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J. Haas—E. J.-Edelényi
L. Gidai—M. Kaiser—M. Kretzoi—J. Oravecz

GEOLOGY OF THE SÜMEG AREA

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Manuscript read
by
J. Fülöp, D. Sc., ord. memb. Hung. Ac. Sci.
and
Dr. Gy. Bárdossy, D. Sc. (bauxite), Dr. E. Dudich, Cand. D. Sc. (Eocene), Dr. A. Galácz (Jurassic), Dr. G. Hámor, Cand. D. Sc. (M. Miocene), Dr. Á. Jámbor, Cand. D. Sc. (Pannonian), Dr. L. Korpás, Cand. D. Sc. (Oligocene—L. Miocene), Dr. M. Pécsi, ord. memb. Hung. Ac. Sci. (Quaternary, geomorphology), Dr. E. Végh-Neubrandt, D. Sc. (Triassic)

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Techn. Editor
Mrs. I. Gergelyffy

Translated by
B. Kecskés

Translation revised by
I. Bérczi

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CONTENT

FOREWORD

From the second half of the 1950's on I dealt for more than twenty years—along with a lot of works of different orientation—with the geological study of the Sümeg area (Southern Transdanubia, Hungary). The first and immediate aim of that work had been to study the Lower Cretaceous formations the results of which were published in the monograph entitled "The Lower Cretaceous (Berriasian-Aptian) formations of the Bakony Mountains" (Geol. Hung. ser. Geol. 1964). The most remarkable result that arose from the investigations was the recognition of distinct paleogeographic connections with the Southern Alps and even with Southern Europe. Among the first who assisted me in the work were G. Hámor, R. Hetényi and E. Lédeczi, students preparing their theses at that time.

In 1958–59, in connection with diggings for a detailed micropaleontological study of the Upper Jurassic-Lower Cretaceous key section of Mogyorós-domb, prehistoric flint mines were discovered. It was the irregular appearance of the Berriasian microfauna that had made it necessary to re-excavate the section and to dig ever deeper in order to get the "disturbed" parts of the section exposed. It was in the course of this work that excavation workman L. Kocsis discovered the first implements made of antlers. In the following year I supported L. Vértes' first archeological examination of the new site by providing him with excavation facilities. The geologist who assisted me that time was J. Knauer.

To bring the new surficial key sections and geological key drillings (Sp-1–3, Süt-1–29, S(G)-1–6, S-7, Cn-850, Crt-12, Ng-1) to completion and to carry out their multidisciplinary geological investigation by M. Báldi-Beke, L. Gidai, F. Góczán, A. Horváth, M. Juhász, M. Kretzoi, M. Kurucz-Sidó, L. Móra-Czabalay and G. Vígh took a rather long time.

Playing a decisive role in the practical implementation of the original goals, my closest associates J. Haas and E. Edelényi joined in the geological study of the Sümeg area in 1971 still preparing their M. Sc. theses. In the last decade they carried out the geological mapping of the area on a 1:10 000 scale, considerably widening the circle of research and gaining contributions by additional specialists, Gy. Lelkes, M. Kaiser, J. Oravecz and A. Oravecz-Scheffer, who did their best to amplify the scope of the project.

Given the unique tectonic setting, the geological features suitable for serving as a stratotype and the presence of a wealth of artifacts of prehistoric flint mining, I proposed the site, in 1973, to be protected by nature conservancy legislation. Motivated by the need for conserving and retaining the site for the purposes of scientific research, pre- and post-graduate training and public education, the proposal was accepted by the president of the National Conservancy Office and the Mogyorós-domb site was declared a nature conservation area, by virtue of the 4/1976. (III. 24.) OTVH decree. In 1980, a considerable part of the site was expropriated by OKTH (=National Environmental Control and Nature Conservancy Office) and it was leased for administration to the Hungarian Geological Institute. At the expropriated site an open-air museum for exhibition of prehistoric flint mining artifacts has been erected.

The plan to establish a Training Base for Geological Fieldwork was conceived in my mind during my visit to the Lomonosov University's summer training center in conjunction with a geological study tour of the Crimea in 1973. The adversity of circumstances under which the geology students had to have their field training, the lack of permanent training grounds and the particular importance of modern facilities for their acquisition of the fundamentals of a geologist's field activities, were causes that urged for an issue. The best opportunity for solving this problem was offered by the Sümeg are awith its wealth of exposures and its diversified geological features. The first joint field training in geology for the geology and geophysics students of the Budapest (Eötvös Loránd University, Faculty of Natural Sciences) and the Miskolc (Heavy Industry Technology) universities was organized in the summer of 1978. During the training course, mixed groups of students (geologist-geophysicist, Budapest–Miskolc) have to carry out a complex geological model case study of a selected subarea from project planning up to completion of the final report including an economic geological assessment of the subject. In their work the students can rely, in addition to field traverses, on the interpretation of aerial photographs, geophysical measurements, trenching and drilling as well as laboratory analyses and tests.

The Sümeg area offers a key to geological understanding with excellent outcrops, stratotypes and fossil-rich stratigraphic units. It is an ideal study area for pre- and postgraduate training of geologists. Marked progress in scientific research and experience of mineral exploration have made it possible to synthesize the geological knowledge of the area—a synthesis to be implemented according to uniform principles and adapted to the didactic requirements of pre- and postgraduate training.

We are publishing this work primarily with the intention to help the training work at the Sümeg base. Hoping that the detailed geological analysis of this small, but geologically rich area may prove a handy tool for the purpose, we are confident that the evidence here expounded may contribute to the solution of geological problems in the wider neighbourhood as well.

Budapest 30 January 1981

JÓZSEF FÜLÖP
Academician

A REVIEW

by

J. Haas

Lying on the southwestern margin of the Bakony, between the Little Hungarian Plain (Kisalföld) and the Tapolca Basin, where mountains and plain meet, Sümeg is a favourite touristic highlight abounding with cultural and historical monuments of the Lake Balaton region (Fig. 1). Few of the visitors to and even of the residents of Sümeg are aware of the opulence with which this region has preserved the records of the geological past, the traces and marks left over by geological phenomena. The diversity of geological formations is worthy of attention not only from scientific viewpoint, but some of them can be exploited as raw materials for the building industry and aluminium industry, proving eventually suitable for being used even to fuel future power plants. As evidenced by archeological finds, the Mogyorós-domb to the south of the town was the scene of an extensive flint mining already in prehistoric times.

Geoscientists have for a long time been aware of the geological significance of the area.

In his travelogue of Hungary published in 1825, Beudant, the famous French geologist, did already mention some formations from the study area, describing limestone beds with Hippurites and Radiolites from the vicinity of Sümeg.

The first regular geological survey was carried out in the 1870's. On the 1:144,000-scale map of János Böckh published in 1875 the geological features and the major formations of the Mesozoic block of Sümeg were already well outlined.

The discovery of the Upper Cretaceous coal seams of Ajka also falls in the fifties of the last century and this development pushed the exploration of the Sümeg area, with its geology similar in many respects to the former, into the fore. It was first of all the works and papers of János Böckh and Miksa Hantken that called attention to this circumstance.

Marked progress after these pioneering ventures came with the activities of Lajos Lóczy Sr. Lóczy's recognition of the particular geological importance of the area is proved best by the fact that in his Balaton monograph he devoted special chapters to the geology of the Sümeg area, even though it does not belong to the immediate neighbourhood of Lake Balaton.

It was in this Balaton monograph, that a description of the Jurassic of Sümeg, the first paper ever penned by Elemér Vadász, came to daylight.

Between the two world wars, encouraged by the surface and subcrop indications and the particular geological features, the first steps toward mineral prospecting and first of all the exploration of coal and bauxite deposits were taken.

Between 1929 and 1935 Sándor Vitális reported in a number of papers on the occurrence of coal near the surface. In this context a few exploratory holes were even drilled. These ventures, however, had but little success.

Tangible results were achieved in bauxite exploration. In 1929 Károly Telegdi Roth found traces of bauxite to the southeast of Sümeg and he declared that area worthy of continued exploration. Eventually the exploration was continued under Elemér Vadász's guidance and the extraction was started, too.

In the interwar period some monographic works mainly of stratigraphic orientation were written (K. Barabás 1937, R. Hojnos 1943). Even though widening the knowledge, these works, on account of the misleading conclusions drawn, did not add much clarity to the geological picture.

A link between pre- and postwar prospecting was represented by the activities of J. Noszky Jr. and S. Vitális. Noszky started his detailed geological mapping of the area in the first half of the 1940's and the results would be published in the postwar years.

During the detailed geological mapping that was carried on in the 1950's an exact survey and description of the outcropping geological formations were made.

In the fifties, the enormous efforts toward industrial development put up again the need for bauxite and coal explorations. Upon S. Vitális' proposal, the Hungarian State Collieries included exploratory drillings in its plan in 1948 already, but its implementation—upon G. Kopek's proposals—could not until 1957 be started. Re-launched in 1950, the bauxite exploration too would witness a marked upswing only in the late 1960's and led to remarkable results to the east and south-east of Sümeg, respectively.

From the late 1950's on, upon J. Fülöp's incentives and under his guidance, a so-called Geological Key Section Program was launched which was to examine the connections between geological features and facies relations and to enable a reliable stratigraphic classification and to clear the tectonic setting as a scientific base to rely on by mineral explorers. Laying foundations for an up-to-date synthesis, these efforts during the 1970's would develop to a regular geological surveying.

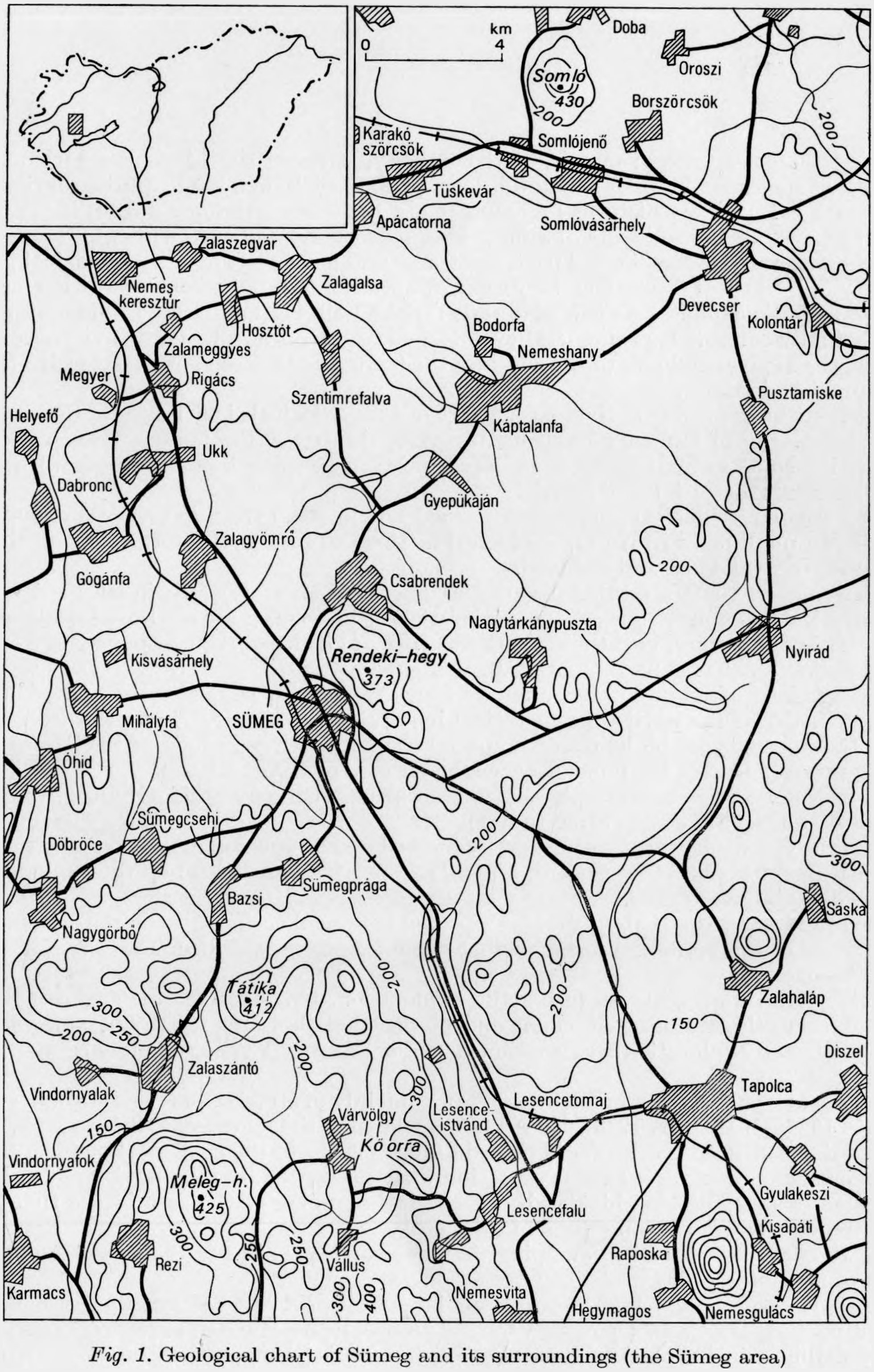


Fig. 1. Geological chart of Sümeg and its surroundings (the Sümeg area)

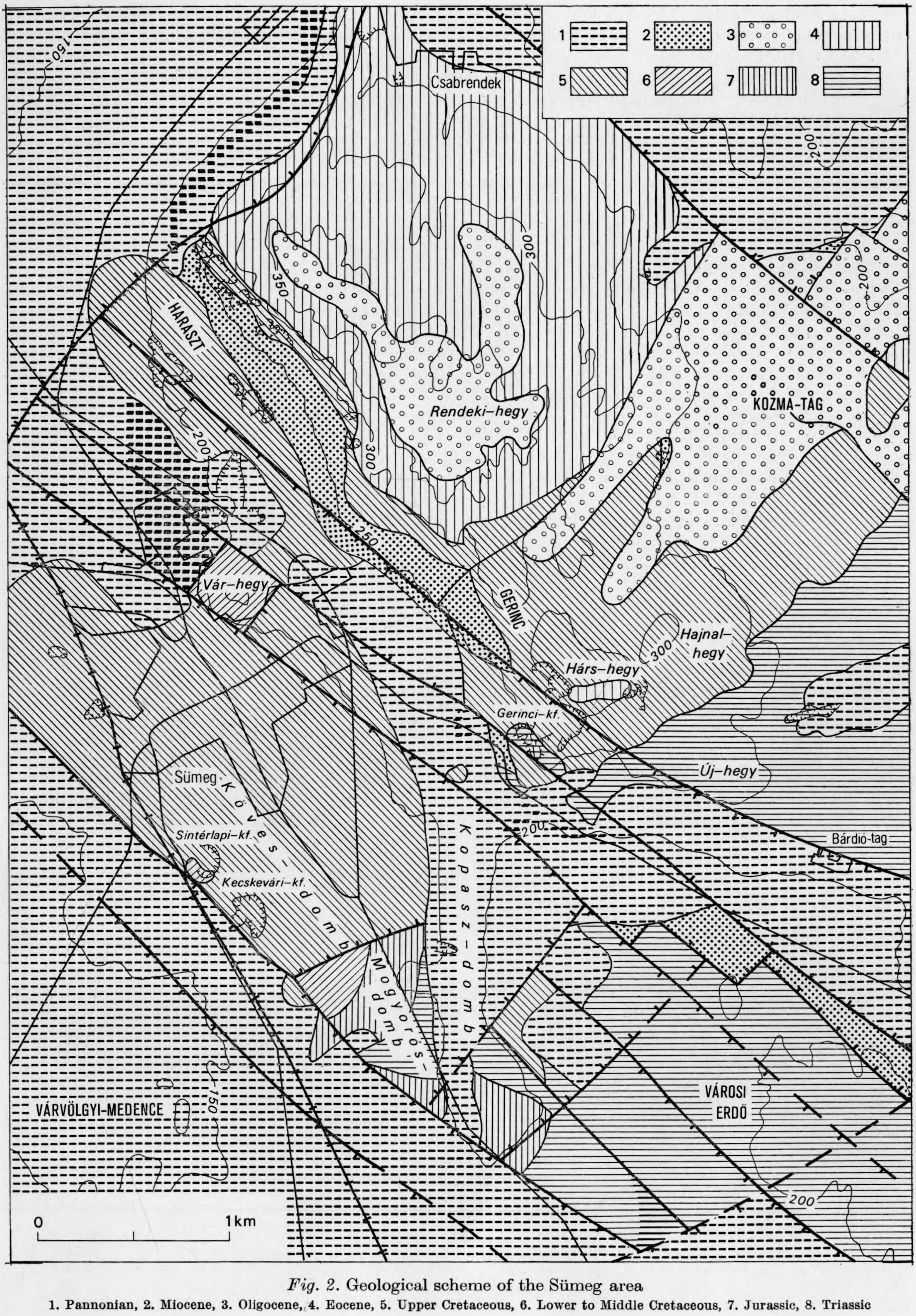


Fig. 2. Geological scheme of the Sümeg area

1. Pannonian, 2. Miocene, 3. Oligocene, 4. Eocene, 5. Upper Cretaceous, 6. Lower to Middle Cretaceous, 7. Jurassic, 8. Triassic

As a result of more than one century of research an ever clearer portrayal of the geology of the study area is being achieved. Armed with present-day knowledge, let us overview now the study area (Fig. 2) as visible from the Vár-hegy, a castle hill soaring high from amid the houses of the settlement and representing a textbook example of a high-perched horst bounded by faults from all sides.

The range extending east of the Vár-hegy (Rendeki-hegy, Hárs-hegy, Szőlő-hegy) is the most elevated part of the basin-surrounded Sümeg horst-block. The northern and the highest structural unit of this is the Rendeki-hegy composed of Eocene rocks overlying an Upper Cretaceous sequence with outliers of an Oligo-Miocene gravel sheet. On the Hárs-hegy occupying an intermediate position even topographically, Senonian marine sediments crop out with a few bauxite-filled dolinas and Eocene outliers on their karsted surface. Surrounded by gentle slopes, the Szőlő-hegy is constituted by Upper Triassic Hauptdolomit.

The rocky basement of the so-called "urban terrace" was trimmed to a subhorizontal face by the Pannonian abrasion. Above it the littoral boulders and pebbles, sandy argillaceous sediments of the one-time Pannonian inland sea occur in isolated patches. In the underlying beds the formations of the Miocene marginal sea can also be encountered, though the bulk of the underlying, often steeply-dipping sequences belong to the Senonian cycle or to pre-Senonian parts of the Mesozoic. On the Köves-domb, a hill lying to the south of the settlement, there are rudist-bearing reefs of Senonian age, on the Mogyorós-domb in turn it is exposures of unmatched beauty of Lower Cretaceous formations that unfold before the eyes of the observer.

Bounding the urban terrace westwards, the young stepped fault system is of regional significance, representing actually the western tectonic ending of the Bakony. In the Várvölgy Basin separating the Bakony from the Keszthely Mts, the Mesozoic basement lies at hundreds of metres depth, while in the Nagygörbő depression representing the northern foreland of the Keszthely Mts even the surface of the Upper Cretaceous sequence is deeper than 1 km. Along deep-penetrating faults basalt lava extruded in Pannonian time, as testified to by the mesa-buttes of Sümeg–Uzsa.

To the north lies the lowland of the Little Hungarian Plain (Kisalföld). As shown by geophysical surveys and some boreholes, the Sümeg block extends well into that area in a northwesterly direction towards Ukk, where Mesozoic formations are hidden beneath a Pannonian overburden of reduced thickness.

The above mozaic, however roughly outlined, is based on evidence derived from a maze of minor observations, that have had to be put together bit by bit. The facts and the conclusions deduced therefrom are detailed in the following chapters.

One may pose the question, if the publication of a geological monograph on the study area does not give the students a ready-made stuff, minimizing their efforts towards the solution of problems? Our answer is that to teach an up-to-date stock of learning and modern techniques requires up-to-date fundamentals and a higher level of understanding will encourage the formulation of the tasks to be solved on a higher level. We wish to instruct the would-be scientists so as to enable them to approach by modern tools and sophisticated techniques to the solution of the more difficult and more complicated tasks they may be confronted with in the years to come.

GEOLOGICAL FORMATIONS

Triassic

by

J. ORAVECZ and J. HAAS

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 differing 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.

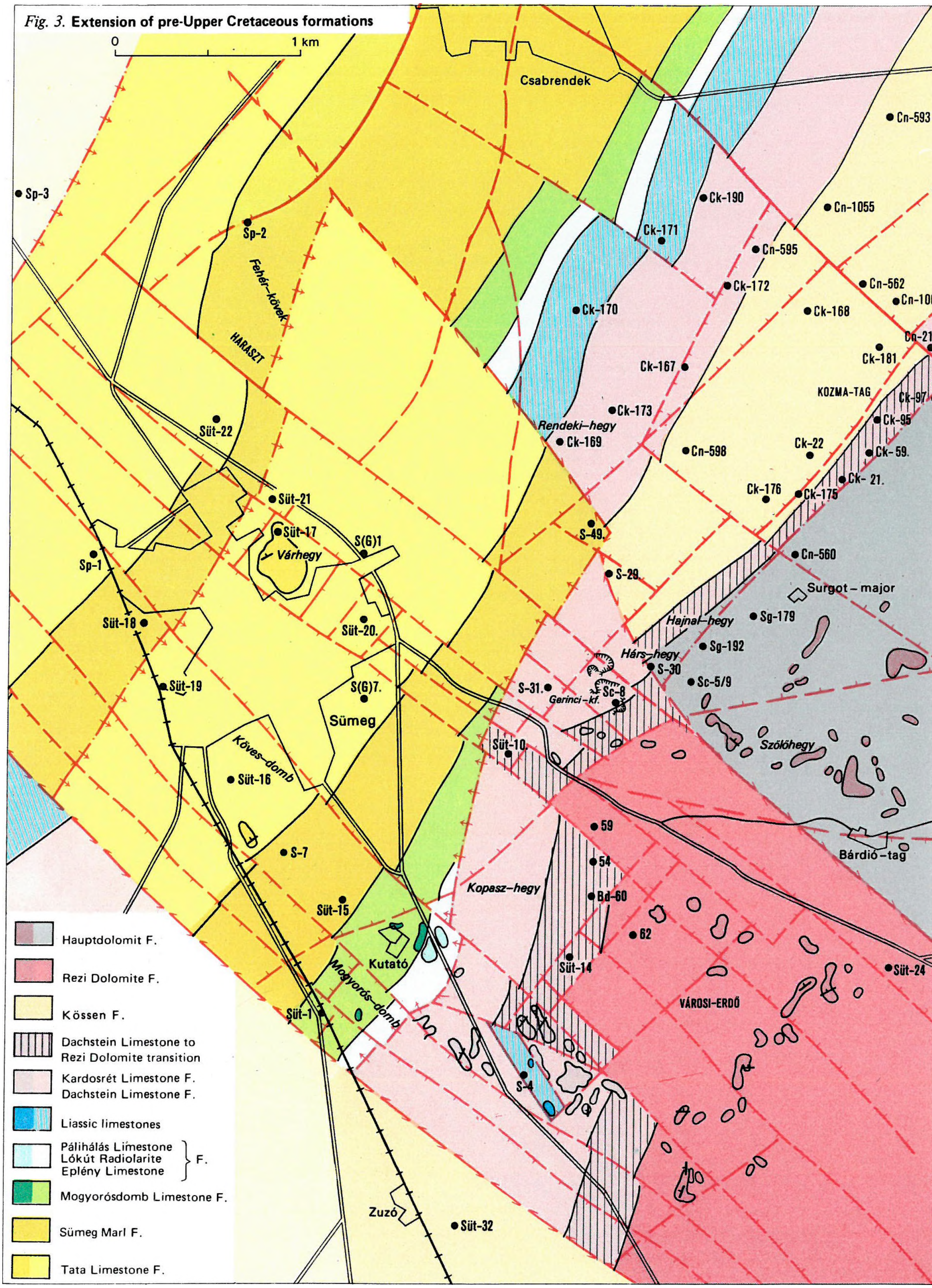


Fig. 3. **Extension of pre-Upper Cretaceous formations**

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).

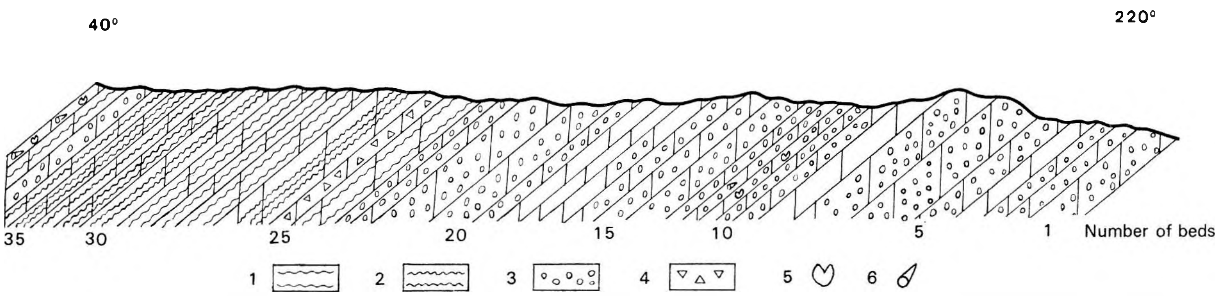


Fig. 4. Sequence belonging to the Hauptdolomit Formation as exposed by trenching on the southern slope of the Szőlő-hegy (Vineyard Hill)

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

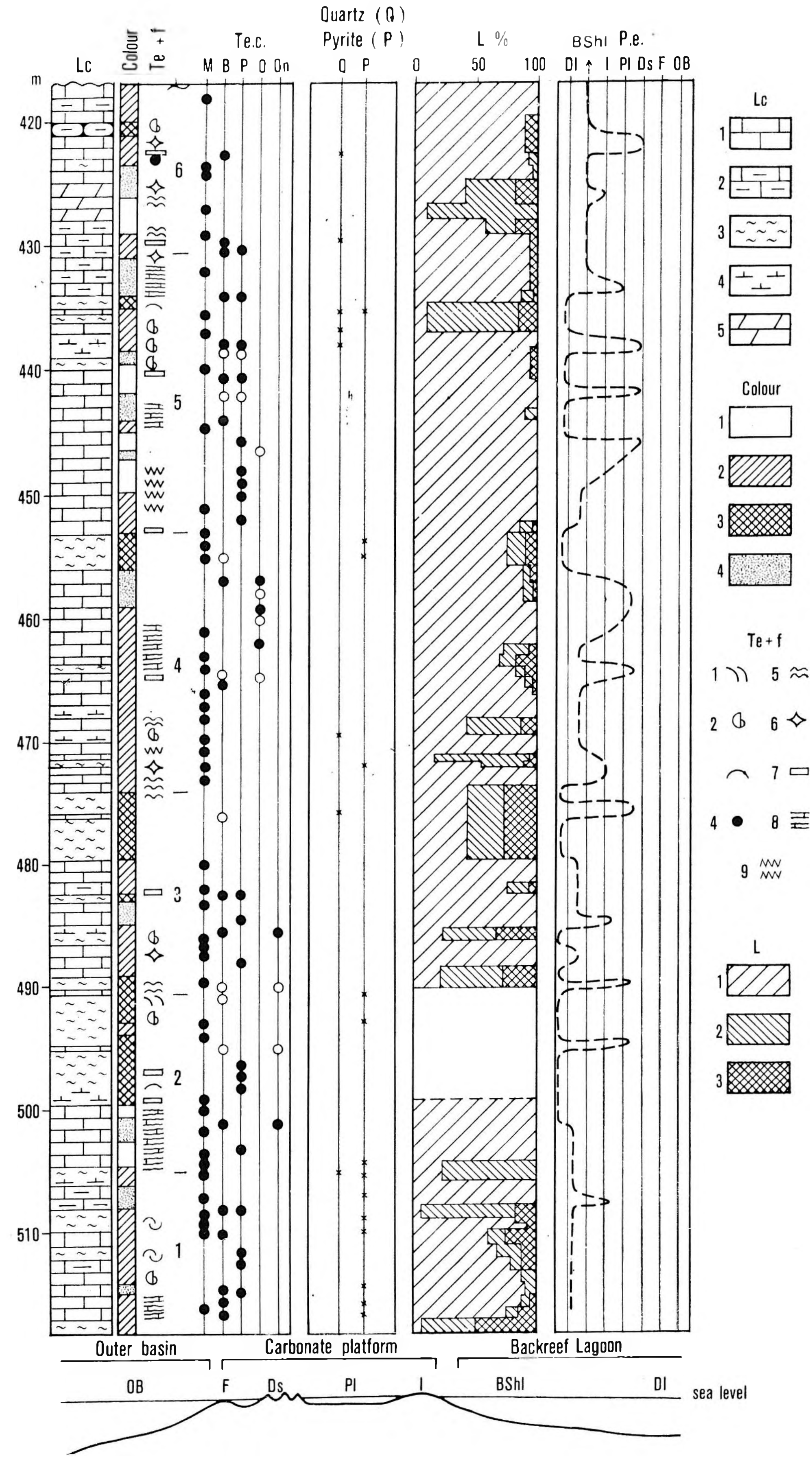
To reconstruct the genetic conditions is difficult because of the marked recrystallization of the rock has obliterated the primary textural pattern, as a rule, beyond recognition. Thus we have to resort primarily to conclusions deduceable from the megafossils and the rock structure.

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
1
2
3
4
5
6
Lc
1
2
3
4
5
Colour
1
2
3
4
Te + f
1 5
2 6
7
4 8
9
L
1
2
3
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

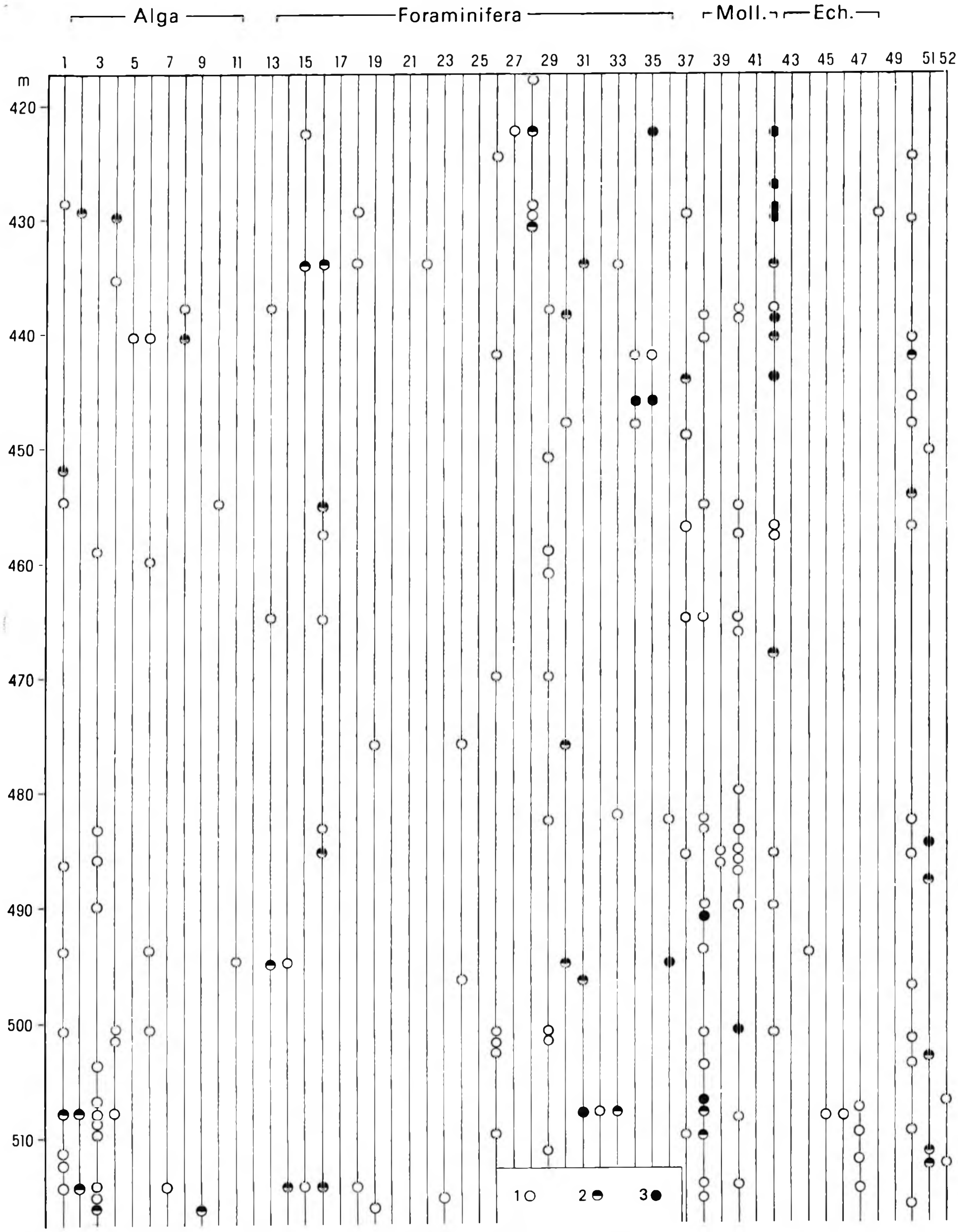


Fig. 6. Microfossils from the borehole Süt-17

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.

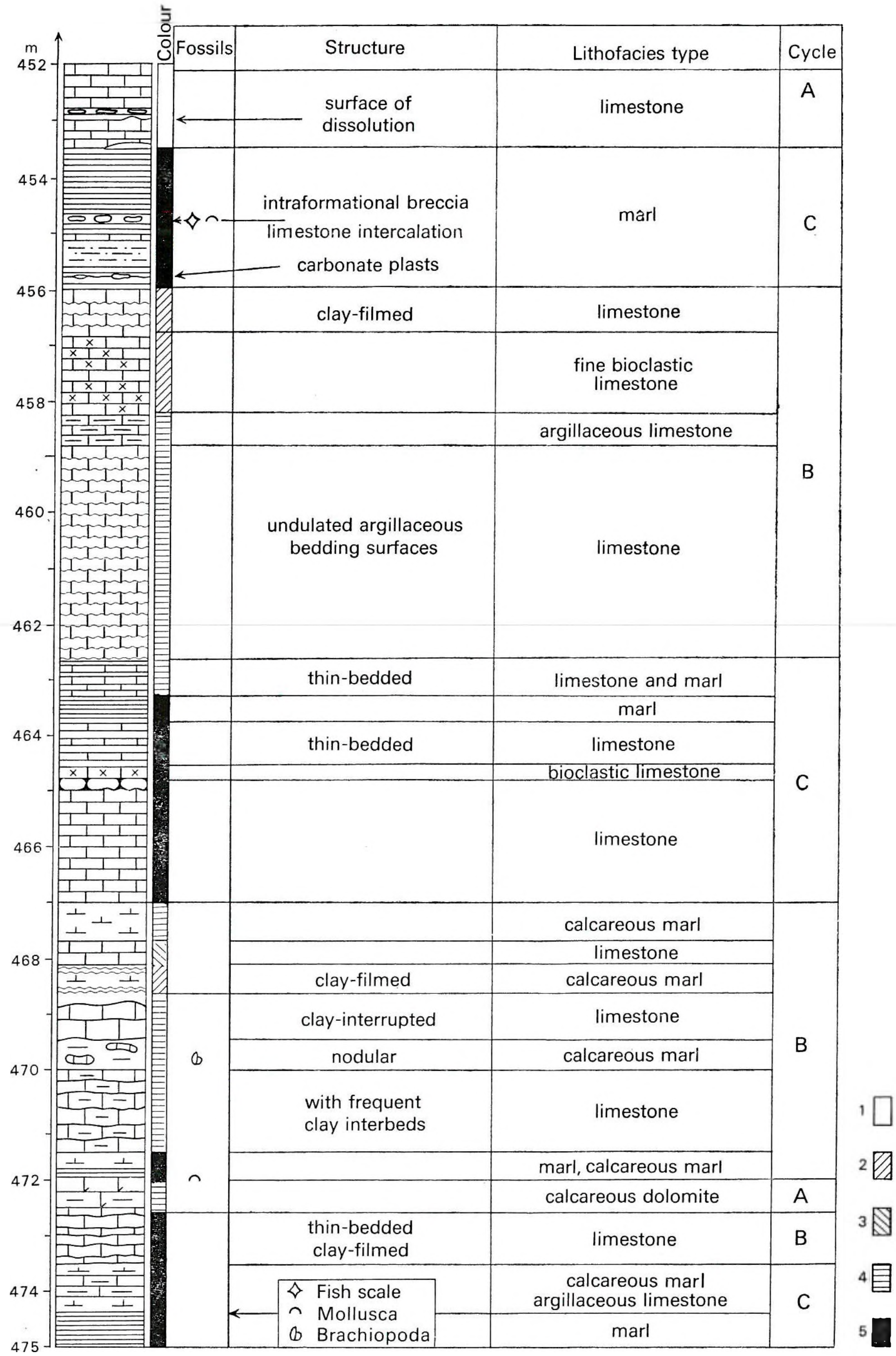


Fig. 7. Cyclic changes in character observable in the Kössen Formation interval of the borehole Süt-17

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 chrono-correlation [*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*

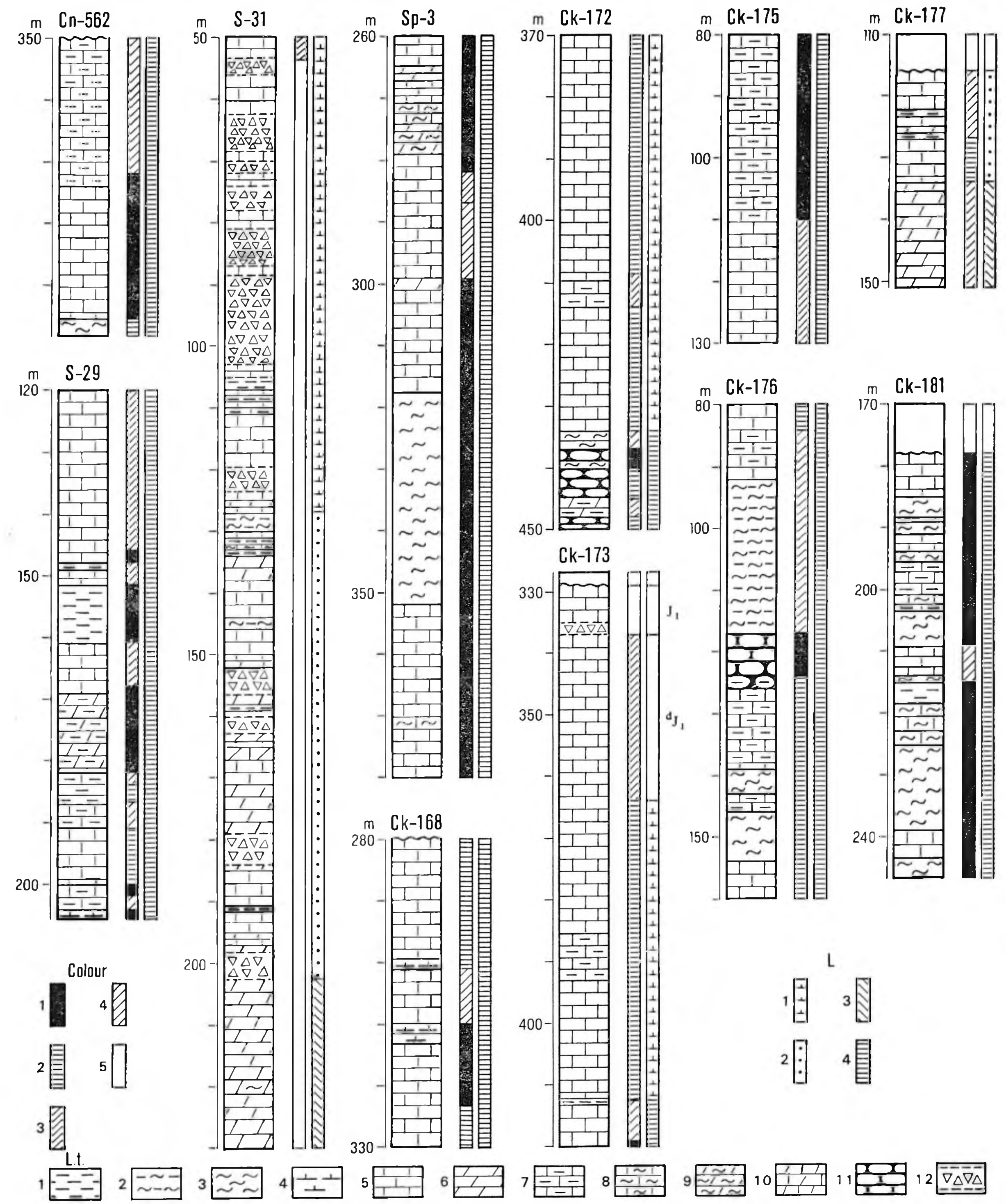


Fig. 8. Boreholes that have exposed Upper Triassic rock in the Sümeg area

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 Ṙezi 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

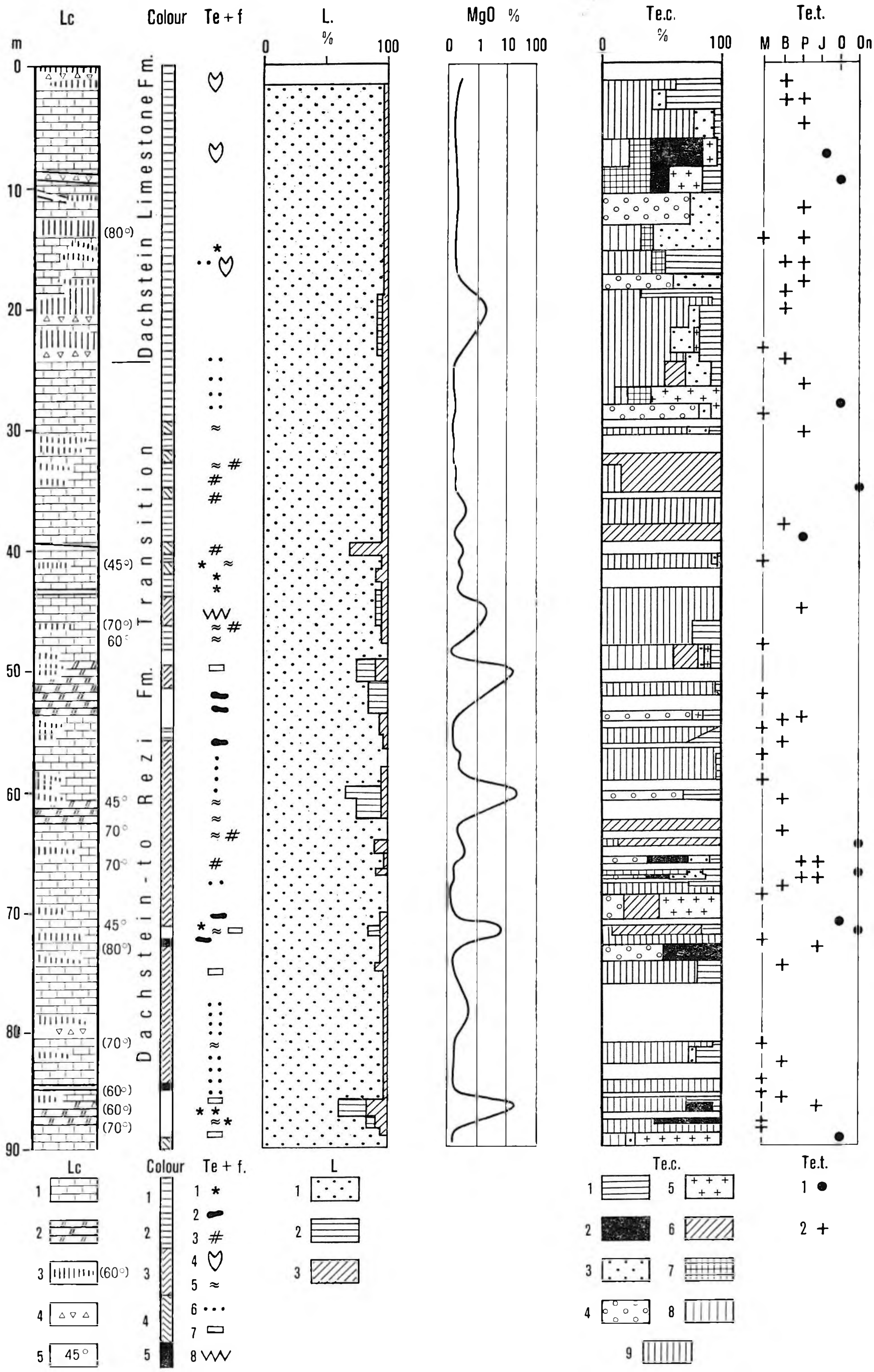
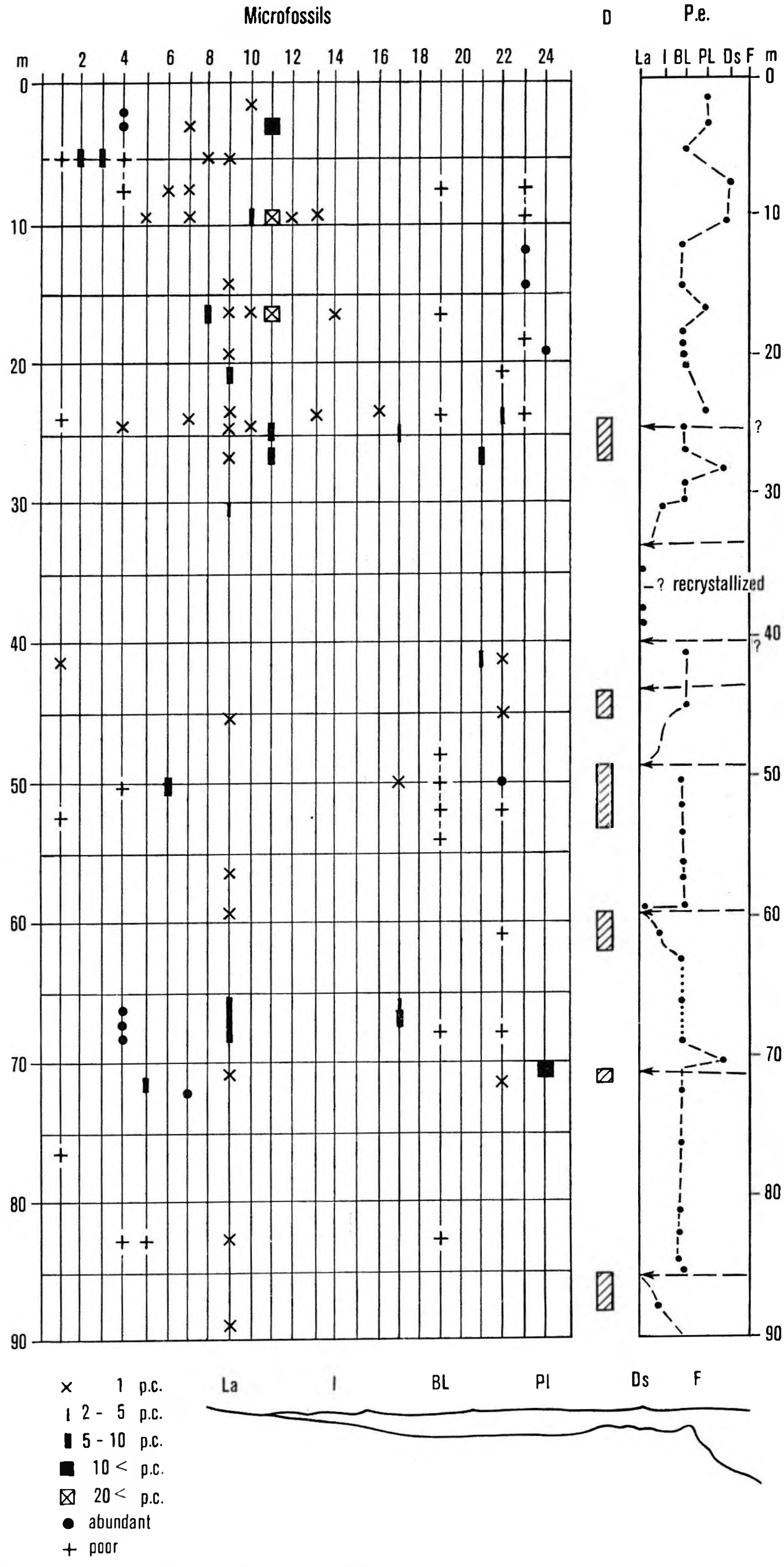


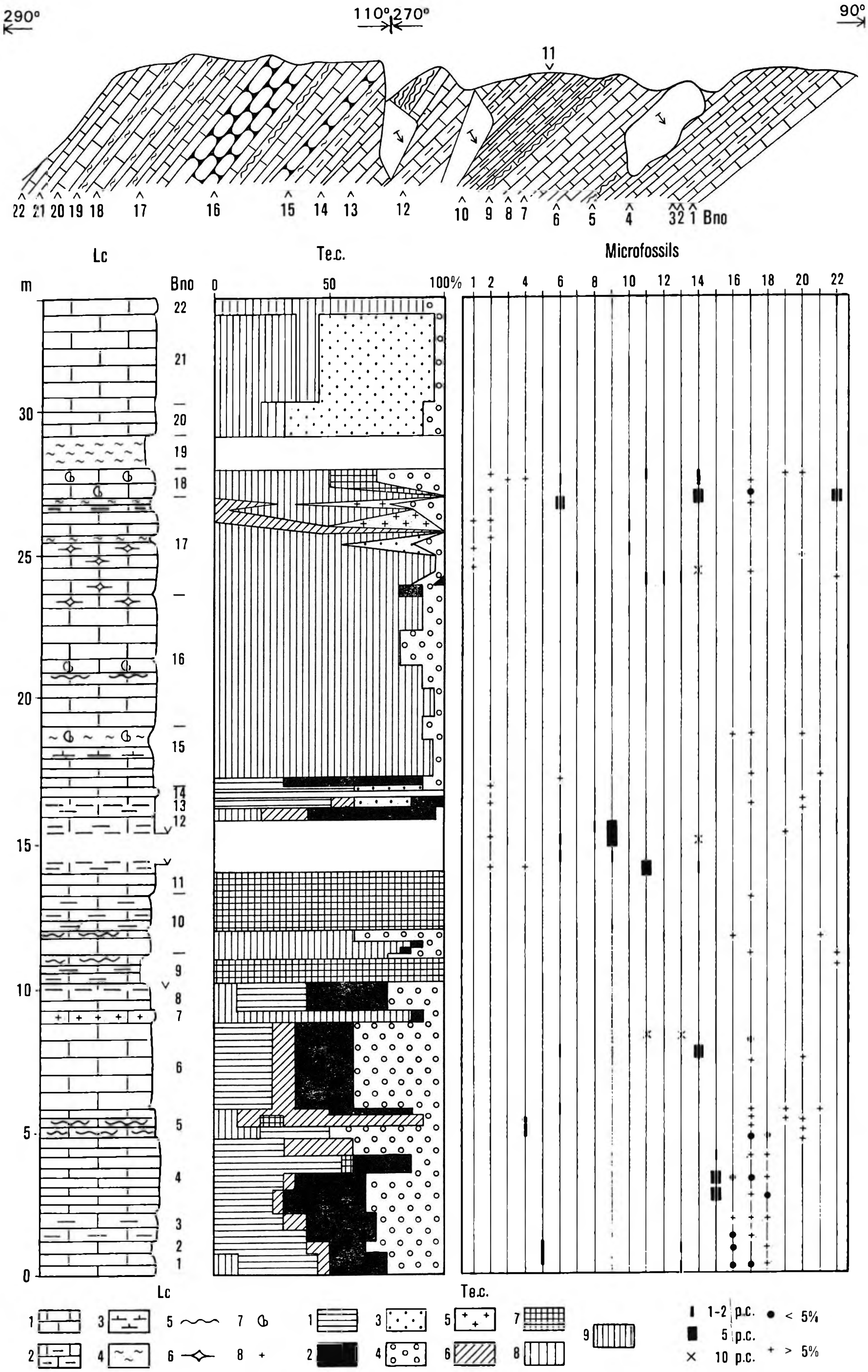
Fig. 9a—b. Lithologic column and analytical diagram of

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 Mogyorósdomb 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.

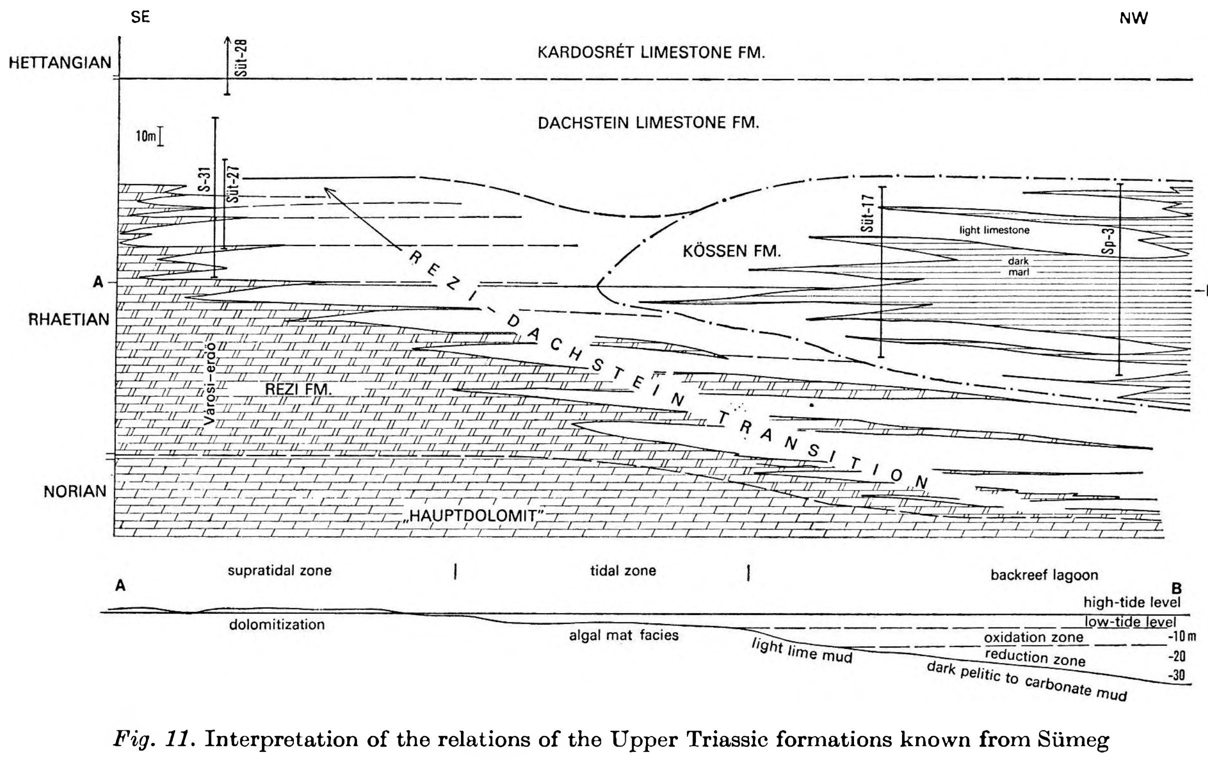


Fig. 11. Interpretation of the relations of the Upper Triassic formations known from Sümeg

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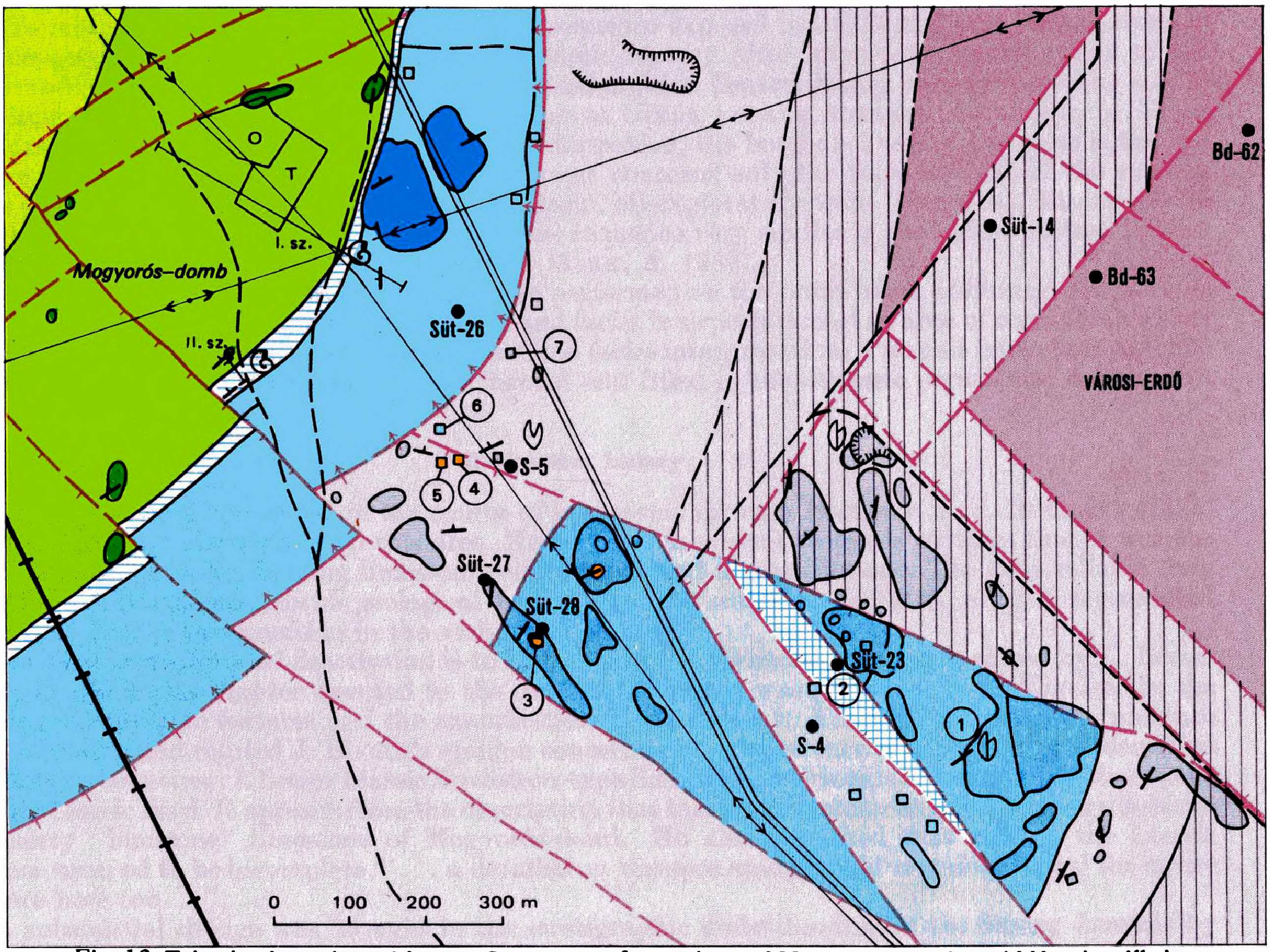
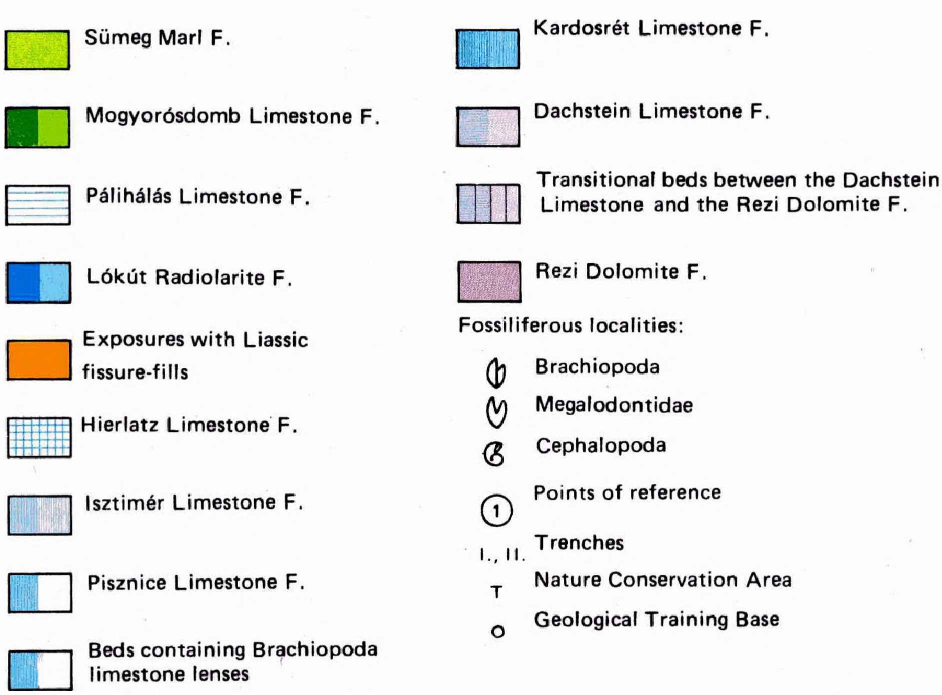


Fig. 12. **Triassic, Jurassic and Lower Cretaceous formations of Mogyorós-domb and Városi-erdő sites**



Jurassic

by

J. Haas

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

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

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

Exploration history

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

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

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

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

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

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

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

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

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

Extension, mode of superposition, stratigraphic subdivisions

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

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

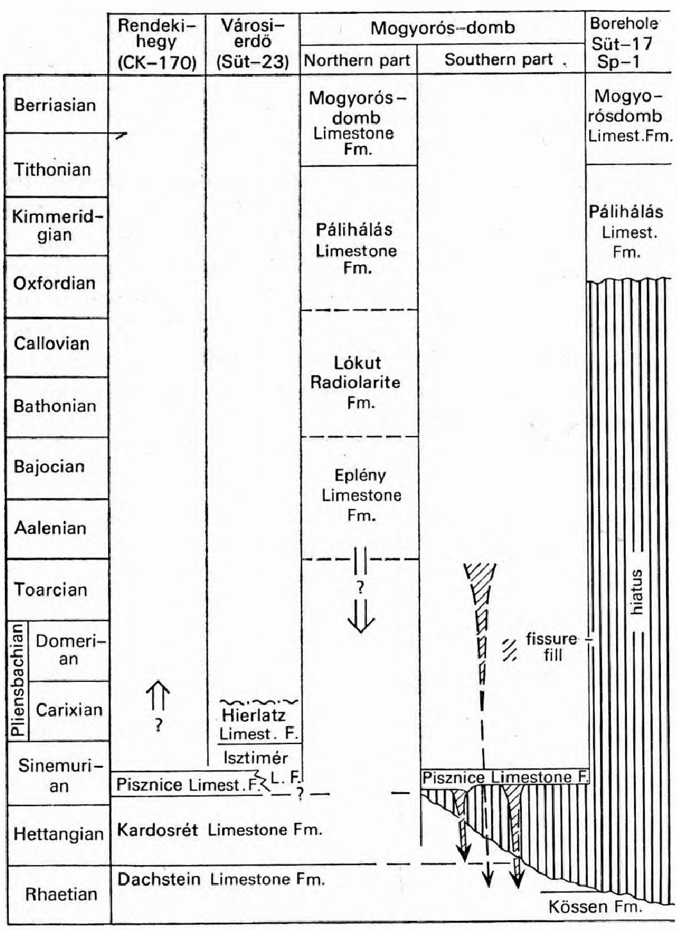


Fig. 13. Stratigraphic position and relations of the Jurassic rocks known from Sümeg

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

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

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

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

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

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

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

Kardosrét Limestone Formation

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

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

Local type section: borehole Süt-28

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

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

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

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

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

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

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

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

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

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

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

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

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

Other exposures

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

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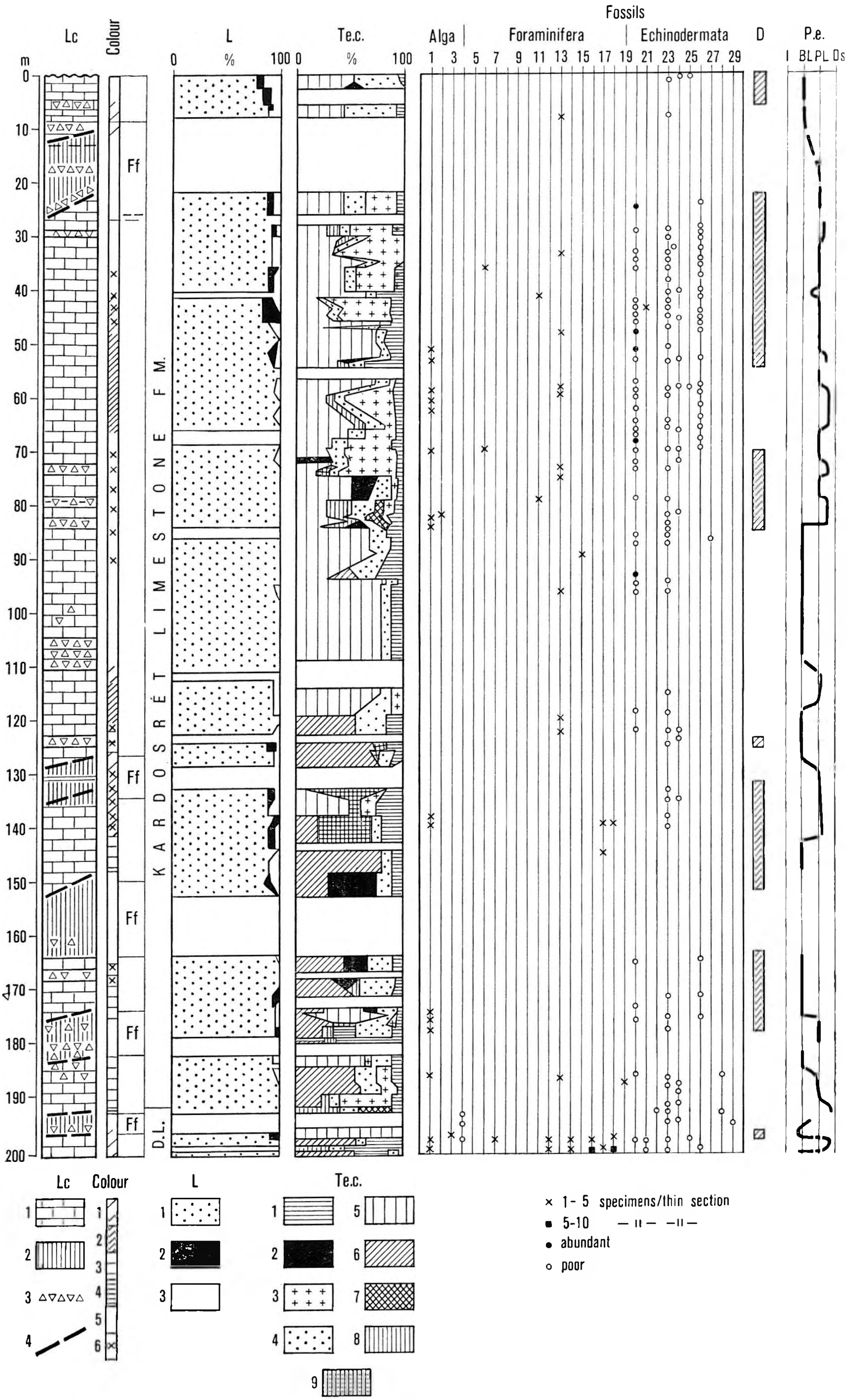
Fig. 14. Lithologic column and analytical results of the borehole Süt-28

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


Fossils
Lc
Colour
L
Te.c.
Alga
Foraminifera
Echinodermata
D
P.e.
m
0 % 100
I BL PL Ds
Ff
KARDOSRÉT LIMESTONE FM.
D.L.
× 1- 5 specimens/thin section
■ 5-10 —"— —"—
● abundant
○ poor

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

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

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

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

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

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

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

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

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

Chronostratigraphy

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

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

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

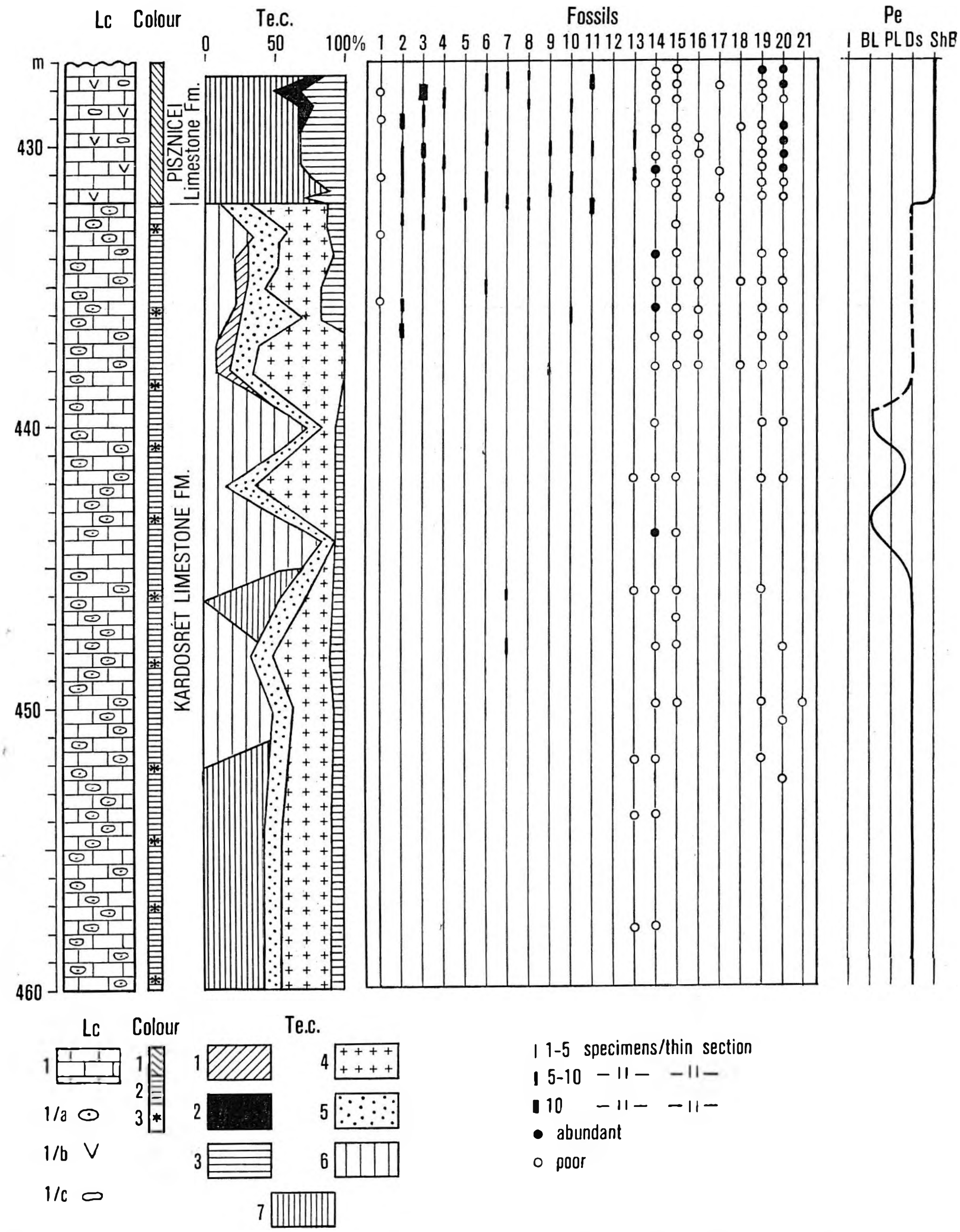


Fig. 15. Lithologic column and analytical results of the Jurassic interval of the borehole Ck-170

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

Paleoenvironment

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

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

Table 2.

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

Distribution data from ALMERAS (1964) and GAETANI (1970)

Species	Rhaetian	Hettangian			Sinemurian					Pliensbachian				
					L.		U.			L.			U.	
		planorbis	liasicus	angulata	bucklandi	semicostatum	obtusum	oxynotum	raricostatum	jamesoni	ibex	davoei	margaritatus	spinatum
Cuneirhynchia? latesinuosa (TRAUTH) (5)				- -	- -	- -								
Calcirhynchia? rectemarginata (VECCHIA) (23)			- -	- -	- -	- -								
„*Rhynchonella*" sp. (11)														
Cadomella sp. (1)														
Spiriferina cf. *alpina* OPPEL (1)														
Spiriferina cf. *darwini* GEMMELLARO (2)					—	—	—	—	—	—	—	—	—	—
Spiriferina spp. (3)					—	—	—	—	—	—	—	—	—	—
Rhaetina gregaria (SUESS) (5)	—													
Rhaetina? sp., aff. *gregaria* (SUESS) (9)														
„*Terebratula*" sp., aff. *sphenoidalis* MENEGHINI (1)														
Zeilleria perforata (PIETTE) (33)														
Zeilleria waehneri (GEMMELLARO) (2)		—	—	—	—	—	—	—	—					
„*Waldheimia*" cf. *ewaldi* (OPPEL) (1)					—	—	—	—	—					
„*Waldheimia*" spp. (9)					—	—	—	—	—					

(5) = number of specimens

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

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

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

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

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

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

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

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

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

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

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

Chronostratigraphy

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

Paleoenvironment

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

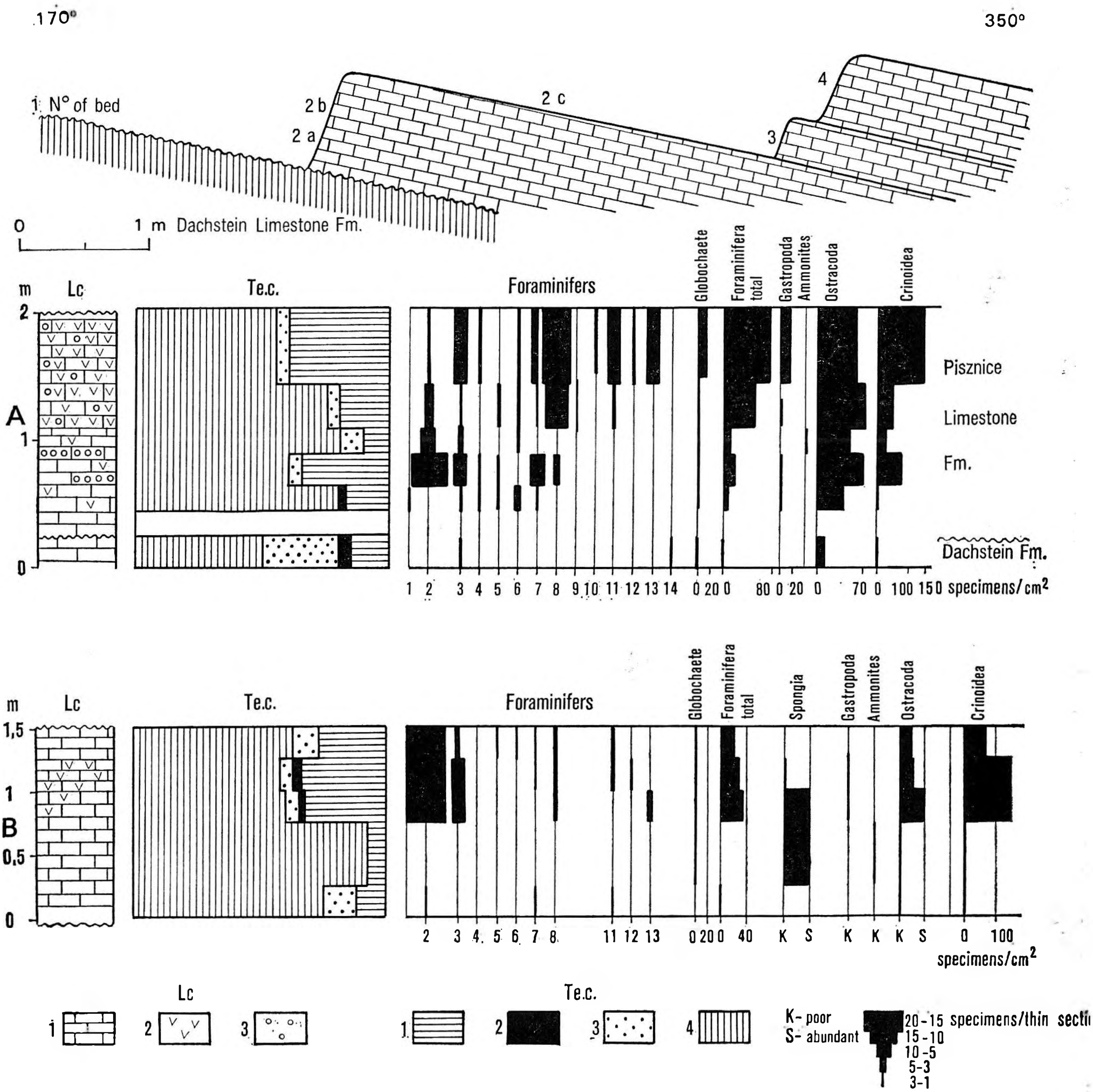


Fig. 16. Exposures of the Pisznice Limestone on the Mogyorós-domb

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

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

Isztimér Limestone Formation

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

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

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

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

Hierlatz Limestone Formation

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

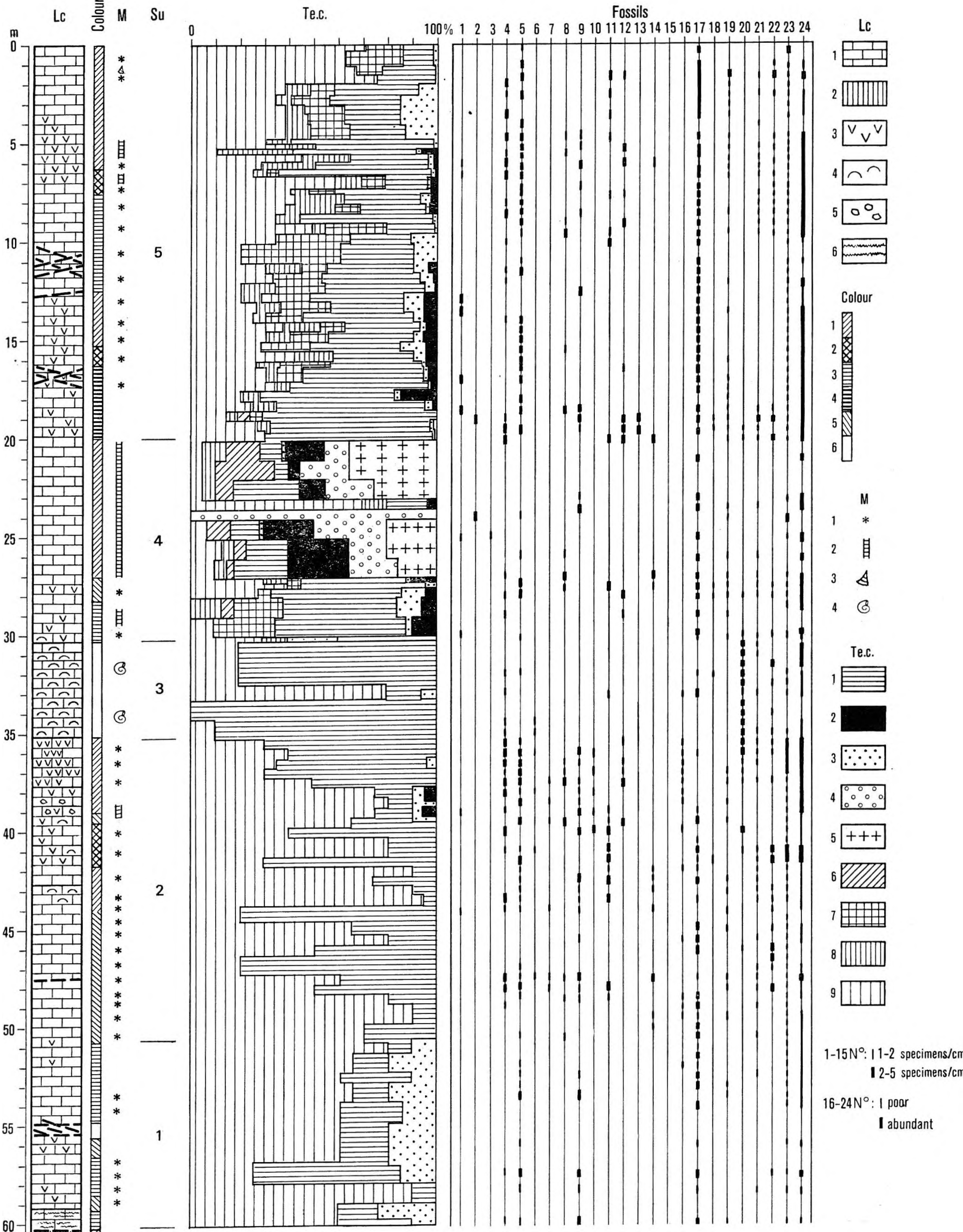
The features of the formation as observed in the borehole Süt-23 are shown in Fig. 17. In terms of its megaloscopic and microfacies patterns the sequence can be subdivided into the following intervals:

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

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

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

The third interval (30.2–35.2 m) is composed of a greyish-white *Posidonia*-lumachelle. As observable in thin section, the original biomicrite texture (the share of the fossils was about 70 to 90%) is for the most part postgenetically recrystallized, sparitized. In addition to the predominant *Posidonia* valves, skeletal fragments of *Crinoidea, Gastropoda, Ostracoda* and *Ammonites* can be recognized (Plate XI, Fig. 1, 3, 4).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1-15N°: | 1-2 specimens/cm
▮ 2-5 specimens/cm
16-24N°: | poor
▮ abundant

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

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

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

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

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

Paleoenvironment

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

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

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

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

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

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

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

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

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

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

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

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

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

— it may be taken to be proved that the onco-oösparite rock types observable in the sequence were deposited in quite shallow-waters;
— on the basis of the trends of continual variation and the facies relations the predominantly shallow-water benthonic fauna of the deeper and higher intervals seems to have undergone only short-distance transport and the depositional environment to have lain beneath the surf zone at the bottom of a shallow-water sea.

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

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

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

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

Fissure-fills

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

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

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

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

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

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

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

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

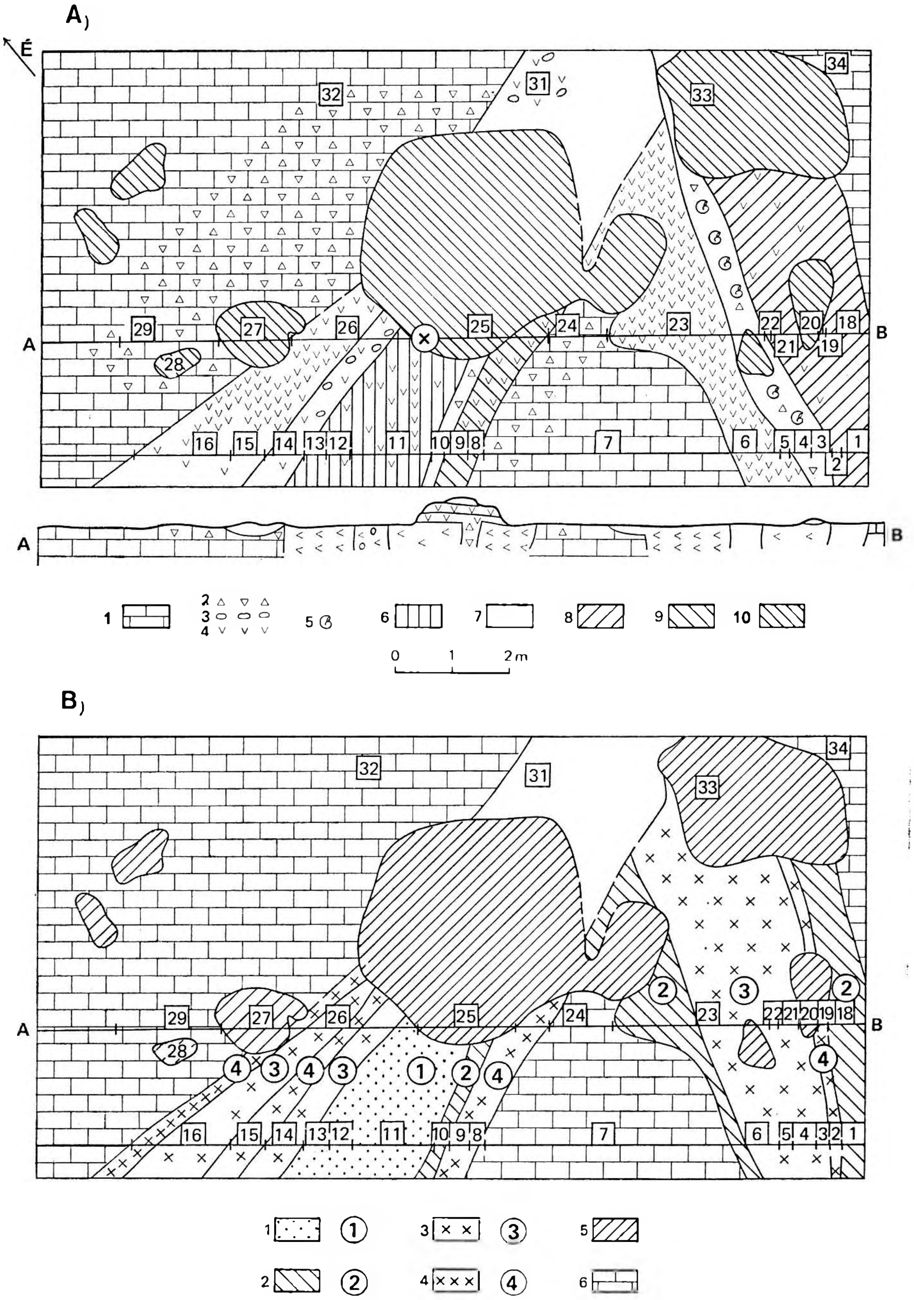


Fig. 18. Liassic fissure-fill system in the southwest part of the Mogyorós-domb

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

2. M i c r i t e. Two varieties of the type were observed. In the one case the fossil elements are subordinate in quantity. Skeletal fragments of *Crinoidea*, *Spongia* spicules, thin-walled *Ostracoda* valves and *Globochaete* remains representing the organic component constitute but 1 to 2% of the texture. In rare cases limonite-coated lumps of corroded edge can also be encountered in which the share of fossil elements is higher (Samples 10 and 18). — The other variety (Sample 1) represents actually a transition to the biomicrite I type. The amount of fossils increases to 4–5% and, though in a low quantity, benthonic Foraminifera such as *Nodosaria, Marginulina, Spirilina, Vidalina, Involutina liassica* (JONES), *Trocholina granosa* FRENTZEN and *Lasiodiscus* sp. also appear.

3. B i o m i c r i t e I t y p e. The amount of fossils increases compared with the foregoing, getting close to 10–20%. Embryonic *Ammonites* shells, *Spongia* spicules, skeletal elements of *Crinoidea*, thick- and thin-walled *Ostracoda* valves are frequent. Foraminifera are similar in quantity and quality to the second variety of the preceding type (Samples 21, 22, 3, 4, 5, 6, 16, 29, 33).

4. B i o m i c r i t e I I t y p e (Plate XIII, Fig. 1, 2, 3, 7). The amount of the fossil fragments is 30 to 50%. Most of these are represented by skeletal elements of *Crinoidea* that are well-preserved and little rounded. Frequent biogenic components include *Bivalvia*, *Gastropoda*, *Ammonites* tests, further, thick-walled *Ostracoda* valves and sponge spicules. Of the Foraminifera, the representatives of *Nodosaria, Lenticulina* and *Marginulina* are common. Specimens of *Ophthalmidium* sp., *Involutina liassica* (JONES), *Trocholina granosa* FRENTZEN and *Tr. turris* FRENTZEN (Samples 2, 8, 9, 15, 16, 23) occur in particularly great numbers.

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

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

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

1. In the first stage a fissure of about 2 m width was formed in the Kardosrét Limestone constituting the substratum (the sea bottom) and this would be filled with materials deriving from the basal bed of the normally deposited sequence.

2. In the course of continued opening another, narrow fissure evolved between the bedrock and the earlier fissure-fill of totally different consistency and it was filled with material of the second bed.

3. During the next opening an open fissure was formed on the opposite side of the fissure and it was filled with material from the third bed.

4. Continued tensile stresses produced, in one or several phases, new fissures within a fissure-fill that had consolidated to some extent and this time the infilling came from the fourth bed.

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

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

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

Phylloceras sp.
Geyeroceras cf. *cylindricum* (SOWERBY, 1831)
Partschiceras sp.
Peltolytoceras altiformis (BONARELLI, 1900) n. subsp.
Juraphyllites sp.
Arnioceras sp.
Asteroceras cf. *reynesi* (FUCINI, 1903)
Riparioceras riparium (OPPEL, 1862) n. subsp.

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

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

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

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

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

Discohelix cf. *ornata* (HÖRNES)
Discohelix inornata SZABÓ
Pentagonodiscus reussi (HÖRNES)
Sisenna cf. *procera* (DESLONGCHAMPS)
Pleurotomaria cf. *platyspira* (DESLONGCHAMPS)
Leptomaria sp.

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

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

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

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

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

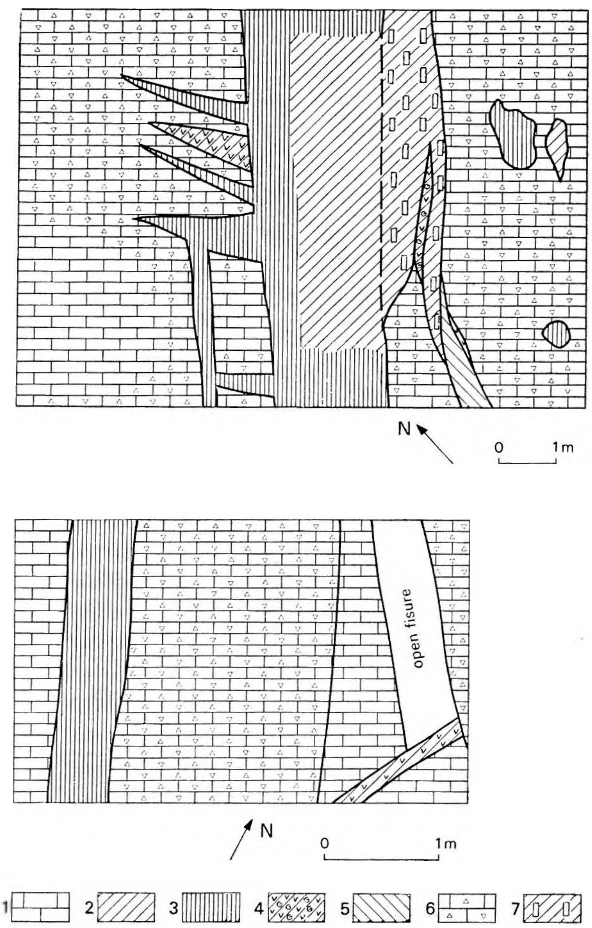


Fig. 19. Fissure-fill systems on the Mogyorós-domb
1. Dachstein Limestone Fm., 2. red calcareous marl, 3. yellow calcareous marl, 4. red crinoidal ammonite-embryoned limestone, 5. light grey aphaneritic limestone, with a few Crinoidea and skeletons of ammonite embryons, 6. brecciated limestone with a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

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

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

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

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

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

Eplény Limestone Formation

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

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

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

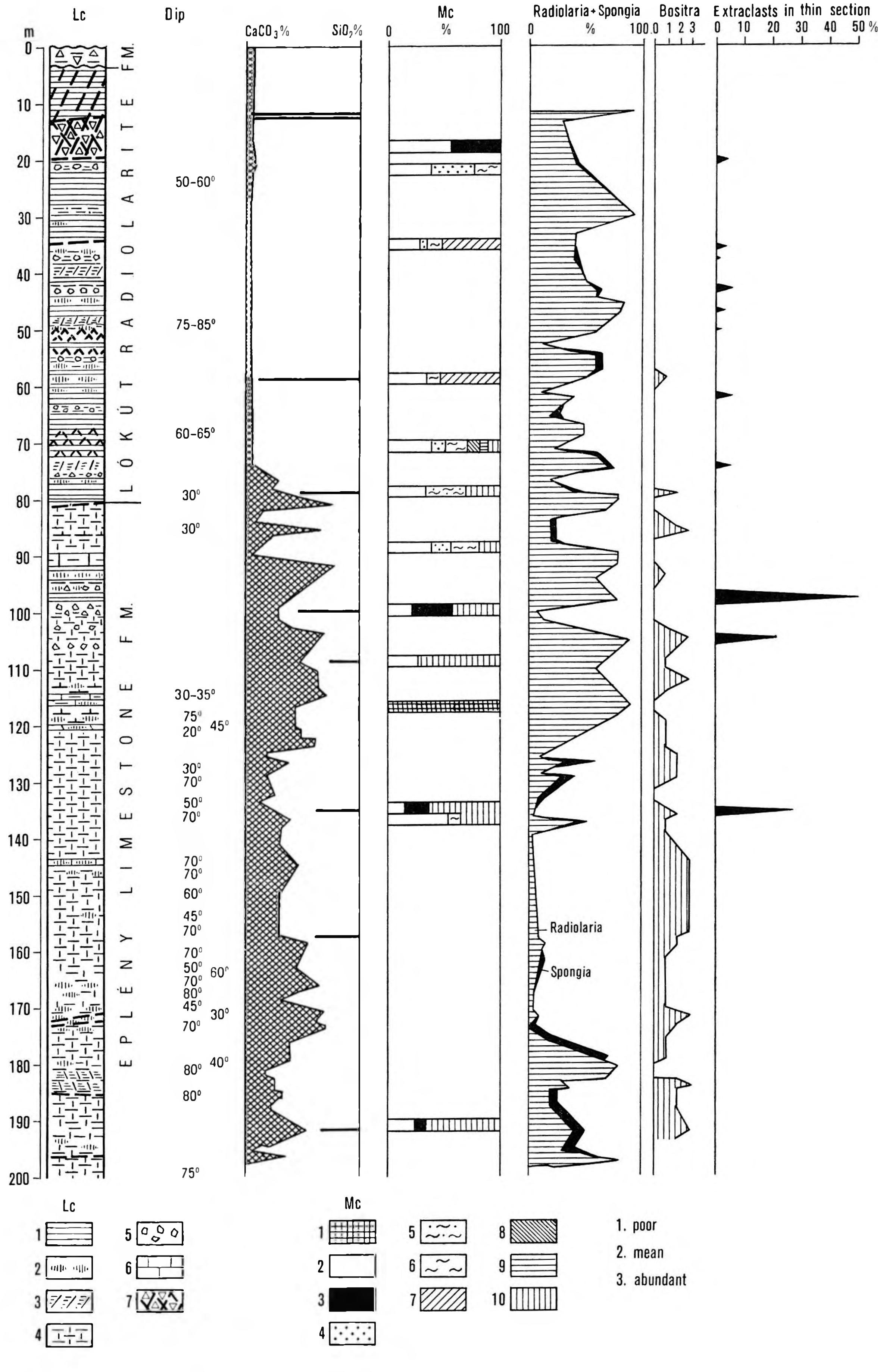
The rock has a $CaCO_3$ content varying from 30 to 60%, the amount of SiO_2 varies between 30 and 40%, being bound mainly to quartz and cristobalite minerals. The clay minerals attain an amount of about 10%. According to X-ray analyses by A. SZEMETHY, the clay minerals are generally represented by illite,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

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

→

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

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


Lc
Dip
CaCO3%
SiO2%
Mc
%
Radiolaria+Spongia
Bositra
Extraclasts in thin section
m
LÓKÚT RADIOLARITE FM.
EPLÉNY LIMESTONE FM.
50-60°
75-85°
60-65°
30°
30°
30-35°
75°
20°
45°
Radiolaria
Spongia
Lc
Mc
1. poor
2. mean
3. abundant

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

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

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

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

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

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

Chronostratigraphy

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

Paleoenvironment

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Chronostratigraphy

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

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

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

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

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

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

Paleoenvironment

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

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

Pálihálás Limestone Formation

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

Local type section: Mogyorós-domb, Section II

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

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

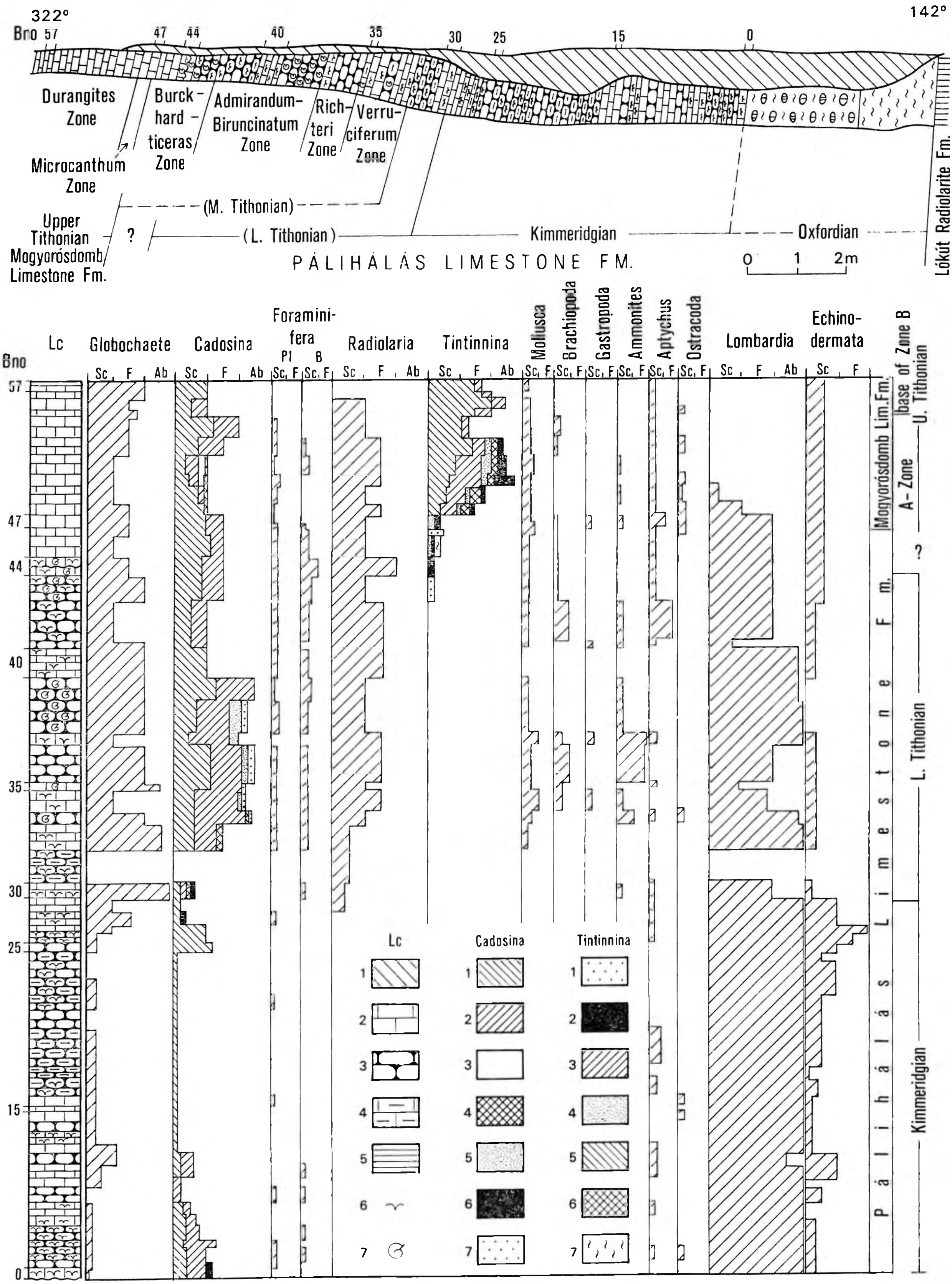


Fig. 21. Excavation trench Mogyorós-domb II: profile and analytical record

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

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

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

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

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

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

A marked change in the megaloscopic lithologic features, the texture pattern and the fossil assemblage can be registered from the 31st bed onwards. The i n t e r v a l o f t h e 3 1 t h t o 3 5 t h b e d s is constituted mainly by grey, locally pale pink, nodular, argillaceous limestone beds of 10 to 50 cm thickness each. That the quantity of the skeletal elements of echinoderms decreases can be observed even with an unaided eye. The texture is represented by biomicrite. Among the biogenic textural elements it is still *Lombardia* that predominate, though the representatives of *Globochaete*, *Radiolaria* and *Cadosina* also increase considerably. *Foraminifera* appear, both benthonic and planktonic forms being present in low quantity, but consistently. *Mollusca* shell fragments and embryonic tests of *Ammonites* can also be observed. Their test is composed of Lombardia biomicrite or a micrite with few biogenic grains. The pelmicrite texture type occurs in rare cases, too. Megafossils show an increase in amount as compared to the deeper parts. In the course of samplings of a biostratigraphic aim a rich *Ammonites* fauna was also recovered from the beds. (For a discussion of the fauna, see the biostratigraphic part.)

The i n t e r v a l b e t w e e n t h e 3 6 t h a n d 4 0 t h b e d s is composed of light grey nodular limestone beds of 20 to 60 cm in thickness. The texture is generally represented by bioclastite, less frequently by biomicrite. Beside rockforming *Lombardia*, the representatives of *Radiolaria* and *Cadosina* are also frequent. Although rare, intraclast grains do occur. In the basal beds of the unit the quantity of the ammonite fauna decreases as compared to the preceding unit, but above the 38th bed the *Ammonites* become rich both in species and in specimens.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

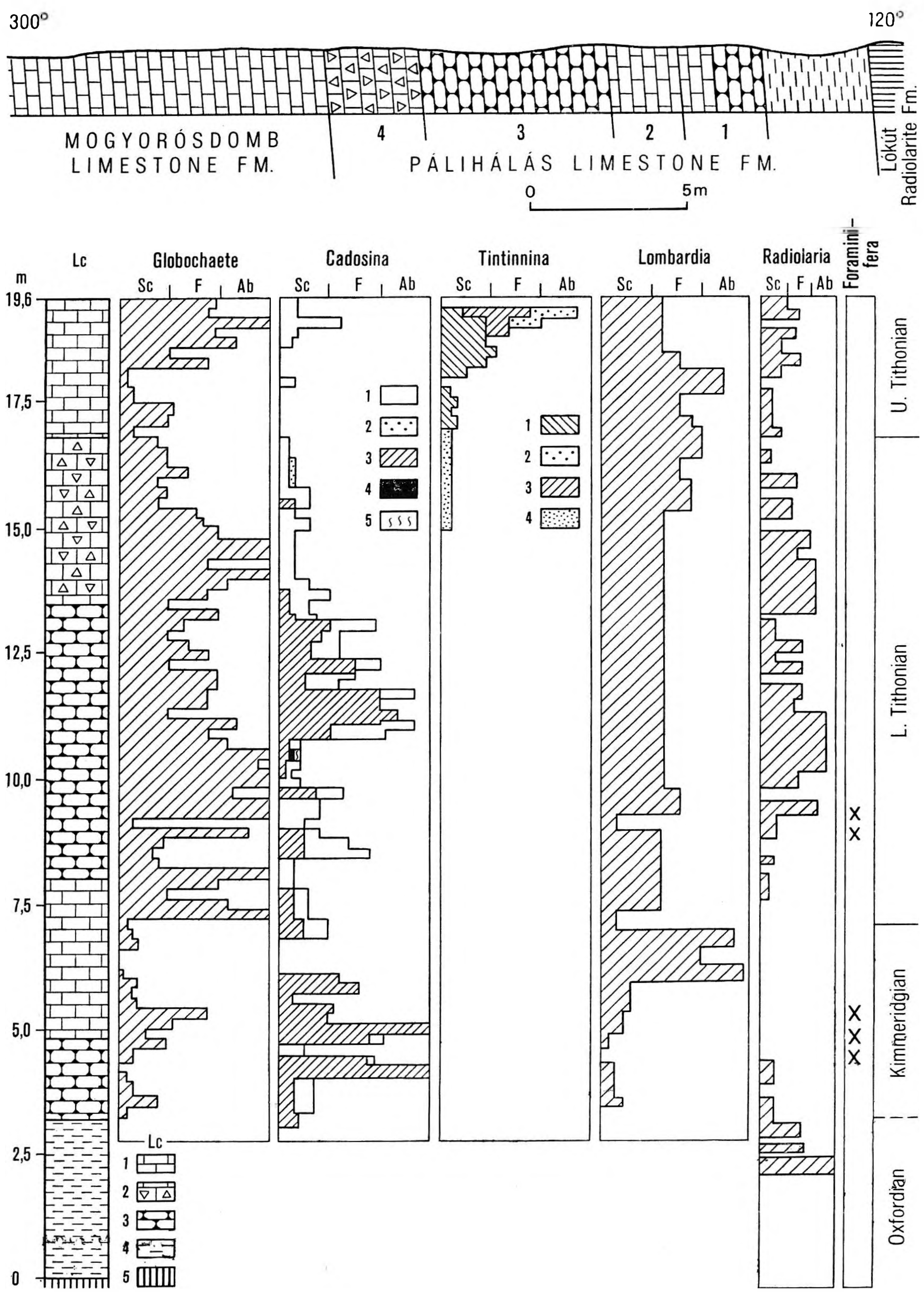


Fig. 22. Upper Jurassic beds in excavation trench Mogyorós-domb I: profile and analytical record

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

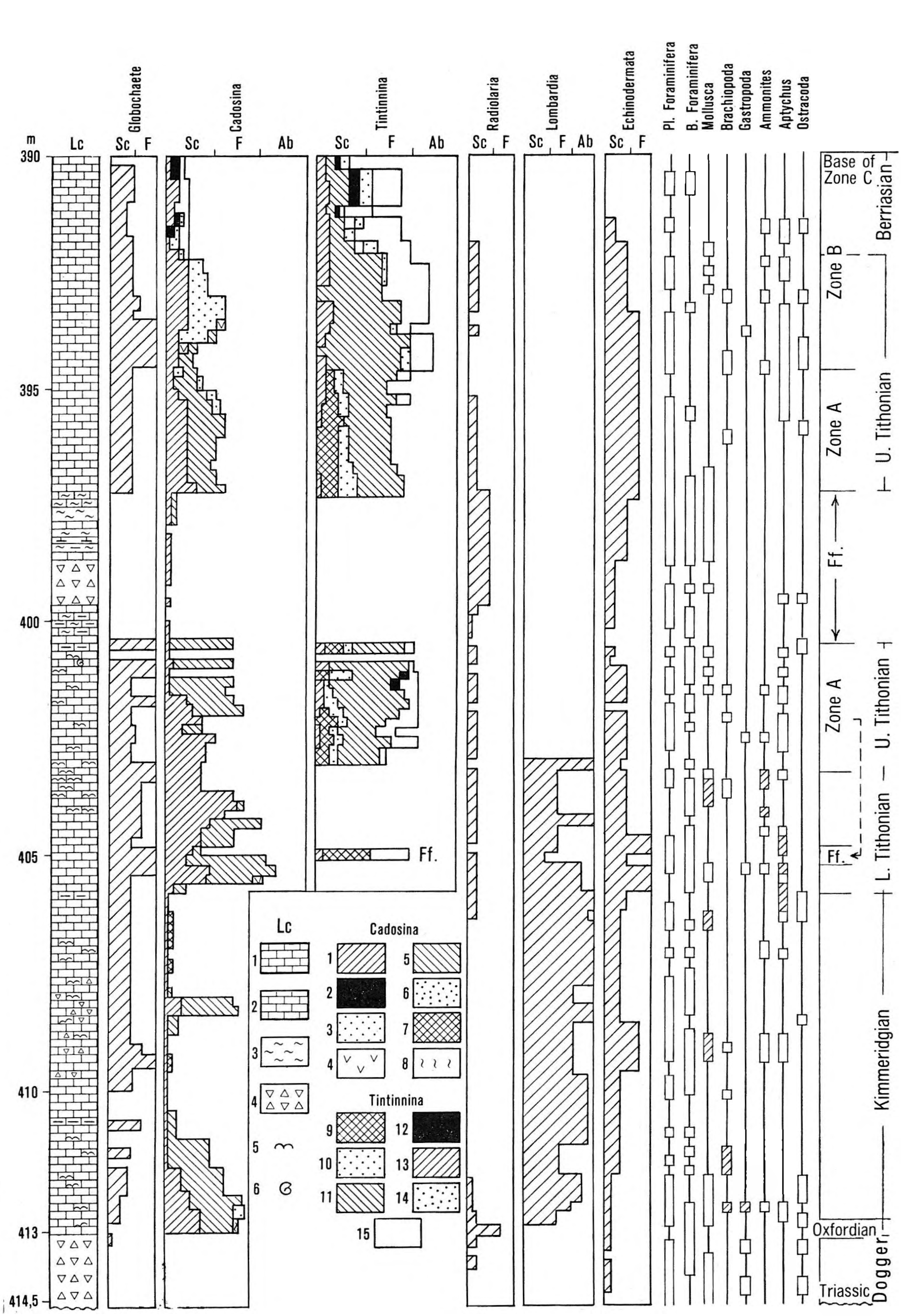


Fig. 23. Upper Jurassic beds in the borehole Süt-17: lithologic column and analytical record

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

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

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

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

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

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

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

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

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

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

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

Bio- and chronostratigraphy

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

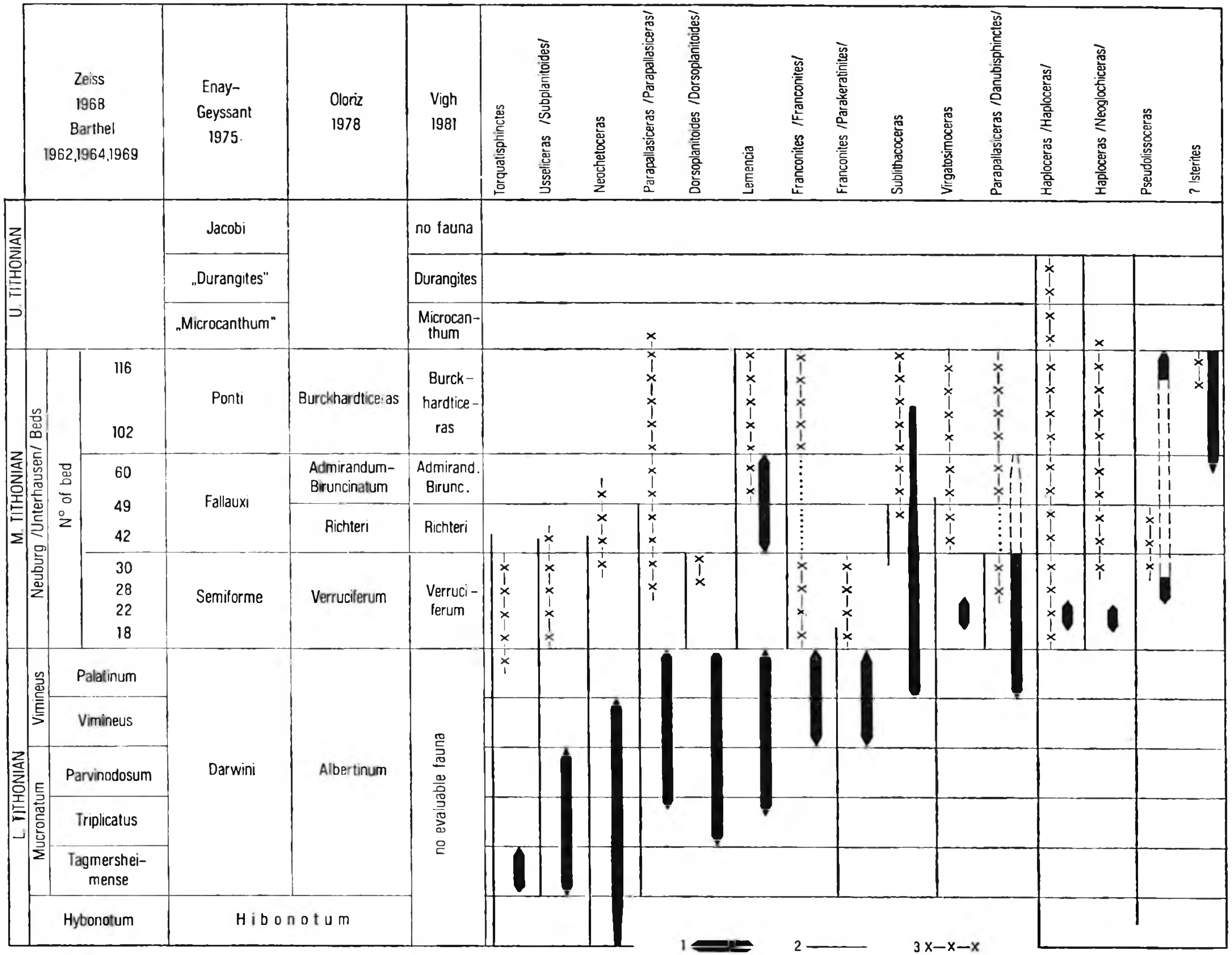


Fig. 24. Comparison of the distribution of the main ammonite genera from the Middle and Upper Tithonian
1. Frankonia, 2. Subbeticum, 3. Sümeg

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

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

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

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

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

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

Paleoenvironment

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

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

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

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

Mogyorósdomb Limestone Formation

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

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

Table 3

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

Species	Lower Tithonian	Middle Tithonian				Upper Tithonian	
		H. (N.) verruciferum	R. richteri	S. (S.) admirandum – biruncinatum	Burckhardticeras	H. (M.) microcanthus	Durangites
1	2	3	4	5	6	7	8
Haploceras (Haploceras) elimatum (Opp.)	*Ptychophylloceras, Pterolytoceras, Protetragonites, Haploceras, Torquatisphinctes, Physodoceras*	—	—	—	—	—	—
Haploceras (Haploceras) staszycii (Zeuschn.)		—	—	—	—	—	
Haploceras (Haploceras) tithonius (Opp.)			—	—	—	—	
Haploceras woehleri (Opp.)		—	—	—	—	—	
Haploceras (Neoglochiceras) carachtheis (Zeuschn.)		—	—	—	—	—	
Haploceras (Neoglochiceras) leiosoma (Opp.)				—	—		
Haploceras (Neolissoceras?) verruciferum (Mgh.)		—					•
Haploceras (s. l.) sp.	—	—	—	—	—	—	—
Pseudolissoceras planiusculum (Zitt.)		—					
Pseudolissoceras sp. (nov. sp.?)			—				
Pseudolissoceras sp.		—					
Streblites sp. [ex gr. *folgariacus* (Opp.)]		—					
Substreblites zonarius (Opp.)							—
Semiformiceras semiforme (Opp.)		—					
Semiformiceras semiforme ssp. ind.		—					
Semiformic. sp. (ex gr. *semiforme rotundus* Oloriz)		—					
Semiformiceras fallauxi (Opp.)			—	—	—		
Semiformiceras sp.		—			—		
Neochetoceras aff. *paternoi* (Di Stef.)			—	—			
Neochetoceras sp.		—	—				
Subdichotomoceras cf. *pseudocolubrinus* (Kil.)		—	—	—	—		
Subdichotomoceras cf. *gajinsarense* Spath		—					
Subdichotomoceras sp.		—	—	—			
Pachysphinctes sp. (ex gr. *robustus* Spath)		—					
Pachysphinctes sp. ind.		—					
Torquatisphinctes sp. (ex gr. *primus-acuticostatus* Spath)		—					
Torquatisphinctes sp.	—	—					
Discosphinctoides (Pseudodiscosphinctes) cf. *rhodaniforme* Oloriz		—					
Discosphinctoides (Pseudodiscosphinctes) sp. (nov. sp.?)		—					
Discosphinctoides (Pseudodiscosphinctes) sp.				—	—		
?Phanerostephanus sp. (nov. sp.?)			—				
Pseudovirgatites sp. [ex gr. *seorsus* (Opp.)]						—	
Pseudovirgatites sp.						—	
Paraulacosphinctes senex (Opp.)						—	
Paraulacosphinctes transitorius (Opp.)						—	—
Paraulacosphinctes sp.						—	
Sublithacoceras aff. *sphinctum* D. et E.					—		
Sublithacoceras sp. (ex gr. *fringilla* Zeiss)			—	—			
Lemencia pseudociliata Oloriz					—		
Lemencia parvicostata D. et E.				—	—		
Lemencia sp. (ex gr. *parvula* D. et E.)				—			
Lemencia patula (Schn.)				—	—		
Lemencia pergrata (Schn.)				—	—		

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

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

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

Stratotype section: Mogyorós-domb I

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

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

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

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

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

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

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

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

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

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

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

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

Bio- and chronostratigraphy

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

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

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

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

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

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

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

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

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Lower to Middle Cretaceous

by

J. Haas

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 indentical 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 resilicified 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 assignation 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 ($CaCO_3$ 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 megaloscopic lithological characteristics are concerned, the Jurassic-Cretaceous boundary cannot be tied to any kind of change, being impossible to delinate 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-Filácz 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 Mogyorósdomb Limestone Formation overlying the Pálihálás 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.

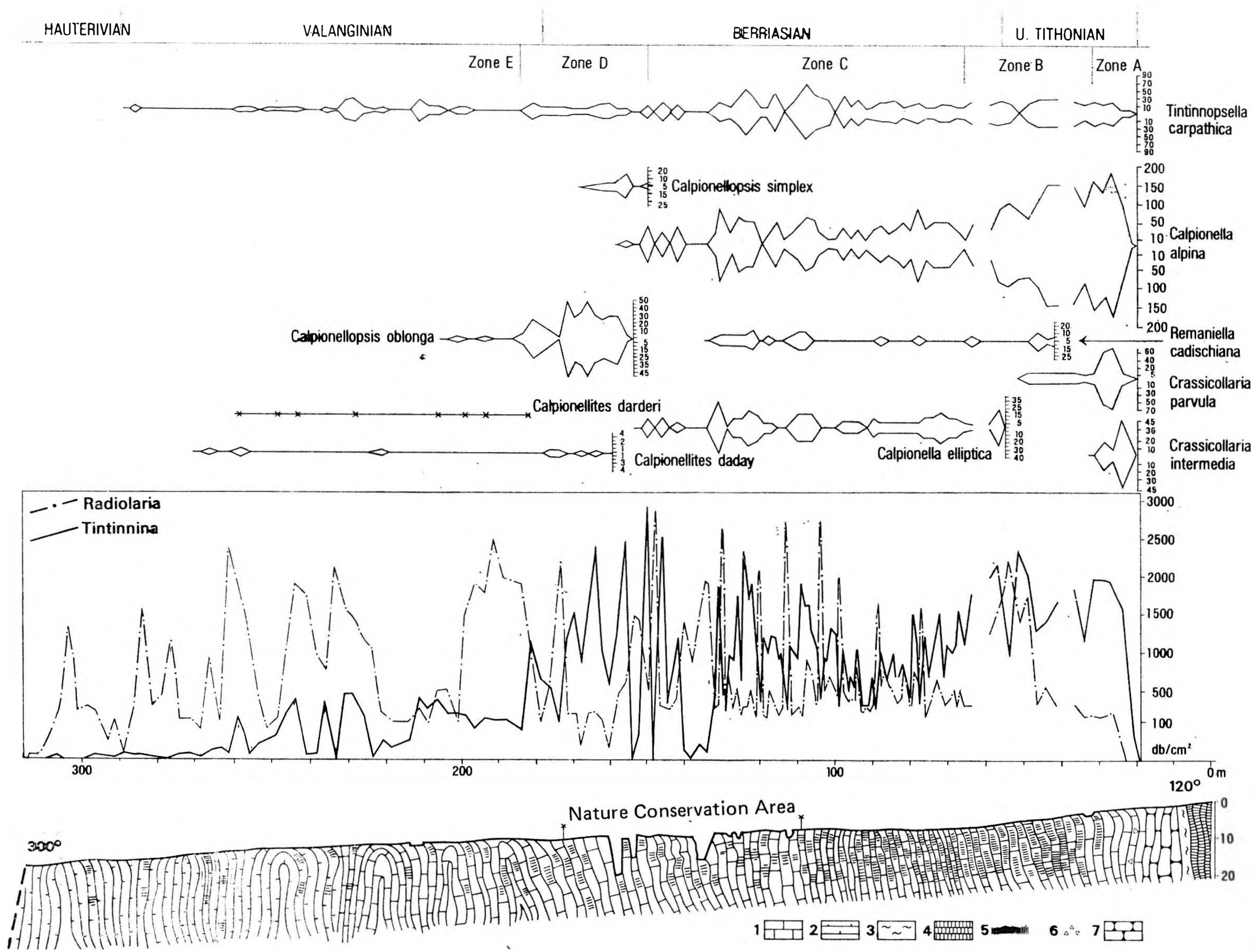


Fig. 25. Geological key section Mogyorós-domb I

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 nannonplankton 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-FILÁCZ 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 D_2 is given by the appearance of *Calpionellopsis oblonga* (CADISCH) (Plate XXIII, Fig. 3), while the lower boundary of Subzone D_3 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 D_3).

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-FILÁCZ, 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.

Located in 1957 near the Sümeg 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 "Sümeg 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 Sümeg type area the diagnostic features of the Sümeg 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 Sümeg 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 Sümeg 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 Sümeg 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 Sümeg 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-Nyírő. 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 invidual 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 Sümeg Marl.

In the upper interval of the unit (302.0–309.3 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 representaives of the *Spumellaria* group having been observed within this interval (Fig. 26).

The nannoplankton is generally significant, being present in a rockforming 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: SiO_2 18.6%, Fe_2O_3 6.3%, FeO 13.9%, MnO 11.6%, CO_2 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: SiO_2 49.7%, Fe_2O_3 7.3%, FeO 2.8%, MnO 1.2%, CO_2 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 *Spumellaria* 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 $CaCO_3$ 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.)

