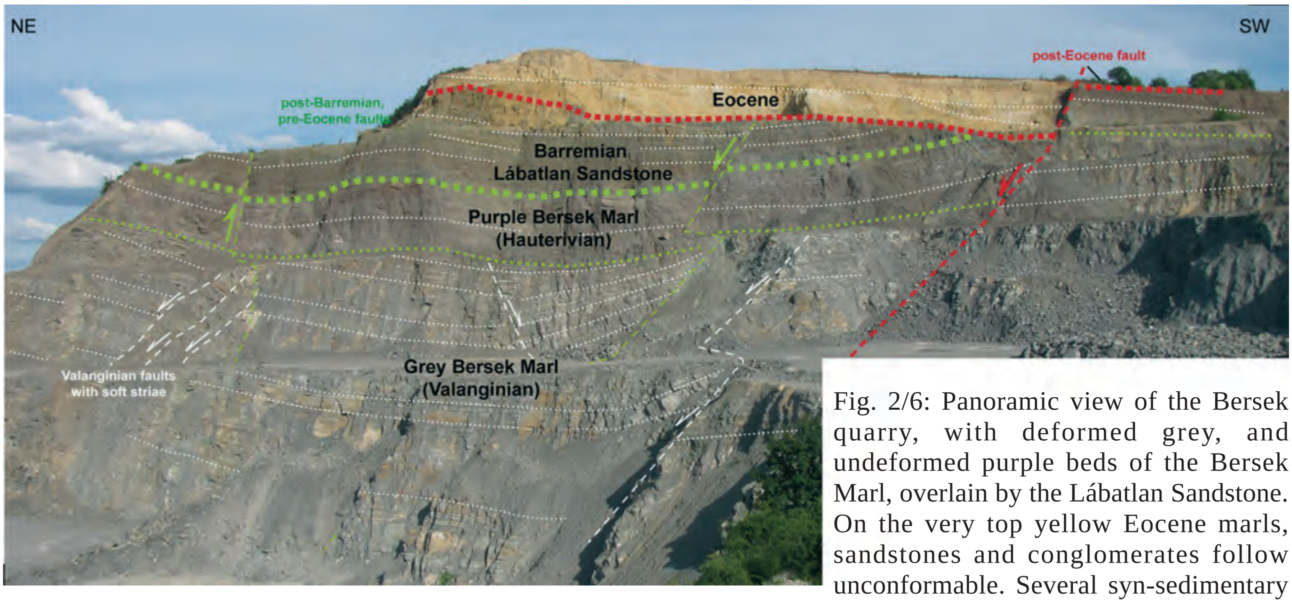


Fig. 2/6: Panoramic view of the Bersek quarry, with deformed grey, and undeformed purple beds of the Bersek Marl, overlain by the Lábatlan Sandstone. On the very top yellow Eocene marls, sandstones and conglomerates follow unconformable. Several syn-sedimentary faults contributed to the deformation of the grey marls, which did not affect the purple marls. (FODOR & SZTANÓ - oral comm.).

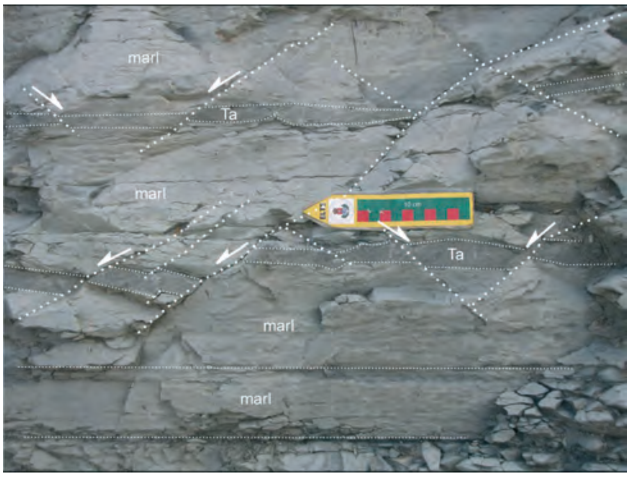


Fig. 2/7: Small normal faults fragmenting and rotating the brittle sandstone layers between plastically deformed, not faulted marl beds (FODOR & SZTANÓ - oral comm.). These indicate gravity-related, i.e. slope directed extension before diagenesis.

the sand dominated series is a wide-spread erosional surface. It is overlain by an internally complex, partly chaotic, partly folded unit of 5 m thickness (Fig. 2/10). It is built up of strata like the overlying undeformed sandstones and marls. The folded unit is understood as a major slump-fold unit. Where it is possible to measure fold axes they dip to NE, suggesting movements towards SW (FOGARASI 1995a).

Sedimentary environments: Palaeo-water depth can be estimated from the presence of the calcite-made aptychi and the lack of aragonite-shells of ammonites. Thus it is inferred that depositional depth might have been between ACD and CCD, whatever that meant in the Early Cretaceous (KÁZMÉR 1987).

The varying carbonate content of the marl is primarily regarded as the result of varying bioproduction in the photic zone, thus may reflect orbitally-controlled climatic forces during the deposition. At the same time fluctuation of precipitation governed both the amount of nutrients and the terrigenous influx to the basin. Therefore “dilution-cycles“ i.e. increasing rate of muddy plumes to pelagic carbonate mud, were also climatically controlled. Based on the cyclo-stratigraphic analyses of clay marl and calcareous marl bed-pairs and bundles of about 5 pairs, it was concluded that the depositional environment was

Fig. 2/8: Small set of rotated blocks within the Bersek Marl, interpreted as a slump-scar (FODOR & SZTANÓ - oral comm.).

le erosional surfaces are mostly part of listric faults of varying size from a few cm to several tens of metres. The oblique bedsets were rotated along the upper segment of these faults, thus small openings developed at the head region, which were filled by beds of different dip.

The common occurrence of these features point to slope instability. Small fissures with cm-scale offset near to head scarps, and several metres to tens of metres long/wide slump scars developed (Fig. 2/8, 2/9). Erosional truncations are mostly related basal slide surfaces, which are small listric faults, fitting finally to the bedding. Toe-thrusts or folds related to slumping are not present in the marl. These morphologic elements can be formed only on submarine slopes, and the presence of the scars with the lack of folds indicates the upper portion of the slope (FOGARASI 1995a). On a larger scale synsedimentary faults with plastic slicken slides and rotations are also present (Fig. 2/6; FODOR & SZTANÓ oral comm.). It is speculated that the increased slope instability during Valanginian was related to steepening, which could have been controlled by structural movements, i.e. activity of major thrust zones controlling basin morphology.

There is another type of deformational structure in the Lábatlan Sandstone. The contact of the purple marl and

Fig. 2/9: Sets of strata with “strange“ dip already recognized by BALKAY (1955). Although the depositional environment and processes were not understood as they are today, a non-tectonic slide-related origin was supposed.

Fig. 2/10: Slump folds at the base of the turbidite sandstones marking rapid deposition and sloping topography again in Early Barremian.

mainly influenced by precession and eccentricity (FOGARASI 1995b).

The cm-thick sand beds in the grey marl were the products of sandy turbidity currents. Their rather coarse grain size and poor grading indicate relatively close source of the currents. The presence of small and larger backfilled slump scars, rotational blocks, and low-angle erosional surfaces point to deposition on an actively forming submarine slope. The bypass and the sedimentation rate as low as 10 mm/ka was characteristic during the Valanginian.

During the Hauterivian synsedimentary structural activity as well as coarse sediment input to the basin ceased. Only horizontally persistent marl beds were present, which do not inform us about the relief of the basin floor. Most likely it became flat.

In the Barremian input of coarse clastics increased significantly. Deposition was mostly governed by gravity mass movements, i.e. turbidity currents, sandy and muddy debris flows. Occasionally slumps also were present. Sandy turbiditic successions known from the Bersek Hill and from small ravines in the Gerecse Mts. comprised only small lobes with low sand to shale ratio. Palaeocurrent directions from E to W (in present direction) were measured from sole marks, while fold axes in the sandy slumps indicates transport towards SW.

In the nearby Neszmély-4 well at least 400 m thick sand-dominated succession was drilled (CSÁSZÁR 1995). It contains massive, thick-bedded turbidites to conglomerates, characterized by high net to gross ratio, revealing a mid-fan environment. The same mid-fan sandstones and conglomerates were also drilled in Lábatlan-36 (ÁRGYELÁN 1995). The topmost, conglomeratic part of the succession - proven to be Early Albian in age - follows above 30 m siltstones (will be studied in the next outcrop). Seemingly a deep-sea fan existed from Barremian to Early Albian. However, the overall thickness is rather small for such a long-lasting fan in an actively fed foreland basin. From sedimentological point of view it is fairly plausible that there was a gap (condensed deposition) between the Barremian and the Late Aptian, which proof (rock record) is not preserved, unfortunately. In the Late Aptian to Early Albian a new fan might have developed.

Stops within the quarry
1. panoramic view point;
2. lower yard: clay-marls and calcareous marls, small extensional features in sandstones, small slump scars;
3. midway: oblique sets and low-angle erosional surfaces at large slump scar;
4. upper yard: large slump folds at the base of sandstone, sandy turbidites, associated trace fossils.

Stop 3: Köszörükőbánya, Lábatlan
Aptian to Early Albian
Orsolya SZTANÓ

Overview of the main units: The topmost part of the Lower Cretaceous siliciclastic succession crops out in the Köszörûkõbánya. In the quarry alternating conglomerate, sandstone and siltstone layers are seen. The Lábatlan-36 well was drilled in the yard, and it was demonstrated, that sandstones and conglomerates similar to those cropping out on the surface and penetrated in the Neszmély-4 well are found below 30 m of siltstones (ÁRGYELÁN 1995, CSÁSZÁR & ÁRGYELÁN 1998). In the quarry three facies associations were distinguished based on grain size, bed thickness and pebble composition (Fig. 2/11). In the lower part thick massive sandstones alternate with siltstones. These are erosively overlain by the major conglomerate body. That is followed by relatively thin beds of alternating sandstones and conglomerates. Finally the upper conglomerate beds with a high portion of limestone clasts are distinguished.

Pebble composition: The bulk of the gravel is well rounded chert with some basalts, and gabbros which together with the chrome-spinells detected in the sandstone beds derived from an ophiolithic suit (CSÁSZÁR & ÁRGYELÁN 1994, ÁRGYELÁN 1995, 1996). The other pebbles are of polycrystalline quartzite sandstones, lithic sandstones, phyllites and dark grey slates arrived from old continental orogenic belts (CSÁSZÁR & ÁRGYELÁN 1994). The third group of clasts is spectacular: they are of hardly rounded fossiliferous limestone boulders (Fig. 2/12) of varying quantity. In the uppermost beds their ratio increases to

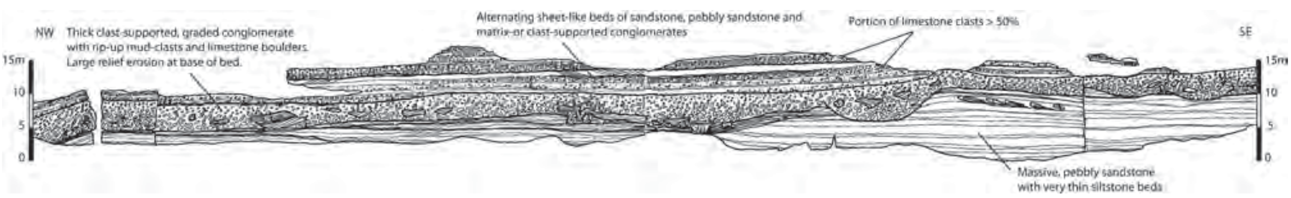


Fig. 2/11: Panoramic view of the facies associations in the Köszörûkõbánya. The quarry wall is perpendicular to the palaeo-transport direction. Note the high relief erosional surface at the bottom of conglomerates (SZTANÓ 1990).

Fig. 2/12: Close-up of a large limestone boulder from the conglomerate.

over 50%. The limestone clasts derived from Aptian to Early Albian lagoons and reefs, which are rich in *Pachyodont* bivalves, gastropods, like *Nerinea,* furthermore hydrozoans and corals.

Age: The siltstones and sandy siltstones either in form of beds between the conglomerates as rip-up mud-clasts contain large foraminifera and nannofossils. Both univocally point to an Aptian to early Albian age (Sztanó & Báldi-Beke 1992, Görög 1995). This indicates that the limestone clasts derived from coeval reefs situating near the shelf margin.

Facies and depositional processes: Grey siltstones are 0.1-0.3 m thick, horizontal massive beds. In one place small-scale slump folds were detected. Siltstones are hemipelagic sediments accumulating between the mass gravity flows. Siltstones also commonly occur in the form of rip-up clasts up to the size of 0.3-1 m within the conglomerates.

Greenish grey medium to coarse-grained, even pebbly sandstones occur both in the lower and upper parts of the succession. Bed thickness varies between 0.3-1 m. They are mostly massive, poorly developed horizontal lamination and poorly developed gradations are also present. Planar cross-bedding was described in a single set. Evident dewatering structures were not recognized. Sandstones were formed by sandy debris flows and/or high-density sandy turbidity currents.

Most of the conglomerates are clast-supported, graded beds (Fig. 2/13). Bed thickness ranges from 0.5-5 m. Sole marks as 0.2 m wide grooves are spectacular (Fig. 2/14). Clast imbrications of a(p) a(i) type is well developed, and is evident on the largest clasts, which are rip-up mud-clasts. The palaeo-transport direction was from NE to SW (in present direction). These conglomerates were formed by powerful high density gravelly turbidity currents, commonly capable of erosion. Matrix-supported, inversely graded conglomerates also occur (Fig. 2/15), which may point to debris flows as well.

The above facies types comprise three main associations. In the lower part, up to an overall thickness of 10 metres

Fig. 2/13: Clast-supported, normal graded, imbricated 5 m thick conglomerate layer. Imbrication is best displayed by large flat rip-up mud-clasts.

massive or graded sandstones, pebbly sandstones alternate with siltstones. The overall geometry is horizontal. The beds are parallel, erosion or incision is not obvious. The next unit is a 5 m thick graded conglomerate, which follows above a pronounced erosional surface with several meter deep incision. Even large sandstone slabs were eroded from the underlying strata and redeposited within the con-

Fig. 2/14: Groove marks at the base of the main conglomerate.

Fig. 2/15: Matrix-supported, inversely graded conglomerate with high amount of limestone clast from the upper part of the outcrop

glomerates. After this major, large-volume mass transport event quantity and power of gravity flows seemingly decreased. Relatively thin beds (0.5-1 m) of sandstones and conglomerate alternated with flat, non-erosive bed contacts. Inversely graded or matrix supported conglomerates also occur in this unit. The uppermost strata are characterized by a high portion of coeval limestone clasts deriving from reefs (Fig. 2/16).

Sedimentary environments: The lower sand-dominated unit may have been deposited as sandstone sheets, i.e. as terminal splays or shallow channel-fills on the middle part of a deep-sea fan. The notable erosional surface is the base of the major channel, which is filled up by thick conglomerates and alternating conglomerates and sandstones. The upwards decreasing bed thickness indicates gradual abandonment of the channel. This feeder channel might have been situated in the mid-fan/upper-fan transitional zone. If the beds cropping out in the quarry are regarded together with those of the subsurface (i.e. drilled by Lábatlan-36 well) the overall high sand/conglomerate to shale ratio reveals a mid-fan without any doubt. The about 30 m thick siltstone (Árgyelán 1995) under the outcropping strata indicates a longer period when clastic input to the basin was at a minimum.

True upper-fan deposits with a large quantity of levee deposits or overbank fines are not known from the area, therefore the proximity of the feeding slope or the source area cannot be estimated. The presence of debrites, however may point to their relative vicinity.

The source of clastics might have been an island arc related thrust belt (Árgyelán 1995), which was rimmed by a unique carbonate platform of Urgonian facies during the Late Aptian to Early Albian time. The marginal reef was composed of coral, hydrozoan and chaetetopsis colonies. Behind the reef in the lagoon rich association of rudists, other bivalves and foraminifera including *Orbitolina* lived (Császár 2002). Limestone debris might be accumulated on the slope as scarp breccias below the steep reef escarpments. When canyon incisions on the slope reached

Fig. 2/16: Normal gradation in clast-supported limestone clast-bearing bed from the upper part of the outcrop.

this area, high amount of carbonate clasts got mixed with terrigenous material carried by passing turbidity currents, and thus both types of clasts were transported to the deep-sea fan in the basin.

Stops within the quarry

1. Close up of the main conglomerate body (pebble composition, imbrications, gradation, and grooved sole);
2. Panoramic view perpendicular to palaeo-flow direction. Incision at channel base;
3. Close up of upper limestone-clast bearing graded conglomerate.

Stop 4: Törökbükk, Lábatlan

Upper Jurassic to Berriasian

Géza Császár

The major aim of this stop is to show the thickest occurrence of the Berriasian breccia of gravitational mass movement origin. The site is found on the north-western slope of the Kis-Pisznice Hill. It is a small natural outcrop which is completed via establishing here a research shaft and a trench (Fig. 2/17). The oldest rock discovered by the shaft is the *Saccocoma*- and a few crinoid-bearing red, slightly clayey, platy Pálihálás Limestone Formation of (Kimmeridgian to) Early Tithonian age with ammonites and belemnites. Among microfossils in addition to the *Saccocoma* among microfossils *Globochaete* and *Cadosina*

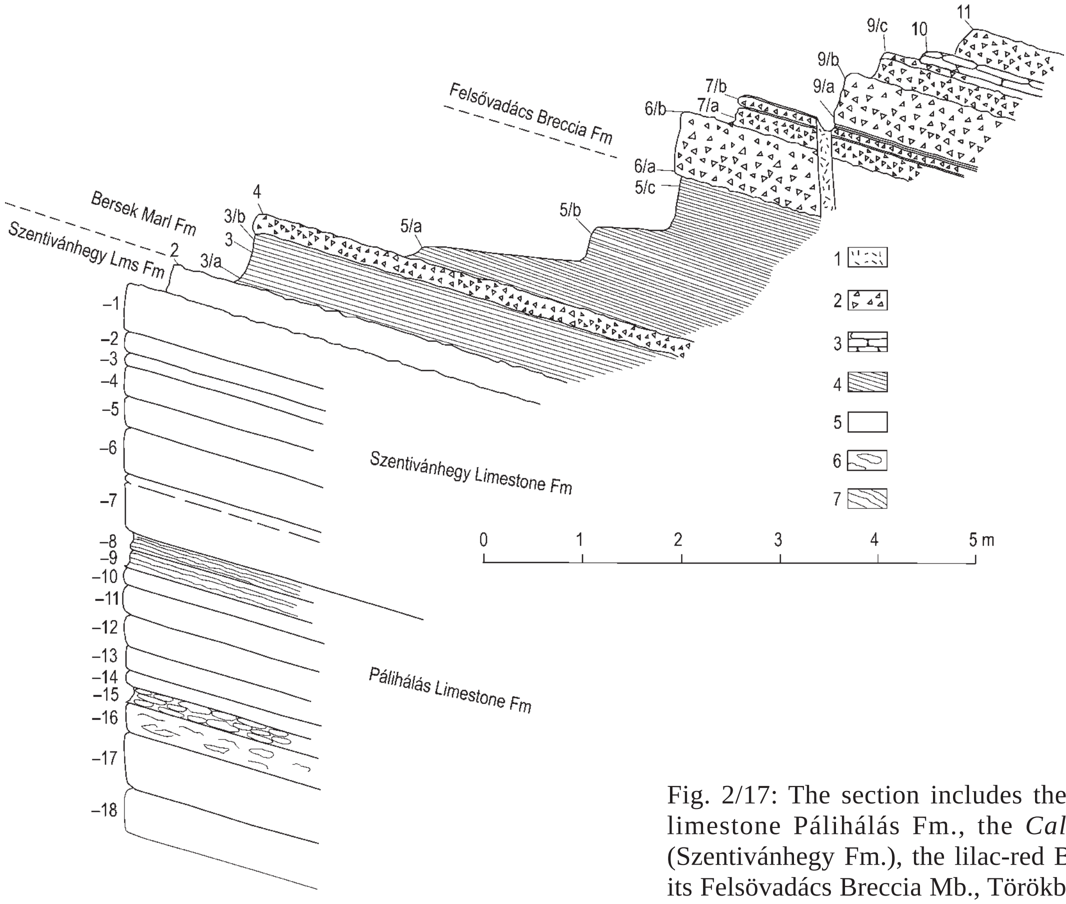


Fig. 2/17: The section includes the clayey, *Saccocoma* limestone Pálihálás Fm., the *Calpionella* limestone (Szentivánhegy Fm.), the lilac-red Bersek Marl Fm. and its Felsövadács Breccia Mb., Törökbükk, Lábatlan.

are the most frequent elements within the wackestone texture. The thickness is unknown, seemingly more than 2.5 m. It is overlain by the red, pale grey to pale lilac-red, platy or medium-banking limestone of wackestone type texture. This Szentivánhegy Limestone of basin facies also contains belemnites and ammonites. In addition to the colour in the microfossil association the *Saccocoma* is replaced by calpionellids. In addition to this there are a few calcareous benthic foraminifera, mainly *Lenticulina* and a few *Cadosina*. The formation is highly condensed, the thickness is 1.2 m. The age of this condensed formation is Late Tithonian to Berriasian, although, the calpionellid zones could not be properly documented. The sedimentary environment is a deep bathyal basin with very moderate water current.

The succession is followed by lilac or brownish-red silty clay-marl or clayey siltstone of 2.5 m thickness. It is part of the Bersek Marl Formation and it contains a fine grained breccia bed of 20 cm thickness close to its base. This bed is part of the Felsövadács Breccia Member which capped the section with its 2.6 m thickness.

The speciality of these breccia beds are as follows:

- the general grain-size is less than 1 cm and the maximum does not exceed 3 cm;
- the prevailing components are limestone fragments, which are often rounded;
- the grain-size distribution is usually random, except the bed no 7a, which is normally graded and shows poorly developed imbrications, except a few cases when they are even measurable;
- the breccia beds are often clast-supported but in some cases red marl occur as matrix which gives a reddish colour to the breccia bed.

The texture of the limestone pebbles is mainly wackestone but grainstone also occur.

At Porckö, 1.5 km to the north in another outcrop the

Fig. 2/18: A discontinuity surface of the Felsövadács Breccia Mb. showing large altered volcanic pebbles or their moulds among the prevailing limestone fragments, Porckö, Lábatlan.

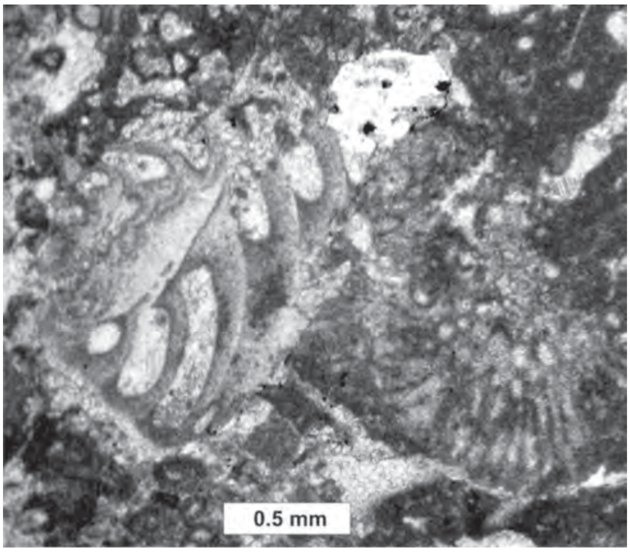


Fig. 2/19: Micrograph of *Mohlerina basiliensis* (MOHLER) benthic foraminifera, Törökbükk section, Lábatlan.

limestone breccia contains quite a lot of well-rounded pebbles of highly altered basic volcanic rocks (Fig. 2/18). Based on the lithological changes it can be supposed that the source rock of the Breccia must have been situated northward.

The microfossil content composed of alga, (mainly green alga), benthic foraminifera, a few crinoids ossicles. The following algae have been identified by SCHLAGINTWEIT and PIROS (in: CSÁSZÁR et al. 2008): *Clypeina jurassica, C.* cf. *estevesi, Salpingoporella annulata, Actinoporella* aff. *podolica,* and *Thaumatoporella parvosesiculifera*. From among the benthic foraminifera SCHLAGINTWEIT & SZINGER (In: CSÁSZÁR et al. 2008) mentioned the following taxa: *Andersenolina* sp., *Mohlerina basiliensis,* (Fig. 2/19) *Protopeneroplis* cf. *ultragranulata, Pseudocyclammina lituus* from here. The Dasycladalean algae and the association of the benthic foraminifera indicate Late Tithonian to Berriasian age. Based on ammonites derived from other places the age can be Berriasian-Valanginian (VÍGH 1984). Similar conclusions have been drawn by FOGARASI (2001 - nannoplankton), by FÖZY (1993 - ammonite), and by BÁRÁNY (2004 - *Calpionellites*).

Three very important aspects to be mentioned (CSÁSZÁR et al. 2008):

1. Similar algae and foraminifera association are found in the matrix and in the limestone fragments. Both the alga and the benthic foraminifera associations derive from a carbonate platform which must have been existed to the north of the recent Gerecse Mts., although the adjacent Gorba High also might have already been a carbonate platform in the Late Tithonian and Early Cretaceous.
2. Basaltic and other volcanic rocks and heavy minerals such as the chrom-spinell could not derive from the Gorba High. This is the case with the dark greyish-green radiolarite fragments which are different from the Middle and Late Jurassic radiolarite in the Gerecse.
3. The formation of the Felsõvadács Breccia is a relatively short event although it consists of series of gravity mass flows with some break between as it is seen in Fig. 2/17). This event is well correlated with the limestone breccia event within the Barmstein Limestone of the Northern Calcareous Alps (GAWLICK at al. 2005, SCHLAGINTWEIT & GAWLICK 2007) notwithstanding that the latter one is a little older, latest middle Berriasian. Similar Berriasian breccias are found in the Western Carpathians: the Nozdrovice Breccia and the Walentowo Breccia (KROBICKI & SLOMKA 1999).

