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Géza Császár

Urgon formations in Hungary

With special reference to the Eastern Alps, the Western Carpathians and the Apuseni Mountains

BUDAPEST, 2002

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The figure on the front page is a combination of the block diagram (on the right) showing the recent geological setting of the Eastern Mecsek Mountains and the probable position of an Early Cretaceous volcano with atoll ring. Colours of the block diagram correspond to the international geological standard. The dark green colour indicates Lower Cretaceous basaltic rocks, light green shows Lower Cretaceous sedimentary rocks. The distribution of shallow marine fossils and basalt pebbles around the volcano allowed me to locate the volcanic build-up on the north-western margin of the recent Eastern Mecsek Mts. In the basin on the right side of the diagram only small tongue of a basin floor fan represents the one-time atoll ring. For further information see p. 34 in this volume. Detail will be given in a separate paper.

Preface

Since the beginning of the 1990s the finance for scientific research has slowly consolidated. This statement is valid even for that group of sciences which fundamentally have national importance and interest. Therefore those involved in the research of these disciplines (e.g. history of Hungary, Hungarian language, etc.) must rely almost exclusively on national sources. The research in the group of disciplines of international interest (mathematics, physics, etc.) can expect support not only from national sources but from a great variety of international sources as well. Geology belongs to the 3rd group of disciplines, situated in between the previous two. Like other natural sciences it also has regular features valid for all over the world. Nevertheless, the geological composition of the crust under our feet in Hungary can be studied only here and detailed results are important from a Hungarian point of view. In spite of the contradictory situation geologists cannot be dissatisfied with the financial circumstances, especially if the economic conditions of the country are taken into consideration. I am deeply indebted to the National Scientific Research Fund (NSRF) because of its generous support for the following projects: T 552, T 016785, and T 025534.

Unfortunately, the situation is far from bright with regard to the publication of a monograph in the field of geology. This monograph has been ready since 1997 and I failed several times in trying to get support for publication from the NSRF. At the same time I must express my sincere gratitude to the Ministry of Environment and Water for financially supporting the publication of this volume through a KAC project.

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In order to reduce the publication expenses the structure of the monograph with regard to figures and photographs (plates) is differ from the traditional pattern. Black and white figures and tables are found at or close to the first reference, and their independent numbering has been kept, while black and white plates are placed at the end of the relevant chapters. Colour figures and plates are placed separately at the end of the text and also numbered independently. In order to distinguish between the black and white and the colour figures and plates, an extra letter (c) has been added in front of the symbol of coloured figures (cFigure X) and colour plates (cPlate X), and an other letter (b) is used for indication of black and white plates (bPlate X). The page of the first colour figures and colour plates are separately indicated at the end of the contents, while black and white plates at the end of the chapters. After the reference number of the colour figures and plates the page where they can be found is also indicated: (cFigure 10 — p.181) or (cPlate X — p.197).

Budapest, 14 November 2002

Géza Császár

Introduction

I first became acquainted withformations of Urgon facies in the second half of the 1960s. At that time I was a co-worker with the coal exploration project in the Oroszlány Basin. Safe mining required thorough knowledge of the hydraulics of the basin and, in particular, the properties and thickness of the footwall protective bed. As the coal-bearing Eocene beds are deposited on an extremely diverse surface of the Mesozoic, numerous drillings were carried out in order to reveal the floor conditions. In some fortunate cases a number of boreholes — *e.g.* Oroszlány–1825 — were found to traverse the both Urgon formations of the basin: namely, the Zirc Limestone and the Környe Limestone Formations. Besides many similarities, there were apparent differences in terms of their lithology, fossil content and general appearance. Since there was no known surface outcrop of the latter formation, it became especially important to provide a basis for distinguishing between the two formations by means of drill cores. This required the collection and evaluation of all their distinctive features.

In spite of the aforementioned work the subject of my candidate's dissertation were the Zirc Limestone Formation, occuring both in surface outcrops and boreholes, and the Tés Clay Formation, which is directly associated with the previous formation. This is thanked to the fact that I had been involved in the mapping project on the Bakony Mountains, and in the key section programme, which also started in the 1970s. This is the reason why, in this monograph I am not concerned with the Zirc Limestone in as much detail as is case with other formations.

As a matter of course, with knowledge of the two formations above, I intended to get to know other formations of similar facies that are situated in different tectonic units or in other environments. That is how I became interested in the Nagyharsány Limestone, then in the unique fossil assemblage occurring in the pyroclastic environs of the Lower Cretaceous of the Mecsek Mountains, and finally, in the limestone debris which appears as olistostromes in the likewise unusual siliciclastic slope-sediments of the Gerecse Mountains.

In addition to the evaluation of Urgon formations of Hungary, I had the very fortunate opportunity to do some studies on columns of similar facies in other countries, too. I acquired detailed knowledge on the Schrattenkalk pertaining to the Helvetic Zone. My findings are recorded in a couple of publications. My investigations on the Urgon limestone of Manín were similar but less voluminous. Moreover, in the course of the IGCP project No 262, I gained some impressions about numerous similar successions across Europe, and even in the Caucasus and in Cuba.

A major part of the field and laboratory work took place in the 1980s. On hearing about the probable changes in the scientific qualification system (but which were not at that time sufficiently known), I broke off preparing of this monograph since I felt that the time at my disposal — one, or maximum two years — would be too short to bring the work to completion. However, a decade later, I began to deal with the material again; I re-examined some sections both in field studies and in the laboratory; I also carried out supplementary studies on others, making an effort to interpret my results in the light of the latest literature.

Two years have passed since I began reworking my thesis, given that a chance for publication had arisen. However, the rate of technical and methodological development has increased so much that it has been necessary to revise several parts of the original thesis. Nevertheless, I strongly hope that the reader will understand that I have not been able to make all the revisions I would have liked.

Although the original thesis was my own work, I am grateful to many colleagues, too numerous to mention, for their useful and expert comments which have helped in improving this work. I am indebted to Erika CSEREKLEI, Gáspár PAULHEIM, Judit BUDAI-UITZ and Dezső SIMONYI for providing invaluable help in assisting with drawing and figure processing. My referees Zoltán NÉMEDI VARGA, Attila VÖRÖS and József KNAUER must be thanked for their suggestions with regard to the improvement of the manuscript. József KNAUER played an essential role because of his passionate commitment to the correction of the text. Last but not least my family, my wife in particular, are acknowledged with love and thanks for treating my official and social duties with forbearance for so long. They were left to with the whole burden of running a houshold while I made my final preparations of this monograph. My son Gábor not only assisted with houshold tasks but also helped me with the computer drawing of the figures.

The term Urgon

A HISTORICAL OVERVIEW AND RECENT INTERPRETATIONS

Urgon as a term owes its derivation to the French 'Orgon', a village situated in South France. It was first used by D'ORBIGNY (1847–1849) who wished to refer to the horizon of changes that had commenced within the Neocomian stage. Being regarded as substage, he placed the shallow marine, initially even ammonite-bearing then in their upsection more and more rudistid formations (the latter of the *Requienia ammonea* Zone), further forward. COQUAND (1962), considering the *Toxaster complanatus* AGASSIZ and *Ostrea couloni* D'ORBIGNY beds which contained ammonites and which were identified with the Urgonian stage of D'ORBIGNY by himself, introduced the designation Barremian. TOUCAS (1888) called the overlying ammonite-bearing beds Bedoulian. It turned out later that the two latter are statigraphically equivalent to the Urgonian stage. For the cause of more reliable correlation, these two stopped using the term "Urgon" as a stratigraphic category. Contemporaneously, to label a column consisting of a repetitive sequence of rudistid limestones and black shales, LEYMERIE (1868) employed an appellation "urgo-Aptien", and regarded it as a stage. As early as 1872, the stratigraphic chart of MAYER unequivocally presents "couches d'Orgon" in such a way. Today one would see this as a chronostratigraphic term, or the lower substage of the Aptian stage. By that time the expression "calcaires suburgoniens" (LORY 1897) was being used to refer to facies. Notwithstanding, a modern usage of the term "facies urgonien" is recorded by LEYMERIE (1868). However, the first unambigous application was estabilished by KILIAN (1912).

Despite the apparent resolution of the problem, a couple of expressions, albeit not satisfactory elucidated, arose five decades later. For instance, "urgo-Albien" (MAYNC 1955), "complexe urgonian", "para-urgoniens", "phase urgonienne basco-cantabrique" (RAT 1959), "barrémo-urgonien" (COTILLON *et al.* 1979), "calcaires urgo-aptiens et urgo-albiens" (CANÉROT *et al.* 1982). Even so, an outstanding example of inexact usage of the term "Urgon" can be found in PEYBERNÈS & FÖRSTER (1987). They referred to orbitolinid limestones which lacked rudists in this way. Yet these are in Tanzania which lies pretty far from the classical Urgon occurrences.

While being a matter of continuous debates, several circumstances appeared to touch the problem of Urgon (CSÁSZÁR 1992). It became obvious that the most peculiar group of fossils in the vicinity of Orgon — *i.e.* the rudists — may show up any stage of the Cretaceous system. Moreover, in a couple of realms they may be present in shallow marine carbonates throughout the entire Cretaceous succession (Figure 1); in some cases however, their occurence is somewhat intermittent. Furthermore, there is no known rudist genus which is stratigraphically restricted to the Upper Barremian and Lower Aptian substages. Another distinctive and concomitant element of the facies is represented by the orbitolines. For the stratigraphical extent of their genera the statements above concerning the rudists arc likewise true.

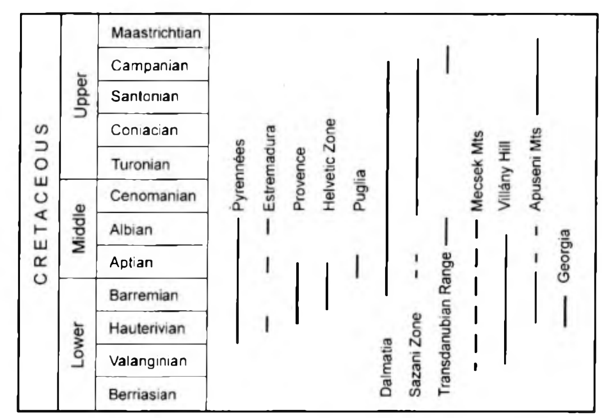


Figure 1. Stratigraphic range of some rudist-bearing formations in the Eurasian Mountain Belt

Surprisingly, the most determined, both former and recent, antagonists of the interpretation of Urgon as a facies are represented by some French geologists. They belive the term "Urgon" should be use in a lithostratigraphic sense. However, a late formulation of the facies interpretation also comes from a French geologist (RAT 1959, 1965). According to him, Urgon should be regarded as a particular biosedimentary system. By agreeing with this, a biosedimentary system should in any case be considered to be of Urgon facies if its important yet never unequivocally declared features are as follows: among macrofauna rudist pelecypods prevail in the platform-carbonate dominated sediments. The characteristic element of microfauna is represented by orbitolines. They may occasionally be accompanied by other macrofaunal (*e.g.* other pelecypods, corals, coralline algae) and microfaunal (*e.g.* foraminifers) and microfloral (algae) elements. Thus in the broad sense any platform carbonate sequence extending from the top of the Jurassic system up to the top of the Cretaceous and containing a considerable amount of rudist pelecypods could be regarded as a sediment of Urgon facies. In everyday practice, however, there are some restrictions which allow the term to be applied only to Lower (Middle) Cretaceous (ARNAUD-VANNEAU & THIEULOY 1972; ARNAUD-VANNEAU 1979; CHERCHI 1979; CONRAD 1969; DIENI *et al.* 1963; LUPERTO SINNI & RICHETTI 1979; MIŠÍK 1990; PEYBERNÈS *et al.* 1979; SCHLAGINTWEIT 1987; SCHROEDER 1964 *etc.*). Yet no reasons have been given for this. One possible explanation could be derived from the fact that at the end of the Middle Cretaceous rudists were affected by fundamental changes: specifically, mainly with respect to shape and size. These forms, being large-sized and upright-fixed, were even able to develop real reefs (KAUFMANN & SOHL 1974). This explanation is supported by the point that the extinction of orbitolines, a peculiar accompanying microfauna of the facies, is coeval with the faunal change of the rudists. As far as I know, greatest number of arguments about drawing the upper temporal boundary of Urgon facies is in the hand-out of the Grenoble colloquium in 1991 on the Cenomanian/Turonian boundary. Many researchers here corroborated the statement of SCHLANGER & JENKYNS (1976): *i.e.* at the Cenomanian–Turonian boundary there was a global lithological and geochemical (*e.g.* manganese accumulation, positive excursion of $\delta^{13}C$) as well as faunal change. The most important feature of this phenomenon is that some of the changes — especially those of geochemical relevance for the Tethys, the boreal zone and the Central Atlantic that can be correlated using palaeontology (POMEROL & MORTIMORE 1991) — are still demonstratable. The widespread products of the Late Cenomanian event, the black shales, the so-called Bonarelli horizon (PREMOLI SILVA 1991) have at least the same importance. Similarly, the increase and the subsequent gradual decrease of the organic carbon in the Late Cenomanian are also very significant (KUHNT & WIEDMAN 1991; KAUFFMAN 1991; REICHERT *et al.* 1993). A considerable element accumulation has been shown in several sections in terms of Fe, Sb, As, Tr, Au, Co, Cr, Ni, Pt and V.