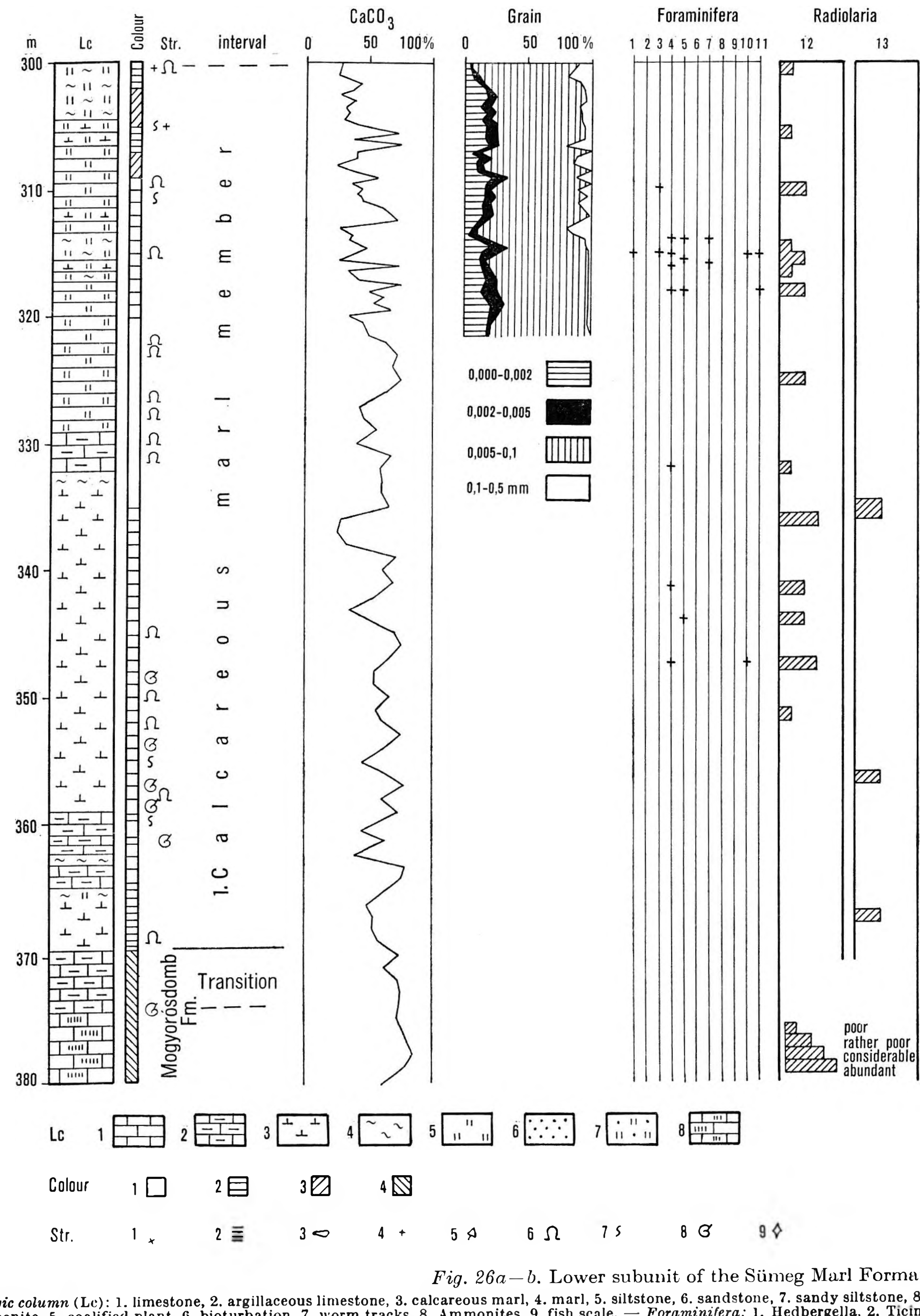
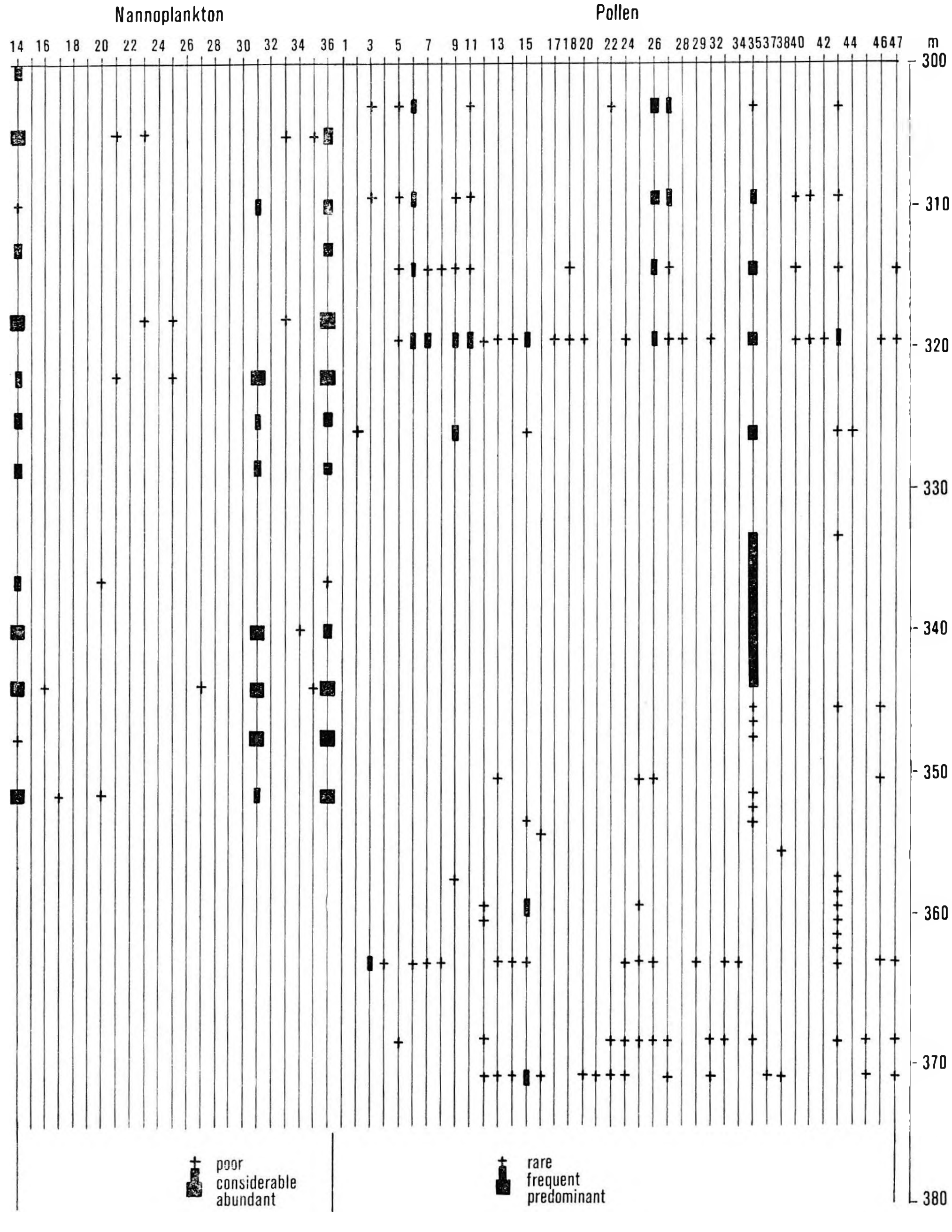


Fig. 26a—b. Lower subunit of the Sümeg Marl Formation in

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 Nasselaria. *Nanno-*
sp., 20. Ahmuerella sp., 21. Braarudosphaera hoschulzi, 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. Densoisporites velatus, 33. Staplinisporites telatus, 34. Verrucosisporites sp., 35. Classopollis classoides,
41. Podocarpidites multesimus, 42. Alisporites thomasii, 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. Pseudo-*plankton:* 14. Watznaueria barnesae, 15. Coccolithus sp. indet., 16. Discolithina embergeri, 17. Zygolithus 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 brevilaesuratus, 4. C. sprumonti, 5. C. globosus, 6. C. mediostriatus, 7. C. tersus, 8. Appendi-tuberosus, 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 obscurilaesuratus, 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

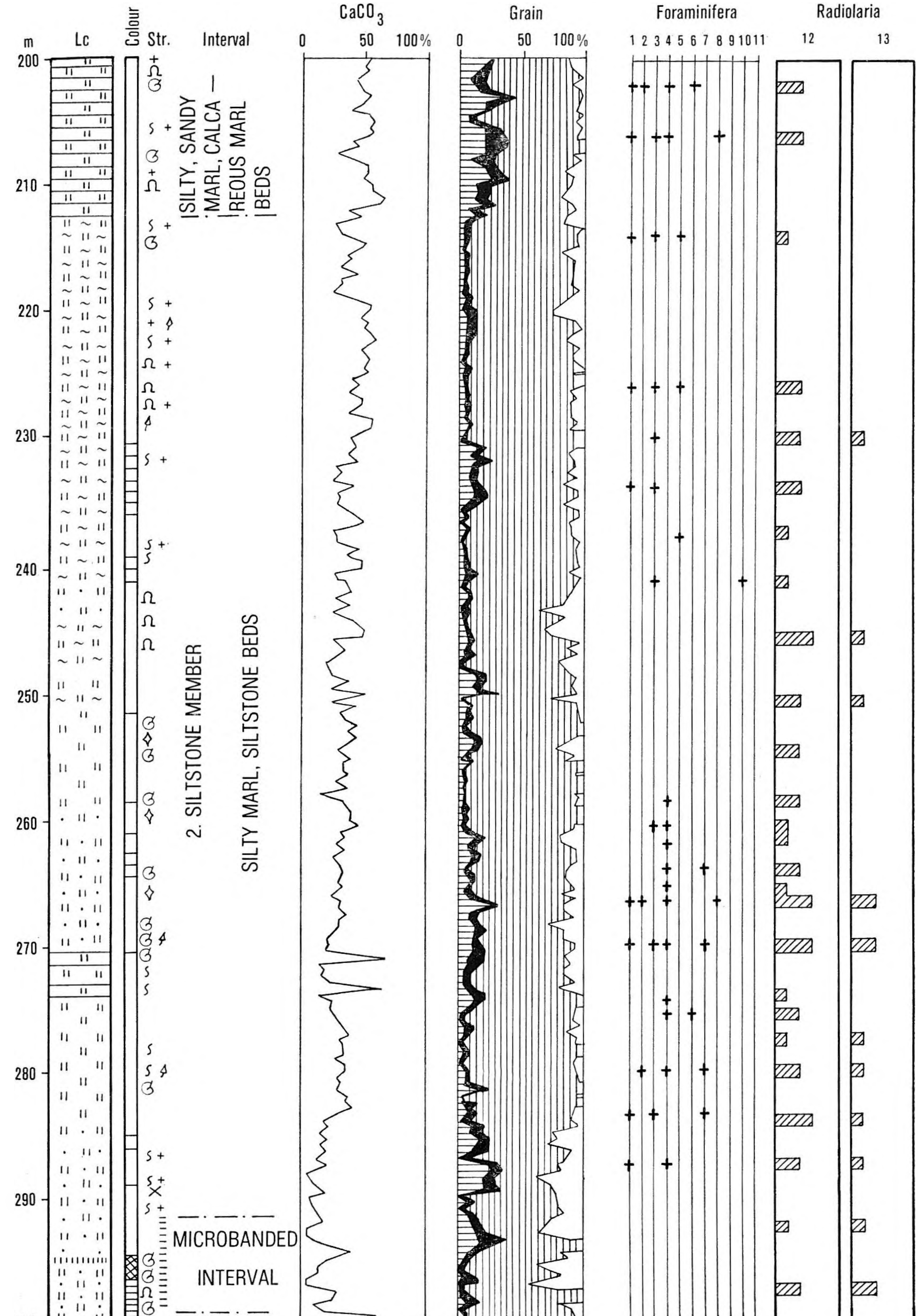


Fig. 27a–b. Middle subunit of the Sümeg Marl Formation in the borehole Süt-17: lithologic column and analytical record. (For explanations, see Fig. 26.)

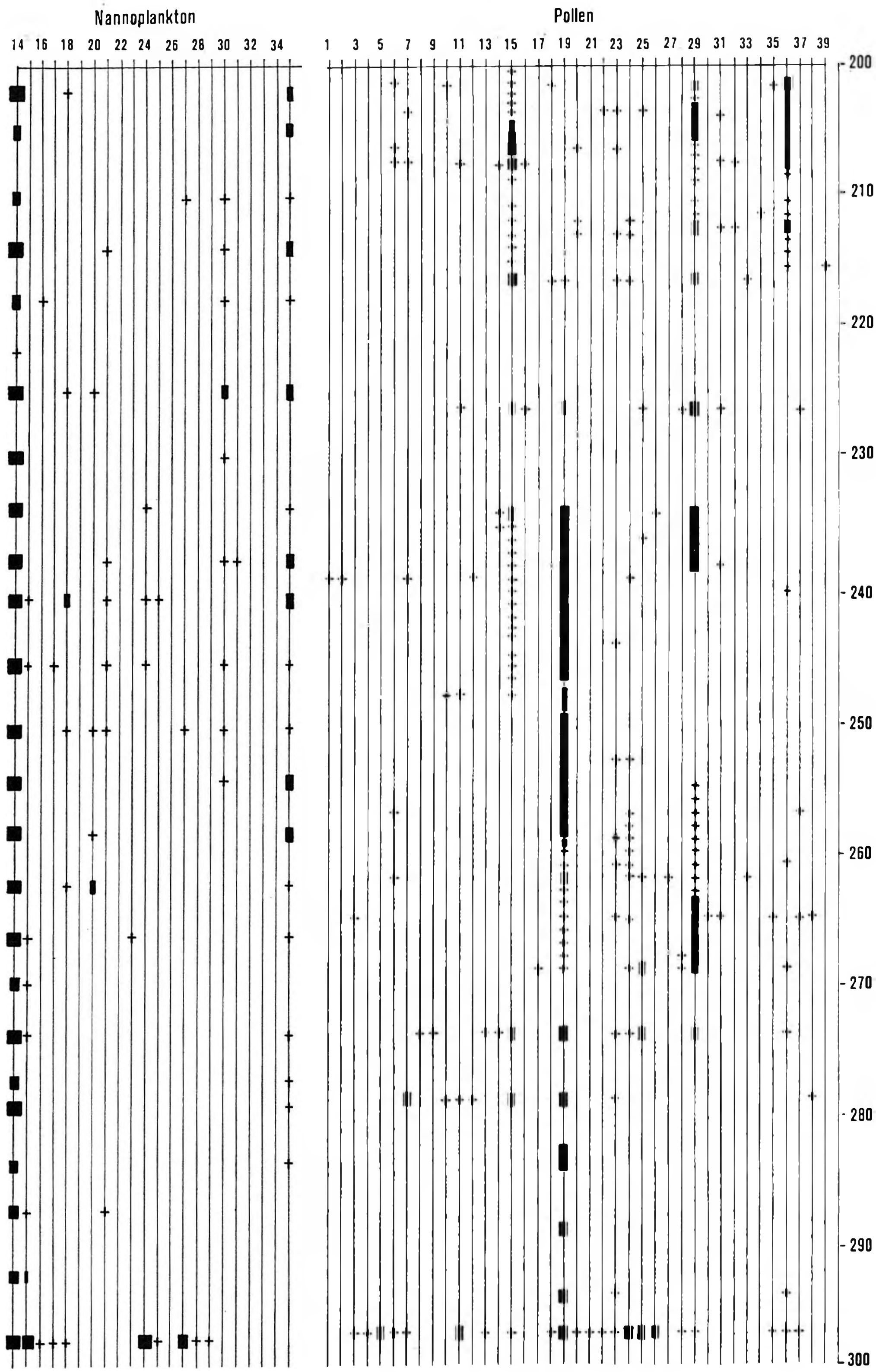

Nannoplankton
14 16 18 20 22 24 26 28 30 32 34
Pollen
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
200
210
220
230
240
250
260
270
280
290
300

Fig. 27b

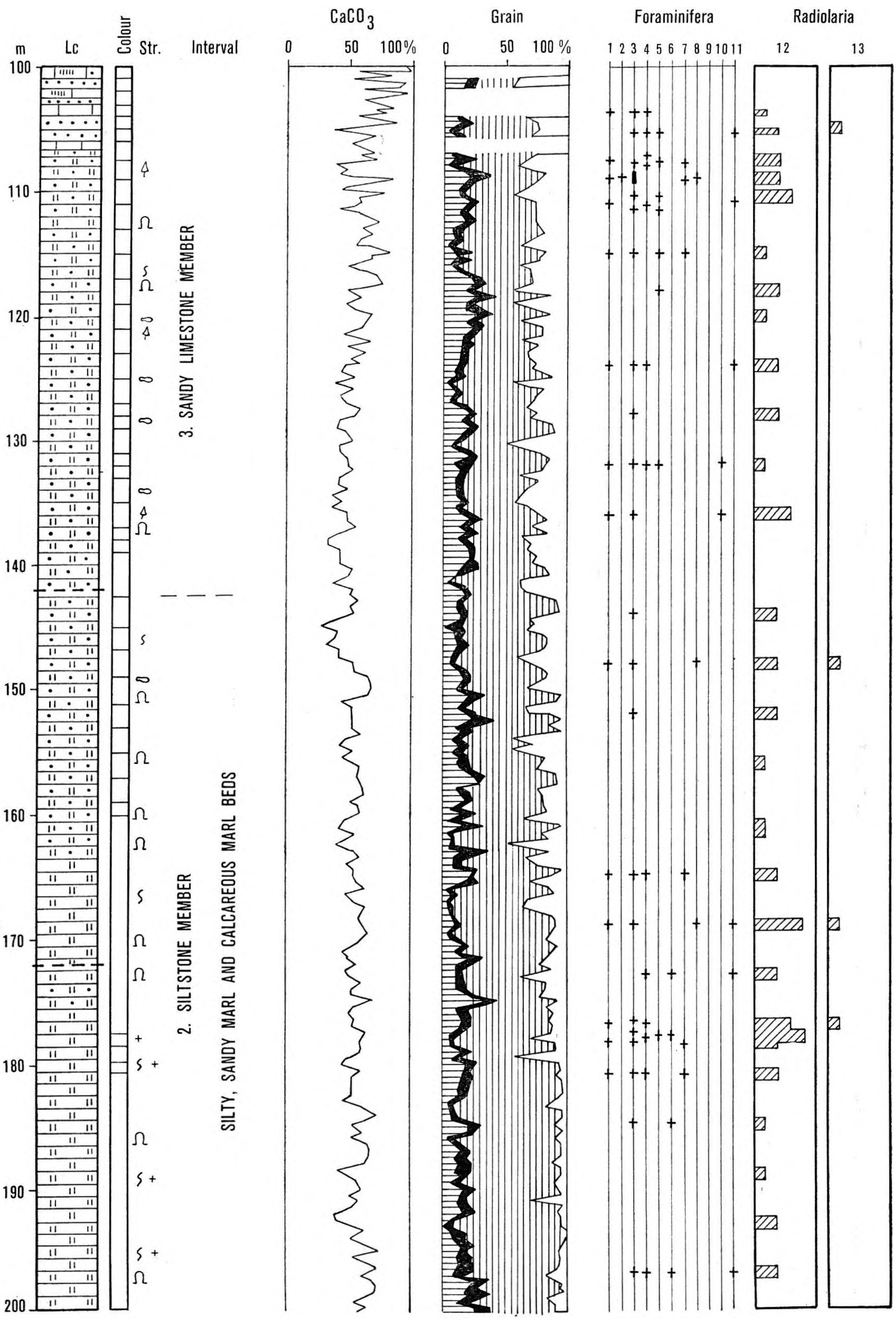
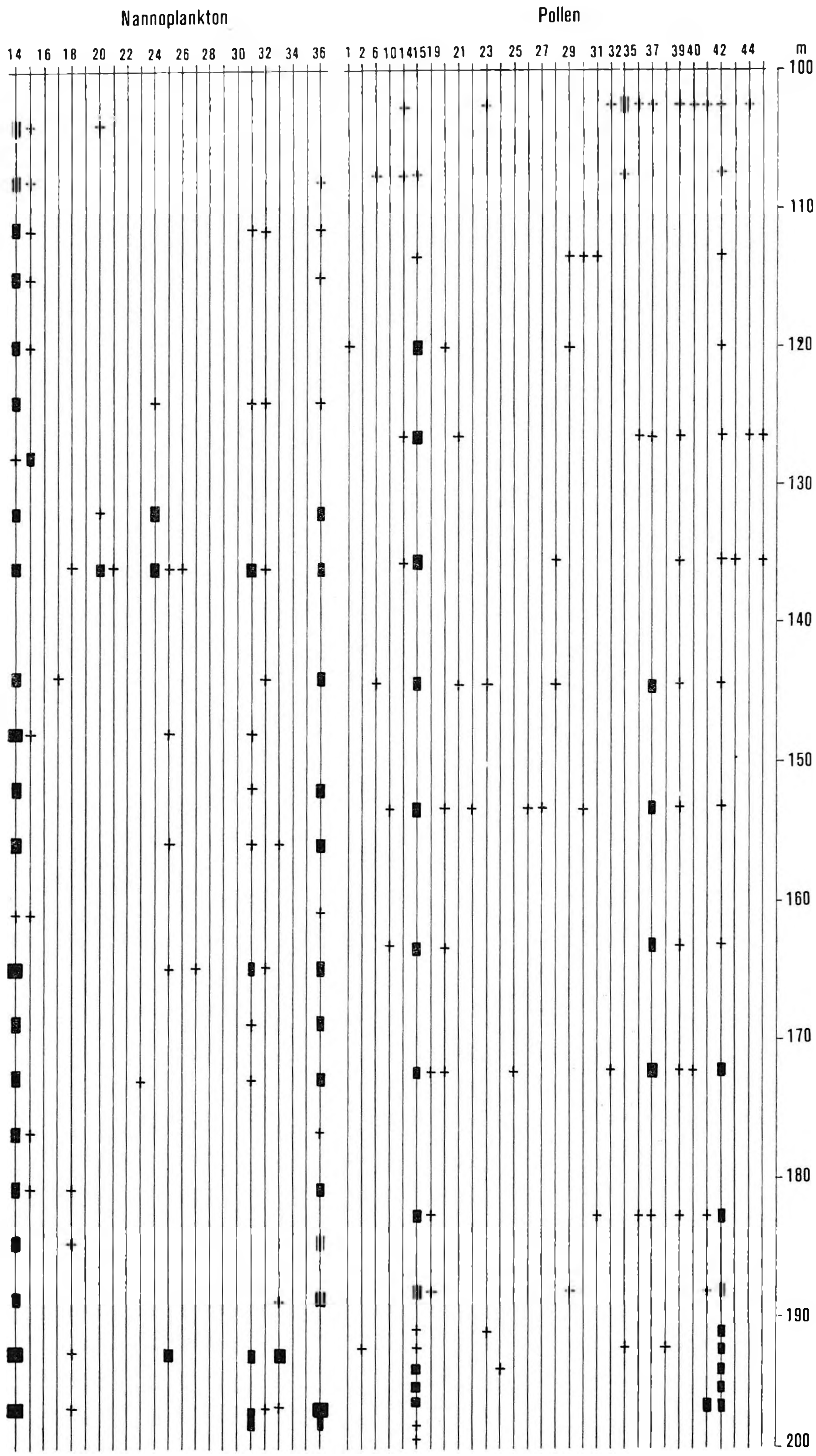


Fig. 28a—b. Upper subunit of the Sümeg Marl Formation in the borehole Süt-17: lithologic column and analytical record. (For explanations, see Fig. 26.)



Nannoplankton
Pollen
14 16 18 20 22 24 26 28 30 32 34 36
1 2 6 10 14 15 19 21 23 25 27 29 31 32 35 37 39 40 42 44
m
100
110
120
130
140
150
160
170
180
190
200

Fig. 28b

Table 4

Cephalopodal fauna of the Sümeg Marl Formation interval of the borehole Süt-17

Species	202,7	214,5	241,9	252,1	252,4	253,0	254,3	254,4	254,5	254,6	254,7	254,9	257,5	257,7	257,8	258,1	262,1	262,4	262,7	263,6	263,8	264,0	266,6	270,1	293,8	296,2	296,3	297,4	297,6	298,4	298,5
Crioceras sp. (ex gr. *C. silesiacum* Uhl.)																												+	+		
Parahoplites cf. *browae* (Uhl.)																												+			
Miodesmoceras cf. *lechitum* (Uhl.)																											+				
Costidiscus sp. (ex gr. *recticostatus* d'Orb.)																	+						+								
Crioceratites sp. ind.															+																
Hamulina sp. (ex gr. *H. ptychoceroides* Hoh.)												+			+																
Barremites cf. *difficilis* (d'Orb.)												+																			
Barremites sp. ind.									+		+							+													
Parahoplites sp. ind.										+																					
Pseudosaynella cf. *strettostoma* Uhl.									+	+		+																			
Leptoceras cf. *parvulum* Uhl.							+		+				+			+			+	+	+	+		+				+			
Ptychoceras sp. (ex gr. *P. puzosianus* d'Orb.)							+					+		+										+					+	+	+
Melchiorites charrierianus (d'Orb.)					+		+	+		+	+														+						
Pseudohaploceras liptoviense (Zeusch.)			+	+	+	+										+										+					
Procheloniceras sp.		+																													
Hamulina sp.	+											+																			
Colombiceras sp. (ex gr. *C. crassicostatum* d'Orb.)	+																														

ana 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 $CaCO_3$ 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 $CaCO_3$ 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.), *Macroscaphites yvani* (PUZOS), *Pseudohaploceras charrierianum* (D'ORB.), *Barremites* sp., *Leptoceras parvulum* UHL., *Phyllopachyceras 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 assignation proved in the first place by the presence of well-preserved fossils, suitable for a convincing identification, such as *Pseudohaploceras liptoviense* (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 *Cheloniceras*, the latter being characteristic of the Aptian.

The *Foraminifera* fauna from the borehole Süt-17 was studied by M. SIDÓ. 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 certainly (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 *Schackoina 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 assignation 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 *Schizaeceae* 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 thomasii*, *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.

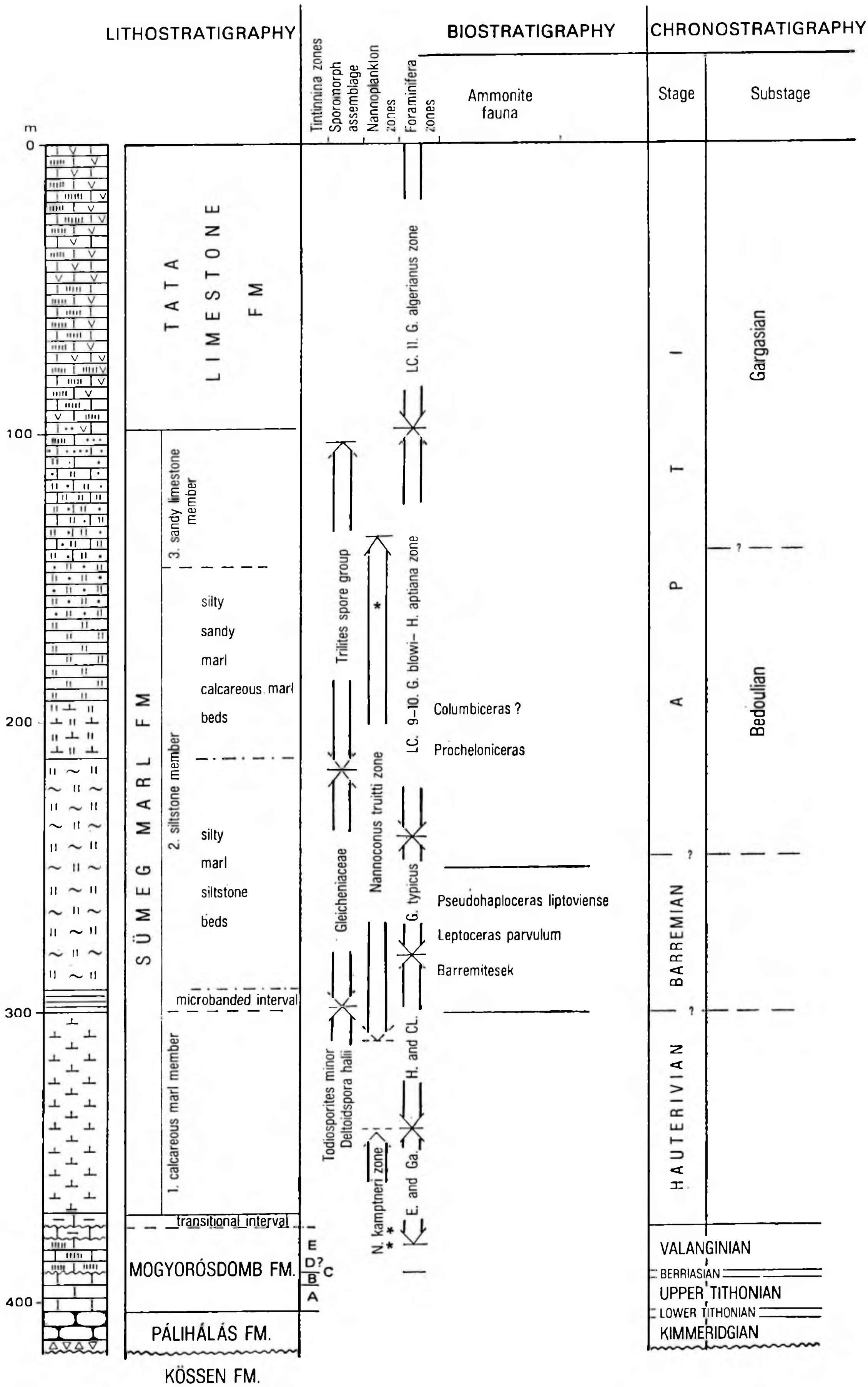
The bulk of the silica content is yielded by *Radiolaria* tests, i.e. similarly by planktonic organisms. The plankton/benthos ratio is high in the *Foraminifera* assemblage as well. All these circumstances are suggestive of a depositional environment that had a communication with the open sea. From among 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


LITHOSTRATIGRAPHY
BIOSTRATIGRAPHY
CHRONOSTRATIGRAPHY
Tintinnina zones
Sporomorph assemblage
Nannoplankton zones
Foraminifera zones
Ammonite fauna
Stage
Substage
m
0
100
200
300
400
TATA LIMESTONE FM
SÜMEG MARL FM
3. sandy limestone member
2. siltstone member
1. calcareous marl member
silty
sandy
marl
calcareous marl
beds
silty
marl
siltstone
beds
microbanded interval
transitional interval
MOGYORÓSDOMB FM.
PÁLIHÁLÁS FM.
KÖSSEN FM.
E
D?
C
B
A
Trilites spore group
Gleicheniaceae
Todiosporites minor
Deltoidspora halii
Nannoconus truitti zone
N. kamptneri zone
LC. 11. G. algerianus zone
LC. 9–10. G. blowi– H. aptiana zone
G. typicus
E. and Ga. H. and CL.
Columbiceras ?
Procheloniceras
Pseudohaploceras liptoviense
Leptoceras parvulum
Barremitesek
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
UPPER TITHONIAN
LOWER TITHONIAN
KIMMERIDGIAN
Gargasian
Bedoulian

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-resistent 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 somwehat 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 overhelming 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–Spiroplectammina* 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 hoschulzi, ** the Nannoconus kamptneri Zone is indicated by N. colomi and N. globulus. — *G* Globigerinelloides, *H* Hedbergella, *Cl* Claihedbergella, *E* Epistomina, *Ga* Gavellinella

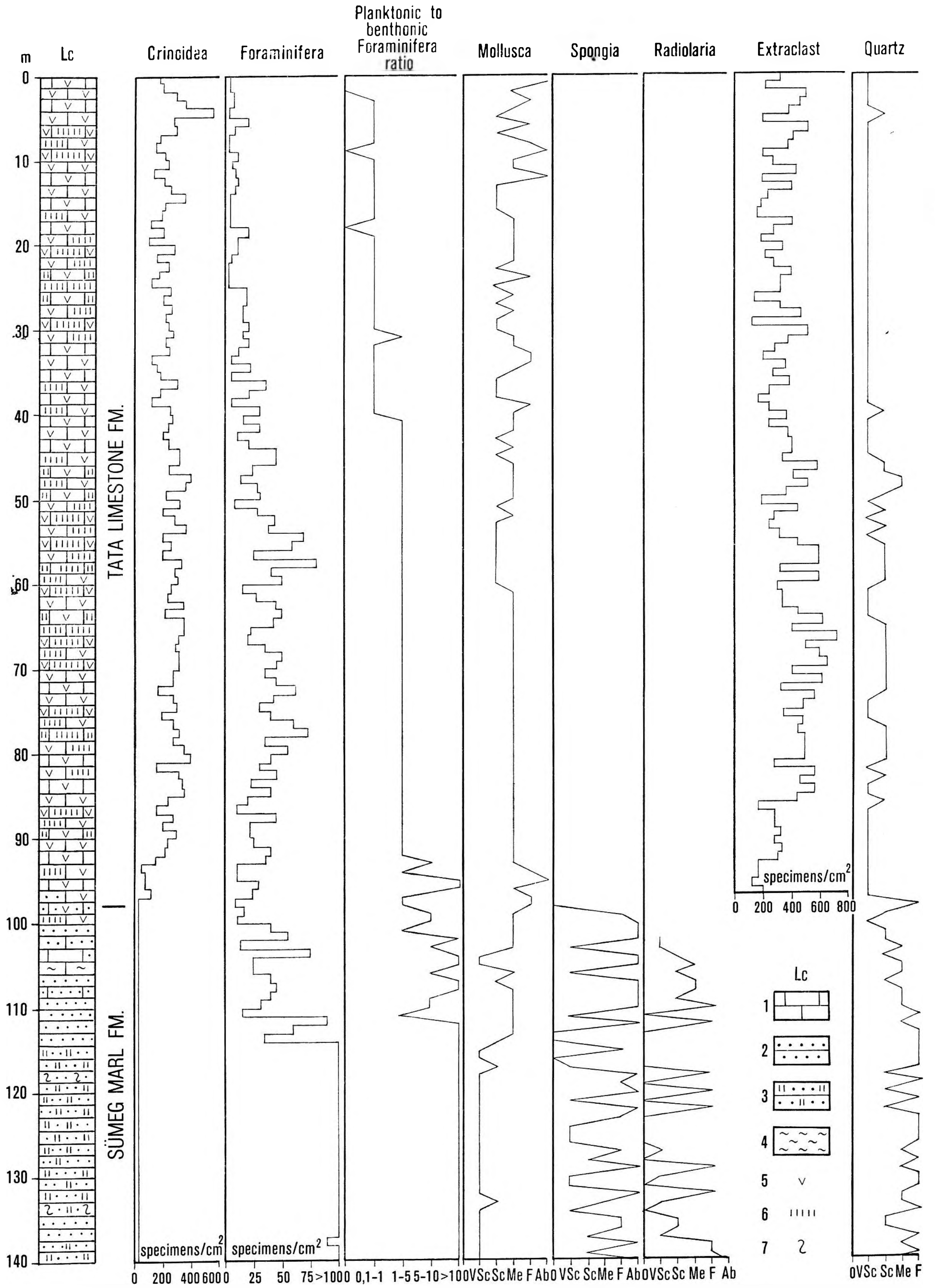


Fig. 30. The Tata Limestone Formation as exposed in the borehole Süt-17: lithologic column and microscopic record

Lithologic column **(Lc): 1. limestone, 2. sandstone, 3. sandy silt, 4. marl, 5. crinoidal, 6. chert, 7. worm tracks. — *0* 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 able 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. 30).

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 oölites (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 and 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* (Roem.), *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 bioextrasparite (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 environent 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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Upper Cretaceous

by

J. HAAS and E. J.-EDELÉNYI

To study the Upper Cretaceous sequence is of outstanding importance for the geological understanding of the Sümeg area. It is in this area that the best-exposed sequences of the Central Range Senonian are found, exposures enabling the student to determine the intricate space and time relations of the lithostratigraphic units and to detect the regularities, interrelations, involved.

In the course of our work the major problem to be solved was to find out the kind of regularity involved in the space and time range of the rock units observed while doing field surveys for the geological map and studying the sequence of a number of artifical exposures and to specify the paleoecological and geohistorical model responsible for the formations therein.

For the solution of these problems it was indispensable to develop a stratigraphic synthesis based on an up-to-date approach. The lithostratigraphic calibration was regarded as a particularly important task, as progress in this respect was believed to have lagged behind progress in biostratigraphic knowledge.

Exploration history

In his travelogue of Hungary, F. S. BEUDANT (1822) described *Hippurites*- and *Radiolites*-bearing limestones "from a hill to the east of the town, in its immediate vicinity" (supposedly from the Köves-domb) to which he referred as "Kalkstein von Sümeg" and which, with a reference to analogies with France, he classified as Jurassic limestones.

F. HAUER (1862) was the first to distinguish Cretaceous lithostratigraphic units of formation character in the Bakony Mts. He mentioned the Rudist limestone of Sümeg too and believed it to belong to the Zirc Beds.

A. KOCH (1872) carried out the separation of the basic stratigraphic units of the Upper Cretaceous formations: "Gryphaea horizon" and "Rudist limestone" which up to latest times served as a basis for the mapping and description of the Cretaceous in the Sümeg area.

J. BÖCKH (1875) was the first to record on a map of 1:144,000 scale the Upper Cretaceous formations of Sümeg, distinguishing between "Hippurites limestone" and "Marly limestone" units.

In his review of the geology of the southern Bakony (1877) he described *Hippurites* species from the Upper Cretaceous limestone and brought the formation in connection with the Alpine "Gosau formation".

While studying the geology in the neighbourhood of Lake Balaton, L. LÓCZY (1913) was the first to attempt at an all-round interpretation of the Upper Cretaceous of Sümeg. In his work he drew the following conclusions: "The Hippurites limestone of the Upper Cretaceous introduces the sequence at Sümeg with a thickness of 50 m or so. These strata are overlain, in 15 m thickness, by marly limestones and bluish-grey marls with enormous quantities of Gosau-type fossils and a thin coal seam. Then, as a third member of 100 m thickness, it is an Upper Senonian Inoceramus-bearing marly limestone that completes an Upper Cretaceous sequence which I venture to estimate at 160 to 170 m". In the light of our present-day knowledge the succession listed by L. Lóczy is not valid, but his description contains some correct observations of detail.

GY. RAKUSZ (1935), relying on the results of a couple of days of observations, registered an opinion approximating our present-day knowledge. He identified the argillaceous marls with traces of coal with the coal-bearing formations of Ajka and then, as beds overlying these, he registered a Gryphaea marl—Hippurites marl—Inoceramus marl succession.

In the early 1930's the Hungarian State Collieries (MÁK) launched a coal exploration project during which several exploratory shafts and two boreholes were located. From 1929 on bauxite prospecting was conducted on the Bárdió-tag to the southeast of Sümeg.

In a paper devoted to the geological and paleontological conditions of the Upper Cretaceous at Sümeg, K. BARNABÁS (1937) listed a rich fauna from the Gerinc quarry and the Köves-domb.

On the basis of a fossil which was recovered from the limestone of the Vár-hegy and which he believed to be a Gryphaea fragment, he assigned the "Vár-hegy limestone" conditionally to the Senonian or, more precisely, he placed it above the Gryphaea limestone. Thus the overlying coal-bearing strata were placed by him, erroneously, beneath the Inoceramus marl.

The work of R. HOJNOS (1943) did not enhance progress in the solution of stratigraphic problems of the Senonian; the less so, his assignment to the Senonian of the "silicified Cretaceous limestone" which already L. LÓCZY (1913) correctly referred to as Tithonian was a retrogressive venture.

The activity of J. NOSZKY jr. was a connecting link between pre- and postwar history of geological research and exploration. He spent a lot of time, from 1943 to 1957, with repeated, very careful studies, mapping, of the Sümeg area.

In the Annual Report for 1944 of the Geological Institute he gave the following succession of Upper Cretaceous stratigraphic units:

1. grey carbonaceous clay sequence with corals and Gastropoda
2. argillaceous Gryphaea limestone
3. Hippurites limestone
4. calcareous marl with Gryphaea, then nodular, laminated marl with worm tracks and chert inclusions
5. Inoceramus marl.

In his report of 1957 he changed this opinion inasmuch as the "Cyclolites marl" quoted as the basal bed in his earlier works he did not consider anymore an independent stratigraphic horizon, but he took it to be a different, local facies of the Hippurites limestone.

Parallel to his detailed geological mapping in 1950 the detailed paleontological study of selected fossil groups was begun.

B. Géczy (1953) wrote a treatise on Cyclolites, G. Kolosváry (1954) on other hermatypical and ahermatypical corals. E. Szörényi (1955) studied and monographed the Echinoidea fauna.

In 1957, under G. Kopek's guidance, coal exploration was recommenced and in this context three boreholes had been put down by 1960 (Sp-1, -2, -3) to the north of Sümeg. These yielded important results contributing to the understanding of stratigraphy, as they had penetrated the most complete sequence ever observed in the study area. That the Rudista limestone cropping out at a number of sites fell out of the sequence to the north of Sümeg had become evident. The results of coal explorations were presented in a manuscript report by G. Kopek (1959). Concerning the genetic circumstances of the coal seams, he pointed out, in his Ph.D. thesis (1961), that the Upper Cretaceous sequence in the Sümeg area was of more marine character than it was the case with Ajka and that this was due to a transgression from the south.

The exploratory activities gave a new impetus to scientific research and monographing. Paleontologist specialists carried out detailed studies of the rich mega- and microfossil collections from the boreholes and, at the same time, they re-studied the materials of surface exposures as well.

F. Bartha studied (1962) the fossils recovered from the coal-bearing sequence of boreholes Sp-1 and -2 and, primarily on the basis of a paleoecological study of Pyrgulifera, he analyzed the process of its formation.

L. Czabalay (1961–1982) devoted a number of publications to the biostratigraphic and facies characterization of the Mollusca fauna. The individual groups of strata were distinguished from one another on the basis of their Bivalvia and Gastropoda faunal assemblages. In more than two papers, he dealt with the Rudista fauna of the formations from the Sümeg area and she processed other molluscs of the Rudista limestone, too. She produced paleontological evidence to confirm the heteropical nature of the Hippurites limestone and the Gryphaea marl.

M. Sidó (1961–1980) carried out detailed foraminiferological study as well as biostratigraphic and facies evaluation of several boreholes from the Sümeg area. In her paper on the examination of the Foraminifera fauna of the Rudista limestone she presented the results obtained for several samples from Sümeg as well.

F. Góczán (1961–1971) studied in detail the sequences of the boreholes Sp-1 and Sp-2, establishing well-defined spore-pollen biozones and assigning the Senonian formations to the Santonian, Campanian and Maastrichtian substages. By examining samples from the Gerinc quarry, he confirmed that the "Hippurites limestone" and the "Gryphaea marl" are heteropical counterparts of each other.

In 1972 in our M. Sc. theses, we dealt in detail with the Upper Cretaceous formations and the stratigraphic, facies and paleogeographic characteritics of two subareas—the Köves-domb (J. Haas) and the Hajnal-hegy (E. Edelényi). Later we devoted several papers to discussing the stratigraphy and paleogeography of the Senonian in the Sümeg area (1977, 1979).

Extension, mode of superposition, stratigraphic subdivisions, local types

The Upper Cretaceous formations are common in the Sümeg area (Fig. 31). Usually denudation- or, in some places, tectonically controlled, the limit of their extension runs at about two kilometres to the southeast of the settlement. The Senonian sequence can be further traced to the northeast, towards Gyepükaján, as shown by drilling results. As regards the Várvölgy basin and the northwest foreland of the Keszthely Mts, the Upper Cretaceous record is just sporadical, so to the southeast of Sümeg both the extension of the Upper Cretaceous and its geological characteristics are quite obscure.

Composed of pelitic rocks, the Upper Cretaceous formations are seldom observable in outcrop, while the surface extension of the carbonate rock units is considerable. On the morphological bench

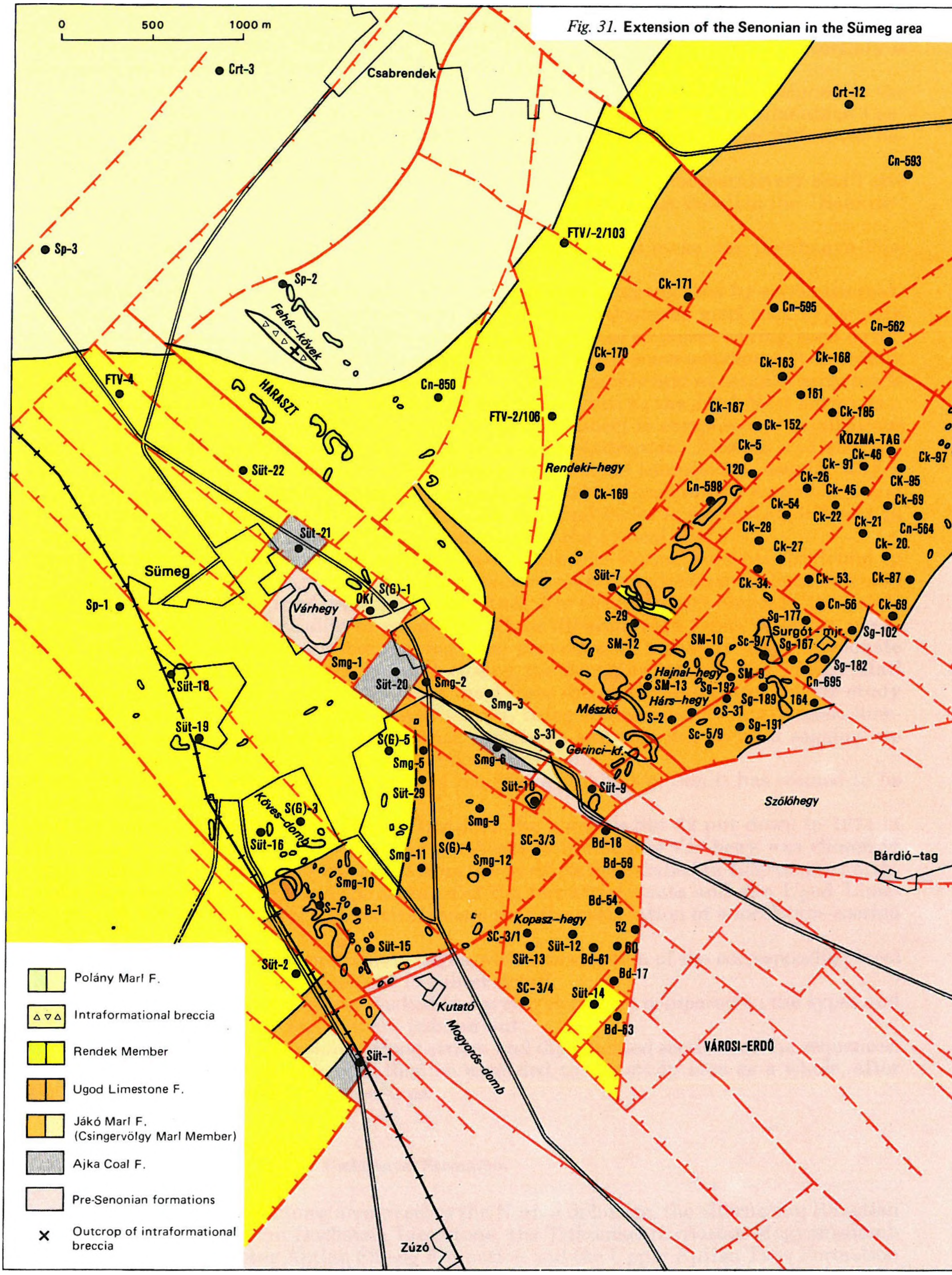


Fig. 31. **Extension of the Senonian in the Sümeg area**

reworked or in-situ rock debris or, in case of marly rocks, by a residual clay layer. The carbonate bottom, as a rule, is little karstified.

At the base of the Senonian sequence, in general, a terrestrial formation only a few metres thick is found, but the terrestrial detritus is sometimes totally absent, so that the beds of the Ajka, Jákó and Ugod Formations can be observed directly at the base of the Senonian sequence.

The common rock types of the Csehbánya Formation are rock debris, argillaceous carbonate detritus, pebbles, breccias, conglomerates, variegated, sandy clays, variegated marls, red clays, bauxitic clays, bauxite, green clays, grey clays, argillaceous marls, carbonaceous clays, freshwater marls, calcareous marls and limestones.

The most typical sequences of the base are shown in Fig. 32. The map shows the contours of the Csehbánya Formation and of the formations directly overlying the pre-Senonian substratum as well. By constructing it, we have tried to answer the question concerning the kind of relationship that may exist between the spatial distribution of the formations directly overlying the terrestrial formations and the geological features of these. To suppose such a relationship has been possible because it is the pattern of the one-time relief that is basically reflected in both geological features.

The terrestrial sediments or the pre-Senonian substratum is covered by various Senonian formations and the worm's eye view of the immediate overburden formations shows a zonal arrangement. (The individual zones are shown in Fig. 32 by the letters A, B and C.)

In the greater, northwest, part of the Senonian-covered area (shown as C) the Ajka Coal Formation is the immediate overburden. Farther southeast, the coal seams are pinching out and in a strip of 200 to 300 m width (shown as B), the overlying beds are constituted by shallow-water marls, calcareous marls, and argillaceous limestones assignable to the Jákó Formation, then farther southeast on, it is the Ugod Limestone Formation that rests directly on a pre-Senonian substratum. In other words, the older Senonian formations will pinch out one after the other in a southeasterly direction and so the younger ones in particular zones will extend beyond the older sediments.

An additional peculiar feature that can be read off the map is the northeast–southwest orientation of the afore-mentioned zones which is broken only at the western margin of the Gerinc range, turning to a north-south direction.

Examining the relationships between the arrangement pattern of the basal formations and the distribution of the terrestrial formations, we can register the following relationships:

1. In the outermost zone (see A in Fig. 32), beneath the Ugod Limestone Formation, no terrestrial formation can be usually found, rock debris of a small thickness and clay detritus (basal bed) being observable in rare cases.
2. Terrestrial formations of rather considerable thickness occur there, where the immediate overburden is represented by the Jákó (Zone B) and the Ajka Formation (Zone C).
3. In some zones—more or less normal to the limits of pinching out of the formation—the terrestrial formations are missing from zones B and C as well.

Regarding pre-Senonian paleogeographic and source area conditions, the most useful information is provided by the pebble-size grains occurring in the terrestrial basal beds. The grains widely vary in size and roundness, though the coarse, scarcely rounded detritus is most frequent. Being of local origin for the most part, each rock variety can be found in situ in the neighbourhood. Where the underlying rock is represented by Upper Triassic limestones or dolomites, there even the pebbles or the breccias are composed of such rock varieties (boreholes Cn-211, -563, -567, -598, Ck-95). In the borehole Ck-167, in addition to poorly rounded Triassic limestone debris accounting for abour 80% of the material, brown-coloured Jurassic chert debris have also been recovered. At the base of the borehole Sp-2 too, Mesozoic chert and limestone pebbles were observed. Where the underlying rock is Lower or Middle Cretaceous, there even the basal detritus, usually very reduced in thickness, is composed for the most part of these formations (boreholes Süt-15, -16, -17).

Beside the coarse-grained detritus, silts and pelites of different lithological character are also abundant in the terrigene sequences. Basically two types of them can be singled out: a green to greenish-grey and variegated, montmorillonite-containing clay on the one hand and kaoliniferous and bauxitiferous clay or bauxite on the other.

In the basal part of the Senonian sequence of the borehole Süt-15, above the debris of local origin of the Upper Barremian calcareous marl, 1.5 m of dark green clay can be found which consists, as shown by the DTA results of M. Földvári and the X-ray analyses of I. Viczián, of montmorillonite as essential mineral and montmorillonite-illite mixed-layer clay minerals as minor components to which some quartz, calcite and pyrite are added.

In the borehole Süt-18, the lowermost 7 metres of the sequence are represented by unfossiliferous, variegated sediments. The montmorillonite content of the dark green, ochre-yellow and purplish-red to purple sandy and silty clay was found to be remarkable (between 11 and 77%) in all of the 10 samples analyzed. (The X-ray diffraction analyses were performed by A. Szemethy.) It is worth mentioning

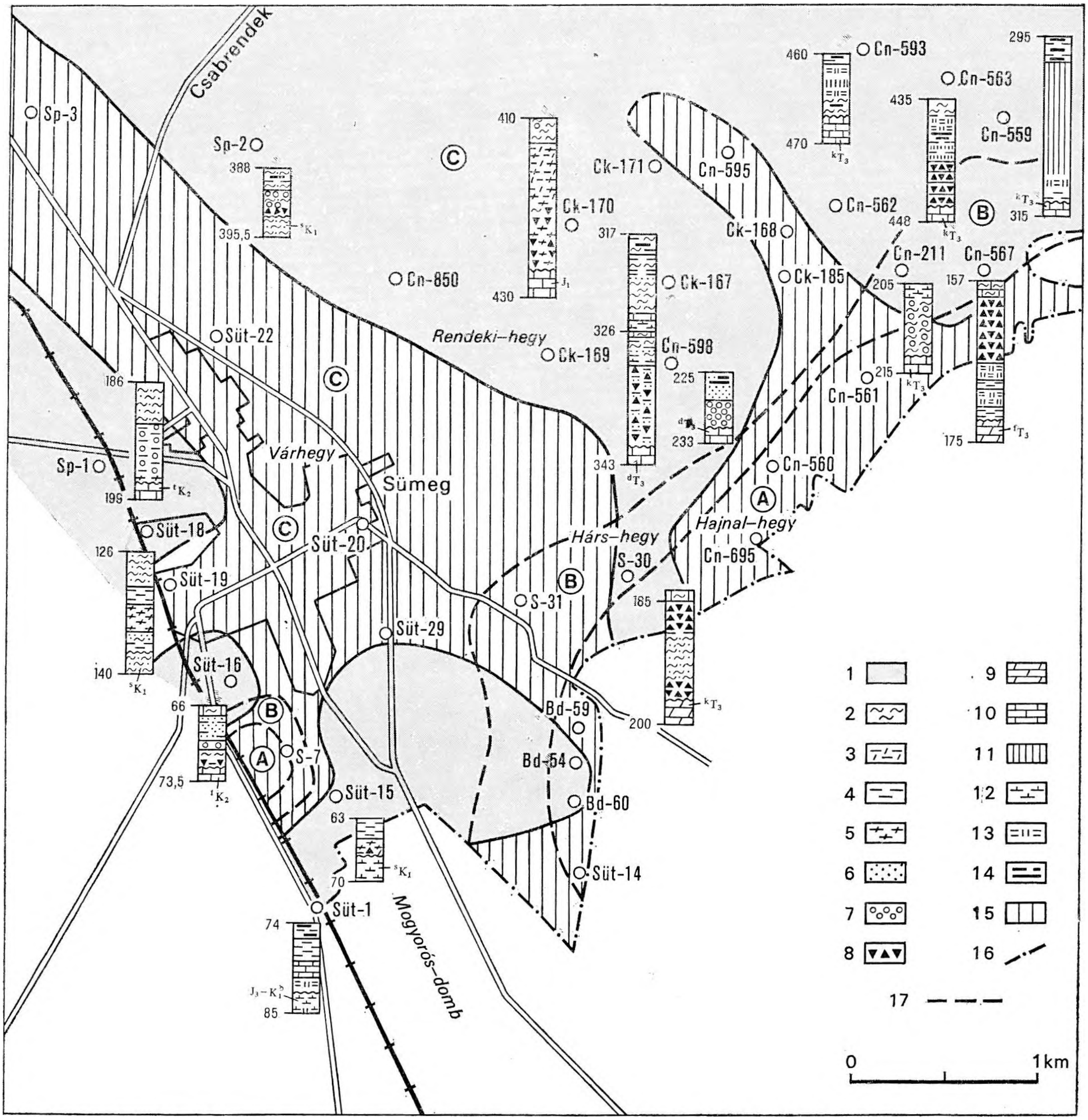


Fig. 32. Extension of the Csehbánya Formation and its geological features

1. Csehbánya Formation, 2. marl, 3. variegated marl, 4. clay, 5. variegated clay, 6. sand, 7. gravel, 8. detritus, 9. dolomite, 10. limestone, 11. bauxite, 12. calcareous marl, 13. bauxitic clay, 14. coal, 15. the Csehbánya Formation is missing from the Senonian sequence, 16. extension limit of the Senonian, 17. boundary of facies zones, facies zones *A-B-C*

that the montmorillonite content in the green rock varieties was 25 to 31%, that in one sample of purple colour it was 40%, in one ochre-yellow sample 58% and that the maximum, 77%, was observed in a sample of purplish-red colour. From among the clay minerals other than montmorillonite only a low amount of illite and mixed-layer illite-montmorillonite mineral could be registered.

From the variegated clay layer above the basal bed composed of detritus of foot-wall origin in the borehole Sp-1 40% mixed-layer illite-montmorillonite was detected by X-ray analysis (M. Melles). The heavy mineral spectrum of the rock material of this bed was shown to be poor by G. Noske-Fazekas, unlike it is the case with the underlying Lower to Mid-Cretaceous formations. Low quantities of zircon, garnet, epidote, tourmaline and chlorite could also be observed. The amount of dolomite grains, however, proved to share a considerable part of the mineralogical composition.

Our discussion of the bauxite rock types here will be quite brief, for their qualitative, genetic, etc. characteristics are to be dealt with under a separate heading. We shall restrict ourselves here to analyze the relations of the bauxites known from the base of the Senonian and other terrestrial formations and the relationships observed between the Senonian formations and the bauxite rock bodies.

Bauxitic rock types were exposed by some boreholes (Cn-593, -563, -559, -567) in the northeast part of the marginal zone, in a belt, where the Ajka Formation is heavily reduced in thickness or it may even be pinching out. That in two boreholes farther northwest (Cn-563, -593) carbonaceous clay interbeds beneath or between the bauxitic layers were observed, is worthy of mention. In three of the four boreholes the Senonian sequence is introduced not by bauxite, but by other terrestrial sediments such as breccias, clays or carbonaceous clays and marls. Thus it is obvious that the Upper-Cretaceous-covered bauxitiferous strata are products of a terrestrial accumulation taken place at the beginning of the Senonian sedimentation cycle, just like it is the case with the multitude of rock varieties listed in the foregoing. It is also worth mentioning that in the cases learned thus far the pre-Senonian basement is an Upper Triassic sequence (Rhaetian) composed of an alternation of limestones, dolomites and marls that cannot be regarded as liable to karstification. This fact suggests that in the cases analyzed here the site of deposition and the conditions of preservation of the bauxites and their isochronous facies counterparts were primarily controlled by the Senonian facies relations and that the lithology of the underlying rock types played only a quite subordinate role in this.

Chronostratigraphy

From the terrestrial formations no fossil has been recovered, their exact age being unknown. According to the results of paleontological studies by F. Góczán, the basal beds of the Ajka Formation are of Upper Santonian age (Oculopollis-, Complexipollis Zone). As supposed by M. Sidó (1969), however, they would be older than Lower Santonian, probably Coniacian.

The terrestrial sediments of the Csehbánya Formation may be regarded as nearly contemporaneous with the lower strata of the Ajka Formation. As already mentioned, as one proceeds from the northwest to the southeast, the older formations pinch out, being overlapped by the younger.

Consequently, a regular transgression cycle can be delineated, where the lowermost beds overlying the terrestrial layers tend to represent a marine facies of normal salinity. Taking one datum level, a configuration with a landward decrease in salinity may be supposed. Hence the hypothesis (otherwise valid to the transgressive cycle in general) suggesting that the formations of one and the same facies (rock type) tend to become younger (or in a boundary case, isochronous) as one proceeds toward the one-time shoreline.

Since the coal-bearing sequence encompassing a complete facies succession (freshwater to shoreline) is normally underlain by only a terrestrial suite of reduced thickness and since terrestrial sediments of greater thickness occur in the zone of thinning of the Ajka Coal Formation, where even the lowermost coal-bearing beds contain brackish-water fossils, we feel fully entitled to suppose that here a considerable part of the terrestrial sediments is contemporaneous with the older limnic beds of the Ajka Formation.

Since palynological results gave an Upper Santonian age for the beginning of the Ajka Formation, the Csehbánya Formation seems to correspond to the same time interval.

Ajka Coal Formation

The Ajka Coal Formation occurs in an area lying northwest of the Köves-domb–Hárs-hegy–Kozma-tag line. No outcrops of it are known. Only a thin Pliocene or Quaternary covers it in the territory of the tectonic blocks to the northwest and southeast of the Vár-hegy.

The formation is composed of rock types varying rapidly both laterally and vertically. High variability is a characteristic feature. Thus, along with the basic similarity, marked divergencies are also observed in the lithologic composition and paleontological pattern of the type sequence (borehole Süt-22) and the additional sections. The major common features are as follows: presence of carbonaceous rock varieties; dark-coloured (dark grey, brownish-grey) pelitic rock varieties of a high organic content; frequency of silty, pelitic sediments with sand lenses and bioclast lenses composed of ground fossil material and lumachelle beds, respectively a regular cyclic repetition of these. The formation may overlie directly the pre-Senonian (Triassic-Aptian) basement or the terrestrial formations. Its thickness varies from 0 to 110 m. Its overburden was in all the observed cases represented by the Csingervölgy Member.

Local type section

For local type of the formation the 101.0 to 162.7 m interval of the borehole Süt-22 (Fig. 33) has been designated.

The weathered surface of the Aptian Tata Limestone in the borehole sequence is directly overlain by the coal beds of the Ajka Formation.

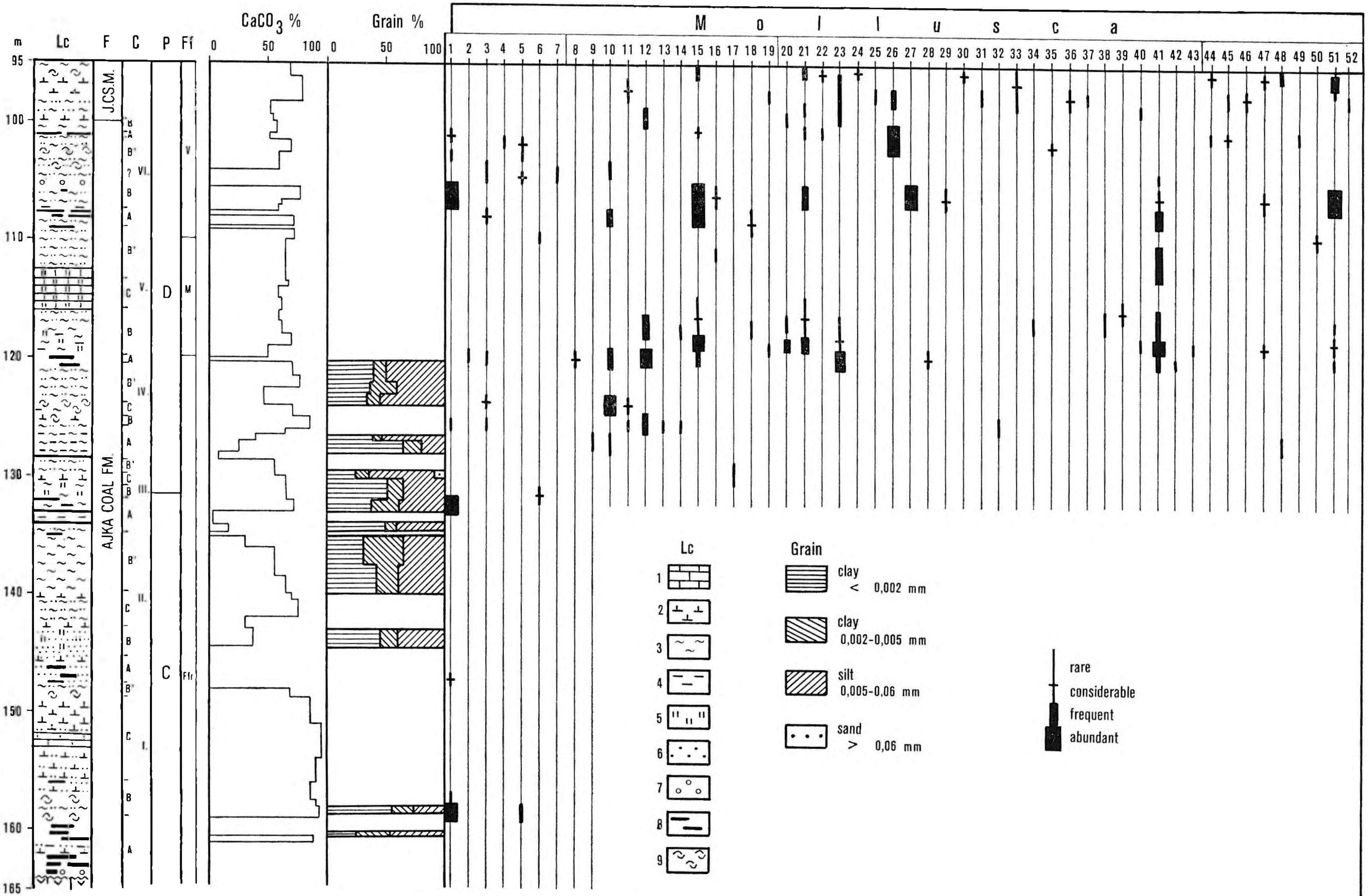


Fig. 33. Local type section of the Ajka Coal Formation: borehole Süt-22

Lithologic column (Lc): 1. limestone, 2. calcareous marl, 3. marl, 4. clay, 5. siltstone, 6. sand, 7. gravel, 8. coal, 9. lumachelle. — *Formations* (F): *J.Cs.M.* Csingervölgy Member of Jákó Marl Formation. — *C* cycles, *P* pollen zone, *Ff* Foraminifera: *M* Miliolina assemblage, *V* Vidalina assemblage, *Ffr* beds free from Foraminifera. — *Mollusca:* B r a c k i s h w a t e r s p e c i e s : 1. Fragment of Pyrgulifera, 2. Potomia, 3. Corbicula, 4. Melania, 5. Hemisinus csingervallensis, 6. H. lignitarius, 7. Goniobasis (1—7. oligo—miohaline), 8. Anomia intercostata, 9. Astarte subcretacea, 10. Cyrena baconica, 11. C. solitaria, 12. Cardita, 13. Cypricardia, 14. Cardium sp., 15. C. ottoi, 16. Cytherea fragment, 17. Glauconia, 18. Cerithium, 19. Turritella sp. (8—19. plio-brachyhaline). S p e c i e s e n d u r i n g c h a n g e s i n s a l i n i t y : 20. Nucula, 21. Limopsis, 22. Pecten sp., 23. P. laevis, 24. Plicatula, 25. Lima sp., 26. Ostrea sp., 27. Lopha sp., 28. Exogyra sp., 29. Modiolus, 30. Mytilus sp., 31. M. antrakopholus, 32. Crassatella galloprovincialis, 33. Dosinia, 34. Cytherea polimorpha, 35. Tanaliopsis, 36. Otostoma, 37. Tectus, 38. Pirenella sp., 39. P. münsteri, 40. Haustator sp., 41. Turritella decipiens repelini, 42. Cryptorhytis baccata, 43. Actaeonella. M a r i n e s p e c i e s : 44. Arca inaequidentata, 45. Cucullaea, 46. Pectunculus, 47. Astarte similis, 48. Crassatella macrodonta var. sulcifera, 49. Tellina sp., 50. Corbula sp., 51. C. angustata, 52. Fusus

The thickness of the formation in the type sequence is 63 m. It is composed for the most part of sands and silty marls with bioclast lenses and, at the top, of dolomitic marls including thin layers of coal and/or marl, calcareous marl and limestone and also sandstone. The vertical variability of the sequence is also significant, changes in lithology having been recorded at an average of 1.5 m intervals in the megaloscopic description of the unit.

The rock types are generally of dark grey or brownish-grey colour, locally with lighter bands and patches.

A regularity, cyclicity, in the alternation of the rock types can be observed and this is followed by qualitative and quantitative changes in the molluscs the most characteristic fossil group. The general structure of the cycles is as follows:

Member A Dark grey carbonaceous clay, argillaceous coal, browncoal abounding with *Mollusca* shells.

Member B Grey to brownish-grey silty marl (less frequently, sandstone) with sand lenses, usually poor in fossils, but the shell fragments of *Mollusca* are locally enriched in thin laminae of cm thickness. Coalified plant remains are abundant.

Member C Light grey calcareous marl, dolomitic marl, limestone and dolomitic limestone (less frequently, siliceous limestone).

The next cycle member (*B'*) shows features that are identical with those of *B*. This is overlain again by carbonaceous beds representing Member *A* of a new cycle. So we have a clear idea of a symmetric cycle of which *C* is the central element. Its formula reads: . . . $A_1B_1C_1B_1'A_2$ . . . The cyclic changes of rock composition are described by the diagram representing the $CaCO_3$ content (Fig. 4), in the lower half of the cycle the carbonate content grows gradually, in the upper one it decreases.

As mentioned above, the abundances of the individual fossil elements are connected with particular cycle members. The correlation is even more clear if the relations between the quantitative distribution patterns of the successive cycles and the fossils indicative of different salinity are examined (Fig. 33). The incoming of brackish-water and normal salinity fossils in higher parts of the sequence and their predominance in Member *B* of the uppermost two cycles (V and VI) can be traced quite clearly.

Enduring freshwater or freshening environments, the Mollusca genera *Pyrgulifera, Hemisinus, Melania (Melania obeloides)*, *Goniobasis*, *Corbicula*, *Potomonya* and *Cyprina* are characteristic in the lower interval of the formation (up to 120 m), where they concur with *Munieria*-type green algal remains, and fructifications of *Chara*. In the coal-bearing cycle-member *A*, however, the aforementioned molluscs regularly recur up to the upper formation boundary. In the lower part of the sequence, Member *B* too is characterized by limnic fossils, but in its upper part is is this very cycle member in which regularly appear the brackish water *Glauconia* and *Turritella* species as well as *Astarte subcretacea* Repelin, *Cyrena buconica* Tausch, *Cypricardita testacea* Zittel, *Cardium ottoi* Geinitz, *Cardita granigera* Gümb., *Anomia intercostata* Zittel, etc. and/or marine to brackish-water forms like *Crassatella gelloprovincialis* Malk., *Mytilus* sp., *Limopsis calvus* Zittel, etc. (see Plate XXIX). Similarly to Member *B* of Cycle V is bound the appearance of Foraminifera with the incoming of *Nummofallotia cretacea* (Schlumb.) (119.5 m), then with the Miliolidae–Cornuspira–Vidalina assemblage.

Members *C* and *B'* are again characterized by the predominance of fossils indicative of waters on the way of freshening.

In addition to the quite distinct cyclicity of the sequence a definite trend is felt in the paleontological features too: it is the marine fossil elements that become increasingly predominant in the successive cycles. Obviously, some difference is also manifested in the lithologic composition of the individual cycles, each showing some individual features. For example, Member *C* may happen to be absent or hardly observable.

Six or six and a half cycles can be traced in the sequence selected for type which varies in thickness between 6 and 16 m with an average of 10 m. The individual coal-bearing intervals are from 1 to 3 m thick. These are coal beds of a few cm thickness alternating with carbonaceous clays and clays.

Some samples of the type section representing Member *C* of particular cycles were analyzed in detail.

As shown by the results, the carbonate content in the Ajka Formation above Member *C* of Cycle II is associated, for the most part, (50–80%) with dolomite. The maximum of dolomite content was obersved in Cycle IV [49% $CaMg(CO_3)_2$ at 5% $CaCO_3$]. That, according to A. Szemethy's X-ray results, the $CaCO_3$ content in some cases is represented or a considerable part by aragonite is worthy of mention.

Of the clay minerals, kaolinite, illite and montmorillonite were present in varying amount, but jointly in almost all samples. Mixed-layer illite-montmorillonite minerals are considerable in quantity.

The quantitative and qualitative variation of the clay minerals throughout the section does not exhibit any regularity.

The allothigenic components of sand size are for the most part quartz grains (70–80%). Potash feldspar grains are present in 5 to 10%. Allothigenic heavy minerals are quite low in amount (0.05–0.7%). According to the results of A. LENKEI, garnet, muscovite, tourmaline, epidote, chlorite and hornblende occur in the lower section interval and garnet and augite at the top, their amount being comparatively high in both cases.

Above the Ajka Formation, with a transitional development, the Csingervölgy Member of the Jákó Formation follows. The transitional interval—including by and large the topmost 10 m of the Ajka Formation and the basal 10 m of the Csingervölgy Marl, respectively—is composed by dark grey to brownish-grey, sand-lensed marls and calcareous marls.

Mostly reduced to tiny debris, the calcareous fossils attain an extremely high, locally rock-forming, percentage.

Taking the whole sequence into consideration, the lithological variability attains its maximum in this interval.

The boundary between the two formations has been drawn by us at the level of the last coal stringers (101 m). At the boundary the Mollusca fauna itself exhibits a marked change, for the genera *Pyrgulifera*, *Hemisimus*, *Melania* and *Corbicula* fall out of the faunal assemblage definitively.

Geological features

The extension and thickness of the Ajka Coal Formation are illustrated in Fig. 34. In the figure 3 sections subperpendicular to the isopachs and crossing the most thoroughly studied exposures (Sections I, II and III) are shown.

By plotting the profiles we have pursued the aim to correlate the geological features observed in the individual drilling sections and to recognize the changes in thickness and geological features displayed by the formation in the direction of greatest thickness variation.

All these circumstances have made it advisable for us to select a geologically well-motivated horizon as a base of reference in dealing with the sequences involved. In the present case the Jákó Formation and the base of the Csingervölgy Member, respectively, were selected as such. This solution has been believed adequate because the low degree of variability of the facies characteristics of the Csingervölgy Marl (at least over the area of distribution of the Ajka Formation) seems to indicate that the deposition of its basal layers was taking place already on a rather level surface. Consequently, profiles that are plotted in this way will enable us to analyze even the morphological features that existed prior to or during the sedimentation of the Ajka Formation. Naturally, reference horizons do not delineate an isochronous level, for the formations may be supposed to tend to become, as a rule, gradually younger from the northwest to the southeast, owing to facies shifts in the course of transgression.

By analyzing the profiles (Fig. 34), we have attempted to draw conclusions as to the causes responsible for the thickness patterns presented too. Namely, it may be figured out that sequences of different thickness were formed during equal time intervals at varying sedimentation rates, but it is also possible that a low thickness reflects a shorter time of deposition.

Profile I (Fig. 35) has been drawn by starting from the Mogyorós-domb, traversing the Köves-domb and past the west side of Sümeg as far as Forrókút.

The easternmost exposure of the section is the borehole Süt-15 (Fig. 36) which intersected the formation in a thickness of 31 m. This is exactly the half of the thickness of the type sequence. The coal-bearing unit is underlain by one metre and a half of clay covering the Sümeg Marl. Above it, rock types standing close to the upper part of the type sequence can be found representing one complete cycle and a half *(A–B–C–B–A–B–C)* with two thin coal beds. Among the fossils no fresh-water species was found.

In the horizon of the lower coal bed the specimens of *Cardium ottoi* GEINITZ, species predominant throughout the sequence, already appear. *Nucula concinna* SOW., *Pecten laevis* NILSSON and *Astarte similis* MÜNSTER are frequent bivalves. The horizon of the upper coal bed is characterized by the incoming of *Glauconia* and *Pyrenella* forms and also *Lima* sp. and *Limopsis calvus* ZITTEL, each being a brackish-water form or one enduring a reduction in salinity (Plate XXIX).

Foraminifera in the lower, coal-bearing interval of the sequence are quite sporadical. It is *Ostracoda* that predominate in the microfaunal assemblage. In the uppermost metres, however, a Vidalina–Miliolina assemblage represented by a wealth of individuals was observed.

In the borehole S-7 (K-1) put down on the Köves-domb Barremian calcareous marls are overlain by about 10 cm of yellow or green clays and a 20-cm-thick bed with coal stringers. In its overburden limestone beds assigned to the Ugod Formation and containing debris of local origin deriving from the Sümeg and Tata Formations were exposed.

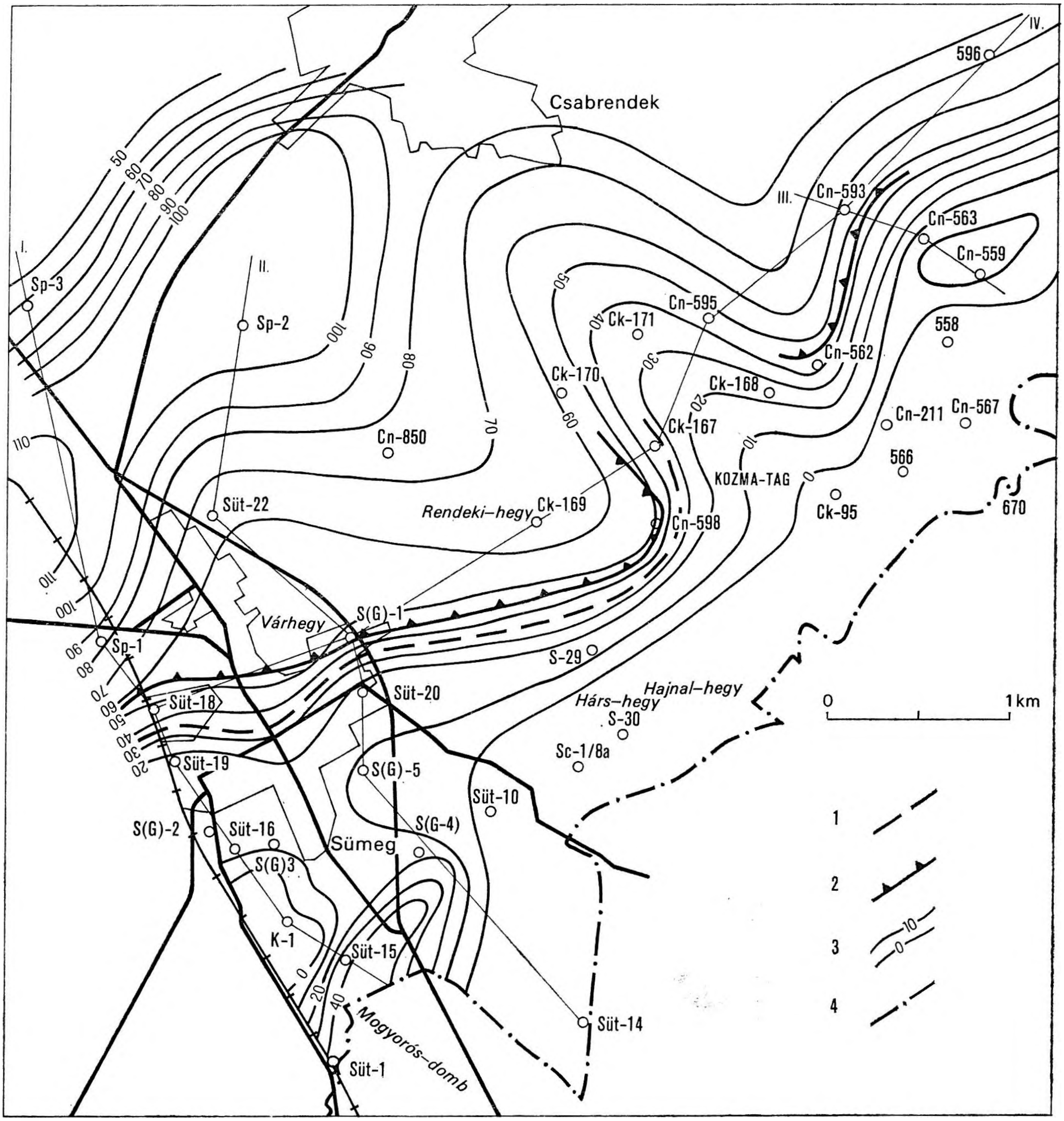


Fig. 34. Thickness of the Ajka Coal Formation

1. Boundary of extension of limnic facies based on the first appearance of Foraminifera, 2. number of coal-bearing cycles in the direction of the spines ≥7, 3. isopachs of the Ajka Coal Formation, 4. boundary of extension of the Senonian

In the Sintérlap quarry to the northwest of the borehole the coal-bearing beds are completely lacking and the Aptian crinoidal limestone is overlain by Hippurites limestone.

In the borehole Süt-16 put down on the northwest margin of the Köves-domb (Fig. 36) 12 m of rock characteristic of the Ajka Formation was observed: dark grey, sandy, sand-lensed argillaceous-marls, sandstones and lumachelle layers rich in coalified plant remains. No coal bed was cut by the drill.

The Mollusca fauna is characterized by a brackish-water assemblage: *Nucula concinna* Sow., *Pecten laevis* NILSSON, *Cardium ottoi* GEINITZ, *Corbula angustata* Sow.

Already at the base of the sequence do *Foraminifera* appear, being represented by the individuals of the brackish-water Vidalina–Nummofallotia–Miliolina assemblage.

The thickness of the formation is only 13 m in the borehole Süt-19 (Fig. 37) too, but a thin coal-bearing group of strata can already be observed. Above the first coal-bearing sequence (at only 1.5 m from the underlying bed) already a brackish-water fossil assemblage was found with the predominance of *Cardium ottoi* GEINITZ and great quantities of specimens of *Nucula*, *Cyrena* and *Pirenella* species.

Similarly to the brackish-water marine molluscs, the Cornuspira–Nummofallotia–Miliolina assemblage of Foraminifera (*Nummofallotia cretacea* SCHL., *Cornuspira senonica* DUN., *Quinqueloculina* div. sp., *Spiroloculina* div. sp., *Valvulineria asterigerinoides* PLUMMER) appears in the basal beds of the formation already. With a view to the cyclicity of the facies, it is not too surprising that, higher up the profile, again a supposedly limnobrackish interval devoid of Foraminifera will follow.

A radical change compared with the foregoing was registered in the sequence of the borehole Süt-18 (Fig. 37), though the exposure lies only 300 m away to the northwest of the borehole Süt-19.

The thickness of the sequences discussed in the foregoing is only a fraction of that observed in the borehole Süt-18 and though the rock types are similar, the coal-bearing beds increase in number. Essential difference is manifested in the distribution of fossils reflecting the environment of deposition. Whereas in the sequences hitherto analyzed the marine molluscs (*Cardium*, *Nucula*, *Corbula*, *Pecten*, *Lima*, etc.) and Foraminifera (*Nummofallotia*, *Vidalina*, *Cornuspira*, *Miliolides*, *Rotalia*, stc.) appeared for the most part at the base of the formation, in the exposure in question this was observed only about 40 m higher.

The section of the Ajka Formation studied in the borehole Süt-18 is close to that of the borehole Süt-22 designated as type both regarding its thickness and other features. A difference does exist, however, is that in this sequence (more precisely, in its lower interval) the carbonaceous cycles typical of the formation are not represented in such a regular development as it is the case with the type section and that even the number of the coal-bearing intervals is reduced compared with the type (a total of only 4).

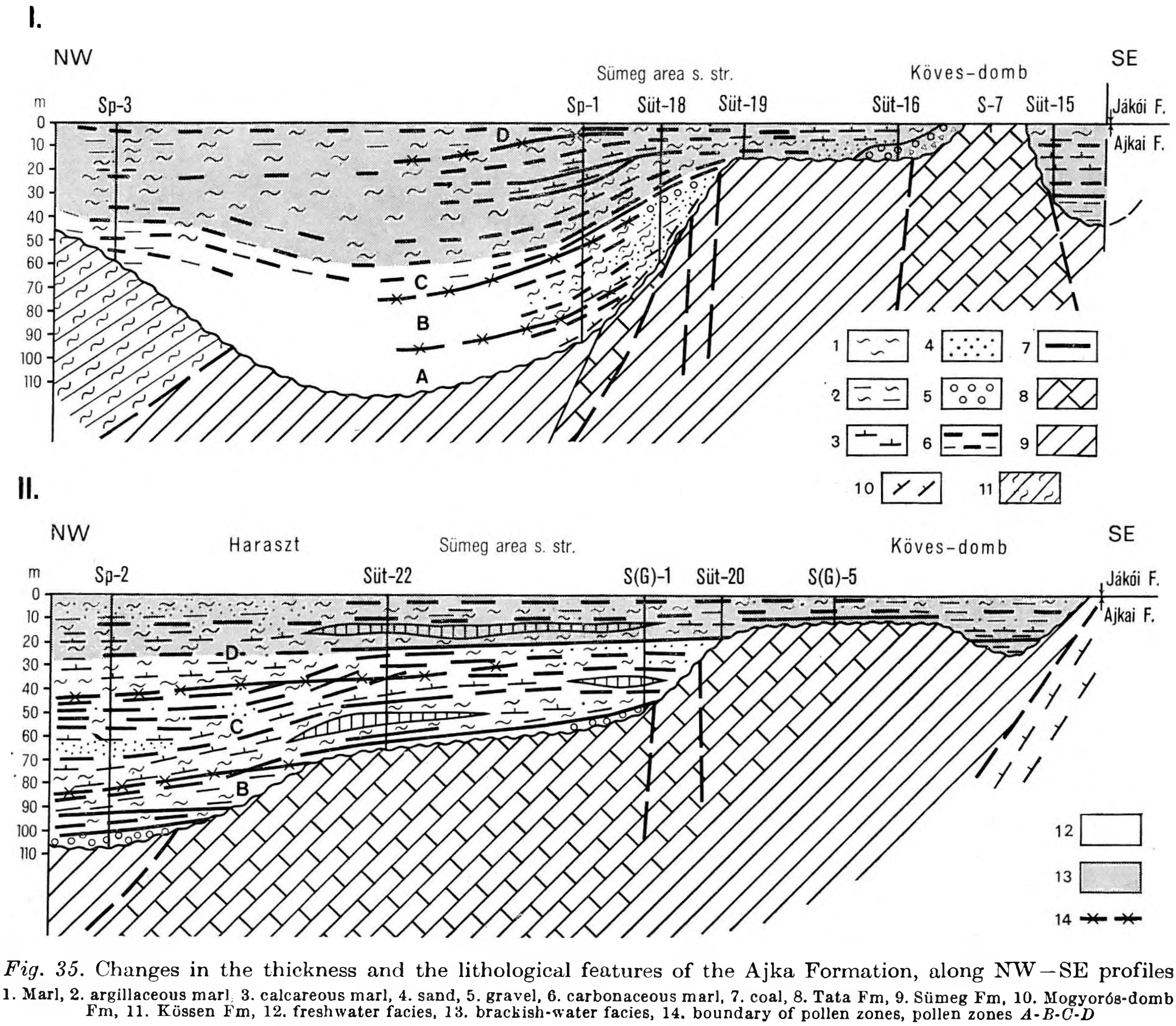


Fig. 35. Changes in the thickness and the lithological features of the Ajka Formation, along NW–SE profiles
1. Marl, 2. argillaceous marl, 3. calcareous marl, 4. sand, 5. gravel, 6. carbonaceous marl, 7. coal, 8. Tata Fm, 9. Sümeg Fm, 10. Mogyorós-domb Fm, 11. Kössen Fm, 12. freshwater facies, 13. brackish-water facies, 14. boundary of pollen zones, pollen zones *A-B-C-D*

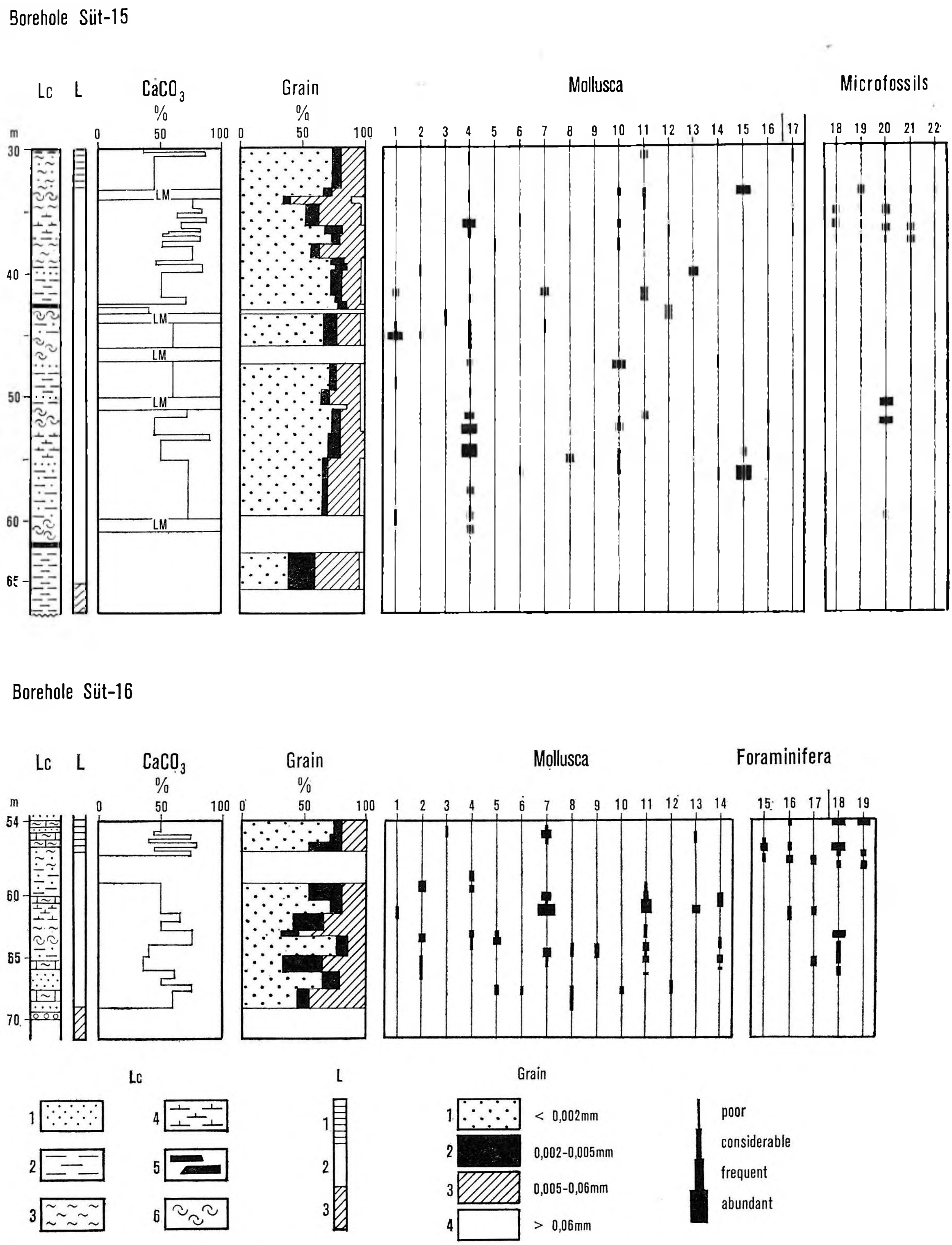


Fig. 36. The Ajka Formation interval of the boreholes Süt-15 and -16: lithologic column and analytical record
Lithologic column (Lc): 1. sand, 2. clay, 3. marl, 4. calcareous marl, 5. coal, 6. lumachelle. — *Lithostratigraphic units* (L): 1. Csingervölgy Member of the Jákó Marl Formation, 2. Ajka Fm., 3. Csehbánya Fm. — *LM* lumachelle bed. — *Grain:* 1—2. clay, 3. silt, 4. sand. — *Brackish-water facies of borehole Süt-15:* 1. Turritella, 2. Glauconia kefersteini, 3. G. obvoluta. 4. Cardium, 5. Cypricardia, 6. Cardita; euryhaline facies of the same borehole: 7. Pirenella, 8. Cerithium, 9. Bulbus, 10. Nucula, 11. Pecten, 12. Lima, 13. Limopsis; its marine facies: 14. Tellina, 15. Astarte, 16. Corbula; 17. Cyclolites, 18. Vidalina, 19. benthonic Foraminifera, 20. Mollusca, 21. Ostracoda, 22. Echinodermata. — Brackish-water facies of the *borehole Süt-16:* 1. Turritella, 2. Cardita; its euryhaline facies: 3. Haustator, 4. Nucula, 5. Mytilus, 6. Modiola, 7. Pecten, 8. Lima, 9. Limopsis, 10. Ostrea; its marine facies: 11. Corbula, 12. Dentalium, 13. Astarte, 14. Corbula; Foraminifera: 15. Vidalina, 16. Nummofallotia, 17. other benthonic Foraminifera. — 18. Ostracoda, 19. Echinodermata

Located in the vicinity of the lime-burning plant of Sümeg, the borehole Sp-1 (Fig. 38) is also characterized by a sequence similar to that of the type section, but the thickness of the formation is greater (83 m) and the coal-bearing intervals too are greater in number than it is the case with the type. In the lower part of the formation the *Foraminifera*-free interval already exceeds 50 m in thickness and, as shown by F. Bartha's results, the brackish-water assemblage gains predominance only 45 m above the base of the formation.

The lower, freshwater interval is characterized by the predominance of *Pyrgulifera glabra* (Hantken) and the presence of the genera *Helix, Bulimus, Melania, Pachyostoma, Goniobasis* and *Cyrena. Pyrgulifera glabra* var. *suemegensis* and varieties of *P. inflata* (Yen) and also the species *Dejaneria bicarinata* Stol. occur in the brackish-water beds. *Foraminifera* appear for the first time in the sequence containing marine-brackish *Mollusca (Turritella, Cardita, Pecten).*

The borehole Sp-3 was put down at 2 km to the northwest of Sümeg and it penetrated the formation in a thickness of 56 m. The cycles are generally irregular, the lower interval being characterized, as a rule, by the disappearance of the sandy-pelitic member *(B)*, the upper one by that of the carbonate one *(C)*. The coal-bearing sequence is of modest thickness, being represented, for the most part, only by carbonaceous clay and carbonaceous marl rock types.

According to the results of studies on molluscs, the brackish-water faunal elements appear at 34 m from the base. Most frequent are *Cardium ottoi* Geinitz, *Corbula angustata* Sow., *Limnopsis calvus* Sow., *Pecten laevis* Nilsson, *Odontostomia* sp., *Astarte similis* Münster and *Nucula* sp.

Plotted across the exposures between the Városi-erdő and the northwest side of the Rendeki-hegy, parallel to No I, Profile II (Fig. 35) provides a picture that is, in its basic features, similar to the former. From the sequence of the borehole Süt-14 representing the southeast end-point the formation is missing and in the borehole S(G)-5 it is yet only 9 m thick and of marine-brackish facies throughout this interval. In the boreholes S(G)-1 and Süt-22 by the Vár-hegy, however, it approximates or even reaches 50 m and, beneath the brackish-water interval, the limnic facies appears, too.

The borehole Sp-2 (Fig. 39) penetrated the thickest Ajka Formation of all boreholes ever put down in the Sümeg area (110 m). In the sequence, 6 cycles can be recognized, though there are cases when it is the coal-bearing member *(A)* of the cycles that is reduced in thickness (e.g. the base of Cycle II) or when it is interrupted by argillaceous marl, marl and sandstone layers. It is difficult to delineate the upper boundary of the formation, for after the disappearance of the coal beds the rock types characteristic of the formation persist and a gradual decrease in sand content and a parallel growth of the carbonate content lead uninterrupted into the overlying lithostratigraphic unit.

According to F. Bartha's results, the Mollusca fauna of the formation is observed to be characterized, in the lower two-thirds of the sequence, by forms indicative of a freshwater environment *(Pyrgulifera glabra* Hantken, *Strophostoma, Megalostoma, Helix, Melanopsis, Bulimus, Cyrena* and *Corbicula)* and, in the upper third, by limno-brackish forms *(Pyrgulifera glabra* var. *suemegensis* Bartha, *P. inflata* Yen, *Dejaneria bicarinata* Stol., *Melanopsis lignitarum)* as well as marine-brackish ones *(Cardita, Turritella, Glauconia, Ampullina).*

The appearance of Foraminifera too (*Nummofallotia cretacea* Schlb., *Cornuspira senonica* Dunikovsky, *Cornuspira* sp., *Vidalina hispanica* Schlb., *Lamarckina ripleyensis* Cush., *Rotalia cretacea* Ten Dam, *Rotalia* sp., *Epistomina subcretacea* Ten Dam) is bound to the third one-third of the sequence of the formation.

Judging by the thickness and the geological features of the Ajka Formation, 2 areas get laterally individualized in the sections shown. In the southeast, a low thickness and a reduced number of coal-bearing intervals are characteristic. That a marine (marine-brackish) faunal assemblage occurs already at the base of the formation and that in all boreholes but Süt-19, curiously one of boundary position, the representatives of *Pyrgulifera* are totally absent is an important feature. The total disappearance of the formation in the sequence of Sintérlap quarry on the Köves-domb calls attention to the particular conditions under which the sedimentation in the immediate neighbourhood of the exposure took place.

In the northwest (boreholes Süt-18, Sp-1, -2, -3), greater formation thickness and greater number and thickness of the coal beds are characteristic. Foraminifera and mollusca indicative of a marine influence appear only in the upper third of the sequences or at their top. In the deeper parts of the sequences, however, freshwater or limno-brackish molluscs are abundant with green algae of *Munieria* type and ostracods.

In the northwest the formation consists of two genetically different parts: a lower one of comparatively greater thickness, predominantly of freshwater or limnobrackish origin, with several coal beds and an upper, marine-brackish one. The transition between the two is continuous or, to be more precise, it manifests itself in such a way that in the upper part of the limnic interval the first manifestations of a brackish-water environment already appear and that, on the other hand, sediments still exhibiting freshwater characteristics can be found in the basal part of the overlying

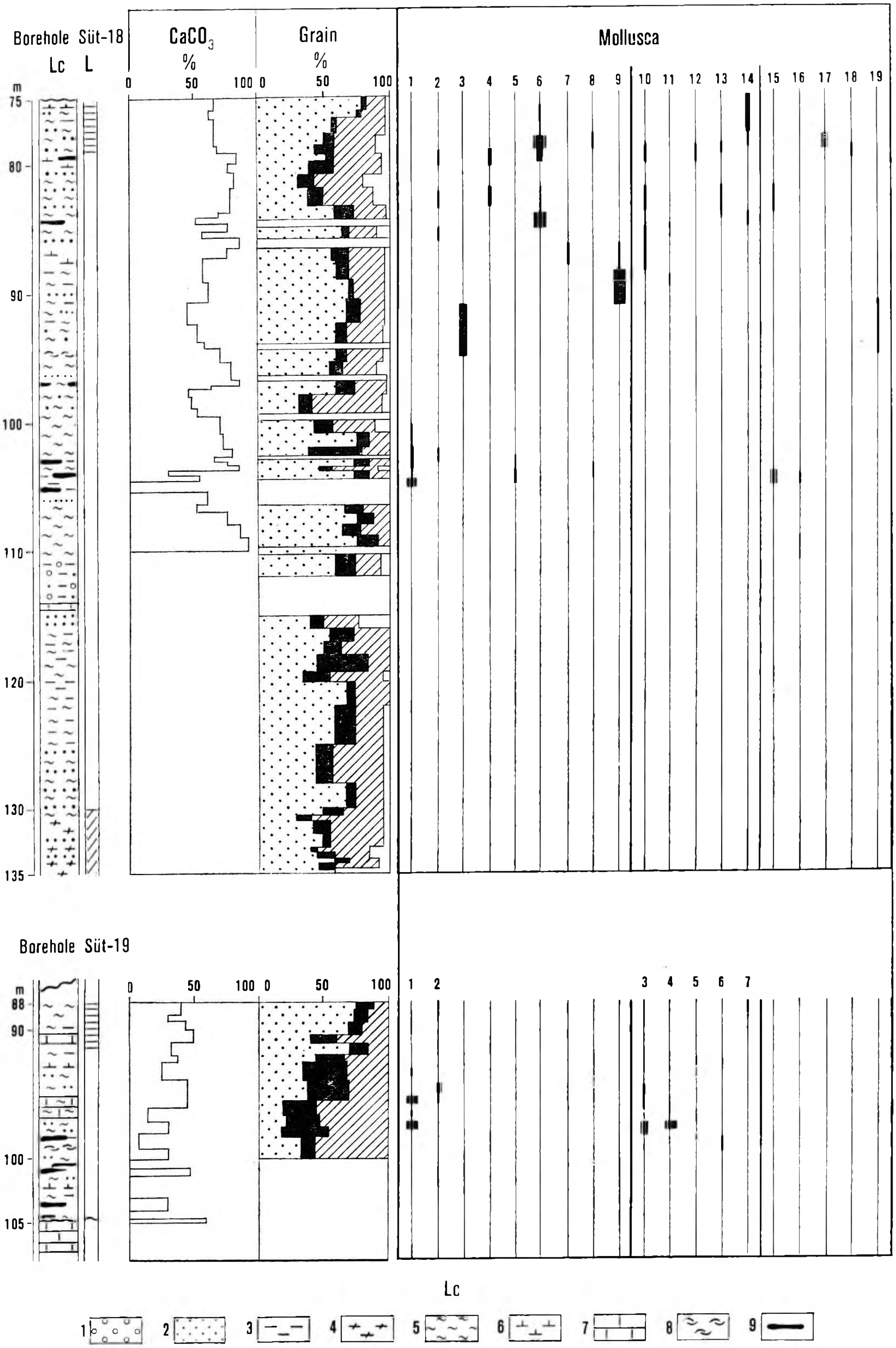


Fig. 37. The Ajka Formation interval of the boreholes Süt-18 and -19: lithologic column and analytical record

Lithologic column (Lc): 1. gravel, 2. sand, 3. clay, 4. variegated clay, 5. marl, 6. calcareous marl, 7. limestone, 8. lumachelle, 9. coal. — B r a c k i s h - w a t e r f a c i e s of the *borehole Süt-18:* 1. Pyrgulifera, 2. Hemisinus sp., 3. H. lignitarius, 4. Glauconia sp., 5. Melanopsis sp., 6. Cardium ottoi, 7. C. sp., 8. Cyrena solitaria, 9. Cyrena baconica; its e u r y h a l i n e f a c i e s : 10. Turritella difficilis repelini, 11. Cerithium sp., 12. Tectus sougrainensis, 13. Nucula concinna, 14. Pecten laevis; its m a r i n e f a c i e s : 15. Aporrhais sp., 16. Astarte similis, 17. Corbula angustata, 18. Crassatella macrocarinata, 19. Corbicula ajkaensis. — B r a c k i s h - w a t e r f a c i e s of the *borehole Süt-19:* 1. Cardium, 2. Cyrena solitaria; its e u r y h a l i n e f a c i e s : 3. Pirenella münsteri, 4. Nucula concinna, 5. Pecten, 6. Cyprina, 7. Lima. — (For the rest of explanations, see Fig. 36.)

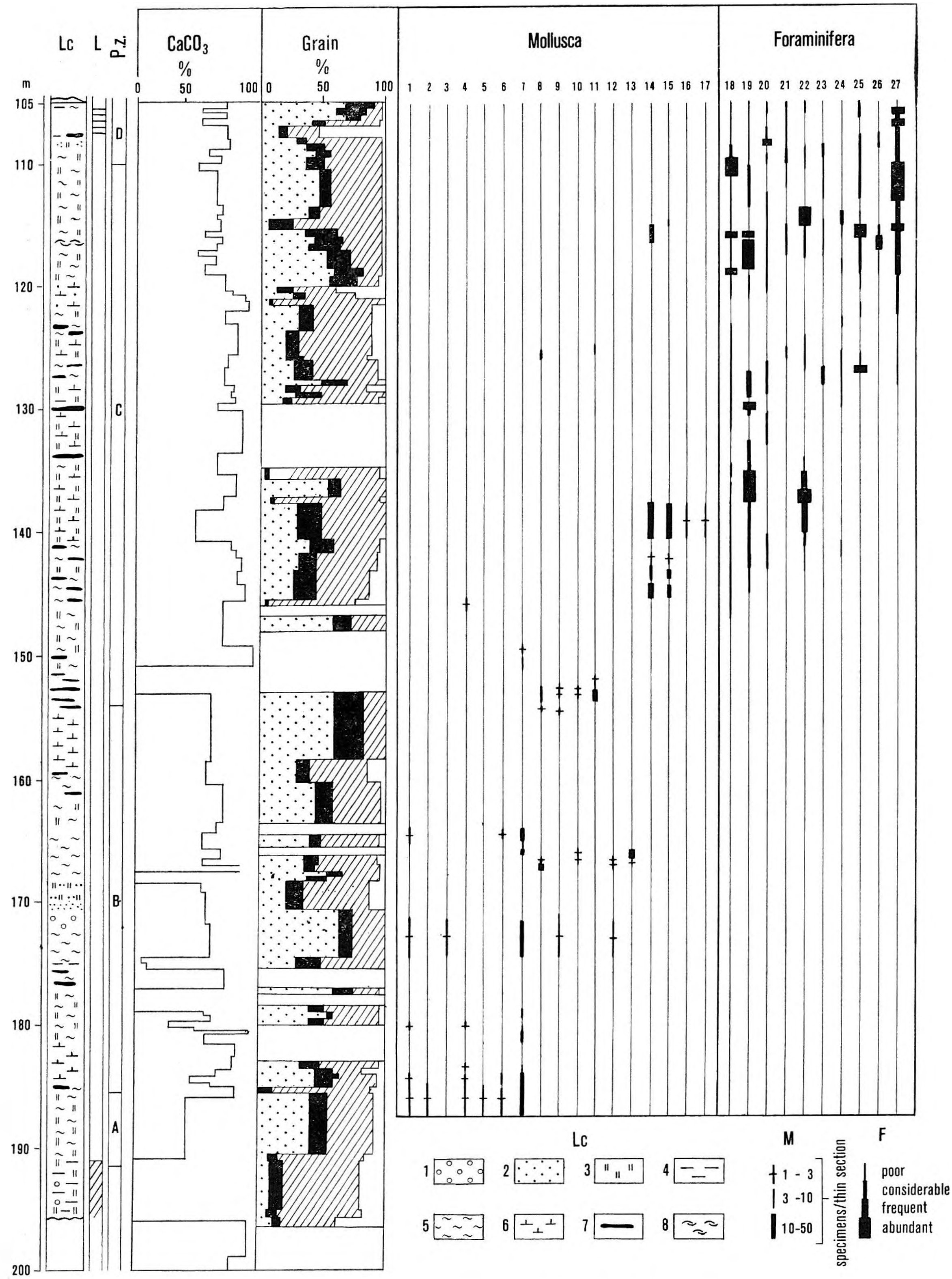
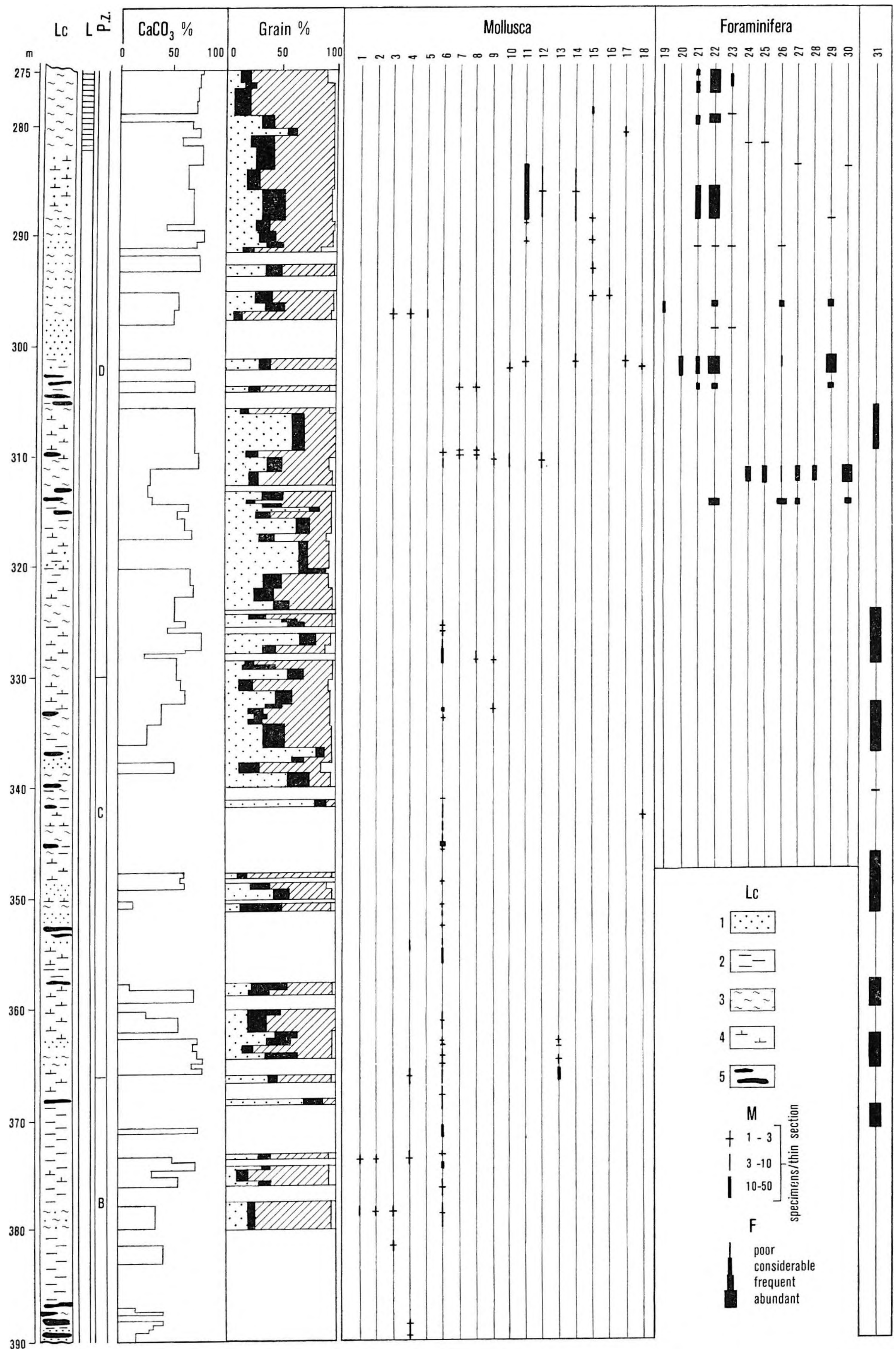


Fig. 38. The Ajka Formation interval of the borehole Sp-1: lithologic column and analytical record

Lithologic column (Lc): 1. gravel, 2. sand, 3. siltstone, 4. clay, 5. marl, 6. calcareous marl, 7. coal, 8. lumachelle. — *Mollusca* (after F. BARTHA): f r e s h w a t e r f a c i e s : 1. Helix sp., 2. Bulimus munieri, 3. Melania heberti, 4. Melania sp., 5. Goniobasis sp., 6. Cyrena baconica, 7. Pyrgulifera glabra; b r a c k i s h - w a t e r f a c i e s : 8. Pyrgulifera glabra or suemegensis, 9. P. inflata, 10. P. inflata or impressa, 11. P. inflata or acutispira, 12. Dejaneria bicarinata, 13. Viviparus; m a r i n e f a c i e s : 14. Cardita sp., 15. Meretnia sp., 16. Turritella sp., 17. Pecten sp., *Foraminifera* (after M. SIDÓ): 18. Miliolidae, 19. Cornuspira, 20. Vidalina, 21. Nonionella, 22. Nummofallotia, 23. Lamarckina, 24. Rotalia, 25. Epistomina, 26. Cibicides, 27. Bryozoa. (For other explanations, see Fig. 36.)



Lc
L
P.z.
CaCO3 %
Grain %
Mollusca
Foraminifera
m
0 50 100
0 50 100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
19 20 21 22 23 24 25 26 27 28 29 30
31
275
280
290
300
310
320
330
340
350
360
370
380
390
D
C
B
Lc
1
2
3
4
5
M
1 - 3
3 -10
10-50
specimens/thin section
F
poor
considerable
frequent
abundant

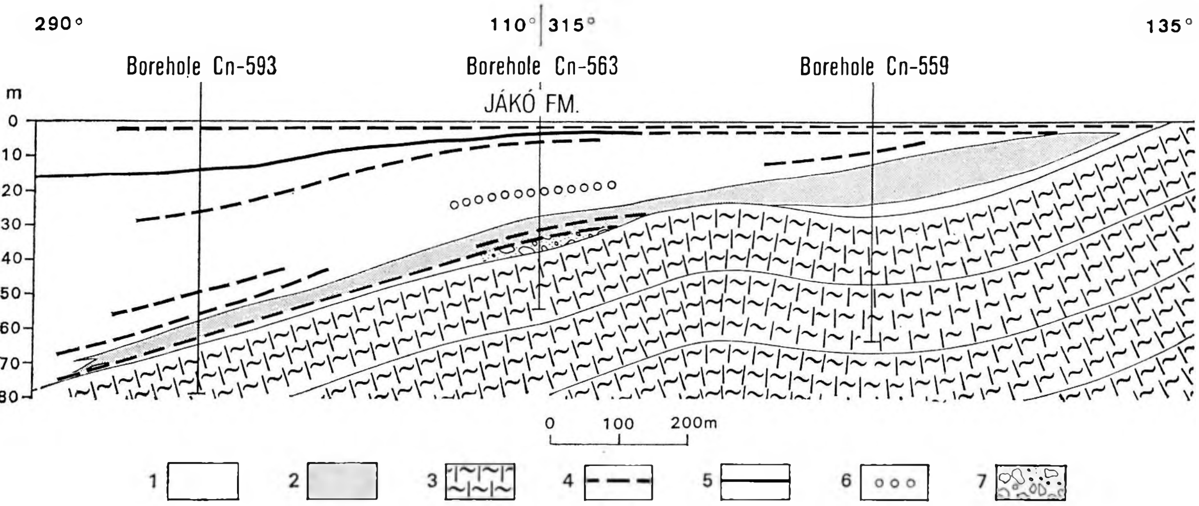


Fig. 40. Relationship of the Ajka, Csehbánya and Halimba Formations (Profile III)
1. Ajka Coal Formation, 2. Halimba Bauxite Fm., 3. Kössen Fm., 4. carbonaceous clay, 5. coal, 6. gravel, 7. detritus

brackish-water facies. The main difference between the two sections is manifested in the character of transition between the afore-mentioned two facies zones. Namely, the steepness of the pre-Senonian substratum as reflected by the changes in thickness in the two sections is different: the single, relatively steep transitional interval of Profile I is extended, in Profile II, into a gentle slope flanked by two, less steep transitional stretches.

The trace of Profile III (Fig. 40) extends east of Rendeki-hegy, to the southeast of Csabrendek settlement and it illustrates, in addition to the thickness and geological features of the Ajka Formation, the relation between the bauxite body here exposed and the coal-bearing beds as well.

In the borehole Cn-559 the Ajka Formation was only 12 m thick and 3 coal-bearing intervals could be observed. No information on fossils is given in the descriptions, so we are unable to give a biofacies interpretation.

At the base of the formation 14 m of grey bauxite has been intersected which overlies the Upper Triassic surface through the intermediary of a couple of metres of clay to variegated clay.

In the borehole Cn-563 the thickness of the coal-bearing strata was as low as 8 m, but underneath there followed 20 m of greyish-green, unfossiliferous marl, underlain, in turn, by red and grey argillaceous bauxite. In a field description by Z. Vörös carbonaceous clay layers interbedded with the bauxite are mentioned.

Nearly 60 m thick in the borehole Cn-593, the Ajka Formation includes, as reported by P. Farkas and P. Fülöp, 8 or possibly 9 coal-bearing intervals and even the cycles can be traced comparatively well. From the uppermost 10 m of the formation the genera *Nucula*, *Pecten* and *Corbula* and, beneath them, *Pyrgulifera*-containing beds were registered as a result of drilling works. At the base of the formation 4 m of red argillaceous bauxite, bauxite and, at the very base, again some carbonaceous marl and *Mollusca*-lumachelle were observed by the describers.

Profile III shows several features in common with the corresponding intervals of the previous two, the main trends being equal. The interval of reduced thickness in the southeast after the appearance of the formation's lower boundary and its growing thicker in a northwesterly direction are clearly noticeable. On the basis of the unfortunately scant fossil record the thicker sequence seems to be of brackish-water to limnic facies here too, while the more reduced thicknesses are composed of only a brackish-water facies.

According to the isopach map, the NE–SW orientation is modified by anomalies perpendicular

←

Fig. 39. The Ajka Formation interval of the borehole Sp-2: lithologic column and analytical record

Lithologic column (Lc): 1. sand, 2. clay, 3. marl, 4. calcareous marl, 5. coal. — *P.z.* pollen zones. — *Mollusca:* terrestrial-freshwater: 1. Strophostoma cretacea, 2. Megalomastoma supracretacea, 3. Helix sp., 4. Cyrena baconica, 5. Corbicula ajkaensis, 6. Pyrgulifera glabra, 7. Unio sp.; brackish-water: oligo-miohaline: 8. Pyrgulifera glabra v. suemegensis, 9. P. inflata, 10. P. inflata v. acutispira, 11. Melania lignitarius, 12. Dejaneria bicarinata, plio-brachyhaline: 13. Cerithium sp., 14. Cyrena sp.; marine: 15. Cardita sp., 16. Turritella sp., 17. Ampullina sp., 18. Glauconia sp.; *Foraminifera:* 19. Haplophragmium, 20. Ammobaculites, 21. Miliolidae, 22. Cornuspira, 23. Vidalina, 24. Nonion, 25. Nonionella, 26. Nummofallotia, 27. Lamarckina, 28. Valvulineria, 29. Rotalia, 30. Epistomina; *alga:* 31. Munieria. (For other explanations, see Fig. 36.)

trend. This is evident from Profile IV which, perpendicularly to the former (Fig. 41), issues from the southern side of Sümeg and after crossing the hill range, extends as far as the southern part of Csabrendek. These parts of it can be singled out. Over the stretch encompassing the Sümeg area and the neighbourhood of Csabrendek the thickness conditions and the geological features are similar, but the middle stretch is characterized by a reduced thickness and a reduced number of coal beds.

At the beginning of the chapter the question concerning the kinds of changes in the characteristics of the formation with which the thickness variation trends shown in Fig. 34 are associated, was posed. On the basis of the interpretation of the profiles and considering the data of exposures outside the profile, the following trends of variation in characteristics of the various area-units could be registered:

1. In the northwest part of the area characterized by the presence of the formation, higher formation thicknesses and greater number and thickness of the coal beds are conspicuous. The formation can be split up into a lower freshwater interval in transition to the limno-brackish facies and an upper one characterized by the preeminence of a brackish-water facies tending to approximate the marine characteristics. Within the area-unit the total thickness of the formation increases northwestwards for about 2 km (up to 40–120 m), to show then again a marked decrease (Profile I).

The question whether the thickness pattern within the NW subarea is due to a change in the thickness of the freshwater or marine (brackish-water) facies group or maybe to a change of both combined, was also examined. For this reason, we were looking for a feature that might be observable in the greatest possible number of exposures and that is indicative of a change in salinity. The boundary between the *green algae–Ostracoda* (Foraminifera-free) and the *Foraminifera* (Vidalina–Nummofallotia) fossil assemblages, the horizon of the first appearance of Foraminifera, seemed to be best suited to that purpose.

This boundary divides the sequences into two parts and though it cannot be said that it divides exactly the rock types formed in a freshwater and a limno-brackish or marine-brackish environment, it is yet supposed to delineate a by and large isohaline horizon. If the exposures in the northwest subarea (Fig. 34) be evaluated in terms of this subdivision, the following observations will be experienced:

a) in the internal parts of the subarea the changes in the thickness of the upper, marine-brackish interval are poor, consequently, most of the remarkable differences in thickness are due to the thickness differences of the lower (freshwater to limno-brackish) interval (boreholes Sp-1, -2, Süt-22) and

b) to the south the thickness of the marine-brackish beds decreases (to 10–20 m),while that of the freshwater ones shows hardly any change, to pinch out eventually all of a sudden (within 100–200 m) (Profile I). The line of pinching out follows by and large the boundary of the southeast subarea, running parallel to the isopachs along the 20 m isopach. In the northwest the higher thickness of the unit is coupled with a greater number (6–9) of coal-bearing cycles. The thickest coal beds are found in the zone of maximal formation thickness (borehole Sp-2), at the base of the sequence, being shifted to the middle third of the formation farther southeast. The coal of highest quality (10,465 kg/Joule) is found in the upper marine-brackish interval of the formation.

2. In the southeast subarea of low formation thickness only marine-brackish facies are found even in the borehole Süt-15 that cut the thickest sequence. No uniform trend of thickness variation is recognizable within the subarea. The coal-bearing sequences are reduced in number (a maximum of three), the coal beds being thin and the coal itself of very low quality.

The external (SE) boundary line of the southeast subarea is subparallel to the isopachs (Fig. 34). To the southwest of the extension limit the Csingervölgy Marl directly overlies the pre-Senonian formations. The situation observable on the Köves-domb is somewhat different from the general trend (Profile I). Namely, in the northwestern part of the hill the Ajka Formation is lacking, being present around it (at least to the northwest and southeast and probably also to the northeast).

Bio- and chronostratigraphy

Based on various fossil groups, the biostratigraphy of the Sümeg area exposures of the Ajka Formation has been dealt with by several authors in recent years.

During his palynological study in key section detail of the boreholes Sp-1 and Sp-2, F. Góczán established the following abundance zones within the Ajka Formation (listed from the bottom to the top):

A — *Oculopollis–Complexipollis* Zone
B — *Trilobosporites* Zone
C — *Tetracolporopollenites (Brecoplites)–Oculopollis zaklinskalae* Zone
D — *Hungaropollis krutzschi* Zone.

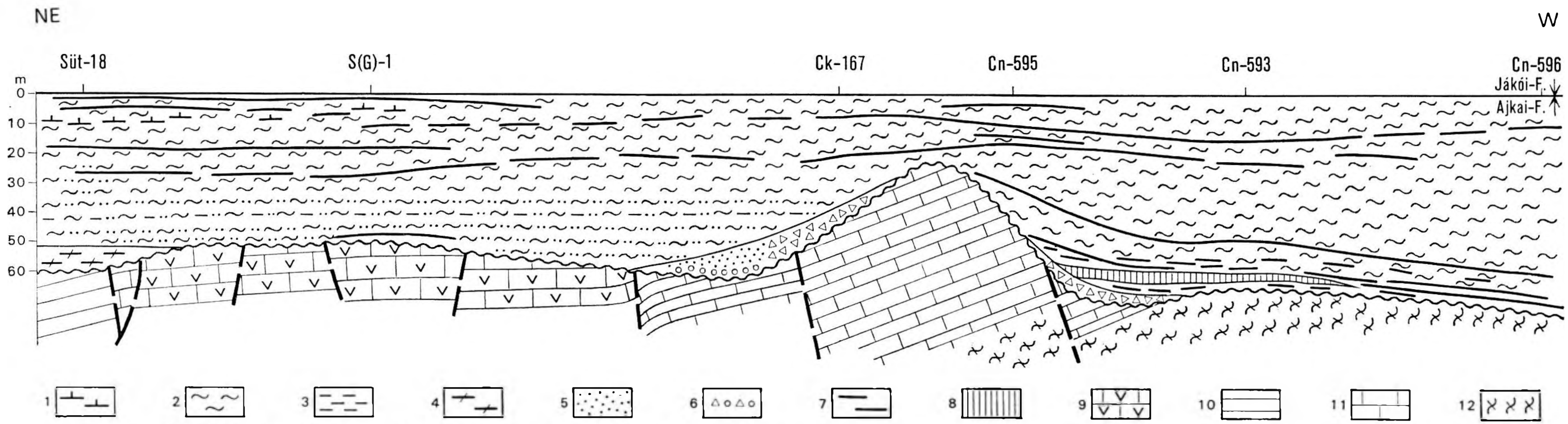


Fig. 41. Variation of the geological features of the Ajka Formation along a NE–SW profile between Sümeg and Csabrendek (Profile IV)
1. Calcareous marl, 2. marl, 3. clay, 4. variegated clay, 5. sand, 6. gravel, detritus, 7. coal, 8. bauxite, 9. Tata Fm., 10. Sümeg Fm., 11. Dachstein Fm., 12. Kössen Fm.

Zone A could be distinguished only at the bottom of the borehole Sp-1, Zone D extends into the Csingervölgy Member, too.

The palynological study of the local type section (borehole Süt-22) was carried out in 1974 by F. GÓCZÁN. Accordingly, the basal 30 metres of the formation (up to 133 m) can be assigned to Zone C, as suggested by the abundances of the *Oculopollis* species and the presence of the zonal index species *Brecoplites globus*. At the base of this interval the specimens of *Appendicisporites tricuspidatus* WEGL. et KRIEG are abundant. The upper interval of the formation (up to 96 m), based on the predominance of the genus *Hungaropollis*, is to be placed in Zone D. The *Occulopollis* species are only subdominant, while the representatives of *Krutzschipollis*, according to their abundances, are pushed back to the third place.

The absence of Zone A known from the borehole Sp-1 and of Zone B known from the boreholes Sp-1 and Sp-2 in the section in discussion is conspicuous. This may be due to the fact that the location of the borehole was a relatively elevated area in the beginning of the Senonian cycle and that sedimentation there did not begin until a little bit later. Similar causes may be ascribed to the fact that the thin coal bed from the borehole S-7 on the Köves-domb shows the pollen pattern of Zone D (F. GÓCZÁN 1973).

That the marked change of the palynoflora (zone boundaries) in the borehole Süt-22 coincides with the changes in facies is also worthy of attention. The end of Zone C is at the same time the end of the freshwater phase, while the top of Zone D roughly coincides with the top of the Ajka Formation. The causes responsible for this may be looked for in the close relationship between pollen predominance and environment of deposition.

Long-distance interregional correlations of biozones in freshwater to brackish-water facies are difficult to carry out which, of course, is a problem for the scientist seeking a more precise chronostratigraphic assignation. Exactly for this reason, it is the evaluation of the spore-pollen remains, spread over vast areas by the winds, of Senonian plants of particularly accelerated evolution, that appears to be most suitable for this purpose, even though, on account of what was said in the foregoing, the possibility of that the zones in some cases are bound to facies boundaries exists here too. The regional correlation of the spore-pollen zones was carried out by F. GÓCZÁN for a number of exposures from the Bakony–Zala facies area and, as experienced by him, the palynological zonation of different facies can be readily correlated.

Considering the zonal scale generally adopted by palynologists, F. GÓCZÁN (1964) assigned the rocks of the formation to the Santonian stage (Zones A and B) and the lower part of the Campanian (Zones C and D).

Based on the boreholes Sp-1 and -2, the foraminiferal zonation of (or biofacies) M. SIDÓ (1969) includes zones that are similarly based on abundances: Cornuspira-, Rotalia I-, Nummofallotia-, Epistomina-, Miliolidae-, Vidalina-, Rotalia II- and Nonionella zones as well as biofacies. These zones cannot be identified consistently in the coal-bearing beds of the Sümeg area boreholes. According to our experiences, the abundances of the individuals of some foraminiferal species depend primarily on the character of facies and thus they change, often cyclically, together with the lithologic features.

Very sensitive to environmental changes and being composed of species of not sufficiently short range, the foraminiferal fauna of the formation is unsuitable for an exact long-distance correlation and does not provide a handy tool for the delineation of stage boundaries. Even the most characteristic species [*Nummofallotia cretacea* SCHLUMBERGER, *Vidalina hispanica* (SCHLB.), etc.] are characterized by a relatively wide range, being present throughout the Senonian inasmuch as the environmental conditions are appropriate (M. SIDÓ 1969).

Among the Molluscs there are few forms of considerable lateral distribution, thus being generally of little interest from the viewpoint of interregional correlation. Some species appearing in the uppermost, brackish-water beds of the formation, e.g. *Turritella repelini decipiens* CZAB., *Astarte similis* MÜNSTER, *Limopsis calvus* ZITTEL, and *Pecten laevis* NILSSON, however, can be encountered in formations of similar facies in the wider neighbourhood (Yugoslavia, Austria, Romania) as well. According to the chronostratigraphic practice adopted by scientists dealing with these faunal elements, the afore-listed fossils are indicative of the Campanian (L. CZABALAY 1964e).

An important role in short-distance (local) time-correlation necessary for paleoenvironmental-geochronological reconstructions may be played by some lithologic features and one-time organisms sensitive to changes in environment (Foraminiferae, molluscs).

A prerequisite for a time correlation based on ecologically sensitive fossils and sediments is a morphologically levelled topography. This was not the case with the study area as a whole. Facies shifts in time must be reckoned with. In other words, it is quite plausible that in case of transgression the land tracts of deeper topographic position (being closer, as a rule to the marine sedimentary basin) provided the conditions for the deposition of sediments of some type and for the spread and proliferation of certain fossils somewhat earlier than it may have been the case with a relatively more elevated terrain. Within particular morphological subunits, however, it is possible to carry out both lithostratigraphic correlations and time correlations based on facies-dependent fossils.

On the basis of bio- and lithostratigraphic analyses, the Ajka Formation in the Sümeg area seems to span the Santonian to Lower Campanian time interval. To be more accurate, the formation of the freshwater sediments in the northwest subarea began as early as Santonian time, while the marine-brackish beds in the southeast unit seem to have formed as late as the Campanian.

Paleoenvironment

The Ajka Formation must have been generated in an initially lacustrine and eventually coastal swamp zone that evolved in a direct or indirect connection with the transgression of the sea and persisted for a comparatively long time with the stabilization of some of the environmental factors.

