

Lower to Middle Cretaceous

by

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To study the Lower to Middle Cretaceous cropping out in the Sümeg horst area is important from both stratigraphic and paleogeographic viewpoints, as the nearest known outcrop of formations of this kind in the Transdanubian Central Range lies at a distance of 60 km or so. Here are the westernmost outcrops within the Central Range. The results of study of the exposed sequences have been crucial for the paleogeographic interpretation of a sizeable portion of the tectonic unit in question.

Exploration history

The determination of the mode of superposition of the Lower to Middle Cretaceous formations at Sümeg and their chronostratigraphic assignment were for a long time problematic to the specialists working there and a lot of erroneous statements, incorrect stratigraphic results, were published mainly in connection with the grey crinoidal limestone constituting the Vár-hegy.

On his geological map J. BÖCKH (1888) indicated the cherty calcareous marl of Mogyorós-domb as Tithonian. As shown by his representation, he included in the Tithonian the whole sequence from the Dogger radiolarite up to the Lower Cretaceous formations. As for the material of the Vár-hegy, he regarded it as Upper Cretaceous.

In the Balaton monograph, E. VADÁSZ (1921), in discussing the "folded, plicated marly cherts", maintained that "these are undoubtedly identical with the siliceous marl beds, i.e. they represent the Upper Lias". In the same work, he published a profile in which the formation making up the Vár-hegy was represented as part of the Upper Cretaceous "Inoceramus-bearing marly limestone".

F. PÁVAI VAJNA and I. MAROS (1937) believed the cherty beds of Mogyorós-domb (Dogger, Tithonian to Lower Cretaceous) to be resiliified Upper Cretaceous formations associated with the Pannonian basalt volcanism, while the Vár-hegy limestone they assigned conditionally to the Jurassic.

Emphasizing his being not sure, K. BARNABÁS (1937) thought the "Várhegy limestone" to belong to the Senonian, more precisely to between the Gryphaea Limestone and the "fossiliferous, coal-bearing marl".

R. HOJNOS (1943) described the siliceous rocks from the Mogyorós-domb as a Campanian formation affected by geyserite silicification, while the rock constituting the Vár-hegy was assigned by him to the Cenomanian—an assignment that had resulted from an erroneous brachiopod determination and from his recovery of "*Gryphaea vesicularis* LAMK." supposedly from the Senonian marl cropping out at the foot of the Vár-hegy.

In a report on his mapping work of 1943, J. NOSZKY Jr. (1953) came to settle the problem of stratigraphic assignment of the Mogyorós-domb sequence. Essentially still valid today, his description of it has been as follows: "... the sequence in the abandoned gravel pits of Mogyorós-domb, which had been considered to be Upper Liassic by earlier students, turned out to include several horizons from the Upper Dogger up to the Lower Cretaceous inclusive. The youngest bed is a Lower Cretaceous of biancone character from which, in addition to *Aptychus*, Lower Cretaceous Cephalopoda have come into the fore. Beneath the biancone, heavily laminated marly layers of the Upper Tithonian crop out which, for want of fossils, are hardly distinguishable from the afore-mentioned formations".

He refuted the assignment of the Vár-hegy rocks into the Upper Cretaceous and identified the formation "with higher Hauterivian crinoidal and brachiopodal layers known from other parts of the Northern Bakony".

In a report on his field survey of 1944 he mentions, from the Sümeg area, a Middle Cretaceous limestone with *Orbitolina* and *Agria*, too. This dating of his—which was confirmed in his report of 1957 as well—proved to be wrong as a result of more scrutinized research. It turned out that the *Agria* Limestone too was Upper Cretaceous and that the fossils he had taken to be *Orbitolina* might well have been *Orbitoides*.

J. FÜLÖP (1954), in his paper on the basement horst block of Tata, referred to the fact that the Crinoidea-Brachiopoda Limestone assigned to the Hauterivian in the Bakony by J. NOSZKY Jr. was very similar to the grey crinoidal limestone of Tata, rock assigned to the Upper Aptian by Fülöp, and that it corresponded to the latter in age, too.

In his work of 1964 devoted to the Berriasian-Aptian of the Bakony, he gave a detailed description of the Tithonian-Lower Cretaceous sequence of Mogyorós-domb, the sections of the boreholes Sp-1 and -2, and also the Aptian formations of the Vár-hegy and the Köves-domb, presenting the results of the relevant sedimentological and paleontological investigations.

In terms of the abundances of *Tintinnina* in the key section developed on the Mogyorós-domb, he added precision to locating the Jurassic-Cretaceous boundary. From the borehole Sp-1 he described

a hitherto unknown formation that had been penetrated beneath the Aptian crinoidal limestones. Relying on diversified special paleontological studies (nannoplankton by M. BÁLDI-BEKE, palynology by F. GÓCZÁN, Foraminifera by M. SIDÓ), further, on determining the recovered Cephalopoda, he dated the formation as Lower Aptian to Berriasian.

The limestone of the Vár-hegy was identified by him with the Aptian crinoidal limestone, a unit common throughout the central zone of the Transdanubian Central Range. He observed that the contact of the unit was unconformable both towards the overlying and underlying beds.

Having studied the light brown, chertless rock of coarser grain size exposed in the northwest part of the Köves-domb, formation strikingly different from the cherty limestone of the Vár-hegy in spite of the short distance between the two, he interpreted it as a local variety.

He published a paleogeographic analysis based on a stratigraphic synthesis concerning the Early Cretaceous and Aptian cycle. He takes the biancone-type facies of Sümeg to be a pelagic, basin's interior facies.

In the explanatory to the 1:200,000-scale map-sheet of Veszprém, J. KNAUER (1972) expresses an opinion suggesting that in the borehole Sp-1 the Aptian crinoidal limestone evolves continuously, without any break in sedimentation, from what he calls the "Sümeg Marl" — a formation of Barremian to Lower Aptian age.

In the second edition of the *Lexique Stratigraphique*, J. KNAUER (1978) discusses the Aptian crinoidal limestone unit under the name "Vár-hegy Limestone" as a reference to the occurrence at Sümeg, while the Lower Aptian to Barremian sequence is referred to as "Sümeg Marl".

J. FÜLÖP, in his monograph on Tata, proposed the name Tata Limestone Formation for the Aptian limestone unit, giving a convincing motivation for his choice of name.

Distribution, mode of superposition, subdivisions

The extension of the Lower to Middle Cretaceous formations in the environs of Sümeg is confined to a northwest-southeast trending, tectonically bounded structural unit (thrust-sheet). Exposures of Lower Cretaceous formations are found on the Mogyorós-domb, the Aptian grey crinoidal limestone is exposed in the northern quarry of Köves-domb and also in the tectonically elevated block of the Vár-hegy (Fig. 3).

The Neocomian sequence overlies the Tithonian beds continuously, without any remarkable change in character. Consequently, the regression limb of the Jurassic cycle extends uninterruptedly into the Cretaceous, reaching up to the Aptian.

The sequence can be divided into three lithostratigraphic units of formation rank. The cherty limestone and calcareous marl unit (biancone) comprising the top of the Jurassic as well will be referred to as Mogyorósdomb Limestone Formation. The siltstones of considerable thickness and grey colour—Sümeg Marl Formation—overlying it are known to us exclusively from boreholes. So far known only from the Sümeg area, the formation will be given a definition and its stratotype described within the frame of the present work. The crinoidal limestone representing the upper part of the Aptian, the Tata Limestone Formation, is common throughout the Transdanubian Central Range, from Tata to Sümeg, but while in the basement of the basins to the north the Vértes and in other parts of the Bakony it unconformably overlies the older formations, at Sümeg it evolves continuously from the Sümeg Marl.

The Tata Limestone is overlain unconformably by the younger formations, for the most part, by the Upper Cretaceous sequence which, however, may overly directly the Neocomian as well. The angular unconformity between the Lower to Middle Cretaceous and the Upper Cretaceous on the Köves-domb is particularly conspicuous.

Mogyorósdomb Limestone Formation

The eponymous type section of the Mogyorósdomb Limestone is exposed, as already mentioned in the context of the Jurassic, in Section I of Mogyorós-domb at Sümeg (Fig. 25). In the Sümeg area this formation in outcrop can be found only on the Mogyorós-domb, primarily in the archeological excavations for artifacts of prehistoric flint mining, though locally in outcrops as well. In addition, it was penetrated by some boreholes as well (Sp-1 and Süt-17).

Stratotype section: Mogyorós-domb I

The stratotype section exposes the formation as a whole in a length of about 300 m, of which 270 m is represented by the Cretaceous sequence. In the southern part of the section the strata dip at 100 to 120°/75 to 85°. The same holds true of the fenced archeological site, but some folds are observable there, too.

To the north of the fenced area the direction and angle of dip will frequently change, folds parallel to the strike being traceable. Then in the northernmost stretch of the section the dip becomes again uniformly steep (100 to 120°/70 to 85°). The section ends with the appearance along a fault of Upper Cretaceous formations.

Considering the dip data a formation thickness of 270 to 280 m is probable over the exposed stretch, of which the Lower Cretaceous accounts for about 250 m. In the southern and middle parts of the section, because of the almost vertical dip, the thickness data can be assessed with high precision. In the upper part of the section, however, they are quite vague owing to folding and plication (Fig. 25).

As shown by the examination of the sequence (Fig. 25), the major characteristics of the Lower Cretaceous part of the formation are as follows:

The geological features are rather uniform, of a low variability: limestones and calcareous marls (CaCO₃ content 80 to 90%) with chert nodules or interbeddings. Anyway, some trends in the lithological features are quite distinct.

In the basal part of the formation (still in the Tithonian interval), after 1.4 m of chertless rock, the quantity of cherts increases gradually. At first only smaller nodules or lenses appear, then chert interbeddings of irregular shape become typical.

Within the fenced area chert lenses and thicker chert layers appear, limestone and chert alternating quite rhythmically (Plate XXII, Fig. 1, 2). This compact chert characterized by the most uniform lithological features was the rock mined in the Neolithic flint pits (Plate XXII, Fig. 3).

To the north of the fence the chert interbeddings decrease in number and eventually disappear completely and, parallel with this, the rock acquires an argillaceous limestone to calcareous marl composition.

The rock is completely light-coloured varying from greyish-white to yellowish-white. The thin-bedded rock structure is typical throughout the sequence. The beds vary from 5 to 15 cm in thickness.

The bedding surfaces are slightly wavy in outline. In the case of the limestone lithofacies type the rock is of conchoidal fracture and aphaneritic texture.

As far as the megascopic lithological characteristics are concerned, the Jurassic-Cretaceous boundary cannot be tied to any kind of change, being impossible to delineate lithologically.

Megafossils are scarce in the sequence, a few *Ammonite* internal moulds being accompanied by *Aptychus* in some beds.

According to the microscopic analyses performed by E. TARDI-FILÁČZ and T. LÉNÁRD, the typical texture is biomicrite. The micrite is for a considerable part of nannoplanktonic (*Nannoconus*) origin (Plate XXIII, Fig. 5). Rockforming fossils are the representatives of *Radiolaria* (Plate XXIII, Fig. 7) and, in the lower reaches of the section, *Calpionellidae* also (Plate XXIII, Fig. 1 to 4). In addition, *Cadosina*, planktonic and benthonic *Foraminifera*, *Mollusca* shell fragments, *Aptychus* and skeletal elements of *Echinodermata* are found.