In accordance with the above, at the Cenomanian/Turonian boundary there were marked changes with several elements of the biosphere. JOHNSON & KAUFFMAN (1991) have shown that a majority of the faunal groups became extinct in a time span between the Early and Middle Cenomanian whereas the dying out of the rudists took place in the Late Cenomanian. The former event was described by PHILIP (1991) as a stepwise extinction. Extinction of numerous radiolarian, rotalipora (PREMOLI SILVA 1991; SALVINI *et al.* 1993), ammonite and pelecypod (VILAMIL & KAUFFMAN 1991) species was contemporaneous with the appearance of the black shales.

Most researchers trace these changes back to certain modifications affecting the ecosystem, the climate and marine streams. These, in turn, may have resulted in eutrophication causing worse circumstances of life for foraminifers (CAUS *et al.* 1997). Concerning the probable primary causes, many possibilities have arisen. Widely accepted theories among them consider either a multiple meteorite and/or comet impact (KAUFFMAN 1991) or volcanic activity of an unusual degree (PREMOLI SILVA 1991; THUROW 1991). The fact of stepwise extinction seems to support strongly the latter concept. According to KAUFFMAN (1991) the tropical territory was 22% larger before the events at the Cenomanian/Turonian boundary than after them. At this time, rudists display significant radiation and mass adaptation to the new ecosystem. Conservative forms were not able to adapt to the reformed circumstances of the Late Cenomanian. However, during the Early to Middle Turonian only 7 rudist species evolved. This is the time when the species *Durania arnaudi* CHOFFAT and other hermatypic Radiolitidae and Hippuritidae were distributed (PHILIP 1991). Synchronously with phylogenetic changes, a shift (regarding the habitat of the rudists) occurred. According to LAVIANO *et al.* (1998) the Early Cretaceous rudists in the central and southern part of the Appenines and on the Apulian Platform lived predominantly in a lagoonal to tidal flat environment, characterized by low to medium agitation. On the other hand, from the Late Turonian on, in the Latium–Abruzzi Region and in the Apulian Platform, they were linked to the open shelf of a carbonate ramp and to platform margin habitats, respectively; both indicated a high level of agitation.Considerable tectonic activity commencing in the Cenomanian resulted in a marked dismembering of the sedimentation area. As a consequence, many rudists appeared in the outer platform by the Late Albian to accompany the ones that had already been occupying the inner platform. The Cenomanian therefore, represents a transitional period in terms of the development of the two different pelecypods: some being attached to lagoonal environment and others being reef-constructing.

In my opinion, in the case of rudists, the changes described above provide a sufficient basis for allowing us to extend the temporal upper boundary of the Urgon facies, in a narrow sense even to the Cenomanian/Turonian boundary. The virtue of this idea is indirectly strengthened by the work of MASSE (1991) — namely, an analysis which takes into consideration the evolution of the rudists and their connections during the time interval between the Berriasian and Albian. Accordingly, three evolutionary etaps, each ending with a radical event — *i.e.* extinction — can be distinguished: Berriasian to Barremian, Barremian to Early Aptian and Late Aptian to Albian. On the other hand a change, which the facies boundary of the Urgon could be linked to, cannot be confined to either of them.

In light of the arguments mentioned above the fact of the spread of small rudists into the Late Cretaceous is no longer confusing.

The author earlier argued for use of the definition of Urgon in the broad sense as well. On the basis of many data and the considerations demonstrated above, he now believes that an extension up to the Cenomanian/Turonian boundary is more reasonable. Without exception, the Cenomanian formations of Hungary are of pelagic facies. Therefore, formations of Urgon facies younger than Albian will not be discussed here. However, a study which is in preparation, will deal with Urgon of Europe and Western Asia also concerning the Cenomanian rudistid formations.

URGON AS REVEALED BY THE HUNGARIAN LITERATURE

The term Urgon appeared in the Hungarian literature relatively early. The formation itself pertaining to the Urgon was first discovered in Hungary by HAUER (1862b). However, the first Hungarian reference to a formation using this term was by an excellent mapping geologist of outstandingly knowledge and ability J. BÖCKH (1875–1878). He identified the occurrences of Cretaceous limestones near Úrkút today referred to as the Zirc Limestone Formation as being similar to those in the Bavarian Alps. He considered these limestones to be Neocomian in age. STAFF (1906–1907) classified the occurrences near Zirc and at Bakonycsernye as "Urgon facies" and estabilished their age as being Urgonian–Barremian–Aptian. The thickness of the "Kaprotina-limestone belonging to the Urgonian stage" in the vicinity of Úrkút was estimated to be 100 m by LÓCZY SEN. (1913). Following STAFF, the term Urgon was also regarded as a facial definition by ROZLOZSNIK (1925, 1928) and he assigned the occurrences near Úrkút to this group.

To the rudistid limestones of the Villány Hills the designation Urgon was first applied by RAKUSZ (1937). RAKUSZ marked the formation — known since PETERS (1863) and called today the Nagyharsány Limestone Formation — as "South European reefal limestone of Urgon facies". According to FÜLÖP (1966) the Cretaceous column at Nagyharsány is a "pachyodontid-orbitolinid limestone of Aptian to Albian age which is a typical formation of the Urgon facies". After a long interruption this expression was used again by PEYBERNÈS (1979), also in order to describe the Nagyharsány Limestone. However, also according to PEYBERNÈS, the formation contains beds of ages younger than Early Aptian. The coral and rudistid limestone boulders found in the Köszörűkőbánya quarry at Lábatlan were first described as Urgon facies by FÜLÖP (1958).

In his monograph which also dealt with the Zirc Limestone, CSÁSZÁR (1986, p. 132, 135) also used the term Urgon. However, no further explanation was given for this. The use of this term, also with reference to the Nagyharsány Limestone, frequently occurs in his later studies (CSÁSZÁR 1989, 1992; CSÁSZÁR *et al.* 1990, 1994). CZABALAY added the Hungarian occurrences to her listing of the Urgon pachyodontid faunal provinces of the Western Tethys (1989), namely both the beds of the Vértes Mountains, now called as Környe Limestone Formation, and the pachyodontid beds of the Mecsek Mountains (1992, 1994). Moreover, besides the Nagyharsány Limestone, both the Zirc Limestone and the olistoliths arising in the Köszörűkőbánya Member of the Lábatlan Sandstone were attached to CZABALAY's listing by SCHLAGINTWEIT (1990a). The microfauna and microflora contained in the Nagyharsány Limestone were referred to as Urgon by BODROGI *et al.* (1994). By considering orbitolines as characteristic elements of "Urgon-type" platforms, GÖRÖG (1996) regarded all the important Hungarian *Orbitolina*-bearing formations as Urgon.

URGON IN THE ALPINE–CARPATHIAN REGION: AN OVERVIEW

In accordance with the fact that in the East Alpine – Carpathian system the Cretaceous period is characterized by enhanced tectonic activity, subaerial, shallow marine and deep marine environments varied both in space and time. Hence the term Urgon facies pertains to many structural units, being their distinctive facies (Figure 2). Also for a better understanding of their mutual relationships a study of KÁZMÉR & KOVÁCS (1985) is of outstanding interest. They recognized Permian and Early Mesozoic facies connections, linking them to outline the primary connections of now dismembered and displaced structural units.

Within the Alps the most well-preserved formations of the Urgon facies occur in the Helvetic Zone. In the Eastern Alps, however, it might be followed towards the East as far as Allgäu (HÖFLING 1979; SCHOLZ 1984; BOLLINGER 1988; FUNK 1988; CSÁSZÁR *et al.* 1990, 1994; SALOMON 1990; BODROGI *et al.* 1994;). The age of this formation is considered to be Late Barremian to Early Aptian. There are no remains of such a formation left in the Northern Calcareous Alps. An allusion to their sometime existence can be found in HAGN (1982) and HARLOFF (1989), but clear evidence was first given by SCHLAGINTWEIT (1987, 1990b) who reported a transported assemblage from both the Upper Cretaceous and Eocene sediments. The fossil association identified in pebbles reveals an exceptionally similar facies to that of the Bakony Mountains. The time-equivalent formations of the Northern Karavankes in the Southern Alps to that of the Pelso Unit have been completely eroded. Thus there is no way to restore the real situations.

The most typical formation of the Urgon facies in the Western Carpathians is found in the Manín Unit (MIŠÍK 1990; MICHALIK 1994). Similarly to that of the Helvetic Zone, it was developed in a gradually shallowing sequence which started under bathyal circumstances and resulted in platform drowning. The facies can be compared to that appearing in the Pieniny Klippen Belt, right in the neighbourhood of Humenné, and, in the High Tatras described here as the Wysoka Turnia Formation (LEFELD *et al.* 1985). In spite of the facies that is analogous to that of the Helvetic Zone, the Urgon of the Western Carpathians reaches up to the Upper Aptian, and may even be present in the Lower Albian, too.

In the Eastern Carpathians Urgon facies, similar also in age to those of the Helvetic Zone, appear in the Marmaros Mountains (CHERNOV 1971; CHERNOV & YANIN 1979; CHERNOV *et al.* 1980; KUSMICHEVA 1980). Moreover, they crop out in the area of Mount Rarău (BALTRES 1969) and the Hăghimasului Mountains (PATRULIUS 1965) too.

Formations in Urgon facies exist in many structural units of Transsylvania. Among them the most well-known ones are represented by the stratigraphic succession found in the Autochtonous of Bihar and in the Pădurea Craiului Mountains, both situated in the Apuseni Mountains (PATRULIUS 1976; MANTEA & BLEHAU 1980; BLEHAU *et al.* 1981; MANTEA 1985; DRAGASTAN *et al.* 1986; BUCUR *et al.* 1993; IONESCU 1994 *etc.*). This column bears good resemblance with the Nagyharsány Limestone of the Villány Zone, exhibiting a direct facial connection to it, as well. The one and only substantial discrepancy is reflected by intercalations of marl and sandstone formations within the Urgonian sequence of the Bihar Mountains. Formations known from the Haţeg Basin and confined to the Getic Unit (STILLA 1985), from the Perşani Mountains (PATRULIUS *et al.* 1968), from Kucaj-Svrljig, parts of the Suva Planina and Kucaj Zones according to DIMITRIJEVIĆ (1997), and from Tupiznica-Tepoš (JANKIČEVIĆ 1979) — the two latter being situated in Serbia — are to some extent comparable to those of the Apuseni Mountains.

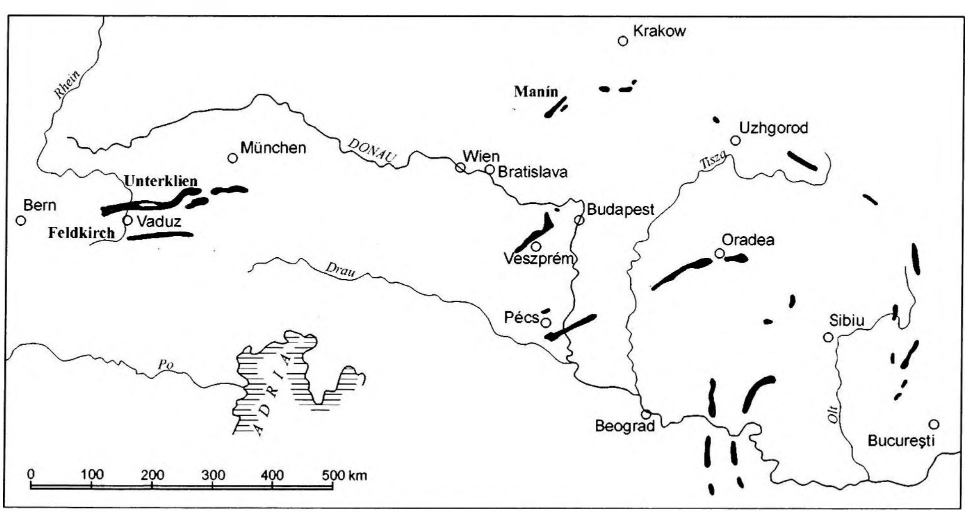


Figure 2. Occurences of the Urgon formations in the East Alpine – Carpathian system

Applied methods

In addition to a review of the whole of the relevant Hungarian literature, I made an attempt to peruse the literature necessary for describing the similar formations of neighbouring countries. With respect to the remarkably extensive literature concerning topics dealing with carbonate sedimentology I mainly focused on works of model value, particulary those concentrating on the Cretaceous. However, my efforts were restricted due to lack of access and, inevitably the review is still far from being complete.

After acquiring my own data and other those of other researchers, I chose field outcrops and borehole sections best suitable for detailed profiling in order to complete macroscopic features with my own observations. On the other hand, this also enabled the further performance of satisfactory sampling, too.

The methods for testing the samples collected were as follows:

— textural and facies analyses and determination of fossils using thin-sections (more than one thousand samples),

— studies of carbonates using the Scheibler-method (a few hundreds of samples — Partényi, Z., Hózer, F., Geological Institute of Hungary — GIH),

— X-ray powder diffractometry (Bognár, L., Farkas, L., Kovács-Pálffy, P., Rischák, G., GIH)

— thermal analyses (Földvári, M., GIH),

— trace element analyses using ICP (Bertalan, É., GIH),

— trace element analyses using flame photometry (12 samples — Spectroscopy Group, GIH)

— macroelement analyses (Soha, I., GIH),

— main element analyses, partly using ICP (GIH),

— radiometric age determinations (Balogh, K., Árva-Sós, E., Nuclear Research Institute, Debrecen),

— stable carbon and oxygen isotope measurements (78 samples — Hertelendi, E., Sándor, L., Veres, M., Nuclear Research Institute, Debrecen),

— Sr measurements (13 specimens — Hertelendi, E., Sándor, L., Veres, M., Nuclear Research Institute, Debrecen),

— micromineralogical analyses (Bagoly-Árgyelán, G.),

— malacological investigations (Czabalay, L., Bartha, A., GIH),

— Orbitolina studies (Görög, Á., Dept. of Palaeontology, Eötvös University),

— Ostracod studies (Monostori, M., Dept. of Palaeontology, Eötvös University).