Relatively constant factors during the birth of the formation may have been the overall pattern of the relief, the amount and quality of the sediment introduced into the basin and the climate.

The relief, as suggested by the profiles presented, tended to rise slightly in a southeasterly direction. The nature of the introduced sediment suggests that the extended neighbourhood was represented by a dolomite karst terrain of a likewise gentle morphology.

The accumulation of the weathering products of sand, silt and clay size introduced into the basin kept pace with the subsidence throughout the history of the formation. Nevertheless, the rate of accumulation may from time to time have lagged behind the subsidence, thus producing the sedimentary cycles.

A good deal of the introduced material is composed of dolomite silt deriving from the immediate neighbourhood which seems to have flowed in as a result of sheetwash. The sand-size quartz and feldspar grains, furthermore, some of the clay minerals of different type were probably redeposited from older Cretaceous formations (as suggested by the presence of redeposited remains of *Radiolaria* and *Spongia*), the rest, however, may have come from comparatively remote magmatic to metamorphic sources.

Information on the climatic circumstances is provided by the floral spectrum that can be inferred from the results of palyonological investigations. According to a climatic analysis by F. Góczán (1961, 1973), the study area at the time of coal generation belonged to a tropical-subtropical zone with one precipitation maximum.

From among the largely varying parameters, the variation of salinity and water depth may be quoted.

There is a clear unidirectional trend in the variation of salinity—a transition from a freshwater environment into a marine one. In the northwest subarea of the formation a freshwater to lacustrine environment is indicated in its the lower part by terrestrial and freshwater gastropods and bivalves (*Helix*, *Strophotoma cretacea*, *Megalomastoma supracretacea*, *Pyrgulifera glabra*, *Melania*, *Pachyostoma*, *Goniobasis*, *Corbicula*, *Bulimus*, *Cyprina*, etc.) that can be encountered in great abundance, in the upper part, by the similarly abundant remains of Munieria algae (*Munieria grambasti* Bistr.) and *Chara* as well as by the total absence of fossils of explicitely marine type such as *Foraminifera*, *Bryozoa*, *corals* and *Echinodermata*.

In the upper part of the formation an increase in salinity, as indicated by fossils of higher salinity demand, can be readily traced on the diagram of the borehole Süt-22 (Fig. 33). The steady growth of salinity is indicative of a marine communication becoming gradually more pronounced, suggesting that the coastal freshwater lake and swamp system developed into a littoral saltwater swamp.

Although the water depth within the swamp system did change a little bit, this minor change led to substantial differences in sedimentation. During the migration of facies provoked by periodical changes in water depth a distinct cyclicity evolved which allows us to deduce, in terms of the facies rule, some conclusions as to the characteristics of the juxtaposed facies as well.

Judging by the composition of the cycles studied in detail in the borehole Süt-22 and by the succession of the cycle-members, the following environments as producers of peculiar types of sediments are believed to have developed on the one-time seaside terrain:

1. *Lake or littoral swamp* (Cycle-member *A*). The coastal-swamp environment was characterized —as suggested by the pollen spectrum—by a rich mangrove vegetation (F. Góczán 1961). The gastropods feeding on plants that are observable in the rock may have lived partly in situ, but their preservation state suggests that most of the shells were emplaced after the organism had died. A permanent water-coverage, but only a few dm of water depth, can be supposed. The decay of a lot of organic matter resulted in a strongly reductive environment of acidic chemistry.

In the light of coal petrographic results obtained for the material of the borehole Sp-2, I. Elek, in 1961, identified shallow- and deepswamp facies and a transitional "zone of currents" between the two. According to the results of facies analysis, the coal beds from the borehole Sp-2 were deposited for the most part in the agitated transitional zone.

2. *Somewhat deeper parts of a lake or lagoon (generally the more internal parts)* (Cycle-member *B*). The bottom was floored by sandy-muddy sediments. Because of the relatively deep water a dense swamp vegetation could not settle in it anymore; the oxygen and the nutrients for the rich Ostracoda and Gastropoda fauna having been supplied by calcareous algae and probably by higher aquatic plants. The presence of lumachelle beds containing a lot of tide-mixed fossil detritus suggests that these bottom tracts got from time to time in the zone of wave action. A water agitation somewhat weaker than this is indicated by the sand and bioclast lenses particularly characteristic of the facies in question, being often bioturbated, i.e. laced by worm tracks. The water depth is estimated at 1 m or so.

3. *The deepest part of the lake or lagoon (its centre)* (Cycle-member *C*). A light-coloured calcareous mud, with a rich green algal flora (Munieria) in the freshwater interval, is characteristic. The water depth may have been a few metres. A relationship between the periodical changes in water level and the salinity can be registered, too. According to the salinity variation diagram of the borehole Süt-22, the marine organisms appeared for the first time in a high water level period (brackish-water fauna), i.e. it was at that time that a communication with the transgressing sea was established. In the subsequent accumulation period again a trend towards the establishment of a freshwater regime may be supposed and then, as evidenced by the subsequent cycles, the process was repeated several times.

Jákó Marl Formation

Extension, mode of superposition, stratigraphic subdivisions

In the Sümeg area the Jákó Marl Formation is common. The only exception to the rule is a marginal zone and the surroundings of the Aptian crinoidal limestone outcrop of Köves-domb. The outcrops of the formation, however, are confined to two places: near the well (Hárs-kút) on the south side of the Köves-domb and in the Gerinc quarry. Within the formation three units of member rank can be singled out, two of which being essentially of equal extension, while the third one is developed quite apart, in the marginal zone (Fig. 42).

The individual members, as a rule, are lithologically uniform, a rather marked variability being noticeable only in the lower one, the Csingervölgy Marl Member, which is represented in the northwest by calcareous marls with a southeastward growth of the pelite content, but which is constituted farther south by sandy rock varieties. The lower member abounds with Mollusca (first of all *Bivalvia*) and with ahermatypical corals.

In the upper member it is uniformly siltstones, silstone-marls and, in subordinate quantities, argillaceous marls are found. Megafossils, if any, are quite sporadical. Selected as a type section, the borehole Süt-22 exhibits the two basin-facies members of the formation.

The member developed in the marginal zone represents a transition towards the Ugod Formation. It is composed of rock types of higher carbonate content such as silty marl, calcareous-nodular marl and sandy, argillaceous limestone. As type exposure the sequence of Gerinc quarry has been selected, its upper part being exposed in the quarry face, its lower part in the borehole Sc-1/8 put down in the quarry-yard.

The problem of the lithostratigraphic calibration of the rock types belonging to the formation came primarily during the scientific exploration of the study area (key section drilling) into the fore. What is now regarded as the lower member of the formation was earlier discussed either independently under the name of "corals- and molluscs-bearing argillaceous marl group" (with the possible separation of the so-called "Lima marl" at its base) distinctly separated from the overlying "Gryphaea marl" or was referred to, combined with the former, as "clay-marl group with corals, molluscs, Gryphaea and crab claws", resp. as "lower clay-marl". The separation of the two units was practised primarily in paleontological studies. The upper part of the upper member, in turn, was often quoted as "calcareous marl with worm tracks".

The Jákó Marl is underlain for the most part by the Ajka Formation; on the margins, however, it transgresses beyond this, overlying terrestrial sediments of the pre-Senonian basement. The thickness of the formation varies between 0 and 110 m, the isopachs running subparallel to those of the Ajka Formation (Fig. 42). A substantial deviation can be found only in the northwest part of the area. The marginal, more carbonate member is found in the zone between the 0 and 30 m isopachs. The formation in its larger, northern subarea is overlain by the Polány Formation, in the south by the Ugod Formation with which it is laterally intertongued.

Local type section: borehole Süt-22

As local type section the 38.5 to 101.0 m interval of the borehole Süt-22 has been selected. The lithologic features of the formation and the results of its examination are presented in Fig. 43. In the type sequence the two members are lithologically quite distinct. The lower 31-m-thick member

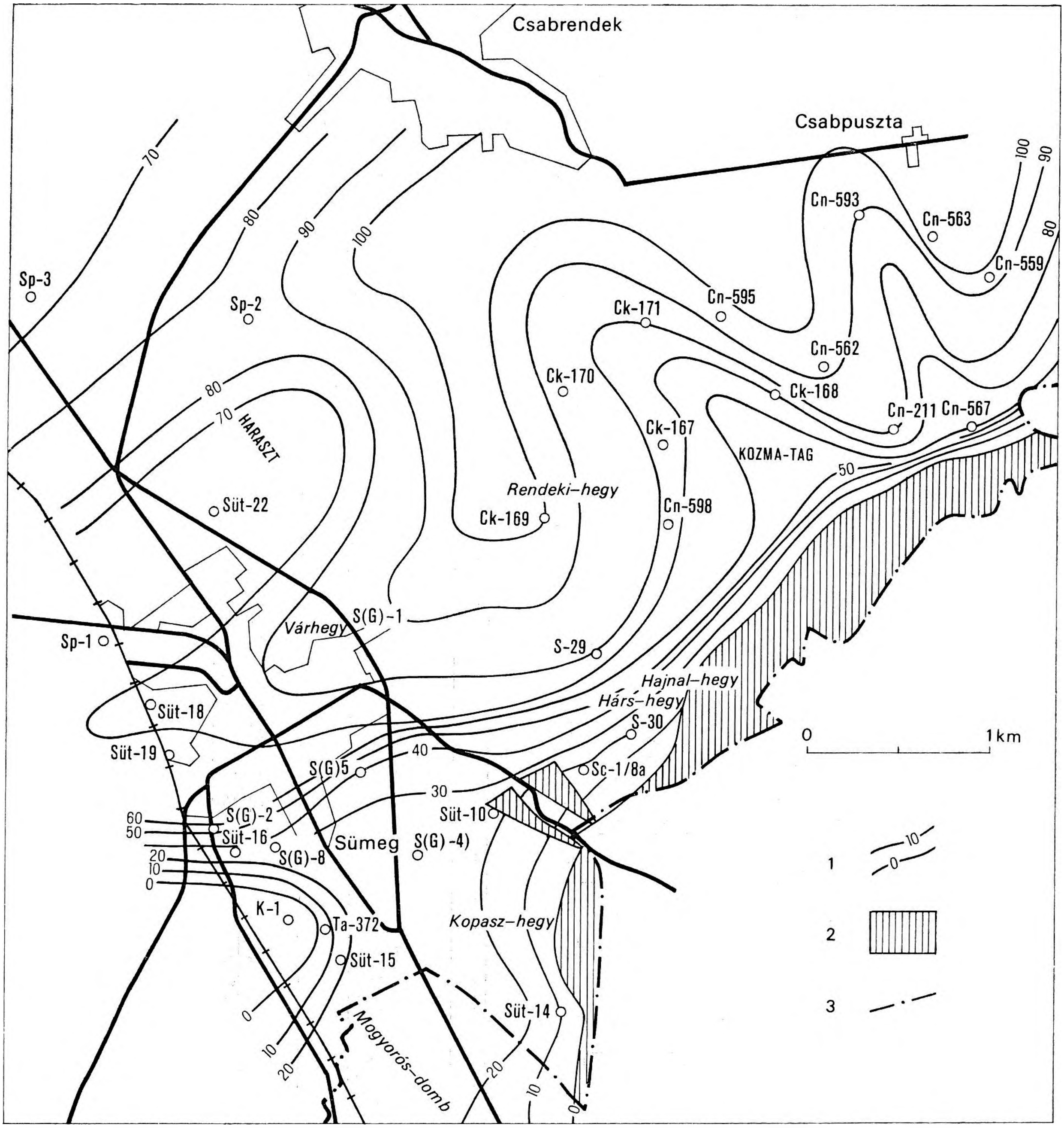


Fig. 42. Extension and thickness of the Jákó Marl Formation

1. Isopachs of the Jákó Marl Formation, 2. the Jákó Marl Fm. is absent within the Senonian area, 3. boundary of extension of the Senonian

is of great diversity and its lower half is of cyclic composition, similarly to the case of the Ajka Formation, being still characterized by a comparatively high dolomite content (up to even 10%). In the upper part of the member the cycles cannot be identified anymore, the individual rock types alternate in a great frequency, though irregularly. The upper member is lithologically uniform (69.2 to 42.6 m), being constituted for the most part by silstone-marls. The dolomite content drops to a few per cent.

The lower boundary of the Jákó Formation is drawn above the coal-stringered, sandy marl regarded as the topmost layer of the Ajka Formation and actually representing the initial *(A)* member of the only regular and complete cycle of the Csingervölgy Member. 7.1 m thick, the cycle shows the *A–B–C–B′–A* cyclicity pattern already presented in the discussion of the Ajka Formation. A half cycle more can be traced above it. Naturally, no coal-bearing beds are found in *Member A*

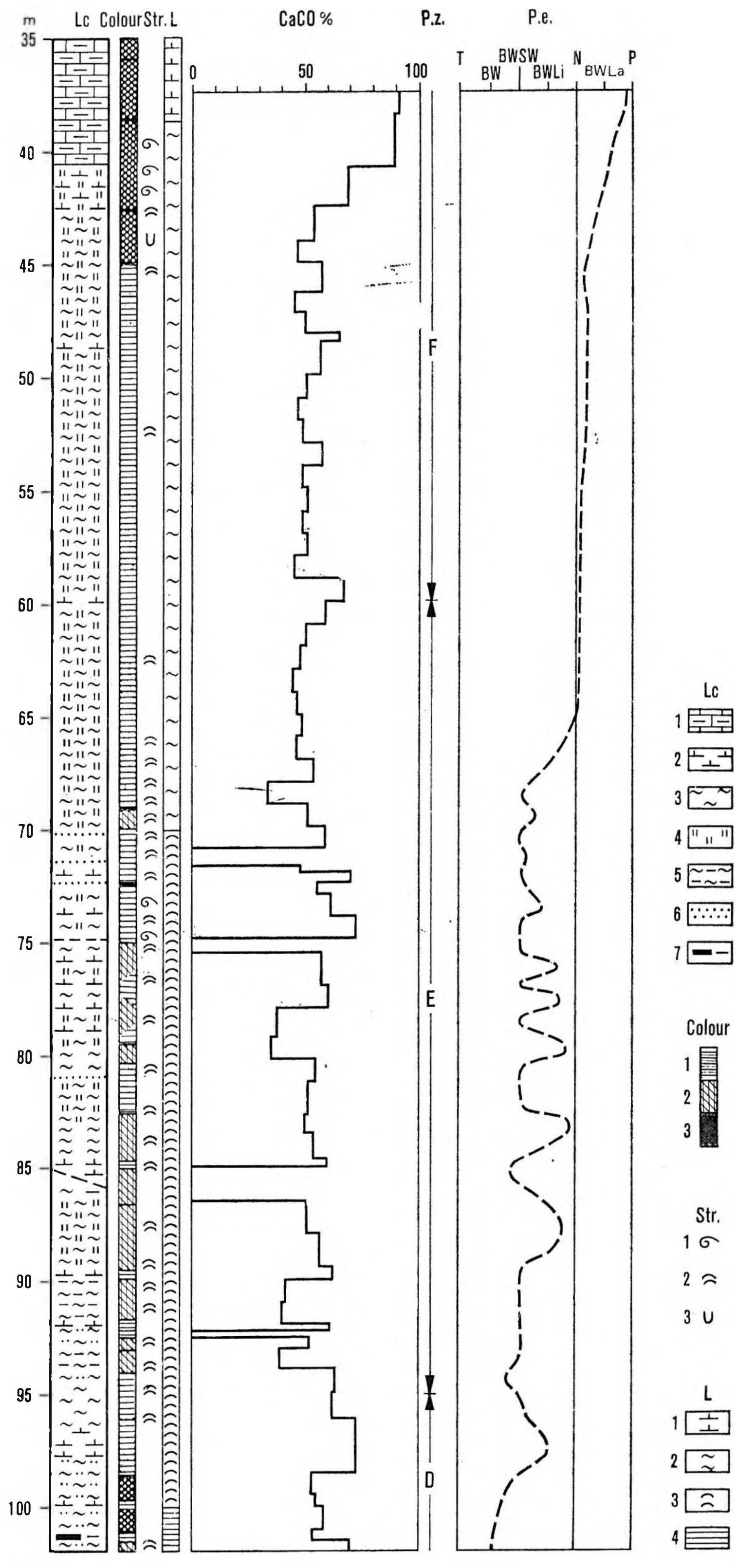


Fig. 43. The Jákó Marl interval of the borehole Sümeg Süt-22: lithologic column and petrographic and palynological record and paleoenvironmental interpretation

Lithologic column **(Lc): 1. argillaceous limestone. 2. calcareous marl, 3. marl, 4. siltstone, 5. argillaceous marl, 6. sand, 7. carbonaceous clay. — *Colours:* 1. light grey, 2. dark grey, 3. brownish-grey. — *Structure* (Str.): 1. Exogyra-Pycnodonta lumachelle, 2. other mollusc lumachelle, 3. worm tracks. — *Lithostratigraphic unit* (L): 1. Polány Marl Fm., lower member, 2. Jákó Marl Fm., upper member, 3. Jákó Marl Fm., lower member, 4. Ajka Coal Fm. — *P.z.* palynological zones. — *Paleoenvironment* (P.e.): *T* terrestrial, *BWSw* brackish-water-swamp, *BWLi* brackish-water-littoral, *BWLa* brackish-water-lagoonal, *N* normal salinity-neritic, *P* pelagic basin**

anymore, being replaced by a dark grey argillaceous marl rock type. A 10-m-thick bed above the cyclic part represents a transition to the overlying member.

The 2.5-m-thick *Member B* of the cycle is represented by grey to brownish-grey, heavily sandy, sand-lensed marls. Its fossil content is generally poor, small mollusc shell fragments being encountered in great quantities associated with the sand lenses. Most of the identifiable faunal elements are euryhaline or marine-brackish forms (*Nucula concinna* Sow., *Pecten laevis* Nilsson, and *Cardita granigera* Gümbel, respectively).

Member C is represented by a grey dolomitic, calcareous marl containing a lot of fossil detritus composed of a few Bivalvia and Gastropoda indicative of normal salinity (*Cantharus* sp., *Fusus tritonium* Zekkeli, *Arca* sp., *Pectunculus* sp.) as well as of euryhaline forms (many *Ostrea* sp., and fairly numerous *Haustator* sp., *Turritella* sp., *Pecten laevis* Nilsson and *Cyrena* sp.). It is here that the first ahermatypical corals appear.

Member B' of the cycle is constituted by marls and sandy marls (2.1 m thick). It contains a great quantity of smaller Bivalvia. In its lower part the marine species are also frequent (*Corbula angustata* Sow., *Crassatella* sp., *Arca inaequidentata* Zittel, *Astarte similis* Münster), being followed, higher up the profile, by an assemblage of forms enduring changes in salinity or brackish-water species (*Cardium ottoi* Geinitz). The traces of *Cliona vestifica* Voltz. on mollusc shells were observed by L. Czabalay.

Member A of the next cycle (0.90 m) is composed of dark grey argillaceous marls. Its fauna consists of sporadically freshwater (*Cyprina* sp.), predominantly marine-brackish (*Cardium ottoi* Geinitz, *Cyrena solitaria* Zittel) and euryhaline forms (*Limopsis calvus* Zittel, *Pecten laevis* Nilsson, *Nucula concinna* Sow.).

Member B is represented by sandy and siltstone-bearing marls and argillaceousmarls. The fauna is composed of euryhaline forms (*Nucula concinna* Sow., *Limopsis calvus* Zittel) and forms indicative of normal salinity (*Corbula angustata* Sow.); higher up the profile the latter become gradually predominant. In the lower interval the traces of *Cliona vestifica* Voltz. are still frequent. In the upper part the ahermatypical corals become ever more frequent.

The last identifiable *cycle-member (C)* is a grey dolomitic calcareous marl. Its fauna is represented almost exclusively by forms of normal salinity environments (*Tellina stoliczkaiae* Zittel). The fossils are often enriched in particular lenses.

In the upper acyclical part of the lower member (84.7–69.2 m) three beds can be singled out on the basis of the lithological features. In the lower third there is a dark grey, argillaceous-marl with rare sand lenses and few fossils. Above it follows, in 7 m thickness, a sandy, marly siltstone or pure silstone unit densely interrupted by thin calcareous marl and argillaceous marl interbeddings of great diversity. The upper few metres are more uniform in lithology, being represented by silty marls and argillaceous marls.

This upper part of the sequence contains fossils in fair to low quantities, its megafossil assemblage consisting for the most part of forms indicative of waters of normal salinity and, in subordinate quantity, of euryhaline Molluscs (*Astarte similis* Münster, *Tellina stoliczkaiae* Zittel or *Dosinia cretacea* Zittel, respectively).

During the study of the megafossils of the lower member, L. Czabalay distinguished two intervals, each with a typical fossil assemblage: *Members B* and *C* of the lower cycle being characterized by a Gastropoda–Pecten–Cardium assemblage, *Members B* and *C* of the next cycle by an Astarte–Nucula–Corbula assemblage.

As shown by the results of analysis of the microfauna (the decanted material was studied by M. Sidó), the lower interval of the member is represented by a Miliolidae–Cornuspira–Vidalina assemblage, the upper part by the appearance of *Goupillaudina lecointrei* Marie, the representatives of *Gavellina* and, eventually, of *Nonionella* and the planktonic forms.

On the basis of the palynological analysis (F. Góczán), the member is characterized by the abundance of *Hungaropollis oculus* Góczán, *H. auritus* Góczán, *H. longianulus* Góczán, resp. *Krutzschipollis spatiosus* Góczán, *K. crassus* Góczán and *Sümegipollis triangularis* Góczán.

The upper member of the Jákó Marl (its thickness–27 m) evolves continuously from that underlying it, showing a gradual reduction in grains, a considerable decrease in the amount of fossils and a change of forms. The lithology of the member is uniform. Predominant rock types are silty marl and marly siltstone interrupted, in rarest cases, by thin interbedded layers of marl. (With minor deviations, the $CaCO_3$ content is around 50%). Megafossils are poor. Fish scales, Echinoidea detritus, coalified plant remains, though sporadical, are observable throughout the member.

From among the molluscs, the thin-shelled, well-preserved *Bivalvia* are characteristic. Typical species are: *Crassatella macrodonta* var. *sulcifera* Zittel, *Tellina stoliczkai* Zittel, *Pholadomya granulosa* Zittel, all being euryhaline forms. *Scaphopoda* are encountered rather frequently. At the upper boundary of the member the representatives of *Exogyra* show a marked enrichment.

The foraminiferal assemblage is composed of rich planktonic and peculiar benthonic species:

Vaginulina cretacea PLUMBER, *V. taylorana* CUSHMAN, *V.* sp., *Gavelinella* sp., *Goupillaudina* sp., *Hedbergella cretacea* (D'ORB.), *Globotruncana marginata* (REUSS).

Peculiar and even quantitatively important species from the association of sporomorphs are *Hungaropollis krutzschi* GÓCZÁN, *H. brevis* GÓCZÁN, *H. oculus* GÓCZÁN, *Krutzschipollis crassus* GÓCZÁN, *K. longanulus* GÓCZÁN, *K. spatiosus* GÓCZÁN, *Longanulipollis bajtayi* GÓCZÁN, *L. longianulus* GÓCZÁN, *L. lenneri* GÓCZÁN.

A good deal of the carbonate content in the formation is associated with dolomite minerals (as shown by A. SZEMETHY's X-ray diffraction results). The amount of dolomite decreases gradually upwards in the lower member. Over a short interval above the member-boundary the two minerals occur in equal quantity, then a marked prevalence of calcite is observed. Likewise in the vicinity of the member boundary, a few per cent ankerite can be registered too. In some samples a good deal of the carbonate is connected with aragonite.

The clay minerals are represented by kaolinite, illite and montmorillonite, their percentage decreases gradually as one proceeds upwards, attaining a marked reduction in the upper part of the member. Montmorillonite is totally absent at the top. The behaviour of illite is opposed to the former. A low percentage of the sand-size constituents is allothigenic mineral. Quarts is predominant among the light minerals. The most frequent allothigenic heavy mineral is augite. A low quantity of epidote, colourless garnet, magnetite, chlorite, muscovite, hornblende and hypersthene is also present (as shown by A. LENKEI).

The upper boundary of the formation and, consequently, that of the formation itself is delineated by a marked growth of the $CaCO_3$ content and the appearance of a nodular, bioturbated rock structure. Near the boundary a remarkable change takes place in the Foraminifera content, as *Vaginulina* disappear and a number of planktonic species make their appearance: *Heterohelix, Pseudotextularia, Globigerinelloides.* Planktonic microfossils of the *Calcisphaerulidae* group and the representatives of *Stomiosphaera* and *Pithonella* appear too.

Geological features

Similarly to the case of the Ajka Formation the basic features of the formation in question are outlined along profiles plotted in the direction of greatest change in thickness (Fig. 43). The boundary between the two members of the formation has been selected as a reference horizon for plotting the sections. With a view to the uniform development of the upper member throughout the area in question, it may be supposed that the sedimentary basin was least differentiated during the deposition of this formation member. Profile I (Fig. 44), issuing from the borehole Sp-3, runs in a southeasterly direction, to cross the Köves-domb along the west side of Sümeg. In the borehole Sp-3, rocks belonging to the Jákó Marl are exposed in 66.9 m thickness between 153.1 and 220.0 m.

The two members of the formation are distinctly individualized. Unlike the cyclicity observable in the type section, here even the deeper part of the lower member is homogeneous.

Attaining a thickness of 28.6 m (between 220.0 and 191.4 m) the lower member is composed of grey to dark grey marls and clay marls. In its lower part there are local occurrences of sands and, quite exceptionally, even thin sandstone interbeds are found. The upper part is silty. The fossils are often enriched so as to form lumachelle accumulations. They show an increase in quantity upwards. In the lower interval the ahermatypical corals and coalified plant detritus are still abundant.

As shown by L. CZABALAY, *Pecten laevis* NILSSON, *Astarte similis* MÜNSTER and *Cyclas ambliqua* appear in greatest number of individuals in the Mollusca assemblage. Specimens of *Nucula concinna* Sow., *Cyrena* sp., *Limopsis* sp., *Gervilleia solinoides* DEFR. are frequent, those of *Pecten* sp., *Cardium ottoi* GEINITZ and *Haustator* sp. are less so.

The upper member is constituted for the most part (between 191.4 and 153.1 m) by grey marls, silty marls with interbedded calcareous marl layers getting gradually more frequent up in the section. The fauna is scant, as a rule, containing primarily fish scales, fish teeth and fragments of crab claws with subordinate shell fragments of molluscs. In the lower part the typical species of the lower member are still present. Faunal elements appearing in the upper member are *Fusus* sp., *Aporrhais* sp. and *Dentalium* sp.

Located in the vicinity of the profile line (and taken into consideration in profile-plotting), the borehole Sp-2 intersected the Jákó Marl in a thickness of 86 m (190.4 to 276.4 m). The borehole is one of the key sections exemplifying the biostratigraphic zonal scale of the Senonian in the Bakony Mountains.

The lower member is 34 m thick, the lowermost 7 m of which form a regular cycle. Above this a sequence of low variability follows. A few metres of silty calcareous marl are overlain, in greater thickness, by a sequence of alternating calcareous marls and silty calcareous marls, the top of the member being predominated by silty marls and calcareous siltstones.

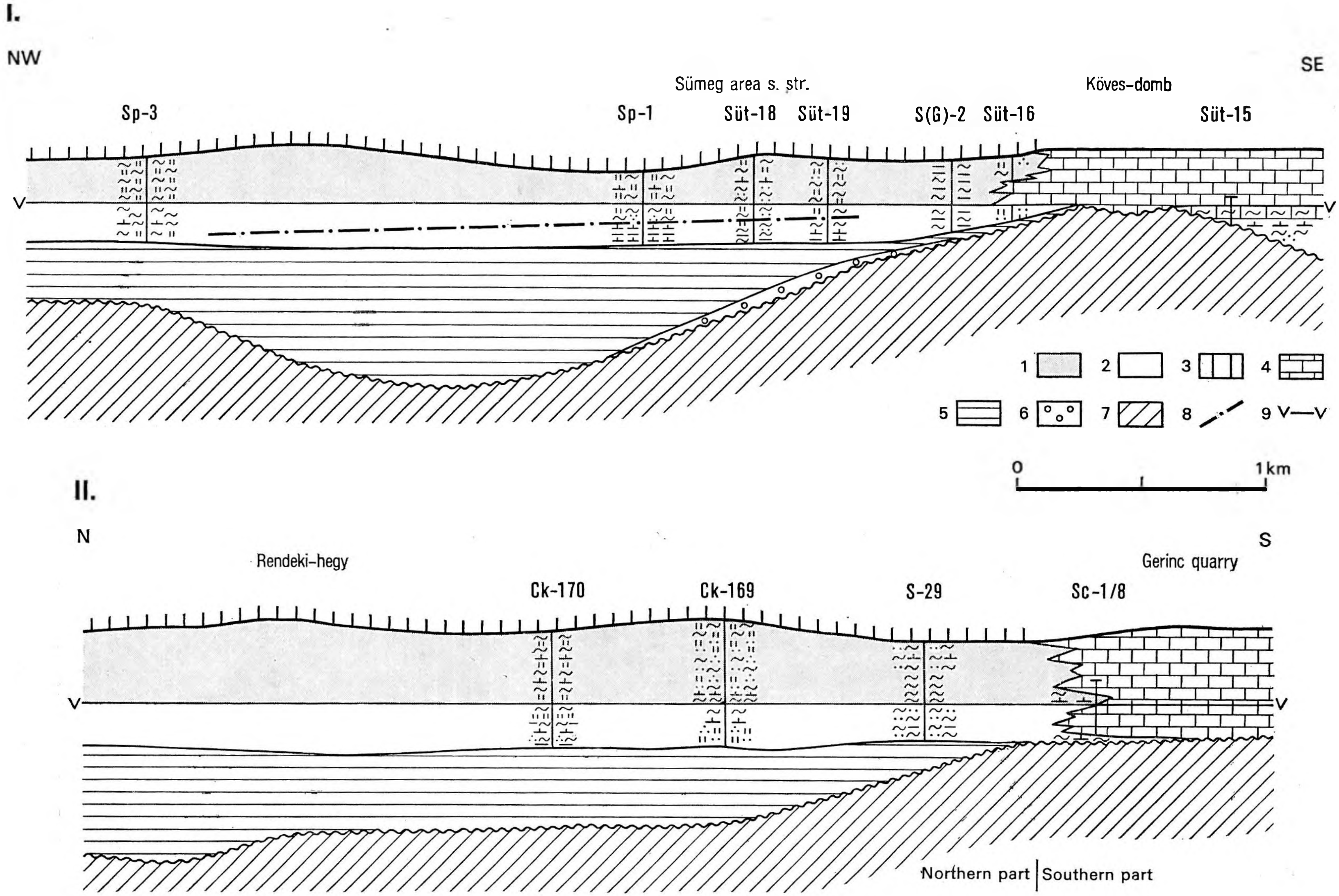
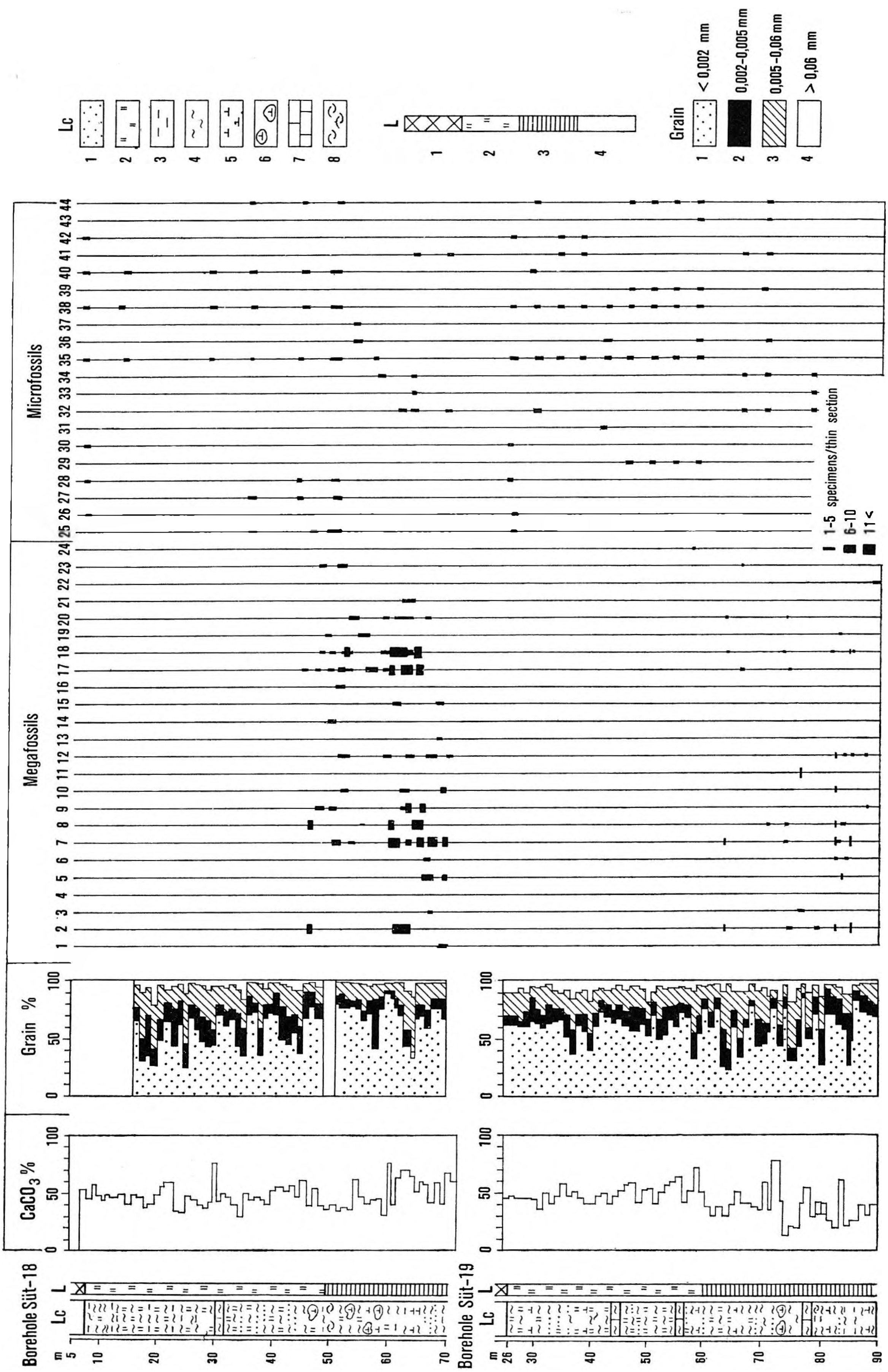


Fig. 44. Transversal profiles across the area of the Csingervölgy Marl Member

1. Upper member, 2. lower member, 3. Polány Fm., 4. Ugod Fm., 5. Ajka Fm., 6. Csehbánya Fm., 7. pre-Senonian basement, 8. upper limit of cyclicity, 9. reference level — boundary of lower and upper members



Lc
1
2
3
4
5
6
7
8
L
1
2
3
4
Grain
1 < 0,002 mm
2 0,002-0,005 mm
3 0,005-0,06 mm
4 > 0,06 mm
Microfossils
Megafossils
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
1-5 specimens/thin section
6-10
11<
Grain %
0
50
100
CaCO3 %
0
50
100
Borehole Süt-18
Borehole Süt-19
L
Lc
m
5
10
20
30
40
50
60
70
26
30
40
50
60
70
80
90

On the basis of her examination of the megafossils, L. CZABALAY showed the presence in the cyclic lower interval of the lower member of a "Gastropoda–Pecten–Cardium–Corals" biofacies, while in its upper interval she identified a "Nucula–Corbula–Corals" biofacies.

Among the representatives of Foraminifera it is *Miliolina* and *Vidalina* that are characteristic. A sharp change is observed at the upper member-boundary, *Miliolidae* and *Vidalina* disappearing and only *Nonionella* reaching a little bit above the member-boundary.

Constituted by silty marls and calcareous marls, the upper member is exposed by the drill (242.3–190.4 m) in a thickness of 51.9 m.

The Mollusca assemblage in the lower part of the member is still represented by a "Nucula–Corbula–Corals" biofacies, but in the upper part it is by a "Clavagella" and a "Dentalium" one.

The microfauna content shows the following distribution: in 10 m thickness above the lower boundary an interval containing exclusively *Nonionella* (otherwise free from Foraminifera) will follow and eventually there appear *Vaginulina*, *Epistomina* and *Globotruncana* and, in the upper part of the member, *Gavelinella* as well.

In the borehole Sp-1 the thickness of the formation is 54.9 m (51.6–106.5 m). Having a thickness of 32 m, the member is composed grey marls, silty marls or nodular marls and calcareous marls alternating with varying frequency, gradually decreasing upwards. The megaloscopic description by M. PAPAJCSIK–GERECS suggests a sequence of cyclic nature with three to four cycles distinguishable. (This number exceeds the figure observed in the borehole Süt-22.) Member *C* of the last identifiable cycle falls at the boundary between two members of the formation.

According to the results of analysis of the megafossils, *Astarte similis* MÜNSTER and *Corbula angustata* SOW., both species indicative of a sea water of normal salinity, are predominant. Frequent forms are: *Ostrea* sp., *Tellina stoliczkai* ZITTEL, *Pholadomya granulosa* MÜNSTER; from among the gastropods a few specimens of *Turritella fittoniana* MÜNSTER were encountered. *Cyclolites* are present in fair quantities. Similarly to the case of the borehole Sp-2, the lower part of the "Gastropoda–Pecten–Cardium–Corals" and "Nucula–Corbula–Corals" biofacies can be identified within the member.

According to the results of the analyses of microfossils a Miliolina–Vidalina–Nummofallotia assemblage is characteristic in the lower part of the member, *Nonionella* being encountered throughout the member.

The upper member is 23 m thick (74.5—51.6 m). Lithologically, it is an extremely homogeneous, grey silty marl interrupted very rarely by single marl beds.

The amount of the megafossils decreases markedly, no new species presenting itself. It is the forms known from the lower member that are persisting. L. CZABALAY assigned the member as a whole to the "Nucula–Corbula–Corals" biofacies. The "Clavagella" and "Dentalium" horizon in this exposure could not be identified. Upon their disappearance it is the "Exogyra" horizon that follows immediately. The microfossil assemblage is significantly different from that of the lower member. After an interval of a couple of metres above the member-boundary it is *Vaginulina*, *Bulimina* and *Epistomina* rather than *Globotruncana cretacea* that appear.

The borehole Süt-18 (Fig. 45) exposed the Jákó Formation in a thickness of 70.4 m (7.7–78.1 m), 29.6 m of which is the thickness of the lower member. A peculiar feature of the sequence is the cyclic development traceable throughout the lower member.

The lower part of the member is characterized by regular cycles (3 of them). In the upper one the development is not completely regular anymore, the regularity being confined to an alternation of more calcareous and more detrital beds with ones of higher pelite and silt content and then, in the uppermost 12 metres of the member, this alternation becomes faded, too. In the lower half of the basal cycle the brackish-water faunal assemblage typical of the upper part of the formation is gradually replaced by species enduring the variation of salinity (*Pecten laevis* NILSSON, *Gervilleia solenoides* DEFR., *Corbula angustata* SOW., *Nucula concinna* SOW.).

←

Fig. 45. The Jákó Marl interval of the boreholes Süt-18 and -19: lithologic column and analytical record

Lithologic column (Lc): 1. sand, 2. siltstone, 3. clay, 4. marl, 5. calcareous marl, 6. nodular limestone, 7. limestone, 8. lumachelle. — ***Lithostratigraphic units*** (L): 1. Polány Formation, 2. Jákó Fm., upper member, 3. Jákó Fm., Csingervölgy Member, 4. Ajka Fm. — ***Grain:*** 1—2. clay, 3. silt, 4. sand. — ***Megafossils: Facies:*** tending to get desalinized: 1. Pyrgulifera sp.; brackish-water: 2. Cardium ottoi, 3. Cyrena solitaria, 4. Cardium sp.; fossils enduring changes in salinity: 5. Turritella difficilis, 6. Haustator sp., 7. Pecten laevis, 8. Nucula concinna, 9. Lima marticensis, 10. Limopsis calvus, 11. Exogyra, 12. Gervilleia solenoides?, 13. Cryptorhytis baccata; marine: 14. Dentalium sp., 15. Cantharulus gosauicus, 16. Acropagia sp., 17. Astarte similis, 18. Corbula angustata, 19. Pectunculus sp., 20. Crassatella macrocarinata, 21. Tellina stoliczkai, 22. Pirenella münsteri, 23. corals, 24. fish scales. — ***Microfossils:*** 25. Globotruncana concavata, 26. Gl. marginata, 27. Gl. globigerinoides, 28. Gl. sp., 29. Globigerinelloides sp., 30. Hedbergella cretacea, 31. Heterohelix striata, 32. Miliolidae, 33. Vidalina hispanica, 34. Cornuspira sp., 35. Vaginulina sp., 36. Nonionella sp., 37. N. cretacea, 38. Gavelinella sp., 39. Valvulineria sp., 40. Epistomina, 41. Nummofallotia cretacea, 42. Goupillaudina lecointrei, 43. Rotalia sp., 44. other benthos

The next interval is characterized by the predominance of euryhaline species, though marine forms *(Echinidea, Cirripedia* and a few *Corals)* are also encountered sporadically in the regularly cyclic sequence of the member. In that part characterized by an alternation of more pelitic rock varieties with more calcareous ones the faunal assemblage is already marine.

In the lithologically distinguishable uppermost interval of the lower member the species enduring a decrease in salinity already disappear. The microfossil assemblage shows the characteristic pattern of the lower member.

The upper member is represented in a thickness of 40.8 m by marly siltstone, silty marl, argillaceous marl and, less frequently, marly limestone. Its mega- and microfossil assemblages agree with those observed in the sections already discussed.

The borehole Süt-19 (Fig. 45) exposed the formation in 64.6 m thickness. It is from 60.2 to 91.0 m that the Csingervölgy Member could be identified, being conspicuous with its comprising a number of cycles greater than is the case with the sequences exposed farther north.

The basal 16 m of the member are composed of six regular cycles, above this, along the member-boundary, marls and silty-sandy marls alternate with thin interbeds of nodular, calcareous marl and, less frequently, of marly limestone with lots of megafossils. As interpreted by L. Czabalay, three megafossil-based intervals can be singled out: at the base of the member (in the lower one cycle and a half) a brackish-water assemblage fairly tolerant of changes in salinity (*Pirenella, Cardium, Cyrena, Nucula* species) appears. Within a short interval above the former, similarly to the case of the borehole Süt-18, it is marine (*Gervilleia solenoides* Defr., *Corbula* sp.) or euryhaline (*Pecten laevis* Nilsson, *Nucula* sp.) species that predominate and the traces of borer-sponge *Clionia,* are abundant. Single brackish-water species (*Limopsis calvus* Zittel) are encountered too. A difference compared with the sequence of the borehole Süt-18 is that there this interval appears already above the cyclic sequence. The third macrofossil-based interval has yielded a marine fossil assemblage in which, in addition to *Bivalvia* and *Gastropoda*, the representatives of *ahermatypical corals* appear too.

In the microfossil assemblage of the member such forms as *Nummofallotia cretacea* Schlumb., *Vidalina hispanica* Schl., *Cornuspira* sp. and *Miliolideae* are abundant, to disappear then a few metres beneath the member-boundary. The uppermost few metres contain *Nonionella* exclusively.

The upper member is lithologically similar to the local stratotype and the fossil assemblage is also akin to that of the type section.

The Jákó Formation can be divided into a lower and an upper member in the section of the borehole Süt-16 too, but a thin limestone bed showing the characteristics of the Ugod Formation is indented between the two.

In 12 m thickness beneath the Ugod Limestone (44.9–56.4 m) the Csingervölgy Member was cut by the drill. This part of the sequence is constituted by a sevenfold alternation of dark grey siltstone and marly limestone of varying sand content and marly limestone and pure limestone. The only cycle of regular development is that one the *A*-member of which is composed of a little sandy, argillaceous marl with traces of coal. Its megafauna is poor, consisting, similarly to what has been previously discussed, of euryhaline and purely marine forms. (The latter are predominant in the limestone beds.) Brackish-water species are subordinate. In the uppermost part *Scaphopoda* and *fish scales* characteristic already of the upper member are found.

Its microfaunal assemblage agrees with the characteristic species of the cyclic part of the lower member, forms disappearing all but *Nummofallotia cretacea* Schl. with the appearance of the Ugod Limestone.

Above the Ugod Limestone of about 17 m thickness the upper member is 19.1 m thick (10.1–29.2 m). Its is constituted by dark grey, locally somewhat sandy siltstone with rare interbeddings of sandy and marly limestone with fossils typical of the member.

The borehole S-7 of Köves-domb did not hit the Jákó Marl, the pre-Senonian basement being overlain, with a thin argillaceous and carbonaceous basal bed, by the Ugod Formation.

Located to the southeast of the borehole S-7, the borehole Süt-15 (Fig. 46) exposed, beneath extraclastic limestone beds of the Ugod Formation, 17 m of the lower member of the Jákó Marl. The geological features are similar to the case of the lower member exposed in the borehole Süt-16. being composed of alternating dark grey argillaceous marls, sandy silty marls and grey calcareous marls.

Both rock types contain a good deal of megafossils among which the euryhaline forms (*Pecten laevis* Nilsson, *Plicatula aspera* Sow.) predominate. In the more calcareous intervals marine forms prevail (*Astarte similis* Münster), the heavily argillaceous beds abounding with brackish-water forms (*Cardium ottoi* Geinitz).

In the southernmost part of the Köves-domb, in the immediate proximity of the roofed well (Hárskút), the extremely fossiliferous beds of the lower member of the formation that have altered ochre-yellow owing to oxidation are present in outcrop as well. The outcrop is a well-known locality, where Upper Cretaceous molluscs and ahermatypical corals have been sampled for a long time. From

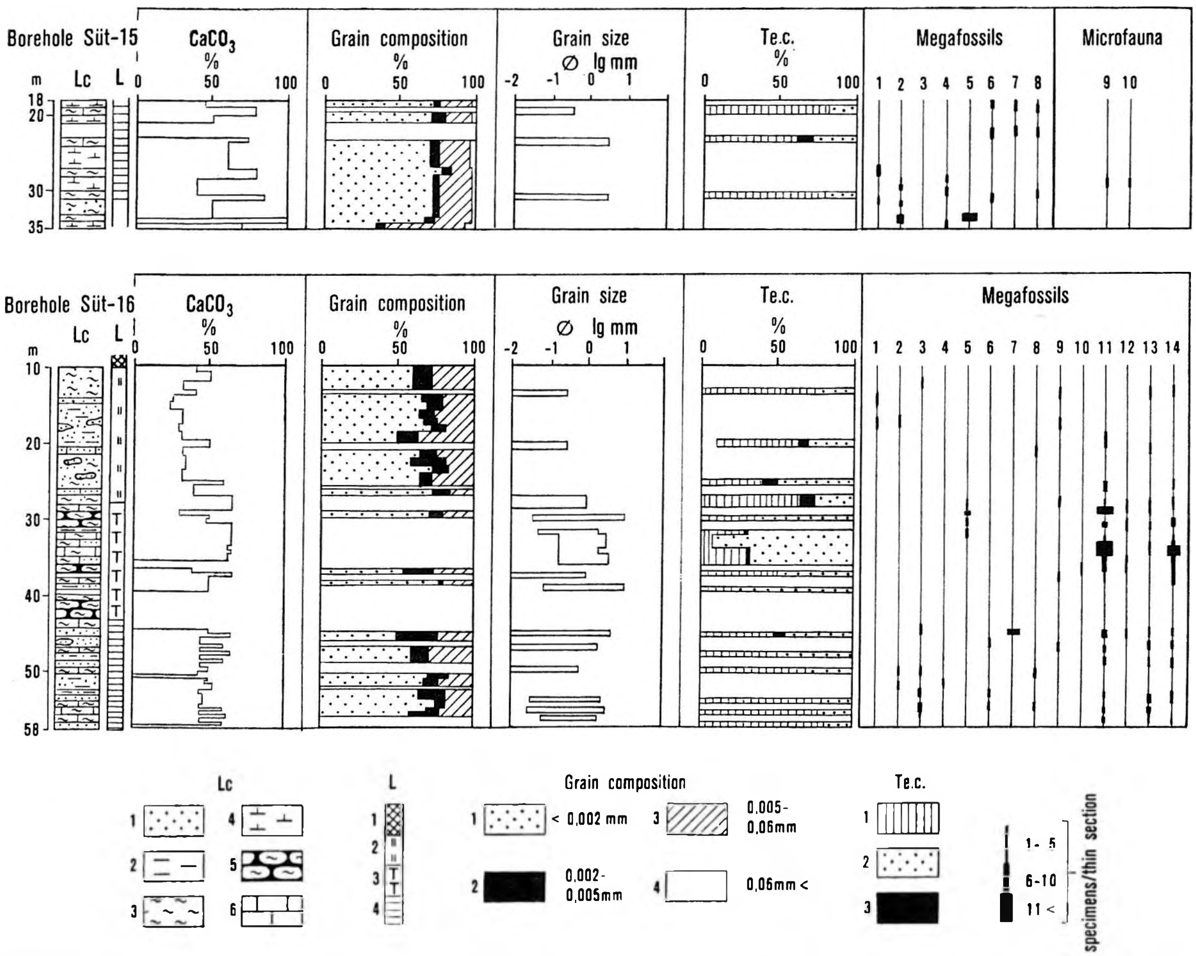


Fig. 46. The Jákó Formation interval of the borehole Süt-15 and -16: lithologic column and analytical record

Lithologic column **(Lc): 1. sand, 2. clay, 3. marl, 4. calcareous marl, 5. nodular marl, 6. limestone. — *Lithostratigraphic units* (L): 1. Polány Marl Fm., 2. Jákó Fm., upper member, 3. Ugod Fm., 4. Jákó Fm., Csingervölgy Member. — *Grain composition:* 1—2. clay, 3. silt, 4. sand. — *Textural composition* (Te.c.): 1. micrite, 2. fossils, 3. pellets. — Megafossils from the *borehole Süt-15:* 1. Cyclolites, 2. Pecten, 3. Plicatula, 4. Cardium, 5. Astarte, 6. Rudist detritus, 7. Ostrea sp., 8. Echinodermata; microfossils: 9. Vidalina, 10. benthonic Foraminifera. — Megafossils from the *borehole Süt-16:* 1. Dentalium, 2. Nucula, 3. Inoceramus, 4. Limopsis, 5. Exogyra, 6. Astarte, 7. Rudista group, 8. Haustator, 9. fish scales, 10. Serpula, 11. Mollusca detritus, 12. Rudista detritus, 13. Ostracoda, 14. Echinodermata**

among the ahermatypical corals *Cyclolites* are represented by the highest number of species and individuals. B. GÉCZY (1953, 1954) devoted a special study to their description. The most frequent species are *C. macrostoma* REUSS, *C. orbigny homoiomacrostoma* GÉCZY, *C. reussi* FROMENTEL and *C. semisubcircularis* GÉCZY.

As shown by G. KOLOSVÁRY (1954), other ahermatypical corals include forms of the genus *Phyllosmilia*, while the representatives of the genera *Montlivaultia*, *Placosmilia* and *Trochosmilia* occur just sporadically. Colonies of *Bryozoa* and worm tubes were observed to be attached by overgrowth to coral skeletons (GÉCZY 1954).

As shown by L. CZABALAY (1961), the Mollusca fauna represents a Gastropoda–Pecten–Cardium assemblage characteristic of the lower part of the lower member. Within it she identified a biofacies containing, for the most part, Glauconia and just a few bivalves (*Cyrena* and *Corbula* species) and one constituted by Cerithium. In the Glauconia facies the following species are abundant: *Glauconia renauxiana* D'ORB., *G. coquiandiana* D'ORB. var. *G. kefersteini* MÜNSTER (Gastropods) and *Cardium ottoi* GEINITZ, *Limopsis calvus* ZITTEL, *Plicatula aspera* ZITTEL, *Cyrena solitaria* ZITTEL *Corbula angustata* SOW. (Bivalvs).

Typical Gastropods of the Cerithium biofacies are *Pirenella, Haustator, Desmieria, Aptyxiella, Rostellaria* and *Fusus* sp. Most frequent Bivalves are *Corbula angustata* SOW., *Tellina stoliczkai* ZITTEL, *Nucula concinna* SOW., *Astarte similis* MÜNSTER and *Lima* sp.

During her study of the Foraminifera fauna, M. SIDÓ (1961) found *Operculina baconica* to be present in largest number of specimens in a decanted material sampled from the exposure. (According to M. SIDÓ 1963, the species is a synonym of *Goupillaudina lecointrei* MARIE.) In addition, specimens of *Nummufallotia cretacea* HANTK., *Cornuspira cretacea* RSS., *Nonionella cretacea* (CUSH.) and Haplophragmoides occur in smaller numbers.

S u m m a r i z i n g the above, let us conclude that, as shown by an analysis of the exposures of Profile I (Fig. 44), the Csingervölgy Member evolves continuously above the Ajka Formation throughout the section, save for a rather shorts tretch of the Köves-domb; moreover, that its peculiar cyclic development can be traced farther over an interval of varying length within the lower member as well. The number of cycles increases from zero in the northwest to six in the southeast up to that point of the section, where a rapid decrease in formation thickness is observable. Before reaching that point, however, no change in the thickness of the lower member is observed. The differences in thickness within the upper member are remarkable.

Changes in fossil content as bound to lithological cycles are generally recognizable, but, in addition, there is a general trend consisting in that the brackish-water forms tend to be replaced up in the sequence by an euryhaline marine assemblage. The two members get individualized in terms of both their mega- and microfossil contents. Near the member-boundary a microfossil-free interval, consistently a few m thick, occurs.

A transition between the northwestern and southeastern stretches of the section is represented by the borehole Süt-16 in which, though two members get individualized, but the thickness of either is reduced. In the northern part of the Köves-domb the Jákó Formation is not developed; to the south of it, in turn, only its lower member covered by the beds of the Ugod Formation can be found.

Normal to the strike of the sedimentary basin (Fig. 44), Profile II starts from the northern side of the Rendeki-hegy and, extending southwards, it crosses the Hárs-hegy and ends in the Gerinc quarry.

The northernmost exposure is the borehole Ck-170 which, in 89.5 m thickness above the Ajka Formation (259.5–349.0 m), exposed the Csingervölgy Marl Formation (Fig. 47).

The lithology of the l o w e r m e m b e r is characterized in the lower half of the unit by alternating marls, sandy marls, siltstones and calcareous marls and calcareous sandstones, in the upper half by that of argillaceous marls, marls and limestones. Nodular structure is frequent. The rock contains a considerable amount of macrofossils consisting for the most part of corals and molluscs.

The u p p e r m e m b e r somewhat differs in lithology from the sequences that we came to know in Profile I, its rock varieties being characterized, as a rule, by a higher carbonate content such as calcareous marl, marl and, subordinately, limestone, siltstone and, less frequently, argillaceous marl. The abundance of *Exogyra* in the fossil assemblage is conspicuous. The appearance of *Scaphopoda* and fish scale and crab remains is a feature corresponding to the development of the local type section. In the overburden, after a transition of a few metres, the Polány Formation (Rendeki Member) is that which follows.

In the borehole Ck-169 the geological features of the formation are similar to those from the borehole Ck-170.

The Jákó Marl sequence of the borehole S-29 (Fig. 47) put down on the Hárs-hegy is composed of rock varieties having a lower carbonate content compared with the case of the previous boreholes. The lower member is constituted by argillaceous marls and sandy marls, the upper member by marls, argillaceous marls and sandy-silty marls. The fossil assemblage is similar to the case of the type section.

The southeast end-point of Profile II is the Gerinc quarry. In the lower, abandoned quarry-yard here, more precisely in the borehole Sc-8 and Sc-8a put down there (Fig. 47), a Jákó Formation member of marginal facies could be studied.

At the entrance to the quarry a few metres of light brown, ochre-yellow and light grey marl and argillaceous limestone are exposed. (The sequence was penetrated by the boreholes Sc-8 and Sc-8a as well.) It is overlain, both in the quarry and the boreholes, by the Ugod Formation in 20 to 30 m thickness. It is after this that the marl lens left unextracted in the lower quarry-yard (owing to its being unsuitable for lime-burning) can be observed. The borehole Sc-8a penetrated it between 8.5 and 30.0 m.

The marl member is composed of light grey to ochre-yellow, nodular, mottled calcareous marls, marls and argillaceous marls. *Ahermatypical corals* and *Bivalvia* are present in considerable quantities in the megafaunal assemblage.

The rich *Cyclolites* fauna recovered during earlier samplings of paleontological aim was processed in detail by B. Géczy (1954). In his work he quotes the following species: *Cyclolites robusta* Quenstedt, *C. macrostoma* Reuss, *C. polymorpha* Goldfuss, *C. discoidea* Goldfuss. Other ahermatypical corals are frequent in the rock too. G. Kolosváry (1954) identified *Stephanosmilia polydectes* Kolosváry, *Coelosmilia niobe* Kolosváry, *Phyllosmilia* sp. and *Ph. sümegensis* Kolosváry.

From among the Vivalvia, small-sized *Chlamys* species and *Pycnodonta* are frequent. K. Barnabás, in his Ph. D. thesis (1937), reported *Gryphaea vesicularis* Lam., *Janira (Vola) quadricostata* Sow., *Lima marticensis* Math. and *Actaeonella* sp.

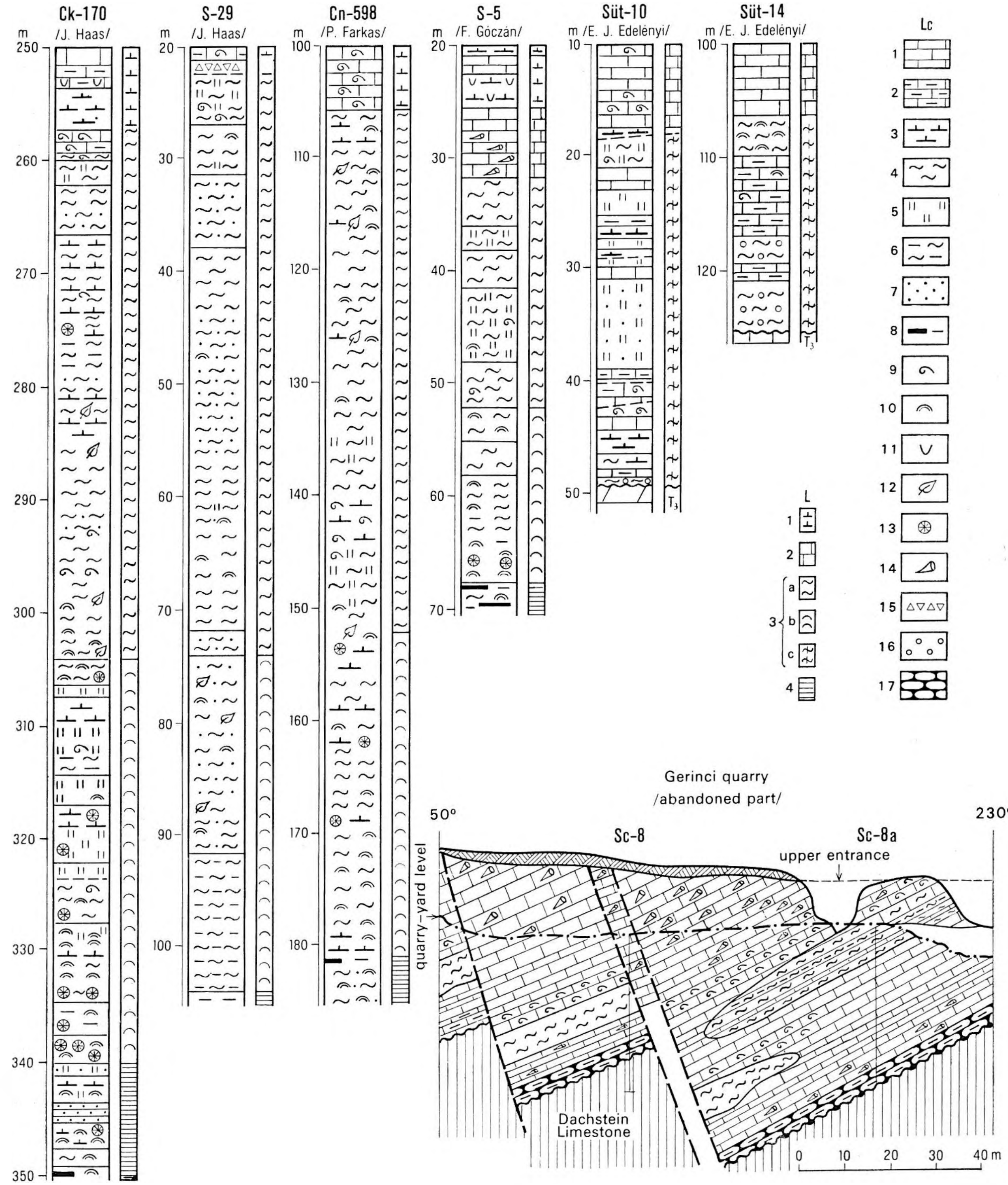


Fig. 47. Characteristic drill logs of the Jákó Marl Formation in the Sümeg area and its lenticular occurrence within the section exposed in the Gerinc quarry

Lithologic column **(Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. marl, 5. silt, 6. argillaceous marl, 7. sand, 8. carbonaceous clay, 9. Exogyra, Pycnodonta lumachelle, 10. mollusc lumachelle, 11. worm tracks, 12. coalified plant remain, 13. ahermatypical coral, 14. rudist valves, 15. intrabreccia, 16. gravel, 17. nodular structure. — *Lithostratigraphic units* (L): 1. Polány Marl Fm., lower member, 2. Ugod Limestone Fm., 3. Jákó Marl Fm.: *a)* upper member, *b)* lower member, *c)* marginal facies, 4. Ajka Coal Fm.**

It is probably from this lens that the Echinoidea—the determination of which is given in the summarizing work of E. SZÖRÉNYI (1955)—derive: *Botriopygus nauclasi* COQUAND, *Echinobrissus pannonicus* SZÖRÉNYI and *Hungaresia hungarica* SZÖRÉNYI.

As shown by M. SIDÓ (1961), its rich Foraminifera fauna in the upper part can be found in a great number of individuals: *Goupillaudina lecointrei* MARIE, *Nonionella cretacea* CUSH., *N. extensa* (BROTZ.) and a few *Haplophragmoides* sp. and *Bulimina ovulum* RSS. In the lower part of the unit the species *Nummofallotia cretacea* SCHLUMB., *Cornuspira cretacea* RSS. and *C. senonica* DUN. predominate.

According to microscopic results, fossil debris account for 30 to 50% of the rock, sand-size quartz grains varying between 5 and 15%. Foraminifera are present in a considerable number in the lower interval of the section too, locally accounting for 5% of the rock volume.

The immediate cover of the marl beds is constituted by brownish-red argillaceous limestones with Exogyra; higher up the profile, the typical, rudist-bearing Ugod Limestone appears too.

Accordingly, similarly to the case of Profile I, two stretches can be distinguished in Profile II as well. The greatest thickness values occur at the end and in the middle part of the northern stretch of the section, followed then by a marked reduction in thickness within a short distance and there appears a unit consisting of rock varieties of higher carbonate content showing a transition towards the Ugod Limestone and intertonguing with it. The thickness differences, in this profile too, are due to changes in the values of the upper member. In the exposures of Profile line II plotted to the northeast of Profile I the formation is lithologically (rock varieties of higher carbonate content) somewhat different from what could be observed in the exposures representing the west side of the area studied. A difference in the fossil assemblage is represented by the massive occurrence of *Exogyra* in the upper member—a feature otherwise common in the upper part of the Jákó Formation in other areas of the Bakony.

The transition between the Jákó and Ugod Limestone was exposed by the boreholes Süt-10 and -14 falling outside the profile traces.

Located on a limestone outcrop on the northern slope of the Kopasz-domb, the borehole Süt-10 (Fig. 47) exposed the transitional member in a thickness of 25 m above Triassic dolomites.

On the basis of the fossil assemblage the lower 19 m can be correlated with the lower member, this being overlain by beds showing characteristics of the upper member. An intertonguing with the Ugod Formation is observable throughout the section. In the lower interval there appear still just a few, 1- to 2-m-thick interbedded layers of marly limestone and limestone, then higher up the section the Ugod Limestone features gain predominance, to become exclusive in the end.

The rocks assignable to the Jákó Formation, as a rule, are of a high carbonate content. The lower interval is constituted by dark grey marly siltstone, light grey sandy, marly siltstone, siltstone and ochre-yellow argillaceous marl. The megafauna is available in a fair quantity with *Exogyra* sp. and *Pecten* sp. as predominant forms, small fragments of *Mollusca*, skeletal elements of *Echinoidea* and the remains of crabs and, in the lower interval, of *algae* being quite frequent.

The upper interval consists of dark grey siltstones and sandy siltstones, a microlamination being frequently observable in the sandy parts. The fossil content is composed of usually small mollusc shell fragments present in low to fair amounts, scattered and poorly preserved external moulds of Bivalvia, pyrite-filled *Nucula* and *Avellana* valves, minor gastropods (*Voluta torasa* ZEKKEL), corals, crab claw fragments, echinoderm elements and fish scales.

The borehole Süt-14 put down in the Városi-erdő intersected the transitional unit in 10 m thickness, overlying coarse-detrital basal formations with a marine fauna (Fig. 56).

The formation is composed of brownish-grey to grey nodular limestones with a few interbedded layers of pelitic sediment. The carbonate content shows a strong fluctuation in the lower half of the unit (35–95%), tending to increase above it. The fossil content is represented for the most part by bivalves *(Chlamys, Pecten, Lima)* and ahermatypical corals; a few small-sized *Rudista* occur, too. In the upper part of the unit the fossil content gets heavily enriched, the rock turns darker in colour and coalified vegetal remains are quite frequent. Among Foraminifera *Nodellum velascoense* is characteristic.

The Csingervölgy Marl is overlain by an Ugod Formation of typical development.

On the basis of the sequences and/or profiles presented and in terms of the dissimilar geological features, the study areas can be split up into the following subareas:

1. In the marginal zone the pre-Senonian basement is directly overlain by the transitional member of the formation the characteristics of which are determined primarily by the intertonguing with the Ugod Limestone, its lithological development being characterized throughout the unit by the high carbonate content. In its lower part it contains the typical microfossil assemblage of the lower member (Csingervölgy Marl), in the upper part that of the upper member.

2. In the western part of the area, the immediate vicinity of Sümeg, the peculiarity of the formation consists in its cyclic development transient from the Ajka Formation.

The megafauna is characterized by a marine brackish-water assemblage and by the fact that forms attached to normal salinity environments become predominant as one proceeds upwards, respectively. In this subarea, the upper member is of monotonous siltstone facies, poor in fossils. There appears no significant change in its characteristics either in the vertical or the lateral sense.

3. In the northern part of the area the characteristics of both members differ somewhat from those in the western part. The lower member is of modest thickness, less than even 10 m in a belt almost 1 km wide. Compared with the rest of the area no remarkable change in thickness of the upper member could be observed. Both members are composed of argillaceous marls, calcareous marls and—subordinately—marly limestones with a preponderance of the more calcareous rock varieties in the upper member. The fossil content of the member is similar to the case of the type section, the only difference being that the upper member generally contains a larger number of *Exogyra* and *Pycnodonta*.

The general conclusion that can be deduced from the spatial changes in formation thickness (Fig. 42) is as follows:

The configuration of the isopachs on the map corresponds by and large to the case of the Ajka Formation. The basic orientation remains northeast–southwest and the direct connection between the thickness values of the two formations is apparent. A resemblance is indicated by the NW-SE trending re-entrants of the isopachs and by the turning of the strike to a north-south direction, as observed to the south of Sümeg.

There is a difference concerning the position of the thickness maximum. Namely in the case of the Jákó Formation the formation is observed to grow thicker to the east of the Rendeki-hegy in a NE-SW trending strip of 1 to 1.5 km width which at the foot of the Rendeki-hegy turns to a southerly direction and is reduced in width to 0.5–1 km only. Less significant divergency is observed on the west side of the area, where a zone of reduced thickness, trending northeast–southwest, 2 km long and 1 km wide, can be observed.

Since the two members of the formation represent two more or less different development stages of the Senonian sedimentary basin, to prepare a separate isopach map for the lower one has been regarded as useful (Fig. 48).

The low variability of the thickness values of the lower member is conspicuous. The thickness maximum is 34 m. Observable in the eastern part, the northeast-southwest orientation of the isopachs turns north-south in the western part in this case, too. The traces of the northeast-southwest strip of reduced thickness on the western side already appear in the lower member.

Bio- and chronostratigraphy

On the basis of a palynological study of the boreholes Sp-1 and Sp-2, F. Góczán identified, the following abundance zones in the Jákó Formation:

D — *Hungaropollis krutzschi* Zone

E — *Sümegipollis triangularis* / *Krutzschipollis spatiosus* Zone

F — *Longanullipollis lenneri* / *L. bajthayi* Zone

In the borehole Sp-1, the boundaries of Zone E extend a little bit even beyond the lower and upper boundaries of the formation.

The study of the borehole Sp-2 produced results that deviate to some extent from this. In that exposure, the lower member of the formation falls completely in Zone D, while from its upper member only the lower part does so. In higher parts of the upper member of the Jákó Marl the characteristic forms of palynological zone E could be identified.

In the local type section of the formation the lower member and the lower half of the upper member belong—as shown by F. Góczán's studies in 1974—to Zone E. The genera *Krutzschipollis* predominate and the eponymous zonal species can be found throughout the interval. *Hungaropollis* and—primarily in the upper part—the species of the genus *Longanullipollis* are quite frequent. The lower boundary of the zone coincides approximately with the lower boundary of the formation.

In the upper part of the upper member it is the species of *Longanullipollis* that predominate, the genera predominant in the deeper parts being here subordinate. Consequently, the presence of Zone F here is likely.

Analyses of materials from the marl beds in the Gerinc quarry (transitional member) showed the probable presence of the upper part of Zone E and the basal one of Zone F. These results are in accordance with the opinion suggesting the member to have formed in the marginal, more elevated zone, i.e. in that strip of land that was later reached by the transgression.

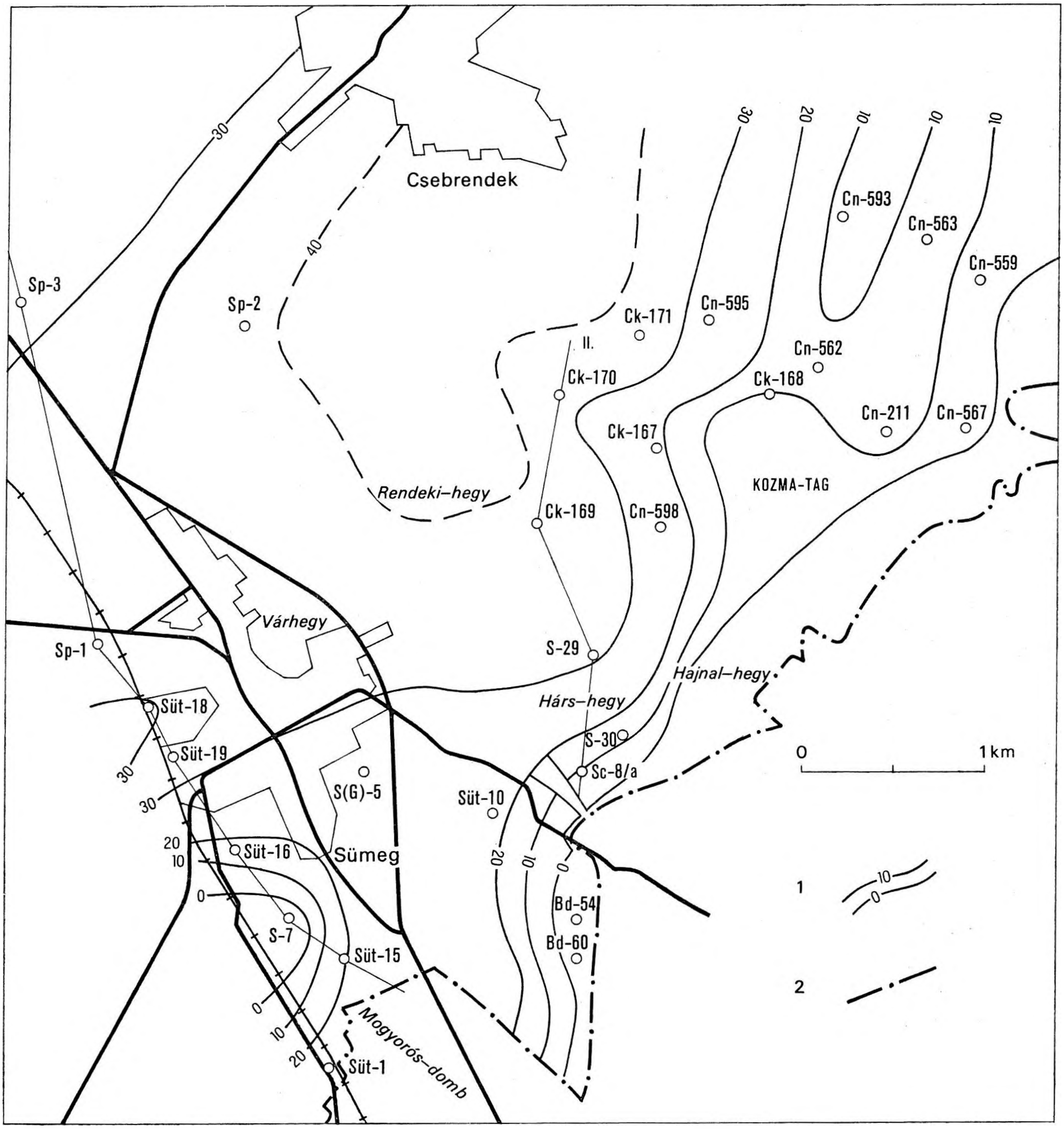


Fig. 48. Thickness of the Csingervölgy Marl Member

1. Thickness of the Csingervölgy Marl Member, 2. boundary of extension of the Senonian

Consequently, in the light of palynological results, it is the upper part of Zone D and the whole Zone E that can be identified in the Csingervölgy Member of the Jákó Marl, while in the upper member of it, Zone E and the lower part of Zone F can be registered. On the basis of these results, F. Góczán believes that the age of the lower member in the nortwest basin-centre area corresponds to the upper Lower Campanian and the lower Upper Campanian and that the age of the upper member and that of the transitional unit known from the Gerinci quarry can be fixed in the Upper Campanian.

As a result of her foraminiferological study of the boreholes Sp-1 and Sp-2, M. Sidó (1969) distinguished in the Jákó Marl Formation the following abundance zones: "Vidalina Zone; Rotalia Zone (II); Nonionella Zone; Operculina Zone; Globigerina Zone; Epistomina Zone; Bulimina Zone and Vaginulina Zone".

All these zones but the "Operculina Zone" cannot be distinguished in a consistent way even in the relatively small Sümeg area, being even less suited to interregional long-distance correlation purposes.

So much can be pointed out anyway that *Cornuspira senonica* DUNIKOVSZKY, *Vidalina hispanica* SCHLUMBERGER and *Nummofallotia cretacea* (SCHLUMBERGER) are typical in the lower part of the Csingervölgy Member and that the species of the genus *Goupillaudina* are so in the upper part of the member.

Characteristic forms of the upper member are the representatives of *Vidalina* and *Gavelinella*.

As shown by the latest results of M. SIDÓ, it is at the boundary of the two members that the planktonic species with the zonal index fossil *Globotruncana concavata*—ranging, according to the international literature (F. T. BARR 1972, E. A. PESSAGNO 1962, J. PREMOLI-SILVA and H. M. BOLLI 1973) from the Upper Coniacian up to the latest Santonian—appear.

During her analysis of the formation for megafossils, relying on the elaboration of key sections Sp.-1,-2,-3, L. CZABALAY distinguished the following four—or, in the local stratotype, three—zones or biofacies, respectively:

"Gastropoda–Pecten–Cardium–Corals"
"Astarte–Nucula–Corbula"
"Clavagella" } and/or "Pecten"
"Dentalium" }

The "Gastropoda–Pecten Zone" is situated within the lower member of the formation, the second zone extends from the lower member well into the upper one, the "Clavagella" and "Dentalium" and the "Pecten" biozones, respectively, representing the upper member.

The Mollusca fauna of the formation is composed predominantly of facies-indicating species, though forms of a wider lateral distribution can be encountered, too. The two lower biozones contain in the first place species of more restricted lateral distribution, being known from localities in southern Greece, Yugoslavia, and Romania. In the upper zones the species of wider lateral distribution tend to play an ever increasing role (forms known from India, the Caucasus and the Crimea).

A good deal of the Glauconia species typical of the lowermost biozone are characteristic of the Campanian stage, similarly to the case of *Desmieria zekeliana* (STOL.) and *D. goldfussi* (MÜNSTER). *Aptyxiella (Acroptyxis) flexuosa* (SOW.) and *A. gracilis* (MÜNSTER) occur solely in the Campanian. *Tanaliopsis spiniger* (ZEKELI), *Rostellaria granulata* SOW. and *Ampullospira bulbiformis* (SOW.) are known Upper Santonian to Lower Campanian sediments.

The "Astarte–Nucula–Corbula" biozone is composed partly of Lower Campanian or older species [*Astarte similis* MÜNSTER, *Lopha semiplana* (LAMARCK), *Pecten laevis* NILSSON], partly of forms reaching their predominance in the upper part of the Campanian [*Pholadomya granulosa* ZITTEL, *Modiola sphaenoides* DEFR.). The typical forms of the upper biozone or biozones, *Dentalium hexapleura* ZITTEL and *D. rudum* ZITTEL, are characteristic of the Upper Campanian.

The *Cyclolites* fauna of the formation consists of forms of considerable lateral extension, but these have not yet been evaluated biostratigraphically.

In the light of foraminiferological studies the lower member of the Jákó Formation can be assigned to the Santonian, its upper member to the Lower Campanian. According to palynological results, F. GÓCZÁN places the lower member in the Lower Campanian, the upper one in the Upper Campanian. As suggested by L. CZABALAY, the Mollusca assemblage of the lower member is composed of Santonian-Campanian, that of the upper one, of Campanian forms.

Naturally, in the case of this formation, we must reckon with a time-shift of the unit and its individual members owing to shifts in facies. It is probable that in synchrony with the formation of the lower member of the internal zone the marginal zone was still witnessing the brackish-water deposition of the higher part of the Ajka Formation and that when in the marginal zones the formation of the lower member began the basin's interior was already undergoing the deposition of the upper member.

Depositional environment

The formation of the Jákó Marl took place in a littoral or sublittoral to neritic environment that gradually replaced the lacustrine or coastal swamp environment of the Ajka Coal Formation, still carrying on itself for varying lengths of time a number of features inherited from the former. Within this environmental unit the differences in environmental parameters led to the disintegration of three typical environmental units which resulted in the formation of three distinct sedimentation types —the three formation-members.

The traces of the cyclic changes in parameters characteristic of the depositional environment of the Ajka Formation are still recognizable in the lower part of the Csingervölgy Member, in spite of the fact that with the decline of swamps and with the more and more pronounced marine communication the environment has changed radically. However, since the amplitude of variation of the individual parameters has been reduced, the differences in the sediment material become less pronounced too.

The minor environmental units within the major types of environment are difficult to assess in the course of analyzing the lithofacies types, because both the sediment and the fossil content were removed from their original site, to be redeposited in a partly mixed form, often heaped into lenses by wave action—a phenomenon observable first of all in the lower member.

In the initial phase of deposition of the lower member the two facies of the depositional environment were still quite distinct. The one facies was characterized by muddy, subordinately muddy-sandy, the other one by muddy-sandy, sandy, periodically sandy-pebbly sedimentation. Between the facies there existed differences in salinity, water depth and the distance to the shoreline.

1. In the subarea of mud—sand, sand and pebble sedimentation—the south and southeast parts of the study area—mainly marine-brackish (*Cardita granigera* GÜMBEL, *Cardium ottoi* GEINITZ) and euryhaline (*Nucula concinna* Sow., *Pecten laevis* NILSSON) faunal elements can be found. However, the freshwater forms are also frequent (*Cyprina* sp.). All these circumstances suggest a mixing of the fossils by wave action. The fossils are commonly crushed which, when taken together with their accumulation into lenses, is indicative of a heavy agitation, i.e. a deposition in the zone of surfs or the tidal zone, respectively. The water depth may have attained a maximum of a few metres.

2. In the environmental unit marked by muddy sedimentation—the northwest part of the study area—the fauna consists predominantly of forms of normal salinity demand (*Cantharus* sp., *Fusus tritonium* ZEKKELI, *Pectunculus* sp., etc.); it is here that *Cyclolites* appear, and the forms tolerant of salinity changes are subordinate, being gradually superseded. The water depth may have varied from a few m to about twenty m. From the anomalies of growth of Cyclolites, B. GÉCZY (1954) inferred a comparatively rapid sedimentation of varying rate (Plate XXXI).

The relative abundance of mollusc shells, often preserved quite intact, and *Bryozoans* and borer-bivalves anchored on Cyclolites skeletons on the one hand and the superposition of various organisms are indicative of a depositional environment that was generally quiet or just periodically agitated, i.e. a zone immediately beneath the zone of wave action.

The sediment was deposited in a well- or fairly light-penetrated (photic) zone. The bottom was partly covered by a lush vegetation as suggested by a fauna composed of tiny *Gastropoda*, further, of *Ostracoda* and *Foraminifera*.

Some of the fossils were represented by forms of high oxygen demand (*Pecten laevis* NILSSON and *Cardium ottoi* GEINITZ), the rest by less oxygen-exigent ones (*Nucula concinna* Sow.). A reductive environment under the water—mud interface is suggested by the presence of pyrite filling the interior of the foraminiferal chambers and scattered elsewhere in the sediment.

Indirect information on water temperature is furnished by the *Cyclolites* fauna that was shown by B. GÉCZY to indicate a temperature range of 20 to 26 °C. A direct evidence was yielded by the C and O-isotope methods of paleotemperature measurements carried out by the Institute of Mining Research that gave a water temperature of 22 °C (transitional member, Gerinc quarry).

The upper member of the formation indicates a depositional environment that differs in several respects from the former case. Sedimentation was rather pelitic and calcareous. Represented by montmorillonite and illite, respectively, the clay mineral composition suggests, on the one hand, a source area made up of basic magmatic rocks and, on the other hand, a deposition in a deeper, more open sea environment farther offshore (E. NEMECZ 1973). The rest of the material introduced into the basin derived from the immediate neighbourhood. The upward decrease of the dolomite content and the almost total lack of sand-size grains are indicative of a depositional environment that must have lain comparatively far away from the shoreline, too.

The composition of the megafossils is suggestive of a seawater of normal salinity [*Tellina stoliczkai* ZITTEL, *Corbula angustata* Sow., *Haustator rigida* (SOW.) etc.]. The good preservation state of the thin-shelled forms of Bivalvia, the scattered distribution of the fauna and the large number of *Scaphopoda* that lived burrowed in the mud make a quiet depositional environment probable, environment that was scarcely agitated or not agitated at all. The marked pyrite content of the sediment is indicative of reductive conditions that have prevailed beneath the water-sediment interface.

The very low amount of the benthonic fauna and the disappearance of forms of high oxygen demand that were typical beforehand suggest that the oxygen content of the water was very low above the water-sediment interface as well, which is probably due to the decline of water plants and so essentially to an increasing water depth and a decrease in light penetration.

A reduction of the oxygen content seems to have caused the extinction of the microfossil assemblage at the boundary between the two members and to have produced sedimentary strata almost free of microfossils.

On the basis of the reconstructable environmental parameters the water depth may be estimated at 20 to 100 m.

Representing a transition between the Jákó and Ugod Formations, the member is obviously transitional even in terms of genetic conditions. In other words, the sedimentation was probably taking place in that part of the neritic zone which lay close to the shallow-water carbonate platform. The ecological features of the fauna correspond to those of the Csingervölgy Member.

Ugod Limestone Formation

Extension, mode of superposition, stratigraphic subdivisions

Composed of an extraordinary variety of limestones of primarily biogenic type, the stratigraphic unit of the Ugod Formation is exposed on a level, barren landscape lying to the south of Sümeg and in the Hajnal-hegy–Hárshegy–Kozma-tag zone traceable along the hill range. These rock variants serving as an excellent raw material for lime burning have been extracted for a long time in several quarries of varying size.

To register the mode of superposition of the Ugod Formation and to analyze it stratigraphically is rendered rather difficult by the fact that a sequence with immediately overlying beds showing a continuous sedimentation can seldom be exposed. In the zone, where the Ugod Formation once developed, the rocks composing it are exposed even at present or they are covered by post-Senonian formations, the extent of their erosion being poorly known. All that can be determined is that the rock thickness lost to erosion in the Eocene-covered areas was by 50 to 100 m less than it was the case in those parts covered by post-Eocene sediments. In the subarea (farther northwest), however, where younger Senonian formations are known too, the Ugod Formation is missing from the sequences, owing obviously to its not having been developed there at all.

In attempts at interpreting the results gained during the study of the Ugod Formation the methods used in the case of the older formations usually do not work. For instance, no help of any virtual use is provided by the isopach maps (Fig. 49), as these do not reflect the original conditions. We have had to refrain from plotting profiles with reference to the base level of the overlying formation, too. On the other hand, a base to start from for reconstructing the paleoenvironment was provided by the fact that we had already had some knowledge of the main features of the one-time morphology, of the sea to land relation, of the position of the shoreline and the general trend of its course.

In addition to the biofacies analysis, an approach used also heretofore in paleoenvironmental interpretation, we could well rely on the results of analysis of the structure and texture of carbonate rocks.

The exposures of the Ugod Formation show—because of the extraordinary variability of the unit—sequences that are rather difficult to correlate either by litho- or by biostratigraphic methods. This has been so remarkable that it has seemed meaningless to designate a type section. As for the solution of the correlation problem, a task of fundamental significance for paleonenvironmental interpretation, we have attempted to approach it in two steps. First we carried out the correlation of sequences exposed along profiles designated parallel to the main strike of the presumed one-time shoreline, because the least pronounced variability and the simplest way of parallelization were supposed to coincide with that direction. Then, as a second step, we attempted at a correlation in a direction normal to the one-time shoreline, first within the formation itself and then with the heteropical formations as well.

On the basis of the analysis we have managed to delineate three distinct facies zones exhibiting different geological features (*A*, *B* and *C* in Fig. 58). Each of these zones is characterized by different mode of superposition of the Ugod Formation.

Geological features

1. Köves-domb

On the barren surface of the Köves-domb the various rock types of the Ugod Formation, particularly suitable for a detailed paleoecological and petrographic study, can be investigated in a comparatively large and coherent area. In addition to several minor pits there are two large quarries giving an excellent insight into subsurface conditions. Orientation is helped by a number of boreholes as well.

In 1971 a map on a scale of 1:5,000 was prepared from this area, during which efforts were made to represent cartographically even minor units within the Ugod Limestone, i.e. rock bodies of only local importance. The map which is informative of the location of boreholes and exposures that are essential for the present work, is shown in Fig. 50.

On the Köves-domb the most complete Ugod Limestone sequence was exposed by the borehole S-7 (K-1) put down in 1962 a few metres to the northeast of the Kecskevári quarry (Fig. 51a–b).

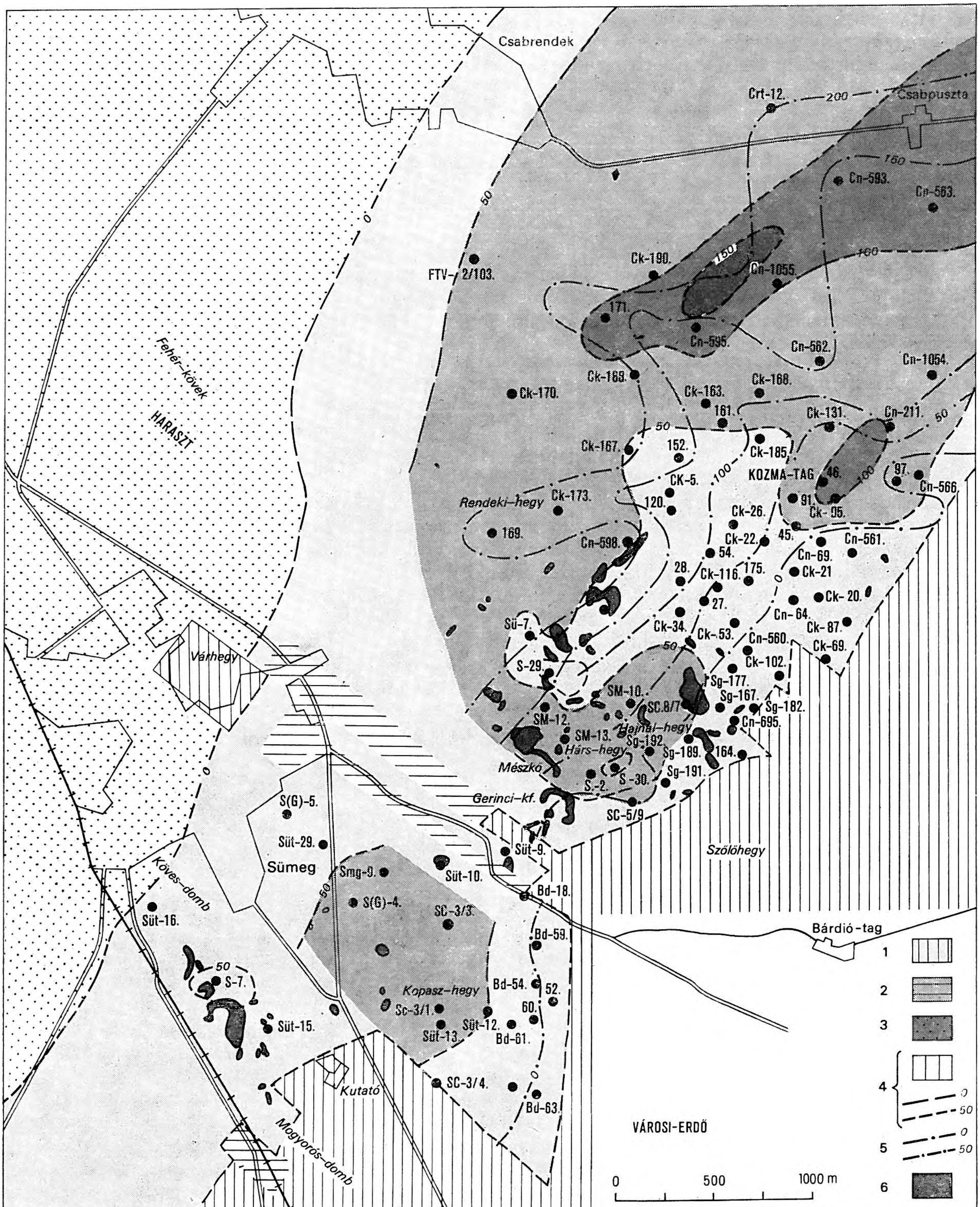


Fig. 49. Thickness of the Ugod Formation and of the Upper Cretaceous underlying it

1. The Upper Cretaceous is absent in the study area owing to erosion, 2. the Ugod Limestone is absent in the study area owing to erosion, 3. the Ugod Limestone Formation is absent because of non-deposition, 4. thickness of the Ugod Limestone, 5. thickness of the Upper Cretaceous underlying the Ugod Limestone, 6. Ugod Limestone in outcrop

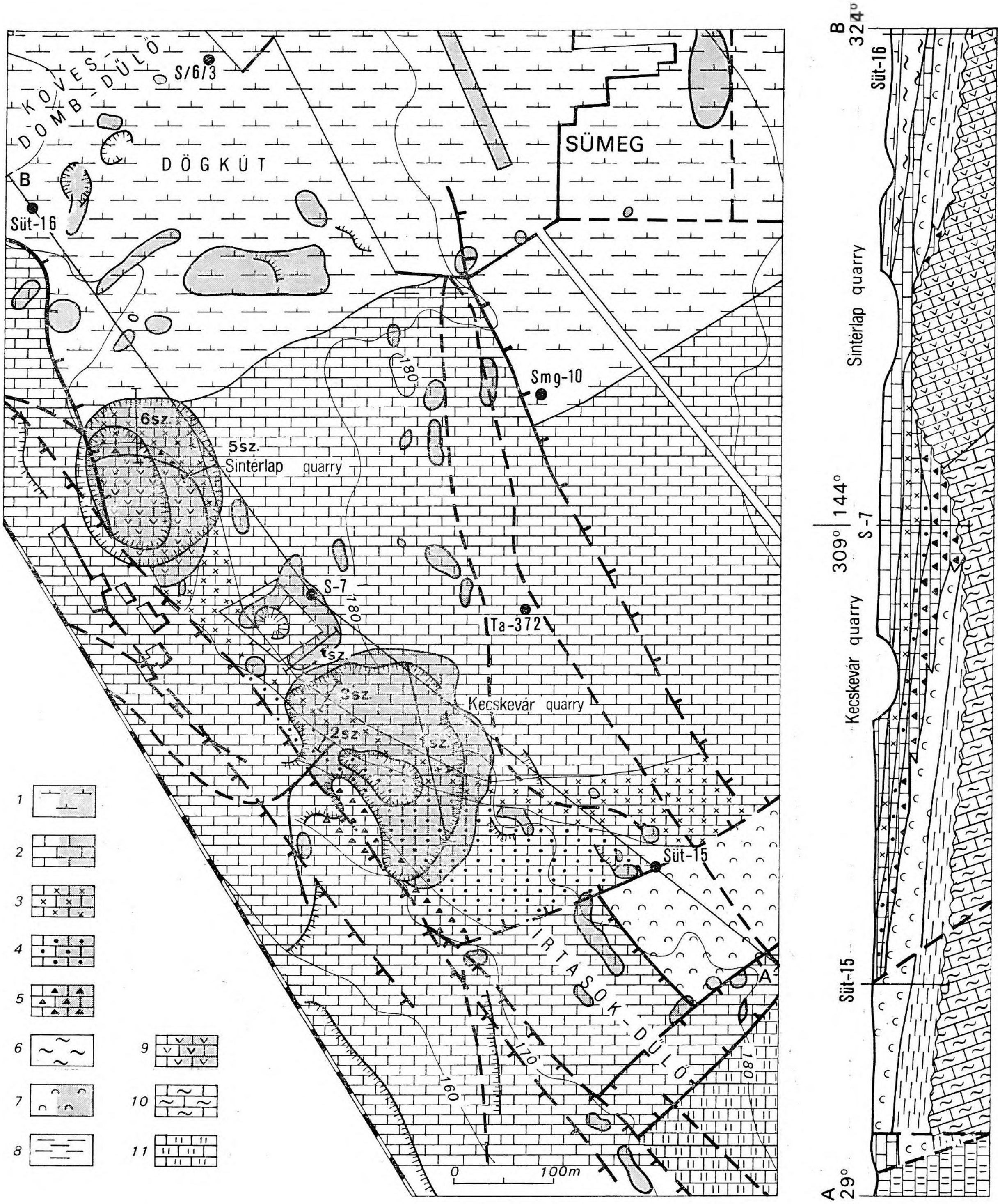


Fig. 50. Geological map chart of the Köves Domb's Mesozoic with the Tertiary and younger rocks peeled off and a detailed subdivision of the Ugod Formation (as of the knowledge of 1971)

1. Polány Fm., Rendek Member, 2. Hippurites-bearing bioclastic limestone, 3. red and light grey, biocalcarenitic limestone, 4. aphaneritic limestone, 5. extraclastic limestone (2—5. Ugod Fm.), 6. Jákó Fm., 7. Csingervölgy Fm., 8. Ajka Fm., 9. Tata Fm. (Aptian), 10. Sümeg Fm., 11. Hárskút Fm. (Lower Cretaceous). Red patches indicaet autcrops. — 1—6. Profiles

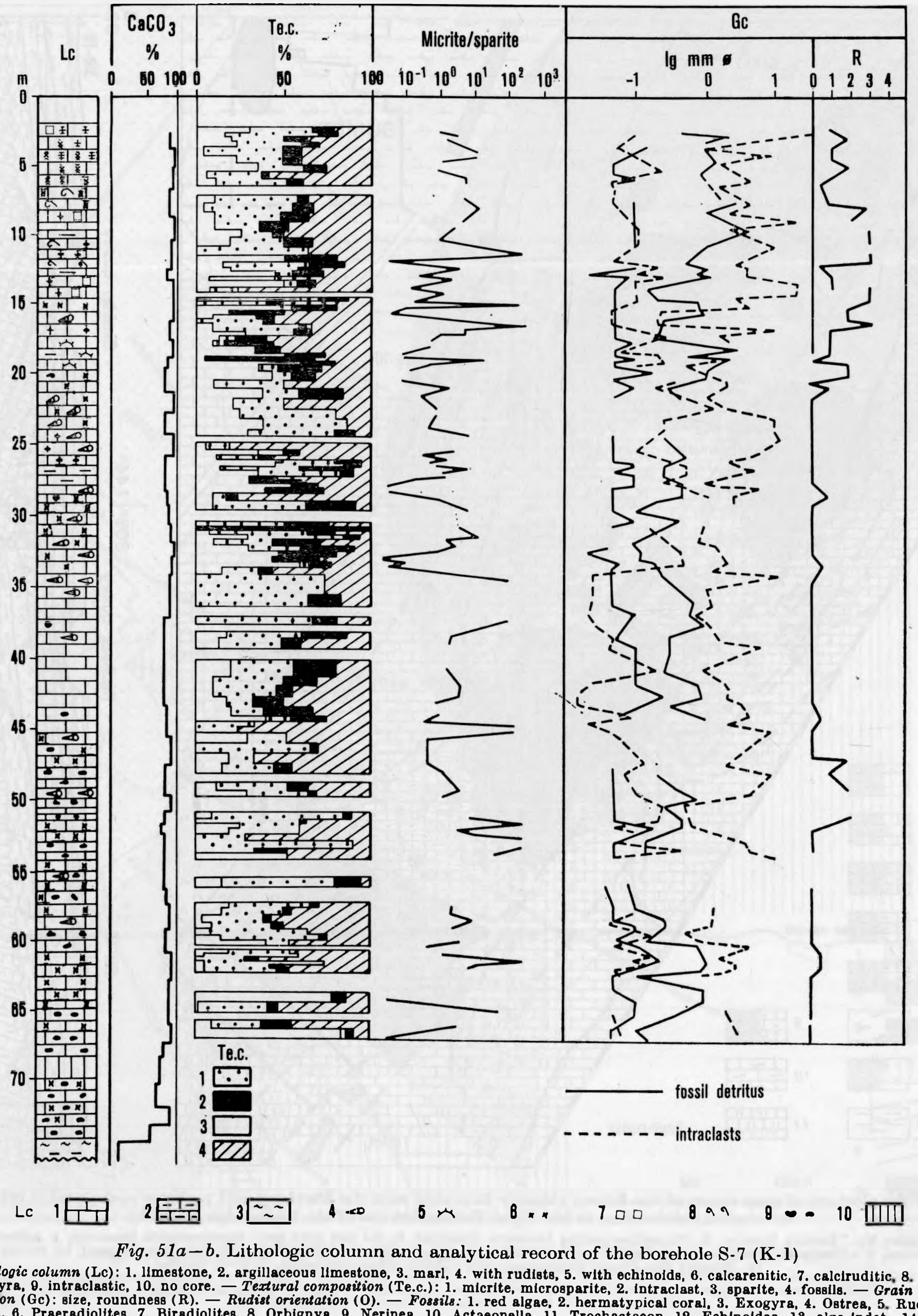


Fig. 51a—b. Lithologic column and analytical record of the borehole S-7 (K-1)

Lithologic column **(Lc): 1. limestone, 2. argillaceous limestone, 3. marl, 4. with rudists, 5. with echinoids, 6. calcarenitic, 7. calciruditic, 8. with Exogyra, 9. intraclastic, 10. no core. — *Textural composition* (Te.c.): 1. micrite, microsparite, 2. intraclast, 3. sparite, 4. fossils. — *Grain composition* (Gc): size, roundness (R). — *Rudist orientation* (O). — *Fossils:* 1. red algae, 2. hermatypical coral, 3. Exogyra, 4. Ostrea, 5. Rudista indet., 6. Praeradiolites, 7. Biradiolites, 8. Orbignya, 9. Nerinea, 10. Actaeonella, 11. Trochactaeon, 12. Echinoidea, 13. alga indet., 14. red algae, 15. Miliolidae, 16. Textulariidae, Nodosariidae, 17. Dicyclina, Cuneolina, 18. Hydrozoa, 19. corals, 20. Mollusca detr., 21. Ostracoda, 22. Bryozoa, 23. Echinodermata. — *Paleoenvironment* (P.e.): *BL* backreef, *Ds* drifting sand, *F* front-reef**

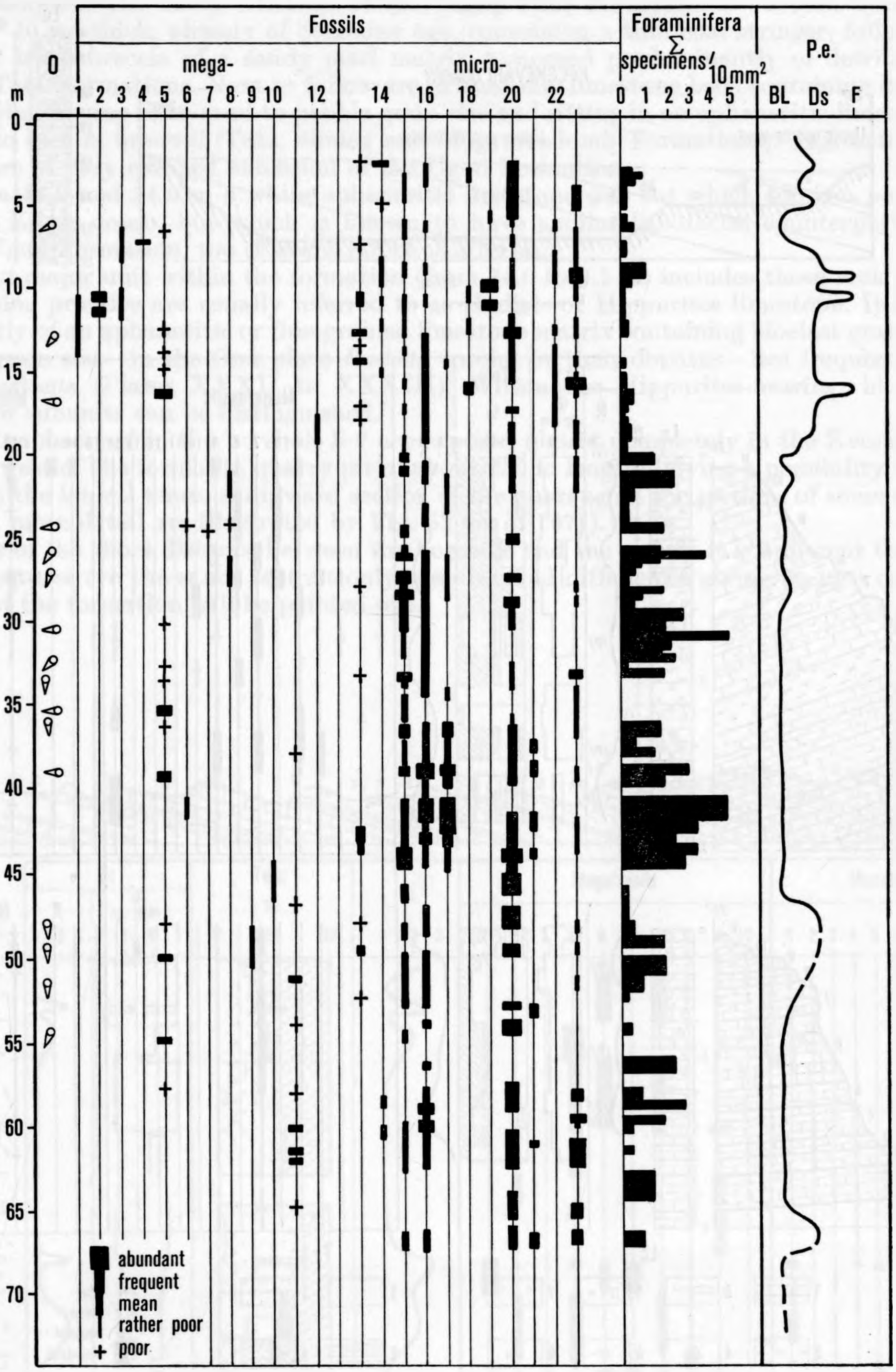

Fossils
O
mega-
micro-
Foraminifera
Σ specimens/10 mm²
P.e.
m
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22
0 1 2 3 4 5
BL Ds F
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
abundant
frequent
mean
rather poor
+ poor

Fig. 51b

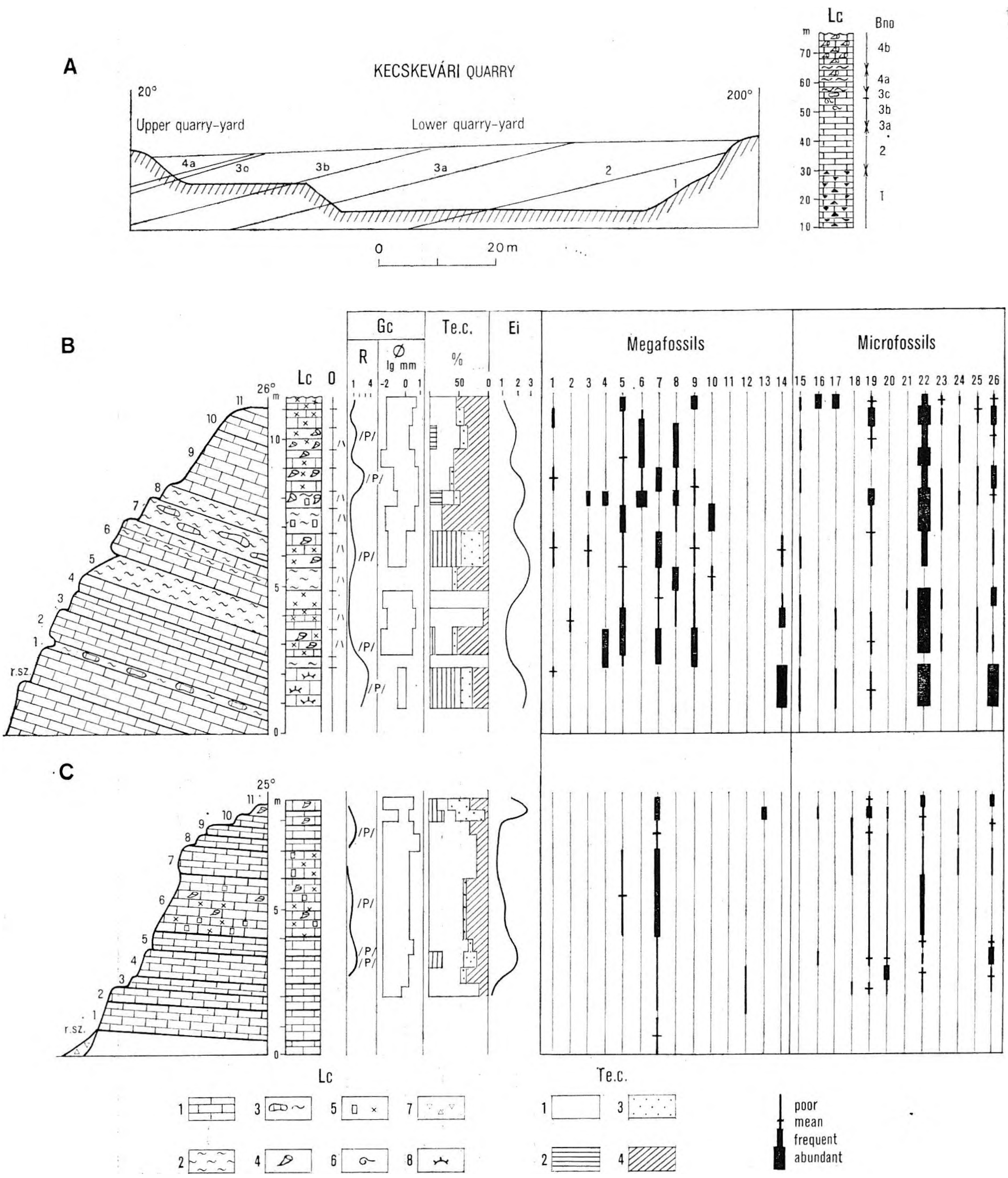


Fig. 52. The sequence of the Kecskevár quarry: analytical results

Lithologic column (Lc): 1. limestone, 2. marl, 3. nodular marl, 4. Rudista, intact, 5. Rudista, fragmentary (calcirudite and calcarenite), 6. Pycnodonta, Exogyra, 7. extraclasts, 8. Echinoidea; *number of bed* (Bno) — *Orientation* (O) — *Grain composition* (Gc): *R* roundness (*P* = pseudoöid): size. — *Textural composition* (Te.c.): 1. micrite, 2. sparite, 3. lump, 4. fossil. — *Energy index* (Ei). — *Megafossils:* 1. red algae, 2. Cyclolites, 3. hermatypical coral, 4. Serpula, 5. Mollusca detr., 6. Rudista detr., 7. smaller Rudista, 8. larger Rudista, 9. Exogyra, 10. Ostrea, 11. Gastropoda, 12. Nerinea, 13. crab's nippers, 14. Echinoidea. — *Microfossils:* 15. alga, 16. green algae, 17. red algae, 18. Calcis, 19. benthonic Foraminifera, 20. larger Foraminifera, 21. Bryozoa, 22. Mollusca detr., 23. Rudista detr., 24. Ostracoda, 25. Crinoidea, 26. Echinoidea

In the borehole the marly siltstone of the Sümeg Marl Formation is covered by a terrestrial layer hardly 40 cm thick, already of Senonian age, containing a thin coal stringer, followed in turn by 5.8 m of basal breccia of a sandy marl matrix composed predominantly of detritus from the Sümeg and Tata Formations. Next to follow are extraclastic limestone beds containing debris of pre-Senonian rocks varying from sand to pebble grain size and sitting in an aphaneritic limestone matrix in the 70.0 to 44.0 m interval (Tata, Sümeg and Mogyorósdomb Formations). This unit is a special representative of very reduced extension of the Ugod Formation.

Between 44.0 and 34.0 m a white aphaneritic limestone was cut which too is a peculiar facies type of the Köves-domb, but which is known to have similar lithofacies counterparts elsewhere within the Ugod Formation, too (Plate XXXII, XXXIII).

The next major unit within the formation (from 34.0 to 0.1 m) includes those rock types which in the mapping practice are usually referred to as Rudist- or Hippurites limestone. It is composed predominantly of an aphaneritic or fine-grained limestone matrix containing bioclast grains of arenite and rudite grain size—in the first place *Rudista* species or their detritus—less frequently of marly limestone variants (Plates XXXII to XXXIII). Within the Hippurites-bearing, bioclastic unit further minor subunits can be distinguished.

The units observed in the borehole S-7 are exposed almost completely in the Kecskevár quarry to the southwest of the former (a quarry pit of about 250 m length), giving a possibility for checking variations in the lateral sense. A dipward section of the quarry and the sections of some quarry faces examined in more detail are illustrated by Fig. 52 (as of 1971).

Because of the short distance between the borehole and the quarry it is apparent that the basic geological features are the same, so that only the observed differences giving an idea on the lateral variability of the formation will be pointed out.

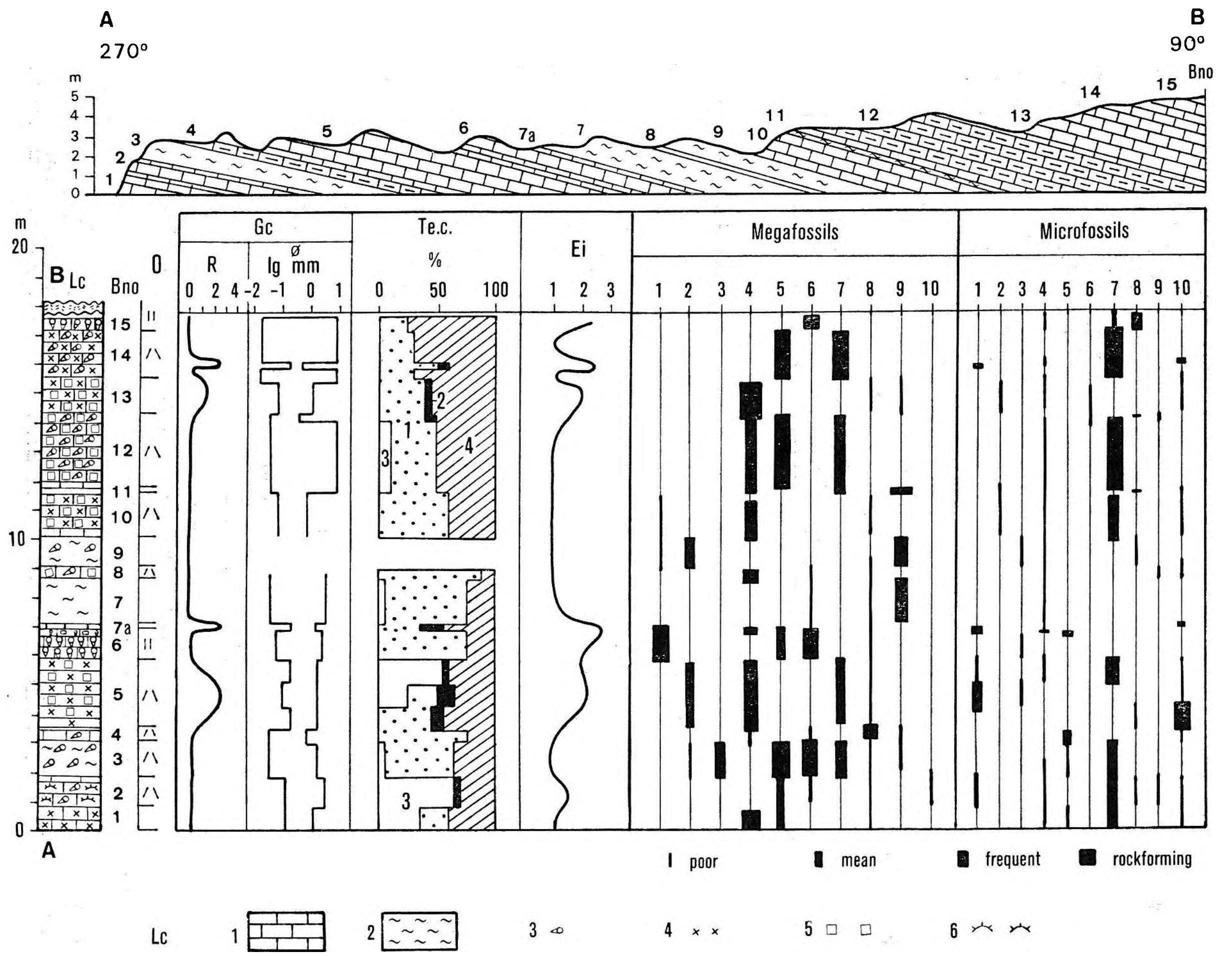


Fig. 53. Sequence exposed along the explosives depository of the Kecskevár quarry and its analytical record

Lithologic column (Lc): 1. limestone, 2. marl, 3. with rudists, 4. calcarenitic, 5. calciruditic, 6. with echinoids. — *Number of bed* (Bno). — *Orientation of rudist valves* (O). — *Grain composition* (Gc): roundness (R); size. — *Textural composition* (Te.c.): 1. micrite, microsparite, 2. intraclast, 3. sparite, 4. fossils. — *Energy index* (Ei). — *Megafossils:* 1. red algae, 2. coral, 3. Serpula, 4. Mollusca detr., 5. Rudista detr., 6. smaller rudist shell, 7. larger rudist shell, 8. Exogyra, 9. Ostrea, 10. Echinoidea. — *Microfossils:* 1. algae, 2. green algae, 3. red algae, 4. Foraminifera, 5. Hydrozoa, 6. coral, 7. Mollusca detr., 8. Rudista detr., 9. Ostracoda, 10. Echinodermata

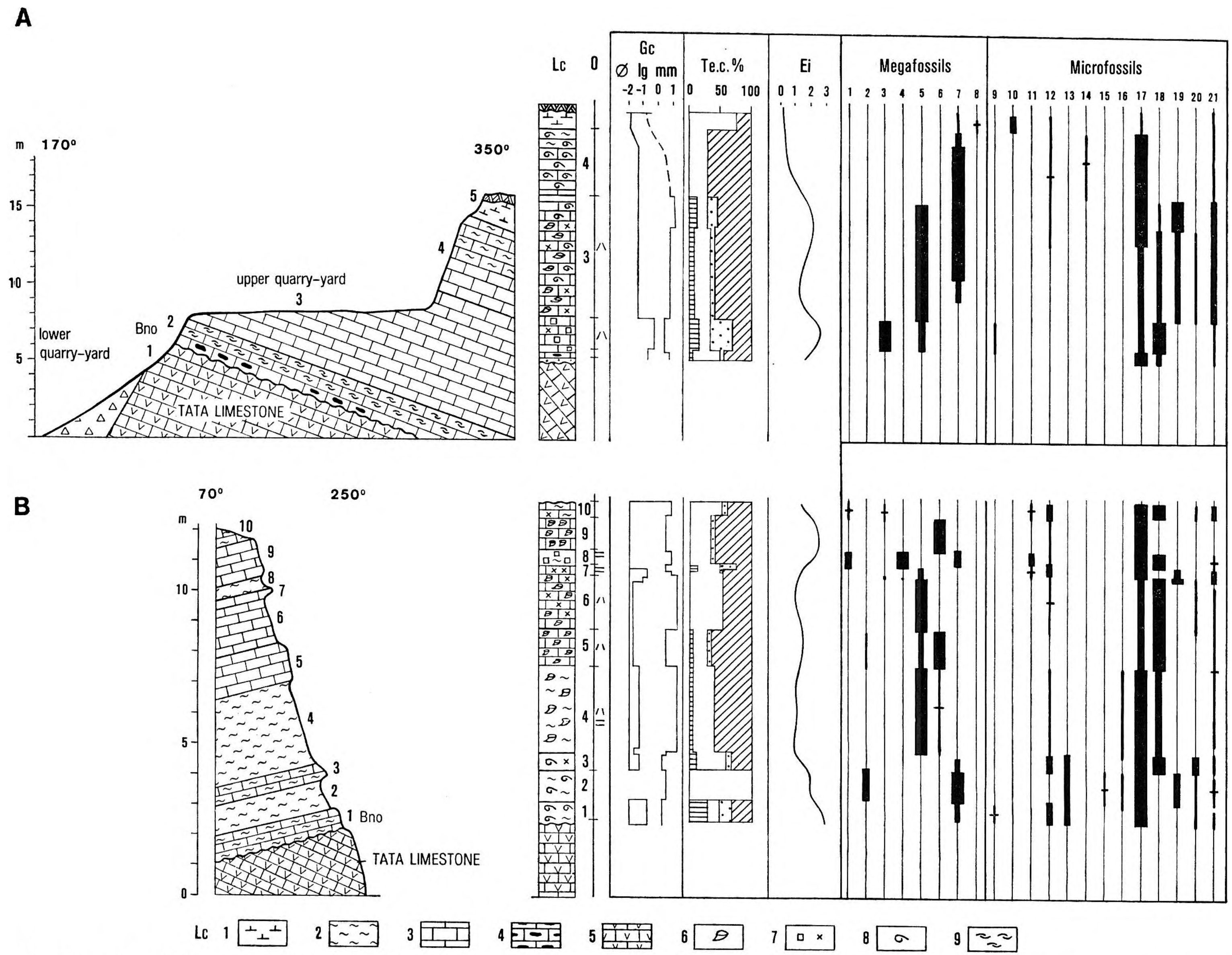


Fig. 54. Lithologic log and analytical record of the sequence exposed in the Sintérlap quarry [*A*) northern quarry face, *B*) eastern quarry face, section in the direction of dip]

Lithologic column **(Lc): 1. calcareous marl, 2. marl, 3. limestone, 4. gravelly limestone, 5. crinoidal limestone, 6. Rudista, intact, 7. Rudista, fragmentary (calcirudite and calcarenite), 8. Pycnodonta, Exogyra, 9. Mollusca detr. —** ***Megafossils:*** **1. red algae, 2. corals, 3. Mollusca detr., 4. Rudista detr., 5. smaller rudist, 6. larger rudist, 7. Exogyra, 8. Ammonites. —** ***Microfossils:*** **9. algae, 10. Calcisphaerulidae, 11. red algae, 12. benthonic Foraminifera, 13. Nummofallotia sp., 14. larger Foraminifera, 15. Hydrozoa, 16. corals, 17. Mollusca detr., 18. Rudista detr., 19. Exogyra, 20. Ostracoda, 21. Echinodermata. (For other symbols, see Fig. 52.)**

In Profile *A* from Fig. 52 the sequence of the quarry can be seen. That the aphaneritic limestone in the quarry is by several metres thicker than that observed in the boreholes S-7 is worthy of attention.

In 1971, in the lower quarry-yard the aphaneritic limestone was excellently exposed (Profile *C* of Fig. 52). Similarly to the corresponding part of the borehole S-7, the texture is biomicrite and micrite, but higher up the profile the amount of intraclasts increases significantly.

The northern face of the upper quarry-yard of Kecskevári quarry exposes the Hippurites-bearing, bioclastic limestone beds, from the upper part of the limestone of medium to fine calcarenite grain size and light grey colour up to the yellowish-brown Hippurites limestone beds of medium- to coarse grain size (Plates XXXIV and XXXV). The dipward section (26/15°), the columnar section and the diagram showing the lithological parameters and genetic features are given in Profile *B* of Fig. 52.

To the north of the Kecskevári quarry, around the explosives deposit of the mine, trenches have exposed the upper subunits of the Hippurites limestone member. The plan of these exposures, the individual profiles and diagrams are given in Fig. 53.

Naturally, the sequence of strata is similar to the upper part of the borehole S-7, as it started with the topmost exposed bed of the section. That marl layers of several metres thickness with sporadical valves of *Rudista* are interbedded with the bioclastic limestones is worthy of mention—a peculiarity not observed either in the Kecskevári quarry or in the borehole S-7.

As evident from a comparison of the profiles presented, the individual beds are laterally so variable that in certain cases a lenticular structure can be spoken of.

The Sintérlapi quarry on the northwest side of the Köves-domb provides an excellent exposure of the Hippurites-bearing, bioclastic limestone overlying the rough surface of the Aptian Tata Limestone.

The west and south sides of the quarry have exposed a Tata Limestone dipping at 310/50°. On the south side of the quarry mining activities in recent years have rendered visible even the extraclastic limestone overlying the Aptian.

The section of dipward orientation taken from the middle part of the south side of the quarry (as of 1971) and the results of its examination are presented in Profile *B* of Fig. 54. The rough surface of the Tata Limestone is overlain by 5 metres of Exogyra-bearing, bioclastic limestone and marls with tiny *Rudista* valves, then above the bioclastic limestones a bed containing tightly intergrown *Hippurites*, forming bunch-like agglomerates resulting from the fact that the animals were buried in their living positions.

The exposures from the north part of the quarry are shown in Profile *A* of Fig. 54. The Ugod Formation in this section is already represented by only a Hippurites-bearing, bioclastic limestone sequence of extremely reduced thickness (10 m) resting on a pre-Senonian basement. It is overlain by a few metres of Exogyra beds that are covered by a peculiar, worm-track-bearing calcareous marl facies of the Polány Formation.

It was considered very probable that beneath the "worm-track"-marl-covered surface of the northern part of the Köves-domb the Ugod Formation was even more reduced in thickness, to pinch out finally, or that it intertongued with other formations representing heteropical facies. It was these hypotheses that we wished to verify by the survey borehole Süt-16 drilled in 1971 (Fig. 46) which we located at a distance of 200 m to the north of the Sintérlapi quarry.

In the borehole, above the middle member, composed mainly of siltstone marls, of the Csingervölgy Marl there evolves—without any break in sedimentation and with a gradual growth of the $CaCO_3$ content of the rock, and an increasing abundance of valve fragments of *Rudista*—a limestone of only 11 m thickness assignable to the Ugod Formation (46.5–35.5 m).

Above the rocks assignable to the Ugod Formation—in contact with a surface of slide seamingly responsible for a slight displacement only—the borehole sequence includes a marly siltstone layer, then there follows an interval of a few metres in which the interbedded layers of Exogyra lumachelles abound. Next to follow is a siltstone-marl exhibiting features of the upper member of the Jákó Formation and the sequence is closed by the basal beds of the Polány Formation.

A sequence somewhat similar to the above was intersected by the borehole, S(G)-3 put down in 1967, at a distance of 200 m to the northeast of this borehole. However, F. Góczán, who described this borehole, does not mention any limestone with *Rudist* detritus.

In the boreholes that have penetrated the Senonian to the northwest of the borehole Süt-16 there is no trace of Ugod Formation rock types, even though the nearest borehole, S(G)-2, was put down at a distance as little as 180 m away.

