Jurassic

by

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The more scrutinized study of the Jurassic sequence exposed in the Sümeg area, the analysis of the paleogeographic conditions and the tectogenetic history offer important contributions to the understanding of the Jurassic history of the Transdanubian Central Range zone. Proceeding southwest along the Bakony range it is for the last time at Úrkút, i.e. at a distance of 30 km from Sümeg that Jurassic beds crop out. As regards drilling information, the borehole Dv-3 of Devecser is the last to have yielded a Jurassic record and even this one concerns only the topmost part of the system. To the southwest of Sümeg, in the North Zala Basin, oil-exploratory wells (Nagytilaj, Misefa, Botfa, Nagylengyel, Szilvágy) have discovered a Jurassic sequence very similar in geological pattern to that of Sümeg (Csongrádiné et al. 1969; Bércziné Makk, A. 1980).

Consequently, the observations that can be performed on the horst-block of Sümeg will provide a base for the exact stratigraphic classification and facies interpretation of an area of considerable size.

In addition to the stratigraphic assessment and facies interpretation, it was an important problem to be solved to explore the fissure system formed and filled in the Jurassic period and to interpret the process of their genesis.

Exploration history

Having touched Sümeg too in the course of his travels through Hungary, F. S. Beudant (1825) recorded Jurassic limestones from this area. However, it is evident from his writings that it was the Upper Cretaceous rudist-bearing limestone that he assigned to the Jurassic. The first reliable data derive from J. Böckh who, on his geological map of 1:144,000 scale, labelled D. 9., of 1875, represented Liassic and Tithonian formation in the vicinity of Sümeg.

The first more detailed description is to be found in the Balaton monograph edited by L. Lóczy (1913), in which the chapter devoted to the Jurassic of Sümeg was prepared by E. Vadász. In the light of the lithologic features and the examination of the fauna E. Vadász confirmed the presence of the Lias only and refuted J. Böckh's opinion concerning the occurrence of Tithonian. He identified the following sequence: *1.* Lower Liassic Dachstein-type limestone, *2.* Crinoidea-Brachiopoda limestone, *3.* Upper Liassic marl. It appears from the description that this latter statement refers to the radiolarite and cherty "biancone" limestone of Mogyorós-domb. He also remarked that though the Liassic sequence seem ed to be incomplete, "... a detailed on-the-spot study would certainly reveal the entire sequence here too...".

A substantial change was brought in the stratigraphic understanding of the Sümeg Jurassic by the mapping work carried out by J. Noszky Jr. in the 1940's. In his report of 1953 he gave a correct stratigraphic scheme for the Mogyorós-domb sequence, a stratigraphy that is judged correct even at the present-day level of knowledge. Let us cite him: "... and the sequence that had earlier been believed to be Upper Liassic turned out to include several horizons, from the Upper Dogger to the Lower Cretaceous inclusive. The flesh-coloured Lower Liassic beds are overlain, with a marked stratigraphic hiatus and unconformably, by Malm-Dogger grey radiolarian, manganiferous, siliceous marls, followed in turn by Aspidoceras-bearing Malm and deeper and higher Tithonian members."

In his manuscript report on the renewed map surveys performed in 1957 by him, he further improved the stratigraphic classification adding more detail to it. He mentioned the following lithofacies types, i.e. cartographically representable units:

1. Dachstein-type Lower Liassic limestone.
2. Liassic brachiopodal limestone.
3. Liassic chert-noduled limestone.
4. Liassic greyish-white limestone with chert lenses.
5. Liassic Crinoidea-Brachiopoda limestone of "Hierlatz" type.
6. Middle Liassic flesh-coloured ammonitic limestone.
7. Dogger grey calcareous marl.
8. Dogger radiolarian, chert-interbedded, calcareous marl with dark grey chert in its upper part.
9. Kimmeridgian limestone.
10. Tithonian red nodular limestone.
11. Higher Tithonian yellow nodular limestone, laminated cherty limestone.

In his summarizing paper presented at the Conference on Mesozoic Stratigraphy, J. Noszky Jr. (1961) included Hettangian, Sinemurian, Bathonian, Callovian, Oxfordian, Kimmeridgian and Tithonian formations in the columnar diagram illustrating the sequence of Sümeg. In his facies diagram a shallow-water marine sedimentation with short interruptions (breaks) spans the Hettangian to Lower Pliensbachian interval, while for the Bathonian-Callovian-Oxfordian he suggests sea depths exceeding 1200 m. The Kimmeridgian-Tithonian is illustrated again as having been characterized by shallow-water conditions.

J. Fülöp (1964), in his monograph of the Lower Cretaceous formations of the Bakony Mts, discussed the Upper Jurassic formations of biancone facies. Encouraged by the investigation of the Mogyorós-domb key section, he took a stand in the problem of the Jurassic-Cretaceous boundary.

J. Konda (1970) studied the Liassic formations in more detail. From the northwest part of the Sümegi-erdő (= Városi-erdő), he mentioned a Dachstein-type Liassic limestone and grey cherty limestone sequence evolving continuously from the Dachstein Limestone.

In the southeast part of the Mogyorós-domb, he observed yellowish-red Crinoidea-Brachiopoda limestones to overlie the rough denudation surface of the Dachstein Limestone and to be overlain in turn by Crinoidea-Brachiopoda-Ammonites limestone. He suggested Upper Sinemurian and Pliensbachian, respectively, as the probable age of the beds in question. The lithofacies observable on the surface of the Dachstein-like limestone and in its fissures in the more northern part of the Mogyorós-domb are taken by him to be of the same age.

Extension, mode of superposition, stratigraphic subdivisions

The surface extension of the Jurassic is confined to an area of about 1 km^2 on the Mogyorós-domb and the northwest margin of the Városi-erdő (Fig. 3 and 12). The knowledge has been considerably amplified by drilling results which have revealed the existence of a Malm sequence beneath Sümeg's central residential area and, thanks to bauxite-exploratory drilling in recent years, even of Liassic formations underlying the Upper Cretaceous rocks there.

The mode of superposition of the Jurassic formations is rather diversified. A Lower Jurassic sequence evolving from the Triassic Dachstein Limestone continuously, with comparatively little change in the lithological features is known to us from the Városi-erdő and a part of the Mogyorós-domb. However, in the same area, in the immediate neighbourhood of the afore-mentioned outcrops, the Upper Triassic or, in other places, the Lower Liassic surface is overlain by Lower to Middle Liassic beds, whereas at the foot of the Vár-hegy and the Sümeg Limeworks Upper Triassic beds overlain by Malm deposits were discovered in boreholes.

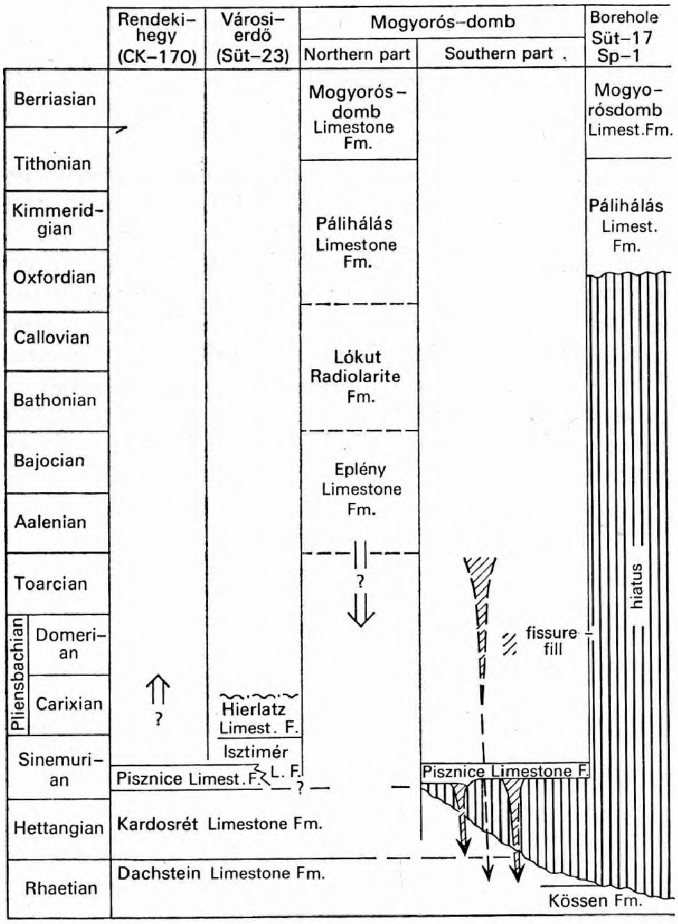

Fig. 13. Stratigraphic position and relations of the Jurassic rocks known from Sümeg

The Jurassic-Cretaceous transition is continuous in all cases known so far, the chronostratigraphic boundary being traceable within the Mogyorós-domb Limestone Formation (biancone).

On account of subsequent denudations the present-day overlying sequences may be represented by a variety of formations [Upper Cretaceous, Pannonian (s.l.) and Quaternary].

In terms of lithological features the Jurassic can be well subdivided, but a serious problem in description is posed by the fact that the lithostratigraphic classification of the Jurassic in the Transdanubian Central Range is not settled definitively as yet. Thus we have been compelled to use even such names for the introduction of which no formal proposal has been made thus far.

Primarily because of difficulties of recovery, the spatial connections of the Liassic formations cannot be determined in an unambiguous way. It is certain that both in the Sümeg area and throughout the Transdanubian Central Range, both continuous and discontinuous sequences are to be reckoned with, their original relations having been controlled by the morphological features of the one-time sea bottom. The present-day spatial relations of the units involved, however, are largely influenced by the subsequent tectonic deformation, which is a great handicap in defining the stratigraphic succession and in reconstructing the paleogeography.

The stratigraphic position and relations of the Jurassic formations are shown in Fig. 13.

In subareas with a continuous sequence the Kardosrét Limestone Formation common to the Bakony area evolves gradually from the Triassic Dachstein Limestone ("Dachstein-type limestone"). It is overlain by the red limestone discovered by boreholes on the Rendek-hegy (Pisznice Limestone Formation), and then by the grey cherty limestone exposed on the margin of the Városi-erdő (Isztimér Limestone Formation). Above this there follow 30 to 40 m of pink Crinoidea-Posidonia limestone (Hierlatz Limestone Formation). A continuous Middle Liassic sequence could not be exposed yet in an integrate form. By analogies with the Bakony, a red aphaneritic, limestone-pelletal, crinoidal limestone seems to have been formed in that span of time. Upper Liassic is known to us only in the form of fissure fill. Exposed on the Mogyorós-domb by drilling, a grey Bositra-bearing calcareous marl (Eplény Limestone Formation) can be assigned to the Lower to Middle Dogger. Compared with other profiles from the Transdanubian Central Range, the very thick radiolarites (Lókút Radiolarite Formation) in turn appear to span the Upper Dogger completely or may possibly extend well into the Oxfordian stage as well. Above it, in the Mogyorós-domb sections there follow low thicknesses of greyish-white, apparently Oxfordian calcareous marl, followed in turn by Kimmeridgian to Lower Tithonian red, nodular cephalopodal limestones (Pálihálás Limestone Formation) and the Jurassic sequence ends with the lower part of the Mogyorós-domb Limestone Formation consisting of white cherty limestone beds. The upper part of the formation already belongs to the Lower Cretaceous.

In the discontinuous sequences (Mogyorós-domb) the Kardosrét Limestone and/or the Dachstein Limestone are unconformably overlain by the Pisznice Formation. Liassic-filled fissures are common. In the boreholes sunk into the ground of the central residential area of Sümeg (Sp-1, Süt-17), the Jurassic sequence begins, after a basal breccia, with the Kimmeridgian Pálihálás Limestone Formation.

Kardosrét Limestone Formation

Outcrops of the Kardosrét Limestone Formation are known from the southern part of the study area, the Mogyorós-domb and the Városi-erdő. These being of very limited extension and heavily affected by tectonic deformation, the mode of superposition could not be established in an unambiguous way. For this reason, a key section suitable even for a more detailed investigation has been developed by putting down the borehole Süt-28 on the Mogyorós-domb.

In recent years (after 1975) exploratory boreholes for bauxite on the range to the east of Sümeg have exposed some parts of the formation and in a few cases even the complete sequence of it, overlain by younger Liassic beds.

Local type section: borehole Süt-28

The borehole Süt-28 was put down on the southwest side of the Mogyorós-domb (its location being shown in Fig. 12). Discovered by the borehole, the Kardosrét Limestone Formation may be taken to be complete, for outliers of the younger Liassic covering having escaped denudation can be traced on the surface for hardly 10 m distance from the borehole location, while the basal part of the exposed profile represents the Dachstein Limestone already. Because of the lack of bedding surfaces the dip is difficult to determine on the core samples. On the basis of the structural and textural orientation a dip between 60° and 80° is likely. Accordingly, for the virtual thickness of the formation penetrated by this borehole, a value of about 70 m is obtained.

The lithological log and analytical data of the profile and the diagram of interpretation are given in Fig. 14. A consecutive and continuous examination of the sequence is jeopardized by the Liassic-filled fissures cut in a great thickness. Their discussion will be given later in this volume.

The transition between the Dachstein and the Kardosrét Formations is continuous. The features of the underlying formation fade gradually and the features typical of the Kardosrét Formation present themselves in the same way. This transitional part (196.5–191.0 m) has been assigned still to the Dachstein Formation.

At the formation boundary the rock texture and the fossil assemblage change considerably. Below the boundary a biopelsparite, intrapelsparite (grainstone) texture is characteristic and a microlaminated structure also occurs (algal mat?). The microfossil assemblage too shows a pattern typical of the Dachstein Formation: *Triasina hantkeni* Majzon occurs in a great number of specimens, there are a few specimens of *Aulotortus friedeli*, *Permodiscus pragsoides* and *Trocholina* and *Involutina* as well. In the immediate vicinity of the boundary, the transitional unit, the Foraminifera considerably decrease in number, the afore-mentioned forms vanish and just a few *Glomospirella*, *Meandrospira* and *Lenticulina* can be observed. Of the other fossil elements *green algae*, *Mollusca*, *Ostracoda* and *Crinoidea* also *coprolith* remains may be mentioned. Above the formation boundary the megaloscopic features show a slight, but perceivable change. For example, the appearance of the formation-diagnostic oncoidal texture is visible to the unaided eye, the finely crystalline texture passes into an aphaneritic one and the colour shade, though not immediately at the boundary, also changes. The change in microfacies is most conspicuous. The texture matrix becomes micrite or microsparite, respectively. Fossil elements considerably decrease in amount (from 30–50% to 3–5%). Foraminifera, if any, can be observed in quite rare cases.

In the studied profile, the Kardosrét Formation can be divided into three parts distinguishable even megaloscopically.

1. The basal part (191.6–165.0 m) is still close in its megaloscopic features to the Dachstein Limestone. Its colour is light grey, less frequently yellowish-grey with scarcely scattered lighter patches. Most frequently aphaneritic, less frequently finely crystalline. No stratification visible. Sporadically, calcite-speckled and in some horizons minute oncoidal grains are also contained in it. *Brachiopoda* are observable in small quantities, too.

The characteristic texture is pelmicrosparite, though the oncomicrite (or microsparite) type also occurs. In some intervals a partial dolomitization (dolosparitization) could also be observed (Plate X, Fig. 5). Peloid grains of nonfecal origin vary between 10 and 30% in quantity. From among the fossil elements thin-walled *Ostracoda* valves, *Mollusca* and *Crinoidea* skeletal fragments, *Globochaete*, and, in higher parts of the section, also *Spongia* needles may be mentioned. The quantity of Foraminifera is very low.

2. The next part (165.0–84.4 m) differs from the preceding one mainly by its colour. It is the yellowish, brownish shade with violet, reddish speckles and patches that gains predominance and becomes characteristic. In some cases the reddish stain is associated with the microoncoidal grains sporadically occurring in this part of the section. In low quantities *Brachiopoda* and *Gastropoda* can be observed, too.

Characteristic texture here is pelmicrosparite. In the lower part of the interval in question the matrix is dolomite in a mottled pattern (Plate IX, Fig. 2). The share of pellets is 10 to 35%, that of fossil grains being 5 to 10%. The microfossil assemblage is similar to that of the preceding unit.

3. In the upper part (84.4–0.0 m) the rock colour is similar to the preceding case, but the pale-red mottled pattern is even more frequent, giving the whole rock a pinkish tonality.

The frequency of microoncoidal grains is conspicuous even to the naked eye, their share being 40 to 50% according to microscopic results. The size of the oncoids is usually 0.2 to 2.0 mm, but even grains attaining 0.5 cm in size can be encountered. The core of the oncoids is represented as a rule by single bioclasts (*Gastropoda, Bivalvia, Ostracoda, Crinoidea, Spongia* needle), though sometimes it may be constituted by grains of other origin too (pellet, intraclast) (Plate VIII). The texture is oncomicrosparite, locally sparite cement also presents itself, and in some horizons the groundmass is dolomitized and the original texture elements are indistinct (Plate IX, Fig. 1, 3, 6). The amount of pellets is also remarkable (5–15%), that of the fossils disregarding those enclosed in oncoids rarely exceeding the 5% figure. The fossil assemblage is similar to the ones described from the preceding units. *Spongia* needles get pretty well enriched in some places (Plate IX, Fig. 7, 8).

Research into the sequence in question has shown the diagnostic features of the Kardosrét Limestone Formation to appear gradually. So, at Sümeg, similarly to the case of a lot of sections from the Bakony (J. Noszky Jr. 1961, B. Géczy 1961), a continuity of sedimentation between the Dachstein and the Kardosrét Formations can be observed.

In spite of the continuity, the two formations can be readily separated, and this can be done not only on the basis of the microscopical textural features and the paleontological characteristics, but on that of the textural and structural patterns visible to the naked eye as well. The fact that the "Lofer" cycles normally characterizing the Dachstein Limestone are not observable is a substantial difference.

Other exposures

In the southwest part of the Mogyorós-domb, near the borehole that has been selected as type section, the beds of the formation are exposed over a comparatively large area (Fig. 12). The lithofacies observable in outcrops shows a similarity to the higher parts of the type section sequence (oncomicrosparite and oncopelsparite texture, respectively). The presence of an extremely intricate

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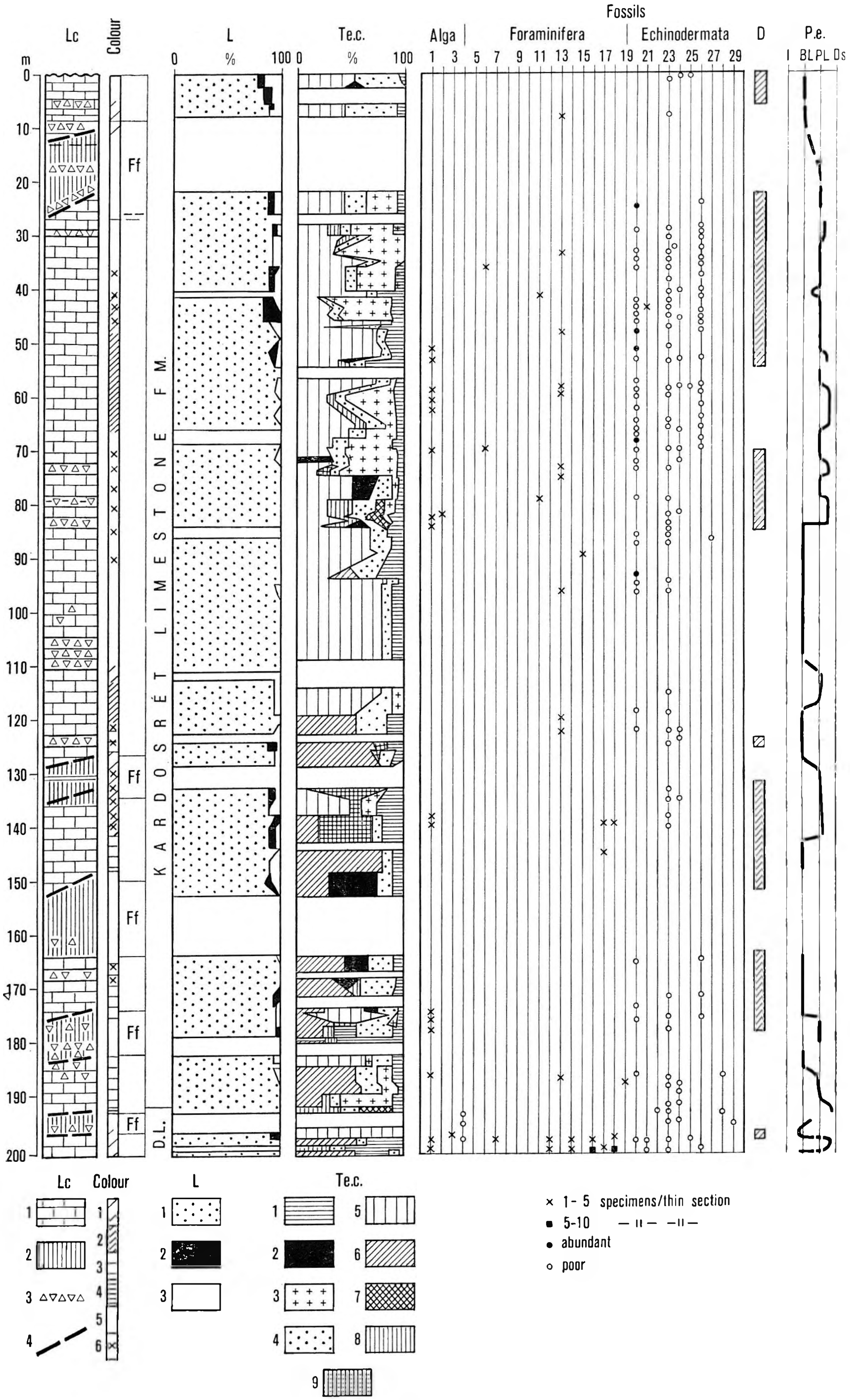
Fig. 14. Lithologic column and analytical results of the borehole Süt-28

Lithologic column (Lc): 1. limestone, 2. fissure-fill, 3. breccia, 4. fracture plane. — ***Colours:*** 1. yellow, 2. brown, 3. light grey, 4. dark grey, 5. white, 6. pink-mottled. — ***Ff:*** fissure-fill interval. — ***D.L.:*** Dachstein Limestone. — ***Lithologic composition*** (L): 1. calcite, 2. dolomite, 3. insoluble residue. — ***Textural composition*** (Te.c.): 1. fossils, 2. dolosparite, 3. oncoid, 4. pellet, 5. micrite, 6. microsparite, 7. intraclast, 8. sparite, 9. recrystallized sparite. — ***Fossils:*** 1. Globochaete, 2. Aeliosaccus, 3. Acicularia, 4. Alga indet., 5. Ammodiscus, 6. Glomospira sp., 7. Glomospirella friedli, 8. Textularia, 9. Ophthalmidium, 10. Nodosariidae, 11. Dentalina, 12. Lenticulina, 13. Frondicularia sp., 14. Fr. woodwardi, 15. Permodiscus pragsoides, 16. Involutina, 17. Trocholina, 18. Triasina, 19. Foram. indet., 20. Spongia, 21. corals 22. Brachiopoda, 23. Mollusca, 24. Gastropoda, 25. Echinoidea, 26. Crinoidea, 27. Holothuroidea, 28. Favreina, 29. coprolith. — ***D*** partial dolomitization during early diagenesis. — ***Paleoenvironment*** (P.e.): ***I*** intertidal zone, ***BL*** backreef lagoon, ***Pl*** shallow-water platform, ***Ds*** drifting sand


Fossils
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● abundant
○ poor

structural pattern is indicated by the fact that Dachstein Limestone and Kardosrét Limestone outcrops occur side by side within a very small area.