I re-evaluated the Mesozoic portions of several hundreds of boreholes drilled in the foreland of the Vértes Mountains and in the Bakony Mountains. My goal was to construct isopach maps of each formation, to elucidate facies associations and to reconstruct the discrete steps of evolution. In order to achieve a critical interpretation of (1) the basin evolution and (2) global event correlation, I applied the most up-to-date results of sequence stratigraphy.

Subdivision of Urgon in Hungary

The most important data on the spatial and temporal relationships of Urgon in Hungary are summarized in cFigure 1, p. 172; Figure 3. Formations of Urgon facies in a narrow sense appear within two of the four substantial structural units — namely, in the Tisza and Pelso Units. It should be pointed out the facies could have never been developed in the deep-sea succession of the Penninic Unit whereas the time-equivalent formations to the west of the Rába Lineament have already been eroded.

The facies most closely related to the classical definition of Urgon is present in the Villány Zone of the Tisza Unit. It exhibits, however, a remarkably larger temporal extent. The lower part of the basal formation, known as Nagyharsány Limestone, does not reflect normal marine conditions. Upsection it then passes gradually, yet with frequent interrupted revertible intercalations, into the true Urgon facies which, in turn, becomes the stamp of the Villány Zone itself. The upper boundary of the formation is sharp because it is related to the abrupt change of the sedimentary environment indicated by the Bisse Marl Formation.

During Early to Middle Cretaceous the Mecsek Zone was dominated by basalt volcanoes and among the volcanic edifices sedimentary and volcano-sedimentary rocks were formed. Within certain horizons, the redeposited volcanic rocks are accompanied to a various extent by reef-constructing organisms and by typical fossils of Urgon — namely, rudist and other pelecypods and gastropods. Thus, a formation typical of Urgon facies has not yet been discovered in the Mecsek Zone.

In comparison with the Tisza Unit, the Pelso Unit exhibits limestones of Urgon facies in two stratigraphic horizons, even though both of them demonstrate a short stratigraphic extent. They are younger than formations traditionally considered to be Urgon. A Lower Albian horizon of Urgon, referred to as the Környe Limestone Formation, is areally restricted to a narrow strip in the foreland of the Gerecse and Vértes Mountains. It passes both horizontally and vertically in

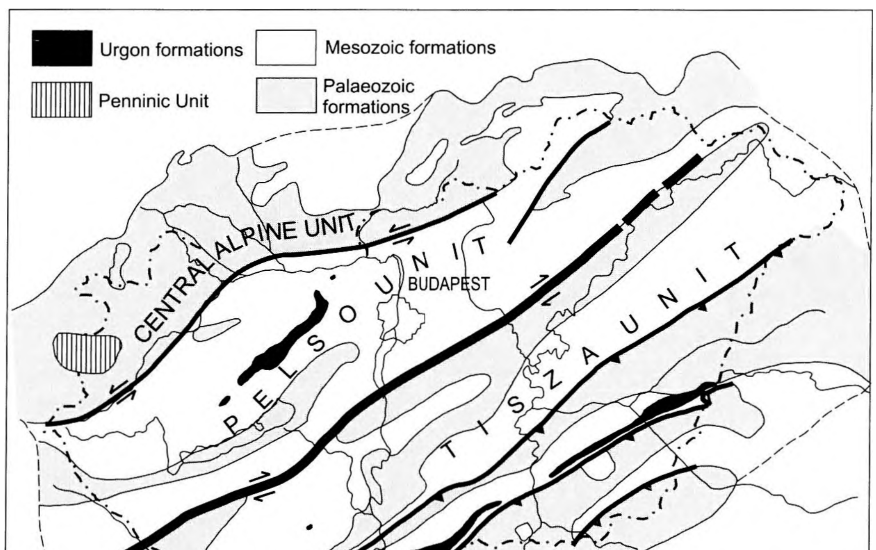


Figure 3. Extent of the Urgon formations in Hungary

various ways to its neighbouring formations. Another Urgon horizon, which is Late Albian in age and called Zirc Limestone Formation, occurs in the area between the localities Úrkút and Oroszlány. Both formations represent mostly a second, but subordinately a first unit of a sedimentary cycle.

A one-time Urgon formation, represented by some limestone boulders and blocks arising from olistoliths in the Gerecse Mountains, very likely occured in both spatial and temporal connection with the Környe Limestone.

Tisza Unit

Formations of Urgon facies are known from two of the three major structural zones of the Tisza Unit, *i.e.* the Mecsek and the Villány Zones. However, the Békés–Kodru Zone, which reflects deeper marine conditions, contains them in only one of its nappes, that is, the Vălani Nappe situated in the Apuseni Mountains. In the Mecsek Zone, the appearance of Urgon formations are linked to the volcanoes of the Mecsekjánosi Basalt Formation, whereas in the Villány Zone there is an Urgon formation developed in a sincere carbonate platform environment.

RUDISTID FORMATIONS OF THE MECSEK MOUNTAINS

While I was working on the project which focused on the Urgon facies in Hungary (rudistid platform limestones), the rudist-bearing volcanoclastics of the Mecsek Mountains aroused my interest, too.

The following evidence suggests a unique sedimentary environment: the rudists are preserved in redeposited volcanoclastics, thus not in their common carbonate environment; there is no gap between these beds and the subjacent pelagic sediments thereof; and there are contemporaneously buried fossils indicative of shallow-marine, neritic and pelagic conditions. Therefore, the goal of studying these rudist-bearing beds was the setup of an ecological, palaeoenvironmental and palaeogeographical reconstruction. For the purposes of stratigraphic age determination I chiefly utilized the results of ammonite studies carried out by Horváth (1968) and Bujtor (1993).

Previous studies and the geological setting

The formations under discussion are exposed in the central part of the Eastern Mecsek (Figure 4) and are a part of a syncline which is dissected by internal anticlines and some thrust planes. The position of the rudistid beds is within the Magyaregregy Conglomerate Formation (cFigure 1, p. 172). I concentrated the investigations on the following sections: Márévár Valley, Mecsekjánosi and Jánosipuszta (Figure 5). However, I also carried through some studies of a lesser intensity at Vékény Valley.

The rudist-bearing formation of the Mecsek Mountains was discovered by Hofmann at the turn of the previous century. He also found the aforementioned sections which have become famous since that time. His activity and results were, however, first posthumously reported by Vadász (1912). Hoffmann managed to collect a remarkably ample assemblage at outcrops of the sections mentioned before; "from tuffs of augite porphyrite and from beds of breccia-conglomerate", as he formulated. He was keenly interested in bivalves. During his life Hoffmann identified 30 taxa which he had collected himself (Hoffmann & Vadász 1912–1913). The most important rudists among them are the following: *Valletia germani* (P. *et* C.), *Heterodiceras semistriatum* (Hofmann), *Monopleura urgonensis* Matheron, *M. boeckhi* Hofmann, *Bicornucopina petersi* Hofmann and *Megadiceras* sp. A *Requienia lonsdalii* (Sow.) was reported by Noszky (1948). It was later redetermined to be *Toucasia* by Czabalay (1971) who, for that matter, described *Megadiceras hofmanni* Czabalay as well.

In addition to bivalves, Vadász (1912) and Hofmann & Vadász (1912) gave an account of an

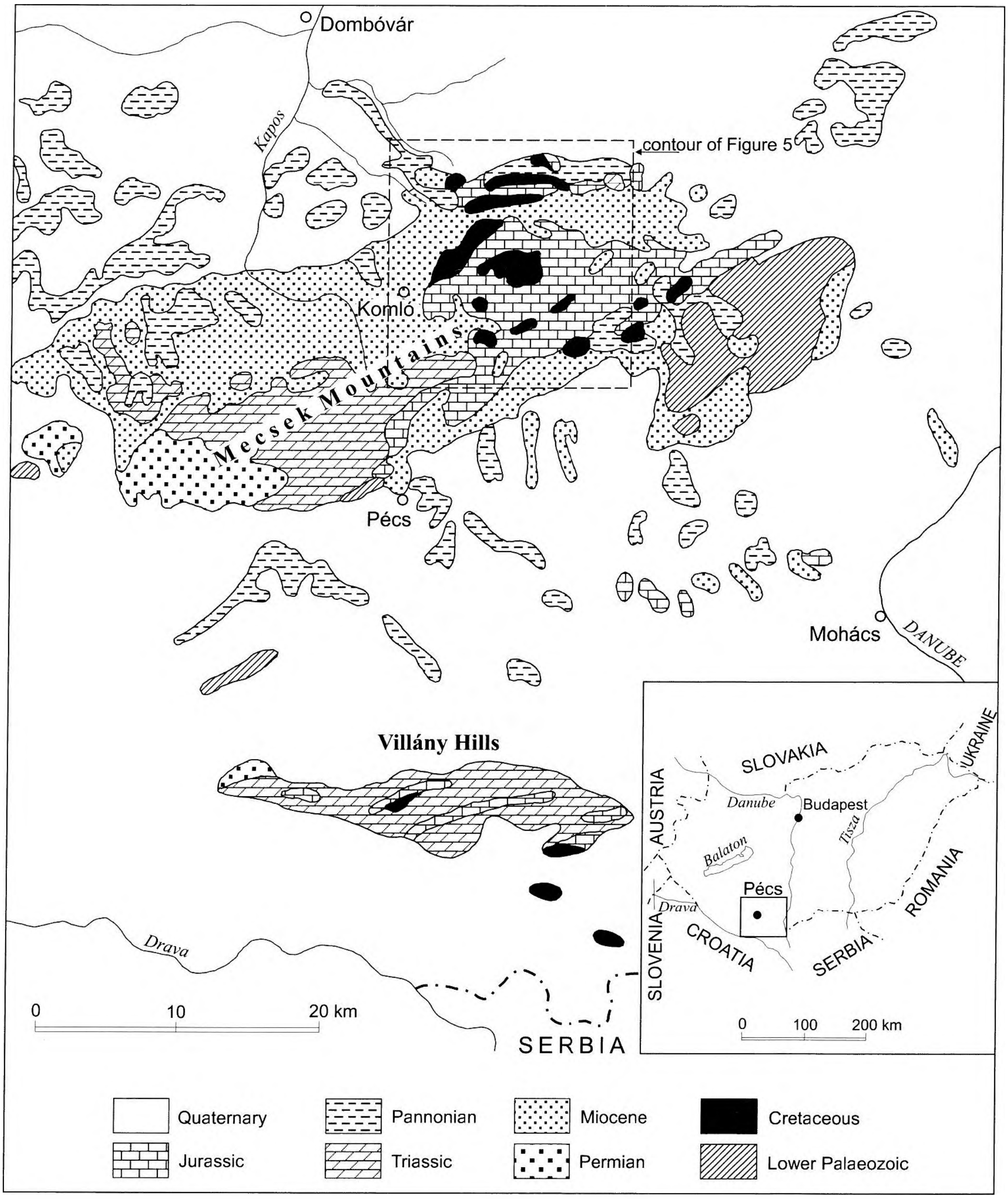


Figure 4. Geological map of the Mecsek Mountains (after Császár & Turnšek 1996) with the frame of Figure 5

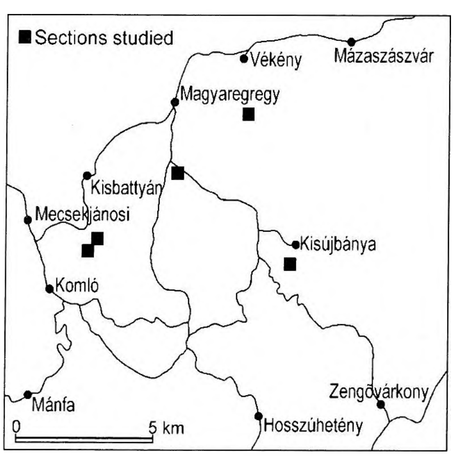


Figure 5. Location map of the sections studied in the Eastern Mecsek (the frame of this map is indicated in Figure 4)

assortment of fossils stored in the collection of the Geological Institute of Hungary: foraminifers, sponges, corals, crinoids, brachiopods, gastropods, ammonites and belemnites. As revealed by palaeontological records, and, in particular, by the taxa Chamidae and Caprinidae, the deposition was suggested by Vadász in a shore (1912) and shallow-marine, beach (1935) environment. By disclosing seven coral taxa, Vadász (1935) again released an important assemblage which had originally been determined by Hofmann. An ample (12 taxa) assembly collected by Hofmann, Noszky, Reményi and

KOLOSVÁRY at the Korhadtfás Valley was published and prettified with some of KOLOSVÁRY's illustrations (1954). This work corroborated with the opinion of TELEGDI-ROTH (1935) who argued that the fauna of the Mecsek Mountains represented a cross between the West European and the South European assemblages.