The Ugod Limestone Formation of the Köves-domb, a quite peculiar formation as it is, shows, all in all, the following geological and mode-of-superposition characteristics (profile from Fig. 50):

In the middle part of the Sintérlap quarry the Ugod Limestone overlies, practically immediately, the pre-Senonian basement. Above the Aptian Tata Limestone about 10 m of bioclastic limestone

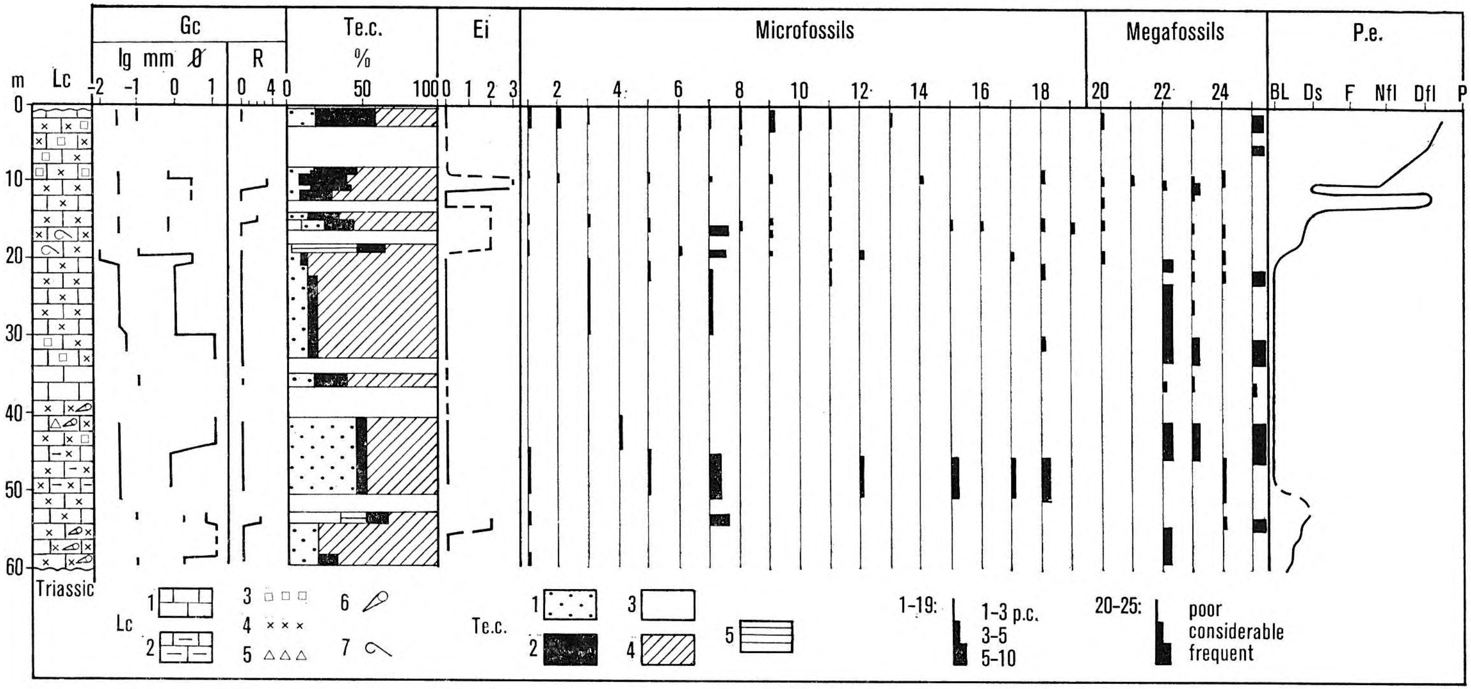


Fig. 55. Lithologic log and analytical record of the borehole Sg-192

Lithologic column **(Lc): 1. limestone, 2. argillaceous limestone, 3. calcirudite, 4. calcarenite, 5. authigenic (intraformational) breccia, 6. rudist shell, 7. Exogyra shell. —** *Grain composition* (Gc): size, roundness (R). — *Textural composition* (Te.c.): 1. micrite, microsparite, 2. intraclast, 3. sparite, 4. fossils, 5. pellets. — *Energy index* (Ei) — *Fossils:* 1. Textulariidae, 2. Spiroplectammina, 3. Dorothia, 4. Orbitolinidae, 5. Dicyclina, 6. Cuneolina, 7. Miliolidae, 8. Spiroloculina, 9. Nodosariidae, 10. Lenticulinae (Robulus) 11. Bulimina, 12. Rotaliidae, 13. Gyroidina, 14. Gavelinella, 15. Stensiöina, 16. Nummofallotia, 17. Orbitoides, 18. Monolepidorbis, 19. Accordiella conica, 20. Stomiosphaera, 21. Cadosina, 22. Rudista detr., 23. Mollusca detr., 24. Ostracoda, 25. Echinoidea. — *Paleoenvironment* (P.e.): *BL* backreef, *Ds* drifting sand, *F* front-reef, *Nfl* near by foreland, *Dfl* distant foreland, *P* pelagic basin with interbedded marl layers can be observed, containing, at its top, *Rudist* specimens grown closely alongside and enclosed in the burying sediment in their living position. In addition, hermatypical, reef-building organisms are also contained in the upper part of the limestone *(corals, Hydrozoans, red algae)*. These strata are traceable on the surface farther south. Beneath them, as evidenced by the sequence of the borehole S-7 and the Kecskevár quarry, the Ugod Formation grows considerably thicker (to about 70 m). Already the Hippurites-bearing, bioclastic limestone itself is thicker and this is followed farther downwards by an aphaneritic limestone and then by an extraclastic one. This latter surrounds as a southward-extending blanket the one-time cliff composed of Aptian crinoidal limestones and covered by only a few metres of bioclastic limestone. Becoming again thinner farther south, the Ugod Limestone overlies there the Csingervölgy Marl (borehole Süt-15).

2. *Városi-erdő–Surgó-tag–Kozma-tag (Facies Zone "A")*

On the margin of the Városi-erdő and farther northeast, in the Bárdió-tag, then in the Surgó-tag and Kozma-tag subareas, a number of bauxite-exploratory boreholes have exposed the Ugod Formation. Unfortunately, most of these boreholes give but little information for a more exact analysis, since for the most part they did not penetrate a Senonian sequence of considerable thickness or since they did not furnish core samples that should be suitable for appropriate studies. At any rate, so much can be pointed out that in the outermost belt known at present the pre-Senonian (upper-Triassic) basement is overlain directly or with a very thin basal layer of marl-cemented breccia or pebble or marl to calcareous marl in between, by a *Rudist*-bearing limestone.

As an example of this facies unit, let us present here the profile of the borehole Sg-192 drilled in 1974 near the Surgó-tag subarea and an evaluation of the results of its examination (Fig. 55). In the borehole the dolomite is overlain by a light brownish-grey, fine-crystalline limestone consisting of bioclastic grains of calcarenite to calcirudite grain size.

A similar sequence was exposed, as suggested by the descriptions, by the boreholes put down earlier in the Surgó-tag subarea and by a number of bauxite exploratory boreholes drilled in the southern Kozma-tag and also by the boreholes Bd-18, -52, -60, -61 and -63 in the Bárdió-tag subarea.

Drilled for cement raw material exploration purposes, the borehole Sc-9/7 was put down in 1974 on the southwest slope of the Hajnal-hegy. It penetrated the Ugod Limestone in a thickness of more than 70 m, but it did not reach the underlying formation. The sequence is composed of beds consisting of coarse biocalcarenite to calcirudite grains with thin limestone and marl layers interbedded in the deeper part (below 40 m) in which the shell fragments of *Exogyra* and other minute molluscs are enriched. The rock texture is generally an intraclastic biomicrite. Interestingly enough, the grains are for the most part well rounded, being often coated by a micrite film.

Although in this borehole the nature of superposition to the pre-Senonian basement is unknown, in the light of the spatial position and the geological features of the drilled sequence an assignment to the Facies Zone "*A*" seems to be justified.

3. *Northern side of Városi-erdő–Hárs-hegy–Hajnal-hegy (Facies Zone "B")*

Drilled in the northwest margin of the Városi-erdő, the borehole Süt-14 exposed a very thick Ugod Limestone sequence preserved in smaller, down-faulted tectonic blocks. The columnar section of the borehole, its stratigraphic subdivisions and lithological and paleoenvironmental parameters are summarized in Fig. 56.

Overlying the Triassic limestones in the basal 9 m, the extraclastic marls and the limestones with detritus of *Rudista* may already be assigned to the Ugod Formation.

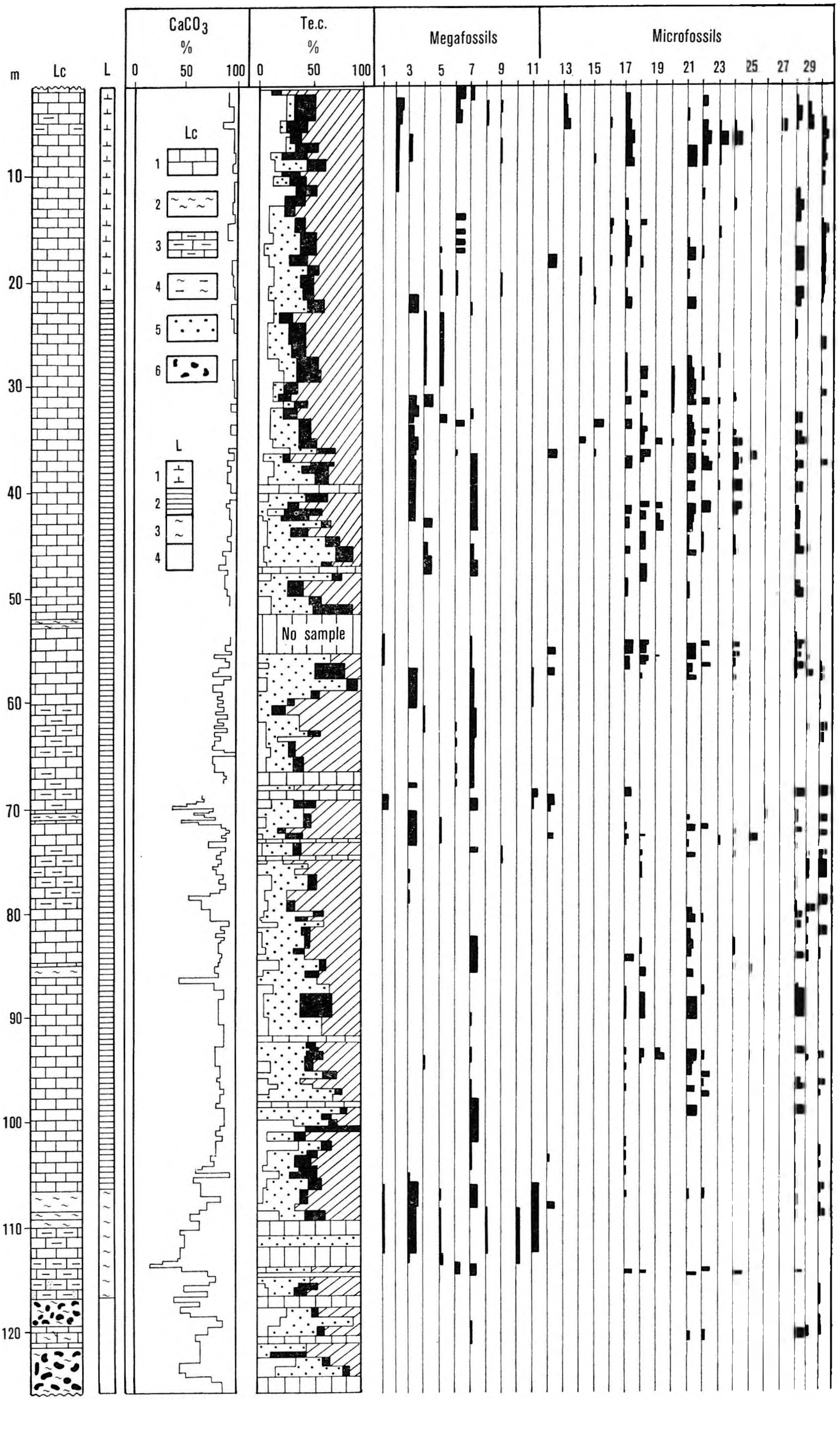
The next 10 metres of marl and calcareous marl represent a transitional member of the Jákó Formation intertonguing with the Ugod Formation.

The 80-m-thick typical Ugod Limestone can be subdivided into 3 subunits: the lower one is characterized by an aphaneritic limestone (similar to the aphaneritic limestone facies of Köves-domb), the middle one is represented by a fine calcarenite with interbedded marl layers, the upper one by fine- to medium-grained calcarenites of uniform lithological character. The last two subunits are close to the Hippurites-bearing, bioclastic limestone of Köves-domb.

The uppermost subunit of the sequence shows the features of the basal interval of the Polány Formation.

A good opportunity for studying the Ugod Formation constituting the Hárs-hegy is provided by the Gerinc limestone quarry. A NNE–SSW oriented profile of the quarry is presented in Fig. 47, complemented with the columnar sections of the cement-exploratory boreholes drilled in 1974 (Sc-8, -8a).

The Ugod Limestone Formation overlies the rough surface of an alternating Upper Triassic limestone and dolomite sequence; the basal layer is 5 to 10 cm thick, ochre-yellow siltstone-marl, in other places, marly limestone containing detritus deriving from the underlying formation. It is followed, higher in the profile, by 4 to 6 metres of light grey, brown, ochre-yellow marly limestone



CaCO3 %
Te.c. %
Megafossils
Microfossils
m
Lc
L
0 50 100
0 50 100
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
10
20
30
40
50
60
70
80
90
100
110
120
Lc
1
2
3
4
5
6
L
1
2
3
4
No sample

with limestone nodules and calcareous marls—a subunit with plenty of shell detritus of *Rudista* and other *Mollusca* and skeletal detritus of *Echinoidea*. Some beds of it contain large quantities of *Rudists* of small size (5 to 6 cm long and 3 to 4 cm in diameter), less frequently the representatives of *Exogyra* are encountered, too.

The next distinct unit is a 18- to 20-m-thick (tectonically reduced in thickness in the borehole Sc-8) light brown to light grey limestone with a large quantity of bioclasts, of fine- to medium size and locally recrystallized. Valves or detritus of *Rudista* in a lying position are extremely abundant. In addition, there are a few internal moulds of *Actaeonella;* in the lower part of the unit, a few *Pycnodonta* can also be encountered, gradually increasing in number as one proceeds higher in the profile. Above this a more pelitic rock body of lower $CaCO_3$ content follows which is nothing else than the intertonguing part of the lower member of the Csingervölgy Marl. The borehole Sc-8 bore witness to that idea—formulated in his report of 1958 already by Noszky Jr.—that the grey argillaceous marl with interbedded layers of ochre-yellow, nodular marl is part of a lenticular rock body of modest spatial extension.

Its lithological and paleontological data were given in discussing the Jákó Formation. Its thickness in the Gerinc quarry is 8 to 9 m.

It is overlain by a unit composed again of limestone beds, 32 to 35 m of which exposed in the middle and upper quarry-yards. (The borehole Sc-8 penetrated 11 m of the formation.) Its rock varieties are of high carbonate content. At the very base there lie 6 m of light brownish-grey, thin-bedded, a little marly, argillaceous limestone containing single valves of *Exogyra* grouped in nests. In its upper part, sporadical specimens of *Rudista* can be observed, too.

The next unit of this interval of high carbonate content is composed of yellowish-grey to brownish-grey, for the most part thin-bedded or, less frequently, thick-bedded limestones of a $CaCO_3$ content of 93 to 96% and characterized by a fine or, just sporadically, coarse crystal size. Frequent forms are the small to medium-size specimens of *Rudista* which are often perpendicular to stratification, particularly so in the lower interval. A considerable part of the rock is built up of *Rudista* shell detritus fragmented to tiny particles and of shell fragments of other molluscs.

On the basis of the quarry section and the supplementary borehole sections, the following general conclusions as to the sequence of the Gerinc quarry can be drawn: 1. in this area the Triassic is overlain directly by *Rudist*-bearing marly limestones; 2. in the lower interval a lens exhibiting characteristics typical of the Csingervölgy Marl is enclosed in the carbonate sequence; 3. up in the profile, rock varieties of increasingly higher carbonate content are characteristic.

The topmost beds of the Ugod Limestone at present are not exposed in the Gerinc limestone quarry. To study them has become possible as a result of the drilling of the borehole S-30 at a distance of 200 m to the northeast of the quarry. The borehole, after intersecting Eocene formations, penetrated Senonian beds in a thickness of 140.4 m. The rocks of the Ugod Formation are in a tectonic contact with the Triassic dolomite, but the dislocation is probably insignificant.

The lower interval of the borehole exhibits features similar to the sequence of the Gerinc quarry. Above the intertonguing beds of a few metres thickness of the Csingervölgy Marl, there are 20 metres of a uniform limestone of coarse biocalcarenite to fine calcirudite grain size representing the Ugod Formation and similar in geological features to the rocks exposed in the upper quarry-yard of Gerinc. Next to follow is a subunit characterizable by an aphaneritic, finely bioclastic limestone with planktonic microfossils interbedded with thin calcareous marl and marl layers; and then the uppermost 30 m are again represented by homogeneous, fine- to medium-grained biocalcarenite limestones.

Located at a distance of 300 m to the southeast of the borehole S-30, the borehole Sc-5/9 exposed a sequence that is a transition between the the unit of Facies "A" and that of Facies "B". Beneath the Ugod Limestone the transitional member of the Jákó Marl is though present, but it is extremely reduced in thickness (4 m). The lower part of the limestone interval is a coarse-grained calcarenite with shell detritus of *Rudista;* higher upwards the grain size slightly decreases.

The northern side of the Hajnal-hegy, as shown by extrapolation of the results, belongs to this zone too, but in this area no borehole penetrating a full sequence was drilled. From among the boreholes in the Kozma-tag subarea it is the sequence penetrated by the borehole Ck-95 that can be assigned to this facies unit.

←

Fig. 56. Lithologic log and analytical record of the borehole Süt-14

Lithologic column (Lc): 1. limestone, 2. marl, 3. argillaceous limestone, 4. argillaceous marl, 5. sand, 6. gravel. — ***Lithostratigraphic units*** (L): 1. Polány Marl Fm., lower member, 2. Ugod Limestone Fm., 3. Jákó Marl Fm., 4. lower interval of the Ugod Limestone Fm. — ***Megafossils:*** 1. corals, 2. worm tracks, 3. Mollusca, 4. Gastropoda, 5. Bivalvia, 6. Pycnodonta, 7. Rudista, 8. Decapoda pincers, 9. Echinodermata, 10. fish scale, 11. vegetal detritus. —***Microfossils:*** 12. algae, 13. Stomiosphaera, 14. Ammodiscus, 15. Lituola, 16. Siderolites, 17. Textulariidae, 18. Orbitolinidae, 19. Dicyclina, 20. Cuneolina, 21. Miliolidae, 22. Nodosariidae, 23. Bulimina, 24. Rotaliidae, 25. Anomalinidae, 26. Nummofallotia, 27. Orbitoides, 28. other benthonic Foraminifera, 29. Ostracoda, 30. Echinodermata. (For other symbols, see Fig. 55.)

Facies Zone "*B*" is characterized as a whole by *Rudist*-bearing carbonate beds directly overlying a Triassic basement, beds surrounding a Csingervölgy Marl interbed present in a lenticular form or jutting in as a tongue. In the middle interval, it is poorly rounded biocalcarenite to calcirudite beds of micritic matrix with *Rudista* and larger benthonic *Foraminifera* that alternate with micrite-cemented sediments of very minute grain size composed of bioclasts and containing planktonic Foraminifera as well, beds already exhibiting the characteristic features of the Polány Formation.

As evidenced by the borehole S-30, the uppermost interval—for the most part lost to erosion in the study area—is represented by a biocalcarenite already free from planktonic fossils; consequently, unlike the lower-situated, intertonguing, transitional subunits, it is composed of a typical, homogeneous Ugod Limestone.

4. Southern side of the Rendeki-hegy (Facies Zone "C")

The northwest facies zone of the Ugod Formation is presented by the example of the sequence exposed by the bauxite-exploratory borehole Ck-168 (Fig. 57).

In the borehole the Ugod Formation overlies the clay-filmed nodular upper subunit of the Rendeki Member of the Polány Formation. At the boundary between the two formations there is a striking change in both the megaloscopic and microscopic characteristics. The light brown, aphaneritic to fine-crystalline limestone is replaced by a white, fine-grained calcarenite. In the bioclast material of sand grain size there occur debris of *Rudists*, too. The typical foraminiferal assemblage of the Rendeki Member of the Polány Formation is replaced, after an interval extremely poor in *Foraminifera*, by a Miliolidae–Nodosariidae–Textulariidae assemblage. *Calcisphaerulidae* show a marked decrease in number.

On the basis of the lithological characteristics of the Ugod Formation the following subunits can be singled out:

At the base (131–160 m) a white, small or, less frequently, medium-grained calcarenite with fine-crystalline matrix is characteristic. The rock texture is of biosparite to biomicrosparite composition.

The middle subunit of the sequence (120–131 m) is composed of a pink, fine-crystalline or aphaneritic limestone. Minute shells of *Rudista* are quite unfrequent in it. The texture is biopelmicrite or biopelmicrosparite, respectively. The number of foraminiferal individuals is considerable. Larger *Miliolidae* or, in the higher beds, *Dycyclina* are predominant.

In the upper part of the sequence (79–120 m) there is a yellowish-white, aphaneritic limestone containing a considerable quantity of bioclasts of arenite and rudite texture. Valves of smaller *Rudista* (in the first place, *Agria*) are abundant in the rock. Accordingly, in the borehole Ck-168 chosen as type, three subunits of the Ugod Limestone overlying the Rendeki Member can be distinguished: 1. finely biocalcarenitic limestone; 2. middle subunit represented by an aphaneritic limestone with few Rudista; and 3. an upper subunit composed of coarse bioarenitic to ruditic limestone.

According to the authors' observations, limestone beds of similar lithological composition and mode of superposition were exposed by the bauxite-exploratory boreholes Ck-167, -169, -170 and -171 and also by the quarry to the northwest of the Kozma-tag and the outcrops in the southern foreland of the Rendeki-hegy. On the basis of the descriptions and the results of analyses, the sequence penetrated by the borehole Cn-598 and probably the Ugod Limestone penetrated by the boreholes Cn-211, -563, -593 and -596 can also be assigned to this facies zone, although in the latter case the descriptions suggest that the textural characteristics could not be determined in an exact way.

All in all, Facies Zone "*C*" is characterized by an aphaneritic to fine-crystalline lithofacies of fine calcarenite grain size, generally unrounded or very poorly rounded, with rudite grains that are usually scarce, but locally considerably enriched sitting in a predominantly micritic matrix.

Spatial relations between the individual facies zones or formations

The spatial relations between the listed facies zones and the relationship of the Ugod Limestone with the under- and overlying beds and heteropical formations were analyzed by studying geological sections parallel and perpendicular to the strike of the facies zones. In Fig. 58, profiles of northwest-southeast direction plotted by taking the top of the underlying formations to be a reference horizon are presented.

The upper profile from Fig. 58 shows that the outermost facies zone, Zone "*A*" in the southeast, characterized by coarse biodetritus and hermatypically intergrown *Hippurites* locally buried in living position coincides with the zone of total pinching out of the Jákó Formation. Attached to the marginal facies zone of the Jákó Formation is the zone "*B*" in which an intertonguing with the Csingervölgy Marl in the deeper part and with the Polány Formation in the middle stretch (borehole S-30) was observed.

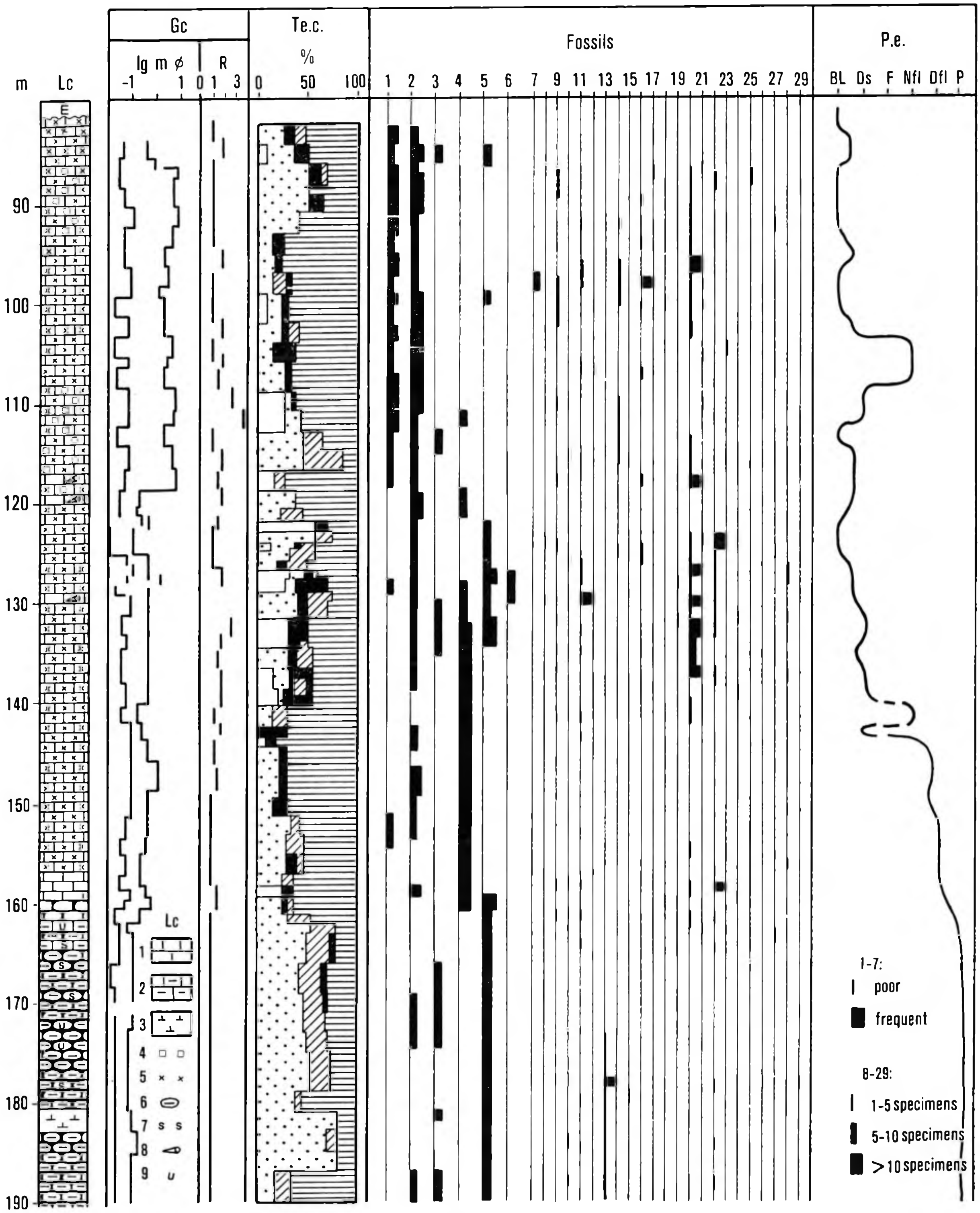


Fig. 57. Lithologic log and analytical record of the borehole Csabrendek Ck-168

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. calcirudite, 5. calcarenite, 6. nodular structure, 7. bioturbation, 8. rudist shell, 9. worm track. — *Fossils:* 1. Rudista detr., 2. Mollusca detr., 3. Ostracoda, 4. Crinoidea, 5. Echinodermata, 6. Holothuroidea, 7. Globochaete. *Foraminifera:* 8. Lituola, 9. Spiroplectammina, 10. Textularia, 11. Dorothia, 12. Ataxophragmium, 13. Bulimina, 14. Cuneolina, 15. Accordiella, 16. Dicyclina, 17. Valvulineria, 18. Valvulammina, 19. Meandrospira, 20. Miliolidae, 21. Rhapydionina, 22. Nodosaria, 23. Lenticulina, 24. Orbitoides, 25. Gyroidina, 26. Stensiöina, 27. Rotaliidae, 28. Nummofallotia, 29. Goupillaudina. (For other symbols, see Fig. 55.)

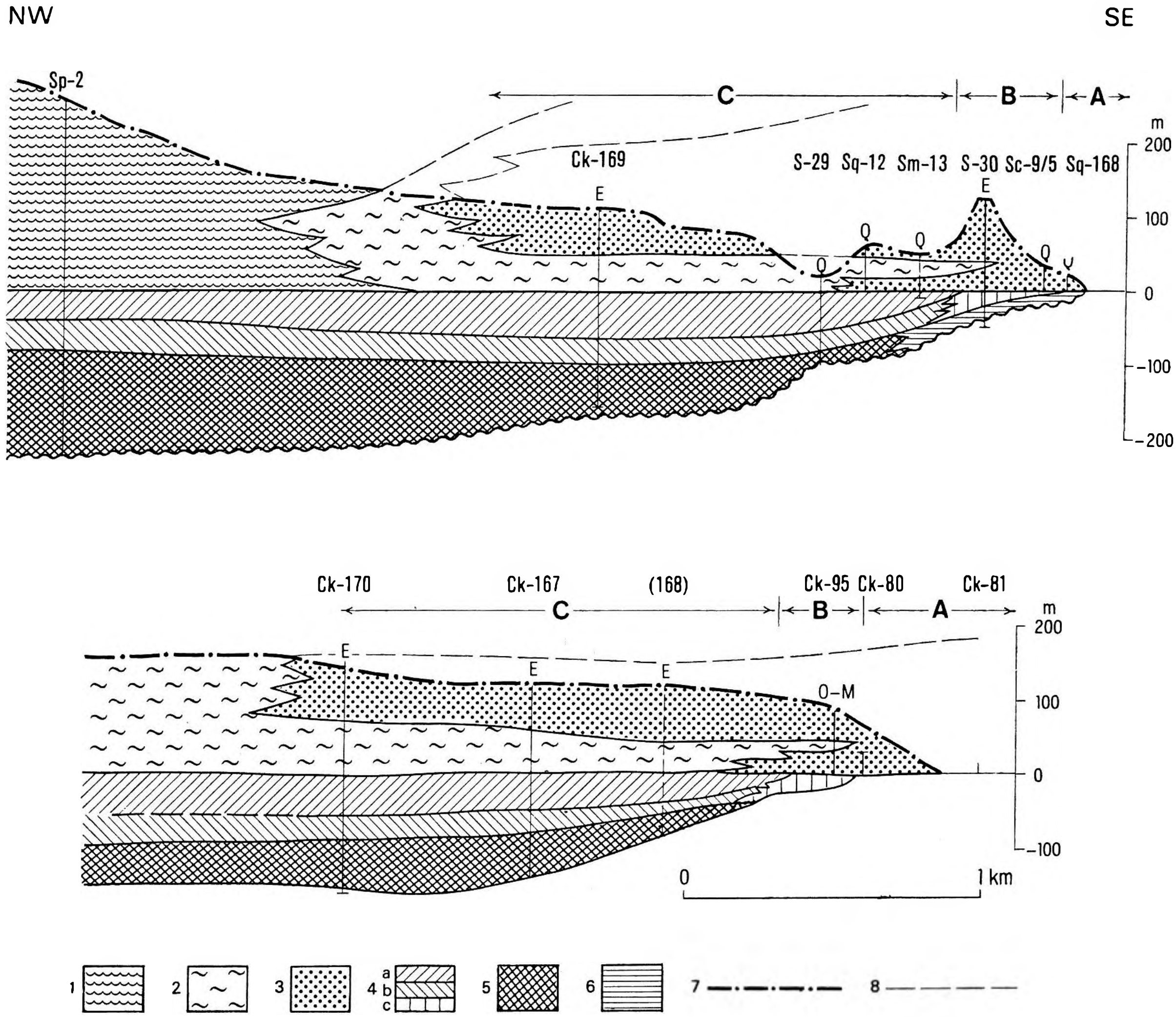


Fig. 58. NW—SE oriented profiles showing the relations between the Senonian formations with reference to the top level of the Jákó Marl

1. Polány Formation, 2. Rendek Member, 3. Ugod Fm., 4. Jákó Fm.: *a)* upper member, *b)* lower member (Csingervölgy Marl), *c)* marginal facies, 5. Ajka Fm., 6. Csehbánya Fm., 7. present-day denudation surface, 8. supposed original formation boundaries. — *E, O-M, Q* symbol of formation overlying the Senonian; *A—B—C* facies zone

It is by and large in the zone of typical, two-member development of the Jákó Formation and appearance of the Ajka Formation, that the characteristic features of Facies Zone "*C*" present themselves in the sequence. An essentially similar arrangement can be seen in the lower profile of Fig. 58 as well.

The lower interval of the Polány Formation is thus intertonguing approximately in the Gerinc quarry–Kozma-tag line with the Ugod Limestone, its upper interval being so at the foot of the Rendeki-hegy. In other words, the area of the Ugod Limestone is shifted by about one kilometre and a half to the northwest, towards the one-time basin. The subsequent trends of potential shifting cannot be traced owing to the loss of formation due to erosion.

Bio- and chronostratigraphy

To single out biostratigraphic units within the Ugod Formation is rather difficult, for the fossil assemblage is composed of reef-dwelling organisms and these excel with their ecological sensitivity rather than with a characteristic, narrow stratigraphic range. In many cases even a radical change in the composition of the fossil assemblage reflects but a slight change in environment, thus having little to do with the range of a species. That the palynological zoning, readily applicable to pelitic formations, can play only a subordinate role in a limestone facies poses another problem.

On the basis of the above, it is obvious that in addition to direct biostratigraphic evidence needed for a chronostratigraphic assignment, the use of indirect methods based on observation of the intertonguing of heteropical facies, the consideration of the chronostratigraphic evidence of the under- and overlying formations and the evaluation of facies relations and facies shifts cannot be dispensed with.

The most peculiar fossil group of the Ugod Formation is represented by *Rudista*. Both *Hippurites* and *Radiolites* are present in a relatively large number of species and an extremely large number of individuals in the Sümeg area. The ranges of the particular index fossils are shown, as compiled by L. Czabalay (1982), in Table 5.

The individual elements of the faunal assemblage can be traced in the northern part of the onetime Tethys from southern France across the Alps-Carpathians-Dinarics range as far as Asia Minor, being bound consistently to facies similar to the Ugod Formation. Their stratigraphic range is comparatively narrow, some of them being restricted to the Upper Santonian and the Lower Campanian, others to the Lower and Upper Campanian intervals, though a few forms spanning the Upper Campanian or the Lower Maastrichtian, respectively, have also been encountered.

Thus, in terms of the *Rudists*, the lower subunit of the Ugod Formation cropping out on the Köves-domb and near the Kozma-tag and represented by hippuritic, bioclastic limestones and the lower rudist-bearing beds of the Gerinc quarry sequence may be assigned to the Lower Campanian, the rocks exposed in the upper part of the borehole Süt-14 and also the upper subunit exposed in the Gerinc quarry, to the Upper Campanian.

In the light of evidence concerning the spatial position of the Ugod and Polány Formations it is not surprising that the *Rudists* encounterable on the Köves-domb suggest an older age and those known from the Hajnal-hegy and Hárs-hegy outcrops are indicative of a younger one. In fact, these data confirm our view about the spatial relations of the formations involved.

The same point is corroborated by the fossil material recovered from the transitional argillaceous beds between the Polány and Ugod Formations on the slope of the valley in the northern part of the Hárs-hegy. From this material, L. Czabalay identified the following fossils which she believed to be characteristic of the Upper Campanian: *Inoceramus capitosus vengarteni* Czabalay, *I.* cf. *striatoconcentricus* Gümbel, *Cucullaea (Trigonarca) austriaca* Zittel, *Biradiolites* sp., *Pycnodonta* sp., *Ostrea canaliculata* (Sow.).

From the interbedded limestone layers and the limestones overlying the formation on the plateau above the valley, limestones abounding with *Rudist* shells, the following fossils have been recovered:

Agriopleura cf. *moroi* (Vidal)
Praeradiolites cf. *subtoucasi* Toucas
Lapeirouseia zitteli Douville
Hippurites (H.) mestrei Vidal
Hippurites exaratus Zittel
Hippurites lapeirousei Goldfuss
Hippurites castroi Vidal
Hippurites nabresinensis Futterer
Biradiolites aff. *stoppanianus* (Pirona)
Radiolites angeiodes (Picot de Lap.)
Ceratostreon matheronianum (d'Orb.)
Janira sp.
Neithaea sp.
Arca (Cucullaea) sp.

L. Czabalay suggests that this faunal assemblage is similar to that recovered from beds dated as Campanian to Maastrichtian in Austria (Gosau) and southern France.

In the Sintérlapi quarry and the extraclastic limestone exposed at the base of the Senonian in the borehole S-7 the following gastropodal assemblage can be found: *Itruria cycloidea* Pcelincev, *I. goldfussi* (d'Orbigny), *I. lamarcki brandenbergensis* Kollmann, *Trochactaeon giganteus subglobosus* (Muenster), *Actaeonella caucasica styriaca* Kollmann. According to L. Czabalay (1975), the aforelisted forms are typical of the Lower Campanian, but some of them appear already in the Santonian.

As shown by L. Czabalay (1964e), the rich fauna of *Bivalvia* from the beds above the hippuritic and bioclastic limestone of Köves-domb (Kecskevár quarry) can be assigned to the Campanian, though assignment of higher precision is impossible.

From among the larger Foraminifera occurring in the upper part of the Ugod Limestone, *Monolepidorbis* is typical of the Campanian, *Orbitoides* and *Siderolites* are characteristic of the Upper Campanian–Maastrichtian. *Cuneolina* and *(Dicyclina)* are known already in the Middle Cretaceous. The range of *Rhipidionina liburnica* (Stache) extends from the Cenomanian up to the Lutetian. *Accordiella conica* Farinacci is characteristic of the Campanian.

Stratigraphic range of the Rudista fauna of the Ugod Limestone
after L. CZABALAY (1982)

Species	Santonian	Campanian		Maastrichtian	
	Upper	Lower	Upper	Lower	Upper
Plagioptychus aguilloni (D'ORBIGNY)	—	—	—		
Vaccinites sulcatus (DEFRANCE)	—	—	—	—	
Vaccinites praesulcatus (DOUVILLÉ)		—	—		
Vaccinites vredenburgi (KÜHN)		—	—	—	
Vaccinites vesiculosus (WOODWARD)		—	—		
Vaccinites inaequicostatus (MÜNSTER)	—	—	—		
Vaccinites gosaviensis (DOUVILLÉ)		—	—	—	
Vaccinites braciensis (SLADIĆ-TRIFUNOVIĆ)	—	—	—	—	
Vaccinites atheniensis (KTENAS)	—	—	—	—	
Vaccinites cornuvaccinum gaudryi (MUN.-CHALM.)		—	—		
Vaccinites taburni GUISCARDI	—	—	—		
Vaccinites chalmasi (DOUVILLÉ)	—	—	—		
Vaccinites archiaci (MUNIER-CHALMAS)			—		
Vaccinites carinthiacus (REDLICH)	—	—	—		
Vaccinites oppeli santoniensis (KÜHN)	—	—	—		
Vaccinites oppeli (DOUVILLÉ)	—	—	—		
Vaccinites giganteus (D'HOMBRES-FIRMAS)	—	—	—		
Vaccinites fortisi (CATULLO)		—	—		
Vaccinites boehmi (DOUVILLÉ)	—	—	—		
Hippurites heberti MUNIER-CHALMAS		—	—		
Hippurites sulcatoides DOUVILLÉ		—	—		
Hippurites crassicostatus DOUVILLÉ		—	—		
Hippurites heritschi KÜHN		—	—	—	
Hippurites nabresinensis FUTTERER	—	—	—		
Hippurites colliciatus WOODWARD	—	—	—		
Hippurites lapeirousei GOLDFUSS		—	—	—	
Hippurites variabilis MUNIER-CHALMAS		—	—		
Hippurites bioculatus LAMARCK		—	—		
Hippurites socialis DOUVILLÉ	—	—	—		
Agriopleura moroi (VIDAL)		—	—		
Agriopleura cf. *garumnica* (ALIBERT)			—	—	
Radiolites spongicola ASTRE			—	—	
Radiolites angeiodes (PICOT DE LAPEIROUSE)	—	—	—	—	
Radiolites albonensis TOUCAS			—	—	
Radiolites aurigerensis MUNIER-CHALMAS	—	—	—		
Radiolites gastaldianus PIRONA	—	—	—		
Radiolites radiosus D'ORBIGNY	—	—	—	—	
Radiolites subradiosus TOUCAS	—	—	—		
Radiolites squamosus D'ORBIGNY	—	—	—		
Radiolites nouleti (BAYLE)		—	—		
Radiolites styriacus (ZITTEL)		—	—		
Radiolites pannonicus BARNABÁS		—			
Radiolites galloprovincialis MATHERON	—	—	—		
Neoradiolites matheroni (TOUCAS)	—	—	—		
Praeradiolites subtoucasi TOUCAS	—	—	—	—	
Praeradiolites aristidis (MUNIER-CHALMAS)	—	—	—		
Praeradiolites hoeninghausi (DES MOULINS)		—	—	—	
Praeradiolites maximus ASTRE			—	—	
Praeradiolites saemanni (BAYLE)			—	—	
Praeradiolites plicatus desmoulinianus (MATHERON)		—	—	—	
Laperiouseia jouanneti (DES MOULINS)			—	—	—
Laperiouseia zitteli DOUVILLÉ		—	—		
Lapeirouseia pervinquieri (TOUCAS)	—	—	—		
Osculigera kuehni LUPU	—	—	—		

Noteworthy from the viewpoint of local correlation is the occurrence of *Nummofallotia cretacea* SCHLUMB. and of forms from the genus *Goupilladina,* as these forms are encountered in the heteropical Jákó Formation and the Polány Formation, respectively, as well. *Nummofallotia* was observed for example in the lower part of the borehole S-7, the basal beds in the Sintérlap quarry, the lower part of the borehole Süt-14 and in the Ugod Limestone of the boreholes Sg-192, S-30 and Ck-167 and -168.

In the basin centre boreholes, the upper limit of occurrence of *Nummofallotia* lies somewhere around the upper boundary of the lower member of the Jákó Marl, coinciding with palynological Zone E.

The sea urchin fauna occurring in the Echinoidea beds of the Köves-domb and the Gerinc quarry is believed by E. SZÖRÉNYI (1955) to be of Coniacian to Lower Santonian age as suggested by the presence of *Pyrina ovolum* (LAMARCK), *Botriopygus toucasianus* ORBIGNY, *B. nanclosi* COQUAND and *Micraster corbaricus* LAMBERT.

F. GÓCZÁN (1964), on the basis of his palynological investigations, assigned the Hippurites-bearing limestones in the upper quarry-yard of the Gerinc quarry to the upper part of the Upper Campanian. From the grey nodular, pelitic basal beds of the Ugod Formation exposed in the borehole Sc-5/9 (Facies Unit "B") at the foot of the Hárs-hegy, F. GÓCZÁN listed species assignable to Zone D, i.e. the upper part of the Lower Campanian.

From marls with tiny rudists interbedded with the hippuritic-bioclastic limestones of the Sintérlap quarry on the Köves-domb, a typical Zone E assemblage was recovered, while from the basal beds of the borehole S-7, a typical assemblage of Zone D came into the fore (F. GÓCZÁN 1973).

The observations that have served as a basis for an indirect chronostratigraphic evaluation are discussed in the context of the geological features of the Jákó, Polány and Ugod Formations. In brief, the results involved have led to the following conclusions:

1. According to observations carried out in the northwest foreland of the Köves-domb (borehole Süt-16), the limestone beds made up for the most part of *Rudist* debris extend well between the lower and upper members of the Jákó Marl. This means that in the immediate vicinity the genesis of the Ugod Formation started already in Late Santonian to Early Campanian time.
2. On the Köves-domb and in the Városi-erdő, the Ugod Limestone is overlain by the Upper Campanian beds of the Polány Formation.
3. On the Hárs-hegy, the Hajnal-hegy and in the northern part of the Kozma-tag subarea, beds exhibiting the characteristics of the Rendek Member of the Polány Formation are overlain by an Ugod Formation composed of *Rudist* detritus which was formed at the end of the Campanian or possibly already at the beginning of the Maastrichtian.
4. During the study of the Polány Formation some samples were observed to contain minute debris of rudists. Of greatest chronostratigraphic value is the middle interval of the borehole Sc-4/2, where, in addition to *Globotruncana arca* (CUSHM.), *G. linneiana* (D'ORB.), i.e. Foraminifera, *Rudist* shell fragments were observed in beds assigned to palynological Zone F.

S u m m a r i z i n g the results of direct and indirect analyses, we may conclude that the Ugod Limestone now known from the Köves-domb, i.e. not lost to erosion, is of Upper Santonian (?) to Lower Campanian age. The beds overlying the Rendek Member of the Polány Formation on the Hajnal-hegy and in the vicinity of the Rendeki-hegy were formed in the latest Campanian and maybe in earliest Maastrichtian time. In the marginal zones (*A* and *B*), similarly to the case of the Köves-domb, the birth of the Ugod Formation may have begun in Late Santonian or Early Campanian time and interrupted by deeperwater facies in Facies Zone "*B*", but uninterrupted in Facies Zone "*A*", it seems to have lasted up to the base of the Maastrichtian.

Depositional environment

In outlining the depositional environment of the Ugod Formation we may start from analyzing the rock structure and texture, the ecological conditions of the biogenic components present in rockforming quantities and from their postmortal changes. Much help in constructing the paleo-environment, however, may be provided by an analysis of the thickness and facies characteristics of the formations underlying the Senonian and by evaluating the relevant profiles with a view to reconstructing the original spatial relations of the Ugod Limestone.

Because of the marked spatial variability of the sequences involved we were, already in discussing the geological observations concerning the Ugod Formation, compelled to delineate facies areas and to examine, first of all in these selected areas, the features that are in common or different and then to proceed to analyzing the discrepancies between the facies. This system is that which we follow during our analysis of the depositional environment, too, discussing in the first place the Köves-domb subarea which is of relatively small size and thus studied in most detail, being considered a relatively independent unit.

Köves-domb

The analysis of the depositional environment of the Ajka and Jákó Formation gave information also on what the topography around the Köves-domb and prior to the birth of the Ugod Formation was like. We have pointed out that the comparatively steep slope on the northern side of the Köves-domb (a morphological bench) resulted in a zone of environmental change at the time of birth of the Ajka and Jákó Formations. Consequently, the area of the Köves-domb as a whole was relatively elevated (as compared to the areas to the northwest).

On the northwest side of the Köves-domb the Ugod Formation rests directly on the denuded surface of the Aptian Tata Formation and it does it with a considerable angular unconformity (Sintérlap quarry). This suggests that the Tata Limestone block cropping out on the northwest side of the Köves-domb had already got elevated during the pre-Senonian movements and that the present condition reflects the preservation of a pre-Senonian tectonic pattern.

The closer neighbourhood of the Sintérlap quarry may be interpreted as a rock cliff that emerged —a little bit—above sea level. By this model a number of characteristic, particular and, for the most part, spatially restricted environmental units of the Köves-domb can be explained.

It is this model that renders the genetics of the extraclastic limestone beds with marine fossils from the borehole S-7 intelligible. It is by this means that we understand the data of the diagram from Fig. 51a–b and the trends therein (a pebble material deriving from the immediate vicinity, an upward shift towards a monomictic composition, a decrease in grain size and an increase in roundness).

In the light of the observations listed in the descriptive chapter and shown in Fig. 51a–b, the circumstances of formation of the rocks involved may be reconstructed as follows.

The block built up of Aptian crinoidal limestones, tectonically heavily disturbed and thereby fragmented in particular parts, got in the course of transgression into the zone of intensive abrasion. Attached by the surfs, the rock cliff was supplying sizeable quantities of detritus, of which the predominantly crinoidal limestone clasts may be the result. That rock materials other than this one occur in the lower part of the unit too (rocks available in the basement of the Köves-domb and the Mogyorós-domb, respectively) indicates that at the outset of the abrasion process a considerable part of the one-time Köves-domb–Mogyorós-domb plateau belonged to the abrasion zone. It was a subsequent overall rise in water level that was responsible for the situation that the greater part of these areas was occupied by the zone of wave action and that then it was already only the emergent cliffs that supplied some detritus.

On the leeward side behind the emerging cliffs not affected by wave action, lime mud was being deposited in which a lush vegetation developed. The living organisms that populated this environment must have largely outnumbered the rather poor fossil assemblage presently available, for the predominant fossils, *Trochactaeon*, were feeding on carrion.

At definite time intervals (e.g. whenever the abrasion reached a particular, heavily crushed zone, thus producing a kind of stone-fall), large amounts of unsorted detritus gushed upon the muddy bottom. Of course, the debris that thus penetrated into the sediment could not be rounded on, once deposited in the back-reef, leeward environment not affected by wave action. This explains the poor roundness of the detritus.

The particular stone-falls of such an intensity would bury and kill the living organisms dwelling there. *Trochactaeon*, extremely thick-shelled as they were, may be supposed to have been able to invade and conquere durably that harsh environment, however adverse to life it was, for the simple reason that they did survive the critical periods. In the quiet periods the bottom would be re-populated and even the representatives of *Rudista* would reappear.

The introduction of extraclasts into the sediment ceased then, when an intensively abraded cliff got definitively under the sea level and, having become an area of accumulation, it was buried with sediments. This process manifests itself in the fact that the detrital material tends to decrease continuously (Fig. 51a–b: borehole S-7, 43.0–50.0 m).

On the basis of the profiles, the extraclastic limestone leaning against the Aptian crinoidal limestone block intertongues with the carbonaceous formations of Köves-domb (penetrated by the borehole Süt-15) and with the lower member of original facies of the Jákó Formation.

Upon cessation of abrasional activities the environment-modelling function of the rock-cliff environment was not lost. When its surface got durably into the tidal zone, the condition for the development in this area of a Hippurites–algae–corals community materialized.

As can be seen on the NW–SE oriented profile of the Köves-domb (Fig. 50), to the southeast of the one-time reef, i.e. the Sintérlap quarry, rock types of different facies are enclosed between the pre-Senonian basement on the one hand and the hippuritic and bioclastic unit representing the upper part of the Senonian sequence on the other. From the genetic viewpoint, a characteristic feature of the sequence is the upward increase of the value of environmental energy—a fact established by means of texture studies.

The environment of formation of the units distinguished in the descriptive part is interpreted as follows:

1. The *aphaneritic limestone unit* is characterized by a texture type composed of micrite grains of 0.1 to 0.5 m diameter (pellets, lumps) or of microcrystalline calcite, respectively. The grains of a few microns size may have been deposited on a quiet sea bottom free from currents or surfs. The beds of intrabiomicrite texture are indicative of a permanently or periodically poorly agitated depositional environment.

It follows from the above that in the areas, where the beds in question occur, the environment during their deposition was free from water movement. Protection against agitation must have been provided by the one-time rock cliff and it was in the leeward side behind the cliff that the conditions, that may be observed at present in the well-protected lagoons behind coral reefs, were provided.

The bios of the non-agitated lagoon was certainly more scant than that of the hippuritic facies complex, oxygen- and nutrient-rich and supplied with fresh seawater. That the lagoon was not poor in organisms, after all, is quite probable. *Foraminifera* leading a benthonic way of life, particularly the larger *Dicyclina* and *Cuneolina* genera, are very frequent. Tiny *Rudista* (primarily *Praeradiolites* and *Agria*), gastropods (*Actaeonella* sp., *Nerinea*), *ostracods* and *echinoderms* are abundant. This faunal assemblage under such closed circumstances can be supported by a rich vegetation only which alone provides it with both oxygen and nutrients (a few green algal debris could be observed even during studies with the microscope). Even between the back-reef lagoons of present-day coral reefs does a type with a lush vegetation occur. The one-time environment in which the aphaneritic limestone unit was formed may have been similar to this.

Judging by the distribution of green algae and the composition of the fauna, the water depth may be estimated at 5 to 10 m. Sunlight must have penetrated as deep as the sea bottom. The presence of stenohaline marine organisms *(Rudista)* is indicative of normal salinity. In the closed, quiet lagoons the water seems to have been strongly warmed up under the tropical to subtropical climate—a circumstance suggested by the presence of organisms with an extremely thick skeleton: *Rudista*, *Gastropoda*, giant-sized *Miliolina*, very large *Dicyclina* species.

2. The *hippuritic, bioclastic facies* on the Köves-domb covers the aphaneritic limestone beds, transgressing beyond these (e.g. Sintérlap quarry).

The occurrence of rock types with a biomicrite to biosparite texture containing grains of arenite and rudite grain size is indicative of a depositional environment affected by comparatively heavy agitation which, however, varied in intensity.

The marked enrichment of bioclasts suggests sedimentation in a shallow-water environment that was a warm water rich in carbonate. In this environment reef-like structures were being built continuously serving as a permanent source of biogenic carbonate detritus.

Within the hippuritic, bioclastic unit various lithofacies of varying spatial extension showing somewhat different geological features can be found. The aphaneritic unit in the borehole S-7 is overlain by a sequence consisting of alternating beds of red, coarse to medium-grained limestones of biosparite and micrite texture. Similar rock varieties can be observed in the Kecskevár quarry and the outcrops in the north of the Köves-domb.

The micritic biosparite texture in a periodically poorly agitated environment can be brought about in such a way that the lime mud settling in the interstices of the grains in the quiet periods is winnowed by the water in periods of agitation. A part of the lime mud, however, may be preserved in the well-protected voids between the grains. The hypothesis suggesting such a poorly agitated environment is corroborated by the roundness of the grains, their being sorted and by the abundance of coated grains and calcareous pellets or lumps.

Thus the sedimentary environment must have been alternately agitated or non-agitated, i.e. quiet and, accordingly, the bottom itself must have been of calcarenitic or lime mud character, respectively. The alternations of the substratum and agitation were followed by corresponding changes in the fauna and flora, too. An example to illustrate this is the growth of the amount of the Foraminifera fauna parallel to the increase in micrite content.

Similar environmental conditions are reflected by the light grey, pink-mottled limestones of micrite and biosparite to biomicrite texture that follow above the afore-discussed beds in the borehole S-7 (and also in the Kecskevár quarry and the southeastern part of the Sintérlap quarry). Water agitation, oxygen content and availability of food seem to have been too poor and the water depth too large to enhance the mass proliferation of the *Rudists*, though solitary forms of smaller size are locally abundant. So it was mainly *Exogyra*, forms less sensitive to environmental effects, that would swarm the muddy, lime-muddy bottom.

The reddish-brown echinoid-bearing limestone beds overlying the above-discussed strata in several exposures (borehole S-7, Kecskevár quarry, outcrops in the southeast part of the Köves-domb) represent a quite peculiar facies.

For the most part, the rock is composed of *Echinoidea* skeletons, their detritus and a biosparite matrix. The orientation of the skeletons is indicative of postmortal redeposition, but given the large quantity of intact skeletons, just a very short-distance transport seems to have been involved. Consequently, the data that can be gained from the way of life of the sea urchin fauna feature the conditions that existed in the immediate vicinity of rock generation. *Botryopygus*, the predominant forms, are, in E. SZÖRÉNYI's opinion (1955), organisms enclosed in the sediment that lived in a shallow, clean seawater. The other genera are inhabitants of shallow-water seas with a calcareous mud bottom, too. Thus the sea urchins, with the advent of ecological conditions favourable for their life, must have populated the muddy bottom in enormous quantities. As a result of revival of water movement at times, the skeletons were transported away to short distances and accumulated there.

The topmost interval of the Köves-domb sequence (the upper 15 m of the borehole S-7, the topmost beds exposed in the Kecskevár and Sintérlap quarries) is composed of micritic biosparite-textured limestone, marly limestone and silty marl beds. Both the petrographic character of the limestone (biosparite texture, grain roundness, pseudooölite pattern) and the composition and morphology of the fossil assemblage (giant-sized, cemented specimens of *Hippurites* enclosed in situ or integrown hermatypically or in a "bunch-like" pattern, larger *Alectryonia*, globular *coral colonies*, *red algal* nodules, etc.) are suggestive of a depositional environment affected by heavy or periodically heavy agitation which may have been a littoral surf-affected zone.

The beds in question (mainly the upper ones) are characterized by larger or smaller, but hermatypically intergrown rudists which, on account of their enormous nutrient- and energy demand, require a clean, warm and oxygen-rich water abounding with planktonic organisms (O. KÜHN 1967). O. KÜHN supposed unicellular *Zooxantella* green algae to have supplied the oxygen that was needed to satisfy the high oxygen demand of the giant forms of *Hippurites*. Lime-secreting, green algae could be observed even directly in thin sections. The listed prerequisites for meeting the light demand of the green algae and the other conditions for the mass occurrence of Rudists were assured, in addition to the heavy agitation, by the low water depth.

The water on a quite shallow-water platform may grow quite warm. By analogy with the present-day environments, a water temperature of even 30 to 32 °C is conceivable. Paleotemperature measurements by O and C isotopes of rock samples and Hippurites, Radiolites and Alectryonia from the Köves-domb (I. CORNIDES et al. 1979) gave values between 30 and 35 °C.

It is a continuous fracturing of fossil skeletons and shells accumulating in abundance that accounts for the scarcity of both *Rudist* valves superimposed on one another in a vertical position and of the formation of genuine reef structures. Fracturing and fragmentation seem to have been caused by the mechanical and chemical effects of etching and borer organisms (traces of etching-sponges and, less frequently, borer-bivalves can be observed on the fossils), the more so by mechanical destruction as a result of wave action. Much of the mud and the finer fraction of detritus from the voids between the skeletal fragments was washed out by the water and was then deposited in the less agitated water of the lagoon. The coarse detritus was accumulated—for the most part—at the place of its birth.

Interbedded marl layers, lenses or just coatings are suggestive of changes of varying duration such as greater water depth, poorer agitation or a temporarily more heavy influx of sediment. In such cases the communities of *Rudista*, initially quite prolific, would dwindle and thin, so that the corresponding beds are now characterized by the remains of *Exogyra*, *Ostrea*, smaller Rudista and calcareous dwelling-tubes of worms.

In conclusion, the circumstances of formation of the uppermost beds may be summarized as follows:

1. The sedimentary environment was predominated, as a rule, by heavy agitation, circumstances under which calcarenite and calcirudite sediments were formed due to the fracturing and fragmentation of biogenic structures. Sometimes, pelitic sedimentation was coupled with the reduction of agitation. Because of intensive bioerosion the formation of bioclasts did not cease even in such cases.
2. The water depth was generally quite low (1 to 10 m), sunlight penetrated down to the bottom. The water may have grown quite warm.
3. Because of the constant agitation of the water its aeration was quite efficient, being well supplied with both oxygen and nutrients. The high quantity of dissolved CO_2 in the water was advantageous for the growth and proliferation of large-sized, calcareous organisms.

On the basis of the ecological analysis of the sequence, two major sedimentation rhythms can be observed to have followed the formation of the extraclastic sediments. The first one took place then, when the emergent block facing the open sea (or possibly a series blocks) was still efficient in screening the effect of wave action, and when in the background fine calcareous mud was being deposited, but the accumulation of coarse rock detritus had already ceased. That may have been the time when the rock cliff got below the wave base level of the sea, so that its desctruction did not continue anymore, though hardly any sediment could escape removal on its surface.

The assumption that during the submergence of the cliff it was on this morphological high that the formation of hermatypical communities of Rudista, algae and Hydrozoans could set in seems to be realistic.

The second rhythm began when the morphological differences in the Köves-domb subarea had been eliminated. The cliff had been reduced by erosion and sediment of reduced thickness was deposited on its surface, while the depression in the back-cliff area was filled with lime mud. It was on the resulting platform, now already quite level, that the reef-like environment came into existence which was populated by Rudist communities of varying size, and smaller coral and hydrozoan colonies and which served as a source for the large-scale production and accumulation of arenite and rudite grains spread as a level blanket on the surface. Composed of bioclast grains rounded as a result of the mechanical action of the waves, the resulting sediment is often characterized by a good sorting. This reef-like environment differed in many respects from the present-day coral reefs. A barrier-reef that might have served as a braker seems to have been absent, so a leeward lagoon could not develop either.

Facies Zones A, B, C

Distinguished in the descriptive part, Facies Zones A, B and C represent a shallow-water carbonate platform and its sloped foreset. The position and orientation of the slope are adjusted to the earlier morphological pattern.

In the following discussion the genetic conditions are interpreted by facies zones. The lithofacies types similar to those of Köves-domb are simply referred to. Emphasis is placed on pointing out the differences and explaining them.

Facies Zone A. On the basis of structural and textural characteristics, the facies zone may be interpreted as the immediate foreland of the platform facies. It follows from the interpretation of lithological analyses that bioclastic sedimentation took place near the lower boundary of the zone of wave action, but mostly below it (unsorted or two-fraction grain composition, micrite or sparry micrite matrix). The *Hippurites* of vertical position intergrown in a bunch-like pattern observable in the Kozma-tag subarea suggest that the area in question belonged—at least temporarily—to the platform already. This feature has not been observed elsewhere either in outcrop or in boreholes. Therefore we presume that the paleoenvironment of the bioherms with Rudists may have lain even farther southeast, i.e. at the top of the slope assumed earlier or on its less steep stretch. This facies now generally lost to erosion may be supposed to be analogous with the Rudist platform of Köves-domb.

Facies Zone B. As far as the facies characteristics of the borehole Süt-14 representing the southwest part of Zone B are concerned, these represent actually a transition between the Köves-domb pattern and the sequences of Hajnal-hegy–Hárs-hegy.

Enclosed in marine sediments and composed of scarcely rounded limestone- and dolomite breccia grains of local origin, the basal beds seem to have been formed similarly to the case of the extraclastic limestone of Köves-domb, being interpretable as submarine talus debris. The next lithofacies showing features of transition between the Csingervölgy Marl and the Ugod Limestone (the zone of pinching-out of the Jákó Formation) was obviously formed in an environment characterized by features representing an intermediate position between the two typical paleoenvironments.

The rock varieties of the typical Ugod Formation are basically similar to their counterparts known from the Köves-domb, but here the individual lithofacies are not pronounced so sharply; the calcareous mud and the bioclastic sediment not being completely separable. Consequently, the genetic conditions appear to have been similar to the case of the Köves-domb, but the presence of a barrier reef crucial for a distinct differentiation of the facies cannot be reckoned with here. The basic trends observed during the investigation of the Köves-domb, however, are recognizable here too. The lower aphaneritic facies is indicative, here also, of a comparatively quiet lagoonal environment protected against wave action, and then, with the filling up of this lagoon, a Rudist-breeding carbonate platform habitat invaded by the surfs or a little bit beneath the zone of wave action developed. Curiously enough, the subsequent feature to be observed here is again the presence of a lower energy level, then the level of environmental energy shows again an increase, to re-decrease eventually as late as the setting in of the deposition of the Polány Formation. It is also remarkable that in the exposures in the immediate vicinity of the borehole Süt-14 (boreholes labelled Bd) the rock types occurring at the base of the sequence are completely different. This discrepancy reflects considerable morphological differences that once existed to the east of the present-day location of the borehole Süt-14.

The Ugod Limestone sequences exposed in the Gerinc quarry and the borehole S-30—in terms of environmental interpretation—differ in important features from the Köves-domb occurrence and, in lesser measure, from that of Városi-erdő, too. Namely, in the Hárs-hegy sequences there is no purely micritic or pelmicritic rock type and there is hardly any rock type composed of well-sorted, rounded and coated grains of sparry matrix; instead of these, biomicrite rocks composed of poorly rounded or unrounded grains or a rock type composed of bioclasts in 80 to 90% amount containing hardly any matrix, are characteristic.

This means that instead of the surfy platform and cliff environment or the lagoon environment protected against wave action known from the Köves-domb, the zone of Hárs-hegy is considered to have witnessed a sedimentation taken place for a considerable length of time beneath the level of wave action. The reduction in grain size of bioclasts as compared to Zone A suggests that the deposition of the sediments took place on a slope that lay farther away from the shallow-water carbonate platform which was the source of the detrital material deposited. This is also reflected by the fact that in the middle part of the sequence beds with planktonic *Foraminifera* exhibiting lithological features typical of the Rendek Member are interbedded. At the time of deposition of the lower interval which got into the zone of formation of the Rendek Member, the depth of the bottom may periodically have reached even the 50 to 80 m value, but during the formation of the Rudist-bearing, bioclastic beds its seems to have been somewhat shallower.

The micritic or, less frequently, sparite-cemented calcarenite and calcirudite rock types in the upper interval of the sequence seem to have been formed immediately beneath the zone of wave action in a periodically agitated environment.

Facies Zone C. The northwest facies zone shows a mode a superposition markedly different from the features hitherto discussed. The Ugod Formation in this zone overlies the thick sequences of the Ajka- and Jákó- and even the Polány Formations (Rendek Member). Consequently, this subarea must have been a sedimentary basin already in an earlier period of the Senonian cycle.

The appearance of the Ugod Limestone apparently indicates a bottom that was becoming gradually shallower—a trend already referred to in our analysis of Zone B.

The predominant biomicrite rock type indicates that the beds were generally deposited beneath the wave base. The appearance of a well-rounded sparite-cemented microfacies, however, indicates that the bottom must have from time to time got into the tidal zone. A very low water depth, good penetration of sunlight and high water temperature are indicated by the abundance of coated grains (algal activities), the presence of oncoid grains (blue-green algae) and the frequency of *Miliolina*, *Dicyclina*, *Cuneolina* and *Rhapidionina*, i.e. genera of larger Foraminifera. The depth of the sea bottom tends to have decreased as one proceeds up in the profile.

On the basis of the ecological analysis of the facies zones two stages of development during the formation of the Ugod Limestone can be distinguished. The earlier stage is characterized by a steeper slope and a more pronounced difference in morphology between the platform and the basin, the second stage by an equilibration of the differences and the extension of the biogenic detrital facies to the pelagic facies area.

Polány Marl Formation

The Polány Marl Formation includes the calcareous marl and limestone beds on which the larger part of the city of Sümeg has been built and which locally crop out even from below the pavement of the streets and which are exposed, day in day out, when house foundations are excavated or wells or trenches are dug. To the northeast of the town, in the Haraszt subarea and on the hillside of the Rendeki-hegy a lot of quarries have exposed the formation.

In the Sümeg area the lower member of the Polány Formation typically composed of grey thin-bedded, laminated calcareous marls and silty calcareous marls is known. In the vicinity of the Ugod Limestone, partly intertongued with it, carbonate rock types of transitional facies occur. This transitional unit is proposed to be distinguished under the name of Rendek Member. The choice of name is justified by the occurrence of a lot of good exposures of the unit on the hillside of the Rendeki-hegy.

Local type section: borehole Sp-2

The features of the Polány Formation or, more precisely, of the lower member observable in the Sümeg area are exhibited most completely by the boreholes Sp-2 and -3. In Sp-2 (Fig. 59), on the basis of the lithological characteristics, two intervals can be singled out:

The l o w e r i n t e r v a l (93–190 m) shows the following basic features: argillaceous lime-

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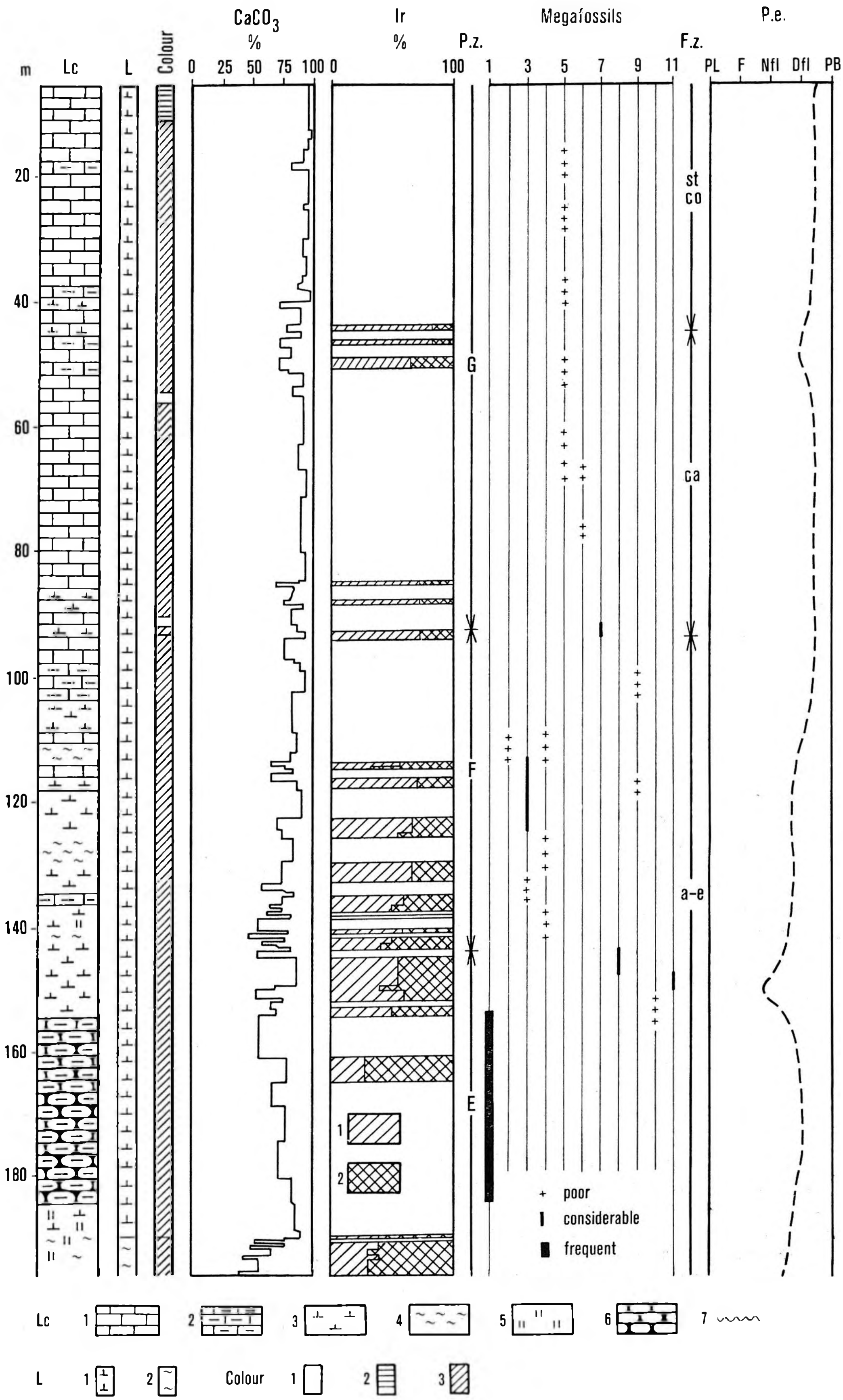
Fig. 59. The Polány Formation interval of the borehole Sp-2: lithologic log and analytical record

Lithologic column **(Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. marl, 5. silt, siltstone, 6. clay structure, 7. wavy clay-filmed bedding surface. — *Lithostratigraphic units* (L): 1. Polány Marl Fm., lower member, 2. Jákó Marl Fm., upper member. — *Colour:* 1. white, 2. dark brown, 3. light grey. — *Grain composition of insoluble residue* (Ir): 1. clay, 2. silt. — *Palynological zones* (P.z.) — *Megafossils:* 1. Aptyxiella flexuosa, 2. Pectunculus sp., 3. Ostrea sp., 4. Pycnodonta vesicularis, 5. Inoceramus regularis, 6. I. balticus, 7. Corbula sp., 8. Limopsis sp., 9. Tellina stoliczkai, 10. Cucullacea austrica, 11. Gervilleia solenoides. — *Foraminiferal zones* (Fz): *st-co*** Globotruncana stuarti — **G. conica Zone; *ca* Calcarata Zone; *a—e* G. arca — G. elevata Zone. — *Paleoenvironment*** (P.e.): *PL* carbonate platform, *F* front-reef (platform margin), *Nfl* nearby foreland slope, *Dfl* distant foreland slope, *PB* pelagic basin



m
Lc
L
Colour
CaCO3 %
0 25 50 75 100
Ir %
0 100
P.z.
Megafossils
1 3 5 7 9 11
F.z.
P.e.
PL F Nfl Dfl PB
20
40
60
80
100
120
140
160
180
G
F
E
st co
ca
a-e
1
2
+ poor
considerable
frequent
Lc 1 2 3 4 5 6 7
L 1 2
Colour 1 2 3

stones, calcareous marls, silty calcareous marls and, less frequently, limestone and marl beds alternate in it ($CaCO_3$ content 60 to 95%, the noncarbonate fraction is constituted, in about 50%, by pelites, in 50% by detritus of silt size).

In the more carbonate parts of the sequence a thin-bedded structure (with beds of 0.1–1.2 m thickness) is characteristic. The beds of argillaceous limestone or limestone are separated by uneven bedding planes covered by argillaceous marl or by clay layers of a few cm thickness. The calcareous marl rock type is characterized by laminated, the marl by foliated, jointing. Layers of bioturbated structure and traces of worm tracks, a few cm long and 0.2 to 0.8 cm in diameter, usually parallel to the bedding planes, are quite frequent and conspicuous. A structure due to mud cracking in a plastic state (plast-dotted pattern), mud creep features and nodularity are typical of the lower 20 to 40 metres of the sequence composed of argillaceous limestones, but they can be observed, in a reduced proportion, even higher up the profile.

The rock colour is generally light grey or, locally, because of subsequent oxidation of the dispersed pyrite content, light brown.

The rock texture is predominantly biomicrite with a fossil content of about 30%. Pelletal, intraclastic rock textures do also occur. The matrix consists for the most part of the detritus of microfossils (*Calcisphaerulidae*, planktonic *Foraminifera*) and skeletons of nannofossils. Tiny detritus of mollusc and echinoderm skeletons and valves of *Ostracoda* are usually abundant.

The foraminiferal fauna is characterized by the joint presence of both planktonic *(Hedbergella, Globotruncana, Globigerinelloides, Heterohelix)* and benthonic *(Arenobulimina, Gavellinella, Stensiöina* and *Goupillaudina)* forms and their nearly equal amounts.

In the upper part of the sequence (6–93 m) the lithofacies is represented by limestone and argillaceous limestone ($CaCO_3$ 90–95%), only in the 44.0 to 51.5 m interval does the carbonate content drop below 75%.

The rock is of light grey colour with a darker shade in the more pelitic interval.

The rock structure is characterized by beds separated by a thin clay film and by slightly wavy bedding surfaces, less frequently the beds are covered by a thin dark grey clay film. Bioturbation, as a rule, is poorly manifested. In rare cases, even microlamination may be observed. Structures of a plast-dotted pattern resulting from mud cracking and mud sagging are common. Some horizons abound with traces of narrow (0.3 to 0.8 cm in diameter) worm tracks.

The texture is micrite with a low quantity of tiny mollusc and echinoderm debris and planktonic microfossils. The biogenic grains show a modest decrease upwards. The matrix-micrite is constituted primarily by the tests of nannofossils. Of the noncarbonate mineralogical components it is pyrite that may be mentioned, partly filling the cavities of microfossils, partly showing a scattered distribution independent of the former or, less frequently, forming large lumps.

Megafossils are seldom found in the rock. In addition to poorly preserved *Echinoidea* remains, some well-preserved *Inoceramus* specimens were found (Fig. 59). Fish scales and tiny coalified vegetal detritus occur sporadically too, The microfossils attain a considerable quantity. From among the Foraminifera it is the planktonic forms *(Globotruncana, Herohelix Hedbergella)* that predominate, though benthonic forms are also frequent, being primarily represented by arenaceous ones *(Spiroplectammina, Textularia, Verneuilina, Tritaxia, Gaudrina, Clavulina, Arenobulimina, Marssonella, Dorothia, Ataxophragmium)*. From among the calcispherulid microfossils the representatives of *Stomiosphaera* and *Pithonella* are very frequent.

In the borehole Sp-3 to the northwest of the borehole Sp-2, i.e. in the direction of the one-time basin, the formation is more pelitic throughout its vertical extent as compared to the case of the borehole Sp-2, the subunits distinguished over there being unidentifiable here. Outcrops of rocks identifiable with the lower part of the Polány Marl intersected in the borehole Sp-2 are known to us on the Haraszt-legelő and on the southwest side of the Rendeki-hegy. In the Haraszt subarea near the boundary between the lower and upper subunits, authigenic breccia beds or rocks containing sporadical debris deriving from the fine calcarenites of the Ugod Limestone can also be observed to crop out. The grains vary in size between 0.5 and 30 cm, being unrounded or just very poorly rounded. The grading in the exposure shown by X in Fig. 31 can be observed, too. The lenticular rock body is a few m in thickness. As suggested by the description, this rock body was intersected by the borehole Sp-2 between 54.0 and 55.5 m.

The strata in the abandoned quarries on the northwest side of the Rendeki-hegy can be identified with the upper part of the Sp-2 borehole sequence (this being exposed there in about 10 to 15 m thickness). The rock exposed by the quarries is generally represented by argillaceous limestones and calcareous marls, locally with single, thicker (a maximum of 1 m) carbonate interbeds. From among the megafossils only the sporadical representatives of Inoceramus and Echinoidea may be mentioned.

Rendek Member

The Rendek Member is characterized by finely crystalline, argillaceous limestone or pure limestone which is of grey or yellowish-brown to brown colour owing to post-sedimentary oxidation. The sedimentary structural characteristics are similar to the case of the lower part of the Polány Formation as exposed in the borehole Sp-2, the only difference consisting primarily in the higher carbonate content. The nodular and plast-dotted features are conspicuous, worm tracks and bioturbated structures abound. In rare cases detrital grains from the Ugod Limestone and, in some beds, even rudist detritus can also be observed.

At the lower member boundary, as a rule, an *Exogyra–Pycnodonta* lumachelle layer is observable.

The characteristic texture is biomicrite and biopelmicrite. The fossil debris are generally 20 to 60 μm in size, grains over 100 μm being quite sporadical.

In the microfauna it is benthonic Foraminifera, primarily *Bulimina, Nodosaria* and *Textularia*, that predominate. In the lowermost subunit the representatives of *Goupillaudina* are frequent. Bioclasts consisting of *Mollusca, Ostracoda* and *Echinodermata* remains are common.

As local type section of the member, the profile of the borehole Ck-168 is presented (Fig. 57). Beds of similar nature are exposed in the boreholes Ck-167, Cn-598, S-29, Süt-14, -16, -19, -22 and S(G)-5 as well, though the mode of superposition of the member may vary from section to section. Outcrops are known to us from the Városi-erdő, the northern part of the Köves-domb, in the western part of Sümeg in an abandoned quarry and also to the northeast of the Vár-hegy.

Relation of the Formation to the neighbouring units

In judging the spatial relations of the Polány Formation the following observations may be relied on:

1. In the northernmost boreholes (Sp-2) it is the Jákó Formation that underlies the Polány Formation, the Ugod Limestone being obviously absent in these areas.

To the south of here, by and large in the municipal area of Sümeg, the boreholes have not exposed beds belonging to the Ugod Limestone either, but the essential difference compared to the previous case is that here the Polány Formation, is for the most part, lost to erosion. Namely, it may be presumed that the Ugod Limestone's beds used to extend like tongues between beds of the Polány Formation. This is suggested by the exposures at the east foot of the Vár-hegy in which limestone beds with rudist detritus and Exogyra are observed between laminated calcareous marls with worm tracks as well as by the tiny rudist detritus observed in the 9 to 20 m interval of the borehole Sc-4/2 and the borehole Süt-18 and on the hillside of the Rendeki-hegy.

2. On the hill range to the east of Sümeg, in the zone Hajnal-hegy–Hárs-hegy–Kozma-tag N, boreholes (S-29, Cn-589, Ck-167, -168, -169, -170 and -171) exposed the Rendek Member of the Polány Formation as underlying the Ugod Limestone.

Although no conclusive evidence is available to us, it may be supposed that above the eroded upper parts of the Ugod Formation rocks exhibiting features of the Rendek Member lie again.

3. As observable in the vicinity of the Köves-domb and in the borehole Süt-14 on the margin of the Városi-erdő, the Ugod Limestone overlies directly the marginal facies of the Rendek Member or it rests directly on the pre-Senonian basement without an Ugod Limestone in-between. On the other hand, the rocks of the Rendek Member are found to overlie the Ugod Limestone. The superposition in the northwest part of the Köves-domb is traceable even on the surface, being quite distinct in the northwestern face of the Sintérlap quarry as well (Fig. 54).

In the uppermost 25 m of the Senonian sequence (as preserved in a minor fault block), exposed by the borehole Süt-14 too, it is above rocks assignable to the Ugod Formation that rock types characteristic of the Rendek Member are encountered (Fig. 56). This subunit stands close in character to the rocks exposed in the topmost part of the borehole S-29 on the hillside of the Hárs-hegy.

Because of denudation that took place repeatedly in post-Senonian time it cannot be found out whether additional rudist-bearing limestone bodies, lenses or possibly bioclastite tongues jutting in may exist, or not, above the beds assignable to the Polány Formation. The only thing we can do in this connection is to admit that the one-time existence of such bodies cannot be precluded. Moreover, an extrapolation of the profiles from Fig. 58 seems to corroborate such a possibility.

4. In the southeast belt of the Senonian-covered part of the hill range no Polány Formation rock can be encountered. Rocks of this kind were not formed at all prior to the birth of the Ugod Formation, while those that may have existed as overlying this formation have been probably lost to erosion together with the higher parts of the Ugod Formation (exposures in the southern part of the Surgo-tag and Kozma-tag).

Bio- and chronostratigraphy

In the general description of the formation we have mentioned that, at its lower boundary, the change in the lithological features is coupled with parallel changes in the nature and composition of the fossil assemblage. The remains of planktonic organisms become significant and the benthonic assemblage, in turn, is characterized by the total absence of euryhaline forms.

Particularly important from the viewpoint of long-distance stratigraphic correlation is the occurrence of cosmopolitan species and the presence of fossils of a wide lateral distribution and short stratigraphic range. Beside the few Ammonite remains it is primarily spores and pollen grains, Foraminifera and bivalves that may come into account for time correlation.

The spore-pollen material of the borehole Sp-2 was studied by F. Góczán (1964) (Fig. 59). He assigned the rock of the lower part of the sequence to Zone E characterized by the predominance of *Krutzschipollis* and *Suemegipollis* and to Zone F with the predominance of species of the genus *Longanulipollis*. In the upper part, Zone G showing the predominance of *Pseudopapillopollis* div. sp. and *Semioculopollis minimus* could be identified.

In the borehole Sp-1 too, Zones E and F were identified by F. Góczán, but the boundary between the two zones here fell close to the lower formation boundary and in the uppermost samples already a spore-pollen assemblage indicative of Zone G could be observed.

In the borehole Süt-22 J. Bóna determined a *Longanulipollis–Krutzschipollis* assemblage characteristic of Zone F. The uppermost sample belongs, as suggested by the predominance of *Pseudopapillopollis praesubherzynicus*, already to Zone G.

Thus, in terms of palynostratigraphy, the rocks of that part of the Polány Formation exposed at Sümeg may be assigned to the Upper Campanian (Zones E and F) and the Lower Maastrichtian (Zone G), respectively.

According to foraminiferal results (M. Sidó 1961, 1980), the lower part of the formation in the borehole Sp-2 can be shown to include a *Globotruncana arca–G. elevata* assemblage zone. It is at about 100 m above the lower formation boundary that specimens of *Globotruncana calcarata* appear (between 45 and 94 m). Above this, forms belonging to the *Globotruncana stuarti–G. conica* assemblage zone could be observed. If we accept, on the basis of the international literature (H. Bolli 1960, E. A. Pessagno 1962, I. Sigal 1977, Van Hinte 1976), that the range of *Globotruncana calcarata* spans the uppermost part of the Campanian, so *that* part of the Polány Formation exposed in the borehole is of Upper Campanian to Lower Maastrichtian age.

In the lower part of the formation peculiar benthonic assemblages are observable. This is of primary importance for local correlation, as over a large part of the territory only the basal beds of the formation are preserved. The top of the Vaginulina Zone distinguished by M. Sidó during her study of the borehole Sp-2 (1961) coincides with the lower boundary of the formation, while the Gavellinella Zone can be recognized in the basal part of the formation.

In corresponding intervals of other boreholes studied from the northwest subarea (Sp-1, Süt-22, -18, -19, -16 and Sc-4/2, similar trends of change in the foraminiferal assemblage can be observed and the zones singled out at the base of the formation in the borehole Sp-2 can be relatively well identified. Based on M. Sidó's and R. Kopek-Nyírő's determinations from a decanted material and on our thin section analyses, the following general trends are recognized: near the lower formation boundary the species of *Vaginulina*, heretofore present in a very significant amount, will disappear or become greatly reduced in quantity (upper boundary of the Vaginulina Zone). As for the genus *Goupillaudina*, also present in a considerable quantity, its vanishing occurs only higher up the profile, at 10 to 20 m above the lower formation boundary. *Stensiöina* reach the maximum of their quantity in the same interval. The representatives of *Gavellina*, however, remain quite frequent even after the disappearance of *Vaginulina*, *Goupillaudina* and *Stensiöina*. Consequently, we have all reason to identify the interval immediately overlying the lower formation boundary in the boreholes just listed with the Gavellina biozone designated in the borehole Sp-2. It is in this interval that *Bulimina* and *Lenticulina* and some arenaceous forms such as *Tritaxia*, *Dorothia* and *Globigerinelloides* grow abundant. The amount of planktonic forms increases as one proceeds upwards.

On the basis of *Bivalvia* and *Gastropoda* from Sp-2, L. Czabalay (1961) distinguished an Exogyra horizon at the lower boundary of the Polány Formation and Aptyxiella-, Gervilleia- and Ostrea horizons higher up the sequence. Actually, the horizons are a result of the succession of fossil assemblages varying with changes in sedimentation. Since the assemblage of benthonic organisms on the sea bottom may often change even within a short distance, it is not surprising that the succession typical of the type section does not repeat itself in an unchanged form in exposures that lie very close to one another. An exception to the rule seems to be the Exogyra horizon, for, as already mentioned, the presence of lots of *Ceratostreon matheronianum* (d'Orb.), a form earlier referred to as *Exogyra matheroniana*, at the formation base is common.

As far as the Aptyxiella horizon is concerned, it is no longer present in either the borehole Sp-1 and -3 or Süt-22 and -18. The predominance of *Gervilleia solenoides* Defr. too is restricted to the above-outlined position in the borehole Sp-2 only. In the borehole Sp-3 it shows an increased abundance partly in the Exogyra horizon, partly underneath, while in the borehole Sp-1 it has not been observed at all. Another difference consists in the fact that in the borehole Sp-2 it occurs in association with *Pycnodonta vesicularis* (LAM.), while in the boreholes Sp-1 and Sp-3 it is dissociated. Similar is the case with the predominance of *Ostrea* typical of the next horizon. In the boreholes Sp-2 and -3 *Inoceramus balticus* could be shown to occur in the upper part of the formation and *I. regularis* D'ORB. higher up the sequence.

L. CZABALAY pointed out that, in France, Yugoslavia, the Crimea and the Caucasus, *Ceratostreon matheronianum* (D'ORB.) reached its quantitative maximum in the Upper Campanian and that *Pycnodonta vesicularis* (LAM.) did it in the Maastrichtian. As shown by Soviet and German authors, *Pholadomya granulosa* ZITTEL and *Gervilleia solenoides* DEFR. are characteristic of the Upper Campanian. The occurrence of *Inoceramus regularis* D'ORB. is suggestive of the lower part of the Lower Maastrichtian.

Based on a material recovered from the quarries of Haraszt, the *Echinoidea* of the formation were monographed by E. SZÖRÉNYI (1955). Species identified: *Conulus albogalerus* KLEIN, *C. globulus* KLEIN, *C. raulini* (D'ORB.), *C. subsonicus* (D'ORB), *Echinocorys sulcatus vulgaris* BREYNIUS and *Micraster (Gibbaster) fastigatus* KLEIN.

Ammonites are scarce. Beside a few *Scaphites*, one specimen of *Pachydiscus neubergicus* SCHLOTH. sampled by J. NOSZKY Jr. from the Városi quarry in the Haraszt subarea is known. In terms of the Ammonite chronozonation, this species is the zonal index fossil of the Maastrichtian Stage. Since the borehole Sc-4/2 was spudded in the yard of this quarry, an exact interregional correlation is possible. A comparison of the sequences suggests that the recovered specimen may have derived from the upper part of the lower interval of the Polány Formation.

Let us summarize our fossil-based interregional correlation considerations by saying that the chronostratigraphic content of the Polány Formation spans the interval from the Upper Campanian up to the lower part of the Maastrichtian. In most exposures, however, only the lower part of the formation, i.e. that assignable to the Campanian, can be observed, because, in part, the higher horizons are occupied by the Ugod Formation as a heteropical counterpart and, in part, the uppermost, younger beds have been lost to erosion.

Paleoenvironment

In analyzing the paleoenvironment, we may start from our paleoecological knowledge derived from the structural and textural features and from the fossils available. The peculiar biomicrite texture and the fact that a sparry matrix cannot be observed to cement the grains at all, are suggestive of a sedimentation on a sea bottom not affected by wave action. The frequency of mud creep and sagging phenomena and the so-called plast-dotted structure suggest that the sediment still unconsolidated or not completely consolidated after its primary deposition may have undergone a little bit of downslope movement and thus been rearranged. In the light of data concerning the phenomena of movement of modern sea bottom sediments of similar grain size, we need not think of a slope of considerable steepness, for slumping may start on a slope of a few degrees already.

With a view to the foregoing, it may be suggested that the lower part of the formation, or the Rendek Member in which the above features are common, was formed on a slope of low steepness beneath the zone of wave action. As regards the dip conditions of the slope, we may have some idea based on the ecological analysis of older formation, but we cannot prove this, nor can we estimate the absolute depth on the basis of fossils.

Generally predominant in the study area at the lower formation boundary, the representatives of *Ceratostreon (=Exogyra)* are epibenthonic organisms that lived in the infralittoral region. The fact that specimens of this genus are common even in the more pelitic sediments between the Rudist-bearing limestone beds of the Ugod Formation and also that at the lithological contact between the Ugod and Polány Formations they tend to grow consistently enriched suggests that these organisms must have well endured ecological conditions similar to the case of the *Rudista* communities extremely sensitive to changes in environmental parameters and bound to quite shallow waters. However, the fact is that they were very far from reacting so sensibly to changes in ecological factors as it was the case with the *Rudists*. It appears that *Ceratostreon (Exogyra)* forms were the first to invade quite systematically the ecological niches that had been becoming unfavourable for the *Rudists* (primarily *Hippurites*). (The disadvantageous conditions may have included the growth of the rate of deposition of pelitic, silty sediments, the worsening of oxygen supply and the increase in water depth.) Since the Hippurites community seems to have dominated the 1 to 10 m depth range, the statement that the predominance of Ceratostreon was confined to the 10 to 30 m water depth interval seems to be acceptable.

As we have seen, the upper member of the Jákó Formation was deposited on a terrain that had been by and large planated and that was sloping gently northwards. Thus the marked increase in

$CaCO_3$ content indicative of the formation boundary and the horizon of enrichment of Ceratostreon seem to have been brought about at approximately the same time over the area of distribution of the formation and the bottom on which these processes took place seems to have been an invariably very gently sloping one. Eventually, the steepness of the slope would increase, for the Rendek Member on the landward side is covered by Rudist-bearing limestone beds suggestive of an even more shallow environment (even though these are of slope-deposited bioclast origin rather than deriving fiom tbe reef body), while in the basinward tracts, an overall trend of increase in pelagicity and a probably parallel trend of increase in depth is suggested by several factors, first of all, by the *Foraminifera.*

Analyzing the composition of the foraminiferal fauna, we observe that the planktonic forms tend to increase in number as one proceeds northwestwards and, in the northwest subarea, from the bottom to the top of the sequences. The amount of planktonic microfossils of *Calcispherulidae* type grows similarly. This must suggest an increase in pelagicity in the given directions.

From among the benthonic Foraminifera the arenaceous forms in the southwest subarea are scarce, but in the northwest they are quite abundant in some horizons of the upper interval. The appearance in larger quantity of arenaceous forms suggests such a bottom water from which the precipitation of carbonate shells requires high energy, consequently, a sea bottom covered by comparatively cold water beneath the photic zone.

On the southeast margin *Orbitoides* specimens absent in the material of the northwest exposures can be observed in the Rendek Member. These forms of larger size in the Tethyan realm occur always in the immediate vicinity of Rudist reef environments. It is very probable that, similarly to the case of the Foraminifera (Elphidium, Ammonia, etc.), the segregation of carbonate needed for building the large shells was accomplished by means of a symbiosis with algae. In this case their confinement to the photic zone readily penetrated by sunlight is apparent. All these circumstances suggest that the scene of deposition of rocks constituting the Rendek Member was that part of the one-time submarine slope lying below the wave base, but still falling in the zone well-penetrated by sunlight (i.e. appr. depth of 10 to 30 m). The northwest, deeper, part of the slope in turn lay deeper than the photic zone. Taking the one-time depth in the line of the borehole S-29 to have been 40 m and reckoning with a slope angle of 3° (slump-affected slopes dip generally at 2 to 4°), the depth of sea bottom in the area between the boreholes Sp-2 and Sp-3 is estimated at 160 m. This depth does not contradict the value that can be estimated on the basis of the ecological evaluation of *Foraminifera* and *Mollusca.*

In those sequences of the northwestern subarea which have exposed the Polány Formation (boreholes Sp-2 and -3) the fossil assemblage indicates a continuous pelagic paleoenvironment. This is suggested by the basically nannoplanktonogenic fraction of the rockforming micrite matrix, the predominance of the planktonic microfossil assemblage and the nektonic organic remains.

The pelagic environment did not imply any considerable distance off the coastline—a fact indicated by the composition of the pollen flora of the formation.

In the context of water depth the following conclusions can be drawn: the textural features, and the lack of green algae and presumably of animals in symbiosis with green algae are suggestive of a paleoenvironment that lay below the zone of wave action and the photic zone.

The relative frequency and specific diversity of benthonic fossils, however, makes it probable that the water depth may not have exceeded the depth of shelf seas (about 200 m).

Because of large-scale oxygen production by the wealthy nannoplankton the upper water layers may have been rich in oxygen. The deeper-situated water layers and primarily the interstitial water of the mud grains being deposited, seem, on account of the large-scale decomposition of organic matter, to have represented a reductive environment—a hypothesis corroborated by the disseminated pyrite content observable throughout the respective sediments.

The wealth of organic matter in the mud is suggested by traces of suspension-feeding, burrowing organisms.

The alternation of an undisturbed microlamination suggestive of quiet sedimentation with intervals carrying features of slumping in the upper part of the sequences of the Polány Formation exposed in the Sümeg area suggests a very gentle slope of the bottom attaining just a few degrees with phenomena of periodical movement confined to the uppermost mud layers.

An episodical intensification of slope-generated sediment movement may have been responsible for the lenticular accumulations of lithoclasts in the Haraszt sequence which appears to coincide with the formation of the thick breccious rock body (the Jákóhegy Breccia Member) observed in the northern Bakony exposures and also in boreholes at Magyarpolány and Devecser that may be indicative of a revival of tectonic movements.

Let us sum up the facts above: The scene of formation of the Rendek Member was the deeper-situated, rather gently dipping part of the slope that connected the relatively elevated platform zone of the southwest subarea and the deeper-situated northwest basin portion. In the deeper northwest basin portion (the lower member of the Polány Marl showing the most typical features of the formation) sedimentation took place on an externally neritic, limemud-covered sea bottom of 100 to 200 m depth and of a gentle slope. Pelagicity and water depth are supposed to have gradually increased with the progress of time.

Paleomorphological reconstruction

In the light of the facies and thickness conditions of the Upper Cretaceous formations of Sümeg we have attempted at analyzing in more detail the morphological conditions that existed at the beginning of the Senonian sedimentary cycle—an analysis providing the basis for the reconstruction of the geohistorical process.

In outlining the paleomorphological image we may first refer to the charts showing the distribution and extension of the individual formations which were presented in their discussion (Fig. 32, 34, 42 and 48). Comparing these, we can see very well that the younger formations tending to acquire an increasingly more marine facies form regular belts transgressing beyond the older ones. Taken in itself, this very image is apt to suggest that two basical morphological provinces, a deeper, northwest one and a relatively higher-situated, southeast one, may have existed for a very long time—at least from the deposition of the terrestrial sediments up to the formation of the rudist-bearing limestones—in the study area and that the contemporaneous slope that lay between the two provinces is marked

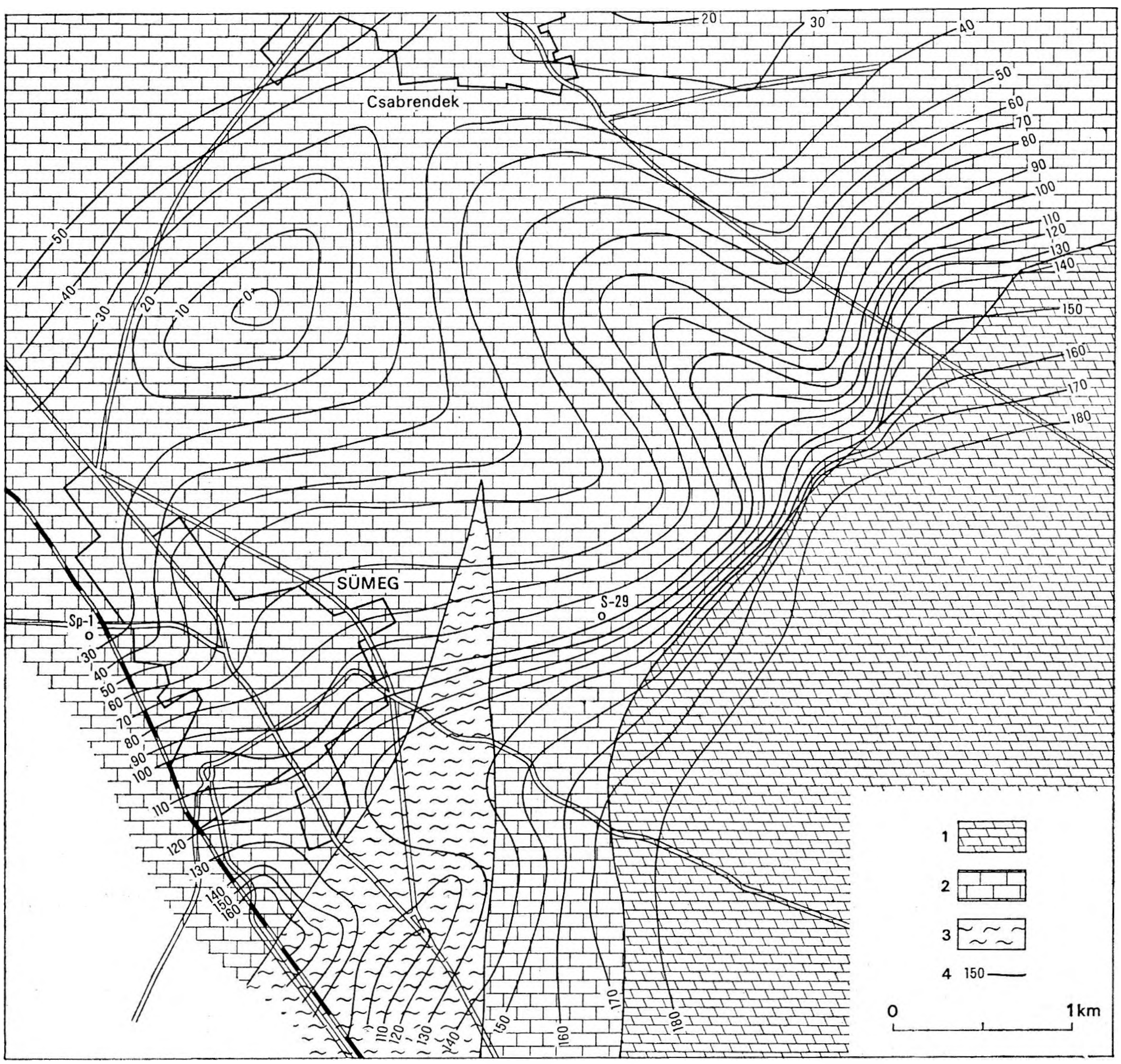


Fig. 60. Paleogeographic and paleomorphologic reconstruction
1. Dolomite, 2. limestone, 3. marl, calcareous marl, 4. supposed contour lines of paleorelief

by parallel, northeast-southwest trending zones of modest width resulting from the overlap of the successive formations.

Such an image is corroborated and new details are shed light upon by the isopach map of the Ajka Formation (Fig. 60) with isopachs distinctly parallel with the marginal boundary line of the formation. As shown in discussing the profiles, the integrate area of distribution of the formation can be divided, on the basis of the characteristics of the sequences, into a northwest and a southeast subarea, the latter being overlapped only by the marine-brackish beds of higher stratigraphic position. The limit of extension of the freshwater (Foraminifera-free) sediments is parallel to the outer boundary of extension of the Ajka and Jákó Formations, too. All in all, the simplest way to illustrate the situation is to design a model according to which an area of mild relief showing a gentle overall rise from the northwest to the southeast becomes gradually inundated, probably in the course of a regional subsidence. If we accept this, then the boundaries of pinching-out of the afore-listed formations and also the facies boundaries (limno-brackish–marine-brackish), and even the isopachs of the Ajka Formation and the Jákó Formation or the Csingervölgy Member, respectively, may be taken to represent almost a kind of contours, for all these indicate, by and large, the one-time line of intersection of water level and relief. The advancing transgression will quasi fathom the one-time relief and preserve it by the protective cover of its sediment. The geomorphological map shown in Fig. 60 is based on this assumption, too. In plotting it, we have started from such basic features as the boundary lines of extension of the formations and the isopachs and facies characteristics of the sediments overlying the substratum. Namely, if a simple subsidence is the case, the difference in altitude between the individual points of the pre-Senonian basement can be assessed. The outer boundary of the Ajka Formation will give the line of intersection of water level and relief at the start of formation of the Csingervölgy Member, and if the estimated water depth for each particular point and the thickness of the Ajka Formation are substracted, the land surface prior to subsidence and accumulation will be restored. When plotting the paleomorphological map, we used, for the case of areas beyond the boundary of the Ajka Formation, the thickness data of the overlapping Csingervölgy Marl.

Naturally, the real picture may have been more or less different, more complicated, compared to our model. For example, it would be easy to imagine that during the long time span of transgression the rates of subsidence varied from subarea to subarea even within this comparatively small area, distorting our model from the reality. Nevertheless, in the light of the observations quoted, we believed that this very simple model would give a good approximation.

On the basis of our model the following geomorphological image for the date of start of Senonian sedimentation may be reconstructed (Fig. 60): the highest-situated part of the area lay to the southeast of the Városi-erdő–Surgo-tag–Kozma-tag line; it was connected by a northwest-southeast trending slope with an almost level, horizontal subarea that was slightly inclined to the northwest. Nearly normal to the NW–SW main direction extended morphological elements of second-order importance such as minor elevations and depressions. The most significant of these may have been a flat ridge of about 50 m relative height which now extends beneath the Rendeki-hegy and which seems to have been comparatively narrow. A ridge of similar orientation, but by far less elevated, is supposed to have existed in that part of the Sümeg area, where the terrestrial deposits are missing (Fig. 32).

To the west of the present-day Hárs-hegy the steepness of the slope separating the principal morphological elements was more reduced and its orientation seems to have turned N–S. The original configuration is difficult to decipher owing to possible subsequent tectonic deformation.

On the geological map (Fig. 3) of the rocks underlying the Senonian, giving a portrayal of pre-Senonian paleogeology, there appears a feature that seems to support our image of the one-time morphology.

Bringing the Norian Hauptdolomit and the Rhaetian formations into contact with each other, the tectonic line extending through the Surgo-tag–Kozma-tag subareas has a position and orientation very well coinciding with the position and strike of the one-time elevation reconstructed. It is obviously no accident either, that the slope of a rough morphology has been formed exactly on the surface of the Rhaetian marl and limestone sequence less resistant to weathering.

In fact, minor faults parallel to this distinct structural line may have been involved in the process responsible for the above paleomorphological image, too. These tectonic lines, however, are difficult to detect in a direct form, because they are not responsible for the juxtaposition of dissimilar lithological types.

On the basis of this model it is expected, and can even be verified by tests, that on the benches of gradually higher position—as one proceeds from the northwest to the southeast—the formations of identical facies (lacustrine, marine) will appear gradually later. Within the individual benches the particular facies may be regarded as geologically isochronous.

The effect of the initial morphology upon Senonian sedimentation and the course of the inundation process are discussed in the chapter "A geohistorical summary".

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Bauxite

by

E. J.-Edelényi

The Sümeg area is situated on the western edge of a more or less continuous bauxite belt extending along the northern margin of the southern Bakony Mts. At present, the westernmost deposits of the paleogeographically controlled bauxite belt are known from here. An added bauxite geological significance of the area is due to the fact that, in addition to bauxites redeposited between younger formations, bauxite deposits are known to occur in two unconformity horizons. The study area belongs to the northwest part of what is called an "area with double bauxite horizon" intensively explored by the Bauxite Exploration Company.

Overlying the karstified surface of Upper Triassic formations, the bauxite bodies are partly covered by Upper Cretaceous sediments and within the same area there are local accumulations of Eocene-covered bauxites sitting in karstic dolinas of the Ugod Limestone.

Exploration history

The bauxite geological significance of the area has been known since 1929, when K. Telegdi Roth, during his prospecting for bauxite on behalf of the Geological Survey, judged the area worthy of detailed exploration, as he had found traces of bauxite on the surface of the Hauptdolomit in the Szőlő-hegy and the Nyírádi-erdő. At the base of the Upper Cretaceous, more precisely under the hippuritic limestone, he did not find any terrestrial formation. Upon exploration projects designed by E. Vadász and T. Kormos, the exploration had started in 1938 under E. Vadász' direction and the Hajnal-hegy and Szőlő-hegy deposits (lenses) thus discovered were soon stripped off. In 1945, after making traverses through the area east of Sümeg, L. Bartkó suggested the presence of a multiple of the bauxite resources known heretofore.

Shallow boreholes spudded in the course of a bauxite-exploration-oriented geological mapping by K. Barnabás in the Halimba–Sümeg area (1951) did not explore any bauxite in the vicinity of Sümeg.

Geological mapping in 1957 directed by J. Noszky detected a bauxite lens of small size in the Kozma-tag subarea. Detailed laboratory analyses of materials sampled from the Szőlő-hegy, Surgó-tag and Kozma-tag deposits were carried out by Gy. Bárdossy (1961). In terms of his results, the Al-minerals of the bauxite resting on the Ugod Limestone are represented primarily by boehmite with which gibbsite is associated in lower quantities, its chemical composition being similar to that of the bauxite from Nyírád. In his opinion, the bauxite was formed in the Turonian and then buried by Senonian formations and after the overburden had been lost to erosion to the beginning of the Eocene, it was redeposited from a rather short distance. Thus, he did not suppose any bauxite formation to have taken place at the beginning of the Eocene.

Upon geophysical measurements in the Sümeg–Csab-puszta area a large-scale exploration by the Bauxite Exploration Company was embarked upon in 1970 in an area forming the continuation of the Nyírád deposit. From the mid-sixties on, the exploration was concentrated in the northwest part of the Nagytárkány deposit and—in addition to the Eocene bauxite horizon—it discovered bauxites underlying Senonian deposits over an area of considerable size. Still going on, the exploration has resulted in the discovery of several bauxite lenses already stripped off by opencast extraction.

Earlier exploration reports on the study area dealt in varying depth with an examination of the bauxite material. In the course of practically-oriented studies, first of all the conventional chemical analyses were carried out, to which a few mineralogical analyses were added. The final exploration reports tackled the question of genesis just tangentially: the post-Upper Cretaceous bauxites were considered to have been repeatedly redeposited.

The reports made in recent years have already dealt in detail with the chemical and mineralogical compositions of the bauxite complex. The intra-deposit variation of the amounts of the "main elements" and their correlations were examined by up-to-date mathematical, computerized techniques and great attention was paid to studying the geological features of the beds immediately overlying the Eocene bauxite sequence.

Lithological, lithostratigraphic and paleogeographic studies of rocks overlying the Upper Cretaceous bauxite sequence were performed by J. Knauer and Mária Gellai (1978) and M. Gellai and F. Ludas (1983), respectively. An analysis of the relationship between the Eocene bauxite and the formations overlying it was carried out by K. Tóth (1980).

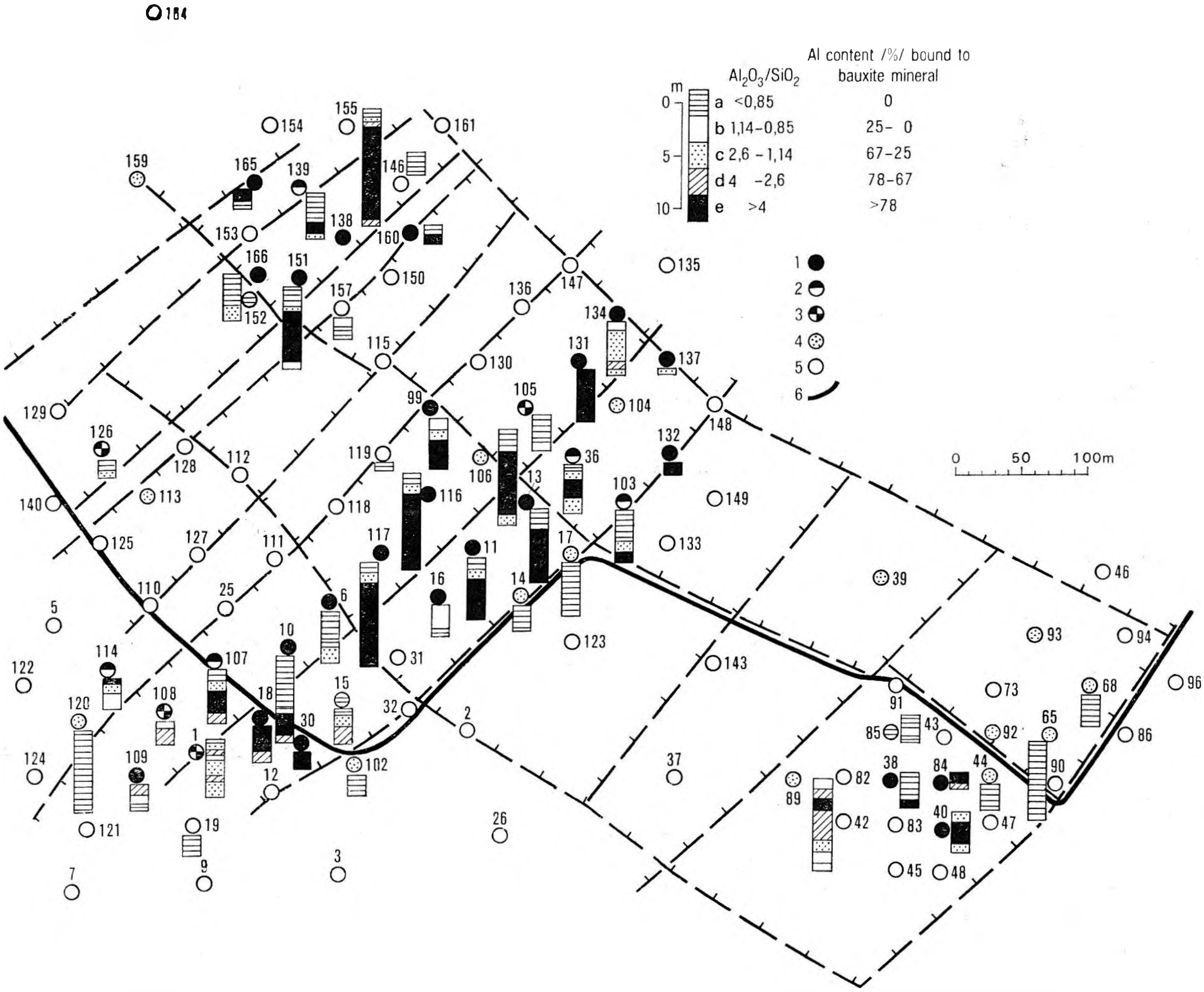

Fig. 63. Structure of the bauxite lenses of Kozma-tag (based on boreholes labelled Ck)

a) clay, *b)* bauxite clay, *c—d)* argillaceous bauxite, *e)* bauxite. — Bauxite lens: 1. its central part, 2. its transitional zone, 3. its marginal zone; 4. argillaceous zone surrounding the bauxite lens, 5. no bauxite cut in the borehole, 6. southern boundary of extension of the Eocene

The other important subarea is the vicinity of Csab-puszta, where several lenses are known, a few of which, rather small in size, occur still within the study area. In these lenses the maximal thickness of the bauxite exceeds ten metres, being even more in the lenses outside the study area. Here the bauxite sequence locally contains some interbedded layers of carbonaceous clay. Its immediate overburden is constituted, according to the data available, by light grey to greenish-grey marls with interbedded conglomerate layers which are overlain by the Ajka Formation.

The weight percentages of the main components of the bauxite-bearing sediments are shown by the results of their chemical analysis for five components (Al_2O_3, SiO_2, Fe_2O_3, TiO_2 and loss on ignition). Although the given sections are characterized by a variation of the main chemical components, they are suitable for a comparison of the particular sequences, but they give little reference to the genesis. Most essential feature of the bauxite-bearing sediments giving the greatest number of clues to an understanding of the genetic circumstances is, in our opinion, the progress of the bauxitization process. Information on this is provided, if the formation of the bauxite minerals from clay minerals be postulated, by the proportion of Al bonded to clay minerals or bauxite minerals, respectively.

In the lenses of Csab-puszta it is often a grey or yellow argillaceous rock that occurs at the base of the bauxite sequence. It is overlain by bauxitic clays or argillaceous bauxite in which the total Al content in an oxy-hydroxide form attains a maximum of 25% or 78%, respectively. This is followed, higher up the profile, by the bauxite part of the bauxite complex in which more than 75% of the total Al content is connected with bauxite minerals. The thickness of this subunit is generally proportional to the thickness of the whole bauxite sequence and at the top of the sequence again a thin subunit of lower bauxite content can be observed.

According to the mineralogical analyses performed by the Bauxite Exploration Company, the predominant bauxite mineral is boehmite, while gibbsite occurs in subordinate quantities. The mineralogical composition has been computed by means of the method proposed by Gy. Bárdossy (1961) from the chemical composition of the material of a few boreholes for which the results of mineralogical analyses have not been available. The calculation method is based on the assumption that the total SiO_2 present in a particular sample is connected with clay minerals. By calculating the clay mineral content of a sample the proportion of Al bonded to clay- or bauxite minerals, respectively, as compared to the total aluminium content can be determined. The ratio of Al bonded to bauxite minerals to the ("free") water deriving from the loss on ignition (i.e. not connected with clay minerals) gives information on the oxy-hydroxide or trihydrate character of the bauxite minerals, i.e. on the gibbsite: boehmite ratio.

According to our calculations too, boehmite is the predominant bauxite mineral, but gibbsite is present in a considerable amount, too. In some places, in the upper part of the sequence, both occur in nearly equal proportions. The material of boreholes located on the margins of the lens is characterized first of all by the prevalence of gibbsite.

Nyírád Bauxite Formation

In the Sümeg area the Eocene-covered bauxite deposits are of greater importance as compared to the case of the Halimba Formation.

The Nyírád Bauxite Formation includes the occurrences at Csab-puszta in the northeast part of the study area which show partly the same areal extension as the Upper Cretaceous bauxite occurring there. On the edge of the study area is the bauxite lens Csab-puszta-I in which the substratum of the bauxite is constituted by the Ugod Limestone and which is overlain, in a thickness of a maximum of 10 m, by pebbles, argillaceous pebbles and conglomerates belonging to the Oligo-Miocene Csatka Formation. The greatest thickness of the bauxite sequence is observed in the boreholes located at the centre of the lens, composed overwhelmingly of bauxite. In some places, a thin bed of bauxitic clay and argillaceous bauxite occurs at the base of the section. In the boreholes a thin bed of argillaceous bauxite, followed by clays, can be generally found. In the boreholes put down to the east or west of the central zone the thickness of the bauxite sequence is considerably smaller. Here the most strongly bauxitized rock in the sections is bauxitic clay, but its quantity is subordinate, being overwhelmed by clays. In boreholes located on the edges of the lens it is already but a thin clay bed that has replaced the bauxite sequence.

The mineralogical composition may be outlined—partly in the light of calculations from the chemical analyses—as follows:

In the boreholes giving the thickest section the bauxite minerals are represented by boehmite

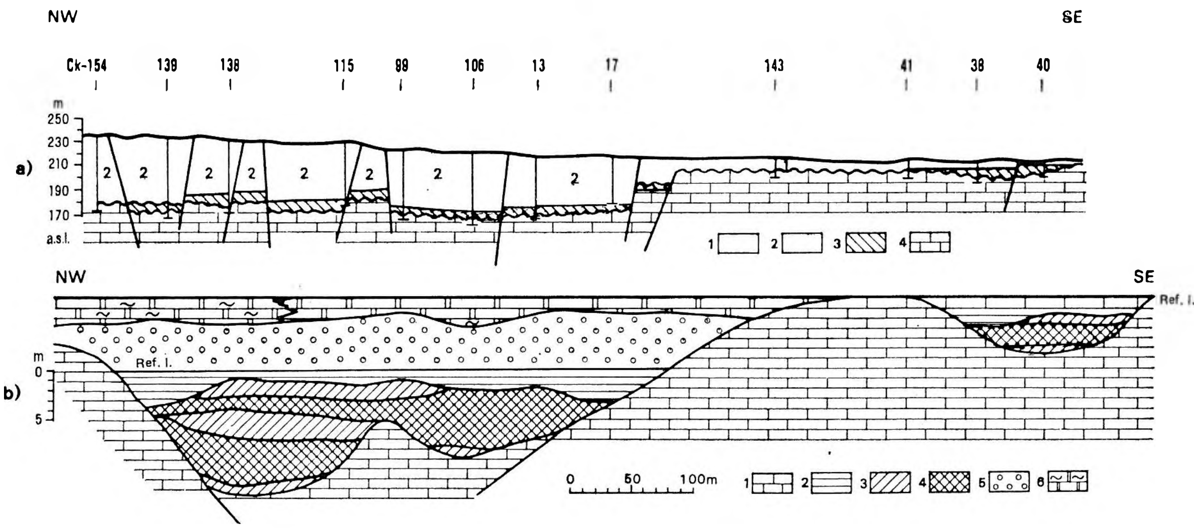

Fig. 64. Profiles across the bauxite lenses of Kozma-tag (*a*) present-day situation, *b*) reconstructed image as of Middle Eocene time)

Profile a): 1. Oligo-Miocene Csatka Fm., 2. Middle Eocene, 3. bauxite sequence, 4. Upper Cretaceous Ugod Limestone Fm. — *Profile b):* 1. Upper Cretaceous Ugod Limestone Fm., 2. clay, 3. argillaceous clay, 4. bauxite, 5. Middle Eocene Haraszt Member, 6. Middle Eocene Szőc Limestone Fm. (represented by limestone and/or calcareous marl). — *Ref.l.* reference level: top of the bauxite sequence and gibbsite, and, in general, a slight prevalence of gibbsite is conspicuous throughout the sequence. The mineralogical composition of the bauxite-bearing part of boreholes of marginal position is similar. In some sequences of maximal thickness the lower two-thirds of the sequence still show the predominance of boehmite, but at the top exclusively gibbsite occurs.

Very important from the bauxite geological viewpoint is the Kozma-tag subarea, where more than ten bauxite lenses are known. The two largest lenses within the study area (Fig. 62) show the following characteristics: the bauxite in both lenses is underlain by the Ugod Limestone, but the original Eocene-overlying beds are preserved in the northern part of the lenses only. The bauxite in the larger lens farther west is underlain by gravels and conglomerates from the argillaceous matrix of which *Miliolina* is often recorded. Its thickness varies between 3 and 11 m. Above this, in the northwestern part of the lens, argillaceous limestones occur in a few metres of vertical distance, while in the southeast it is immediately the limestone beds of the Szőc Formation that follow. On the other, smaller lens the immediate overburden is represented by the Szőc Formation. In the southern part of the lenses the bauxite is covered by Miocene gravels or Pannonian formations, respectively.

The maximal thickness of the bauxite sequence in these two lenses is 11 m. The thickness of the bauxite and the overburden formations and the geological features of the latter are shown in Fig. 62, the geology of the bauxite sequence being illustrated by Fig. 63. In the central part of the larger lens the overwhelming part of the sections is represented by bauxite in which the Al content is fixed in more than 78% in bauxite minerals, the percentage of "free" aluminium in most cases being above 91%. The sequences composed for the most part of bauxite show a high Al_2O_3 and a low SiO_2 at the very base of the section already, but in some places—almost exclusively in boreholes located in the zone of transition to the edge of the lens—the basal half metre to one metre and a half is constituted by argillaceous bauxite. In the upper part of the bauxite sequence a reduction in Al_2O_3 and an increase in SiO_2 are conspicuous; the uppermost one or two metres being composed of clays.

The transition is generally continuous and the bauxite is overlain by half to one metre of argillaceous bauxite. The sharp change in lithology observable without any transition in some profiles appears to us to be just an apparent phenomenon due to formation thicknesses smaller than the density of sampling (in these boreholes the analyses were carried out at 1 m intervals).

In some boreholes even the very top of the bauxite sequence is represented by bauxite. As evidenced by the profiles plotted, however, these boreholes have not exposed the upper part of the bauxite sequence owing to tectonic causes. In the southern part of the lens, in turn, there are a few boreholes indicating that the upper part of the bauxite sequence is lost to erosion, as the bauxite of good quality is overlain by the Oligo-Miocene Csatka Formation rather than by an Eocene bedrock.

That the lens is heavily affected by tectonic deformation was already mentioned. Consequently, the structure and lithology of the original deposit's marginal part can be studied primarily on the southeast side, but, as indicated by some boreholes, a similar makeup is to be expected on the northwest side as well. On the southeast side the central part of the lens is accompanied by a strip of a hundred to a hundred and fifty metres width in which no bauxite can be found. The most desilicified rock variety itself is merely an argillaceous bauxite. In rocks of this kind, as a rule, 25 to 67%, less frequently, 67 to 78%, of the aluminium content is linked to bauxite minerals. The sequences show geological features similar to those in the central part.

In some boreholes, sections showing a transition between the geological pattern typical of the deposit's centre and of its marginal zone can also be observed.

Over much of the southeast lens of considerably smaller size, the Eocene overburden is lost to erosion, the bauxite sequence being covered by Oligo-Miocene gravels. Denudation has removed a large part of the bauxite lens itself, the denudation boundary being located in the central part of the lens (Fig. 62). The geological features observable in the larger lens are recognizable here too and a bauxite body of essentially smaller original extension and thickness can be delineated (Fig. 62 and 63).

Mineralogical analyses from these two Kozma-tag deposits have been made in a low number, so that the mineralogical composition that we can discuss here is primarily one calculated from the relevant chemical analyses. From among the bauxite minerals, gibbsite and boehmite can be found throughout the two lenses, but the prevalence of gibbsite is characteristic. No vertical trend in the section is observable. What is conspicuous laterally is that in the boreholes of the marginal zone the predominance of gibbsite is more significant than it is in the case of the profiles from the central part. On the basis of the few mineralogical analyses the clay minerals are represented by kaolinite, except for the upper part of the profiles, where montmorillonite appears and, less frequently, illite was observed, too. Fe-minerals are usually represented by hematite, goethite was observed in such samples in which gibbsite was present in a considerable quantity, too.

From the material of the lenses the Bauxite Exploratory Company made some spectral analyses as well. None of the trace elements shows any marked deviation compared with other Hungarian bauxite deposits.