Borehole sections: Sp-1 and Süt-17

In the section of the borehole Süt-17 put down at the northern foot of the Vár-hegy the Mogyórsódomb Limestone Formation overlying the Pálhálás Limestone can be split up, upon lithological features, into four units: the lower unit was discussed with the Jurassic formations, though its upper part, according to microfaunistic results, extends well into the Berriasian. The chertless limestone of pinkish colour is overlain with a sharp boundary, a hardground at 389.9 m, by the largely cherty, similarly pinkish, aphaneritic limestone of the middle unit. At the boundary between the lower and middle units fissure-fills issuing from the hardground and penetrating a few decimetres downwards were also observed.

The 374.0 to 389.9 m interval shows a marked difference, even in microfacies, from the lower unit. *Radiolaria* (generally filled by calcite) appear and *Calpionellidae* almost completely disappear (just a few *Tintinnopsella carpathica* can be encountered).

The texture is for the most part nannoplankton-micrite, less frequently, radiolarian biomicrite (Plate XXIII, Fig. 6). *Cadosina* and benthonic *Foraminifera* are regularly observable (Plate XXIII, Fig. 6, 7). Heavily worn-off skeletal elements of *Echinodermata* and shell fragments of *Mollusca* can also be observed in low quantities.

In the upper part of the middle unit the clay content of the rock increases, wavy, argillaceous bedding surfaces, thin interbedded clay layers being conspicuous. In the uppermost 1.5 m no chert lens can be found anymore.

A change can be seen in the microfacies as well, the radiolarians show a marked decrease in quantity, while the amount of land-derived mineral grains increases. The fossil elements are the same as those found in the lower part of the unit, but their quantity is reduced. *Calpionellidae* could be observed up to 374.2 m.

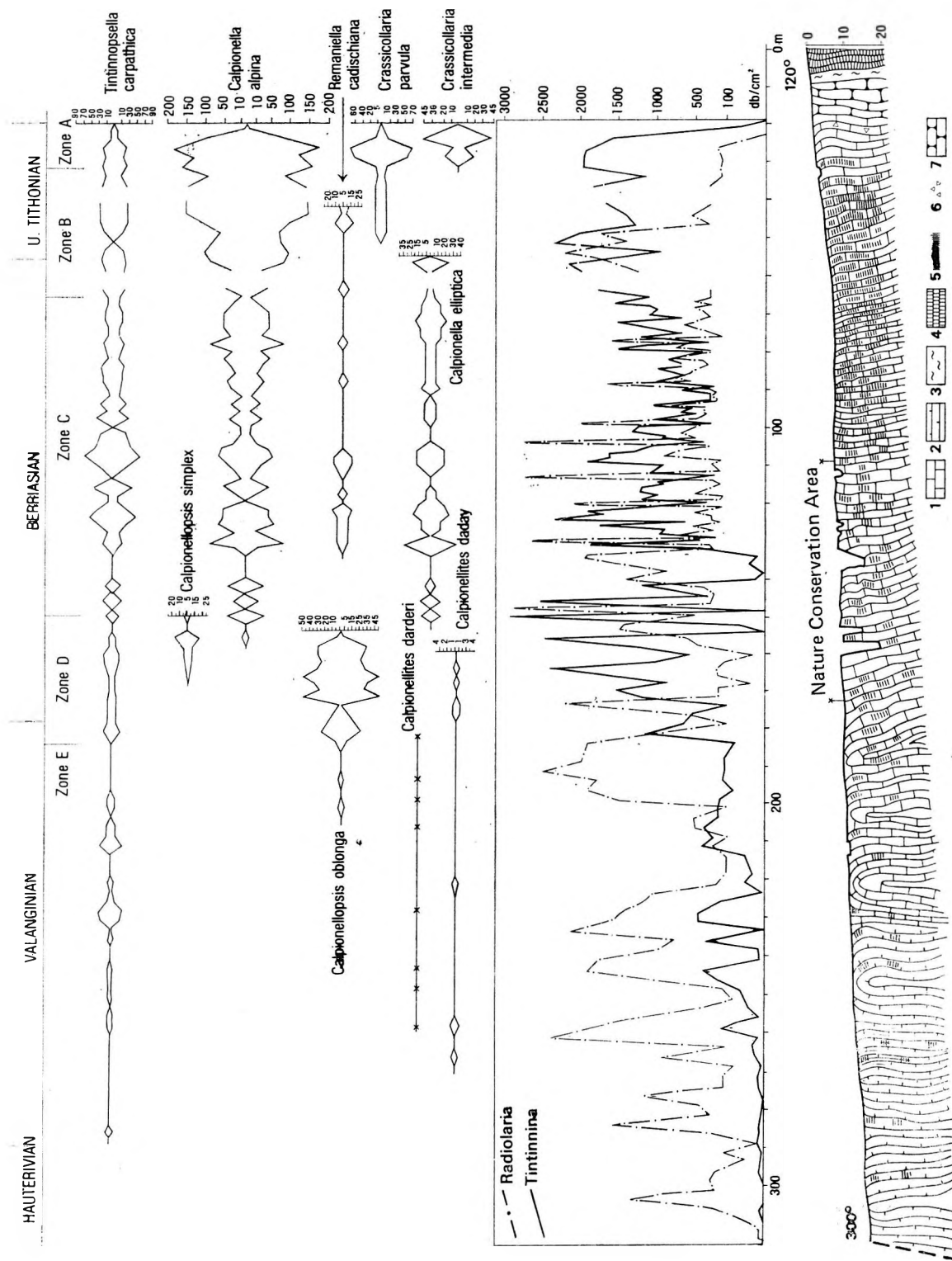


Fig. 25. Geological key section Mogyóros-domb I

1. Limestone, 2. calcareous marl, 3. marl, 4. radiolarite, 5. chert lenses, 6. intraformational (authigenic) breccia, 7. nodular structure

The uppermost 5 metres of the Mogyorósdomb Formation (369.2–374.0 m) represent a transition to the Sümeg Marl. The rock is a pale pinkish to dull green, aphaneritic limestone with thin interbedded marl layers. The topmost chert lens occurs at the base of the transitional unit. A few *Ammonite* fragments [*Barremites difficilis* (D'ORB.) — one specimen] and *Aptychus* were observed, too.

The microfacies is transitional too, but it comes nearer to the Mogyorósdomb Limestone than to the Sümeg Marl. The nannoplankton remains invariably rockforming, but the share of other biogenic components is scant.

From the borehole Sp-1, from beneath the Sümeg Marl, J. FÜLÖP (1964) quoted 9 m of greyish-white calcareous marl with *Calpionellidae*, *Nannoconus*, *Radiolaria* and a few *Ammonites*. The interval of biancone facies has tectonic boundaries, both at its bottom and its top.

Bio- and chronostratigraphy

In our attempts at a chronostratigraphic assignation we can rely primarily on *Calpionellidae*, further on *Cadosina*, the nannoplankton as well as on the *Ammonite* recovered from the Mogyorósdomb section.

The Mogyorós-domb I section was studied biostratigraphically in detail, with repeated samplings, by E. TARDI-FILÁ CZ and T. LÉNÁRD. Upon the entries and exits of *Calpionellidae* species, the changes in quantity and size, the internationally adopted zones (J. REMANE 1974), as a rule, could be identified (Fig. 25).

The Tithonian-Berriasian boundary can be drawn within Zone B based on the predominance of the genus *Calpionella*, there, where *C. alpina* decreases in quantity and the typical representatives of *C. elliptica* appear (Plate XXIII, Fig 1). In a low number of individuals though, *Remaniella cadischiana* (COLOM) appears, too.

To delineate the next zone, Zone C, in the section is difficult, because the criterion of identification of the zone, the coincidence of the incoming of larger forms of *Tintinnopsella carpathica* (MURG. et FIL.) with the quantitative maximum of the species, does not materialize here. Therefore the boundary shown in Fig. 25 is rather vague.

The lower boundary of Zone D is marked by the incoming of the genus *Calpionellopsis*, i.e. the species *Calpionellopsis simplex* (COLOM). This zone can be divided into subzones. The lower boundary of Subzone D₂ is given by the appearance of *Calpionellopsis oblonga* (CADISCH) (Plate XXIII, Fig. 3), while the lower boundary of Subzone D₃ by the incoming of *Lorenziella hungarica* KNAUER et NAGY.

The Berriasian-Valanginian boundary can be drawn in the upper part of Zone D (within Subzone D₃).

The boundary of Zone E spanning the Valanginian completely is indicated by the first appearance of *Calpionellites darderi* (COLOM) (Plate XXIII, Fig. 2) and it ranges up to the extinction of *Calpionellidae*.

At the top of the section Mogyorós-domb I (the northernmost part of it) the *Calpionellidae* (*Calpionellites darderi*, *C. daday* and *Tintinnopsella carpathica*) already disappear. Thus the topmost 20 to 25 m appear to be assignable to the Hauterivian already.

From the uppermost strata of the sequence, beds having a tectonic contact with the Upper Cretaceous, J. FÜLÖP (1964) has listed the following *Ammonites* of stratigraphic value: *Crioceras* sp., *Neolissoceras grasianum* (ORB.), *N. salinarium* (UHLIG), *Olcostephanus asterianus* (ORB.), *O. cf. multiplicatus* NEUM. et UHL., *Kilianella pexiptycha* (UHLIG) — assemblage indicative of the Valanginian-Hauterivian boundary.

According to the results of E. TARDI-FILÁ CZ, the Jurassic-Cretaceous boundary in the borehole Süt-17 can be drawn in the upper part of the chertless, lower interval of the Mogyorósdomb Formation, precisely at the top of Zone B readily identifiable in terms of *Calpionellidae*.

The hardground separating the lower and middle units can be located in the lower part of Zone C (Fig. 25). Above this an exact correlation is handicapped by the scarcity of *Calpionellidae* (*Tintinnopsella carpathica*). Of *Cadosina* *C. vogleri*, *C. lapidosa* and *C. heliosphaera* could be identified in a low quantity. Of the *Nannoconus* *N. steinmanni*, *N. globulus* and *N. camptneri* were observed.

Suggesting the presence of the Valanginian-Hauterivian boundary, the total disappearance of *Calpionellidae* falls at the top of the middle unit. On the basis of the foregoing, the middle unit can be placed conditionally in the Valanginian, the upper, transitional part seems to represent the base of the Hauterivian.

The Mogyorós-domb Limestone interval intersected in the borehole Sp-1 can be put, as suggested by the microfossils quoted by J. FÜLÖP (1964) (*Calpionellopsis simplex*, *C. oblonga* and *Calpionellites darderi*), at the end of Zone D or the beginning of Zone E, i.e. somewhere near the Berriasian-Valanginian boundary. In addition to the microfauna, the fossils *Neolissoceras grasianum* (ORB.) and *Lamellaptychus angulicostatus* (ORB.) are also mentioned from the interval in question.

Sümege Marl Formation

Located in 1957 near the Sümege Limeworks, the borehole Sp-1 penetrated 258 m of siltstone and marl, formation hitherto unknown from the study area, underlying an Upper Cretaceous and Aptian crinoidal limestone sequence. The unit is defined by its first describer, J. FÜLÖP (1964), as follows: "... light grey, poorly stratified, compact, siliceous, calcareous marls of locally nodular habit with interbedded layers of foliated clay-marls and with a considerable silt content".

In the original description the unit is referred to as "siliceous marl sequence". The name "Sümege Marl" was first used by J. KNAUER in his explanatory to the geological map series of Veszprém, scale 1:200,000 (English-language edition: 1969, Hungarian: 1972) and the same term is used in the second edition of the *Lexique Stratigraphique* (1978).

On the basis of the studies carried out in the Sümege type area the diagnostic features of the Sümege Marl Formation can be summarized as follows:

The characteristic rock composition is silty marl or, in some parts, sandy-silty marl. The CaCO_3 content varies between 10 and 70%, averaging around 50%. The silt (0.05–0.1 mm) content varies between 10 and 50% with an average of about 35%. The sand (over 0.1 mm) content is 2 to 20%, averaging about 5%.