The first mention of ammonites and belemnites in the Cretaceous of Mecsek was made in 1912 (VADÁSZ 1912). In 1935, he listed 10 ammonites and belemnites taxa. In 1959, HORVÁTH (1959, 1968) collected for her thesis a rich ammonite assemblage at the classical occurrences mentioned above. Besides pelecypods, brachiopods, and echinoderms she also identified the ammonite assemblage derived from the variegated, tuffitic beds of the Kisújbánya section characteristic for the Upper Valanginian [*Neocomites neocomiensis* (D'ORBIGNY), *Lithoceras regale* BEAN, *Holcostephanus (Astieria)* sp., *Acanthoceras hystrichoides* UHLIG, *A. cf. hoheneggeri* UHLIG]. HORVÁTH found this breccia and conglomerate bed of 30 to 40 cm thickness to be different from its underlying rocks, on the basis of its abundant fauna of a wide variety, which is as follows: calcareous algae, sponges, hydrozoans, corals, bivalves, gastropods and echinoderms. Following VADÁSZ's theory, she pointed out that "apart from the elements of the littoral zone, in this clastic succession fossils of shallow neritic zone are also present. Regarding both the species and specimens, a predominance of thick-shelled pelecypods and gastropods predominate." She considered the ammonites to be "redeposited items of Valangian beds".

HORVÁTH, although her work was deficient in its listing of the fossil taxa, stated that the fossils of the conglomerate banks situated behind the open-air pool at the Márévár Valley display similarities to those found in the conglomerate banks of the Kisújbánya section. According to HORVÁTH (1959) corals prevail in the fossiliferous conglomerate bed of the Korhadtfás Vallley at Jánosipuszta.

The first comments on the Early Cretaceous geological history of the Mecsek Zone, supplemented with palaeogeographical sketch maps, were recorded by FÜLÖP (1961); accordingly, sedimentation, taking into consideration the entire area of Hungary, progressed only in separate firths. HORVÁTH (1968) summarizes the Early Cretaceous geological history of the Mecsek as follows: at the end of the Valanginian the seafloor started to emerge, whereas sediment grain size gradually increased; finally, the sea transformed into land. However, ammonites found in the "transgressive conglomerate" gave her the "impression of weird items within the faunal assemblage". HOFMANN (in VADÁSZ 1935) asserts that yields of Early Cretaceous volcanism were extruded via elongated supply gashes. VADÁSZ assigned their occurrence to the orogenic phases. The volcanism, commencing with lava production and proceeding with tuff scatter, is Hauterivian (VADÁSZ 1935) or Berriasian to Hauterivian (WEIN 1967) in age. According to BILIK (1974, 1983) there was a Berriasian to Valanginian, and then, an Hauterivian phase. There are various sorts of dykes and conduits intersecting Triassic formations so that they can be tracked to the west to as far as Hetvehely. Moreover, in the east they occur within the granitoid rocks near Fazekasboda (WEIN 1967). WEIN (1965, 1967) and MAURITZ (1913) recognized a volcanic centre in the vicinity of Magyaregregy, whereas VADÁSZ (1935) detected one between Kisújbánya and Magyaregregy. The thickness of the volcanic sequence was estimated to be 675 m at this place, 300 m on the northwestern limb, 90 m in the central part of the Kisújbánya Basin, and in some places, only 30 m. The volcanism represented the final stage of a continental rifting under shallow-marine circumstances (BILIK 1980). The volcanic sequence is made up of alternations of hyaloclastites, lava breccias, massive lava flows and pillow lavas. BILIK found that the thicknesses of the volcanic products did not not exceed 1000 m. The marl comprising Valanginian cephalopods is considered as a bathyal sediment by WEIN (1967). Conglomerates and sandstones of Hauterivian age were regarded being littoral facies by every author (HOFMANN & VADÁSZ 1912–1913; VADÁSZ 1935; WEIN 1967; VADÁSZ & FÜLÖP 1959; HORVÁTH 1968).

The picture delineated above was also accepted and included in the explanatory notes published along with the 1:10 000 scale geological maps by mapping geologists (BILIK *et al.* 1978; FÖLDI *et al.* 1977; HÁMOR *et al.* 1967, 1974; HETÉNYI *et al.* 1968; NAGY *et al.* 1973b, 1978). Instead of lithostratigraphic or lithologic units these maps display chronostratigraphic units. In spite of this, the Mecsekjánosi Basalt Formation and members thereof are easy to recognize on the map. However, formations deposited within and/or above the Mecsekjánosi Basalt Formation, namely the Hidasivölgy Marl Formation, the Magyaregregy Conglomerate Formation and the Apátvarasd Limestone Formation cannot be distinguished from each other.

Mineralogical, petrological and geochemical as well as genetical studies on the Mecsekjánosi Basalt Formation were recently carried out by HARANGI (1994), HARANGI & ÁRVA-SÓS (1993) and HARANGI *et al.* (1996), partly in order to decipher its role in the structural evolution.

Magyaregregy Conglomerate is characterized by an alternation of conglomerates, sandstones and siltstones, all of them derived from the Mecsekjánosi Basalt. It may interbeddedly contain various carbonate beds of the Hidasivölgy Marl and crinoidal beds of the Apátvarasd Limestone, respectively. Rudists and other shallow-marine fossils have accumulated, occasionally in rock-forming masses, in the lower third of the Magyaregregy Formation.

ATOLL-TYPE STRUCTURES AND RUDISTS

In *The Concise Oxford Dictionary of Earth Sciences* [ALLABY & ALLABY (eds) 1990] an atoll is briefly defined as a "ring-shaped organic reef that encloses or almost encloses a lagoon, and which is surrounded by the open sea. The reef may be built of coral and/or calcareous algae. An atoll is built on an existing structure such an extinct, submerged volcano". The most comprehensive formulation is found in *Glossary of Geology* [BATES & JACKSON (eds) 1987]. It says: "A coral reef appearing in plan view as roughly circular and surmounted by a chain or ring of closely spaced low coral islets that encircle or nearly encircle a shallow lagoon in which there is no pre-existing land or islands of non coral origin; the reef is surrounded by a deep water of the open sea, either oceanic or continental shelf. Atolls range in diameter from 1 km to more than 130 km, and are especially common today in the western and central Pacific Ocean. Several fossil atolls have also been described. Etymol: native name in the Maldive Islands which are typical examples of this structure. Syn: lagoon island, ring reef, reef ring."

The geological study of atoll structures dates back to DARWIN (1842, 1851). He framed his model as follows: "There is but one alternative; namely, the prolonged subsidence on the foundations on which the atolls were primarily based, together with the upward growth of the reef-constructing corals. On this view every difficulty vanishes; fringing reefs are thus converted into atolls, the instant the last pinnacle of land sinks beneath the surface of the ocean." (quotation from WOODROFFE *et al.* 1990). Thus one of the conditions of the formation of an atoll is a continuously subsiding substrate. He mentioned hanging reefs and front reefs as its preceding stages. He expected his model to be proved with the help of the keen interest of some millionaire. The aim was to locate a borehole. His dream, however, came only true one century later. On the Eniwetok atoll, beneath coral limestone 1200 m thick, basalt was cored (LADD *et al.* 1953).

Stages of atoll evolution were summarized in an illustrative manner by AYERS (1984) and ANDRI & ROSSI (1993). The volcano emerges above the surface of the sea. Along the edifice, reef-forming organisms constitute to form a zone that is on and off interrupted at the sea level. Hence fringing reefs are developed (Figures 6 and 7). Owing to the — presumably progressive — subsidence of the seafloor the build-up of the ring structure can keep up (NEUMANN & MACINTYRE 1985; JAMES & MACINTYRE 1985) with this sinking. Therefore, the ring structure will more and more move away from the subaerial part of the volcanic mass whereas the lagoon beyond the ring takes on an increasingly definite shape. The coral ring acting as a carbonate factory, together with its environs, provides a remarkable amount of detrital material. These clastics then stretch seaward deep down on the comparatively slight flanks of the volcanic edifice. Accordingly, the accumulated detrital mass builds a fore-reef slope that is significantly steeper than the slope of the volcano itself.

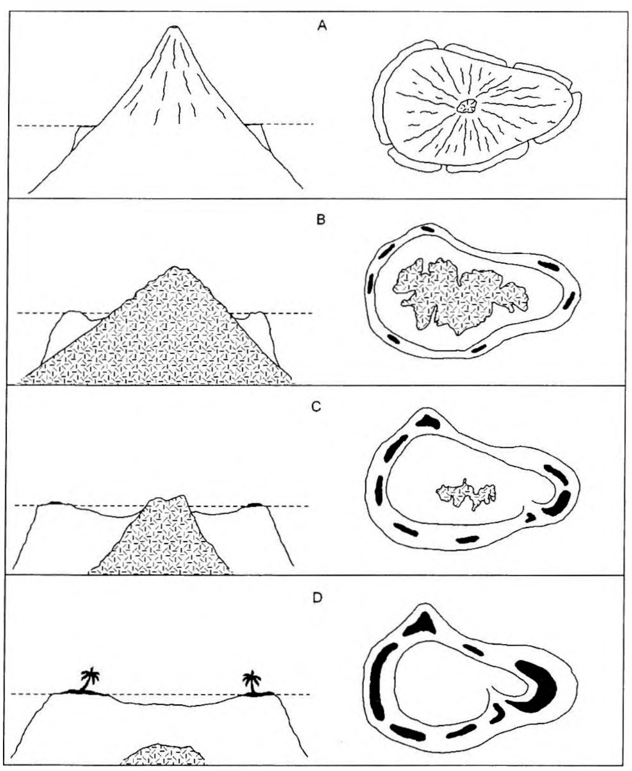


Figure 6. Formations and development of atolls according to AYERS (1984)

An abrupt sea level rise or sea level fall bears hard on the evolution of the atoll (Figure 8). A sudden sea level drop results in the emersion of the atoll to the surface; karstification commences. On the other hand, a rapid sea level rise cannot be counterbalanced by bioproduction. Thus on the surface of the atoll, pelagic sedimentation of a reduced rate takes the place of carbonate production.

The reconstruction depicted above strongly simplifies the function of a volcano. We are scant of works that consider the volcanoes also from their mass-provider point of view. Or rather, they are difficult to find.

From the standpoint of the present study, the most important information available does deal with guyot-like atolls from the Pacific area, south-west to Japan (LADD *et al.* 1974; MATTHEWS *et al.* 1974; SHIBA 1979; KONISHI 1984; WINTERER & METZLER 1984; GRÖTSCH 1991; GRÖTSCH & FLÜGEL 1992; GRÖTSCH *et al.* 1995 and ARNAUD-VANNEAU *et al.* 1995). Their studies go back to the 1950s. Their attention focuses on acoustic, magnetic and seismic surveys of the ocean floor (*e.g.* HAMILTON 1956; MENARD 1964; HEEZEN *et al.* 1973a, 1973b). Guyot is defined in the *Collins Dictionary of Geology* (FARRIS LAPIDUS 1990) as "guyot or tablemount, n. a seamount of more or less circular form and having a flat top. Guyots are thought to be volcanic cones whose tops have been truncated by surface-wave action. They occur in deep ocean, usually at depths exceeding 200 m, and are generally composed of alkali basalt, which differs from the oceanic tholeiite in having a higher content of K, Na and Ti. Guyots are found chiefly in the Pacific Basin, where they occur in groups, as do the present volcanic island chains." The respective origins of countless seamounts and of the hot-spot volcanism itself is explained by the Cretaceous shift of the Pacific plate above a mantle plume, or, South Pacific megaridge (MCNUTT & JUDGE 1990; MCNUTT *et al.* 1990). The similar or even uniform geochemical patterns of guyots and those of Mecsekjánosi Basalt, respectively, are very apparent. In the light of the findings on Pacific atolls mentioned below, interpreting flat tops by means of the concept of abrasion due to wave action is suggested here to be fictious.

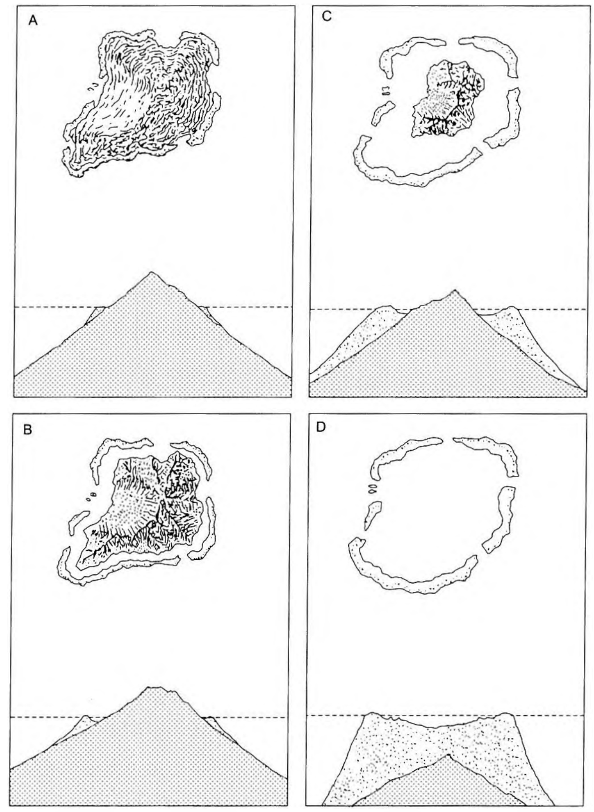


Figure 7. Formations and development of atolls according to ANDRI & ROSSI (1993)

On the basis of their shape and structure, seamounts are classified by WINTERER et al. (1989) as:

— Type V: volcanic edifices with slight acoustic penetrativity, and with their primordial morphology retained.

— Type B: seamounts with frontal fringing reef.

— Type A: submerged, flat-topped atolls whose shallow internal depressions are encircled by mildly emerged fringes.

