GEOLOGICAL FORMATIONS

Triassic

by

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The oldest formations in outcrop or artificially exposed in the Sümeg area are of Upper Triassic age. To the southeast and east of the settlement they can be traced in outcrops as far as the Tapolca and the Nyírád basins. Borehole drilled recently have shown the presence of sequences differing in facies from those known from the surface.

Exploration history

On his geological map of 1875, scale 1:144,000, labelled D.9., JÁNOS BÖCKH has figured the following Triassic formations: "Hauptdolomit" (Városi-erdő) and "Rhaetian limestones and calcareous marls" (Városi-erdő, Mogyorós-domb).

LAJOS LÓCZY (1913) discussed in more detail the Triassic rocks of the study area in his Balaton monograph, FERENC FRECH did so in the paleontological chapter of the same monograph. In the dolomite sequence of the Szőlő-hegy, to the southeast of the settlement, LÓCZY discovered two successive fossiliferous horizons the fauna of which was determined by FRECH. From the lower horizon, this author described the taxa "*Dicerocardium mediofasciatum* FRECH, *Megalodus triqueter* mut. *acuminata* FRECH, *M. Guembeli* STOPP., *M. Lóczyi* HOERN. var. *angulata* FRECH, *M. Böckhi* R. HOERN., *M. Damesi* HOERN., *Conodus dolomiticus* nov. sp.", from the upper one: "*Megalodus triqueter* mut. *acuminata* FRECH, *M. Böckhi* R. HOERN. *M. Laczkói* R. HOERN." The fauna of the upper horizon was taken by LÓCZY to be representative of the transition between the Norian (Juvavian) and the Rhaetian, the deeper beds were correlated with the lower part of the "Veszprém Dolomite".

Near the watering-well Lókút (=Horse's Well) at the northeastern margin of the Városi-erdő (Sümegi-erdő) he found a fauna strikingly different from that of the Szőlő-hegy which was determined by FRECH, too: "*Cardita austriaca* HAUER, *Sisenna? Oldae* STOPP., *Avicula Galeazzi* STOPP., *Perna Lóczyi* FRECH, *Cardita* cf. *Luerae* STOPP., *Pleurotomaria* sp.". According to FRECH, the fauna can be assigned quite clearly to the Rhaetian, primarily on the basis of *Cardita austriaca*.

About the differring sequences of the Szőlő-hegy and the Városi-erdő of Sümeg LÓCZY wrote summarizingly as follows: "There is even a difference in facies... in the development of the upper part of the Hauptdolomit, inasmuch as in the Sümegi-erdő the dolomite with Rhaetian faunal elements passes into the Dachstein Limestone and this one into the Lias; in the Szőlő-hegy, a little bit farther away, however, a Juvavian Hauptdolomit with a mixed fauna is suggestive of an indistinct transition into the Rhaetian."

ENDRE KUTASSY (1940) carried out a new sampling from the Triassic exposures in the Sümeg area. From the edge of the Városi-erdő (Lókút), a locality mentioned already by LÓCZY, he listed "*Megalodus guembeli* STOPP., *Myophoria inaequicostata* KLIPST., *Perna* sp., *Pleuromia loeschmanni* FRECH, *Macrodon rudis* STOPP., *Modiola gracilis* KLIPST., *Worthenia oldae* STOPP.". He noted that he had not found L. LÓCZY's *Cardita austriaca* and that—according to him—the fauna suggested the presence of the Norian.

In the dolomite outcrops of Ódörögd-puszta locality 7 km southeast from the settlement, he observed the frequent occurrence of "*Megalodus*" *carinthiacus* HAUER and on this basis he registered the presence of Carnian dolomites as well.

JENŐ NOSZKY (1958), in his report on mapping in the Sümeg area, assigned the bulk of the exposed dolomites to the Norian; at the same time he distinguished between two lithological types: the lighter and thicker-bedded variety of Szőlő-hegy and the laminated, darker dolomite of Városi-erdő. He also mentioned the occurrence of a "Kössen Dolomite" with Rhaetian fauna at the edge of the Városi-erdő, but he did not discuss its relation to the "Városi-erdő type" of the Hauptdolomit.

From the Szőlő-hegy he reported the presence of Dachstein Limestone, but the exact location of the site is not indicated either in his report or on its map. He quoted Dachstein Limestone outcrops from the base of Upper Cretaceous rocks in Gerinci quarry, along the Sümeg–Uzsa road and on the western side of the Városi-erdő. For lack of evidence, he rejected an interpretation of the Dachstein Limestone and the "Kössen Dolomite" as facies mutually replacing each other.

S. VÉGH devoted several papers (1961, 1964) to the Triassic and, in more detail, to the Rhaetian of the Sümeg area. In his summarizing work on the Rhaetian in the southern Bakony Mts (1964), he gave a comprehensive list of the fauna known from the dolomite exposures in the northeastern part of the Városi-erdő. He pointed out that most of the species were typical forms of the Alpine Kössen Beds.

From the Dachstein Limestone known in outcrop from the Mogyorós-domb he mentions the "*Paramegalodus*" *incisus* (FRECH) and *Conchodus infraliassicus* STOPP. bivalves and the coral *Thecosmilia clathrata* EMMR. and on the basis of the fauna he assigns the enclosing beds to the upper part of the Rhaetian.

He published a profile and description too from that part of the borehole Sp-3 put down to the northwest of Sümeg composed of limestones, dolomites and dark grey marls and assigned it to the middle third of the Kössen sequence. From the marl beds of the 317.5–353.0 m interval he identified the following fossils: *Modiola faba* (WINKL.), *M. minuta* (GOLDF.), *Pteria falcata* (STOPP.), *P.* sp. ind., *Rhaetavicula contorta* (PORTL.), *Placunopsis alpina* (WINKL.), *Myophoriopsis isosceles* (STOPP.), *Cardita austriaca* (HAU.), *C.* sp. ind., *Lucina alpina* (WINK.), *Anatina* sp. ind.

The results of the palynological analyses carried out in the afore-mentioned part of the borehole Sp-3 were published by VENKATACHALA and GÓCZÁN (1964). They pointed out the predominance in the terrestrial flora of the genera *Classopollis*, *Corollina* and *Granuloperculatipollenites* added to a considerable quantity of *Hystrichosphaeridae*.

Extension, mode of superposition, stratigraphy

The Triassic formations are common in the study area, but their outcrops are limited to the southern and southeastern parts, namely the southern part of the Mogyorós-domb, the Városi-erdő and the Szőlő-hegy (Fig. 3).

In the Upper Triassic of the Sümeg area lithostratigraphic units known from other parts of the Transdanubian Central Range and also from the Alpine zone can be identified. In several cases, however, the intertonguing, transitional part of the formation is that which falls in the study area. This circumstance renders the geological features more intricate, but enables the researcher to study the space and time relations between the lithostratigraphic units.

The thick dolomite body of peculiar structure common in the Upper Triassic of the Alpine-Carpathian realm—which is referred to conventionally as Hauptdolomit in this work—can be clearly identified. The dolomite exposed in the Városi-erdő which we have identified with the Rezi Dolomite Formation proposed for introduction by P. BOHN (1979) differs from it both lithologically and paleontologically. In the northwestern part of the area a Rhaetian sequence of alternating marls, limestones and dolomites has been exposed by drilling. As recommended by the Subcommission on Triassic Stratigraphy of the Stratigraphic Commission of Hungary, this lithostratigraphic unit is referred to as Kössen Formation. In several points of the southern-southwestern subarea (Mogyorós-domb, Városi-erdő, roadside of the Sümeg–Tapolca road) the beds of the Dachstein Limestone Formation of overall distribution in the Transdanubian Central Range are exposed. In the vertical and lateral transitional zones of the Rezi, Kössen and Dachstein Formations sequences of extremely varied lithology are observed to be intertonguing. In earlier mapping practice and in the literature these transitional beds and also the Rhaetian formations of marly facies as well as the sequence of the Rezi Formation were referred to as Kössen Beds ("Kössen Dolomite"). Like many other terms still in use, this one is of Alpine origin. Its meaning may as much refer to the lithological pattern (dark grey marl) of the eponymous type locality as to its peculiar faunistic element (*Rhaetavicula contorta* PORTL.), in other words, it may have litho-, bio- and even chronostratigraphic implications, though these are far from being identical. This multiple and misleading usage has caused a lot of trouble during stratigraphic, mapping and exploratory activities. In the present work the content of the Kössen Formation is restricted to the unit consisting of an alternation of dark grey marls and limestone.

Because of the international openness of the chronostratigraphic scale of the Upper Triassic the stratigraphic assignation of the formations is confronted with difficulties. The quintessence of the problem is that specimens of *Rhabdoceras suessi*, a species earlier believed to be an index fossil of the Norian, were found together with *Choristoceras marshi*, a zonal index fossil in the Rhaetian, and on account of this, several authors proposed the inclusion of the Rhaetian in the Norian.

Concrete problems of stratigraphic assignation will be tackled in the context of discussion of the individual formations.

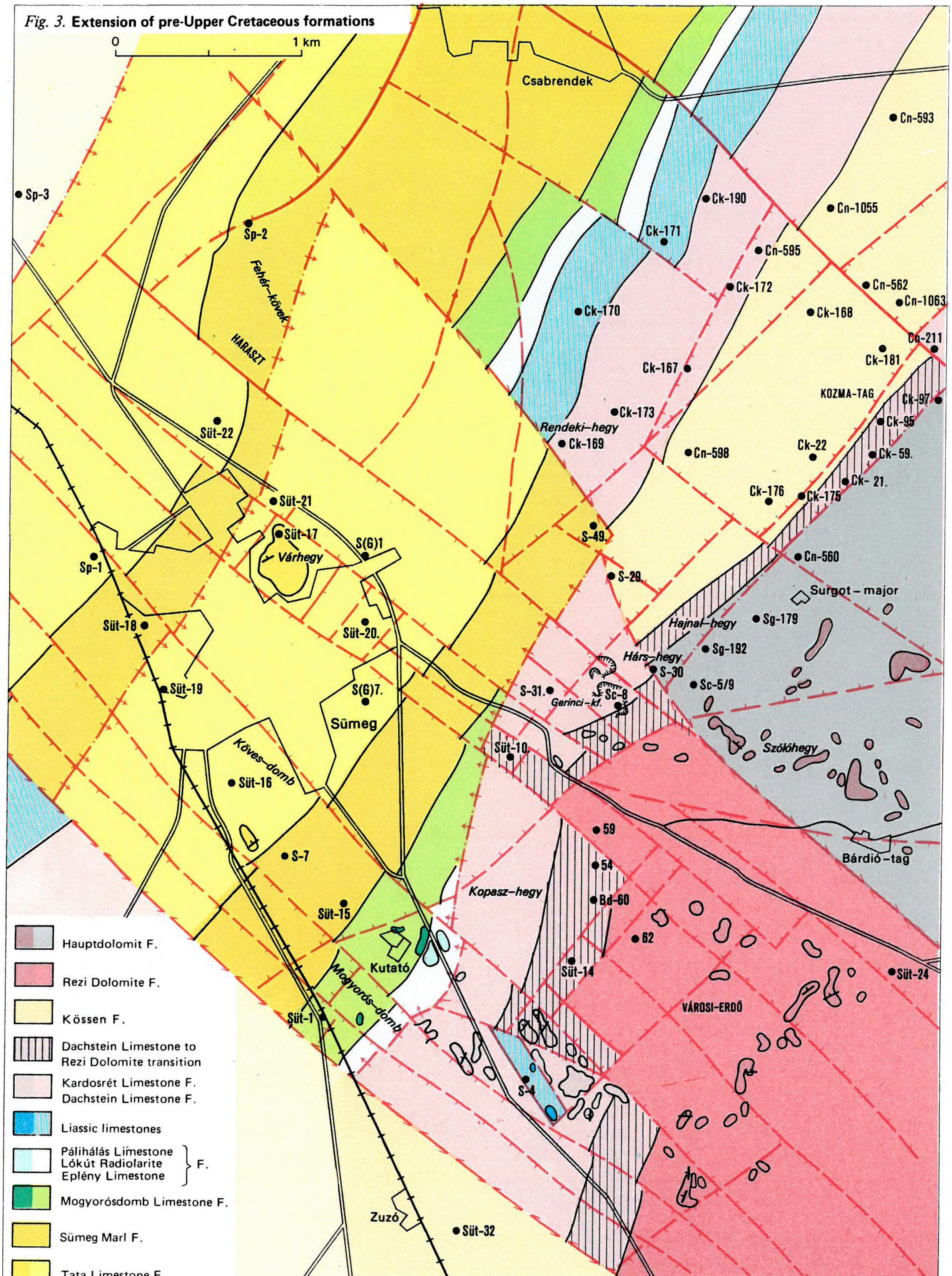


Fig. 3. **Extension of pre-Upper Cretaceous formations**

The oldest rocks overlying the Triassic sequence are known from the southeastern structural zone of the study area (Fig. 3). Namely, on the southwestern margin of the Városi-erdő the Dachstein Limestone passes without any break into a Lower Liassic limestone of similar facies. On the nearby Mogyorós-domb, however, a break in sedimentation is observable in a number of places, the Dachstein Limestone being overlain by Lower and Middle Liassic rocks. In the middle structural zone, beds immediately overlying the Dachstein Limestone are represented by Upper Jurassic formations (borehole Sp-1, Süt-17). In the northwestern thrust-sheet the Triassic is overlain by Upper Cretaceous rocks. Similar is the situation on the southeastern side of Hajnal-hegy–Hárshegy–Kozma-tag. In the southeastern part of the Sümeg area the Triassic sequence is often overlain by Cainozoic rocks.