Generally, the rock is of grey colour with an alternation of lighter thin intervals with darker ones. (Within one interval a brown and reddish rock appears, too.)

Distinct bedding surfaces are usually unobservable. The rock structure is characterized by the frequency of bioturbated beds and by the burrows of worms filled with green clay.

Of the fossils observable with an unaided eye the occurrence of *Ammonites* is conspicuous. In some intervals their quantity is quite significant.

Among the microscopical remains the nannoplankton and the radiolarians are rockforming. *Foraminifera* are abundant.

The unit evolves from the Mogyorósdomb Limestone underlying it with an intervening transitional interval of a few metres thickness and with gradual changes in the characteristics. These changes show the following trends:

The pelite and silt content increases at the expense of the lime content as one proceeds towards the Sümege Marl Formation. The colour is shifted from white or pale pink to a greyish shade. In the Mogyorósdomb Formation the characteristic chert lenses are lacking. The microfacies changes, too. After a gradual decrease in quantity the representatives of *Calpionellidae* disappear at the formation boundary.

The transition to the overlying Tata Limestone is also continuous. The upper, sandy member of the Sümege Marl Formation already shows a lot of resemblance to the Tata Limestone. The most important diagnostic features of distinction are as follows:

- the decrease in sand content towards the Tata Formation,
- the appearance of masses of Crinoidea skeletal elements at the base of the Tata Limestone,
- the appearance of glauconite grains in the Tata Limestone,
- that the chert lenses appearing at the top of the Sümege Marl Formation become frequent in the Tata Formation,
- a marked change in texture and microfacies.

The formation can be split up into several members, but since we have had the possibility to carry out this subdivision in the stratotype only, we cannot afford to submit a proposal on designating formal members.

Stratotype section: borehole Süt-17 (98.5–369.3 m interval)

For stratotype the 98.5 to 369.3 m interval of the borehole Süt-17 put down at the northeast foot of the Vár-hegy of Sümege is proposed. (For the borehole location, see Fig. 3.) The borehole cut the formation in full thickness with a slight dip (2–8°). The complete core sample material is deposited in the Szépvízér Depository of the Hungarian Geological Institute.

The columnar section of the stratotype, its members- and finer subdivisions scheme, the colours of rock types and the results of sedimentological and paleontological analyses are presented in Fig. 26 to 28. The sedimentological studies were carried out in the laboratories of the National Exploration and Drilling Enterprise, the Geology Department of the Eötvös University and the Hungarian Geological Institute. The *Ammonites* were studied by A. HORVÁTH, the plankton by J. BÓNA, the spore-pollen material by M. JUHÁSZ and the microfauna by R. KOPEK-NYÍRÓ. Thin section analyses of the texture were performed by GY. LELKES.

1. Calcareous marl member (229.0-369.3 m)

The member is composed of alternating light-coloured silty marls of high carbonate content and darker silty marls. The individual beds vary between 0.1 and 1.5 m in thickness. There is generally no distinct bedding surface, no sharp boundary between them. The bioturbated rock structure, primarily in the calcareous marl beds, is conspicuous.

The lower boundary of the member is not sharp, the Mogyorósdomb Limestone passing with a continuous change in lithology into the lower member of the Sűmeg Marl.

In the upper interval of the unit (302.0-369.3 m) the rock in the pelitic parts is of a reddish colour, but the top of the member is again characterized by a grey colour. In some intervals within the member, chiefly in the deeper parts, the remains of *Ammonites* are rather frequent. The species identified are given in Table 4. According to the results of analysis of the microfauna after decantation, the amount of *Foraminifera* is low, a total of a few planktonic forms (*Hedbergella* sp., *Globigerinelloides* sp.) could be observed. The quantity of *Radiolaria* is comparatively high, mainly the representatives of the *Spunellaria* group having been observed within this interval (Fig. 26).

The nannoplankton is generally significant, being present in a rock-forming quantity with *Nannoconus steinmanni* KAMPT. and *Coccolithus pelagicus* (WALLACH) as predominant elements.

The sporomorphs are present, excepting the lowermost part of the member, in a very low amount. The species *Classopollis classoides* is predominant throughout the member. The whole member is characterized by a high number of species and a low number of individuals (Fig. 26).

2. Siltstone member (146.0-299.0 m)

The siltstone member is a unit of generally grey colour often displaying a banded variation in tonality, with hardly any bedding surface interrupting the sequence, locally showing a bioturbated structure, being composed of silts, pelites and carbonate. A member of great thickness, it can be divided into further subdivisions on the basis of the lithological features.

The basal bed (291.2-299.0 m) is composed of sandy, silty marl or ankeritic marl. The finely laminated and microlaminated structure is conspicuous (Plate XXIV, Fig. 1). The thin lamination is due to the alternation of 2- to 4-cm-thick marl and sandstone laminae, the microlamination resulting from the mm-thick clay laminae within the sand layers. The rock colour is greenish-grey or, in the middle part of the bed, rust-brown to yellowish-brown. At the top of the interval in question bedding surfaces coated by a green clay film and worm tracks filled by the same material can be observed. As shown by the X-ray and DTG analyses of samples from the brown, microbanded interval (295.5 m) (A. SZEMETHY, M. FÖLDVÁRI), the bands of lighter shade contain 16 to 17% Mn-bearing ankerite as well as rhodochrosite, kaolinite, calcite and pyrite. The chemical analyses have given the following rock composition: SiO₂ 18.6%, Fe₂O₃ 6.3%, FeO 13.9%, MnO 11.6%, CO₂ 25.35%. According to X-ray results, the bands of darker shade are composed of quartz (36%), calcite (32%), illite (14%), chlorite and pyrite. The principal chemical components are present in the following quantities: SiO₂ 49.7%, Fe₂O₃ 7.3%, FeO 2.8%, MnO 1.2%, CO₂ 8.3%. Consequently, the light bands may be regarded as being composed of a particular material alien to the rest of the formation, owing to their Fe- and Mn-carbonate mineral composition. The darker bands, in turn, show a composition typical of the formation.

From the lower part of the interval a host of well-preserved ammonites (Plate XXIV, Fig. 2) have been recovered. From among the microfossils hardly any representative of *Foraminifera* can be encountered, the radiolarians are—at least in the lower interval—frequent and along with *Spunellaria* a considerable proportion is shared by the *Nascellaria* type as well (Fig. 27). The nannofossils manifest themselves by greater numbers of both species and specimens in the lower part of the interval with the genera *Watznaueria* and *Biscutum* as predominant forms, while *Nannoconus* could not be observed at all.

The sporomorph assemblage shows a marked change at the member-boundary. Spores of various species of the *Gleicheniaceae* fern family appear as predominant elements of the flora.

The next interval (211.7-291.2 m) is represented by silty marl and siltstone. Grey beds of darker colour alternate with lighter, i.e. more pelitic and calcareous ones. In the lower part, in addition, the sand fraction is significant, the structure here being often microlaminated.

Bioturbated beds alternate with non-bioturbated ones throughout the interval. In the uppermost metres worm tracks of green clay fill and tiny coalified plant remains are rather frequent.

The CaCO₃ content of the rock, as a rule, remains below 50%, showing a slight increase upwards. Attaining a total of a few per cent only, the pelite fraction is composed of illite and chlorite. According to X-ray results, the grey clay fill of the worm tracks is constituted by montmorillonite or illite-montmorillonite, respectively.

In the lower part of the interval some beds contain a great number of Ammonites (Plate XXIV, Fig. 3-5). Among *Foraminifera* a small quantity of plankton (*Hedbergella* sp., *Globigerinelloides* sp.)

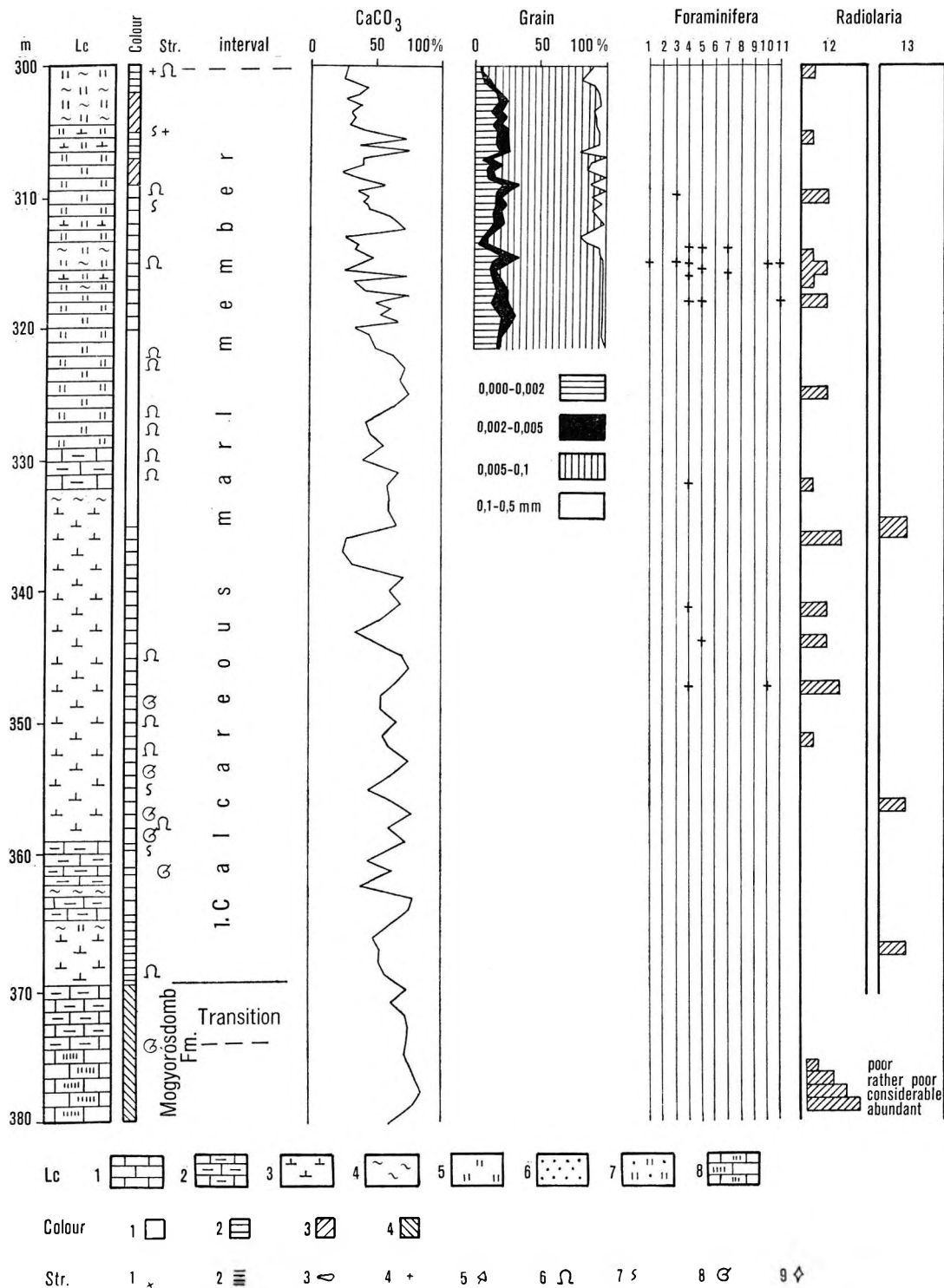
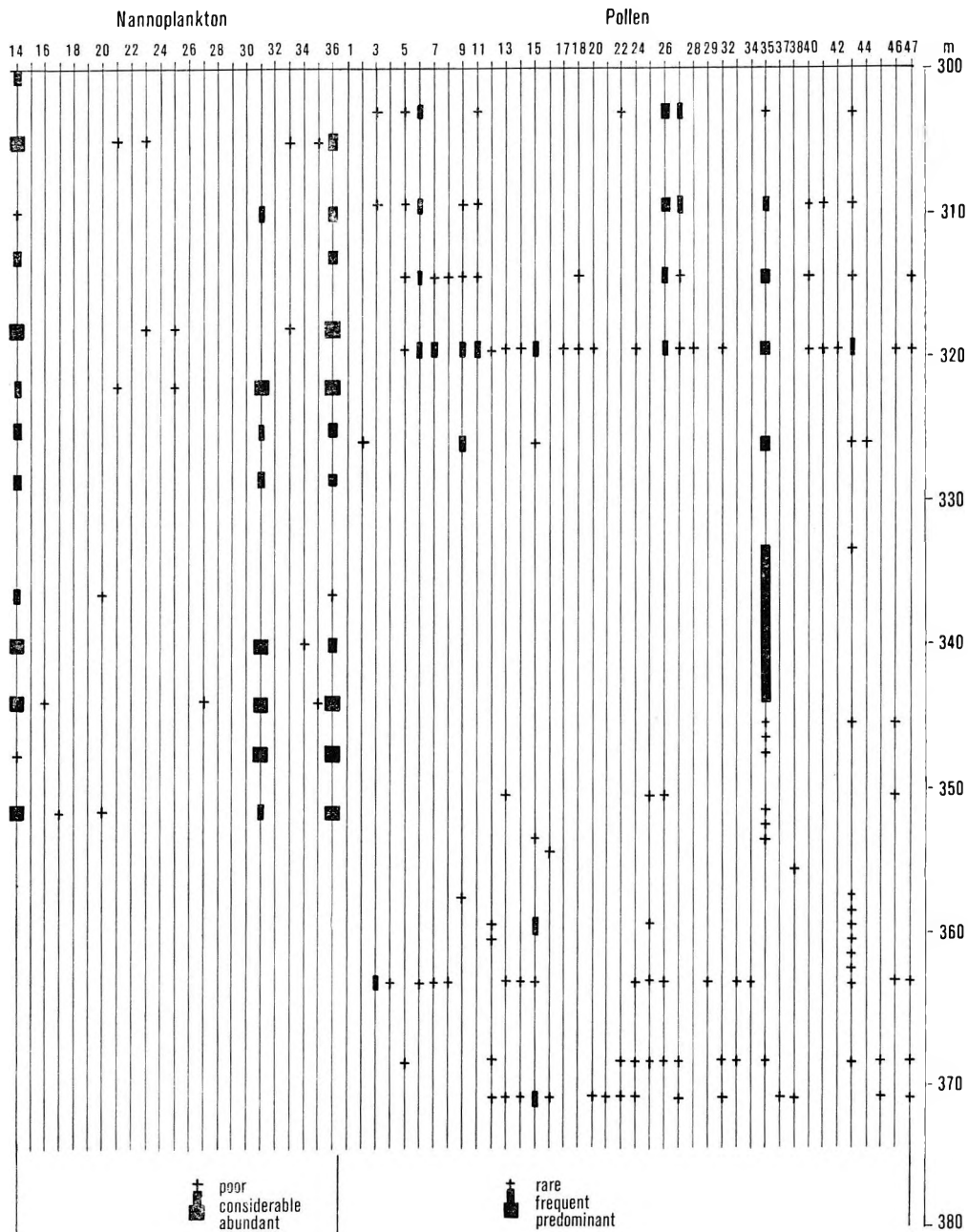