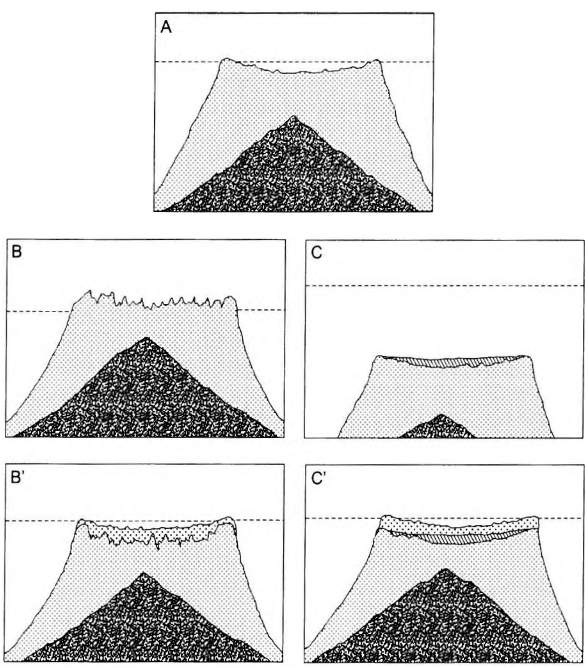


Figure 8. The effect of sea level changes on the development of atolls (ANDRI & ROSSI 1993)

The knowledge of the buildup of atolls was considerably supplemented by rock samplings. In order to do this the most rapid and most economical dredging techniques are used. Although a large proportion of DSDP drillings were located on atolls, the data available to me originated from dredge samples (MCNUTT *et al.* 1990; GRÖTSCH 1991; GRÖTSCH & FLÜGEL 1992).

In what follows I shall give a synopsis of the data from atolls found in, or related to, the Cretaceous formations. Volcanoes providing the basis for atoll development were formed in the region of the Pacific realm in question until the Hauterivian. Palaeontological and stratigraphical data derived from overlying sediments caused GRÖTSCH & FLÜGEL (1992) to arrive at the conclusion that a strong aggradation took place during the Barremian–Aptian. It was followed by a sea level fall and then by a considerable sea level rise in the Late Albian, the latter being 180 m in amplitude. The lowstand resulted in karstification and in the formation of fringing reefs (WINTERER & METZLER 1984; KONISHI 1989; MCNUTT *et al.* 1990). During the time of the sea level rise phosphatic hardgrounds were formed and condensed sedimentation took place at many atolls in the area studied. On the basis of samples collected chiefly from Type A atolls, a couple of facies relative to platform drowning were distinguished by GRÖTSCH & FLÜGEL (1992): a) reef facies (platform rim), b) oolite facies (platform top), c) beach cobbles facies (shore), d) reef facies (platform rim/upper slope), e) rudist meadow facies (platform top/upper slope), f) subtidal to hemipelagic sand facies (platform top/slope), g) hemipelagic quiet water facies (platform top/?upper slope), h) fore-reef slope facies (platform slope), i) pelagic facies, j) Fe-Mn stromatolites, k) pelagic reworking and breccia formation.

Facies a) to c) are considered as pre-drowning, d) to h) as syn-drowning, and i) to k) as post-drowning.

In the following a couple of important facies are considered.

The reef facies (platform rim) exhibits a wide variety of fauna and flora: scleractinian corals, hydrozoans, calcareous sponges, pelecypods (including monopleurids and caprinids), gastropods (including nerineids), echinoderms, various foraminifers (including orbitolines), coralline algae, green algae, solenoporacae and microproblematica. The fossils are embedded in framestone, rudstone or grainstone fabrics. Individual constituents are consistently coated by early marine, pore-lining isopachous cement.

Tiny, well-sorted, concentric ooids predominate in the oolite facies at the platform top. The grains are also bound by a thin, early marine isopachous cement. Both the cement and the ooids may have become silicified later.

Beach cobble facies on the shore was reported by GRÖTSCH & FLÜGEL (1992) in the case of only two atolls. The basalt pebbles 2 to 5 cm in diameter of the Type V atoll Woods Hole are derived from the coastal area of the still preserved volcano. The same pebbles were found at Darwin atolls.

Typical elements of the platform rim/upper slope reef facies are scleractinian corals and calcareous sponges which originate from the neighborhood of the rudist meadow. Therefore, this facies is regarded as a transitional facies to the rudist meadow. The absence of the early meteoric leaching event is evidenced by the occurrence of phosphatization that allowed the original structure of the preserved aragonitic organisms.

The rudist meadow is the most abundant type of facies; it is present at all three types of atolls. It is considered as the last high-energy facies before the passage into pelagic sedimentation. The eponymous monopleurids and caprinids, up to 25 cm in size, are often embedded in grainstone or in packstone. Skeletal fragments of sea urchins are quite frequent. (The presence of crinoids is indicative of platform drowning.) Solitary corals, calcisponges, bryozoans, calcareous algae, microproblematica and various foraminifer assemblages can also be mentioned here. Some foraminifer taxa should be highlighted, such as *Cuneolina cf. pavonia* D'ORBIGNY, *Nezzazata* and some poorly preserved planktonic forms. The grains are coated with a thin, early marine-phreatic, isopachous cement, occasionally accompanied by dogtooth spar. Blocky calcites may also occur in place of the above. In many cases, the rock underwent significant phosphatization.

The subtidal to hemipelagic sand facies at the platform top/slope is viewed as the youngest formation above the wave base. It consists of fine-grained material of packstone texture, with a substantial fraction of detritus of reef-constructing organisms (sponges, corals, gastropods) and that of reef-dwellers (gastropods, rudists, echinoderms), foraminifers, as well as oncoids and ooids. Among the grains there is a marine, thin isopachous cement.

The most characteristic textures of the hemipelagic quiet water facies of the platform upper slope are: foraminiferal wackestone, and subordinately rudistid or gastropod-bearing floatstone. Other important fossils are ostracods and various detrital algae, thus indicating the lower part of the photic zone as the region of formation (GRÖTSCH & FLÜGEL 1992). The rock is often strongly bioturbed and phosphatized. In the case of "MIT" and Allison atolls, the formation was found to be deposited on a karstified surface. Dating was advanced by the following fossils: *Cuneolina pavonia* D'ORBIGNY, *Rotalipora* sp., *?Rotalipora ticinensis* (GANDOLFI), *?Rotalipora appenninica* (RENZ) and *Hedbergella* sp. This assemblage suggests a Late Albian age.

The pelagic facies occurs above a strongly phosphatized hardground which is associated to a hiatus of various degrees. The stretch of the hiatus depends on excessive currents which are, in spite of the fact of several hundreds of metres of water depth, devastating. Another factor is the hindered sedimentation (SHIBA 1979). The hiatus may extend to the *Rotalipora cushmani* Zone of the Middle Cenomanian; however, it may even reach the Miocene. The rock is often bioturbed, pelletoidal, it displays a wackestone texture, and it is rich in planktonic foraminifers. However, a couple of *Lenticulina* sp., phosphatized fish remain and belemnites also occur. The matrix was subject to phosphatization to a various extent; this might have affected the sparse pelagic ooids and oncoids, too.

The Late Cretaceous carbonate platform succession of the Wodejebato guyot was subdivided by ARNAUD-VANNEAU *et al.* (1995) by means of seismic measurements. Furthermore, palaeontological and carbonate sedimentological analyses were carried out on core samples derived from five boreholes. The thickness of the column ranges between 100 and 160 m. Boreholes were drilled in the lagoon, both in the internal and external edges of the guyot. Within the four sequences recognized, they distinguished mostly transgressive and highstand systems tracts. Three of the four sequences were roughly parallelled with the sea level change curve of HAQ *et al.* (1988), whereas the last one proved to be unidentifiable. They demonstrated that the greatest sea level fall took place just before the submersion of the platform. This is explained by the fact that pelagic sediments are deposited, without any transitional features, onto the karstified surface of a shallow-marine sediment pertaining to the highstand systems tract of the most restricted facies.

SECTIONS STUDIED IN DETAIL

Kisújbánya

Shallow-marine fossils occur in two outcrops, along a dirt road between Kisújbánya and Pusztaszentlászló, and in the road cut itself (Figure 9). The first schematic sketch was drawn by HORVÁTH (1959, 1968). In spite of the structural uncertainties of the figure, the position of the breccia-conglomerate bed is unambiguous. The position of the section I created is in accordance with that of HORVÁTH; this is located at the northern junction of the road and the forest. The Lower Cretaceous volcanoclastic sequence is underlain by the Tithonian to Berriasian Márévár Limestone Formation (Figure 10: a). This is in tectonic contact with the hyaloclastites of the Mecsekjánosi Basalt. The hyaloclastites then progressively develop upsection into the grey to greyish-red, ammonite-bearing beds of the Hidasivölgy Marl Formation. Above the marl there is a breccia-conglomerate bed of 40 cm thickness. It is overlain by a soft, pelitic sandstone body of the Magyaregregy Conglomerate containing transported, that is, ripped and crumpled, silty marl lenses. Due to tectonic deformation the initially northern dip direction of the succession is now pointing to the south. Thus the stratigraphic column portrayed above appears to be repeated towards the north. The section is capped by an alternation of bluish-grey, micritic, platy pelagic limestone and dark grey clay and clay marl. The only macrofossil in these beds is represented by carbonized plant remains. The actual relationships between the succession above and the beds consisting of marl and limestone are still unclear.

Hitherto 47 pelecypod and gastropod taxa were found in Kisújbánya. Having worked on my collection from the road cut, CZABALAY

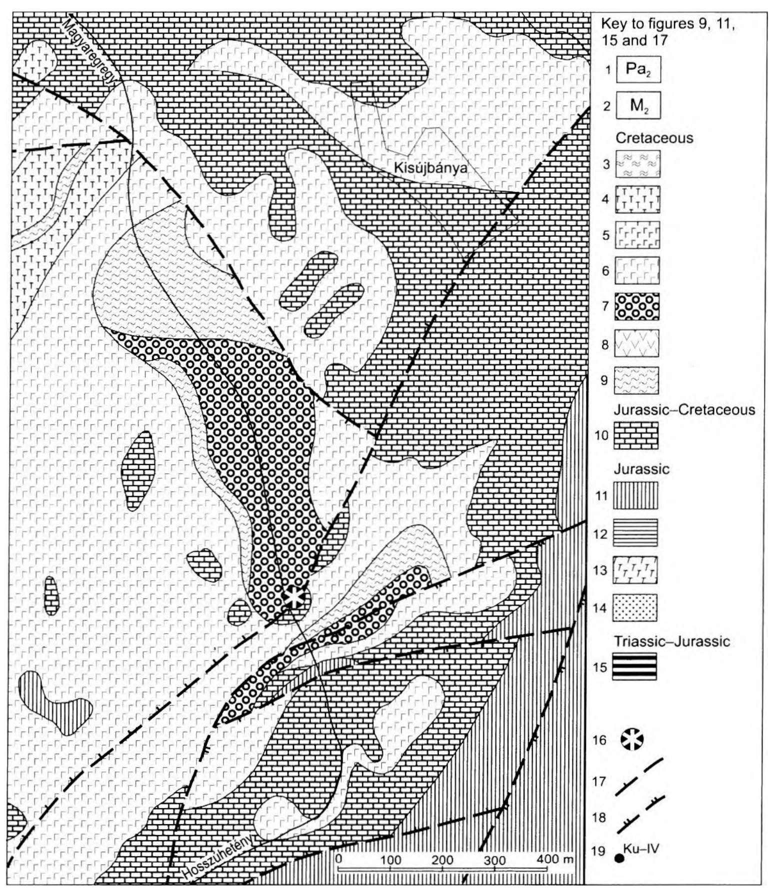


Figure 9. Geological map of the Kisújbánya environ with indication of the Kisújbánya section, after NAGY *et al.* (1975) and HETÉNYI *et al.* (1976)

1 — Upper Pannonian; 2 — Middle Miocene; 3 — Vékény Marl Formation; 4–6 — Mecsekjánosi Basalt Formation: 4 — Alkaline trachite; 5 — Spilite pillow lava; 6 — Basalt; 7 — Magyaregregy Conglomerate Formation; 8 — Apátvarasd Limestone Formation; 9 — Hidasivölgy Marl Formation; 10 — Márévár Limestone Formation; 11 — Upper Jurassic (limestone) formations; 12 — Dorogó Calcareous Marl Formation (Middle Jurassic); 13 — Komló Marl Formation (Lower to Middle Jurassic); 14 — Sandstone and marl with Gryphaea (Lower Jurassic); 15 — Mecsek Coal Formations; 16 — Sections studied; 17 — Normal faults; 18 — Reverse faults; 19 — Boreholes

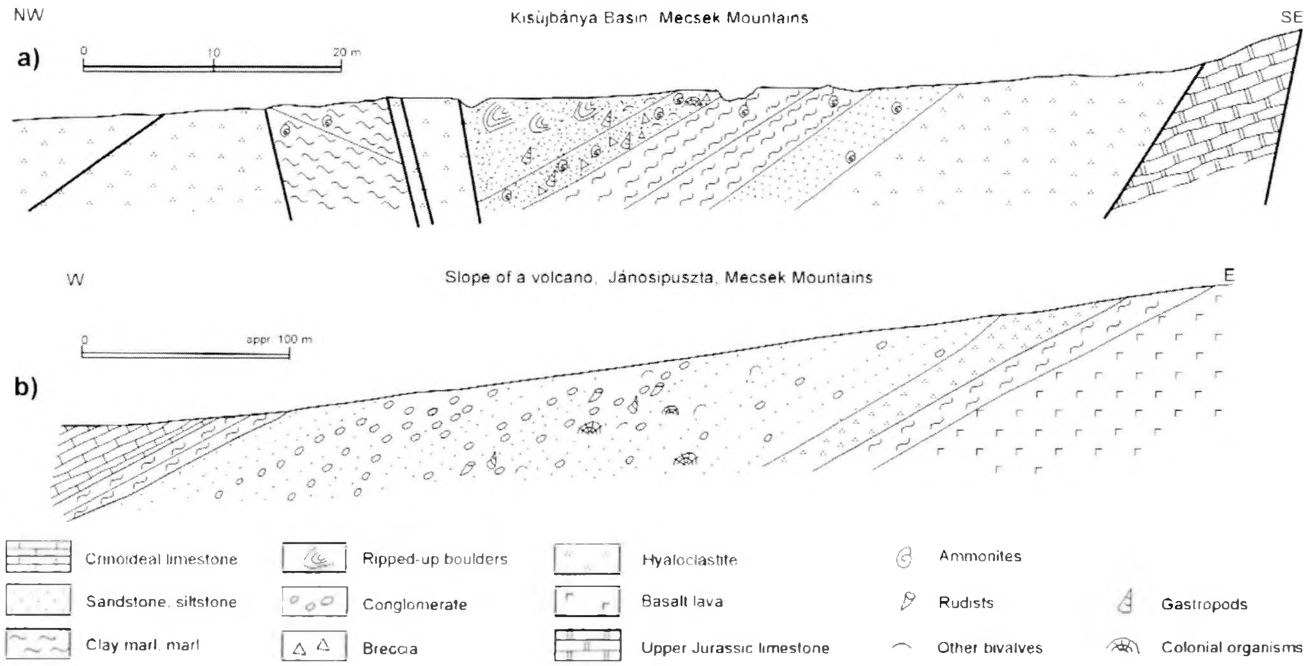


Figure 10. Geological cross-sections at Kisújbánya and Jánosipuszta

(1990, 1991) was the first to determine 25 taxa thereof (Table 1). A majority of the fossils is obtained from the breccia-conglomerate bed.