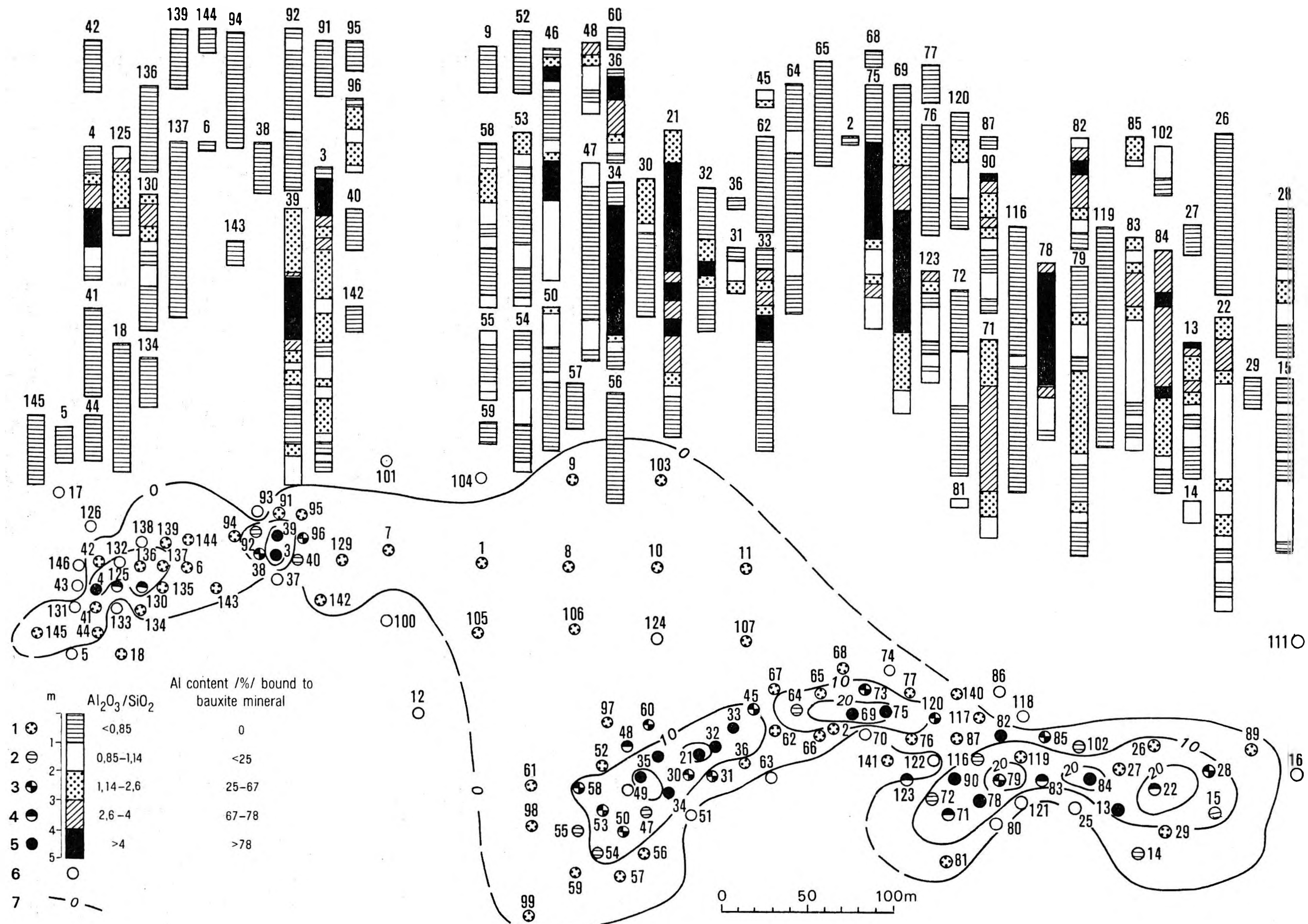

Fig. 65. Thickness and geological features of the bauxite lens in the lens of Surgó-tag (based on the boreholes labelled Sg)
1. Clay, 2. bauxitic clay, 3—4. argillaceous bauxite, 5. bauxite, 6. no bauxite cut in the borehole, 7. thickness of the bauxite sequence (m)

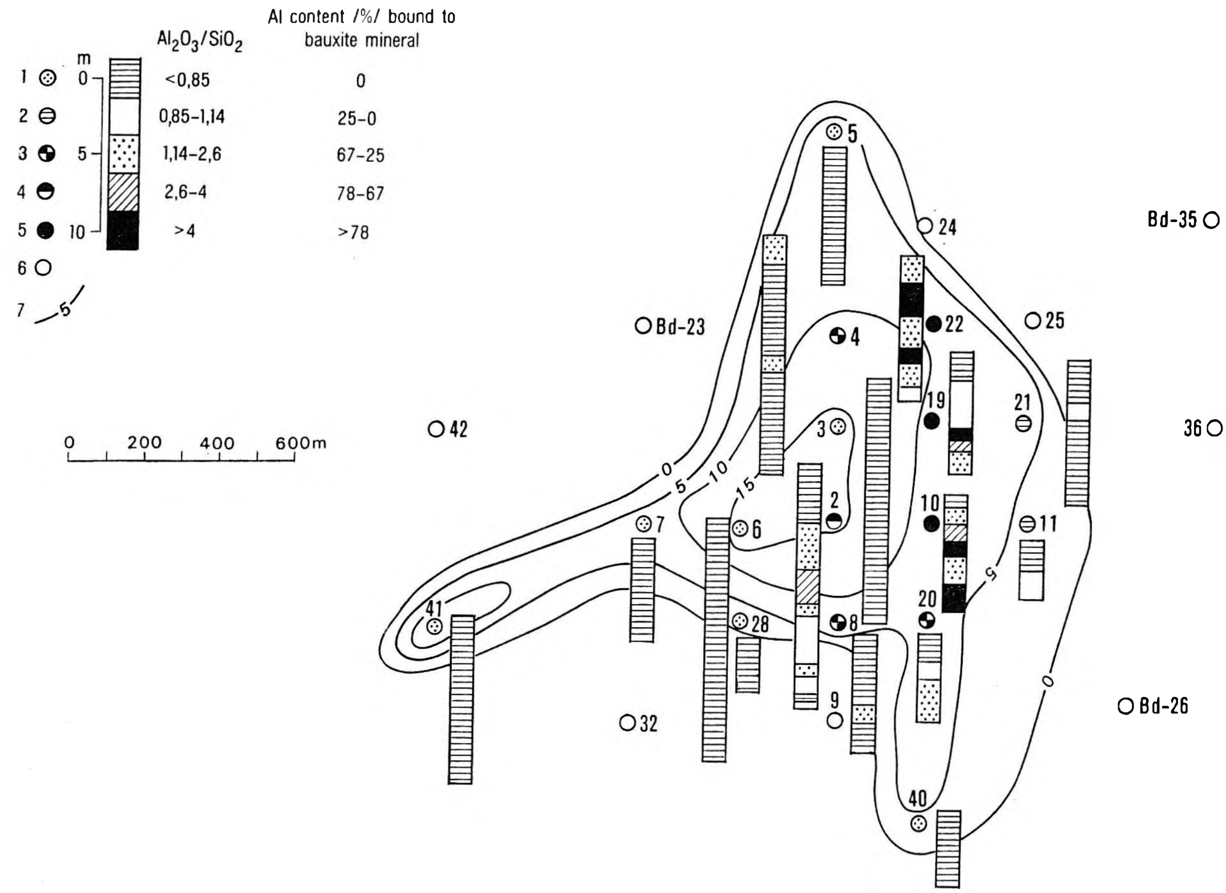

Fig. 66. Thickness and geological features of the bauxite lens of Bárdió-tag

(For other symbols, see Fig. 65.)

As far as the relationship between the geological features of the bauxite body and its overburden are concerned, the fact is that the greatest thickness of the bauxite sequence and, consequently, the best quality has evolved in that subarea, where above the Eocene conglomerate directly covering the bauxite, calcareous marl beds are deposited. The marginal zone coincides for the most part with that zone, where the gravels are directly overlain by limestones (Szőc Formation). A bauxite of more reduced thickness and poorer quality is found in the southeast subarea, where the bauxite sequence is immediately overlain by limestone beds (Fig. 64).

The formation includes the bauxite stripped off in the 1940's by open-pit mining in the József I mine the geological features of which can be formulated primarily in the light of data from the literature (E. Vadász 1946, Gy. Bárdossy 1961). The bauxite sequence is underlain by the Ugod Limestone and overlain, in the western part of the deposit, by Eocene sandy clay and sand above which the Szőc Formation occurs. (The Eocene sequence in the eastern part of the lens is lost to erosion, the overburden here being composed of Quaternary formations.) The thickness of the bauxite sequence in the central part of the lens was 7 to 10 m. In terms of descriptions, the bauxite was situated above a few metres of bauxitic clay and argillaceous bauxite and was overlain again by an argillaceous bauxite attaining a maximum of 1 m in thickness. In the lower part of the section, from among the bauxite minerals, gibbsite and boehmite were present in equal quantities, but in the bauxite and the argillaceous bauxite of the upper part a remarkable boehmite prevalence was conspicuous.

Similar geological features are quoted from the József II—a bauxite deposit stripped off similarly. The only difference is restricted to one feature, the original Eocene overburden being completely lost to erosion and the bauxite having been covered by Quaternary sediments.

The last two lenses are situated in karstic dolinas formed along a NE-SW trending line of tectonic control. The same line is joined by the fissure in the Gerinc quarry, a fissure filled with bauxitic clay which is overlain by Eocene formations confined to a patch that has escaped denudation (Plate XLIII, Fig. 1).

The bauxite lens of Surgó-tag lies in a NE-SW oriented depression of tectonic control (Plate XLIII, Fig. 2). The bauxite sequence is underlain by sandy clay and gravels, less frequently, by conglomerates. These formations, however, attain only a few metres in thickness (an average of 1 to 2 m and a maximum of 6 m). The sequence is overlain, as a rule, by a little sandy, less frequently, gravelly, clays. The sandy clays, as a rule, are directly superimposed to the sequence. In some boreholes, however, the immediate overburden is constituted by gravels. In the upper part of the bauxite sequence thin sand and gravel intercalations were often observed.

The bauxite sequence of the lens of Surgó-tag is composed predominantly of clays, bauxitic clays and argillaceous bauxites. Bauxite is found in a few boreholes only, locally interrupted by strips of varying thickness and lower quality (Fig. 65). Under and above the bauxite-composed interval there is some argillaceous bauxite or, less frequently, some bauxitic clay, but in some places the immediate overburden is clay. The boreholes, which have penetrated bauxite too, do not fall in the thickest parts of the lens. The boreholes put down in the immediate vicinity of these have exposed argillaceous bauxite or bauxitic clay, but in some places only rocks free from bauxite minerals were cut by the drill. The mineralogical composition of the lens, as inferred from chemical analyses, has yielded the following characteristics: gibbsite and boehmite are present throughout the bauxite sequence. In the bauxite rock type, as a rule, the prevalence of boehmite is characteristic: the argillaceous bauxite and the bauxitic clay show alternatively now the prevalence of gibbsite, now that of boehmite, the alternation in some sections being quite frequent (locally at intervals of 0.5 to 1 m).

The X-ray analyses performed by the Bauxite Exploration Company have shown the almost exclusive presence of boehmite and only traces of gibbsite. The discrepancy between the calculated and observed gibbsite quantities seems to be due to the fact that during the chemical analysis generally no CaO determination was carried out. Consequently, the analysts were unable to take into consideration the CO_2 bonded to calcite from the loss on ignition and so the calculated gibbsite quantity gave a value that was higher than the factual one.

Judging by the results of spectral analysis, in the trace element content there is no note-worthy difference as compared to the other Hungarian bauxites. Relating to the bauxite of the Nyírád–Nagytárkány area, the BeO, Ga_2O_3, ZrO_2, CuO and Cr_2O_3 contents are a little bit lower here. As shown by analyses for impurities, CaO, MgO, P_2O_5 and S are present in very low quantities.

The Bárdió-tag lens is likewise situated in a tectonically pre-formed dolina of the Hauptdolomit (Fig. 66). It is overlain, in a thickness of a few metres—a maximum of 27 m—by Oligocene to Lower Miocene formations. The lens was stripped off by openwork and, as a result of those efforts, the beds of the overburden could be readily studied. The bauxite is directly overlain by coarse abrasion conglomerates of Badenian age followed, in turn, by 3 to 4 m of gravels that are overlain by the Fertőrákos Limestone Formation.

The bauxite sequence varies in thickness and quality, rock detritus, sand and gravel intercalations being quite frequent. The texture indicates quite clearly the presence of redeposition, as bauxite debris of varying grain size (0.5 to 10 cm in diameter) are observable in a matrix composed of clay and bauxitic clay.

The sequence is composed for the most part of argillaceous rocks, while rock that may be identified with bauxite occurs in a low thickness, in a few boreholes only. The bauxite subunits within the sequence are distributed at random, being interrupted as a rule by intervals characterized by a bauxite of lower quality. Under and above the bauxite there are ordinarily argillaceous bauxite accumulations, though, in the immediate overburden, bauxitic clay occurs, too. No mineralogical analysis of the rock material has so far been carried out. The predominant bauxite mineral is, as inferred from the chemical analyses, boehmite, though gibbsite occurs throughout the sequence too, moreover, in some places—generally in the lower parts of the sections within the argillaceous bauxite or bauxitic clay deposited there—it may even acquire a marked prevalence. In some places, the amount of CaO is rather high (1 to 7%).

Between the Városi-erdő and the Szőlőhegy, in the Nyelőke subarea, 2.2 m of dolomite was exposed in the borehole Süt-11, overlain by a bauxite that is covered by Pannonian formations. The bauxite mineral is predominantly boehmite, subordinately gibbsite. The ore is overlain by 4 m of variegated, a little-bit sandy clay which then grades into sandy clays.

Paleoenvironment

Having reviewed the major bauxite occurrences in the Sümeg area, now in the light of the mode of superposition, the geological features and the spatial characteristics of the bauxite sequence, we may conclude that in the study area bauxite formation took place in two periods—the Late Cretaceous and the Eocene; consequently, at that time the accumulation of the bauxite's source material and the bauxitization process took place too. Bauxitic rock types would accumulate even later, but then the process would be restricted to removal of earlier-deposited, bauxites from their original site and their reaccumulation.

According to the karstic bauxite accumulation model of the Transdanubian Central Range, a model accepted by the majority of the specialists, the source material of the bauxite was a product of lateritic weathering of magmatic and metamorphic rocks exposed to a humid, tropical to subtropical climate.

In the Transdanubian Central Range's tectonic zone, Paleozoic formations suitable for lateritization were exposed on the margins of a syncline produced by the Austrian and pre-Gosau movements of the main Alpine folding phase, having been uplifted to hundreds of m of altitude a.s.l. Well-known climatic prerequisites for lateritization are mean annual temperatures of 20 to 26 °C, 1,500 mm of annual precipitation and an alternation of a rainy season with a drier one of 1 to 4-months duration (Gy. Bárdossy 1977). According to the results of palynological analyses (F. Góczán 1973) and the isotopic paleotemperature measurements (I. Cornides et al. 1975), the climatic conditions were suitable for this pupose in Albian, Santonian and Campanian and then in Paleocene to Early Eocene times when the area involved belonged to a tropical-subtropical climatic zone with one precipitation maximum.

In accordance with the synclinal structure, a zone of lower topographic position, a few tens of km wide, composed of Mesozoic sedimentary rocks was adhering to the marginal zone. In that zone no younger Mesozoic formations had been formed or, if they had, so they were removed by an intensive denudation and Upper Triassic limestones and dolomites liable to karstification were exposed to daylight and their karstification progressed considerably owing to the favourable climatic conditions.

The laterite material from the flanks was transported upon continuous erosion towards the centre of the syncline, to the deeper-situated areas, and was accumulated in the karstic traps of the carbonate subarea. The carbonate substratum provided the prerequisites for the desilicification and Al-enrichment processes, and for the development of an oxidative Eh, a slightly alkaline pH and a good drainage of the water. Naturally, since the area was a kind of denudation terrain, continuous denudation removed from it even the bauxites already accumulated. However, upon epeirogenic subsidence, this denudation terrain gradually became an area of accumulation. Its central zone, that was deepest even originally, became first a terrestrial sedimentary basin and then gradually developed into a marine one. This succession of processes led to completion of the bauxite accumulation process and, at the same time, to the burial of the bauxite bodies. Deposits belonging to the oldest, Albian, bauxite generation horizon known from the Transdanubian Central Range cannot be detected in the study area. This is due to the absence of formations of the Albian cycle to the west of Padragkút. Thus, even if an accumulation of bauxites did take place at the beginning of the Albian, the resulting deposits seem to have been lost to intensive pre-Late Cretaceous denudation.

The oldest bauxite horizon detectable in the Sümeg area is the Halimba Bauxite Formation appearing at the base of the Late Cretaceous sedimentary cycle.

The general sedimentation circumstances that evolved at the beginning of the Senonian are discussed in detail in the chapter devoted to the Upper Cretaceous formations. In the same chapter, the relation of the bauxite to the other basal Senonian formations are analyzed, too. The relations of the Halimba Formation, the terrestrial sediments and the Ajka Formation suggest that the bauxite was deposited simultaneously with the terrestrial and paludal formations generated in the initial, heavily oscillative, period of the Senonian cycle, but its deposition took place under different conditions at the time of a minor, local regression. The sedimentary material of lateritic origin, that had reached to a bauxitization phase impossible to determine exactly, seems to have been transported to its final site of accumulation by intermittent water flows or torrential streams. The mode of transport of the material being not exactly known, it may have been transported in form of a kind of mud-flows or colloidal solutions.

In the local sedimentary basin the bauxitization continued and came to completion and the final minerological composition of the rock was attained. That these processes played an important role is indicated by the trends of variation in composition. The bauxitization process progressed at the most rapid rate in the central part of the local sedimentary basin, where the basin was deepest and the accumulated sediment thickest.

In these places, as a rule, the sections are composed as a whole of the bauxite rock type. On the margins of the sedimentary basin the argillaceous bauxite to bauxitic clay facies indicates that there the bauxitization process was less complete. Given the relatively small size of the sedimentary basin, the conditions for bauxitization seem to have been identical in both the central and the marginal parts of the basin. The only essential difference is supposed to have consisted in the span of time during which the bauxitization process had to take place. The material of reduced thickness on the edges of the lens—both after the arrival of the material and the subsequent tropical rains—seems to have been emplaced during a shorter span of time than it was the case with the central part of considerable thickness. In other words, the possibility for bauxitization on the margins ceased to exist sooner. (Recently, some laboratory experiments have called attention to the important role played by the time factor in the bauxitization process too: see Gy. Bárdossy 1977.) The predominantly boehmitic, subordinately gibbsitic, composition of the bauxite sequence indicates that the bauxitization process must have taken place under less oxidative conditions and in a less efficient regime of drainage. The predominance of gibbsite on the lens margins too suggests that these parts must have been better drained. In Beneslavski's opinion (in Gy. Bárdossy 1977), if the source material is an amorphous, complex Al-Fe-Ti-Si gel, so mainly cryptocrystalline boehmite is formed.

The thin layer composed of clay minerals at the base of the bauxite sequence seems to have been formed in that part of the sedimentary basin underlying the groundwater table, where the drainage of the solutions was not granted and the bauxitization process in the reductive environment could not evolve. The presence of more oxidative conditions and better drainage in the upper part of the sedimentary basin is indicated by the fact that the gibbsite: boehmite ratio increases as one proceeds upwards in the sections. On top of that, after burial of the bauxite, the infiltrating groundwater provided possibilities even for the hydratation of boehmite. The bauxite formation in the study area was put an end by a minor latest Santonian transgression, as the permanent water coverage cancelled the conditions favourable for bauxitization. The differential movements that can be revealed in the subsequent history of the study area did not cause anymore a regression that might have again enabled the formation of bauxite enduring the Late Cretaceous. Only a redeposition of debris from the earlier-formed bauxite could take place during the formation of the "Kozma-tag member" (M. Gellai–F. Ludas 1983).

The tectonic movements that closed the Late Cretaceous sedimentary cycle resulted in a new phase of emergence and erosion during which, on the margins, a part of the Senonian sediments was removed and even the Ugod Limestone of good karstification characteristics was exposed. At the beginning of the new—Eocene—sedimentary cycle, the conditions necessary for bauxite formation were again available, similarly to the case of the initial period of the Senonian sedimentary cycle. The temperature—after a cold spell at the end of the Senonian—rose again to the proper level (F. Góczán 1973). In the Kozma-tag subarea, on the basis of the oldest Eocene formations covering the bauxite (conglomerate member and Szőc Limestone, respectively), a deeper-situated northeast subarea and a relatively elevated, southwest subarea can be outlined. The difference in altitude between the two subareas may not have been too much in absolute values, but from the viewpoint of accumulation of bauxitic sediments it did play a decisive role. A particularly important role may be ascribed to the NE-SW-oriented faults separating the two subareas, because the bauxite-accumulating karstic depressions were formed primarily along them. The material on the way of bauxitization was probably transported from the relatively elevated limb that lay to the south to southeast, the transportation medium having been represented by intermittent streams or intensive sheetwash. The bulk of the bauxite accumulated in the dolinas was not a redeposited product formed in a bauxitization period. The character of constitution of the deposit and the trends of variation in the mineralogical composition suggest that the sediment transported into the dolinas was considerably altered, bauxitized, after being deposited there (Kozma-tag).

In the more elevated subarea a less significant bauxite accumulation seems to have taken place, the bulk of the material having been transported to the deeper subarea owing to the difference in altitude. After accumulation, prior to inundation or dessication, respectively, a desilicification, i.e. aluminium concentration process set in. In each sedimentary basin the most intensive accumulation of bauxite occurred in the central part, where the sediment was the thickest. In basin parts with small thickness of sediment a more rapid dessication left less time for the bauxitization process to take place in full. A more rapid percolation and elutriation is suggested by the gibbsite-dominated composition on the margins of the profile, too.

The mineralogical composition of the Eocene bauxite indicates that this was formed under more oxidative circumstances than it had been the case with the Senonian bauxite, as the bauxite minerals are represented by gibbsite and boehmite present in nearly equal proportions.

A continued subsidence of what is now the study area led to a transgression of the sea: detrital sedimentation set in and the conditions for bauxitization ceased to be available. After Eocene time, circumstances suitable for bauxitization have never evolved anymore. In the periods of emergence, of course, sizeable amounts of bauxite may have been lost to erosion or, respectively, partly accumulated in the dolinas of the Upper Triassic and Upper Cretaceous rocks exposed. Such a redeposition must have taken place before the Badenian transgression (Bárdió-tag, Surgó-tag), but red clay sediments deriving from bauxites can be found both above the Badenian sediments and below the Lower Pannonian beds.

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Eocene

by

L. Gidai and J. Haas

Eocene formations make up the unit of highest morphological position of the hill range extending to the east of Sümeg, the Rendeki-hegy, and, in addition, they crop out in a number of minor patches, too. The sequence was exposed by a lot of exploratory boreholes. All these results have provided possibilities for the clarification of some stratigraphic problems that have been problematic for a long time. The Eocene sequence of the horst block of Sümeg presents the general geological features typical of the western part of the Transdanubian Central Range. Type section of several proposed lithostratigraphic unit occur within the study area.

Exploration history

The monograph of J. Böckh (1874) is the first among the summarizing accounts of the Bakony's Eocene to mention the Eocene formations from the Sümeg area. He distinguished two sequences within the Eocene: the "Nummulites limestone" at the base and the "Orbitoidea-rich calcareous marl" at the top.

M. Hantken (1875) singled out, upon his elaboration of the larger Foraminifera of the southern Bakony Mountains, three horizons:

1. the "*Nummulites Tchihatsheffi*" *(= N. millecaput)* Beds
2. the "*Nummulites spira*" *(Assilina spira)* Beds and
3. the "*Nummulites laevigatus*" Beds

R. Hojnos (1943) divided the Eocene sequence of the immediate vicinity of Sümeg into two parts. The lower part, the Main Nummulites Limestone, was assigned by him to the Parisian-Bartonian, The upper one, the marly Orthophragmina Limestone, to the Priabonian.

E. Szőts (1956), in his summarizing work, discussed the Bakony dividing it into 8 subareas. One of these is the Sümeg–Csabrendek subarea presenting the following sequence:

"Nummulites-Orthophragmina limestone and marl"	— Lutetian
"Main Nummulites Limestone"	— Lutetian
"Nummulites-Miliolina Limestone"	— Londonian

E. Szőts' treatise gave, in addition to a stratigraphic synthesis, a paleogeographic interpretation as well.

G. Kopek and T. Kecskeméti (1960) singled out 7 horizons within the marine Eocene of the Bakony. The lowermost horizon, the *Nummulites laevigatus* Horizon, was placed in the Ypresian, the rest, mainly upon evaluation of the larger Foraminifera, was assigned to the Lutetian stage. In the Sümeg area they supposed the presence of an unconformity between the Lower and Middle Eocene and they identified this with the overall unconformity supposed to exist throughout the eastern part of the Bakony Mountains.

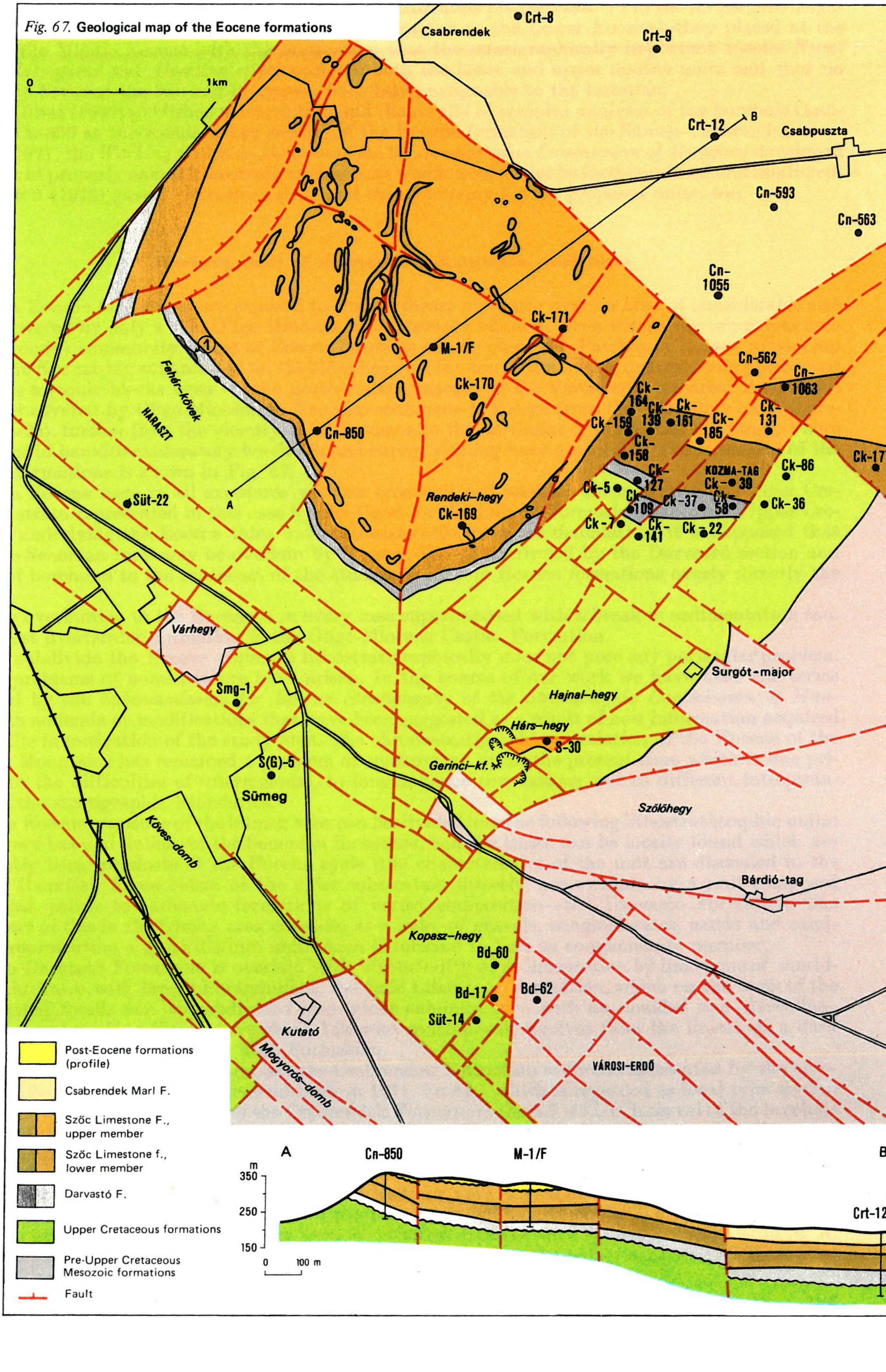
In a summarizing paper, G. Kopek, T. Kecskeméti and E. Dudich (1966) registered 16 horizons of the Eocene in the Transdanubian Central Range. In their tabulation they listed, within the Sümeg–Darvastó–Nyírád subarea, the following horizons:

XIII. Glauconite Horizon (the uppermost horizon of the Middle Eocene)
XII. *N. millecaput* Horizon
XI. *N. striatus* Horizon
X. *N. perforatus* Horizon (marker horizon–Upper Lutetian)
IX. *Assilina spira* Horizon
(VIII. to II. intra-Lutetian denudation)
I. *Alveolina oblonga* Horizon (Lower Eocene)

In their paper published in 1971, the afore-mentioned authors revised, for the southern Bakony, their statement concerning the "intra-Lutetian denudation" and took the Lower to Middle Eocene transition to be continuous.

M. Jámbor-Kness (1971), after studying the larger Foraminifera from the borehole Nagytárkány (Nt) No. 1103 put down in the vicinity of the Sümeg area, pointed out the presence of a continuous sequence from the Lower Eocene up to the end of the Middle Eocene, refuting thereby the existence of an intra-Lutetian denudation.

Fig. 67. **Geological map of the Eocene formations**



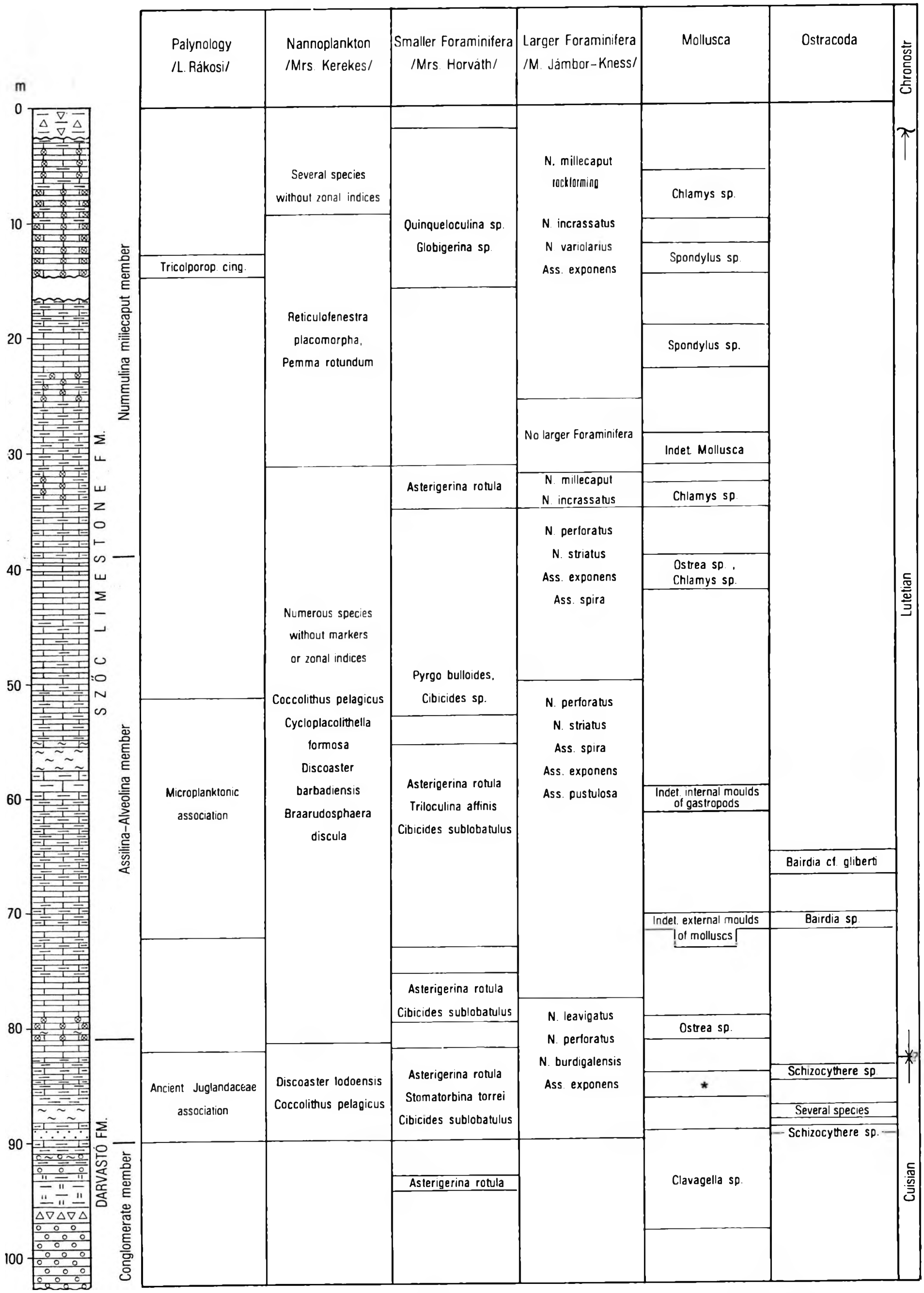


Fig. 68. Lithologic log and stratigraphic record of the borehole Csabrendek Cn-850

* Corbula exarata, Natica sp., Ampullina cf. perusta, Lima sp., Cardium sp., Spondylus sp.

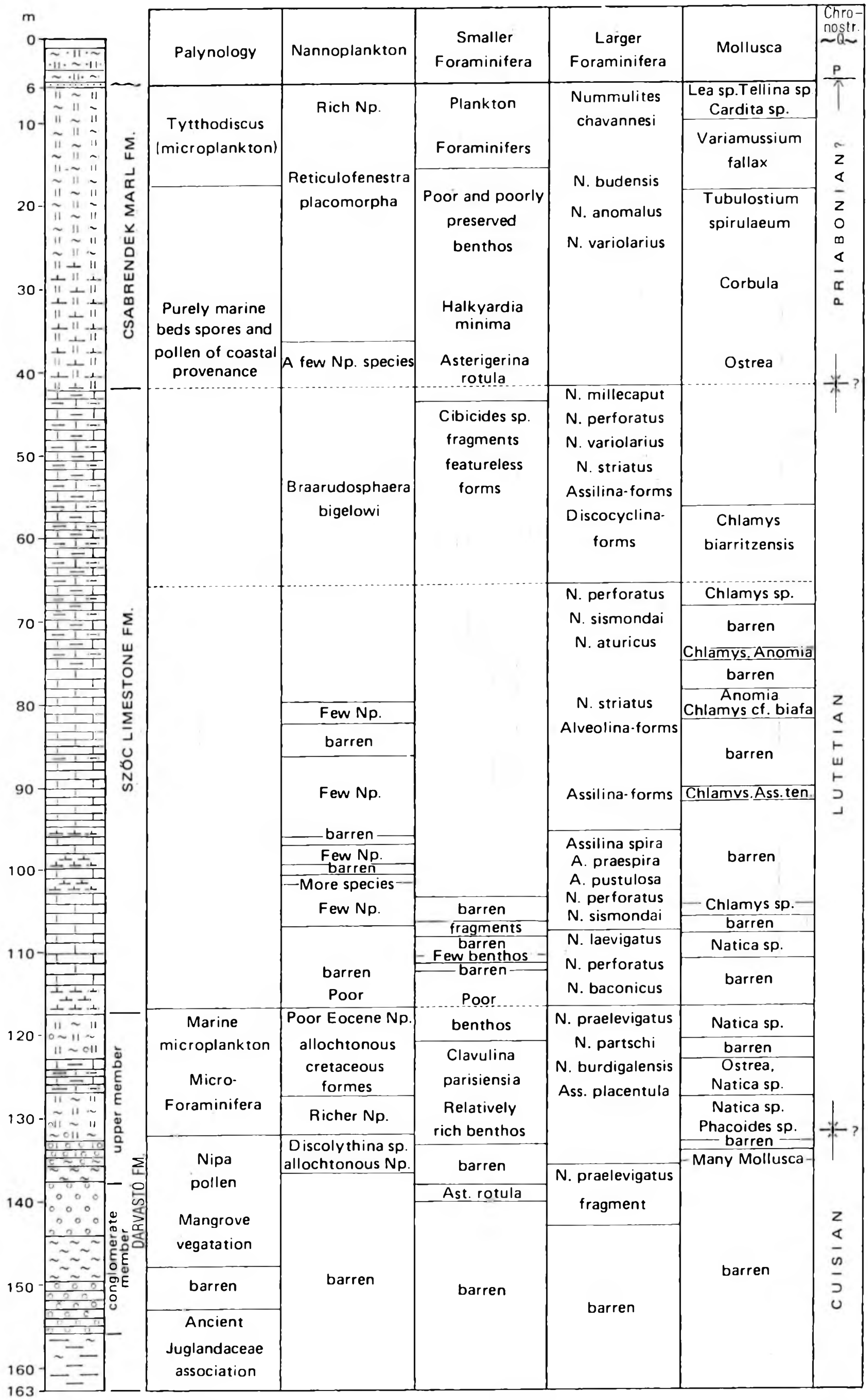


Fig. 69. Lithologic log, stratigraphic record and fossil content of the borehole Crt-12: a review

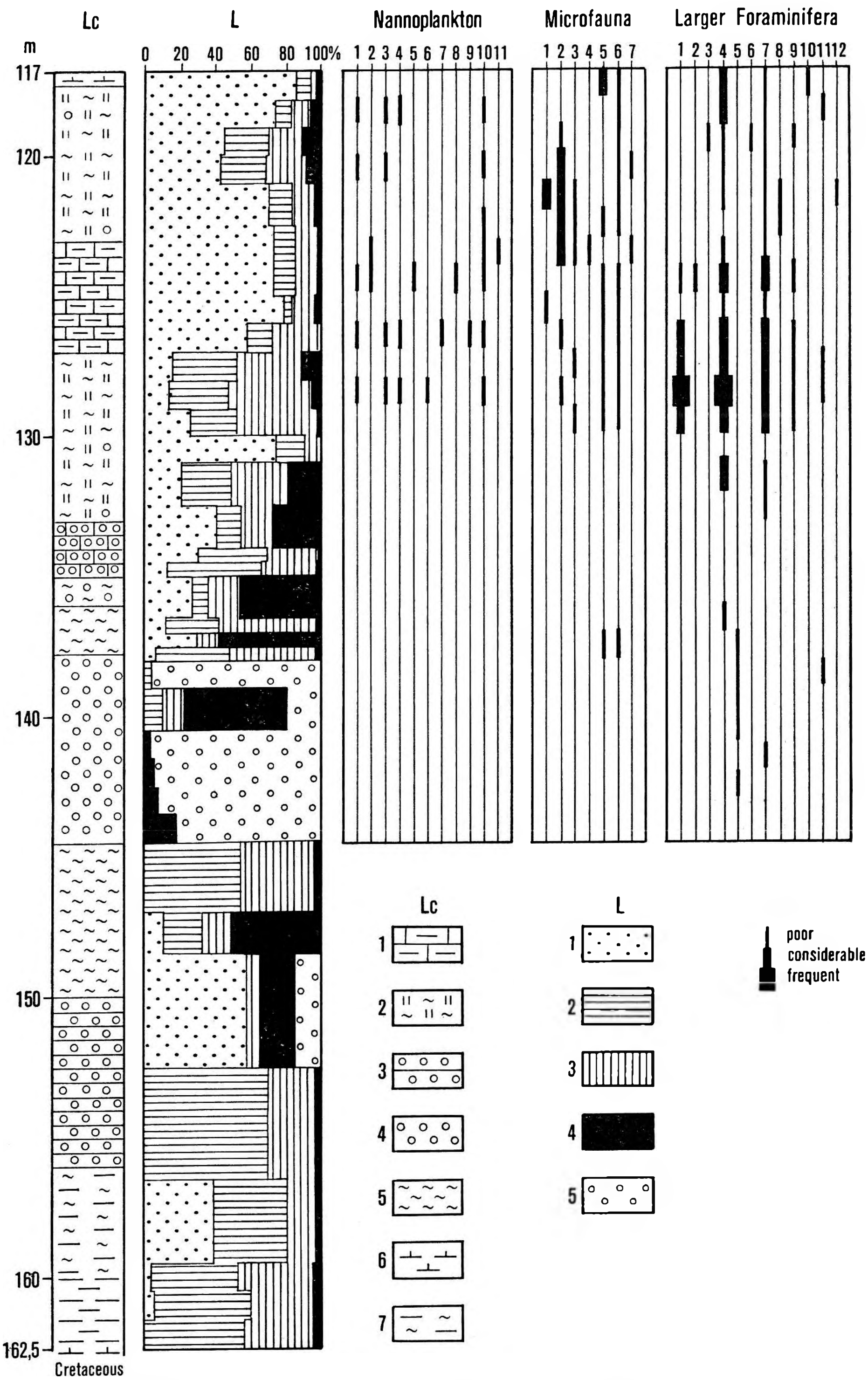


Fig. 70. The Darvastó Formation interval of the borehole Crt-12: lithologic column and analytical record

Lithologic column (Lc): 1. argillaceous limestone, 2. silty marl, 3. conglomerate, 4. gravel, 5. marl, 6. calcareous marl, 7. argillaceous marl. — ***Lithologic composition*** (L): 1. $CaCO_3$, 2. clay, 3. silt, 4. sand, 5. gravel. — *Nannoplankton*: 1. Ericsonia muiri, 2. Sphenolithus radians, 3. S. pseudoradians, 4. S. moriformis, 5. S. sp., 6. Helicopontosphaera sp., 7. Cyclococcolithina sp., 8. Rhabdosphaera tenuis, 9. R. crebra, 10. Cyclocargolithus sp., 11. Coccolithus cf. marismontium. — *Microfauna:* 1. Valvulina terquemi, 2. Clavulina parisiensis, 3. Quincqueloculina sp., 4. Globulina gibba, 5. Asterigerina rotula, 6. Cibicides sp., 7. Pararotalia inermis. — *Larger Foraminifera:* 1. Nummulites burdigalensis, 2. N. partschi, 3. N. aff. partschi, 4. N. praelaevigatus, 5. N. aff. praelaevigatus, 6. N. aff. burdigalensis, 7. N. sp., 8. Alveolina sp., 9. Assilina placentula, 10. A. cf. placentula, 11. A. sp., 12. Orbitolites sp.

KOLLÁNYI with examining the microfauna, M. MONOSTORI with studying the Ostracoda fauna, M. JÁMBOR-KNESS with her results on the larger Forminifera and A. KECSKEMÉTI-KÖRMENDY on Mollusca.

The columnar sections of the key boreholes and the diagrams summarizing the analytical results are given in Fig. 68 to 72. The analytical results on the borehole Cn-850 are presented in detail by L. GIDAI (1977) as well, so that in the case of this section we have restricted ourselves to publishing a summarizing profile and a section presenting the biostratigraphically most important fossils.

Darvastó Formation

Conglomerate member

On the Rendeki-hegy and also in the Kozma-tag subarea, at the base of the Eocene sequence, a 10- to 15-m-thick unit consisting mainly of gravel and conglomerate beds with interbedded silty clay layers can be found. Exposures of this peculiar, well-mappable formation occur in the so-called Haraszt subarea to the northeast of Sümeg and in quarries on the southwestern side of the Rendeki-hegy. Near the outcrops, the unit has been exposed in full thickness, between 89.4 and 100.4 m, by the borehole Cn-850 (Fig. 68).

Overlying the Upper Cretaceous Polány Formation, the basal part of the sequence is composed of conglomerate beds. The pebbles are constituted by grey, black and brown chert (radiolarite) and also by quartzite and siliceous schist. Most of the carbonate pebbles are lost to dissolution, just the cavities after dissolution being observable. The pebbles vary between 1 and 5 cm in size and their roundness varies, too. The matrix between the pebbles is generally calcite, less frequently marl or silty marl.

Fossils are very scant. All that has come into the fore is one *Clavagella* sp., a few *Foraminifera* specimens [*Asterigerina rotula* (KAUFMANN), *Cibicides* sp.], further, single specimens of *Cycloplacolithella* sp. and *Discoaster* nannofosils.

The higher part of the member (89.4–93.6 m) is composed predominantly of silty clay and siltstone. The subunit ends at the top with gravelly sands. The pebbles are composed of chert, quartzite and limestone, 2 to 6 mm in diameter, very poorly rounded (0–1). The sands are composed for the most part of quartz grains, though quartzite and feldspar grains are rather frequent, too. The heavy mineral fraction accounts for 0.23%, from among the allothigenic minerals, magnetite is present in a rather considerable quantity.

From among the organic remains, tiny coalified plant fragments, the foraminiferal specimens quoted from the lower interval and also detritus of *Bryozoans*, *Echinoderms* and *Molluscs* could be observed.

The quarry-row on the slope of the Rendeki-hegy has exposed, in 4 to 8 m thickness, the lower beds of the conglomerate member overlying the Polány Formation. The most complete section of the conglomerate member is in the largest quarry of the quarry-row (Fig. 67, 1 and Plate XLIV, Fig. 2). In this quarry the Cretaceous formations are overlain by 1 to 3 m of yellow sand in which more and more pebbles occur as one proceeds upwards. Up in the section, this formation grades into conglomerates. The conglomerate beds have a total thickness of 6 m. The gravel lenses above them are contained in sands that may be correlated with the upper member mentioned in the borehole Cn-850.

The conglomerate member could be identified in the section of the borehole Crt-12, too (Fig. 69, 70), but the Eocene sequence there begins with 10 m of grey clay. From the bed containing tiny coalified vegetal debris, L. RÁKOSI recovered a "*Juglandaceae*" pollen assemblage.

The conglomerate member overlying the clay bed is 18 m thick. It is composed of gravel, conglomerate and sandstone beds between which thin layers of clay and siltstone are interbedded. The pebble grains are on the average smaller in size compared to those observed in the Haraszt exposures and in the borehole Cn-850 (below 1 cm). Sporadically, however, pebbles attaining even 10 cm in diameter can be found, too. Poorly rounded, the pebbles are made up of quartz, chert and dolomite.

In the upper part of the member (138.1–144.4 m) marine fossils can be found sporadically: *Nummulites praelaevigatus* SCHAUB, *Asterigerina rotulata* (KAUFMANN), *Cibicides* sp. The pollen assemblage differs considerably from the basal clay layer.

As shown by L. RÁKOSI and K. TÓTH (1980), the situation farther east, in the Csabrendek–Nagytárkány subarea, is similar—the conglomerats are underlain by 8 to 10 m of clay-marl (they proposed for it the name Cseteberek Argillaceous Marl).

In the southeastern foreland of the Rendeki-hegy the member is exposed by bauxite-exploratory boreholes within the Kozma-tag-subarea, where it forms the immediate overburden of the bauxite lenses (see the chapter Bauxite). On the eastern side of the Kozma-tag subarea the conglomerate member is covered by younger Eocene formations gradually decreasing in thickness eastwards owing to erosion. The Eocene overburden in the eastern part of the area is completely lacking already: here the member is overlain by Oligo-Miocene and Neogene gravels. To separate the gravel formations of different age from one another in this area requires a detailed analysis of the pebbles.

In the southern part of the Kozma-tag subarea the thickness of the Darvastó Formation decreases, the conglomerate member missing from the sequence; the boreholes Ck-181 and Cn-211 exposed only a few metres of sandy, gravelly marl beneath the Szőc Limestone. In the borehole Ck-177, in turn, bauxite and then carbonaceous clay are superimposed on the Senonian limestone surface.

In K. Tóth's opinion (oral communication, 1977), an intertonguing of the conglomerate and the argillaceous marl or the pinching-out of the conglomerate member can be observed in the adjacent Csabrendek–Nagytárkány bauxite area.

At the top of the Hárshegy the conglomerate member is greatly reduced in thickness (8 m in the borehole S-30), while in the section exposed in the Gerinc quarry it is completely missing. Here the Upper Cretaceous limestone and/or the bauxites filling its fissures are overlain, with a thin argillaceous, basal bed, directly by the Szőc Limestone.

On the edge of the Városi-erdő, in the borehole Bd-17, the coarse-detrital sediments are also lacking in the exposed section.

Upper member of the Darvastó Formation

Above the conglomerate member or, in this absence, directly above pre-Eocene formations, there occur grey to yellowish-grey, pelitic beds that are very similar to the lower beds exposed in the section of the Darvastó VI mine pit.

In the borehole Cn-850 (80.5–90.0 m) this unit is readily dissociated from the underlying conglomerate member and the overlying limestone with larger Foraminifera. The lithology is diversified—grey (secondarily, yellowish-brown) siltstones, argillaceous marls, marls and calcareous marls alternate with argillaceous limestones. The sand content of the rocks varies between 5 and 40%. As shown by mineralogical analyses, 60 to 70% of the sand grains is quartz, 7 to 13% is quartzite, 10 to 13% is plagioclase and 3 to 8% is glauconite. The amount of the heavy fraction is 0.2 to 1.3 per cent by weight. From among the allothigenic grains it is magnetite, ilmenite, garnet, tourmaline and chlorite that are present in significant quantities.

The fossils at the lower boundary show a sudden increase in quantity. The *larger Foraminifera* are represented by a large number of individuals and by several genera. The individual species and their quantities are shown in Fig. 71.

In addition to *Nummulites laevigatus* Lamarck, an index fossil of great stratigraphic value, *Nummulites perforatus* Montfort appears already in the lower part of the unit, becoming gradually more frequent higher up the profile.

In addition to these, the following Nummulites species are encounterable:

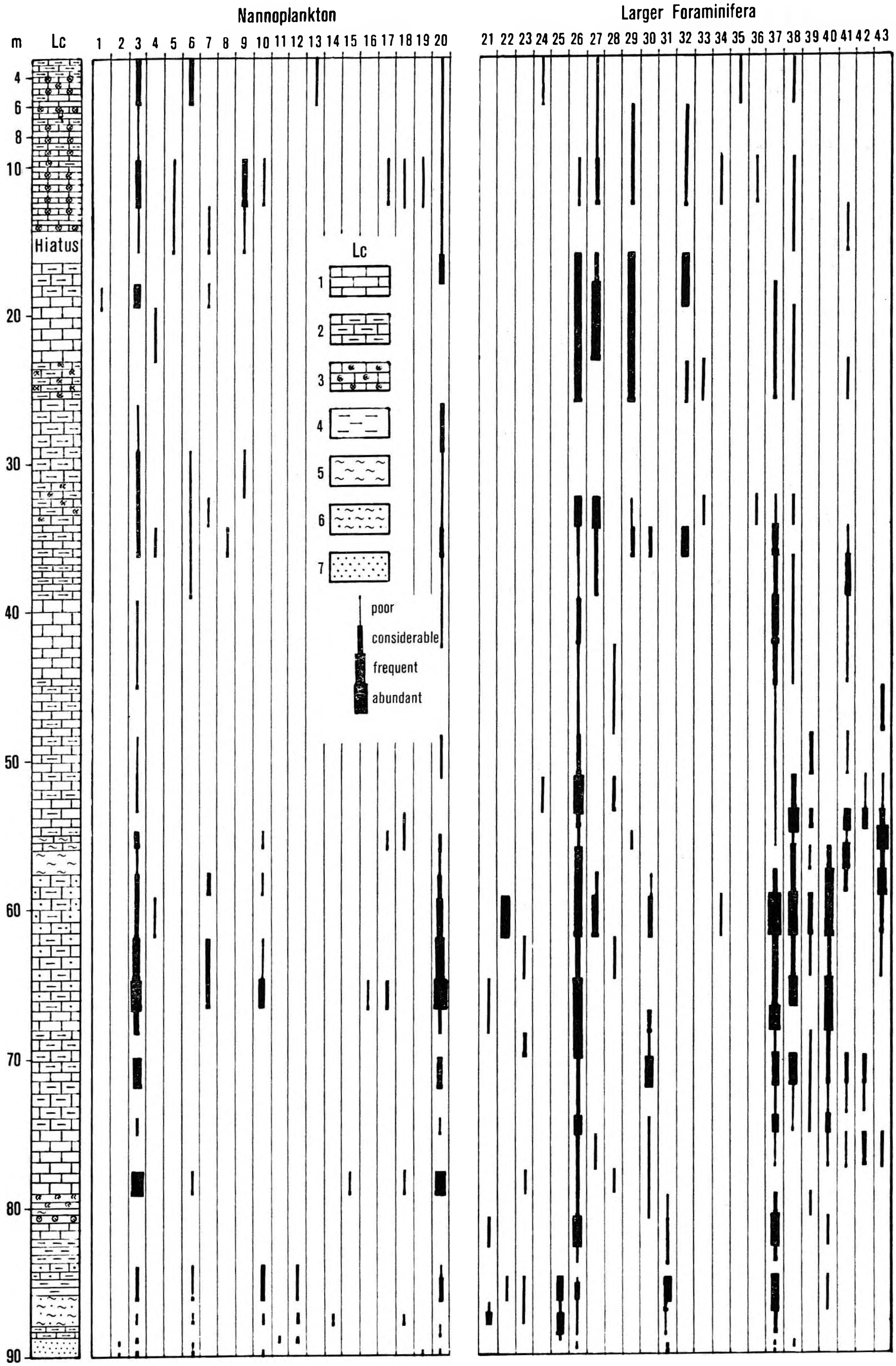
Nummulites partschi de la Harpe, A
Nummulites aff. *pernotus* Schaub., A
Nummulites globulus Leymerie, A
Nummulites anomalus de la Harpe, A
Nummulites burdigalensis de la Harpe

It is noteworthy that, in M. Jámbor-Kness' option based on the study of the fossils, these species are not allochtonous.

Assilina exponens (Sow.), Form A, appears at the base of the sequence being encounterable in fair abundance throughout the unit. Let us add to this, that at the base of the unit, M. Jámbor-Kness found one specimen of *Assilina spira* de Roissy, Form A too, which is the zonal index fossil of the next larger Foraminifera zone.

Fig. 71. Nannoplanktonic and larger foraminiferal record of the borehole Csabrendek Cn-850

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. limestone with larger Foraminifera and lumachelle, 4. clay, 5. marl, 6. sandy marl, 7. sand. — *Nannoplankton:* 1. Discolithina rimosa, 2. Cyclococcolithus gammation, 3. Coccolithus pelagicus, 4. C. eopelagicus, 5. Reticulofenestra placomorpha, 6. Braarudosphaera bigelowi, 7. B. discula, 8. Micrantholithus crenulatus, 9. Pemma rotundum, 10. Discoaster barbediensis, 11. D. mirus, 12. D. lodoensis, 13. D. trinus, 14. D. aff. diastypus, 15. D. cf. crassus, 16. Clathrolithus spinosus, 17. Chiasmolithus grandis, 18. Ch. solitus, 19. Neococcolithes dubius, 20. Cycloplacolithella formosa. — *Larger Foraminifera:* 21. Nummulites partschi A, 22. N. pernotus A, 23. N. globulus A, 24. N. anomalus A, 25. N. burdigalensis A, 26. N. perforatus A, 27. N. variolarius A, 28. N. aturicus B, 29. Nummulites millecaput A, B, 30. N. sismondai B. 31. N. laevigatus A, 32. N. incrassatus A, 33. N. baconicus B, 34. Discocyclina nummulitica, 35. D. papyracea, 36. D. scalaris, 37. Assilina exponens A, 38. A. spira A, 39. A. praespira A, 40. A. pustulosa A, 41. Alveolina aff. callosa, 42. Alv. munieri, 43. Alv. aff. tenuis


Nannoplankton
Larger Foraminifera
m
Lc
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43
4
6
8
10
20
30
40
50
60
70
80
90
Hiatus
Lc
1
2
3
4
5
6
7
poor
considerable
frequent
abundant

From the 84.0 to 84.7 m interval of the member, A. KEREKES determined a fairly rich autochtonous nannoplanktonic association. Most frequent forms of this association are:

Coccolithus pelagicus (WALLICH)
Cycloplacolithella formosa (KAMPT.)
Discoaster lodoensis BRAML. et RIED.
Discoaster aff. *lodoensis* BRAML. et RIED.
Discoaster barbadiensis TAN
Discoaster aff. *diastypus* (BRAML. et SULL.)

Mollusca are present in a rather poor number of species and individuals. Forms identified:

Ampullina cfr. *perusta* DEFR.
Cardium sp.
Spondylus sp.
Lima sp.
? *Natica* sp.

Some forms, like the representatives of *Ostrea* and *Clavagella*, are suggestive of a marine environment.

In the lower half of the unit, 84.0 to 90.0 m, L. RÁKOSI identified an ancient Juglandaceae vegetation that can be traced even regionally in Transdanubia.

In the borehole Crt-12 (Fig. 70), above the conglomerate member and below the Szőc Limestone abounding with larger Foraminifera, a grey silty marl subunit could be distinguished (117.0–138.1 m). The basal part of this (below 136.3 m) is poor in organic remains, but eventually the amount of *Foraminifera* and *Mollusca* will suddenly increase. Between 135.0 and 136.3 m, A. KECSKEMÉTI-KÖRMENDY found one specimen of brackish-water *Brachyodontes corrugatus* (BRONGN.) in addition to marine forms. From the beds above 136.3 m, M. JÁMBOR-KNESS determined the following larger Foraminifera: *Nummulites praelaevigatus* SCHAUB., *N. partschi* DE LA HARPE, *N. burdigalensis* DE LA HARPE, *Assilina placentula* DESH., *Alveolina* sp. Among the other Foraminifera solely benthonic forms can be found in a low number of species and specimens. As shown by M. BÁLDI-BEKE, the nannoplanktonic assemblage abounds in forms redeposited from the Cretaceous (*Watznaueria bernesae*).

Outcrops of the upper member of the Darvastó Formation are unknown from the study area, but drilling results have proved its being common.

Bio- and chronostratigraphy

It is the larger Foraminifera and the nannoplanktonic assemblages that are of most important time marker value.

The larger Foraminifera appear above the conglomerate member, being represented, in the borehole Crt-12, by an assemblage composed of *Nummulites praelaevigatus*, *N. partschi*, *N. burdigalensis*, and *Assilina placentula* which M. JÁMBOR-KNESS assigned to the Upper Cuisian. According to the international stratigraphic practice, the representatives of *N. laevigatus* indicative of the very base of the Lutetian stage (CH. POMEROL 1973) appear in calcareous marl and limestone beds assignable, upon lithological features, to the Szőc Formation. In the borehole Cn-850, *N. laevigatus* appears already in the marls overlying the gravels.

The nannoplankton occurs together with the larger Foraminifera. As observed by M. BÁLDI-BEKE, in the borehole Crt-12, *Rhabdosphaera inflata* BRAML. et SULL. and *Discoaster sublodoensis* BRAML. et SULL. occuring in the upper member of the formation are suggestive of a deeper part of the Middle Eocene. The presence of *Sphenolithus pseudoradians* BRAML. et WILC. precludes, in turn, a pre-Middle Eocene age of the member (the first appearance of the species is at 132 m).

From the beds overlying the conglomerate member in the borehole Cn-850, A. KEREKES identified *Discoaster lodoensis* BRAML. et RIED.—a zonal index fossil of the middle to upper part of the Cuisian.

According to palynological results (L. RÁKOSI), the clays underlying the conglomerate beds in the borehole Crt-12 contain a spore-pollen assemblage indicative of an ancient Juglandaceae vegetation (*Plicapollis pseudoexcelsus–Triporopollenites urkutensis* Assemblage Zone) which is in favour of an assignment to the Lower Eocene. In the borehole Cn-850 a similar spore-pollen assemblage could be observed above the conglomerate member. In the borehole Crt-12, however, a different type of vegetation, probably that of the Middle Eocene already, could be detected above the conglomerates.

Thus the chronostratigraphic evaluation has to be based on the biostratigraphic evidence remarkably pregnant with contradictions.

The beds of marine fossils overlying the conglomerate member may represent the base of the Lutetian (*N. laevigatus*—borehole Cn-850), but in some places the deposition of pelitic sediments seems to have begun as early as the Cuisian. The conglomerate member as well as the clays and argillaceous marls underneath appear to be assignable to the Cuisian. The upper, marly, member, however, certainly belongs to the lower part of the Lutetian.

Paleoenvironment

At the base of the Darvastó Formation near Sümeg generally coarse-detrital formations occur. The clays of grey colour with coalified plant remains observed below the conglomerate member in the borehole Crt-12 seem to be of lacustrine, paludal origin. Lacking any marine or brackish-water fossils, they contain spores and pollen grains of terrestrial plants. The presence of plenty of allochtonous Upper Cretaceous pollen grains indicates an erosion of Senonian formations.

In evaluating the genetic circumstances of the conglomerate member we can rely on sporadical paleontological data and the results of analyses of the gravels. The fossils recovered *(Mollusca, Foraminifera, Bryozoa, Echinodermata, nannoplankton)* suggest that the detrital sediment was deposited in a seawater of normal salinity. The low quantity of fossils may be due to forbidding conditions for life and disadvantageous fossilization conditions.

In the material of the pebbles, the lithology of the directly underlying Senonian can seldom be recognized, if at all. This fact and the feeble roundness of the noncarbonate pebbles suggest the presence of a sediment other than abrasion product. The pebbles—for the most part of Mesozoic origin—indicate, with a view to their lithologic composition, a rather short distance of transport. This fact is supported by the observation that the roundness of the carbonate pebbles attains even the 3rd grade, while the siliceous pebbles are generally of 1st grade. Consequently, it is probable that we have to do with an alluvium introduced by streams into the sea, but left unaffected by the surfs. The finer-grained detritus too may have been brought into the sedimentary basin by fluviatile transport. At any rate, this model of deposition will account also for the protection the bauxite deposits had against abrasion. Namely, in case of abrasional activities, the preservation of earlier-deposited bauxite bodies would be less plausible.

In the borehole Cn-850, at the boundary between the lower and upper members, the fauna showing a decrease in salinity and the absence of nannoplankton is indicative of partial landlocking. The presence of pollen grains of *Nipa (Echimorphomonocolpites echinatus)* suggests that a mangrove vegetation had evolved. The introduction of pebble-size grains discontinued and fine terrigeneous detritus was brought in that derived, probably in a considerable part, from the erosion of a Barremian-Aptian sequence (redeposited nannoplankton and spores and pollen grains). The deposition took place in a near-shore, shallow water environment, where organic-rich muds were deposited.

Szőc Limestone Formation

The Szőc Formation is a biogenic limestone body which contains the shells of larger Foraminifera, usually in rockforming quantities. Essentially, this is the unit which was referred to as "Hauptnummulitenkalk" (Main Nummulites Limestone) in the earlier literature. On the basis of the abounding fossils, strikingly different even when viewed with an unaided eye, E. Dudich (1978) proposed to divide the formation into the following (informal) members: 1. *Nummulites laevigatus* Member, 2. *Assilina spira* Member, 3. *Nummulites perforatus* Member, 4. *Nummulites millecaput* Member. This classification follows essentially the earlier (G. Kopek, T. Kecskeméti, E. Dudich 1966) so-called horizon scale. In the study area this classification cannot be used without modification either in the litho- or the biostratigraphical sense. A part or the whole of the unit characterized by the predominance of *Nummulites laevigatus* is represented by grey marls and calcareous marls, thus being part of the Darvastó Formation. It is overlain by a limestone unit that can be assigned to the Szőc Formation. On the basis of rock composition and textural and structural characteristics and in terms of the rockforming fossils two distinct units of member rank can be singled out. The lower unit is composed of thick-bedded Assilina-Alveolina limestones, the upper one being characterized by thin-bedded, often glauconitic and argillaceous limestones with *Nummulites millecaput.*

The borehole Cn-850 intersected the formation in a thickness of almost 80 m (2.7–79.0 m) (Fig. 68, 71). The rock is light brownish-grey to grey limestone or argillaceous limestone. Its clay content in the lower part of the formation (55.8–80.5 m) varies between 5 and 20%, in the middle part it is only about 5%, but it is more in the upper part (2.7–19.5 m), where the rock is composed of an argillaceous limestone.

The larger Foraminifera, as a rule, are abundant, forming 80 to 90% of the rock in some beds. However, beds free from larger Foraminifera can be observed, too. The intervals showing an enrichment or an impoverishment of the fauna are of local character, not being traceable over larger distances.

In terms of larger Foraminifera, as already mentioned, two subunits could be distinguished (Fig. 71).

1. The lower subunit (36.1–79.0 m) is characterized by the predominance of species of the genera *Alveolina* and *Assilina* [*Assilina spira* de Roissy, *A. praespira* Douv., *A. exponens* (Sow.), *A. pustulosa* Donc., *Alveolina elongata* d'Orb., *A. fragilis* Hott., *A. fusiformis* Sow.]. In addition, *Nummulites peforatus* Montfort can be encountered in a great quantity too.

2. In the upper subunit (5.7–36.1 m) *Nummulites millecaput* BOUBÉE predominates, but in the deeper parts (below 17 m) *N. perforatus* MONTFORT and *N. variolarius* (LAMARCK) are very frequent, too.

Beside larger Foraminifera, the presence of smaller Foraminifera, Ostracoda and Mollusca is also common in the faunal assemblage (Fig. 68). In the beds poor in larger Foraminifera (25.4–31.6 m) the remains of *Lithothamnium*, *Brachiopoda*, *Mollusca* and *smaller Foraminifera* could be observed. The nannoplanktonic assemblage is shown in Fig. 71.

In the borehole Crt-12, the basal, lithologically transitional part of the formation (113–117 m)

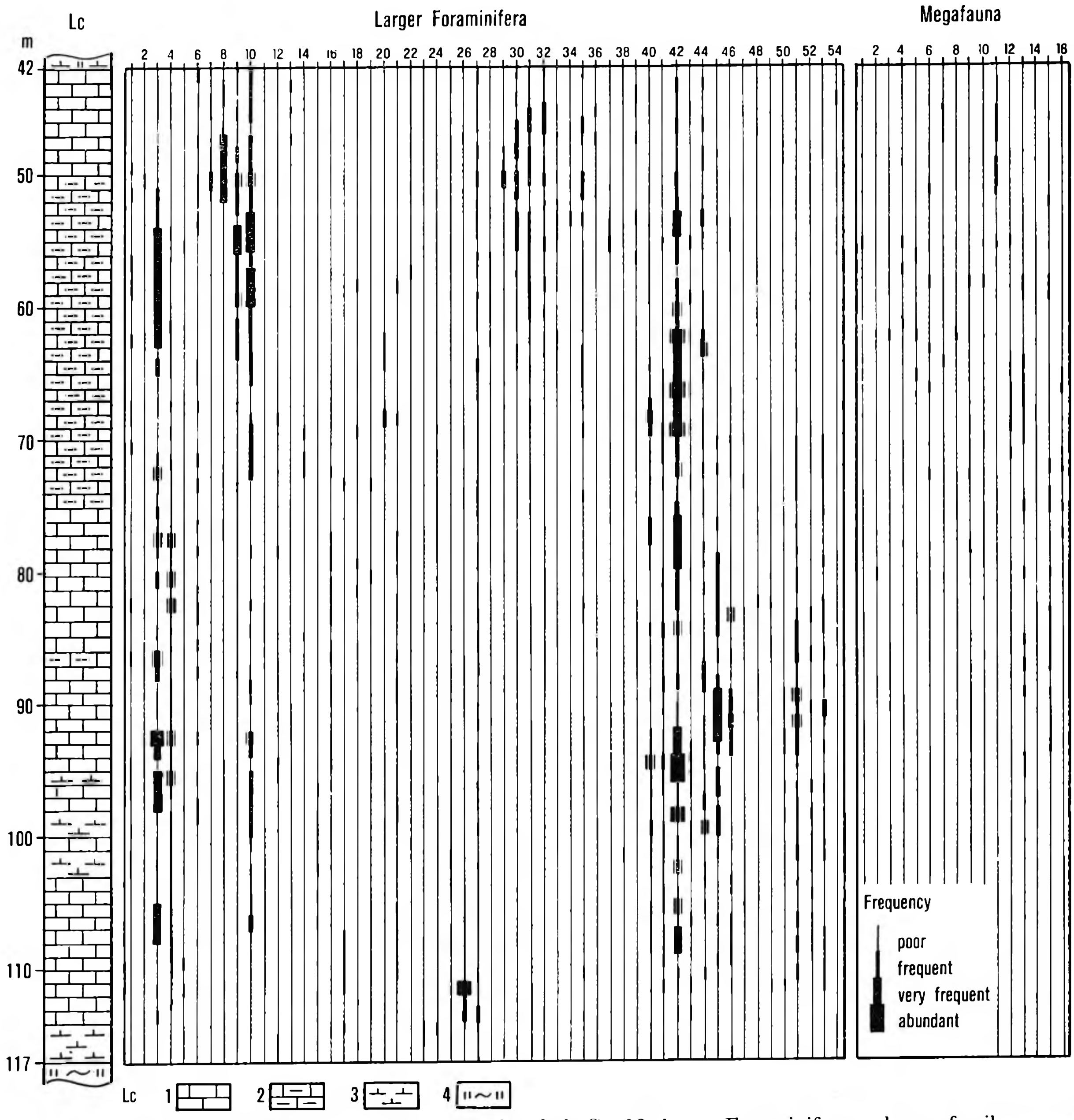


Fig. 72. The Szőc Formation interval of the borehole Crt-12: larger Foraminifera and megafossils

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. silty marl. — *Larger Foraminifera:* 1. Nummulites apertus, 2. N. brongniarti, 3. N. perforatus, 4. N. ex gr. perforatus, 5. N. deshayesi, 6. N. striatus, 7. N. anomalus, 8. N. incrassatus, 9. N. millecaput, 10. N. variolarius, 11. N. aff. striatus, 12. N. aff. partschi, 13. N. aff. discorbinus, 14. N. dufrenoyi, 15. N. sismondai, 16. N. aff. sismondai, 17. N. aff. globulus, 18. N. aff. urbiensis, 19. N. aff. puschi, 20. N. aff. dufrenoyi, 21. N. bakonicus, 22. N. aff. millecaput, 23. N. praelaevigatus, 24. N. aff. burdigalensis, 25. N. gidaiensis nov. sp., 26. N. laevigatus, 27. N. sp., 28. Discocyclina scalaris, 29. D. aspera, 30. D. nummulitica, 31. D. papyracea, 32. D. pratti, 33. D. sella, 34. D. varians, 35. D. sp., 36. Operculina alpina, 37. O. parva, 38. O. granulosa, 39. O. sp., 40. Assilina spira, 41. A. praespira, 42. A. exponens, 43. A. pustulosa, 44. A. sp., 45. Alveolina elongata, 46. A. fragilis, 47. A. aff. elongata, 48. A. aff. fragilis, 49. A. fusiformis, 50. A. gigantea, 51. A. sp., 52. Orbitolites complanatus, 53. O. sp., 54. Actinocyclina sp. — *Megafossils:* 1. Tubulostium spirulaeum, 2. T. sp. 3. Chlamys multicarinata, 4. C. biarritzensis, 5. C. aff. biarritzensis, 6. C. sp., 7. Pecten sp., 8. Anomia tenuistriata, 9. A. sp., 10. Ostrea cf. plicata, 11. O. sp., 12. Rotalia sp., 13. Asterigerina rotula, 14. Cibicides sublobatulus, 15. C. sp., 16. Sphaerogypsina sp.

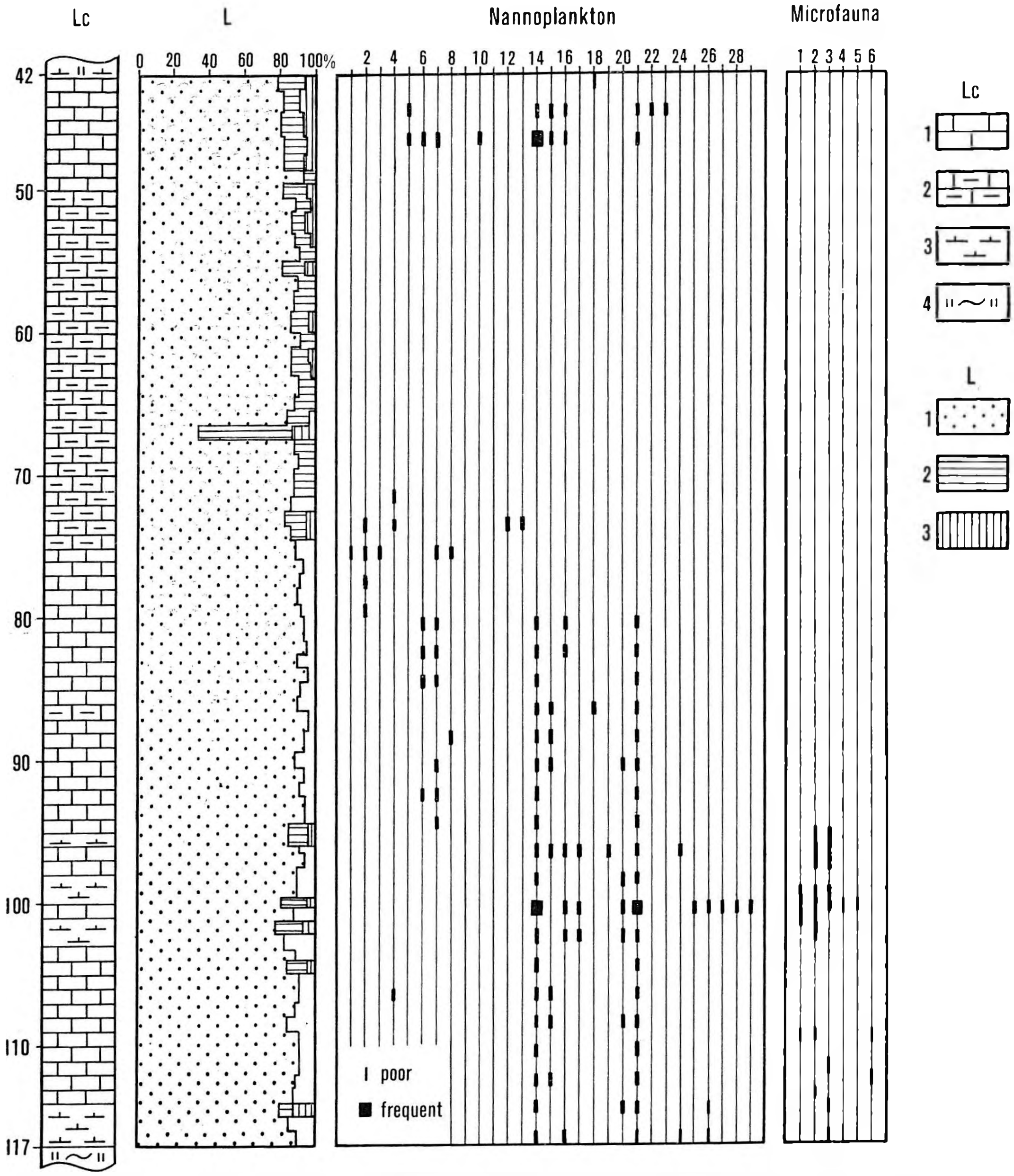
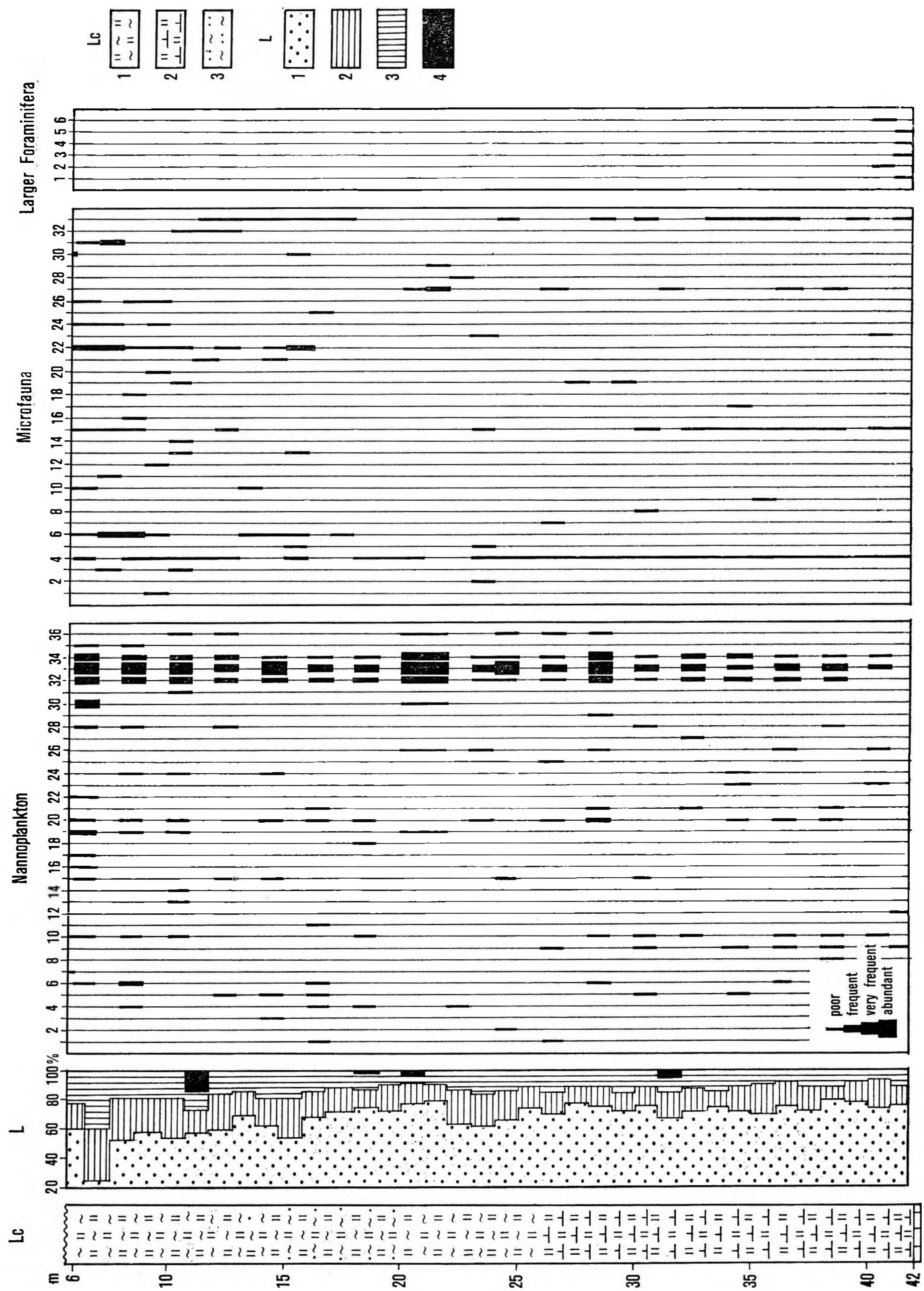


Fig. 73. The Szőc Formation interval of the borehole Crt-12: lithologic column and analytical record

Lithologic column (Lc): 1. limestone, 2. argillaceous limestone, 3. calcareous marl, 4. silty marl. — ***Lithologic composition*** (L): 1. $CaCO_3$, 2. clay, 3. silt. — ***Nannoplankton:*** 1. Discolithina pulchra, 2. D. sp., 3. Coccolithus eopelagicus, 4. Reticulofenestra bisecta, 5. R. cf. bisecta, 6. R. sp., 7. Braarudofenestra bigelowi, 8. B. sp. indet., 9. Pemma rotundum, 10. Discoaster barbadiensis, 11. D. crassus, 12. D. sublodoensis, 13. D. cf. lodoensis, 14. Cyclocargolithus sp., 15. Cyclococcolithina formosa, 16. Sphenolithus moriformis, 17. S. radians, 18. S. cf. radians, 19. S. cf. furcotolithoides, 20. S. sp., 21. Ericsonia muiri, 22. Chiasmolithus grandis, 23. C. solitus, 24. Sphenolithus pseudoradians, 25. Helicopontosphaera sp., 26. Cyclococcolithina sp., 27. Rhabdosphaera tenuis, 28. R. inflata, 29. Coronocyclus nitescens. — ***Microfossils:*** 1. Quinqueloculina sp., 2. Asterigerina rotula, 3. Cibicides sp., 4. Planulina sp., 5. Sphaerogypsina sp., 6. Triloculina angularis

is dominated by *N. laevigatus*, though *N. perforatus* appears, too (Fig. 72). The topmost part of the formation in the borehole Cn-850 is absent, but this subunit too is well exposed in the borehole Crt-12 (Fig. 72 and 73, Plate XLVI).

A gradual transition in the sequence is observable between the Szőc and Csabrendek Formation. The features of the Szőc Limestone disappear gradually to be replaced progressively by the characteristics of the Csabrendek Marl. As one proceeds upwards, the carbonate content decreases (from 90% to 75% $CaCO_3$), the clay content increases, the argillaceous limestone is replaced by calcareous marl, the colour turns greenish-grey to grey. Near the formation boundary (from 52 m on) the glauconite content shows a marked growth, reaching 80 to 85% of the light mineral fraction. (The frequent occurrence of glauconite grains is characteristic of the lower part of the Csabrendek Marl, too.) The glauconite often fills the chamberlets of Foraminifera.


Lc
1
2
3
L
1
2
3
4
Larger Foraminifera
Microfauna
Nannoplankton
poor
frequent
very frequent
abundant
100%
m

The amount of the specimens of larger Foraminifera, especially of those of *Nummulites millecaput* characteristic of the upper part of the formation, is reduced (Fig. 72). The fossils abounding in the Csabrendek Marl appear (e.g. *Tubulostium spirulaeum* in the 47.5 to 48.5 m interval). The upper boundary of the formation can be drawn there, where the larger Foraminifera cease to play a rockforming role. This coincides with the disappearance of *N. millecaput* (42.0 m).

The surface extension of the formation is shown in Fig. 67. There are outcrops in the valleys of slopes around the Rendek-hegy and near the hilltop level (e.g. "Fehér kövek" = White Stones), in the ravines lacing the hill and also in Csabrendek village. In the vicinity of Csabrendek, several minor quarries have exposed the higher parts of the formation (Plate XLIV, Fig. 1).

The boreholes drilled for construction raw materials and bauxites on the Rendek-hegy and the Kozma-tag subarea cut the formation in a number of cases, finding it, as a rule, in a facies similar to the type section of the borehole Cn-850. In some cases (e.g. the location of the borehole M 1/F in Fig. 67), however, a lithofacies of calcarenite and calcilutite texture, poor in larger Foraminifera, but abounding with red algal remains, could be observed.

To the east of the Rendek-hegy a number of boreholes other than Crt-12 (Cn-562, -563 and -593) exposed the Szőc Limestone as underlying the Csabrendek Marl.

On the hilltop of the Hárs-hegy the lower, Alveolina-Assilina-bearing limestone beds of the formation overlie Darvastó Formation of reduced thickness (boreholes S-30 and Süt-8). In the upper yard of the Gerinc quarry the limestone overlies, with a marly layer of reduced thickness in-between, directly the Upper Cretaceous limestone or the bauxite filling the funnel-shaped dolinas in it.

Bio- and chronostratigraphy

The primary basis of chronocorrelation is the assemblage of larger Foraminifera (Fig. 71 and 72). In the discussion of the formations we have already mentioned that *Nummulites laevigatus* disappears by and large at the boundary of the Darvastó and Szőc Formations, thus the biozonal boundary and the formation boundary roughly coincide in this area.

As shown by M. Jámbor-Kness, in terms of foraminiferal assemblages and the abundances of the fossils, two biozones could be distinguished within the Szőc Formation: 1. the *Assilina spira* Zone and 2. the *Nummulites millecaput* Zone. No separate *N. perforatus* unit (horizon) is distinguishable. As shown by a detailed study of the larger Foraminifera (boreholes Cn-850, Crt-12), the individuals of *Assilina spira* are encounterable in considerable quantities up to the appearance of *N. millecaput*. *N. perforatus*, however, appears already with *N. laevigatus*, being observable associated with specimens of *Assilina spira* and *N. millecaput* as well, mainly as dominant or subdominant species.

Since the appearance of *N. laevigatus* indicates the base of the Lutetian and since the Csabrendek Formation represents the top of the Middle Eocene (with nannoplankton and a smaller foraminiferal assemblage in the borehole Crt-12) or possibly the very base of the Upper Eocene (larger foraminiferal fauna), the Szőc Formation as a whole can be assigned to the Lutetian stage.

Paleoenvironment

Composed of biogenic carbonate rocks, the formation was deposited in a shallow warm-water sea of normal salinity. The paleoenvironment is interpreted, similarly to the case of the Upper Cretaceous rudist-bearing limestone, as a shallow-water carbonate platform, the only difference consisting in that the role of the main lime-secreting fossil group has been taken over—from the extinct rudists—by *larger Foraminifera* now having their flourish. As a matter of course, there may be marked differences in the development of minor paleoenvironmental units within the platform, discrepancies that may be ascribed primarily to differences in the ecological features of the predominant fossil group. Foraminiferal shells were obviously insufficient for the construction of biogenic structures

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Fig. 74. The Csabrendek Marl Formation interval of the borehole Crt-12: lithologic log and analytical record

Lithologic column (Lc): 1. silty marl, 2. silty calcareous marl, 3. sandy marl. — ***Lithologic composition*** (L): 1. $CaCO_3$, 2. clay, 3. silt, 4. sand. — ***Nannoplankton:*** 1. Discolithina pulchra, 2. D. multipora, 3. Rhabdolithus sp., 4. Zygrhabdolithus bijugatus, 5. Coccolithus eopelagicus, 6. Reticulofenestra placomorpha, 7. R. bisecta, 8. R. cf. bisecta, 9. R. sp., 10. Braarudosphaera bigelowi, 11. B. sp., 12. Pemma rotundum, 13. P. cf. rotundum, 14. P. sp., 15. Discoaster barbadiensis, 16. D. saipanensis, 17. D. floreus, 18. D. sp. ind., 19. D. sp., 20. Sphenolithus moriformis, 21. S. radians, 22. S. cf. radians, 23. S. pseudoradians, 24. S. furcatolithoides, 25. S. cf. furcatolithoides, 26. S. spiniger, 27. S. sp., 28. Chrasmolithus grandis, 29. C. cf. grandis, 30. C. solitus, 31. Lanternithus minutus, 32. Ericsonia muiri, 33. C. sp., 34. Cyclococcolithina formosa, 35. C. protoannula, 36. Helicopontosphaera sp. — ***Microfossils:*** 1. Globorotalia broedermanni, 2. G. sp., 3. Planulina costata, 4. Cibicides sp., 5. Globigerapsis kugleri, 6. G. index, 7. G. sp., 8. Pararotalia inermis, 9. Dorothia sp., 10. Truncorotaloides rohri, 11. Tritaxia szabói, 12. Tursenkoina hungarica, 13. Hantkenina dumblei, 14. H. longispira, 15. Spiroplectammina carinata, 16. Textularia sp., 17. Valvulina sp., 18. Quinqueloculina sp., 19. Lenticulina sp., 20. Marginulina gladius, 21. M. fragaria, 22. Dentalia elegans, 23. D. sp., 24. Bolivina elongata, 25 Uvigerina multistriata, 26. U. sp., 27. Asterigerina rotula, 28. Rotalia sp., 29. Halkyardia minima, 30. Globigerina yeguaensis, 31. G. corpuleta, 32. G. linaperta, 33. G. sp. — ***Larger Foraminifera:*** 1. Nummulites anomalus, 2. N. millecaput, 3. N. variolarius, 4. N. sp., 5. Discocyclina pratti, 6. Operculina alpina (reefs) that should have led to remarkable sedimentary differentiation of the platform. For this rea son, the resulting facies pattern is less varied than it is the case e.g. with the Ugod Limestone.

Anyway, two lithofacies types are readily distinguishable: 1. a rock made up mainly of larger foraminiferal shells and 2. an aphaneritic, finely crystalline limestone with but sporadical larger Foraminifera in which nodules of *red algae*, skeletal elements of *echinoderms* and, in certain cases, even *crab* remains are usually quite frequent.

During the formation of larger foraminiferal "lumachelles" the shells of organisms lived in the vicinity of the site of accumulation were deposited. Thus this rock type was formed in areas most favourable from the viewpoint of biogenic carbonate segregation, i.e. in the agitated parts of the platform well-penetrated by sunlight and rich in oxygen and nutrients; while the fine-grained, calcareous mud to bioclastic sediments were deposited in the relatively deeper parts of the platform, where the water was less agitated. Since a sharp morphological or other ecological boundary cannot be supposed to have existed between the two paleoenvironments, the situation of the environments may have changed considerably even within a short span of time and therefore the relationship of the facies, their intertonguing, seems to be very complex.

The fact that glauconite tends to become abundant in the upper part of the formation seems to be due to the volcanism that set in that time in the Lake Balaton–Velence Mountains line, even though the glauconite does not derive directly from a halmyrolitic alteration of the tuff material of the volcanism. The formation of glauconite may often be linked with the decay of organic matter, thus being associated with the microenvironment of foraminiferal shells, etc.

Csabrendek Marl Formation

The term Csabrendek Marl Formation was proposed—in agreement with the *Eocene Subcommission of the Stratigraphic Commission of Hungary*—by E. Dudich (1977). Accordingly, the Csabrendek Formation would correspond to that unit referred to in the earlier literature as "glauconitic-tuffaceous marl" or "marls with crabs and *Tubulostium*", respectively. The proposal, however, does not include either the designation of a stratotype or a description. In our opinion, the borehole Crt-12 put down at a distance of 2 km southeast of Csabrendek and analyzed in detail provides a good representation for the formation and therefore we recommend it for stratotype. The complete core material of the borehole is deposited in the Szépvízér Core Depository of the Hungarian Geological Institute.

Stratotype section: borehole Crt-12

Beneath a thin soil and Pannonian layer, the borehole exposed the Csabrendek Formation in the interval between 5.7 and 42.0 m. The upper part of the unit is constituted by silty argillaceous marls. The $CaCO_3$ content increases progressively from 25% at the top to 75% at the bottom and the clay and silt content decreases parallel to this (Fig. 74) so that the calcareous marl lithofacies type is characteristic in the lower interval. The rock colour is grey to light grey throughout the unit or, at the base, owing to the glauconite content, it turns greenish-grey.

Typical of the unit in question, glauconite between 7.5 and 9.0 m appears in larger aggregates, nodules, then, below 17 m depth, it is represented by smaller grains. The maximum of its abundance was observed in the 19.0 to 20.0 m interval. According to micromineralogical results (E. Sárközi-Farkas), the glauconite in the 17 to 42 m interval accounts for 75 to 95% of the light mineral fraction. Between 25 and 29 m even biotite grains could be identified. From among the allothigenic heavy minerals, garnet and tourmaline could be observed in almost all samples: in the light fraction quartz, quartzite and plagioclase are common.

The megafossils, primarily larger Foraminifera, show a marked decrease in quantity compared to the Szőc Formation. Larger quantities of larger Foraminifera are observable only in the lowermost, transitional beds (38–42 m) (Fig. 72) [*Nummulites anomalus* de la Harpe, *N. variolarius* (Lam.), *Discocyclina papyracea* (Boub.), *D. pratti* (Mich.), *Actinocyclina* sp., *Operculina alpina* Douv.]. Higher upwards single larger foraminiferal specimens can be found but sporadically.

Planktonic Foraminifera are frequent in the topmost part of the formation (15.7 to 16.0 m) (species of the genera *Globigerina*, *Globigerapsis*, *Globorotalia*, *Truncorotaloides*). Farther downwards the plankton gets gradually impoverished; only one or two specimens per sample are observable and even the benthonic assemblage is meagre and poorly preserved (Plate XLVII, Fig. 73).

Molluscs occur sporadically. Characteristic species: *Tubulostium spirulaeum* (Lam.), *Variamussium squamulus* Korobkov, *V. fallax* (Korobkov). Other megafossils: *crab's nippers*, *Brachiopoda*, *Bryozoa*, *Echinoidea*, *fish scales* and *fish teeth*.

The nannoplanktonic assemblage in the upper part of the formation (5.7–30 m) is extremely rich in species and individuals, becoming substantially poorer underneath (30–40 m) (Fig. 74). The spore-pollen assemblage is poor in both species and individuals throughout the sequence.

In addition to borehole Crt-12, the formation was penetrated in a considerable thickness by the boreholes Cn-563 and Cn-1055. Over quite a small area, at the bottom of the Pannonian gravel pit by the road from Csabrendek to Kozma-tag, the basal beds of the formation do even crop out.

Bio- and chronostratigraphy

The chronostratigraphic assignation of the formation cannot be considered finally settled. G. Kopek, T. Kecskeméti and E. Dudich (1966) placed the unit, on the basis of the larger Foraminifera, at the top of the Middle Eocene and they did not change their opinion even later. On the basis of larger Foraminifera from the borehole Crt-12, however, M. Jámbor-Kness places the unit as a whole at the base of the Upper Eocene.

In the light of planktonic Foraminifera [*Truncorotaloides rohri* (Brönn. et Berm.), *Globorotalia broedermanni* Cush. et B., *Globigerapsis kugleri* Bolli, Loeb. et Tapp.), K. Kollányi believes that the unit in question belongs to the Globorotalia lehneri Zone of the Lutetian.

Based on her studies of the nannoplankton, M. Báldi-Beke's opinion is that even the topmost beds from the borehole Crt-12 are assignable to the Middle Eocene. Namely, the Middle/Upper Eocene boundary would be indicated by the extinction of *Chiasmolithus grandis* (Braml. et Ried.)—a species regularly occurring throughout the sequence involved (boundary of NP zones 17 and 18). It is quite probable that even NP zone 17 representing the uppermost part of the Middle Eocene is absent for a considerable part, for the range of *Sphenolithus furcatoides* Loecher encounterable in the samples from below 7 m depth passes but into the lower part of NP zone 17.

Paleoenvironment

The formation evolves with a transitional subunit, but without any break in sedimentation, from the shallow-water carbonate platform facies sediments of the Szőc Formation, thus its lower part must still have been deposited close to the shallow-water platform, on a bottom that lay not very much deeper than that. The fine muddy sediment originated in a slightly agitated water, beneath the zone of wave action. The comparatively rich benthonic fauna *(Mollusca, Foraminifera, Brachiopoda, Bryozoa)* may have lived on a shallow sublittoral bottom more weakly penetrated by sunlight as compared to the case of the shallow-water platform.

Typical of the lower part of the formation, the enrichment of glauconite seems to have been connected with the volcanic activities—a probability referred to by the rather frequent presence of biotite as well.

Towards the upper part of the formation an increase in pelagicity and water depth is indicated by achieved predominance of planktonic fossils and, parallel to this, by the complete disappearance of the larger Foraminifera of the shallow-water platform environment. Consequently, the environment of deposition seems to have been a pelagic shelf area.

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Oligocene – Lower Miocene

by

J. Haas

On the hill range extending east of Sümeg the Csatka Gravel Formation, a lithostratigraphic unit of Oligocene to Lower Miocene age common to the Bakony area, can be studied over a large area even in outcrop. The vicinity of Sümeg is of particular importance and of genetic value because it is here within the known area of the formation that pebbles and boulders of largest size can be found.

Exploration history

Information on the Sümeg-area occurrence of formations assigned to the Csatka Gravel Formation in earlier literature is scant.

Regarding even the extended neighbourhood, J. Böckh (1878) was the first to discuss this formation in detail in his work devoted to the southern Bakony Mountains, assigning it as "conglomerate and gravel" to the "younger Mediterranean" stage. However, under this collective term they grouped various gravel deposits, not only Oligocene to Lower Miocene, but also Middle and Upper Miocene and even Pannonian ones.

L. Lóczy (1913) in his Balaton monograph, attempted at subdividing the "Mediterranean" gravel formations of the Bakony on the basis of the elevation above sea level. Thus he singled out four different horizons. The three lower gravel horizons were proved to be littoral deposits—a fact evidenced by their fauna. Regarding the stratigraphy "of the large gravel sheets soaring above 400 m altitude on the plateau of the Nagybakony and around Városlőd-Ajka", he is of the opinion that it is a still open problem, but in summarizing the results he concludes: "I consider the gravel conglomerate of the Bakony . . . to represent a terrestrial formation . . . belonging, for a larger part or completely, already to the Sarmatian beds". He considered this terrestrial facies of highermost position to include the gravel formation found on the 360-m-high plateau of the "Csúcsos-hegy" (= Rendeki-hegy) as well.

F. Pávai Vajna and I. Maros (1937), in the map-supplement to their paper on questions of water prospecting, gave relatively exactly the extension of the "Mediterranean gravel" of the Csúcsos-hegy.

J. Noszky Jr. (1958) was also unable to solve reliably the problem of separation from one another of the different "Mediterranean" gravel formations of the Bakony, often juxtaposed or superimposed on one another as they are. The gravel formation with giant pebbles and boulders in it on the hilltop of the Rendeki-hegy was assigned by him—with an emphasis placed on his being uncertain—to the Miocene.

In the light of the geological mapping of the Transdanubian Central Range system and the processing of materials recovered from a great number of boreholes, by the end of the 1960's the principal features of the stratigraphy of the gravel formations of the Bakony and of their genetic conditions have been cleared.

In the summarizing paper, Á. Jámbor and L. Korpás (1971) considered the fluviatile sand, pebble and clay sequence, hitherto assigned to different stratigraphic horizons, to be of "Upper Oligocene (Lower Miocene?)" age—an assignment based on the mode of superposition and the facies relations.

P. Jakus (1970), during his surveying the Csabrendek quadrangle of a map of 1:25,000 scale shed a clear light, in the immediate vicinity of our study area, on the mode of superposition of the formation, its extension and most important sedimentological features.

A detailed description of the Csatka Gravel Formation is contained in a monograph by L. Korpás (1981). References concretely to the Sümeg area are few in this monograph, but, in evaluating the Sümeg deposits, we have taken into consideration the data concerning the unit as a whole, the facies analysis and the paleogeographic synthesis.

Csatka Gravel Formation

Extension, mode of superposition, geological features

The Csatka Gravel Formation is known from the Bakony Mountains and also from their northern and western forelands. It is composed of cyclicly alternating gravel-conglomerates, sands to sandstones, variegated clays, argillaceous marls, marls and siltstones. At its base, as a rule, grey clays, argillaceous marls, and carbonaceous clays are found (Szápár Lignite Member).

In the Sümeg area the surface extension of the formation is difficult to determine with precision owing to the lack of boreholes. Exposures suitable for a scrutinized examination are very rare, if any. All that which can generally be observed are "sporadical gravels" scattered over the surface. Whether these constitute outcrops of the Csatka Formation or represent pebbles redeposited from them subsequently, is difficult to decide.

A rather large and coherent gravel outcrop that is undoubtedly in its primary position is known from the hilltop level of the Rendeki-hegy. Here some boreholes have exposed the Csatka Formation too, which in this area overlies the upper member of the Szőc Formation without any remarkable angular unconformity. On the southwestern margin of the plateau of the Rendeki-hegy, the biggest boulders are known to occur, boulders which, judging by their position, may represent the basal part of the Csatka Formation. Set loose by erosion from the sandy rock, the boulders seem to have been exposed already prior to the Pleistocene. Their surface is usually polished bright and even "sharp, angular pebbles" are quite frequent.

The boulders are composed (listed in their order of frequency) of meta-sandstone, gravelly meta-sandstone, breccia and conglomerate of very low-grade metamorphism (meta-breccia and meta-conglomerate), yellowish-white to grey quartzite, tourmaline-bearing quartzite, dark grey sandstone, andesite, in lesser quantity, red sandstone (Permian), quartz-porhyry, dark grey limestone, white spongiolite, quartz-phyllite, and biotite-quartz mica-schist.

A thin section analysis of type samples of the boulders was carried out by Gy. Lelkes-Felvári. Upon examining the gravelly meta-sandstone type predominant within the gravels, she came to the conclusion that it had undergone but a very slight metamorphism. Its detrital grains: quartz, feldspar, muscovite, biotite and rock debris. The grains show a faint orientation, the original roundness not being recognizable owing to recrystallization of the matrix between the grains.

Presenting the habit of lydite when viewed with an unaided eye, the dark grey quartzite boulders are of metamorphic origin, being heavily mylonitized. They do not exhibit the layered texture typical of lydite.

In the type sample of the tourmaline-bearing quartzite gravel, the rock texture was breccious; in addition to angular quartzite detritus, sandstone debris and recrystallized, acidic effusive detrital material were recognizable in it. The debris are cemented by tourmaline.

In the quartz-phyllite gravel the predominant quartz mineral could be shown to be associated with muscovite and, as accessories, tourmaline and zircon. Muscovite is oriented according to schistosity.

The sandstone gravel samples are medium- to coarse-grained, being composed predominantly of quartz grains. The matrix is very poor, being constituted by silica and sericite-muscovite. In addition to quartz, the detrital grains are: albite, microcline, muscovite and rock debris. The percentage of feldspar is 10 to 15%.

Described megaloscopically as quartz porphyry, the gravel was identified with rhyolite tuff and quartz-porphyry tuff. The porphyric impregnations are represented by quartz and mafic silicates (mainly rhombic pyroxenes). The matrix has altered to microcrystalline quartz.

Similarly from the top of the Rendeki-hegy derives the boulder which, as found by Cs. Ravasz, is made up of decomposed acidic effusives of rhyolite and dacite. From its phenocrysts, only quartz is preserved intact. The place of the mafic silicates is occupied by chlorite, prehnite and ore minerals. The glass phase of the groundmass is recrystallized, the feldspars are argillitized, the mafic constituents are chloritized. Primary ore minerals: magnetite, titanomagnetite; secondary minerals: hematite, limonite and leucoxene.

The boulders at the top of the Rendeki-hegy are 40 to 50 cm in size. The biggest boulder ever found in the study area was observed there. It measured 85 cm in length, 45 cm in width and 35 cm in height. The material constituting it is andesite (Plate XLVIII, Fig. 1). Each boulder is strongly rounded (K = 3–4 in terms of Rukhin's 5-division scale).

Information on the thickness of the Oligocene to Lower Miocene gravels covering the top level of the hill and on its geological features is furnished by a few boreholes spudded for the purpose of prospecting for construction raw materials. The borehole M-1/F exposed a formation made up of argillaceous, sandy gravels of 8 m thickness above the Szőc Limestone. The pebbles vary from 1 to 4 cm in size with a maximum of 25 cm. Well-rounded (K = 3–4), they are composed in 25% of Cretaceous limestone, in 25% of Eocene limestone, the remaining 50% being represented by meta-sandstone, mica-schist, quartzite, siliceous shale and chert.

The thickness of the formation on the hilltop of the Rendeki-hegy is estimated at a maximum of 20 m.

In the area between the Rendeki-hegy and the Hárs-hegy–Hajnal-hegy range there are two narrow belts of northeast-southwest trend in which the typical gravels of the Csatka Formation are recognizable at every step, but whether we have to do with an outcrop in primary position or with redeposited gravels is particularly difficult to decide there. In the neighbourhood of the minor clearing at the southwest foot of the Rendeki-hegy boulders are found in abundance, for the most part in mounds accumulated as a result of farming. The boulders are composed of white, grey or, sometimes pinkish quartzite, meta-sandstone, meta-conglomerate, siliceous shale, chert (radiolarite, spongiolite), quartz porphyry, sandstone and quartz-phyllite varying between 10 and 40 cm and a maximum of 45 cm in size. Their roundness is fair (1–3).

Based on measurements of 77 pebbles or boulders, respectively, the size and roundness data are presented in Fig. 75.

In a tectonically down-faulted block on the southeast side of the Rendeki-hegy, the borehole Ck-167 exposed, above the Eocene Szőc Limestone, a 20-m-thick sequence of the formation. The exposed formation is represented by argillaceous, sandy gravels. The boulders or pebbles vary from 0.5 to 20 cm in size, being made up of meta-sandstone, meta-conglomerate, quartzite, siliceous shale, dark grey limestone and radiolarite. In the Kozma-tag subarea the Senonian Ugod Limestone (e.g. in the borehole Ck-176), the conglomerate member of the Eocene Darvastó Formation (e.g. boreholes Ck-18, -30, -37, -109) and various members of the Szőc Limestone Formation (Ck-165, -166 and -181) are respectively overlain by rocks assignable to the Csatka Formation.

The sequence is well represented by the section of the borehole Ck-176 in which the Ugod Limestone is overlain by a 13-m-thick sequence of the Csatka Formation. At the very base there are sandy, gravelly variegated clays, followed higher up the profile by clay beds with pebbles. The pebbles vary between 3 and 15 cm in size, being composed of quartzite and meta-sandstone. At the top, gravelly red clays are found.

For a chronostratigraphic assignation, no directin formation is available. As far as the mode of superposition is concerned, all that which we know is that the youngest formation is the Middle

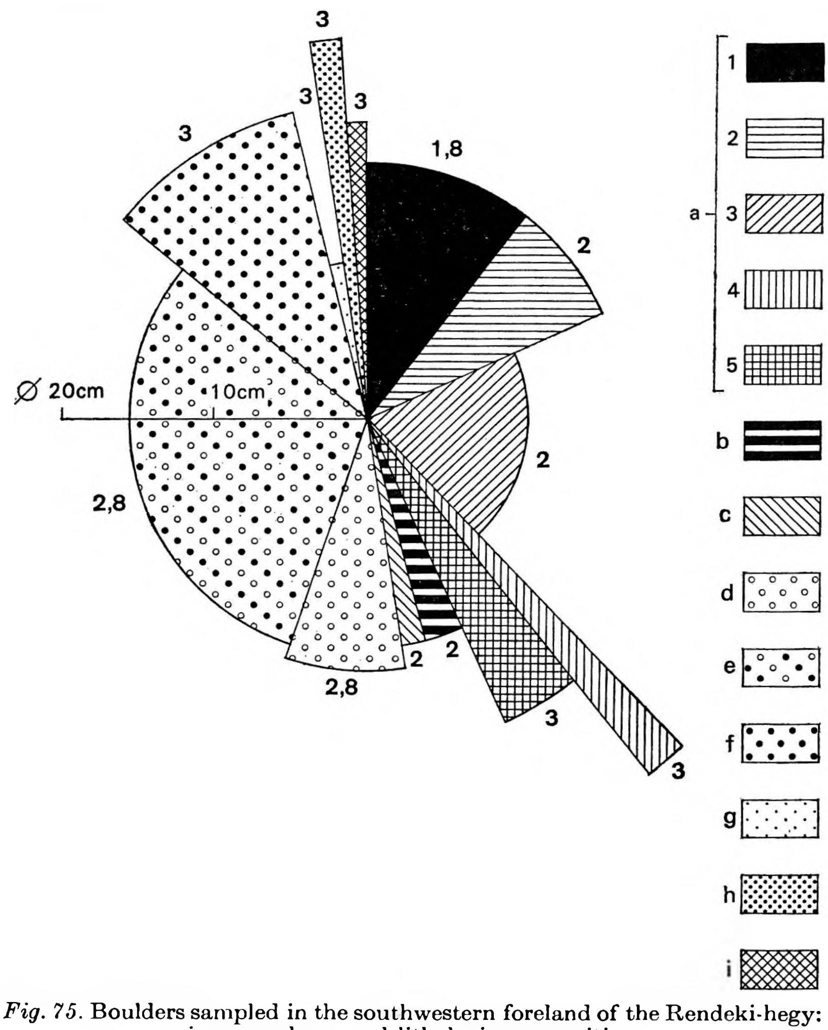

Fig. 75. Boulders sampled in the southwestern foreland of the Rendeki-hegy: size, roundness and lithologic composition

a) Quartzite: 1. dark grey, 2. light grey, 3. white to yellowish-white, 4. red, 5. brown to brownish-grey, *b)* chert, *c)* black shale, *d)* sandstone, *e)* metasandstone, *f)* metabreccia, *g)* metasandstone breccia, *h)* quartz—porphyry, *i)* pulverulent dolomite. — Fat numerals indicate degree of roundness (RUKHIN's scale) to Upper Eocene Csabrendek Marl Formation (Fig. 67), Badenian gravels being regarded as oldest overburden rock. The chronostratigraphy of the formation is controversial elsewhere in the Central Range as well.

L. Korpás (1981) believes that it encompasses the Oligocene as a whole or possibly even the lower part of the Miocene. T. Báldi (1976), however, is of the opinion that it is confined to the Upper Oligocene only.

Paleoenvironment

The outcrops in the Sümeg area of the Csatka Formation have provided important data for a paleogeographical interpretation of this widespread formation as a whole, primarily as far as the location of the source area, its geology and characteristics are concerned.

The largest amount of information was furnished by the analysis of the boulders. L. Korpás (1981) considers what he refers to as "giant gravel" facies to have been the stream-load of mountainous rivers that flowed into an Oligocene main stream. On the basis of the size of the boulders (the maximum being, as observed by him, 30 cm), he postulates a transport for a maximum distance of 30 km. Since in the Sümeg area boulders outnumbering two and even three to one the maximum size observed by L. Korpás have become known, the transport by streams of upper-course type and the supposition of small transport distances and great differences in altitude have been convincingly corroborated by facts. That from among the Central Range outcrop areas of the Csatka Formation the Sümeg area must have lain nearest to the mountain's source area cannot be doubted either. In the gravels there are representatives of rocks (Lower Paleozoic quartz-phyllite, Permian red sandstone, quartz-porphyry and Eocene andesite) that seem to have derived, by all probability, from a ridge (the Pelsonian Ridge) that lay in the area of what is now Lake Balaton or farther south, representing an emergent landmass at the time of accumulation of the deposits. That ridge may have lain at a distance of 30 to 35 km away.

It is from the southern marginal zone of the Central Range syncline that the other boulders and pebbles made up of crystalline rocks may be derived, though the fact that the commonest constituents of the gravels—meta-sandstones and meta-conglomerates—are for the moment still unknown from the area does certainly pose a problem.

For an interpretation of the finer-grained detrital and pelitic rocks, the analysis of the Sümeg area does not give any new contribution.

From the diversified mode of superposition of the formation, it may be concluded that, in post-Eocene and pre-Csatka Formation times (Pyrenean phase), the study area was block-faulted and tilted to the north (with the Rendeki-hegy block faulted to a deeper position) and eventually the disrupted blocks would slide down the underlying rocks. It was upon this surface of "décollement" that the predominantly fluviatile alluvium would be deposited in Oligocene time.

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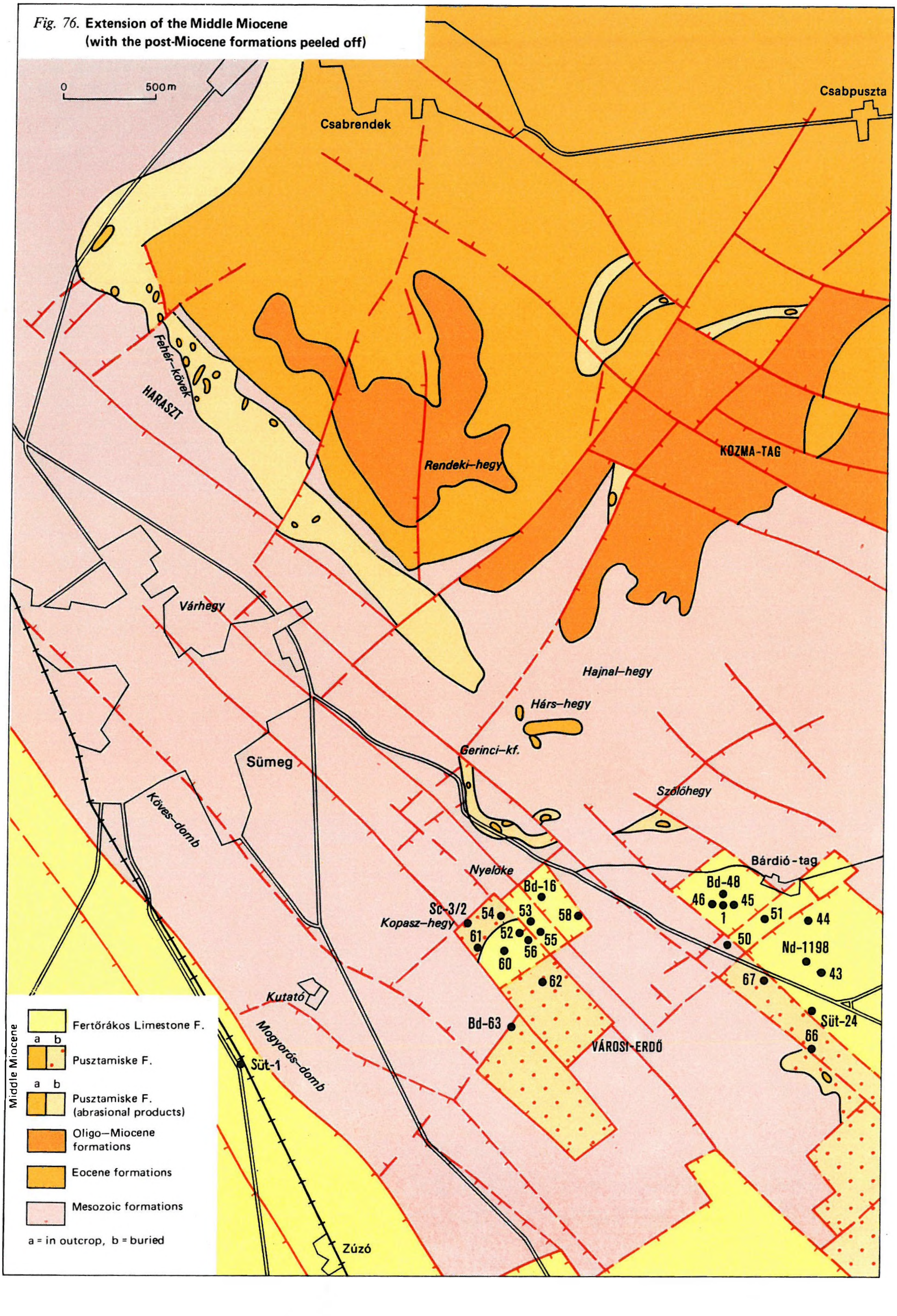
Fig. 76. **Extension of the Middle Miocene (with the post-Miocene formations peeled off)**



Middle Miocene

- Fertőrákos Limestone F.
- a b — Pusztamiske F.
- a b — Pusztamiske F. (abrasional products)
- Oligo–Miocene formations
- Eocene formations
- Mesozoic formations

a = in outcrop, b = buried

Middle Miocene

by

E. J.-Edelényi

Miocene rocks postdating the Csatka Formation form a continuous outcrop to the southeast of Sümeg, in the Nyelőke and Városi-erdő subareas and to the west of the fault constituting the edge of the Köves-domb–Mogyorós-domb morphological unit. Smaller outcrops are known on the Szőlő-hegy and in form of outliers that escaped denudation in several points at the foot of the Rendeki-hegy (Fig. 76).

The geological significance of the Middle Miocene in the Sümeg area stems primarily from the presence of coarse-detrital sediments of not too wide areal extension, but of diversified facies. Coarse-detrital sediments of similar character can be found even in several stratigraphic horizons in the study area, therefore to identify, i.e. distinguish the respective gravel formations in the earlier stages of geological exploration proved rather difficult. Clues to solving the problem have been provided by pebble analyses. An essential problem to be solved has been the correlation of Miocene formations of marginal facies or of discontinuous stratigraphy with the basin-centre sequences farther away.

Exploration history

The literature dedicated to the Middle Miocene from the Sümeg area deals almost exclusively with coarse-detrital formations, as no carbonate sediment of this age can be observed in outcrop and it was not until exploratory drilling in recent years that such could be discovered in boreholes. The literature on coarse-detrital formations is extremely diversified, as these formation were assigned to different stratigraphic horizons by different authors.

J. Böckh in Volume II (1875–79) of his work "The geology of the southern Bakony Mountains" quotes his having found "Leithakalk" and "Late Mediterranean conglomerates" in a number of points to the south and southeast of Sümeg, around Deáki- and Dörögdi-puszta. These occurrences were regarded by him as coherent formations—a statement based on his observation in a number of places of a very remarkable amount of gravels within the Leithakalk. The rightness of his observations has been corroborated by a maze of data multiplied by repeated drilling activities.

L. Lóczy (1913) emphasized the possibility of repeated multiple redeposition of the gravel beds. He regarded the Mediterranean gravels surrounding the Bakony as coastal deposits and, on the basis of their location, he singled out three gravel horizons. The Mediterranean gravels of Sümeg were assigned by him to the second horizon spanning the interval between 180 and 200 m depth. From the neighbourhood of Bárdió-tag to the southwest of Sümeg—from the southern foot of the Szőlő-hegy—he collected, from an altitude of 200 m, even a fauna which would be determined by Z. Schréter (*Heliastraea reussana* M. Edw. et H., *Ostrea camellosa* Brocc., *Gigantostrea crassicostata* Sow.). Having studied the coarse gravels interbedded within red clays in the Sümeg–Tapolca–Devecser zone, he concluded that they represented a terrestrial formation and because of their being locally superimposed on the Tortonian (Upper Mediterranean) Leithakalk he considered them to have been formed in Sarmatian time.

The gravels on the northern side of the Rendeki-hegy along the Csabrendek–Sümeg road and the excellently rounded boulders of the Haraszt deriving primarily from Upper Cretaceous and Eocene rocks were assigned, without any paleontological evidence to rely on, to the Pannonian. At the steepening of the Tapolca–Sümeg road near Ódörögd-puszta he sampled Lithothamnium limestone.

During his mapping of the Sümeg area, R. Hojnos (1943) assigned the gravels forming a kind of plateau on the hilltop of the Rendeki-hegy—gravels belonging in terms of present-day knowledge to the Oligo-Miocene Csatka Formation—to the Mediterranean stage. He quoted fossils sampled by L. Lóczy from the gravel sheet of the Szőlő-hegy and he found himself specimens of *Balanus*, but he did not discuss the relation of the formation to the beds on the Csúcsos-hegy.

L. Strausz (1952) performed a systematic examination of the gravel formations of Transdanubia and, on the basis of the roundness of the quartzite pebbles or boulders, he regarded the gravels on the Csúcsos-hegy to be Miocene, a deposit from which the gravels encounterable on the slope of the Csúcsos-hegy had been subsequently removed by erosion and emplaced at their new site, where they would be rapidly buried together with the fallen Eocene blocks.

In his report on bauxite exploration activities performed at Sümeg and in its extended environs, K. Barnabás (1951) described the quartzite, sandstone and crystalline schist pebbles from the hilltop of the Csúcsos-hegy as fluviatile sediments deposited immediately before the Late Mediterranean transgression. In his opinion, that formation was a sub-isochronous, heteropical counterpart of the quartzite gravels underlying the Tortonian Leithakalk in the vicinity of Iza-major which, in turn, seems to be a littoral formation that was, as suggested by the quartzite grains frequent in the Leithakalk, still being deposited during the formation of this latter. As put by him, since the Leithakalk is of Tortonian age, the gravel must be so too or, in its basal part, it may be of Helvetian age, i.e. synchronous with the Helvetian gravels of the Csúcsos-hegy.

During his mapping work of 1957, J. NOSZKY JR. assigned the gravels, believed to be Grundian by L. LÓCZY and K. BARBANÁS and Lower Pannonian by A. RÓNAI and J. SÜMEGHY, to the Eocene—an assignation based primarily on the bauxite and variegated clays underlying the gravels. The strongly cemented conglomerate and what was referred to as "schotterartiger" unconsolidated, sandy gravel and even the huge boulders and the subspherical coarse pebbles were assigned to the Eocene, too.

He considered the red-brown, very compact, strongly cemented conglomerate rocks of the Városi-erdő (the so-called Oltárkő = Altar-Stones) to be of Miocene age and pointed out that materials deriving from the conglomerate can be found scattered over the hillocky area of the forest. In the southeast part of the Városi-erdő, he found grey, slightly argillaceous sandstones dated Miocene by fossils.

The Oligo-Miocene gravel blanketing the hilltop of the Csúcsos-hegy was regarded as Miocene too and LÓCZY's standpoint was criticized, since, in judging the age, he had taken into consideration the elevation above sea level too, neglecting the role of recent crustal movements.

In 1969, it was P. JAKUS who was mapping in the study area. He considered the coarse-grained and predominantly carbonate-constituted gravels of rather low topographic position along the Csabrendek–Sümeg road as of Lower Miocene age, while the topographically higher-situated gravels composed almost completely of siliceous matter were assigned to the Upper Pannonian. As described by him, the Miocene gravels are often superimposed on an Eocene limestone with traces of borer-bivalves and *Anomia* sp. was recorded, too.

Á. JÁMBOR and L. KORPÁS were the last to discuss the stratigraphic position of the gravel formations of the Transdanubian Central Range. In their summarizing work (1971), they assigned the gravels by the Sümeg–Csabrendek road, on the basis of the large holes bored by *Lithodomus* specimens in the underlying Eocene limestone, to the Lower Tortonian. [Let us note here that the opinion expressed in the paper just quoted on this matter is that of L. KORPÁS, because in Á. JÁMBOR's opinion (oral communication) that gravel, together with its counterpart on the northeast slope of the Vár-hegy of Sümeg, is of Pannonian age.]

Extension, mode of superposition, stratigraphic subdivisions

Miocene rocks postdating the Csatka Formation form a rather large, contiguous outcrop in the Városi-erdő and Nyelőke subareas (Fig. 76), where they overlie for the most part the Rezi Dolomite and, in lesser measure, in the Nyelőke subarea, the Upper Cretaceous Ugod Formation (Fig. 77). Their overburden is constituted, as evidenced by the results of exploratory drilling for bauxite there, by 10 to 15 m of Pannonian formation. Occurring at sub-crop level in the Városi-erdő, the Middle Miocene rocks do even crop out in some places in the southern and southeastern parts of the subarea. Their extension is considerable to the west of the railway line running on the western edge of the Mogyorós-domb, where they are superimposed on Mesozoic formations. Here too they are overlain by Pannonian formations in 10 to 40 m thickness with a westward increase of this parameter. In outcrop or in sub-crop position are relicts that have escaped denudation and that overlie the Rezi Dolomite, the Hauptdolomit and the Ugod Limestone in the Szőlő-hegy area. On the other hand, they overlie the Rendek Member at the northwestern foot of the Rendeki-hegy and on its slope of the same exposition and the Ugod Limestone on the eastern slope.

Miocene rocks younger than the Csatka Formation may be subdivided into two large lithostratigraphic units. It is the identification of the coarse-detrital sediments that is faced with difficulties in the stratigraphic assignation of the formations. On the older basement, they are superimposed with a marked break in sedimentation. They are usually unfossiliferous, similarly to the case of other coarse-detrital formations from the study area and, on account of their being exposed to daylight or in a sub-crop position, they often lack an overburden, their upper strata may have been redeposited into younger formations. An identification of these formations could be achieved by a great number of statistical analyses of gravels during which the lithological composition, the grain size, the sorting, the roundness and the flatness of the boulders and pebbles were examined.

As a result of these studies, the Middle Miocene coarse-detrital sediments can be assigned to one formation that can be identified with the Pusztamiske Formation—a lithostratigraphic unit listed in the stratigraphic scale proposed by the *Miocene Working Group of the Stratigraphic Commission*. Within the formation two facies are distinguishable: the abrasional conglomerate and gravel unit of the Rendeki-hegy and the Szőlő-hegy on the one hand and the fluviatile gravel and conglomerate unit of the Városi-erdő subarea clearly separable from the former even geographically, on the other. Given their limited geographic extension, in our opinion, it would be unjustified to distinguish or name either of the two separately as an independent unit, at least as far as the study area is concerned. Another lithostratigraphical unit of formation rank made up of biogenic limestones and known from the northern part of the Városi-erdő and in the Nyelőke subarea as well as in the southwest facies area of the Middle Miocene can be identified with the Fertőrákos Limestone Formation. It overlies partly the Pusztamiske Formation, partly being superimposed directly on Mesozoic rocks.

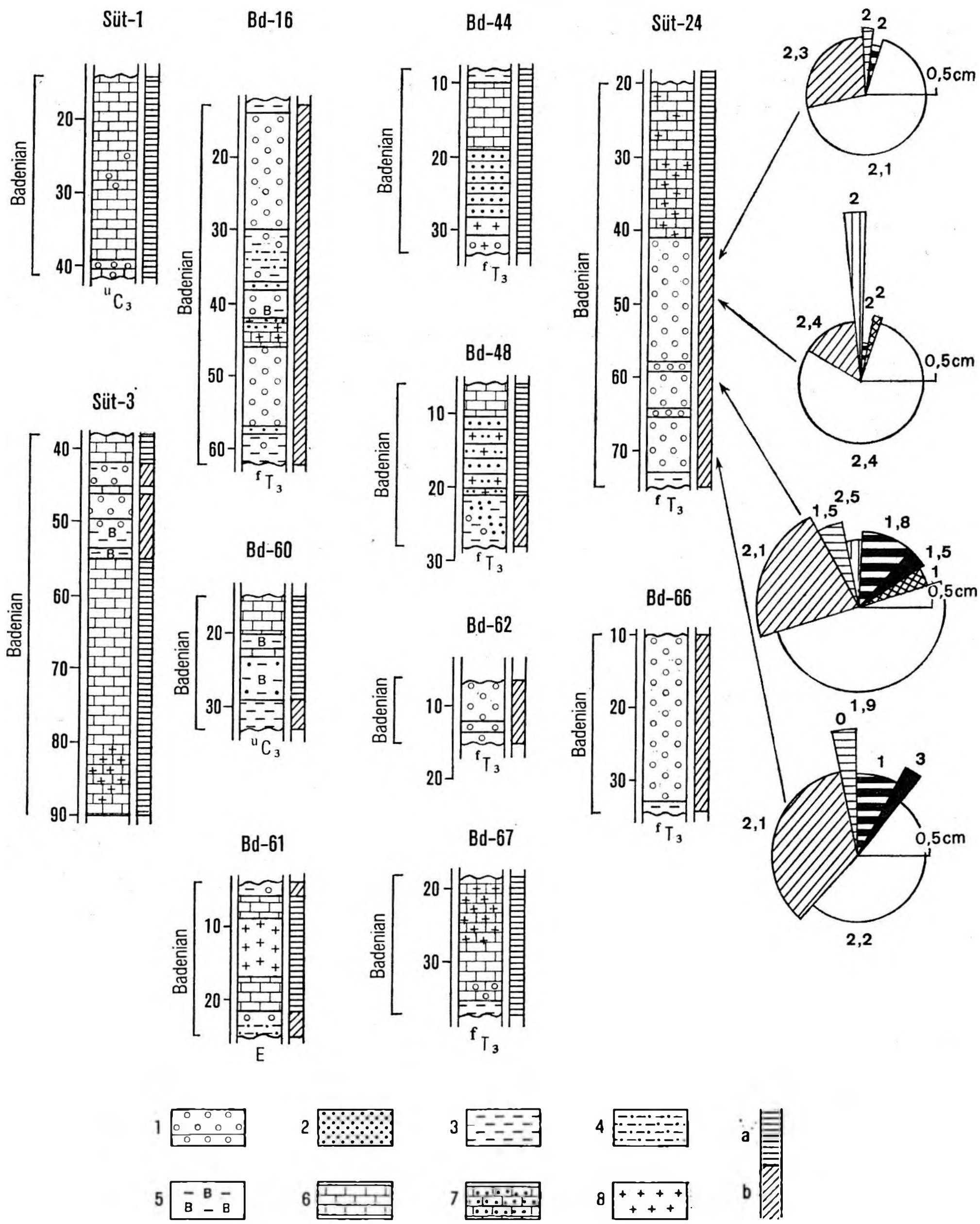


Fig. 77. Lithologic logs of borehole that have exposed Middle Miocene rocks

1. Gravel, conglomerate, 2. sand, 3. clay, 4. sandy clay, 5. bentonitic clay, 6. limestone, 7. sandy limestone and sandstone, 8. tuffite, — *a)* Fertőrákos Fm., *b)* Pusztamiske Fm. (The legend for the circular diagrams is given with Fig. 78.)