Oldest among the formations in question is the Hauptdolomit (Norian or, in the immediate neighbourhood, also Carnian). The footwall formations nearest to the study area are known from the Balaton Highland, so that the well-known sequence of the Balaton Highland is that which can serve as a basis for extrapolation.

Hauptdolomit Formation

The Hauptdolomit Formation can be studied first of all in the outcrops known from the Szőlő-hegy of Sümeg, but is known from a number of boreholes put down in the Surgótag and Kozma-tag subareas as well. An extremely widespread stratigraphic unit as it is, the study of the exposures of the Sümeg area cannot but contribute to an exhaustive knowledge of the formation. Because of the great thickness of the formation to study a sequence of considerable thickness was impossible and even the interval studied in detail could not be fitted exactly in a complete stratigraphic sequence.

Given the above facts, the authors wished to solve two fundamental tasks:

(1) to re-assess the chronostratigraphic classification in the light of the fossils hitherto known and recovered in the course of new samplings and to verify it by evidence;
(2) to identify the most peculiar lithofacies types by textural and other lithologic studies and to reconstruct on this basis the sedimentary environment and its changes.

Since a lithologically rather uniform unit or, more precisely, one showing a kind of cyclic recurrence in some of its features, was being dealt with, even the study of smaller profiles could have been promising for deducing genetic conclusions extrapolable to a considerable part of the formation or maybe even the whole of it, even though it was impossible for us to assess the trends of evolution.

Petrographic and microfacies analyses

For a more detailed study and the sampling of megafossils, a sequence of 13 m thickness and 44/38° dip was exposed by digging a trench of 20 m length normal to the strike on the southern slope of the Szőlő-hegy (Fig. 4).

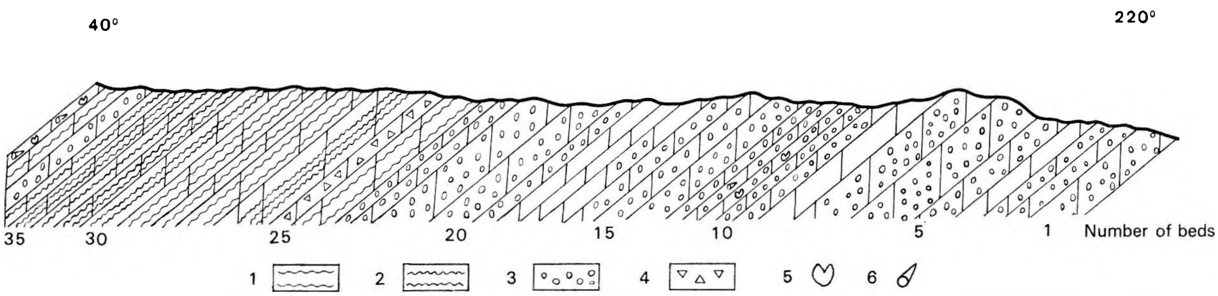


Fig. 4. Sequence belonging to the Hauptdolomit Formation as exposed by trenching on the southern slope of the Szőlő-hegy (Vineyard Hill)

1. Wavy, microlaminated structure, 2. microlaminated structure, 3. dissolution pores (tubules), 4. intraformational breccia structure, 5. Megalodontidae shell, 6. Gastropoda

The lower, 9-m-thick part of the profile (Beds 1–23) has exposed white, light grey, yellowish-white, brownish-yellow, light brown, for the most part coarsely crystalline dolomite beds, varying from 0.3 to 0.8 m in thickness. Macroscopically remarkable features of the rock are the tiny pores (1 to 4 mm in diameter and a few cm in length) left over for the most part by the dissolved calcareous skeletons of *Dasycladaceae* algae (Plate II, Fig. 3). Regarding their size and shape, these agree with the poorly preserved algal remains recovered from the Norian Dachstein Limestone of the Buda Hills (Hárs-hegy–János-hegy). It is this part of the sequence that contains the relatively rich *Megalodontidae* fauna.

As shown by microscopic study, the texture is usually dolopelsparite. The pellets are 0.1 to 0.2 mm in diameter, consisting of micrite and giving an elliptical cross-section when viewed in thin section. Intraclasts (authigenic breccia) resulting from the remobilization of a once-deposited and consolidated sediment which are usually coated by a thin micrite layer (Plate I, Fig. 1, 2), are commonly encountered. Less frequently, pseudo-oöid, microoncoid grains can also be recognized.

Fossil elements other than the dissolved cavities of algal origin are rare, only a few mollusc shell fragments, *Ostracoda* valves and fragments of *Bryozoa* can be mentioned. The finer details of algal structure invisible to the unaided eye cannot be seen owing to recrystallization and dissolution. The outline of the outer margin, however, is quite distinct.

The space between the allochemical constituents is filled with sparry dolomite crystals of 20 to 100 μm size (the intraclasts too are formed of a substance of similar crystal size which may refer to a early diagenetic cementation). A dolomicrite-microsparite matrix is less frequent (Bed 20). In this textural type major idiomorphic dolomite crystals (400 μm in size) are scattered in the matrix. The cavities are filled with a sparite of coarse crystal size (druses).

In the upper part of the profile (Beds 24–37) white, greyish-white, yellowish-white dolomites of wavy microlamination (Plate I, Fig. 4, 5), of laminated jointing and frequently porous structure are characteristic with an oöidal pattern visible to the naked eye in the majority of the beds and with authigenic brecciation. According to observations with the microscope, the microlaminated structure is due to the alternation of dolomicrite and dolosparite layers of mm thickness.

Mollusc shell fragments, completely recrystallized fragments of *Dasycladacea* and larger intraclast grains (4–5 mm) sit in the micritic microlayers. In some beds even the cracking of the micrite laminae (microlaminae) can be observed, a sparry intraclastic fabric being observable in such cases.

The sparitic microlaminae often contain fragments of *Dasycladacea*, *Foraminifera*, *Ostracoda* and *Mollusca* shells as well as oöid, pseudo-oöid and intraclast grains (Plate I, Fig. 1–3), the grains being graded (varying between 150 and 200 μm in size) and rounded.

The sequence exposed in the trench seems to represent the terminal part of a cycle of the cyclic dolomite unit (massive, crystalline dolomite) and the lower part of the next cycle (microlaminated dolomite). In the rocks exposed on the slope and at the top of the Szőlő-hegy the same two rock types can be observed. Megaloscopically, the porosity due to the dissolved algal skeletons can be observed in both types. In the massive beds cavities left behind by the dissolution of gastropodal and megalodontid shells of poor preservation can be found. The occurrence of the microscopic texture shows the commonness of the afore-mentioned two lithofacies types, too. Some of the examined surface samples have a dolosparite texture, consisting of crystals varying between 50 and 150 μm in size, the allochemical components being indistinct in them. The other group is predominantly oösparitic, with intraclasts, *Dasycladacea* remains and recrystallized *Foraminifera*.

The overall distribution of the two basic lithofacies types recognized in the studied profile suggests that the sequence in the Szőlő-hegy subarea is made up of an alternation of these two members.

Bio- and chronostratigraphy

Of the Foraminifera found in the upper part of the trench cross-section the following could be identified: *Aulotortus* cf. *friedli* Kristan–Tollmann, *Involutina gaschei* (Koehn-Zaninetti and Brönnimann), *Involutina communis* (Kristan), *Triasina* cf. *hantkeni* Majzon.

From the trench and the rock slabs carried during farming activities from the adjacent field to the border of the plot the following megafossils have been recovered:

Parallelodon rudis Stopp.
Myoconcha cf. *loeschmanni* Frech
Myoconcha taegeri Frech
Schäfhautlia dolomitica Frech
Pleuromya loeschmanni Frech
Isognomon exilis Stopp.
Mysidioptera dieneri Frech
Costatoria inaequicostata Stopp.
"*Avicula*" sp.
"*Pecten*" sp.
Mysidioptera sp.
Triadomegalodon rátóti Végh-Neub.
Neomegalodon boeckhi (Hoern.)
Neomegalodon complanatus (Gümb.)
Neomegalodon guembeli (Stopp.)
Neomegalodon laczkói (Hoern.)
Neomegalodon mediofasciatus (Frech)
Neomegalodon triqueter acuminatus (Frech)
Gemmellarodus paronai praenoricus (Végh-Neub.)
Gemmellarodus seccoi (Par.)
Dicerocardium pteriiformes Végh-Neub.
Worthenia contabulata Costa
Worthenia escheri Stopp.
Purpuroidea excelsior Kok.
Amauropsis sp.
Coelostylina sp.

Of the megafossils, the predominance of *Neomegalodon boeckhi* (Hoern.), *N. complanatus* (Gümb.) and *N. guembeli* (Stopp.), further the presence of *Dicerocardia* confined to the Norian and, finally, the abundance of the two *Worthenia* species indicate the upper part of the Norian. The identified *Foraminifera* are species typical of the Norian-Rhaetian and thus do not contradict the above assignation.

Paleoenvironment

As well-known from the rich literature concerning the genetic conditions of the formation (A. G. FISCHER 1964, A. BOSSELLINI and D. ROSSI 1974, I. L. WILSON 1975) and evident also from the sedimentological analyses of the examined rocks, the environment in which the unit involved was formed seems to have been a quite shallow-water carbonate platform of the extensive Tethyan shelf. Within this shelf, over the studied stretch representing both members of the cycle composed of grey thick-bedded, megalodontid-bearing dolomites and dolomites with algal mat structure, the peculiar sediments, sedimentary structures and fossils have enabled us to distinguish the following environmental units:

1. *Environment of mobil calcareous sand on the platform margin* (oösparite, microoncoid and intraclast grains). The environment is the zone of overspill of the waves characterized by heavy agitation and turbidity of the water, its high oxygen content and an intensive carbonate precipitation. The water is quite shallow, above the normal wave-base.
2. *Back-lagoon environment with calcareous mud* peldolosparite transformed from pelmicrite (with Megalodontidae). The deposition of sediments was taking place in the well-protected area behind the zone of the mobil calcareous sand. The water depth was greater than in the former case, but, as evidenced by the frequent green algal remains, it may not have exceeded the euphotic depth figure.
3. *Intertidal algal mat facies* (beds of wavy microlamination). The sediment is constituted by the accumulation of carbonate grains entrapped by blue-green algae living in the intertidal zone. At low tide the bottom emerges, desiccation cracks are formed along which the sedimentary lamina is blistered.

In the upper part of the section the repeated alternation of the mobil sand and the algal mat facies indicates a change upon a slight modification of the environmental parameters.

The above discussion does not account for the causes of dolomite formation, for limestones of similar age exhibiting the same structural and textural characteristics are also known from within the Transdanubian Central Range realm. The faunal assemblage of the beds in question is indicative of a marine environment of normal salinity suggesting that the case we have to do with is not the precipitation of a dolomite sediment in a supersaline environment, but a dolomitization taken place during early diagenesis.

Thanks to modern observations and experiments it is a matter of general knowledge that diagenetic dolomitization may be caused by different processes which, however, have in common that a marine sediment is periodically exundated (WILSON 1975). Under an arid climate sabkha-type evaporative sedimentation is taking place on the emerged surface and during this process, because of precipitation of gypsum, the Mg/Ca ratio in the interstitial water increases and the Mg-rich solution migrating downwards infiltrates (soaks) the porous $CaCO_3$ sediment.

According to BATHURST (1975), an enrichment of a saline interstitial water with Mg^{2+} ions may also be due to the dissolution of calcite sediments of high Mg content. During diagenesis the interstitial water of high Mg concentration provokes the dolomitization of a marine $CaCO_3$ sediment deposited in an environment of normal salinity.

Under humid tropical climate, as shown by HANSHAW et al. (1971), the mixing of rainwater and seawater may result in such an interstitial solution (in case of a marine water of 5 to 30‰ salt content) which is undersaturated to calcite, but is supersaturated to dolomite. This condition is fulfilled in the sediment at the interface between the interstitial water of seawater origin and the rainwater-filled lenses. Consequently, dolomitization zones are formed there. In case of a water level sinking, as a result of temporary regression, sediments of considerable thickness deposited earlier may be dolomitized this way.

Since the Late Triassic in this area was characterized by an arid climate, the firstly discussed series of processes seems to have taken place. In other words, the dolomitized rock would suggest that in addition to the environments identified on the basis of petrological and paleontological features a cyclic recurrence of emergence should also be reckoned with, in spite of the absence of any terrestrial sediment.

Consequently, the "transgression-regression" series periodically repeating itself on the marginal shelf platform consists of the following episodes: *1.* with a rise in water level, the terrain emerged at the end of the preceding cycle is completely covered by a shallow-water sea—an algal mat is formed over large areas; *2.* continued rise in water level and differentiation of the environment—mobil calcareous sand zone and a protected back-lagoon behind it, are formed; *3.* the sea retreats—larger and larger areas emerge and the dolomitization of the sediments deposited during this very cycle begins.

Rezi Dolomite Formation

The brownish-grey thinly laminated dolomite beds assigned to the Rezi Formation are exposed in the Városi-erdő subarea (Fig. 3). This formation was distinguished, upon its lithological and paleontological characteristics, already by L. LÓCZY (1913) from the Hauptdolomit, while J. NOSZKY (1958) referred to it as "Kössen Dolomite".