Ammonites and belemnites that occur in Cretaceous sediments of the Mecsek Mountains were already mentioned by VADÁSZ in 1912, who described 10 taxa of amonnites and belemnites in 1935. HORVÁTH (1968) recognized rich rudist assemblage in her record collected in 1959 for her thesis from the above-mentioned well-know localities. CZABALAY (1971) identified the *Megadiceras hofmanni* CZABALAY species from this record.

Although rudists [*Valletia germani* (P. *et* C.), *Megadiceras hofmanni* CZABALAY, *Heterodiceras* sp. and *Monopleura* sp.] are the most frequent components of this assemblage, nearly half of the rudist genera (*e.g. Caprina, Bicornucopina* and *Toucasia*) present in the Mecsek Mountains are missing from this outcrop. Other shallow water pelecypods (Ostreidae, *Chlamys etc.*) and different varieties of gastropods (mainly *Nerinea* species) are also quite frequent.

HORVÁTH (1959) mentioned four Anthozoan taxa that originated from this section, whereas TURNŠEK (CSÁSZÁR & TURNŠEK 1996, 1997) identified only three species in the record that I collected.

The numbers of pelecypod and gastropod species, as well as their density, are less abundant in sandstone layers overlying the conglomerate bed; rudists are completely absent. In spite of the breccia–conglomerate horizon, in sandy and marly beds shallow marine fossils are absent but these beds are enriched in ammonites. Most of them come directly from under the conglomerate, and from the conglomerate itself. HORVÁTH's lists of fossils contain 19 ammonite and 4 belemnite taxa. BUJTOR (1993) described the following ammonites: *Phylloceras (Hypophylloceras) ex. gr. thetys* (D'ORBIGNY), *Calliphylloceras calypso* (D'ORBIGNY), *Haploceras (Neolissoceras) salinarium* UHLIG, *H. (N.) grasianum* (D'ORBIGNY), *Leptotetragonites honnoratianus* (D'ORBIGNY), *Kilianella lucensis* SAYN., *Protetragonites quadrisulcatus* (D'ORBIGNY), *Lytoceras* sp. *aff. sutile* OPPEL, *Olcostephanus drumensis* KILIAN, *Thurmanniceras pertransiens* (SAYN.).

The conglomerate bed occurring at the south-eastern corner of the cemetery at Kisújbánya (Figure 9) is characterized by the same lithologic features. According to HORVÁTH its fossil assemblage is also similar to the southern outcrop.

Table 1

List of bivalves and gastropods of the Kisújbánya section, determined by L. CZABALAY

Nerinea zumoffeni DELPEY	*Gyrodes* sp.
Nerinea sp.	*Nerita* sp.
Nerinella lomparti CALZADA	*Neritopsis* sp.
Nerinella sp.	*Tylostoma bulimoides* D'ORB.
Eucyclus sp.	*Arcostreon rectangularis* (ROEMER)
Tethis renevieri DE LOR.	*Aetostreon* sp.
Chlamys landeronensis DE LOR.	*Ctenostreon probiscideum* DE LOR.
Chlamys sp.	*Astarte dimidiata* COQUAND
Diplodonta sp.	*Panopea carteroni* D'ORB.
Semisolarium moniliferum (MICHELIN)	*Fimbria* cf. *gaultina* PICTET et ROUX
Semisolarium conoideum (FITTON)	*Heterodiceras* sp.
Nummocalcar sp.	*Monopleura* sp.

Mapping-borehole, Kisújbánya–IV, situated close to the southern outcrop, revealed a 1.1 m thick intercalation of coral-bearing limestone in sandstone (Földi *et al.* 1977). Unfortunately the borehole is not accessible and therefore its coral-bearing limestone is not an option for control.

Jánosipuszta

The Korhadtfás Valley, which is situated close to the children-sanatorium next to Mecsekjánosi has been well known since the work of Hofmann (see Figure 11, bPlate I: 1, 2, p. 65; cPlate I: 1–4, p. 188). The detailed geological map made by Noszky (1948) indicates small patches of crinoidal limestone underlain by Lower Cretaceous volcanic rocks in the valley. A thin-section made from this limestone contains the following assemblage of fossils: foraminifers, radiolarians, gastropods and pelecypods.

The first cross-section of the valley was made by Horváth (1959) in her thesis. On the sketchy profile compiled by myself, the Mecsekjánosi Basalt is overlain by a relatively thick bundle of the Hidasivölgy Marl (Figure 10: b) in which Horváth recognized a *Neocomites neocomiensis* (d'Orbigny). This formation is followed by the Magyaregregy Conglomerate, which is characterized by an alternation of sand and conglomerate beds derived from the underlying volcanic rocks. Layers of this formation enriched in fossils can be found 30 m above the hidden boundary of the Hidasivölgy and Magyaregregy Formations. The section is composed of poorly bedded, altered sandstone with diverse amounts (16–64%) of carbonate cement in which well-rounded basalt pebbles of 1–5 cm in diameter also occur (Figure 12). The hardness and carbonate content of the rock is strongly associated with the fossil content, which usually accumulates in irregular-shaped lenses.

Anthozoans are the most frequent fossil components of the sections labelled as Jánosipuszta 1 and 1/a. (The earlier collected fossils are not indicated in Figure 13, because their exact places cannot be identified). The sizes of the colonies vary between 2 and 20 cm. Kolosváry (1954) described 12, whereas Turnšek mentioned 28 taxa from here. (Table 2)

The other important groups of fossils are gastropods and pelecypods. In reports made by Czabalay there are only 5 gastropod taxa and 23 bivalve taxa. Among these bivalves rudists and ostreids are significant. These, together with nerineids, are typical components of the shallow water environment. Brachiopods and 4 ammonites indicating a deeper water (bathial) environment are

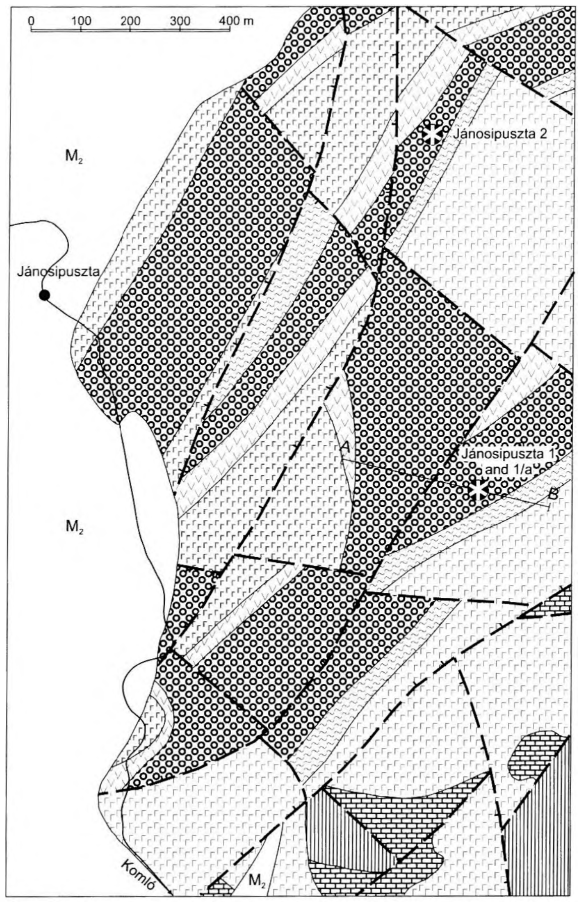


Figure 11. Geological map of the Jánosipuszta environ with indication of the Jánosipuszta sections, after Hámor *et al.* (1969, 1974a). For legend see Fig. 9