Stop 5: Szél-hegy, Tardos

Upper Jurassic to Berriasian limestone and breccia

Géza CSÁSZÁR

The Szél Hill is situated northward from the village Tardos and it is represented by two Upper Jurassic outcrops. On the northern slope the clayey, nodular, *Saccocoma*-bearing Pálihálás Limestone Formation directly deposited on the

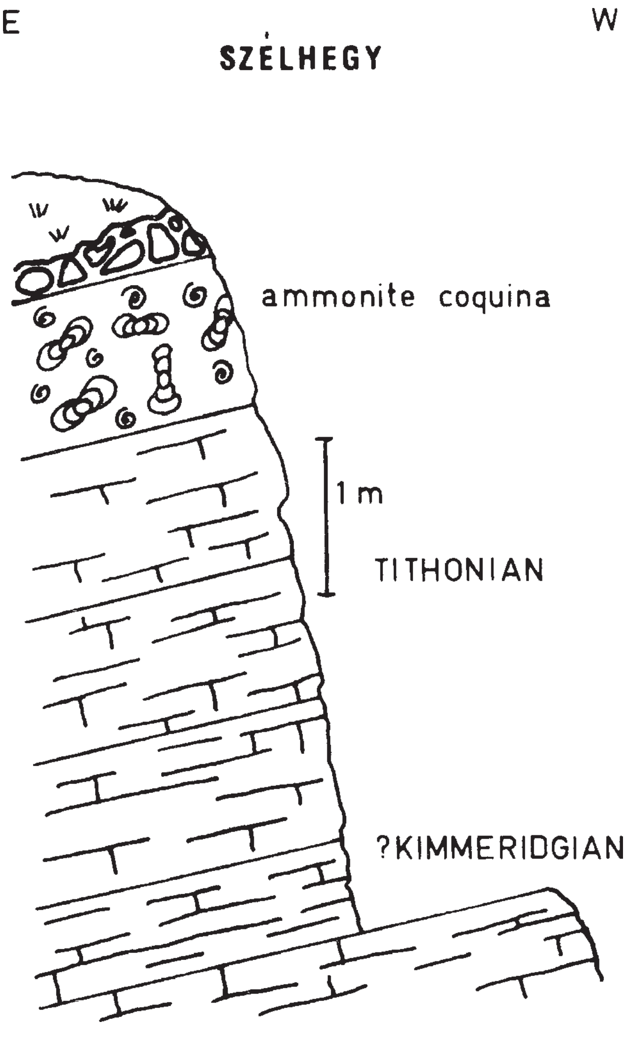


Fig. 2/20: Columnar section of the shaft Szél Hill North (FÖZY et al. 1994). The section is capped by the Hierlatz-type limestone of a dominantly ammonite composition in which crinoid ossicles and fragmented brachiopod shells are also frequent. It is underlain by clayey, thick-bedded Kimmeridgian to Lower Tithonian limestone.

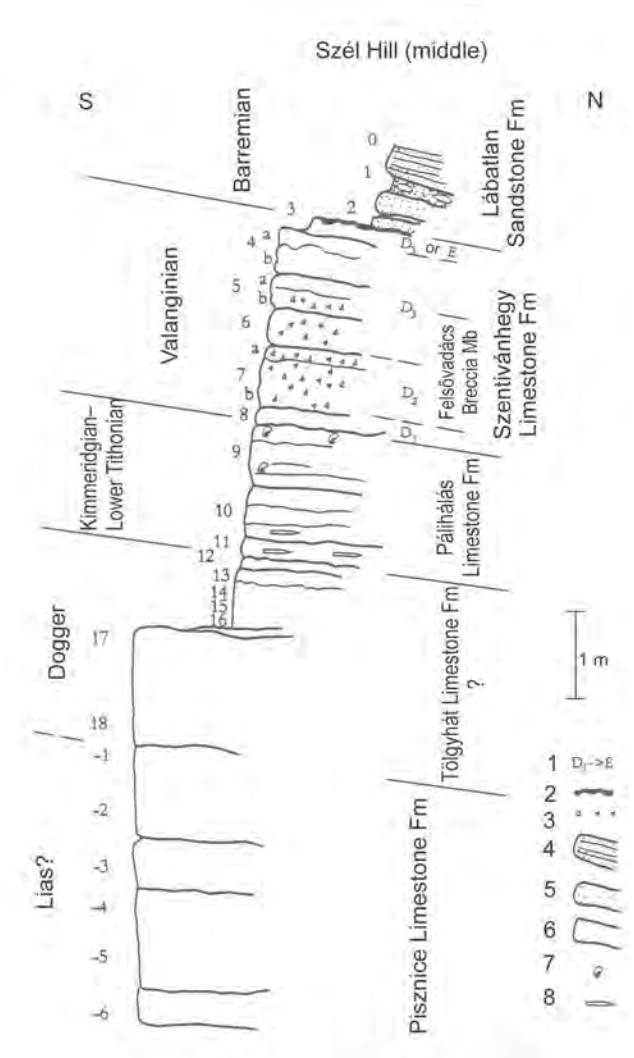


Fig. 2/21: In the considerably condensed Jurassic succession the following formations are exposed: Lower Jurassic Pisznice Limestone, properly not identified (*Bositra*-bearing) Middle Jurassic limestone, well-bedded Kimmeridgian to Lower Tithonian Pálihálás Limestone, Valanginian Szentivánhegy Limestone and Barremian Lábatlan Sandstone. The larger part of the Szentivánhegy Limestone consists of the Felsõvadács Breccia. Abandoned quarry on the eastern side of the Szél Hill, Tardos (CSÁSZÁR et al 1998).
Legend: 1 - Detected *Calpionella* zones; 2 - Stromatolite crust; 3 - Breccia; 4 - Platy sandstone; 5 - Sandstone; 6 - Limestone beds; 7 - ammonite; 8 - belemnite.

eroded surface of the Dachstein Limestone, as it can be seen in the trench.
The specialty of this outcrop is that close to this trench, less than 10 m away there is a shaft in which within (or above) the Pálihálás Limestone a 70 cm thick “Hierlatz Tithon“ (Fig. 2/20) intercalates (KONDA 1991) while in the trench there is not any indication for the presence of this significant formation. This greyish-white or pinkish, lumachelle-like lentil is characterized by a great number of small size ammonites, crinoid ossicles and with much less frequency brachiopods, and bivalves. The ammonites are filled mainly by white calcite and subordinately by red mudstone. After revision of the ammonite collection, collected by VÍGH Gy. (1935) and VÍGH G. (1953, 1978), FÖZY (1993) identified 20 ammonite species and based on the *Semiformiceras semiforme* (OPPEL), *Haploceras verruciferum* (ZITTEL), *Pseudohimalayites steinmanni* (HAUPTMANN), and *Volanoceras* cf. *aesiense* (MENEGHINI) confirmed the Early Tithonian age of this bed. In addition to the ammonites 2 brachiopoda species and 6 bivalve taxa have been identified by KÁZMÉR and SZENTE respectively (in: FÖZY et al. 1994). Crinoids were living on the steps of normal faults on the Gorba High situated to the west, and the non-filled ammonites were accumulated in the crinoids fields. Brachiopods and certain part of the bivalves may have derived from the margin of the Gorba High or in part lived in the crinoidal mud. The slump must have been initiated by a stronger storm and the result is a mass movement of the rock fragments accumulated during stormless time interval. It stopped close to the foot of the slope. The other possibility is that a current initiated by a strong storm swept the fossils and bioclasts from the top of the submarine high, than they continued their way on the slope as gravity mass flow and deposited them near the foot of the slope (SZTANÓ O. oral comm.).
The other Upper Jurassic outcrop is a very small abandoned quarry in the middle part of the Szél Hill, on the upper part of the south-western side-valley of the Szárazkút Valley. The basal part of the succession is composed of a red, *Bositra*-bearing, micritic platy limestone which is a non-typical development of the Middle Jurassic Tölgyhát Limestone Fm. Without radiolarite beds it is directly overlain by the red, platy and *Saccocoma*-bearing Kimmeridgian to Lower Tithonian, like-wise non typical Pálihálás Limestone, the thickness of which is less than 2 m (Fig. 2/21). These beds contain a few ammonites indicating *Hybonoticeras beckery* Zone of the Upper Kimmeridgian.
The *Saccocoma*-limestone is covered by pinkish, violet or yellowish white micritic limestone (Szentivánhegy Limestone Fm.) with a few ammonites, belemnites. Calpionellids,

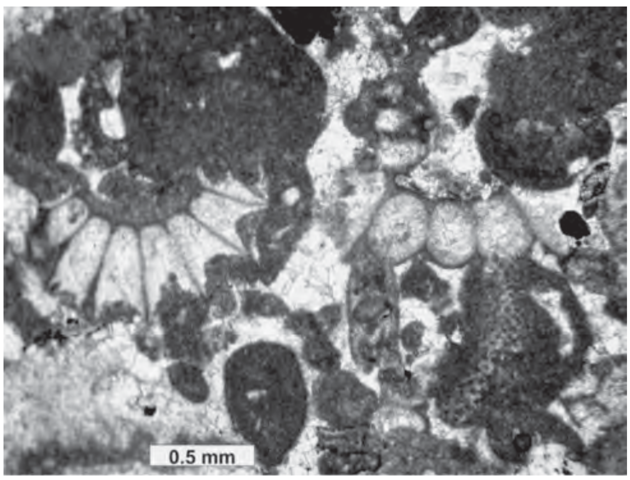


Fig. 2/22: Micrograph showing *Clypeina jurassica* (FAVRE & RICHARDS) Dasycladalean alga in grainstone texture, Tardosbánya Tb-2 borehole.

radiolarians, cadosinids and *Globochaete* are its characteristic microfossils. Based on calpionellids the D_1, D_2 and D_3 zones are proven by E. TARDI-FILÁCZ (oral communication). The exact age of the formation is made uncertain by synsedimentary and early post-sedimentary reworking and minor horizontal fissures. The specialty of this outcrop is that in the larger part of the formation it contains rock fragments typical of the Felsõvadács Breccia: Upper Jurassic to Lower Cretaceous (Berriasian) limestones of platform origin (Fig. 2/22), radiolaria-bearing, Middle to Upper Jurassic small chert fragments and pebble-like varied volcanic rocks. The thickness of the breccia and pebble-bearing beds are more than 1 m. The fact that rock fragments occur in D_2 and D_3 calpionellid zones clearly evidences that the formation of the Felsövadács Breccia is a product of at least two or more events.

The sequence is capped by the Lábatlan Sandstone Formation which was deposited after a long break in sedimentation.

4.3. Third day: Gerecse - Tata Geological Garden, Vértes and North Bakony: Upper Triassic to Lower Cretaceous

Today's program

- In the geological garden (open air museum): From the Upper Triassic Lofer cyclic Dachstein Limestone a thinning upward Jurassic and Lower Cretaceous succession with a deep-water stromatolitic submarine gap between the Berriasian to Aptian.
- Another deeper marine Jurassic succession in the Northern Bakony from the Pliensbachian up to the Berriasian and another type of Aptian crinoidal limestone with no evidences of submarine conditions in between.
- Giant (app. 1000 m deep) Middle Jurassic submarine dykes parallel to the recent Mór Trough.
- Upper part of the Lower Cretaceous sequences deposited after the Austrian tectonic phase including interfingering of the fluvial/lacustrine, fine-grained siliciclastics and the first Urgonian limestone.
- Transitional Lower Cretaceous beds between the 2nd Urgonian limestone and the hemipelagic marl as product of a global sea-level rise.

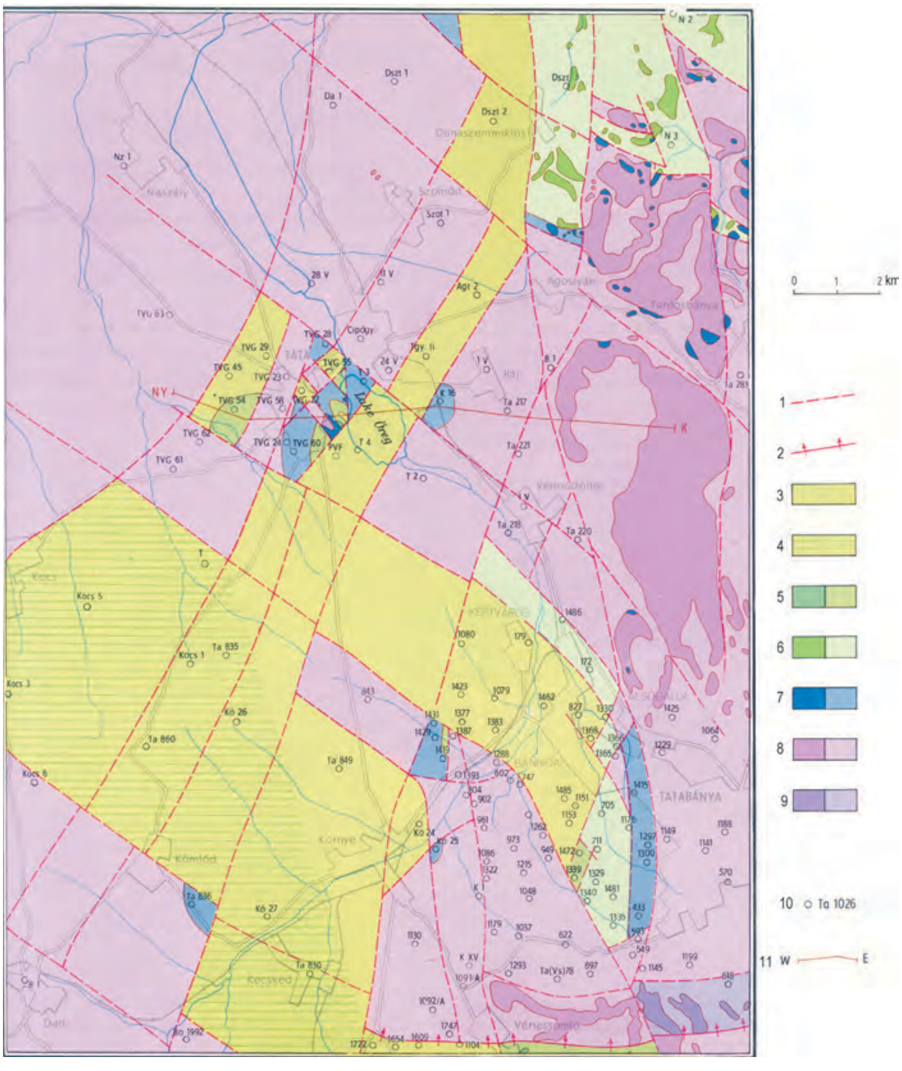


Fig. 3/1: Geological map of the Western Gerecse and its western foreland without Cenozoic formations (FÜLÖP & CSÁSZÁR 1976, modified).

Legend: 1 - normal fault; 2 - overthrust and strike-slip fault; 3 - Lower Albian (Vértessomló Siltstone); 4 - Lower Albian (Környe Limestone); 5 - Upper Aptian to Lower Albian (Tata Limestone); 6 - Barremian to Aptian (Labatlan Sanstone); 7 - Jurassic in general; 8 - Norian to Rhaetian Dachstein Limestone; 9 - Norian Hauptdolomite. Darker shades represent surface outcrops;

10 - Boreholes penetrated Mesozoic formations, 11 - Site of the cross section compiled.

Stop 1: Kálvária Hill, Tata Geological Garden
Upper Triassic to Lower Cretaceous
Géza Császár, János Haas, Balázs Szinger

More than a hundred million years of history of the Mesozoic evolution of the Tethyan realm is recorded in the layers of the Kálvária (Calvary) Hill at Tata (Fig. 3/1), a town 70 km north-west of Budapest, between the Gerecse and Vértes Mountains. On the ruins of a medieval church, located on the top of a projecting cliff, a chapel as well as calvary monuments were built in the 18th century lending the name of the hill.

Kálvária Hill is a small fault-bounded Mesozoic horst. It is surrounded by Oligocene fluvial formations and deposits of the Late Miocene Pannonian Lake. Hot spring activity in the Quaternary led to formation of caves within the horst and patches of travertine in the surrounding area. All these geological phenomena together with prehistoric chert pits are visible in a tiny area, in the central part of a picturesque baroque town, in the neighbourhood of many historical

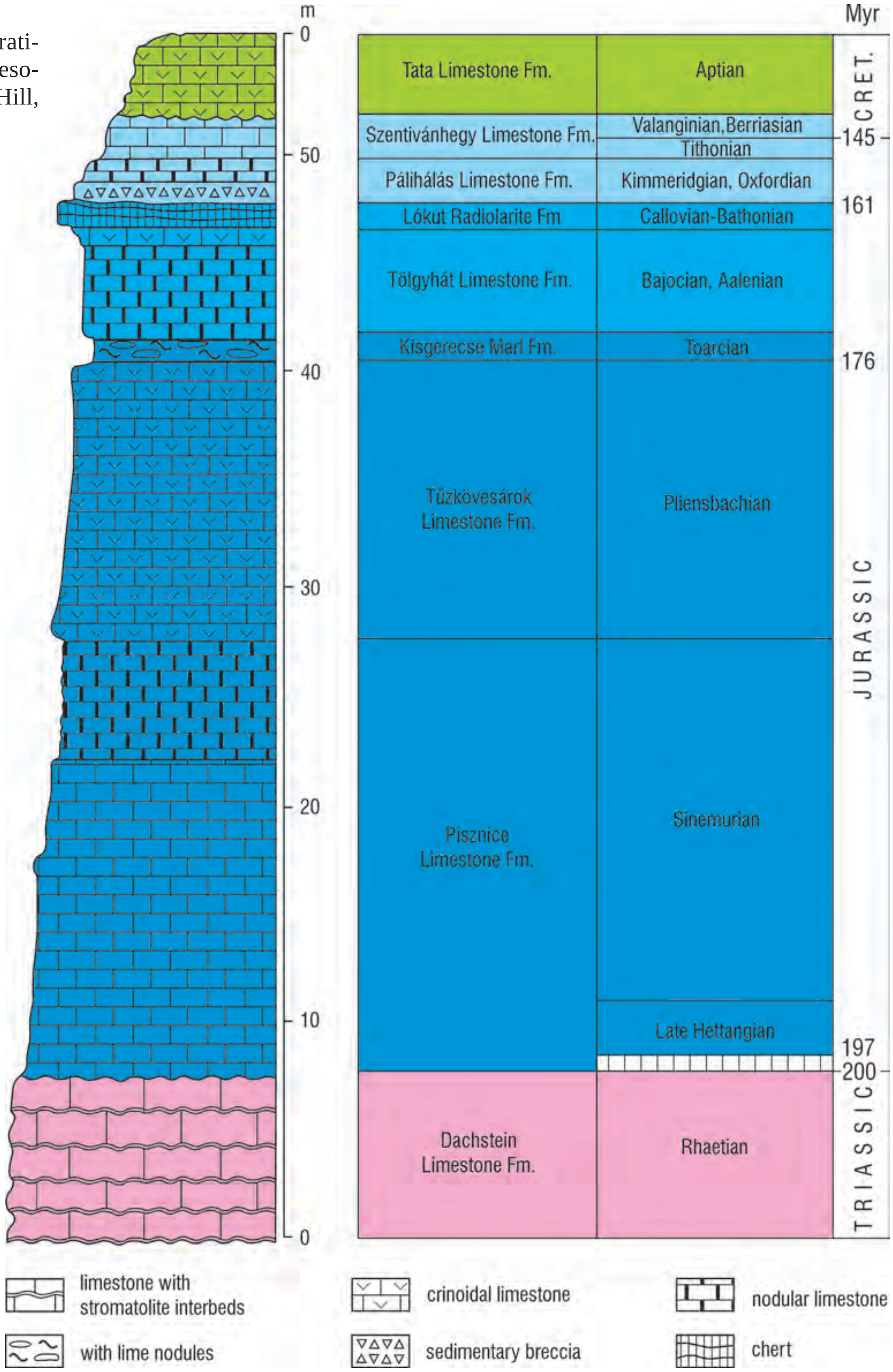


Fig. 3/2: Lithologic and stratigraphic columns of the Mesozoic succession, Kálvária Hill, Tata.

Fig. 3/3: The uppermost beds of the light grey Rhaetian Dachstein Limestone that is overlain by the Hettangian Pisznice Limestone of pinkish colour; there is a sharp drowning boundary and a gap between them.

sites. The geological park, extending to an area of 2.8 hectare is under auspices of the Eötvös Loránd University, Budapest.

The Upper Triassic (Rhaetian) Dachstein Limestone is the oldest formation exposed on the Kálvária Hill (Fig. 3/2). The outcropping beds provide a superb example of the cyclic peritidal inner platform deposits (Fig. 3/3). They show every characteristic of the Lofer cycles described by Fischer (1964) from the type locality of the Dachstein Limestone in the Northern Calcareous Alps. The metre-scale cycles reflect probably high frequency sea-level oscillation triggered by orbital forcing (precession cycle) (Schwarzacher & Haas 1986, Haas 1994, Balog et al. 1997).

In the north-western part of the protected area, four and a half cycles are exposed on the steep wall of a former quarry. A disconformity surface occurs at the base of the cycles, as a rule. A few decimetres thick stromatolitic layer with desiccation phenomena overlie it. Rip-ups of microbial mat origin and tiny black pebbles are common. The thin basal layers are followed by a thicker subtidal one, containing plenty of megalodonts, embedded usually in life position (Fig. 3/4). In the topmost part of the cycles the tidal flat facies, punctuated by subaerial erosion surfaces, returns. The uppermost cycle of the Dachstein Limestone is truncated. The very sharp and surprisingly flat truncation surface commonly cut the megalodonts, suggesting that the erosion had already affected lithified deposits. Solution cavities and moldic pores of megalodonts in the topmost layer are filled by marine sediments (crinoidal limestone) of the overlying lowermost Jurassic layers. Although the truncation horizon appears to be parallel with the bedding planes of the Dachstein Limestone, detailed measurements of the sections revealed that in reality a very low angle angular unconformity does exist (Haas 1995).

The basal layer of the Jurassic series is made up of pinkish crinoidal limestone, 30-40 cm in thickness. It is overlain by a 20-30 cm thick oncoidal bed, containing microbially encrusted fossils, predominantly ammonites and brachiopods. Concurrent occurrence of *Alsatites* s.l. and *Paracaloceras*?, found in the oncoidal bed, refers to an interval from the upper part of the Middle Hettangian to the lower part of the Upper Hettangian (Pálfy 1997).

Based on the previously described characteristics, the following scenario can be reconstructed for the Tr/J boundary interval. Disruption of the Dachstein platform started at the very end of the Rhaetian. Due to sea-level drop at the end of the Triassic, the slightly tilted blocks were probably affected by subaerial erosion. Rising sea-level in the earliest Hettangian led to inundation and hence the hard bottom was affected by submarine bioerosion. Biotic crisis after the massive extinction at the Tr/J-boundary may have contributed to the drowning of the former carbonate platform and the long lasting lag-time during the Early to early Middle Hettangian.

A complete, gently dipping Lower Jurassic succession is exposed in a single continuous section in part of the conservation area, whereas the Middle and Upper Jurassic layers are visible in the upper terrace of the park. So,

Fig. 3/4: Moulds of megalodonts in a subtidal bed of the Lofer-cyclic Dachstein Limestone. The original shells are dissolved and filled by pink mudstone.

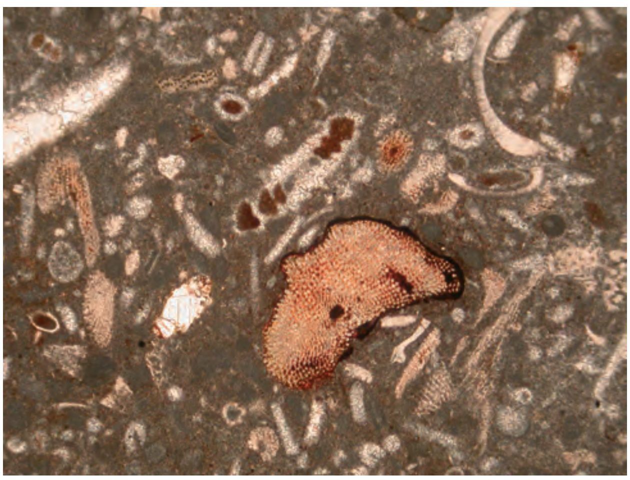


Fig. 3/5: Micrograph of bioclastic wackestone texture of the Pisznice Limestone Fm. in which crinoid ossicles, brachiopods and foraminifera are the main constituents.

Fig. 3/6: Neptunian dike filled by pink mudstone deriving from the overlying Pisznice Limestone with scattered fragments of the Dachstein Limestone host rock.

walking in the park, the visitor may get an impression of a typical Mediterranean Jurassic sequence. The stratigraphic subdivision of the 43 m-thick sequence is presented in Fig. 3/2.
The basal beds are overlain by about 10 m-thick, light pink, thick-bedded limestones (Pisznice Limestone). Along with the scattered crinoid ossicles, benthic foraminifera are also common (Fig. 3/5). In these beds, dm-size lens-shaped filled cavities (stromatactoid structures) occur, parallel with the bedding. In the lower part, these cavities are filled by bioclastic wackestone and mudstone internal sediment, while in the upper part they are lined by fibrous calcite and filled by drusy spare.
A well-developed network of neptunian dikes cuts the Dachstein Limestone and the lowermost Jurassic beds and peter out within slightly nodular upper beds of the Pisznice Limestone. The dikes may reach 20-30 cm in width. The walls of the fissures are usually lined by sparry calcite whereas pinkish micritic sediment containing pieces of the host rock fills the inner part of the fissures (Fig. 3/6). Formation of neptunian dikes was connected to the extensional tectonics prevailed in the Early Jurassic. In the first evolutionary stage the fissures were lined by sparry calcite and filled by infiltrated marine carbonate mud, and laminated peloidal lime mud probably of microbial origin. That was followed by injection of mud into minor fractures, pre-existing voids, dissolution cavities of the host rock probably as a result of seismic shocks (Lantos & Mallarino 2000, Lantos 2004).

Fig. 3/7: Borrowing traces in a restricted upper horizon of the Pisznice Limestone Formation. Note that the red marl infillings within the not real tubes, penetrating two or three beds, are always perpendicular against the bedding planes. Kálvária Hill, Tata.

The 4 m-thick middle member of the Pisznice Limestone is made up of well-bedded, somewhat darker pink limestone with brachiopod and lenses of crinoid sand. It is overlain by about 6 m thick red limestones, resembling the “Ammonitico Rosso“. Uneven, commonly stylolithic bedding planes punctuate it. The layers are equally rich in brachiopods and ammonites and small-sized, mainly plasticlasts or reworked internal rock fragments of angular shape occur in various levels of the beds. They are perfect indications of the frequent storm events that often generated currents. Significant elements of this interval are the abundant tubular casts of “burrowing organisms“ (Fig. 3/7). They are exclusively perpendicular to the bedding planes and often penetrating two or three beds which are usually separated by red clayey hardgrounds.

Fig. 3/8: Red, nodular to lenticular limestone with intercalating clayey crinoidal lenses with borrowings in the middle of the photo. Both the underlying and overlying beds are crinoidal limestone with scattered rip-up clasts, Pliensbachian Törökbükk Limestone, Kálvária Hill, Tata.

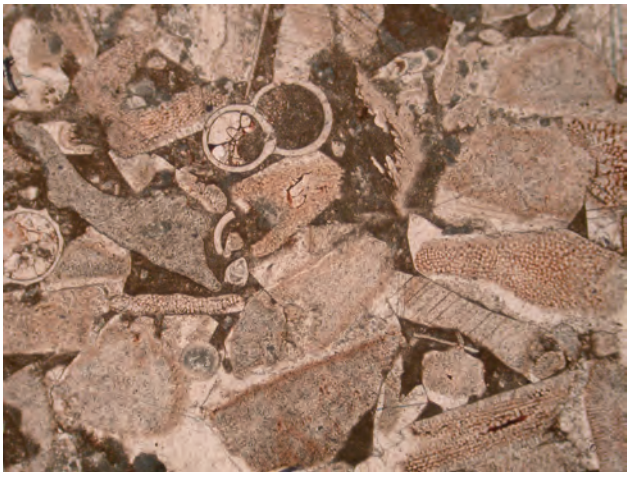


Fig. 3/9: Micrograph showing crinoid ossicles in rock forming quantity with calcareous benthic foraminifera in the Törökbükk Limestone of Pliensbachian age.