The largest contiguous outcrops occur on the southwestern side of the Városi-erdő, but even there only a few metres of the sequence's interval can be traced owing to tectonic dismembering and disadvantageous dip angles. The rock is a dark grey, finely crystalline, laminated or thin-layered (or medium-to thick-bedded), bituminous dolomite (Plate II, Fig. 1). In some places it contains tiny dissolution cavities or pores. A rock of conformable lithology can be observed also along the valley crossing the Városi-erdő in a NE–SW direction.

Upon microscopic studies, the rock is composed of dolomite crystals of 10 to 200 μm size. In rare cases, micrite patches occur, too. The sediment seems to have been totally recrystallized during dolomitization, for it has lost its original textural features and the traces of microfossils, if any, cannot be recognized either.

A typical outcrop, rich even in megafossils, of the upper part of the formation can be found on the northwestern side of the Városi-erdő, near the watering-well (Lókút), having been described already by L. LÓCZY and eventually by S. VÉGH. In a rock wall about 2 m tall, dark brown, finely crystalline dolomite is exposed here. Varying between 1 and 2 cm as a rule, the thickness of the beds may be as much as 10 cm in rare cases. The thinly laminated beds are characterized by a microlaminated internal structure. Texturally this lithofacies type is an equigranular dolosparite consisting of 10 to 50 μm crystals. The microlaminated pattern is due to the alternation of lighter and less coarsely crystalline laminae with darker ones (a structure of nonalgal origin being dealt with).

The thicker beds, as a rule, are composed of dolosparite of rather coarse crystal size (50–100 μm) and even micrite patches can often be observed which were probably formed as a result of dissolution of green algal skeletons, the resulting cavities having eventually been filled with mud.

The beds and lenses rich in megafossils are also composed of dolomite (Plate II, Fig. 2) which is worthy of being emphasized for the very simple reason that in the type area of the formation near the village of Rezi the limestone lenses are rich in fossils. The characteristic texture is biomicrosparite or biosparite. Dissolved and then sparite-filled mollusc shell fragments and the remains of green algae, partly dissolved and partly filled with calcareous mud *(Dasycladacea)*, are frequent.

From the exposure, S. VÉGH listed a fauna as follows:

Modiola minuta (GOLDF.)
Pteria galeazzi (STOPP.)
Izognomon lóczyi (FRECH)
Cardita austriaca (HAU.)
Cardita cf. *luerae* (STOPP.)
Worthenia aldae (STOPP.)
Pleurotomaria sp. (aff. *costifera* KOKEN)
Promathildia hemes (D'ORB.)

In addition Cs. DETRE, from the material sampled by ourselves, identified the following forms:

Lima praecursor (QU.)
Entolium hehlii (D'ORB.)

The fauna is characterized by a relatively low number of species and a very high number of specimens.

The chemical composition of the Rezi Dolomite does not differ substantially from that of the Norian Hauptdolomit. This is clearly indicated by the analyses of type samples from the formation (the analyses were performed at the Central Research and Design Institute for the Silicate Industry):

	Hauptdolomit Szőlő-hegy	*Rezi Dolomite Formation* Városi-erdő (Lókút)
SiO_2	tr	tr
TiO_2	0.01	tr
Al_2O_3	tr	tr
FeO	0.14	0.08
MgO	20.81	20.78
CaO	31.60	31.90
Na_2O	0.04	0.01
K_2O	tr	tr
SO_2	tr	tr
Loss on ignition	47.40	47.34

The DTG and X-ray patterns obtained for the samples are also very similar in the case of the Hauptdolomit and the Rezi Dolomite, respectively. Consequently, no characteristic divergence between the two formations can be observed in the crystallization characteristics of the dolomite either.

The borehole Süt-30 put down in 1979 by the exposure at the watering-well penetrated into the unit in question with a dip of 20 to 40° and in a thickness of 153 m. No remarkable lithological change could be observed within the penetrated interval. The rock is a medium to dark grey dolomite throughout the interval (CaO 27–29%, MgO 19–21%). It is generally thick-bedded and includes thin- and even microlaminated interbeddings as well. In some horizons the tiny dissolution cavities (probably deriving from the dissolution of algae) are quite frequent. In general, the remains of *Bivalvia*, *Gastropoda* and *Brachiopoda* are locally enriched in the thinly laminated parts. As shown by the analyses of type samples, the insoluble residue varies between 0.2 and 1.0%, the organic C content between 0.02 and 0.06% and the light bitumen content between 0.001 and 0.01%.

From the Városi-erdő outcrops the Rezi Formation can be traced over several kilometres in SW direction (the vicinity of the Lesence valley) farther on, but owing to the lack of proper outcrops the line and the character of the contact with the Hauptdolomit could not be determined. To the northeast of the Városi-erdő subarea the Hauptdolomit has a tectonic contact with the Rezi Dolomite.

In the range extending east of Sümeg, the data concerning the presence of the formation are scarce. The dolomites underlying the alternating limestone-dolomite interval at the base of the S-31 borehole section may be probably assigned to this unit. The dark grey bituminous dolomite cut by bauxite-exploratory boreholes near Kozma-tag and Csabrendek can also be identified with the Rezi Dolomite.

The calcareous dolomite (CaO 32.8–33.4%, MgO 18.2–18.6%) intersected in the lowermost part (541.9–560.1 m) of the borehole Sp-1 can be assigned, conditionally though, to the Rezi Formation.

Chronostratigraphy

The Rhaetian age (in the earlier sense) of the Mollusca fauna known from the exposure at the Városi-erdő (Lókút) and representing the upper part of the formation is proved convincingly (S. Végh 1964).

In the light of the results of the examination of the type section near Kössen (Ulrichs 1973), however, the *Rhaetavicula contorta* beds seem to be older than the horizon of the zonal fossil *Rhabdoceras suessi* and thus older than the Rhaetian in the revised sense.

No doubt, Rhaetian formations of considerable thickness are still to be found above the Rezi Dolomite:Rezi-Dachstein transitional unit and the Dachstein Limestone and, in the range east of Sümeg, supposedly also above the Kössen Formation to the northwest of the Városi-erdő subarea. Judging by the above, the Rezi Formation would belong chronostratigraphically to the Upper Norian, the top of the Alaunian, or possibly to the lowermost Rhaetian.

Paleoenvironment

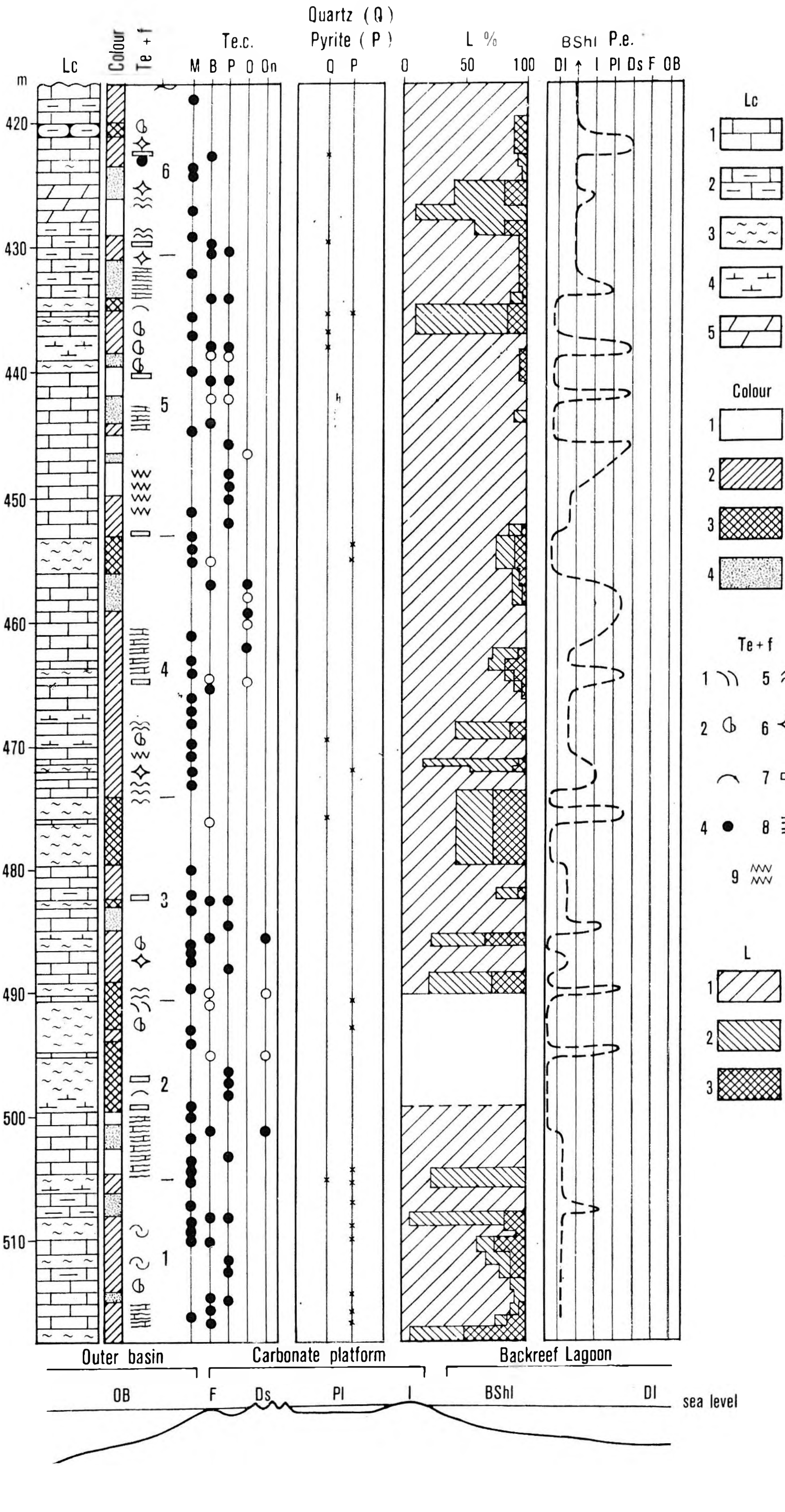
To reconstruct the genetic conditions is difficult because of the marked recrystallization of the rock has obliterated the primary textural pattern, as a rule, beyond recognition. Thus we have to resort primarily to conclusions deduceable from the megafossils and the rock structure.

The rock's dark grey colour, its bitumen content, suggests reductive conditions to have existed near the one-time bottom, the accumulating mud rich in organic material was usually neither stirred nor reworked by currents or wave action. The laminated or microlaminated rock structure locally observable suggests a quiet, non-agitated sedimentary environment, too.

The bivalve fauna consists mostly of thin-shelled, benthonic forms that lived in a poorly-agitated shallow-water regime. The locally observable lumachelle-like accumulations of mollusc shells indicate, however, that the bottom got periodically into the zone of wave action.

As observed in the borehole Süt-30, some individual lithofacies types detected in outcrop repeat themselves, alternate, i.e. the environment of sedimentation too seems to have changed cyclically.

Accordingly, sedimentation took place, as a rule, in a bay or lagoon that was landlocked and generally quiet, liable only to periodical wave action. The sediment that was deposited in it originally seems to have been calcareous mud. Dolomitization is the result of early diagenesis and probably due to the reaction of the Mg^{2+}-rich bottom waters produced by the periodical evaporation of the lagoon and having got into interaction with the earlier-deposited calcareous mud. The dissolution of fossil shells and tests was probably connected with later phases of emergence.



Quartz (Q)
Pyrite (P)
Lc
Colour
Te + f
Te.c.
M B P O On
Q P
L %
0 50 100
BShl P.e.
Dl I Pl Ds F OB
m
420
430
440
450
460
470
480
490
500
510
Outer basin
Carbonate platform
Backreef Lagoon
OB F Ds Pl I BShl Dl
sea level

Kössen Formation

In outcrop no typical representative of the Kössen Formation is known. Namely, in the western part of the study area, where the Triassic is exposed, the sequences already show a character of transition between the Kössen and the Dachstein Formations. Such a sequence is exposed in the abandoned quarry lying at the northern fringe of the Városi-erdő.

The typical development of the formation was discovered first in the borehole Sp-3 put down to the northwest of Sümeg in 1960, then it was cut in a different facies by the borehole Süt-17 at the foot of the Vár-hegy, its section having been studied in detail as a key section. In recent years the unit involved has been intersected, in varying thickness, by several bauxite-exploratory wells as well.

Local type section: borehole Süt-17

The basic lithological features and fossils of the sequence selected as a local type of the formation are contained in Fig. 5 and 6 and in Table 1. On the basis of the lithological features the Upper Triassic sequence of the borehole can be split up into two major parts within which several cycles can be distinguished.

The typical form of the Kössen Formation is represented by that part below the depth of 453.5 m whereas above that level (453.5–417.0 m) a transitional facies between the Kössen and Dachstein Formations could be observed.

The Kössen Formation is characterized basically by grey, dark grey marls, argillaceous-marls, calcareous marls and limestones the alternation of which is governed by a definite pattern (Fig. 7). Here are the features of the cycles composing the system:

Member A. Grey, less frequently greyish-white, yellowish-brown, dolomitic limestone, calcareous dolomite with a wavy microlaminated structure, and desiccation pores. A peculiar type of texture is micrite (mudstone). The thinly laminated structure is often conspicuous even during microscopic examination. Fossils are usually absent, in rare cases remains of coproliths being observable (*Parafavreina thorontensis* Brön. in Cycle 3). In a definite interval of Cycle 2 *Globochaete*, *Ostracoda* and small *Gastropoda* remains were recognizable in minor quantities.