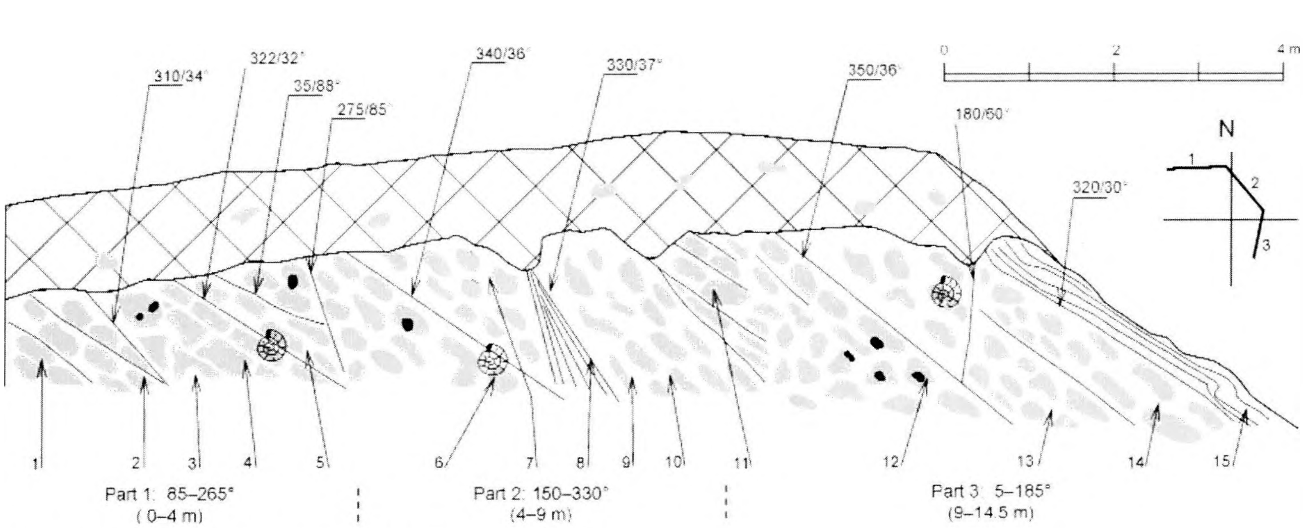


Figure 12. Geological cross-section of the Jánosipuszta 1 section

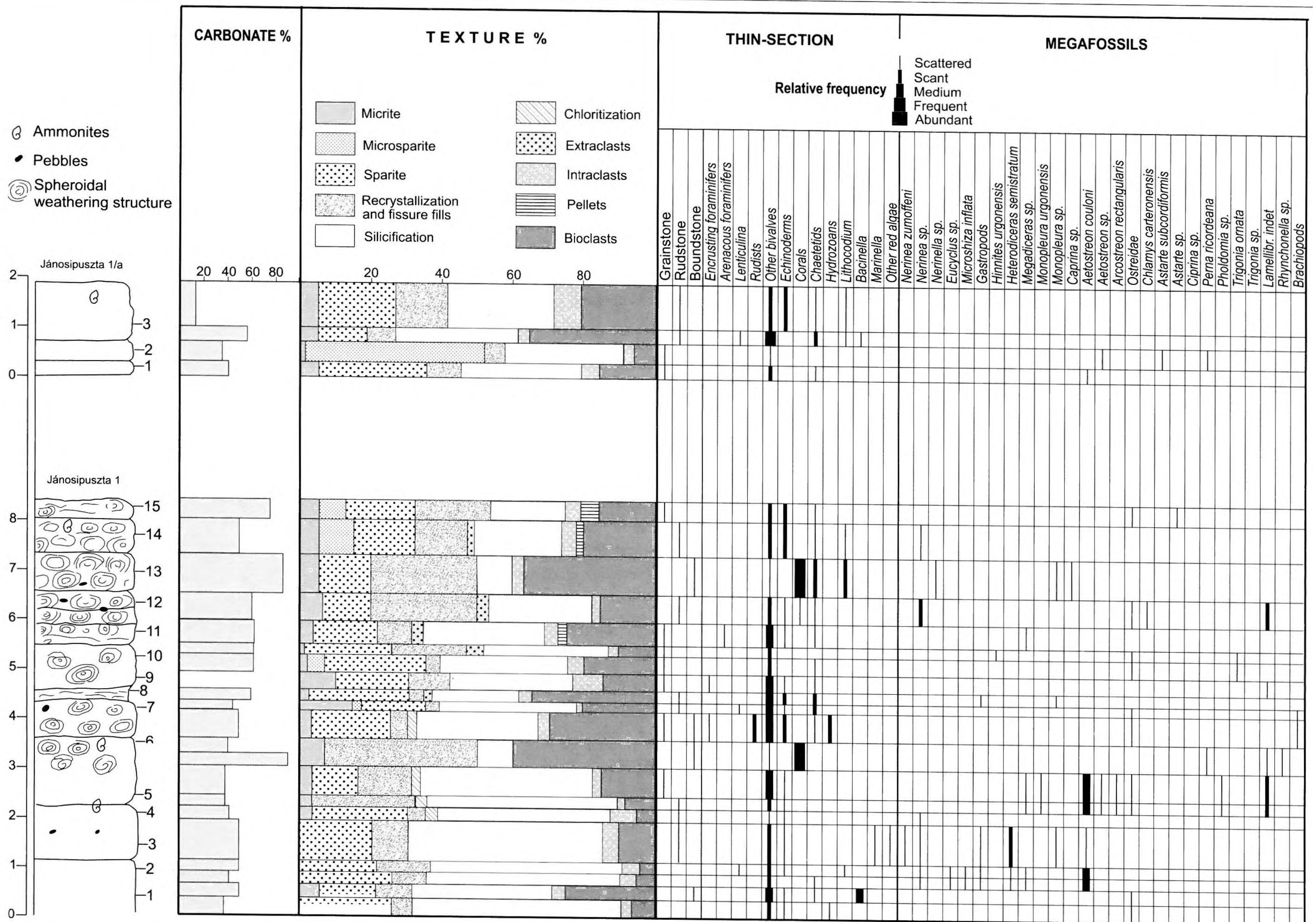


Figure 13. Lithologic column of the Jánosipuszta 1 and 1/a sections with results of investigations

Table 2

List, number and stratigraphic range of corals, chaetetopsis and stromatoporids collected in the Mecsek Mountains (after TURNŠEK in CSÁSZÁR & TURNŠEK 1996)

Species	Mecsek			Stratigraphic range					
	J	M	K	V	H	B	A	Al	C
Diplocoenia decaseptata KUSMICHEVA 1966	1			—					
Microsolena guttata KOBY 1898	2			—	—	—	—		
Microphyllia cf. *undans* (KOBY 1885)	1			—	—	—	—	—	
Paretallonia bendukidzae SIHARULIDZE 1972	1				—				
Synastraea bellula D'ORBIGNY 1850	3				—	—			
Actinaraea tenuis MORYCOWA 1971	5				—	—	—		
Columnocoenia ksiazkiewiczi MORYCOWA 1964	3		1		—	—	—		
Adelocoenia biedai MORYCOWA 1964	1				—	—	—		
Dimorpharaea barcenai (FELIX 1891)	1	2			—	—	—		
Eugyra pussila KOBY 1898	1				—	—	—		
Microsolena distefanoi PREVER 1909	2				—	—	—		—
Polyphylloseris convexa FROMENTEL 1857	1				—	—	—		
Microsolena exigua KOBY 1887	8	2			—	—	—		
Siderofungia irregularis FELIX 1891	1				—	—	—		
Stylina parvistella VOLZ 1903	12				—	—	—		
Thamnasteria meandra (KOBY 1898)	2				—	—	—		
Thamnasteria sinuosa MORYCOWA 1964	6				—	—	—		
Placophyllia curvata TURNŠEK 1974	1					—	—		
Microsolenastraea balcanica TURNŠEK 1981	2					—	—		
Palaeopsammia zljebinensis TURNŠEK 1981	2					—	—		
Thamnaraea mammelonata TURNŠEK 1981		1				—	—		
Mesomorpha ornata MORYCOWA 1971	1						—		—
Heliocoenia rarauensis MORYCOWA 1971	3	1					—		
Dimorphastraeopsis patellaris (STOLICZ. 1873)		3	1					—	
Latiastraea mucronata SIHARULIDZE 1979	1							—	
Myriophyllia propria SIHARULIDZE 1979	1							—	
Confusiforma sp.	3								
Enallhelia sp.	1								
Epistreptophyllum sp.	2								
Dehornella sp.	1								
Solenopora sp.			1						

Abbrevation of the locations: J = Jánosipuszta, M = Márévár Valley, K = Kisújbánya. *Stratigraphic terms:* V = Valanginian, H = Hauterivian, B = Barremian, A = Aptian, Al = Albian, C = Cenomanian.

still unidentified. According to NOSZKY (1948) these beds are Valanginian based on *Toucasia carinata* (MATHERON), based on *Requienia lonsdalii* (SOW.), *Nerinea zumoffeni* DELPEY and *Nerinella lomparti* CALZADA; CZABALAY (unpublished report) considers their age to be Barremian–Aptian, although some *Heterodiceras* and *Megadiceras* species, which do not cross the Valanginian–Hauterivian border, are also present. Only two orbitolinas are mentioned from this environ of the outcrop and they represent their total amount.

The *Orbitolina scutum* (NOSZKY 1948) — sometimes written as *O. acuta* (NOSZKY 1952) — was found in glauconitic limestone at the northern edge of the Korhadtfás Valley; the *Orbitolinopsis kiliani* (PREVER) from the limestone bed, of 20 cm thickness and deposited between lava flows of the borehole Komló–XX was identified by MÉHES (1969). GÖRÖG (1996) expected a Barremian–Aptian age of the host rock (of an unknown sedimentary position) because of the uncontrollable specimens. In addition to the fossils recognized with on unaided eye the following ones were identified by myself in thin-sections: crinoid ossicles, Bacinella-colonies encrusted by *Lithocodium*, redalgae fragments, encrusting foraminifers, arenoceous benthic foraminifers and *Lenticulina* sp. Red algae and especially *Lenticulina* indicate a much deeper water environment than the other fossils. As the majority of macrofossils (gastropods and bivalves) have aragonite shells their preservation rate is very bad. Shells and other tests as well as rocks have been altered, so they cannot be easily identified. The degree of recrystallization sometimes exceeds 40%, in strong association with the ability of alteration (which in agreement with numerous researchers I prefer, as opposed to neomorphism). The matrix is sparry calcite.

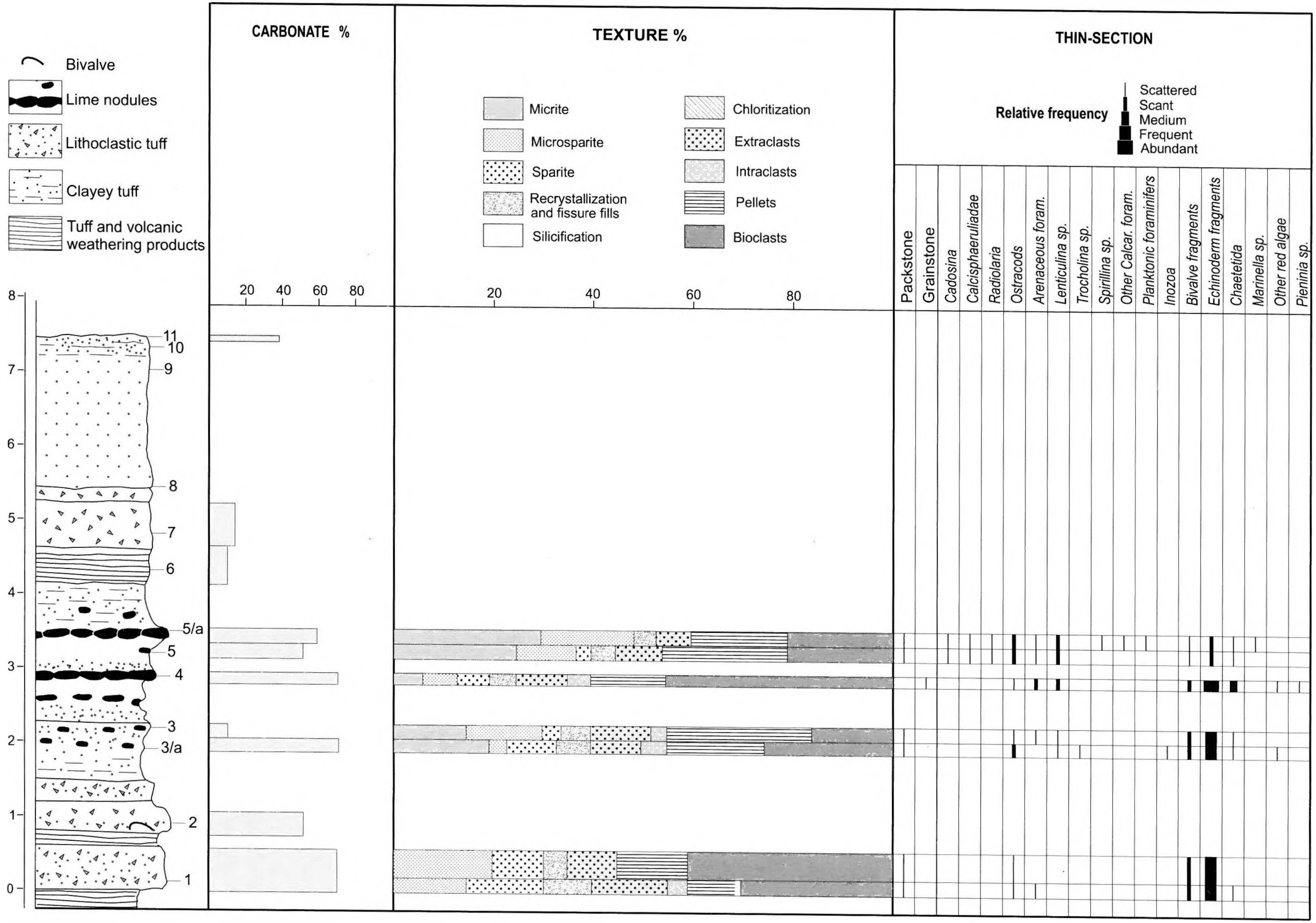


Figure 14. Lithologic column of the Jánosipuszta 2 section with results of investigations

Volcaniclast containing plagioclase of various size and type and other mineral fragments is the dominanat allochemical component (more than 40%). The section of Jánosipuszta 2 can be found in a valley, on the eastern side of the Korhadtfás Valley and oriented parallel to it. The section shows a gradual transition into the Hidasivölgyi Marl (Figure 11). In the 8 m thick section the following rock types, all barren of macrofossils, are found in alternation: sandy, silty marl, mildly calcareous marl with lithoclasts, calcareous siltstone and occasionally horizons of calcareous marl nodules. Some of the siltstone beds are of turbiditic origin (Figure 14). In contrast to section 1, the matrix in section 2 is mainly micritic, and in some cases, as a secondary feature, microsparry. Pellets and biogenic components are the most abundant allochemical constituents. Section 1 is characterized by grainstone, rudstone and boundstone texture, whereas section 2 displays a mainly packstone texture. The fossil assemblage under a microscope is also significantly different from those of section 1: amounts of shallow-water specimens (Chaetetidea and *Pieninia* sp.) are subordinate. The definitely deep-water taxa are *Cadosina* sp., a few badly preservesed Calpionellidae, radiolarian, *Spirillina* sp. and *Lenticulina div.* sp. Based on these fossils the correct age determination of these beds cannot be given. The environment suggests that these beds probably underlie the fossil bearing conglommerate layers. Where planktonic forms are not reworked the age of these beds could be Late Valanginian to Early Hauterivian.