The upper boundary of the burrowing always coincides with these clayey horizons where the burrowings end upwards. Little is known about these organisms but based on the data mentioned above they must have produced their holes in consolidated rocks. Based on ammonites, this member was assigned to the Upper Sinemurian (GÉCZY in FÜLÖP 1975).

The next unit of the Lower Jurassic succession is made up of red unevenly crinoidal limestone (Törökbükk Limestone Fm.) of Pliensbachian age. It is characterized by an intensely bioturbated structure (Fig. 3/8) and a rich shallow-marine microfossil assemblage with crinoids, benthic foraminifera, sponge spicules and ostracods (Fig. 3/9). Its basal beds are characterized by ferruginous and manganese nodules of a few mm in diameter that developed around small bioclasts or pellets. The only one syn-sedimentary fault was found in the upper part of the formation along which 30 cm of movement have been detected.

The 34 m thick lower and middle Lower Jurassic formations are followed by a very condensed, altogether 9 m thick succession. It was developed from the Toarcian till the Valanginian, although the Kálvária Hill represented a step with uneven surface between the basin and the submarine high since the Toarcian.

The upper Lower Jurassic is represented by an 80 cm thick, Ammonitico Rosso-type red, nodular marl and calcareous marl unit that is called Kisgerecse Marl Fm. (FÜLÖP 1975). The lower boundary is a hardground. The upper boundary is less sharp because the overlying formation is also nodular but the sizes of the nodules are much larger and often form clayey limestone beds with uneven surfaces. The Toarcian age of the formation is well proved by GÉCZY (in: FÜLÖP 1975) based on the identification of the plentiful ammonite casts. The texture of the Kisgerecse Marl is a micritic mudstone and biomicritic wackestone with a small amount of microfossils: *Globochaete*, sponge spicules, *Bositra* shell fragments and benthic foraminifera. As this radical change in lithology can be noticed in large area in the Tethyan realm it can be a result of an extended sea-level rise.

The red, clayey occasionally nodular limestone (Tölgyhát Limestone Fm. - Fig. 3/10) is a direct continuation of the Kisgerecse Marl Fm. Although it is more calcareous its microfossil content is similar. The maximum 4.5 m thick formation may contains 10-20 cm thick crinoidal limestone intercalations close to its upper boundary. It also can be interpreted as fissure fill of a few cm thickness. *Bositra* shells can also occur in rock-forming quantity in the upper part of the formation with 10-15 cm thickness. The ammonite association indicates an Aalenian to Bajocian age.

The contact between the Tölgyhát Limestone and the Lókút Radiolarite Fm. is sharp (Fig. 3/11). The latter one is 0.8-1.2 m thick and consists of reddish-brown to brownish-grey radiolarian chert beds of varying thicknesses. The reddish-brown calcareous clay intercalates among chert layers. In addition to the rock-forming radiolarians it contains a few nannoplankton, sponge spicules and *Globochaete* as well. During the sedimentation of the radiolarite the basement must have been below the CCD

Fig. 3/10: Well-bedded nodular Tölgyhát Limestone between the red Kisgerecse Marl (on the right), and the Lókút Radiolarite (on the left).

Fig. 3/11: The red, fragmented chert beds in the middle (Lókút Radiolarite Fm.) underlain by the *Bositra*-rich layers of the Middle Jurassic Tölgyhát Limestone and overlain by the white bank of the “Oxfordian Breccia“.

Fig. 3/12: Rip-up clast in the Upper Jurassic limestone just above the "Oxfordian Breccia" bed (right upper corner), Kálvária Hill, Tata.

level considered to be around 800 m only.

The hardground surface of the radiolarite is covered by the Pálihálás Limestone Fm. which is composed of two different members. The lower member is called "Oxfordian Breccia" of 25 to 50 cm thickness (Fig. 3/11). It consists of greyish-white unequally consolidated limestone fragments of varied grain sizes and crystallinity. The matrix is usually microsparitic and almost completely barren of fossils. Exceptionally it may contain belemnite rostra. The breccia bank is considered to be a product of a bottom current above a dissected surface. The consistency of the breccia grains indicates a repeated redeposition. Aside the Kálvária Hill there is a lateral transition between the breccia and the typical Pálihálás Limestone with a clear indication that the currents had different intensities. It is worthwhile mentioning that this breccia event does not show a random but a regular coincidence with the eohellenic tectonic phase that had an important role in the Alpine history. The thickness of the upper member of the formation varies among 20-60 cm. It is a red clayey limestone with manganese nodules. In addition to the rock-forming quantity of *Saccocoma* and ammonite it contains *Cadosina*, *Stomiosphaera*, *Globochaete*, *Protoglobigerina*, radiolaria, echinoderm and mollusc shell fragments, micro-brachiopoda and micro-gastropoda as well. In spite of the condensed sedimentation all of the ammonite zones have been represented.

The Kálvária Hill is the type-locality of the Szentivánhegy Limestone Fm. in spite of the fact that the total thickness of the formation is 145 cm only. The poorly bedded lower part of the formation is purple and light grey in colour and occasionally may contain even 10 cm size of Oxfordian to Kimmeridgian limestone fragments. The Berriasian and Valangian part of the formation is platy; the colour is greyish- and yellowish-white. The megafossil content is incredibly rich, especially in ammonites and brachiopods. Among the microfossils calpionellids, cadosinids, *Globochaete alpina* and benthic foraminifera are worth mentioning. The age of the formation is well documented via both macro- and microfossils by Fülöp (1976) and lately by Szinger (Szinger et al. 2007) who documented the presence of the following microplankton zones with close to equal thicknesses: *Chitinoidella*, *Crassicollaria intermedia*, *Calpionella alpina*, *Calpionellopsis simplex* and *Calpionellites darderi*. Thin section and isolated studies were done on detailed samples throughout the section of this formation simultaneously for the first time.

Fig. 3/13: Unevenly eroded Upper Jurassic to Lower Cretaceous surface encrusted by reddish-brown stromatolite (in the middle) covered by the Tata Limestone Fm., Kálvária Hill, Tata.

Fig. 3/14: Pinkish-white Szentivánhegy Limestone (down and middle left) covered by deep-water stromatolite crust (in the middle) is overlain by the Aptian to Albian Tata Limestone, Kálvária Hill, Tata.

The two studies proved rich benthic and less rich planktonic foraminifera associations. Among the benthic foraminifera shallow subtidal forms (*Spirillina, Trocholina, Miliolina and Paalzowella* species), deeper subtidal (slope) forms (*Lenticulina, Euguttulina, Nodosaria* species) and small-sized planktonic foraminifera (*Globuligerina, Favusella* and Prehedbergellid foraminifera) were found together (SZINGER at al 2007). From palaeoenvironmental point of view it is very important that planktonic forms are found in the stromatolitic crust together with those forms characteristic for the overlying Tata Limestone as well. It is evidence, that the Tata block had an internal position between the submarine high and the basin, and that it was continuously in underwater conditions without sedimentation. Within this condensed but not lacunar sequence there are several hardground levels seen on the subsolution surfaces of the ammonites. The reworked limestone fragments (Fig. 3/12) and the small sized neptunian dykes filled with Lower to Upper Tithonian limestones bear witness about the tectonic activity and continuous differentiation of the basement.

The Upper Jurassic to Lower Cretaceous (Valanginian) condensed sedimentation is replaced by submarine erosion, the result of which is a morphologically and geologically uneven surface. This event was later followed by the sedimentation of the Tata Limestone Fm. (Fig. 3/13). The eroded rough surface and rock fragments of the Upper Jurassic to Lower Cretaceous formation is covered by brown or ochre colour deep-water stromatolite crust of varied thicknesses up to 20 cm, which is rich in Fe_2O_3 and P_2O_5 (Fig. 3/14). According to FÜLÖP (1976), among coated rock fragments in addition to the Jurassic limestone there are Dachstein Limestone, quartz, basalt pebbles, sand and silt size magmatic and metamorphic minerals as well. The broad spectrum of the rock fragments indicates an occasional water transport from the land in addition to the local sources. The overlying Tata Limestone is a grey, coarse-grained, occasionally glauconitic and chertified crinoidal limestone. The microfacies vary between coarse-grained grainstone and fine-grained packstone according to which the allochemical constituents are the major components of the limestone. Not far from the Kálvária Hill the basal bed is composed by ammonite bearing, glauconitic limestone of 20-30 cm thickness, which is followed by half a metre of glauconitic marl.

A great number of ammonites and brachiopods, bivalves and gastropods have been drifted into the erosional holes (FÜLÖP 1976). Based on the revision of the ammonites collected earlier, the time interval of the fossil association is proved to be Late Aptian to Early Albian (SZIVES 1999, SZIVES et al. 2007).

Summarizing: The Tata Limestone is the first sediment after the Szentivánhegy Limestone which temporarily connected the South Bakony and the western end of the Gerecse. Eastwards of Tata calcareous crinoidal sandstone beds may still intercalate into the Lábatlan Sandstone in the Gerecse but with decreasing frequency. After the sedimentation of the Tata Limestone this temporal connection between the Gerecse and the Bakony interrupted again.

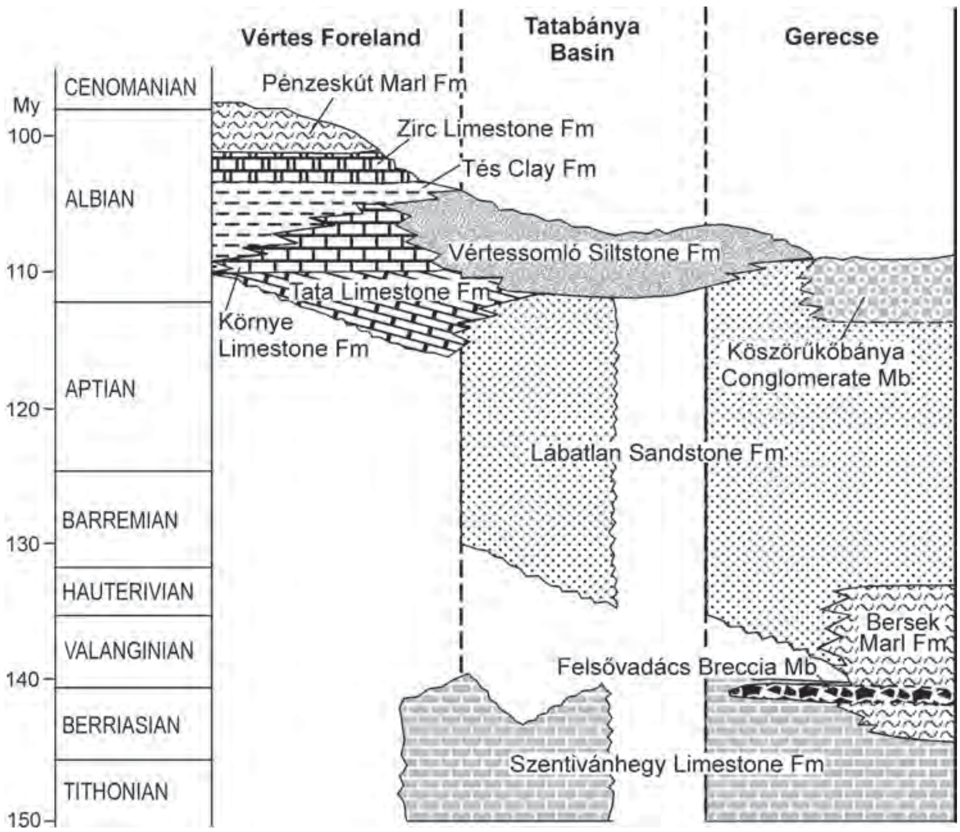


Fig. 3/15: Connections between the Cretaceous formations in the Vértes Foreland and the Gerecse Hills in space and time (CSÁSZÁR 2002).

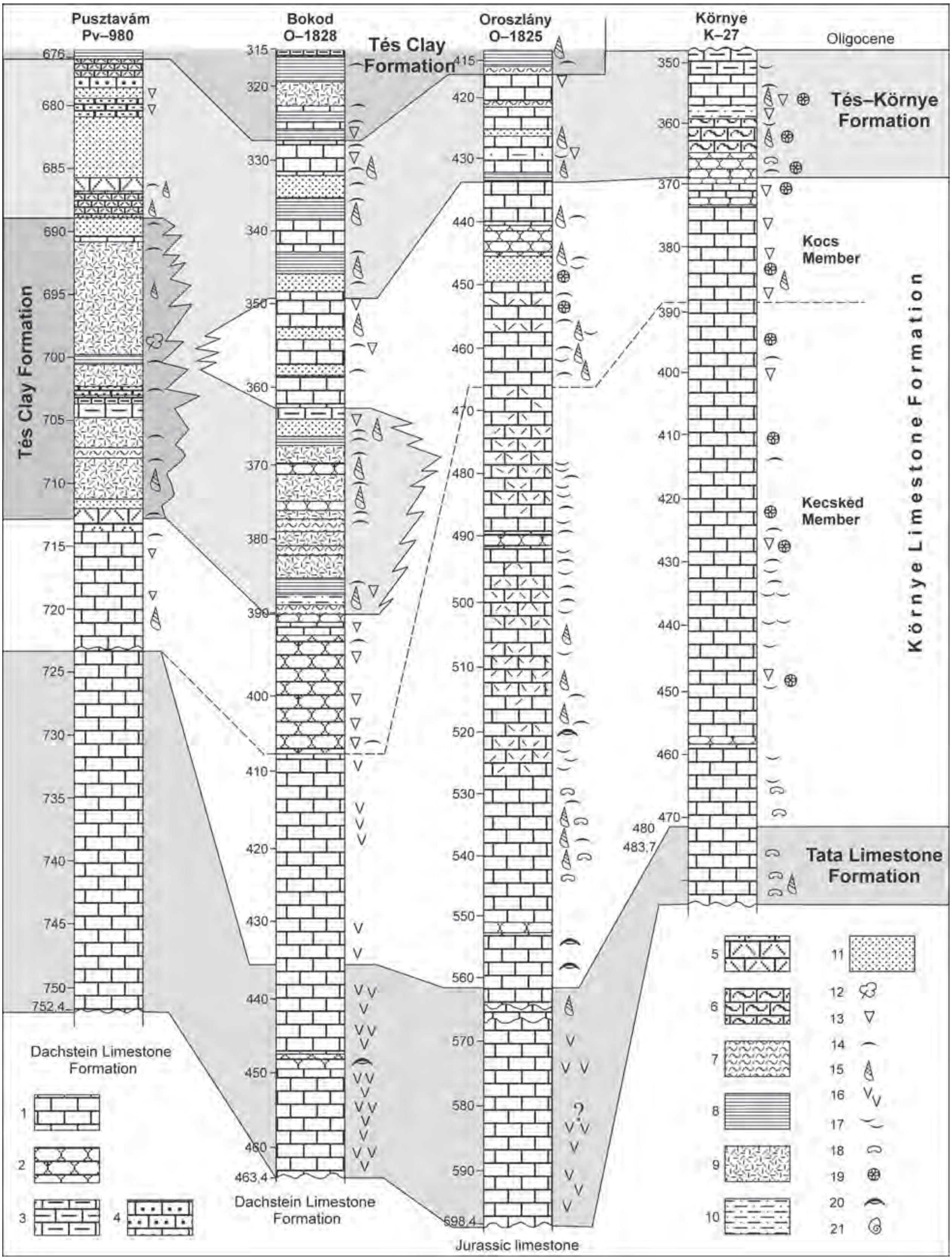


Fig. 3/16: Connections between the following formations: Környe Limestone, Tata Limestone and Tés Clay in the Vértes Foreland based on the cores of 4 boreholes (Császár 2002).
Legend: 1 - thick-bedded limestone; 2 - nodular limestone; 3 - limestone with clay intercalations; 4 - sandy limestone; 5 - bioclastic limestone; 6 - limestone with calcareous marl intercalations; 7 - marl; 8 - clay; 9 - variegated clay; 10 - siltstone; 11 - sandstone; 12 - plant remains; 13 - rudist bivalves; 14 - other bivalves; 15 - gastropods; 16 - Echinoderm fragments, 17 - Orbitolina; 18 - echinoids; 19 - corals; 20 - brachiopods, 21 - Ammonites.

Stop 2: Harmatos/LófarValley, Mór (optional stop)
upper Lower Cretaceous
Géza Császár

There are only two surface outcrops showing the interfingering of the lacustrine Tés Clay and the platform-type Környe Limestone Formation. Both of them are found on the south-western margin of the Vértes Mts. (Budai et al 2008). The simplified relation of the Cretaceous facies between the Gerecse and Vértes Foreland is shown in Fig. 3/15. Their connection is better expressed in the lithologic columns of the boreholes drilled in the Vértes Foreland (Fig. 3/16). According to this figure between the Tés Clay Fm. and the Környe Limestone Fm. there are 15-30 m thick intervals which can be called Tés-Környe Fm. because the beds of both formations (clay/sandstone and limestone respectively) frequently occur in addition to the brackish-water clayey limestone and marl.

1. In smaller size this is also the case in the Bükkös Valley quarry, south-east of Pusztavám village (Fig. 3/17). The 2 m thick Toucasia biostrome is an intercalation within the variegated clay beds of the Tés Clay Fm. (Császár 2002). Note that the Toucasia bed is not uniform. At the 2/3rd level there is a thin reddish-brown clay layer which indicates a short time subaerial condition. The returning flooding is not fully marine, and the upper part of the nodular, clayey limestone contains only smaller sized bivalves. The texture of the lower fully marine part is prevailingly wackestone but with varied allochemical constituents. In the micrograph (Fig. 3/18) the green algae are the dominant elements, while elsewhere foraminifera are the most common fossils. There are also pelintrabiosparitic grainstone textures in which rudist shell fragments and foraminifera are the most frequent fossil constituents (Fig. 3/19).

2. The other outcrop is found at the entrance of the

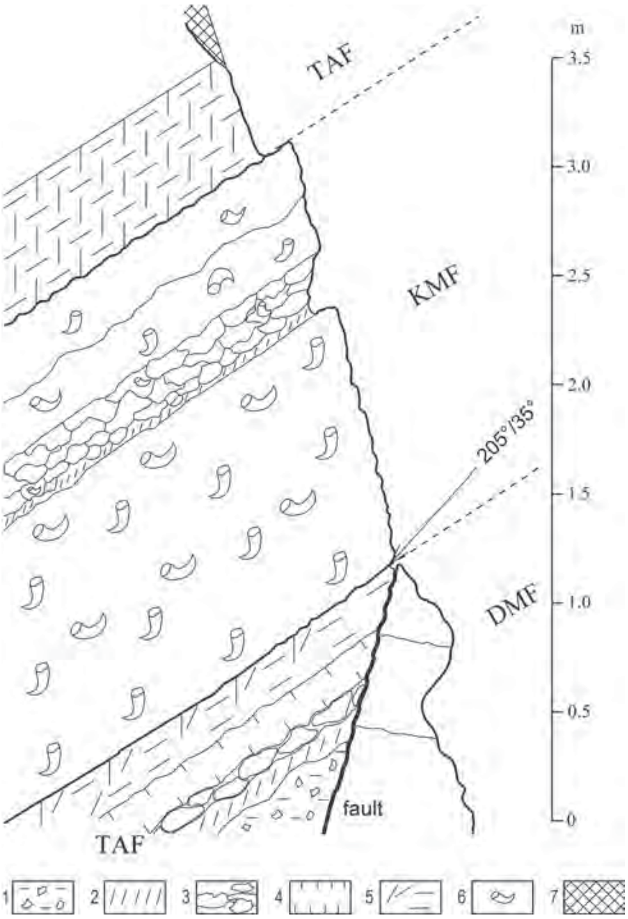


Fig. 3/17: Intercalation of the Lower Cretaceous Környe Limestone Fm in the Tés Clay Fm. with tectonic contact of the Dachstein Limestone. Bükkös Valley quarry, Pusztavám (Császár 2002).
Legend: 1 - greyish small-sized nodules; 2 - reddish-brown clay; 3 - limestone nodules, nodular limestone; 4 - red clay; 5 - variegated clay; 6 - rudistid limestone; 7 - soil. *Abbreviations*: DMF = Dachstein Limestone Fm.; KMF= Környe Limestone Fm.; TAF= Tés Clay Fm.

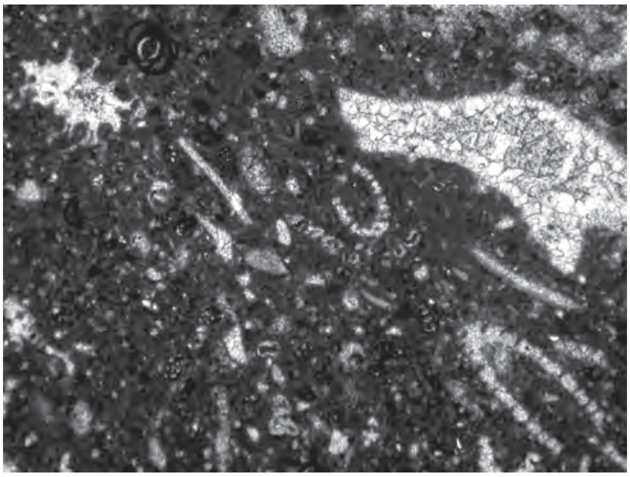


Fig. 3/18: Micrograph of the Környe Limestone Fm. of wackestone texture containing green algae (*Salpingoporella* sp. (det. O. Piros), small benthic foraminifera and Mollusc shell fragments, limestone intercalation within the Tés Clay Fm., Bükkös Valley, Vértes Mts.

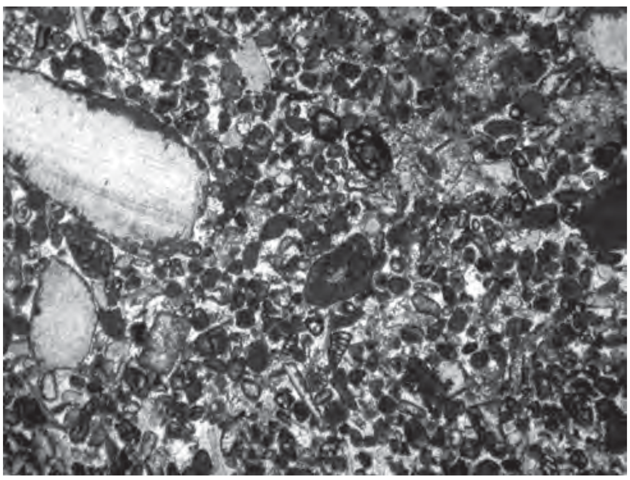


Fig. 3/19: Micrograph of the Környe Limestone Fm. of grainstone texture containing a large rudist shell fragment and divers benthic foraminifera, Bükkös Valley, Vértes Mts.

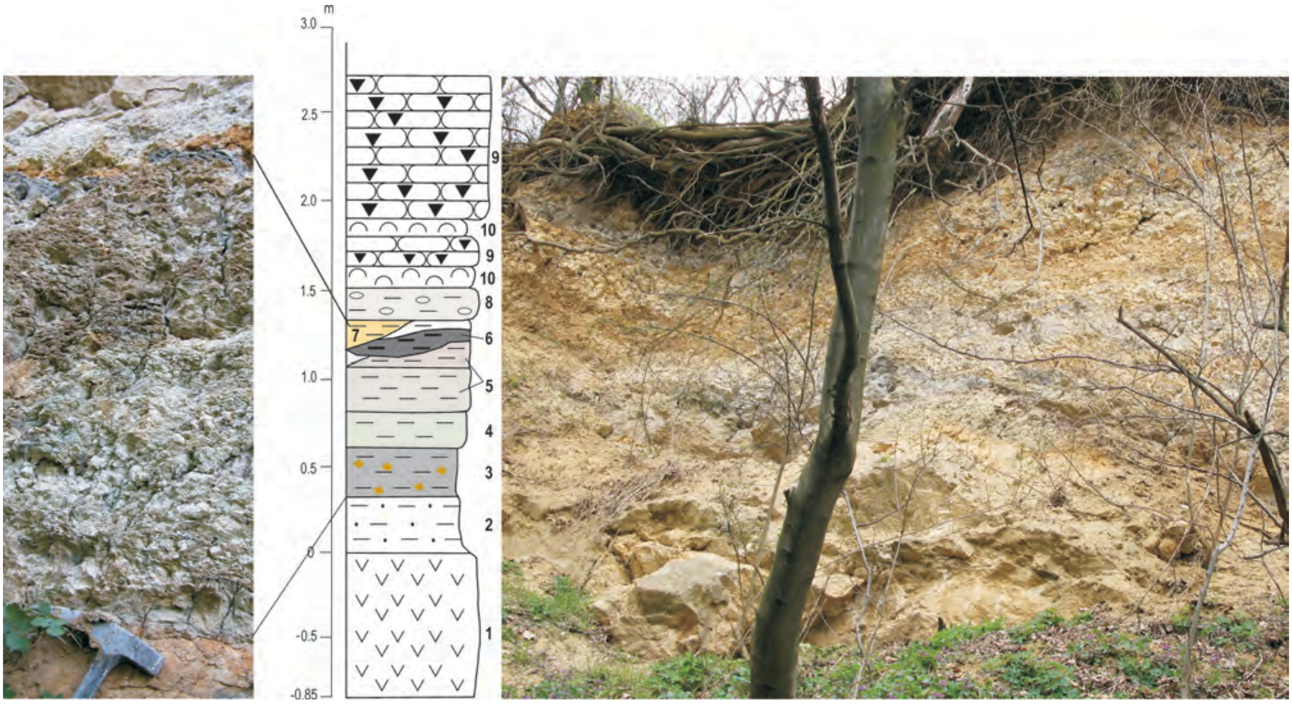


Fig. 3/20: On the right: The basal part of the cliff is composed of Aptian crinoidal limestone, covered by a 2-3 m thick variegated (yellow, grey, green and yellowish-brown) clay beds of the Tés Clay Fm. The Cretaceous part of the succession is capped by clayey nodular limestone of the Környe Fm which is an intercalation within the Tés Clay.
In the middle: Columnar section shows the Lower Cretaceous formations from the crinoidal Tata Limestone, through variegated Tés Clay to the rudistid Környe Limestone Fm.
Legend: 1 - crinoidal limestone; 2 - sandy siltstone; 3 - grey clay with lime nodules; 4 - greyish-green clay; 5 - pale-grey clay; 6 - dark-grey clay; 7 - yellow clay; 8 - pale-grey clay with limestone nodules; 9 - rudist bivalve; 10 - other bivalve.
On the left: Detail of the Tés Clay succession shown (on the right). The base of the photo is represented by the weathered version of the Tata Limestone. It is followed by lime nodule-bearing greenish-grey clay, then first by a brownish-grey, and a dark-grey clay bed, the upper part of which highly oxidized and became reddish-brown. Entrance of the Harmatos/Lófar valley, Mór.