Fig. 26a-b. Lower subunit of the Sümeg Marl Formation in

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. marl, 5. siltstone, 6. sandstone, 7. sandy siltstone, 8. cherty
 4. glauconite, 5. coalified plant, 6. bioturbation, 7. worm tracks, 8. Ammonites, 9. fish scale. — **Foraminifera:** 1. Hedbergella, 2. Ticinella sp.,
 glandulina sp., 10. Epistomina sp., 11. other benthos. **Radiolaria:** 12. representatives of Spumellaria, 13. representatives of Nassellaria. **Nanno-**
 sp., 20. Ahmuereja sp., 21. Braarudosphaera hoshuizi, 22. B. cf. africana, 23. B. bigelowi, 24. Biscutum sp., 25. Reticulofenestra sp.,
 steinmanni, 32. N. truitti, 33. N. bucheri, 34. N. colomi, 35. N. globulus, 36. N. sp. — **Pollen grains:** 1. Retitriletes austroclavatidites,
 cisporites irregularis, 9. A. parviangulatus, 10. A. degeneratus, 11. A. clavatus, 12. Concavissimisporites apiverrucatus, 13. Ischyosporites
 major, 19. G. rasilis, 20. G. senonicus, 21. G. laetus, 22. Matonisporites phlebopteroides, 23. M. simplex, 24. Todisporites minor, 25. Cyathidites
 lentiformis, 31. Leptolepidites major, 32. Densosporites velatus, 33. Stapiinisporites velatus, 34. Verrucosporites sp., 35. Classopollis classoides,
 41. Podocarpidites multesimus, 42. Alisporites thomasi, 43. Disaccites indet., 44. Tsugaepolle-



the borehole Süt-17: lithologic column and analytical record

limestone. — *Colours*: 1. light grey, 2. dark grey, 3. brown, 4. pink. — *Structure (Str.)*: 1. cross-bedding, 2. microlamination, 3. slumping, 3. *Globigerinelloides* sp., 4. arenaceous benthonic organisms, 5. *Lenticulina*, 6. *Gavelinella* sp., 7. *Valvulineria* sp., 8. *Gavellina* sp., 9. *Pseudoplankton*: 14. *Watznaueria barnesae*, 15. *Coccolithus* sp. indet., 16. *Discolithina embergeri*, 17. *Zygothothus erectus*, 18. *Z.* sp., 19. *Stephanolithon* 26. *Cretaohabdus* sp., 27. *Crusiplacolithus* sp., 28. *Umbilicosphaera germanica*, 29. *Porhabdolithus* sp., 30. *Cribrosphaerella* sp., 31. *Nannoconus* 2. *Osmundacidites wellmannii*, 3. *Cicatricosisporites breviaesuratus*, 4. *C. sprumonti*, 5. *C. globosus*, 6. *C. mediodstriatus*, 7. *C. tersus*, 8. *Appendituberosus*, 14. *Trilites triangulus*, 15. *T. (Bikolisporites) toratus*, 16. *Foveosporites canalis*, 17. *Corniculatisporites virgatus*, 18. *Gleicheniidites australis*, 26. *C. minor*, 27. *Deltoidospora hallii*, 28. *Maculatisporites granulatus*, 29. *Rotverrusporites obscuriaesuratus*, 30. *Varirugosisporites* 36. *Araucariacites australis*, 37. *Inaperturopollenites limbatus*, 38. *I. undulatus*, 39. *Vitreisporites pallidus*, 40. *Parvisaccites radiatus*, nites mesozoicus, 45. *Monosulcites minor*, 46. *Callialasporites dampieri*, 47. *C. trilobatus*

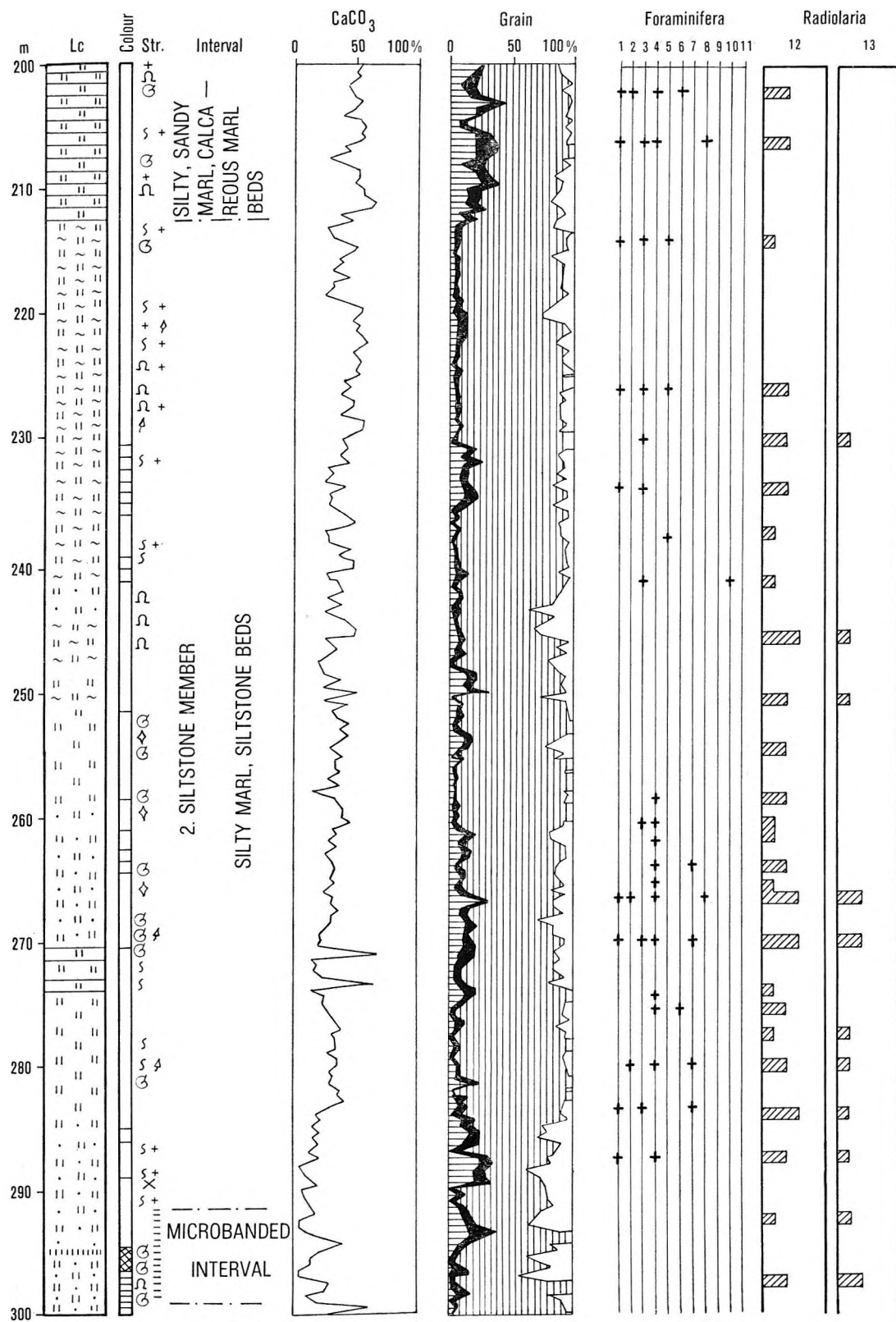


Fig. 27a-b. Middle subunit of the Sümeg Marl Formation in the borehole Süt-17: lithologic column and analytical record. (For explanations, see Fig. 26.)