Abrasional conglomerate and gravel

Exposed to the surface or occurring at sub-crop level, the Pusztamiske Formation, generally only a few metres thick, is found exclusively to the north of the Sümeg–Tapolca road, its denudation patches being known in the first place from the northwest slope of the Rendeki-hegy or from its foot. Its geological features can be registered solely on the basis of its outcrops.

Its southernmost occurrences are on the Szőlő-hegy. The characteristics of the formation could be observed in a provisional exposure brought about as a result of a construction project. Above the Hauptdolomit, at the base of the unit, a gravel bed attaining a maximum of 0.5 m in thickness, but impossible to determine with precision, composed of well-rounded and/or strongly flattened boulders and pebbles of Ugod Limestone material averaging 3 to 4 and attaining a maximum of 15 cm in grain size, is interbedded with a loose, unconsolidated, medium-grained sand. It is overlain by sandstones and conglomerates of calcareous or, locally, limonitic cement which was observed to contain, in 40 to 60%, well-rounded pebbles averaging 1 to 2 cm and attaining a maximum of 5 cm in size. These are composed, for the most part, of Triassic dolomitic limestone and Upper Cretaceous and Eocene limestone with subordinated quartz; the pebbles of carbonate composition are usually lost to dissolution. The strata contain very poorly preserved internal moulds of a few *Anadacna (Arca)* sp., *Modiolus* sp., and *Clavatula* sp.

Beneath the Gerinc quarry, close to the large bend of the Sümeg–Tapolca road, the formation is superimposed partly to the Dachstein Limestone, partly to the Ugod Limestone. The abraded surface of a Middle Eocene Szőc Limestone of limited extension observable at the top of the Gerinc quarry is overlain, in one m thickness, by a lime- and clay-cemented conglomerate containing mostly flattened pebbles of varied size with a maximum of 15 cm, composed of Szőc and Ugod Limestone or, subordinately, of dark grey Triassic dolomite. At the northern end of the Kopasz-hegy a small Ugod Limestone block is exposed on the surface of which traces of borer-bivalves can be observed. It is quite probable that the abrasional gravel covered, prior to denudation, this area, too.

At the southeastern foot of the Szőlő-hegy, in the bauxite openwork of Bárdió-tag, the immediate overburden of the bauxite is a 1.5-m-thick gravel bed consisting of flat dolomite pebbles of 5 to 10 cm size. (Plate XLIX, Fig. 1–4; Plate L, Fig. 4). On the eastern slope of the Rendeki-hegy, near the Kozma-tag, the unit under discussion is exposed in a Senonian limestone quarry, being superimposed to the abrasional paleorelief of the Ugod Limestone and filling even the cavities in the latter.

At the very base, a 0.2-m-thick conglomerate can be observed: the pebbles are from 0.2 to 5 cm with an average of 0.5 cm in size, poorly to fairly rounded, composed of quartz, quartzite and lydite. The rock in the exposure has a siliceous, locally bentonitic, matrix. It is overlain by 2 m of coarse-grained sandstone to small-grained conglomerate with a siliceous cement. Attaining a maximum of 1 cm in grain size, the pebbles are made up mainly of lydite, subordinately, of light-coloured quartzite, being poorly rounded. The surface of these beds too is abraded, the traces of corrosion being observable on it. They are overlain by sandy gravels with boulders and pebbles 1 to 15 cm in size, well-rounded and flat. They are composed predominantly of Ugod Limestone and Szőc Limestone rock, being constituted subordinately by lydite, quartz and quartzite. The surface of the pebbles or boulders often carries the traces of borer-bivalves or of organisms of corrosive behaviour (Plate L, Fig. 3). Such a bed is exposed above the quarry. Superimposed on it, are Pannonian sandy gravels and gravelly sands. Rocks belonging to the abrasional unit are exposed in a few points at the northeastern foot of the Rendeki-hegy, close to the road leading to Nyírespuszta too, where they are represented by well-rounded and flat boulders of a maximum of 30 cm size composed of Eocene and Cretaceous limestone and light grey quartzite and dark grey chert. An outcrop of rather considerable size of the unit under discussion is known from the north to northwest foot of the Rendeki-hegy. At the closure of the large valley at the northern foot of the hill, abrasional gravels of predominantly Eocene material composed of boulders and pebbles attaining a maximum of 40 cm in size are known to occur.

Peculiar exposures of the unit under discussion are found in several quarries of the Haraszt (Plate L, Fig. 2) and in outcrop close to the former (Plate L, Fig. 1), where on the abraded surface of the Polány Formation there are large blocks of the Eocene Szőc Limestone. Above these or partly flowed between and even below the blocks, there is a formation constituted by flat pebbles and boulders of mainly Eocene and Cretaceous limestone material, measuring a maximum of 40 cm and an average of 5 to 15 cm, cemented by a calcareous, sandy and locally limonitic matrix, with some blocks exhibiting traces of borer-bivalves (Fig. 78). Subordinately, pebbles composed of light quartzite, bituminous dolomite, radiolarite and meta-sandstone, 1 to 4 cm in size, can also be observed, cavities left over in the place of dissolved pebbles being quite frequent. Reduced to a few m in thickness, they are overlain generally by talus. Denudation patches are observable by the Sümeg–Csabrendek road as well, being superimposed on corroded blocks of 1 to 2 m size of Middle Eocene Szőc Limestone resting on the surface of abraded Upper Cretaceous rocks. The pebbles of the lime- and limonite-cemented conglomerate attain a maximum of 15 cm in size, being quite flat. Their clastics used to be limestone which, however, has been lost, for the most part, to dissolution, so it is quartz that predominates now. Traces of dissolution ore often visible on the conglomerate blocks. Reduced in thickness, the conglomerate is overlain by Pannonian sediments.

The biostratigraphic assignation of the unit cannot be solved, because the fauna composed of few and poorly preserved fossils in it is confined to the Szőlő-hegy, being insufficient for biostratigraphic evaluation. Since the Middle Miocene formation s are closely interrelated genetically, the chronostratigraphic evaluation and the paleoenvironmental analysis of the lithostratigraphic units will be carried out jointly.

Pusztamiske Formation: other, non-abrasional representatives

Non-abrasional representatives of the Pusztamiske Formation are known to occur to the south of the Sümeg–Tapolca road and in the southwestern Middle Miocene facies area. Rocks belonging to this category were cut by drilling, above the Rezi Limestone and, subordinately, above the Ugod Limestone in a number of bauxite exploratory boreholes spudded in the Nyelőke and the Városi-erdő subareas. Superimposed on them, in a minor tectonic block, both in the northern Városi-erdő and the Nyelőke subarea, is the Fertőrákos Formation with which it is even intertongued, as evidenced by some boreholes. Outcrops of the unit under consideration occur over a small area in the northeastern Városi-erdő, the rest of the subareas being characterized by the superposition of Pannonian formations on them.

In the southwest, the borehole Süt-1 (Fig. 76, 77) exposed only a couple of metres of a Pusztamiske Formation represented by siltstones and fine-grained sandstones overlying the Ajka Formation. Composed mainly of quartz, the pebbles are fairly rounded, varying between 1 and 2 cm in size. Put down farther south, the borehole Süt-3 stopped in the Fertőrákos Formation in the upper part of which gravelly layers are interbedded in a thickness of a few metres. Attaining a maximum of 3 cm and averaging between 0.5 and 0.8 cm in size, the pebbles are well-rounded, composed mainly of quartz, though radiolarite and chert and Eocene limestone pebbles could be observed in lesser measure, too. A notable exposure in the Városi-erdő is the Oltárkövek (Altar Stones) outcrop soaring 4 to 5 m high above the gravel blanket of its neighbourhood, in a length of 60 to 70 m and a width of 20 to 25 m—a phenomenon due to a strong limonitic cementation along faults. The conglomerate is cemented by coarse-grained sandstone, the pebbles constitute 80 to 90% of the rock and vary between 0.3 and 15 cm in size, being characterized by a roundness that is generally fair, locally good, and some-

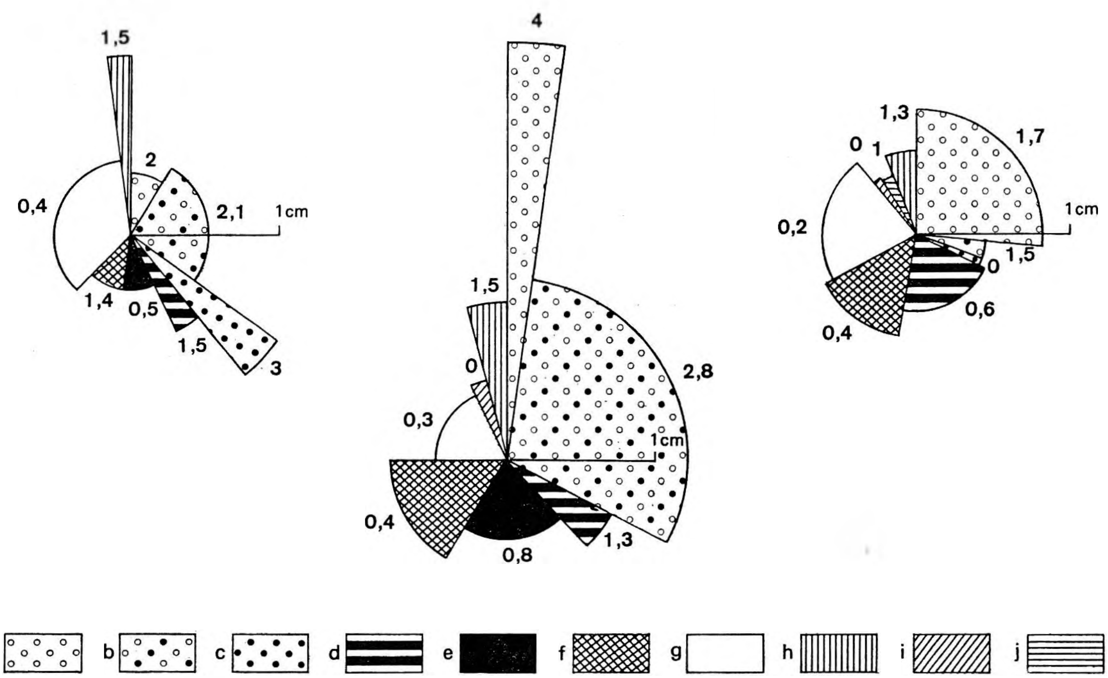


Fig. 78. Composition of abrasional gravels and conglomerates as observed in the exposure of Haraszt

Lithology of gravels: a) Cretaceous limestone, *b)* Triassic carbonate, *c)* other limestone, *d)* grey chert, *e)* black chert, *f)* brown chert, *g)* white quartz, *h)* other noncarbonate rock, *i)* black quartzite, *j)* lydite (black shale). — The radius of the circles indicates the grain size of the pebbles: $\frac{a+c+2b}{4}$; fat numerals give pebble roundness according to the RUKHIN scale times poor. The pebbles show graded bedding, a mixing of the coarsest material with the finest one being seldom observable. The orientation of the large boulders is suggestive of cross-bedding. The pebbles and boulders are composed, for the most part, of quartz and quartzite, to which some chert and dolomite is added.

A few hundred m to the north of the Oltárkövek, the borehole Süt-24 drilled for a better understanding of the Middle Miocene formations (Fig. 77) has yielded but very little information owing to the extremely bad core recovery, the Pusztamiske Formation having been exposed by it, in the 41.3–75.0 m interval, between the Fertőrákos Formation and the Rezi Dolomite with a tectonic contact toward the underlying formations. The unit here is constituted, for the most part, by gravels, with short intervals (41.3–42.00 m, 58.0–59.0 m, 73.0–75.0 m) being represented by lime-cemented conglomerates, the amount of pebbles in which is 60 to 70%. The size of the pebbles varies between 0.2 and 1.5 cm in general and 3 and 4 cm in particular. Well- to fairly-rounded, they are composed mainly of white quartz and quartzite, with a lot of black quartzite on some places. Primarily at the base, the chert (radiolarite) and mica-schist grains of weathered surface are more abundant, in the most basal layer some dolomite occurs, too. In the consolidated intervals unidentifiable shell fragments of molluscs crushed to tiny particles were observed in rare cases. In the upper part of the Pusztamiske Formation the matrix contained some volcanic matter as well.

The boreholes located to the north of Süt-24 did not cut the formation within a belt of a few hundred metres, here the Fertőrákos Formation overlies the pre-Tertiary basement. On the other side of the afore-mentioned belt, in some boreholes, the Pusztamiske Formation re-appears—a phenomenon observed in a down-faulted part of the overburden, faulting along lines of east–west direction, superimposed on the bauxite deposit near the Bárdió-tag, a deposit prepared for openwork in 1977 and since stripped off and re-buried. The bauxite-covering abrasional conglomerate and the Fertőrákos Limestone Formation are interlain by 6 to 8 m of variegated—yellow, greyish-brown to reddish-brown—gravelly sands in which the pebbles are composed of quartz, varying between 1 and 6 cm in size and being well-rounded (Plate XLIX, Fig. 1; Plate L, Fig. 5).

The gravelly sand is exposed at the base of the Szőlő-hegy too, in a very small patch. It was probably here that L. Lóczy sampled the fauna cited above.

Isolated from the Városi-erdő subarea, as a result of denudation, is situated the Nyelőke subarea, where the formation is found above the Ugod Limestone and or the Rezi Dolomite, respectively, generally in a thickness of 20 m or so. As shown by the results of bauxite-exploratory drilling here, the formation is composed of gravels and gravelly sands and, subordinately, of gravelly, sandy clay (Fig. 77). In some boreholes it is immediately underlain by 1 to 2 m of low-quality, redeposited bauxite. The overburden of the formation is constituted, as a rule, by Pannonian formations and, in a small tectonic block, by the Fertőrákos Formation. An interesting sequence was exposed by the borehole Bd-16 drilled specially for geophysical exploration purposes in which the Pusztamiske Formation is 40 m thick with interbedded layers of the Fertőrákos Formation in its middle part. The gravels of the formation in the borehole are composed predominantly of quartz and quartzite with pebbles of small size and generally well-rounded. Variegated clay intercalations occur in several horizons. In the northern part of the subarea a bentonitic clay intercalation within the coarse-detrital rocks of the Pusztamiske Formation is common, and the boreholes have exposed intertonguing beds of the Pusztamiske and Fertőrákos Formations.

Fertőrákos Limestone Formation

The area of distribution of the Fertőrákos Limestone Formation is smaller than that of the Pusztamiske Formation, being confined to the northern part of the Városi-erdő and the Nyelőke or a Middle Miocene outcrop to the west of the Mogyorós-domb, respectively. Here the Fertőrákos Limestone overlies the Pusztamiske Formation or intertongues with it or has transgressed over the pre-Tertiary basement.

In the southwestern facies subarea, it is exposed in the boreholes Süt-1 and Süt-2 (Fig. 76, 77), being represented by light grey unstratified bioclastites. Composed for the most part of *Lithothamnium* nodules or their fragments of varying size, the limestone contains sporadical mollusc internal mould detritus or fragments and casts (*Pirenella* sp., *Cardium* sp., *Turritella* sp.) and, locally in very great quantities, *Heterostegina*, too. Pebbles in it are quite frequent; in the borehole Süt-3 the Pusztamiske Formation is interbedded in a subunit of considerable thickness. The borehole exposed the unit in 40 m thickness, but did not penetrate it completely. In its lower part, the interbedded layers of tuffs and bentonitic rocks are very frequent. In the borehole Süt-1 the Fertőrákos Formation is superimposed, with a thin gravelly basal layer, on the Senonian.

The borehole Süt-24 exposed, above the Pusztamiske Formation, a Fertőrákos Formation of 21 m thickness which has a tectonic contact with the overlying Pannonian (Fig. 77). The u p p e r p a r t of the unit (20.4—33.8 m) is constituted by greyish-white, tuffaceous bioclastites composed for the most part of Lithothamnium-bearing limestone detritus and, subordinately, but heavily enriched at intervals, bryozoans and echinoids and, locally, a few intact *Chlamys elegans* (ANDRZ.) appear or, respectively, *Chlamys* sp., *Cardium* and *Ostrea* sp. can be observed. The rock varies between 84 and 93% in CaC_3 content. It contains a dissemination or, locally, bands of a few cm thickness of tuffs or tuffites. The tuffs are strongly decomposed, containing a lot of glauconite and biotite. Glauconite often fills the inside of *Foraminifera* present in great quantities. The microfossils are heavily fragmented and recrystallized, consisting, as shown by I. KORECZ-LAKY, of the following forms (listed in the order of increasing abundance): *Heterostegina simplex* D'ORB., *H. costata* D'ORB., *H. costata carinata* PAPP-KÜPPER, *Asterigerina planorbis* D'ORB., *Rotalia calcar* (D'ORB.), *R. boueana* (D'ORB.), *Elphidium crispum* (L.), *Cibicides dutemplei* (D'ORB.), *C. boueanus* (D'ORB.), *Gyroidina soldanii* D'ORB., *Eponides haidingerii* D'ORB., *Amphistegina haueriana* D'ORB., and *Discorbis* sp.

I n t h e l o w e r s u b u n i t (33.8–41.3 m) the amount of volcanic matter shows a marked increase, the $CaCO_3$ content varying between 56 and 97%. The bioclasts are generally enriched to form lenses; along with *Lithothamnium* the bryozoans acquire a significant role and the quantity of echinoids increases too. As determined by M. BOHN-HAVAS, a few *Phalium miolaevigata* SACCO, *Cardium* sp. and *Chlamys* sp. can be found. The composition of the microfauna shows a pattern similar to the case of the upper subunit, the only difference consisting in the appearance of a few genera or species that are absent there, namely: *Robulus cultratus* MONTF., *R. vortex* (F. M.), *Bolivina dilatata* RSS., *Elphidium macellum* (F. M.), *Nonion boueanum* (D'ORB.), *Uvigerina* sp.

In terms of the results of the micromineralogical analyses carried out by M. SALLAY, quartz and plagioclase feldspar are predominant, the latter being usually heavily weathered. Glauconite (represented in most cases as the fill of fossils) is strikingly abundant, biotite is fair and muscovite may be found occasionally, too. The heavy mineral content constitutes a few to a maximum of four per cent of the residue left over after an attack by a 10% solution of HCl and sieving. Predominant heavy mineral is magnetite which is often limonitized; in the upper reaches of the formation some pyrite occurs, showing a downward growth in quantity, to become prevalent in the lowermost sample already. A little bit of garnet, epidote, tourmaline, rutile, disthene and, sporadically, some hornblende, chlorite and zoisite are observable, too.

The mineral grains are usually fragmentary or rounded, idiomorphic and hypidiomorphic grains being few. In the lower part of the formation interbedded layers of tiny quartz pebbles are observable in a thickness of 10 to 20 cm, showing a downward increase in amount.

The bauxite-exploratory wells drilled to the north of Süt-24, cut, in a thickness of 20 to 25 m, in a zone of approximately 500 m width, a Fertőrákos Limestone Formation superimposed directly on the Rezi Dolomite. To the north of this zone the Pusztamiske Formation re-appears beneath the Fertőrákos Limestone. All that can be said about the geological features of the Fertőrákos Limestone upon the description is, that it is a bioclastite composed mainly of *Lithothamnium* detritus, locally very sandy or gravelly and that tuffaceous intercalations were observed in all sections. The bauxite openwork of Bárdió-tag has exposed the formation in a facies similar to the tuffaceous limestone intersected by Süt-24. The microfossils from the rock were determined by M. HORVÁTH as follows: *Lenticulina* cf. *inornata* (D'ORB.), *Uvigerina* sp., *Discorbis* sp., *Asterigerina planorbis* (D'ORB.), *Elphidium fichtelianum* (D'ORB.), *E. flexuosum* s. l., *Protelphidium tuberculatum* (D'ORB.), *Heterostegina* sp., *Anomalina* sp., *Cibicides* cf. *letkésiensis* (FRANZENAU), *Heterolepa dutemplei* (D'ORB.), *Melonis* sp.

In the Nyelőke subarea, some bauxite-exploratory boreholes exposed the Fertőrákos Formation, partly above the Pusztamiske Formation, partly directly above the Ugod Limestone, as represented by Lithothamnium limestone facies with varying amounts of volcanic material. In the borehole Bd-16, in the upper part of the lower third of the Pusztamiske Formation there is a four-metre-thick intercalation of Fertőrákos Formation represented by a strongly tuffaceous, a little bit sandy bioclastite facies (Fig. 79).

Bio- and chronostratigraphy

A chronostratigraphic assignation can be done on the basis of the fossil content of the Fertőrákos Formation and an analysis of the stratigraphic position of the tuffites interlain between the Pusztamiske and the Fertőrákos Formations.

Upon proposal and definition by A. PAPP and I. CICHA, it was in 1968 that the Badenian stage, a chronostratigraphic unit of the Middle Miocene in the Central Paratethys, was introduced in the international literature. Situated between the Karpatian and the Sarmatian stages, the stratigraphic unit was defined on the basis of the planktonic foraminiferal fauna, but for the western part of the Central Paratethys and the Vienna Basin, respectively, a correlation of the zonal scale based on, the planktonic biozones and the evolution of the genera *Uvigerina* and *Heterostegina* was given too. Upon a K/Ar dating of volcanic rocks deriving from the Central Paratethyan area the absolute age of the boundaries of the Badenian stage is respectively 16.5 ± 0.5 m.y. and 13.0 ± 0.3 m.y., the Lower-

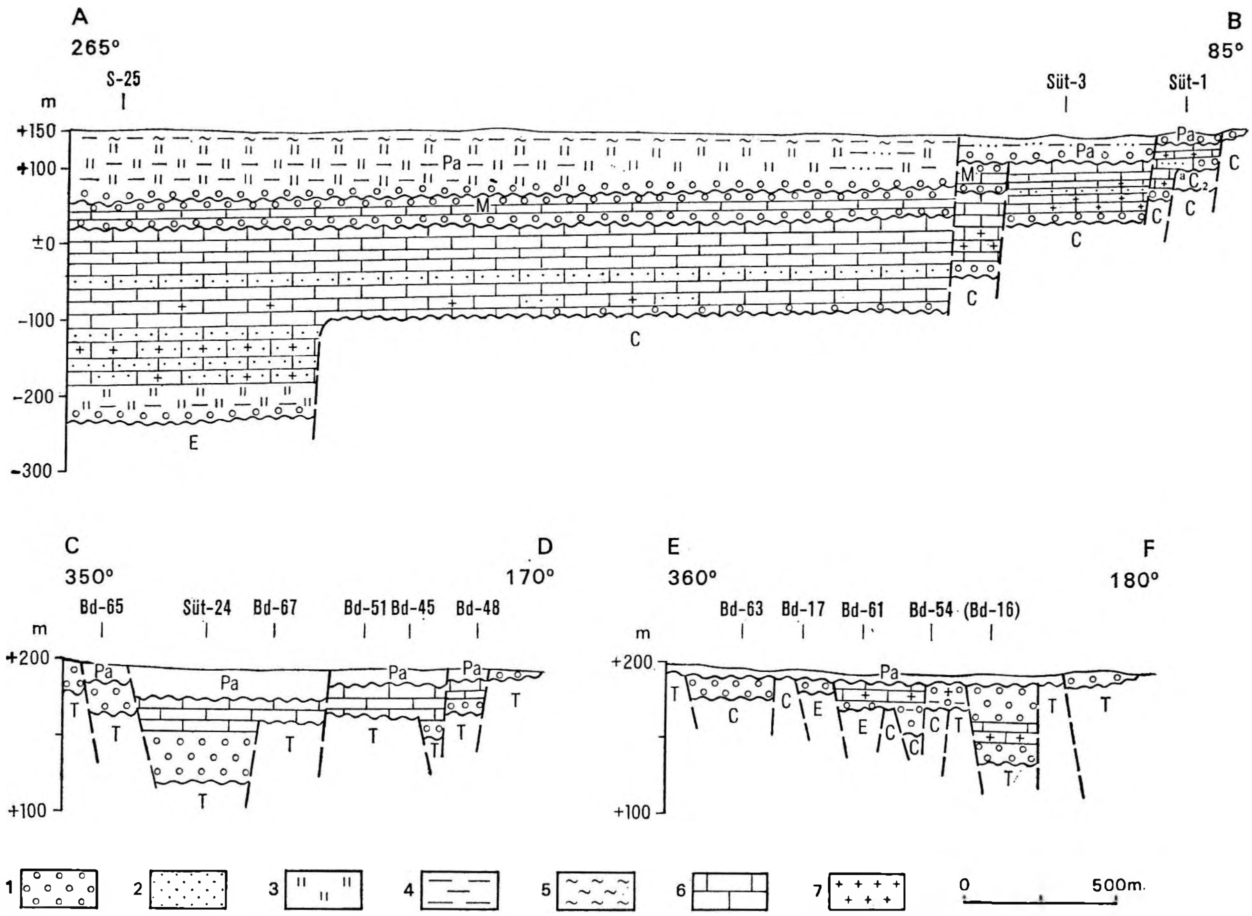


Fig. 79. Profiles presenting the characteristics of the individual facies of the Middle Miocene
1. Gravel, 2. sand, 3. silt, 4. clay, 5. marl, 6. limestone, 7. tuffite. — *Pa* Pannonian, *M* Miocene, *E* Eocene, *C* Cretaceous, *T* Upper Triassic

Middle and Upper Badenian boundary being dated as 15.0 m.y. (D. Vass et al. 1978). On the basis of a radiometric measurement of the Miocene pyroclastics of Hungary the "Middle Rhyolite Tuff" representing the Karpatian/Badenian boundary is dated as 16.4 ± 0.8 m.y., the average age of the tuff bands within the Badenian andesite volcanics being 14.5 ± 0.4 m.y. (G. Hámor et al. 1980).

The microfossil content of the Fertőrákos Formation was analyzed in samples from the borehole Süt-24 and the bauxite openwork of Bárdió-tag. As shown by L. Korecz-Laky, the faunal assemblage determined by her from the limestones of Süt-24 is characteristic of the Lower Badenian, while the foraminiferal assemblage from the openwork of Bárdió-tag is typical, according to M. Horváth, of the Badenian. As pointed out by M. Bohn-Havas, the megafossil assemblage from Süt-24 has a composition that is typical of the Badenian.

The Pusztamiske Formation contains no biostratigraphically evaluable faunal element, only one exposure, the abrasional conglomerate of Szőlő-hegy, has yielded internal moulds of molluscs characteristic of the Badenian. In determining the unit chronostratigraphically, we must start from its mode of superposition or, respectively, from the time of formation of the interbedded, tuffaceous and bentonitic layers.

That the mode of superposition of the Badenian on the older Miocene in what used to be basin margins is often an overlapping, transgressive and unconformable one and that it is continuous, without any break in sedimentation, in the one-time basin interior is a matter of common knowledge. Nagygörbő (Ng)-1, a structure-exploratory borehole put down at a distance of 8 km to the southwest of Sümeg, exposed a continuous Oligocene-Miocene sequence that could be dated chronostratigraphically on the basis of the lithological features, the fossil content and the appearance of volcanics that correlate with the readily recognizable Lower and Middle Rhyolite Tuffs (Á. Jámbor–L. Korpás 1974). K/Ar dating of the basal bed of the Middle Rhyolite Tuff by the *Institute of Nuclear Physics of the Hungarian Academy of Sciences* gave a result of 13.5 ± 0.6 m.y. Since the absolute age of the Badenian volcanics as found by the K/Ar method is 16.5 to 13 m.y., the afore-mentioned figure corresponds to the upper part of the Badenian. Let us note in this context that though the Lithothamnium limestone bed, a marker taken to be the Karpatian-Badenian boundary, lies above the sampling point of the analyzed sample, the results obtained for the microfauna suggest that the lower boundary of the Badenian is to be drawn deeper, at the base of the calcareous sandstone situated well below the tuff.

The lithologic log of the borehole Süt-25 put down at a distance of 400 m from the southwest limit of the study area, a sequence of transition to the sequences of marginal facies studied by us correlates well with that part of the borehole Ng-1 assigned to the Karpatian or the upper part of the Ottnangian, respectively. In the borehole that Karpatian/Badenian boundary was drawn with the appearance of the Lithothamnium limestone with interbedded tuff layers and these interbedded tuff bands were identified with the "Middle Rhyolite Tuff". In the light of all these circumstances the Fertőrákos Limestone Formation is of Badenian age. To determine its stratigraphic identity with higher precision is faced with difficulty, because the composition of the foraminiferal fauna of the unit is characteristic not only of the Lower Badenian, but the whole Badenian stage as well. The tuffaceous-tuffitic layers associated with the rocks of the formation can be correlated with the "Middle Rhyolite Tuff" which would support an assignation to the Lower Badenian, but the information available does not enable us to decide unambiguously whether the material we have to do with is a primary pyroclastic matter or a redeposited one. The absolute dates from the borehole Nagygörbő-1 indicate the presence of the Upper Badenian. The transgressive, overlapping occurrence of the Fertőrákos Limestone in the study area, a phenomenon linkable to the Leithaian orogenic phase, suggests an Upper Badenian age, too. Closely interrelated genetically with the Fertőrákos Limestone and often even intertonguing with it, the abrasional and other—non-abrasional—rocks of the Pusztamiske Formation are of Badenian age.

Paleoenvironment

The Middle Miocene formations of the Sümeg area are products of different paleoenvironments closely interrelated with one another. Attaining a couple of tens of m in thickness, the coarse-detrital beds of the Pusztamiske Formation are products of fluvial sedimentation deposited in the immediate neighbourhood of the base level, on a planated surface. These sediments ore often interbedded with bauxite-like rock varieties very little resistant to erosion whose preservation on a rough terrain subject to erosion is very unlikely. The red stain of the resulting deposits in the immediate vicinity of the lenses seems to have been provoked by the admixture via infiltration of material removed from the exposed bauxite bodies. The deeper areas that controlled the direction of transport are supposed to have lain to the northwest-west of the study area; in the northeast, in turn, there extended a considerably elevated zone in front of which there were minor isolated, morphological units that lay in a deeper topographic position, but were still emergent too.

The cyclicity of the sediment material may be due, for that matter, to rhythmic changes in the energy of the depositing agent but the enrichment of metamorphic rock variants in the material of higher grain size is striking to the eye. These derive probably from periodical denudation of the Csatka Formation's material that covered the surface of the northeastern swell. The same explanation is plausible for the origin of the Eocene, Upper Cretaceous and Triassic carbonate pebbles belonging almost exclusively to the coarser grain size classes. The stream-transported quartz and quartzite material must have travelled a considerable distance before being deposited—a fact evidenced by the marked roundness of the pebbles.

Having lain close to the base level even initially, the terrain would durably submerge as a result of differencial movements—a change indicated by the good roundness of the pebbles, their being flattened, the periodical appearance of marine mollusc detritus and, respectively, by the appearance of biogenic carbonate formations. The oscillative changes in altitute seem to have been related with the initiation of volcanism indicated by the tuffs appearing in the upper part of the formation and by the bentonite resulting from their subaquatic decomposition, respectively. The centre of eruption seems to have lain far away from the sedimentary basin. The tuffs may be in part redeposited ones.

It was the onset of differential, oscillative movements that led to the formation of the abrasional conglomerate or gravel unit. In the northeast the abrasion by seawater affected an emergent and steep rocky coast, blocks and slabs several metres in size having broken off and fallen into the forefront. The presence of oscillation here too is indicated by the appearance in several horizons of traces of borer-organisms, partly on basement outcrops, partly on conglomerate blocks. The pebbles formed of the material of basement carbonate rocks are well-rounded, those deriving from the Csatka Formation and made up of quartz are less so. Volcanic material of distant origin appears here too, naturally it does so as a heavily decomposed substance, i.e. in form of a bentonitic matrix.

Upon oscillation movements, the relatively low-situated swell areas in front of the northeastern subarea got for a varying length of time submerged. Composed for the most part of *Lithothamnium* detritus, the bioclastic reef sediment had its depositional environment in the upper neritic zone of a shallow-water sea of normal salinity. An extremely shallow water is indicated by the strongly crushed nature of the mollusc fauna and the *Foraminifera*. Their having been formed at the beginning of the cycle is suggested by the appearance of the tuff horizons and the detectability of the oscillation movements owing to the intertonguing of the gravelly beds. The paleoenvironment of the upper part of the Fertőrákos Formation cannot be reconstructed owing to its being lost to erosion, but a durable submergence of the swell parts of the northeastern subarea during the subsequent history is quite certain.

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Pannonian

by

E. J.-Edelényi

In the Sümeg area, except for the relatively elevated morphological units, the Lower Pannonian is common, being represented by diversified geological features resulting from the once basin-marginal position of the area involved. While studying the facies distribution of the Pannonian formations from Sümeg the features generalizable for the Transdanubian Central Range of the basin margin formations are readily traceable. The relationship between abrasional landforms and abrasional sediments is conspicuous.

The Upper Pannonian is represented by karstic fissure-fill with a rich paleovertebrate fauna—extremely important for terrestrial stratigraphy—occurring on the margin of the Gerinc quarry. Upper Pannonian sediments other than this one are unknown over much of the study area but the Várvölgy basin farther southwest, where the Upper Pannonian attains a couple of tens of metres in thickness. Boreholes located farther away exposed the Somló Formation in 20 to 30 m thickness, represented by argillaceous and sandy silts and fine sands with siltstone. These are underlain, in a thickness of 10 to 20 m, by the Kálla Gravel Formation constituted, for the most part, by well-sorted and well-rounded pebbles made up almost exclusively of quartz and 0.5 cm in diameter. Let us note here that the redeposited sands forming the overburden of the bauxite body in the bauxite opencast pit of Hajnal-hegy has been derived by several students of the study area from Upper Pannonian deposits, but we do not see any evidence that should corroborate this statement.

Lower Pannonian

Exploration history

L. Lóczy (1913) in his Balaton monograph correlated the Pliocene formations of the Sümeg area with the sand and unconsolidated "rustbrown" sandstone beds extending from the Keszthely Mountains as far as Nyirád and, respectively, with clay layers locally observable at an altitude of +180 to 190 m a.s.l. The traces of abrasion and corrosion that we believe to be of Badenian age and that are observable on the Haraszt and the Csúcsos-hegy as well as the similarly Badenian conglomerates of the Oltár-kövek (Altar Stones) were taken to be products of wave action in Pannonian time.

Similarly to the case of the Balaton Highland and the Somogy Hill Country, he drew the upper boundary of extension of the Pannonian formations at an altitude of +260 m a.s.l. From this altitude, he mentioned unconsolidated sands from the Szőlő-hegy and coarse conglomerates from the slope of the Csúcsos-hegy, conglomerates which he supposed to occur beneath the sands of the Szőlő-hegy, too. As for the genetic circumstances of the strata exposed in the clay pit of the brick-yard on the Kopasz-hegy and their relation to the rocks of coarser grain size from the neighbourhood, he explained them by the fact that the NW–SE trend of the mountain here turns abruptly W–E and by suggesting that the resulting spur would have caused the currents from the northwest and east that met here to be broken and bend southwards and to deposit first the coarse gravels, then the small gravels and finally the fine sands they had been carrying all the time. In the quiet, non-agitated water not affected by the currents fine-sandy muds would be deposited. On the basis of the fauna collected from the brick yard's clay pit and the Sümeg–Tapolca saddle, respectively, he dated the rocks as Lower Pannonian.

In his summarizing account of the Pannonian sediments, J. Sümeghy (1938) assigned the deposits preserved as deflation and erosion residues in the Sümeg area to among the Pannonian breccias, calcareous conglomerates, slightly cemented limonitic gravels, gravelly sands, whitish-grey sands and sandstones that are traceable in a narrow belt or minor patches along the southwest and southeast margins of the Bakony. On the basis of the fauna listed already by L. Lóczy, he considered these formations to be of Lower Pannonian age.

During his geological investigation of the Sümeg area, R. Hojnos (1943) came to conclude that the sediments of largest extension of the area belonged to the Pannonian-Pontian stage and were observable not only on the level tracts but they were encounterable at higher altitudes as well.

L. Strausz (1952), in his study on Transdanubian gravels examined the roundness of the quartz pebbles. Those on the slope of the Csúcsos-hegy were derived by him from the gravels on top of the hill that he believed to be of Miocene age. He considered of course that the gravels produced by redeposition, together with the Eocene blocks broken off by erosion from the lake-shore and then rapidly buried, were younger than Miocene. The strongly flattened pebbles in the sand pit of Haraszt, now assigned to among the products of Badenian abrasion, were similarly taken to be lacustrine formations.

K. BARNABÁS (1951), in his report on bauxite exploration in the Sümeg area and its extended neighbourhood, took the existence of differences in roundness between the pebbles, as determined by the examination of the pebbles by L. STRAUSZ, to be proved. He ascribed these differences to differential water agitation, but he did not go into particular detail as far as the age of the pebbles was concerned, because, in his opinion, the problem was irrelevant for the geology of bauxites. That the gravel deposits that were not blanketed by limestone had been mostly redeposited by the dynamic action of the Pannonian inland sea, i.e. the emplacement of their bulk had taken place that time was to him a probability, though the role of the Pleistocene events was not negligible either. For this reason, he assigned all gravels and sands and even the silica-cemented conglomerates to the Pannonian, whenever he failed to discover evidence in favour of their being older or younger.

During his lowland mapping work in the study area, A. RÓNAI (1952) postulated an earliest Pliocene transgression that would follow after a terrestrial and lacustrine accumulation period. The gravel and sand beds of the Haraszt were assigned by him to the Lower Pannonian. As for the age of the large limestone and quartz boulders overlying the former, he did not take a stand. The clay and sand beds constituting the Kopasz-domb were regarded as Upper Pannonian and the mechanism responsible for their birth suggested by L. LÓCZY was believed unlikely by him.

J. NOSZKY, in his report on the mapping of 1957, criticized L. STRAUSZ' roundness measurements and K. BARNABÁS' opinion suggesting the irrelevance for bauxite prospecting of an exact distinction between gravel formations of similar character formed in different times. From the ditch at the Tapolca–Nyírád fork, he mentioned an alternation of grey, yellow and variegated, argillaceous and looser yellow, fine-sandy beds which he assigned to the Miocene gravel and sand sequence of the Városi-erdő. The Pannonian beds occupying large areas and showing a diversified pattern in the lower-situated tracts were not specified in terms of an exact dating. The small gravel material from the gravel pits on the northern and eastern slopes of the Vár-hegy were correlated with the conglomerate and coarse-grained sandstone beds with small pebbles underlying the clay deposits on the Kopasz-hegy. He mentions in this context that the limonitic sand bed with small pebbles at the very base of the Pannonian is often very thin, to pinch out completely in some places. The fingertip-like corrasion phenomena observable on the carbonate surfaces were correlated, all without exception, with the Pannonian. The superposition of Miocene and Pannonian coarse-detrital sediments on one another is not mentioned by him.

In 1970, P. JAKUS, mapped the Csabrendek quadrangle lying north of the study area, where Lower Pannonian formations occur over a considerable area, too. As initial member of the Lower Pannonian sedimentary cycle there is here a thin gravel bed overlain, in a considerable thickness, by argillaceous marls and siltstones representing the *Congeria czjzeki* Horizon. The gravel beds traceable along the Sümeg–Csabrendek road Jakus regarded as Pannonian abrasion deposits.

In a summarizing work dedicated to the gravel formations of the Transdanubian Central Range, Á. JÁMBOR and L. KORPÁS (1971) considered the pebbles of the gravel pit by the Sümeg–Csabrendek road to be of Lower Tortonian age—a judgement based on the *Lithodomus* borings they had observed in the underlying rock. Lower Pannonian pebbles were mentioned only from the Tapolca basin as opposed to the Upper Pannonian gravels common in the Tapolca basin, the Devecser basin and on the margin of the Keszthely Mountains.

Á. JÁMBOR (1980), in his summarizing account of the Pannonian in the Central Range, assigned the Pannonian formations known from outcrops and boreholes in the Sümeg area to the Kisbér Pearl-Gravel and the Szák Claymarl Members of the Lower Pannonian Formation.

Situated in the northwest foreland of the Rendeki-hegy and represented throughout its occurrence by pearl-gravels and quartz sands, the Kisbér Member is the product of an abraded shore environment that submerged during the upper third of the Lower Pannonian and that was, as a result of growing water depth, eventually replaced by an environment which deposited inland-sea argillaceous marls.

Extension, mode of superposition and stratigraphic subdivisions

Except for the swells represented by the Rendeki-hegy–Hárs-hegy–Hajnal-hegy and the Vár-hegy and Köves-domb–Mogyorós-domb hill ranges and the Városi-erdő, the Lower Pannonian formations are common to the study area (Fig. 80). Irrespective of some very small outcrops, the Lower Pannonian rocks can be studied in artificial exposures only. They overlie the older rocks underneath, as a rule, subhorizontally with a marked hiatus. Attaining a few tens of metres in thickness, they are overlain by Pleistocene or Holocene formations (Fig. 84).

The Lower Pannonian of the study area includes two lithostratigraphic units. In the monograph of Á. JÁMBOR (1980) dedicated to the Pannonian of the Transdanubian Central Range, the Kisbér Pearl-Gravel and the Szák Claymarl figured as members of the Lower Pannonian Formation.

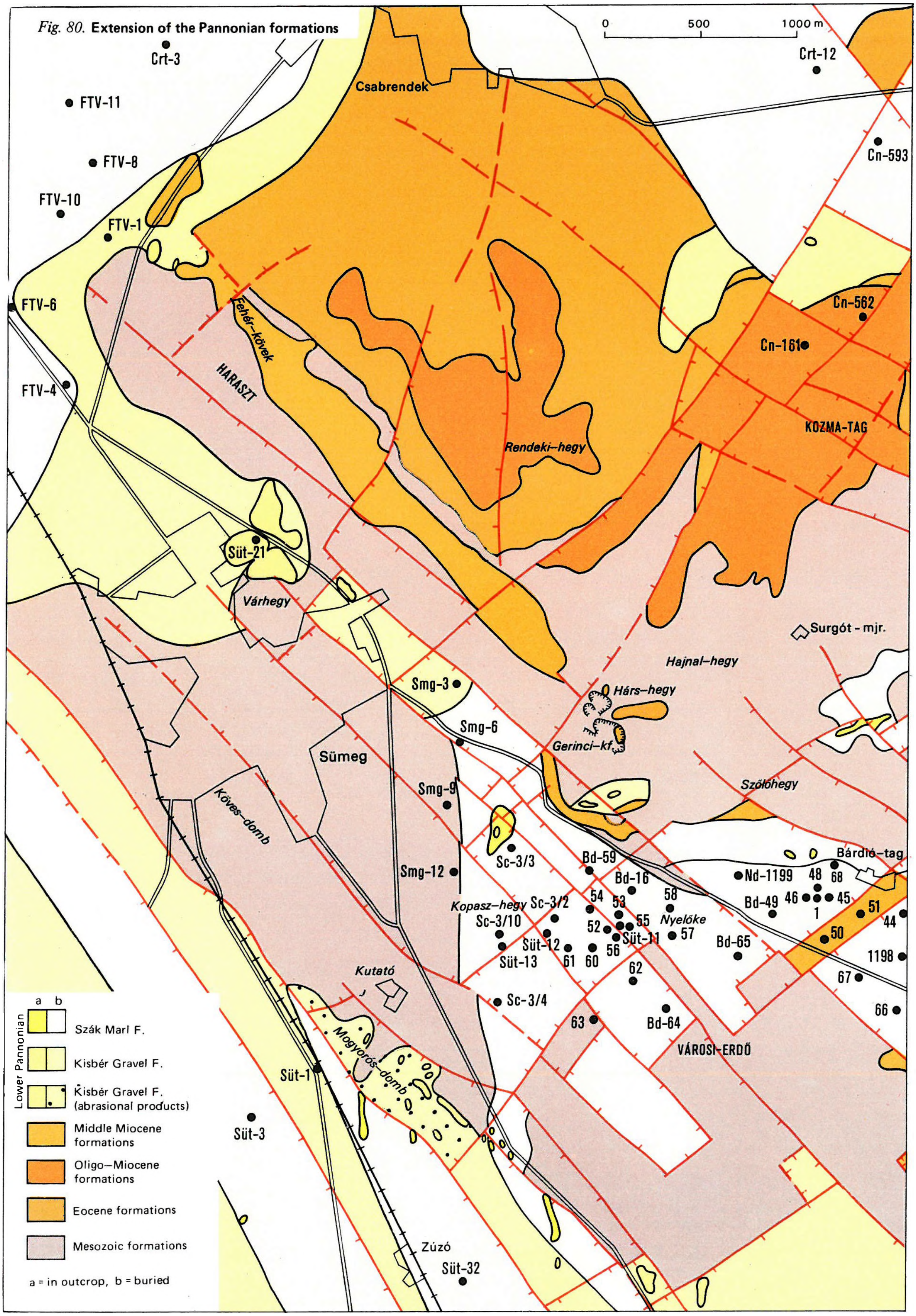

Fig. 80. **Extension of the Pannonian formations**

In the table proposed in 1982 by the *Subcommission on Pannonian Stratigraphy of the Stratigraphic Commission of Hungary* the Szák Claymarl and the Kisbér Gravel figure as formation-rank units of the Peremarton Claymarl Group. In this work the official nomenclature has been used. A Kisbér Gravel of special abraded shore facies can be observed in a few m thickness on the slope of the Mogyorós-domb overlying Mesozoic rocks. In our opinion, inasmuch as they occur elsewhere in the distribution area of the formation, these beds should be separated as an independent member of the unit. A typical facies represents the Kisbér Gravel over much of the Lower Pannonian area, the only exception to the rule being the northern subarea, the Kopasz-domb and the southern part of the Nyelőke, where it pinches out gradually. Its thickness is as low as a few m, the maximum (30–35 m) being reached in the western part of the Városi-erdő. Stratigraphically, its overburden is represented by the Szák Claymarl Formation which, in the northern subarea and in a narrow zone on the Kopasz-domb as well as in the northern part of the Nyelőke, is superimposed on the Kisbér Formation, while to the north or to the south of the pinch-out zone of the latter, it overlies Upper Cretaceous or Eocene and Mesozoic or Badenian rocks, respectively, attaining a total of a couple of tens of m in thickness.

Kisbér Formation

Abrasional deposits

On the tectonically controlled southwest margin of the Mogyorós-domb and the southern part of the Köves-domb, the abrasional sediments lie on the abraded surface of different Mesozoic formations (Fig. 80). On the gently sloping hillside representing the one-time rocky coast the abrasional landforms of the rock surface and the abrasional deposits such as abrasional gravels and sandy gravels are observable.

Abrasional landforms of the rocky surface

The abrasional landforms produced by the surfs along the shoreline are still observable on some rocky surfaces even today. Lithology must have played, of course, an important role in the birth of these forms. On surfaces of thin-bedded cherty limestone or radiolarite, respectively, no traces of abrasion are found. On Triassic and mainly on Upper Cretaceous thick-bedded limestones, however, wave action produced smoothed, slightly inclined surfaces, abrasional platforms and also some arched depressions of different size, varying mostly between 5 and 15 cm. These are on the southwest slope of the Köves-domb most suited to observation (Plate LI, Fig. 1).

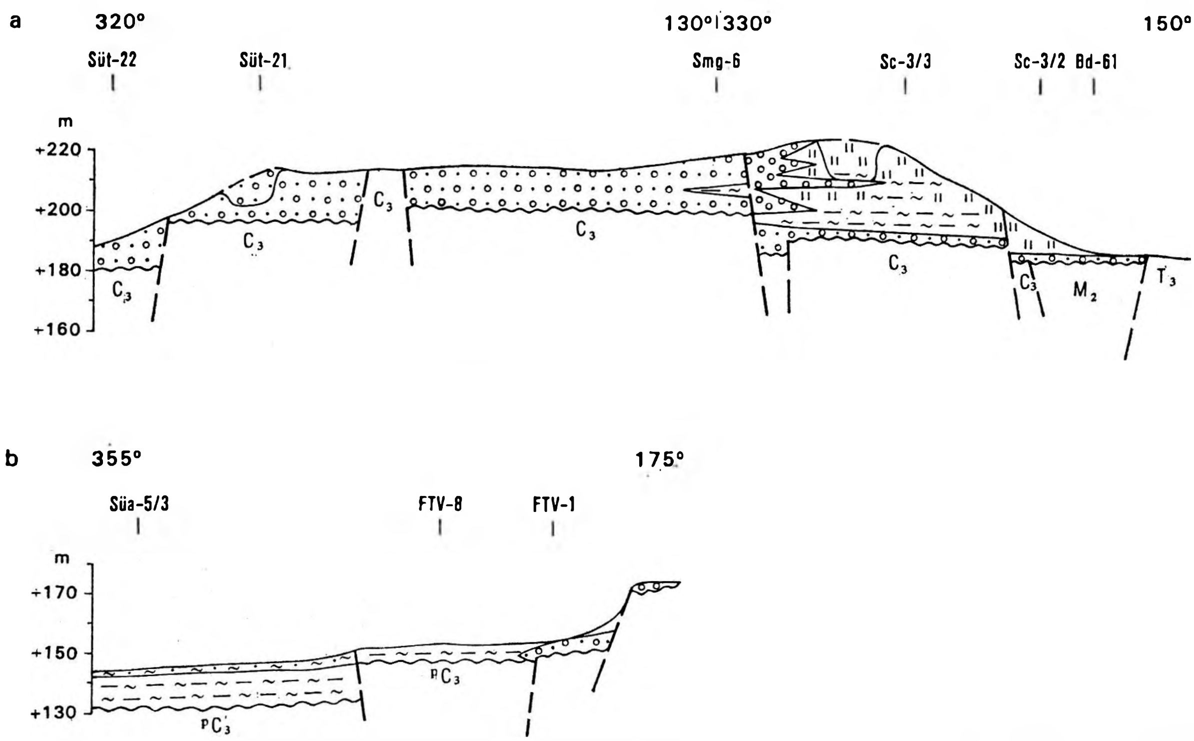

Fig. 81. Profiles presenting the individual facies areas of the Lower Pannonian. (For the explanations, see Fig. 84.)

Rounded surfaces similar to the abrasional landforms of Köves-domb, i.e. abrasional platforms, could be observed a few years ago on the surface of the Ugod Limestone beneath the Gerinc quarry, but they are now hidden by the spoil-heap of the quarry. Corrosion markings occurring, at present, at an altitude of +225 m on the Vár-hegy should also be quoted among the abrasional phenomena, markings probably associated, however, with the Upper Pannonian cycle (Plate LI, Fig. 2).

Abrasional deposits

On the slope of the Mogyorós-domb, at an altitude of 170 to 190 m a.s.l., in a zone of 200 to 300 m width, a course boulder deposit is superimposed on the Mesozoic basement or on a very thin basal sandy gravel bed (Plate LI, Fig. 3, 4). The boulders vary between 0.2 and 0.4 m in size, but they may, in rare cases, attain even 1 to 2 m in diameter. The boulders of smaller size are very well-rounded, entirely globular, even the bigger ones being very well-rounded. The giant pebbles are similarly composed of local rock varieties, i.e. in the southern part of the Mogyorós-domb consisting of Upper Triassic–Lower Liassic limestones only boulders and pebbles of Dachstein Limestone (the variety with chert globules, in the thin section of which *Triasina hantkeni* Majzon was observable, is abundant), Kardosrét Limestone and Hierlatz Limestone occur and, in addition, the boulders of a pink, ammonitic-gastropodal limestone of Pliensbachian age representing a facies unknown from the study area are encountered. In the radiolarite zone, mainly chert pebbles, in the Tithonian to Lower Cretaceous tracts, gravels of biancone facies occur. On the margin of the Köves-domb, a hill made up of Upper Cretaceous rock, in turn, Ugod Limestone boulders are predominant.

To the southwest of the boulder zone—nearer to the one-time basin—the Mesozoic substratum carries very well-rounded (3–4), usually a little flat pebbles measuring 5 to 8 cm in diameter and traceable in a strip of 100 m width. The pebbles agree in lithology with the boulders. On their surface no traces of borer or corroding organisms can be observed.

Farther southwest of the coarse gravel strip, the basement is overlain by sandy gravels showing a close resemblance to the material of the typical exposures of the Kisbér Gravel.

Other, non-abrasional, facies of the Kisbér Formation

The non-abrasional facies of the Kisbér Formation occur over almost the entire area of the Lower Pannonian. Their most typical and thickest occurrence is around the Vár-hegy, to the southwest of which its intertonguing with the Szák Formation is observable (Fig. 81, Profile a).

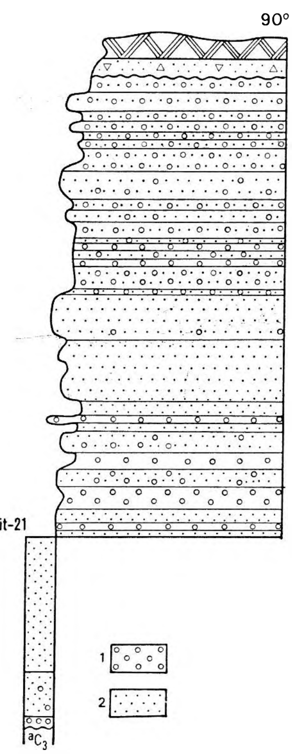

Fig. 82. Section of the Kisbér Formation in the exposure by the Vár-hegy
1. Gravel, 2. sand

The most conspicuous exposures are found in the quarries around the Vár-hegy (Fig. 80, 82). The unit under consideration is underlain, as observed in the borehole Süt-21 spudded in the yard of the quarry to the north of the Vár-hegy, by the Senonian Ajka Formation, while it rests elsewhere on the Polány Formation. Within the 3.5 m interval exposed by the drill, the Senonian beds are overlain by gravels and gravelly sands with pebbles of 0.1 to 1.0 cm size, of varying roundness (1–3), composed of quartz, quartzite and, in lesser measure, of chert. The beds that lie above these and that are represented by gravels, sandy gravels, gravelly sands and, subordinately, by sands are exposed, in a thickness of 8 m, in the quarry face (Plate LII). Higher upwards in the profile the gravels are observed to become prevalent. The pebbles have a size of 0.2 to 3 cm and an average of 0.5 cm. Varying in roundness, they are usually well-rounded, being composed almost exclusively of quartz with a little chert and Mesozoic limestone admixed to it. The sand is generally light grey, predominantly coarse- to medium-grained, subordinately fine-grained, in some places a strong limonitic cementation being observable. Gravel lenses of a couple of cm size are frequent in the sandy beds and even cross-bedding can be observed in some places.

A typical facies represents the unit under consideration in a part of the Haraszt, to the north of the quarries around the Vár-hegy (Plate LIII, Fig. 1) and on the northwest and northeastern slope of the Rendeki-hegy, in a strip of a width of a few hundred m, where, however, it will considerably decrease in thickness as one proceeds northwest- and northeastwards. Overlain by the Szák Claymarl Formation, it appears locally in a strongly sandy facies. To the south of the Vár-hegy quarries, in the neighbourhood of the abrasional formations of Mogyorós-domb and/or to the southwest of the fault bounding the Mogyorós-domb in the southwest the unit is present in a typical facies (Fig. 83, Diagram a), while in the southeastern neighbourhood of the quarries its intertonguing with the Szák Formation can be observed. It is known to be finer-grained as compared to the typical facies and sandy in the Nyelőke and the Szőlő-hegy subareas and also in the southern part of the Mogyorós-domb as well as on the southwest side of the fault extending on the margin of the Köves-domb.

A few metres of sand with small pebbles at their base that overlie the bauxite on the Hajnal-hegy and in the József II Openwork stripped off in the 1940's seem to have derived by redeposition from a sandy facies of the Kisbér Gravel.

To the north of the mine pits by the Vár-hegy, on the Haraszt, the borehole Süt-22 exposed the unit in a thickness of 6 m represented mainly by gravelly sands and subordinately by sands and argillaceous sands.

On the Haraszt there are a few small patches, along the Sümeg–Csabrendek road (Fig. 83, Diagram b) there is a larger continuous zone in which gravels and sandy gravels are superimposed on the Senonian or, within a small patch, on the Badenian abrasional conglomerate (Plate LIII, Fig. 2–3). In this area the Kisbér Gravel is exposed, in a thickness of 2.5 to 3 m, by a gravel pit (Plate LIV, Fig. 1). At the base of the section there are gravelly sands exposed in a thickness of 35 cm, containing very poorly rounded, locally corroded limestone detritus. This is followed, in a thickness of 1.5 m, by sandy gravels with pebbles of light quartz and black chert material, very poorly rounded, averaging between 0.5 and 0.6 cm and attaining a maximum of 1.5 cm in grain size, less frequently with Eocene detrital material and chert pebbles of greater size. This bed is overlain by a conglomerate of limonitic matrix in which the pebbles are bigger with a maximum of 5–6 cm, being a little more rounded, too. Some poorly rounded Eocene limestone material occurs in this bed, too. Next to follow are limonite-stained gravelly sands presenting a facies similar to their counterparts beneath the conglomerate bed.

Rocks of the unit under consideration were exposed in a strip a couple of hundred m wide to the northwest of the nortwestern foot of the Rendeki-hegy by boreholes spudded by the Surveying and Geotechnique Company and by the survey borehole Crt-3 (Fig. 84). In these, only a few m of gravel and gravelly sand with sporadical *Limnocardium* detritus underlie the Szák Formation.

On the northern slope of the Rendeki-hegy 9 m of sandy gravel are exposed in the wall of a gravel pit of Csabrendek (Fig. 83, Diagram c). The pebbles have a maximum size of 5 cm at the bottom and 3 cm at the top, and an average of 0.5 cm. Their roundness degree is 2, their material is composed mainly of quartz, in lesser measure of lydite (black shale) with an admixture of some Triassic limestone and chert and sporadical metamorphite. Some bigger boulders of 20 to 30 cm size represented by a

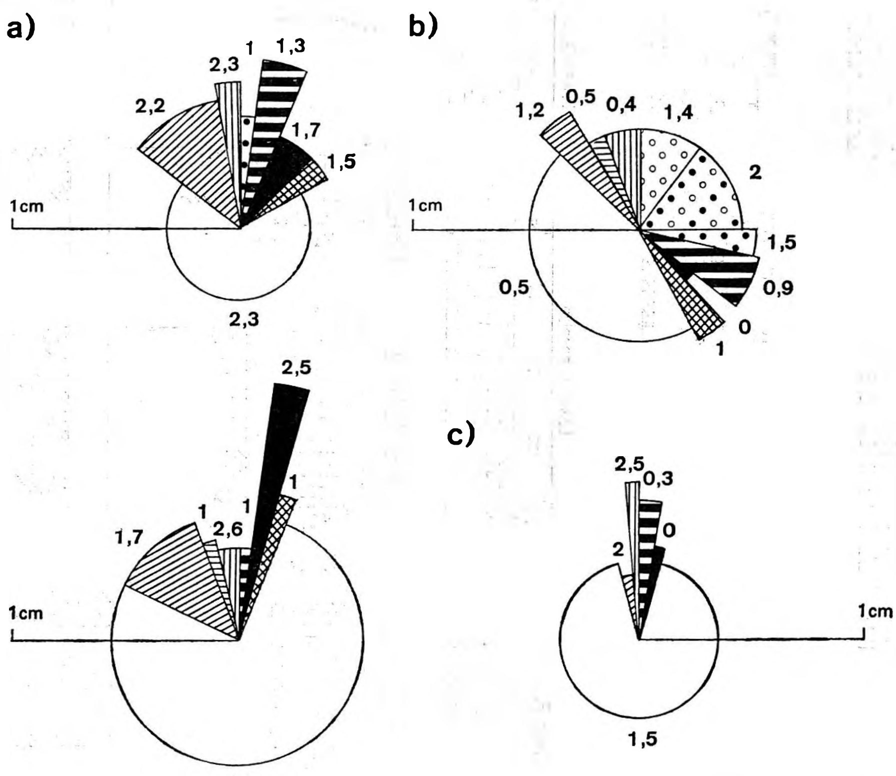

Fig. 83. Composition of the gravels of the Kisbér Formation. (For the explanations, see Fig. 85.)
a) Mogyorós-domb, *b)* along the Sümeg-Csabrendek road, *c)* the quarry at Csabrendek

metamorphic material of Csatka Formation origin also occur in the gravel. The sands are yellowish-grey to ochre-yellow, limonite-banded and medium-grained growing gradually upwards in amount.

A sequence of similar facies can be observed to the NE–E of the afore-mentioned gravel pit, at a distance of 500 to 600 m, close to the road to Nyíres-puszta, in another gravel pit. Here the gravel sequence overlies the Eocene Csabrendek Formation.

Behind the barn facilities of the one-time Csabrendek farming estate the unit under consideration appears in a strongly micaceous sand resembling to the Szák Formation.

On the eastern slope of the Rendeki-hegy, in the quarry devoted to extracting the Ugod Limestone, above the Badenian abrasional beds an alternation of sandy gravels and gravelly sand bands is observable, the pebbles varying between 1 and 2 cm, being poorly rounded.

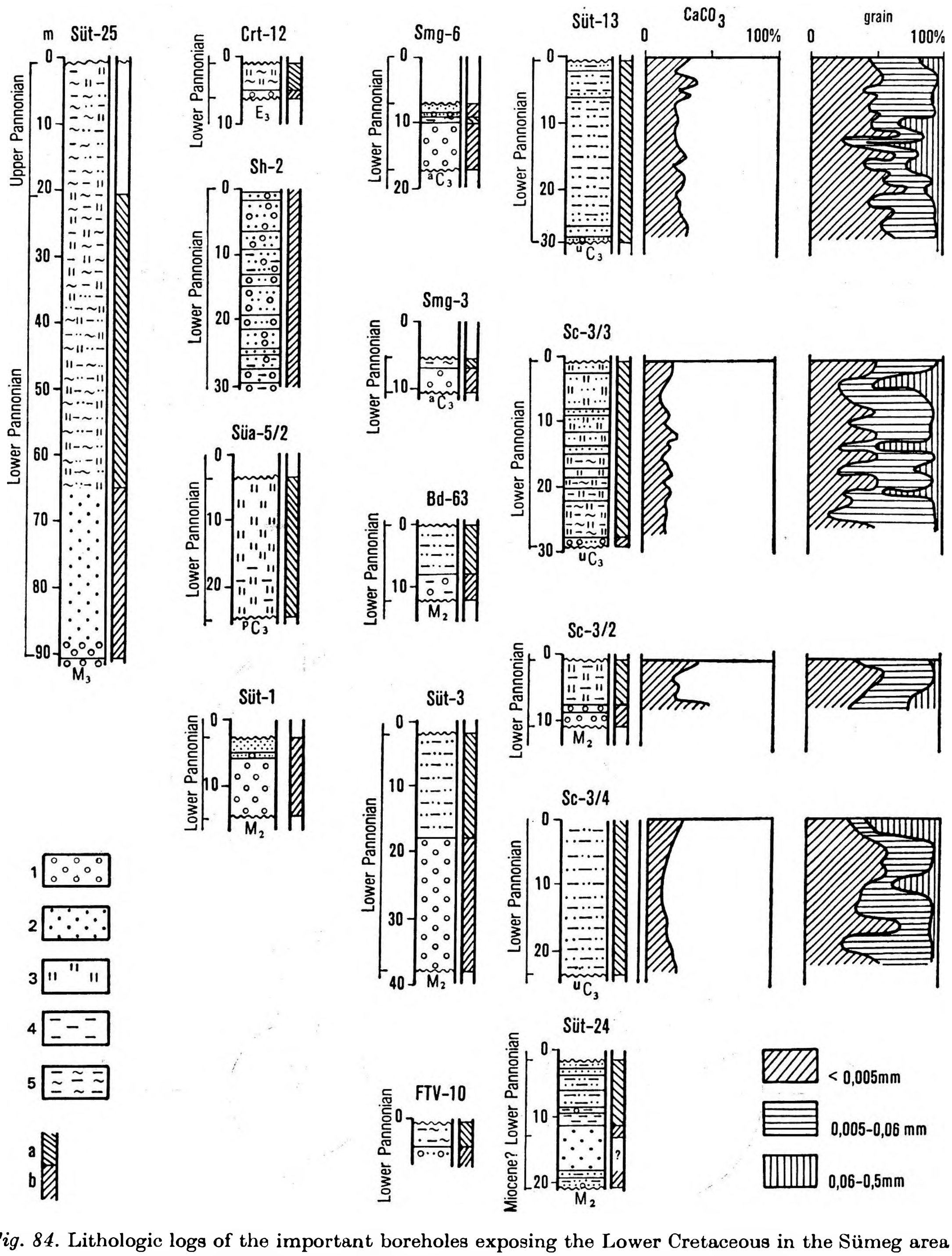

Fig. 84. Lithologic logs of the important boreholes exposing the Lower Cretaceous in the Sümeg area

1. Gravel, 2. sand, 3. siltstone, 4. clay, 5. argillaceous marl. — *a)* Szák Marl Formation, *b)* Kisbér Gravel Fm.

At a distance of 500 m to the northeast of the Kozma-tag, in blocks heaped on the boundary between forest and arable land, a conglomerate with pebbles of 0.5 to 5 cm size and a roundness of 0 to 2 can be recognized. The poor sandy matrix is heavily cemented by limonite. The gravel sheet covering the neighbourhood seems to be composed of material deriving from this conglomerate.

At a distance of 600 to 700 m to the east of the Kozma-tag, gravels composed of quartz, quartzite and, subordinately, lydite (black shale) with a grain size of 0.5 to 1.5 cm and an average of 0.7 to 0.8 cm and a roundness degree of 2 to 3 are observed to occur beneath redeposited Quaternary boulders or a gravel blanket, respectively. In boreholes located in a strip a couple of hundred m wide on the eastern slope of the Rendeki-hegy the thickness of the unit is only a few m, in boreholes farther away it is only a couple of dm, being composed of gravels, gravelly sands and sandstones. The pebble size attains a maximum of 1.5 cm, the constituting material being, for the most part quartz, subordinately lydite (black shale); detritus of *Congeria* and *Limnocardium* occur quite frequently. The unit is overlain here by the Szák Formation.

On the Mogyorós-domb lying south of the type exposures, locally between the abrasional boulders or under them, there are a few dm of poorly or, in some places, strongly cemented, often limonitic, medium to coarse-grained, heavily micaceous sand of calcareous cement. The proportion of the gravels often increase markedly so that the rock is cemented into conglomerate. The pebbles are constituted by well-rounded quartz in the majority of the cases, less frequently by Triassic limestone or Jurassic chert, respectively. In some places, the internal moulds of small gastropods or cavities left over after their dissolution abound. This sandy, gravelly bed of calcareous cement, to the southwest of the abrasional coarse gravel strip on the Mogyorós-domb, is superimposed directly on the Mesozoic. A 20-cm-thick bed exposed in an excavation trench for the exposure of the Kimmeridgian-Tithonian sequence contains, as pointed out by M. Korpás-Hódi, the following fauna: *Theodoxus leobersdorfensis dacicus* J., *Melanopsis* sp., *M. (bouei?)*, *M. (sturi?)*, *Limnocardium* sp. *(? mayeri)*, *L.* sp. *(penslii)*, *Congeria* sp.

In the boreholes (labelled Süt) (Fig. 84) to the west of the fault bounding the Mogyorós-domb in the west, the Kisbér Gravel overlying mainly Badenian formations is represented by 2 to 20 m of gravel, sandy gravel, gravelly sand at the base and sands at the top. Attaining a maximum of 5 cm and an average of 0.5 to 1.0 cm in size and generally well- to fairly-well rounded, the pebbles are made up for the most part of white and grey, subordinately red quartz; lydite (black shale) is abundant, while poorly rounded Mesozoic limestone pebbles are subordinate, metamorphic pebbles may occur in rare cases, too. The sands are fine-grained, slightly cemented by a calcareous matrix. An atypical, finer-grained facies showing a transition to the Szák Claymarl represents the unit under consideration in the southern part of the Mogyorós-domb, in the sand pit by the road (Plate LIV, Fig. 2, 3). In the exposure the contact with the underlying formation cannot be seen. At the base of the exposed section 5 m of light grey, small-grained, locally microlaminated, micaceous sand are observable. This subunit is overlain, in a thickness of 3 m or so, by an ochre-yellow, heavily limonitic sand, strongly reworked at the top. As evidenced by the trench dug above the sand pit, the overburden is represented by the Szák Claymarl, though a continuous superposition cannot be observed. A Kisbér Gravel of similar facies is exposed in the now abandoned quarry on the southwest side of the marginal fault, adjacent to the northern part of the Köves-domb, where a little gravelly coarse sands, strongly cemented in particular bands can be observed. Made up of quartz, the pebbles attain a maximum of 0.5 cm in size, being poorly rounded and containing some very poorly rounded limestone debris fairly often.

One of the most intriguing exposures of the formation is the gravel pit by the Sümeg–Balatonederics road (Fig. 85, Plate LV). In the sequence exposed in a thickness of 8 to 9 m here strongly cross-bedded, coarse- to medium-grained sands alternate cyclically with similarly cross-bedded gravels of 0.3 to 1.0 m thickness composed of pebbles and boulders of varying size. The rock is in some places strongly cemented by a limonitic or calcareous matrix. The grains vary from coarse sand grain size to 20 cm, are very poorly sorted, generally well- or, fairly often, very well-rounded and even flattened in particular cases. They are made up mostly of quartz, subordinately of Jurassic cherty limestone, radiolarite, metamorphic conglomerate, sandstone and mica-schist. One of the cycles of the unit, that of 5 m thickness, beginning with a marked surface of outwash observable in the northern half of the quarry face is shown in Fig. 85. In the vicinity of the quarry, in both eastern and southern directions, the surface is covered over considerable distances by the rock types here observable. The Kisbér Gravel was exposed, in a thickness of several tens of metres, by the sand-exploratory boreholes labelled Sh (Fig. 84) without having reached the underlying formation. The exposed beds in the upper part showed geological features similar to the case of the quarry; in the lower part the clay content was abundant and a red stain appeared in some places.

To the southeast of the Vár-hegy exposures, over a distance of e few hundred metres, the unit was exposed, in a couple of m thickness and in a gravel to gravelly sand facies, by engineering geological boreholes labelled Smg. A characteristic feature of the sequences is the appearance in them of silty argillaceous marl beds of 1 to 2 m thickness belonging to the Szák Formation. In the yard of

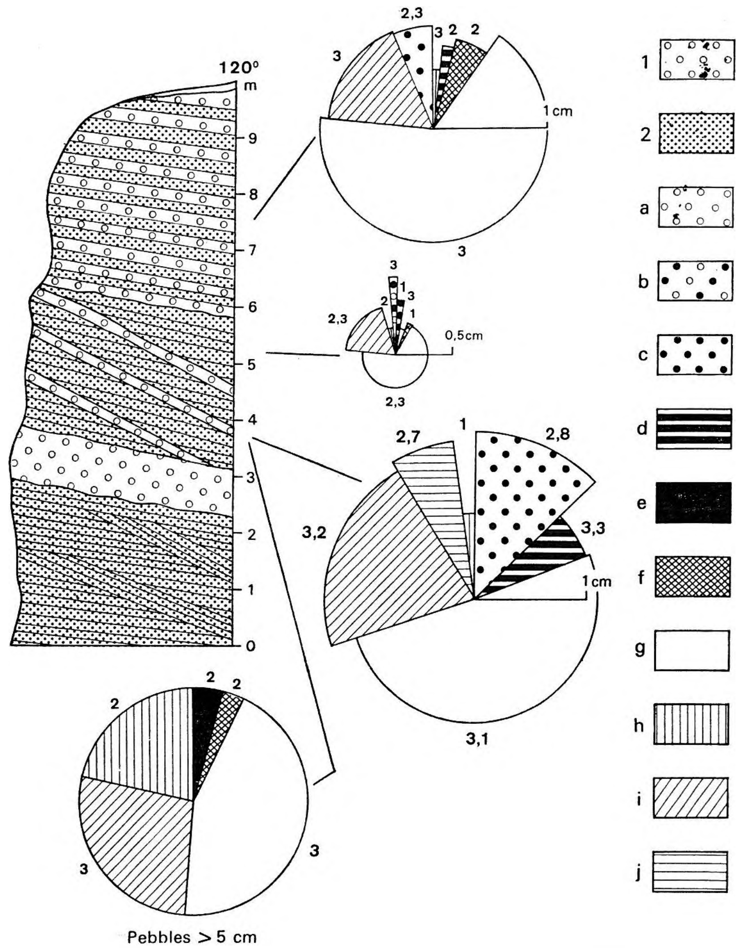

Fig. 85. Section of the Kisbér Formation in the exposure by the Sümeg-Balatonederics road

1. Gravel, 2. sand. — *Lithology of gravels: a)* Cretaceous limestone, *b)* Triassic carbonate, *c)* other limestone, *d)* grey chert, *e)* black chert, *f)* brown chert, *g)* white quartz, *h)* other noncarbonate rock, *i)* black quartzite, *j)* lydite (black shale). — The radius of the circles indicates the grain size of the pebbles: $\frac{a+c+2b}{4}$; fat numerals give pebble roundness according to the RUKHIN scale

the quarry, in the northern part of the Kopasz-domb the Kisbér Formation was explored by us by means of exploratory threnches that exposed it—below the Szák Formation—in a sandy gravel, gravelly sand and gravelly, argillaceous sand facies attaining a maximum of 1 m in thickness. The pebbles are characterized by an average of 0.2 to 0.4 and a maximum of 2 cm in grain size, a roundness degree of 2 to 3, being composed for the most part of light grey, less frequently of dark grey quartz. The pebbles show an upward decrease in amount, and a host of poorly preserved fossil debris is found at the top which M. KORPÁS-HÓDI identified as follows: *Dreissena* sp., *Limnocardium* sp., and *L.* cf. *apertum* (MÜNST.).

The Szák Formation is underlain, in a maximum thickness of 1.5 m, by limonite-cemented small-gravel conglomerate and gravelly, coarse-grained sand, as exposed in the cement-exploratory borehole Sc-3/3 put down near the quarry. The borehole Süt-13 spudded at a distance of 500 m farther south cut, already in a thickness of only 0.5 m, a sandy gravel strongly cemented by limonite in which the amount of the pebbles is 40%, their size varies between 0.5 and 2 cm, their roundness degree is 3 and their material is quartz. This is overlain, in a thickness of nearly 4 m, by yellowish-grey, heavily micaceous, microlaminated, slightly silty, medium- to fine-grained sands underlying the Szák Formation's silty clay beds.

In the light of the lithological logs of bauxite-exploratory drilling performed in the Nyelőke subarea, the Kisbér Formation, if any, is very reduced in thickness beneath the Szák Formation in the study area.

A very interesting sequence was explored in the east, near the road, but still within the Városierdő forest, by the borehole Süt-24, which penetrated it, in a thickness of about 10 m, above the Badenian beds. At the base there are is a gravelly sand layer of modest thickness containing pebbles of 0.1 to 1 cm size and a roundness degree of 2, overlain by medium-grained sands, fairly cemented by a calcareous matrix and locally containing even some gravel. A peculiar feature of the sequence is its variegated—red, purple-red, ochre-yellow and grey—colour with prevalence of the red colour associated with the argillaceous beds, microlayers and lenses. A micromineralogical analysis of the rock was carried out by M. SALLAY. As determined by her, the rock is made up overwhelmingly of quartz of igneous origin; in addition, only a few plagioclase feldspar grains are observable in the light mineral assemblage. The heavy minerals are scant, only 0.1%, the predominant component being magnetite, for the most part limonitized; tourmaline is frequent; there is some garnet, too, and even hornblende, biotite, chlorite, disthene, crystalline pyrite, epidote, rutile and anthophyllite are sporadically observable. Strata of similar facies were observed in the bauxite-exploratory boreholes put down close to the borehole Süt-24 and in the bauxite openwork of Bárdió-tag as well. These formations may possibly belong to the Kisbér Formation, too, their peculiar structure being due to redeposition of bauxitic rocks from an immediate neighbourhood. It is, however, more likely that these rock types are older than the ones belonging to the formation. Notably, as shown by the results of mineralogical analyses, they correlate with the bentonite of Ódörögd, being overlain in the borehole Süt-24 by a thin bed with gravels including even a flat pebble and assignable probably to a subsequent sedimentary process already.

Szák Claymarl Formation

A typical Szák Formation represented by siltstone and claymarl is known in the north of the study area, where it is generally superimposed directly on the Mesozoic. Another important occurrence is the Nyelőke and the Kopasz-hegy and the southern part of the Mogyorós-domb. Intertongued between beds of the Kisbér Formation it is known to us, in a low thickness, from the area between the Kopasz-domb and the Vár-hegy.

In the southern part of the Mogyorós-domb, in an excavation trench located above the sand pit exposing the beds belonging to the Kisbér Formation, the basal deposit is a grey, argillaceous siltstone stained yellow by limonite which is exposed in a thickness of 0.5 m without its contact with the beds of the sand pit having been discovered. It is overlain by a 3.0 to 3.5 m alternation of sandy argillaceous marls and argillaceous sands with a little prevalence gained upwards by the small-grained, micaceous sands. In the lower, heavily argillaceous interval *Congeria* detritus ground to tiny particles abound.

In the excavation trench located in the quarry at the northern tip of the Kopasz-domb (Fig. 86) there is a continuous transition of rocks of the Kisbér Formation into a greenish-grey, sandy siltstone locally containing even some pebbles from which Á. JÁMBOR identified, upon observation in situ, some poorly preserved fossil detritus as follows: *Orygoceras* sp., *Congeria czjzeki* M. HÖRN., *Limnocardium abichi* and *L. mayeri*.

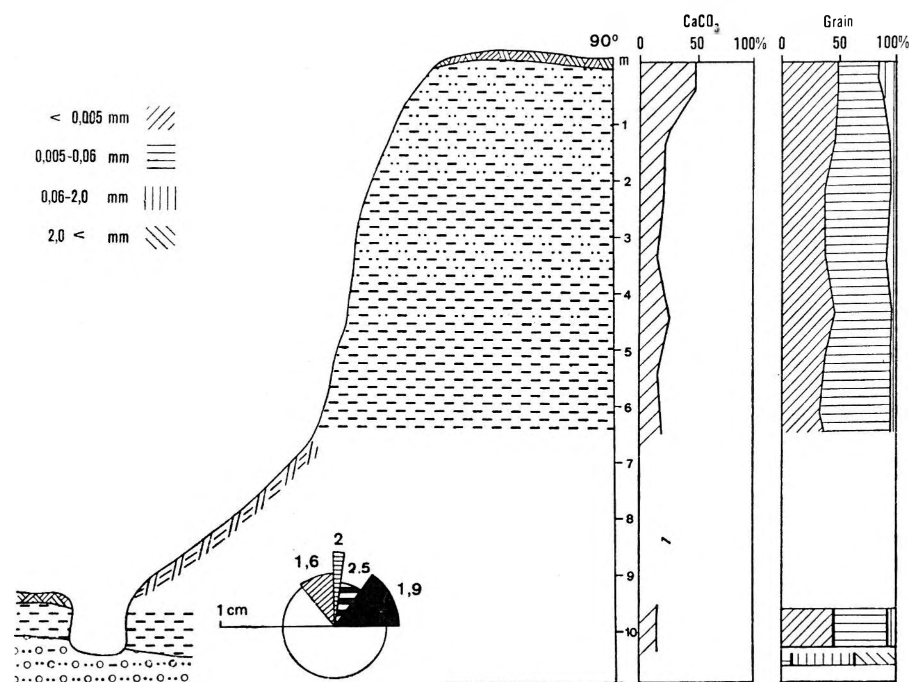

Fig. 86. Section of the Szák Marl Formation in the exposure at the northern end of the Kopasz-domb. (For the diagram illustrating the composition of the gravels, see Fig. 85.)

Next to follow, above a covered interval of 1.5 m thickness, are 8 to 9 m of strongly micaceous, argillaceous siltstone and siltstone-bearing claymarl varying between 15 and 25% in carbonate content. The rock is grey with 2- to 5-cm-thick yellow bands stained at 10 to 15 cm intervals by limonite, It contains sporadical detritus of poorly preserved molluscs.

In the boreholes put down between the Kopasz-domb and the Vár-hegy greyish-yellow to yellowish-brown silty argillaceous marl beds of a few m thickness are interbedded with the gravel, and gravelly sand beds of the Kisbér Formation. In the boreholes located on the Kopasz-domb (Fig. 84) the member overlies a very thin Kisbér Formation or is directly superimposed on the Ugod Limestone, in a thickness of 15 to 25 m. Grey at the base, it is stained yellow by limonite at the top, being constituted by siltstone-bearing, argillaceous marl and argillaceous-marly siltstone. Constituting an average of 10%, the sand content locally increases generally at the expense of the carbonate content On the bedding planes the traces of sand-filled worm-tracks are quite frequent. *Mollusc* debris are rare, only 1 or 2 fragments of *Congeria (? czjzeki)* and *Limnocardium* having come into the fore.

In the borehole Süt-12 put down in the Nyelőke subarea a Szák Formation preserved in only a few m thickness overlies the Ugod Limestone above a limonitic manganese dioxide crust of a thickness of only a few cm, being constituted by siltstone-bearing argillaceous marl, and argillaceous-marly siltstone. In micro-laminae, lenses and bands, fine-grained sands occur in some places. In the bauxite-exploratory boreholes spudded in the Nyelőke subarea the unit shows similar geological features, being approximately 10 m thick in general and superimposed, as pointed out by the relevant descriptions, almost always directly on older—mostly Badenian—formations.

In the eastern part of the study area, the Szák Formation is represented by the lithological log of the borehole Süt-24 in which the unit is 11 m thick and composed of argillaceous-marly siltstones of predominantly grey or, when stained by limonite, light brown colour, with a grain size a little bit coarser as compared to the rocks known from the western part of the area, being locally strikingly sandy and sometimes containing even quartz pebbles of 1 to 2 cm size. The argillaceous beds at the base are variegated—a frequent alternation of ochre-yellow, grey and purple bands of reduced thickness and fluidal structures are observable. At the top, in some places, a lot of poorly preserved, unrounded but weathered shell debris and a few fish teeth are contained in some intervals and such bioclastite lenses can be observed around which a thin interbedded carbonaceous clay layer occurs. As determined by M. Korpás-Hódi, the megafauna consists of the following forms: *Dreissena* sp., *Limnocardium* sp., *Melanopsis* cf. *fuchsi* Handm., *M.* cf. *pygmaea turrita* Handm., *M.* sp., *Pseudoamnicola* cf. *caradiensis* Jek., *Hydrobia* sp., *Micromelania* sp., *Planorbidae* sp. juv. The rock samples examined did not contain any microfossil.

A typical Szák Formation appears in the northern part of the study area. It was the boreholes for the exploration of raw materials for cement put down by the *Geodesic and Geomechanical Company* to the northwest of the Rendeki-hegy and the survey borehole Crt-3 that exposed it above the Kisbér Formation and the Senonian respectively, in a thickness of a few m near the hill with a northward increase up to a maximum (within the study area) of 24 m (Fig. 81 b). At the base, it is composed of grey to greenish-grey argillaceous marls and argillaceous siltstones stained with limonite mottles, containing specimens of *Congeria* and *Limnocardium.* At the top, sandy siltstone occurs in a thickness of a few m. In the sequences above the Kisbér Formation the sand content is characteristic throughout the sequence.

The only surface exposure is the sand pit at the northern foot of the Rendeki-hegy and its vicinity, where a few metres of greenish-grey argillaceous marl interbedded with sand bands of 10 to 15 cm stained by limonite are exposed and an upward increase in the sand content can be observed.

Survey- and bauxite-exploratory drilling on the northeast slope of the hill exposed, superimposed to Eocene rocks, 5 to 10 m of greenish-grey, less frequently limonite-stained argillaceous-marly siltstones that contained, in rare cases, some fine-grained sand, too. In addition, a few debris of *Limnocardium* and *Congeria* were encountered, too. In some boreholes the beds of the Kisbér Formation appear beneath the Szák Claymarl. In the borehole Crt-12, the sequence is heavily sandy, tiny quartz pebbles and Y-shaped worm-track fills being rather common in it.

The material of the boreholes labelled Crt was analyzed for megafossils by M. Korpás-Hódi who (according to data presented in the explanatory to the Csabrendek mapsheet of 1:20,000 scale) determined *Congeria czjzeki* M. Hörn. from Crt-6 and *Congeria* cf. *partschi* and *C.* cf. *czjzeki* from Crt-9.

Bio- and chronostratigraphy

The biostratigraphic scale of the Pannonian in Hungary was earlier based exclusively on the mollusc fauna. In recent years the biostratigraphy based on ostracods and organic microplanktonic fauna has progressed quite considerably.

While monographing the Pannonian in the Transdanubian Central Range, Á. JÁMBOR and M. KORPÁS-HÓDI, in 1976, distinguished seven biostratigraphic horizons. Of these only the *Paradacna abichi–Congeria czjzeki–Congeria zagrabiensis* Horizon can be identified unambiguously in part of the formations in the study area. The beds of the Szák Formation exposed in the extraction face of the quarry of Kopasz-domb and in boreholes put down in the northern subarea are characterized by the species *Limnocardium mayeri* appearing together with *Congeria czjzeki* and *Paradacna (Limnocardium) abichi* as well as by the genus *Orygoceras*. The genera *Dreissena*, *Hydrobia*, *Micromelania* and *Planorbis* occurring in beds belonging to the Szák Formation in the borehole Süt-24, however, are typical, as a rule, of the biostratigraphic horizon or horizons overlying the Czjzeki Horizon (JÁMBOR–KORPÁS-HÓDI 1971). The species of the concurring genus *Melanopsis*, in turn, are encountered both above and below the Czjzeki Horizon.

The *Melanopsis* species appearing in rocks of the Kisbér Formation on the Mogyorós-domb *(M. bouei, M. sturi)* are typical below the Czjzeki Horizon; the *Theodoxus* species that is associated with them, in turn, is conspicuous above this horizon. In the Kisbér Formation beds in the quarry of Kopasz-domb, it is the genus *Dreissena* and the species *Limnocardium apertum* generally characteristic above the Czjzeki Horizon that appear, but they are overlain by the Czjzeki Beds of the Szák Formation. The contradiction between bio- and lithostratigraphic zonation manifested itself in other parts of the Central Range as well (JÁMBOR–KORPÁS-HÓDI 1971).

Probably on account of the sensitivity of the mollusc fauna to facies, the biostratigraphic assignation cannot be solved unequivocally, since the faunal assemblage is not—in the first place—a chronostratigraphic marker but rather a facies indicator.

Palynological studies were performed for the boreholes coded Crt only. On the basis of the results E. HUTTER assigned the beds with *Congeria czjzeki* to palynological Zone B usually correlated with the *C. ungulacaprae* Horizon.

Unfortunately, the exposures from the study area have not been studied either for Ostracoda or for organic planktonic microfossils. The contradictory biostratigraphic data cannot be properly evaluated, unless lithostratigraphy is relied on.

The Szák Foramation can be correlated with the *C. czjzeki* Horizon. The Kisbér Formation underlies it or is intertongued with it in all exposures. Consequently, its rock was formed, for the most part, prior to the formation of the *C. czjzeki* Horizon or simultaneously with the upper reaches of its lower part. The *C. czjzeki* Horizon belongs unambiguously to the upper beds of the lower part of the Pannonian sequence. Its chronostratigraphic assignation is problematic, as the chronostratigraphic scale developed for the Central Paratethys has stipulated only the order of succession of the Pannonian, Pontian, Dacian and Romanian stages between the Sarmatian and the Pleistocene, but it has left their timing still unsolved and since no absolute dating record of the formations involved is so far available.

Paleoenvironment

Prior to the deposition of Pannonian sediments a heavy denudation had taken place which removed the bulk of the Miocene as well. With the subsidence that started at the beginning of the Pannonian, the aquatic sedimentary basin that had continuously been existing to the southwest of the study area started to expand progressively northeastwards. It was in late Early Pannonian time that the 4-km-wide bay which lay in what is now the Mogyorós-domb–Köves-domb–Vár-hegy–Haraszt-Rendeki-hegy–Csúcsos-hegy zone and which penetrated 5 to 6 km deep into the landmass was reached by the transgression. That was the time when the abrasional shores and the abrasional sediments started to evolve. In the coarse-detrital sedimentary material there appear the well-rounded debris of various Mesozoic and/or Eocene rocks making up the neighbourhood. The high degree of roundness of the quartz pebbles too bears witness to their having been redeposited from older detrital sediments, i.e. their abrasional origin. The monotonous composition of the sand-size detritus, their clay mineral content deriving from the weathering of feldspars and the crushed state of the grains are also indicative of redeposition. The strongly crushed brackish-water fossils in the sediment, their being washed into a mixture, is suggestive of heavy wave action. The most typical traces of abrasional activity are preserved on the southeast edge of the one-time bay, in the tectonically-controlled Mogyorós-domb subarea, where the Mesozoic formations set into an upright position were heavily abraded on the surf-stricken rocky shore.

That time on the southeast side of the bay abrasion may have been replaced, over a slightly emerged surface tracts, by sedimentation, and medium-grained detrital sediments started to accumulate in the local sedimentary basins. Some of the bauxite sediment of the immediate vicinity was also washed into these basins which resulted in a variegated banded-mottled pattern of the sediment. As a result of a continued subsidence, with the progress of transgression, the marginal parts of the bay would progressively submerge, and become recipients of fine-grained sediments. In the southeast part of the area, in what is now the Kopasz-domb and the Nyelőke, first an abrasional platform was formed and then it was inundated too giving rise to the setting-in of sedimentation there. Initially, the rocky shore of Mogyorós-domb still had its effect felt, functioning as a breaker that blocked the surfs and secured virtually quiet-water sedimentation conditions for the hinterland.

Continued progressive subsidence led to a submergence of even the northern tracts that had hitherto been emerging. The Mogyorós-domb, because of the increased water depth, now stopped playing the role of a breaker and a little bit coarser-grained sediment was being deposited even in what is now the Kopasz-domb. Under the circumstances of an open-water, non-agitated, near-shore sedimentation regime that now existed throughout the study area, slightly sandy siltstone and argillaceous marl were being formed. The fauna suggests a brackish-water environment of mio- to mesohaline salinity degree (5 to 15‰). The water depth seems to have been, as a rule, more than 25 m, but it did probably not exceed the 50 m figure. The shallowest water is likely to have occurred in the southern subarea, as suggested by the allochtonous fossil content and the carbonaceous clay intercalations observable in the borehole Süt-24. The deepest part of the basin within the study area then lay to the north of the Rendeki-hegy, where fine-grained sediments were deposited in a comparatively greater thickness. Manifesting itself in the upper part of the preserved sequences, a trend of increase in sand content is either suggestive of the onset of already a new emergence or it indicates merely an oscillation which we are unable to trace or decipher owing to the modest thickness of the sediment preserved.

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Upper Pannonian

The fauna and faunal age of Sümeg–Gerinc

by

M. Kretzoi

It follows from the stratigraphic and tectonic circumstances of Hungary that, irrespective of the Middle Oligocene faunal assemblage of the unique fissure-fill of Bodajk-Kajmát (which has supplied, by the way, one of the richest Oligocene micromammal faunas ever found in Europe), not even a single paleovertebrate fauna of importance can be recorded up to the Mio-Pliocene boundary, nor used for biochronological purposes. Above this boundary, however, a unique biochronological succession recoverable from the deposits of the Paratethys on the way of disintegration and exundation can be put in the service of terrestrial stratigraphy and/or biochronology (M. Kretzoi 1969, etc.).

Our Pannonian vertebrate faunas represent a prominent element of the afore-mentioned post-Miocene biosuccession. Within this succession the fauna from the so-called Bohr's sand pit at Sopron and from the foundry-sand pit of Diósd is representative of the lower member of the Lower Pannonian, predating the Hipparion invasion; the fauna from the locality Rudabánya and from Tataros (Rumania) represents the middle and the upper members of the Lower Pannonian respectively. Subsequent, with a break in the fauna, to the Csákvár fauna of already Upper Pannonian age, the fauna of Hatvan and then the faunas of Baltavár-Polgárdi, representing the final member of the succession, encompass, save for a single break, the entire Pannonian span of time. And it is the Sümeg–Gerinc fauna to be reported here in brief that provides a possibility to fill the hiatus observed between the faunas of Csákvár and Hatvan. Added to the rich taxonal material, this fact lends particular significance to this locality and this faunal assemblage.

Although the Sümeg–Gerinc site is a karstic fissure und thus it does not join, in itself, the lithostratigraphic record, this deficiency is satisfactorily compensated by the circumstance that from the strata underlying the (stratified) sequence of Hatvan representing the next member in the faunal succession, a floral assemblage strikingly different from the former, both floristically and sedimentologically, and reflecting climatological conditions congruent with the implications of the faunal record of Sümeg has been recovered (Rózsaszentmárton, see I. Pálfalvy 1952).

Those facts account for the importance of the fauna and faunal horizon of Sümeg–Gerinc.

The fossil vertebrate assemblage

From the Sümeg–Gerinc site, a total of 61 taxa could be identified. Of these, 3 are amphibians (frogs), 6 are reptiles, 5 are birds and 47 mammal species. This specific distribution is very unfavourable as far as the amphibians, reptiles and birds are concerned, but the number of mammal taxa provides a reliable clue to reconstruct the once-lived fauna. Namely, we must not forget that these 47 species account for about 50% of the total number of mammal species of the time (80–90), the representation of the taxonal composition of the orders being, by the way, rather proportional compared to the reality.

Let us give hereinafter a concise description of the 61 taxa examined or identified:

1. *Pelobates* sp. ind. — In spite of the deficient material—fragment of a frontoparietale—representing the species, so much can be pointed out anyway, that a species of the genus Pelobates, one known already from the Upper Pannonian, rather than a Miocene to Lower Pannonian Miopelobates lived here.

2. *?Hyla* sp. ind. — A fragment of an ilium impossible to identify with more precisity. Most probable is the presence of a European tree-frog or, less probably, we may have to do with a Bombina.

3. *Ranidae* ind. — A few unidentified fragments of limb bones which, on account of their proportions, may derive only from a Ranid, but the fragments are unsuitable for any more scrutinized examination.

4. *Lacerta* sp. ind. — 4 to 5 lizard limb bone fragments suggest the presence of a rather small member of the genus, but the fragments are unsuitable for a nearer determination.

5. *Varanus marathonensis* Weithofer — This giant lizard, richly represented by vertebra remains, has been hitherto known from a Hipparion fauna only from the type locality of Pikermi near Athens (A. Weithofer 1888); Sümeg thus represents a very remarkable extension to the north of the known Pannonian distribution area of the species which indicates the important zoogeographic role played by the locality.

6. *Ophidia* ind. — 16 vertebrae of snakes testify to the occurrence of a Colubrid snake; at any rate, the number of finds suggests the presence of a rare, occasional occurrence (all finds derive from one nest).

7. *Testudo* sp. ind. I. — A few fragments of limb bones and skeletons of a gracile-boned Testudo species exhibits the size characteristics of the modern graeca-hermanni group. Their presence is suggestive of a karstic, arid habitat.

8. *Testudo* sp. ind. II. — A few fragments of carapace of a larger Chelonian is informative of nothing more than just the presence of a terrestrial giant Chelonian.

9. *Clemmys* (?) sp. ind. — The sculpture of a few carapace fragments are reminiscent of the Caspian turtle. In want of proper evidence, however, the presence of a species of Emys cannot be excluded from the list of fauna either.

10. *Falconiformis* ind. — The presence of a characteristically predatory Phal. 3 is indicative of a falcon species of medium size, but it is impossible to identify.

11. *Perdicidae* ind. I. — A coracoid fragment that allows nothing more than just suppose that we have to do with a larger Perdicid (Perdix, Alectoris or Francolinus), but because of the incompleteness of the find no further detail can be cleared.

12. *Perdicidae* ind. II. — Scarce limb bone fragments of a bird of small size corresponding to that of Coturnix suggest the presence of the family Perdicidae, but a reliable identification is impossible.

13. *Passeriformis* ind. — Fragments of limb bones of a few tiny birds seem to belong to Passeriformes, but even a family rank determination cannot be attempted.

14. *The few bone remains* allow nothing more than just point out that they derive from birds, so that their value in judging the kind of fauna we have to do with is restricted to quantitative information as to the distribution in the fauna.

15. *Talpa* sp. ind. — The few remains of a Talpa species of scarcely medium size (P, Phal.) give no reliable clue to a specific determination. This is due to the fact that the rather poorly known Talpid fauna of the Pannonian appears to have been rather diversified, as inferred from its counterparts known from other periods. At any rate, uppermost Pliocene T. csarnotana from the locality of Csarnóta, a Talpa species closest in age to Talpa sp. ind., is of smaller size.

16. *Desmana* (s. l.) sp. ind. — One Desmanine specimen outscores in size the known *Desmana pontica* SCHROEDER of the Hipparion faunas, but is more squat than this. The finds available, however, are too incomplete to enable us to give a more scrutinized characterization of the second Desmana species of the time-unit involved.

17. *Trimylus* cf. *sansaniensis* (LARTET). — A typical lower incisor of a larger Soricid which, with a view to its size characteristics, must be the representative of this giant shrew that got extinct with Pannonian time. Its specific identification, owing to the controversy about the Trimylus–Dinosorex group, is quite uncertain (CH. A. REPENNING 1967 and B. ENGESSER 1972). For this reason, it would be most correct to assign the remains from Sümeg provisionally to the genus Trimylus and place them conditionally in the group sansaniensis of that genus—a group including all Trimylines ranging in age from the Sansanian up to the Upper Pannonian.

18. "*Anourosorex*" *kormosi* BACHMAYER et WILSON. — The more than 100 specimens (jaw fragments, isolated teeth) registered suggest the presence of a medium-size shrew taxon that can be identified, beyond any doubt, with *A. kormosi*, a species described from Gyepüfüzes. Given the pattern of joint of the jaw, however, the possibility of whether it may be virtually identified with the genus Anourosorex may be seriously doubted. It remains for detailed comparative studies in the course of forthcoming research to shed light on this question.

19. *Amblycoptus* cf. *vicinus* KRETZOI. — Described from Csákvár, and known to have a related but larger counterpart which was described from Polgárdi by KORMOS (1926), the species *Amblycoptus* cf. *vicinus* KRETZOI is repesented by a few fragments of teeth and jaws at Sümeg-Gerinc as well. The material available to us, however, is too incomplete to enable us to judge the kind of genetic or taxonomic relationship that we ought to look for between the genus Amblycoptus and the aforementioned "*Anourosorex*" *kormosi* assigned to Anourosorex—a genus typical of Southeast Asia.

20. *Petényia dubia* BACHMAYER et WILSON. — Another shrew-mouse represented similarly by more than 150 specimens from Sümeg–Gerinc is a medium-size species described under the name of *Petényia dubia* from Gyepüfüzes which agrees very well with its—maybe somewhat younger—counterpart discovered at the afore-mentioned Burgenland locality. The remains recovered from both localities differ from the genotype described from the Lower Pleistocene, the taxon *P. hungarica* KORMOS, by their more slender shape and the finer features of their teeth.

21. *Petényiella repenningi* BACHMAYER et WILSON. — Known, similarly to the case of Petényia, so far from the lowermost (Beremend) and/or Lower (Villány-3, etc.) Pleistocene, the genus is rooted, as evidenced by the Gyepüfüzes fauna, down in the Hipparion faunas (F. BACHMAYER–F. ZAPFE 1969). As turned out lately, however, the genus is not absent from the lowermost Pannonian of Rudabánya either (KRETZOI et al. 1976). So it is not surprising that it can be identified in the fauna of Sümeg–Gerinc as well, even though the 30 to 35 speciemens recovered from here fall short of the abundance of the larger shrews.

22. *?Dimylechinus* sp. ind. — One mental jaw fragment with the antemolar preserved in it suggests the presence of a species of the genus Dimylechinus, but the material is too incomplete to enable us to give any further precision of the taxon we have to do with.

23. *?Plesiodimylus* sp. ind. — The other rare Insectivore taxon represented by a quite insignificant number of finds at Sümeg-Gerinc probably belongs to this genus, but to decide the question definitively would be possible only on the basis of a richer material.

24. *Galerix socialis* (v. MEYER). — The most abundant insectivore of the fauna (represented by more than 360 fragments) is a species representing a minor side-branch of the phylogeny of the Erinaceids which is the most frequent insectivore throughout the time span between the Upper Miocene up to the Upper Pannonian, wherever smaller mammals are present in the recovered material. In spite of this fact, its determination is always questionable, since it is very often mistaken by the paleontologists for *G. exilis* DE BLAINVILLE—a species that is geologically older, though is quoted, erroneously, still from the Upper Pannonian, too. In addition, the question of its separation from *G. éhiki* and *G. hipparionum,* species based on a small number of specimens, or their identification with them, is still to be settled, too.

25. *Lantanotherium* sp. ind. — With the 50 to 60 isolated teeth and jaw fragments recovered, *Lantanotherium* sp. ind. may be said to represent a frequent constituent of the fauna, but, in absence of jaw fragments informative of the number of P and their location, the question whether we have to do with *L. sansaniense* (LARTET), or *L. tobieni* BAUDELOT or maybe another species in the case of the Sümeg-Gerinc fauna cannot be settled. All three agree in size, so this parameter does not provide a clue to the problem of specific identification either. At any rate, *L. sansaniense* is mentioned from the Pannonian of Lower Austria, thus—knowing the long ranges of the insectivores—the appearance of deeper Upper Miocene forms in the mid-Upper Pannonian is not impossible.

26. *Erinaceus* (s.l.) sp. ind. — One large Erinaceine is represented by rare remnants of teeth that are unsuitable for a more precise taxonomic determination: in spite of this fact, the presence of a large hedgehog species in the fauna is important both zoogeographically and taxonally.

27. *Rhinolophus* sp. ind. (cf. *ferrumequinum* LINNÉ). — A few C and fragments of humeri derive from a Rhinolophus species attaining the size of a large horseshoed bat. Because of our deficient knowledge of the bat fauna of the Hipparion faunas the material we have is insufficient for a more detailed determination.

28–29. *Myotis* sp. ind. I–II. — Tooth- and limb bone fragments not too great in number of two Myotis species of different size that are not suited to a specific determination. With all the great number and diversity of the Myotis species, we would be unable to give a closer definition, unless specimens of better preservation state (complete jaws at least!) were available.

30–31. *Vespertilionidarum* g. et sp. ind. I–II. — Additional isolated teeth indicate the presence of two or three Vespertilionids in the fauna. In presence of a well-preserved material at least one Plecotus and one Barbastella species would be identifiable among these.

32. *Csákváromys* cf. *sciurinus* KRETZOI. — Related to the Southeast Asian genus Sciurotamias, Csákváromys was described on the basis of a material from the locality of Csákvár (M. KRETZOI 1930, 1952). This genus seems to include the smaller squirrel remains assigned to the so-called *Sciurus bredai* group widespread in the European Miocene—forms characterized by an uniformly elongated, low jaw and finely longitudinally-ribbed incisors. In recent years this genus has been referred to, in the relevant literature, as Spermophilinus—an undoubtedly synonymous generic name erected in 1966; consequently, its use leads to confusion. — The few teeth from Sümeg-Gerinc are enough only for a tentative identification with the species involved, being unsuitable for comparing it with the Miocene bredai group and/or the spermophilinus species extending well into the Pliocene. With the same logic, by relying on these considerations, we cannot decide the question of whether spermohilinus is identical with csákvárensis. If it were so, it would have to be icluded again in the synonymy of the form from Csákvár.

33. *Allospalax plenus* KRETZOI (Plate LVI, Fig. 6–8; Textfig. 87). — An interesting feature of the fauna is this lineage reminding of the group of Spalacids, but being—as proved by H. STEHLIN and S. SCHAUB (1951)—geohistorically very distant from it, i.e. a representative of Anomalomyids described from the Sümeg–Gerinc site. The robust, barrel-shaped teeth externally greatly resemble to the tooth structure of the genus Pliospalax known from the base of the Pleistocene, though they are even more complex on one side; on the other side, however, they resemble to the youngest species of the genus Anomalomys extending well into the Pannonian, *A. depéretschaubi,* with the difference that, unlike the case of the latter, they have a somewhat more evolved tooth structure and mainly that it carries a cement fill in the folds and isles—a feature never observable either in the case of Spalacids or in that of the other Anomalomyids. The 10 to 12 teeth representing the species indicate that the animal was less liable to falling prey to predators owing to its hidden—underground—way of life rather than that we should have to do with a rare animal.

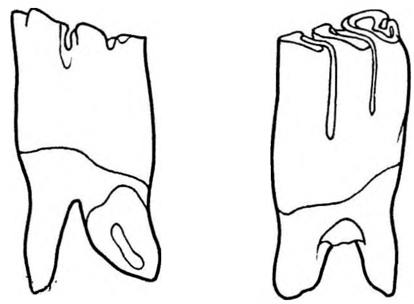

Fig. 87. Allospalax plenus KRETZOI (M₁d) 10×

34. *Graphiglis nanus* n.g. n.sp. (Plate LVI, Fig. 1). — One tooth of a Glirid that does not fit in one of the genera of the family; thus it must be regarded as a new taxon. Its description can be summarized, in brief, as follows: its h o l o t y p e is M_2 dext. registered and deposited with inventory number V-10. No. 1 at the museum of the Hungarian Geological Institute. — D i a g n o s i s : Resembling to the genus Claviglis, a very simple occlusal face on which the enamel ribs form a double loop converging on the buccal margin (and open on the lingual one), just like it is the case with *Claviglis murinus* (DESMAREST). The deviation from this consists primarily in that a short spur juts from the lingual angle of the median furrow between the two folds without closing the median furrow lingually. In the same way, though rather in the form of just a rudiment, a small spur issues from the middle stretch of the second and the fourth transversal ribs, also being pointed forwards. The occlusal face of the tooth is posteriorly a little bit wider, forming anteriorly a narrower, more irregular rectangle. Size: length of occlusal face: 0,91 mm, its width: 0,79 mm. — Represented by a single molar, the new species of dormouse is of very great significance, being particularly important from the geohistorical and paleozoogeographical points of view rather than from the viewpoint of appearance of a new taxon. Namely, Glirids are one the rare paleoarctic families which, rooted in early European ancestors and lacking almost any prehistory in Asia and completely lacking in Africa (Ethiopia), are exhibiting a primary center area of distribution in Southeast Asia and a secondary area in Africa these days. The very close European relatives of African Graphiurines seem, at any rate, to provide the first clue to account for their present-day spread in Africa.

35. *Miodyromys alter* n. sp. (Plate LVI, Fig. 4). — H o l o t y p e : Hungarian Geological Institute. V–10. M_1 dext. — D i a g n o s i s : A new species differing from both *M. hamadryas* (F. MAJOR) and *M. aegercii* BAUDELOT et MEIN, though attributable, beyond any doubt, to the group of forms related with them. Based on the single tooth known, it differs from *M. hamadryas*, irrespective of its somewhat richer patterns, by the features of its posteroloph which is lingually open and buccally linked to the metaloph, by the somewhat more rounded shape of the occlusal face. On top of these differences, it deviates from *M. aegercii* by its free anteroloph. Partly more primitive, partly more evolved and then again exhibiting a different evolutionary trend, its characteristic features suggest that the dormous species from Sümeg–Gerinc is not a direct descendant of the former, but has developed from a different evolutionary line.

36. *Muscardinus* cf. *gemmula* KRETZOI (Plate LVI, Fig. 2–3). — One M^1 and one M^2 that may be assigned, beyond any serious doubt, to the second of the two lineages of Mio-Pliocene Muscardinines — *Heteromyoxus (= Eomuscardinus)* being the first and *Muscardinus* s. str. being the second one. — Since they differ sensibly from the Miocene forms, upon their approximately equal size level, we see a close relation of theirs in *M. gemmula*, a species described from Polgárdi, but, unfortunately enough, represented by a lower tooth. The fact is, however, that our form representing a somewhat earlier age is not documented by a spectrum of teeth that should enable us to settle the problem of identification definitively. *M. pliocaenicus* KOWALSKI, in addition to being much younger, differs with its more simple tooth structure as well.

37. *Glis* sp. ind. — The fat dormice is represented by one small Glis species with a few teeth. Because of the marked morphological conservativism of the genus and the incomplete record available to us, it would be difficult, however, to decide whether the Pannonian remains are related to *Glis minor* KOWALSKI, a deeper Upper Pliocene (Podlesice) species, or represent an independent lineage hitherto unknown.

38. *Neocricetodon* cf. *schaubi* KRETZOI. — Despite their falling short of the abundance of mice, the hamsters, on account of their primary importance for terrestrial stratigraphy, play a very important role in terrestrial stratigraphy, representing two species of one genus, Neocricetodon. One of them is identical with *N. schaubi*, a form described from Csákvár, or with its somewhat higher tooth crown, it is a more evolved descendant of this, while the other species, because of its markedly larger size, should be separated from the form from Csákvár. — It is interesting to note in this context that the genus Neocricetodon, from which both the later-established North American genus Copemys and the genus Democricetodon known from the Miocene of Europe differ but insignificantly, includes the genus Kowalskia established in 1969 as well. Accordingly, even though the taxon Democricetodon with its Miocene to Lower Pannonian forms may be maintained as a more ancient group separable from Neocricetodon, the Upper Pliocene species united under the name Kowalskia is a synonym of Neocricetodon. For this reason, when drawing comparisons, we have to compare the two species from Sümeg–Gerinc with the species described under the name Kovalskia, too. Notably, small-sized *N.* cf. *schaubi* has to be compared with *K. polonica* FAHLBUSCH, the larger second species in turn with

K. magna FAHLBUSCH. — Turning now to the comparison of *N. schaubi* and *K. polonica*, so, irrespective of insignificant differences in size, there are two main points in which the two can be distinguished. These points are, on the one hand, that in the case of the form from Sümeg–Gerinc the splitting into two of the anteroconus and the -conid is even more imperfect and, on the other hand, its lingual anteroconus branch and buccal anteroconid branch are still more poorly developed, while its transversal ribs are stronger; in other words, our form, in accordance with its older geohistorical age, is, as a rule, of more ancient pattern.

39. *Neocricetodon transdanubicus* n. sp. (Plate LVI, Fig. 5). — Holotype: Hungarian Geological Institute. V–10. M^1 dext. — Diagnosis: A species more brachiodont compared to *N. schaubi* or to cf. *schaubi* from Sümeg–Gerinc and considerably larger than these (length of M^1: 2.3 mm), being more brachiodont and more primitive than "*Kowalskia*" *major*. — The larger Neocricetodon species here being characterized is—with the hardly 6 to 7 tooth finds recovered—the less frequent one among the Sümeg–Gerinc representatives of hamsters including a low number of taxa. Even so is it suprising that—as opposed to the case of the nearest known occurrences in Bavaria—a large non-Cricetine species ranges up to the Upper Pannonian, whilst, so far only the smaller species were known to extend so high in the stratigraphic column. The fact, however, that "*Kowalskia*" *major* is known to us as representing a very closely related large-size form from the Upper Pliocene of Poland corroborates the hypothesis that this branch in Eastern Europe outlived the West European population, whilst there the descendants of the giant forms which in Hungary are known but from Rudabánya (Cotimus) or which here disappeared in Miocene time *(Cricetodon suburbanus)* are missing from the Pliocene assemblage.

40. *Parapodemus* cf. *albae* KRETZOI. — The most frequent rodent in the fauna is a Murid which must certainly be assigned to this genus—even after its being split up into several genera—being difficult to assess specifically, as the three species that may come into account, *P. gaudryi*, *P. schaubi* and *P. albae*, ought to be previously distinguished by statistical—allometrical techniques. In fact, such a specific determination is handicapped by the multiple overlapping of their respective diagnostic features. Thus the only thing we can do is to identify the remains from Sümeg-Gerinc with the forms from Csákvár that are close to them in age and that are the first to come into consideration of all localities known.

41. *Progonomys* sp. ind. — 3 molars are proving that, along with abundant Parapodemus, another Murid, of smaller size and morphologically largely different, also appears at the locality. The structure of its M_1 makes it doubtless that the genus based on remains from Montredon is present in our fauna. Because of the scarcity of the material available it is impossible to identify any of the species assigned to that genus or to separate the form of Sümeg-Gerinc from all of them.

42. *Muridae (Anthracomys?)* ind. — A strong upper incisor which cannot be identified either with Cricetids or with Glirids but which is suggestive definitively of the presence of a Murid. Its size dimensions, however, would be indicative of a form of the magnitude of Anthracomys, this being the only form coming into consideration on the basis of the information available. In want of remains suitable for a more precise determination, however, we must content ourselves with simply quoting that there is a third form at the locality, a Murida much greater in size compared the former two, that may be reckoned with.

43. *Proctictitherium sümegense* n. sp. — Holotype: Hungarian Geological Institute. V–10. Mand. dext. with teeth P_2—M_2. — Diagnosis: In addition to its somewhat smaller size, it is the allometry of P and the longer, more dissected and stronger talonids of M_1 that enable us to distinguish it from the genoholotype *P. csákvárense*. Its allometric deviations prove the lack of any geohistorical, phylogenetical connection between the two species and, consequently, the absence of any chronological indication between them.

44. *Ictitherium* sp. ind. — On the basis of incomplete tooth fragments the presence at Sümeg-Gerinc of a larger Ictitheriine belonging to the group of *Ictitherium* s. l. must be regarded as proved —a form that seems to have represented a rarity along with the abundant smaller representatives of Protictitherium. It is interesting to note that the large Ictitherium forms becoming predominant in the later history of our Hipparion faunas are, even at Csákvár, represented by only scattered remains added to the relatively frequent Protictitherium specimens which, in turn, are already absent in our young Hipparion faunas.

45. *Hyaenictis graeca* GAUDRY. — The occurrence in our fauna of this very rare hyenid described from Pikermi does not only widen the limits of extension of the species quite substantially, but even pushes them far to the north. Although in the early literature (E. SUESS 1861) the species is listed erroneously from Baltavár—*Adcrocuta eximia* (ROTH et WAGNER) having been mistaken for it—and though this erroneous information was for a long time maintained in the foreign literature, its valid occurrences hitherto not disapproved are restricted to the Hipparion faunas of the present-day Mediterranean. Thus, its occurrence at Sümeg-Gerinc is certainly worthy of attention. Its rarity, however, is not surprising, since it is present throughout our faunas, the locality Pikermi not being exception to the rule either, as an unfrequent admixture lending merely a colouring feature to the fauna.

46. *Lycyaena chaeretis* (HENSEL). — The same may be repeated regarding this Hyaenid as was said in the context of the previous species: characteristic of rather southern latitudes, this species is rare not only in the Hipparion fauna of Hungary, but represents a novelty, at similar latitudes, in the animal assemblages of similar age elsewhere in Europe as well.

47. *Mustelidarum* g. et sp. indet. — The tooth fragment of a small Mustelid sufficient only for recording the presence of the family, but not enabling a more detailed determination.

48. *Atticofelis* cf. *attica* (WEITHOFER). — The fragment of an M_1 which allows us just to point out that we have to do with a small Felid of the size of a wild cat which we identify—as the most plausible solution to the problem and with a cf. mark—with the Pikermi cat which is a form rather frequent in the Hipparion faunas.

49. *Parapseudailurus* cf. *osborni* KRETZOI. — The peculiar $Phal_2$ of a feloid of a size between that of a lynx and a panther agreeing in proportions and size with the form described from Csákvár. Given, however, the complexity of the systematics of this medium-size feloid and with a view to the multitude of unsettled problems, the specific determination is taken to be a conditional venture.

50. *Prolagus oeningensis* (KÖNIG) (Plate LVI, Fig. 9). The only Lagomorph in the fauna is quite common in the Upper Miocene faunal assemblages of Europe which, however, is rather unfrequent here (25 to 26 tooth remains). As noticed by STROMER, to the east of Bavaria, Prolagus is absent, while to the west of the line it may be regarded as the most abundant mammal even in the Middle-Upper Miocene. This is corroborated by the fact that, for instance, it is absent in both the very rich Upper Miocene faunae of Dévényújfalu and in the fauna of Opole. This is not contradicted by the Prolagus finds recovered from Hungary either: from the Miocene this form is unknown in the Carpathian Basin. And that only remains of Amphilagus have so far been recovered from the lowermost Pannonian of Felsőtárkány (Heves County) and Rudabánya (M. KRETZOI et al. 1976) does is not contradictory to the former. It is interesting to note that the representatives of Prolagus have been recorded from the Upper Pannonian of Csákvár as a probable occurrence constituting a rarity (M. KRETZOI 1954a) and that they were reported as unfrequent forms from Sümeg-Gerinc and as abundant faunal elements from Polgárdi. Their last occurrence is the Lower Pleistocene fauna of Kisláng (M. KRETZOI 1954b). Along with them, the genuine ochotonids of Eastern Europe probably did not reach the Carpathian Basin until Early Pleistocene time.

51. *Hipparion (brachypus) sümegense* n. ssp. — Holotype: Hungarian Geological Institute. V–10. Metacarpale III, sin. — Diagnosis: Similarly to the case of *H. brachypus*, this is a short-legged form which has, in turn, a more crenulated tooth surface. — Prevalent macromammal of the fauna is—like it is throughout our Hipparion faunas— this Hipparion species which, however, differs, in its allometric data, from the corresponding forms of all the other Pannonian faunas of Hungary (M. KRETZOI 1983). Let us remark in this context that during the last hundred and fifty years nearly 200 taxa have been introduced based on the European Hipparion specimens, most of them on specific rank. This has led, of course, to a fiasco in the determination of the fossils without having contributed to progress in our knowledge even in questions of principle. This proliferation of taxa has nevertheless had its benefit—a succession of synthesis-minded monographs which, by statistical methods and by conclusions based on materials of more or less statistical amount, have made it clear: the enormous masses of Hipparion of the European Pannonian forms regionally isolated, local micro-units. What we are still unaware of is the kind of mosaic into which these metrically-assessable discrepancies, deviations in distribution can be arranged, not to speak of the chronological sequence of these synchronous mosaics that should also be taken into consideration! Anyway, that these micro-units (should they be morpho-populations or sub-subspecies or else) deserve to be, and must be, taken into consideration and registered, we can already admit. Only so can we hope to become able with time to be clear about the fine-taxonomic problems of this group and this way the units in question may be made use of as "markers" not only in drawing the boundaries between major stratigraphic units (on account of their sudden appearance), but also in fine stratigraphy and paleogeography and in reconstructing the chronology of faunal movements. In the material from Sümeg-Gerinc this Hipparion—with its 18 teeth and tooth-fragments, to which a good 120 of other bone fragments represented mainly by heavily crushed- and splittered limb bone, vertebra and rib remains are added—outnoumbers enormously the finds of other major vertebrates and, practically, those of ruminants ever recovered from the locality.

52. *Hemihipparion* cf. *minus* (PAVLOV). — One of the peculiarities of the fauna is the appearance of dwarf Hipparion hitherto known from southern Hipparion faunas only. Although the finds are restricted to one metatarsal fragment and one phalanx, the presence of the species can be shown with certainty. However, inasmuch as the form that lived here was specifically different from the peri-Euxinic one of Samos, so it is quite natural that the finds recovered at the Sümeg-Gerinc site are far from being sufficient for a scrutinized specific identification. So, we have judged it reasonable to mark the form under consideration with a cf. under the valid name of the species based on a type from southern Russia (and re-described on the basis of the skull of "*Hipparion*" *mathewi* ABEL of Samos

now being deposited in the collection of the Hungarian Geological Institute), hoping that subsequent excavations may prove so lucky as to enable us to settle the problem.

53. *Aceratherium incisivum* KAUP. — One tooth which, with its shape and size characteristics, makes the presence of the small, bare-nosed rhinocerotid from Eppelsheim unquestionable. At any rate, the single find recovered shows its being rare.

54. *Suidae* ind. — One tooth fragment which derives surely from a suid, but which does not allow a more detailed determination. This being the case, irrespective of the ecological information, the fauna is deprived of a very important chronological index form.

55. *Lagomeryx* or *Micromeryx*. sp. — A few limb bone fragments which, with their tiny size characteristics, make the presence of a dwarf ruminant in the fauna unquestionable. To further scrutinize the determination would be unjustified, however, because two dwarf ruminants of approximately the same size and growth have been observed to occur in our Hipparion fauna between which we can distinguish only on the basis of the teeth and the metapodials. Thus even a generic identification is impossible.

56. *Pikermicerus* sp. — Despite its imperfection the single fragment of a horncore shows clearly that we have to do with a form belonging to that Tragocerine with a flat and short horn discovered at Pikermi. The remain available to us is not complete enough so as to enable us to decide if it can be identified with the species *P. gaudryi* or it differs from this taxonally.

57–59. Three Tragocerine remains of different size and shape are unsuitable for a nearer determination, not even a generic one. Thus they have been listed as *Tragocerinae* ind. I–III. One of them seems to represent the genus Dystychoceras, but the other two could not be identified even to this point. Anyway, to distinguish them even in such an incomplete form, i.e. without a closer identification, is important, because it is informative of the abundance of antelopes in the fauna which is another deviation from the habitual composition of the Hipparion fauna in Hungary, strikingly poor in species compared with their southern counterparts as they are.

60. *Ovicaprinae* ind. — Maybe the most striking zoogeographic-zoogenetic peculiarity of the fauna is the presence of an ovicaprine which is, unfortunately, represented by only a few characteristic limb bone fragments. Anyway, these finds are enough to distinguish the form under consideration from any other representatives of antelopes, but they are insufficient for the determination of its closer systematic position. Particularly noteworthy in this context is the fact that the nearest genuine ovicaprine finds (Ovis) were discovered at Samos, i.e. in Asia Minor and not at Pikermi or any other South European locality.

61. *Procapra* sp. ind. — Our gazelles from the Hipparion fauna were earlier assigned, by error, to the genus Gazella. The females of the genus Gazella, however, carry, all without exception, horns, like the males do, but theirs is half the size of the male's horn. Among gazelle horns of non-African Hipparion faunas, however, we have never found any that should be considerably smaller which indicates that these were not observed to include small-horned females. Hence the implication that their females, similarly to the case of the modern Procapra species in Central Asia, must not have borne any kind of horn. This was the reason that led the author (M. KRETZOI, 1965) to consider that our gazelles from the Hipparion fauna should be assigned to the genus Procapra. This is all the more logical as, irrespective of one or two genera representing the most striking rarities (Pliohyrax, Orycteropus), no genus is of African origin in our Hipparion faunas, but the overwhelming majority shows Central Asian connections. — Consisting of a few pieces, the gazelle finds of Sümeg-Gerinc are so poorly preserved that they do not enable us to assess minor divergencies between the individual species that might come in question, their corroded surfaces being unsuitable even for being measured. Thus we have to content ourselves with simply recording the presence of the genus which is of secondary importance, on account of the ecological characteristics typical of all the gazelle species alike, i.e. of their being inhabitants of grasslands or in extreme cases even of grassy steppes grading into semi-deserts.

* * *

I n c o n c l u s i o n, having reviewed the taxonal material, we see that when the number of species of amphibians (3 taxa), reptiles (6 taxa) and birds (5 taxa) does not permit us to handle the material as a "fauna" (the class Urodelidia not being represented at all), the 47 mammal species are already sufficient for being considered as a fauna (no matter how incomplete).

Comparing the systematic distribution of mammal species in the fauna with the percentage distribution of the modern mammal faunas of Europe and Subsaharan Africa, we obtain the following results:

	Sümeg-Gerinc	Europe	Africa
Insectivores	25.5	11.9	11.0
Bats	10.6	23.0	11.6
Rodents	23.4	34.8	38.0
Carnivores	14.9	17.0	12.3
Leporines	2.1	3.0	2.6
Perissodactyla	6.4	—	0.6
Artiodactyla	17.0	9.6	13.6

This comparison suggests that in the Sümeg-Gerinc fauna the insectivores are comparatively diversified, that the bats are few in number, but that the rodent taxa are few, too. An essential unproportionality is only exhibited by the insectivores with their high percentage share. This ought to be ascribed to the food specialization of the owls, as, even in our present-day faunas, especially in the more southern regions, the bulk in the pellets of the barn owls is represented by insectivores, while the other owl species are commonly known to catch shrews just occasionally (owing to their peculiar odour). The other deviations may—mainly in the case of the rodents—rather be due to accidental causes or to the technique of recovery, consequently, they probably do not correspond to the original distribution pattern.

Vertebrate taphocoenosis of the locality

What first strikes to the eye when the taphonomic conditions of the fossil assemblage are examined are the two very different types of preservation state of the finds recovered: in contrast to a mass of fresh but finely crushed microfossils, there is a strikingly large number of megafossils that are also heavily crushed, but of corroded surface resulting in a remarkable difference between the two.

If we consider that the bone material of the microfossils may have been exposed to quite different mechanical effects prior to and during burial than it was the case with the bones of the larger animals, the difference between the two kinds of preservation states is certainly conspicuous. The causes to account for this must be sought elsewhere.

In examining this problem we should start from finding out the possibilities that may have existed for such a type and rate of accumulation of the two different kinds of material on either side and how the joint occurrence of materials of two different preservation states within one and the same accumulation is conceivable.

First of all let us point out that such an amount of microfossils can only be accumulated in places where owls have their sleeping or digestion sites. Only the pellets of owls dropped in a concentrated manner within a comparatively small area on the site can result in such an abundant accumulation of minor vertebrate remains. This means at the same time that these owl pellets had been dropping continuously at the locality and that, upon disintegration, they gave rise to a veritable rodent-bed there. However, this required the presence of caves, rock niches or at least cliff ledges. The relatively low number of bat remains is rather in favour of cliff ledges. Otherwise, bats would account for the majority of the microfauna within the fossil assemblage.