Harmatos/Lófar Valley where the variegated siltstone and claystone beds of the Tés Clay Formation are covering the Tata Formation consisting of silty and sandy crinoidal limestone of Aptian-Early Albian age (Fig. 3/20). The basal bed in the latter picture is greyish-green, freshwater clay with lime nodules. It is covered by greenish and brownish clay bed which is gradually replaced first by bluish dark-grey clay bed and then by reddish and yellowish-brown clay just below the Quaternary loess. At other places the succession is continued by rudistid clayey limestone.

Stop 3: Csókakö, Giant neptunian dykes (optional stop)
Middle Jurassic
Géza Császár

The outcrops are situated on the south-western slope of the Vértes Mts. between the Csókakö Fortress and Csókakö Hill, east of Mór. This slope matches to the main fault of the Mór Trough which is considered to be the renewal of the Jurassic fault. On the fault plane which is the south-eastward continuation of the main fault, remnants of Jurassic limestone (pinkish, reddish patches) can be seen above the yellowish-white Hauptdolomite (Fig. 3/21). The geological map of the area of the Csóka Hill and Csókakö village is shown in Fig. 3/22. The strike of the giant dykes are predominantly parallel to the major faults but the dip of the dykes are steeper than that of the faults, but occasionally some minor faults cut the dykes and in these cases larger holes were formed and filled with Jurassic sedimentsThe infilling rock of the dykes is limestone with varied (up to several metres) sizes of older Jurassic

Fig. 3/21: A fault plane on the Upper Triassic Hauptdolomite with erosional remnants of the Jurassic limestone patches behind the Castle Hill Csövár.

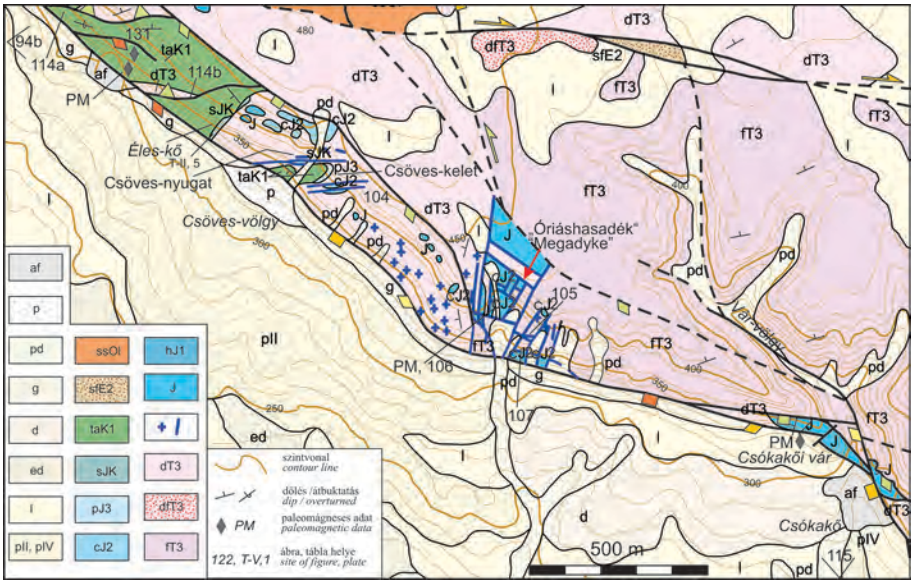


Fig. 3/22: Detailed geological map of the Csóka Hill - Csókakö area with the occurrences of the giant neptunian dykes (BUDAI & FODOR et al. 2008, modified).

limestones, Upper Triassic Dachstein Limestone and even Hauptdolomite. This broad variety of carbonate rock fragments can be recognised even in a small scale polished surface (Fig. 3/23) and simple rock fragments (Fig. 3/24). The lower part of the bed consists of *Bositra* Limestone on which in unconsolidated conditions various Jurassic rock fragments fell down and the larger pieces sagged down. In broader dykes the rock fragments can also be larger even within the Hauptdolomite (Fig. 3/25).

The frequency of these rock fragments increases downwards. The matrix is built up of pale- or dark-red, generally massive or poorly bedded, locally slightly nodular limestone in the small fissures along the south-western edge of the Vértes Mts. (CSÁSZÁR & PEREGI 2001). The matrix and its varied rock fragments together are called Csókakö Limestone Formation. The matrix of the limestone is prevailingly micritic but occasionally scattered crinoid ossicles are also present. In some exceptional cases it contains white or pink

Fig. 3/24: A 20 cm size rock fragment from the slope of the Csóka Hill. The lower part composed of *Bositra* shells on the bedding plane of which limestone fragments fell down in the deep hole of fissure origin when the *Bositra* calcareous mud was still unconsolidated and the largest rock fragment sagged into.

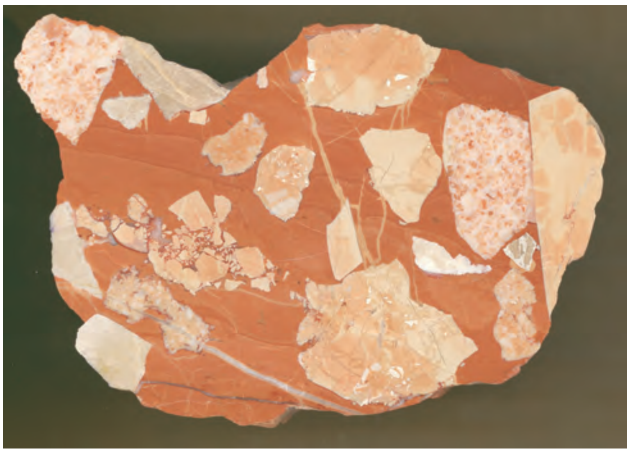


Fig. 3/23: A multi-generation breccia grains in the Middle Jurassic Csókakö Limestone Fm. of neptunian dyke origin. The dominant rock types are Jurassic of varied sedimentary environment and lithology but Dachstein Limestone and Hauptdolomite fragments can also be recognized.

lenses made up of coarse-grained crinoid skeletal fragments.

In thin sections various type of rock fragments can be recognised. In micrograph (Fig. 3/26) divers wackestone to packstone type Jurassic rocks and ooidic grainstone type Dachstein limestone can be seen in the packstone type matrix. The next micrograph (Fig. 3/27) gave evidence of some aspects of the dyke history. Half of the picture is occupied by an ammonite- and *Bositra*-bearing limestone clast incorporated in a packstone type *Bositra* Limestone. The photo shows that the younger (upper) part of the two generation fissure fillings contains the material of the first-generation fissure filling as consolidated debris.

The majority of the outcrops of the Csókakö Limestone is

Fig. 3/25 Cobble and boulder size dolomite fragments embedded into the Csókakö Limestone in a dyke within the Hauptdolomite on the slope of the Csóka Hill.

located on the steep slope to the south of the Éleskö cliff but the largest and most important ones are around the contact of the Dachstein Limestone and the Hauptdolomite. Its width here is at least 50 m with the conditions as shown in Fig. 3/28. The broadest dyke within the lowest formation (Upper Triassic Hauptdolomite) is 4 m (Fig. 3/29). Thinner dykes can also be found south-eastwards of the ruins of the Csókakö fortress (Fig. 3/22). The macrofossils are represented mainly by ammonites and brachiopods. Usually they are concentrated in smaller or larger lenses. The outcrops around Éleskö contain almost exclusively ammonites (Fülöp et al. 1960). Based on the great variety of ammonites according to Galácz (1995) the majority of them indicate Late Bajocian (*Parkinsonia parkinsoni* chron), while the rest indicate/show Late Bathonian ages (*Oxycerites orbis* chron). The brachiopod association is restricted to the Late Bajocian. Other megafossils are represented by crinoids and pine-needle like teeth.
The neptunian dykes were formed along the margin of the

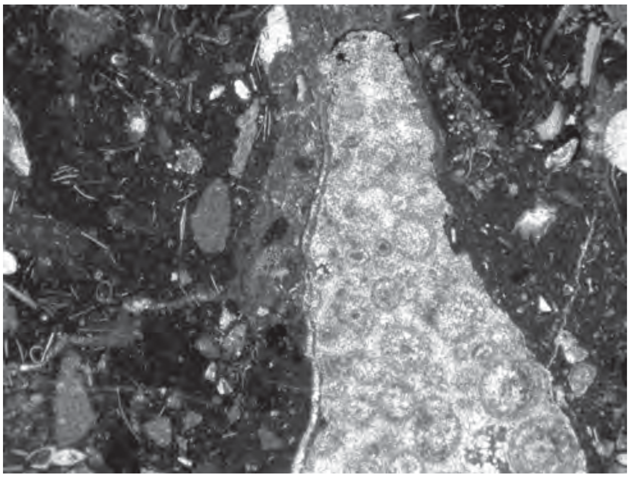


Fig. 3/26: Micrograph of extraclastic Csókakö Limestone with *Bositra*, crinoid ossicles and hyaline foraminifera in a wackestone and packstone matrix. The largest fragment is re-crystallised Dachstein Limestone.

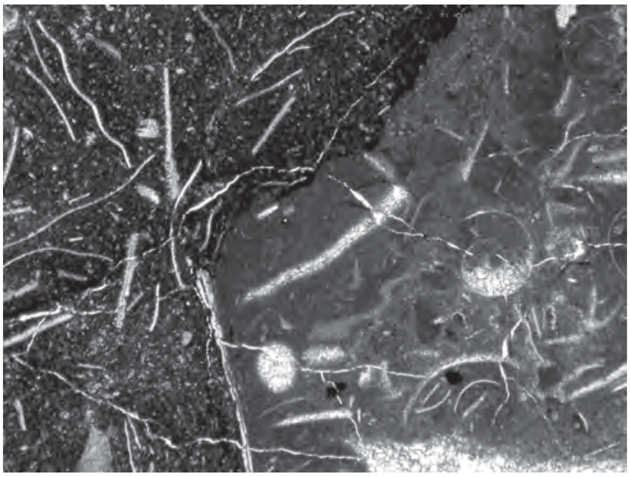


Fig. 3/27: Micrograph of ammonite- and *Bositra* shell-bearing angular limestone fragment within a *Bositra*-rich matrix.

Fig. 3/28: Mass occurrence of the Csókakö Limestone Formation close to the tectonic contact of the Dachstein Limestone and the Hauptdolomite.

Fig. 3/29: Detail of a giant neptunian dyke of the Csókakö Limestone Fm. within the Hauptdolomite (on the left margin of the photo). The size of the dyke is more than 4 m and contains cobble- and boulder-size Jurassic limestone fragments of varied fossil association.

Vértes Ridge in two sub-phases in the Middle Jurassic time as a consequence of the opening of the Piemont-Pennine

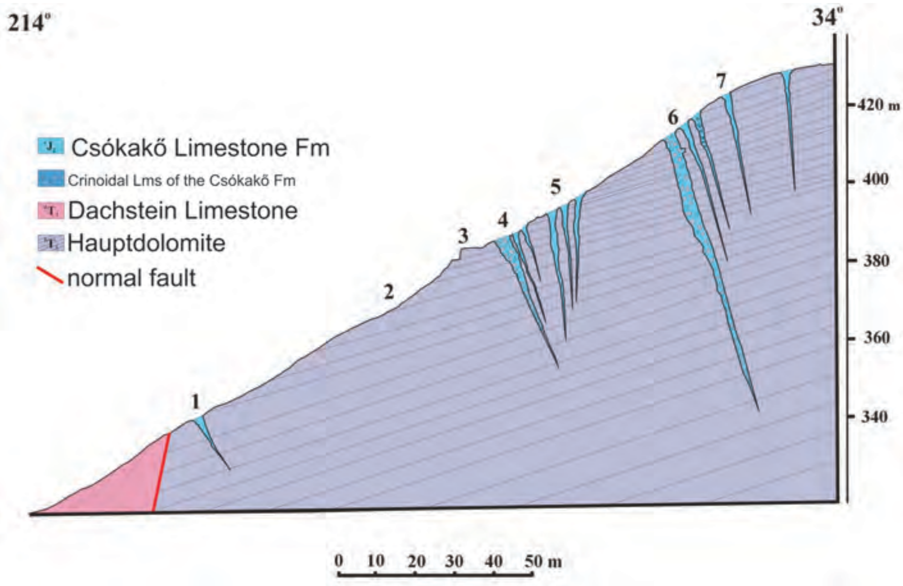


Fig. 3/30: Geological profile on the slope of the Csóka Hill, indicating the neptunian dykes developed in the Upper Triassic Hauptdolomite. Compiled by Gy. FERENCZ (2004).

Ocean. The formation of the Vértes Ridge already started in the early Early Jurassic time but it formed very slowly. FERENCZ's profile (2004) made perpendicular to the slope (Fig. 3/30) shows deep-seated neptunian dykes in the Hauptdolomite. She transformed her measurements into a model (Fig. 3/31). According to this model the neptunian dykes were filled in two ways. When the fissure opened the water and the unconsolidated sediments from the bottom of the sea were sniffed into the fissure while smaller and larger rock fragments from the wall of the fissure fell down together with them. From this moment the currents swept the mud from the bottom of the sea into the fissure hole from time to time and occasionally a few rock fragments also fell down the fissure hole. This Late Bajocian event was repeated in the Late Bathonian. The situation resembles the phenomenon introduced by FERRARI (1982) from the Southern Alps.

Stop 4: Tüzköves Ravine, Bakonycsernye
Jurassic and some Lower Cretaceous
Géza CSÁSZÁR

The succession to be shown is found 3 km to the south of village Bakonycsernye (Fig. 3/32). The program starts at the entrance of the Tüzköves Ravine with the Ammonitico Rosso-type Pliensbachian limestone (Tüzkövesárok Limestone Fm.), continues with the Toarcian nodular marl (Kisgerecse Marl) and then with the Middle Jurassic clayey, nodular limestone (Tölgyhát Limestone Fm.). This nodular limestone is replaced upwards with the *Bositra* Limestone (Eplény Limestone Fm.) and then with the Lókút Radiolarite (Fig. 3/33). The uppermost part of the succession is represented by the Upper Jurassic to Lower Cretaceous *Calpionella* limestone (Szentivánhegy Limestone Fm.) and above an erosional surface by the crinoidal limestone (Tata Limestone Fm.) of Aptian age (Fig. 3/34).
The oldermost Jurassic formation namely the cherty,

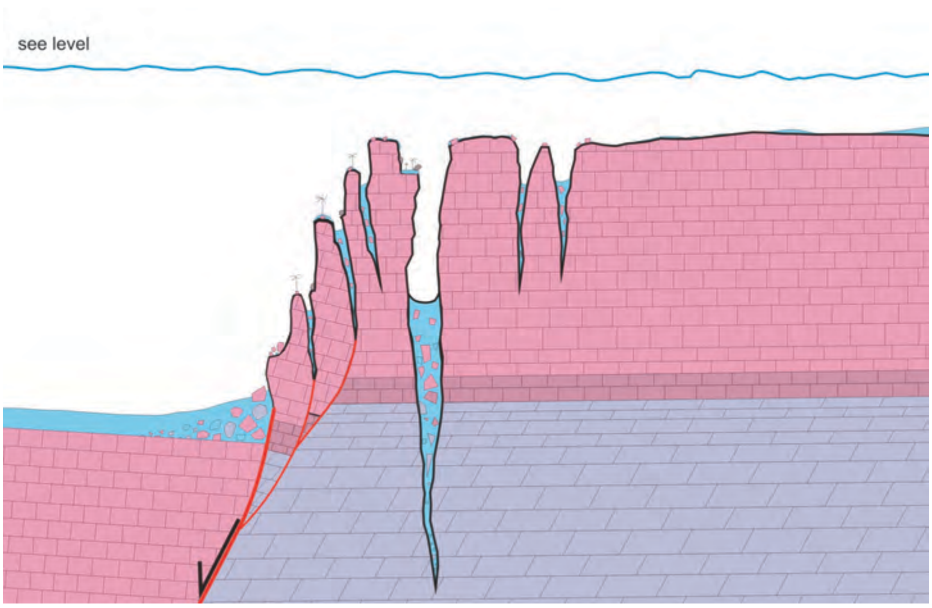


Fig. 3/31: Middle Jurassic palaeogeographic reconstruction showing the palaeo-Mór Trough (on the left side) and the deep-seated neptunian dykes (on the right). Note that they developed mainly parallel to the main fault penetrating the total Dachstein Limestone, the transitional formation and even a large part of the Hauptdolomite too. Compiled by Gy. FERENCZ (2004).

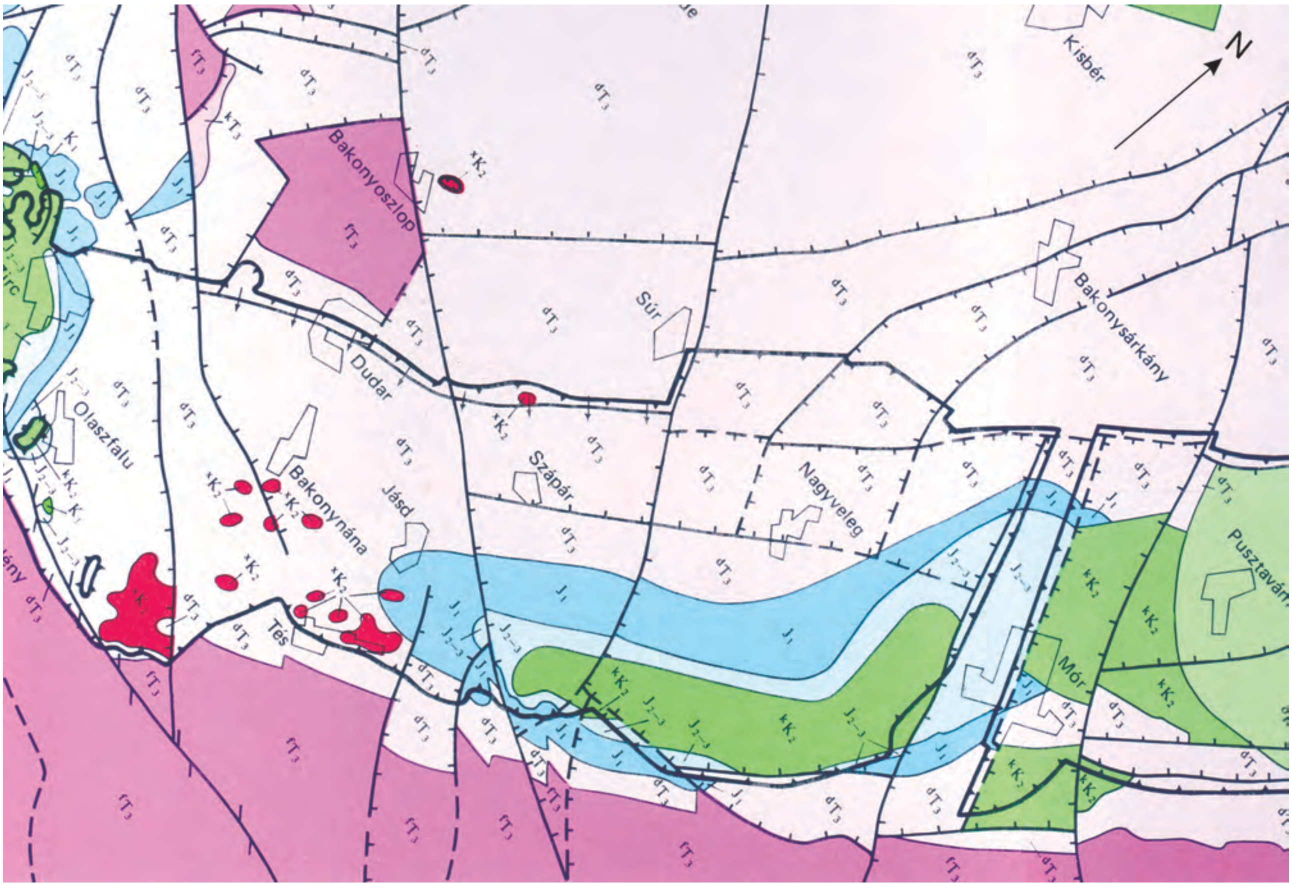


Fig. 3/32: Geological map of the Northern Bakony without formations younger than Albian (footwall of the Tés Clay Fm.).
Legend: $^{ö}K_2$= Környe Limestone Fm.; $^{x}K_2$= Lower Cretaceous Alsópere Bauxite Fm.; K_2= Lower Cretaceous Tata Limestone Fm.; K_1= Lower Cretaceous; $J_{2\text{-}3}$=Middle and Upper Jurassic; J_1= Lower Jurassic; $^{d}T_3$= Dachstein Limestone Fm.; $^{k}T_3$= Kössen Fm.; $^{f}T_3$= Upper Triassic Hauptdolomite.

crinoidal Isztimér Limestone Formation is not cropping out at this site. It is overlain by the red, platy to thin-bedded, ammonite-bearing Tüzkövesárok Limestone Fm. of 10 m thickness (Fig. 3/35) with thin brownish-red clays or ferruginous manganese-oxidic covers on the stylolithic bedding planes. The texture of the limestone is a biomicritic or pelbiomicritic wackestone seldom with a few intraclasts of limonitic impregnation. According to KONDA (1989) the repartition of the microscopic fossil fragments are homogenous. Their frequency in decreasing order is as follows: Echinoderm ossicles, calcified sponge spicules, ostracode shells, fragmented foraminifera, small gastropoda, ammonite shell fragments and juvenile ammonites, *Globochaete* and holothurian sclerites. The age and the ammonite zones indicated on Fig. 3/33 were determined by GÉCZY (1971).

The Tüzkövesárok Limestone is followed by the Kisgerecse Marl Formation of 5 m thickness. It is brownish-red, exfoliated marl with calcareous marl and limestone nodules, at the base with ferruginous manganese crust. The transition to the Tölgyhát Limestone is gradual. Ammonites are found exclusively as casts but in spite of this they gave evidences for the age of the formation, see Fig. 3/33. The texture of the basal beds is mudstone with a few ostracodes, calcified radiolarians, small-sized brachiopods, gastropods and foraminifera. The frequency of the fossils above is increasing upwards and the texture is becoming a biomicritic wackestone in which *Bositra* shell fragments, calcified radiolarians and *Globochaetes* are the ruling fossils.

The next formation is the Tölgyhát Limestone Fm. of 10 m thickness. It is also red, prevailingly nodular, ammonite-bearing limestone where the matrix among the nodules is marl with varying clay content. This succession of regular character is occasionally interrupted by thin or thicker platy limestone beds without ammonites, but thin exfoliated marl beds also intercalate. It is worth while mentioning that ammonites are missing from the platy, nodulless limestone beds. The texture type is dominantly wackestone but occasionally bioclastic packstone types also occur. According to KONDA (1998) the fossil elements are practically the same but *Bositra* and *Globochaete* are the most frequent elements throughout the formation. Radiolarians are calcified also here but their frequency is rapidly increasing, while in the uppermost beds they are composed of chalcedony. The relatively frequent echinoderm fragments and the scarce calcified sponge spicules are the products of the currents transporting them from shallower environments.

Based on ammonites the age of the formation is Late

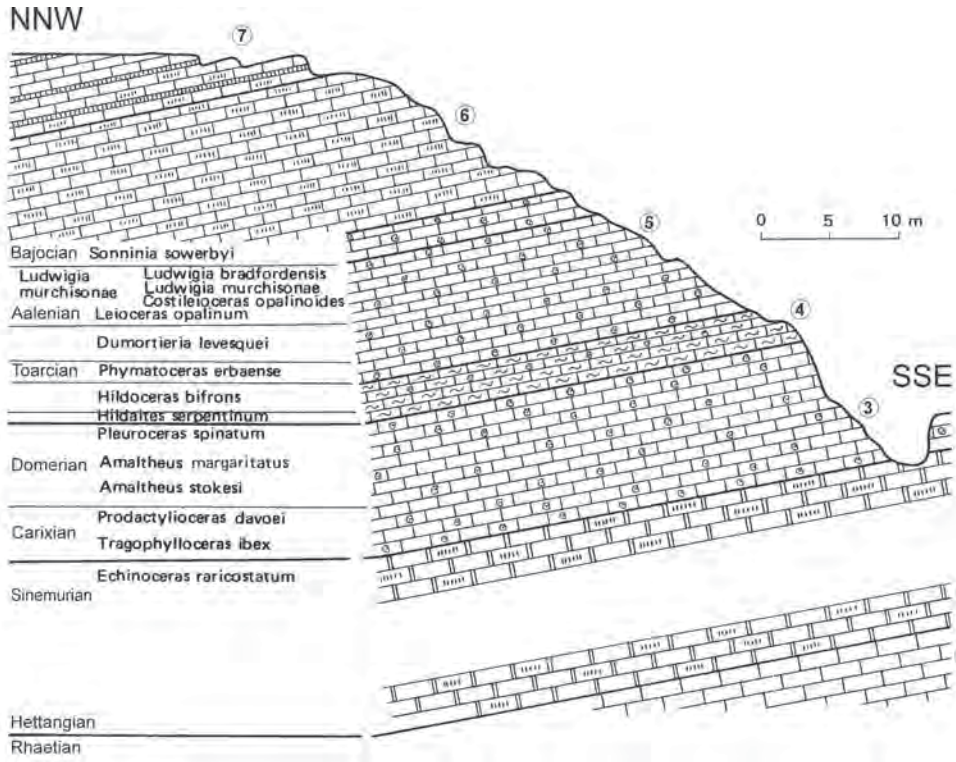


Fig. 3/33: Geological cross section showing the lower part of the Tüzköves Ravine succession of the Lower and Middle Jurassic formations (After KONDA 1989).
Legend: 1 - Dachstein Limestone Fm. (recently cannot be seen); 2 - Isztimér Limestone Fm. (recently cannot be seen); 3 - Tüzkövesárok Limestone Fm.; 4 - Kisgerecse Marl Fm.; 5 - Tölgyhát Limestone Fm.; 6 - Eplény Limestone Fm.; 7 - Lókút Radiolarite Fm.