In the clearing in the west part of the Városi-erdő, the Kardosrét Limestone beds crop out with a dip of 270°/60° in a position overlying the Dachstein Limestone. Counted on the basis of the dip, the virtual thickness of the exposed sequence would be about 100 m or so. A tectonic repetition, however, may also be supposed, which is all the more likely, as the section that seems to be very thick in the light of microfacies analyses can be as a whole identified with the lower two of the units singled out in the local type section. Of course a change in facies cannot be precluded. The rock is light grey, greyish-white, finely crystalline, thick-bedded with sporadical *Gastropoda* and *Brachiopoda*. The texture is pelmicrosparite with 5 to 25% anorganic peloids and a low amount of fossils (3–15%).

Microoncoid grains can be observed sporadically, too. Of the fossil elements *Ostracoda* valves, *Crinoidea* and *Globochaete* remains and sponge spicules may be mentioned, in addition to the subordinate *Foraminifera*.

The beds exposed on the southwest side of the clearing and containing *Brachiopoda* valves in rockforming quantities (J. Noszky Jr. described and mapped them as an independent unit) represent the topmost part of the profile (Fig. 12, Location 1). Consequently, the fauna of chronostratigraphic value recovered from here (Table 1) may refer to the age of the middle unit of the formation.

In the area representing the dipward continuation of the profile, i.e. at the northwest corner of the Városi-erdő, the rock is tectonically deformed, so a continuous sequence cannot be recorded there. The samples deriving from that area show a pelmicrite, oncopelmicrite texture and thus probably represent a stratigraphically higher part of the formation.

Some bauxite-exploratory boreholes in the Rendeki-hegy (Ck-170, -171, -173) explored the topmost part of the formation. Of these the borehole Ck-170 which penetrated the formation in 26 m thickness has been studied in greatest detail. The lithological log and the diagrams summarizing the analytical results are shown in Fig. 15.

In the exposed interval the rock is light grey to brownish-grey with minute reddish mottles. Its matrix is aphaneritic, finely crystalline. Its being composed of microoncoid grains predominantly a few mm in diameter is visible even to the unaided eye. *Crinoidea* fragments, small *Gastropoda* and *Brachiopoda* can also be observed sporadically. In tenuous intervals in the topmost part of the formation the rock colour is pinkish becoming brownish in shade and the quantity of the *Crinoidea* skeletal elements increases. These are features of transition towards the overlying red Liassic limestone (Pisznice Limestone Formation).

The rock texture is oncomicrosparite, oncopelmicrosparite. The amount of the oncoid grains varies between 10 and 65%. The textural composition shows a good agreement with the upper part of the borehole Süt-28 (Fig. 14). The same holds true of the quantity and quality of the fossils. That in the uppermost 4 m of the formation oncoidally coated benthonic *Foraminifera* [*Involutina liassica* (Jones), *Ophthalmidium* sp.] (Plate VIII, Fig. 4) becoming really characteristic eventually in the overlying formation appear seems to be essential—phenomenon not observed in the borehole Süt-28.

This fact and also the afore-mentioned change in colour suggest that the transition between the two formations is—at least in this area—continuous, the substantially differring lithological features being due to the relatively rapid change in facies.

Chronostratigraphy

In a more precise dating of the Kardosrét Formation we can rely on comparatively few data. The most interesting information has been provided by the *Brachiopoda*. From the rock abounding with *Brachiopoda* in the Városi-erdő clearing (Fig. 12, Location 1) A. Vörös identified the forms listed in Table 2. On the basis of the ranges of genera the age of the brachiopodal bed or lens can be fixed somewhere near the Hettangian–Sinemurian boundary.

From the sporadical Brachiopoda fauna found in the boreholes put down in the range to the east of Sümeg (Ck-170, -173), G. Vígh identified *Lobophyres ovatissimaeformis* (Böckh) which corroborates the Lower Liassic dating.

Since the Foraminifera thought to be typical of the Upper Triassic (*Triasina hantkeni* Majzon, *Aulotortus friedeli* Kristan) disappear at the lower boundary of the Kardosrét Limestone, the lower beds of this formation span the Hettangian completely, but do not reach down into the Triassic. The largely oncoidal upper interval above the brachiopodal bed, however, seems to pass in turn well into the Sinemurian. On the basis of the sporadical *Brachiopoda* fauna and the analogies with the Bakony Mountains, the grey cherty limestones exposed in the borehole Süt-23 can be assigned to the Upper Sinemurian. Accordingly, the Kardosrét Formation at Sümeg may be taken to have spanned the Hettangian to Lower Sinemurian time interval.

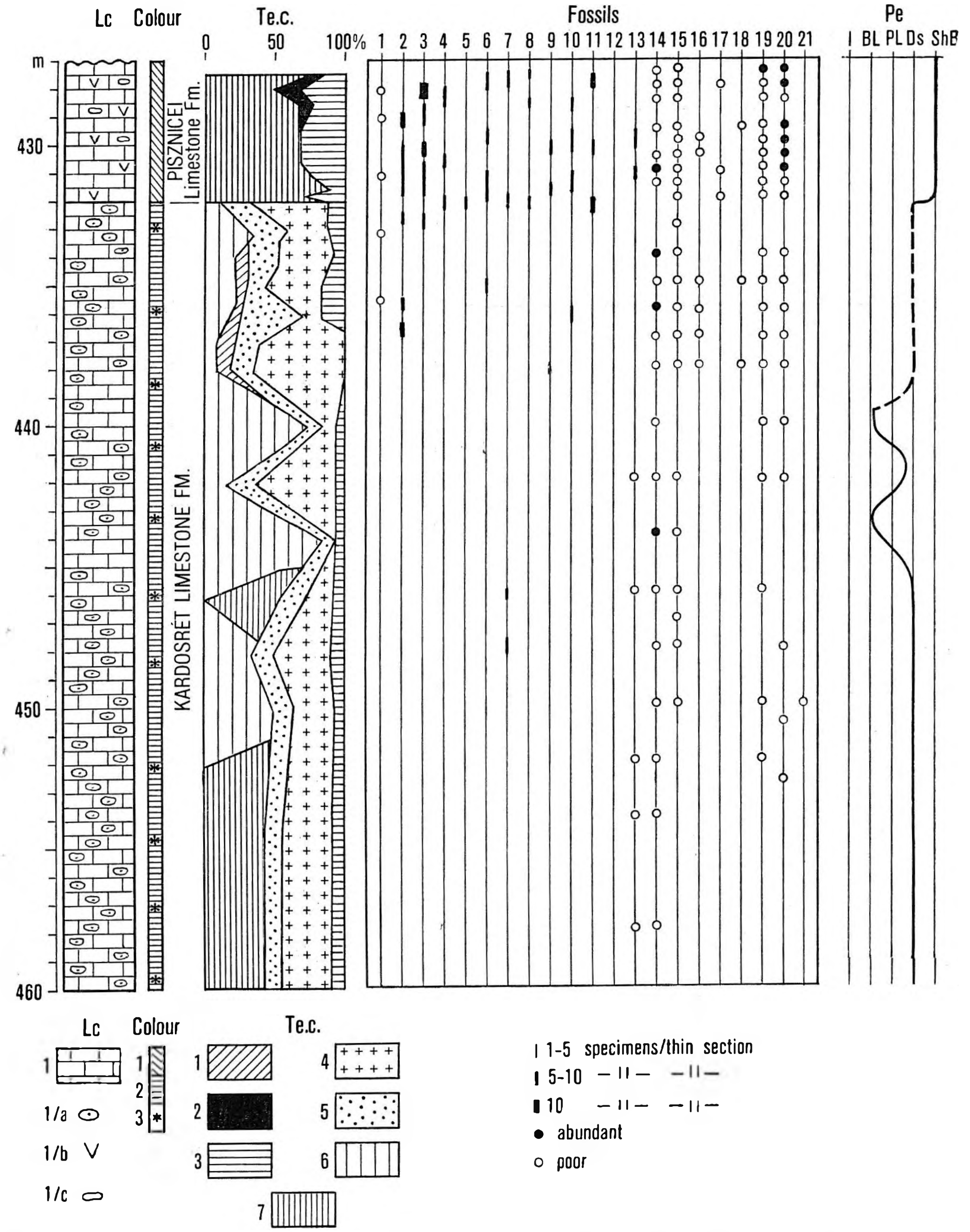


Fig. 15. Lithologic column and analytical results of the Jurassic interval of the borehole Ck-170

Lithologic column (Lc): 1. limestone: 1/a oncoidal, 1/b crinoidal, 1/c pelletal. — *Colours:* 1. red, 2. light grey, 3. pink-mottled. — *Textural composition* (Te.c.): 1. sparite, 2. intraclast, 3. fossils, 4. oncoid, 5. pellet, 6. microsparite, 7. micrite. — *Fossils:* 1. Globochaete, 2. Nodosaria, 3. Ophthalmidium sp., 4. Dentalina sp., 5. Bigenerina sp., 6. Lenticulina sp., 7. Marginulina sp., 8. Frondicularia woodwardi, 9. Fr. sp., 10. Involutina sp., 11. I. liassica, 12. Trocholina turris, 13. Spirillina sp., 14. Spongia, 15. Mollusca, 16. Gastropoda, 17. Ammonites, 18. Echinoidea, 19. Crinoidea, 20. Ostracoda, 21. Favreina. — *Paleoenvironment* (P.e.): *I* intertidal zone, *BL* backreef lagoon, *Pl* platform, *Ds* drifting sand, *ShB* shallow-water basin

Paleoenvironment

The environment in which the Kardosrét Limestone was formed was the carbonate platform of the Tethys shelf area, similarly to the case of the Upper Triassic formations. The overwhelming majority of the formations was deposited in the moving sand zone of the platform or in its well-protected hinterland.

By analyzing the Süt-28 and Ck-170 borehole sequences we could trace the formation circumstances and their changes from the beginning up the end (Fig. 14, 15). The topmost part of the Dachstein Limestone Formation penetrated by the borehole Süt-28 is of marginal moving sand and lagoonal

Table 2.

Brachiopods sampled from the outcrop of the Kardosrét Limestone Formation in the northwest part of Városi-erdő

Distribution data from Almeras (1964) and Gaetani (1970)

Species	Rhaetian	Hettangian			Sinemurian					Pliensbachian				
					L.		U.			L.			U.	
		planorbis	liasicus	angulata	bucklandi	semicostatum	obtusum	oxynotum	raricostatum	jamesoni	ibex	davoei	margaritatus	spinatum
Cuneirhynchia? latesinuosa (Trauth) (5)				– –	– –									
Calcirhynchia? rectemarginata (Vecchia) (23)			– –	– –	– –									
„*Rhynchonella*" sp. (11)														
Cadomella sp. (1)														
Spiriferina cf. *alpina* Oppel (1)														
Spiriferina cf. *darwini* Gemmellaro (2)					—	—	—	—	—	—	—	—	—	—
Spiriferina spp. (3)					—	—	—	—	—	—	—	—	—	—
Rhaetina gregaria (Suess) (5)	—													
Rhaetina? sp., aff. *gregaria* (Suess) (9)														
„*Terebratula*" sp., aff. *sphenoidalis* Meneghini (1)														
Zeilleria perforata (Piette) (33)														
Zeilleria waehneri (Gemmellaro) (2)		—	—	—	—	—	—	—	—					
„*Waldheimia*" cf. *ewaldi* (Oppel) (1)					—	—	—	—	—					
„*Waldheimia*" spp. (9)					—	—	—	—	—					

(5) = number of specimens

facies. The strongly winnowed (mudless) and rounded platform sand sediment in the transitional unit is indicative again of intensive water movement. It is after this that the microoncoidal-pelletal grain composition characteristic of the Kardosrét Formation appears. Oncoids are formed as a result of the carbonate-precipitating action of blue-green algae around a kind of core (fossil, pellet, intraclast) in a shallow warm-water environment. The concentric structure and the oval or spherical shape are suggestive of water agitation during the formation process. It is quite probable, however, that the water was less agitated than in the environment in which the oöidal sediments frequently observable in the Upper Triassic were formed (Wilson 1975). This is also suggested by the fact that whereas in the oöidal texture the calcareous mud can be usually shown to have been lost to winnowing, the oncoidal texture is characterized by a predominantly calcareous mud matrix or possibly by very slight effects of winnowing. Consequently, the oncoidal sediments seem to have been formed on the leeward side of the zone of moving sand dunes, but in the latter case a generally weaker agitation of water must be presumed throughout the area, where the formation is distributed. Because of the remarkable extension of the oncoidal sediments and the lack of intertonguing with the oöidal ones the second alternative seems to be plausible.

A great part of the lower interval of the formation was deposited as a pelletal or lumpy calcareous mud in the leeward back-lagoon environment. The back-lagoon was shallow and its water was of normal salinity. The last-mentioned factor is suggested primarily by the benthonic organisms *(Crinoidea, Brachiopoda)*.

Minor facies fluctuations in this interval are suggested by the repeated reappearance of the oncoidal facies and the early diagenetic, partial dolomitization indicative of a presuably brief emergence.

In the upper part of the formation the genetic environment is rather permanent. The sedimentation seems to have taken place in the platform-marginal sand dunes. Minor changes within this environment can be certainly observed depending on whether the site of deposition was near the margin more heavily attacked by wave action or close to the protected hinterland area. It should be noted that partial dolomitization is observable in the upper interval too, but to interpret this with an ephemeral emergence in this case does not pose a problem.

Of the bauxite-exploratory boreholes put down in the range to the east of Sümeg, some penetrated, above the Kardosrét Limestone and beneath the Upper Cretaceous complex, a few metres of red limestone. So far the formation is known to us from the following boreholes: Ck-170— 5 m, Ck-171 — 9 m, Ck-173 — 9 m. The locations of the boreholes are shown in Fig. 3. Small denudation remnants of a rock of similar facies are known to us from the Mogyorós-domb. The features of the unit will be presented with the more detailed discussion of the sequence penetrated by the borehole Ck-170 (Fig. 15).

Showing uniform lithological features, this rock overlies, with a sharp boundary, the Kardosrét Limestone, but the presence of an unconformity cannot be established. Let us mention in this context that the top of the Kardosrét Limestone is already represented by beds of light pink to brownish colour. The rock is a light red to brownish-red limestone of aphaneritic texture with traces of bioturbation. It contains varying amounts of Crinoidea skeletal fragments. In the lower part of the sequence a few lumps of corroded surface coated with a ferromanganese film could be observed. In the upper part these were observed in a considerable quantity (Plate X, Fig. 5, 6, 7). Stylolithic contacts are frequent. The texture is biomicrite (wackestone), less frequently micrite with a fossil content of 10 to 30%. Of the fossil elements, *Ostracoda, Crinoidea, Mollusca* and *Spongia* are abundant, *Gastropoda* and *Ammonites* shells also occur. The amount of *Foraminifera* is considerable, particularly so is that of *Ophthalmidium* specimens (a maximum of 50 specimens per cm^2). In some parts, *Involutina liassica* is also present. In addition, the representatives of *Nodosaria, Lenticulina* and *Trocholina* are abundant (Plate X, Fig. 2, 3, 4).

It is worthy of attention that the afore-described microfossil assemblage already appears in the topmost drill-penetrated part of the Kardosrét Formation—in a rock of microsparite texture—, though its presence is rather limited in quantity. In the cores of oncoid grains *Involutina liassica* and *Ophthalmidium* could be observed. In spite of the sharp cesura in the texture and the change in colour, the afore-mentioned circumstances suggest an uninterrupted sedimentation.

Small denudation remnants of rock varieties assignable to the Pisznice Limestone Formation are exposed on the Mogyorós-domb as well.

In that part of the Mogyorós-domb represented by Location 6 in Fig. 12, the about 2-m-thick rock body overlying the Dachstein Limestone is composed of red aphaneritic limestone which in the basal bed is poorly, higher up more strongly, crinoid-bearing. The textural composition of the rock and its microfauna are shown in Section "A" of Fig. 16.

Rock varieties of similar facies occur in the northwest part of the Mogyorós-domb (Fig. 12, Location 3), overlying the rough, eroded surface of the Kardosrét Limestone. The results of analysis of the sequence observed in the exposure are presented in section "B" of Fig. 16. The microfacies features of the two exposures are by and large the same.

Similar lithofacies types are observable as fissure-fills as well. They will be mentioned in the discussion of the fissure-fills.

Chronostratigraphy

There is no direct biostratigraphic evidence of the more exact chronostratigraphic position of the unit. The range of the characteristic *Foraminifera* [*Involutina liassica* (JONES), *Trocholina turris* FRENTZEN] is Lower to Middle Lias. On the basis of observations in the Central Range area, the representatives of *Ophthalmidium* show their maximum of frequency in the Sinemurian. The upper part of the underlying Kardosrét Formation, on the basis of the *Brachiopoda* fauna, extends from the Hettangian well into the Lower Sinemurian. Accordingly, the unit can be assigned to higher parts of the Lower Sinemurian. As shown by experiences from the Transdanubian Central Range (Zirc–Borzavár subarea), there is a great probability to suppose that originally the formation had been overlain by that Upper Sinemurian grey cherty limestone which became known to us from the Városi-erdő margin (borehole Süt-23). So it may be hoped that drilling in the coming years will penetrate this formation too in the basement of the Rendeki-hegy.