Member B. Grey, less frequently greyish-brown limestone, argillaceous limestone, dolomitic limestone, calcareous marl with thin interbeddings of dark grey marl. The limestone is often patterned with a dense clay film structure, in rare cases even authigene breccia can be observed. Characteristic texture types: micrite (mudstone), bio- and pelmicrite, and intramicrite (wackestone). In Cycle 4 an oömicrite, oösparite texture is typical. Beside carbonate components some quartz silt can also be observed in some samples. Of the fossils the *Brachiopoda* and, mainly in the marly parts, the thin shells of *Bivalvia* are frequent. Small *Gastropoda*, *Ostracoda* shells and skeletal elements of *Echinodermata* can be found quite regularly. In the lowermost exposed cycle the representatives of *Globochaete* are also frequent, being eventually present just sporadically. Foraminifera, if any, are present just sporadically, the representatives of *Glomospirella* and *Aulotortus* appearing to be characteristic (Table V, Fig. 1).

Member C. Dark grey, thinly laminated, locally authigene-brecciated marl and calcareous marl. According to X-ray results (A. Szemethy), in addition to about 50% calcite and 20% illite, illite-montmorillonite and montmorillonite clay minerals, the marl beds contain 20% ankerite as well (in the gasometric examination of calcite-dolomite samples, this presented itself as dolomite). In addition, a little quartz, pyrite and K-feldspar could also be identified. The carbonate rock types examinable in thin section show usually a micritic or pelmicritic texture, though thin layers of oösparite texture can also be shown to have been interbedded.

The quantity of fossils is usually poor, some beds being totally unfossiliferous, while in others there are masses of thin-shelled *Bivalvia* fragments or *Ostracoda* valves and the fragments of *Crinoidea* and *Ophiuroidae* are also abundant. In beds of oösparite texture specimens of *Aulotortus* and, in one place, *Triasina hantkeni* Majzon specimens could also be observed (Plate IV, Fig. 3, Plate V, Fig. 3).

In the Kössen Formation of the borehole section four cycles could be identified. The cycles are asymmetric. The sequence can be described by the general formula *ABC*... *ABC*...

←

Fig. 5. Results of analysis and genetic interpretation of the Kössen Formation interval of the sequence cut by the borehole Süt-17

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. marl, 4. calcareous marl, 5. dolomite. — ***Colours:*** 1. white, 2. grey, 3. black, 4. yellow. — ***Characteristic texture and fossils*** (Te+f): 1. Ostracoda, 2. Brachiopoda, 3. Mollusca, 4. oöid, 5. algal mat structure, 6. desiccation pore, 7. intraformational (authigenic) breccia, 8. clay film texture, 9. stylolitic pattern. — ***Textural composition*** (Te.c.): ○ sparite (cement), ● micrite (matrix), B bioclast, P pellet, O oöid, On oncoid (B-On grains determining the character of texture), M micrite (grain <10%). — ***Lithofacies composition*** (L): 1. calcite, 2. dolomite (ankerite), 3. insoluble residue. — ***Paleoenvironment*** (P.e.): *Dl* deeper part of lagoon, *BShL* backreef shallow-water lagoon, *I* intertidal zone, *Pl* platform, *Ds* drifting sand, *F* front-reef, *OB* outer basin

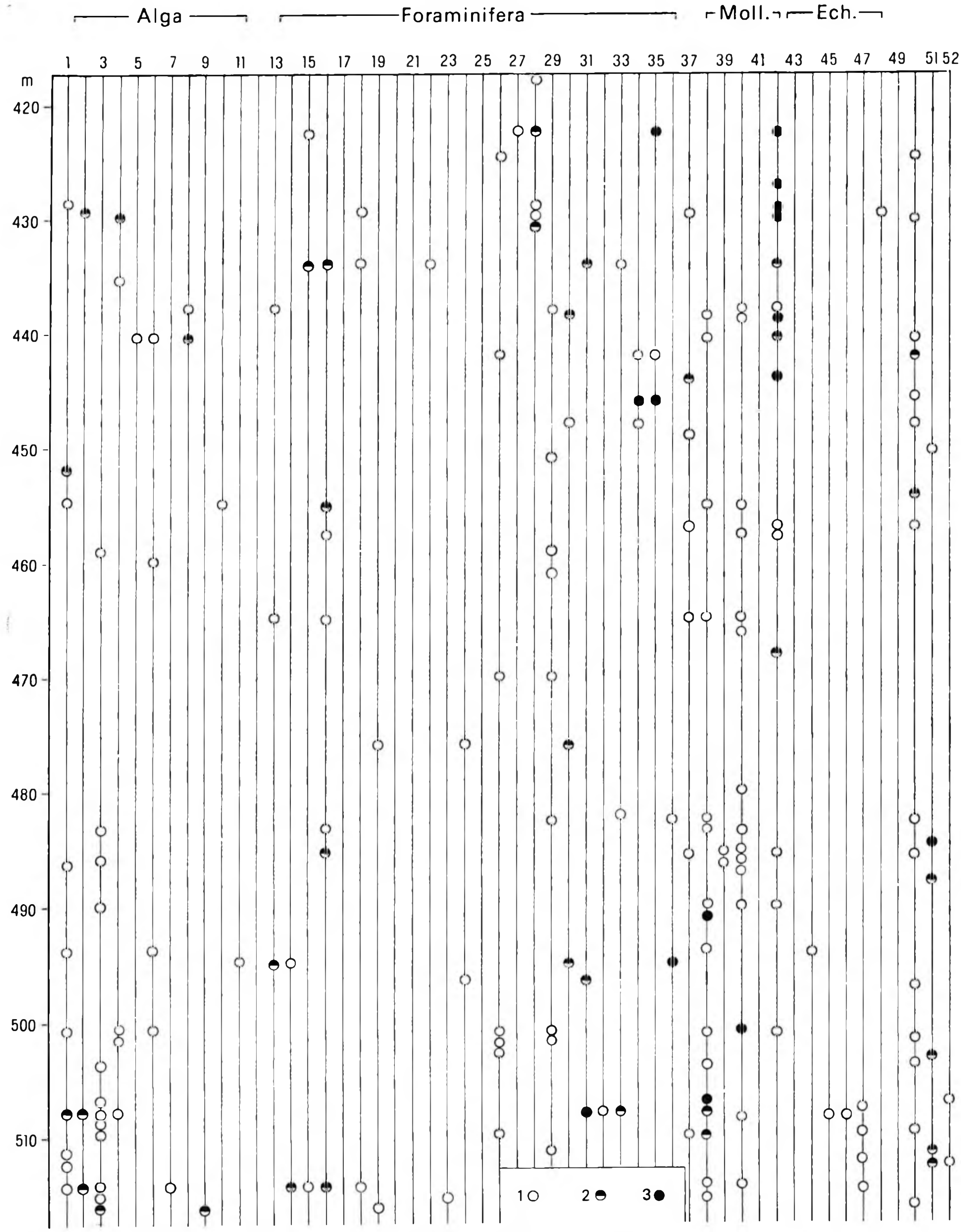


Fig. 6. Microfossils from the borehole Süt-17

1. Scarce, 2. fair, 3. abundant

1. Globochaete alpina, 2. G. hronica, 3. G. tatrica, 4. Calcisphaera sp. 4., 5. Aeliosaccus dunningtoni, 6. A. sp., 7. Baccanella floriformis, 8. Halicoryne sp., 9. Microtubus communis, 10. Aciculella cf. bacillum, 11. Thaumatoporella parvovasiculifera, 12. Mikroproblematika 4., 13. Glomospira tenuifistula, 14. Glomospirella hoi, 15. Gl. amplificata, 16. Gl. sp., 17. Tolypammina eisenthelensis, 18. T. sp., 19. Ammobaculites cf. zlambachensis, 20. Trochammina alpina, 21. T. sp., 22. Tetrataxis humilis, 23. Agathammina austroalpina, 24. Planiinvoluta sp., 25. Pseudonodosaria pupoides, 26. Nodosaria sp., 27. Lenticulina sp., 28. Frondicularia woodwardi, 29. F. sp., 30. Aulotortus friedli, 31. A. sinuosus, 32. A. cf. pragsoides, 33. A. tenuis, 34. A. sp., 35. Triasina hantkeni, 36. Foraminifera indet. sp., 37. Brachiopoda (Pelagic? juv.), 38. Mollusca, 39. Pelagic Moll., 40. Gastropoda, 41. Pelagic Gastr., 42. Echinodermata, 43. Pelagic Echinodermata, 44. Priscopedatus sp., 45. Theelia cf. florida, 46. T. insorbicula, 47. T. sp. (44—47. Holothuroidea), 48. Ophiuroidea, 49. Echinoidea spine, 50. Ostracoda, 51. Parafavrenia thoronetensis, 52. Thoronetia sp.

The cyclic structure of the sequence can be traced even above the typical Kössen Formation (Fig. 5). The only difference is that here the *Member C* of dark grey marl composition is absent. This implies, however, a marked change in the megaloscopic pattern of the rock which now becomes similar to the Dachstein Limestone. Its microfacies features too stand close to those of the typical Dachstein Limestone and it is in this interval that the typical Foraminifera, *Aulotortus* and first of all *Triasina hantkeni* MAJZON, become common.

There are also marked differences in some features between the cycles, of which the variation of the thickness of *Member C* is most conspicuous.

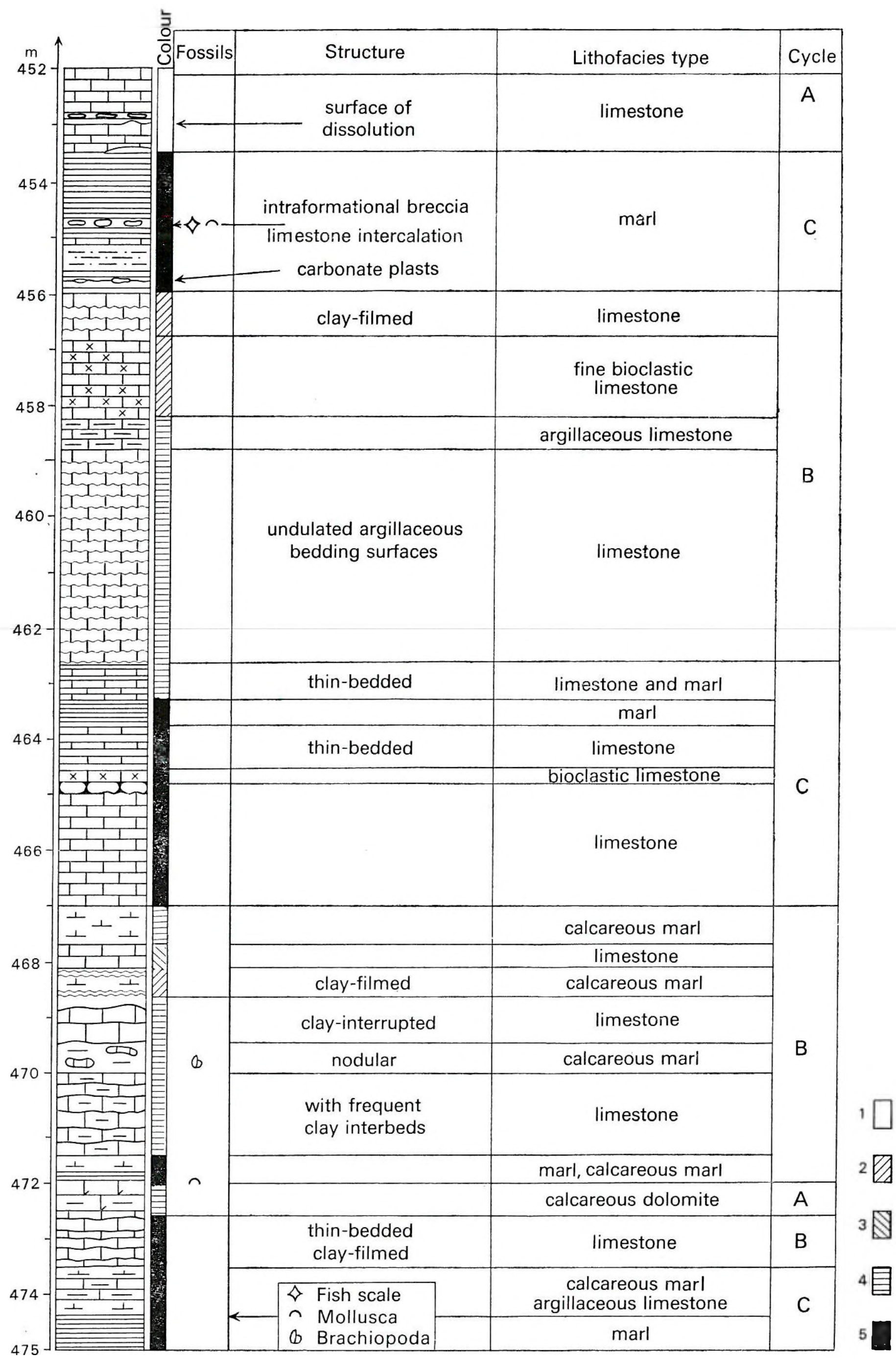


Fig. 7. Cyclic changes in character observable in the Kössen Formation interval of the borehole Süt-17