Toarcian to Aalenian as determined by GÉCZY (1967). Ammonite zones can be seen in Fig. 3/33.
The Tölgyhát Limestone is overlain by the Eplény Limestone Fm., the elements occurred in the previous formation as independent beds, but the 2.3 m thick formation is consistently composed of platy or thin-bedded limestones of light red, yellowish-grey or greenish-grey colour with intercalation of thin reddish-brown in the lower part and then grey to dark-grey marl beds. Less frequently but calcarenitic and cherty limestones may also occur. Its poor macrofossil content is represented by belemnite rostra only. Its texture is a biomicritic wackestone to packstone. The microfossil content is prevailed by *Bositra* shells of rock forming quantity but radiolarians are also common. The latter ones are dominantly chalcedony pseudomorphoses. In spite of the continuous deepening still this formation also contains small crinoid ossicles and calcified sponge

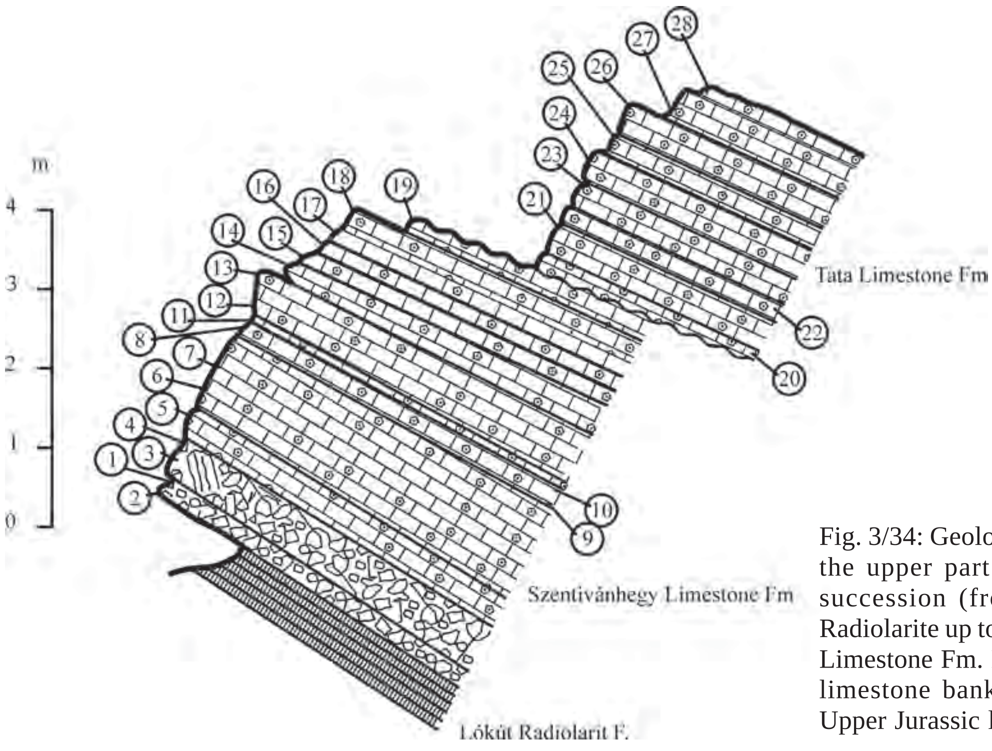


Fig. 3/34: Geological cross section showing the upper part of the Tüzköves Ravine succession (from the top of the Lókút Radiolarite up to the Lower Cretaceous Tata Limestone Fm. Note the heavily brecciated limestone banks at the contact with the Upper Jurassic limestone.

Fig. 3/35: Tüzkövesárok Limestone Fm. of red, ammonite-bearing beds of alternating thickness at the entrance of the Tüzköves Ravine, Bakonycsernye.

Fig. 3/37: Transition between the Zirc Limestone and the nodular Pénzeskút Marl Fm. Note the foreset beds in the upper part of the Zirc Limestone which is covered by a bank of rock fragments representing a condensation level of the rapid sea-level rise.

spicules. The age of the formation is based only on the ammonite content of the underlying formation and suggested to be Bajocian and perhaps Bathonian? The next formation is called Lókút Radiolarite Fm., which develops continuously but rapidly from the underlying Eplény Formation via the disappearance of the *Bositra* bivalves and the multiplication of the radiolarians. This is a well-bedded, variegated (brownish-red, greenish-grey, occasionally dark-grey or even black) chert or radiolarite with thin clay intercalations. The fossil content is almost completely restricted to the radiolarians of varied preservation. The thickness of the formation is supposed to be 20-30 m. The age is suggested to be Bathonian to Oxfordian. The lithological change of the succession clearly shows that from the Middle Early Jurassic till the formation of the Lókút Radiolarite the broader environment of the Tüzköves-árok Ravine continuously subsided until achieved the approximately 800-1000 m water depth. It can be seen not only from the lithologic change but also from the change of the fauna association. The sudden increase of the clay content in the Toarcian is also an indication of the sea-level rise but it also indicates that at this time there was still an elevated area within a few hundreds of km distance from where still some weathering products could still reach the Transdanubian Range.

The Lókut Radiolarite is overlain by two breccia beds supposed to be Oxfordian in age. (It can not be excluded that the contact between the breccia and the radiolarite is tectonic.) It is followed by medium- to thick-bedded greyish-white or yellowish-white limestone beds of 4.5 m thickness. Its texture is a packstone to grainstone, in the upper beds with plenty of echinoderm fragments of several mm in size and a few small-sized calpionellids, showing Early Berriasian age. The sediments must have been deposited in a quickly shallowing marine sedimentary environment. It is in harmony with the model introduced at the introduction part of this guidebook according to which the eastern part of the Bakony raised above the sea-

Fig. 3/36: The Upper Jurassic Szentivánhegy Limestone is overlapped disconformably by the Aptian Tata Limestone. The disconformity surface is slightly uneven, Tüzköves Ravine.

Fig. 3/38: The contact between the middle (Mesterhajag) and upper (Gajavölgy) members of the Zirc Limestone Fm. is highly uneven because of a short sea-level drop followed by a sea-level rise. The upper member is glauconitic, sandy limestone, and from this moment it is not the member of the Urgonian facies contrarily to the underlying two members. The photo made at a nearby outcrop, Jásd.

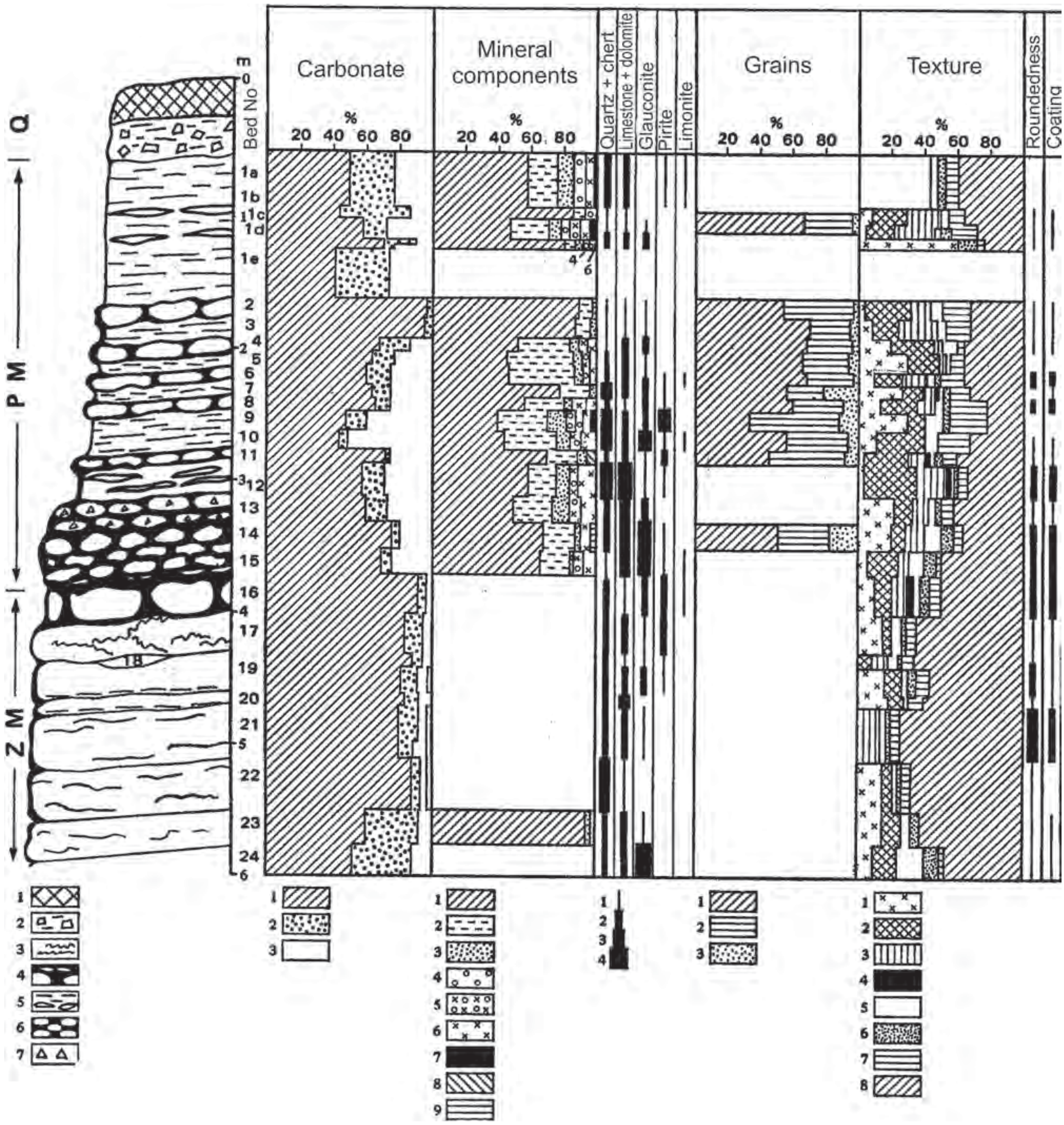


Fig. 3/39: Columnar section and the results of mineralogical and textural investigations of the transitional beds between the upper member of the Zirc Limestone (ZM) and the Pénzeskút Marl Fm. (PM) of the Early Cretaceous (Albian) age. Note the high dolomite content of the lower and the upper beds of the columnar section.
Legend
Lithological log: 1 - soil; 2 - scree; 3 - limestone with clay film; 4 - nodular limestone; 5 - clay clay-marl and limestone noduls/clasts; 6 - nodular marl and calcareous marl; 7 - reworked limestone fragments.
Carbonate: 1 - calcite; 2 - dolomite, 3 - insoluble residue;
Mineral components: 1 - calcite; 2 - dolomite; 3 - quartz; 4 - montmorillonite; 5 - montmorillonite-illite; 6 - illite; 7 - chlorite; 8 - unidentified clay minerals; 9 - siderite.
Grain-size: 1 - clay; 2 - silt; 3 - sand.
Texture: 1 - micrite, 2 - microsparite; 3 - sparite; 4 - neomorphous calcite, 5 - extraclast, 6 - intraclasts; 7 - pellets; 8 - bioclasts (fossils).
Frequency: 1 - spars; 2 - a few; 3 - mean; 4 - frequent.

level in the early Early Cretaceous time and separating with this event the Gerecse Basin from the South Bakony Basin. After a long break in sedimentation the Tata Limestone (Fig. 3/36) composed of coarse-grained crinoid fragments was deposited with a disconformity on the Szentivánhegy Limestone Formation uniting again the south-western and the north-eastern basins of the Transdanubian Range.

Stop 5: Zsidó-hegy, Bakonynána
Lower Cretaceous
Géza Császár

The outcrop is situated on the southern side of the Gaja creek, south of the village Bakonynána (Fig. 3/32). This is the best outcrop where the transition between the upper member (Zsidóhegy Limestone) of the Zirc Limestone Fm. and the Pénzeskút Marl Fm. is accessible (Fig. 3/37) (Császár 1986). The boundary between the middle member (Mesterhajag Limestone - look at it at the stop Eperjes Hill [stop No 1 tomorrow]) and the Gajavölgy Member is erosional but it doesn't crop out here. Fig. 3/38 made at an abandoned quarry at Jásd shows the erosional surface of the grainstone type Mesterhajag Limestone and its overlying fine-grained sandy glauconitic limestone representing the basal bed of the Gajavölgy Member. This change in sedimentation is caused by a rapid sea-level rise. Similar types of rocks are exposed in the Zsidó-hegy outcrop as well (Fig. 3/39). The maximum 5 m thick limestone of tabular to nodular character contains a large amount of carbonate sand fraction including 5-40% dolomite, a few siliciclastics and glauconite (Fig. 3/40a). Just below the uppermost bed of the Zsidóhegy Member there is an 80 cm thick foreset bundle, at the base of which a few 3-4 cm thick graded laminae repeatedly occur. The foreset bundle is an indication of a strong coastal current. The echinoderm fragments are the predominant fossil components but the foraminifera content is also relatively high, especially the planktonic forms, among which *Hedbergella* taxa predominate, but a few *Rotalipra* (e.g. *R. appeninica*), *Planomalina* and *Preglobotruncana* species are also documented by Kovács-Bodrogi (1986). Macrofossils are scarce. In the underlying beds of the foreset bundle *Ophiomorpha*-like bioturbation including junctions can frequently be found. They are supposed to be crab traces. Within this interval there are coalified plant traces and a few well-rounded 2-4 cm size chert pebbles (Fig. 3/40b) which are supposed to be used as gastrolith in the stomach of a large fish.
The boundary between the Zirc Limestone Fm. and Pénzeskút Marl Fm. can be drown at the base of the condensed bed of 40-50 cm thickness (Nána Bed) which is formed by the reworked limestone fragments of the underlying Gajavölgy Limestone Member and embedded into the highly glauconitic sandy siltstone matrix together with ammonites and echinoids. The latter ones are often filled by phosphates. In the matrix of the Nána Bed and in its covering beds there are plenty of ammonites that's why these beds can be called as ammonite lumachelle in which the foraminifera content is also multiplied. This Nána Bed

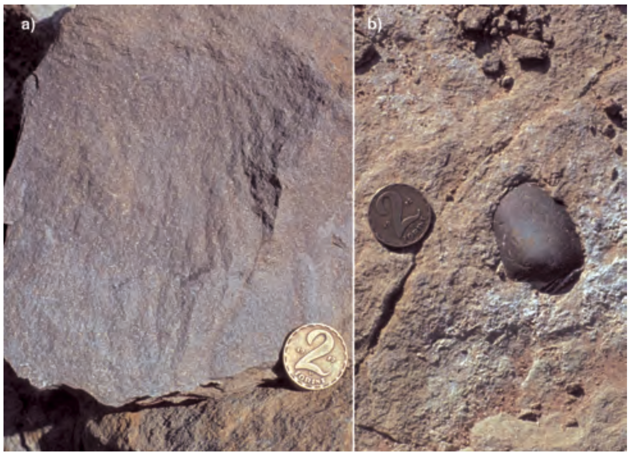


Fig. 3/40: a) Sandy limestone from the upper (Gajavölgy) member of the Zirc Limestone Fm. The white sand grains are dolomite which derived from the Middle Triassic, Zsidó Hill, Bakonynána, b) Gastrolith of chert origin in the upper member of the Zirc Limestone, Zsidó Hill, Bakonynána.

and its continuation is called Zsidóhegy Marl Member of the Pénzeskút Marl Fm. is a greenish-grey, silty, occasionally fine-grained sandy, glauconitic and dolomitic marl succession of 150 m thickness with dolomitic limestone nodules. The ammonite and planktonic foraminfera content is invariably high albeit they are not as frequent as they are in the condensed Nána Bed.
The change in the lithology within the Zirc Limestone is a consequence of a radical change of the tectono-sedimentary system/regime. The occurrence of dolomite within sublittoral environment is not considered as primary product. It is well seen that the dolomite occurs as sand fraction. The idea is supported by the Middle Triassic palynomorphs which occur together with the Cretaceous spore and pollen grains (Góczán in: Császár 1986). Further supporting data was gained from the study of vitrinite reflectance. Based on 44 measurements the mean data calculated bed by bed are as follows: 0.44, 0.58, and 1.25%; 0.65 and 1.30%. According to the investigator Iharos-Laczó (in: Császár 1986) the values below 1% are characteristic for the mid-Cretaceous, while those above 1% suit the Lower Triassic within large part of the Pannonian Basin. The conclusion: in the early Late Albian time the limbs of the Transdanubian Syncline must have been raised above the base level of erosion and the thin Jurassic and the very thick Triassic rocks were eroded and transported to the sea which flooded the syncline zone.
The condensed Nána Bed is the product of the second Albian global sea-level rise the rate of which is estimated to be 150 m.

4.4. Fourth Day: North and South Bakony: Lower Jurassic to Lower Cretaceous

Today's program

- A highly lacunary Jurassic succession on the margin of a submarine high with middle Jurassic collaps breccia and its lacunary continuation in the Lower Cretaceous and then the 2nd Urgonian limestone.

- Limestone of Lower Cretaceous basin margin as heteropic facies of the Majolica limestone.
- Thick Upper Jurassic to Berriasian limestones of basin facies followed by Aptian coarse-grained crinoidal limestone.
- Optional stop at the Triassic Jurassic boundary section indicating rapid transition from the intertidal facies into shallow sublittoral one with a short gap.
- Another Lower Cretaceous Urgonian facies different from the previous one with alternation of significant fossil communities.
- Submarine Jurassic karstic holes protected after the exploitation of manganese ore filled the holes.

Stop 1: Eperjes Hill, Olaszfalu village
Upper Triassic to Lower Cretaceous
Géza CSÁSZÁR

The outcrops are located on the western slope of the Eperjes Hill (Fig. 3/32) acting as the western margin of the Ámos submarine high (VÖRÖS & GALÁCZ 1998) from the middle Early Jurassic till the early Early Cretaceous. The oldest rocks such as the Upper Triassic Dachstein Limestone and the Lower Jurassic Kardosrét Limestone of Hettangian and the Hierlatz Limestone of Pliensbachian ages are represented only by slabs and smaller rock fragments below the Upper Jurassic and also at the base of the Aptian/Albian Tata Limestone. To the west of the strike-slip fault a more or less continuous Jurassic succession is known to occur while eastwards it is highly lacunose up to the Middle Albian.

Except the topmost part of the hill the succession is badly exposed naturally therefore 2 artificial trenches and 2 strippings help in the recognition of the bedding and sedimentary character of the succession. On the surface at the western end of the long trench (Fig. 4/1) and (Fig. 4/2) red clayey lenticular to nodular marl and limestone of uppermost Oxfordian and Kimmeridgian age (NAGY & FŐZY respectively in: CSÁSZÁR et al. 2008) with ammonites, aptychi, some crinoid ossicles and in thin sections plenty of *Saccocoma*, *Globochaete*, *Cadosina* and benthic foraminifera occur. This is called Pálihálás Limestone Fm. (Fig. 4/3). In the trench formerly the Middle and Upper Jurassic cherty limestone (Lókút Radiolarite Fm.) could be seen. The thin-bedded, platy Pálihálás Limestone is overlain by a thick-bedded Hierlatz type, highly

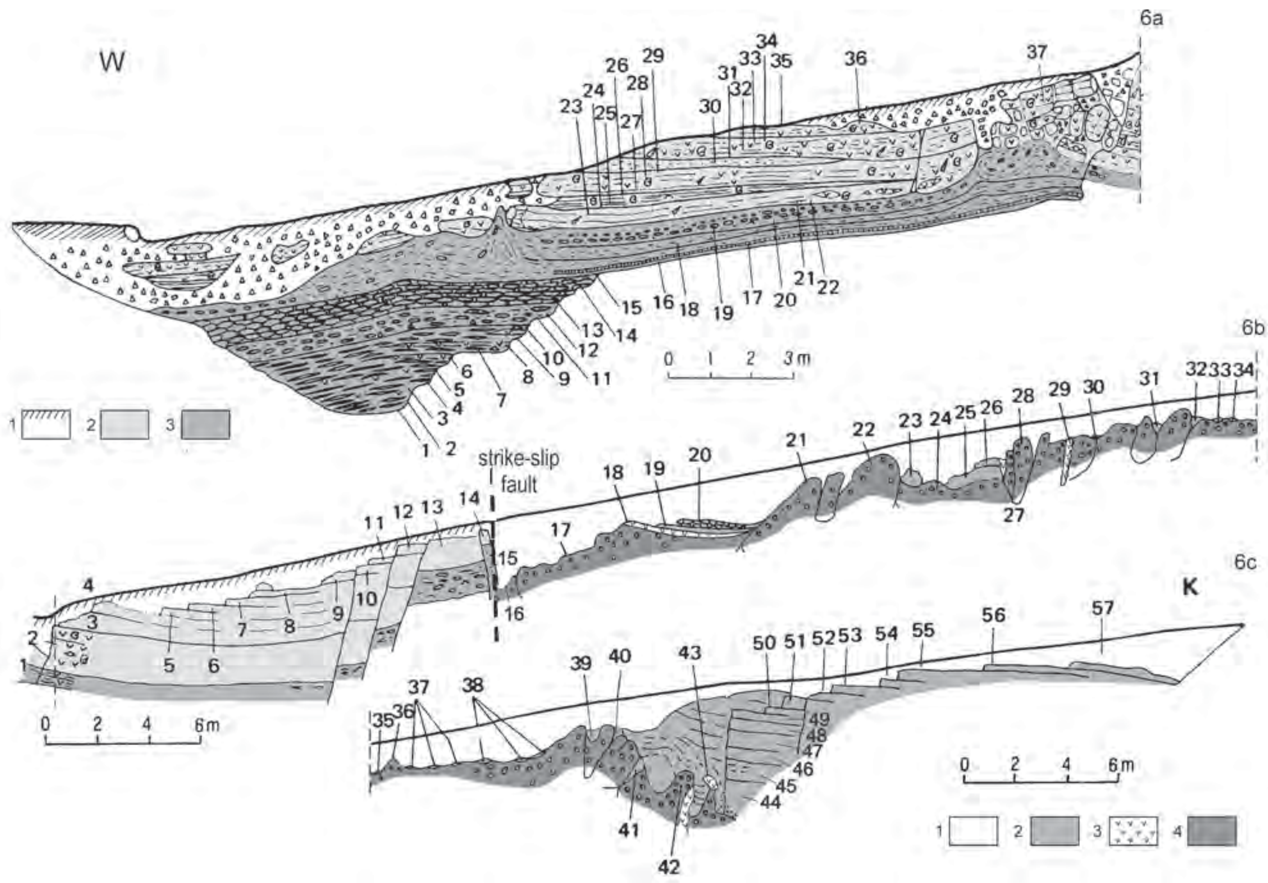


Fig. 4/1: Geological profile of the long trench with indication of the sample numbers, Eperjes Hill, Olaszfalu.
Legend (upper left): 1 - Quaternary; 2 - Szentivánhegy Limestone Fm. of Hierlatz type facies, 3 - Pálihálás Limestone Fm. with much clay content;
Legend (lower right): 1 - Quaternary; 2 - Szentivánhegy Limestone Fm.; 3 - Hierlatz Limestone Fm., often as fissure fill; 4 - Kardosrét Limestone Fm.

Fig. 4/2: Eastward view of the long trench on the Eperjes Hill, Olaszfalu. The Lókút Radiolarite is covered by the scree in the deepest part of the trench. Its overlying formation is the dark-red, clayey Pálihálás Limestone which is followed by the well-bedded, white Szentivánhegy Limestone of Hierlatz-facies.

Fig. 4/3: A detail of the previous photo showing the transitional beds of the Pálihálás Limestone and Szentivánhegy Limestone, Eperjes Hill.

fossiliferous limestone (Szélhegy Fm.) of biomicritic wackestone texture. Its major macrofossil content is as follows: crinoid ossicles, ammonites, belemnites and brachiopods. Among microfossils a few *Saccocoma* still can be found, but *Cadosina* and radiolaria are frequent, and in the topmost bed *Chitinoidella* also occurs indicating its age as Late Tithonian.

In the middle of the trench there is a left lateral strike-slip fault, on its eastern side Lower Jurassic limestone slabs (Kardosrét Limestone: Fig. 4/4) and crinoidal and brachiopod-bearing Hierlatz Limestone) are known. Some holes of the karstified Kardosrét Limestone are filled by manganese ore, as it is seen in the core of a borehole (Fig. 4/5). The texture of the Kardosrét Limestone is prevailingly an oncomicritic wackestone to packstone, occasionally it can also be an oncosparitic or intra-oncosparitic grainstone. Among and above the slabs the Szentivánhegy Limestone Fm. is found and the fissures in the Kardosrét Limestone are also filled by the same limestone. Its colour is pink to dark red, well bedded to laminated. The fossil content of the formation is poor consisting of a few ammonites, aptychi, belemnites, *Saccocoma* (in the upper part only), radiolaria and very few planktonic foraminifera. Its dominant texture type is biomicritic mudstone, wackestone or packstone, occasionally intraclastic too. Close to the eastern end of the trench as an erosional remnant above the red limestone whitish-pink limestones are found above a hard ground, its *Calpionella* content indicates Berriasian.

Fig. 4/4: Oncoidic Hettangian Kardosrét Limestone block in the upper part of the long trench, Eperjes Hill.

Fig. 4/5: Oxidic manganese ore infilling in the dissolution holes of the Kardosrét Limestone in core of a borehole drilled on the western side of the strike-slip fault of the long trench.

In the middle of the large stripping the short trench is found (Fig. 4/6) in which the slabs almost exclusively consist of the Dachstein Limestone Fm. with shells of *Megalodus* and the foraminifera *Triasina* sp. It is overlain by the same Szentivánhegy Limestone with a thickness of about 5 m as it is in the long trench but its fossil content is richer both in mega- and microfossils. Its age is Early to Middle Tithonian. Out of the short trench close to the northern end of the stripping in a 0.5-3 cm thick bed, masses of worm tubes form the crust in which *Calpionella* sp. specimens incl. *C. alpina*, one coral *Desmoseris* sp. (Fig. 4/7), several foraminifera, and fragments of brachiopods and belemnites have been reported (CSÁSZÁR et al. 2008). According to these and other data on the margin of Ámos High (VÖRÖS & GALÁCZ 1998) the sedimentation was highly lacunose for a long time interval from the middle Early Jurassic up to the Early Cretaceous albeit the water depth in the Early Cretaceous must have been shallow.

After a longer break in sedimentation the Szentivánhegy Limestone (Fig. 4/8) or in some cases the blocks of the

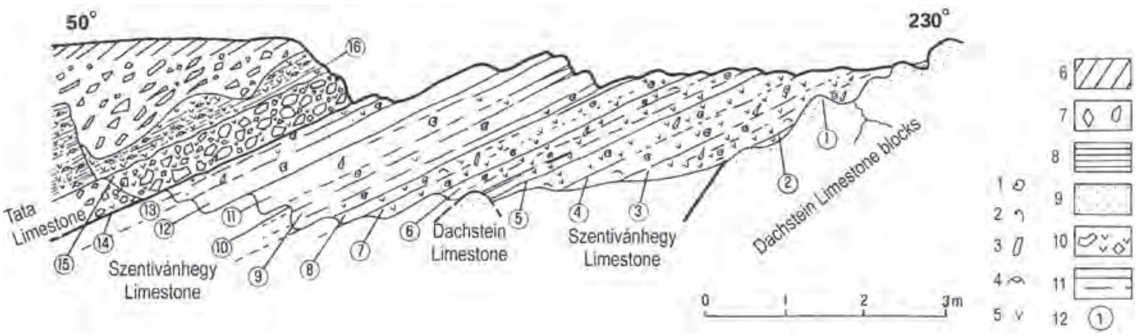


Fig. 4/6: Geological profile of the short trench in the middle of the large stripping, Eperjes Hill, Olaszfalu.
Legend: 1 - ammonite; 2 - aptychus; 3 - belemnite; 4 - brachiopod; 5 - crinoid stem; 6 - soil; 7 - scree; 8 - platy, laminated limestone; 9 - Dachstein Limestone with calcite spots (*Triasina* sp.?); 10 - basal breccia of the Tata Limestone with crinoidal matrix; 11 - light-red limestone banks; 12 - sample number.