Paleoenvironment

The genetic conditions of the rock do not seem to have been very far from those of the shallow-water Kardosrét Limestone. This is suggested, on the one hand, by the continuous transition (facies juxtaposition), on the other hand, by the identity of the characteristic foraminiferal fauna. At the same time, it cannot be doubted that the calcareous mud must have been deposited in a weakly-agitated, quiet environment, beneath the zone of wave action, consequently, deeper than the accumulation of the Kardosrét Limestone may have taken place. The lumps with dissolved edges and the corroded ammonites refer undoubtedly to periodical dissolution of carbonate; however, in terms of the above, this cannot be connected with a more considerable depth of the bottom, but may be due

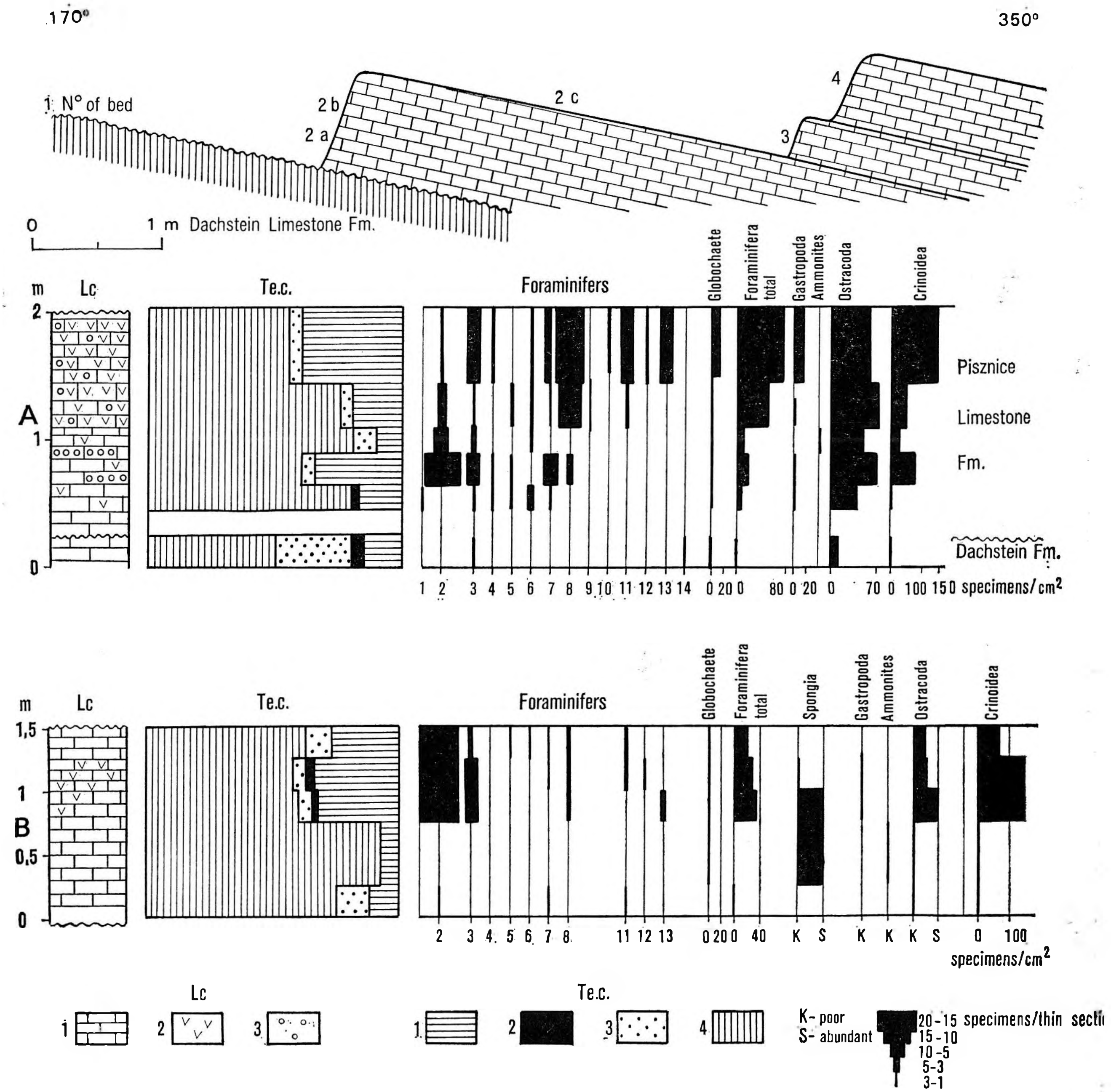


Fig. 16. Exposures of the Pisznice Limestone on the Mogyorós-domb

Lithologic column **(Lc): 1. limestone, 2. crinoidal, 3. pelletal. — *Textural composition* (Te.c.): 1. fossils, 2. intraclast, 3. pellet, 4. micrite + microsparite. — *Foraminifera:* 1. Cornuspira sp., 2. Ophthalmidium sp., 3. Nodosariidae, 4. Dentalina sp., 5. Spirillina sp., 6. Frondicularia, 7. Lenticulina, 8. Involutina sp., 9. I. liassica, 10. I. cf. turgida, 11. Trocholina sp., 12. T. granosa, 13. T. turris, 14. Triasina sp.**

perhaps to the particular chemism of the water or, what is even more likely, to a decrease in the rate of sedimentation. In case of a very slow sedimentation even a very slight degree of $CaCO_3$ under-saturation of the water may cause striking dissolution phenomena (A. Hallam 1971, H. C. Jenkins 1974, J. Haas 1976). The red colour and the oxide coating of the lumps suggest an oxidative environment at the sediment-water interface.

Isztimér Limestone Formation

In the west part of the Városi-erdő, in a narrow belt, grey chert-nodular limestones are exposed (Fig. 12). Having penetrated the unit in a considerable thickness, the borehole S-4 put down on the margin of the forest could not intersect it completely owing to the steep dip. In the borehole Süt-23 located at a distance of 100 m to the north from here, the downward increase in dip made it again impossible to intersect the formation completely, but the higher parts of the unit and its relation to the overlying rocks could be observed. The penetrated thickness was 133.5 m (60.0–193.5 m). In the higher parts the dip is 15 to 20°, but it becomes steeper downwards, to determine a more precise value having been impossible. Thus the penetrated stratigraphic thickness is also uncertain, being estimated at 60 to 80 m.

The rock is a light grey, yellowish, greenish, aphaneritic or very finely crystalline limestone with small fragments of *Crinoidea* in which chert nodules, lenses of varying size or chert beds of several m thickness can be observed. The chert is of light to dark grey colour with a little bluish shade. In the upper part of the penetrated interval the rock is interrupted by green clay films and/or clay interbeddings of green colour and a couple of cm thick. The characteristic textural type is biopelmicrite with a very large amount of sponge spicules and *Crinoidea* and *Ostracoda* remains and a few *Foraminifera.* The *Spongia* spicules are often composed of a siliceous matter and a finely crystalline impregnation of the matrix can also be observed.

The transition upwards into the Hierlatz-facies Crinoidea-Posidonia limestone is rapid, though no break in sedimentation could be observed, the changes in the textural pattern having been continuous.

The cherty limestone just discussed agrees in its geological features with the Sinemurian-dated cherty limestone known from elsewhere in the Bakony. For this reason, their attribution to the Isztimér Formation cannot be doubted. By analogies with the Bakony it may be supposed that the formation overlies the Kardosrét Limestone or the Pisznice Limestone. Since in the study area the formation seems—as suggested by the *Brachiopoda* fauna—to extend well up into the Lower Sinemurian, the grey cherty limestone units can be assigned to higher parts of the Sinemurian. The formation in which it was formed must have been a shallow-water sea bottom that lay deeper than the zone of wave action (estimated at 50 to 100 m) and was populated with siliceous sponges.

Hierlatz Limestone Formation

In a narrow tectonic graben in the northwestern part of the Városi-erdő a limestone of varied lithology and diversified paleontological features is exposed (Fig. 12, Location 2). White *Posidonia*-lumachelle, pink, aphaneritic limestones and crinoidal limestones of sparry-calcite matrix with calcite druses can be observed, but a continuous sequence could not be exposed by surface trenching. Drilled with the aim of adding further precision to the geological knowledge, the borehole Süt-23 penetrated, in a thickness of about 60 m, a sequence consisting of an alternation of the afore-mentioned rock varieties (dip 5 to 15°) and reached underneath the cherty limestone beds of the Isztimér Formation. Rock types of similar character from outside the afore-mentioned subarea are known from only a few minor outliers and as fissure-fills on the Mogyorós-domb.

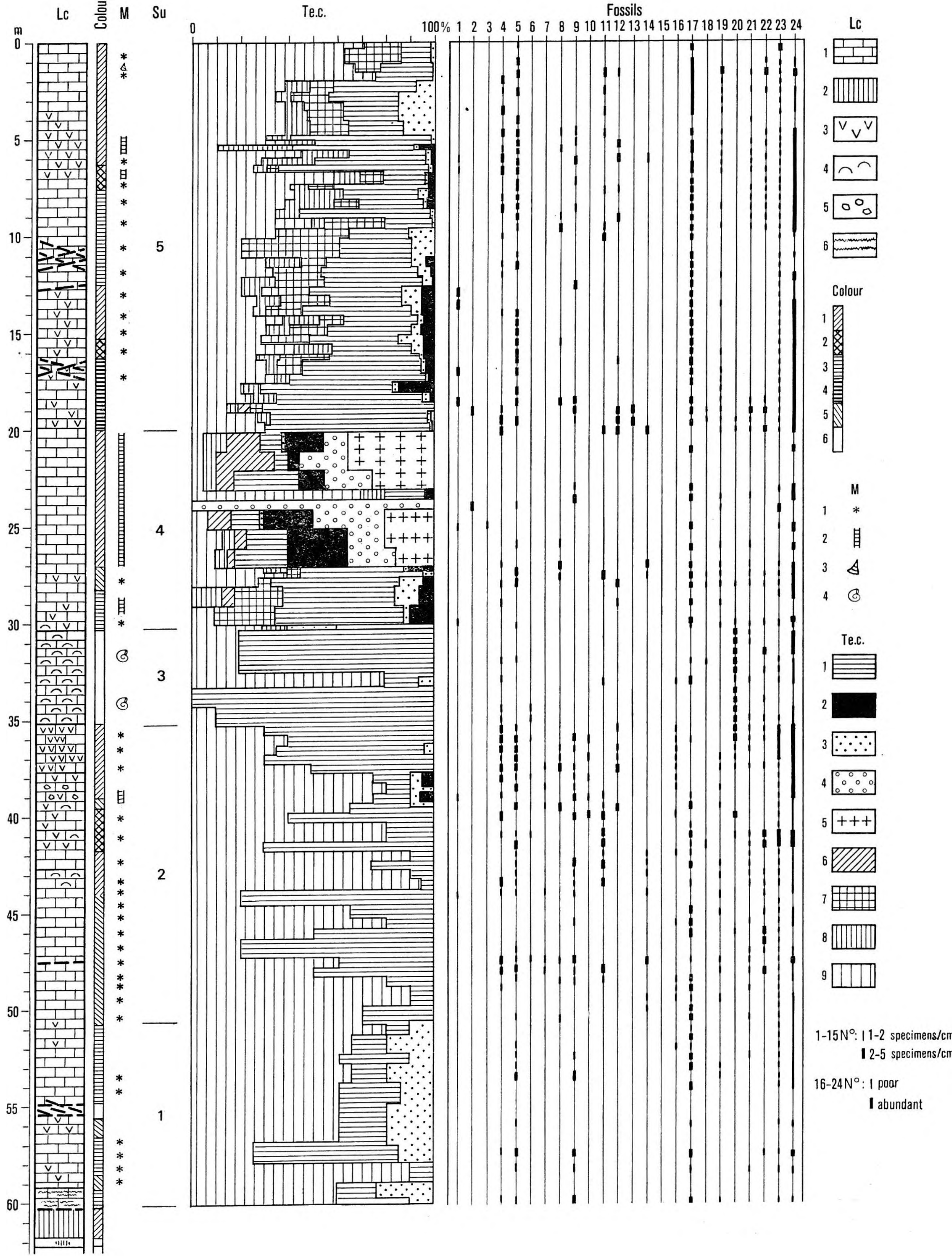
The features of the formation as observed in the borehole Süt-23 are shown in Fig. 17. In terms of its megaloscopic and microfacies patterns the sequence can be subdivided into the following intervals:

The basal interval is constituted (50.6–60.2 m) by a light grey or pale red limestone. In its aphaneritic matrix sporadical *Crinoidea* skeletal fragments are observable. The texture is characterized by a pelbiomicrite composition. The quantity of *Spongia* spicules is considerable. In addition, thin-shelled *Ostracoda* and *Crinoidea* skeletal elements are abundant. *Foraminifera* are observable sporadically.

The next interval (35.2–50.6 m) is represented by a brownish-grey crinoidal limestone of reddish shade. Sparry druses, fissure-fills are abundant. The texture is biomicrite, the postdiagenetic subsolution of the rock is quite distinct and the filling of the cavities with coarse calcite sparite is conspicuous.

The fossils, primarily the Mollusca shells, are often filled with a sparry matter. In the upper part of the interval the *Posidonia* valves become quite frequent, gradually increasing in quantity downwards. The skeletal elements of *Crinoidea* and the *Ostracoda* valves are abundant in the whole interval (generally thick-walled valves predominate), locally, the embryonal shells of *Ammonites* also show a considerable enrichment and smaller *Gastropoda* are also common (Plate XI, Fig. 6). In deeper parts of the interval the *Spongia* spicules still attain a considerable quantity (Plate XI, Fig. 7, 8). The forams are usually of medium frequency, though just sporadical at the base. The genera *Involutina, Trocholina, Lenticulina, Nodosaria* and *Ophthalmidium* are common.

The third interval (30.2–35.2 m) is composed of a greyish-white *Posidonia*-lumachelle. As observable in thin section, the original biomicrite texture (the share of the fossils was about 70 to 90%) is for the most part postgenetically recrystallized, sparitized. In addition to the predominant *Posidonia* valves, skeletal fragments of *Crinoidea, Gastropoda, Ostracoda* and *Ammonites* can be recognized (Plate XI, Fig. 1, 3, 4).



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4
Te.c.
1
2
3
4
5
6
7
8
9
1-15N°: | 1-2 specimens/cm
▌2-5 specimens/cm
16-24N°: | poor
▌abundant

The fourth interval (20.0–30.2 m) is a pale pink to faded brownish-grey to grey, aphaneritic limestone with calcite druses. The micrite matrix is usually poor and the allochemical components are of remarkable quantity. The 20.0 to 27.0 m interval is dominated by onco-oösparite and onco-oöintrasparite texture types. In the lower part of the interval it is the quantity of the bioclasts that shows a considerable increase. Of the fossils it is *Crinoidea* and *Spongia* that abound in the upper part of the interval, being accompanied by skeletal elements of *Posidonia* and *Ammonites* in the lower part. In the Foraminifera composition no remarkable change is observed.

The upper interval (0.0–20.0 m) is composed of pale pink, less frequently brownish-red, and also light brownish-grey or, sometimes, dark grey, aphaneritic limestones. Cavities and fissures filled by coarsely crystalline calcite are common throughout the interval in question. The typical texture is represented by a sparite-drusy biomicrite (with a fossil content of 20–50%). From among the fossil elements the *Crinoidea* remains are observable even to the unaided eye. They vary in quantity: being heavily enriched in lenses (accounting in such cases for 40 to 50% of the rock). The occurrence of *Spongia* spicules is common; where the skeletal elements of *Crinoidea* become quantitatively subordinate, they slip into the role of the predominant fossil component. They are exclusively calcitic in composition.

Of the other organic remains the *Ostracoda* valves, the *Mollusca* shell fragments, the small *Gastropoda* and *Ammonites* shells, *Globochaete* elements and *Foraminifera* are worth mentioning.

In the basal part of the interval the quantity of *Posidonia* shells is remarkable. From among the Foraminifera the representatives of *Nodosaridae* are frequent. Characteristic and relatively frequent species are *Involutina liassica* (JONES), *I. turgida* KRISTAN, *I.* sp., *Lasiodiscus* sp., and *Ophthalmidium* sp.

In the light of the stratigraphic position, the microfacies and analogies with the Bakony the sequence may be assigned to the Lower Pliensbachian.

Paleoenvironment

Crinoidal, brachiopodal, ammonitic limestones of Hierlatz facies with a biosparite matrix are frequently observable in the Tethyan realm, a wealthy literature having been devoted to their environmental interpretation (H. C. JENKYNS and H. S. TORRENS 1971, D. BERNOULLI 1971, D. BERNOULLI and H. C. JENKYNS 1974).

In the literature concerning the Transdanubian Central Range there are two conflicting opinions:

J. KONDA (1970a, b) believes that the Hierlatz facies is typical of the discontinuous, marginal sequences, where "shallow-water and, in fact, littoral formations occur..." "The break in sedimentation in these places was caused by virtual emergence." The "ammonitico rosso" facies according to him is characteristic of the comparatively deeper-water regions.

A. GALÁCZ and A. VÖRÖS (1972), in turn, are of the opinion that the discontinuous "ammonitico rosso" sequences must have been deposited on relatively elevated blocks, "seamounts", and that "the Hierlatz-type limestone was formed in en-echelon-faulted areas characterized by discontinuous sequences and still belonging to the 'seamounts'. "The fauna is composed partly of autochtonous elements, partly of ones introduced from the relatively elevated blocks which, however, still lay beneath the photic zone. The formation of the rather frequent biosparite matrix they explain by admitting that "the copious supplies of skeletal material removed to deeper tracts from the seamount pushed the red micrite accumulation into the background (resulting in a kind of 'dilution')".

Sedimentological and microfacies analyses of the section exposed at Sümeg have yielded data that may foster a better understanding of the genetic problems. It should be remarked, however, that the section studied is merely one section of a formation that is extremely diversified even within the Central Range, being on top of that not the most typical one at all (the underlying Isztimér Limestone offers a more or less continuous sequence) and thus the extrapolability of the interpretation is limited.

←

Fig. 17. Lithological column and analytical results from the Hierlatz Limestone Formation interval of the borehole Süt-23

Lithologic column (Lc): 1. limestone, 2. chert, 3. crinoidal, 4. Posidonia-bearing, 5. pelletal, 6. clay-filmed. — *Colours:* 1. light brown, 2. dark red, 3. light grey, 4. dark grey, 5. pink, 6. white. — *Megaloscopic character* (M): 1. calcite druses, 2. calcite fissure-fill, 3. Gastropoda, 4. Ammonites. — *Subunits of the Hierlatz Limestone Formation* (Su): 1. light grey to pale-red limestone, 2. brownish-grey crinoidal limestone, 3. Posidonia lumachelle, 4. pink oncoidal-oöidal limestone, 5. pink aphaneritic limestone. — *Textural composition* (Te.c.): 1. fossils, 2. intraclast, 3. pellet, 4. oöid, 5. oncoid, 6. interstitial sparite, 7. recrystallized sparite (drusy sparite), 8. microsparite, 9. micrite. — *Fossils:* 1. Glomospira sp., 2. Lasiodiscus sp., 3. Textulariidae, 4. Ophthalmidium sp., 5. Nodosaria sp., 6. Austrocolomia sp., 7. Dentalina sp., 8. Frondicularia sp., 9. Lenticulina sp., 10. Marginulina sp., 11. Involutina sp., 12. I. liassica, 13. I. turgida, 14. Trocholina sp., 15. Foraminifera indet., 16. Globochaete, 17. Spongia, 18. Brachiopoda, 19. Mollusca shell detritus, 20. Posidonia, 21. Gastropoda, 22. Ammonites, 23. Ostracoda, 24. Crinoidea

The pelbiomicrite rock type rich in sponge spicules of the interval overlying the Isztimér Formation and representing the basal part of the Hierlatz Formation suggests convincingly a deposition in a non-agitated environment beneath the zone of wave action.

The crinoidal biomicrite lithofacies type of the second interval must have been formed beneath the surf zone, too. However, the fact that here the large, calcareous, benthonic *Foraminifera* become more and more frequent up in the profile and the thick-shelled skeletal elements of *Crinoidea* and the *Gastropoda* suggest a quite shallow-water environment inasmuch as these were buried by the sediment in the proximity of their habitat.

The *Posidonia*-lumachelle in the middle part of the sequence seems to have been formed in a shallow-water as a result of mixing by wave action.

The oncosparite-oösparite (grainstone) texture type observed in the fourth interval and characterizing a considerable part of the unit was deposited with high probability in a quite shallow-water environment, above the wave base, in a heavily agitated zone (E. Flügel 1972, L. J. Wilson 1975). With a view to the textural features, however, a large-scale redeposition seems to be improbable.

The Crinoidea-Spongia spicules-bearing rock type of the uppermost interval is a formation essentially similar to the lower intervals, having been accumulated beneath the wave base, though probably also in shallow-waters.

Summarizing the above-mentioned facts, we can draw the following conclusions:

— it may be taken to be proved that the onco-oösparite rock types observable in the sequence were deposited in quite shallow-waters;

— on the basis of the trends of continual variation and the facies relations the predominantly shallow-water benthonic fauna of the deeper and higher intervals seems to have undergone only short-distance transport and the depositional environment to have lain beneath the surf zone at the bottom of a shallow-water sea.

Observable to the naked eye over the almost full vertical length of the sequence and representing, as shown by texture analysis, early diagenetic products, the calcite druses are worthy of attention. Filled with limpid, coarsely crystalline sparry calcite and partly with marine sediment, the cavities were obviously formed by postdepositional dissolution.

According to G. M. Friedman (1968), the drusy mosaic-sparite cavity-fills would have been brought about as a result of emergence or, in the subsurface though, but by precipitation from freshwater.

R. G. C. Bathurst (1975) is of the opinion that such a direct and simple relationship does not exist between the chemism of the interstitial water and the character of the cavity-filling sparite.

In the case of the *Posidonia*-lumachelle predominantly a sparry overgrowth of the shell, the formation of a syntaxial margin, can be spoken of.

Fissure-fills

A particular type of the Jurassic in the Sümeg area is represented by the rock varieties filling the fissure system in the Upper Triassic Dachstein Limestone and the Lower Liassic Kardosrét Limestone.

The fissure systems can be studied excellently in the southern part of the Mogyorós-domb, but they are observable on the northwest margin of the Városi-erdő as well. The boreholes put down in the southern part of the Mogyorós-domb and penetrating the Dachstein and the Kardosrét Formations have given valuable information on the nature of the fissures and the peculiarities of the infilling.

That the infilling of the fissure system explored in the southwest part of the Mogyorós-domb is particularly suitable for study is due to the fact that here, in addition to fissure-filling sediments, the erosional remnants of the Middle Liassic beds overlying, with a break in sedimentation, the Lower Liassic Limestone can also be found. This provides a good base for a more precise stratigraphic classification of the fissure-fills by comparing the microfacies types and the fossils.

On the rock surface cleaned in 16.5 × 12.0 m extent in the southwest part of the Mogyorós-domb (Fig. 12, Location 3) the Kardosrét Formation is intersected by several-m-wide bands, with trends of 70°–90°—250°–270° and 20–200°, respectively and composed of diversified rock varieties largely differing from the country rock and interpretable as fissure-fills. Along the fissures the rock becomes heavily brecciated. Completely nonrounded debris, deriving partly from the country rock, partly from older fissure-fills, are frequent in the fissure-filling sediment as well, the bioclasts being arranged parallel to the strike of the fissures.