Colours: 1. white, 2. yellow, 3. brown, 4. grey, 5. dark grey, black

Depth m	Dtg %					Wet chemical analyses %													
	Kalcit	Dolomit	Illit	Ankerit	Pirit	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	$-H_2O$	$+H_2O$	CO_2	P_2O_5
408.2	96		tr			1.69	tr	0.45	0.35	0.04	0.05	53.28	1.04	0.3	0.19	0.12	0.98	41.46	0.05
415.5	91	tr				5.38	0.08	0.67	0.43	0.08	tr	49.66	2.09	0.31	0.43	0.04	0.99	39.73	tr
429,7	89		tr			6.66	0.12	2.39	0.71	0.05	0.04	49.3	tr	0.32	0.47	0.2	1.41	38.5	tr
438.0	97					1.08	tr	0.23	0.19	0.04	tr	53.79	1.2	0.28	0.13	0.03	0.56	42.6	tr
444.5	94					2.15	0.03	0.60	0.32	0.04	tr	52.56	1.04	0.31	0.26	0.08	0.57	41.8	tr
450.2	99					0.28	tr	tr	0.05	0.02	tr	55.38	0.29	0.28	0.04	0.03	0.45	42.85	tr
455.0	*			73		14.28	0.22	5.03	1.59	0.37	0.03	36.25	5.22	0.35	1.24	0.61	2.35	31.98	0.05
460.0	100					0.28	tr	tr	0.07	tr	tr	54.73	0.52	0.26	0.01	0.08	0.4	43.0	tr
463.0	*			95	tr	3.44	0.07	2.52	0.5	0.12	tr	47.12	4.18	0.25	0.22	0.17	0.51	40.55	0.02
472.0						4.49	0.07	1.96	0.79	0.24	tr	31.9	16.2	0.32	0.25	0.16	2.27	41.35	0.05
475.0	tr			74	tr	13.22	0.16	5.26	1.07	0.49	tr	38.42	3.7	0.25	1.16	1.0	3.3	31.41	0.05
479.0		91	tr																
488.0	98					0.43	tr	0.12	0.11	tr	tr	54.88	0.42	0.22	tr	tr	0.58	43.02	0.01
488.9	99					0.5	tr	0.19	0.05	tr	tr	54.73	0.78	0.2	0.05	0.03	1.05	42.45	tr
506.1	tr	89	tr			5.6	tr	2.36	0.8	0.46	tr	32.62	14.1	0.36	0.55	0.2	2.68	39.87	0.04

tr = in traces

* Results obtained for both calcite and ankerite combined

The thickness of the marl beds is in the middle part of the exposed interval the highest (Cycles 2 and 3), decreasing from there both up- and downwards, while the number and thickness of the limestone interbeddings increases.

There is a change in the texture and the fossil content of *Member B* too, for the lower cycles are characterized by a micrite with planktonic microfossils, but very poor in allochemical components, while in the upper parts the biogenic components, the pellets and oöid grains increase in quantity, the planktonic organisms disappearing almost totally and the benthonic ones gaining a little bit in importance.

Other exposures

Similar in its basic features to the sequence of the borehole Süt-17 is the section of the borehole Sp-3 put down 2.5 km to the northwest of the former (Fig. 8). Here the Upper Triassic is exposed in 130 m. On the basis of the description, the sequence can be divided into three major parts: at the top (264.0–317.5 m) a dark grey to yellowish-brown limestone predominates with thin interbedded layers of greenish-grey marls and calcareous marls in the higher parts of the interval. In the middle (317.5–353.0 m) dark grey to black marls were intersected, while the basal part is represented again by a dark grey limestone. The 36-m-thick marl interval can be identified probably with the middle cycles of borehole Süt-17.

The middle part yielded the Mollusca fauna from which S. Végh (1964) identified forms similar to the Kössen Beds in Austria, as listed in the chapter Exploration History, and the palynological data concern (B. S. Venkatachala and F. Góczán 1964) this interval too.

In the range to the east of Sümeg and in the vicinity of Csabrendek several bauxite-exploratory boreholes have intersected the formation in smaller or greater thickness. The locations of these are shown in Fig. 3, the corresponding columnar diagrams being shown in Fig. 8. None of the boreholes has cut the formation completely, but the borehole sections enable us to compile a tentative stratigraphic sequence. Beneath the Dachstein Limestone the upper part of the Kössen Formation is represented by dark grey, brownish-grey limestone and dolomitic limestone (lower part of the borehole Ck-173, borehole Ck-169 and the upper part of the boreholes Ck-172 and S-29). The middle part of the formation is composed of dark grey to brown clay-marls, marls, calcareous marls, dolomitic marls with interbedded limestone layers (lower parts of the borehole S-29 and of the borehole Ck-172 and boreholes Ck-181, 176). The lower part of the formation is again more calcareous, being represented by limestone and dolomitic limestone (borehole Ck-177).

Consequently, the sequences exposed in the mountain range in question agree in main features with the sequence of the local key section provided by borehole Süt-17.

from the borehole Süt-17

Table 1

Trace elements ppm												Org. C %	Bitumen content %
B	Mn	Cu	Pb	Ga	V	Ti	Ni	Co	Sr	Cr	Ba		
25	1,600	60	4	1	10	160	16	10	1,000	10	100	0.0245	tr
25	1,000	60	4	1	16	160	6	10	600	25	100	0.0624	0.0025
25	600	60	4	1	10	160	16	6	1,000	25	160	0.0343	0.0025
25	1,600	60	4	1	10	160	4	6	1,600	25	100	0.0499	∅
25	1,600	40	4	1.6	16	160	6	6	1,000	25	100	0.0271	tr
25	1,000	40	4	1	16	160	4	6	1,000	1	100	—	tr
250	1,600	60	16	16	40	600	60	25	600	60	400	0.2313	0.0025
25	1,000	60	4	1	10	160	10	6	1,000	1	100	—	tr
25	1,000	40	4	1.6	10	160	10	6	1,000	16	100	0.0272	0.04
100	1,000	100	4	1	16	250	25	6	600	10	100	0.0408	0.0014
160	1,000	60	25	25	25	400	100	25	600	60	600	0.1427	0.00185
												—	—
25	1,000	40	4	1	25	160	4	6	1,000	1	160	—	0.02
25	1,000	40	4	1	10	160	4	6	1,000	2.5	100	—	0.0006
100	1,000	25	10	10	25	250	25	16	600	16	250	0.0613	0.0009

Chronostratigraphy

For judging the chronostratigraphy of the formation the following paleontological data are available:

From the marls exposed in the middle part of the Kössen sequence of borehole Sp-3, S. VÉGH (1964) identified the following faunal assemblage:

Modiola faba (WINKL.)
Modiola minuta (GOLDF.)
Pteria falcata (STOPP.)
Pteria sp.
Rhaetavicula contorta (PORTL.)
Cardita sp.
Lucina alpina (WINKL.)
Anatina sp.

No doubt, the Bivalvia fauna, as stated by S. VÉGH (1964), can be well identified with the assemblage known from rocks of similar facies (Swabian facies of the Kössen Beds) of the Alpine type sections. A number of species of a short biochron considered important from the viewpoint of chronocorrelation [*Modiola minuta* (GOLDF.), *Rhaetavicula contorta* PORTL.] can be found in the classic Kössen section as well. On the basis of faunal correlation, S. VÉGH assigned the sequence of the borehole Sp-3 to the Rhaetian.

During a revision of the section by Kössen (M. URLICHS 1973) it turned out that the typical Mollusca fauna of the Sümeg section, in spite of the unchanged basic facies characteristics, disappears from the sequence before the appearance of the zonal index fossil *Rhabdoceras suessi*. Accordingly, that part of the section correlated with the middle interval of the borehole Sp-3 of Sümeg would belong to the Alaunian substage of the Norian stage or possibly to the lower part of the Rhaetian.

From the afore-mentioned interval of the borehole, B. S. VENKATACHALA and F. GÓCZÁN (1964) listed the following spore-pollen assemblage:

Classopollis, *Corollina* and *Granuloperculatipollenites* assemblage	41%
Ovalopollis	4%
Vitreisporites	2%
Hystrichosphaeridae	23%
Other spore elements: *Anapiculatisporites*, *Todiosporites*	
Gymnospermae pollen grains: *Vatreisporites*, *Podocarpidites*	

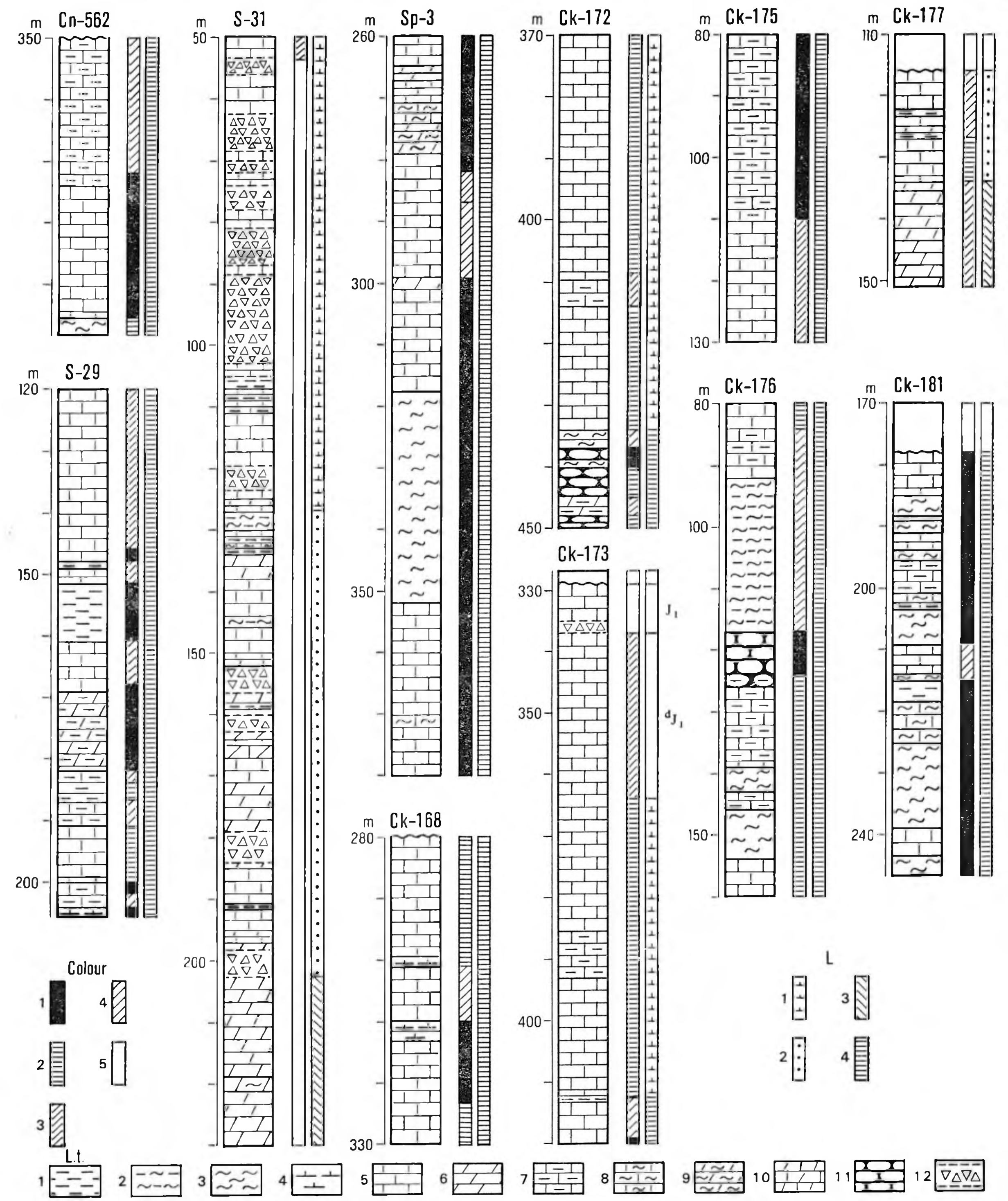


Fig. 8. Boreholes that have exposed Upper Triassic rock in the Sümeg area

Lithofacies type **(L.t.): 1. clay, 2. argillaceous marl, 3. marl, 4. calcareous marl, 5. limestone, 6. dolomite, 7. argillaceous limestone, 8. marly limestone, 9. marly dolomite, 10. calcareous dolomite, 11. nodular limestone, 12. fault zone. — *Colours:* 1. dark grey. 2. light grey, 3. brown, 4. yellow, 5. white. — *Lithostratigraphic units* (L): 1. Dachstein Limestone, 2. Rezi—Dachstein transition, 3. Rezi Dolomite, 4. Kössen Formation**

A similar assemblage was found by F. GÓCZÁN in samples from the borehole Süt-17.

By studying thin sections from that borehole J. ORAVECZ determined the following, chronostratigraphically interpretable microfossils:

Glomospirella amplificata KRISTAN–TOLLMANN
Glomospirella hoi KRISTAN
Glomospira tenuifistula HO
Tolypammina eisentealensis KRISTAN–TOLLMANN
Aulotortus friedli (KRISTAN)
Aulotortus sinuosus WEYN.
Aulotortus pragsoides (OBERHAUSER)
Aulotortus tenuis (KRISTAN)
Ammobaculites cf. *rhaeticus* KRISTAN
Ammobaculites zlambachensis KRISTAN
Triasina hantkeni MAJZON
Parafavreina thoronetensis BRÖNNIMANN
Thoronetia quinaria BRÖNNIMANN
Calcisphaera sp. 2. BORZA
Microtubus communis FLÜGEL
Aeolisaccus sp.
Globochaeta tatrica RADV.