Fig. 4/7: *Desmoseris* sp. solitary coral from a Lower Cretaceous patch of the large stripping, Eperjes Hill (det. by D. TURNSEK).

Fig. 4/8: A detail of the short trench located in the large strippig, showing the Upper Jurassic Szentivánhegy Limestone (left lower corner), above it its reworked fragment as a base of the overlying platy crinoidal limestone of (Barremian-)Aptian age.

Fig. 4/9: Dachstein Limestone blocks as a base of a new sequence started with the Tata Limestone Fm.

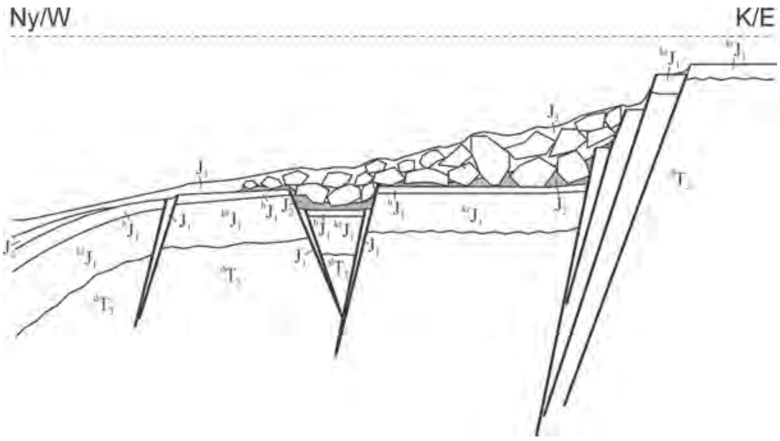


Fig. 4/10: Middle and Late Jurassic hypothetical palaeogeographic section on the western slope of the Eperjes Hill, Olaszfalu. It indicates the sudden subsidence of the western part of the Ámos High generating the formation of the rockfall/scarp breccia. The space between the big blocks supposed to be filled partially in the Middle Jurassic (J_2), while its larger part was filled in the Oxfordian and Early Kimmeridgian (J_3) only (Császár et al. 2008); other formations: $^{h}J_1$ - Hierlatz Limestone Fm.; $^{kr}J_1$ - Kardosrét Limestone Fm; $^{d}T_3$ - Dachstein Limestone Fm.

Dachstein Limestone (Fig. 4/9) were directly covered by the Tata Limestone Fm. In the short trench at the base of it half a metre of breccia deriving from the Szentivánhegy Limestone is found. The Tata Limestone is laminated, brownish red in colour and consists of crinoid ossicles, echinoid fragments and single brachiopod shells. In addition to the previous fossils it also contains planktonic and benthic foraminifera, bryozoans, and sponge spicules. The dominant fossils are clear indications of the high water agitation.

Special attention is paid to the study of the genesis of breccia composed of Upper Triassic (Dachstein Limestone) and Lower Jurassic (Kardosrét Limestone and Hierlatz Limestone). The palaeogeographic section is shown in Fig. 4/10. Because it is covered by Oxfordian, Kimmeridgian and Lower Tithonian Limestones for a long time the age of the breccias formation was considered to be Late Jurassic. Taking into consideration that on the platform there was no sedimentation during the middle and early Late Jurassic time and that the rockfall breccia must have been several tens of metres thick the ephemeral sedimentation could not have filled the big holes among the blocks if the rockfall had happened in Late Jurassic time. Another argument is that in the Early Late Jurassic the former extensional stress field changed to a compressional one. The third argument is that the Middle Jurassic was ruled by extensional stress field when the Penninic or Ligurian Ocean was formed, and its effect well documented at the margin of the Mór Trough, Vértes Hill.

Only one formation cannot be shown from the succession of the Eperjes Hill because of its soft character, this is the Tés Clay Formation. It was introduced at Mór, at the foot of the Vértes Hill. This formation was deposited mainly in non-marine environment after an elevation and erosion period in the Early Albian. Its presence is proved by boreholes but it is evidenced by the special flora element growing along the cliff of the hill. The hill is capped by the Zirc Limestone of Urgonian facies. The lower two member rank units can be seen here. The Lower part (Eperjeshegy Limestone Mb.) is composed of thick-bedded or massive rudistid limestone (Fig. 4/11) of dominantly biomicritic or intrapel-biomicritic packstone, seldom biosparitic grainstone. Rudists occur in rock forming

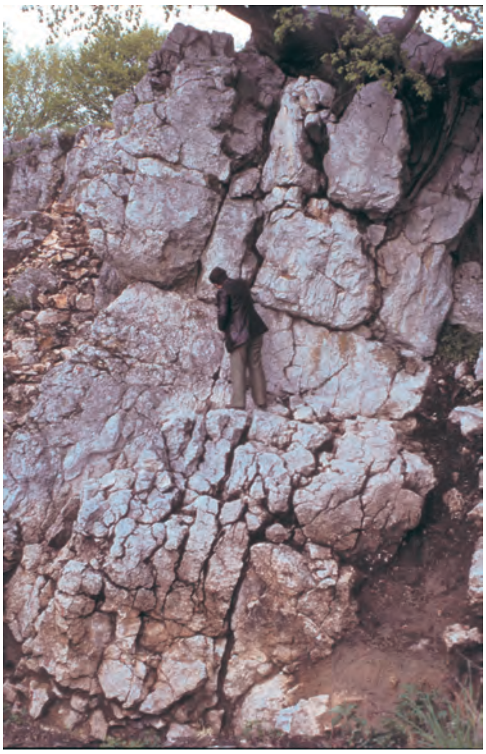


Fig. 4/11: Lower (Eperkéshegy) Member of the Zirc Limestone Fm. of rudistid Urgonian facies on the top of the Eperjes Hill.

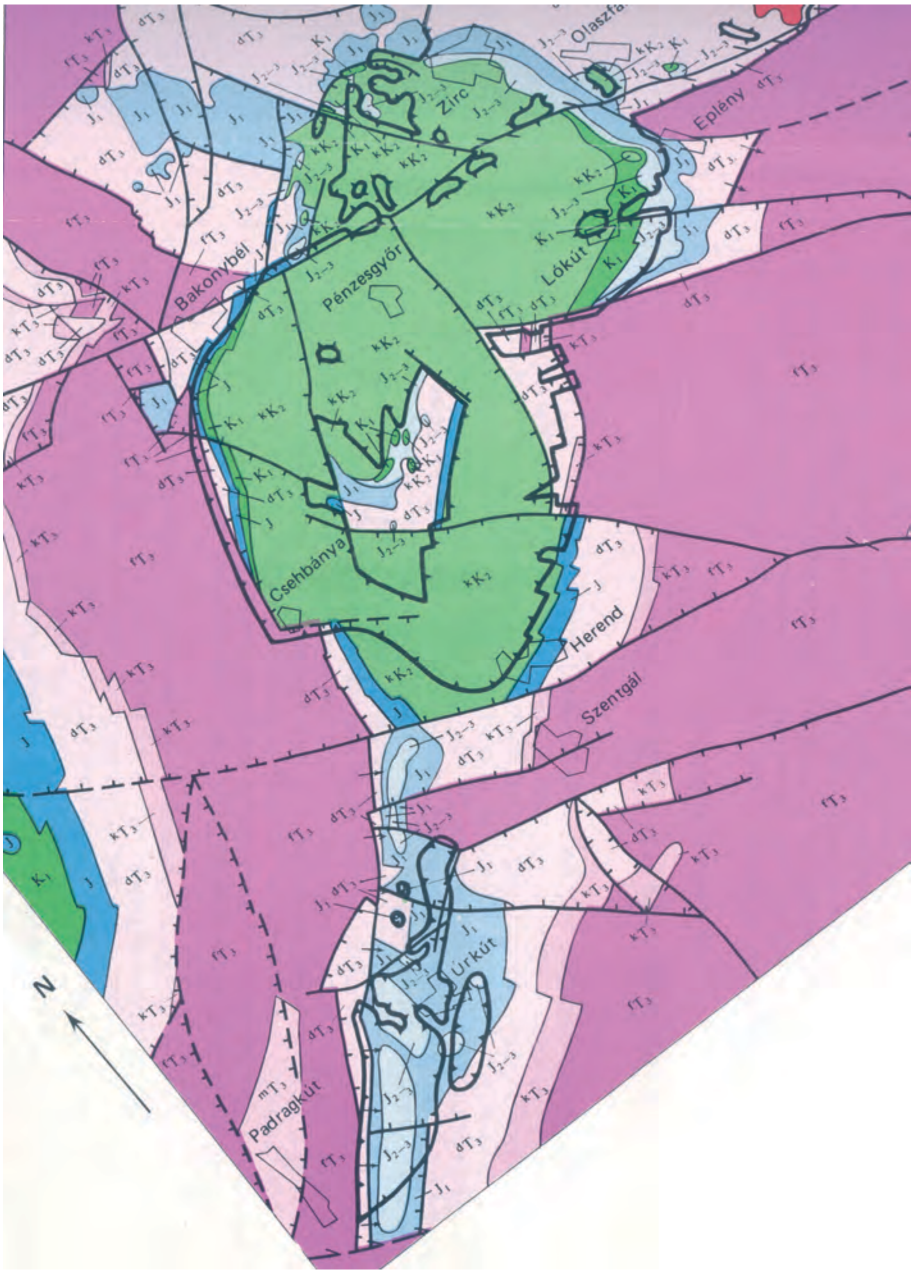


Fig. 4/12: Geological map of the Northern Bakony without formations younger than Albian (footwall of the Tés Clay Fm.). Legend*:* $^{ö}K_2$ = Környe Limestone Fm.; $^{x}K2$ = Lower Cretaceous Alsópere Bauxite Fm.; $^{k}K_2$ = Lower Cretaceous Tata Limestone Fm.; K_1 = lower Lower Cretaceous formations; $J_{2\text{-}3}$ = Middle and Upper Jurassic; J_1 = Lower Jurassic; J = Jurassic Fm. at large; $^{k}T_3$ = Kössen Fm.; $^{d}T_3$ = Dachstein Limestone Fm.; $^{f}T_3$ = Upper Triassic Hautdolomite Fm.

quantity. According to CZABALAY (in CSÁSZÁR 2002), the ruling genus is the *Agriopleura* (*A. blumenbachi, A. marticensis*) but there are *Toucasia carinata, Pseudotoucasia santanderensis, Requenia pellati, Eoradiolites davidsoni* and *E. murgensis* species as well. Among them not only independent specimen can be found but in the upper half some bunches/bouquets as well. Almost all of them capsized or overturned. In thin sections the following fossils have been noted: foraminifera (*Orbitolina, Cuneolina, and Dicyclina),* algae and a few *Salpingoporella* green algae. There is a rapid transition between the Eperjeshegy Member and its overlying; the well bedded Mesterhajag Member. The rudists are replaced by foraminifera within a few beds. The lower part of this member is predominated by the small size benthic foraminifera although there are some *Orbitolina* and planktonic foraminifera and algae as well. In the upper part of the Mesterhajag Member *Orbitolina* often occur in rock-forming frequency. GÖRÖG (1996) identified the following taxa: *Orbitolina (O.) concava, O. (O.) sefini, O. (M.) aperta, O. (C.) baconica, Cuneolina* sp., *Dicyclina schlumbergeri*. The texture of these beds is mainly biointrasparitic grainstone or packstone.

The sedimentary environment of the Eperkéshegy Member is supposed to be slightly or occasionally strongly turbulent lagoon, while it is at the case of the Mesterhajag Member is a sand facies behind the reef-like barrier.

Stop 2. Abandoned quarry between villages Zirc and Borzavár

Lower Cretaceous limestones

Géza CSÁSZÁR

This quarry is situated in the Zirc Basin (Fig. 4/12), at the boundary between the Northern and the Southern Bakony

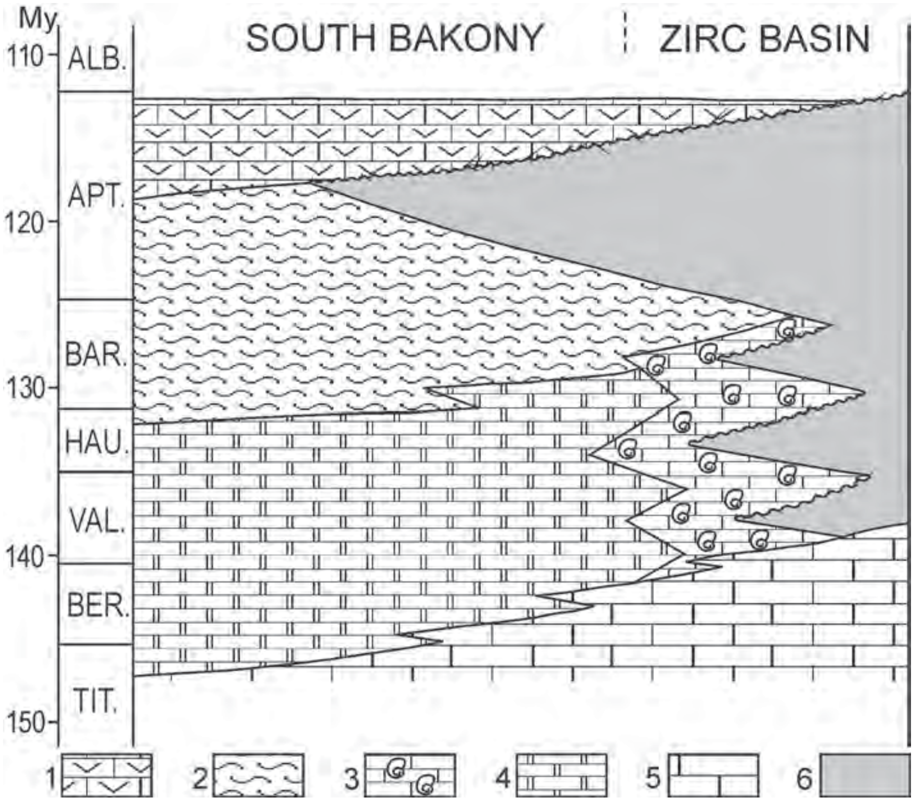


Fig. 4/13: Connection between the Mogyorósdomb Limestone, the Sümeg Marl and the Borzavár Limestone Fm. in the Zirc Basin. Legend: 1 - Tata Limestone Fm.; 2 - Sümeg Marl Fm.; 3 - Borzavár Limestone Fm.; 4 - Mogyorósdomb Limestone Fm.; 5 - Szentivánhegy Limestone Fm.; 6 - submarine to subaerial gap.

representing the easternmost occurrence of the Borzavár Limestone Fm. interfingering with the Sümeg Marl Formation within a short distance to the west (Fig. 4/13). The eastward shallowing tendency of the Sümeg Marl can be noticed in the radical decrease of the chertification and that of the thickness of the Sümeg Marl. The Maiolica-type facies of the Mogyorósdomb Limestone is well developed in the nearby Lókút Basin.

The Borzavár Limestone is well-bedded (Fig. 4/14; Fig. 4/15) violet and yellow in colour, and contains plenty of crinoid ossicles, including well preserved calyxes (Fig. 4/16), among others new species were described from here, several brachiopods, and a few badly preserved ammonites. The lack of calpionellids, the ruling community and their preservation condition indicate a relatively shallow and at least in parts separated basin with gentle water agitation. Seldom it can still contain a few chert nodules. The age of the app. 15 m thick formation is supposed to be Valanginian-Hauterivian (Fülöp 1964).

One km distance to the south-eastward in the forest of Zirc (Pintér Hill) a 40 cm thick, surprisingly condensed limestone bundle (Fig. 4/17) substitutes the app. 15 m thick succession described above from the abandoned quarry. Unfortunately this ammonite rich bundle has completely been destroyed over the last 20 years (Fig. 4/18). After reinvestigation of the rich ammonite and belemnite collection according to Főzy & Janssen (2005) the age of the Borzavár Limestone is Late Valanginian to Early Hauterivian, Marble Quarry, Zirc.

The Borzavár Limestone Formation in the abandoned quarry - see above - is capped by a hardground surface which is the product of a gap of a not well known time

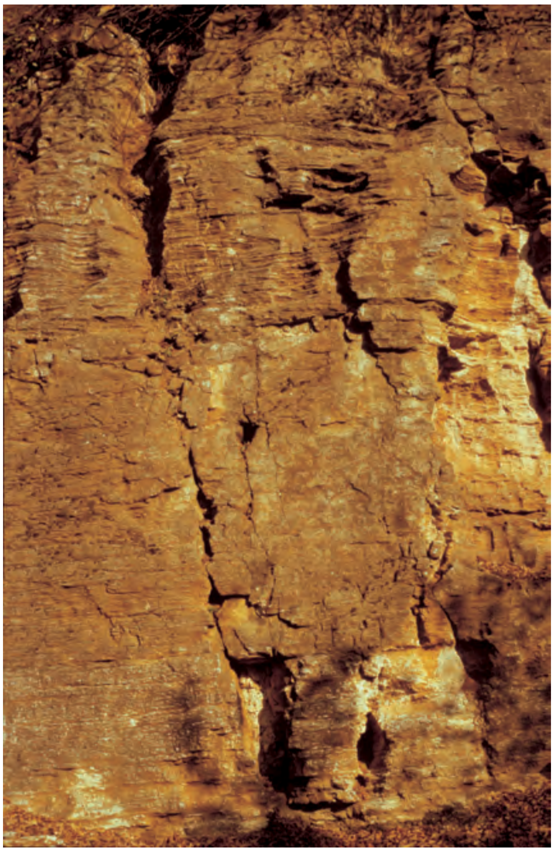
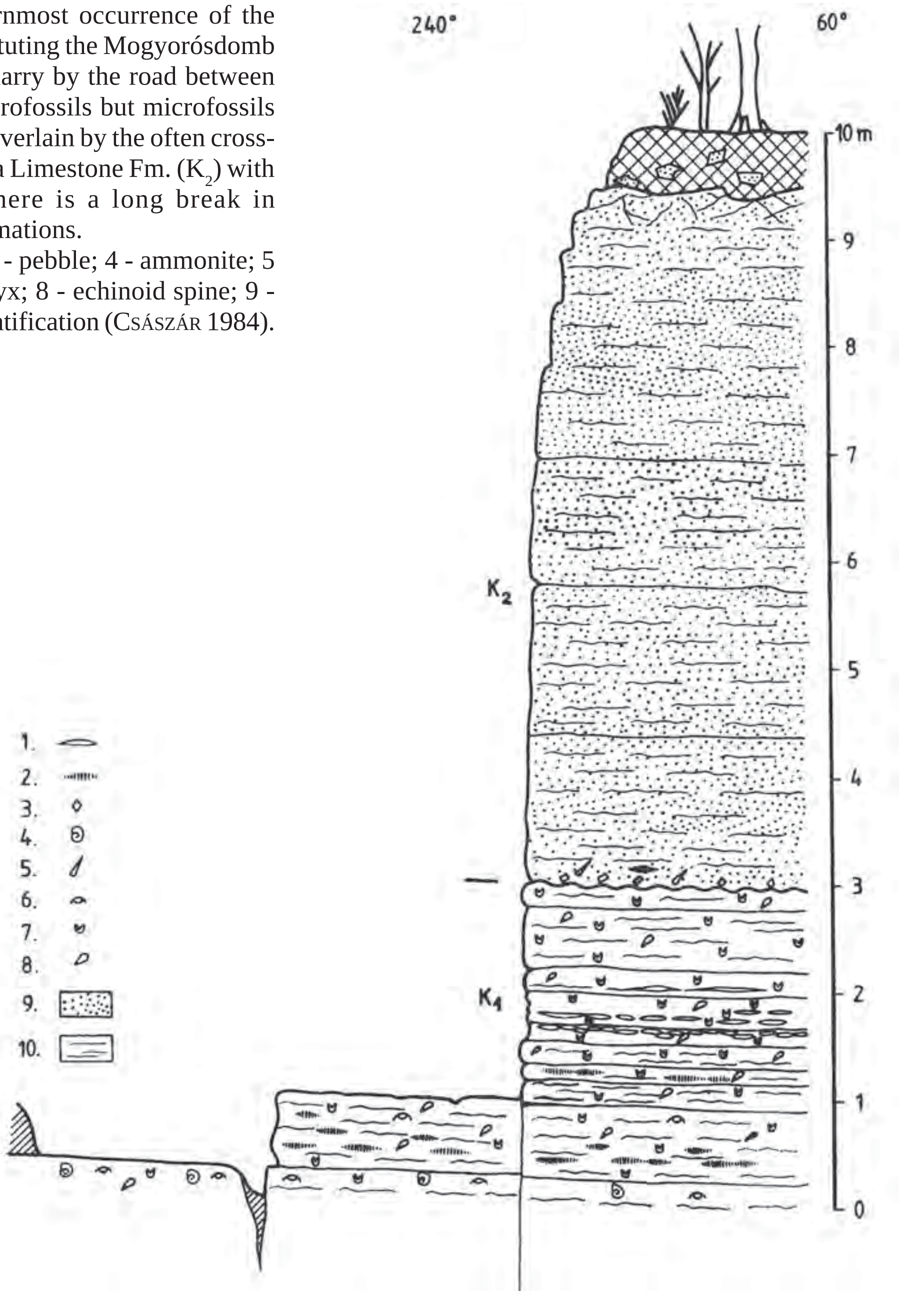


Fig. 4/14 One time condition of the abandoned quarry between Zirc and Borzavár. The boundary between the Tata Limestone (upper part) and the Borzavár Limestone (lower fourth) can be recognized along the change of the shade.

Fig. 4/15: Type locality and easternmost occurrence of the Borzavár Limestone Fm. (K_1) substituting the Mogyorósdomb Limestone Fm. in an abandoned quarry by the road between Zirc and Borzavár. It is rich in macrofossils but microfossils are also not scars. The formation is overlain by the often cross-bedded, shallow marine, coastal Tata Limestone Fm. (K_2) with gentle angular unconformity. There is a long break in sedimentation between the two formations.
Legend: 1 - lens; 2 - chert nodule; 3 - pebble; 4 - ammonite; 5 - belemnite; 6 - brachiopod; 7 - calyx; 8 - echinoid spine; 9 - crinoidal sand; 10 - week internal stratification (CSÁSZÁR 1984).



interval. The overlying formation belongs to the Tata Limestone of probably Aptian age. There is a very small angular unconformity between the two formations (5º difference between the dip of the bedding planes of the Borzavár Limestone and the erosional surface). In the basal bed of the Tata Limestone a few small size, subangular pebbles of chert origin can be found. This limestone consists of crinoid and echinoid fragments forming a cross-bedded, consolidated biodetrital sand of shallow marine origin. The transport direction is highly variable, often alternating; the major dip direction is northerly and southerly probably indicating the ruling current (transport) directions (Fig. 4/19). In addition to the echinoderm fragments the formation contains belemnites, brachiopods, foraminifers (mainly benthic ones), occasionally Bryozoans and coralline algae. Its significant local texture types are bioextrasparitic and extrabiosparitic grainstone. The

Fig. 4/16: Lower Cretaceous Borzavár Limestone Fm. rich in crinoid ossicles including well preserved calyxes (on the right side), abandoned quarry, under natural protection.

Fig. 4/17: Highly condensed, ammonite-rich bed as erosional remnants of the special type of Borzavár Limestone Fm. in the “Marble Quarry“ at the western end of Zirc, close to the Zirc-Borzavár road. The underlying limestone is the unusually thick-bedded Szentivánhegy Limestone Fm. of Late Jurassic age.
Legend: 1 - calcareous nodule, 2 - intraformational limestone fragment, 3 - chert nodule, 4 - ammonite, 5 - brachiopod, 6 - bivalve, 7 - coral (CSÁSZÁR 1984).

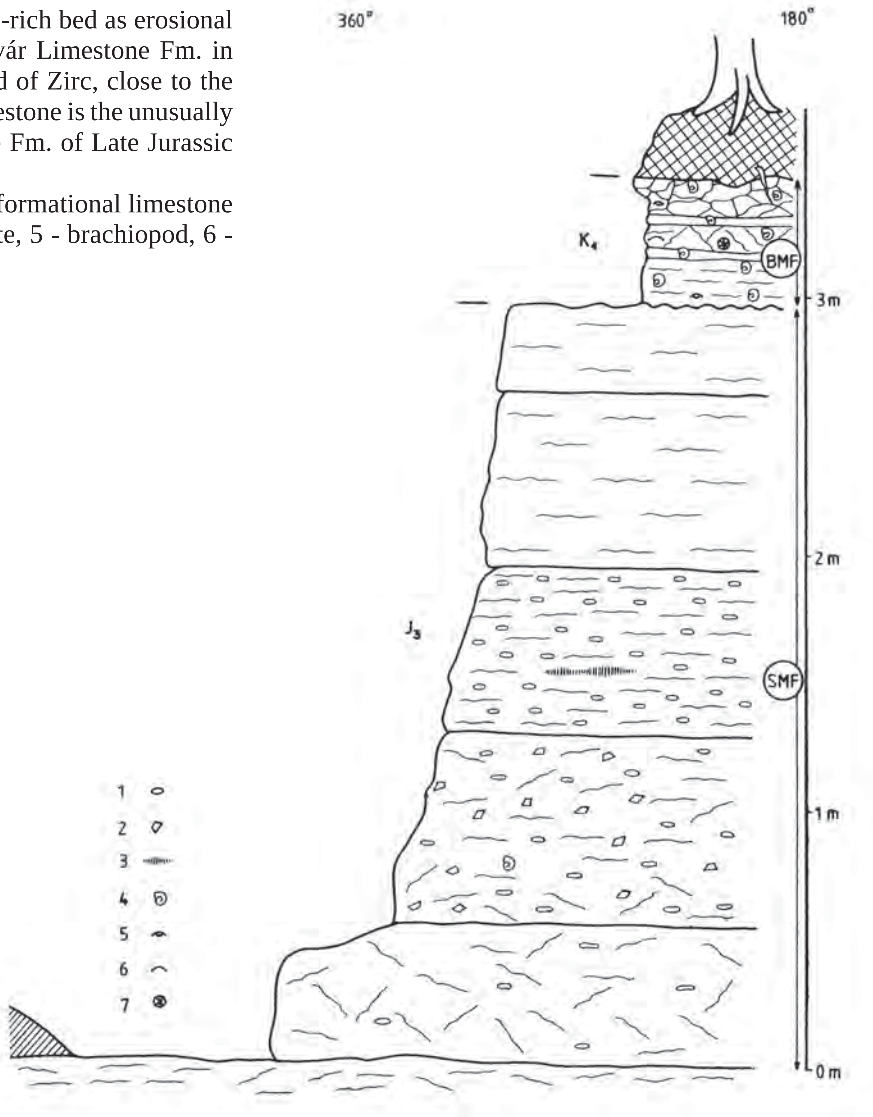


Fig. 4/18: Late Valanginian to Early Hauterivian ammonite-rich beds of 40 cm total thickness under the tree in the middle of the photo. It is underlain by the Upper Jurassic Szentivánhegy Limestone Fm.

depositional environment is coastal shallow marine with frequent and changeable currents.
The interfingering of the two formations and the lacunose succession are the consequence of the upwarping of the central part of the Transdanubian Range in the Early Cretaceous and its combination with the Austrian tectonic phase in the Late Aptian to Early Albian.