The fissure-fill material (Plate XII, Fig. 2, 3) is a yellowish-white, pink-shaded, aphaneritic and often crinoidal limestone. Minor denudation remnants of the red or pink limestones overlying the country rock were also encountered in the exposure. These are rock varieties of normal mode of bedding which were discussed in more detail in the discussion of the Pisznice Limestone (Fig. 16).

The cleaned rock surface, as viewed from atop, and the rock varieties megaloscopically distinguishable therein are shown in Fig. 18. The locations of the samples taken for microfacies analyses are also indicated in it.

As a result of the microfacies analysis of the fissure-fills the following types could be singled out (Fig. 18):

1. Pelmicrite. Texture banded, of fluidal character. Micrite matrix locally converted into microsparite. The amount of the minute (20 μm) round peloids of probably nonfecal origin is 50 to 80%. The quantity of fossil elements is usually low, but in some bands the organic debris, *Crinoidea, Ostracoda, Foraminifera* (Samples 11, 12, 13), get enriched.

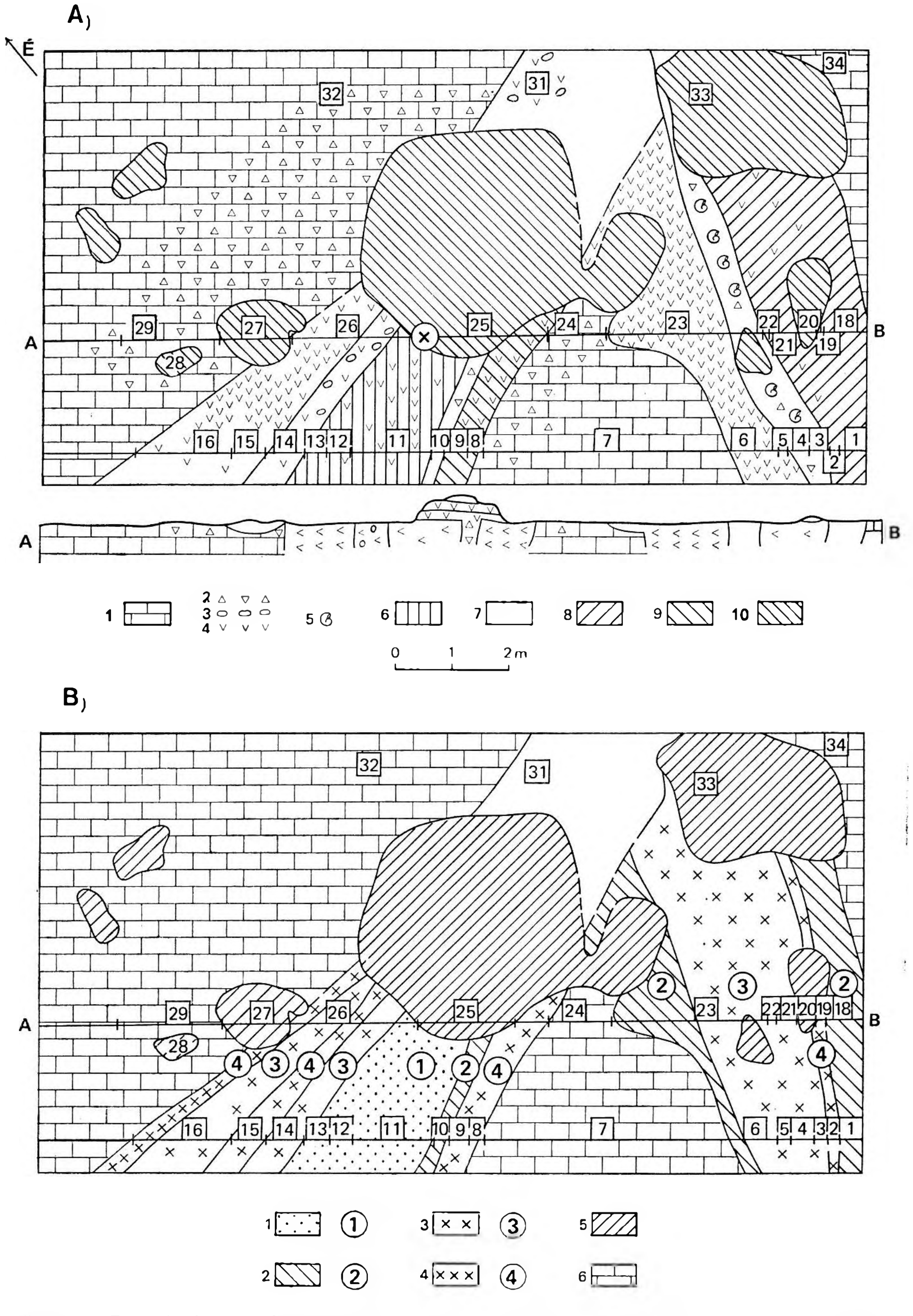


Fig. 18. Liassic fissure-fill system in the southwest part of the Mogyorós-domb

A) Megaloscopic survey: **1. Kardosrét Limestone Formation (bedrock), 2. tectonically brecciated rock, 3. pelletal, 4. crinoidal, 5. with ammonite embryons; fissure-filling lithofacies types: 6. grey, 7. white, 8. yellow, 9. pink, 10. red. — *B) Microfacies:* 1. pelmicrite (banded-fluidal texture), 2. micrite, 3. biomicrite I (foss. 10—20%), 4. biomicrite II (foss. 30—50%), 5. red micrite, 6. oncoidal pelmicrite (bedrock). — The numbers in rectangular frame indicate the sampling points**

2. Micrite. Two varieties of the type were observed. In the one case the fossil elements are subordinate in quantity. Skeletal fragments of *Crinoidea*, *Spongia* spicules, thin-walled *Ostracoda* valves and *Globochaete* remains representing the organic component constitute but 1 to 2% of the texture. In rare cases limonite-coated lumps of corroded edge can also be encountered in which the share of fossil elements is higher (Samples 10 and 18). — The other variety (Sample 1) represents actually a transition to the biomicrite I type. The amount of fossils increases to 4–5% and, though in a low quantity, benthonic Foraminifera such as *Nodosaria, Marginulina, Spirilina, Vidalina, Involutina liassica* (Jones), *Trocholina granosa* Frentzen and *Lasiodiscus* sp. also appear.
3. Biomicrite I type. The amount of fossils increases compared with the foregoing, getting close to 10–20%. Embryonic *Ammonites* shells, *Spongia* spicules, skeletal elements of *Crinoidea*, thick- and thin-walled *Ostracoda* valves are frequent. Foraminifera are similar in quantity and quality to the second variety of the preceding type (Samples 21, 22, 3, 4, 5, 6, 16, 29, 33).
4. Biomicrite II type (Plate XIII, Fig. 1, 2, 3, 7). The amount of the fossil fragments is 30 to 50%. Most of these are represented by skeletal elements of *Crinoidea* that are well-preserved and little rounded. Frequent biogenic components include *Bivalvia*, *Gastropoda*, *Ammonites* tests, further, thick-walled *Ostracoda* valves and sponge spicules. Of the Foraminifera, the representatives of *Nodosaria*, *Lenticulina* and *Marginulina* are common. Specimens of *Ophthalmidium* sp., *Involutina liassica* (Jones), *Trocholina granosa* Frentzen and *Tr. turris* Frentzen (Samples 2, 8, 9, 15, 16, 23) occur in particularly great numbers.

Comparing the microfacies types of the fissure-fills with the data of a sequence of normal mode of deposition, we can find that the second bed of profile B shown in Fig. 16 (for its location, see the symbol × in Fig. 18) is similar in its features to Type 2, the third bed to Type 3, the fourth, fifth and sixth ones being similar to Type 4. The rock corresponding to Type 1 could not be observed in a sequence of normal mode of deposition. It may be imagined that this rock type is specially manifested in fissure-fill form. In the sketch labelled B of Fig. 18 the locations of the microfacies types within the explored fissure system are indicated.

As can be concluded on the basis of the analysis, the fissures were filled during post-Early Sinemurian tectonic movements in the initial stage of the sedimentation that followed the denudation associated with tectonic deformation and the material that filled them had come from the basal layers of the sequence of normal deposition. A multiple repetition of the fissure opening and filling process must also be reckoned with.

It is in the axis of the fissure running in the middle part of the exposure that the oldest generation of fissure-fills was observed. Deviating in both directions from that axis, the fissure-fills tend to be more and more young. The opening and filling process may be interpreted as follows:

1. In the first stage a fissure of about 2 m width was formed in the Kardosrét Limestone constituting the substratum (the sea bottom) and this would be filled with materials deriving from the basal bed of the normally deposited sequence.
2. In the course of continued opening another, narrow fissure evolved between the bedrock and the earlier fissure-fill of totally different consistency and it was filled with material of the second bed.
3. During the next opening an open fissure was formed on the opposite side of the fissure and it was filled with material from the third bed.
4. Continued tensile stresses produced, in one or several phases, new fissures within a fissure-fill that had consolidated to some extent and this time the infilling came from the fourth bed.

Somewhat different is the case with the fissure extending on the southwest side of the exposure. Namely, it is the younger fill that is found in central position and the supposedly older fissure-fill generations occur towards the flanks. This means that in this case new fissures were formed and filled during fracturing within the fissure-fill itself.

To add precision to the dating of the basal beds overlying the Kardosrét Limestone and the fissure-fills that show textural features essentially identical with the former is permitted by the Ammonites fauna sampled by J. Konda and determined by B. Géczy (1970).

According to B. Géczy's studies, the collected fauna can be divided into two parts. From the red calcite-streaked limestone type, he determined the following fauna (48 specimens):

Phylloceras sp.
Geyeroceras cf. *cylindricum* (Sowerby, 1831)
Partschiceras sp.
Peltolytoceras altiformis (Bonarelli, 1900) n. subsp.
Juraphyllites sp.
Arnioceras sp.
Asteroceras cf. *reynesi* (Fucini, 1903)
Riparioceras riparium (Oppel, 1862) n. subsp.

With a view to the presence of the genera *Arnioceras* and *Asteroceras*, B. Géczy suggests that the fauna may represent the lower part of the Upper Sinemurian (Obtusum Zone).

From the red-whitish, grey, crinoidal, brachiopodal, ammonitic (Hierlatz-type) limestone the following fauna was recovered (84 specimens):

Phylloceras sp.
Geyeroceras cf. *cylindricum* (Sowerby, 1831)
Partschiceras sp.
Juraphyllites sp.
Lytoceras sp.
Angulaticeras sp.
Oxynoticeras sp.
Paroxynoticeras cf. *salisburgense pulchellum* (Fucini, 1901)
Paroxynoticeras sp.
Arnioceras sp.
Asteroceras sp.
Leptechioceras sp.
Palaeoechioceras ? *variabile* (Gugenberger, 1936)
Palaeoechioceras n. sp.
Platechioceras sp.
Coeloceras costeri (Hug, 1899)
Coeloderoceras sp.

According to B. Géczy, the bulk of the fauna belongs to the lower part of the uppermost Sinemurian Raricostatum Zone, a few specimens having been admixed to the fauna from a deeper horizon (lower Upper Sinemurian, Obtusum Zone).

The Gastropoda fauna collected by J. Konda was processed and published by J. Szabó (1979, 1980). He mentions the following forms:

Discohelix cf. *ornata* (Hörnes)
Discohelix inornata Szabó
Pentagonodiscus reussi (Hörnes)
Sisenna cf. *procera* (Deslongchamps)
Pleurotomaria cf. *platyspira* (Deslongchamps)
Leptomaria sp.

The borehole Süt-28 located at the northern corner of the cleaned rock surface penetrated fissure-fills in a great thickness. The locations of the fissure-fills are shown in Fig. 14. That the thickness of the filled fissures does not decrease event at 200 m depth is worthy of attention.

The microfacies observed in the course of thin section analyses can be assigned to the types singled out during the examination of the surface exposure (Plate XIII, Fig. 4, 5, 6).

In the Upper Triassic sequence of the borehole Süt-27 put down at a distance of 100 m from the exposure, the intervals with fissure-fills also amount to a considerable thickness (Fig. 9a–b). The microfacies characters are similar to those just mentioned. The microscopic brecciation associated with the fissures is illustrated in Fig. 1 to 6 of Plate XIV.

The fissure systems were also studied on two minor cleaned rock surfaces at 200 m to the northwest of the exposure (Locations 4 and 5, Fig. 12; for the lithofacies types, see Fig. 19). The country rock in these cases is Dachstein Limestone with a rich *Triasina* and *Aulotortus* fauna. The principal fissure directions are 80 to 95°, 260 to 275° and 125 to 305°, respectively. The width of the fissures varies from a few cm to a couple of metres.

Most frequent among the fissure-filling materials is a brick-red or ochre-yellow, argillaceous limestone, and calcareous marl in which even clastic grains deriving from the host rock or from the fissure-fill can be observed near the fissure walls.

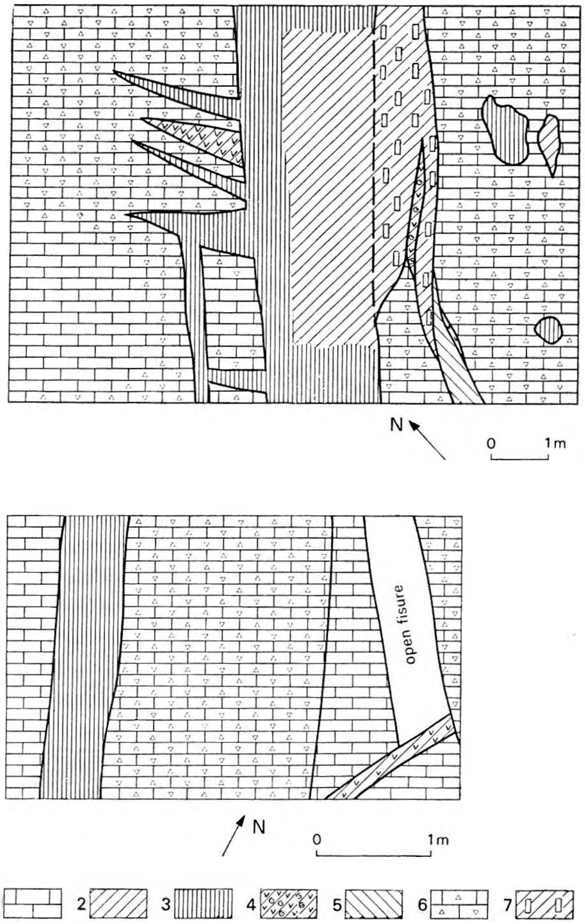


Fig. 19. Fissure-fill systems on the Mogyorós-domb
1. Dachstein Limestone Fm., 2. red calcareous marl, 3. yellow calcareous marl, 4. red crinoidal ammonite-embryoned limestone, 5. light grey aphaneritic limestone, with a few Crinoidea and skeletons of ammonite embryons, 6. brecciated limestone with a yellow to pale-red or light grey interstitial matrix, 7. red calcareous marl matrix containing white aphaneritic limestone laminae fragments

According to thin section analysis, the rock type is texturally micrite (mudstone), containing only a 1 to 10% amount of small fossil debris. In addition to a few *Crinoidea* skeletal elements, thin-walled *Ostracoda* valves and minute benthonic *Foraminifera*, almost every sample examined was observed to contain debris of *Bositra*, frequently in a considerable amount. A *Bositra*-bearing rock in the study area is known from the Eplény Limestone Formation penetrated by the borehole Süt-26 which seems to have been formed in the Late Liassic to Early Dogger interval. It is probable that the fissure-fill in question corresponds to the lower part of this formation and is assignable to the Toarcian. This dating is confirmed by the *Harpoceras* sp., fragment quoted by J. Konda (1970) from this exposure as well as by the *Hildoceras* sp., specimens collected by A. Galácz.

The other component of the fissure-fills is a red limestone with biomicrite and 25 to 50% fossil content of which the bulk is composed of skeletal elements of *Crinoidea*. In addition embryonic shells of *Ammonites*, *Ostracoda*, *Posidonia* shell fragments and a few benthonic *Foraminifera* have been recovered. This microfacies is similar to Type 4 of the exposure discussed in detail. On the basis of the examination of the erosion remnants of the normal succession of strata observed at the surface this lithofacies type is that which has overlain the eroded rock surface here.

On the east side of the road leading to Balatonederics, on the margin of the Városi-erdő, the fissure-filling sediments observable in the Upper Triassic and Lower Liassic limestones belong as a rule to the micrite facies type poor in fossil components, though less frequently a crinoidal limestone of biomicrite texture also occurs. Bositra-bearing fissure-fills in this area were not observed.

The development of fissures filled with Jurassic marine sediment (neptunian dykes) is not a local phenomenon. Filled fissures of similar character can be frequently observed in the discontinuous sequences of other subareas in the Transdanubian Central Range, too (J. Konda 1970) and may be considered to be common from the Upper Triassic up to the end of the Jurassic, with their bulk in the Lias though, in the units of similar facies of the Tethys (D. Bernoulli and H. C. Jenkyns 1974).

Generated parallel with marine sedimentation and repeatedly reopening for a long span of time, the fissures and the fault blocks, reflected as they are in the differentiation of the facies, may be connected with the disintegration of the lowermost Liassic carbonate platform and, tectonically, with the Jurassic rifting of the Tethys (D. Bernoulli and H. C. Jenkyns 1974).

Eplény Limestone Formation

The small outcrop of a grey siliceous marl from beneath the radiolarites exposed over a relatively large area on the Mogyorós-domb was first mentioned by J. Noszky in his manuscript report of 1957. When locating the surface trenches on the Mogyorós-domb we encountered this lithofacies type ourselves near the contact between the Triassic–Lower Liassic limestone and the Jurassic of steep dip, but because of the strong tectonic deformation the exact stratigraphic position could not be determined.

It was with the aim of exploring a hardly known Jurassic sequence beneath the radiolarite that we put down the borehole Süt-26 (Fig. 20) which, between 80.0 and 199.0 m, penetrated the unit composed of grey siliceous marls in a considerable thickness. The strata seem to be plicated, for the dip values vary continuously from 45° to 80°. This makes it difficult to assess the virtual thickness of the formation. Thus only an approximate value can be given: 60 to 80 m.

The rock characteristic of the sequence is a light grey siliceous marl or calcareous marl. Rather monotonous, the sequence is sometimes interrupted by thin, greenish clay-marl beds. In varying frequency though, black chert lenses could be observed throughout the penetrated interval.

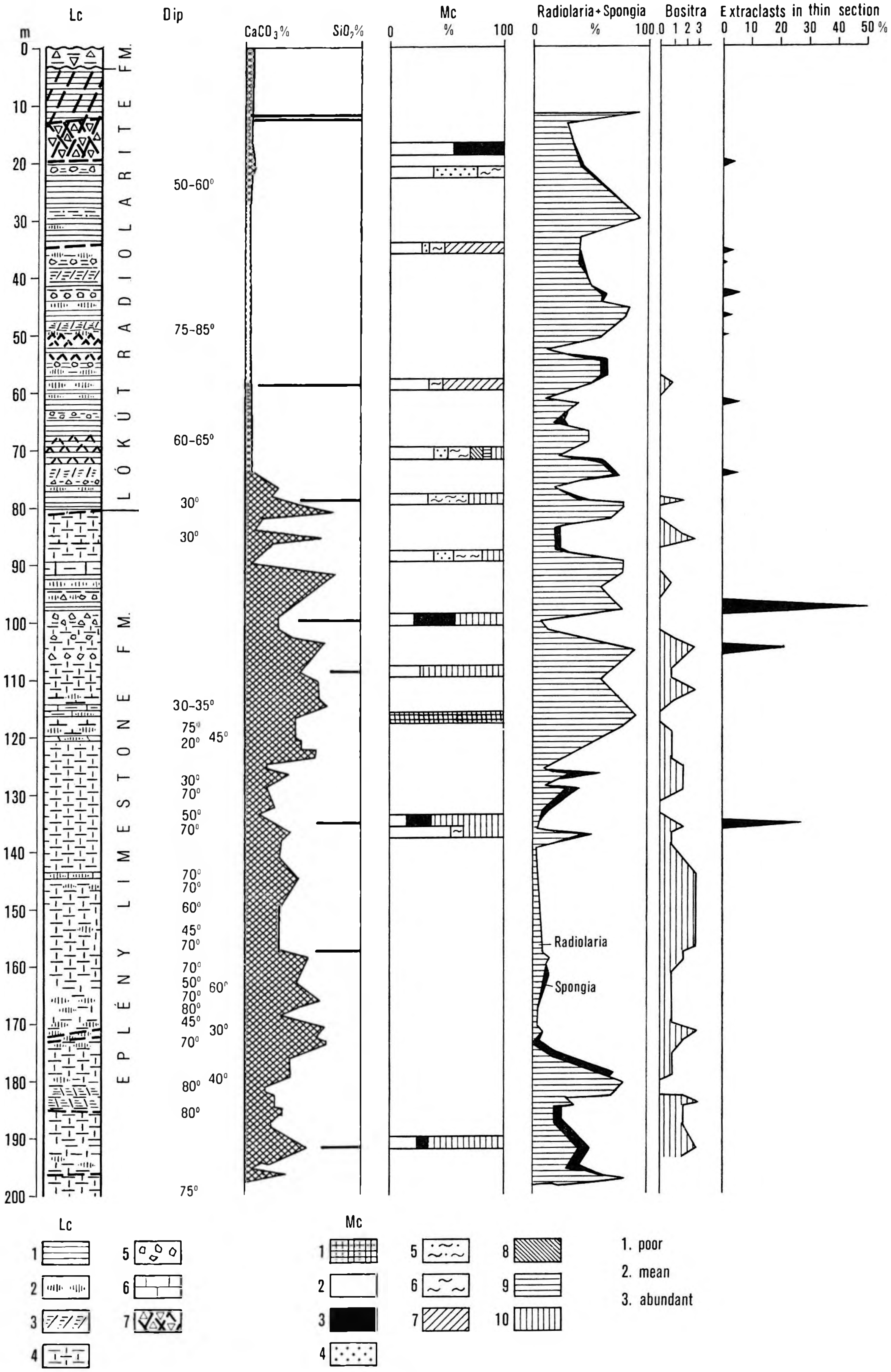
The rock has a $CaCO_3$ content varying from 30 to 60%, the amount of SiO_2 varies between 30 and 40%, being bound mainly to quartz and cristobalite minerals. The clay minerals attain an amount of about 10%. According to X-ray analyses by A. Szemethy, the clay minerals are generally represented by illite, but the thin pelitic interlayer within the uppermost interval was observed to contain 18% montmorillonite in addition to 24% illite.