As known at present, the afore-listed species span chronostratigraphically the Norian-Rhaetian, a more precise chronostratigraphic determination being impossible.

From the residue of washing from the 504.8th m of the borehole A. ORAVECZ-SCHEFFER determined the following Ostracoda remains (Plate V, Fig. 4, 6, 7):

Lutkevichinella keuperea WILL.
Healdia martini (ANDERSON)
Paracypris cf. *redcarensis* (BLAKE)

These species have come to the fore from the lower part of the classic type section near Kössen ("Swabian" facies). The joint occurrence of the species refers to the upper part of the lower interval, for in the upper interval of the profile *Lutkevichinella* are already absent, while *Healdia martini* and *Paracypris redcarensis* are not known in the lower part of the "Swabian" facies (ULRICHS 1973). Chronostratigraphically, this would mean the deeper part of the Rhaetian in the sense of the conventional classification and the upper part of the Norian stage according to the more recent concepts just mentioned.

Paleoenvironment

In analyzing the genetic conditions of the formation we can rely first of all on the results of detailed key section studies. The individual cycle-members discussed in the type section's description can be interpreted environmentally as follows:

The light-coloured limestone types of *Member A* seem to have been formed on a shallow-water carbonate platform of a warm sea, partly in the intertidal zone (microlaminated structure, desiccation pores), partly on a subtidal platform area characterized by weak water agitation. The water depth could not be more than a maximum of a few metres, the water was well-penetrated by sunlight. The oxygen supply for the seawater and also for the interstitial water of the topmost layers of the sediment was assured. The dolomitization of some beds seems to suggest a temporary emergence.

The pelitic facies of dark grey colour of *Member C* seem to have been deposited in deeper subbasins, lagoons, blocked by a reef—shallow platform zone from the open sea. There is no trace referring to a reduction in salinity which is indicative of a constant water exhange with the open sea—a statement confirmed by the sporadical marine microplankton and also by the *Hystrichosphaeridae* assemblage discovered by palynological investigations. The same is suggested by the *Ostracoda* assemblage and by the frequent *Crinoidea* and *Ophiuroidea* fragments recovered from the washing residue.

The closeness of the particular part of the lagoon and at the same time an arid climate is suggested by the floral assemblage (*Operculati* group–littoral gymnosperms) that can be reconstructed as a result of spore-pollen studies. There may have been hardly any water agitation at the lagoon bottom level (micritic-pelitic rocks), the muddy substratum became non-oxygenated environment which did not enable the oxidation of the incoming organic material either. The shortage of oxygen is suggested by the poor quantity of the benthonic faunal elements in the pelitic intervals, too. From time to time, the water became more agitated and consequently, richer in oxygen, as indicated by the oöidic interbeddings containing a rich benthonic fauna.

Judging by the oöidic interbeddings and the nature of the transitions into the platform formations, the water depth does not seem to have been great, being estimated at 10 to 50 m at the most.

Member B represents a transition between *Member A* and *Member C* so that the circumstances under which it was formed can also be taken to have been intermediate between the two and the facies area in question seems to have occupied an intermediate position in space as well.

The cyclic character of the sequence implies that the environment in which it was formed underwent permanent changes, that the facies were shifted in space, i.e. that the character of the system was periodically changing.

Dachstein Limestone Formation

The Dachstein Limestone is known to us from minor outcrops in the southern part of the Mogyorós-domb, the northwest part of the Városi-erdő and at the foot of the Hárs-hegy (Fig. 3). The outcrops, however, do not provide a well-examinable sequence of considerable thickness. For this reason, the local type section of the formation had to be explored by drilling on the Mogyorós-domb (borehole Süt-27). Like in the other profiles of the Sümeg area, the Dachstein Limestone is of relatively low thickness. On the basis of the geological features it appears that in the sequence, both downwards and lateraly, there are transitions and intertonguings with the adjacent, heteropical formations (Kössen and Rezi Formations). When discussing the Kössen Formation, mention was made of the concomitant transitional formations, while the transitions towards the Rezi Formation are discussed in this chapter. To trace the formation boundary upwards, towards the Lower Liassic Kardosrét Formation, is rather difficult, for the most striking lithological features are the same. A more scrutinized observation, however, allows us to distinguish between the two formations even with an unaided eye, the differences in the microfacies being rather conspicuous.

Local type section: borehole Süt-27

The local type section of the formation is exposed in the borehole Süt-27 put down at a distance of 150 m to the south of the *Conchodon*-bearing Dachstein Limestone outcrop (Fig. 9a–b). A typical Dachstein Limestone was intersected in the upper 0 to 24 m interval (virtual thickness: 10 m) of the borehole, while the interval underneath (24–90 m, virtual thickness 30–40 m) represents a transition between the Dachstein and the Rezi Formations. Identification of the original sequence of strata, primarily in the upper part of the borehole, is often hindered by a system of fissures, filled for the most part with Liassic rock.

The upper interval is made up of light grey to yellowish-grey, very finely crystalline limestone, containing sporadical Megalodon shell fragments. The texture of the rock is characterized by a mudstone or wackestone composition, though oö-, pel- and intrasparite (grainstone) types can also be observed (Plate VII, Fig. 3, 6). Chemically, the rock in 97 to 99% is made up of $CaCO_3$, its MgO content being 0.2 to 0.3%. Only in the lower part of the sequence does the amount of MgO attain 1.2%.

Among the microfossils the frequency of algae is conspicuous *(Thaumatoporella, Dasycladacea, Aeolisaccus)*. Of the Foraminifera the species *Triasina hantkeni* Majzon occurs in a great number of individuals (Plate VI, Fig. 3). *Triasina oberhauseni* Kristan and the representatives of *Aulotortus* and *Trocholina* are also confined to this interval (Plate VI, Fig. 2). *Frondicularia woodwardi* Howch. (Plate VI, Fig. 5) is represented in a great number of specimens. Sporadically, Ostracoda and Mollusca shell fragments can also be encountered.

The Lofer cyclicity, a feature often characterizing the Dachstein Limestone and represented by an alternation of occasional presence of a red, greenish limestone above the unconformity surface *(Member A)*, a limestone with algal laminae *(Member B)* and a massive Megalodus limestone *(Member C)*, cannot be observed in the topmost interval of the borehole. This interval shows features corresponding to *Member C* of the cyclic sequence.

Below the depth of 33 m in the borehole section a marked change can be observed in the lithological features and the fossil content as compared to those in the upper interval. In contrast with the pure limestone composition of the uppermost interval, the intercalation of dolomitic limestone beds is observable here. Quartz grains of silt size are also frequently observed, being present in considerable quantities in some beds. The rock colour is more diversified with an alternation of darker shades of grey with yellowish-brown and light grey. The Foraminifera characteristic of the upper interval *(Triasina, Trocholina, Aulotortus)* disappear and the other species show a marked decrease in the number of individuals, too. The cyclicity of the sequence is quite distinct. Two lithofacies types alternate:

1. Grey, brownish-grey, yellowish-brown dolomitic limestone and calcareous dolomite of 0.5 to 1.0 m thickness. The porous-cavernous structure probably due to dissolution of easily dissolvable evaporites is quite frequent. Desiccation pores, cracks and calcite druses are conspicuous. The microlaminated (algal mat) structure is also bound to these beds. The texture is usually micrite (or dolomicrite), though a heavily recrystallized dolosparite texture can also be observed. The rock is often unfossiliferous, less frequently containing a modest amount of fossil fragments.

2. Homogeneous limestone of usually lighter colour and of about 5 m thickness. Finely crystalline, locally calcite-speckled. Its chemical composition is similar to that of the upper interval, the $CaCO_3$ content is 97–99%—a pure limestone. The predomiant type of texture is micrite (mudstone), though bio-, pel- and intramicrite combinations also occur. The microfauna is rather poor, a few algal remains incertae sedis and a low quantity of Foraminifera *(Frondicularia, Textularia)* being encountered. Five cycles consisting of an alternation of the aforementioned types could be identified in the drilled section.

Other exposures

The borehole Süt-28 put down at a distance of 50 m to the south of the borehole Süt-27 on the Mogyorós-domb intersected the top of the Dachstein Formation in 5–6 m thickness, beneath the Lower Liassic Kardosrét Formation (below 189.6 m).

The rock is a darker grey, finely crystalline, calcite-speckled limestone or, the basal bed penetrated, a dolomitic limestone. The limestone texture is intra- or biopelmicrite or biopelsparite (Plate VII, Fig. 1, 4, 5, 7). The dolomite is recrystallized into a microsparite of micrite matrix. In the microfossil assemblage characteristic species of the Dachstein Limestone Formation can be found: the Foraminifera *Triasina hantkeni* Majzon, *Permodiscus pragsoides* Oberhauser, *Trocholina* sp., *Aulotortus* sp., *Aulotortus friedeli* (Kristan), *Frondicularia woodwardi* Howch., green algae, Globochaete, corals, Ostracoda, Mollusca and Crinoidea.

The drilled sequence cannot be correlated exactly with the local type section, the break between the two sections being obvious. It is, however, impossible to determine the size of this gap.

At 300 m north of the borehole Süt-28 (Fig. 12, 7th location), at the tectonic contact of the Triassic–Liassic and Dogger formations, a bed showing Dachstein Limestone features and containing chert globules of 1 to 1.5 cm diameter have been uncovered by trenching. The rock contains a great quantity of *Triasina hantkeni* Majzon specimens. The limited extension of the chert-globuled limestone suggests that we have to do only with a local modification rather than with a horizon of peculiar facies, a modification characterized by the settlement of a colony of Silicospongia.

Similar, chert-globuled rock blocks are otherwise common on the surface of the Mogyorós-domb. These were assigned to the Lower Lias by J. Noszky Jr. In the light of our results, these blocks derive from the Dachstein Formation.

At 170 m distance to the north of the type section is the site where the subhorizontal beds of the Dachstein Limestone (10°) are exposed in outcrop. These contain great quantities of *Megalodontidae* (specimens enclosed in lying position, Plate VI, Fig. 6). It is from here that the *Rhaetomegalodon (=Paramegalodus), Conchodon (=Conchodus)* and *Thecosmilia* remains described by S. Végh (1964) had been recovered. In the immediate neighbourhood of this outcrop was put down the borehole Süt-5 which went down to a T.D. of 202 m intersecting various types of limestone in full depth. Because of the very intense brecciation and the extremely great thickness of the Jurassic-filled fissure system the borehole section has not been suitable for a stratigraphic study with a key section approach.

On the northwestern side of the Városi-erdő there are outcrops of the Dachstein Limestone and its transitional variants, respectively, occupying a relatively large area (Fig. 3).

Exposed in the clearing along the road to Balatonederics with a WNW dip of 50 to 65°, the beds involved constitute essentially a continuous sequence extending from the lower transitional part of the Dachstein Limestone up to the Liassic Kardosrét Formation, though the faults, proved or supposed, may have provoked minor displacements anyway. The nature of the contact between the Upper Triassic limestones and the Rezi Dolomite exposed a little bit farther south, is obscure here owing to the lack of exposure.

In the basal part of the exposed sequence dark grey bituminous limestones and interbedded thin marl layers can be observed. The limestones have an intrabiosparite texture. The share of the biogenic component is 10 to 50%. Beside a few Echinodermata and Mollusca shell fragments the specimens of *Triasina hantkeni* Majzon occur in a great number in some beds.

The dark grey beds are akin to the Kössen Formation rocks both in habit and microscopic characters (in the upper part of the Süt-17 borehole section there is a lithofacies of this kind). Above them follows a typical greyish-white Dachstein Limestone with predominantly oösparite (grainstone) texture.