Fig. 4/19: Unusual combination of cross-beddings in the Tata Limestone, upper part of the cliff in the protected quarry between Zirc and Borzavár.

Stop 3: Szilas Valley/Pálihálás homestead, Borzavár Village
Upper Jurassic and Lower Cretaceous limestones
Géza CSÁSZÁR

The natural outcrop extended artificially (Fig. 4/12) comprises the upper part of the Jurassic succession from the Oxfordian to the Berriasian in basinal development and the basal (Aptian) beds of a Lower Cretaceous sedimentary sequence (Figs. 4/20a, b: CSÁSZÁR 1984, 1988). The total thickness of the section is 28 m. Its lowermost unit is the Lókút Radiolarite Fm. which is brownish-pink or violet-brownish-yellow, laminated, clayey with reddish brown chert lenses. In thin sections chertyfied bioclast-bearing mudstone and wackestone are seen. The fossil association consists almost exclusively of radiolaria in addition to which a few small echinoderm fragments, ostracods and a single *Nodosaria* sp. are attached.
The transition between the Lókút Radiolarite and the Pálihálás Limestone is gradual. It means that the basal part of the Pálihálás Limestone is also laminated or thin-bedded and nodular (Fig. 4/21). The colour is red, brownish- or greyish-red. Its dominant fossil elements are ammonites, their aptychi and brachiopods. The frequency of the latter one increases upwards. Based on the macroscopic features the formation can be subdivided into two subunits. The thinner lower subunit and especially its basal part is characterized by nodule-like rock fragments which are supposed to be either sedimentary breccia grains, without considerable transport or they look like well rounded pebbles. It is very important to mention that this phenomenon also occurs in the Oxfordian but it is less significant as in the Gerecse Mts. Upwards in the section (mainly in the upper subunits) they lose this accentuated contour and look like ordinary nodules of smaller sizes. The ammonites are the dominant macrofossils among them, according to GALÁCZ, *Ptycophylloceras*, *Phylloceras, Haploceras, Protetragonites* and *Perisphinctes* are the most important genera. Among macrofossils brachiopods are common in the upper third of the formation only, while Belemnites are scarce but may occur even among breccia grains. Fragments of echinoderms are found throughout the formation.
The *Saccocoma* and the *Globochaete* are the most frequent microfossil elements of the formation. From among

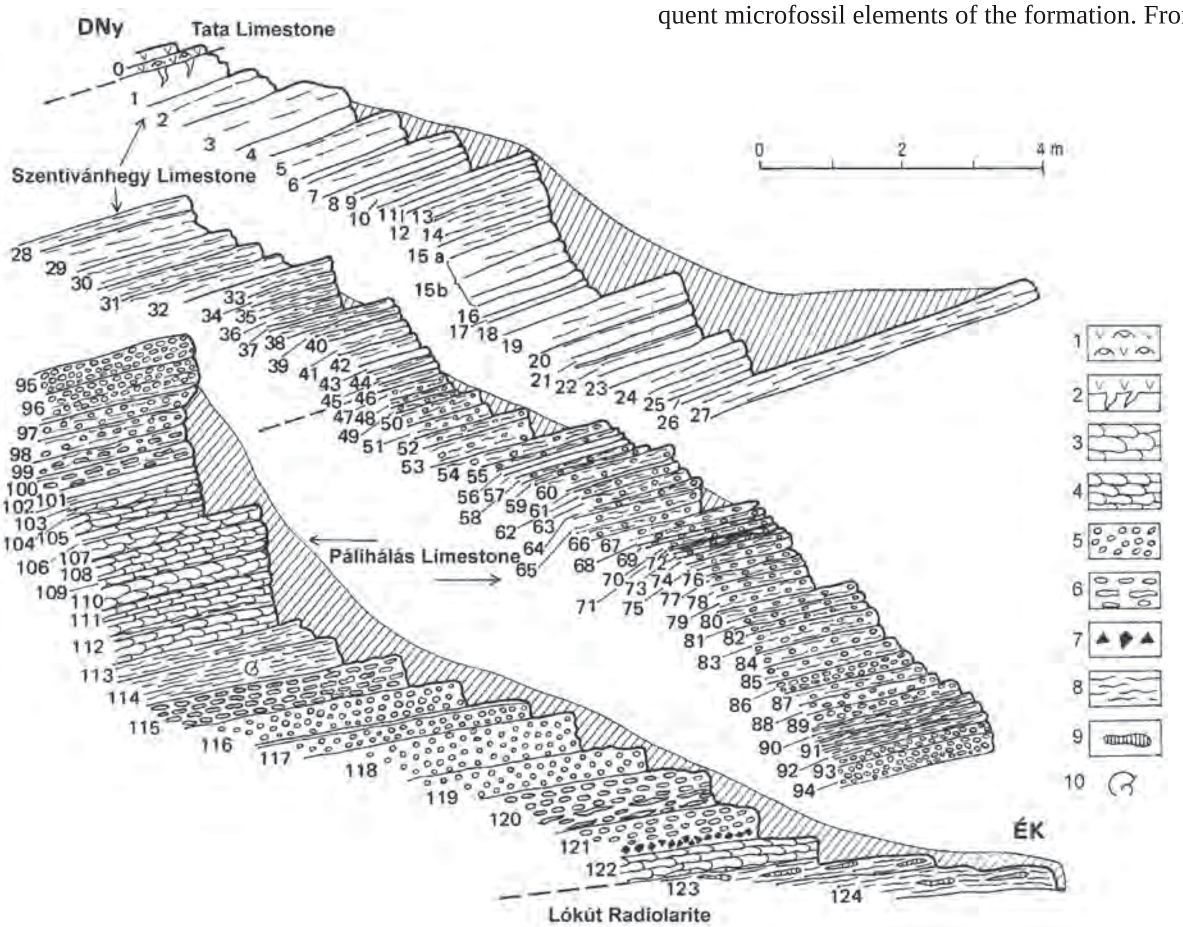


Fig. 4/20a: One of the thickest Upper Jurassic succession is explored in the natural outcrop located at the entrance of the Szilas Valley. The typical “Ammonitico Rosso“ type, *Saccocoma*-bearing Kimmeridgean to Lower Tithonian Pálihálás Limestone continuously developed from the slightly calcareous Lókút Radiolarite Formation. The contact of the Szentivánhegy Limestone Fm. and the Aptian Tata Limestone Fm. is sharp, erosional (after CSÁSZÁR 1988).
Legend: 1 - crinoideal, brachiopodal limestone, 2 - karstic infilling, 3 - slightly clayey limestone with irregular lenses, 4 - lenticular limestone, 5 - red clayey limestone with small nodules, 6 - nodulose, lenticular limestone, 7 - limestone breccia, 8 - clay film, 9 - chert, 10 - ammonites.

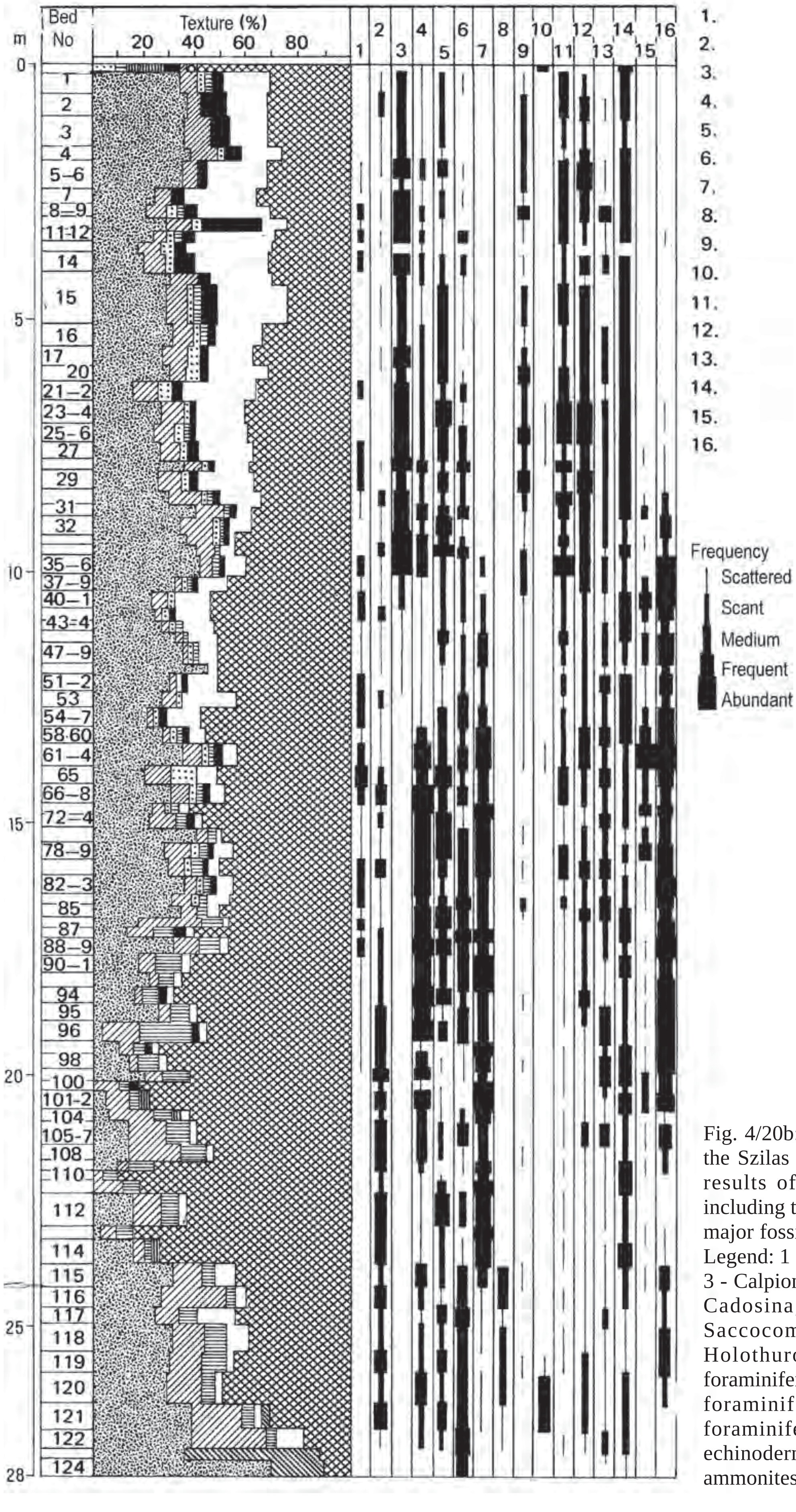


Fig. 4/20b: The columnar section of the Szilas Valley outcrop shows the results of the thin section study including the textural pattern and the major fossil elements as well.
Legend: 1 - coated grains, 2 - quartz; 3 - Calpionella; 4 - Globochaete; 5 - Cadosina; 6 - Radiolaria; 7 - Saccocoma; 8 - filaments; 9 - Holothuroidea; 10 - planktonic foraminifera; 11 - arenaceous benthic foraminifera; 12. hyalin benthic foraminifera; 13. ostracode; 14 - echinoderm; 15 - brachiopod; 16 - ammonites (after CSÁSZÁR 1988).

Fig. 4/21: Well-bedded, "Ammonitico Rosso" type nodular limestone at the entrance of the Szilas Valley, Borzavár.

other planktonic fossils the followings are very significant components of the formation: radiolaria and *Cadosina* (mainly in the middle and upper third of the formation). From the latter one I. Nagy identified 11 species. These are the most frequent ones: *Cadosina parvula*, *C. lapidisa* and, *Colomisphaera carpathica*. The algal filaments and planktonic foraminifera are restricted to the lowermost beds of the formation. Other echinoderm fragments found throughout the section. Foraminifera are represented by both hyaline (*Cornuspira, Lenticulina* forms) and arenaceous ones (*Textularia* sp.), mainly in the upper part of the formation. The first appearance of Calpionellids coincides with the rapid disappearance of *Saccocoma* elements.

Based on texture the formation can be subdivided into two parts. The lower interval below bed number 115 the micritic matrix predominates but the microsparry texture is also common. The bioclast content is represented by a relatively low amount. The typical texture types are wackestone and packstone. It is important that in this macroscopically debris-like rock the lack of intraclasts is apparent. The upper boundary of the formation is indicated by the disappearance of the nodules.

The Szentivánhegy Limestone Formation pales from light red to white. The lower part of the formation is thin bedded, which upsection becomes thicker bedded (Fig. 4/22). The macrofauna is restricted mainly for the lower 15 layers. Ammonites are the leading forms, but brachiopods and belemnites are also more frequent here. The few shells are almost concentrated in this part of the formation. In thin-sections the texture is relatively homogenous: intraclastic pelbiomiocrite, i.e. wackestone, less often packstone. The microspar content is characteristic and dominant throughout the formation. The most typical microfossil element is *Calpionella,* occurring in great masses except the lowest beds. The most important group among them is the *Calpionella alpina* one. According to Knauer J. in the lower part of the formation *Crassicollaria* (*C. parvula, C. intermedia, C. brevis, C. massutiniana*) are typical, while in the bulky layers *Remaniella* (*R. cadishiana, R. ferasini*) occur. Foraminifera are always very frequent, echinoderm debris, *Cadosina* and in the lower part radiolaria are also abound. The numbers of *Globochaete* and ostracoda decreases; *Saccocoma* is found only in the bottom.

The youngest part of the sequence is the Tata Limestone Fm., appearing after a considerable disconformity but also as infilling in cracks and holes. It is light red, sometimes grey and is made up mainly of echinoderm debris with a few brachiopods and belemnites. The texture in thin-sections is an extrabiosparitic grainstone, in which besides echinoderm ossicles, planktonic foraminifera and bryozoa are found as well.

In the sequence the Lókút Radiolarite Fm. represents the deepest water environment. Later the water depth decreases first slowly, then abruptly, and the limestone varieties reflect shallowing shelf condition. The pelite content decreased, biomass significantly increased and within this benthic foraminifera, pelletal grains and intraclasts are frequent. For the lower forth of the Pálihálás Limestone occasional strong currents and bioturbation is characteristic. After the uplift and erosion shallow-water sedimentation started in littoral, well-agitated water during the sedimentation of the Tata Limestone Formation.

Based on palaeontological investigation the ages of the formations are as follows: Lókút Radiolarite: Oxfordian, possibly Kimmeridgian, and Pálihálás Limestone: Late Kimmeridgian to Late Tithonian, Szentivánhegy Limestone: Late Tithonian to Berriasian. The age of the Tata Limestone Fm. is Early Aptian by analogy.

Fig. 4/22: Upper part of the thick-bedded, white or pinky Upper Tithonian to Berriasian Szentivánhegy Limestone Fm., Szilas Valley, Borzavár.

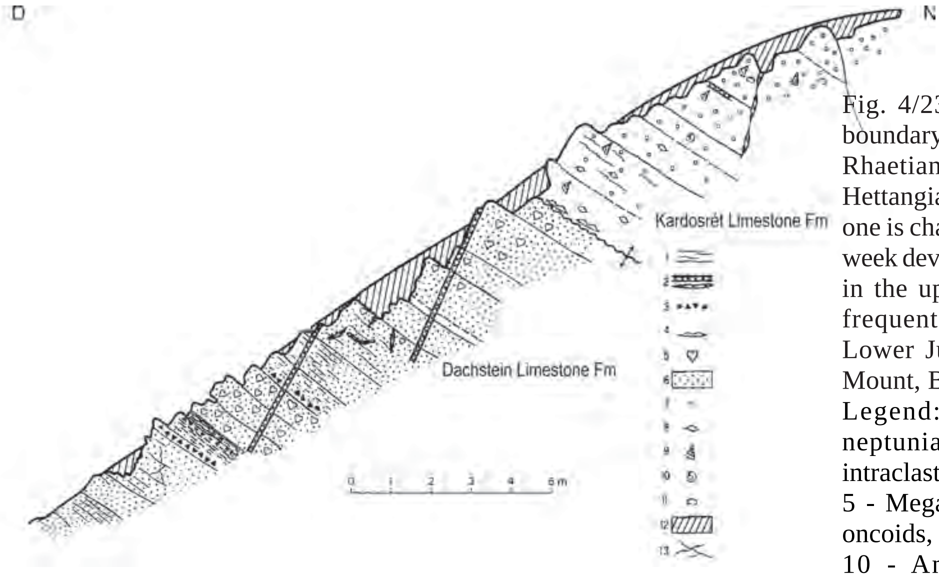


Fig. 4/23: The section is acting as the boundary stratotype for the contact of the Rhaetian Dachstein Limestone and the Hettangian Kardosrét Limestone. The first one is characterized by *Megalodus* sp. and week development of the Lofer-cycle while in the upper one the oncoids are found frequently. The section is crosscut by Lower Jurassic neptunian dykes, Köris Mount, Bakonybél.
Legend: 1 - algal mat, 2 - Liassic neptunian dyke, 3 - black and brown intraclast, 4 - flat calcite coated fissure fill, 5 - Megalodus, 6 - calcite speckles, 7 - oncoids, 8 - Brachiopoda, 9 - Gastropoda, 10 - Ammonites, 11 - Echinoderm fragments, 12 - soil, 13 - fissures.

Stop 4: Köris Mount, Bakonybél (optional stop)
Triassic/Jurassic boundary
Géza Császár

The section is located on the SE slope of the Köris Mount, the highest point of the Bakony Mountains. The 23 m thick sequence serves as lithostratigraphic boundary stratotype for the boundary between the Dachstein Limestone and the Kardosrét Limestone Formations. The succession is penetrated by two Lower Jurassic neptunian dykes. The natural outcrop is excavated to improve exposure.

The greater part of the section is composed of Dachstein Limestone (Fig. 4/23), the prevailing part of which is member C of Lofer cycle. It is typical for the major part of the Transdanubian Range. It is thick-bedded, sometimes massive and greyish-white with frequent purple or pinkish mottles. To unaided eye it looks aphaneritic or fine-crystalline with abundant calcite speckles and occasionally with megalodontid bivalves. The intertidal member B shows transitional character between members B and C; the rock can be purple, reddish or dull-grey, slightly laminated and aphaneritic and occasionally contains sparse, disseminated, tiny, black or brown intraclasts. Bird's eye structure is limited to a single bed (bed 15).

The supratidal member A is 5-6 cm in thickness of red clay-lense-dotted limestone below bed no 4 of member B. The texture in thin sections are prevailingly biomicritic wackestone to packstone but there in a few cases there pelmicritic mudstone or biosparitic grainstone as well. Processes of both micritization and sparitization of matrix and fossils can be observed which hinders the textural characterization and palaeoenvironmental interpretation. The microfossil assemblage consists of foraminifera, green and red algae, ostracods, coprolites, gastropods and echinoderm fragments (Császár & Oravecz-Scheffer 1987, Császár et al. 2005). Based on the presence of *Triasina hantkeni* and *Griphoporella curvata* the age of the formation is Late Rhaetian.

The upper part of the section starting with bed no. 20 belongs to the Kardosrét Limestone. The contact with the Dachstein Limestone is sharp, although the Kardosrét Limestone is also thick-bedded here. Its colour varies from greyish dull yellow to brownish shades and to purplish-red especially in the case of oncoids, the frequency of which is rapidly increasing upwards.

Stop 5: Manganese slurry reservoir, Úrkút village
Lower Cretaceous marl and limestone
Géza Császár

The Cretaceous succession of the Southern Bakony shows significant differences compared to the Northern Bakony one. The underlying rocks are represented by varied Jurassic limestones and the Lókut Radiolarite Fm. The extent of the Lower Cretaceous formations is restricted to the area around the Hajag Hills Group and separately to the Padagkút and Úrkút environs. In the first area the irregular diversification of the Zirc Limestone already started, while in the Úrkút area the succession is fundamentally different from those, developed in the North Bakony and Vértes Foreland. The Tés Clay can be subdivided into two parts. Its lower third is a member rank unit and it consists of reworked and highly weathered Jurassic cherts (mainly radiolarite) and limestone fragments forming a thick breccia body. The larger upper part of the formation is grey, marine clay, clay-marl and marl.

At the site of the manganese slurry reservoir (Fig. 4/12) the underlying rock of the Tés Clay Fm is the cherty Isztimér Limestone Fm. Above and within this formation variegated clay is found (Császár 1986, 2002). At the base of the Zirc Limestone the clay is impregnated by manganese (see the columnar section compiled on the northern slope - Fig. 4/24). The transitional beds between the Tés Clay and the Zirc Limestone are made up of calcareous marl and clayey limestone, devoid of macrofauna or just a few gastropods occur. The considerable quantity of sponge spicules and the dominance of arenaceous foraminifera indicate a fore-slope sedimentary environment. In this

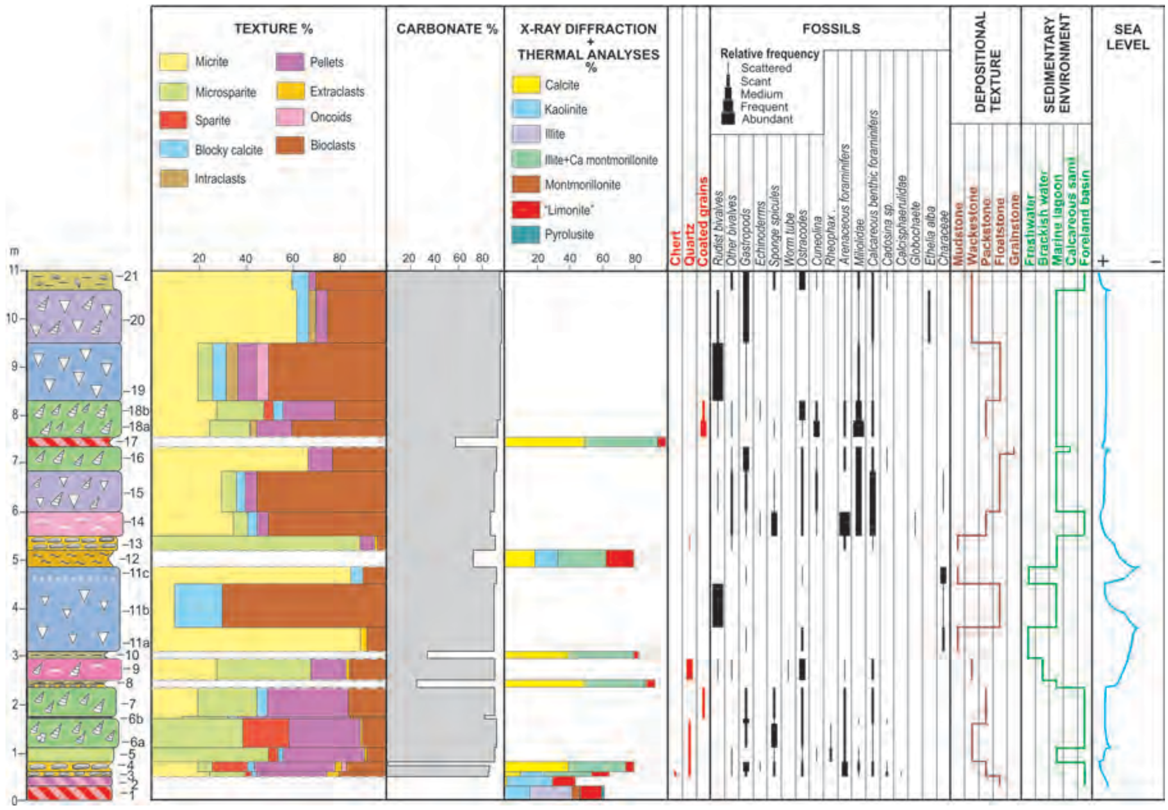


Fig. 4/24: The columnar section shows the lower part of the Zirc Limestone Fm. and the transitional beds between the Zirc Limestone and its underlying Tés Clay Fm. with the results of thin section study, X-ray diffraction analyses and their interpretation. Manganese slurry reservoir, Úrkút village.

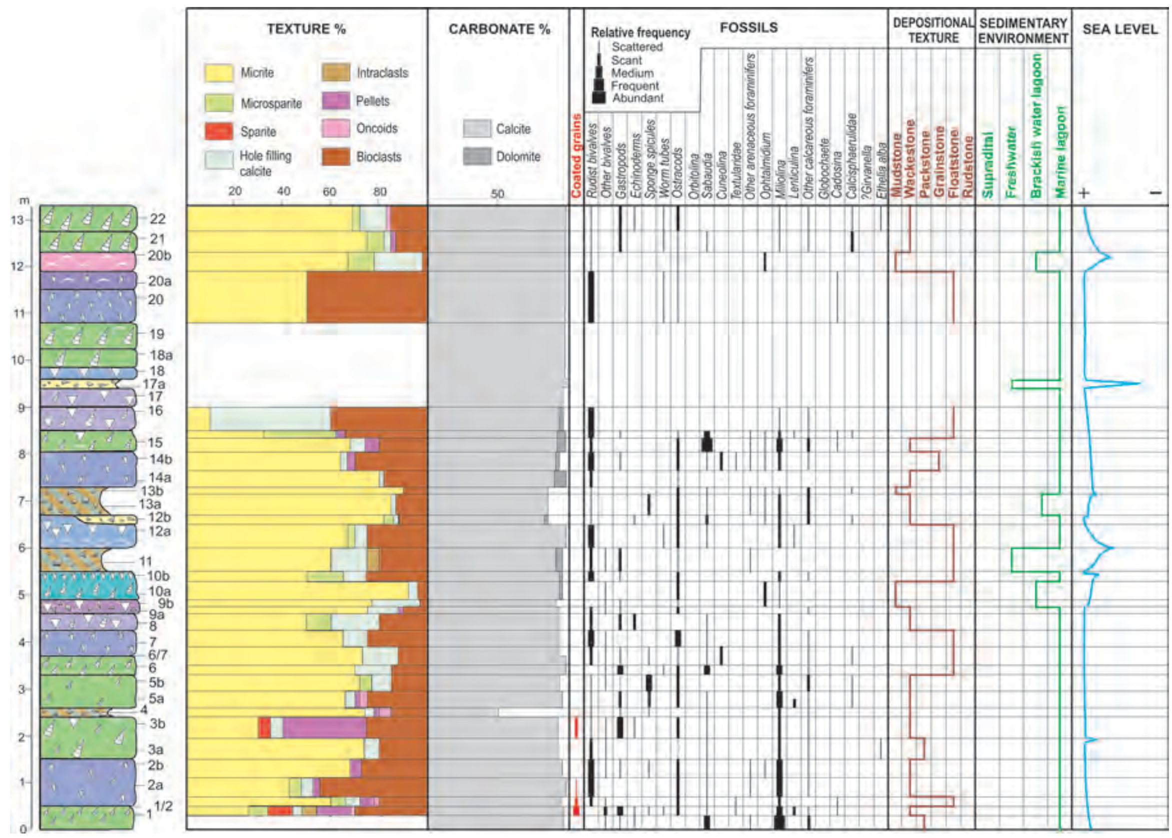


Fig. 4/25: Continuation of the Zirc Limestone succession with the same parameters as in the previous Fig. Manganese slurry reservoir, Úrkút village.