According to thin section analysis, the texture is usually represented by biomicrite, the matrix being often more or less recrystallized.

→

Fig. 20. Lithologic column and analytical results from the borehole Süt-26

Lithologic column **(Lc): 1. radiolarite, 2. diagenetic chert, 3. epigenetic chert, 4. siliceous marl, 5. extraclast, 6. limestone, 7. tectonically crushed. — *Mineralogical composition* (X-ray) (Mc): 1. alpha-quartz, 2. quartz, 3. cristobalite, 4. montmorillonite, 5. illite-montmorillonite, 6. illite, 7. tridymite, 8. K-feldspar, 9. plagioclase, 10. calcite**


Lc
Dip
CaCO₃%
SiO₂%
Mc
%
Radiolaria+Spongia
%
Bositra
Extraclasts in thin section
m
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
0
100
0
100
0 1 2 3
0 10 20 30 40 50 %
LÓKÚT RADIOLARITE FM.
EPLÉNY LIMESTONE FM.
50-60°
75-85°
60-65°
30°
30°
30-35°
75°
20° 45°
30°
70°
50°
70°
70°
70°
60°
45°
70°
70°
50° 60°
70°
80°
45° 30°
70°
80° 40°
80°
75°
Radiolaria
Spongia
Lc
1
2
3
4
5
6
7
Mc
1
2
3
4
5
6
7
8
9
10
1. poor
2. mean
3. abundant

The microfacies pattern of the formation is characterized first of all by the abundance of *Bositra* fossils. A microfacies composed almost entirely of *Bositra* tests does even occur, but the type characterizable by the joint abundance of both *Bositra* and *Radiolaria* is more common. In the first case the *Bositra* shells are larger in size, seemingly intact and well-oriented, in the latter case, however, they are crushed into tiny fragments and the orientation is less conspicuous. Particularly in the top part of the formation is the amount of silica-filled *Radiolaria* shells (up to 80%) remarkable. *Spongia* spicules can also be observed in a maximum of 3 to 10%.

In single samples a few *Ostracoda* and benthonic *Foraminifera* remains could also be observed. Large *Crinoidea* ossicles are relatively frequent, mainly in the upper reaches of the sequence, being often associated with extraclasts. This induces us to suppose that the skeletal elements of *Crinoidea* are allochtonous, too. However, no manifestation of more heavy rounding is observable on the fossils.

The microfossils recovered by decantation from the pelitic intervals were studied by R. Kopek-Nyírő. From among the *Radiolaria* she identified *Cenodiscus* sp., *Lithopium* sp. *Cenosphaera* sp., *Cenelipsis* sp., *Aphaerostylus* sp., *Druppula* sp. from the *Spumellaria* type, *Lithostrobus* sp., *Dictyomitra* sp. from the *Nascellaria* group. Beside the afore-mentioned radiolarians some ill-preserved *Foraminifera* were also observed: *Lenticulina* cf. *mariae* Schiff., *L.* cf. *velascoensis* White, *Reussella* sp., *Guttulina* sp., *Gavelinella* sp. In addition to unicellular (protozoan) tests, *Spongia* spicules, *Mollusca*, *Echinoidea* and *Ostracoda* fragments and a few *fish teeth* are worthy of mention from the residue of washing.

While investigating the nannoplankton J. Bóna found but a few recrystallized *Coccolithus* sp.

Already in the lowermost part of the profile, and particularly at the top of the formation, come some beds close in character to the overlying radiolarite unit.

Similarly in the upper part and generally linked to rocks of radiolarite type, rock debris (intra- and extraclasts) were observed to be enclosed in a maximum of 70% amount. The grains are unrounded, varying in size between 0.2 and 1.5 cm. Their lithologic composition is extremely diversified. As for the intraclasts, on the one hand, the radiolarite chert debris (namely, secondarily silicified, chert fragments of oöid texture also occur), on the other hand, the Bositra-bearing grains, were classified as such. Greater part of the clastic material is extraclast deriving from carbonate rocks, being composed of dolomite and limestone material. The following texture types could be identified: micrite, microsparite, intramicrosparite, pelmicrosparite, dolomicrosparite, dolosparite, oösparite, oömicrite showing the microfacies pattern of the Upper Triassic rocks, furthermore, ammonitic micrite, crinoidal micrite, crinoidal intrasparite, Spongia spicule-Ostracoda micrite, Spongia spicule-Posidonia micrite that may derive from Liassic rocks as suggested by their microfacies patterns (Plate XV, Plate XVI, Fig. 3).

Chronostratigraphy

No fossil enabling a more precise chronostratigraphic assignment has been recovered from the Sümeg exposure of the formation. The only information available is that the Bositra fossils abounding here are known to be present in great quantities in the Toarcian, Aalenian and Bajocian stages elsewhere in the Transdanubian Central Range (J. Fülöp 1971). In the Bakonycsernye section it is in the lower Upper Dogger that both Radiolaria and Bositra are observed in abundance (B. Géczy 1961). Such a Radiolaria-Bositra biofacies is conspicuous in the Süt-26 borehole sequence, too. And though these facies features, in principle, cannot be considered isochronous, to place the penetrated interval so as to extend from the end of the Middle Dogger up to the beginning of the Upper Dogger seems to be conditionally acceptable. The lower part of the formation in the study area is unknown.

Paleoenvironment

The determination of the environment in which the formation was generated may provide an important clue to judging the controversial paleogeography of the Transdanubian Central Range.*

In analyzing the environmental conditions we can rely on the ecological character of the fossils and their lithological composition, furthermore, on the lithology of the observed intra- and extraclasts and their morphological characteristics. Bositra and Radiolaria are planktonic forms, hence their predominance suggests undoubtedly an openwater marine sedimentation. We can add immediately to the foregoing that the pelagic character does not necessarily imply any greater water depth or great distance offshore.

The presence of benthonic elements cannot be left out of consideration either, though they are quantitatively subordinate. They include Spongia, benthonic Foraminifera, Ostracoda and Crinoidea remains. That a part of these or all of them may not have lived in the same habitat, but were introduced postmortally, cannot be precluded. As far as the lithology of the tests is concerned, the marked

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* The quintessence of the problem and the conflicting views have been recently summarized by J. Fülöp (1975)

frequency of siliceous tests (Radiolaria, Spongia) and, in fact, their locally rockforming presence is conspicuous.

The enrichment of siliceous fossils, the formation of radiolarite, has been an old problem in geology, a lot of ideas, hypotheses and observations having been reported in the context of the Tethyan Jurassic radiolarite sediments alone.

According to a group of scientists, the accumulation of radiolarian tests in rockforming abundance beneath the $CaCO_3$ compensation depth (CCD) is the result of carbonate dissolution, thus being depth-dependent.

In connection with the Jurassic radiolarites of the Tethys this view was represented by R. Trümpy 1960, J. Aubouin 1965, R. E. Garrison and A. G. Fischer 1969, A. Bosellini and E. L. Winterer 1975. A similar opinion concerning the Transdanubian Central Range was advocated by A. Galácz and A. Vörös (1972), though they admitted the lack of direct data concerning the CCD in the Jurassic.

Attention to the limitations in extrapolating the dissolution of carbonate in modern oceans to the geological past was called by A. Hallam (1971). In my paper of 1976 I discussed the question myself, too. As expounded therein, I am of the opinion that not only depth values cannot be inferred from the present-day model, but the model itself is not suitable for judging how the Tethyan sedimentation in Jurassic time may have looked like. According to I. Worsley (1974), the CCD did not even exist prior to Late Jurassic-Early Cretaceous time. Namely, before the explosion of the carbonate microplankton no sizeable pelagic precipitation of carbonate had taken place and the entire carbonate regime had been basically different than is today.

To connect the formation of radiolarites with submarine volcanism has been attempted for a long time now by scientists. Some are of the belief that cherts are direct products of submarine magmatism. This cannot be the case with the Transdanubian Central Range.

A more general opinion suggests magmatism to have had an indirect effect. During the halmyrolysis of volcanic ashes the silica content of the seawater increases and this adds to the productivity of siliceous microplanktonic organism (H. R. Grunau 1965, R. A. Hart 1973).

Again others ascribe the changes in the silica content of the seawater primarily to fluctuations in the quantity of dissolved silicate incoming from the continents (G. R. Heath 1974), a phenomenon that is controlled in the first place by climatic changes (J. D. Hays et al. 1974, M. Steinberg et al. 1977).

A considerable part of the authors believe that the main role in the silicate regime of the oceans is played by the planktonic microorganism (S. E. Calvert 1974, W. M. Berger 1974). Planktonic productivity is controlled primarily by the distribution of nutrients, the upwelling on the continental margins playing an important role.

S. E. Calvert (1966), during his study of the Gulf of California, called attention to the definitive role local factors (indirect effect of volcanism, upwelling) played in a relatively confined area affected by rifting.

M. Steinberg (1981) proposed an idea supposing global silica enrichment periods during which siliceous sediments got enriched both in the oceans and shallow-water seas.

One of the most significant periods of silica enrichment in Earth's history corresponds to the Late Jurassic when radiolarite sediments are known to have accumulated not only from the one-time Tethyan realm, from Morocco to Indonesia, but also beyond it, from a number of areas from Alaska to Venezuela.

The investigation of the Bositra-Radiolaria-bearing Eplény Formation and the Lókút Radiolarite evolving from it as exposed in the Sümeg section has provided informations enabling us to approach from several viewpoints to the problem of radiolarite generation.

What is considered to be essential from the viewpoint of interpretation is that the studied section comprises a complete series of transition from the predominance of calcareous fossils up to that of the siliceous ones. The examination of the transitional lithofacies types and other observations seem to suggest that the enrichment of silica was not basically due to selective dissolution either in the case of the Eplény Formation or in that of the overlying radiolarites. Our arguments are as follows:

1. In the case of the Radiolaria-Bositra rock variety, where a sizeable part of the rock is composed of quite tenuous calcareous valves and skeletons, an intensive carbonate dissolution can be hardly spoken of and yet the share of the silica-shelled fossils is considerable.

2. Even in the radiolarite composed in 70 to 80% of silica-shelled fossils do a few calcareous Bositra valves usually occur which in case of selective dissolution would be hardly imaginable.

3. In the upper part of the formation, where radiolarites and Bositra-bearing marls alternate, there is no visible dissolution surface which actually ought to be expected to occur, once a calcareous sediment has got in an environment of intensive dissolution.

4. On thicker-walled benthonic calcareous fossils no corrosion can be observed.
5. No trace of subsolution is observable on the edges of carbonate extraclasts either.

If the siliceous tests get enriched owing to causes other than $CaCO_3$ dissolution, it has to be supposed that the ecologic conditions of silica-shelled organisms have become favourable at the expense of the calcareous organisms. It is the quantity of the silica dissolved in water that seems to have increased. The most probable cause for this may be an increased accumulation of land-derived dissolved silica and/or the introduction of volcanogenic materials into the sedimentary basin and its halymrolytic decomposition therein. This assumption seems to be corroborated by the remarkable montmorillonite content of the interbedded green clay layers and by their being linked primarily to radiolarite interbeddings. According to I. VICZIÁN (1977), montmorillonite mineral assemblages in the Transdanubian Central Range appear from the Middle Dogger onwards. The older Jurassic sediments are dominated by illite, and even kaolinite accumulations could be locally observed.

Another argument in favour of an interpretation assuming bathyal depths is the lack of benthonic fossils. In reality, the benthonic forms are not lacking even in the radiolarite beds, for the quantity of Spongia remains is considerable, and in the worst case it is the calcareous benthonic forms that may be scarce. Naturally, the subordinate role of the calcareous benthos compared with their Lower and Middle Liassic abundance does indicate a relative increase in depth.

To judge the distance offshore is also essential and rather controversial. Important clues to this and also to the reconstruction of the geology of the source area are provided by the evaluation of the extraclasts observed in the sequence. This is all the more so, as according to the information available to us, no earlier observation of this kind was carried out in the units involved.

The relatively large nonrounded debris referred to in the descriptive part may have been removed from the emergent and intensively eroded islands and cliffs into the marine sedimentary basin. Their having been involved in terrestrial transport is very unlikely and they do not show any abrasional feature either. So a steep rocky shore possibly continuing in a relatively steep submarine slope is supposed and the detritus produced there by the surfs or possibly by bioerosional action was accumulated at the base of the slope as a result of mass-gravity movement.

The extraclasts suggest that the source rocks on the emergent highs were represented mainly by Upper Triassic dolomite and limestone and also by Lower Liassic Kardosrét Limestone. In some places, however, the erosion-attacked surface may have been composed of younger, Lower, Middle and even Upper Liassic formations, though their having filled fissures in Triassic to Lower Liassic rocks and eventually been eroded together with the host rock is not unlikely either. The intraclasts derive obviously from the cracking of sediment on the subaquatic reaches of the slope.

Another question to be answered concerns the character of the emergent lands and their one-time location. Information on this matter is provided by the analysis of hiatuses. In the boreholes Sp-1 and Süt-17 at 2.5 km north of the continuous Dogger–Lower Cretaceous sequence exposed in several places on the Mogyorós-domb the Upper Triassic is overlain by a (Upper Dogger?) Malm sequence beginning with a marine basal bed of a few m thickness in which Triassic-Liassic debris are enclosed. On the southern slope of the Mogyorós-domb, separated tectonically from the northern one, the Jurassic sequence is discontinuous, too.

In the light of the experience acquired in the Sümeg area we believe that, at least at this site, the archipelagic features supposed on the basis of the Liassic facies from the Transdanubian Central Range (E. VADÁSZ 1961, G. VÍGH 1961, J. FÜLÖP 1969, 1971, J. KONDA 1970) persisted in Dogger time too. The tectonic blocks of varying size which were emerging as islands or submarine cliffs, were separated by narrow and comparatively deep (a few hundred metres) submarine trenches, channels, in which pelagic-type accumulation of silt, predominantly calcareous or, subordinately, siliceous biogenic, in dependence of the water chemism, was taking place. The relatively elevated tectonic blocks are interpreted in a way similar to the case of the seamounts as interpreted by D. BERNOULLI and H. C. JENKYNS (1970, 1974) and also by A. GALÁCZ and A. VÖRÖS (1972), the only, essential though not basical, difference being that some blocks are believed to have emerged above sea level.

If the Sümeg section is examined in a wider geological environment, the above-outlined conditions in a Tethys getting rifted from the Lias onwards (D. BERNOULLI and H. C. JENKYNS 1974) can be explained. The periodical enrichment of biogenic siliceous sediments is inferred from the Bay of California model [an area on the way of getting rifted, as suggested by G. R. HEATH (1974)], rather than from the modern oceans. The fact is that in the Bay of California the role of upwelling can be shown to be coupled with the indirect effect of submarine volcanism. This model may have been modified by two specific global factors: a climate which, as a rule, is favourable for the terrestrial dissolution of silica on the one hand and the situation prior to the explosion of the calcareous plankton on the other.

Lókút Radiolarite Formation

The formation is known exclusively on the Mogyorós-domb within the Sümeg area. Here the sequence showing an extremely steep dip (70°–90°) and heavy folding has been exposed by one borehole and several trenches (Fig. 12).

It is underlain by the Bositra-bearing calcareous marl of grey colour penetrated by the borehole Süt-26 (Eplény Limestone Formation) and overlain by the Lower Malm light grey marls with limestone nodules developed by trenching (Trench I) on the Mogyorós-domb.

As contoured from trenching and drilling results, the thickness of the formation is an estimated 150 to 160 m, assuming a tectonically undisturbed sequence. Because of the closeness of the tectonic contact with the Triassic rocks, however, a completely undisturbed sequence cannot be reckoned with. Accordingly, a more intensive tectonic deformation was observed in the upper part of the borehole Süt-26. The lower interval of this borehole sequence and the trench-exposed upper part of the formation looked less affected by deformation. No repetition of beds was observed. In the light of all these circumstances, we are of the opinion that the graphically inferred thickness value nearly corresponds to the virtual formation thickness.

The borehole Süt-26 intersected the lower part of the formation in a considerable thickness (3.0 to 80.0 m, dip 50° to 80°). The lithologic column of the borehole and the relevant analytical diagrams are shown in Fig. 20.

The transition from the underlying Eplény Formation is continuous. The radiolarite rock type occurs in several horizons as an interbed in the Eplény Formation as well. Above the formation boundary, however, typical radiolarite was observable throughout the sequence which was interrupted only by a few thin green clay laminae and secondarily carbonated intervals and brecciated zones. The fissures in the tectonically fractured radiolarite are filled with chert or calcite-sparite.

The SiO_2 content in the rocks of the formation varies between 85 and 100%, the $CaCO_3$ content between 0 and 15%, only in the lowermost metres does it increase markedly with the decreasing SiO_2 content. According to X-ray analyses by A. Szemethy, the SiO_2 content is bound to quartz and tridymite minerals which are present in equal proportions. In the basal part (79.0 m), however, cristobalite appears in addition to quartz.

According to thin section analyses, the microcrystalline, often resilicified matrix contains 20 to 90% (an average of 50%) *Radiolaria* tests (mainly *Spumellaria*, subordinately *Nascellaria* type). The original shell structure in the *Spumellaria* type can seldom be recognized, in the *Nascellaria* type being more often identifiable (Plate XVI, Fig. 2). The shell is filled for the most part with silica. Beside radiolarians, siliceous sponge-spicules can also be observed, in smaller amounts (5–10%). A few benthonic *Foraminifera* and *Ostracoda* tests were observed, too (Plate XVI, Fig. 1, 5). In deeper parts of the sequence (first at 59.0 m) *Bositra* shell fragments appear in a poor quantity, too. It is beneath 79.0 m that they attain, in some beds, a higher percentage. From the decantable material of the thin pelitic layers a few poorly preserved *Radiolaria* and *Spongia* spicules, *Echinoidea* spines and *fish teeth* were recovered.

In the basal part of the sequence the $CaCO_3$ content attains 66 to 82%. It turned out from the thin section analyses that the rock was composed, in 80% or so, of *Radiolaria* remains. Consequently, calcitisation is due to a secondary, diagenetic process. In some places the SiO_2-made shells are affected by subsolution, in other cases the original texture is completely lost. It is this dissolution-reprecipitation process that may be responsible for the formation of chert lenses. In the course of examination under the microscope it also turned out that the megaloscopically observable microlamination pattern was due to the alternation of radiolarite bands composed of pure silica with ones partially calcitized. The differentiation is a diagenetic phenomenon in this case too, calcitization and chert formation being closely linked here as well. That part of the formation overlying the drill-penetrated interval is exposed in a few shafts, the topmost part being developed in the key-section trench of Mogyorós-domb. The structural and textural characteristics of the radiolarites in the shafts and the trench agree with those in the upper interval of the drill-penetrated sequence.

The uppermost 10 metres of the formation are composed of dark grey to black cherts that consist actually of thin chert laminae separated by a pelitic-calcareous film and which, when exposed to the surface, will, upon weathering, fall into laminae (Plate XVI, Fig. 4). Manifested by a slight relief at the surface and usually covered by a thin soil layer, the chert bed crossing the Mogyorós-domb in a NE–SW direction can be traced for a long distance and even farther away, on the northeast side of the Sümeg–Balatonederics road.

Chronostratigraphy

No fossil enabling a more precise chronostratigraphic determination of the formation has so far become known, thus our judgement concerning its age has to rely on the mode of superposition and on extrapolation of knowledge from remote areas.

As far as the mode of superposition is concerned, the conclusion can be deduced that the member overlying the formation in question with a sharp contact, though not unconformably, can be assigned conditonally to the Oxfordian, but safe data available concern only the Kimmeridgian-Lower Tithonian age of the Pálihálás Limestone Formation which overlies that member.

Toward the underlying formation the transition is continuous, to draw the boundary is difficult. The dating of the Bositra-bearing marl unit is again rather uncertain, its formation seeming to have continued even during the early Late Dogger. In the Transdanubian Central Range the mass appearance of *Radiolaria*, as a rule, seems to have taken place in Late Dogger (Callovian) time (B. GÉCZY 1961, J. NOSZKY 1961).