The other component of the fossil assemblage got into the sediment by an accumulation of bones of larger animals, i.e. mammals (carnivores, ungulate animals). Here again a distinction must be made between adult and juvenile animals, for the bulk of the Hipparion remains, just like most of the antelope remains, derives from young animals the age of which was relatively easy to determine by inferring it from their state of changing milk dentition by the time they died. As found out during this survey, the fauna, which consisted almost completely of young animals, except for a few adults, must have died uniformly in late January to early February time. It follows from this that the Hipparion-antelope remains accumulated in the bone collection derived from animals which had died at the same time, probably as a result of a disaster and that the corpses of these had attracted scavengers and that their de-fleshed bones, chewed and strewn all over the base of the ledge as they were, had been lying for a considerable span of time there before being buried. In the meantime microfossil elements deriving from the owl pellets roosting on the ledge were admixed to those bones, while the bones of scavengers, primarily those of hyenas, got into the bone material owing to the death of animals that had been denning there.

The disproportional rate of accumulation of sediment implies, in the final analysis, considering the Mediterranean climatic conditions, that in the dry period that followed the rainy early-winter period characterized by a higher rate of transport and accumulation of sediment the corpses of herbivores and eventually their bones had been lying on the surface, chewed asunder by scavengers and exposed to the effect of cold, heat and rain, till the next winter, while the scavengers were buried immediately after having died in winter.

Let us note in this context that the succession of events just outlined is not corroborated by the sedimentation record—stratification—which, however, with a view to the uneven accumulation of sediment in rock fissures and on ledges, does neither prove, nor disprove the above supposition.

Zoogeographic and stratigraphic significance of the fauna

Since the unexpected chronological dynamism due to the immigration or infiltration of faunal elements into the chronological sequence of the Hipparion faunas or to the disappearance of others or to the different origins of these immigrations was discovered, the historical–zoogeographical composition of the individual faunas has been analyzed more profoundly in the relevant literature.

From this viewpoint, the fauna of Sümeg-Gerinc represents a new colour in the diversified pattern of the Hipparion faunas of Europe. Laced with dominant North American and South Asian associate elements, the Miocene faunal portray is re-painted in a completely novel fashion by the Sümeg faunal phase—based on the fauna of Sümeg-Gerinc—which deviates from the faunal type of Csákvár practically and primarily by the fact that the hitherto prevalent faunal elements of the contemporaneous West and Central European climatic belt—not damped by the indigenous colouring elements admixed to them—were continously replaced by the contemporaneous faunal elements of the Mediterranean belt and that even if an old "Central European" taxon may appear in this faunal assemblage, it is represented by a little different variety. Along with these, the appearance of ovines in the Hipparion fauna reflects the immigration of an element of definitely Central Asian—Asia Minor origin which, as far as our knowledge goes, had not spread beyond Asia Minor westwards. Composed of southern and southeastern elements, this Hipparion fauna breaks so sharply the faunal pattern based on "European" Miocene constituents that it must be regarded as a "hot peak" stage of the Upper Pannonian very well characterizable in terms of faunal successions.

As a striking antagonist of this faunal type of southern pattern, the next fauna is that of a "cold peak" characterized quite distinctly by the immigration of Siberian-Central Asian elements, i.e. the fauna of Hatvan which is delimited very well by the Central European deciduous forest type of the associated floral elements.

This is the frame in which the Sümeg faunal phase fits, between the Csákvár and the Hatvan phases. Its faunistic characteristics based on the stratotype fauna, that of Sümeg-Gerinc, can be detailed as follows:

Wedged between the Sümeg and Hatvan phases and exhibiting characteristic southern faunal elements *(Progonomys, Hyaenictis, Lycyaena, Hipparion brachypus, Hemihipparion minus)* and testifying to typical Central Asian-Asia Minor (Ovine) and African connections (Graphiglis), this is a Hipparion fauna with the modernized or unchanged basic species stock of the faunal type of Csákvár, but with the characteristic features of a predominantly southern admixture.

Although the rock fissure- to ledge-type site is not consistent with the malacostratigraphically-calibrated Pannonian sedimentation system, its pre-Hatvan stratigraphic position is registered very well by a floral assemblage of identical climatic implication recovered from the base of the Hatvan phase, dated by both fauna and flora, within the section of the Pannonian in the Mátraalja–Hatvan region and in the Rózsaszentmárton–Petőfibánya sequence stratigraphically underlying the former.

It remains for a more intimate study of the fauna and the associated flora of the stratotype of Hatvan and its comparison with the underlying lignitiferous sequence of Rózsaszentmárton–Petőfibánya characterized by a thermophilous flora to determine the final position of the Sümeg faunal phase within the intra-Carpathian sedimentational-biochronological sequence and/or to carry out its actual correlation with the malacostratigraphic scale.

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Quaternary

by

M. Kaiser

The Quaternary deposits in the Sümeg area cover the surface in the form of a thin, discontinuous blanket. In the Marcal Basin tracts there are fluviatile sediments, while elsewhere the Quaternary is represented by slope-deposited sediments. The geographic distribution of the formations is shown in Fig. 88.

The lithostratigraphic classification of the Quaternary deposits has not been completed yet, so that, beside the chronostratigraphic scale, a genetic and a granulometric classification is used.

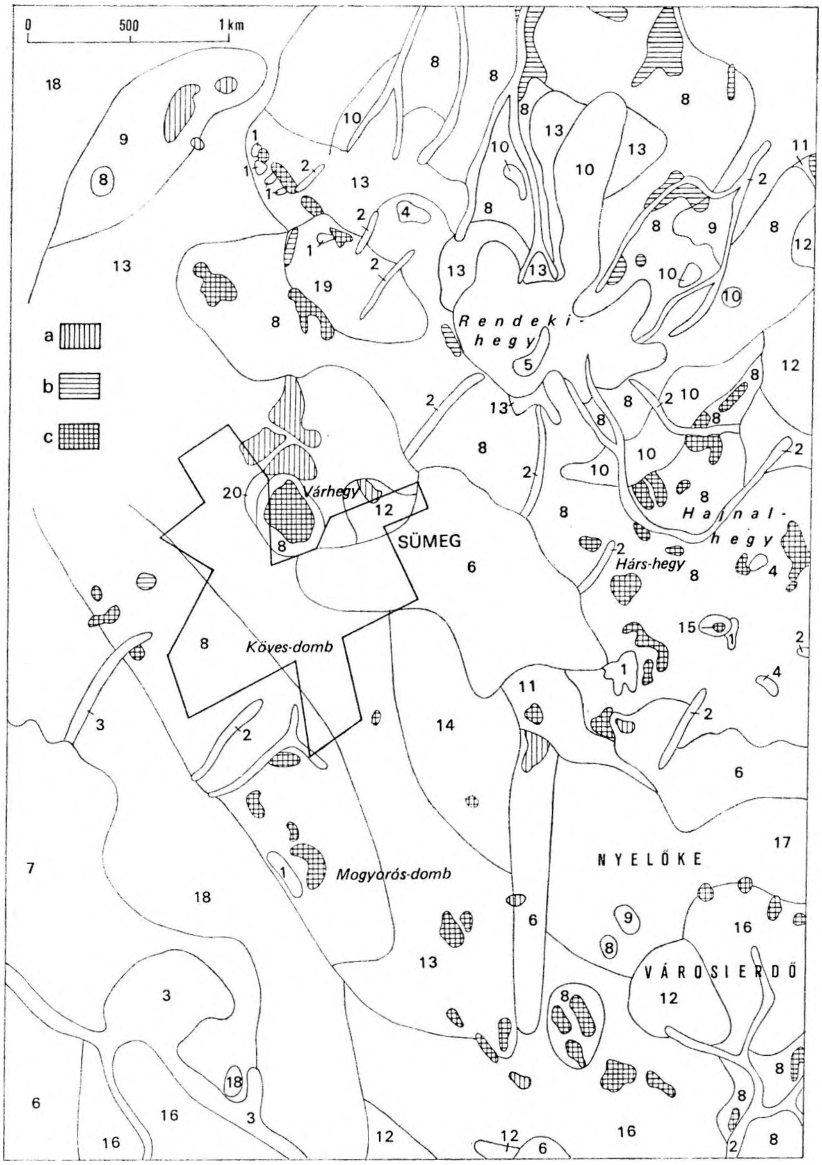

Fig. 88. The Quaternary of the Sümeg area

1. Mine spoil-heap, 2. derasion valley-fill 3. alluvium (mud, sand, gravel, detritus) (1—3. Holocene), 4. eluvial detritus, 5. eluvial gravel, 6. deluvial and proluvial sand, 7. fluviatile sand, gravel (4—7. U. Pleistocene to Holocene), 8. talus, 9. deluvial gravel deriving from the Uzsa Fm. and from Pannonian gravels, 10. deluvial gravel from the Csatka Formation and from Miocene abrasion pebble, 11. deluvial sand and debris, 12. deluvial sand and gravel, 13. deluvial gravel and debris, 14. deluvial and solifluctional clay and sand, 15. deluvial and solifluctional clay, bauxitic clay, bauxite and sand, 16. deluvial sand, gravel and debris, 17. deluvial and solifluctional clay, sand gravel and debris (8—17. U. Pleistocene), 18. fluviatile gravel and debris (M. to U. Pleistocene), 19. blocky talus and gravel 20. deluvial and colluvial sand and clasts. — Pre-Quaternary formations: *a)* Neogene, *b)* Paleogene, *c)* Mesozoic

Fluviatile sand and gravel

In the Sümeg area it is the Marcal Basin tracts that are covered by fluviatile sediments of comparatively large areal extension. They are composed of sands, gravelly sands, gravel lenses and stringers enclosed in sands and, in the deeper-situated parts, silty sands. The sediments are usually cross-bedded. Their average thickness is 2 m, their colour varies between yellow and grey. The Quaternary is underlain by Pannonian sands.

On the margin of the Marcal Basin, the oldest fluviatile beds coming into contact with the pediment formed on the slope of the Rendeki-hegy are found at altitudes of 150 to 160 m a.s.l. During the Pleistocene, detrital and gravelly sediments arrived from the direction of the pediment and got deposited, in some places, in the study area—a process during which the fluviatile sediment was partly lost to erosion. A high flood-plain below 150 m a.s.l. and a marshy low flood-plain at even lower altitudes, can be distinguished. The deposits of the high flood-plain are primarily sands and gravelly sands. The gravels occur scattered or possibly in thin beds or lenses of 10 to 20 cm. The low flood-plain and the present-day alluvium being accumulated at the valley floor of the Marcal river contains, in addition to coarser sediments, a comparatively high percentage of silt and clay.

The valley floor- and the low flood-plain deposits are of Holocene age, those of the high flood plain, as suggested by its geomorphological setting and the absence of cryoturbation phenomena, being of Early Holocene age, while the higher ridges above 145 m altitude may correspond to the Upper Pleistocene. The fluviatile sediments deposited at altitudes higher than 148 to 150 m are of Middle to Upper Pleistocene age.

Eluvial sediments

At the top level of highs composed of pre-Pleistocene rocks an in-situ blanket consisting of weathering products has evolved. Its areal extension is reduced to minor patches, since its material is lost to denudation even at a gentle angle of slope. Its thickness if 1 to 2 m. On the Hajnal-hegy and to the south of it there are small patches of eluvial limestone and dolomite detritus. At the flat top level of the Rendeki-hegy degraded in-situ weathering products of Oligocene to Lower Miocene gravels are found. Because of the gradual transitions and the lack of exposures the eluvium and the slope sediments surrounding the hilltop are difficult to delimit from each other. The weathering blanket was formed mainly in Pleistocene time when the climate was favourable for cryogenic fracturing and disintegration of rocks, but in lesser part it continued to exist during the Holocene as well.

Slope deposits

The overwhelming part of the Sümeg area, except for the Marcal Basin tracts, is covered by slope deposits of varying composition showing the following distribution:

At the southwest foot of the Rendeki-hegy, to the northwest of Sümeg, an area of about 1 km^2 is covered by blocky rock detritus composed mainly of Eocene limestone blocks enclosed in clay, silt and sand. In lesser amount, the clastics include debris of Cretaceous limestones weathering and products from well-rounded boulders of Eocene limestone attacked by abrasion in Miocene time. They widely vary in grain size. A characteristic feature strikingly different as compared to the other slope deposits surrounding the hill is the block-like enclosure of huge slabs of Eocene limestone (Fig. 89; Plate LVII, Fig. 1–2). The biggest blocks vary between 3 and 6 m × 8 and 10 m in size. The complex is 4 to 8 m thick and extremely ill-sorted. In the deeper strata the rock is cemented by a calcareous cement, the interstitial material being of whitish grey to grey colour. As far as the medium of transport is concerned, the various forms of mass-gravity movement, the direct effect of gravity, the intermittent streams, the sheetwash of slopes and slides seem to have played a role in it.

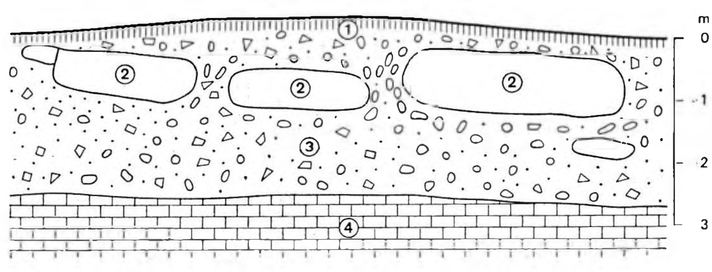

Fig. 89. Blocky talus (quarry to the northwest of Sümeg)
1. Soil, 2. allochtonous Eocene limestone blocks, 3. limestone debris and redeposited silt and sand, 4. Cretaceous limestone

On the platform of the Rendeki-hegy mainly a clastic blanket was formed. On the steep slopes of the hill rockfall, stone-fall, downslope flow of clastics and formation of stone rings were conspicuous mainly in Pleistocene time, but are observable even nowadays. The detritus enclosed in the finer-grained interstitial material was redeposited by solifluction, sheetwash and minor slides on the slopes. The accumulated talus is of mixed composition including unrounded Eocene limestone debris, Eocene basal conglomerate pebbles of mainly chert composition and weathering products of Oligocene to Lower Miocene gravels. In some places, Cretaceous limestones and, mainly on the southern slope of the hill, Eocene limestone detritus is admixed as a result of their abrasion and reworking in Miocene time. The matrix is represented by polished, wind-blown sands; in other places, the sands are accompanied by silts and clays (Fig. 90, Plate LVII, Fig. 3). In some beds the sandy silts and clays outscore the coarse detritus.

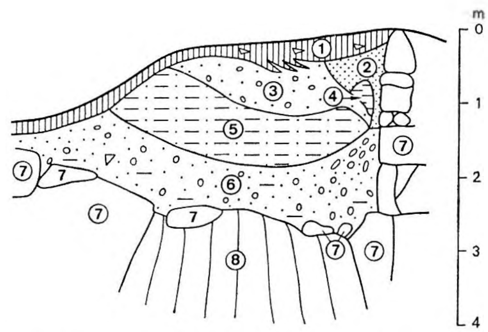

Fig. 90. Fissure filled by slope deposit in limestone (abandoned quarry on the eastern slope of the Rendeki-hegy

1. Soil, 2. sand, 3. gravelly (quartz) sand, 4. redbrown clay, 5. argillaceous sand, 6. argillaceous, gravelly (quartz and limestone) sand, 7. Eocene limestone, 8. talus

To the southeast of the Rendeki-hegy (Hárs-hegy–Hajnal-hegy group), in the northwestern part of the slope, the deposits are composed of Oligocene to Lower Miocene gravels, the products of weathering of Upper Cretaceous to Eocene limestones and, elsewhere, of weathering products of Triassic dolomites and Upper Cretaceous limestones, clays, red clays, bauxites and Upper Pannonian sands.

The southern foot of the hill between Sümeg and Bárdió-tag is covered in a thickness of 1 to 6 m by sands and deluvial and proluvial sediments transported by sheetwash and, in the derasion valleys, by intermittent streams. The sands were removed from Upper Pannonian beds. They largely vary in grain size, being medium- to small-grained in the majority of the cases with an average of 0.2 to 0.6 mm and a maximum of 0.1 to 1.0 mm. Cross-bedding can be observed in some places. The colour of the sediment is yellowish-grey and there is a little muscovite in it, being disintegrated into minute particles. Upon deflation, the grain surfaces are polished, well-rounded.

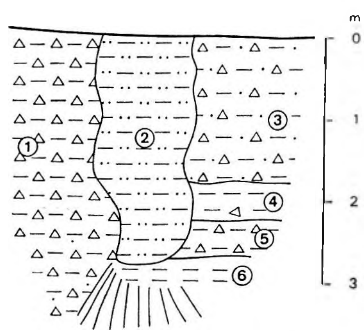

Fig. 91. Ice-sack in slope deposit (abandoned bauxite mine by the Bárdió-tag)

1. Detritus and clay (yellow, grey and greenish-grey), 2. clay, sand (grey to whitish-grey), 3. detritus, clay, sand (grey to whitish-grey), 4. clay (greenish-grey), 5. clay and detritus (greenish-grey), 6. clay (greenish-grey)

In the small basin to the north of the Városi-erdő (Nyelőke) an argillaceous, silty, sandy and clastic blanket has developed on the slopes and in the derasion valleys (Fig. 91). In the Városi-erdő the surface is covered by a mixture of Neogene gravels and Triassic dolomite detritus with sands. Its average thickness is of 1 to 2 m (Fig. 92).

On the pediment surrounding the Rendeki-hegy a detritus deriving from Cretaceous and Eocene limestones, Eocene conglomerates, Oligocene to Lower Miocene gravels and Miocene abrasional gravels is intermixed with the redeposited material of Pannonian gravels and sands.

The Pannonian gravels, to the north of Sümeg is covered by 1 to 2 m of limestone detritus. Under the detritus—and particularly where the detritus is absent—the upper part, on the average 1 m thick, of the Pannonian gravel is reworked, redeposited by slope processes.

At the western foot of the Vár-hegy of Sümeg talus enclosed in Pannonian sands is accumulated in a thickness of 20 to 50 cm. The talus, unconformably overlying Pannonian sand and sandstones, is cemented by a calcareous and limonitic cement, being greyish-yellow to yellow in colour. The unrounded detritus consists of Cretaceous limestone of Vár-hegy origin and, in lesser amount, of well-rounded Pannonian quartz pebbles. A little bit further away from the foot of the hill (at a distance

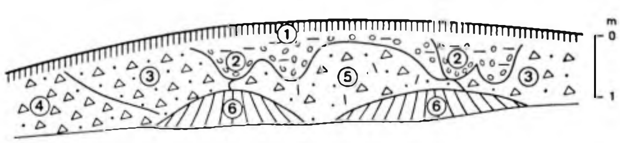

Fig. 92. Ice-sacks in slope deposit (Városi-erdő, road-cut at a distance of 500 m to the north of the gravel pit)

1. Soil, 2. gravelly clay, 3. detrital sand, 4. sandy detritus, 5. detrital, loessy sand, 6. talus

of about 100 m), it contains Eocene limestone debris deriving from the Rendeki-hegy, too. The detritus has an average grain size of 2 to 4 cm with a maximum of 15 cm. The interstitial sand is redeposited with a short-distance transport and is rather unrounded, ill-sorted, reworked, and loosened.

On the Köves-domb and the Mogyorós-domb the loosened detritus of Mesozoic rocks and—locally—the upper strata of the Pannonian abrasional conglomerates are redeposited by different Quaternary slope processes.

On the pedimented margin of the Marcal Basin around the Rendeki-hegy, i.e. its zone of greatest altitude, a thin layer of talus is superimposed on the underlying fluviatile sand and gravels. In the southwest part of the study area, to the west of the Marcal valley, sands with basalt detritus redeposited by slope-sheetwash are found.

The narrow floor of the derasion valleys is filled with sediment removed and introduced from the adjacent areas, ordinarily mixed with solifluction products. Its thickness is 1 to 4 m.

The processes responsible for the slope-deposited blanket were extremely intensive under the periglacial climate that recurred repeatedly during the Pleistocene. Heavy freeze action resulted in large-scale fracturing and disintegration. The resulting detritus underwent a mass gravity movement which, coupled with the solifluction and the sheetwash by snowmelt and periodical torrential rains, brought about a sedimentary blanket that has covered the slopes and piedmont areas as a result of areal transport processes. The effect of gravity and the sheetwash and linear erosion by meteoric waters manifested itself even in Holocene time, while the other agents were pushed into the background.

The slope deposits are for the most part of Upper Pleistocene age. On the basis of the appearance of cemented clastic sands at the western foot of the Vár-hegy and by virtue of its being cemented, the boulders and blocks seem to be older as compared to the rest of the slope deposits. Their Pleistocene age, however, is proved by the cryoturbation phenomena observable in some exposures, by the cryogenic orientation and sorting of the detritus (a phenomenon observable even under huge blocks) and, finally, by the roundness of the intercalated sands—a feature typical of Pleistocene sands in the Central Range. The probable age is Lower or Middle Pleistocene. The bulk of the slope deposits is of Upper Pleistocene age; however, mainly on the steeper slopes, a redeposition was still going on even in Holocene time.

The accumulation of sediments of sandy composition liable to an easy destruction in the area between Sümeg and the Bárdió-tag and to the west of the Marcal valley and also the filling-up of the derasion valleys started in Late Pleistocene time, but continued well during the Holocene.

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GEOMORPHOLOGY

by

M. Kaiser

The Sümeg area lies on the southwestern margin of the Bakony Mountains and its meeting with the basin of the Marcal river. Its larger, eastern, part belongs to the southern Bakony, its western, smaller, part to the Little Hungarian Plain including the Marcal Basin.

From the geomorphological point of view the study area can be divided into the following distinct types of relief (Fig. 93):

1. In the north, it is the Rendeki-hegy that emerges above its surroundings. This hill, obliquely tilted as it is, represents a horst of what used to be the peneplain, re-modelled by pediplanation, of the Bakony, a horst now subsided to the position of a swell.
2. The Rendeki-hegy is surrounded by a slightly-dissected pediment and an abrasional platform.
3. In the western part of the study area there is the alluvial plain of the Marcal Basin.

Structure forms

The block-faulting tectonic style of the study area is reflected in its geomorphology. First of all, the morphological reflection of the faults of varying size is conspicuous. The Marcal Basin is bounded in the south, at the foot of the Mogyorós-domb, by a sharp fault. Further north, the fault continues in the basin's interior without being reflected by morphological benches. The small basin to the north of the Városi-erdő (Nyelőke) is of complex origin. It is bounded by faults both on its northern and southern margins, but denudation was also involved in its modelling. The obliquely-tilted Rendeki-hegy is also bounded by faults that are particularly steep and conspicuous in the northwest and the southeast. The Városi-erdő subarea is constituted by Mesozoic rocks that are block-faulted in a mosaic pattern and reduced by pediplanation to one and the same level. The Vár-hegy of Sümeg is an imposing horst bounded by extremely steep faults.

Planation—denudation surfaces

The origin of the level or slightly undulate degraded surfaces of the Transdanubian Central Range was earlier explained, in some of the areas studied, by abrasion (L. Lóczy 1913), then, in terms of the Davis theory, by peneplanation and, according to the newer concepts, by tropical peneplanation (B. Bulla 1962) and pediplanation (M. Pécsi 1969).

In the Transdanubian Central Range the following planation forms can be distinguished:

1. *Tropical peneplain remnants.* According to the tropical peneplanation theory, heavy lateritic weathering in the tropical forest and savannah zone and copious sheetwash upon torrential rains removing the products of weathering are the processes resulting in the development of vast tropical peneplains of slightly undulate surface due to selective denudation (B. Bulla 1962). Limestone and dolomite areas under such a climate undergo tropical karstification, resulting in karstic cones and pinnacles.

In several places within the Transdanubian Central Range remnants of Cretaceous to Eocene tropical karstic surfaces can be observed. Subsided to different depths, the paleokarstic surfaces owe their preservation, as a rule, to protection by an Eocene overburden. Filled with lateritic-bauxitic sediment, these karstic residues are suggestive of the contemporaneous tropical peneplanation of the Transdanubian Central Range.

The tropical karst remains are preserved only in patches within a small area. Near Sümeg, to the east of the Hárs-hegy, a few minor bauxite-filled dolinas can be observed. A little bit farther away, the bauxite mine of Nyírád has exposed a buried tropical paleokarst (open-pit mine of Darvastó).

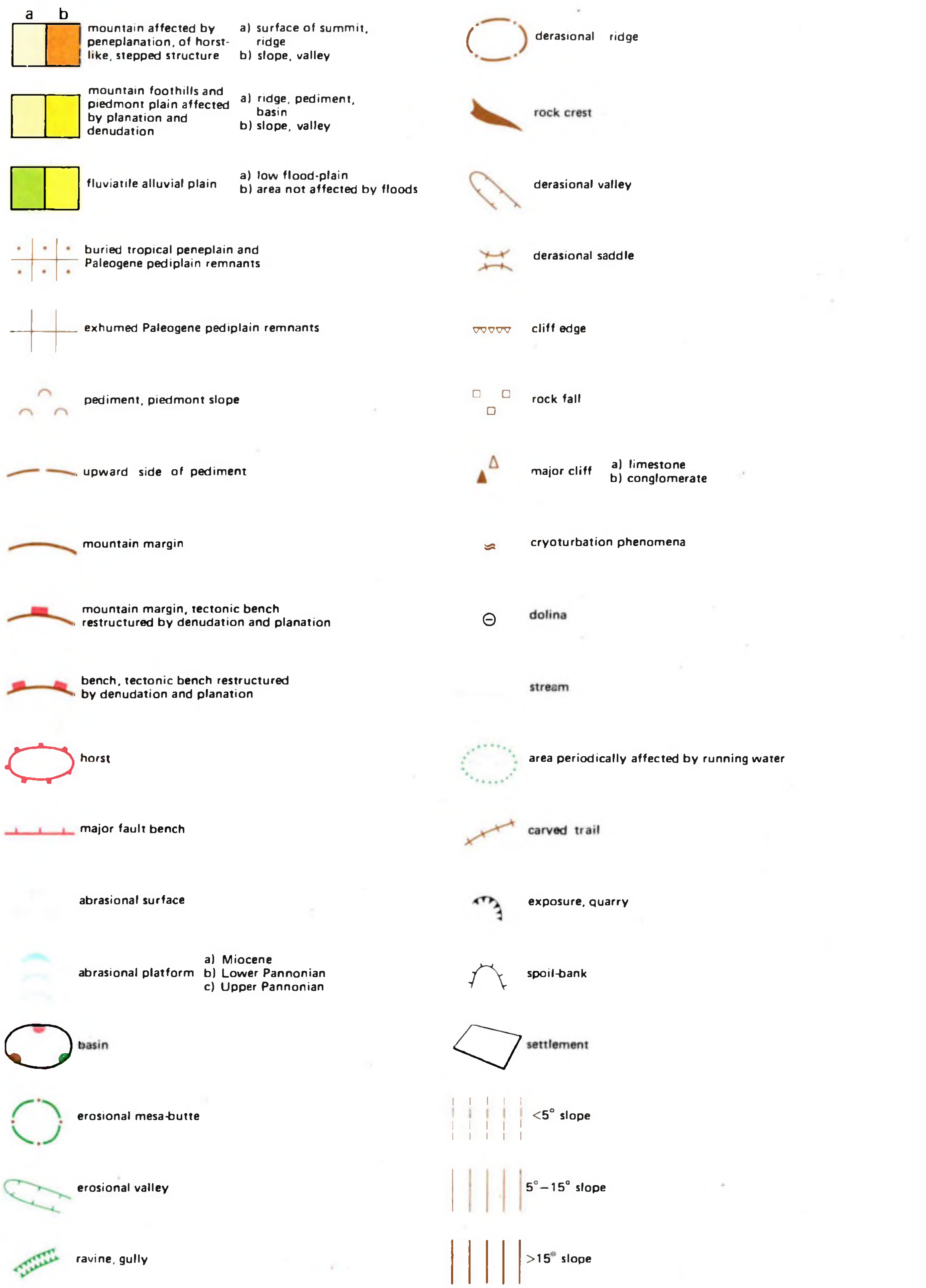

Fig. 93b. **Geomorphological map of the Sümeg area**

is an indication of the age of the abrasion. To the west of the Kopasz-domb the gravel is absent, while on the southwest margin of the Köves-domb and the Mogyorós-domb abrasional boulders, well-rounded, 10 to 40 cm in diameter, are found, resting in part on wave-worn cliffs.

The entire level of 180 to 200 m beneath the Kopasz-domb, and also to the west of the Rendeki-hegy and the Kopasz-domb used to be a continuous abrasion platform that covered an area of about 3 km^2. The Upper Pannonian sediment traceable over a distance of 300 m on the Rendeki-hegy has blanketed the abrasion platform and its neighbourhood. As a result of the uplift of the Rendeki-hegy, a process in action since the Pliocene, the Upper Pannonian and partly the Lower Pannonian sediment has been lost to erosion, a process in which the pedimentation around the hill has played a considerable role. Pedimentation has re-modelled the abrasion platform, at present the traces of both effects are observable.

On the southern and western slopes of the Vár-hegy of Sümeg, at an altitude of 220 to 230 m, wave-worn cliffs and a few abrasion pebbles occur on the hillside. Their age is Lower Pannonian (Pannonian s. str.) or possibly Upper Pannonian (Pontian). That no material removed by erosion from the Vár-hegy is found in the Lower Pannonian (Pannonian s. str.) deposists at the foot of the hill is in favour of the second.

Erosion forms

The most important erosion forms have evolved in the Marcal Basin. The river Marcal at present is flowing, incised 1 to 2 m deep, in an excavated streambed. The Sümeg-area part of the basin is covered mainly by alluvial formations. The surface of the high flood-plain, formed in Early Holocene time and flooded in more recent times only at highest water stage, emerges from an even now active low flood-plain forming an irregular system of patches. Since the time when the river was trained and a system of drainage ditches was developed, the high flood-plain has not been reached even by the highest water head. Between the high flood-plain and the pediment surrounding the Rendeki-hegy at an altitude of 150 to 160 m there is a surface which passes unheeded into the basin and which belonged to the Marcal valley in Pleistocene time. In addition to being partly reduced by erosion, the fluviatile sediments were later covered by a thin layer of slope deposit.

One of the sources of the river Marcal is found in the study area. Around the spring there are a few erosion-derasion mesa-buttes protected by a gravel blanket. These are relicts of the one-time topography into which the river Marcal has been incised.

The rest of the streams of the study area are insignificant, being incised to shallow depth in flat and broad valleys and accumulating a narrow strip of alluvium, they are flowing, for the most part, in man-made channels.

Derasion forms

Derasion is a summarizing term including all the kinds of mass-gravity movement taking place on a slope (slide, solifluction, sheetwash by rain- and meltwater, etc.). They played a role of utmost importance in modelling under the periglacial climate that prevailed in Pleistocene time, solifluction and the impact of snowmelt having been at the premium. At present, the steeper slopes of the mountains and hills are characterized by the predominance of gravity movements such as rockfall, stonefall, downslope creep of clastics and sheetwash, the less dissected and rugged topographies being mainly affected by sheetwash resulting from rainwater.

The most common landform in the study area is the derasion valley dry, lacking a permanent drainage, usually in shape of a flat bowland, when formed on harder rock, often deeper, of hemicircular cross-section. As can be generally observed, the larger valleys follow the tectonic lines. In the formation of derasion valleys not only the linear erosion responsible for the longitudinal valley form is important, but the areally-acting derasion processes producing the peculiar derasion valley form also play an important role. Linear erosion is only intermittently active, carving the valley floor and partly wearing away the derasion sediment accumulated there. The circumstances for the birth of derasion valleys are favourable in the case when the areally-acting processes play a significant role in the surface-modelling. This was the case when the area of Hungary was a periglacial terrain and it has been so in recent times since the clearing of the natural vegetation, for the felling of woods and agriculture have largely contributed to soil erosion.

In the vicinity of Sümeg the derasion valleys have densely dissected the higher topographies, particularly the piedmont slopes, but they are scarce in the deeper-situated tracts. On the plateau of the Rendeki-hegy large, steep-walled valleys have evolved. The deepest incision has been attained by the valleys of northern orientation. The southwest slopes of the hills are dissected by shorter valleys of great inclination.

The lowland and hillocky tracts are characterized by gentle forms with flat bowl-shaped valleys.

Between the derasion valleys, derasion ridges, mesa-buttes have been formed. The slopes of these are modelled by derasion, at present mainly by sheetwash upon precipitation. Steep lateral crests occur on the slopes of the mountain, while on the lower levels flat ridges are observable. The flat Kopasz-domb extending in nort–south direction is an interesting form. As suggested by L. Lóczy (1913), at the junction of the NW–SE- and E–W-oriented margins of the Szőlő-hegy of Sümeg, between two parallel currents there evolved a counter-current which resulted in stagnation and the deposition of finer-grained sediment. Eventually, after the area had emerged, the easily removable sands were carried away and the argillaceous deposits making up the Kopasz-domb were left over. The idea of L. Lóczy cannot be either confirmed or refuted. Degraded and covered by a thin layer of slope deposit, the surface of the Kopasz-domb at present is the relict of a Lower or Middle Pleistocene pediment (glacis), modelled in the interspace between an Upper Pleistocene pedimentation to the west and the Nyelőke-Basin to the east. In its present-day form, it may be interpreted as a derasion ridge.

Of the minor denudation forms, stand-up rocks are conspicuous. The derasion valley incised deeply and running from the Rendeki-hegy plateau towards Csabrendek is flanked by steep rock walls. On the valley-side some stand-up rocks have also evolved. Their formation is mainly the result of fracturing and disintegration in Pleistocene time. In the Városi-erdő stand-up rocks have been carved out of quartz-conglomerates cemented probably upon hot water action ("Altar Stones").

In some exposures of clastics (quarries to the north of Sümeg, north of the Hajnal-hegy, in some road-cuts accross the Városi-erdő, on the eastern face of the bauxite open pit by the Bárdió-tag) ice-sacks and cryoturbation phenomena manifested in a frost-controlled orientation of the clastics could be observed (Plate LVII, Fig 4. and Textfig. 91, 92).

Karstic forms

The karstic forms are landforms less important, scattered in the Sümeg area. On the Mogyorós-domb, at a distance of about 300 m from the Pannonian sand pit, after extraction of the soil a karren-field was unearthed. Because of the soil cover its extension is unknown. At a distance of 600 m north-east of Surgót-major, a small dolina deepens into Cretaceous Hippurites limestone.

The scattered bauxite patches are locally observed to be underlain by relicts of Cretaceous paleokarst.

Anthropogenic forms

Consequences of human activities are observable, in varying measure though, over much of the study area. The quarries aligned on the southwest side of the Rendeki-hegy and their spoil-heaps, the gravel pits, the partly erosion-controlled 1- to 4-m-deep dirt roads incised into the sand blanketing the southern side of the mountain and the drainage ditches dug in the Marcal Basin are the most characteristic examples.

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GEOHISTORICAL EVOLUTION: A RECAPITULATION

by

J. Haas

In the light of researches into the geological formations of the Sümeg area, let us attempt, as a recapitulation of our work, to outline the geological history of the study area. Because of the heavy tectonic deformation, the geohistorical processes are difficult to trace or the possibilities for achieving this goal are rather limited. Naturally, a discussion of the individual geohistorical units cannot be done in equal detail, nor in equal profundity. As a corollary of the geological constitution of the area, some intervals (e.g. the Upper Cretaceous) can be outlined in a more sophisticated form, while others can be portrayed but in rough lines.

Pre-Upper Triassic rocks are not known either in outcrop or in borehole. Thus, though the evidence of the megatectonic unit as a whole would enable a tentative geohistorical portrayal of even the earlier prehistory, we prefer to refrain from entering into details on this matter. The only point we should like to quote from the earlier history is that in the Transdanubian Central Range zone the accumulation of sediments connected with the Alpine tectonic cycle started in Late Permian time. The first sub-cycle culminated in the Ladinian, while from the end of the Carnian the entire Central Range zone became a shallow-water carbonate platform in which the carbonate sediments were being accumulated at a rate that equalled the comparatively rapid and uniform rate of subsidence. The Norian Hauptdolomit, which crops out in the Sümeg area too, was formed in the far-reaching shallow-water carbonate platform environment. Considerable parts of this may have periodically emerged for varying spans of time.

In periods of emergence the subtidal and/or intertidal calcareous sediments of the preceding submergence phase underwent a dolomitization process in an early diagenetic state. The rate of subsidence and the rate of sedimentation that kept pace with it can be estimated at 0.3 to 0.4 m/thousand years.

The diversified formations, which were produced in Rhaetian time (Rezi Dolomite Formation, Kössen Formation, Dachstein Limestone Formation), are indicative of a more dissected sedimentary basin of uneven bottom morphology which seems to have been resulted from differential subsidence of the platform that had a planated morphology during the deposition of the Hauptdolomit.

On the shallow-water shelf, in the background of a relatively elevated swell zone, an internal depression (back-reef basin) came into existence (Fig. 11). In the context of facies relations, it is also likely that the fore-reef (if any) and also the slope and the opensea basin may have lain somewhere in S–SW direction. There is, however, no tangible evidence in favour of this, for in the afore-mentioned direction the formations of corresponding age within the tectonic unit involved have all been lost to erosion.

It is probably a periodical variation in water level, a widely discussed phenomenon quite common throughout the Alpine Triassic and most probably due to minor climatic fluctuations, that is reflected in sedimentation—hence the cyclicity. At the maximum of the transgressive phase a shallow-water carbonate bank (with moving sand and back-reef facies and a sedimentation of transition between these two) was formed, in the deeper basins, in turn, a non-oxygenated lagoon of very weak water-agitation evolved.

In the regressive phases a considerable part of the swell emerged and the marine carbonate sediments of the preceding phase got dolomitized. The deeper parts were overlapped by the back-reef facies of the shallow-water bank which probably communicated with the sea through the intermediary of tidal channels that were crossing the swell zone.

The facies relations suggest (Fig. 11) that the relatively elevated swell zone would—with the passing of time—more and more seldom emerge and, consequently, that the process of subsidence would gradually progress. In the north, the maximum of the rhythmic subsidence fell in the middle of the time-span. This means at the same time that by the end of the Triassic the differences in morphology between the subareas had again decreased and that again a uniform, vast carbonate bank had developed which, however, emerged for a very short span of time, if at all, and that thus dolomitization became quite subordinate. This setting was inherited by the beginning of the Jurassic.

The Jurassic history can be subdivided into two markedly dissimilar sub-periods:

At the beginning of the Lias (Hettangian–Lower Sinemurian) the shallow-water platform carbonate sedimentation, which had started in Late Triassic time, probably continued. Back-reef-lagoonal and subtidal drifting sand facies are known (Kardosrét Limestone). During this period the rate of subsidence may have been 0.2 to 0.3 metres per thousand years—a rate with which sedimentation kept pace for a long time. Consequently, the earliest Jurassic paleoenvironmental setting is till intimely linked with the Permian-Triassic cycle, representing its regressional final phase and/or a phase transient into the Jurassic to Early Cretaceous cycle.

The beginning of the second sub-period seems to have corresponded to the Late Sinemurian when the platform, which had hitherto been subsiding uniformly, fell, along with fissures that were continually reopened and widened and partly filled with sediment, into segments, i.e. blocks and thus the uniformity of sedimentation ceased to exist. The individual blocks subsided or, for that matter, uplifted at varying rates. From the emerged blocks the Kardosrét Limestone was, partly or completely, removed. The surface of denudation became recipient of Upper Sinemurian to Pliensbachian shallow-water carbonate mud and it was primarily this sediment that filled in the fissures that had been reopened in the course of sedimentation (Városi-erdő, Mogyorós-domb).

A change in facies occurred in the Late Sinemurian in areas of uninterrupted sedimentation as well (profile of the borehole Ck-170). The equilibrium between sedimentation and subsidence was upset. The carbonate bank sedimentation was replaced by the deposition of red carbonate sediments that were being accumulated in the subtidal zone.

As suggested by a comparatively rich benthonic fossil assemblage, the grey cherty limestone, indicative of the spread of *Spongia* communities, was also deposited in a shallow-water environment.

The crinoidal limestones of Hierlatz facies abounding with embryonic shells of *Ammonites* and also the textural features and the fossil assemblage (larger calcareous, benthonic *Foraminifera*, thick-shelled, larger *Ostracod* valves) of the Posidonia limestone are suggestive of a water-depth well penetrated by sunlight.

As for the Late Liassic history, no evidence for its reconstruction is available to us. By analogy with the Bakony Mountains and areas further away, the setting-in of a new subsidence and open-sea sedimentation are plausible.

During the Dogger an ooze abounding with planktonic microorganisms (Bositra, Radiolaria) was sedimented upon an open- and relatively deep-water sea bottom. The rate of sedimentation was 0.015 to 0.02 metres per thousand years. The high SiO_2 content of the sediment is due to the high percentage of siliceous microfossils (mainly Radiolarians, in lesser proportion, siliceous Sponges); this in turn may be connected with a change in the chemism of the seawater and possibly even with a submarine volcanism (naturally, not with one in the immediate vicinity). $CaCO_3$ dissolution may also have contributed to the enrichment of silica.

The morphological differences of the bottom persisted, as minor island and cliffs may have emerged above the water level—a probability suggested by extraclasts within the sediment (sequence of the borehole Süt-26). Some areas did not submerge until Kimmeridgian time (borehole Süt-17).

In the Kimmeridgian and the Early Tithonian red calcareous muds rich in pelagic planktonic Crinoidea *(Lombardia)* were formed, representing a facies common in the Central Range. The rate of sedimentation may be estimated at 0.03 metres per thousand years.

A continued drop of water level is supposed to have taken place from the Late Tithonian onwards. The similarly pelagic Upper Tithonian to Berriasian-Hauterivian formations (Mogyorós-domb Limestone Formation) could be deposited at a rate of 0.15 metres per thousand years upon a sea bottom of about 100 to 200 m depth. At a distance of 50 km to the northeast of Sümeg even the contemporaneous near-shore facies are known (J. Fülöp 1964).

The pelagic sedimentation with a growth in non-carbonate, land-derived material (clay, silt, sand) continued up to the Late Aptian (Sümeg Marl Formation). This change in sedimentation appears to be due to climatic causes, in the first place. The rate of sedimentation corresponds to 0.25 metres per thousand years.

Progressing in time, the increase in the grain size of the detrital fraction of terrigenous origin is indicative of a regression trend with an acceleration in the Late Aptian.

The proportion of planktonic fossil elements gradually decreases, the amount of land-derived carbonate detritus (extraclasts) increases (Tata Limestone Formation). The crinoidal limestone was formed in an agitated water in a shallow-water, near-shore shelf zone (moving sand facies) which was populated by *Crinoidea* and *Spongia* communities.

It should be mentioned that this process, manifested by a regression, or, more precisely, by a decrease in water depth in the earlier basin areas, manifested itself by a transgression in the more northeastern parts of the Central Range axial zone, where erosion was taking place. The presence in the formation of detritus from older Mesozoic rocks is common—a phenomenon suggesting the birth of the syncline-like structure of the Central Range in which the limbs were uplifting, while the central zone was undergoing an overall subsidence at a uniform rate.

Started in the Aptian and manifested by a marked compression throughout the Central Range zone, the Austrian movements gave rise to folds, strike-slip faults and imbrications, emergence and denudation. This phase of tectonic deformation seems to be responsible for the birth of the heavily folded and imbricated structure of Sümeg, unusual as it is in the Central Range zone. The explanation for this phenomenon is that between the two NW-SE trending dislocation lines the Central Range geosyncline was broken down and the northwestern and southeastern limbs, respectively, were thrust upon each other (Fig. 3). This accounts for the distinct folding and imbrication of the Jurassic to Lower Cretaceous formations that are observable on the Mogyorós-domb.

In the Albian, the northeast part of the Central Range zone was that which subsided more intensively, so that the Albian transgression did probably not reach the study area.

Before the Senonian the effects of a new phase of movement (Pre-Gosau phase) are known in the Central Range, but this one, unlike the compressional Austrian, was characterized by tensile stresses. This seems to have produced the fissures, attaining even 2 m in diameter, which intersect an already dislocated Aptian Tata Limestone, but in the Senonian basal sediments the fissure-fill is already redeposited in the form of pebbles (Köves-domb). It was similarly as a result of Pre-Gosau movements that the NE–SW-oriented fault structures controlling the Pre-Senonian-cycle morphology and, consequently, the Senonian sedimentation itself, were brought into existence. Thus, prior to Senonian transgression, a dissected morphology had evolved with a dolomite platform of comparatively higher position (Városi-erdő–Hajnal-hegy–Kozma-tag) in the southeast and a comparatively deeper basin in the northwest and a slope of varying steepness between the two.

The modest thickness and/or the frequent absence of Senonian terrestrial sediments suggests that the transition of the study area from a denudation terrain, through a short terrestrial accumulation phase, into a zone of subaquatic sedimentation was relatively rapid. Consequently, the terrestrial accumulation phase almost fell out and the deeper-situated tracts were covered by water.

On the northeastern, relatively elevated dolomite-substrated platform—under the tropical climate with one maximum of rainfall of the Late Cretaceous— large-scale karstic weathering, dolina formation and associated accumulation of terrestrial sediments (kaolinic clay, bauxitic rock types, etc.) may have been going on. In minor depressions at the base of the slopes 10 to 20 m of detritus accumulated (Fig. 94). The pebbles of nearly local origin are indicative of minor, probably intermittent, streams in valleys between ridges of little elevation and NW–SE orientation. On the Barremian marl substratum of the deeper morphological bench montmorillonitic clay was accumulated in minor, drainless depressions.

In the upper part of the Santonian, the deeper areas got beneath the ground-water table that had risen owing to regional transgression. Consequently, the oldest freshwater Upper Cretaceous sediments were deposited in the deepest northwestern depression.

By analyzing the coal-bearing cycles the paleoenvironmental zonation of the resulting lake (or lake system) could be reconstructed. According to the reconstruction, there was a marginal swamp zone with a lush swamp vegetation liable to large-scale destruction and regeneration. It was followed next by a surf-affected sandy beach, followed in turn by an inner zone of a few metres of water depth. On the basis of the cyclicity a periodical water level fluctuation can also be registered—periods of high water level alternated with periods characterizable by a low water level. The changes in water level did not provoke any considerable shift of the shoreline, as the amplitude of variation (a few metres) was smaller than the morphological difference.

In the study area 3 to 4 periods of variation in the one-time lacustrine paleoenvironment can be singled out. On the basis of *Pyrgulifera* and *Bivalvia*, in the high water level stages of the younger periods the waters of the seaside lakes and of the sea are supposed to have got already mixed to a limited extent.

On the gentle slope that formed the southeast margin of the lake-swamp area just described and bounded by a more or less steady shoreline, the terrestrial sedimentation continued. In the minor depressions of some parts of the seaside-slope, lateritic weathering products—probably transported in from a southeastern direction—were accumulated (surroundings of Kozma-tag). This area seems to have lain generally a few metres above the karstwater table, but in the light of the coal stringer interbedded with the bauxite sequence (Fig. 94) it may be concluded that its northwestern part was from time to time water-covered, in other words, that it had developed into a swamp. The closeness to the shoreline, to the karstwater table—a position that usually lay above the karstwater level—and the tropical climate were favourable for bauxitization (a large-scale, repeated leaching in an oxidative environment of basic pH), whilst the mostly water-covered swamp environment of a lush vegetation (reductive and acidic pH) was prohibitive to the process.

deeper, into the zone of pelitic sedimentation, resulting in a mixed thanatocoenosis. In the zone of contact, of course, an alternation of the facies is conceivable, too.

By the beginning of the Late Campanian the minor morphological differences had been for the most part levelled off, but the two main elements, the comparatively deep trough in the northwest and the comparatively elevated swell in the southeast as well as the slope connecting the two, persisted which basically determined the character of the sedimentation. A marked change in sedimentation resulted from the coverage by shallow water of the karstic plateau above the slope during which a shallow-water carbonate platform sedimentation evolved.

The basin's interior got into the deeper neritic zone (a water depth of 100 to 200 m) and pelitic muds of pelagic character containing mainly planktonic micro- and megafossils were deposited. On the lower reaches of the slope mostly pelagic sediments were still being formed with slumps, mud-crackings in an agitated environment. The detrital material from the carbonate platform only seldom reached down to the lower reaches of the slope.

The upper part of the slope became actually the fore-reef zone to the rudist-bearing carbonate bank. A considerable part of the carbonate matter being produced in the rudist-bearing environment was spread over the slope partly as a result of physical disintegration, partly owing to biogenic disintegration, producing a broad detrital zone.

The peculiar sedimentation evolved in the Köves-domb subarea continued. The constant destruction of the bioherms that had evolved on the submerged rock cliff and, parallel with this process, the filling-up of the back-reef area, led to planation of the morphological differences. A shallow-water platform developed here too which in the course of continued subsidence was covered, in Late Campanian time, by pelagic muds.

With progressing subsidence in the Late Campanian the pelagic zone further expanded southeastwards (Polány Formation at the foot of the Rendeki-hegy). At the very end of the Campanian an inversion of the process took place; the rudist-detrital facies on the marginal slope advanced, probably as a result of a regional regression, to the northwest. During the Early Maastrichtian again a transgression seems to have taken place—the rudist-bearing shallow-water platform having been covered by pelagic muds. Because of an intensive Post-Cretaceous denudation, no direct evidence of this last-mentioned process could be found in the Sümeg area.

During the latest Cretaceous to Paleocene emergence (Laramian phase), large-scale erosion took place which removed the Upper Cretaceous which was probably several hundred metres thick (much of the Polány and the Ugod Formations).

In the southeast part of the study area, with the removal of the Upper Cretaceous, the Triassic carbonate sequence was again exposed (the once-buried dolomite plateau was exhumed). Towards the northwest, the surface was constituted by the Ugod Limestone and, farther on in the same direction, by the lower, carbonate-facies part of the Polány Formation. The carbonate terrain underwent a large-scale karstification—sinkholes and dolinas were formed.

In Early Eocene time, with the onset of terrestrial erosion, the resulting rough topography started to subside and eventually, during the Cuisian, an ingression of the sea set in. In the minor depressions of the near-shore swells bauxite was being accumulated, probably as a result of redeposition of older, Cretaceous, deposits. The deeper-situated areas evolved into swamps or they were durably flooded by freshwater (lower part of the Darvastó Formation).

Probably still during the Cuisian, much of what is now the study area was invaded by the sea. Coarse to fine detritus introduced by minor streams was being deposited in an environment of normal salinity (conglomerate member). Farther west (Nagytárkány) no introduction of clastics can be observed anymore. Here, in the deeper-situated subareas, pelitic sediments were deposited, while the higher-situated ones were not yet invaded by the sea.

By the beginning of the Lutetian the larger morphological differences had been levelled off and the transport of coarse clastics into the basin had stopped. The subsidence seems not to have been able to keep pace with sedimentation so that a brackish-water lagoon partly landlocked came into existence in which muds rich in organic matter were being deposited (upper part of the Darvastó Formation).

During the new transgression in Lutetian time a sea environment of normal salinity evolved. The planated topography became a shallow-water carbonate platform. In the warm seawater, primarily as a result of the lime-secreting action of larger Foraminifera, a large-scale accumulation of carbonate set in and lasted up to the end of the Lutetian (Szőc Limestone Formation). In addition to the predominant larger foraminiferal facies, a bioclastic-red algal environment came also into being.

In the second half of the Lutetian, in the Balaton–Velence Mountains zone, volcanic pyroclastics material may also have got into the sedimentary basin; this seems to have been involved in the widespread glauconitization observable in the study area.

At the end of the Middle Eocene and/or the beginning of the Late Eocene a relatively rapid increase in water depth and the distance to the shoreline seems to have occurred. The carbonate platform was covered by shallow-sublittoral and, eventually, by pelagic and deeper-water pelitic sediments (Csabrendek Marl Formation). The introduction of pyroclastics into the basin continued.

The formations that closed the Eocene cycle and locally the whole Eocene and, in many cases, even the Senonian, fell prey to infra-Oligocene erosion. In the Oligocene a piedmont zone evolved in the Sümeg area, where the streams that rushed down from the mountains in the south and southwest deposited their coarse streamload. Metamorphic and igneous rocks that were exposed in the source area supplied the material for accumulation of a fluvio-lacustrine sequence that appears to have been originally very thick (Csatka Formation).

In later stages of geohistory too the gravels deposited in Oligocene time seem to have been the source for the redeposited sediment.

In latest Oligocene to earliest Miocene time, terrestrial sedimentation ended with an overall uplift. The structural elements basically controlling the present-day morphology were brought about during the Miocene (Late Styrian phase). The pediment, that had been produced by removal and planation of in Oligocene time, was dissected, by faults of NE–SW direction and of a direction perpendicular to this, into tectonic terraces and blocks. It was then that the Sümeg horst block dissociated from the intensively subsiding Vár-völgy basin and that the mountain range to the east of Sümeg was uplifted. In the interior of the basin to the west of Sümeg, from the Ottnangian onwards, a thick sequence of basin sediments was deposited (borehole Nagygörbő-1). In the small basins of the Sümeg horst (Bárdió-tag, Kozma-tag) bauxite was accumulated at the beginning of the Miocene. Marine sedimentation started in the Badenian and only an abraded shore- and deltaic clastics sedimentary sequence of low thickness and quite shallow-water limestone were formed which got mixed with the volcanic tuffs fallen into the sedimentary basin (Middle Rhyolite Tuff).

That the area once emerged as an island or a peninsula is a proved by the abrasional conglomerate and the traces of abrasion on rock surfaces with traces of borer-organisms surrounding the Sümeg hill range.

To the west of the horst a marine (brackish-water) environment can be reconstructed even for the Sarmatian (borehole S-25); the more elevated Sümeg horst belonged to the landmass.

The morphological pattern, that had been brought about in Middle Miocene time, was preserved during the Pliocene. In the Early Pannonian, above an environment that consisted of continuously water-covered basins, the Sümeg horst was uplifted, its deeper parts having been gradually invaded by the Pannonian inland sea. The first phase of inundation is marked by the traces of abrasion observable throughout the western boundary fault of the Mogyorós-domb–Köves-domb range: abrasion platforms, abrasional boulders and gravels. It was then that the large abrasion platform comprising the Köves-domb, the Mogyorós-domb, the Városi-erdő, the Kopasz-domb, the central municipal area of Sümeg and the pasture Haraszt to the north of it was formed, which, when the Pannonian formations and the Vár-hegy, supposed to have uplifted later, are disregarded, shows a surprisingly level topography. Degraded by erosion, the surface exposes Triassic, Jurassic, Lower and Upper Cretaceous, Eocene and Miocene formations alike. In the younger phase of the cycle beginning with pearl-gravel on the terrace, clays, silts and sands were deposited (Kopasz-domb), but that time the shoreline lay apparently on the side of the Gerinc ridge.

In the Late Pannonian, the mountain range to the northeast of Sümeg was a landmass which was populated by a thermophilous vertebrate faunal assemblage that had immigrated from the Mediterranean coastal region.

The central part, still standing upright along faults, of the Vár-hegy horst block is likely to have emerged in Late Pannonian time, probably simultaneously with the basalt volcanism. The abrasion platforms, still observable on the side of the Vár-hegy, may have formed at that time.

The hill range to the east of Sümeg seems to have emerged as a peninsula from the Pannonian lake. Upper Pannonian lacustrine sediments have been preserved only in the southwest corner of the study area, but the sandstone residue preserved on the slope of the Hajnal-hegy (supposedly redeposited in Quaternary time) indicates that the Upper Pannonian sediments originally covered much of the study area.

Pleistocene morphogenesis and sedimentogenesis were controlled primarily by the uplift of the Bakony and the subsidence of the Marcal Basin as well as by climatic changes. From the surroundings of the Rendeki-hegy, about 110 to 120 m of Pannonian sediment were removed by erosion, similarly to the case of the mesa-buttes on the western and southern margins of the Bakony. Erosion by the permanent and intermittent streams, the various types of slope processes and deflation were the primary agents of destruction. The arid climate of Mediterranean character at the end of the Pliocene was favourable for disintegration, sedimentation and deflation. In the Pleistocene, during the glacial periods, a planation of the surface by periglacial processes, solifluction and derasion was active. In the cold dry periods the production of clastics and the effect of deflation were strong, which is evidenced by angular boulders and pebbles scattered over the study area. During the interglacials the degradation of the earth's surface by areally-acting processes was outscoured by the prevailing fluviatile valley-modelling processes.

The Marcal valley has been incised since the birth of the Győr Basin's subsidence in Middle Pleistocene time. The original and surface that existed prior to the incision of the valley has been preserved in the form of a few, gravel-protected mesa-buttes soaring above the valley floor.

The formation of the pediment to the west of the Bakony was in action with varying intensity throughout the Pleistocene, the present-day pediment was formed in Late Pleistocene time. The relict of a Lower or (judging by its little-emerged position) Middle Pleistocene pediment has been preserved by the narrow surface of the Kopasz-domb that escaped Late Pleistocene erosion.

The Holocene modelling of earth's surface is predominant, similarly to the case of the interglacial, but it is of valley-modelling nature, while the accumulation of clastics on the hill margins is a deluvial redeposition of the clastic material. On the southern slope of the Rendeki-hegy the proluvial removal of the sand blanket is still going on. The tilling of land has speeded up the erosion of soils and the development of derasion valleys. Stream valleys and derasion valleys now form a network encompassing the whole land surface. On the steeper slopes, mainly in the sand blanket covering the southern slope of the Rendeki-hegy, ravines and gullies are being formed. In the broad valley of the Marcal an Early Holocene high flood-plain and a Late Holocene low flood-plain were formed.

The last important morphogenetic process in modelling the landscape has been man's nature-transforming activity.

PLATES

Photo: J. Haas
M. J.-Kness
E. J.-Edelényi
L. Klinda
T. Lénárd
J. Oravetz
A. O.-Scheffer
M. Pellérdy
E. T.-Filácz

PLATE I

Hauptdolomit Formation

1–2. Foraminiferal biointrasparite. *Involutina gaschei* (KOEHN-ZANINETTI BRÖNNIMANN). 70×
Profile of Szőlő-hegy, Bed 23

3. Green algal biosparite. 30×
Profile of Szőlő-hegy, Bed 23

4. Dolomite of algal mat structure
Szőlő-hegy

5. Micrograph of an algal mat structure
Szőlő-hegy

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L. Klinda
T. Lénárd
J. Oravetz
A. O.-Scheffer
M. Pellérdy
E. T.-Filácz

PLATE I

Hauptdolomit Formation

1–2. Foraminiferal biointrasparite. *Involutina gaschei* (KOEHN-ZANINETTI BRÖNNIMANN). 70×
Profile of Szőlő-hegy, Bed 23

3. Green algal biosparite. 30×
Profile of Szőlő-hegy, Bed 23

4. Dolomite of algal mat structure
Szőlő-hegy

5. Micrograph of an algal mat structure
Szőlő-hegy

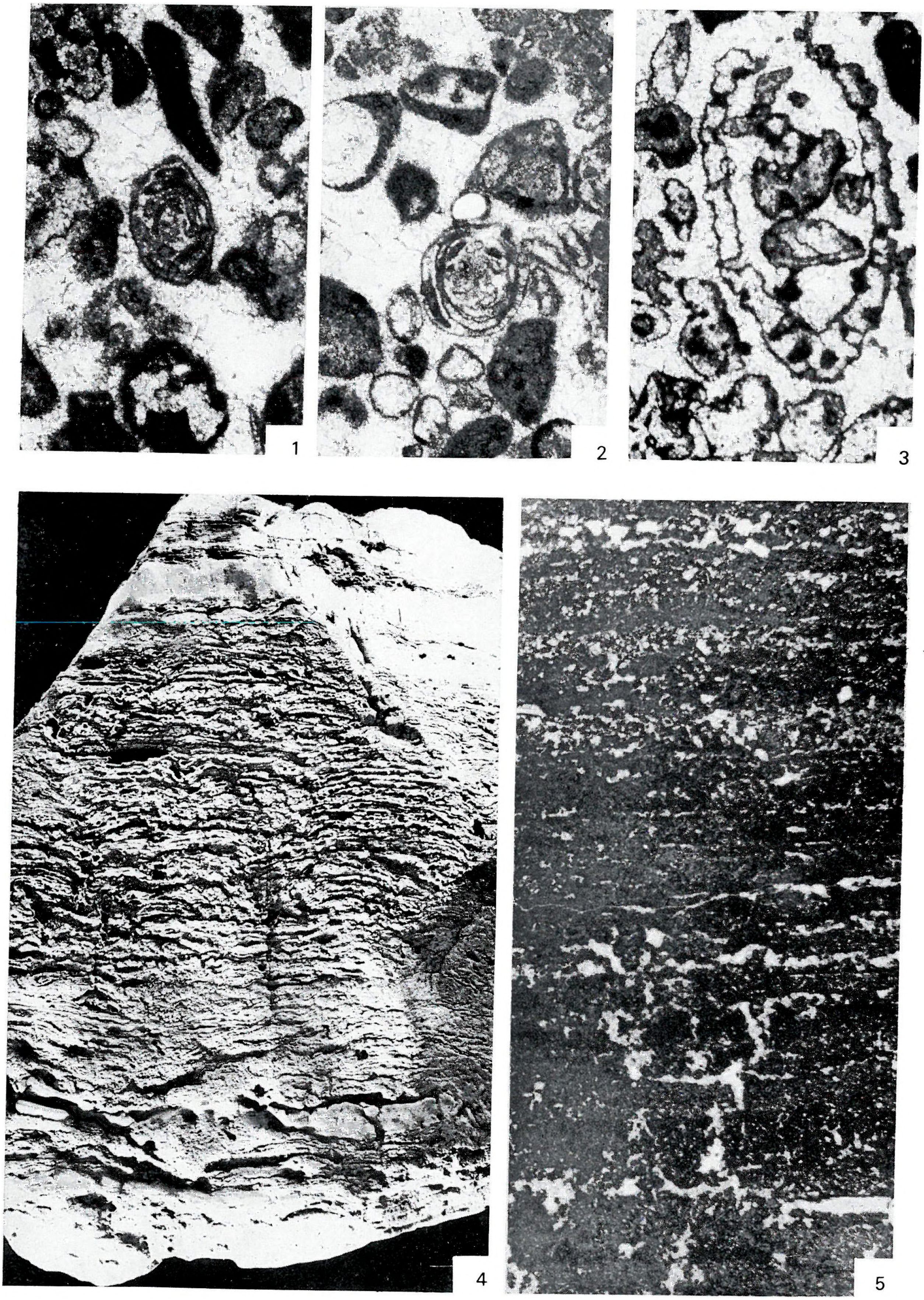
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PLATE II

Hauptdolomit Formation

Szőlő-hegy

1. Green algal biosparite. 10×
2. Green algal biopelsparite. 30×
3. Dolomite with green algal remains. 1×

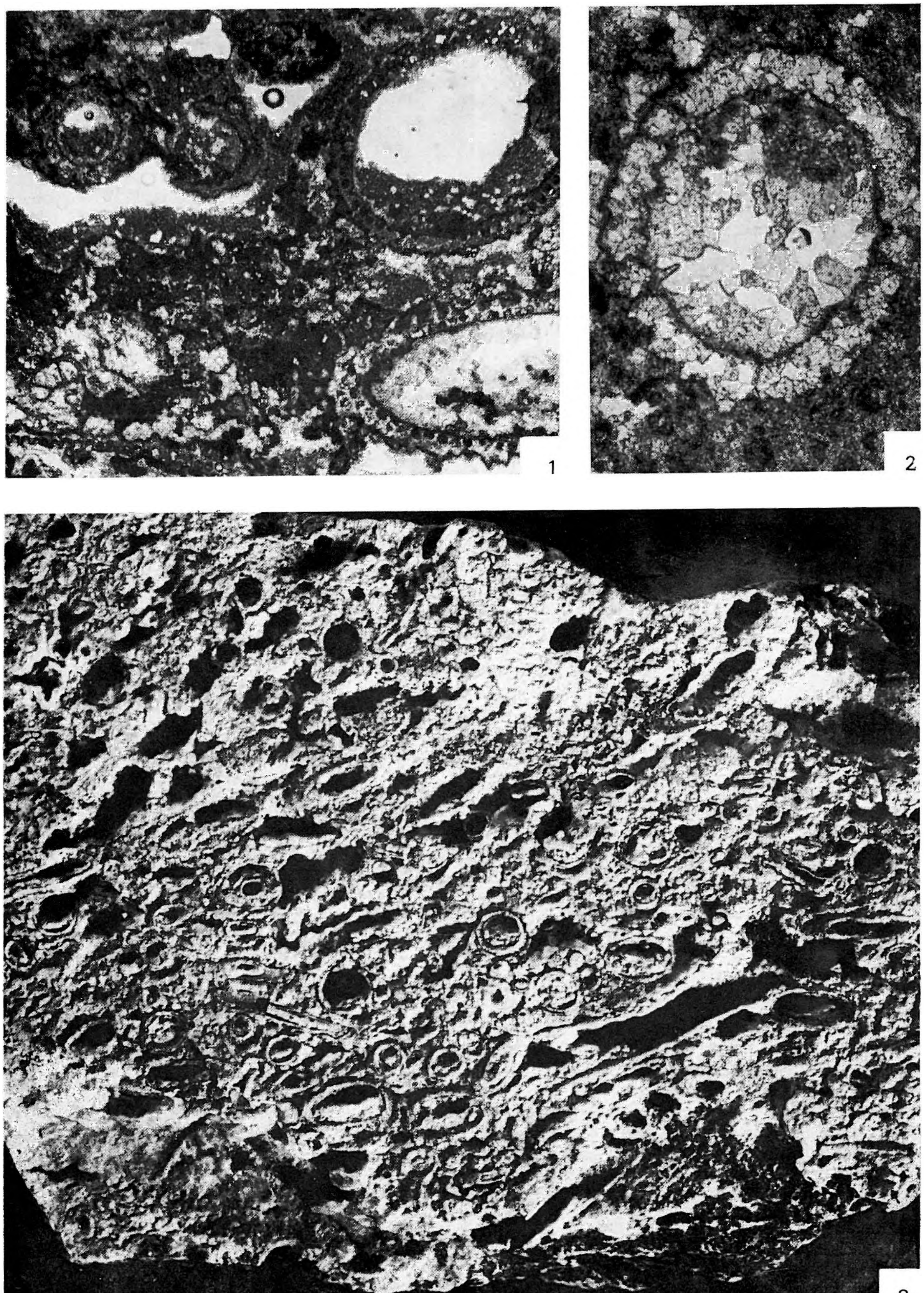
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PLATE III

Rezi Dolomite Formation

Northeast part of the Városi-erdő

1. Thin-bedded facies of the Rezi Dolomite
2. Dolomite bed with internal moulds and casts of bivalves

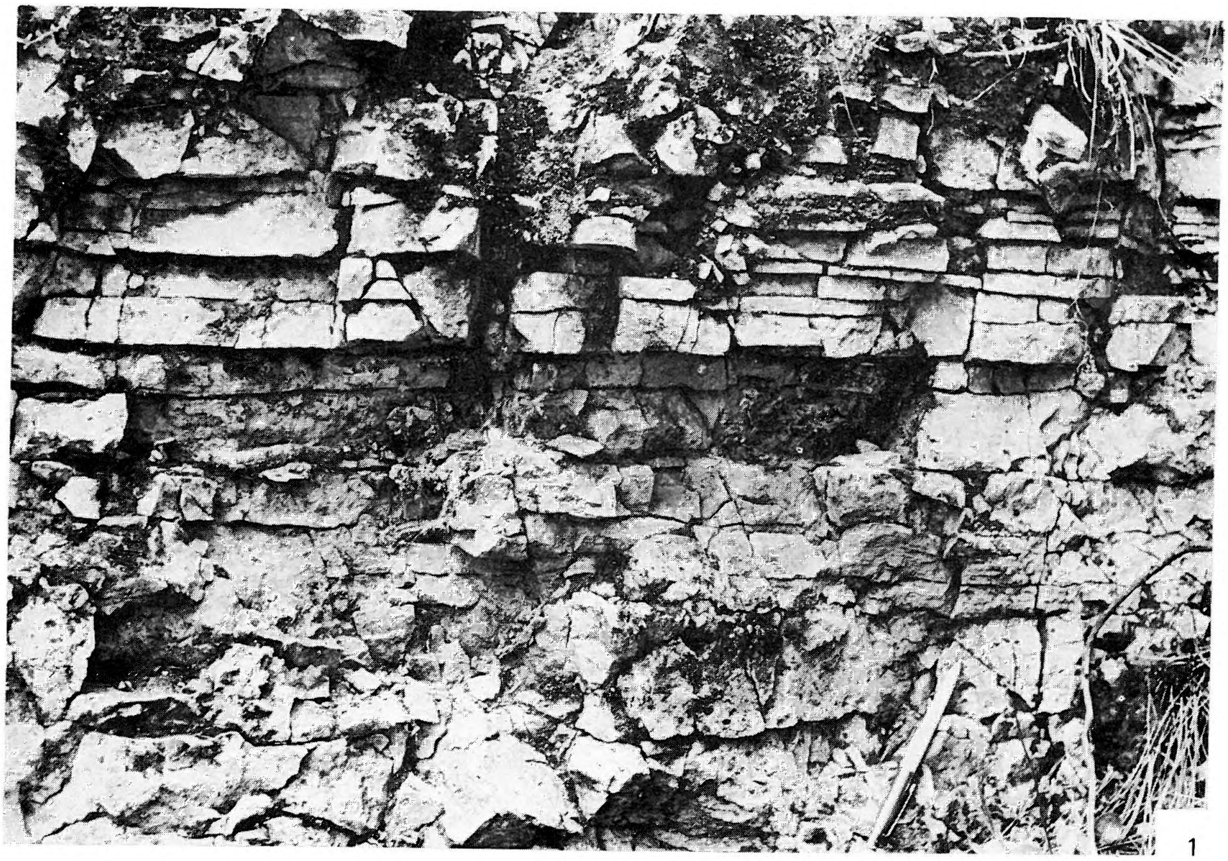

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PLATE IV

Characteristic microfacies and fossils of the Kössen Formation

Borehole Süt-17

1. *Agathammina austroalpina* KRISTAN—TOLLMANN. 170×
   495.1 m
2. *Theelia* sp. (Holothuroidea). 130×
   508.3 m
3. *Thaumatoporella parvovesi culifera* RAINER (alga). 52×
   434.5 m
4. Foraminiferal biosparite texture. 72×
   446.5 m
5. Micrite, with shell fragments of gastropods and other molluscs. 50×
   501.0 m
6. Echinodermous biomicrosparite. 75×
   452.9 m
7. *Pseudonodosaria* cf. *pupoides* (BORNEMANN). 130×
   496.5 m

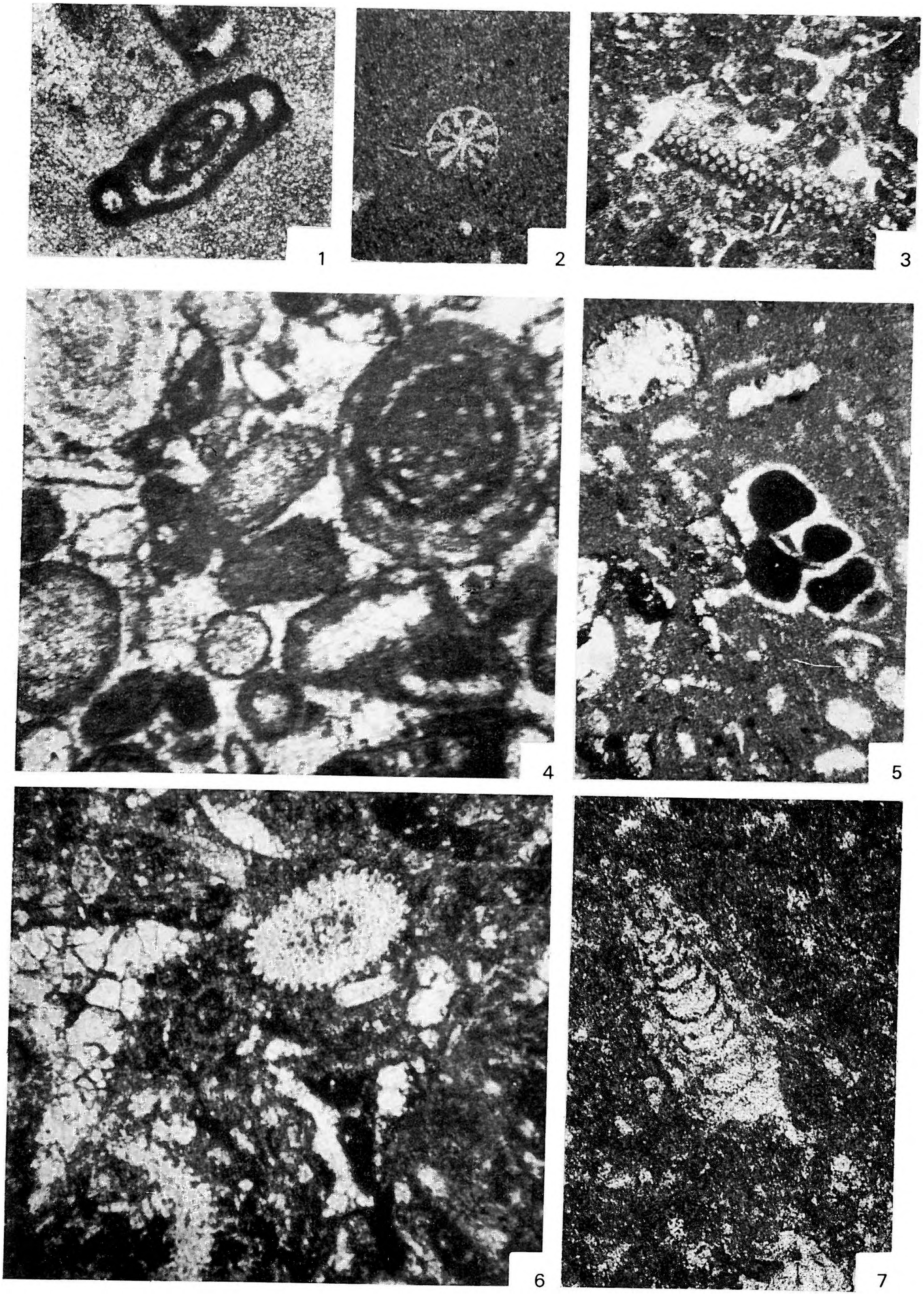
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PLATE V

Characteristic microfaunal elements of the Kössen Formation

Borehole Süt-17

1. *Aulotortus friedli* Kristan—Tollman. 130×
   495.1 m
2. *Schlagerina* sp. 130×
   476.0 m
3. *Triasina hantkeni* Majzon. 39×
   495.1 m
4. *Lutkevichinella keuperea* (Will 1969). 200×
   504.8 m
5. *Eutrochus?* sp. 54×
   504.8 m
6. *Paracypris* cf. *redcarensis* (Blake 1876). 200×
   504.8 m
7. *Healdia martini* (Anderson 1964). 200×
   504.8 m

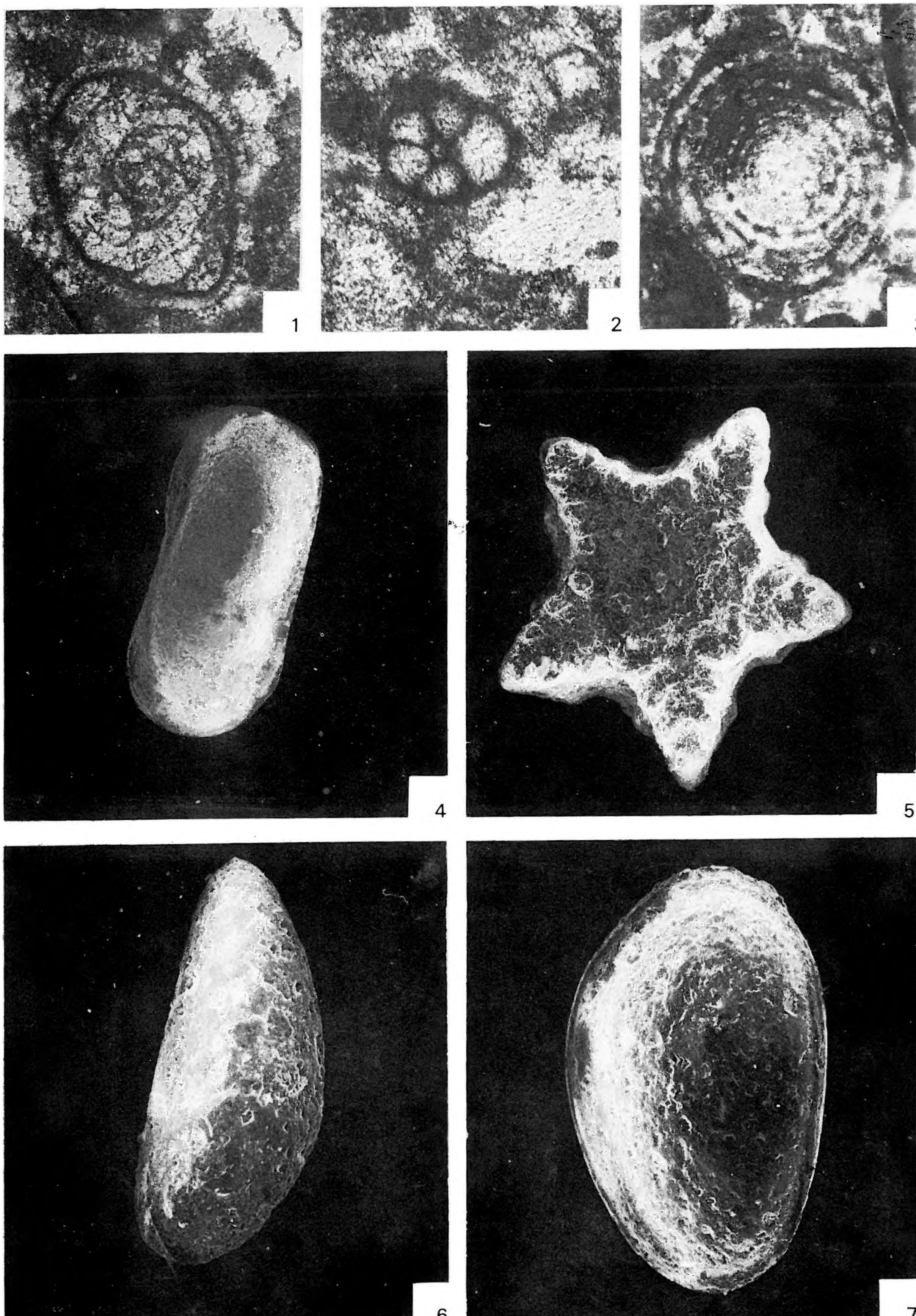
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PLATE VI

Dachstein Limestone Formation

1. Favreina-type coprolite. 68×
   Borehole Süt-27. 14.5 m
2. *Trocholina permodiscoides* PAALZOW? 68×
   Borehole Süt-27. 16.3 m
3. *Triasina hantkeni* MAJZON. 27.5×
   Borehole Süt-27. 9.8 m
4. Alga indet. 27.5×
   Borehole Süt-27. 26.5 m
5. *Frondicularia woodwardi* HOWCH. 27.5×
   Borehole Süt-27. 23.8 m
6. Limestone containing sections of Megalodontidae Mogyorós-domb

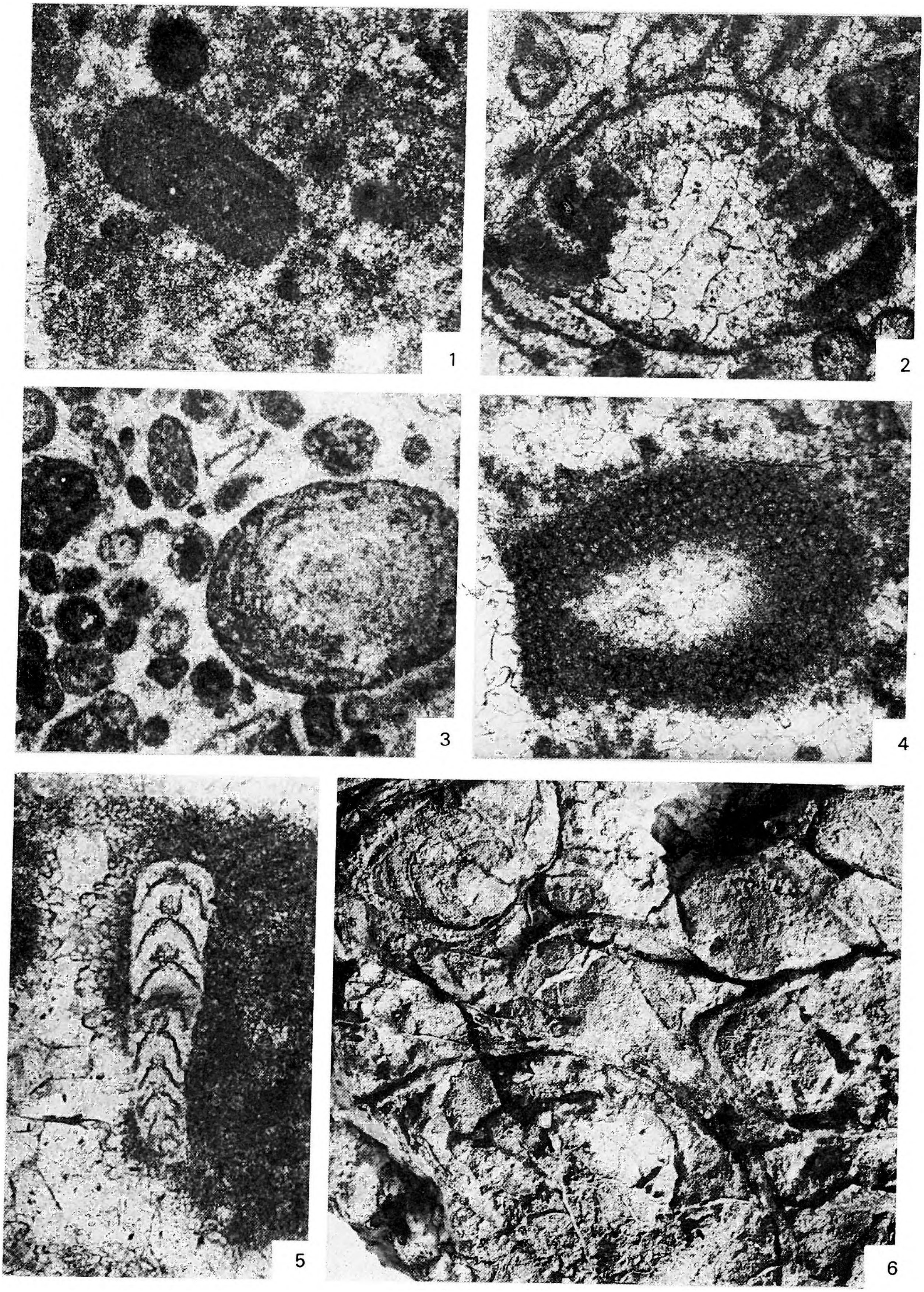
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PLATE VII

Dachstein Limestone Formation

1. Intrabiosparite. 27.5×
   Borehole Süt-28. 191.3 m
2. Biopelsparite. 68×
   Borehole Süt-27. 16.3 m
3. Foraminiferal (Triasina) pelbiosparite. 27.5×
   Borehole Süt-27. 9.8 m
4. Sparite with pseudooöid. 68×
   Borehole Süt-28. 191.3 m
5. Intrapelsparite. 27.5×
   Borehole Süt-28. 191.3 m
6. Pelsparite. 27.5×
   Borehole Süt-27. 7.5 m
7. Pelbiosparite. 27.5×
   Borehole Süt-28. 191.3 m

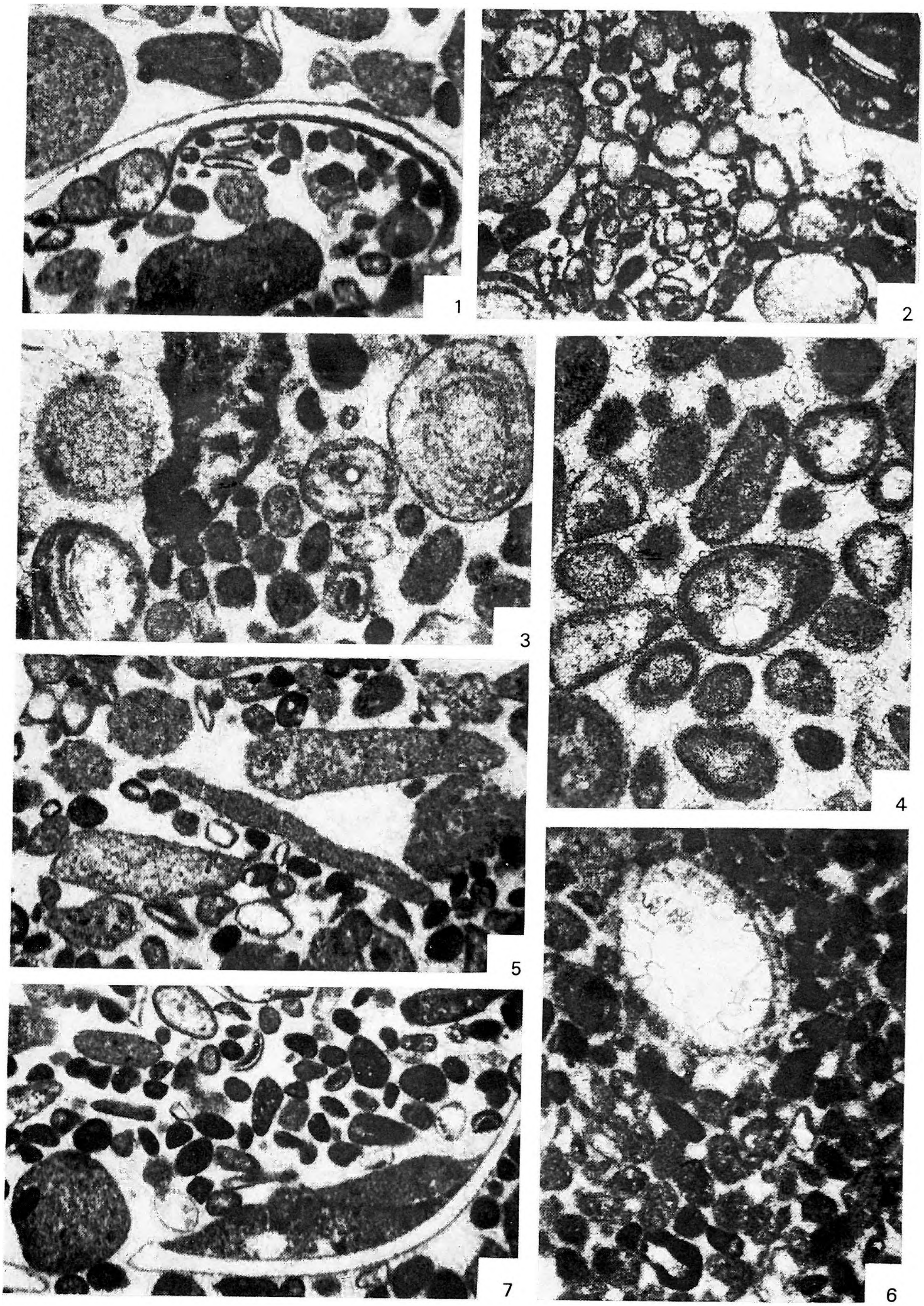
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PLATE VIII

Kardosrét Limestone Formation

1–2. Oncoidal pelsparite. 27.5×
1. Borehole Süt-28. 29.4 m
2. Borehole Süt-28. 47.0 m

3. Oncoid grains with a bioclastic core; note the coating of a gastropod in the grain at bottom right. 27.5×
Borehole Süt-28. 33.5 m

4. *Involutina liassica* as an oncoid core. 68×
Borehole Ck-170. 436.0 m

5. Two-cored, composite oncoid grain. 27.5×
Borehole Süt-28. 33.5 m

6–7. A gastropod coated oncoidally. 27.5×
6. Borehole Süt-28. 34.6 m
7. Borehole Ck-170. 442.0 m

8. A texture composed of sponge spicules. 68×
Borehole Süt-28. 40.7 m

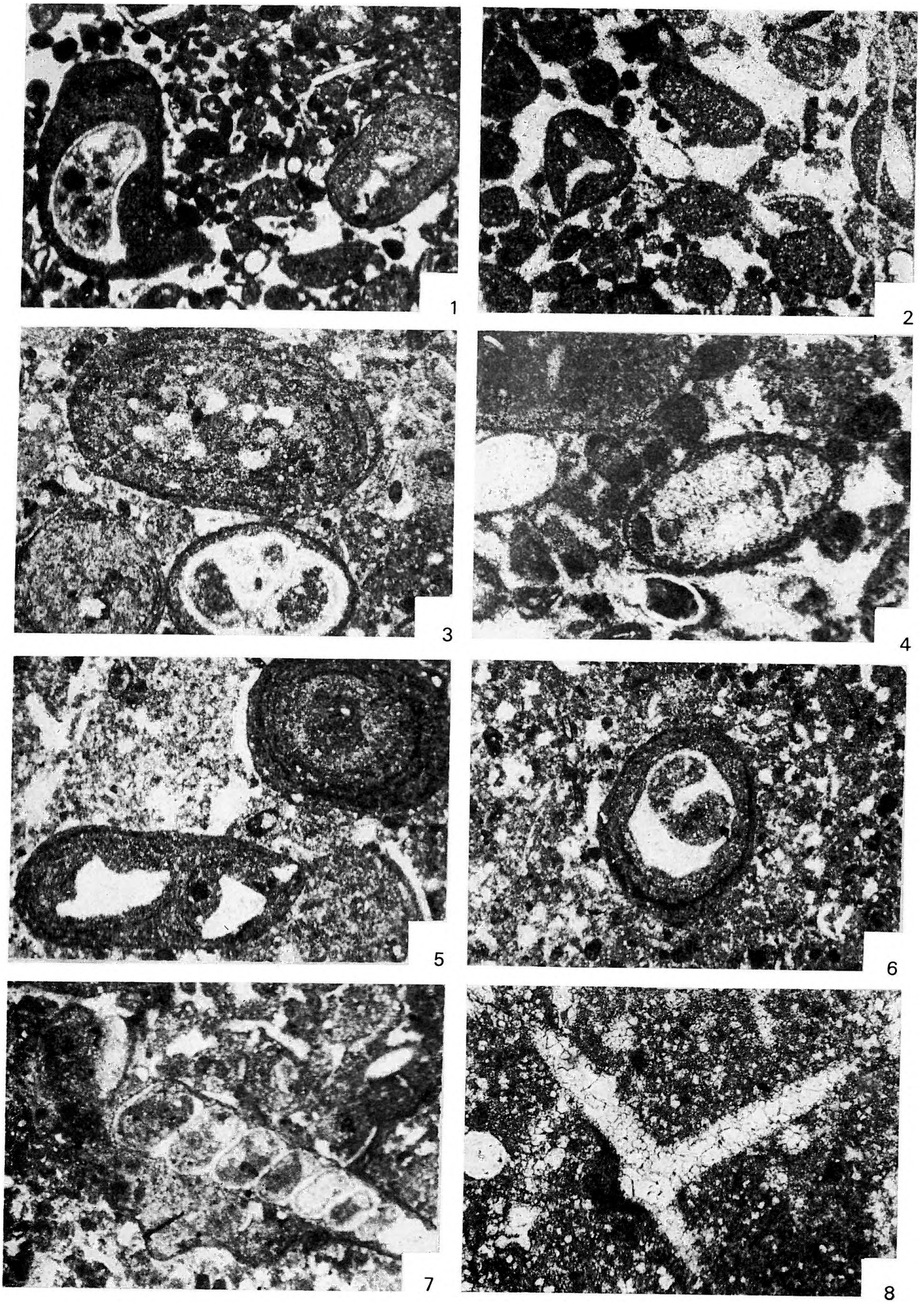
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PLATE IX

Kardosrét Limestone Formation
Partially dolomitized rock types

Borehole Süt-28

1. Pelmicrite with rhombohedral dolomite crystals. 68×
   71.3 m
2. Intrapelmicrite, both the micritic matrix and the intraclast are partially dolomitized. 27.5×
   134.4 m

3—6. Dolomitized pelmicrite
   3. 52.3 m 68×
   4. 40.7 m 68×
   5. 177.3 m 68×
   6. 83.4 m 27.5×

7—8. Biopelmicrite with sponge spicules
   7. 41.8 m 68×
   8. 50.4 m 27.5×

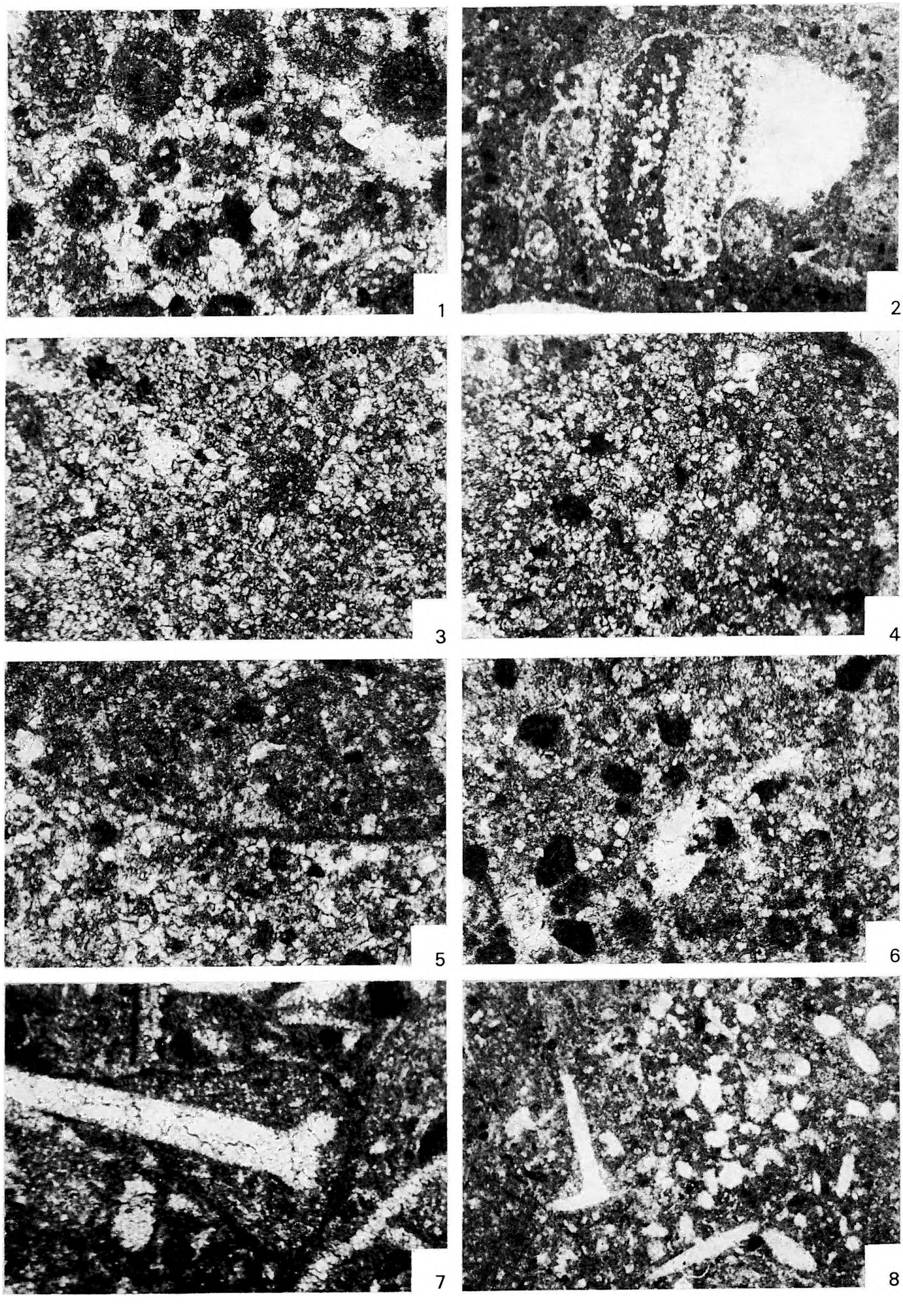
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PLATE X

Structural and microfacies characteristics of the Pisznice Limestone Formation

1. Biomicrite lump with a dissolved margin, coated by iron oxide, in a biomicrite containing a few tiny bioclastic elements. 27.5×
   Borehole Ck-170. 422.0 m
2. Biomicrite benthos with Foraminifera and with detritus of molluscs and crinoids. 27.5×
   Borehole Ck-170. 430.0 m
3. Biomicrite with Foraminifera of Ophthalmidium type or other. 68×
   Borehole Ck-170. 422.0 m
4. Biomicrite with *Involutina liassica* JONES, other benthonic Foraminifera and Ostracoda and Mollusca remains. Note the Fe-oxide-coated biomicrosparite lump of dissolved edge in the upper part of the image. 27.5×
   Borehole Ck-170. 432.1 m

5–7. Peculiar peloctal-lumped structure of the formation, intersected by pelitic bands of darker colour. 1×
Borehole Ck-171. 396–396.3 m

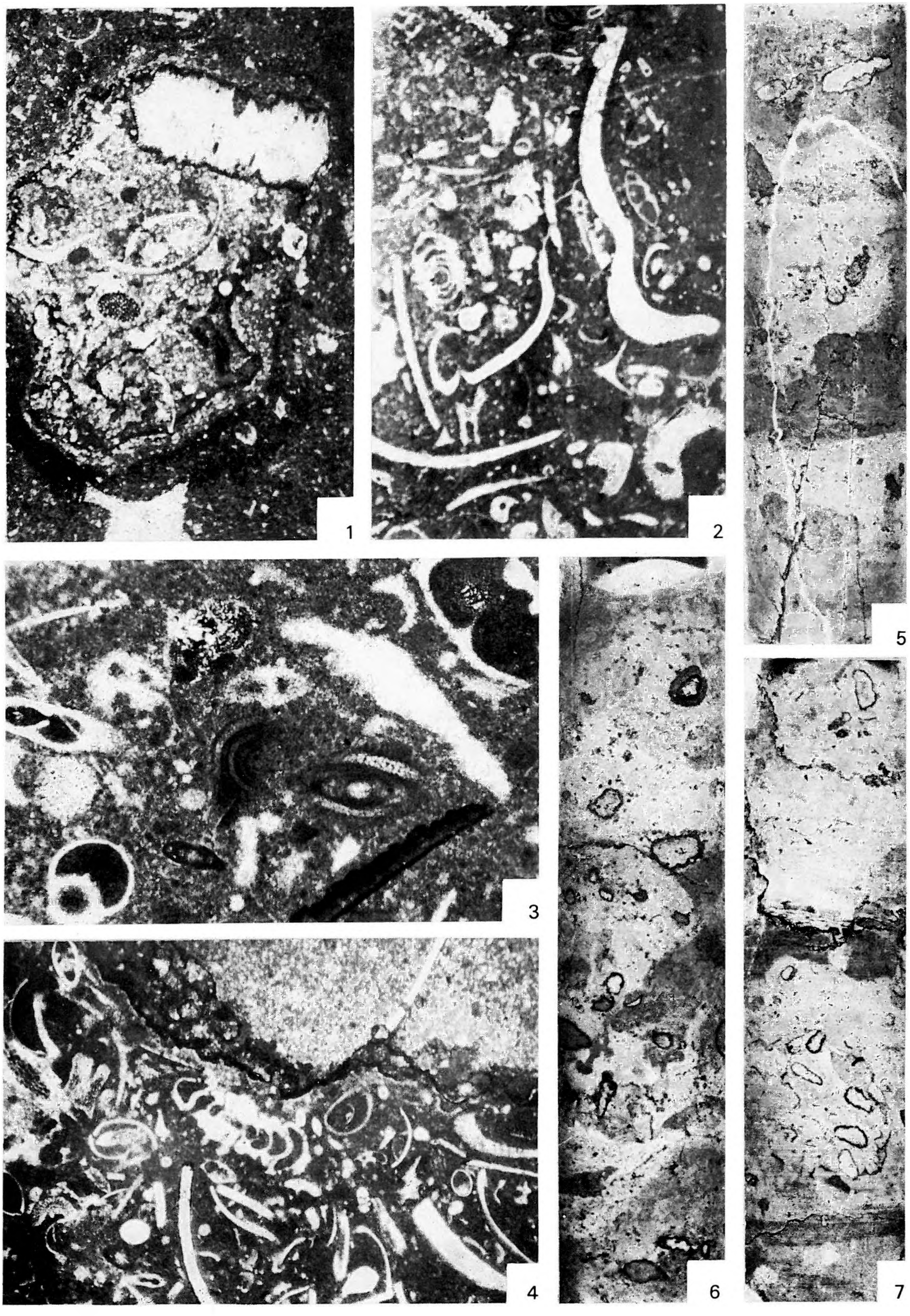
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PLATE XI

Microfacies types of the Hierlatz Limestone Formation

Borehole Süt-23

1. Posidonia biosparite (lumachelle). 6×
   33.5 m
2. Biomicrite with ammonite embryons filled by sporite. 6×
   47.0 m
3. Posidonia-bearing biosparite (lumachelle). 27.5×
   33.5 m
4. Biosparite with ammonite embryons. 6×
   31.0 m
5. Biosparite benthos with Foraminifera and Ostracoda and Crinoidea remains. 27.5×
   37.0 m
6. Biosparite with Ostracoda. 27.5×
   35.5 m
7. Biomicrite with secondarily calcitized Silicospongia spicules. 68×
   47.5 m
8. Biomicrite. 27.5×
   47.5 m

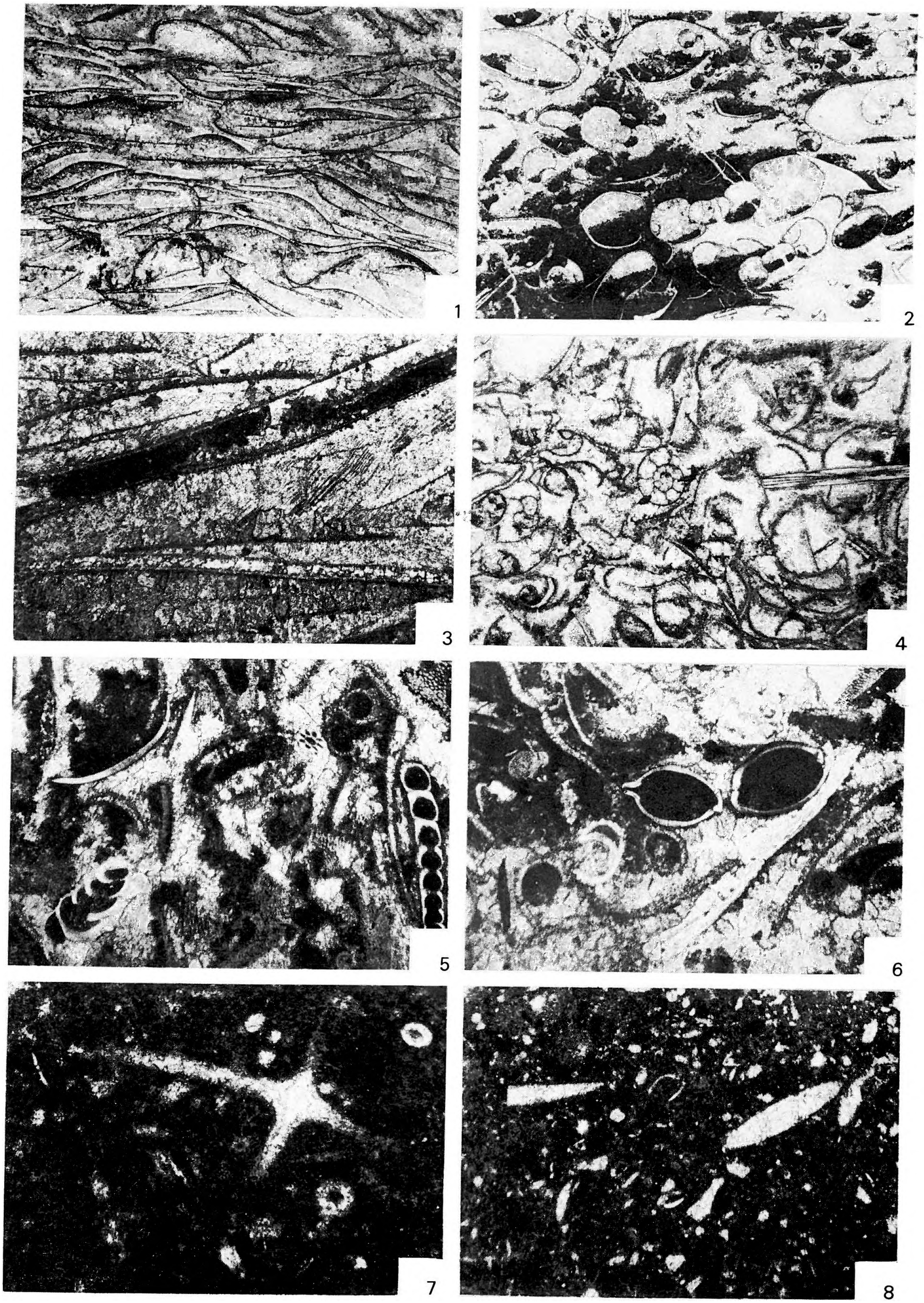
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PLATE XII

Types of Jurassic fissure fills on the Mogyorós-domb

1. Red calcareous marl fissure-fill with lighter-shaded breccia from an older fissure-fill generation
2. Light grey microcristalline limestone fissure-fill with bioclastic bands parallel to the fissure walls
3. Fissure system filled in several phases by sediment materials of different type

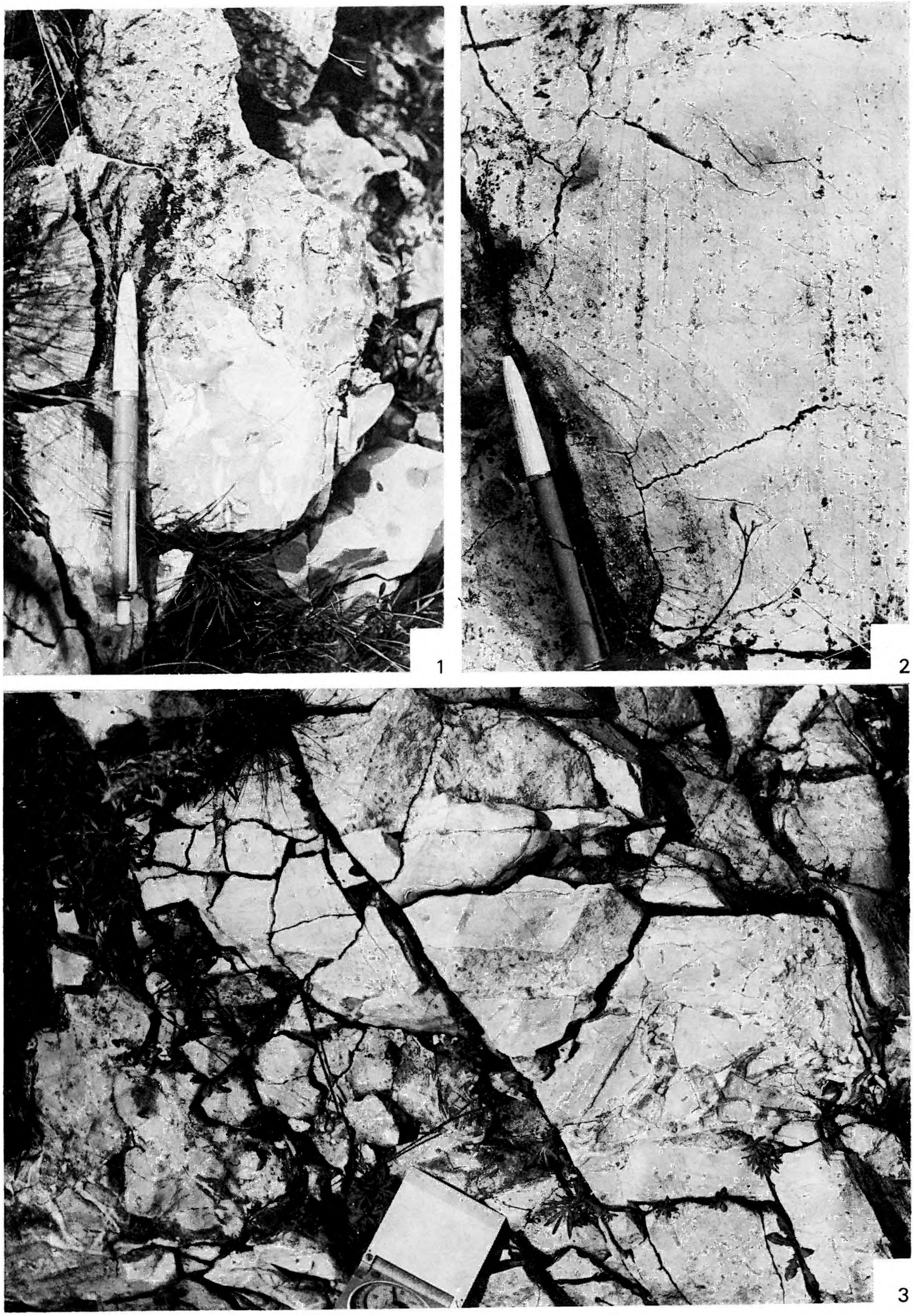
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PLATE XIII

Texture types and microfossils of Liassic fissure-fills

1. Biopelmicrite, *Trocholina granosa*. 68×
   Mogyorós-domb
2. Biomicrite with representatives of Trocholina, Crinoidea and Ostracoda. 27.5×
   Mogyorós-domb
3. Biomicrite with *Involutina liassica* JONES as well as with remains of Crinoidea, Ostracoda and Mollusca. 27.5×
   Mogyorós-domb
4. Biopelmicrite with remains of Trocholina, Crinoidea, Ostracoda and Mollusca. 27.5×
   Borehole Süt-28. 23.8 m
5. Foraminiferal biointrapelmicrite *Involutina turgida* KRISTAN. 27.5×
   Borehole Süt-28. 23.8 m
6. Biomicrite with Spongia spicules. 27.5×
   Borehole Süt-28. 15.6 m
7. Biomicrite with lumps coated by Fe—Mn oxide. 27.5×
   Mogyorós-domb

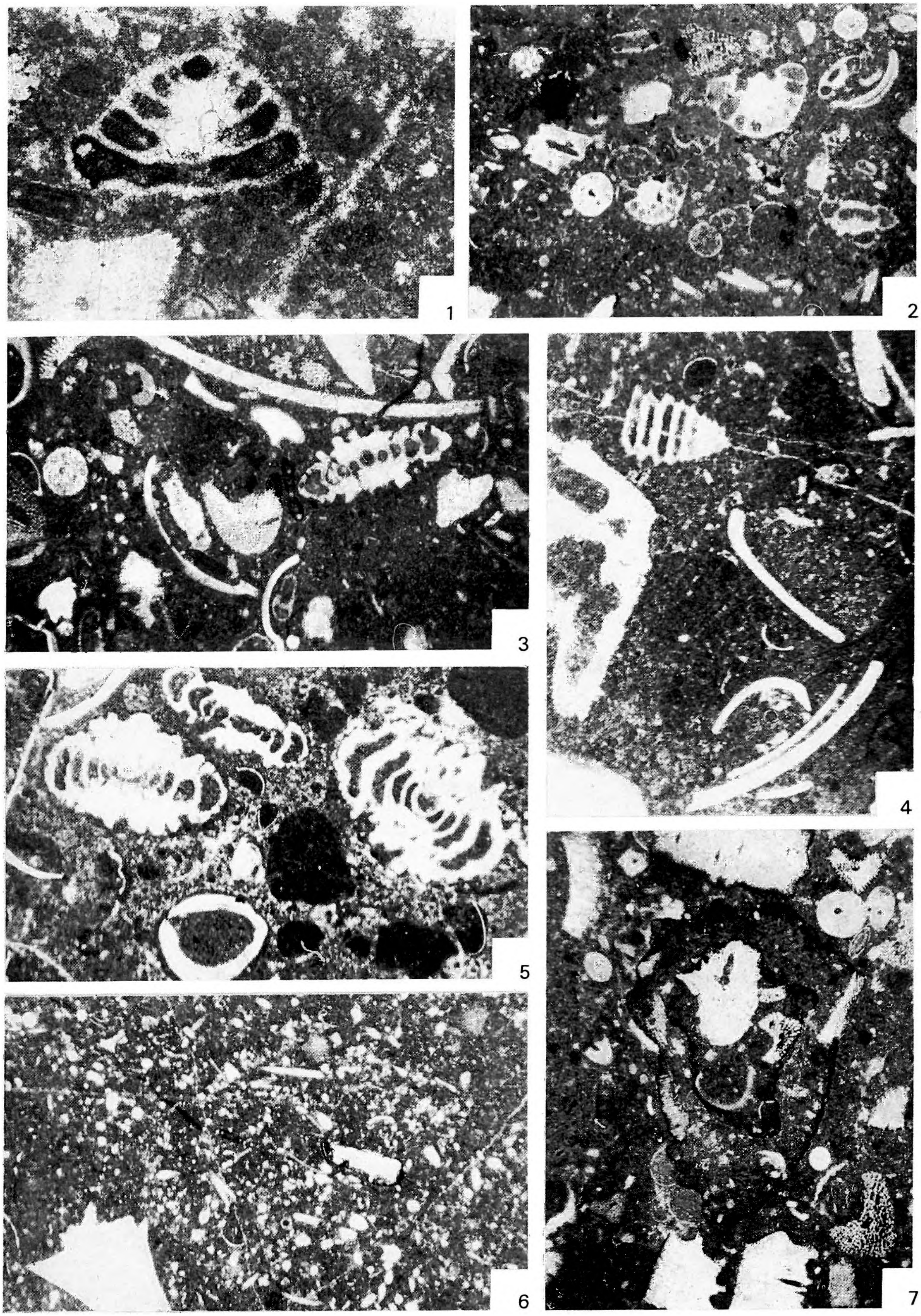

PLATE XIV

Fissure-fills

1. Crinoidal limestone fissure-fill in the northern part of the Mogyorós-domb
2. Polygeneticaly brecciated and sparry fissure-fill. 27.5×
   Borehole Süt-27. 64.5 m
3. Detritus of the enclosing rock in a microsparite fissure-fill material. 27.5×
   Borehole Süt-27. 64.5 m
4. Thin red micrite fissure-fill with detritus of the enclosing rock. 27.5×
   Borehole Süt-27. 88.5 m
5. Polygenetically brecciated fissure-fill. 27.5×
   Borehole Süt-27. 32.0 m
6. Several generations of sparite, microsparite and red micrite as fissure-fill. 27.5×
   Borehole Süt-27. 63.5 m
7. Crinoidea ossicle disintegrated by fissure; the fissure is filled by a micrite-microsparite containing small bioclasts. 27.5×
   Southwest part of the Mogyorós-domb
8. Polygenetically brecciated coarse sparite and biomicrite and micrite as fissure-fill. 27.5×
   Borehole Süt-27. 63.5 m

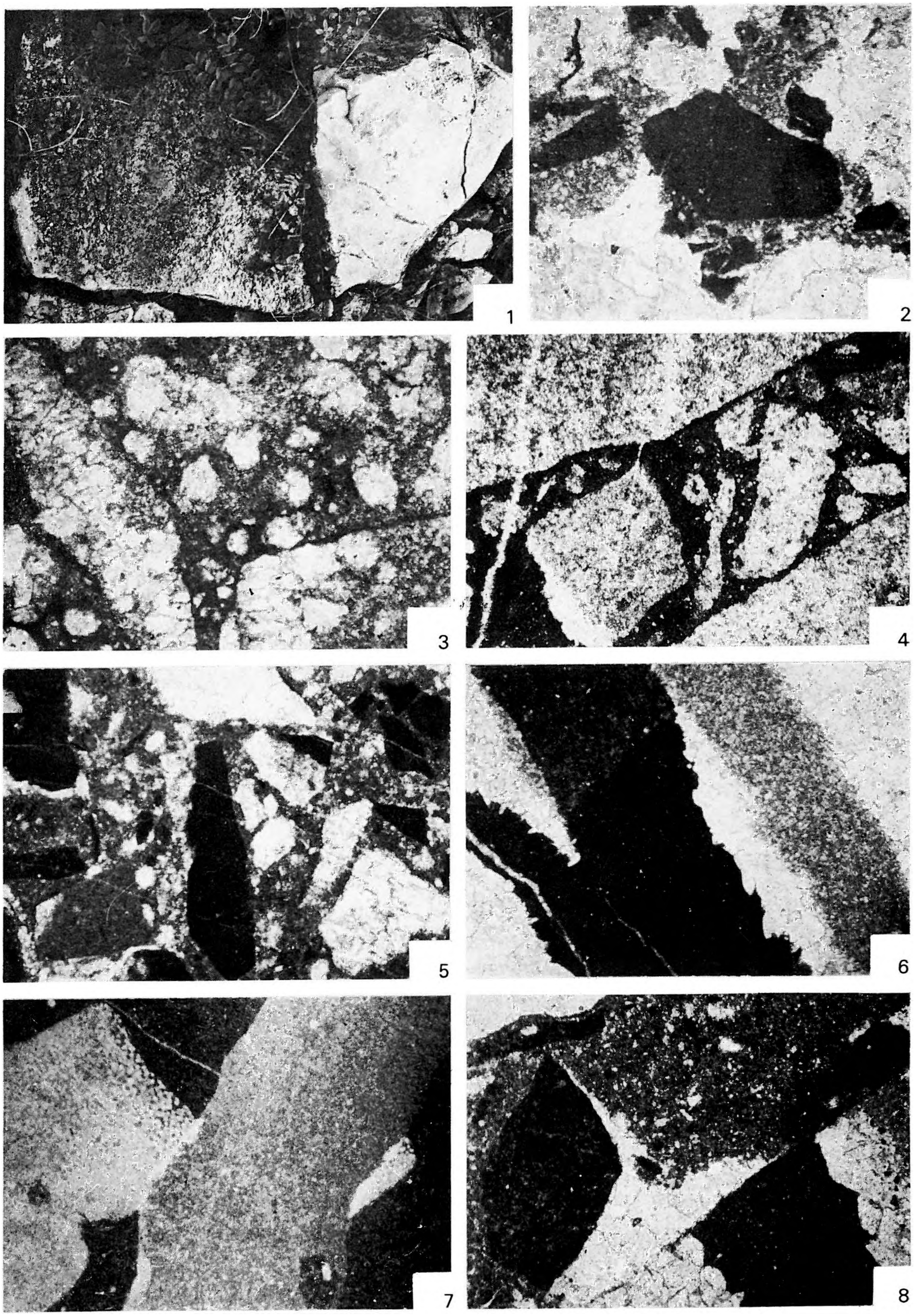
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PLATE XV

Extraclasts observable in the particular horizons of the Eplény Limestone Formation

Borehole Süt-26

1. Carbonate and silicified extraclasts and radiolarian calcareous marl intraclasts in a radiolarian micrite matrix: the extraclast in the upper part of the picture derives from a rock of shallow-water platform origin with oöid to pseudooöid grains. 23×
   98.5—98.6 m
2. Silicified extraclast in a radiolarian micrite matrix; note the rock detritus of oöidic, bioclastic shallow-water platform origin in the upper part of the picture. 23×
   98.5—98.6 m
3. Radiolarian micrite with extraclasts. 23×
   98.5—98.6 m


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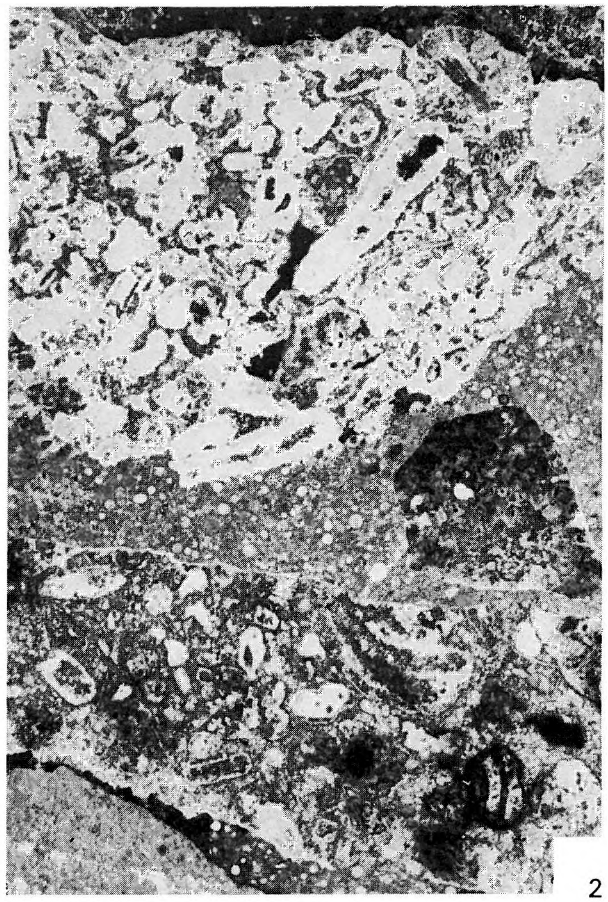
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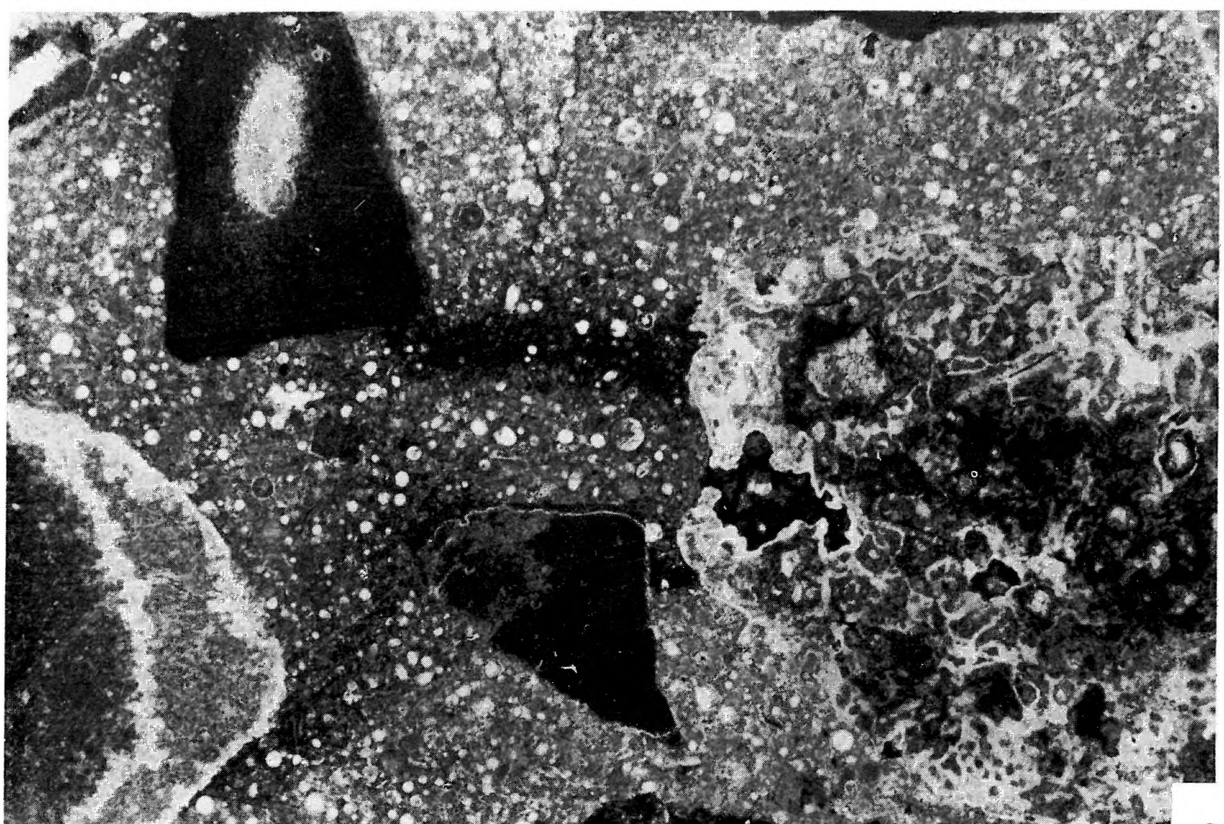
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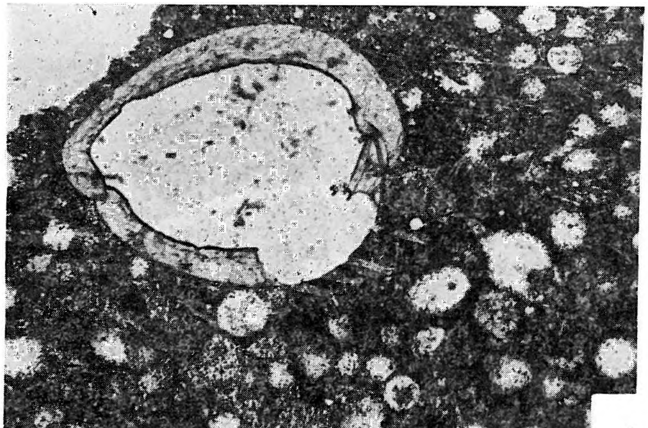
PLATE XVI