An atypical sequence, including marl interbeddings, of the Dachstein Limestone is exposed in the abandoned quarry on the northwestern margin of the Városi-erdő (Fig. 10). At the base of this sequence of 270/50° dip (Beds 1–8) a laminated to thick-bedded, brownish-grey, finely crystalline limestone can be observed. The characteristic texture is biointramicrosparite, intramicrosparite. The proportion of fossil elements is 25 to 35%, most of them *Mollusca, Brachiopoda* and *Echinodermata* shell fragments. Foraminifera, if any, are poor, a few *Glomospira* and *Trocholina* specimens having been observed. The bioclasts vary between 50 μm and 2.0 mm (average 300 μm) in size, being usually

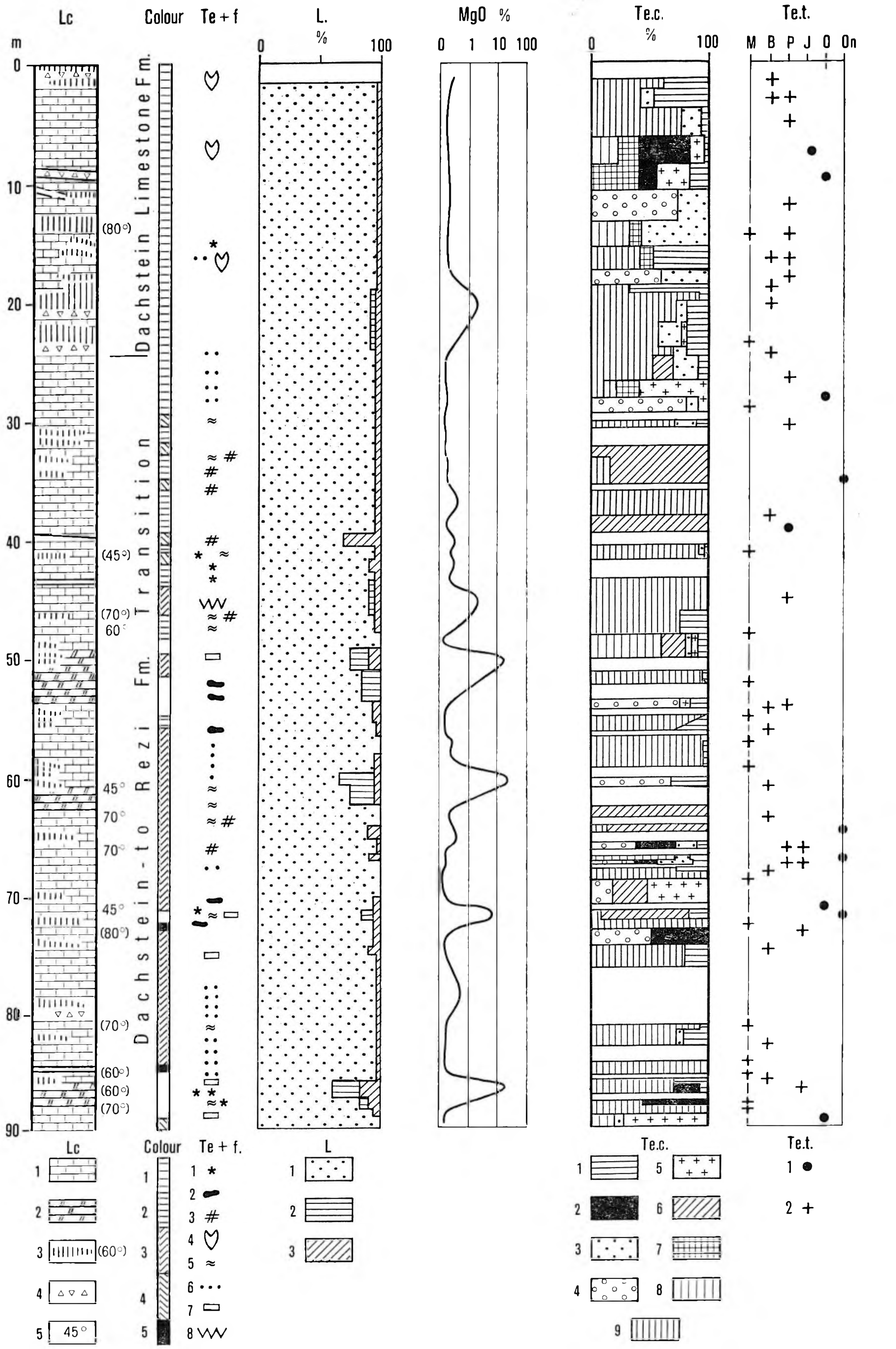
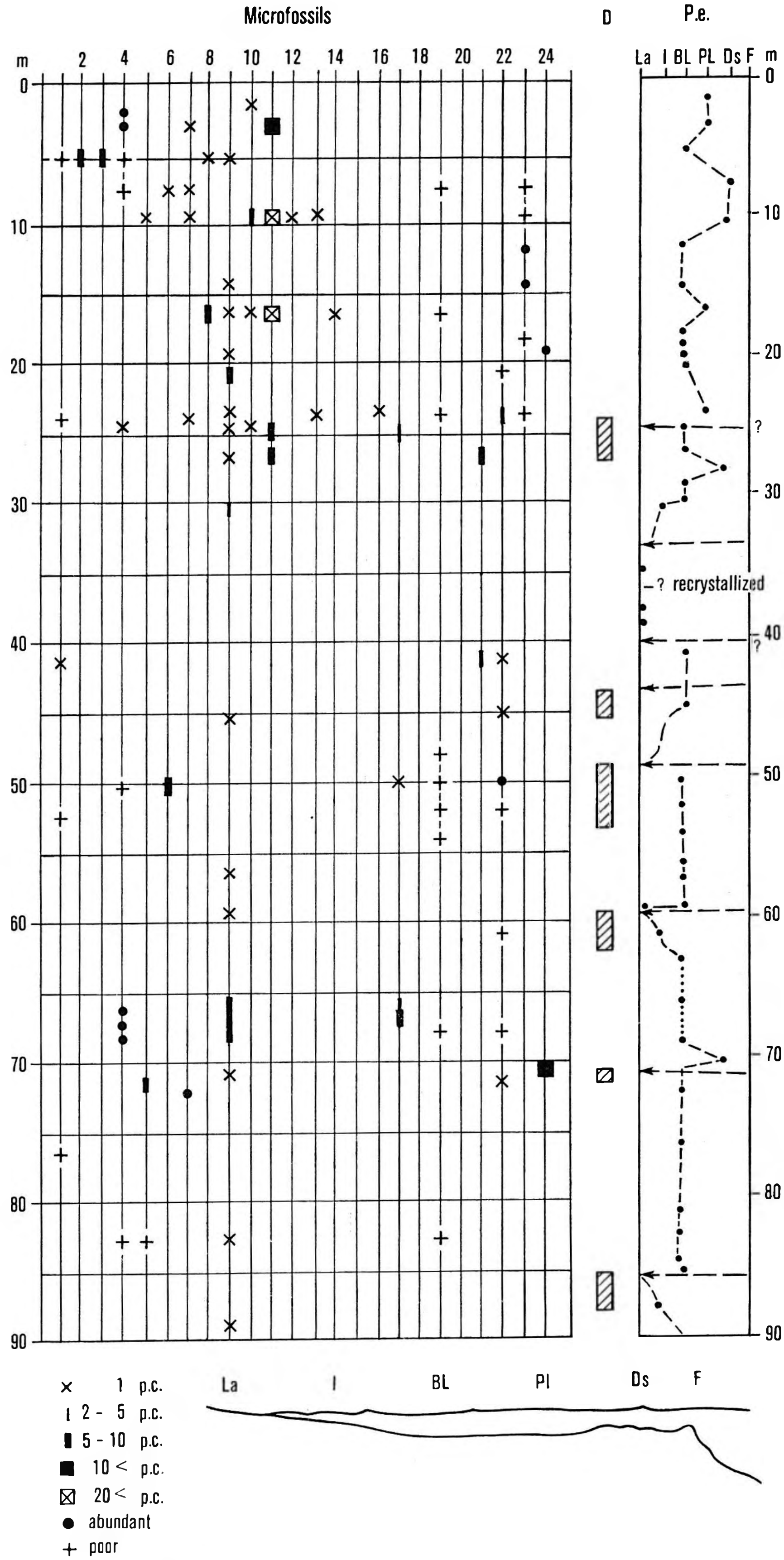


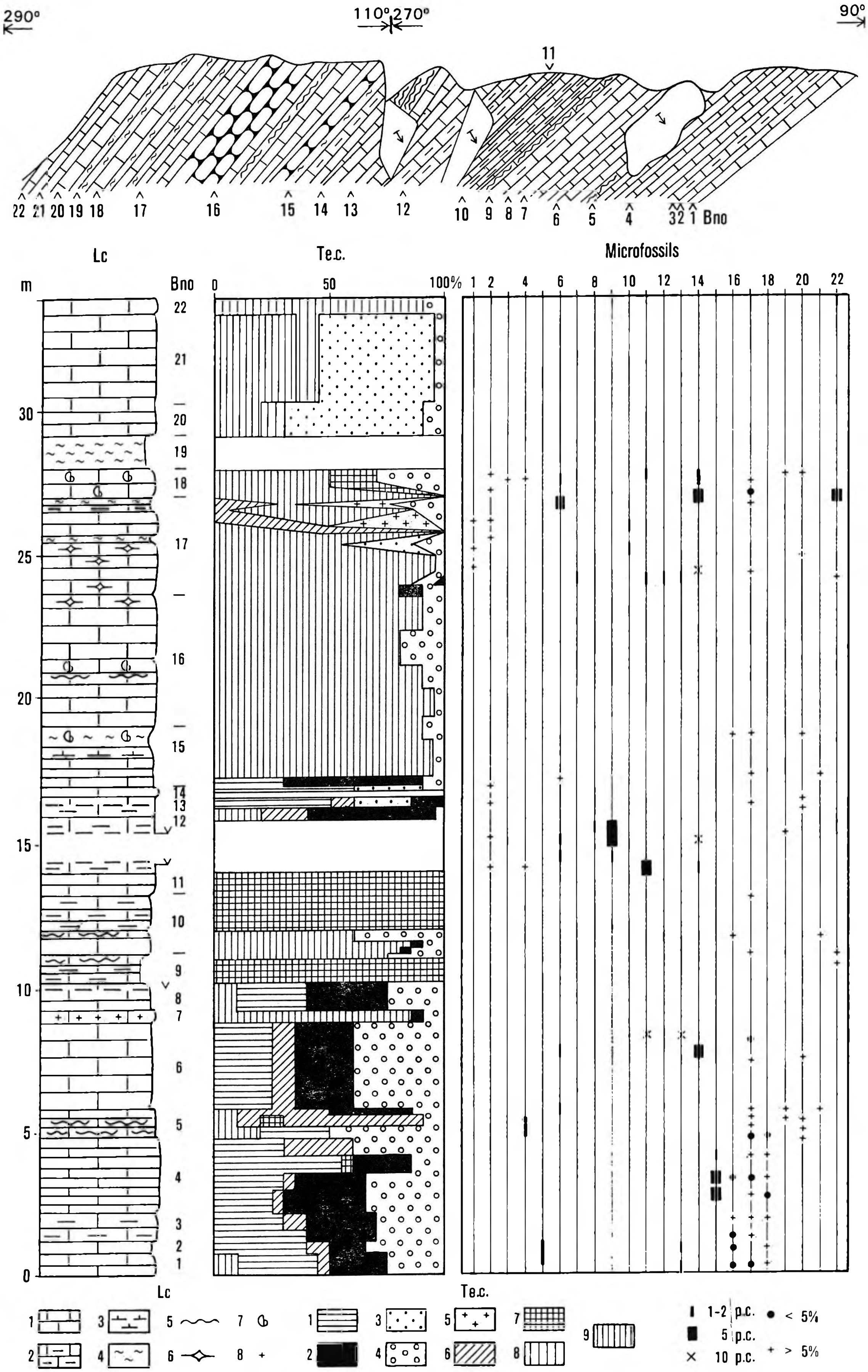
Fig. 9a—b. Lithologic column and analytical diagram of

Lithologic column **(Lc): 1. limestone, 2. dolomitic limestone, 3. Jurassic fissure-fill (with the angle of dip of fissure), 4. breccia along fissure,**
(Te + f): 1. druses, 2. colour patch, 3. porously dissolved rock, 4. Megalodus, 5. algal mat structure, 6. calcite-speckled, 7. intraclast, 8. stylo-
4. oöid, 5. oncoid, 6. interstitial sparite, 7. recrystallized sparite, 8. microsparite, 9. micrite. — ***Texture types*** **(after FOLK) (Te.t.):**
3. Thaumatoporella, 4. Alga indet., 5. Dasycladaceae, 6. Glomospira sp., 7. Nodosariidea, 8. Frondicularia woodwardi, 9. Aulotortus friedli,
18. Brachiopoda, 19. Mollusca, 20. Posidonia, 21. Gastropoda, 22. Ostracoda, 23. Coprolith, 24. Favreina. — ***D*** **reworked**



the borehole Süt-27 and evaluation of the paleoenvironment

5. dip of strata. — *Colours:* 1. light yellow, 2. dark yellow, 3. light grey, 4. medium grey, 5. dark grey. — ***Characteristic texture and fossils***
lite. — ***Lithofacies composition*** (L): 1. calcite, 2. dolomite, 3. insoluble residue. — ***Textural composition*** (Te.c.): 1. fossil, 2. intraclast, 3. pellet,
1. sparry cement, 2. micrite matrix, *M* micrite, *B* bio-, *P* pel-, *I* intra-, *O* oö-, *On* onco-. — ***Microfossils:*** 1. Globochaete, 2. Aeliosaccus,
10. A. sp., 11. Triasina hantkeni, 12 T. oberhauseni, 13. Trocholina, 14. Tr. permodiscoides, 15. Austrocolomia, 16. Adasaccus, 17. Textularia,
beds. — *Paleoenvironment* (P.e.): *La* land, *I* intertidal zone, *BL* backreef lagoon, *Pl* platform, *Ds* drifting sand, *F* front-reef



290°
110° 270°
90°
11
22 21 20 19 18 17 16 15 14 13 12 10 9 8 7 6 5 4 3 2 1 Bno
Lc
Te.c.
Microfossils
m
Bno
0 50 100%
1 2 4 6 8 10 12 14 16 18 20 22
30
25
20
15
10
5
0
Lc
Te.c.
1-2 p.c.
5 p.c.
10 p.c.
< 5%
> 5%

rounded. The intraclasts vary from 20 to 35%, their size from 200 to 800 μm (average 100–300 μm), being also rounded. The matrix and often also the allochemical components are recrystallized to varying extent.

The above beds get along a fault in contact with the second interval of the profile. The change in lithology is sharp. The rock is thin-layered, pelitic and often algal lamellar. Greenish argillaceous marl, marl and calcareous marl layers are interbedded with the dark grey to yellowish-brown limestones. Desiccation pores and cracks and a honeycomb of dissolution cavities can also be observed in them.