On the basis of the observations carried out by G. VÍGH in the Gerecse area, J. FÜLÖP (1971) assigned the formation in the Transdanubian Central Range to the Bathonian-Callovian. Whether the observation in the Gerecse can be generalized for the Central Range, however, is questionable. The asynchrony of the initial part of the formation in the profiles of Lókút was demonstrated by B. GÉCZY (1968), in those of Gyenes-puszta by A. GALÁCZ (1970).

The asynchrony of the lower formation boundary is not surprising. Namely, in the Sümeg sections and other sections of continuous sedimentation (e.g. Bakonycsernye, B. GÉCZY 1961) there is a facies transition from the Bositra-Radiolaria-bearing carbonate-chert formations towards the radiolarite rock type, a transition characterized by repeated minor inversions. In the Sümeg profile the lower boundary of the Lókút Formation has been somehow arbitrarily drawn and, as already mentioned, radiolarite intervals occur in the Eplény Formation already. In the discontinuous sections, however, there is a hiatus between the radiolarite and the limestone underlying it, a break that may vary in size, similarly to the case of the hiatuses within the condensed limestone sequences interrupted by hardgrounds.

On the basis of the above, the present writer believes to be more probable that at Sümeg the birth of the formation began in the higher parts of the Bathonian and that it continued up to the end of the Dogger and maybe even well into the Oxfordian.

Paleoenvironment

The depositional environment in which the formation was generated seems to have not differred substantially from the case of the Eplény Formation. Thus the environmental interpretation given in that context applies for the most part to this formation as well. Without repeating that interpretation we may state that the Lókút Radiolarite too was formed in an opensea basin dotted with islands and rock cliffs and that it was formed of the radiolarian ooze deposited there. The enrichment of SiO_2 is ascribed basically to ecological factors rather than $CaCO_3$ dissolution, though in the case of radiolarites of a low carbonate content the dissolution factor may have been involved, too. The proliferation of siliceous microorganisms is supposed to have been provoked primarily by gradual changes in the chemism of the seawater owing to submarine volcanism and also to climatic factors. Chert lenses and beds formed as a result of early diagenetic dissolution and re-precipitation.

The afore-mentioned asynchrony of the lower formation boundary does not refute our ideas concerning the genesis. The setting-in or revival of submarine volcanism and the afore-mentioned factors do not change at one stroke the chemism of the water and the productivity of the siliceous plankton, just a unidirectional trend being involved at the most. On the other hand, in areas of discontinuous Jurassic sedimentation the siliceous sediments are condensed, too, or, similarly to the case of the carbonate sediments in earlier times, they were not sedimented at all on the particular, relatively elevated blocks.

Pálihálás Limestone Formation

Outcrops of the Pálihálás Limestone Formation are known to us (Fig. 11) on the Mogyorós-domb, where they have been exposed in full by two trenches. Of the boreholes, it is Süt-17 and Sp-1 that penetrated the unit.

Local type section: Mogyorós-domb, Section II

The local type section of the Pálihálás Limestone Formation has been provided by the trench (Section II) developed in 1961 in the northwest part of the Mogyorós-domb. In the trench of the uppermost chert member of the Lókút Radiolarite, the Oxfordian-dated calcareous marl member of the Pálihálás Formation and, above it, in a virtual thickness of 15 m, the typical sequence of 300/75° dip of the Pálihálás Formation can be studied. The overlying Mogyorós-domb Formation is also exposed (Fig. 21).

At the base of the Pálihálás Formation 1.5 m of homogeneous, light grey calcareous marl can be observed from which no megafossil has been recovered. The marl passes without any break into the limestone making up the bulk of the formation, the transition being characterized by the appearance first of calcareous nodules in the marl and by their gradual growth in quantity higher up the section.

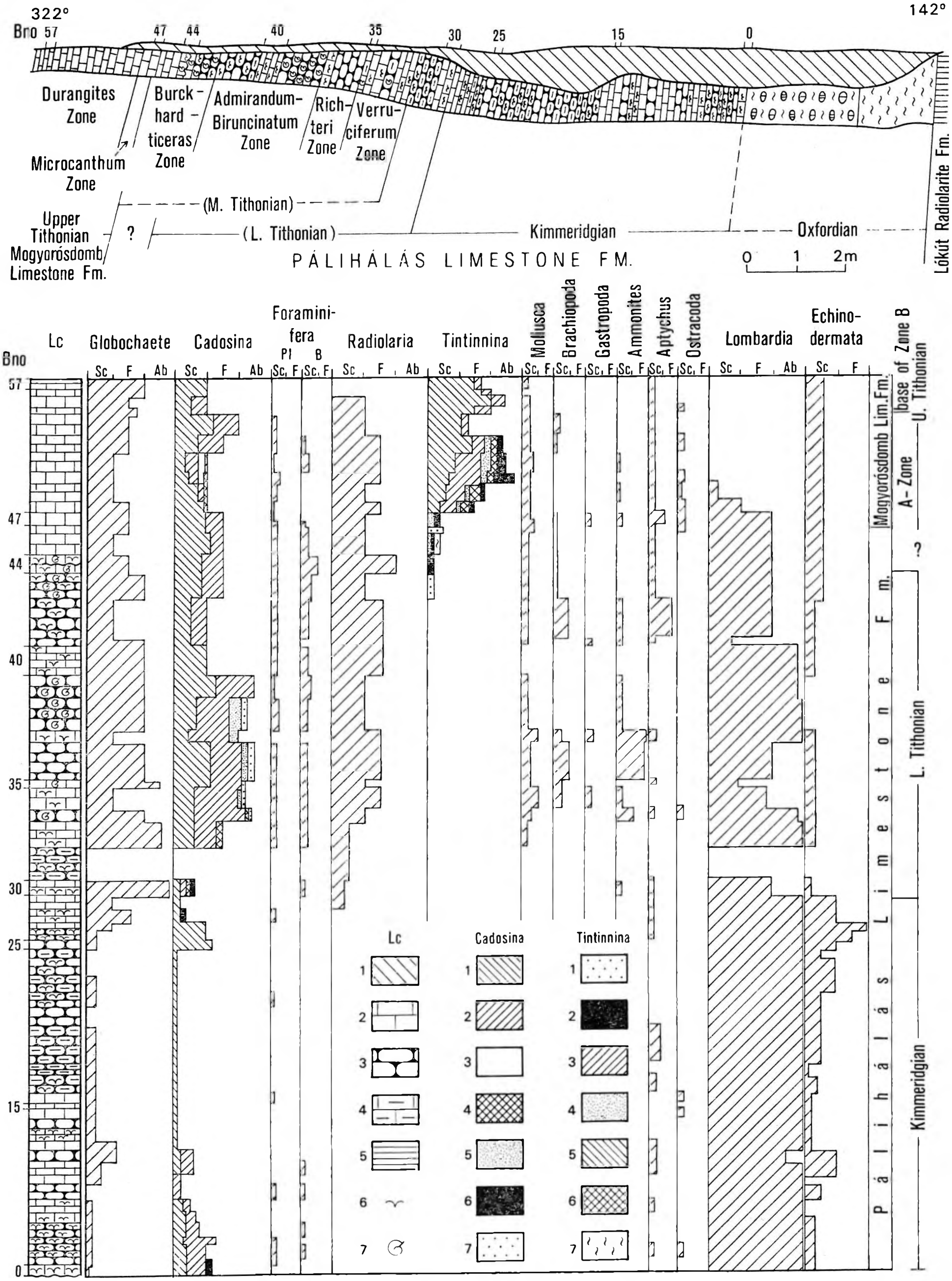


Fig. 21. Excavation trench Mogyorós-domb II: profile and analytical record

Lithologic column (Lc): 1. young detrital overburden, 2. limestone, 3. nodular limestone, 4. argillaceous limestone, 5. chert, 6. Lombardia, 7. Ammonites. — *Bno* number of bed. *Pl* plankton. *B* benthos. — *Sc* scarce, *F* fair, *Ab* abundant. — *Cadosina:* 1. lapidosa, 2. parvula, 3. fisca, 4. malmica, 5. pulla, 6. Stomiosphaera mollucana, 7. Cadosina sp. — *Tintinnina:* 1. Chitinoidella, 2. Crassicollaria intermedia, 3. Cr. parvula, 4. Cr. massutiniana, 5. Calpionella alpina, 6. C. elliptica, 7. Tintinnopsella carpathica

The member boundary can be drawn there, where the limestone-nodular marl passes into a marl-nodular, argillaceous limestone. The total thickness of the lower member is 3.7 m.

In the section the overwhelming majority of the Pálihálás Formation is made up of redbrown or light grey argillaceous medium-thick (10–30 cm) or thin-bedded, nodular limestone interrupted by argillaceous bedding planes (Plate XVII). On the basis of finer changes in lithology and microfacies the sequence can be split up into several units (Fig. 21).

The lowermost unit (1st to 14th beds) is composed of redbrown, medium-thick argillaceous limestone beds. These are separated by inhomogeneous, argillaceous bedding surfaces. Nodular structure is frequent, though not typical of all beds. It can be seen even megaloscopically that a considerable part of the rock is made up of coarser or finer skeletal elements of echinoderms. According to microscopic analysis, the characteristic texture is bioclastite (bioclast content above 90%) or biomicrite (bioclast content 70 to 90%). Predominant biogenic rockforming constituents are skeletal elements of planktonic *Saccocoma (Lombardia)* (Plate XVIII and XIX). Their size is 50–400 μm. Sporadically, larger *Crinoidea* elements (0.5–2.0 mm) occur, too. Their edges are often rounded off, but in some cases they are resorbed and limonite-coated. From among the microfossils, it is the comparatively abundant representatives of *Cadosina* that may be mentioned. Noncarbonate grains (quartz, glauconite) are subordinate, but observable.

The next unit (15th to 24th beds) is composed of a brown and light to greenish-grey thin-bedded argillaceous limestone with small limestone nodules which consists for the most part of small skeletal fragments of echinoderms (minute plates). The rock texture is bioclastite with *Lombardia* exceeding 90%. The size of the skeletal elements is from 70 to 260 μm. Other microfossils are extremely rare. In addition to *Aptychus* remains, a few poorly preserved *Ammonites* might be mentioned.

The next unit (25th to 30th beds) is represented by light grey, thin to medium-bedded, argillaceous limestone and pure limestone, *Lombardia* bioclastite. The size of the skeletal elements varies between 70 and 360 μm. Above the 28th bed the intraclastic texture type becomes characteristic. In the intraclasts (or plasts) the amount of *Lombardia* is generally lower than it is in the host material and even the mudflow type of micrite texture is observable as intraclast. In some beds, a pelletal texture appears, too. The skeletal elements of benthonic Foraminifera shows an increase compared with the preceding unit. Slightly rounded, they vary from 0.5 to 1.5 mm in size. At the top of the unit, *Radiolaria* and *Globochaete* appear, too. The megafossils are characterized by the same quantity and composition as in the preceding unit.

A marked change in the megaloscopic lithologic features, the texture pattern and the fossil assemblage can be registered from the 31st bed onwards. The interval of the 31th to 35th beds is constituted mainly by grey, locally pale pink, nodular, argillaceous limestone beds of 10 to 50 cm thickness each. That the quantity of the skeletal elements of echinoderms decreases can be observed even with an unaided eye. The texture is represented by biomicrite. Among the biogenic textural elements it is still *Lombardia* that predominate, though the representatives of *Globochaete*, *Radiolaria* and *Cadosina* also increase considerably. *Foraminifera* appear, both benthonic and planktonic forms being present in low quantity, but consistently. *Mollusca* shell fragments and embryonic tests of *Ammonites* can also be observed. Their test is composed of Lombardia biomicrite or a micrite with few biogenic grains. The pelmicrite texture type occurs in rare cases, too. Megafossils show an increase in amount as compared to the deeper parts. In the course of samplings of a biostratigraphic aim a rich *Ammonites* fauna was also recovered from the beds. (For a discussion of the fauna, see the biostratigraphic part.)

The interval between the 36th and 40th beds is composed of light grey nodular limestone beds of 20 to 60 cm in thickness. The texture is generally represented by bioclastite, less frequently by biomicrite. Beside rockforming *Lombardia*, the representatives of *Radiolaria* and *Cadosina* are also frequent. Although rare, intraclast grains do occur. In the basal beds of the unit the quantity of the ammonite fauna decreases as compared to the preceding unit, but above the 38th bed the *Ammonites* become rich both in species and in specimens.

In the next unit (41st to 47th beds) the rock hardly changes in colour or stratification. The heavy reduction of the bioclasts is quite distinct even to the naked eye, just a few, minute bioclasts of medium quantity at the most being observable in the aphaneritic matrix. According to microscopic analysis, the texture is represented by biomicrite, still invariably with predominance of skeletal elements of *Saccocoma*. In addition, benthonic *Crinoidea* elements of greater size, benthonic and planktonic *Foraminifera* and *Globochaete* and *Radiolaria* remains appear continually. The forerunners of *Calpionellidae (Chitinoidella)* appear in a small number in the 43rd bed. In higher parts of the same bed more developed *Calpionellidae* faunas could already be observed. As suggested by microfacies analyses, the interval of the 43th to 45th beds seems to have been deposited by repeated resedimentation of the mud with repeated cracking of the once semi consolidated sediment. A normal *Calpionellidae* lineage can be traced from the 46th bed upwards. From that point on there is an increase in both species and individuals. The fauna of the upper part (46th to 47th beds) is substantially poorer and, similarly to the case of the microfauna, there is a marked change in the faunal pattern here also.

The boundary between the Pálihálás Limestone Formation and the Mogyorósdomb Formation overlying it without any break was drawn above the 47th bed. The greyish-white thin-bedded, aphaneritic limestone appearing in the 48th bed shows already explicitely the characteristics of the overlying formation. In the microfacies the representatives of *Lombardia* vanish. *Calpionellidae* appear as predominant elements.

An equally quasi-complete section of the Pálihálás Formation is exposed in the Mogyorós-domb I key section, too (its location is shown in Fig. 12, the relevant analytical results are so in Fig. 22).

In spite of the short distance between the two Mogyorós-domb sections the two sequences show remarkable differences in formation thickness, geological features and rock colour alike.

In the Mogyorós-domb I section the thickness of the calcareous marl member is 3.4 m. The transition into the limestone rock type is similar to that described in the context of the Mogyorós-domb II section. According to X-ray and DTG results (A. Szemethy and M. Földvári), the rock consists for the most part of calcite (80–90%). In addition, a few % quartz and mixed-layer illite-montmorillonite clay minerals could be identified. According to micromineralogical results (E. Radócz), the 0.1–0.2 mm fraction is dominated by quartz, and, in addition, a little feldspar was observable. From among the heavy minerals, garnet is relatively frequent. In addition, low quantities of magnetite, biotite, epidote, zoisite and tourmaline could be observed.

The thickness of the limestone overlying the calcareous marl member is 13.5 m. In terms of lithologic features the sequence can be divided into four quite distinct units:

The lower unit (2.5 m thick) is composed of a red, very completely fine-crystalline limestone. Higher up the section the nodular structure passes into a thin-bedded one. The essential microfacies features are micrite, biomicrite texture with *Lombardia* varying in amount within the unit. *Cadosina*-type forms are frequent. The unit can be correlated the lower parts of the Mogyorós-domb II section (Beds 0 to 24).

The second unit (thickness 2.2 m) is a red Lombardia limestone. The beds are of medium thickness, and they are separated by wavy, argillaceous bedding surfaces. The characteristic microfacies is Lombardia biomicrite with a great amount of *Globochaete, Cadosina* and *Radiolaria.* The unit in question can be correlated with Beds 25 to 30 of the Mogyorós-domb II section. While the colour in that case is grey, here the red colour is conspicuous.

The third unit (5.8 m) is represented by brick-red, locally ochre-yellow, thin-bedded, nodular, argillaceous limestones. In the lower part of the unit there are lots of *Ammonites.* The unit in question shows essentially the same geological features as the Beds 31 to 40 of the Mogyorós-domb II section.

The 3-m-thick upper unit is constituted by light grey, locally yellow or pinkish, thin-bedded Lombardia limestone which often contains authigenic breccia grains attaining even a few cm size. The texture is represented by Lombardia biomicrite. The abundance of *Globochaete*, *Cadosina* and *Radiolaria* decreases markedly. On the basis of the microfacies features this unit can be correlated with Beds 41 to 47 of the Mogyorós-domb II section, but the intraclastic character is more pronounced here.

The borehole Süt-17 penetrated between 402.9 and 413.2 m a subhorizontally bedded Pálihálás Limestone Formation, the penetrated thickness having been 10 m (Fig. 23). The formation in this section overlies a 4-m-thick bed of Triassic-Liassic carbonate rock debris enclosed in a red clay above the Upper Triassic Kössen Formation.

Limestone grains of varying type (dark grey, pale pink to yellowish-grey, aphaneritic or yellowish-white, finely crystalline, calcite-speckled) can be observed in the basal layer. They vary from a few mm to a few decimetres in size, being usually unrounded or poorly rounded, less frequently relatively well rounded. In the basal part of the bed the grains are often coated with an Fe-Mn-oxide layer, and tiny ferromanganese oxide concretions can also be observed.

According to microscopic analysis, the majority of the debris grains derive from the Lower Liassic Kardosrét Limestone, showing an oncomicrosparite, oncosparite or pelmicrosparite texture with a microbiofacies characteristic of the formation. A considerable part of the grains shows the typical Dachstein Limestone microfacies pattern, though grains deriving from the Kössen Formation also occur, and, in fact, a few dolomite fragments have been recovered, too. Among the clastic grains the enclosing matrix is generally poor, though the sediment is undoubtedly a marine one. At the base of the bed larger, usually manganese-coated *Crinoidea* elements can be observed added to the extraclastic grains. In higher parts of the detrital bed the matrix contains thin-shelled *Mollusca (Bositra?)* fragments as well.

In the light of microscopic and megaloscopic observations it is obvious that a tectonic breccia cannot be spoken of. Jurassic sedimentation begins with a detrital basal bed consisting of a marine

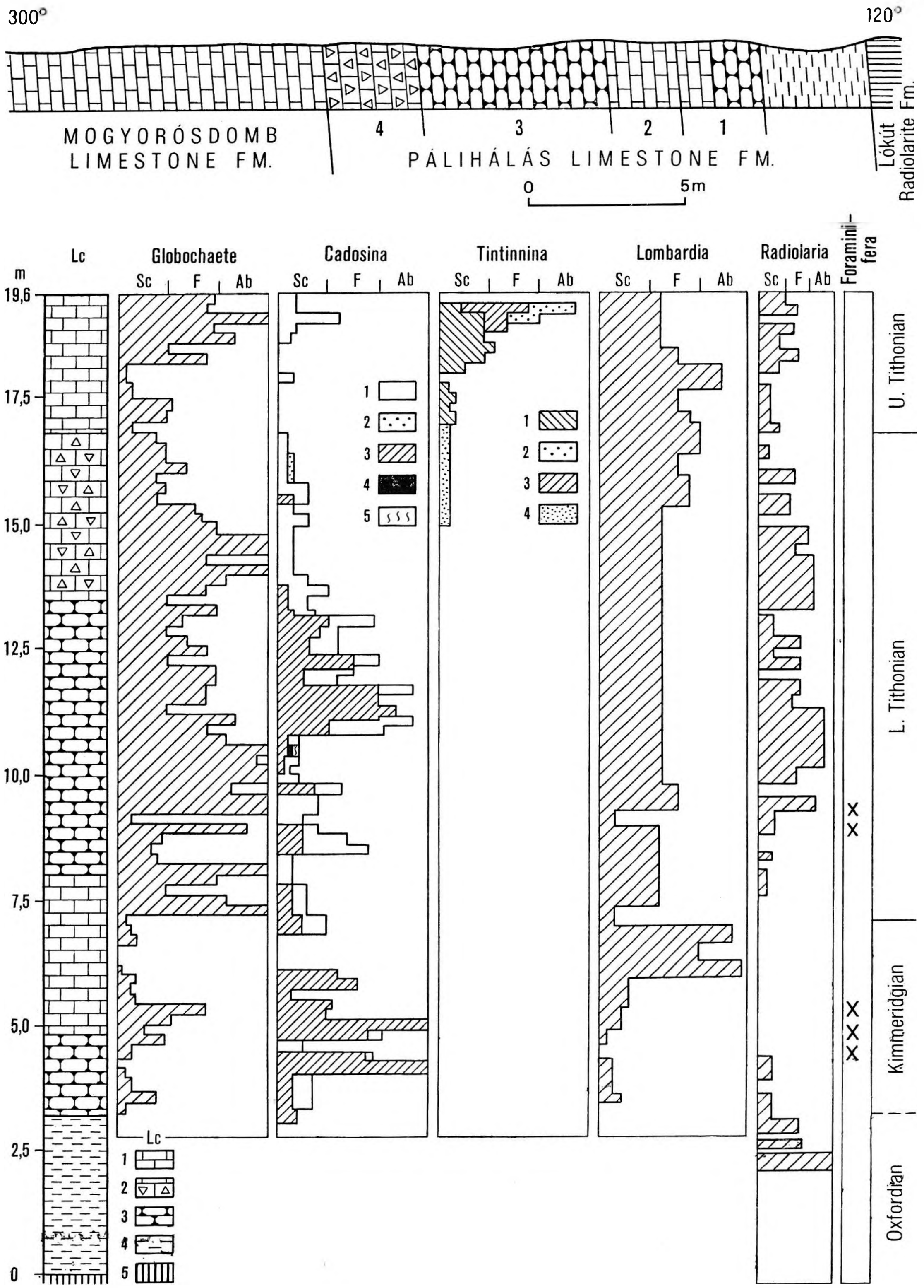


Fig. 22. Upper Jurassic beds in excavation trench Mogyorós-domb I: profile and analytical record