Eplény Limestone Formation and Lókút Radiolarite Formation

1. Radiolarian biomicrite with silica-filled ostracodal remain. 68×
   Borehole Süt-26. 43.4 m
2. Radiolaria with traces of the inner structure of shell. 170×
   Borehole Süt-26. 67.0 m
3. Radiolarian biomicrite with extraclasts. 23×
   Borehole Süt-26. 105.5 m
4. Strata composed of chert laminae separated by thin clay films
   Profile II on the Mogyorós-domb
5. Benthonic foraminiferal remain in radiolarite. 68×
   Borehole Süt-26. 93.0 m



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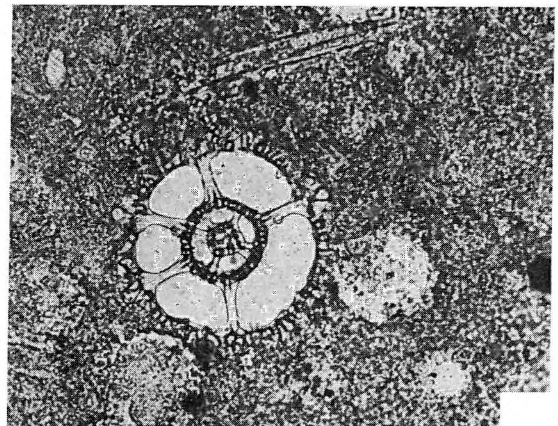

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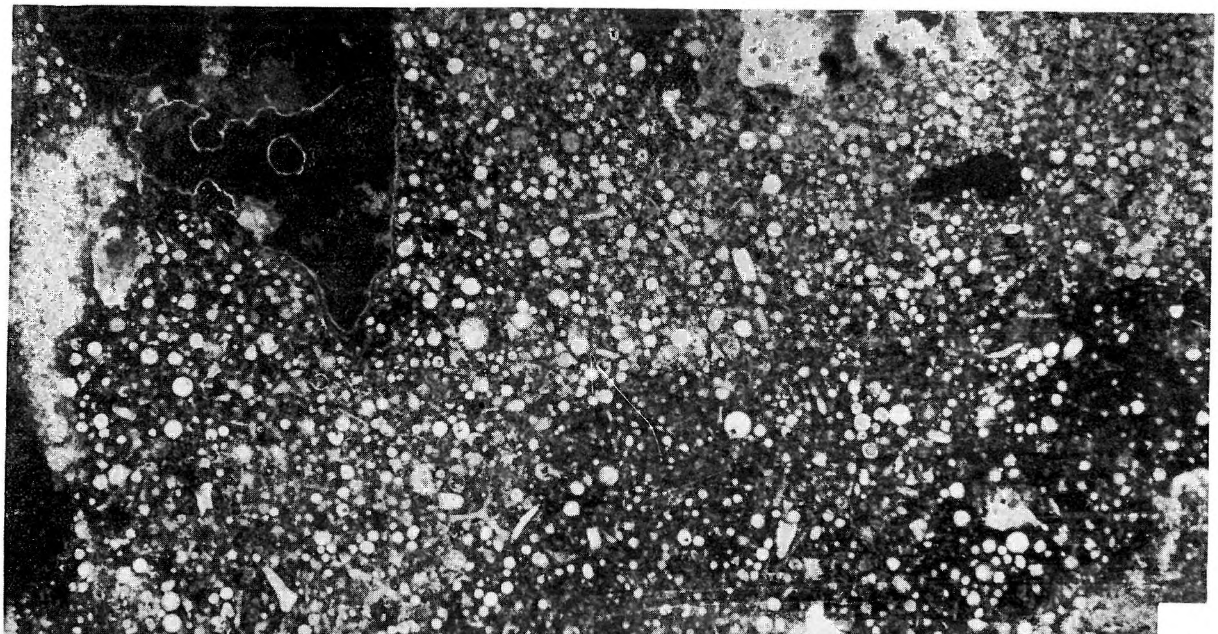

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PLATE XVII

The Pálihálás Limestone Formation in Profile Mogyorós-domb II

1. Limestone of medium thickness intersected by rough bedding surfaces
2. Thin-bedded, nodular, argillaceous limestone

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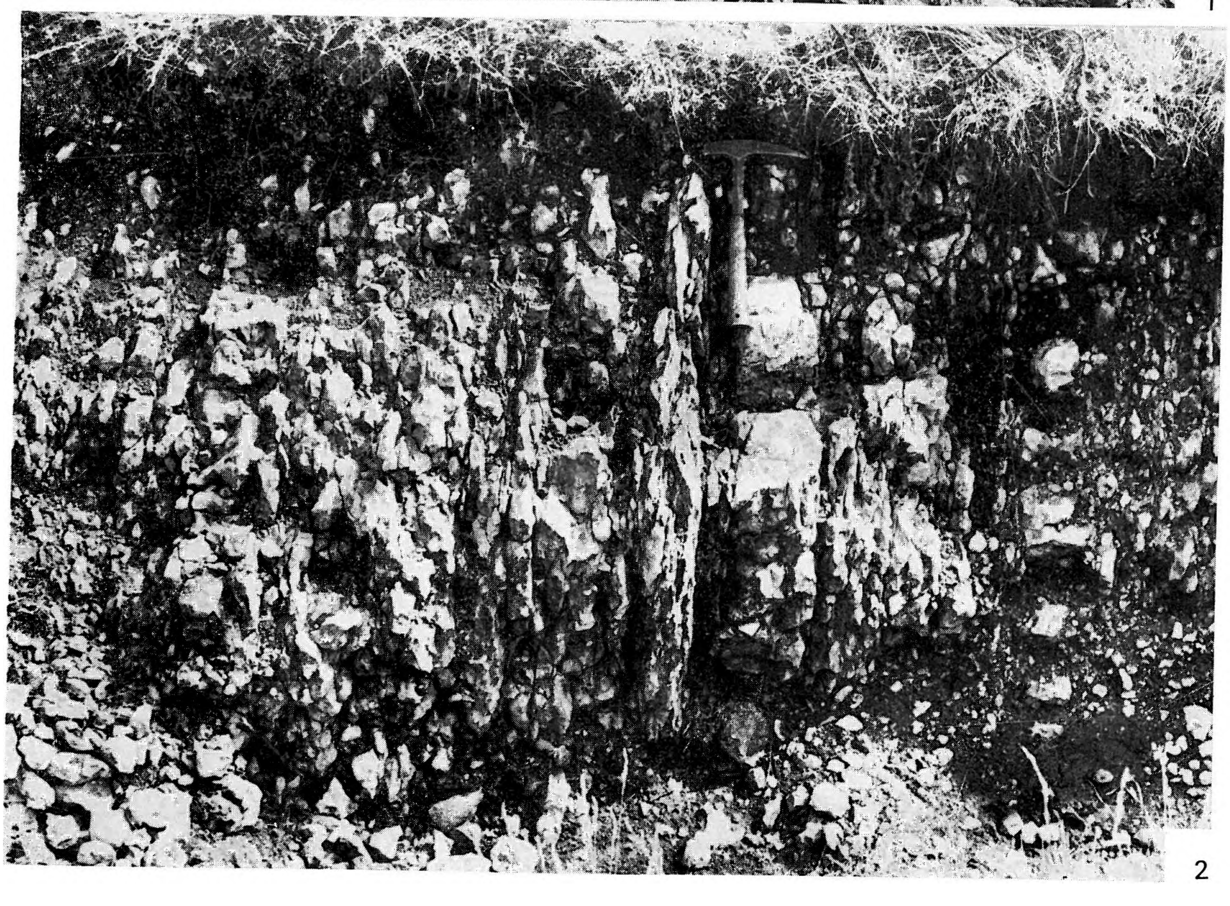

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PLATE XVIII

Microfacies types of the Pálihálás Limestone Formation

1. Lombardia-bearing biomicrite to bioclastite. 43×
   Borehole Süt-17. 406.0 m
2. Biomicrite with Foraminifera and Ostracoda remains. 43×
   Borehole Süt-17. 410.6 m
3. Intraclastic texture. 43×
   Borehole Süt-17. 410.6 m
4. Benthonic Foraminifera, *Cadosina parvula*, in a biomicrite matrix. 86×
   Borehole Süt-17. 408.3 m
5. Section of crinoid ossicle. 43×
   Profile Sümeg II
6. The same. +N 43×

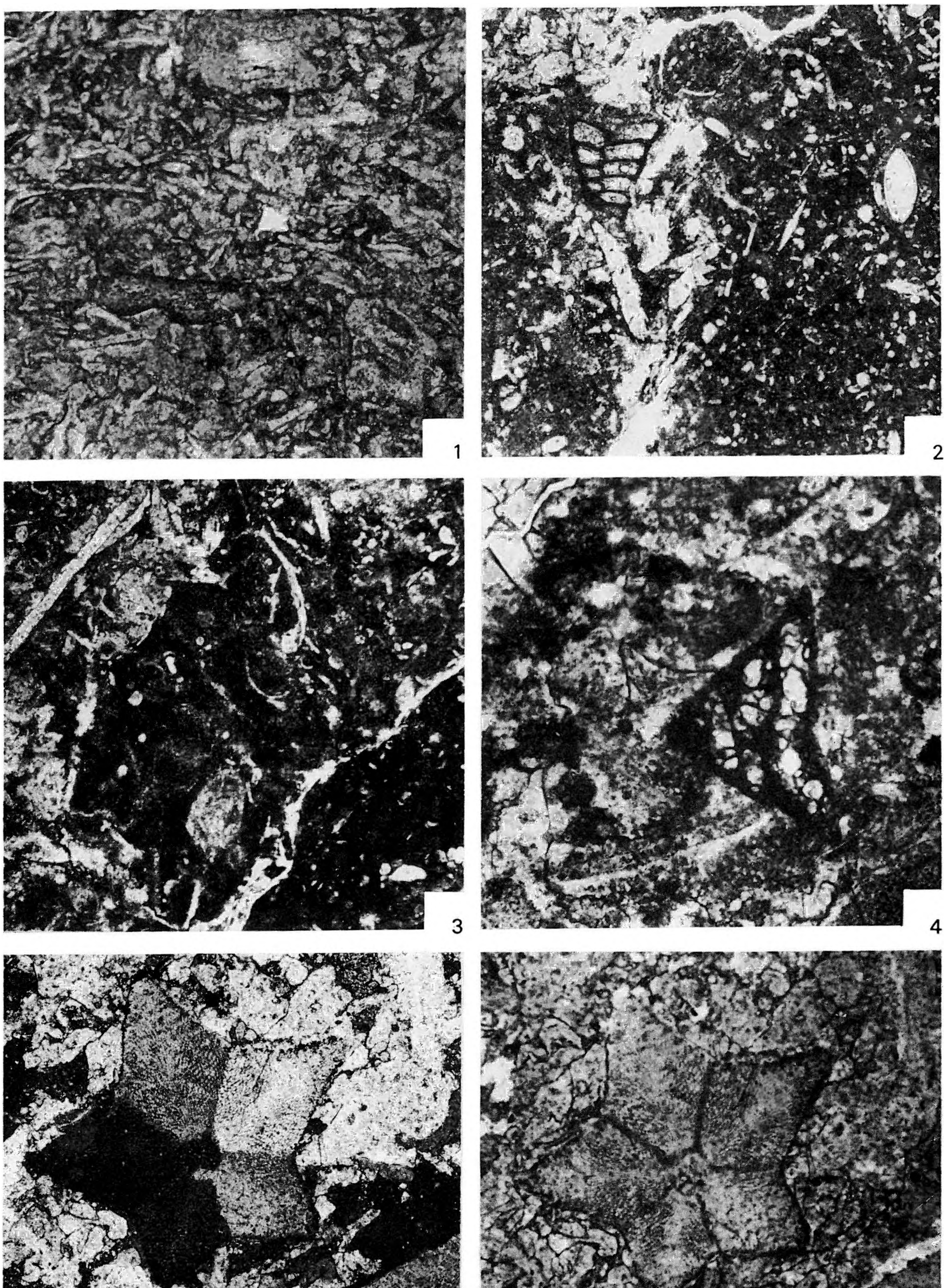
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PLATE XIX

Microfacies types and characteristic fossils of the Pálihálás Limestone Formation

1. *Globochaete alpina*. 545×
   Profile Sümeg II, Bed 46
2. The same. +N. 545×
3. Stomiosphaera. 426×
   Borehole Süt-17. 405.4 m
4. Lombardia fragments, *Cadosina parvula*, Radiolaria biomicrite. 66×
   Profile Sümeg II, Bed 32
5. Lombardia–Globochaete biomicrite, *Cadosina parvula*. 43×
   Profile Sümeg II, Bed 38
6. Biomicrite, Ammonite embryon, Brachiopoda, Lombardia, Aptychus. 43×
   Profile Sümeg II, Bed 38
7. Biomicrite with ammonite embryons. 43×
   Profile Sümeg II, Bed 38

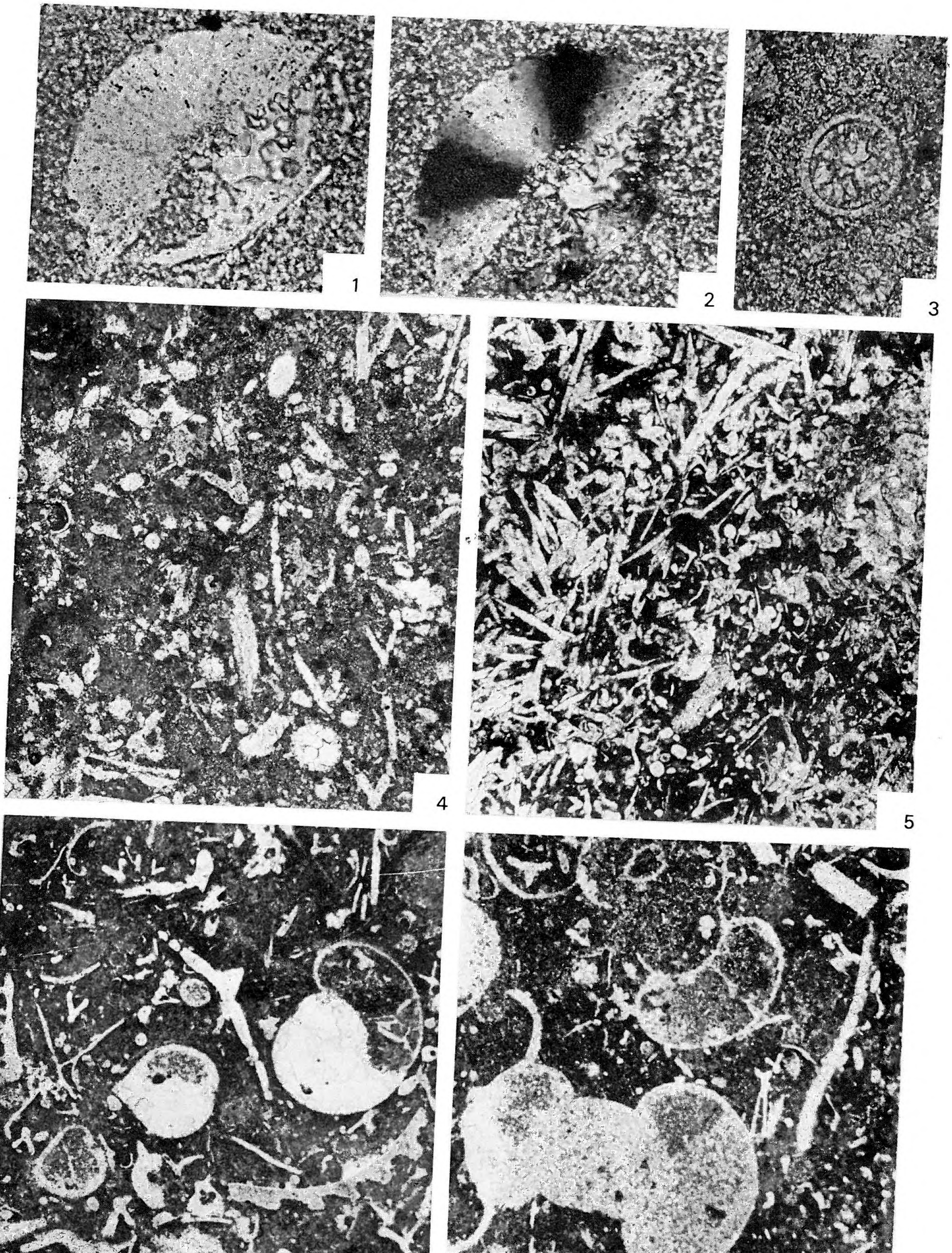
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PLATE XX

Middle to Upper Tithonian zonal index fossils and associated forms

1. *Haploceras (Neolissoceras?) verruciferum* (Menegh.) J. 10 210. — Verruciferum Zone
2. *Richterella richteri* (Opp.) J. 9840. — Richteri Zone
3. *Simoceras (Simoceras) admirandum* Zitt. J. 9808. — Admirandum—Biruncinatum Zone
4. *Simoceras (Simolytoceras?) biruncinatum* (Qu.) J. 9792. — Admirandum—Biruncinatum Zone
5. *Burckhardticeras peroni* (Rom.) s. l. J. 9822. — Burckhardticeras Zone
6. *Burckhardticeras peroni* (Rom.) J. 9836. — Burckhardticeras Zone
7. *Himalayites (Micracanthoceras) microcanthus* (Opp.) J. 9801. — Microcanthus Zone
8. *Durangites vulgaris* Burckh. J. 9812. — Durangites Zone
9. *Pseudhimalayites steinmanni* (Haupt.) J. 9819. — Verruciferum Zone
10. *Ptychophylloceras semisulcatum* (d'Orb.) J. 10 198. Specimen with peristomal border. — Verruciferum Zone

N = 1 ×

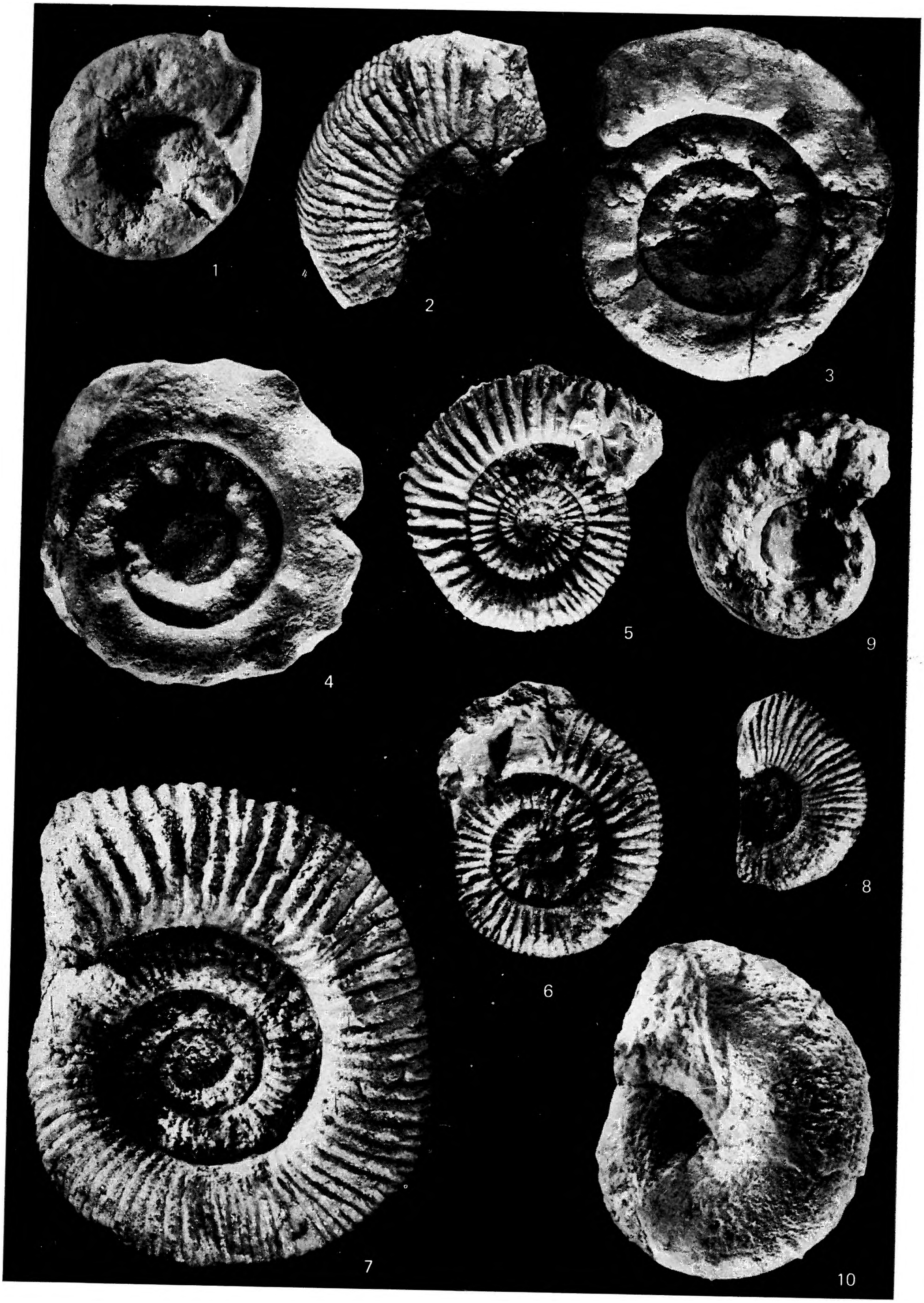
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PLATE XXI

Microfacies types and characteristic microfossils of the Mogyorós-domb Limestone Formation

1. Tintinnina–Globochaete biomicrite. 54×
   Profile Sümeg II, Bed 51
2. Lombardia–Tintinnina biomicrite. 54×
   Profile Sümeg II, Bed 49
3. *Calpionella alpina* LORENCZ. 545×
   Profile Sümeg II, Bed 52
4. Radiolaria–Calpionella biomicrite. 86×
   Borehole Süt-17, 395.2 m
5. *Crassicolaria parvula* REMANE. 545×
   Borehole Süt-17. 401.2 m
6. Holothuroidea sclerite. 218×
   Borehole Süt-17. 393.7 m

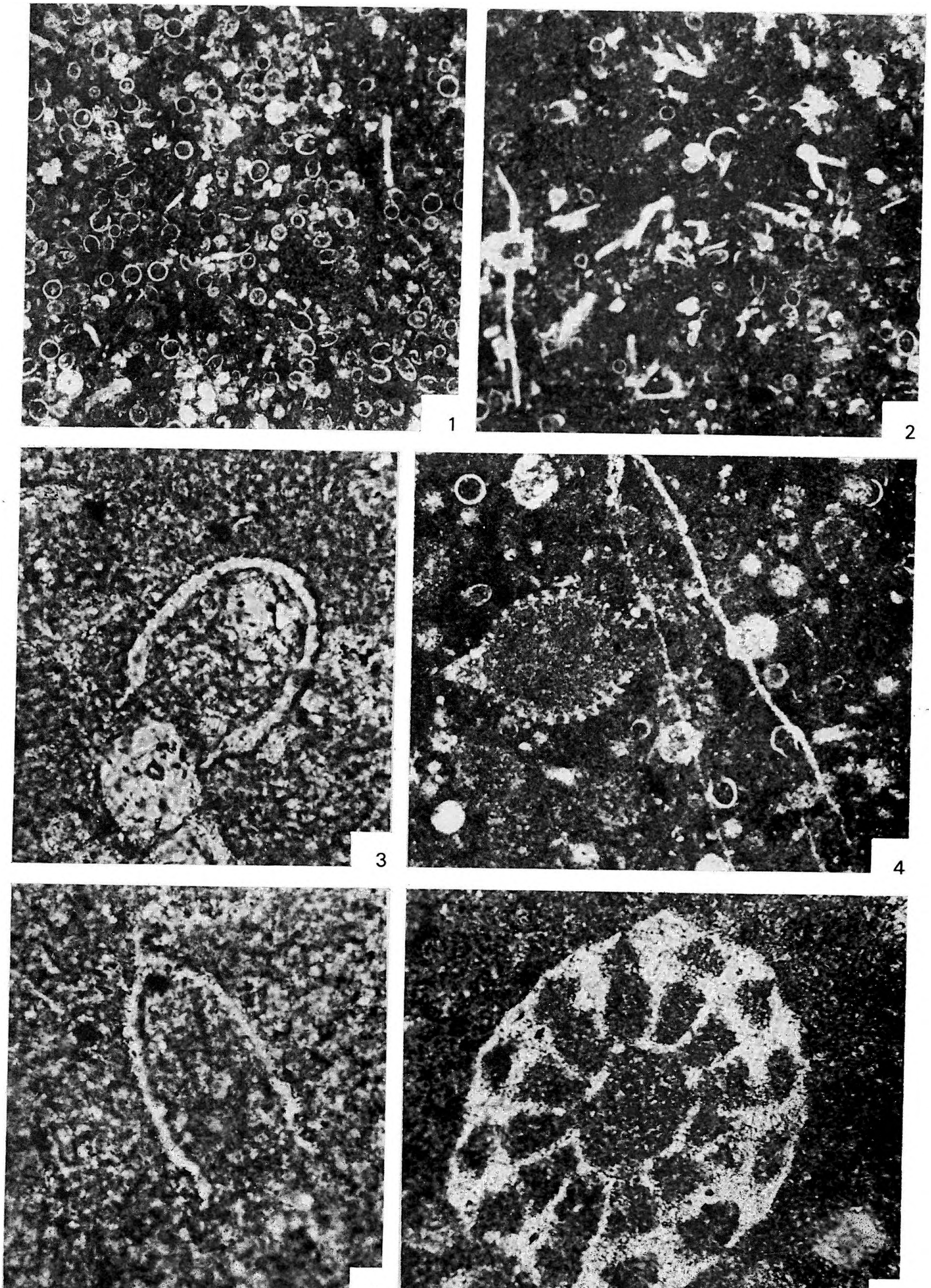
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PLATE XXII

Mogyorósdomb Limestone Formation

Profile Mogyorósdomb I, geological conservation area

1–2. Thin-bedded limestone with chert lenses and laminae (top view)

3. Beds of steep dip of the Mogyorósdomb Limestone in the wall of a prehistoric flint mine

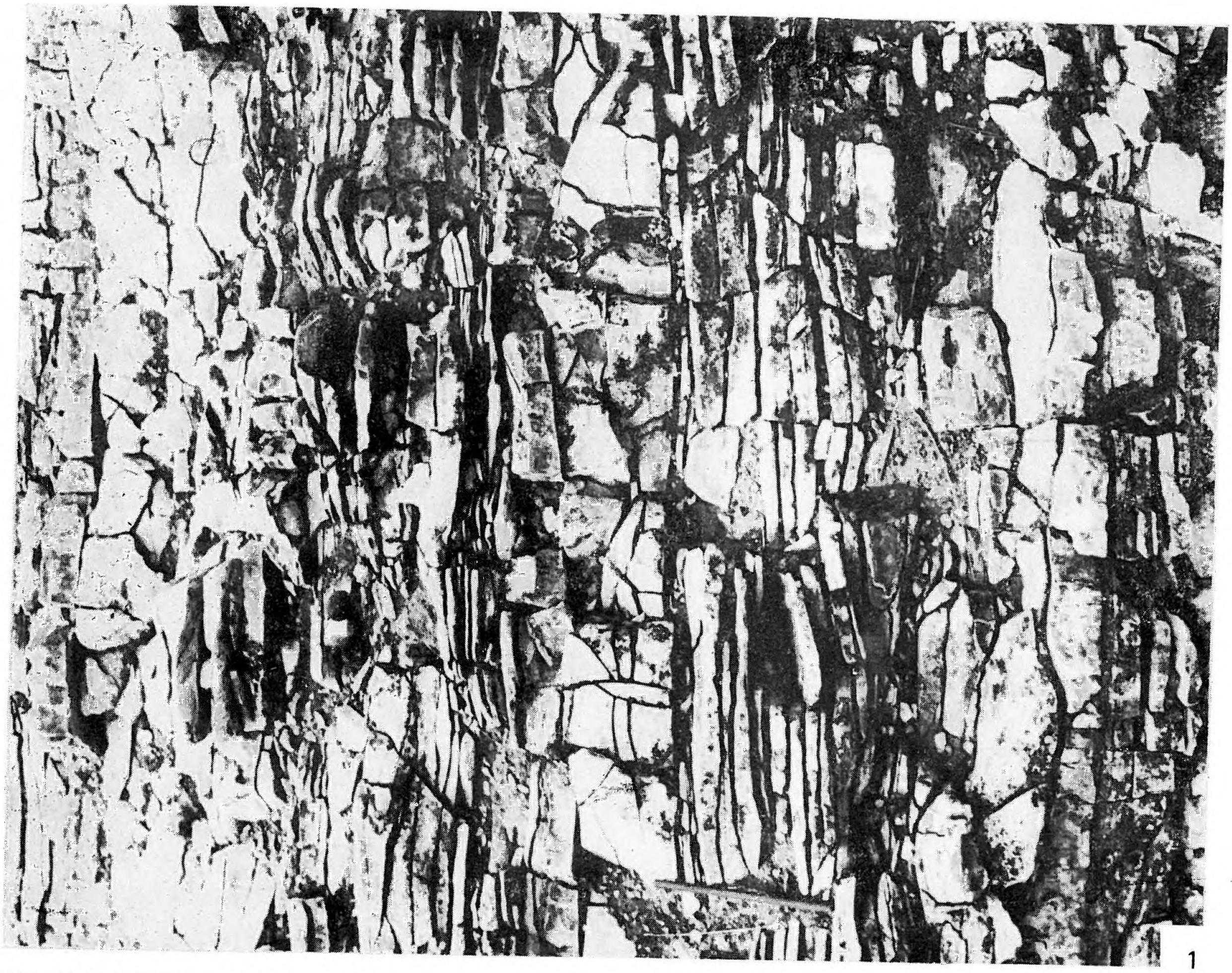

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PLATE XXIII

Mogyorósdomb Limestone Formation

1. *Calpionella elliptica.* 218×
   Profile Mogyorós-domb I. 110.5 m
2. *Calpionellites darderi.* 218×
   Profile Mogyorós-domb I. 181.5 m
3. *Calpionellopsis oblonga.* 218×
   Profile Mogyorós-domb I. 181.5 m
4. *Calpionella alpina.* 317×
   Profile Mogyorós-domb I. 101.0 m
5. Nannoconus-patterned rock texture *(Nannoconus steinmanni).* 545×
   Profile Mogyorós-domb I. 181.5 m
6. *Lenticulina* sp. 218×
   Borehole Süt-17. 374.2 m
7. *Spiroplectammina* sp. in a radiolarian biomicrite texture. 86×
   Borehole Süt-17. 380.2 m

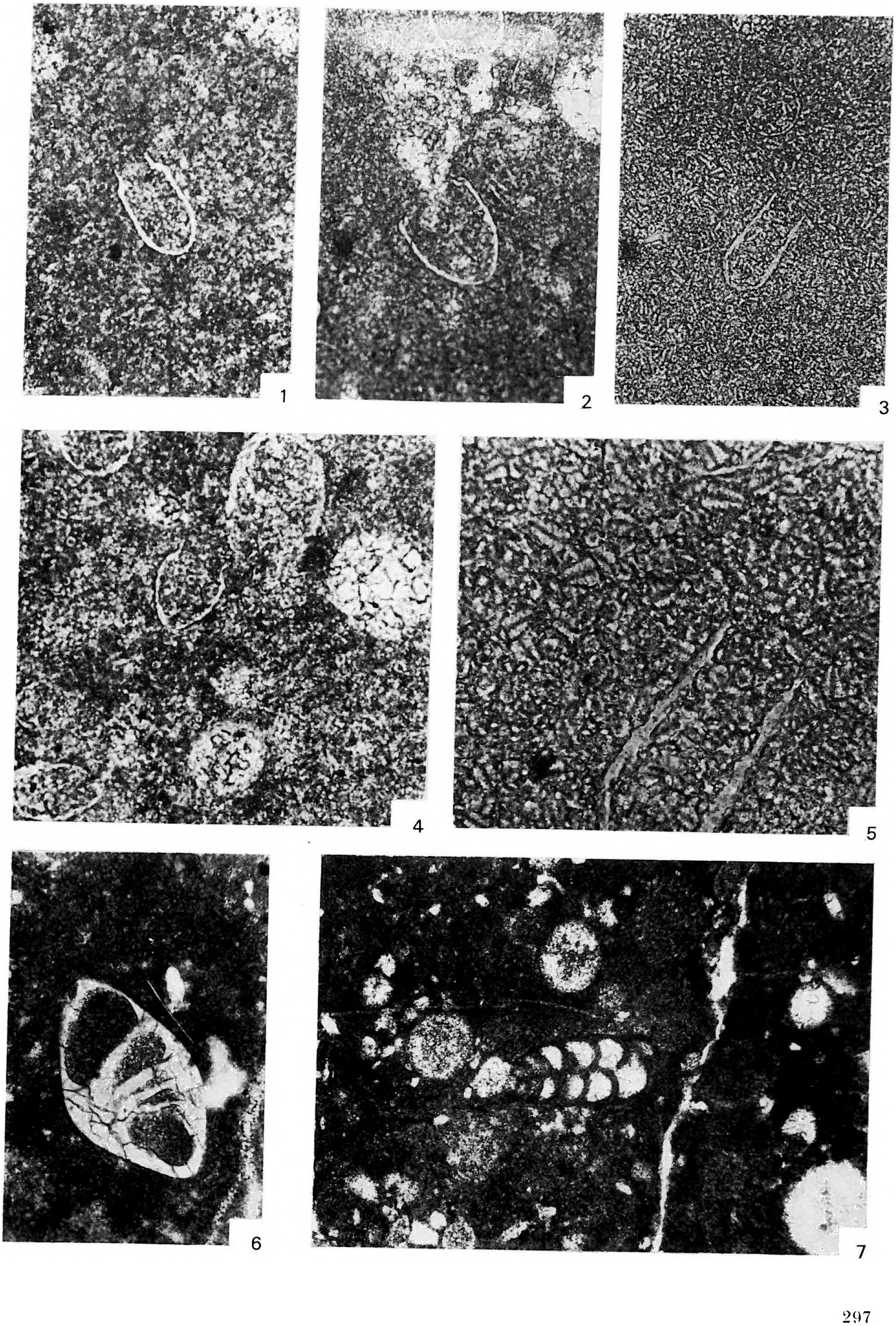
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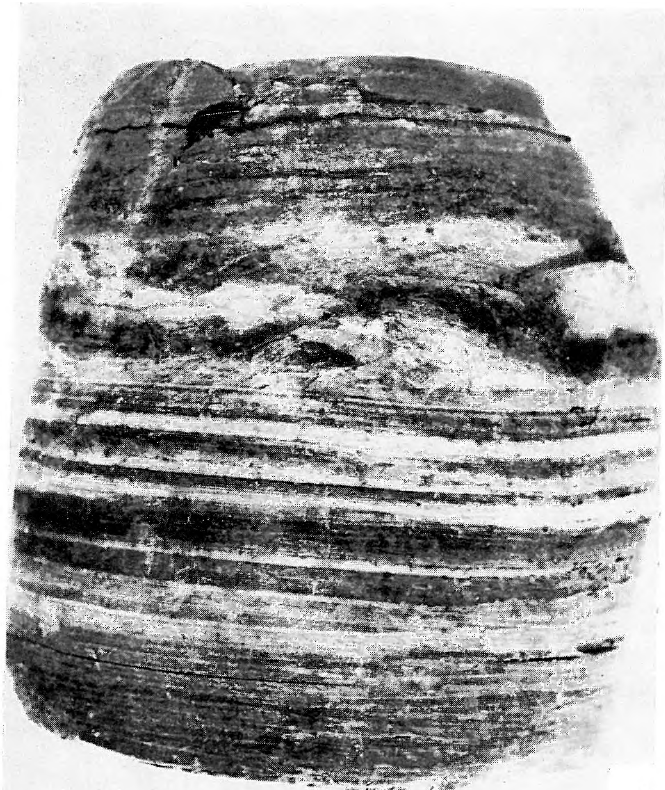
PLATE XXIV

Sümeg Marl Formation

Borehole Süt-17

1. Peculiar microbanded marl facies observed in the lower part of the siltstone member of the formation. 1×
   296.1–296.2 m
2. *Parahoplites* cfr. *browae* (Uhl.). 1×
   297.4 m
3. *Leptoceras parvulum* Uhl. 1×
   263.6 m
4. *Pseudohaploceras liptoviense* (Zeuschn.). 1×
   252.1 m
5. *Barremites difficilis* (d'Orb.). 1×
   370.0 m



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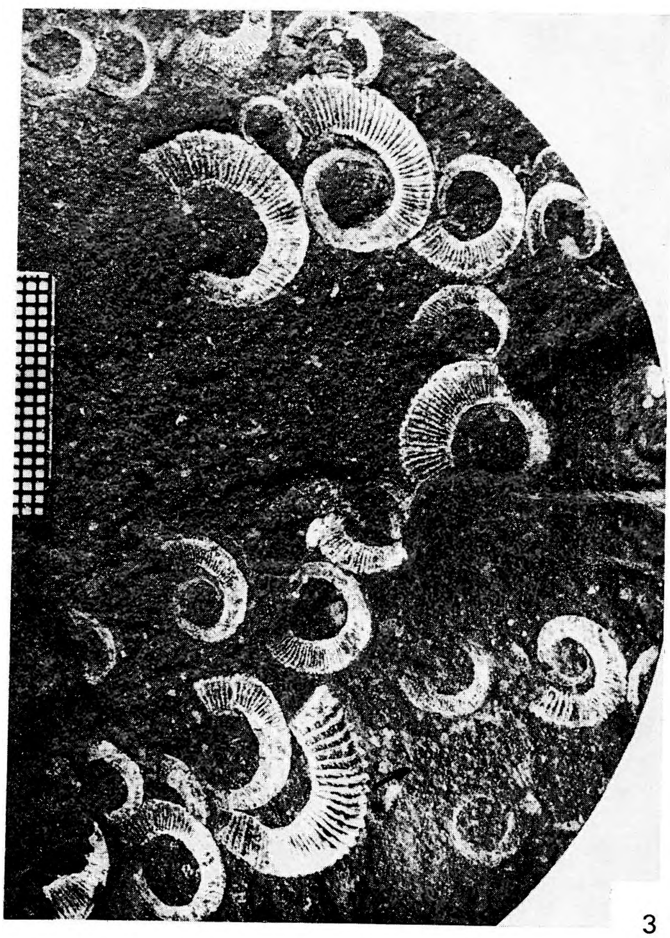

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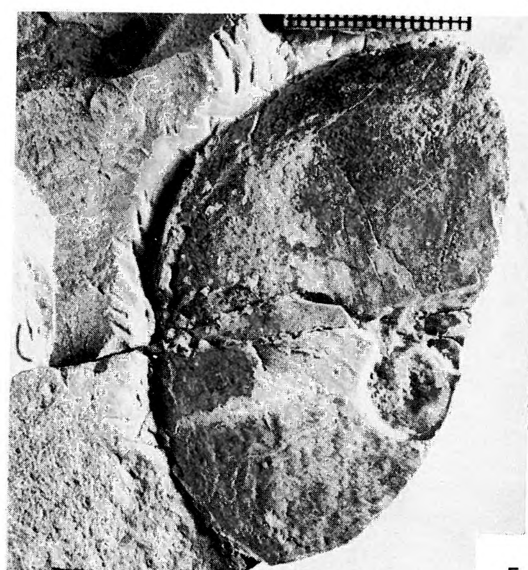

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PLATE XXV

Tata Limestone Formation

1. Cross-bedded texture lenticularly pinching out
   Inner part of the Sümeg Castle
2. Chert lenses in the crinoidal limestone dissected by lithoclases
   Northern slope of the Vár-hegy

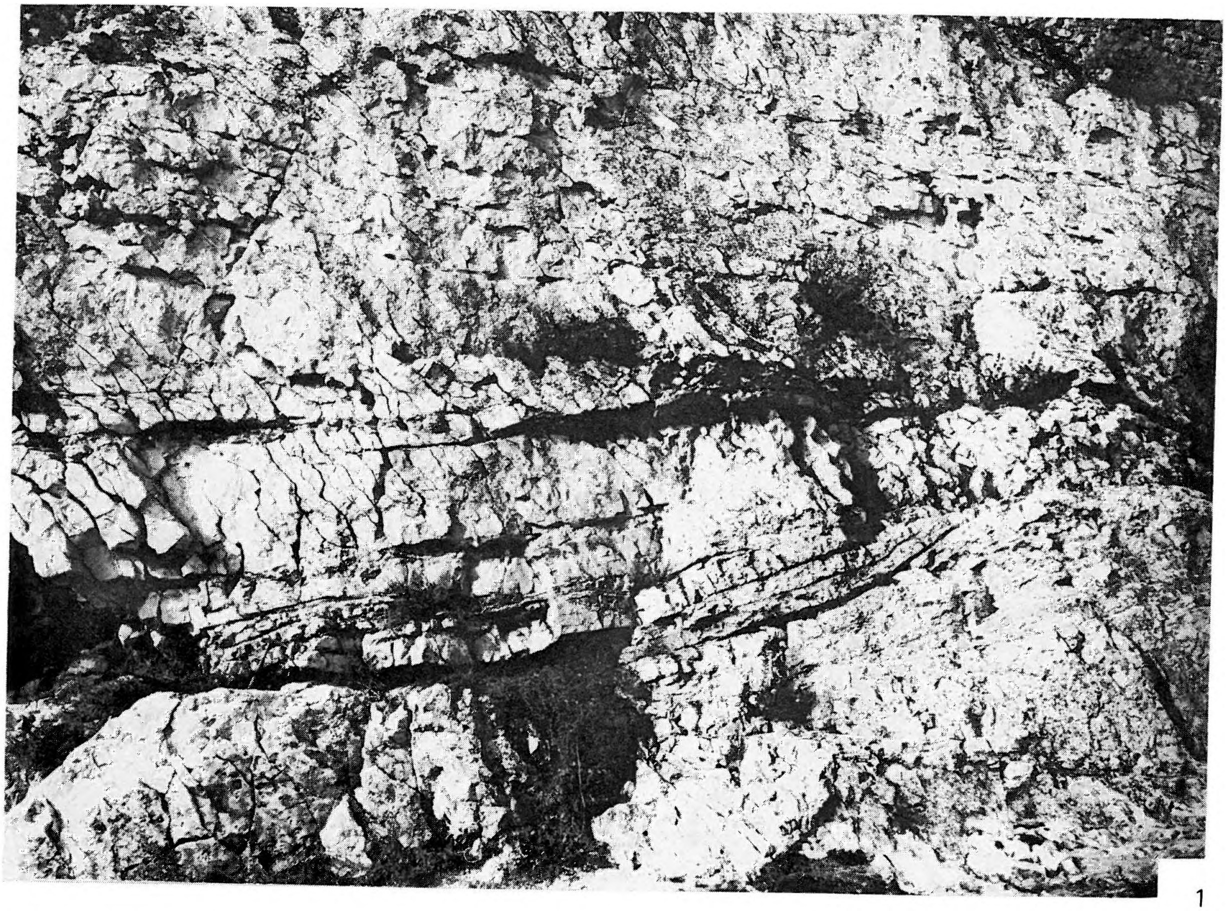
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PLATE XXVI

Tata Limestone Formation

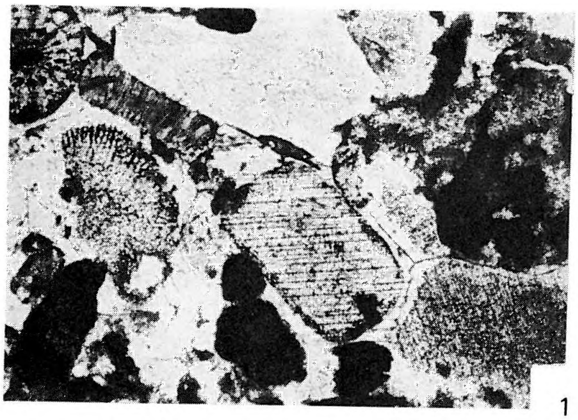
1–3., 7. Well-rounded biosparite
- 1. Borehole Süt-17. 23.5 m. 30×
- 2. Borehole Süt-17. 19.5 m. 30×
- 3. Borehole Süt-17. 9.0 m. 74×
- 7. Köves-domb, Sintérlap quarry, Bed 1. 74×

4. Green alga in biosparite. 30×
Köves-domb, Sintérlap quarry, Bed 12

5. Well-rounded biosparite with a rim of continued growth. 74×
Köves-domb, Sintérlap quarry, Bed 47

6. Mollusc shell fragment. 74×
Köves-domb. Sintérlap quarry, Bed 1

8. Biosparite. 74×
Köves-domb, Sintérlap quarry, Bed 1



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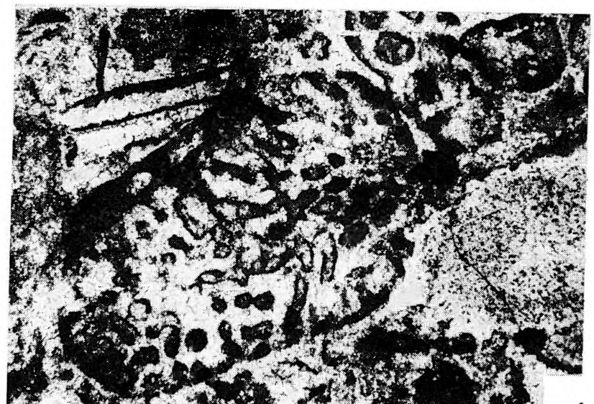

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PLATE XXVII

Tata Limestone Formation

Textural and microfacies features

1. Crinoidal biomicrite with remains of Bryozoa and Foraminifera. 30×
   Köves-domb, Sintérlap quarry, Bed 22
2. Crinoidal biomicrite with sections of Textularia, *Nezzezata* sp.? 30×
   Köves-domb, Sintérlap quarry, Bed 62
3. Foraminiferal biomicrite, *Globigerinelloides* cf. *algerianus* TEN DAM, *Glomospira* sp. 74×
   Köved-domb, Sintérlap quarry, Bed 47
4. Bryozoa. 74×
   Köves-domb, Sintérlap quarry, Bed 12
5. Biosparite with sections of corals and fragments of Glomospirella. 74×
   Köves-domb, Sintérlap quarry, Bed 1
6. Crinoidal biomicrite with *Globigerinelloides algerianus* in the middle. 15×
   Borehole Süt-17, 84.5 m
7. Detritus of red alga. 74×
   Köves-domb, Sintérlap quarry, Bed 1
8. Biosparite Marssonella (Dorothia). 74×
   Köves-domb, Sintérlap quarry, Bed 16

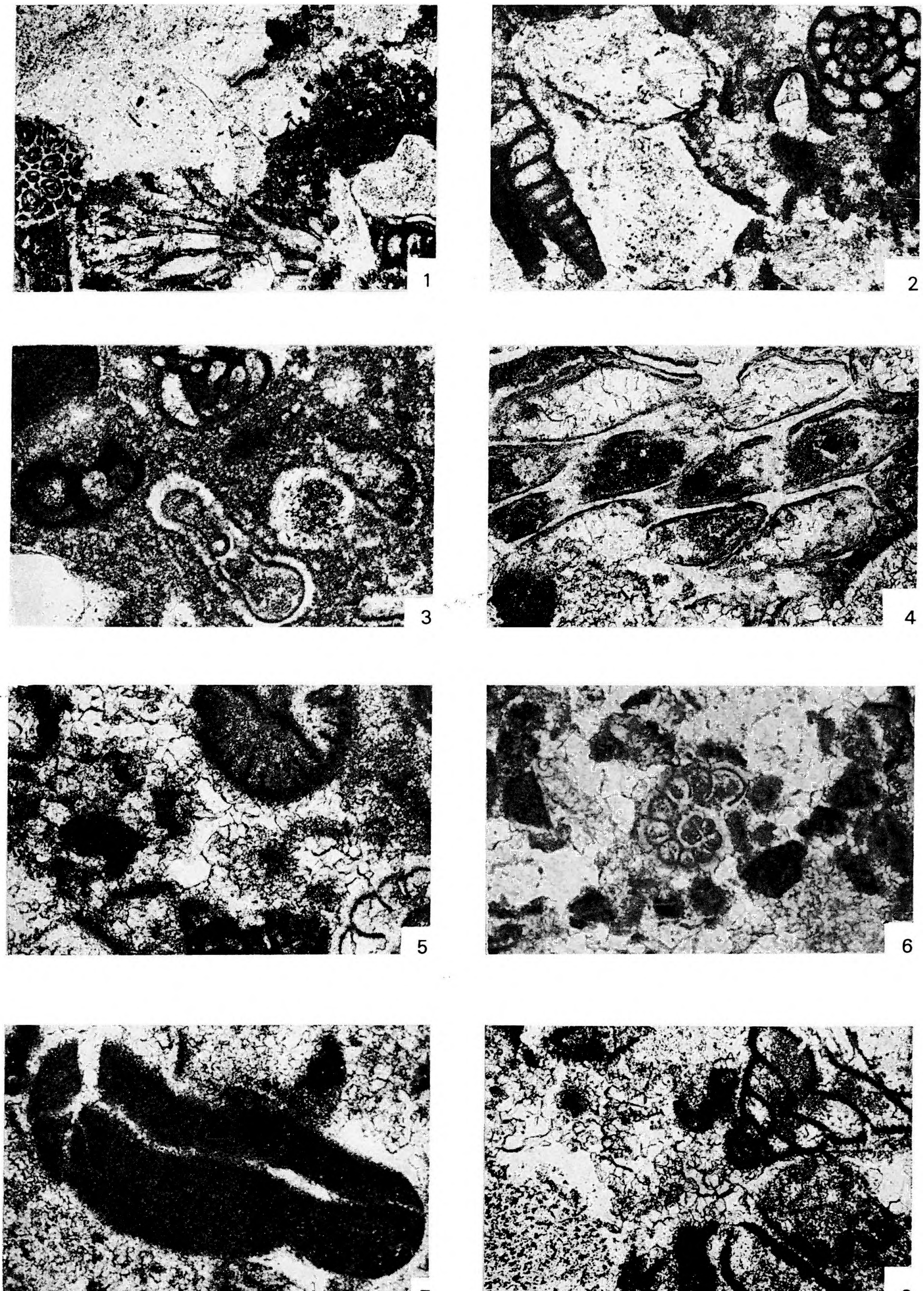
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PLATE XXVIII

Tata Limestone Formation

1. Plicated beds of the Tata Limestone on the western side of the Sintérlap quarry of Köves-domb
2. Kimmeridgian extraclast with Lombardia in Aptian crinoidal limestone. 74×
   Sintérlap quarry, Bed 10
3. *Orbitolina* sp. 85×
   Sintérlap quarry, Bed 23
4. Calpionella-bearing extraclast. 53×
   Sintérlap quarry, Bed 16
5. *Orbitolina* sp. 84×
   Sintérlap quarry, Bed 16

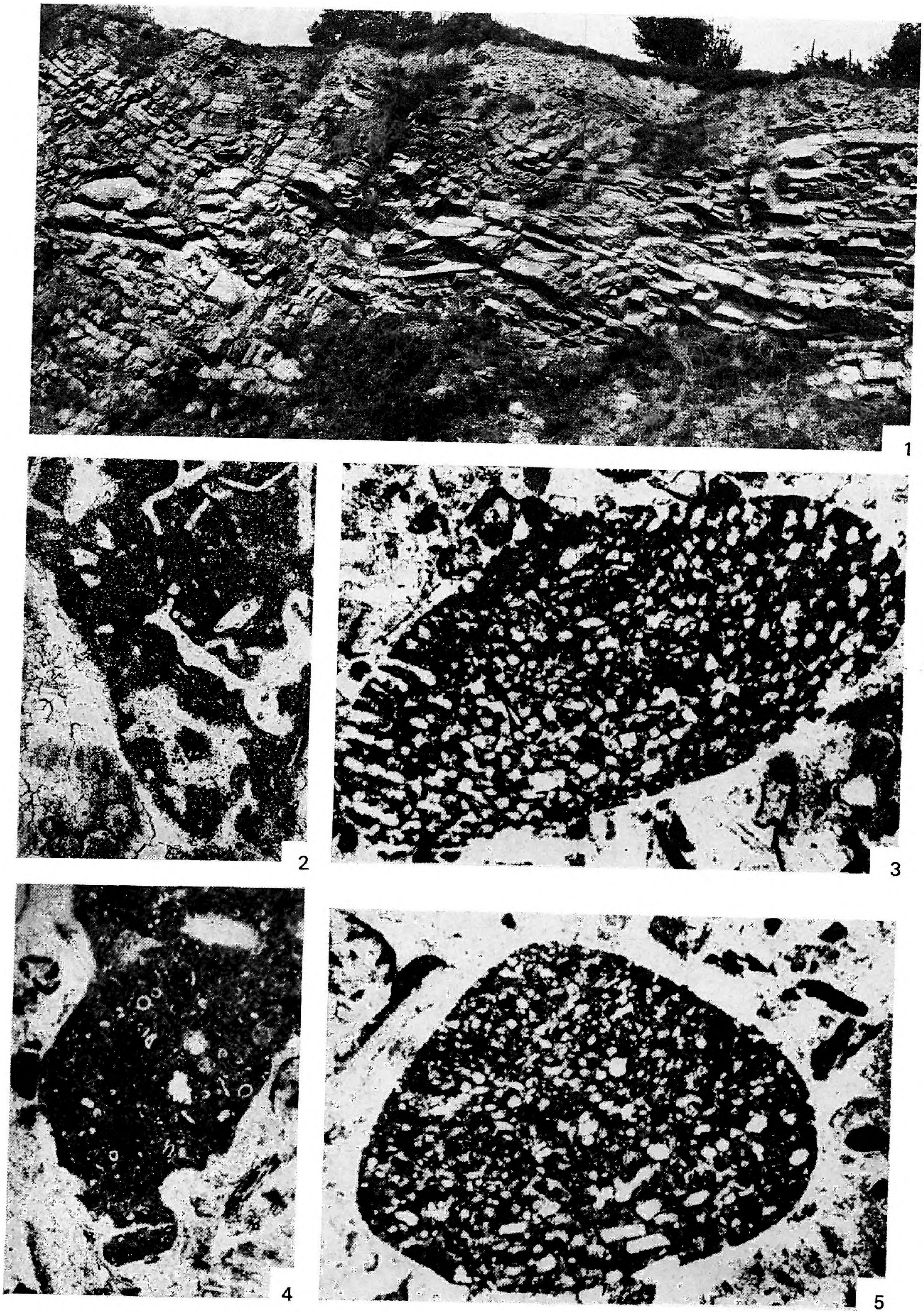
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PLATE XXIX

Ajka Coal Formation

1. *Turritella difficilis repelini* Czabalay
   Haustator fittonianus (Sow.)
   Tympanotonos inferiore (Schnarr)
   Cardium ottoi Geinitz
   Borehole Süt-22. 118–119 m
2. *Hemisinus* sp.
   Potanomya incerta Tausch
   Borehole Süt-22. 139.50–141 m

Jákó Marl Formation, Csingervölgy Marl Member

3. *Pecten membranaceus* Nilsson
   Borehole Süt-22, 60.3 m
4. Sandy, silty marl with a Cardium-bearing biofacies (forms enduring changes in salinity)
   Gordium ottoi Geinitz
   Borehole Süt-15. 52.50 m

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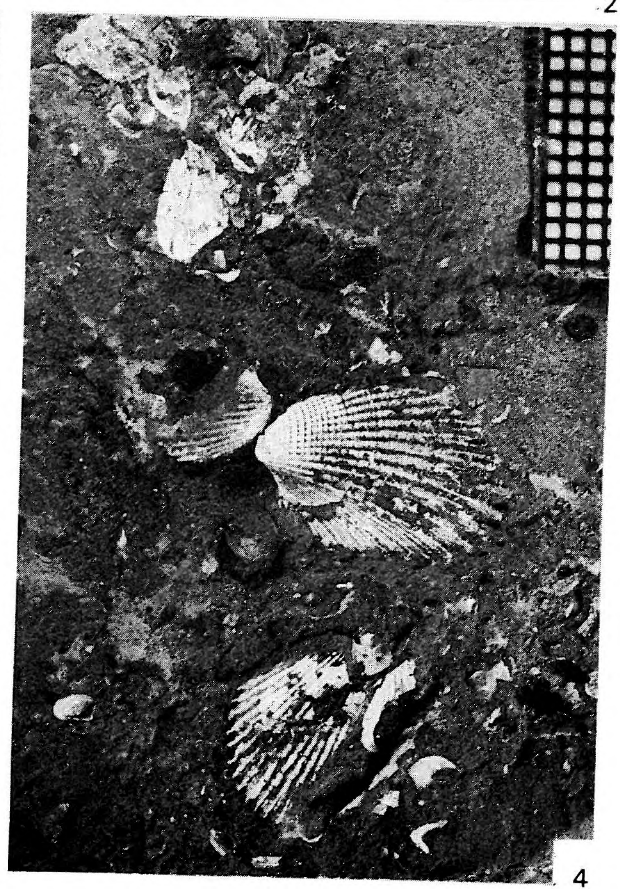

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PLATE XXX

Jákó Marl Formation, Csingervölgy Marl Member

Borehole Süt-22

1. *Nummofallotia cretacea* (SCHLUMBERGER). 170×
   99.6 – 100.0 m
2. *Paleodasycladus?* 43×
   99.6 – 100.0 m
3. *Vidalina* sp. 218×
   99.6 – 100.0 m
4. Biomicrite with fragments of Paleodasycladus? 43×
   99.6 – 100.0 m

Ajka Coal Formation

5 – 6. *Munieria grambasti* BISTRICZKY. 34×
140.0 – 140.5 m

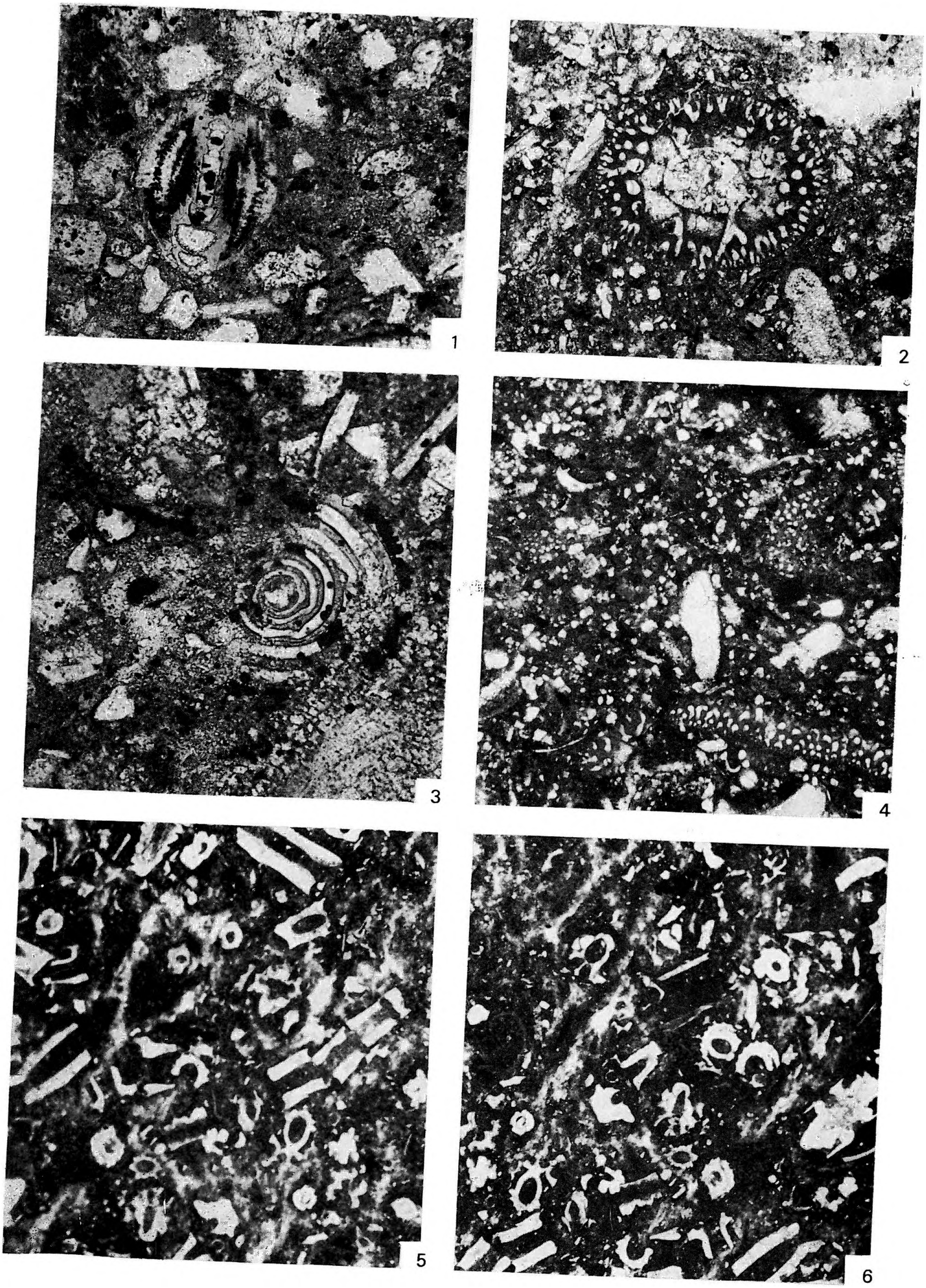
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PLATE XXXII

Ugod Limestone Formation

Borehole S-7

1. Bioclastite composed of coated, poorly or fairly rounded mollusc shell fragments. 21×
   17.2—18.5 m, centre
2. Biointrasparite; the bio- and intraclast grains are strongly rounded and coated. 21×
   10.3—12.1, base

3—4. Foraminiferal biopelsparite. 34×
   3. 40.3—41.6 m
   4. 32.9—34.2 m

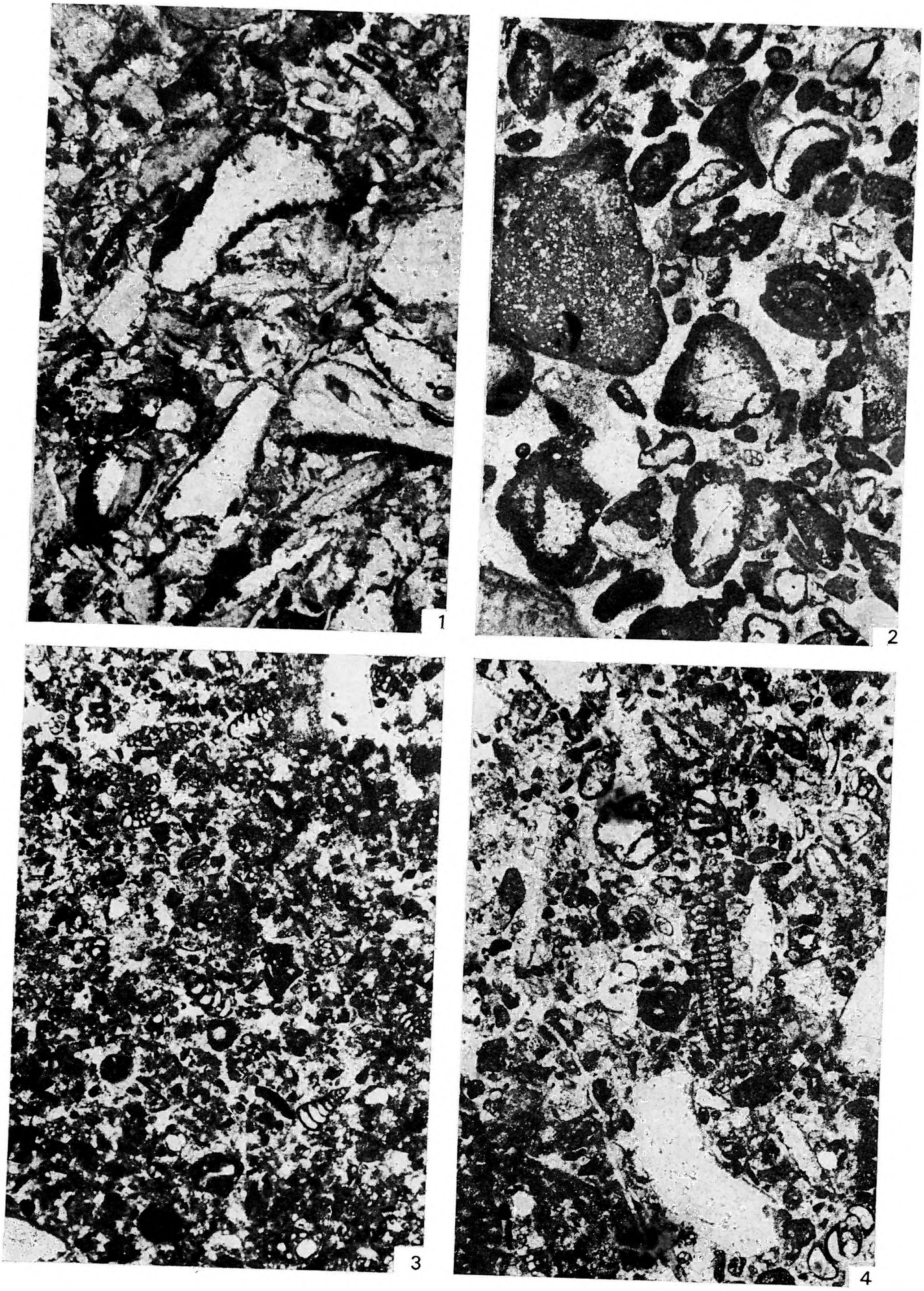
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PLATE XXXIII

Ugod Limestone Formation

Borehole S-7

1. Hippurites shell, typical micrograph. 8×
   12.1 — 13.1 m, top
2. Biointramicrite, *Dicyclina* sp. 34×
   37.2 — 38.7 m, base
3. Foraminiferal biopelsparite — microsparite
   Dicyclina schlumbergeri MUNIER — CHALMAS. 21×
   40.3 — 41.6 m
4. Foraminiferal biopelsparite — microsparite, *Cuneolina* sp., Miliolidae, Textularidae. 34×
   40.3 — 41.6 m

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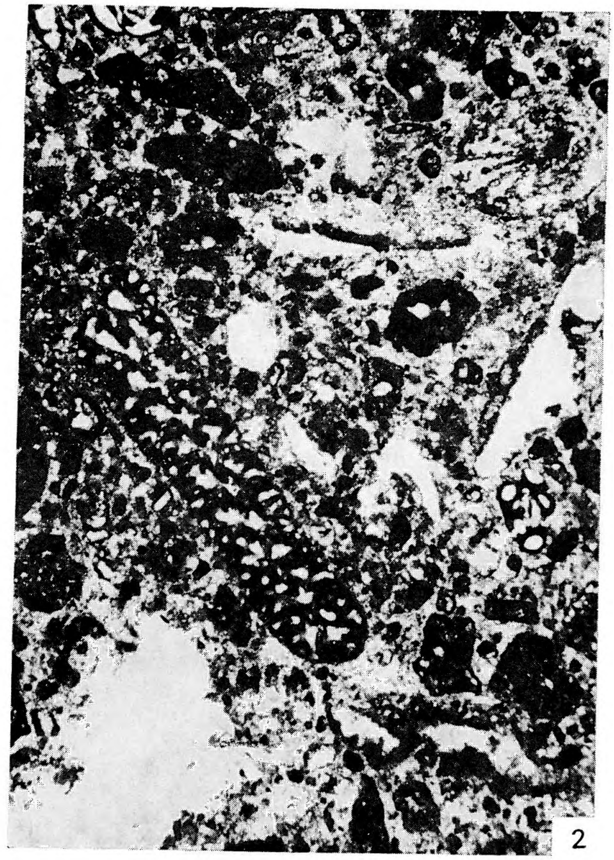

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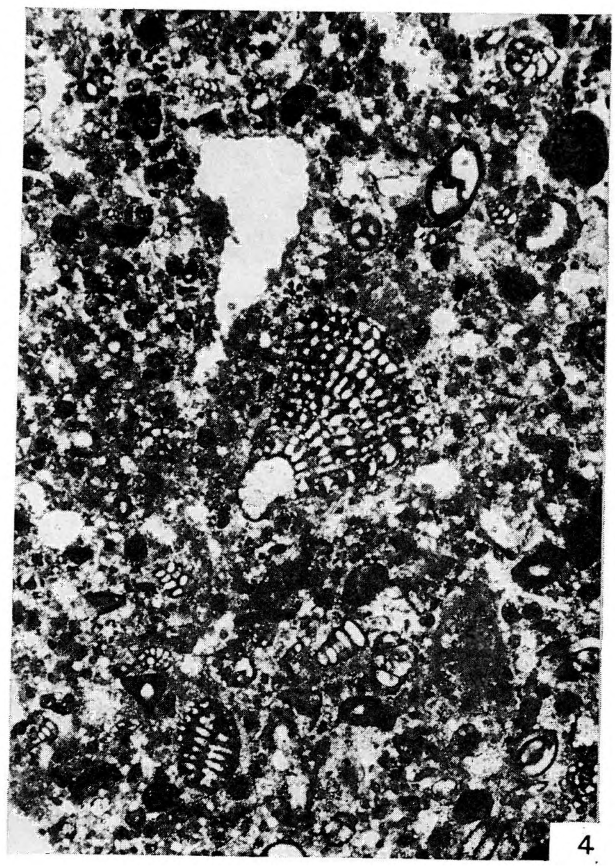

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PLATE XXXIV

Ugod Limestone Formation

1. Thick-bedded, rudist-bearing, bioclastic limestone
   Gerinc quarry, upper quarry-yard
2. Argillaceous limestone with small, thin-shelled rudist shells
   Köves-domb, eastern wall of Kecskevár quarry

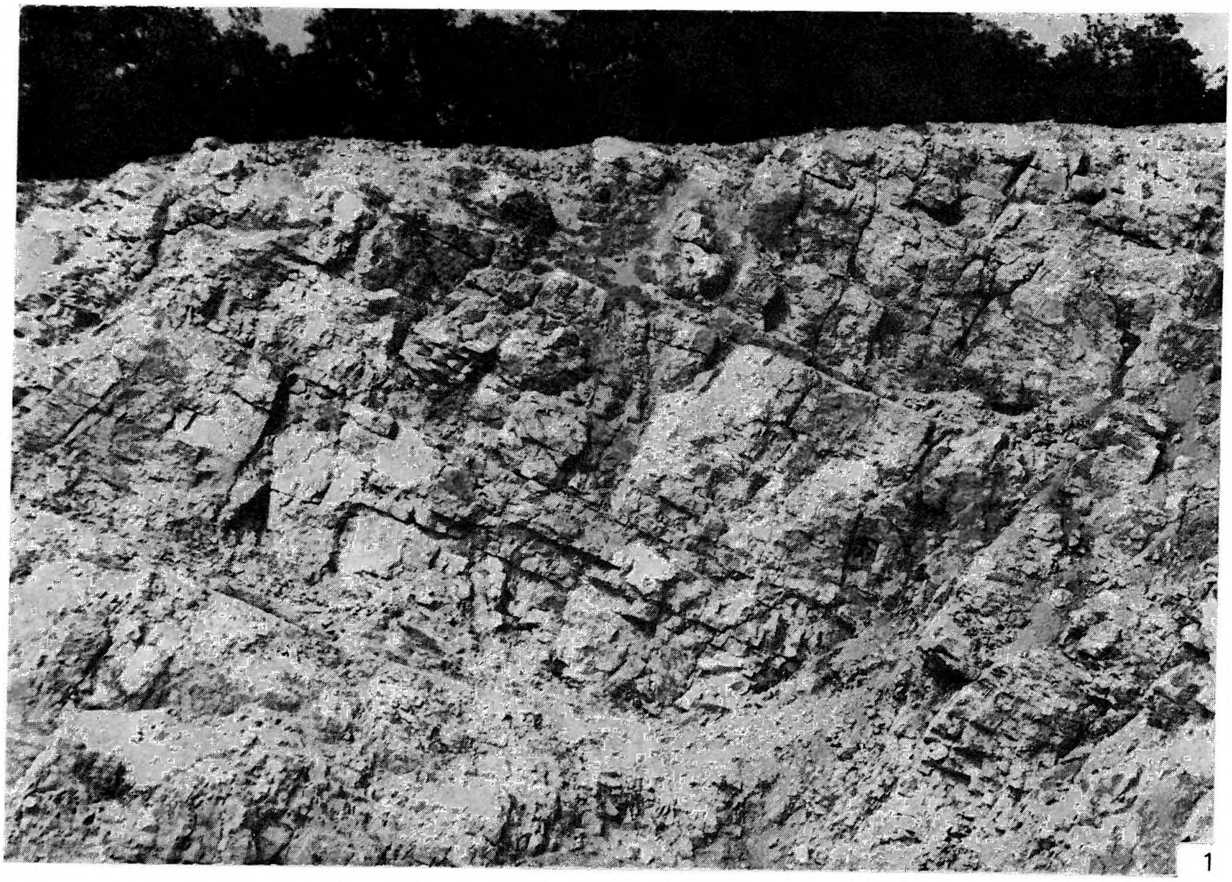

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PLATE XXXV

Ugod Limestone Formation

Köves-domb, Kecskevár limestone quarry

1. Echinoidal biofacies; a great percentage of the red rock is composed of skeletons or fragments of skeletons of Echinoidea; note the distinct orientation of the skeletal elements parallel to the bedding plane
2. Bioclastic rock type (calcirudite-bearing calcarenite) containing skeletal fragments of rudists

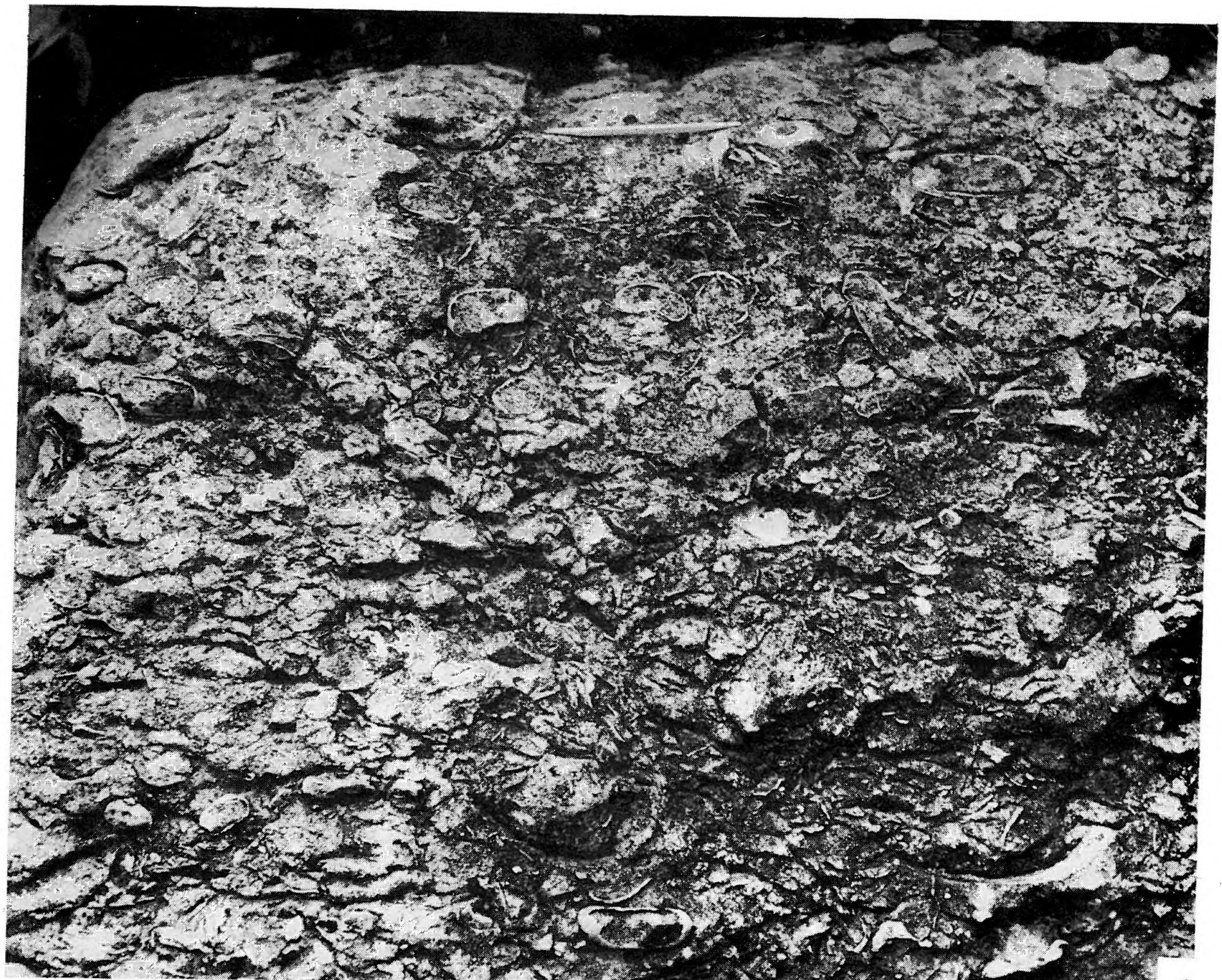

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PLATE XXXVI

Ugod Limestone Formation

1. Reef body facies; elongated Hippurites specimens dissected by partition laminae
Köves-domb, southwest part
2. Rudist valves filled partly with syngenetic sediment, partly with coarse-crystalline sparite. 1×
Hippurites lapeirousei GOLDFUSS, *H. colliciatus* WOODWARD
Köves-domb

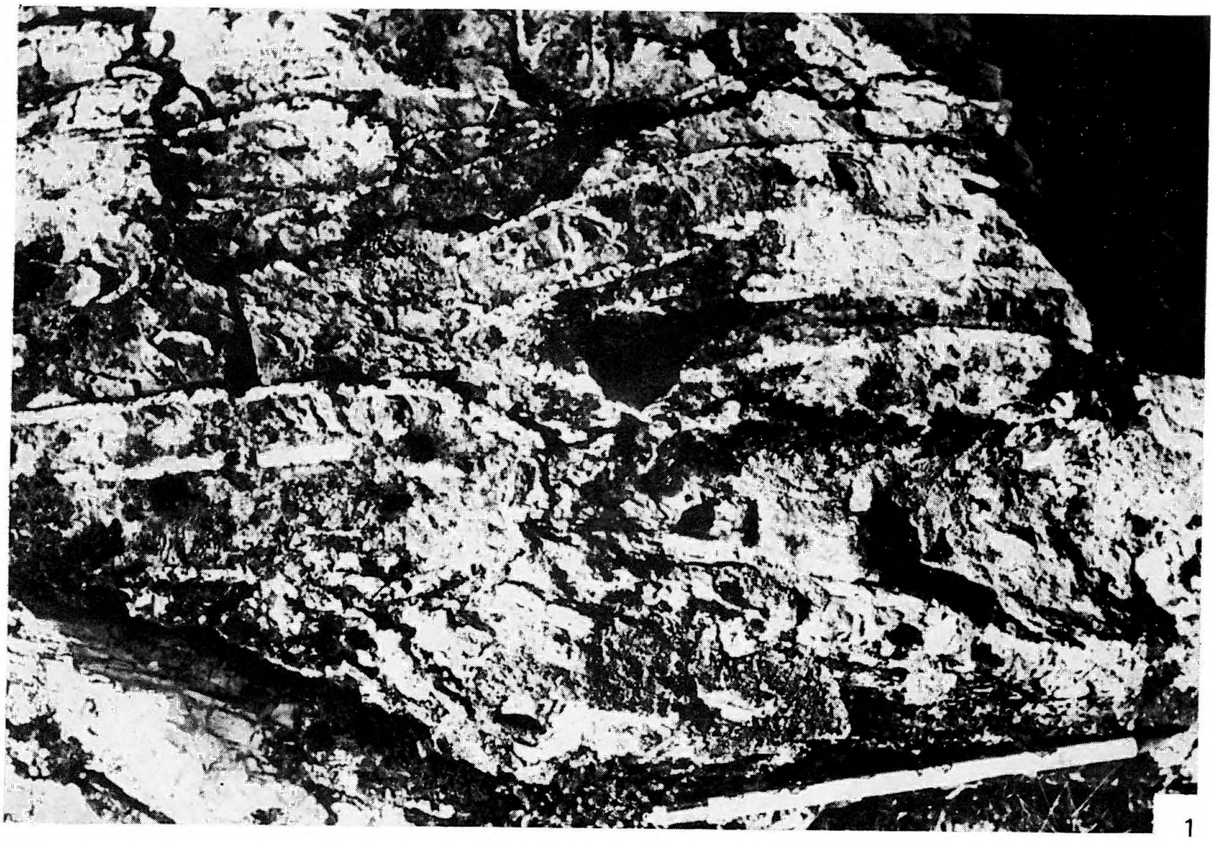

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PLATE XXXVII

Ugod Limestone Formation

Actaeonella biofacies. 1×
Sintérlap quarry

1

PLATE XXXVIII

Ugod Limestone Formation

Kecskevár quarry

1. *Trochactaeon (Tr.) giganteus subglobosus* (MUENSTER). 1×
2. *Nerinea (Simploptyxis) buchi* (KEFERSTEIN). 2×
3. *Nerinea (Simploptyxis)* cf. *pailletteana* (D'ORB.). 3×
4. *Trochactaeon (Tr.) knetrui* KOLLMANN. 1×

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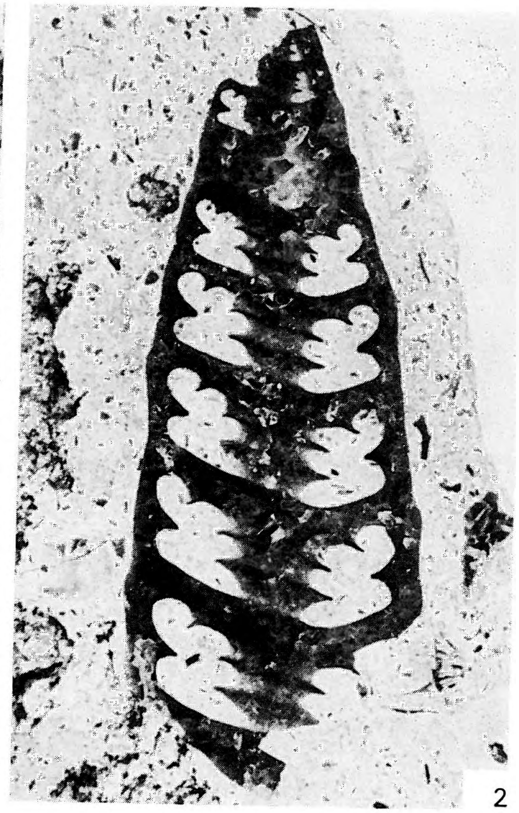

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PLATE XXXIX

Ugod Limestone Formation

Kecskevár quarry

1. *Actaeonella caucasica styriaca* KOLLMANN. 0.5×
2. *Intruria cycloidea* PACELINCEV. 1×
3. *Pterotrigonia limbata* (D'ORB.). 1×
4. *Trochactaeon (T.) goldfussi* (D'ORB.). 1×

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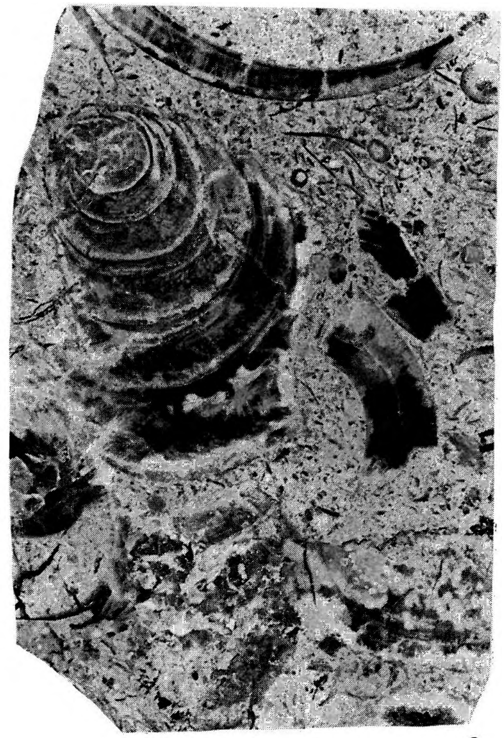

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PLATE XL

Ugod Limestone Formation

Kecskevár quarry

1. *Vaccinites atheniensis* (KTENAS). 0.5×
2. *Vaccinites atheniensis* (KTENAS), cross-section. 0.5×

1

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PLATE XLI

Ugod Limestone Formation

1–2. *Vaccinites archiaci* (Munier–Chalmas). 1×
Kecskevár quarry

3. *Radiolites pannonicus* Barnabás. 1.5×
Köves-domb

4. *Radiolites angeoides* (Lapeirouse). 3×
Sümeg

5. *Vaccinites sulcatus* (Defrance). 1×
Sintérlap quarry

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PLATE XLII

Polány Marl Formation (lower beds)

1. *Bulimina* sp. 170×
   Borehole Süt-20. 11.0 m
2. *Pithonella trejoi* BONET. 170×
   Borehole Süt-22. 28.7–30.1 m
3. Biomicrite with Calcisphaerulidae specimens and detritus of planktonic Foraminifera and sporadical pyrite grains. 218×
   Borehole Süt-22. 22.0–23.0 m
4. Biomicrite with Calcisphaerulidae and fragments of planktonic Foraminifera. 218×
   Borehole Süt-22. 20.0–22.0 m
5. Biomicrite, *Conocella ugodensis* HAAS. 86×
   Borehole Süt-22. 25.8–27.0 m
6. Pelmicrite with Calcisphaerulidae and *Bulimina* sp. 218×
   Borehole Süt-22. 13.0 m

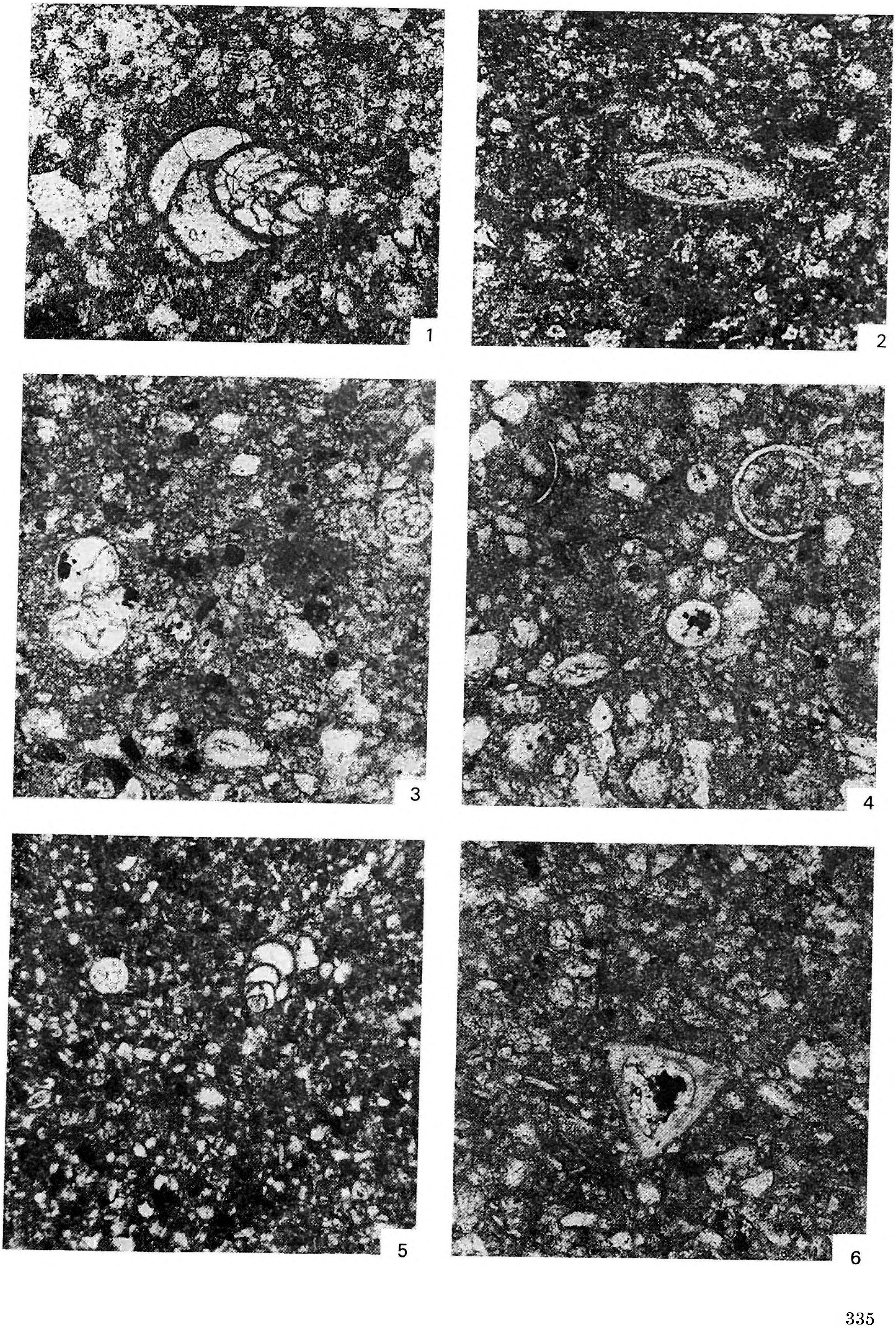
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PLATE XLIII

1. Bauxitic clay accumulated at the beginning of the Eocene cycle in the karstic cavity of the Ugod Limestone in the Gerinc quarry (Nyírád Bauxite Formation)
2. Open-pit mine for exploitation of the bauxite lens of Surgó-tag. The bauxite sequence has been accumulated in a karstic depression of a length of 200 to 300 m formed in the Hauptdolomit along a fault of SW—NE trend and one perpendicular to it

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PLATE XLIV

1. The middle and upper parts of the Szőc Limestone Formation (thick-bedded Assilina—N. perforatus limestone and thin-bedded argillaceous limestone with N. millecaput)
   Csabrendek, quarry on the northeast side of the Rendeki-hegy
2. Lower, conglomerate, member of the Darvastó Formation unconformably overlying the Upper Cretaceous Polány Formation
   Sümeg, quarry on the western side of the Rendeki-hegy

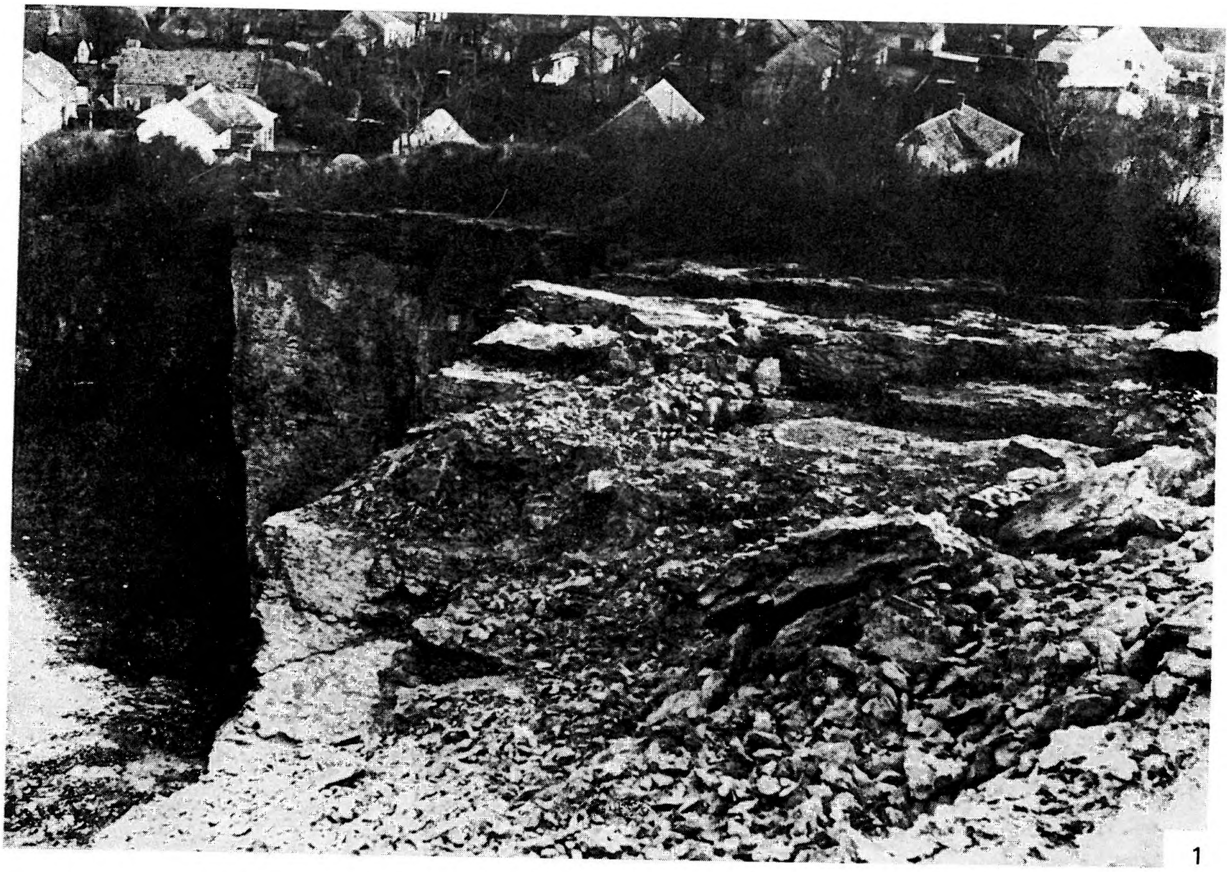

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PLATE XLV

Szőc Limestone Formation

1. *Nummulites perforatus* (MONTF.)
   Nummulites anomalus DE LA HARPE A
   Nummulites sp.
   Assilina exponens (SOW.)
   Discocyclina sella (D'ARCH.)?
   Discocyclina nummulitica (GÜMB.)
   Discocyclina varians (KANFENI)?
   Discocyclina sp.
   Alveolina levantina HOTT?
   Alveolina sp.
   Orbitolites sp.
   Smaller Foraminifera

   Borehole Csabrendek-850. 16.0–39.0 m. 10×

2. *Nummulites millecaput* BOUB. A, B
   Nummulites perforatus (MONTF.) A
   Nummulites sp.
   Asterocyclina stellaris BRUNNER
   Operculina hungarica (HANT.)

   Borehole Csabrendek-850. 16.0–39.0 m. 10×


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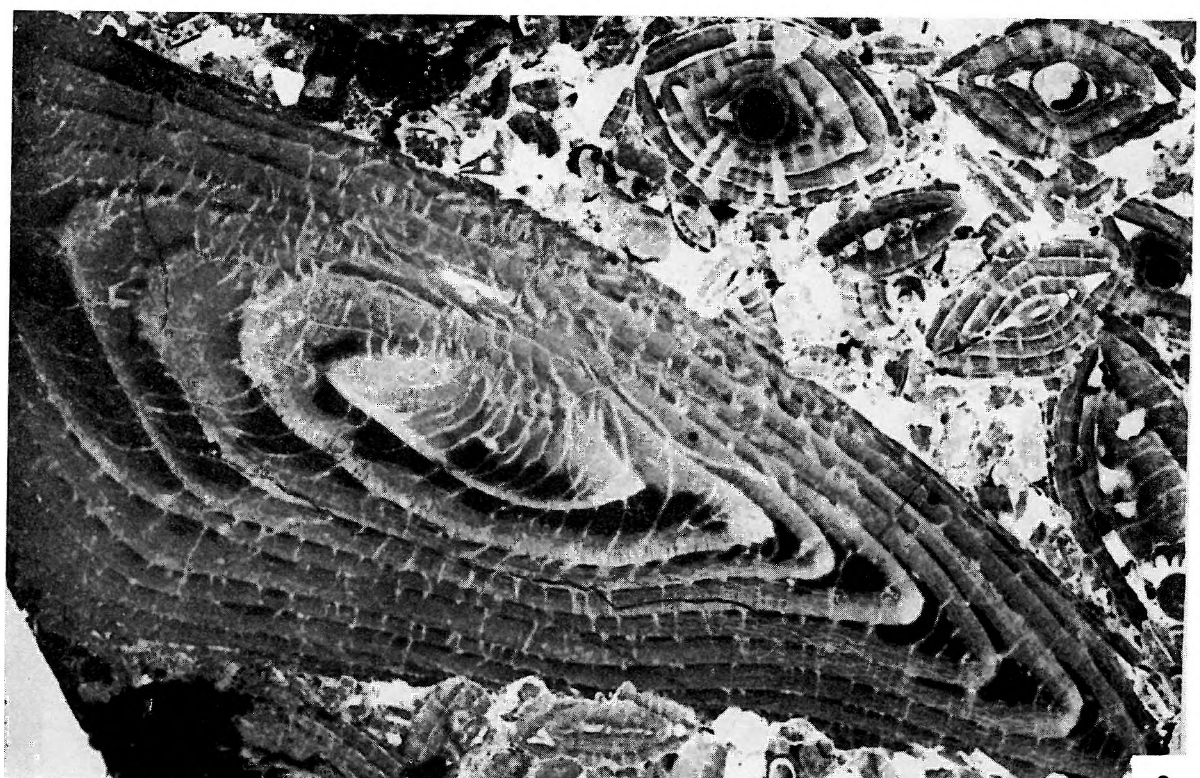
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PLATE XLVI

Szőc Limestone Formation

1. *Nummulites perforatus* MONTFORT A
   Nummulites striatus (BRUG.) A
   Nummulites sp.
   Assilina spira (DE ROISSY) A
   Assilina exponens (SOW.) A
   Assilina pustulosa DOC. A
   Assilina sp.
   Alveolina sp.

   Borehole Csabrendek-12. 107.0—108.0 m. 3×

2. Miliolina-Orbitolites-bearing calcareous marl
   Nummulites laevigatus (BRUG.) A
   Nummulites discorbinus (SCHLOTHEIM)
   Assilina praespira DOUV. A
   Alveolina hungarica n. sp. A
   Alveolina levantina HOTT. A
   Alveolina sp.
   Orbitolites sp.
   Lithothamnium, Miliolina and other smaller Foraminifera

   Borehole Nagytárkány-1103. 233.4—241.0 m. 7×

3. *Alveolina* sp.
   Assilina spira (DE ROISSY)
   Assilina exponens (SOW.)
   Assilina pustulosa DONC.
   Nummulites perforatus (MONTFORT)
   Nummulites striatus (BRUG.)
   Nummulites sp.

   Borehole Csabrendek-12. 107.0—108.0 m. 3×


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PLATE XLVIII

Csatka Gravel Formation

Hilltop of the Rendeki-hegy

1. Andesite boulder
2. Quartzite pebble. 0.5×
3. Meta-breccia gravel with a selective weathering of the breccia grains. 0.5×

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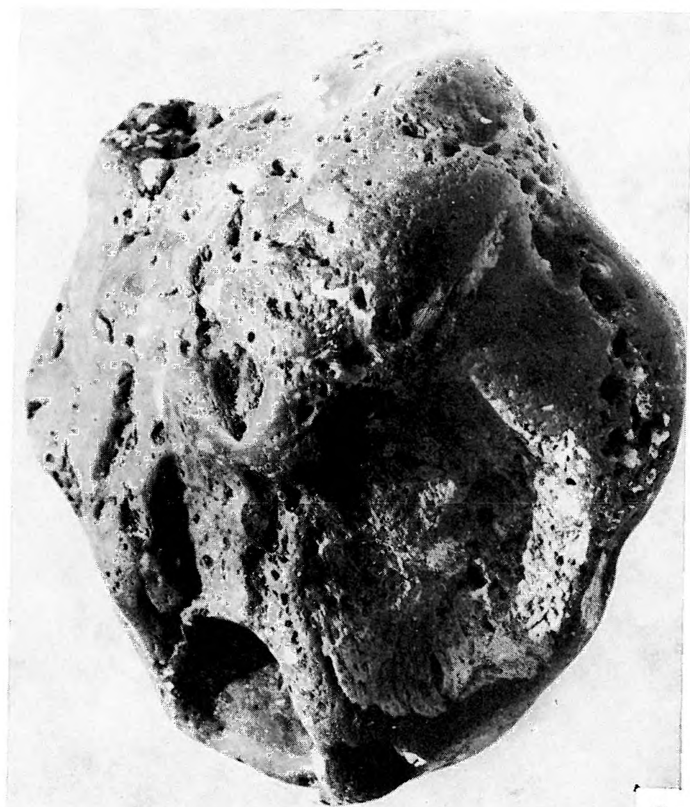

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PLATE XLIX

Middle Miocene formations in the open-pit bauxite mine of Bárdió-tag

1. The bauxite is overlain by the Pusztamiske Formation represented by abrasional gravels, conglomerates at the base and by gravelly sands in the higher parts; the unit is overlain by the Fertőrákos Limestone Formation
2. Weathered dolomite and bauxite pebbles at the very base of the abrasional unit

3–4. Typical features of the abrasional gravel


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PLATE L

1–2. Corrasion markings associated with the Badenian transgression as observable on the surface of the Polány Formation and the Eocene basal conglomerate along the Sümeg–Csabrendek road and in the Haraszt quarry

3–4. Traces of activities of borer organisms as observable on Ugod Limestone pebbles from the Kozma-tag mine and on abrasional gravels from the Bárdió-tag mine

5. Pebbles deriving from the sediment deposited during the upper, fluviatile, phase of the Pusztamiske Formation, Bárdió-tag mine

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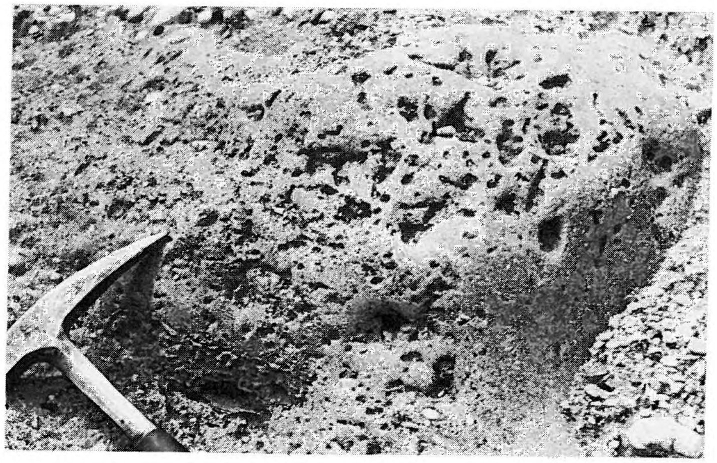

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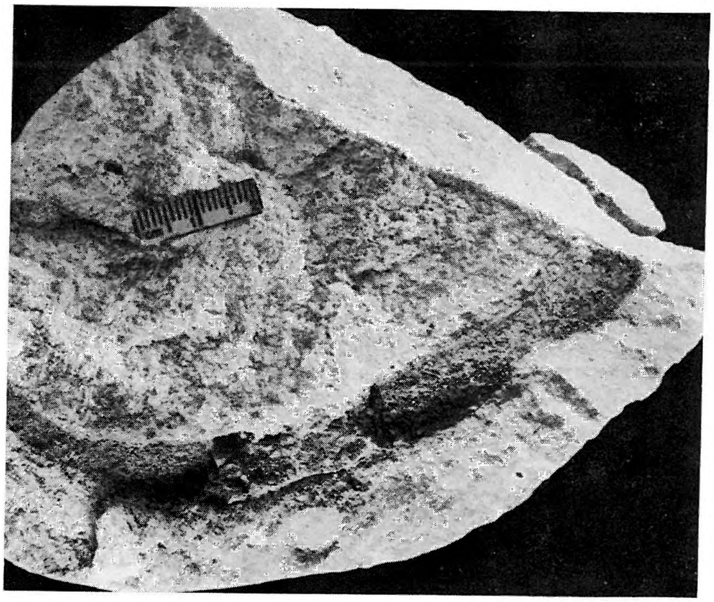

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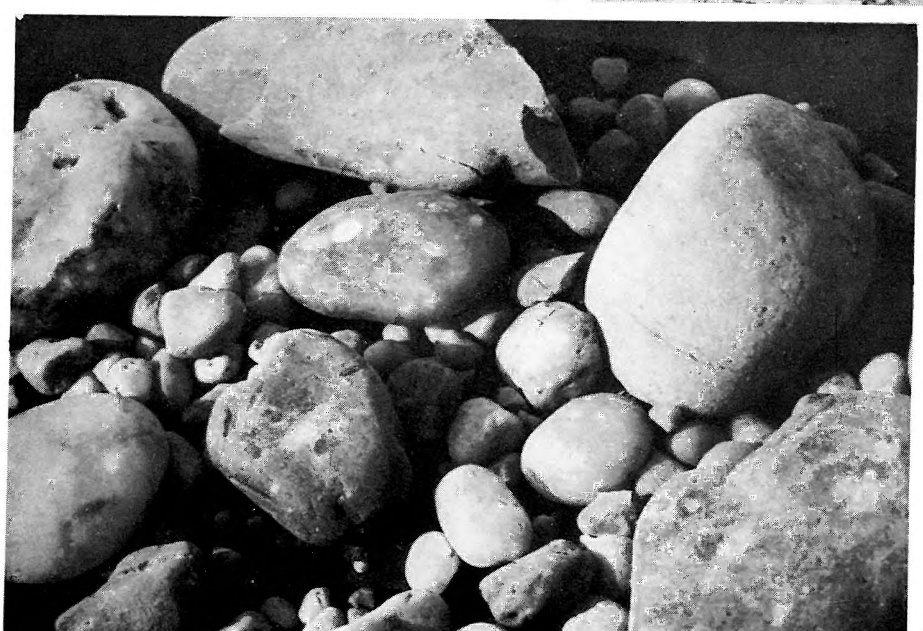

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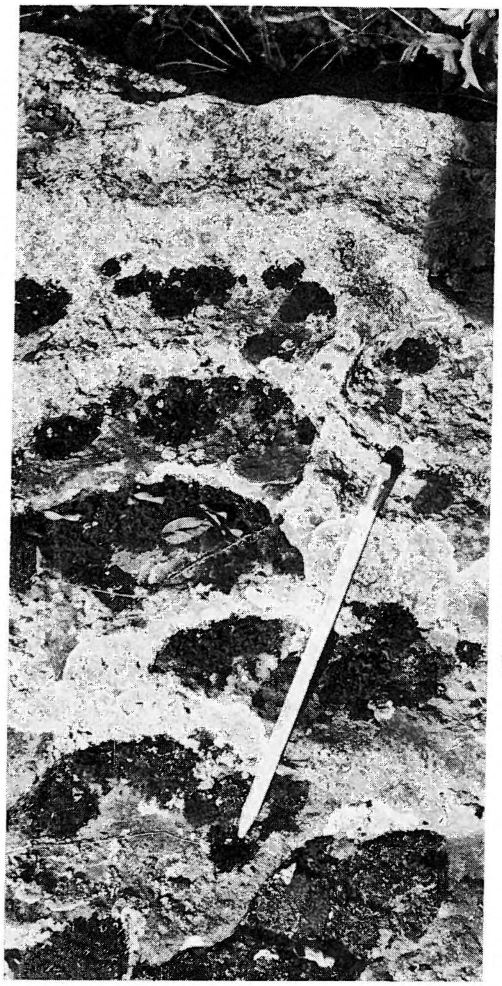
PLATE LI

1. Abrasion markings in the Kecskevár quarry on the Köves-domb
2. Upper Pannonian abrasion markings on the Vár-hegy

3–4. Boulders from the abrasional unit of the Kisbér Formation on the Mogyorós-domb



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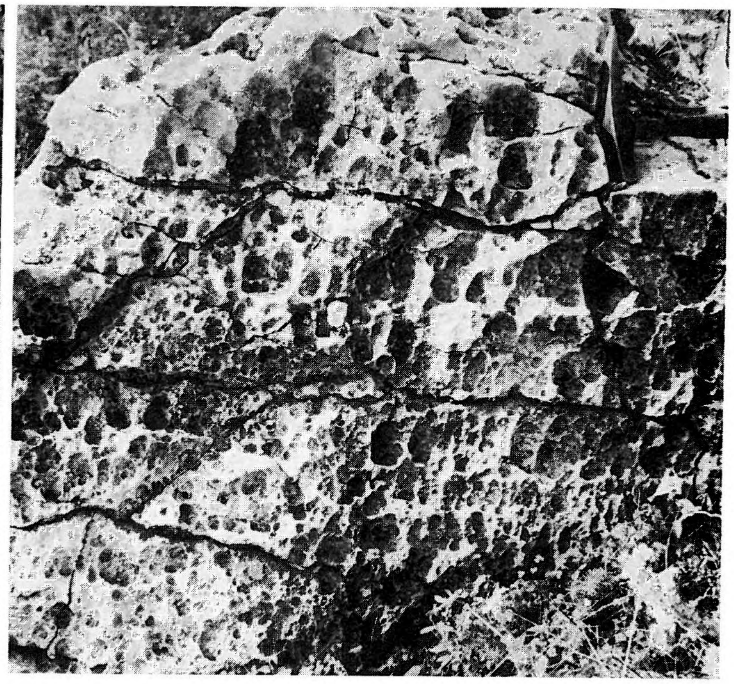

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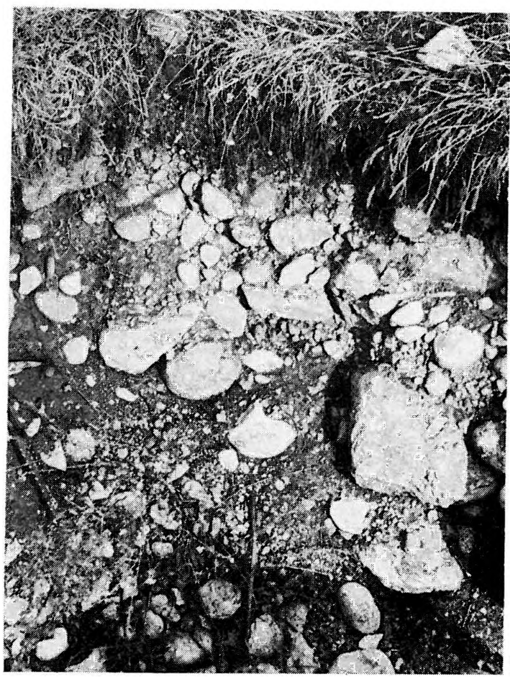

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PLATE LII

1–2. Exposure of the Kisbér Formation in the quarry by the Vár-hegy

3. Limonite-cemented gravel beds of the Kisbér Formation in the quarry by the Vár-hegy

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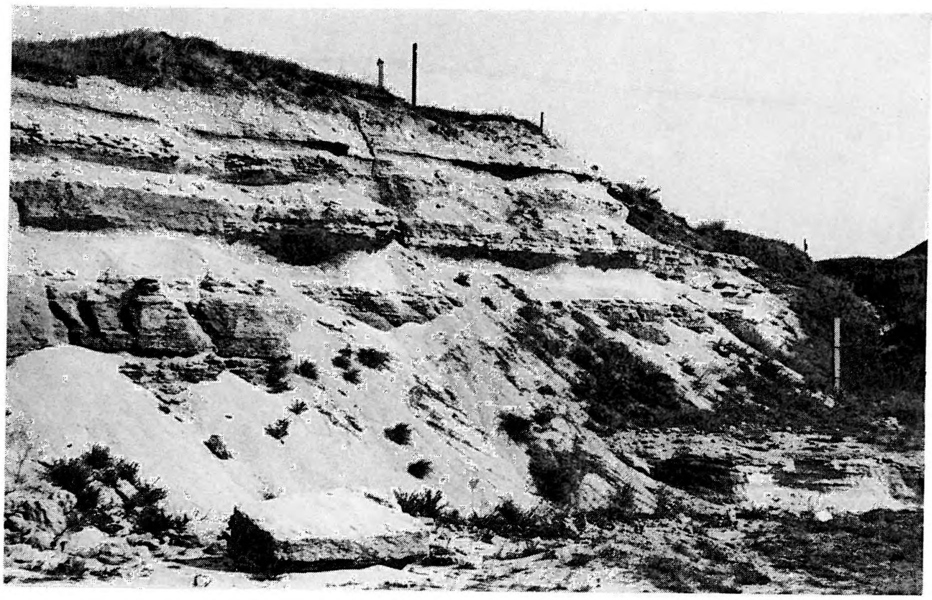

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PLATE LIII

1. The Kisbér Formation overlying the abrasional beds of the Middle Miocene Pusztamiske Formation on the Haraszt

2–3. The Kisbér Formation as filling depressions in the Miocene-abraded surface of the Polány Marl by the Sümeg–Csabrendek road

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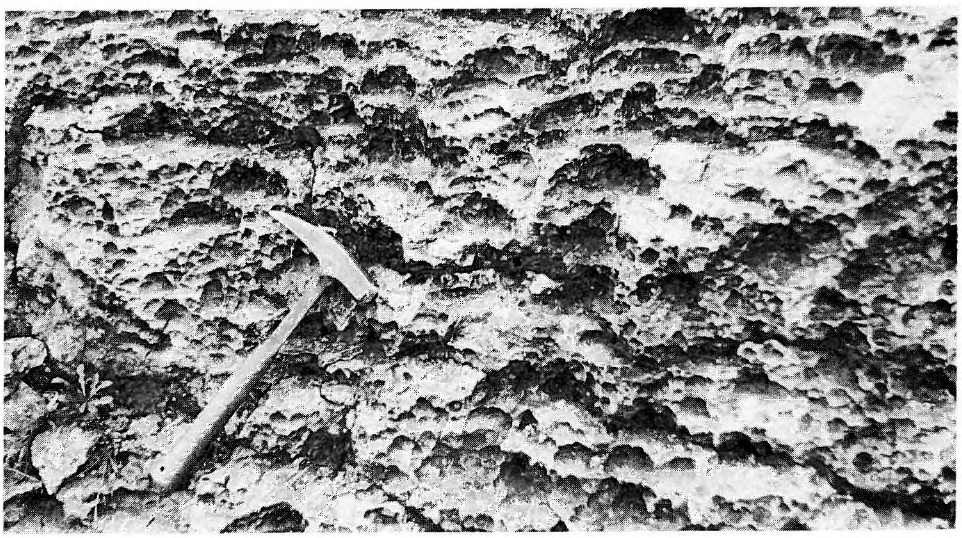

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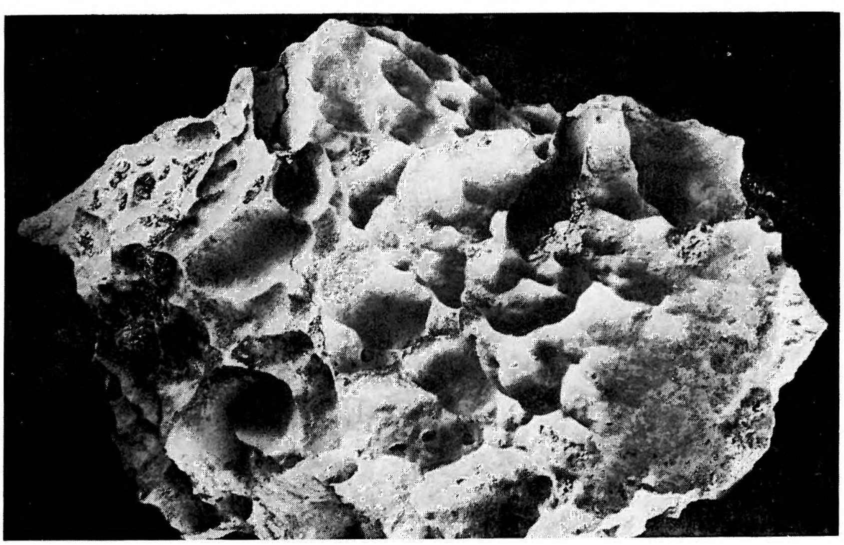

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PLATE LIV

1. The Kisbér Gravel as exposed in the quarry by the Sümeg—Csabrendek road

2—3. A sandy facies of the Kisbér Formation representing a transition to the Szák Marl Formation in the quarry in the southern part of the Mogyorós-domb

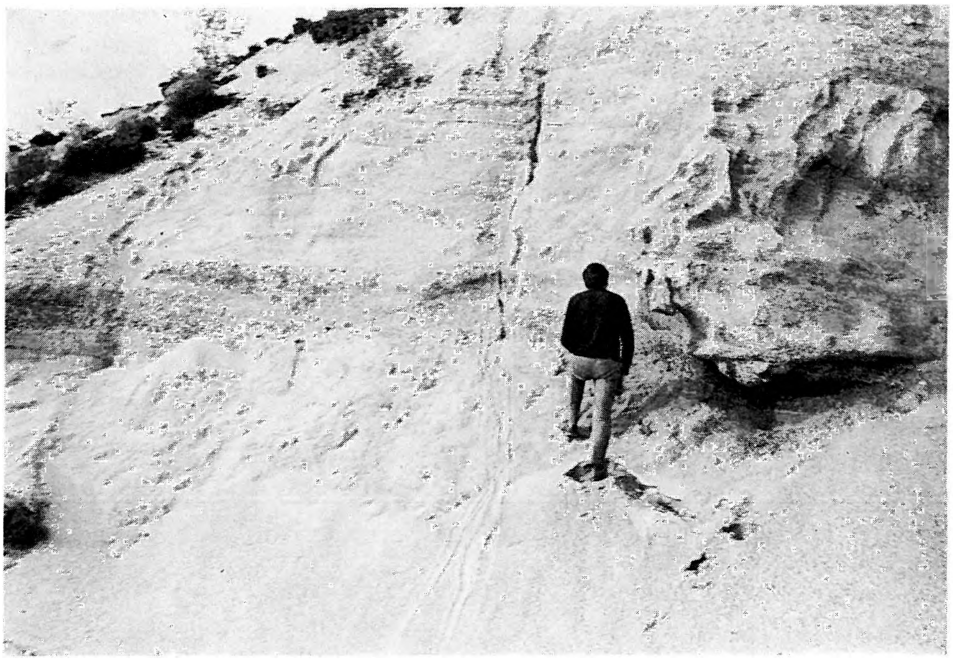

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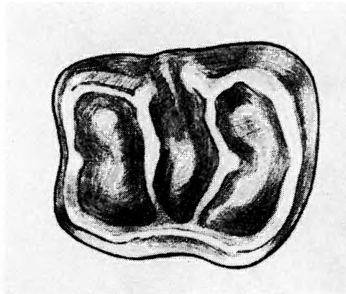
PLATE LVI

1. *Graphiglis nanus* ng. n. sp. (M_1s). 40×
2. *Muscardinus* cf. *gemmula* KRETZOI (M^1s). 40×
3. *Muscardinus* cf. *gemmula* KRETZOI (M^2s). 40×
4. *Miodyromys alter* n. sp. (M^1d). 40×
5. *Neocricetodon transdanubicus* n. sp. (M^1d). 20×
6. *Allospalax plenus* KRETZOI (M^1s). 20×
7. *Allospalax plenus* KRETZOI (M_1d). 20×
8. *Allospalax plenus* KRETZOI (M_1s). 20×
9. *Prolagus oeningensis* (KÖNIG) (P_3s). 10×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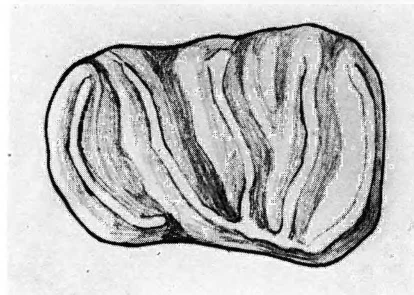
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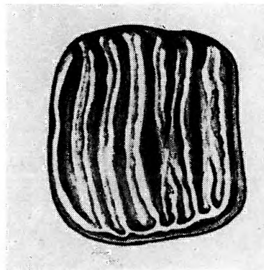
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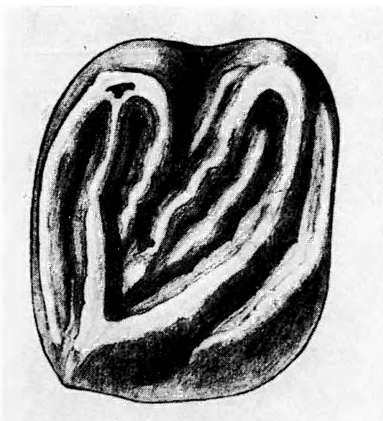
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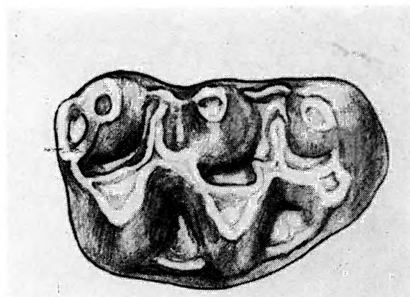
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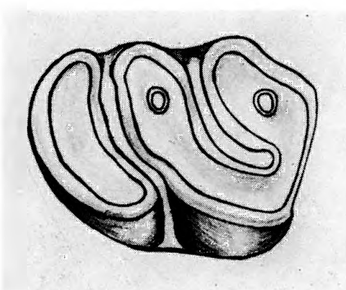
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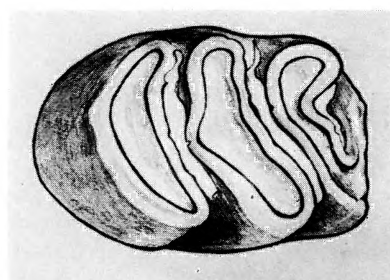
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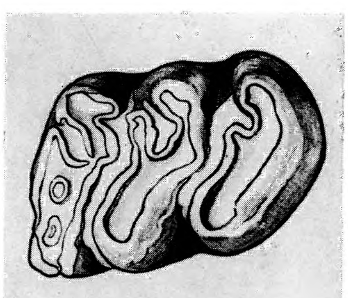
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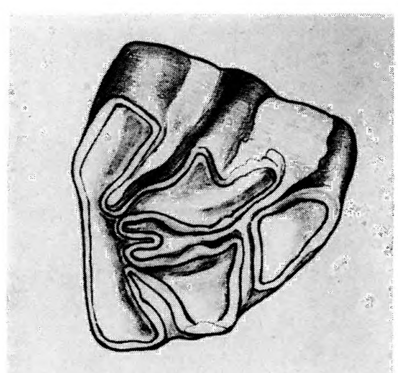
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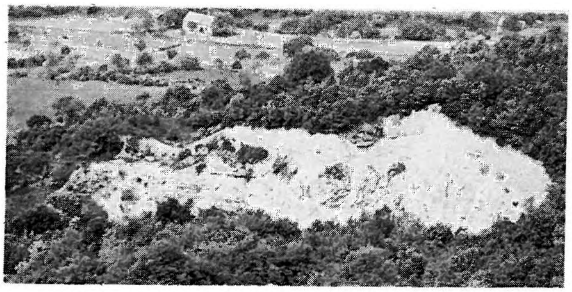
PLATE LVII

1–2. Blocky talus in the quarry beneath the Fehér-kövek (White Stones)

3. Talus on the southwest slope of the Rendeki-hegy

4. Ice sacs formed in slope deposit as observable in the replenished bauxite mine pit by the Bárdió-tag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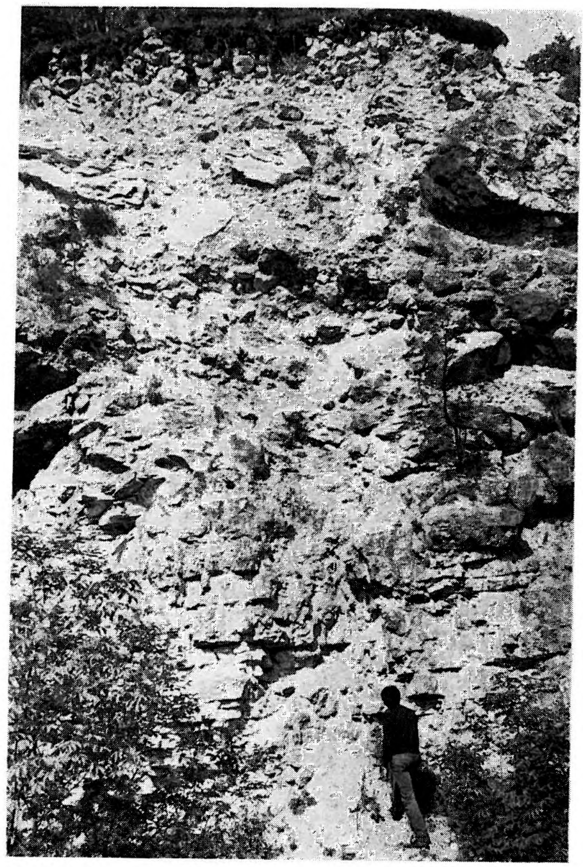
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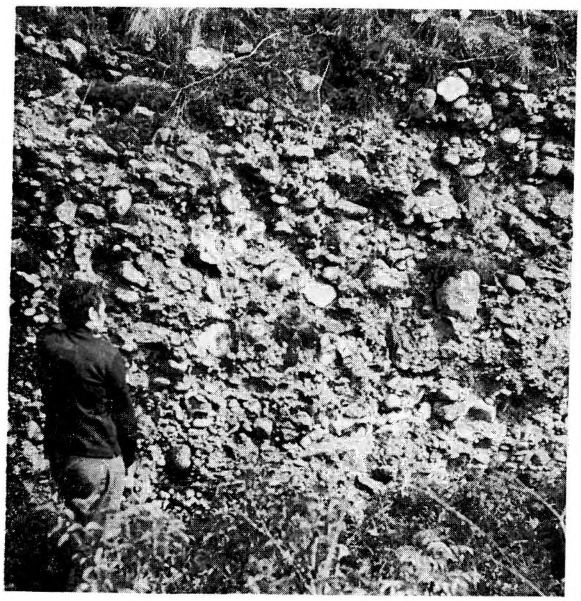
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