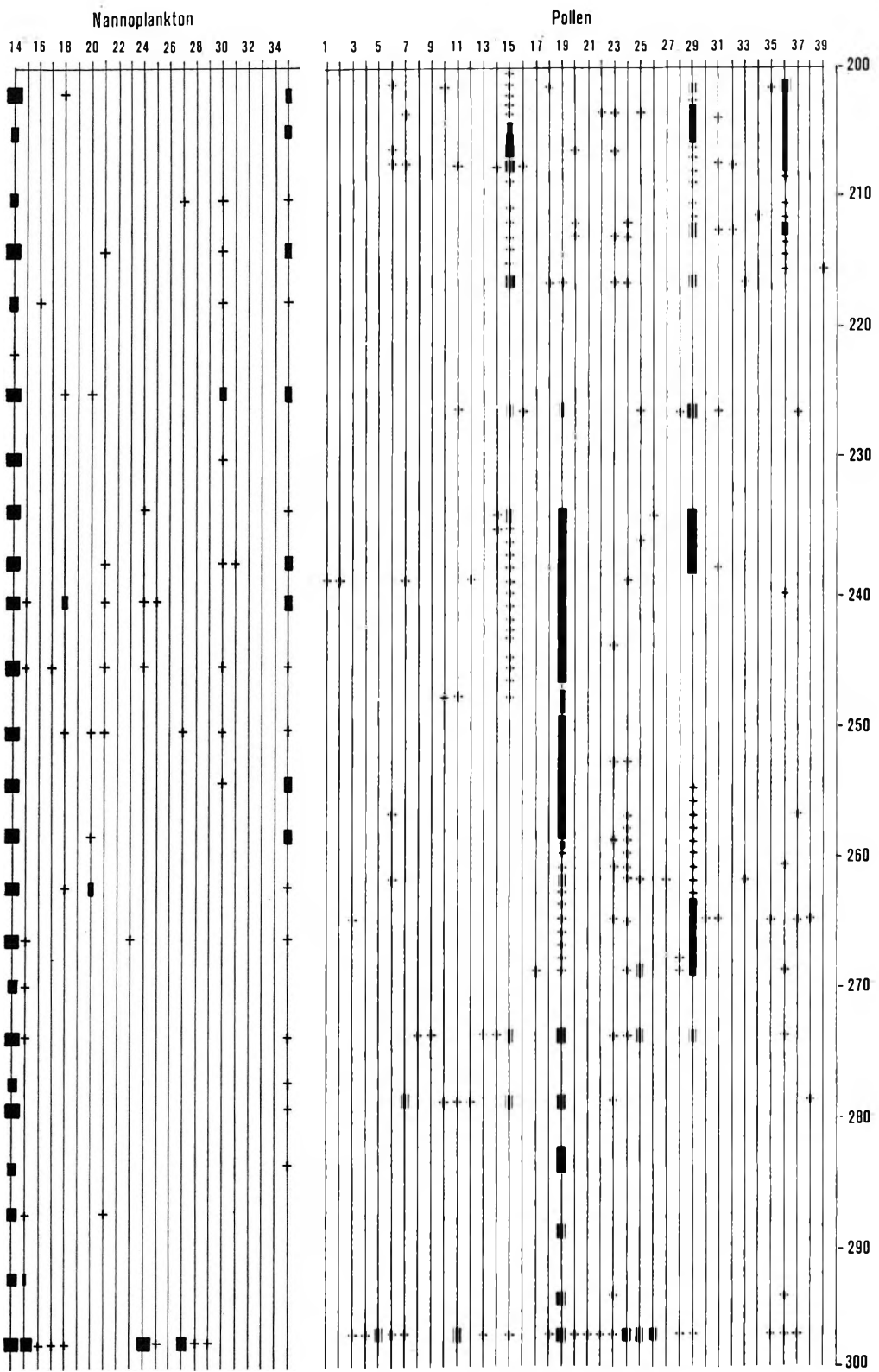


Fig. 27b

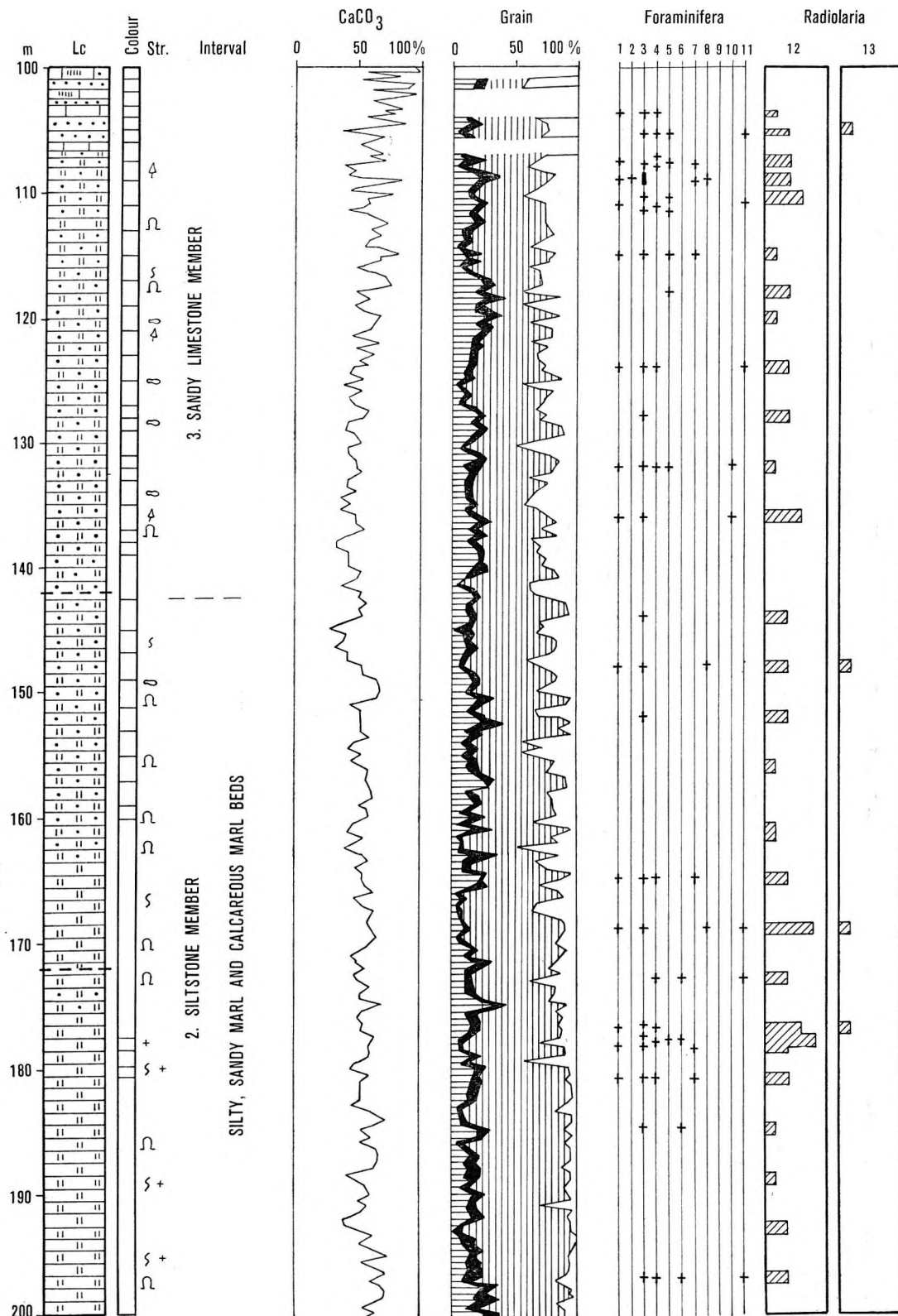


Fig. 28a-b. Upper subunit of the Sümeg Marl Formation in the borehole Süt-17: lithologic column and analytical record. (For explanations, see Fig. 26.)

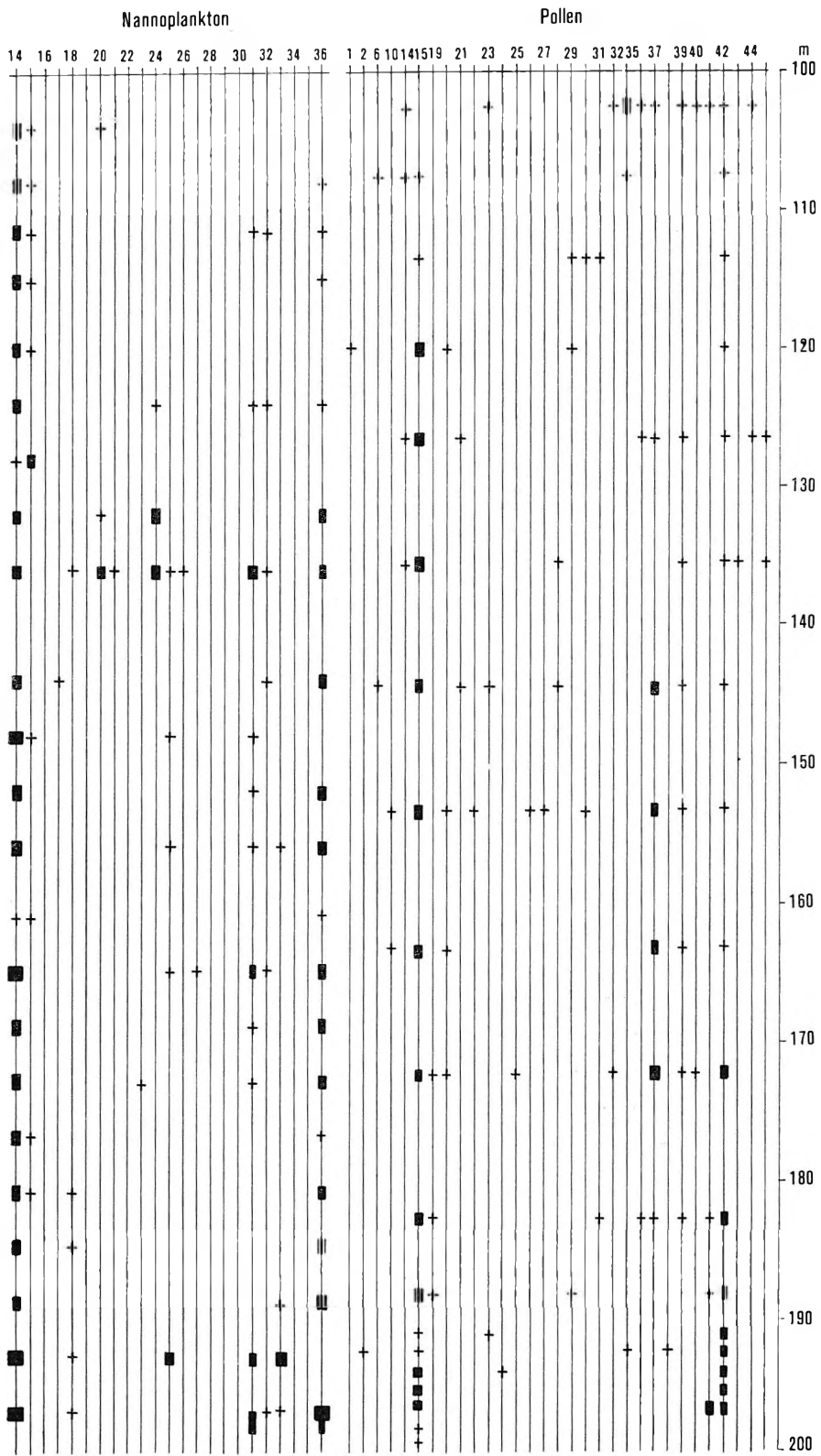


Fig. 28b

and a few benthonic forms (*Dorothia* sp., *Trochammina* sp.) can be observed. In the nannoplanktonic assemblage, predominant *Watznaueria barnesae* (BLACK) is accompanied by *Nannoconus* species in a rather great number of individuals, too. There is no remarkable change in the sporomorph pattern as compared to the foregoing interval.