Lithological column (Lc): 1. limestone, 2. intraformational (authigenic) breccia in limestone, 3. nodular limestone, 4. white marl, 5. chert. — *Sc* scarce, *F* fair, *Ab* abundant. — *Cadosina:* 1. lapidosa, 2. tenuis, 3. parvula, 4. malmica, 5. pulla; *Tintinnina:* 1. Crassicollaria intermedia, 2. Calpionella alpina, 3. Crassicollaria parvula, 4. Chitinoidella

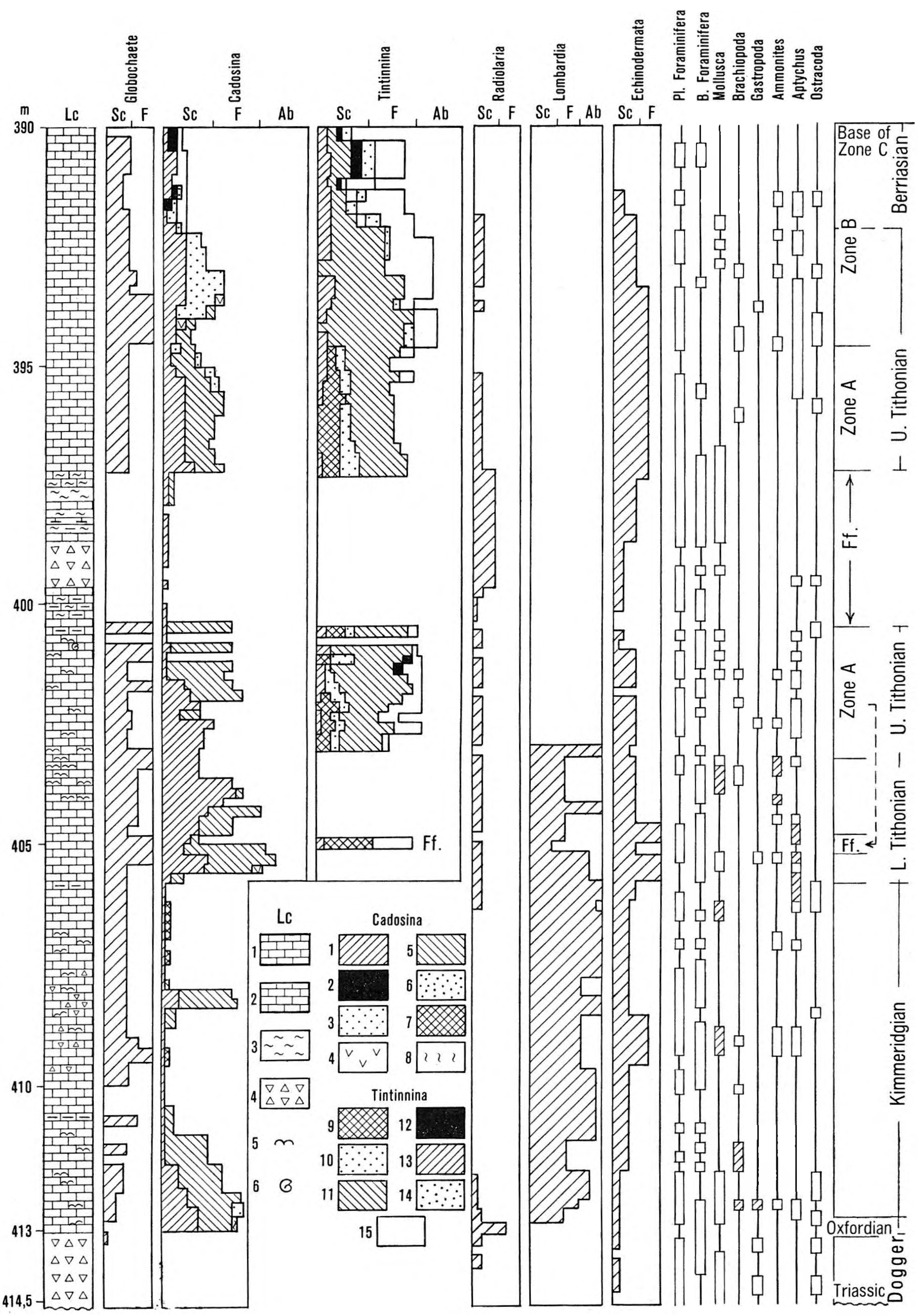


Fig. 23. Upper Jurassic beds in the borehole Süt-17: lithologic column and analytical record

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. marl, 4. detritus, 5. Lombardia, 6. Ammonites. — *Sc* scarce, *F* fair, *Ab* abundant. — *Ff* fissure-fill. — *Cadosina:* 1. Cadosina lapidosa, 2. Stomiosphaera wanneri, 3. Cadosina fusca, 4. C. malmica, 5. C. parvula, 6. C. tenuis, 7. Stomiosphaera mollucana, 8. Cadosina fibrata; *Tintinnina:* 9. Crassicollaria intermedia, 10. C. parvula, 11. Calpionella alpina, 12. C. elliptica, 13. Tintinnopsella carpathica, 14. Remaniella cadischiana, 15. Tintinnina indet.

accumulation of coarse detritus deriving from different formations and its position is characterized by a remarkable angular unconformity compared with the underlying Triassic sequence.

The detrital bed is overlain in 20 cm thickness by greyish-brown, manganese-speckled, aphaneritic limestones. Their texture is radiolarian micrite, with *Globochaete*, *Cadosina* and *Ostracoda* valves and fragments of *Ammonites* and *Aptychus*. The manganese speckling is due to the presence of a few major manganese-oxide-coated *Crinoidea* fragments visible to the naked eye. The microfacies of this thin bed differs from that of the overlying beds primarily by the lack of *Lombardia* in the latter.

The unit between 411.2 and 413.2 m shows already explicitely the typical features of the Pálihálás Formation. The rock is pale-violet-coloured, finely crystalline (smaller *Lombardia* specimens), locally nodular limestone. Fossils coated by a manganese oxide film are observable, too.

The texture is represented by Lombardia biomicrite (Plate XVIII). *Cadosina* are present in considerable quantities. In addition, planktonic and benthonic *Foraminifera*, in some beds benthonic *Crinoidea*, *Brachiopoda*, *Gastropoda* and *Mollusca* shell fragments can be observed.

At the base of the unit (412.3 m) a 5-cm-thick interbedding with manganese-oxide-coated Triassic debris and small rock fragments was observed. Its red pelitic matrix is similar to that of the lower detrital bed.

The next unit is represented by pale violet, pale red, fine- to medium-grained Lombardia limestones (405.6 to 411.2 m) and, in some beds, by nodular, argillaceous limestones. At the base manganese-coated corals, in the upper part *Aptychi* could be observed. The texture is a Lombardia-bearing biomicrite or bioclastite. In addition to *Lombardia* of 50 to 350 μm size, the benthonic *Crinoidea* elements are relatively abundant in some beds. *Globochaete* are present throughout the unit. The amount of *Cadosina* is usually poor.

The unit between 402.9 and 405.6 m is constituted by pale greyish-brown to light pink limestones containing sporadical *Crinoidea* elements visible even to the unaided eye. The lower part of the unit shows a clay-filmed structure, the upper one a nodular, authigene-breccious structure. Some of the authigene breccia grains are rounded, the rest consisting of angular sediment debris cracked off in form of laminae. At the edges of the nodules and near the clay surfaces the presence of a stylolitic contact is rather frequent. The characteristic texture is biomicrite (with 70 to 80% fossil component). The abundant representatives of *Lombardia* vary from 80 to 180 μm in size. *Cadosina* are present in evenly distributed, but mean quantity. In addition, *Globochaete*, *Radiolaria*, *Crinoidea* skeletal elements, *Foraminifera*, *Bivalvia* shell fragments and embryonic *Ammonites* tests can be encountered throughout the interval in question.

The pale red to pink, aphaneritic limestone unit that follows above 402.9 m is assigned already to the Mogyorósdomb Formation.

On the basis of the documentation a similar sequence appears to have been cut by the borehole Sp-1 above Upper Triassic sediments, but the description and the analytical record do not enable a more precise comparison.

As far as the Pálihálás Limestone sequences of a few m thickness penetrated by boreholes or represented in outcrop are concerned, they show, however, comparatively great differences in both the mode of superposition and the geological features. On the Mogyorós-domb the formation overlies the Lókút Radiolarite with the interference of a thin Oxfordian member, but without any break in sedimentation. In the borehole Süt-17 and apparently also in Sp-1, it overlies the Triassic beds with a hiatus, and angular and erosional unconformity, with a detrital basal bed. The lower part of the formation is composed of red or light grey, clay-jointed or nodular, Lombardia limestones or argillaceous limestones. In its upper part an authigenic breccia member was observed in all sections and this one is overlain by the Mogyorósdomb Formation.

Bio- and chronostratigraphy

Bio- and chronostratigraphically, the most satisfactory profile is Mogyorós-domb II which was twice (1961, 1979) sampled layer-by-layer for macrofauna and, parallel to the processing of this, fossils of microscopic size were also determined.

A microfossil-based correlation was carried out for the Mogyorós-domb I profile as well. The megafossils were determined and stratigraphically evaluated by G. Vígh. The microfossils were studied by T. Lénárd and E. Tardi-Filácz. The final results of these studies, the biozonal scales and the chronostratigraphic scheme are shown in Fig. 21 and 22.

The bulk of the marl member representing the basal part of the formation seems to constitute the Oxfordian, though a firm paleontological evidence is not available. The location of both the lower and the upper boundaries of the Oxfordian has been rather uncertain.

The lower part of the limestone member of the formation (Mogyorós-domb II section: Beds 0 to 29, Mogyorós-domb I: Unit 1) is assigned to the Kimmeridgian. This is indicated first of all by the rockforming abundance of *Lombardia*, further by the species *Cadosina parvula* and *Stomiosphaera* *mollucana*, the acme of which corresponds to the Kimmeridgian (I. Nagy 1966, K. Borza 1969). No megafossil of chronostratigraphic value could be recovered from these beds.

The higher unit of the formation (Mogyorós-domb II section: Beds 30 to 47, Mogyorós-domb I section: Units 2 to 4) is assigned to the Lower Tithonian or, if the tripartite scheme based on *Ammonite* zones be used, to the Lower to Middle Tithonian.

From the beds of the Mogyorós-domb II section only few and poorly preserved fossils could be recovered, but the full pattern of the fauna, and particularly *Physodoceras* sp., a form found in two specimens, suggests, according to G. Vígh, the presence of the Lower Tithonian. The Middle Tithonian *Ammonite* assemblage is rich. The closest relationship detectable is in connection with forms known from the Betic Cordilleras. Thus the system developed by F. S. Oloriz (1978) could be used for the zonal scale (Fig. 24).

Accordingly, the Middle Tithonian can be divided into 4 zones. Beds 32 to 35 of the Mogyorós-domb II section represent the *Verruciferum* Zone (Fig. 21). The most typical faunal elements are contained in Table 3.

The rich fauna shows the presence even in several specimens of nicely developed representatives of *Haploceras (Neolissoceras?) verruciferum* and *Semiformiceras semiforma*, species characteristic of the Middle Tithonian in the Mediterranean province. Because of the presence of *verruciferum* in considerably greater number it is purposeful, in agreement with Oloriz, to select this species as a zonal index here too. The genus *Pseudolissoceras* is represented in a quite insignificant number of specimens. It can be readily seen from the comparative generic tabulation that some genera and even species which in Franconia are restricted to the Lower Tithonian may, in this fauna, extend well into the Middle Tithonian as well [e.g. *Usseliceras (Subplanitoides)*, *Franconites (Franconites)*, etc.].

Beds 36 to 37 of the section are assignable to the *Richteri* Zone (Fig. 21). The fauna is substantially poorer than in the preceding case. The first appearance here of *Haploceras (Haploceras) tithonicus* is worthy of attention. The zonal index *Richterella richteri* confined to these beds is most characteristic.

The *Admirandum-Biruncinatum* Zone is represented by Beds 38 to 42 of the section. The fauna is again rich and diversified. The most typical faunal elements are presented in Table 3. A change in the faunal pattern is represented by the appearance as a new form of *Haploceras (Neoglochiceras) leiosoma*, a *Sublithacoceras* standing near to *fringilla* and the setting-in of the first *Lemencia.* Of greatest significance are, however, the representatives of *Simoceratidae* including *Simoceras (Simoceras) admirandum* and *Simoceras (Simolytoceras?) biruncinatum* zonal fossils (Plate XX).

The *Burckhardticeras* Zone (Section II, Beds 42–46) is also represented by a rich fauna and a number of new forms appear, too (Table 3). The last representatives of a number of genera (or species) can be met with in this faunal assemblage. *Haploceras woehleri*, the representatives of *Semiformiceras*, *Discosphinctoides (Pseudodiscosphinctes)*, *Sublithacoceras* and *Lemencia* as well as *Virgatosimoceras* disappear. Taken here to be zonal indices and hitherto totally unknown from Hungary, the representatives of *Burckhardticeras* and of the genus *Djurjuriceras* can be observed only in these beds. An increase in the abundance of *Simoceras* and particularly the presence of *S. volanense volanense*, *S. volanense schwertschlageri* and *S. volanense magnum* are conspicuous in the fossil assemblage.

The 47th bed of the section, i.e. essentially the upper limit of the Pálihálás Limestone contains, as shown by G. Vígh, a fauna already characteristic of the basal part of the Upper Tithonian.

On the basis of the microfossils the Kimmeridgian-Tithonian boundary can be traced between the 29th and 30th beds, where the characteristically Tithonian *Cadosina malmica* and *C. pulla* set in and the quantity of *Lombardia* starts to decrease. This is in accordance with the chronostratigraphic judgement deduced from *ammonite* biostratigraphy.

In terms of microfossils, some authors (K. Borza–E. Köhler–O. Samuel 1978) divide the Tithonian into two parts, others (G. Hégarat–J. Remane 1968) into three ones. In accordance with this, *Chitinoidella* Doben 1973, a genus regarded as the forerunner of Calpionella, is placed, by adherents to a tripartite Tithonian in the Middle Tithonian and by the advocators of a bipartite one in the upper reaches of the Lower Tithonian. (In the Hungarian practice, this second standpoint has been adopted.) On what the authors generally agree is that the type genus of the family *Calpionellidae* Bonet 1956 is *Calpionella* Lorenz 1902 and that the genus *Crassicollaria* Remane 1962 (and especially the genotype *Crassicollaria brevis* Remane 1962) represents the base of the Upper Tithonian and the Zone A, respectively.

Thus according to the international literature, the microfossil-based lower boundary of the Upper Tithonian might be drawn at the first appearance of the genus *Crassicollaria*, i.e. at the base of Bed 44. The fact is that up to the 47th bed, the boundary drawn on the basis of megafossils, the representatives of *Tintinnina* are scarce and that there is a sudden increase above that boundary. *Lombardia* in turn show an abrupt decrease in the same place. The flourish of *Tintinnina* and the reduction of *Lombardia* falls near to the upper boundary of the Pálihálás Limestone in the Mogyorós-domb I and II sections as well. A more exact judgement is rendered difficult by the fact that in both sections there are beds with authigene breccious sediment crackings at the boundary and that, interestingly

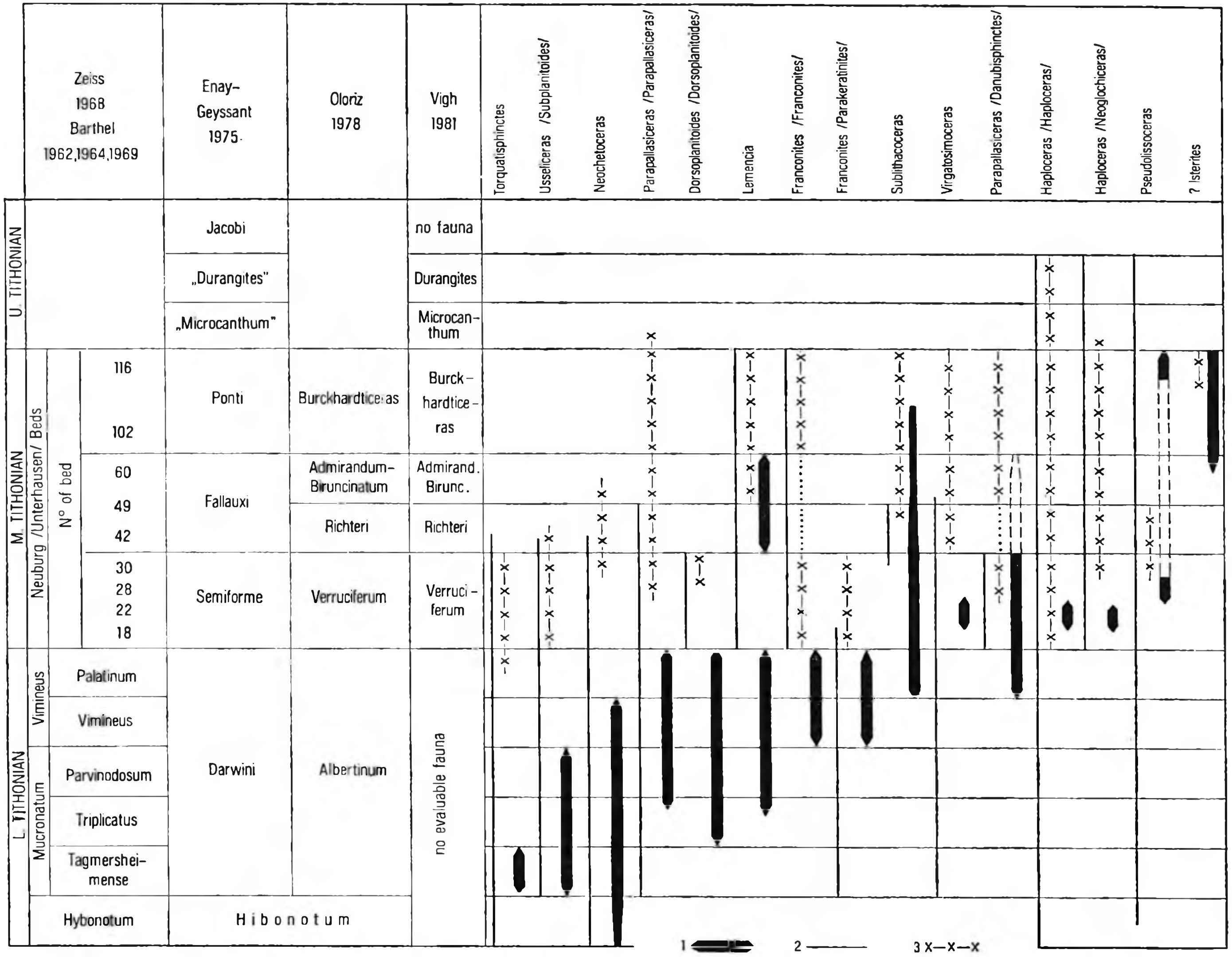


Fig. 24. Comparison of the distribution of the main ammonite genera from the Middle and Upper Tithonian

1. Frankonia, 2. Subbeticum, 3. Sümeg

enough, the first *Calpionellidae* too appear in the breccia grains and that the *Chitinoidella* too seem to recur in such a form at the base of the Upper Tithonian interval of the Mogyorós-domb II section.

All the data of chronostratigraphic value available to us in the detrital bed underlying the Pálihálás Limestone in the Süt-17 borehole section are restricted to the information that the matrix enclosing the grains of Upper Triassic to Lower Liassic origin comprises *Bositra* (?) fragments. In the light of the Central Range records, this poses the possibility of assigning the detrital bed to the Dogger.

The microfaunal results (Fig. 23) show the same trends as were observed in the case of the Mogyorós-domb sections. The 20 cm interval overlying the detrital basal bed contains neither *Lombardia*, nor *Cadosina*, thus being assignable, with some reserve though, to the Oxfordian. Above this, in the lower part of the Pálihálás Formation, the striking quantity of *Cadosina parvula* and *C. lapidosa* presents itself in entirely the same way as it does in the Mogyorós-domb sections.

The Kimmeridgian-Lower Tithonian boundary can be drawn at 405.6 m, where *Cadosina malmica* appears and *Lombardia* show a decrease in quantity and the changes in the quantities of other fossil elements are also the same as it is the case with the Mogyorós-domb sections.

The Lower and Upper Tithonian boundary could be located at 403.0 m, where *Crassicollaria* first appear and the large specimens of *Calpionella alpina* set in and the *Lombardia* suddenly disappear.

In summary, let us conclude that the Pálihálás Limestone Formation in the Sümeg sections begins in the Oxfordian, that it spans the Kimmeridgian in full, comprising the Lower (respectively Lower and Middle) Tithonian too.

Paleoenvironment

In analyzing the genetic circumstances we may start from the biofacies and the sedimentological characterictics.