According to textural studies, there is an alternation of micrite, biomicrite, and dolosparite and dolomicrosparite layers. Dolomitization has reached different degrees, in some places only dolosparite patches can be seen in a micrite matrix, in other cases there is a complete recrystallization. Fossils are scarce, just a few *Glomospira*, *Mollusca* and *Echinodermata* fragments are coupled with *coproliths*.

The contact of the upper interval (Beds 16–20) with the preceding one is similarly tectonic. The rock is a light grey, finely crystalline limestone interbedded with calcareous marl and marl layers of varying thickness. The marly interbeds frequently contain a great quantity of *Brachiopoda*. The predominant texture is micrite, biomicrite, in some intervals the pellets, intraclasts and even the oncoid grains are considerable in quantity. The topmost beds show a pelmicrite texture.

The sporadical microfauna is composed of Foraminifera *(Triasina, Aulotortus, Frondicularia)*, *green algae*, *Globochaete*, *Mollusca*, *Ostracoda* and *Crinoidea*.

On the plateau at the top level of the quarry there is a great number of outcrops showing Dachstein Limestone features, locally with *Megalodontidae* and *hermatypical corals*. These can be identified with the limestone beds of the quarry section. The marly parts of the sequence are not observable in outcrop.

Along the Sümeg–Tapolca road, beneath the Gerinc quarry, minor outcrops of a light grey, finely crystalline Dachstein Limestone of peculiar lithological feature with *Megalodontidae* are known (Fig. 3). At about 150 m northwards from the outcrop, the borehole Süt-9 beneath the Upper Cretaceous penetrated into grey to dark grey calcareous dolomites and dolomitic limestones. A similar lithofacies type occurs in some minor outcrops at the entrance to the Gerinci quarry.

A more complete sequence of the transition between the Dachstein and the Rezi Formations was intersected by the bauxite-exploratory borehole S-31 drilled on the hillside behind the distillery to the west of the Gerinc quarry (interval 49.7–231.3 m, Fig. 8). Because of the steep dip (70–80°) and mainly because of the heavy tectonic deformation a more exact stratigraphic study could not be carried out.

The upper part of the sequence (up to 120 m) shows explicitely Dachstein Limestone features: light grey, somewhat pinkish, brownish, finely crystalline limestones alternate with grey to pink algal lamellar and greenish-grey, brownish-red-mottled argillaceous limestones. In the uppermost part the typical Foraminifera of the formation can also be encountered (*Triasina hantkeni* MAJZON, *Glomospira* sp., *Trocholina* sp.).

The middle interval of the sequence shows an alternation of limestones, dolomitic limestones and calcareous dolomites (dolomite content 0–80%). This interval represents the transition between the Dachstein and the Rezi Formations and can be correlated with the sequence of the borehole Süt-27.

During thin section studies observations indicative of a dolomitization process could be made. Scattered dolomite crystals, and minor dolomitized patches occur in the dolomitic limestone beds. In the calcareous dolomite samples the bulk of the matrix is already converted into dolomite; there some minor calcite-composed micrite islands and the outlines of the allochemical components (oöids, fossils) are still visible. In some cases the texture is already completely homogenized by dolomitic recrystallization and even relicts of allochemical components cannot be observed.

At the base of the sequence (below 226 m) the limestone beds already disappear. The dark grey, brownish-grey, calcareous and argillaceous dolomite can be assigned to the Rezi Formation.

←

Fig. 10. Sequence of strata exposed in the quarry on the northwestern margin of the Városi-erdő and analytical results

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. marl, 5. algal mat structure, 6. calcite druses, 7. Brachiopoda, 8. Desiccation pores. — ***Bed number*** (Bno) — ***Textural composition*** (Te.c.): 1. fossils, 2. intraclasts, 3. pellets, 4. oöids, 5. oncoids, 6. interstitial sparite, 7. recrystallized sparite, 8. microsparite, 9. micrite. — ***Microfossils:*** 1. Spongia, 2. Globochaete, 3. Acicularia, 4. Alga indet., 5. Glomospira, 6. Glomospirella friedli, 7. Nodosaria, 8. Lenticulina, 9. Frondicularia sp., 10. F. woodwardi, 11. Involutina, 12. I. communis, 13. Trocholina, 14. Triasina, 15. Foraminifera indet., 16. Brachiopoda, 17. Mollusca, 18. Echinodermata, 19. Crinoidea, 20. Ostracoda, 21. Echinoidea, 22. Coprolite

Of the boreholes put down in the range to the east of Sümeg, it is Ck-173 that discovered some Dachstein Limestone in a position underlying the Liassic Kardosrét Limestone. In addition, the boreholes Ck-167 and -169 did so beneath Upper Cretaceous formations.

Chronostratigraphy

Containing well-evaluable mega- and microfossils, the Dachstein Limestone beds of Mogyorós-domb represent, as suggested by *Conchodon infraliasicus* STOPP., *Rhaetomegalodon incisus* (FRECH) and the microfossils *Triasina hantkeni* MAJZON and *Aulotortus friedli* (KRISTAN), the upper part of the Rhaetian and, in continuous sequences, even the Triassic-Jurassic boundary can be drawn with good approximation (on the basis of Megalodus, Triasina disappearance, borehole Süt-28).

The complete sequence of the Dachstein Limestone in the Sümeg area is not known. Supposedly, the basal part of the formation is intersected by the borehole Süt-27, where the lower interval with alternating limestones and dolomites (a transition between the Dachstein and the Rezi Formations) could not be assessed chronostratigraphically with more precision owing to the poor microfauna. Only on the basis of the mode of occurrence is it probable that this interval may represent the lower (deeper) Rhaetian in the conventional sense, i.e. that it is approximately equal in age to the Kössen Formation discovered in boreholes Süt-17 and Sp-3.

In the light of the Süt-28 borehole section comprising the topmost part of the formation and the overlying Lower Liassic Kardosrét Limestone, it appears to be certain that the Dachstein Limestone encompasses upwards the totality of the Rhaetian stage.

Paleoenvironment

The genetic conditions of the Dachstein Limestone showing a large lateral extension and an enormous mass within the one-time Tethyan realm are known to us from a number of studies (H. ZANKL 1971, A. G. FISCHER 1964, E. FLÜGEL 1973, F. FABRICIUS 1966). It is evident from these works that the characteristic cycles of the formation reflect periodical changes in supratidal, wide intertidal and shallow-water backreef shelf platform environments.

In the Sümeg area too the genetic conditions of this formation may be obviously interpreted in a similar way, even though, in absence of proper profiles, a more exact study of the characteristics of the cycles has been impossible. The existence of the platform facies is proved by tangible facts (Süt-27 and S-31, microfacies analyses of surface samples, etc.), and in some cases even the intertidal algal mat facies could be identified.

A much more exact idea can be gained on the genetic conditions of the unit of transition between the Dachstein and the Rezi Formations, mainly in the light of the results from the borehole Süt-27. The environmental interpretation is presented, in Fig. 9, together with the analytical diagrams.

The cyclic nature of the sequence is conspicuous even in the transitional unit, as evidenced by the alternation of limestones and dolomitic limestones. On the basis of the microfacies we could draw the conclusion that both the dolomitic and the nondolomitic rock varieties had been formed in the back-lagoon tracts of the shallow-water platform. In some cases an intertidal facies can be recognized in the dolomitic unit. By virtue of the judgement expounded in detail in the discussion of the Hauptdolomit, even the phenomenon of partial dolomitization refers to the probability of a change in environment, namely a periodic emergence. During the short-lived emergence, dolomitization started to evolve in the upper reaches of the calcareous mud of the preceding cycle, but the process did not reach to complete dolomitization. Consequently, it can be assumed that the rock varieties of the transitional unit must have been formed generally in a more shallow-water environment as compared to the case of the typical Dachstein Limestone. Thus the emergence phase could last for a longer time than it was the case with the Dachstein Limestone, but shorter than in the case of the Hauptdolomit cycles.

Formation interrelations and environmental model

After describing the Upper Triassic formations exposed in the Sümeg area let us at tempt now to clear the interrelations of the rock bodies and to draft the paleoenvironmental model for the entire study area.

The Hauptdolomit exhibits uniform characteristics throughout the study area and even beyond it, no remarkable local change being observable. This means that during the formation of the Hauptdolomit in Carnian-Norian times, the study area belonged to a vast shallow-water environment and at that time the marine calcareous sediments of the preceding phase underwent an early diagenetic dolomitization.

Much more varied facies pattern is exhibited by the uppermost Norian and the Rhaetian formations, respectively. The sequences vary in character considerably even within short distances, heteropical, intertonguing formations being known, too. To the south of Sümeg (Városi-erdő, Mogyorós-domb), above the Hauptdolomit, lies the Rezi Dolomite differring considerably from the former, then, after a rather thick transitional unit, it is the Dachstein Limestone that follows (boreholes S-31 and Süt-27) grading into the Liassic Kardosrét Limestone (borehole Süt-28). In the northern part of the area the beds immediately overlying the Hauptdolomit are not known, though the calcareous marls and calcareous dolomites exposed in the lowermost part of the borehole Sp-1 seems to represent a transition from the Hauptdolomit to the Kössen Formation. The Kössen Formation and its transition to the Dachstein Limestone (boreholes Süt-17 and Sp-3) are known to us in more than 100 m thickness.

A common feature of the formations is the cyclicity. The limestone members of the cycles are very similar in the heteropical formations and the transitional units as well. A difference manifests itself primarily in the geological features of the marl and dolomite members.

On the basis of the spatial distribution of the sequences, the character of the intertonguings, the interpretation of the cycles and the chronocorrelation, the formation relations shown in Fig. 11 could be reconstructed.

In the light of tectonic observations it is well-known that the present-day position of the formations is not the same as the original one was, for considerable dislocations, imbrications are to be reckoned with in the post-Triassic history, mainly in the Austrian phase. According to our judgement, however, the principal features of the relative location of the formations have not changed essentially and thus the portray deduced from the present-day situation (a sketch without absolute distance values) does reflect the original conditions.

On the basis of the spatial position and the interpretation of the environmental characteristics of the individual formations, the environmental model shown in Fig. 11 has been developed. The area in question seems to represent the back-reef part of a shallow-water carbonate platform which in the regressive phase being figured encompassed an island range modestly emerging above sea level, the intertidal zone and the deeper back-lagoon. At transgression the land area would dwindle and the zones migrate (in terms of present-day directions) east to southeast. The fact that the Dachstein Limestone becomes common in the uppermost Rhaetian suggests a little differentiated morphology in latest Rhaetian time, when the deeper portion of the lagoon disappeared, the emergences being restricted to shorter spans of time, resulting but in partial dolomitization, if any.

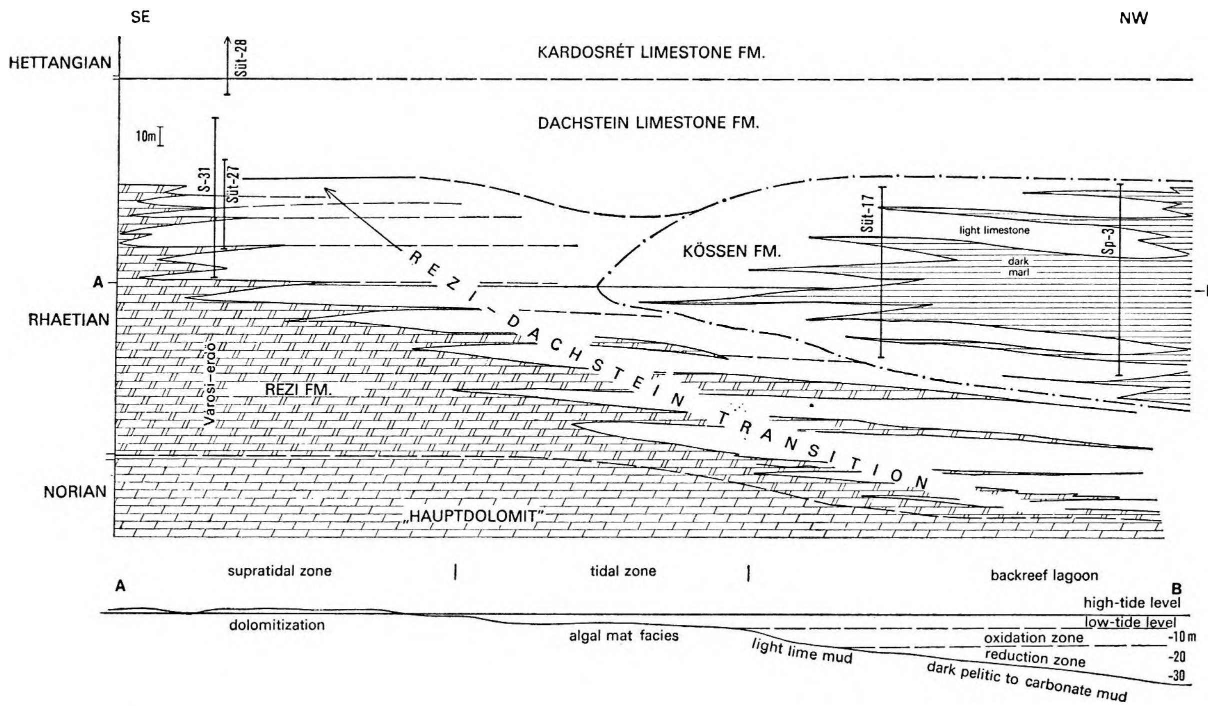


Fig. 11. Interpretation of the relations of the Upper Triassic formations known from Sümeg

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