The upper interval (146.0–211.7 m) is represented by silty, sandy marl and calcareous marl, being colour-banded, rhythmically bioturbated with worm tracks.

The CaCO₃ content shows a trend of upward growth, the quantity of fine quartz sands at the expense of the silt increases too. According to thin section analyses, the texture is fine-grained biomicrite (packstone).

Of the microfossils, *Gastropoda*, *Ammonites* and *Echinoidea* remains have come into the fore. *Foraminifera* show a slight growth in species and specimens numbers compared to the deeper intervals, particularly so in the centre of the interval in question. The ratio of the planktonic forms to the benthonic ones is higher than 10. It is invariably the radiolarians that predominate in the microfauna. Over 190 m sponge spicules can also be found in the washing residue; from 165.0 m and higher they are found in abundance. The amount of the nannoplankton and the abundances are unchanged.

There is a change in turn in the spore-pollen assemblage: *Gleicheniaceae* spores are on the increase, the representatives of *Trilites*, a spore group previously quite subordinate, become predominant. There is an increase in the number of ribbed or ornamented, sculptured spore forms, the *Conifera* pollen grains being frequent, too.

3. Sandy limestone member (98.5–146.0 m)

The sandy limestone member is composed of grey sandy, silty marls, calcareous marls and limestones. The CaCO₃ content shows a trend of upward increase (from 50% to 95%), indicating the transition towards the Tata Limestone. In the upper part of the member (above 102.5 m) even the chert lenses and glauconite grains characteristic of the overlying formation will appear. The rock composition and the structural features (traces of slumping, nodularity, bioturbation, worm tracks filled with green clay) justify an assignment to the Sümeg Formation.

Megafossils are scarce, fragments of *Echinoidea* and *Mollusca* and also *Brachiopoda* may be mentioned. In some intervals coalified vegetal remains occur quite frequently.

The rock texture is fine-grained biomicrite (packstone). GY. LELKES, in the course of his microscopic analyses, distinguished two microfacies subtypes. They are as follows:

1. spicular, radiolarian biomicrite with plenty of planktonic *Foraminifera*, a low quantity of skeletal elements of echinoderms and a few quartz grains;
2. sandy biomicrite with a host of carbonate extraclasts, a lot of planktonic *Foraminifera*, but a low amount of other kinds of bioclasts.

Higher upwards, at the formation boundary, there is a rather marked change in microfacies. The radiolarians disappear, while the amount of the *Crinoidea* skeletal elements shows a sudden growth and the benthonic *Foraminifera* also increase in quantity (Fig. 28).

Other outcrops

In addition to the borehole Süt-17 comprising the stratotype section, the formation was penetrated, in a form similar to the stratotype, by the borehole Sp-1. The relevant research results are given in the work of J. FÜLÖP (1964).

Parts of the formation were developed by the boreholes Süt-15, Süt-18, S-7 and Sp-2 as well. The borehole locations and the distribution of the formation over the pre-Upper Cretaceous substratum are shown in Fig. 3.

Bio- and chronostratigraphy

Clues to chronostratigraphic correlation are provided primarily by the *Ammonites* fauna, the planktonic foraminiferal assemblage and the nannoplanktonic and spore-pollen remains. *Ammonites* in a comparatively great number were recovered from the boreholes Sp-1 and Süt-17.

From the lower interval of the borehole Sp-1 (330.0–509.0 m), J. FÜLÖP (1964) lists the following forms: *Hammulina dissimilis* D'ORB., *H. paxilosa* UHL., *Nicklesia* sp., *Zurcherella zurcheri* (JACOB), *Z.* sp., *Costidiscus recticostatus* (D'ORB.), *Macroscephites yvani* (PUZOS), *Pseudohaploceras charrierianum* (D'ORB.), *Barremites* sp., *Leptoceras parvulum* UHL., *Phyllopacchyceras infundibulum* (D'ORB.), *Eulithoceras* cf. *phaestum* MATH. and *E.* sp.

According to J. FÜLÖP, the fauna "is a sound indicator of the fact that the lower part of the siliceous marl sequence belongs to the Barremian". From higher parts of the formation (251.0–330.0 m) *Mesohibolites* cf. *fallauxi* (UHL.) was recovered.

The *Cephalopoda* fauna recovered from the borehole Süt-17 and determined by A. HORVÁTH is listed in Table 4.

On the basis of the evaluation of the fauna the lower interval of the formation, the middle part of the siltstone member, should be assigned to the Barremian, an assignment proved in the first place by the presence of well-preserved fossils, suitable for a convincing identification, such as *Pseudohaploceras leptoviense* (ZEUSCHN.), *Leptoceras parvulum* UHL., and the *Barremites* species (Plate XXIV, Fig 3–5).

The faunal pattern resembles to that of the Wernsdorf Beds, but is much poorer than that, the representatives of *Phylloceras*, *Lythoceras* and *Holcodiscus* being absent. *Costidiscus* is represented by two uncertain fossils, *Hammulina* and *Crioceratites* being also poorer.

The *Ammonites* found in the upper interval (202.7 m) almost certainly belongs to the Upper Aptian *Colombiceras* genus, while the poorly preserved fragments from 214.5 m belong to *Procheloniceras* or *Chelonicerias*, the latter being characteristic of the Aptian.

The *Foraminifera* fauna from the borehole Süt-17 was studied by M. SÍDÓ. She distinguished the following assemblages:

1. An *Epistomina*–*Gavellina* benthonic assemblage with vaguely determined *Hedbergella* in the lower part of the formation (340–380 m).
2. A *Hedbergella*–*Clavihedbergella* assemblage composed of smaller forms in the upper part of the calcareous marl member (280–340 m).
3. A *Globigerinelloides typicus*–*Clavihedbergella subcretacea* assemblage in the lower part of the siltstone member (240–280 m).
4. A *Globigerinelloides blowi*–*Hedbergella aptiana* assemblage in the upper part of the formation (200–240 m).

As already mentioned in discussing the Mogyorósdomb Formation, because of the disappearance of *Calpionellidae* the Valanginian–Hauterivian boundary is supposed to lie in the transitional unit at the lower boundary of the Sümeg Marl. Since the appearance of the genus *Hedbergella* is attributed to the middle part of the Hauterivian (VAN HINTE 1976), the interval characterized by the *Epistomina*–*Gavellina* assemblage is placed in the lower part of the Hauterivian, that of the *Hedbergella*–*Clavihedbergella* assemblage in its upper part.

The *Globigerinelloides typicus* – *Clavihedbergella subcretacea* assemblage, as indicated primarily by *Hedbergella sigali*, species included in it, may be assigned to the Barremian or possibly it may extend into the Aptian as well.

Appearing at 240 m, *Globigerinelloides blowi* indicates the lower part of the Aptian with high certainty (Bedoulian substage), being the zonal index fossil of the LC-9 *Globigerinelloides blowi* Zone in the zonation proposed by VAN HINTE (1976) and generally adopted. The *Schackoïna cabri* Zone (LC-10) representing the basal part of the Gargasian could not be unambiguously separated from the *Globigerinelloides blowi* Zone, as the species *Gl. blowi* can be observed to occur up to the incoming of *Gl. algerianus* which is, in turn, the zonal index of the LC-11 Zone representing already the upper part of the Lower Gargasian.

Data concerning the nannoplankton assemblage are available from the boreholes Süt-17, Sp-1 and S-7. Relying on the results obtained by M. BÁLDI-BEKE in the borehole Sp-1, J. FÜLÖP (1964) split up the formation into two parts: “In the upper part (251.0–330.0 m) predominant *Nannoconus steinmanni* is accompanied by *N. truitti*, *N. bucheri*, *N. wassalli*, *N. cf. kamptneri* and *N. cf. globulus*. The older group of strata (beneath 330.0 m) contains, in addition to predominant *N. steinmanni*, such species as *N. colomi*, *N. kamptneri*, *N. globulus* and *N. truitti* (1 specimen)”. Adopting BRÖNNIMANN’S *Nannoconus* biozonation, M. BÁLDI-BEKE (1965) believed the lower part of the sequence to belong to the *Nannoconus kamptneri* Zone, the upper part to the *Nannoconus truitti* Zone.

In the sequence of the borehole Süt-17, upon determinations by J. BÓNA, the two biozones could also be identified. The upper boundary of the *Nannoconus kamptneri* Zone is to be located within the 310.0 and 340.0 m interval. Although the zonal index fossil could not be observed, *N. colomi* and *N. globulus*, both typical of the zone, could be encountered in a couple of specimens. To assign the upper part to the *Nannoconus truitti* Zone is justified by the presence of the index species of the zone too.

As shown by M. BÁLDI-BEKE’S results (1965), the interval cut in borehole Köves-domb S-7 (75.8–94.7 m) may be assigned in full to the *Nannoconus kamptneri* Zone.

As regards the chronostratigraphic assignment of the zones, M. BÁLDI-BEKE (1965) is of the opinion that the *Nannoconus kamptneri* Zone indicates the presence of the Barremian, the *Nannoconus truitti* Zone that of the Aptian-Albian.

F. GÓCZÁN was the first to analyze palynologically rocks belonging to the formation, using samples from the borehole Sp-1 (for a description, see J. FÜLÖP 1964). In higher parts of the sequence (337.0 m) he found *Gleichenia* species indicative of an Aptian age and forms belonging to the genus *Schizaeaceae* of the same age connotation. In the deeper part (387.8–990.3 m), however, he observed spores suggesting the presence of the Upper Barremian already.

The material of the stratotype was analyzed palynologically in detail by M. JUHÁSZ (Fig. 28). In his summarizing report, he distinguished three different intervals.

In the lower one (372.0–397.9 m) gymnosperms transient from the Neocomian are represented still in a great number, for instance, *Todisporites minor*, *Deltoidospora halii*, *Cyatgidites* species, *Classopollis classoides*, *Vitreisporites pallidus*, *Alisporites thomasi*, *Callialasporites trilobatus*, *C. dampieri* and *Monosulcites minor*. A new feature is the incoming of *Schizeaceae* spores: *Cicatricosisporites* and *Appendicisporites* species, *Ischyosporites tuberosus* and *Corniculatisporites virgatus*. On the basis of a Hungarian comparative material M. JUHÁSZ assigns this interval to the Barremian, calling attention to the difficulties of interregional long-distance correlation.

In the middle interval *Gleicheniaceae* species (*G. minor*, *G. delcourti*, *G. major*, *G. umbonatus*, *G. laetus* and *G. carinatus*) predominate.

The flora is characterized, in addition, by a more reduced number of Conifera pollen grains, so by a decline of *Classopollis* as well as the consistent occurrence of the *Trilites* group [*T. triangulus*, *T. minor*, *T. (Bikolisporites) toratus*], a characteristic fern group of the Lower Albian. The middle interval, 217.0 to 297.9 m, is probably of Lower Aptian age.

The upper interval (103.0–217.0 m) is characterizable palynologically by the following.

The *Gleicheniaceae* spores are reduced in number, the representatives of *Trilites*, a spore group previously subordinate, gain predominance. The ribbed or sculptured spore forms increase in number, Conifera pollen grains being frequent too.

Faveosporites canalis, *Clavifera triplex*, *Varirugosisporites lentiformis* and *Matonisporites phlebopteroides*, also recovered from this interval, may be regarded as Aptian forms. The other spore and pollen forms are of greater stratigraphic range.

Chronostratigraphically, this interval corresponds either to the upper horizon of the Lower Aptian or to the lower horizon of the Upper Aptian.

All in all, the Valanginian-Hauterivian boundary can be drawn, in the stratotype section of the borehole Süt-17, near the lower boundary of the Sümeg Marl Formation.