The fossil assemblage is dominated by planktonic and nektonic forms, respectively, throughout the sequence. In the first place, the skeletal elements of planktonic *Crinoidea (Lombardia)*, further the representatives of one-chambered planktonic *Cadosina*, *Radiolaria* and, in some beds, swimming *Ammonites* are abundant. All these facts suggest undoubtedly a pelagic sedimentation. The skeletal elements of benthonic *Crinoidea* are usually rounded and often coated with a limonitic or Fe-Mn oxide crust. They seem to have been introduced from more shallow-water areas. The benthonic *Foraminifera* and benthonic *Mollusca* fragments that are present in a low quantity, but regularly, do not show any roundness or coating. These seem to have lived in the sedimentary environment itself. Accordingly, a water depth of a few hundred metres (deep-neritic or possibly shallow-bathyal zone) is supposed.

Let us mention in this context that no correlation between the colour and the biofacies of the rocks could be recognized. Red or grey beds in similar stratigraphic position do not differ substantially in biofacies. At the same time, the usually grey colour of the authigene breccious (intraclastic) beds seems to be a regularity.

On the basis of the textural characteristics the sedimentation must have taken place in a quiet environment beneath the wave base. The supply of fine grained, land-derived detritus (pelite, silt) was extremely poor. The intraclasts that are common in the upper part of the formation seem to derive from a sediment of approximately equal age that was semi- or completely consolidated on a nearby slope. The appearance of nodular structures is associated with beds of higher pelite content, their genesis may be bound to early diagenesis, whereas the microstylolitic pattern observable at the contact of the nodules and the country rock seems to be the result of a subsequent pressure-solution. In more carbonate-bearing beds the formation of styloliths is associated with the bedding planes. No syngenetic resorbtion surfaces could be observed.

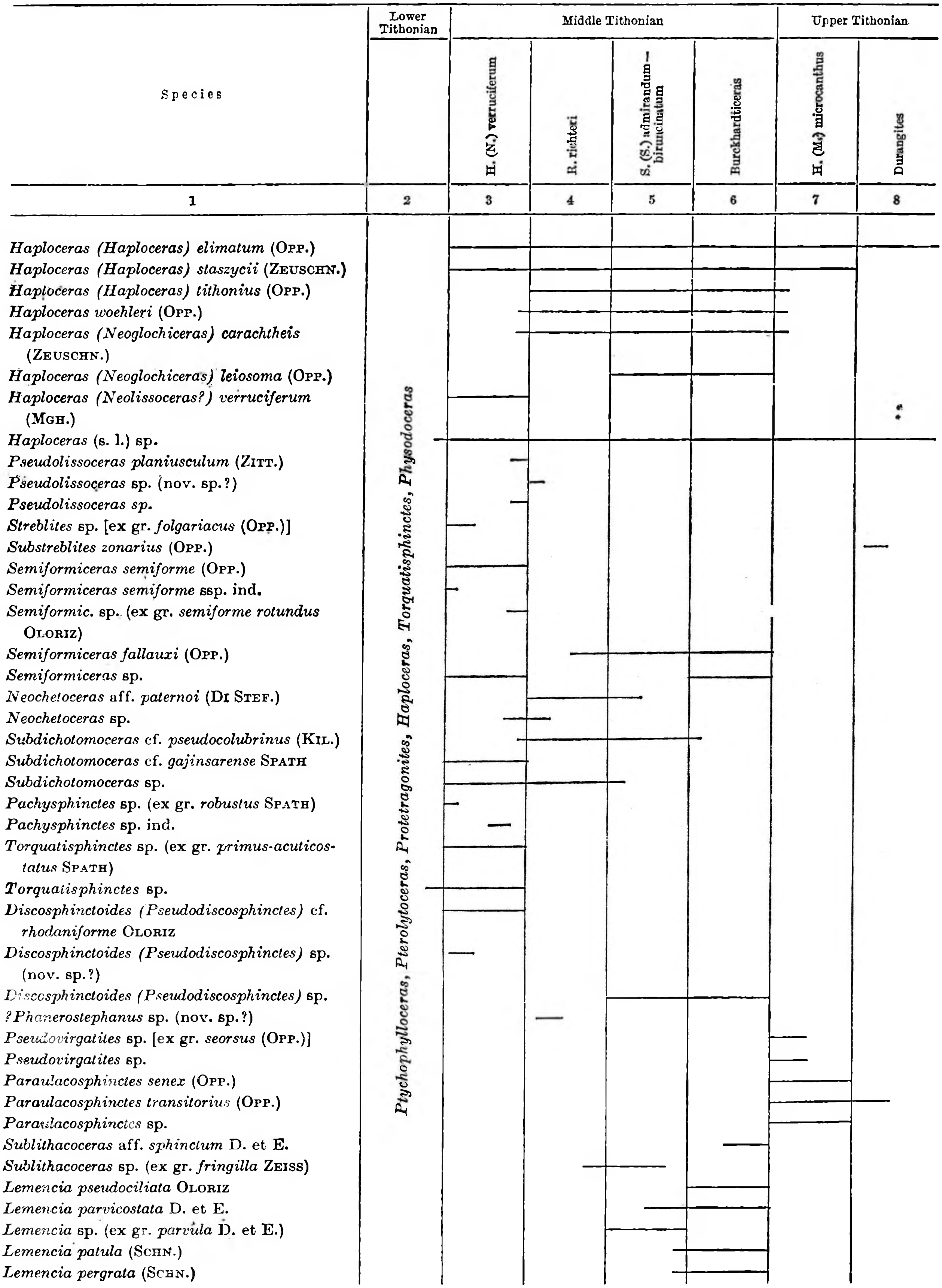
Mogyorósdomb Limestone Formation

In outcrop, the Mogyorósdomb Limestone Formation is confined to the Mogyorós-domb area (Fig. 12), where it crops out of a thin soil layer in a number of places and where Trench I has exposed its whole sequence. This trench may be proposed to be selected as surface stratotype section of the formation. To the north of the Mogyorós-domb the unit in question is penetrated in a considerable thickness by the boreholes Süt-17 and Sp-1.

In the Jurassic chapter only the lower part of Jurassic age of the formation is dealt with. The higher part that is lithologically essentially similar will be discussed in the chapter devoted to the Lower and Middle Cretaceous and the genetic circumstances will be discussed there too.

Table 3

Ammonite fauna from the section Mogyorós-domb II and the relevant zonal scale



1	2	3	4	5	6	7	8
Lemencia aff. *prava* (SCHN.)	*Ptychophylloceras, Pterolytoceras, Protetragonites, Haploceras, Torquatisphinctes, Physodoceras*			—	—		
Lemencia rigida D. et E.					—		
Lemencia aff. *strangulata* OLORIZ					—		
Lemencia subjacobi D. et E.					—		
Lemencia sp. [ex gr. *ciliata* (SCHN.)]					—		
Lemencia sp. (nov. sp.?)					—		
Lemencia sp.				—	—		
Parapallasiceras (Parapall.) cf. *paracolubrinus* OLORIZ				—			
Parapallasiceras (Parapall.) praecox (SCHN.)		—		—	—		
Parapallasiceras (Parapall.) eudichotomus (ZITT.)						—	
Parapallasiceras (Parapall.) aff. *recticostata* OLORIZ					—		
Parapallasiceras (Parapall.) nov. sp. [ex gr. *praecox* (SCHN.)]		—					
Parapallasiceras (Parapall.) nov. sp.? [ex gr. *pseudocontiguus* (D. et E.)]		—					
Parapallasiceras (Parapall.) sp.		—	—	—	—	—	
Parapall. (Danubisphinctes) aff. *bartheli* OLORIZ		—					
Parapall. (Danubisphinctes) sp. [ex gr. *subdanubiensis* (SCHN.)]					—		
Parapall. (Danubisphinctes) sp.		—		—	—		
?Isterites sp.					—		
Franconites (Franconites) sp. [ex gr. *pseudojubatus* (D. et E.)]		—			—		
Franconites (Parakeratinites) communis ssp. nov.		—					
Dorsoplanitoides (Dorsoplanitoides) nov. sp. (et nov. sp.?)		—					
?Dorsoplanitoides (Ammerfeldia) sp.					—		
Richterella richteri (OPP.)			—				
Usseliceras (Subplanitoides) cf. *radiatus* OLORIZ		—					
Usseliceras (Subplanitoides) spindelense grande ZEISS		—					
Usseliceras (Subplanitoides) cf. *schwertschlageri* ZEISS		—					
Usseliceras (Subplanitoides) schwertschlageri nov. ssp.		—					
Usseliceras (Subplanitoides) waltheri ssp. nov.		—					
Usseliceras (Subplanitoides) sp. (ex gr. *altegyratum* nov. ssp.)		—					
Usseliceras (Subplanitoides) sp. (nov. sp.?) div.		—	—				
Usseliceras (Subplanitoides) sp.		—					
Pseudosubplanites cf. *fraudator* (ZITT.)						—	
Pseudosubplanites aff. *lorioli* (ZITT.)						—	—
?Pseudosubplanites sp. (nov. sp.?)					—		
Pseudosubplanites sp.						—	—
Aspidoceras rogoznicense (ZEUSCHN.)				- - -	—	—	
Aspidoceras sp.					—		—
Physodoceras neoburgense cyclotum (OPP.)	—	—					
?Physodoceras sp.	—						
Pseudhimalayites steinmanni (HAUPT.)		—					
Virgatosimoceras cf. *broili* (SCHN.)					—		
Virgatosimoceras cf. *rothpletzi* (SCHN.)				—			

Table 3 (2. continued)

1	2	3	4	5	6	7	8
Virgatosimoceras sp. (nov. sp.?) div.	*Ptychophylloceras, Pterolytoceras, Protetragonites, Haploceras, Torquatisphinctes, Physodoceras*		— — —				
Virgatosimoceras sp. [ex gr. *achiardii* (Del Camp.)]					—		
Virgatosimoceras sp.			—	—	—		
Simoceras (Simoceras) admirandum Zitt.				—	—		
Simoceras (Simoceras) admirandum nov. ssp.				—	—		
Simoceras (Simoceras) volanense volanense (Opp.)		—			—		
Simoceras (Simoceras) volanense schwertschlageri Schn.					—		
Simoceras (Simoceras) volanense magnum Oloriz					—		
Simoceras (Lytogyroceras) lytogyrum (Zitt.)		—		—	—		
Simoceras (Lytogyroceras) cf. *strictum* (Cat.)					—		
Simoceras (Lytogyroceras) sp. (ex gr. *subbeticum* Oloriz)					—		
Simoceras (Lytogyroceras) sp.		—		—	—		
Simoceras (Simolytoceras?) biruncinatum (Qu.)				—	—		
Simoceras (Simolytoceras?) catrianum (Zitt.)				—			
Simoceras (Simolytoceras?) sp.				—			
Simoceras (s. l.) sp.				—	—		
Proniceras aff. *jacobi* Djan.							—
Proniceras sp. (ex gr. *gracile* Djan.)						—	—
Proniceras sp. [ex gr. *pronum* (Opp.)]						—	
Proniceras sp.						—	
? *Fauriella (Strambergella?)* sp. [cf. *carpathica* (Zitt.)]						—	
Burckhardticeras peroni (Rom.) s. l.					—		
Burckhardticeras sp.					—		
Himalayites faucium Coll.							—
Himalayites sp.						—	
Himalayites (Micracanthoceras) microcanthus (Opp.)						—	
Himalayites (Micracanthoceras) cf. *microcanthus marocana* Rom.						—	
Himalayites (Micracanthoceras) microcanthus nov. ssp. div.						—	
Himalayites (Micracanthoceras) sp. (ex gr. *microcanthus* nov. ssp.)					—		
Himalayites (Micracanthoceras?) sp. (nov. sp.?) div.						—	—
Corongoceras (Corongoceras) aff. *köllikeri* (Opp.)						—	—
Corongoceras (Corongoceras) cf. *symbolus* (Opp.)						—	
Corongoceras (Corongoceras) sp. (ex gr. *inflatiforme* Coll.)							—
Corongoceras (Corongoceras) sp. (ex gr. *lamberti* Rom.)						—	
Corongoceras (Corongoceras) sp. (ex gr. *rebillyi* Coll.)						—	
Corongoceras cf. *abnormis* (Rom.)							—
Corongoceras abnormis nov. ssp.						—	
Corongoceras sp. (nov. sp.?)						—	—
Aulacosphinctes cf. *berriaselliformis* Oloriz					—		
Aulacosphinctes linoptychus Uhl.					—		
Aulacosphinctes cf. *natricoides* Uhl.					—		
Aulacosphinctes cf. *rectefurcatus* (Zitt.)				—			

1	2	3	4	5	6	7	8
Aulacosphinctes cf. *parvulus* Uhl.	*Ptychophylloceras, Pterolytoceras, Protetragonites, Haploceras, Torquatisphinctes, Physodoceras*					—	
Aulacosphinctes sp. (ex gr. *hollandi* Uhl.)					—	—	
Aulacosphinctes sp. (ex gr. *hundesianus* Uhl.)					—		
Aulacosphinctes sp. (ex gr. *la touchei* Uhl.)					—		
Aulacosphinctes sp. div.		- - -	- - -	- - -	- - -		
Djurjuriceras aff. *armonicus* Oloriz					—		
Djurjuriceras djurjurense Rom.					—		
Djurjuriceras sp. [ex gr. *ponti* (Fallot et Term.)]					—		
Djurjuriceras sp.					—		
Durangites vulgaris Burckh.							—
Durangites sp. (ex gr. *acanthicus* Burckh.)							—
Durangites sp. (ex gr. *densestriatus* Burckh.)							—
Durangites nov. sp. (aff. *vulgaris* Burckh.)							—
Durangites sp. (nov. sp.?) div.							—
Durangites sp.							—
Himalayitinae (nov. gen., nov. sp.)						—	
„*Pseudokatroliceras*" sp. (nov. sp.?) Incertae sedis!		—					
„*Pseudokatroliceras*" sp. Incertae sedis!		—					

Stratotype section: Mogyorós-domb I

The greyish-white cherty limestone sequence exposed in the northern part of the Mogyorós-domb was got developed by J. Fülöp in 1960 for the purpose of key section studies. The profile drawing of the trench and the results of analysis of the microfauna were published in his monograph issued in 1964. The results of a reambulatory study undertaken owing to the extraordinary litho- and biostratigraphic importance of the section are presented in Fig. 22.

The formation overlies the underlying Pálihálás Limestone without any break in sedimentation. The lithologic and microfacies features vary continuously, too. The red or brownish colour that is as a rule typical of the Pálihálás Formation ceases to exist and the nodular rock structure and the authigenic brecciation characterizing the upper interval of the Pálihálás Limestone also disappear at the formation boundary. The representatives of *Lombardia* gradually disappear and in the same transitional interval of about 1 m *Calpionellidae* appear in a great number. Characteristic of the Mogyorós-domb Formation, the chert interbeds in turn present themselves at about 1.4 m above the lower formation boundary.

The Jurassic formation part overlying the chertless basal interval is persistently homogeneous, greyish-white, aphaneritic, thin-bedded limestone, argillaceous limestone or siliceous limestone. The bedding surfaces are slightly wavy. The limestone beds can be observed to contain chert lenses or nodules of darker grey colour and, higher up the sequence, chert layers are interbedded at an increasing rate. Near the Jurassic-Cretaceous boundary the chert layers succeed to one another quite densely, at 10 to 20 cm distances.

Megafossils are poor in the sequence, only *Aptychi* are found, in some beds in comparatively great quantity, and a few poorly preserved *Ammonites* remains were encountered.

The microfacies is uniform too. Texturally the rock is micrite or biomicrite, respectively (Plate XX).

From among the microfossils the representatives of *Calpionellidae* and *Cadosina* are conspicuous, and *Radiolaria* attain generally a remarkable amount. The inside of the radiolarians is filled by calcite or silica and this varies from bed to bed, or even within one bed, in a patched pattern. In addition to the above, *Globochaete*, planktonic and benthonic *Foraminifera*, *Mollusca* shell fragments, skeletal elements of benthonic Crinoidea, less frequently *Brachiopoda* and *Ammonite* remains, can be observed continuously.

Completely similar to the stratotype section are the geological features exhibited by the sequence of the development trench Mogyorós-domb II (Fig. 21) exposing the Jurassic part of the Mogyorós-domb Formation almost completely.

Similarly to the case of the stratotype section, the lower interval of 1.5 m underlying the first appearance of a chert bed (Beds 48 to 53) are of transitional character as far as the microfacies is concerned. What is rather curious is that in Bed 49 rhombohedral dolomite crystals of 17 to 40 μm size could be observed sporadically in the micrite matrix. The interval above the first chert bed shows textural, structural and microfacies features that are conformable to those observed in the Mogyorós-domb I key section. From the base of this interval a rather poor *Ammonite* fauna has been recovered. Megafossils will further decrease in quantity higher up the sequence.

In the borehole Süt-17 the uppermost, authigenic breccious part of the Pálihálás Limestone is overlain, probably with a minor hiatus, by the Mogyorós-domb Limestone (Fig. 23). The features of the formation deviate rather significantly from those of the Mogyorós-domb sections, inasmuch as here the Upper Tithonian to Berriasian interval is of red colour and not cherty.

In that part of the formation assignable to the Jurassic (below 392.0 m) the rock exhibits identical megaloscopic characteristics throughout the corresponding interval. These are red or pink, aphaneritic limestones, locally clay-filmed, interrupted by stylolitic surfaces.

Texturally, the rock is micrite or biomicrite with a considerable amount of *Calpionellidae* and *Cadosina*. *Radiolaria,* however, unlike to the case of the Mogyorós-domb sections, are extremely scarcely represented. Quite sporadically, skeletal elements of *Crinoidea,* 0.1 to 0.4 mm in diameter, can be encountered, being usually unrounded, less frequently, slightly rounded. In a low quantity though, planktonic and benthonic *Foraminifera* are represented throughout the Jurassic sequence.

According to the description, a sequence similar to that of the borehole Süt-17 was penetrated in the 518 to 540 m interval by the borehole Sp-1, too.

Bio- and chronostratigraphy

The Mogyorós-domb Limestone Formation contains few megafossils, though a few *Ammonite* index fossils could even be recovered in the course of systematic sampling. Extremely rich and suitable for fine stratigraphic purposes is, however, the microfossil assemblage of the formation, primarily that of *Calpionellidae*. The megafossils were studied by G. Vígh, the microfossils by T. Lénárd and E. Tardi Filácz.

Ammonites were recovered from the Mogyorós-domb II section during the sampling of 1961 (Fig. 21). As mentioned in the discussion of the Pálihálás Formation, the Bed 47 forming the upper boundary of the formation has a comparatively rich fauna which, according to G. Vígh, suggests the presence of the base of the Upper Tithonian (*Microcanthus* Zone). The typical Middle Tithonian genera almost completely disappear from the faunal pattern, only some of the *Simoceratidae* extend into the lowermost bed which, however, may be due to an allochtony. The disappeared forms are replaced by *Pseudovirgatites*, *Paraulacosphinctes* and *Pseudosubplanites*, forms typical of the basal Upper Tithonian, but the first *Proniceras* and even the genuine *Himalayites* appear here, too. Among these latter, G. Vígh found even a new genus and species.

At 1.5 m above the boundary bed, interval not developed by trenching yet, the fauna consists of only a few genera. Some of these are transient from the preceding zone, others vanish forever, but instead completely new genera make their appearance. It is here that *Substreblites zonarius* and several representatives, even new species, of *Durangites*, a new Mexican genus never recorded so far from Hungary, were first met with. The latter genus was proposed to be designated as a zonal index by G. Vígh (who used provisionally just the generic name — *Durangites* Zone).

The topmost Tithonian (*Jakobi* Zone) and the Jurassic-Cretaceous boundary cannot be identified with the help of *Ammonites* in the Mogyorós-domb sections.

Upon evaluation of the microfauna from the Mogyorós-domb II section, a work carried out parallel with the examination of the megafossils, there is no substantial deviation in tracing the lower boundary of the Upper Tithonian (Fig. 21). In terms of Remane's zonation, namely, the lower boundary of the Ammonite zone indicating the lower Upper Tithonian can be drawn at the 47th bed, too. It is here that two species of the genus *Crassicollaria*, *Crassicollaria intermedia* (Dur. Delga) and *Cr. massutiniana* (Colom) first appear. At the same time, the *Lombardia* rapidly decrease in quantity.

The boundary between Zones A and B can be drawn above the 52nd Bed. Namely, it is here that the species characteristic of Zone A, i.e. *Crassicollaria intermedia* and *Cr. massutiniana,* disappear, while the species *Calpionella alpina* shows an increase in the number of individuals in Zone B. Additionally, a characteristic species of this zone is *Crassicollaria parvula* as well. The topmost beds of the developed section represent the lower part of Zone B which corresponds by and large to the *Jakobi* Zone.

In the borehole Süt-17 the boundary of the Lower Tithonian and the Upper Tithonian is less distinct. *Lombardia* vanish abruptly and, at 403 m, the forms of Zone A appear immediately. (Only one *Chitinoidella* specimen could be observed, at 403.3 m.) For this reason, a slight hiatus, a loss of sediment to erosion at the base of the Upper Tithonian, may be supposed.

Zone B with *Crassicollaria parvula*, *Tintinnopsella carpathica*, *Calpionella alpina*, *C. elliptica* and *Remaniella cadischiana* can be identified between 390.5 and 394.5 m. The Tithonian-Berriasian boundary is drawn, following Remane, in the middle part of Zone B and at the appearance of *Calpionella elliptica* (around 392.3 m), respectively.

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