Fig. 4/26: Fundamental changes in the fossil community of the Úrkút Member of the Zirc Limestone. Lower bank: brecciated with high porosity and root structure filled with grey clay of probably tuff origin. This thin clay is separating the lower bank from the upper one. The thicker upper bed is divided by its fossil content into two subunits. The lower part consists of tiny gastropods (*Nerinella* and *Nododelfinula*), the upper part of *Eoradiolites* while in the matrix cannot be seen difference, manganese slurry reservoir, Úrkút (photo: H. Arnaud).

columnar section upwards gastropod-bearing beds predominate but two rudistid and some thin clay and marl beds intercalate. Another columnar section showing the succession of the western slope (Fig. 4/25) is similar to the previous figure. The well bedded succession is also rich in macrofossils, mainly gastropods often monogeneric or even monospecific character. It is characteristic for both the tiny gastropods such as the *Nododelfinula* or *Nerinella* and for the giant *Adizoptyxis coquandiana* (D'Orb.). Much less frequent are the rudistid beds which often seem to be monogeneric. It is very scarce that two types of fossils occur together in the same beds. It is a very special situation when within a limestone bed without any break in sedimentation the genera of different kinds of fossils suddenly replace each other (Fig. 4/26). The previous section was characterized by clayey bed intercalations, while the latter one by breccia intercalations the majority of which can be qualified as storm and desiccation breccia. Two of them are proved to be of brackish-water origin. The intercalation of bauxite clay is an indication of the nearby coastal zone behind which the bauxitization process was going on in the Middle Albian. Seldom root structure can also be recognized, which is an indication of the temporal existence of the forested karsts (Fig. 4/26). The composition of the infilling clay in the photo suggests tuff origin.

The carbonate content, the microfossils, the depositional texture, the sedimentary environment, and the relative sea-level change can be seen on the Fig. 4/24 and Fig. 4/25. All in all, it's time to compare the middle Lower Cretaceous of the Northern and the Southern Bakony (Fig. 4/27). The prevailingly freshwater and brackish-water Tés Clay are interfingering with the Környe Limestone and probably partly with the Eperkéshegy Member of the Zirc Limestone Fm. and getting thinner westwards. The profile clearly indicates the direction of the transgression towards SW. In spite of the fact that the maximum thickness of the Zirc Limestone in the Northern Bakony is 50 m, it can be subdivided vertically into 3 member rank units, because the radical change in the sedimentary environment is expressed in the lithology as well. At the same time the

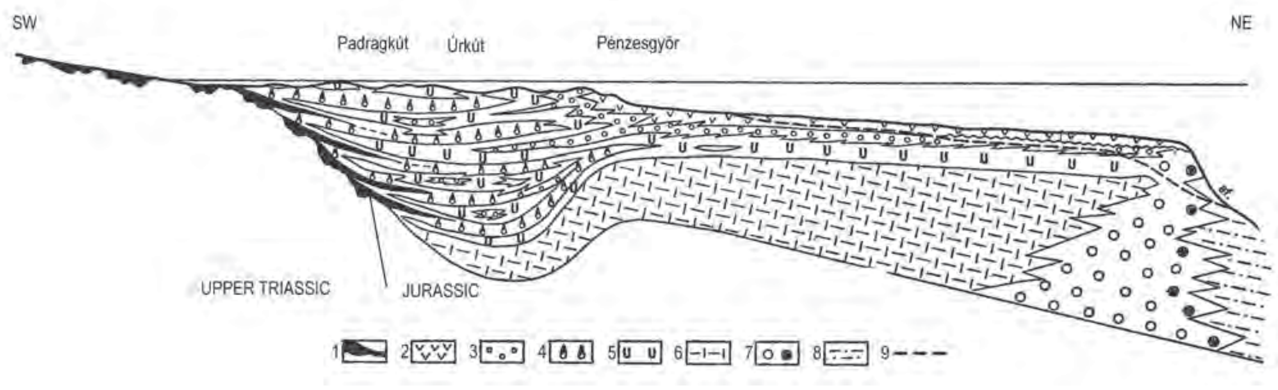


Fig. 4/27: Relationship between the South Bakony and the North Bakony facies areas and between the Zirc Limestone and the Környe Limestone just prior to the mid-Vraconian uplift (after Császár 1986).
Legend: 1 - bauxite; 2 - extraclastic limestone with echinoderm detritus (Gajavölgy Mb.); 3 - intraclastic and foraminifera-rich limestone; 4 - gastropodal limestone; 5 - rudistid limestone; (2-5: Zirc Limestone Fm.); 6 - Tés Clay Fm.; 7 - Környe Limestone Fm.; 8 - Vértessomló Siltstone Fm.; 9 - Mid-Vraconian erosional surface.

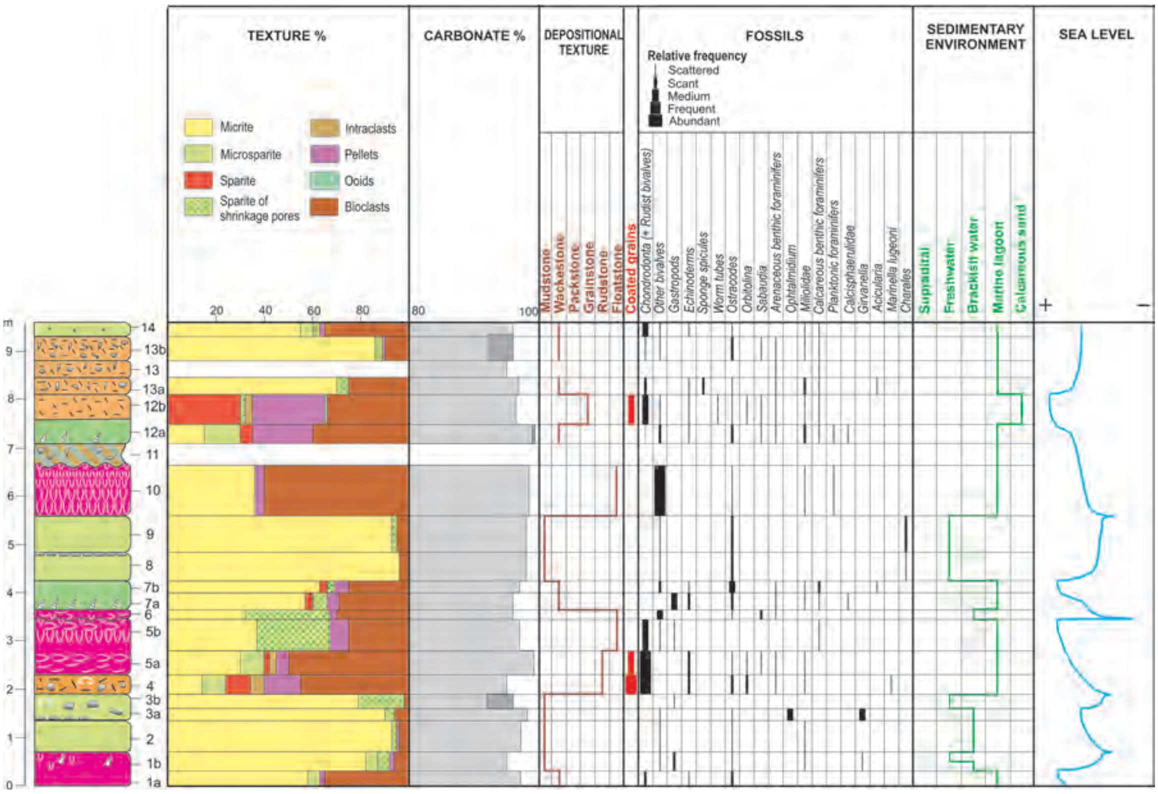


Fig. 4/28: Columnar section with results of related thin section study and their interpretation from one of the abandoned quarry close to the road Úrkút and Ajka. Note the Chondrodont generations in life position in two biostromes.

thickness of the Zirc Limestone is multiplied, it is over 200 m although it has no direct sedimentary cover. The peculiarity of the situation is that this succession has no significant lithologic differences in spite of the rich fossil community. It means the carbonate production could keep space with the rapid subsidence while in the Vértes Foreland and in the Northern Bakony it couldn't.

Stop 6: Abandoned quarry between Úrkút and Ajka (optional stop)
Lower Cretaceous Urgonian limestone
Géza CSÁSZÁR

The quarry is situated on the south-western side of the road in the forest after 500 m from the western end of Úrkút (Fig. 4/12). The uppermost beds of the Úrkút Limestone Member are exposed (Fig. 28) in one of the string of quarries (DOSZTÁLY 1985, CSÁSZÁR 2002). The most exciting feature of the 13 m thick Urgon-type limestone is the biostrome formed by several generations of Chondrodonts in life position (Fig. 4/29). The development of the lower biostrome ended at a relative sea-level fall. During the exposed position the consolidation of the lime mud proceeded rapidly and when the sea encroached it met a uniform, hardgrounded sea-floor morphology. This process inevitably resulted in Chondrodont shells sticking out of the sea-floor, being entirely cut off, some of the fragments of which exclusively make up the basal clastics of the next bed.

The other peculiarity of the section is that it does not contain rudist shells but does contain gastropods of *Acteonella baconica* CZABALAY (CZABALAY 1985). The texture of the limestone is dominated by biomicritic to biopelmicritic wackestone, mudstone and rarely floatstone which are evidence for a tranquil shallow lagoonal environment. The occurrence of characean alga shows freshwater-lacustrine intercalations, but there are also brackish-water sedimentary environment. The shrinkage pores are the indication of the intertidal environment.
The exact age of these beds and the entire Úrkút Member and their relation to the Pénzeskút Marl Fm. are unknown.

Stop 7: Manganese ore deposit, Csárda Hill, Úrkút
Jurassic limestones and manganese ore
Géza CSÁSZÁR

The so called palaeokarst field (Figs. 4/12, 4/30a, b) is the oldest protected natural value among geological objects. The way of genesis of the palaeokarst and its former infilling is a long debated subject in the Hungarian geological literature. The description below is based on POLGÁRI et al. (2004), POCSAI & SASVÁRI (2005) and POLGÁRI (2010). The extraction of manganese ore was made by hand tools between 1926 and 1933 and thanks to this method the original karstic form is preserved. Unfortunately on the other part of the Csárda Hill and the adjacent area during the mechanized exploitation from the 50's to the 70's the basement forms were destroyed. The basement

Fig. 4/29: Chondrodont generations in life position in rock forming quantity, abandoned quarry on the left side, next to the road between Úrkút and Ajka.

Figs. 4/30a and b: Palaeokarst cliffs of Lower Jurassic Hierlatz Limestone Fm. after exploitation of oxidic manganese ore, Nature Conservation site, Úrkút.

rocks of the manganese deposit prevailingly consist of Hierlatz Limestone of Sinemurian-Pliensbachian age but exceptionally the Hettangian Kardosrét Limestone also contributes. The texture of the latter limestone ranges between pelmicritic through oncopelmicritic, oncopelmicrosparitic wackestone to packstone. Its fossil content is poor and consists of a few crinoid ossicles, small gastropods, sponge spicules and brachiopods. The sedimentary environment must have been a shallow-water carbonate platform.

The Hierlatz Limestone in the geological conservation area is represented mainly by pinkish and light red crinoidal and brachiopod-bearing limestone with a few ammonites and gastropods. The dominant rock-type is accompanied by crinoidal calcarenite and occasionally with lenses of brachiopods and *Posidonia* shells. The depositional environment of the formation is an internal block between a higher remained part of a submarine high and the basin. The age of the formation of the stratotype section is Late Sinemurian. As a consequence of the extensional tectonic movement in the lower and middle part of the Lower Jurassic formations often neptunian dykes are found. Fig. 4/31 shows a neptunian dyke filled with red, bioclastic (mainly crinoidal) limestone in the Hierlatz Limestone.

Fig. 4/31: Neptunian dyke of dark red, bioclastic (crinoidal) limestone in the karstified Lower Jurassic Hierlatz Limestone, Nature Conservation site, Úrkút.

By origin the manganese ore deposit at Úrkút (Úrkút Manganese Ore Fm.) can be subdivided into two groups; the primary one is the carbonatic manganese ore the composition of which hasn't changed since the original deposition. Its green colour derives from the seladonite, a special clay mineral. The other manganese ore group called Csárda Hill type also belongs to the primary ore variety but it is oxide ore composed of cryptomelane, pyrolusite and manganite minerals. It occurs in varied shapes of nodular form (Fig. 4/32), and in different sizes from the

Fig. 4/32: Accrited nodules of primarily oxidic manganese ore (Bakony Natural Science Museum), Photo: POCSAI, SASVÁRI 2005).

millimetre up to several metres thicknesses. Their internal structure is concentric. The stratigraphic position of the Úrkút Manganese Ore Formation is Early Toarcian and it is in tight connection with the extensional fragmentation of the basement of the sea and with the volcanic exhalation of manganese- and iron-rich fluid came up along the deep seated faults. The product of those upwellings which came up to the basement surface at shallower and oxygen-rich condition was the primary manganese oxide ore while in the deeper and oxygen depleted environment carbonatic manganese ore has been precipitated. The manganese ore is restricted to the Southern Bakony (Fig. 4/12) although a few indications are known to occur on the other areas too.

The secondary manganese ore are also known at Úrkút. This is the product of the oxidization during reworking on surface condition. In this case it was formed in the Palaeocene to Early Eocene time and covered by a Middle Eocene sequence.

5. Summary of the connection between the geodynamic history and the change of the sedimentary systems in the Eastern Alps and the Transdanubian Range

5.1. Short summary of the Jurassic sedimentary environments of the Transdanubian Range

Apart from the Danube Left Side Block the significant Upper Triassic formations are characterized by Lofer-cyclicity. At the Triassic/Jurassic boundary the Transdanubian Range broke into two parts. The western part subsided and became a shallow subtidal lagoon environment characterized by oncoidic limestone with very few megafossils, while the eastern part became land with limited erosion.

The overall extensional movement started at the end of the Hettangian the result of which was the first unequal fragmentation of Transdanubian Range. The altitude differentiation of the basement increased step by step until the late Middle Jurassic. Up to the middle Early Jurassic submarine highs and basin developed. At the beginning the Pisznice Limestone accumulated on the highs and around it, later on the steps of the slope crinoidal and brachiopoda limestone including Hierlatz Limestone and Törökbükk Limestone were formed. In the basin around the highs cherty crinoidal limestone (Isztimér Limestone), while farther from the highs Ammonitico Rosso-type Tüzkövesárok Limestone deposited. A radical change came about in the Toarcian, around deep-seated faults manganese ore precipitated. Because of general subsidence (or sea-level rise) from this moment on the highs there was no sedimentation while in the basin red nodular marl was formed (Kisgerecse Marl Fm.). In the middle bathyal part of the basin similar, clayey, nodular *Bositra*-limestone (Tölgyhát Limestone), around the CCD cherty limestone, (incl. Eplény Limestone) and below the CCD pure radiolarite or radiolarian chert accumulated. This was the

time of the formation of the giant Neptunian dykes (Csókakö Limestone).
The general subsidence tendency was replaced by the uplift of the basement, through the change of the extensional tectonics to the compressional one. At the beginning the nodular limestone returned again but with *Saccocoma* content instead of *Bositra.* Higher up (in the Tithonian) it was replaced by platy pelagic *Calpionella*-bearing limestone. This is the time interval, when the difference between the South Bakony and the Gerecse radically increased although the difference existed from the very beginning of the deposition of the Jurassic.

5.2. Short summary of the main characteristics of the Cretaceous platform carbonates in the Transdanubian Range

Geza CSÁSZÁR

The shallowing process of the Tethyan Sea was a general tendency within the East-Alpine - Carpathian realm in the early Late Jurassic time (GAWLICK & SCHLAGINTWEIT 2006, GAWLICK at al. 2010, MISSONI & GAWLICK 2010a). The root cause of the shallowing process is the Eohellenic tectonic phase which closed the "Meliata Ocean". The pile of nappes, the Kimmeridgian to earliest Cretaceous carbonate platform and the Bathonian to "Oxfordian Breccia" intercalations in the basinal succession composed of mainly Triassic rocks were the obvious products of the closure of this ocean in the Eastern Alps while in the Transdanubian Range the thin "Oxfordian Breccia" bed or beds in the basin or on gentle slopes are the only evidence of this event. This breccia can be found either within the Lókút Radiolarite or just above it in the Gerecse Mts. but there is no platform carbonates among the breccia grains. That was the time when the sedimentation which had stopped in the Early Jurassic restarted again on the submarine highs of the Transdanubian Range, especially in the Northern Bakony and the Vértes areas.
The 2nd breccia horizon occurred in a broad area within the Alpine-Carpathian Realm in the Berriasian. In the Rossfeld Basin the Upper Tithonian to Middle Berriasian hemipelagic Oberalm Limestone and its upward continuation (Schrambach Marl) contain breccia intercalations composed exclusively of Barmstein Limestone of platform origin (MISSONI & GAWLICK 2010b). In the Gerecse the Upper Jurassic to Lower Cretaceous Szentivánhegy Limestone partly interfingers with the Bersek Marl Fm. and higher up the marl substitutes the limestone, while both of them contain Felsövadács Breccia (see Fig. 3/15). Its major constituents are limestone fragments of platform origin. The presence of basic rock fragments and chrome spinel grains gave evidences about the nearby sources of both the platform carbonate and the obducted oceanic basement. They are missing from the "Oxfordian Breccia" and this is a great difference between the two formations not only from lithologic but also from genetic point of view.
In the Northern Calcareous Alps, in the Lower Tirolic unit the Schrambach Fm. is replaced by the Rossfeld Formation which is characterized by a coarsening upward trend (MISSONI & GAWLICK 2010b). The situation is just the same in the Gerecse where the Lábatlan Sandstone overlies the Bersek Marl. The result of the coarsening upward trend is that the sequence is capped by the Köszörüköbánya Conglomerate in the upper part of which limestone debris are found in bed-forming frequency (Fig. III). The boulder and cobble-sized Urgon limestone fragments derive from a nearby lagoon and reef (Fig. IV - for detail see 2nd day Stop 3).
The next (3rd) platform limestone within the Jurassic-Cretaceous succession is found in the western foreland of the Gerecse and in the north-western foreland of the Vértes forming a narrow 5-15 km broad zone between the semi-restricted basin of the Vértessomló Siltstone Fm. and Tés Clay Fm. of fluvial, lacustrine to palustrine origin. It is underlain by the Tata Limestone. The transition between the crinoidal and brachiopoda-rich Tata Limestone and the Környe Limestone of Urgon facies is gradual. The deposition of the Urgon limestone started with the slow sea-level drop when a platform with patch-reef developed and prograded into the basin (Fig. V).
The situation fundamentally changed very soon still in the

Fig. III: Limestone breccia bed of Urgonian facies in the Köszörüköbánya Conglomerate Member of the Lábatlan Sandstone Fm. The sand and small pebble-sized grey rock fragments are mainly radiolarian chert from the obducted basement, Lábatlan Gerecse Mts.

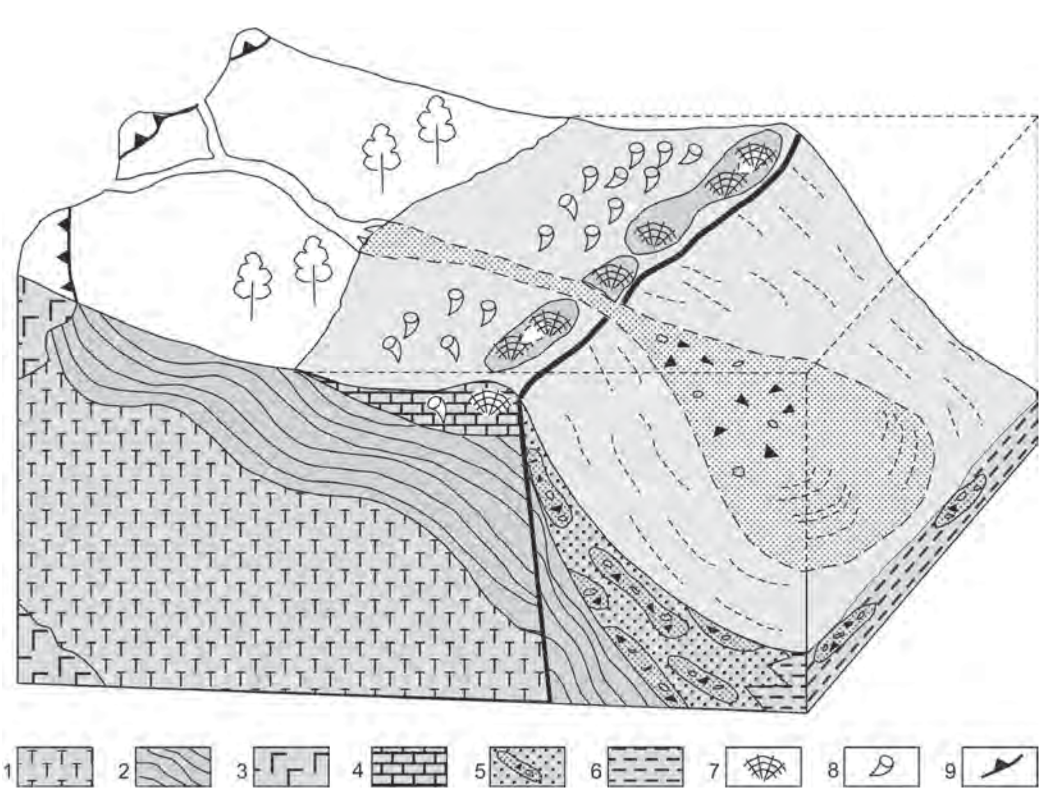


Fig. IV: Block diagram, showing the relation between the marginal carbonate platform with hanging reef and the siliciclastic foreland basin in the Gerecse.
Legend: 1 - Triassic and older formations, 2 - Jurassic, 3 - Obducted oceanic basement, mainly basalt, 4 - Cretaceous platform carbonate, 5 - Slope deposit, 6 - Basin sediment, 7 - Coral, 8 - Rudist bivalve 9 - Obduction surface.

Middle Albian when the slow regression gave place to a rapid transgression which was proceeded from the Gerecse Basin and rapidly invaded the Transdanubian Range syncline producing the 2nd Urgon facies limestone called Zirc Limestone Fm. This process passed off differently in the Northern Bakony-Vértes Foreland area and in the Southern Bakony (for detail see: 3rd day Stop 1 and Stop 5). The history was crowned by a global sea-level rise in two phases in the Late Albian.

The Pre-Gosau tectonic phase generated an overall but unequal uplift and a heavy erosion in the area which was followed by a new transgression on the strongly dissected field but in this case from the opposite direction (north-eastwards). Among the diverse sedimentary environment

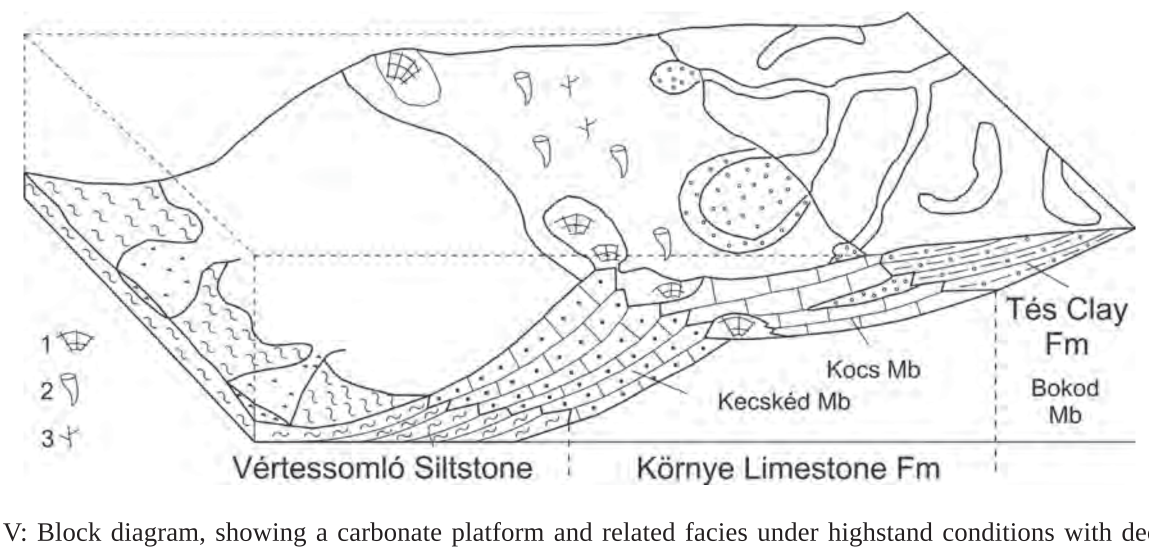


Fig. V: Block diagram, showing a carbonate platform and related facies under highstand conditions with decreasing water level in the Vértes Foreland in the Middle Albian.
Legend: 1 Patch-reef (corals and stromatoporoids), 2 - Rudists, 3 - Dasycladaceans.

another rudistid carbonate platform also developed (see 1st day Stop 3).

5.3. A few notes to Cretaceous clastics of the Gerecse Mts.

Orsolya SZTANÓ

With the onset of the Cretaceous the carbonate-dominated sediments of the Triassic and Jurassic changed first to mixed carbonate-siliciclastic and later to clastic ones. Accumulation of coarse clastics continued to the early Albian, most likely with significant periods of breaks. The thickness of massive to graded sandstones and conglomerates formed as deep-sea fan lobes with channels (SZTANÓ 1990) the remnant of which attains 400m. Siliciclastics were derived from obducting and colliding plate fragments, as revealed by ophiolite-derived clasts, metamorphics of a mixed-provenance orogenic belt (CSÁSZÁR & ÁRGYELÁN 1994, ÁRGYELÁN 1996). In the uppermost part of the clastic succession coeval reef-debris became an increasingly important constituent, indicating that widespread Urgonian-type platform with reefs existed along the basin margin (CSÁSZÁR 1995).

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- Don't litter kids on the beach!
- Let them do what they want! Or have you forgotten that tomorrow the Paleocene is dawning?

- Now, look what they are putting together under the pretext of sedimentology!