The Hauterivian-Barremian boundary can be located, with some reserve though, at the base of the microbanded marl interval observed at the base of the siltstone member, but it may lie somewhat deeper as well. The Barremian-Aptian boundary can be drawn within the silty marl part of the siltstone member (around 250 m).

Within the Aptian the Bedoulian-Gargasian boundary coincides by and large with the boundary between the siltstone and the sandstone members.

The major litho- and biostratigraphic results and the chronostratigraphic evaluation are summarized in Fig. 29.

Paleoenvironment

The formation as a whole is characterized by the finely detrital (silty) biomicrite rock type. This material must have been deposited as a fine mud beneath the zone of wave action, on a relatively deep sea bottom protected from heavier agitation. Much of the carbonate of the rock is of nannoplanktonic origin.

The bulk of the silica content is yielded by *Radiolaria* tests, i.e. similarly by planktonic organisms. The plankton/benthos ratio is high in the *Foraminifera* assemblage as well. All these circumstances are suggestive of a depositional environment that had a communication with the open sea. From among the nektonic elements *Ammonites* and fish teeth may be mentioned. Benthonic elements occur, too. In the upper part of the formation sponge spicules are frequent. Rarely present, the remains of *Crinoidea*, *Mollusca* and *Bryozoa* may have come from a higher bathymetric position into the depositional environment.

Intensive bioturbation and the presence of worm tracks are suggestive of an organics-rich mud deposited on the bottom.

The comparatively high amount of land-derived material (quartz, quartzite chert, illite, chlorite) indicates the relative proximity of land.

The upward growth of the sand fraction and the increasing frequency of coalified vegetal detritus may indicate that, by Aptian time, the one-time shoreline had come closer. The parallel growth of the carbonate component of bioclastic origin and the manifestations of some characteristics of the definitely shallow-water Tata Limestone, in turn, are suggestive of an environment that was becoming gradually more shallow.

The appearance in greater amount of land-derived detritus of sand size is particularly remarkable for the simple reason as in the older Mesozoic formations of the Transdanubian Central Range zone —except for the Lower Cretaceous in the Gerecse—this component is subordinate. This circumstance would thus imply a change in the lithological character of the source area and in its morphology as well as in its climatic regime. It may be supposed that within the structural zone in question the crystalline rocks had got exposed over a larger area and that physical weathering had a considerable

part in the weathering processes which would refer to a less humid and/or cooler climate and greater differences in the relief.

Information on the climate of coastal areas was furnished by palynological analysis, too. According to M. JUHÁSZ, the ribbed spores characteristic of the lower reaches of the formation may be related to ferns that are at present drought-resistant and thermophilic.

Predominant in the middle interval, the fern family *Gleicheniaceae* now lives in tropical to subtropical regions. In the upper part of the formation again the ribbed spores are frequent. It is interesting that a somewhat xerotic flora correlates in some measure with the higher sand content. Taking into consideration the foregoing, the climate of the surrounding terrestrial areas seems to have been characterized by a high temperature during the whole length of time concerned, but the climate at the beginning of the time span (Barremian) and at its end (end of Early Aptian) was probably less humid, while in the middle part (the beginning of the Early Aptian) rather tropical in character.

Tata Limestone Formation

The proposal for the introduction of the Tata Limestone Formation, a detailed description of the sections from the type area and the results of their analyses are contained in the work "The Mesozoic basement horst blocks of Tata" by J. FÜLÖP (1975). In the sections exposed in the vicinity of Sümeg the lithological features and the mode of superposition differ to some extent from those observed in the type area. For this reason, a hypostratotype was designated here.

Local type section (formation hypostratotype)

For local key section of the formation, the upper part of the borehole Süt-17 has been chosen, on the one hand, because here the almost 100-m-thick sequence evolves continuously from the stratotype section of the Sümeg Marl Formation, and the changes in character can be readily followed and, on the other hand, because the sequence may be regarded as a continuation of the Vár-hegy section, even though on account of tectonic deformation, the rocks cropping out of the hillside do not form a continuous sequence.

The borehole penetrated the formation between 0 and 98.5 m with a dip of 5 to 10° (for the lithologic log and the analytical results, see Fig. 30).

The geological features are uniform throughout the formation — light grey to yellowish-grey limestone consisting, in a considerable part, of 0.5 to 1.0 mm elements of *Crinoidea* skeletons and of limestone and calcareous marl debris grains visible even to the unaided eye. Chert lenses or layers can be observed at 1 to 5 m intervals, varying from 5 to 10 cm, though locally exceeding even 1 m in thickness. The maximum of frequency and thickness of the chert layers falls in the middle part of the sequence (45–80 m). In the basal part of the formation (beneath 90 m) the frequency and comparatively large size of glauconite grains is remarkable. They are often enriched in form of lenses. The glauconite grains have their quantitative maximum in the immediate vicinity of the lower formation boundary. In the same interval even such clay-filmed surfaces can be found as are conspicuous in the Sümeg Formation.

In the light of thin section studies performed by GY. LELKES, the formation is rather uniform even texturally within the section, the extrasparite and biosparite (grainstone) texture type being conspicuous (Plate XXVI, Fig. 1–3) throughout the sequence. The quantities of the individual textural elements are given in Fig. 30.

From among the biogenic rockforming components, it is the skeletal elements of echinoderms that predominate, of which the overwhelming majority is represented by *Crinoidea* elements. They vary in size from 10 µm to 2–3 mm.

Foraminifera occur in every examined sample. They vary between 0.1 and 1 mm in size. Both planktonic and benthonic forms can be observed. Most of the benthonic specimens are arenaceous, uni- to biserial forms (*Dorothia-Spiroplectamina* assemblage). The calcareous forms (*Lagena*, *Dentalina*, *Lenticulina*) are less significant. M. Sidó observed *Orbitolina* species in two intervals (35–39 and 75–79 m). The planktonic forms are represented by the genera *Hedbergella*, *Globigerinelloides* and *Ticinella*.

Fig. 29. Upper Jurassic to Cretaceous interval of the borehole Süt-17: a summarizing stratigraphic record

* Occurrence of *Braarudosphaera hoshulzi*, ** the *Nannoconus kamptneri* Zone is indicated by *N. colomi* and *N. globulus*. — *G* *Globigerinelloides*, *H* *Hedbergella*, *Cl* *Clathrobergella*, *E* *Epistomina*, *Gz* *Gavellinella*

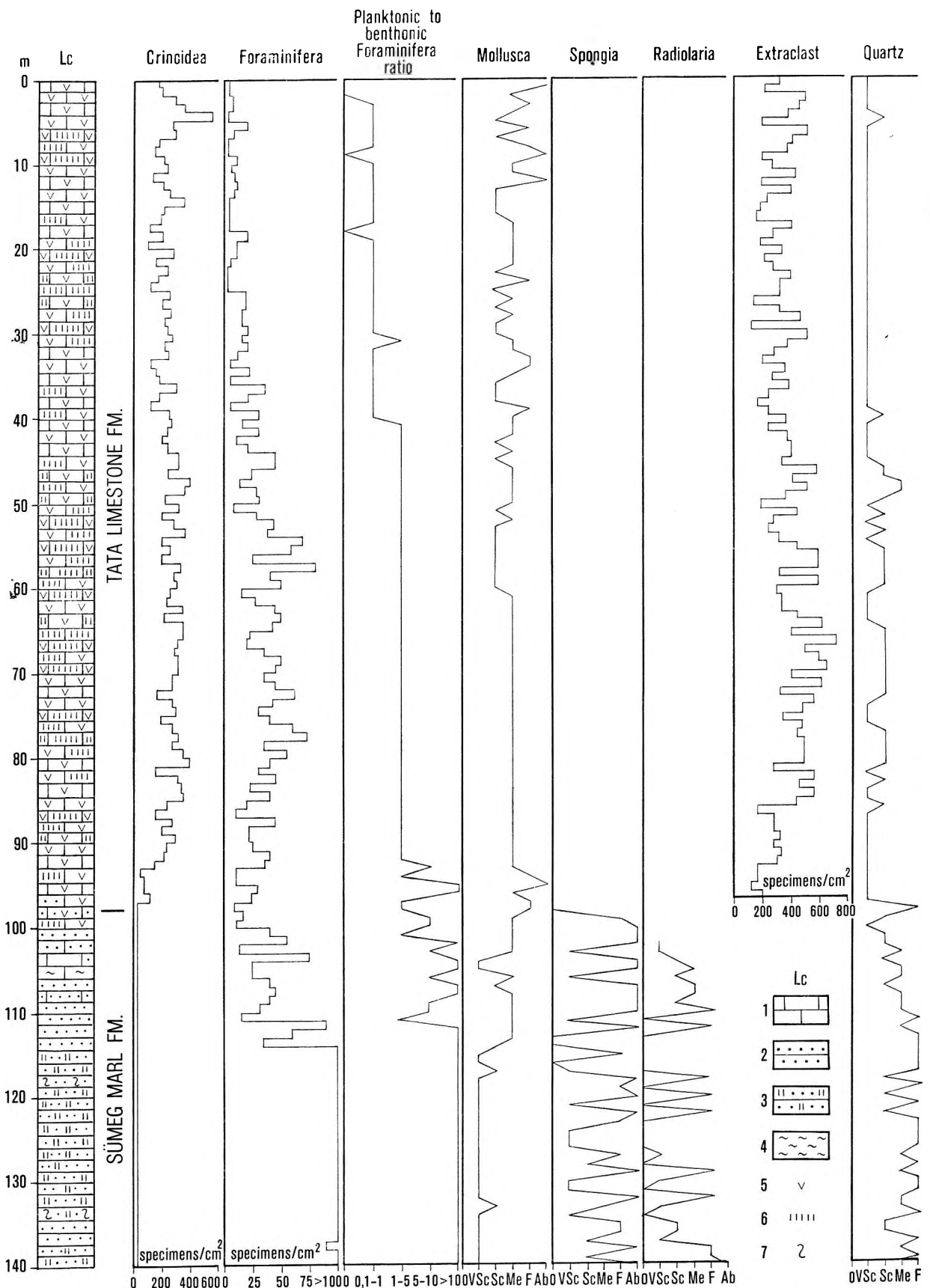


Fig. 30. The Tata Limestone Formation as exposed in the borehole Süt-17: lithologic column and microscopic record

Lithologic column (Lc): 1. limestone, 2. sandstone, 3. sandy silt, 4. marl, 5. crinoidal, 6. chert, 7. worm tracks. — O naught, VSc very scarce, Sc scarce, Me median, F fair, Ab abundant

The P/B ratio varies within wide limits, from 0.1 to over 10.

Mollusca skeletal elements are observable throughout the formation in question, being more frequent in the upper reaches of the borehole. They vary in size between a few tenths of mm and 1–2 mm. Both intact and recrystallized skeletal elements occur. The intact skeletal elements of small size cannot be clearly separated from the *Brachiopoda* elements. The recrystallized elements are well-rounded and micrite-coated.

Beside the afore-mentioned, some *Gastropoda* shells, coral fragments, *Ostracoda* and worm-tubes could be observed. Frequently, though in a very low amount, tiny phosphate grains are observable too.

The chert lenses and layers seem to have been formed from the silica of sponge spicules by a diagenetic dissolution-precipitation mechanism, even though the spicules could not be identified in the course of microscopic studies (Fig. 3C).

In addition to biogenic grains, land-derived ones, especially small extraclasts of carbonate matter, are quite frequent. Their overwhelming majority is represented by nonfossiliferous, micritic grains (Valanginian-Hauterivian). In addition, some extraclasts with *Calpionella* (Tithonian), *Bositra* (Dogger) and oolites (Upper Triassic to Lower Jurassic) were observed.

Another group of land-derived grains is constituted by quartz, quartzite, chert, opaque (chromite) grains present in a quite insignificant amount.

In the 15.5–97.5 m interval of the borehole some samples (bioextrasparites-extrabiosparites) can be observed to contain intraclasts too, which in the lithologic sense are spicular biomicrites. The matrix between the grains is a sparry calcite, though in some samples details represented by micrite (microsparite) can be observed, too. Much of the sparite forms a syntaxial rim that is in an optical continuity with the skeletal elements of echinoderms, the rest being mosaic-patterned.

In the studied interval two microfacies could be singled out:

The 1st microfacies type is composed mainly of medium-grained extrabiosparite-bioextrasparite rock varieties. From among the biogenic components the skeletal elements of echinoderms (*Crinoidea*) are most frequent; of *Foraminifera* the planktonic specimens are more frequent than the benthonic ones [the P/B ratio is usually 1.0 to 3.0].

Intact and recrystallized *mollusc* elements, *Bryozoa* and red algal fragments are scant. Of the land-derived components it is the extraclasts that predominate, the quartz grains being scant. The overwhelming bulk of the cement around the echinoderm skeletal elements is developed in the form of a syntaxial rim, the rest being mosaic-patterned. This microfacies type is characteristic first of all of the 40.0 to 75.0 m interval of the borehole.

The 2nd microfacies type is constituted by medium to coarse-grained bioextrasparite. Of the biogenic grains the skeletal elements of *Echinodermata* and *Mollusca* are predominant. For the most part recrystallized, well-rounded and micrite-coated, the mollusc elements are conspicuous. Other bioclasts are present in low quantities. From among the land-derived grains, the extraclasts are predominant, the quartz grains being very scant.

The cement is observed in the form of a syntaxial rim around the bioclastic elements and as a mosaic-sparite. The 2nd microfacies type is characteristic primarily of the 0 to 40.0 m and 75.0 to 95.0 m intervals.

Other exposures

In the Vár-hegy block the structural and geological features of the Tata Limestone can be studied excellently. A section that should represent a considerable part of the sequence and should be suited for a more scrutinized stratigraphic investigation could not be designated, however, owing to the heavy tectonic deformation of the escarpments of the Vár-hegy. It is probable that the borehole Süt-17 was located on a faulted step of the block, and thus the availability of stratigraphically higher parts compared to the sequence penetrated by drilling cannot be reckoned with even in the topographically higher tracts.

To the southeast of the borehole Süt-17, in a section surveyed up to the hilltop, yellowish-grey to light yellow limestones composed of arenite-sized echinoderm skeletal elements and varying quantities of extraclasts of different size could be observed throughout the section. In the deeper part of the section no chert layer was observed, but in the higher parts of it the cherts proved to be quite frequent, represented by lenses and layers a couple of metres wide and a few cm or dm thick. In many cases a siliceous impregnation of the rock can be observed. Such layers of cherty composition can be seen along the upper reaches of the promenade leading to the castle (Plate XXV, Fig. 2) and even in the outcrops in the inside of the castle walls. On the basis of the frequency of the chert layers, that part cropping out at the hilltop of the Vár-hegy can be identified with the middle part of the drill-penetrated sequence.

On the hilltop, in the outcrops inside the castle walls, the cross-laminated rock structure and the pinching-out of the strata are quite distinct (Plate XXV, Fig. 1).

The rock is poor in megafossils. J. FÜLÖP (1964) mentions a few poorly preserved *Ammonites* [*Desmoceras* (*D.*) *getulinum* (COQUAND), *Lytoceras* sp.], *Brachiopods* [*Rhynchonella* cf. *multiformis* RÖM., *R.* sp., *Terebratula biplicata* DAV., *T.* sp., *Nucleata hippopus* (RÖEM.), *Waldheimia* sp.] and *Cidaris* spicules.

A sequence similar in geological features to that of Vár-hegy was cut by the borehole Sp-1 in a thickness of 50 m or so. The description of the sequence and the relevant sedimentological and paleontological results were published by J. FÜLÖP in his work of 1964. From the fossil assemblage, beside the rockforming skeletal elements of *Echinoidea*, he mentions benthonic (mainly arenaceous) and planktonic *Foraminifera*, further, *Radiolaria*, sponge spicules, *Brachiopods*, *Belemnites* rostra as well as *Coccolithophoridae* and spore-pollen remains.

In the boreholes that exposed a more reduced part of the Tata Formation (Süt-16, -19, -20, -21, -22, SG-1, -5) the geological features are similar to the Vár-hegy type.

The pattern of the Tata Limestone exposed in the Sintérlap quarry in the northwest part of the Köves-domb is rather different from that of Vár-hegy.

The Köves-domb quarry exposes the Tata Limestone sequence in a thickness of about 70 m with 310/45° dip (Plate XXVIII, Fig. 1). The lithofacies is rather homogeneous, being composed of limestone beds of yellowish-brown colour, from 20 to 30 cm thick. In some beds, however, the skeletal elements of echinoderms and the extraclasts are of quite different size and quantity. No chert layer or siliceous impregnation is observable. Megafossils are very scarce. According to a revision by A. HORVÁTH, the brachiopods collected by R. HOJNOS are *Rhynchonella* cf. *lamarckiana* ORB., *Rh.* sp. and *Waldheimia* sp.

A strikingly interesting feature of the Tata Limestone exposure in the Sintérlapi quarry is that the strata are laced by calcite-filled fissures of 0.5 to 3 m width. These calcite veins do not intersect the unconformable Senonian, but their detritus can be encountered in the Senonian extraclastic limestone directly overlying the formation. The light yellow, aphaneritic limestone lenses of a few dm size are probably of fissure-fill origin.

On the basis of the thin section analyses carried out by Gy. LELKES the predominant rock type on the exposed sequence is bioextraspate (grainstone), less frequently bioclastite (crinoidite) occurs, too (Plate XXVI, Fig. 4-8; Plate XXVII, Fig. 1-4, 7-8).

Foraminifera are frequent, dominated, as a rule, by the plankton with the genera *Globigerinelloides* and *Hedbergella* [P/B 0.1 to 5.0].

Most of the benthonic elements are arenaceous. Striking is the presence of *Orbitolina* (Plate XXVIII, Fig. 3, 5) which in the Tata Formation have been known so far only from Sümeg. The detritus of red algae and *Mollusca* is much more frequent than in the samples from the borehole Süt-17. Sponge spicules could be observed only in a few samples, in subordinate quantities even in those. Extraclasts, as a rule, are rockforming components, being mostly visible even to the unaided eye or with a magnifying lens. As extraclasts the Calpionella limestone debris of the Tithonian-Hauterivian Mogyorós-domb Formation and the Lombardia limestone detritus of the Kimmeridgian Pálihálás Formation are recognizable in thin sections (Plate XXVIII, Fig. 2, 4). Quartz grains are subordinate in quantity.

Bio- and chronostratigraphy

In the chronostratigraphic evaluation we can rely primarily on the results of foraminiferological studies. According to the results arrived at by M. SIDÓ, in the borehole Süt-17 the zonal index *Foraminifera* species *Globigerinelloides algerianus* CUSHMAN et TEN DAM appears at the lower boundary of the Tata Limestone (98.0 m), but there it is still scarce and of small size. Higher up the sequence both frequency and size will increase.

In the light of the international literature the *Globigerinelloides algerianus* Zone is clearly suggestive of the Upper Aptian, Gargasian, substage (VAN HINTE 1976, SIGAL 1977).

According to the classification proposed by VAN HINTE (1976), the *Globigerinelloides algerianus* Zone represents the middle part of the Gargasian (LC 11). The lower boundary of the zone was defined by him with the extinction of *Schachoina cabri* SIGAL, the upper boundary with that of *Gl. algerianus* CUSHMAN et TEN DAM. According to SIGAL (1977), the range of *Gl. algerianus* can be located in the upper part of the Gargasian.

Beside *Globigerinelloides algerianus*, *Gl. ferreolensis* (MOULL.) can also be observed which was shown by SIGAL (1977) to appear in the middle part of the Gargasian. Additional typically Aptian planktonic species: *Gl. breggiensis* (GAND.), *Hedbergella trocoidea* (GAND.), *H. infracretacea* (GLAESSNER), *H. planispira* (TAPPAN), *Ticinella roberti* (GAND.).

It is worth mentioning that *Ticinella bejauensis* SIGAL, species appearing in the topmost Gargasian, could not be identified in the section of the borehole Süt-17.

Orbitolinoids (*Planorbitolina*, *Mesorbitolina*, *Orbitolinopsis*) were observed in two horizons (35–39 m and 75–79 m), but because of recrystallization of the specimens and the improper section a determination down to the sp. level was impossible.

On the basis of the foregoing, the lower formation boundary in the Süt-17-penetrated section of the Tata Limestone Formation represents the middle part of the Upper Aptian, Gargasian, substage and it is probable that the drilled uppermost beds do not pass over into the Clansayan substage (Fig. 29).

Paleoenvironment

The formation of the Tata Limestone took place without any doubt in a shallow-water agitated environment which was communicating with the open sea.

According to the results obtained for the borehole Süt-17, the basal interval of the formation evolves with a gradual transition from the Sümeg Marl. Land-derived quartz sands are considerable in quantity, gradually superseding the bioclasts, components of mainly *Crinoidea* origin, and the extractlasts consisting of limestone.

The reduction of the amount of planktonic *Foraminifera* and the growth of the share of the benthonic elements are similarly gradual. Thus the lowermost interval was characterized by sedimentation in a less agitated, relatively open marine environment, where the non-carbonate detritus arriving from the land is still little "diluted" in the biogenic carbonate sediment.

The overwhelming bulk of the formation is composed of bio- or extraclastic calcarenites. The bioclast fraction is composed mainly of parts of *Crinoidea* skeletons — a material supplied by the *Crinoidea* fields of the shallow-water shelf.

Halimeda meadows may be regarded as modern equivalents of that kind of environment. The *Halimeda* green algae dwell in the seaward outer zone of the shallow-water shelf and their skeletal elements serve as a source for a well-sorted and often cross-bedded sand sediment varying in size and roundness in dependence on local factors.

These same features can be observed in the case of the Tata Limestone exposed at Sümeg too. A lot of examples of a cross-bedded structure suggestive of heavy agitation can be observed on the hilltop of the Vár-hegy. Heavy water movement is indicated by the interstitial sparite, the roundness of the grains and their being well-sorted.

The fossils are suggestive of normal salinity and the presence of the photic zone. That the planktonic elements are common is indicative of a communication with the open sea.

The chert lenses and layers characteristic of the Vár-hegy sequence are associated with sponge-bearing facies indicating only that the *Crinoidea* community was locally or from time to time replaced by a *Spongia* community. Regarding the facies relations, it is quite clear that the two biofacies are interchangeable and that their alternation cannot be tied to changes in water depth.

The absence of the *Spongia* facies in the Köves-domb sections is conspicuous, but, in the light of the foregoing, it does not make any substantial difference in the interpretation of the paleoenvironment. The abundance in some beds of *Orbitolina*, phenomenon doubtlessly suggesting a quite shallow-water, photic, zone is worthy of mention.

The abundance of sand- to small pebble-sized extraclast grains of terrestrial origin indicates the proximity of a source area (island range?) in which Jurassic to Lower Cretaceous formations were exposed. This fact, in turn, indicates a remarkable mobility prior to the formation of the Tata Limestone and maybe even during it.

S u m m a r i z i n g, let us conclude that the environment of deposition of the Tata Limestone may have been the so-called drifting calcareous sand which seems to have joined the foreshore flat with a gentle slope.

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