Magyaregregy, Márévár Valley

Lower Cretaceous sedimentary and volcanic sequences, of several hundreds of metres length, are found the southern side of the entrance of the valley (Figure 15) (known as Krajcár mill since Hofmann). Horváth (1959, 1968) and Czabalay (1971) also contributed to the enrichment of the collection derived from this artificial outcrop. Horváth (1968) published a section that is in harmony with a palaeogeographic model mentioned above. The lower third of the section is characterized by a coarse-grained conglomerate of exlusively basalt composition.This is a matrix-supported at its lower part, grain-supported in the upper portion, and dipping in the direction of the valley. This conglomerrate is composed of only basalt pebbles. The first occurence of megafossils coincides with the lithological changes where the conglomerate is gradually replaced by altered volcanoclastic deposits in which well-rounded pebbles may also occur. The quantity of fossils increases upward in the section, although their occurence seems to be lenticular. Unsorted volcanosediments are replaced by silty, slightly lithoclastic and plant-imprint-bearing marl behind the swimming pool. It is roughly 6 m thick (Figure 16). The transition at the lower boundary is slightly uncertain because it is not very well exposed: *i.e.* highly altered volcaniclastic deposit with 2-4 cm grain size, showing unknown bedding and deep patterns (it should be

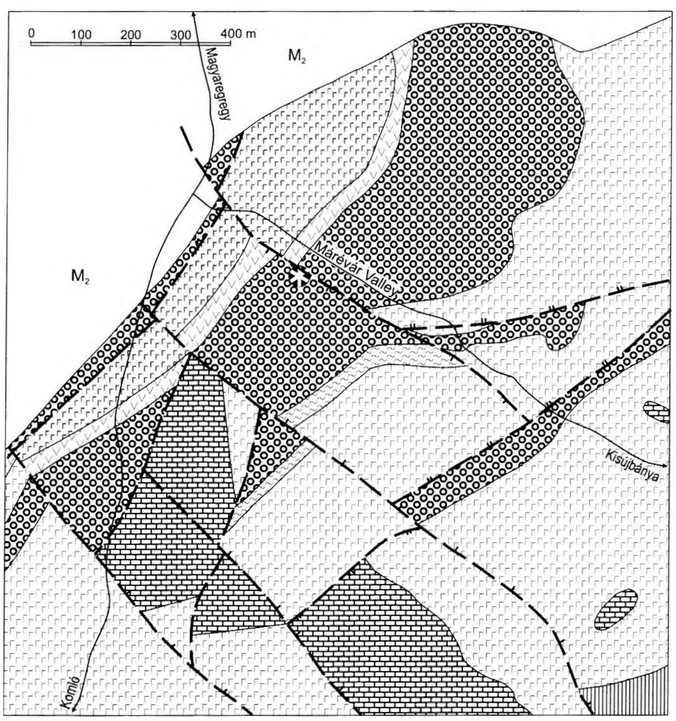


Figure 15. Geological map of the Márévár Valley and its environ with an indication of the Márévár Valley section (after Hámor *et al.* 1974a, Nagy *et al.* 1975). For legend see Figure 9

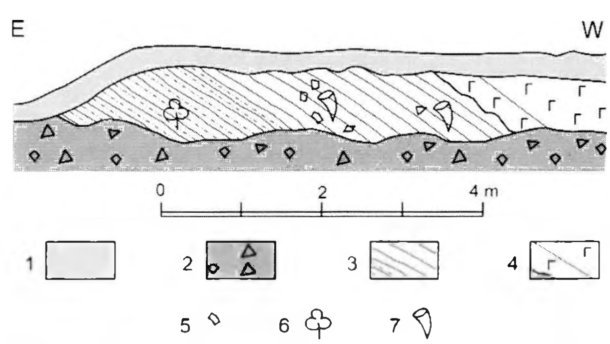


Figure 16. Stratigraphic position of the silty marl body below the 2nd lava horizons, southern side of the valley entrance, Márévár Valley, Magyaregregy

1 — Soil; 2 — Scree; 3 — Hidasivölgy Marl Formation; 4 — Mecsekjánosi Basalt Formation; 5 — Fossil fragments; 6 — Rudist bivalves; 7 — Carbonised plant remnants

similar to the overlying bed). It is overlain first by a 20-30 cm thick violet-brown unsorted and sandy silty-marl and then a 5 m thick brownish-grey bed. The stratal dip is 320°/45°. The upper boundary of the silty marl is sharp and it is overlain by a highly altered, variegated volcaniclastic deposit of 30 cm thickness, which is covered by lava flow composed of amygdaloidal basalt. Fossils have not been recorded from the marl so far. During my incidental visits I observed coral- and chaetetopsis-bearing pebbles, up to 18 cm in diameter (bPlate IV: 1, p. 68), and also rudists (among others *Toucasia*), ostreids, 0.5-1.5 m below the basalt flow. The fossils there have not been identified so far.

Megafossils collected over three generations from the volcaniclastic deposit are mainly represented by molluscs. CZABALAY described 25 taxa in her unpublished report; the most important ones are the following: *Heterodiceras semistriatum* HOFMANN, *Heterodiceras* sp., *Megadiceras hofmanni* CZABALAY, *Bicornucopina petersi* HOFMANN and *Requienia* sp. Gastropods are also frequent, especially the large-sized specimens like *Nerinea* and *Purporoidea* species. Ostreids are rare, whereas ammonites are not mentioned by any report. Five species of colonial organisms (Table 2) were identified in the old collection by TURNŠEK (CSÁSZÁR & TURNŠEK 1996). CZABALAY (1991) listed five brachiopods, which were collected by herself, and described in one of her unpublished reports.

The exact age of the section discussed above cannot be determined. The fauna-free conglomerate bed is thought to be the oldest part of this section; based on analogy (see the proposed model of the area), its probable age is Early Valanginen. According to this model, the pebbly volcaniclastic deposit is Late Valanginien, while the silty marl could be Hauterivian. CZABALAY (1971) and TURNŠEK (CSÁSZÁR & TURNŠEK 1996) think that these beds are the products of the Barremian–Aptian stage, in spite of the previous model.

Vékény Valley

In the upper part of the valley, around the only occurence of the Vékény Marl Formation (CSÁSZÁR 1985; Balla 1986; BALLA & BODROGI 1993), variously altered and unbedded volcaniclastic deposits of the Magyregregy Conglomerate can be found (Figure17), instead of Mecsekjánosi Basalt as it was indicated formerly. The northern part of the 18 m thick sequence of red, nodular marl dips steeply (60°-80°) towards the north (Figure 18). A 10-15 cm and a few 1-3 cm thick strongly elongated marl lenses can be found outside of the main marl body. These lenses are oriented according to the main body. Both, their upper and lower contacts are undisturbed. According to WEIN (1965) both contacts of the main body of the Vékény Marl are tectonic, while according to BALLA (1986) and BALLA & BODROGI (1993) the northern contact can be sedimentary, but the southern one is strongly tectonized.

Although tectonic contact also cannot be excluded at the southern end of the Vékény Marl's basis, in contrast with my previous idea (CSÁSZÁR 1985), I am convinced the following features indicate sedimentary contact there: the chaotic structures, sliding planes at the contact between the volcaniclastic deposit and the Vékény Marl, lack of the calcite fracture fillings often strongly related to the tectonic structures, and the irregular contact of the two formations. Chaotic crinkling along the southern contact and also the appearance of limestone fragments of exotic origin and a significant accumulation of lava debris is related to either synsedimentary or postsedimentary sliding (CSÁSZÁR 1984).

Two types of 2-15 cm sized, angular and slightly rounded, limestone pebbles can be distinguished (Figure 19). One type of limestone (Figure 19: a) represented by five thin-sections shows a micritic matrix and an extrabiomictritic wackstone texture (cPlates III: 3, p. 190; IV: 3, p. 191), and also packstone, by chance mudstone. Owing to the alternation of mud-

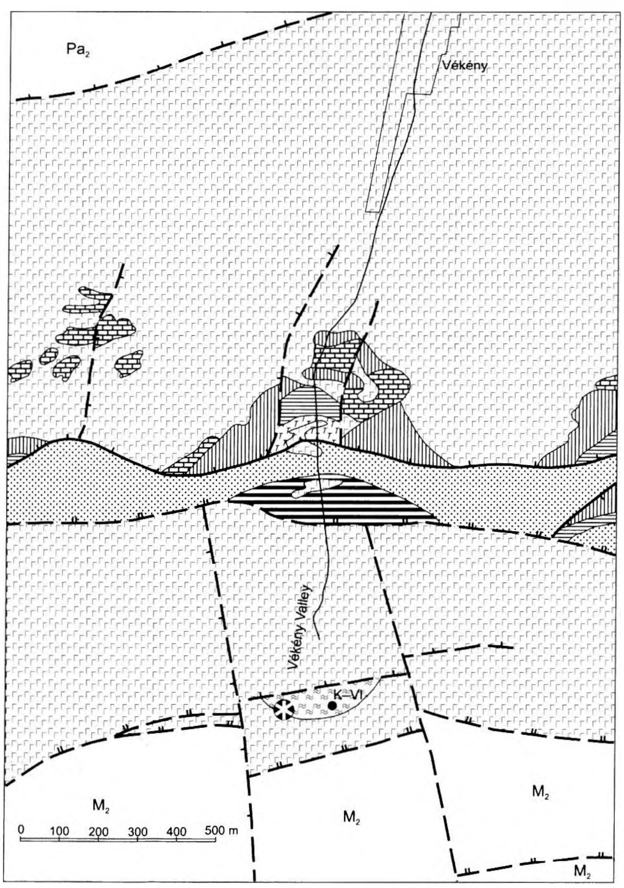


Figure 17. Geological map of the Vékény Valley environ with an indication of the site of the Vékény section (NAGY *et al.* 1973). For legend see Figure 9

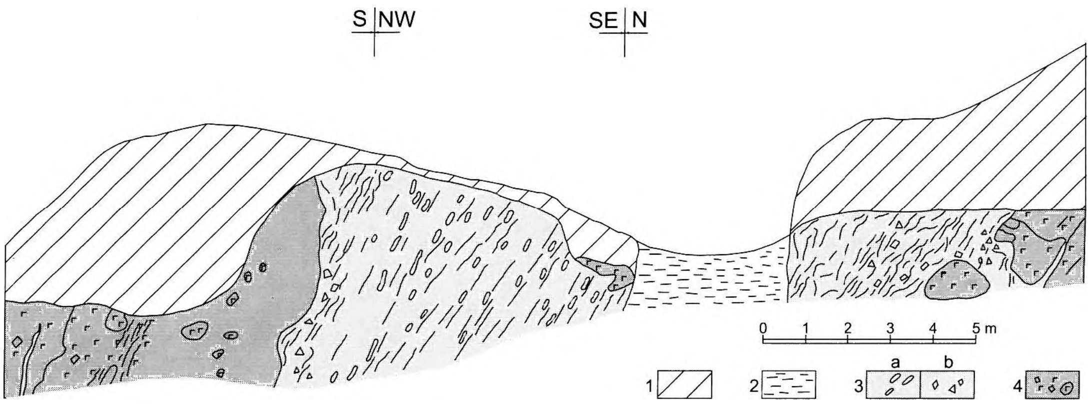


Figure 18. Key section of the Vékény Marl Formation in the Vékény Valley, after CSÁSZÁR (1985)
1 — Soil, loess, scree; 2 — Clayey scree; 3 — Vékény Marl Formation; a) red, nodular marl; b) bioclastic limestone debris; 4 — Magyaregregy Conglomerate Formation

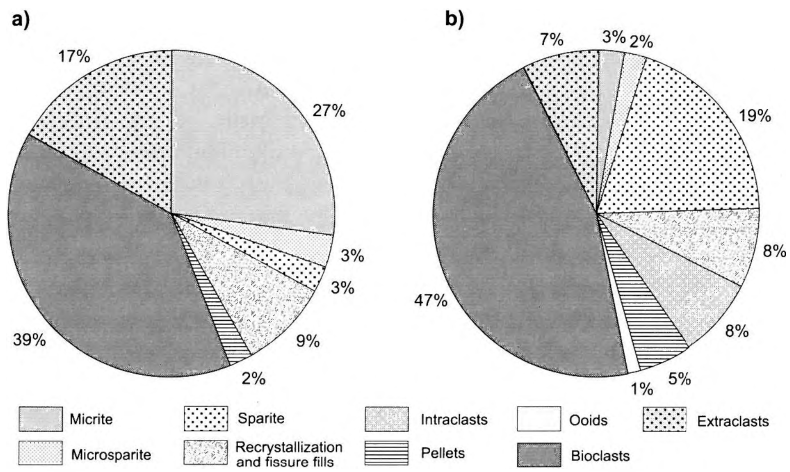


Figure 19. Textural pattern of the limestone fragments in thin-sections derived from the base of the Vékény Marl Formation, Vékény Valley: a) limestones of micritic matrix (mean of 5 thin-sections); b) limestones of sparitic cements (based on 12 thin-sections)

stone and packstone of the scattered volcaniclastics the rock are often laminated. Its dominant fossils are planktonic foraminifers and Calcisphaerulidae. GÖRÖG (1996) identified the following planktonic taxa: *Hedbergella* sp. and *Favusella washitensis* (CARSEY), and the following benthic ones: *Sabaudia minuta* (HOFKER), *Pseudotextulariella cretosa* (CUSHMAN), *Nezzezatinella picardi* (HENSON), *Textularidae*, *Dentalia* sp. and *Cylindroporella* sp. and some other dasycladacean algae. Skeletal components (*e.g.* holothuroidean sclerites) of mainly planktonic echinoderms, ostracods and (exceptionally) bryozoans are also major constituents of the previous deposit. Based on *Pseudotaxtuleriella cretosa* (CUSHMAN), according to GÖRÖG (1996) this limestone is Albian – Early Cenomanian. Angular limestone debris of Calcisphearulidae-dominated wackstone is hosted in a bit crinoidal wackstone with small-sized volcaniclasts and frequent planktonic foraminifers in two related thin-sections.

Characterisitic features of the second type of limestone were identified by observing 11 thin-sections (Figure 19: b). The texture of the limestone is bioextra-intrasparitic grainstone, rudstone, packstone, boundstone and floatstone (cPlates II: 1–4, p. 189; III: 1, 2, 4, p. 190; IV: 1, 2, 4, p. 191). Grains are often well rounded and coated. Some simple ooid grains also indicate rather high water agitation. Extrasclasts of this carbonate platform-like rock are only basalt, which originated from the Magyaregregy Formation or directly from the Mecsekjánosi Basalt Formation. GÖRÖG (1996) listed the following fossils from the biogenic constituents: gastropods, pelecypods, echinoderms, some benthic foraminifers [*e.g. Nezzezatinella picardi* (HENSON), *Coxites zubairensis* (SMOUT)] and *Cylindroporella* alga. According to my thin-section studies, the majority of the pelecypod shells proved to be rudists and with not so many ostreids. In addition to these, *Lithocodium*, ostracod, bryozoan and in some cases sponge (Inozoa) and an unknown colony (cPlate VIII: 4, p. 195) also occur. BALLA & BODROGI (1993) described the following fossils from the same facies: crionoid, pachyodont, corals, *Halimeda* sp., *Gavelinella* sp., *Dorothia* sp., *Suppilulimaella* sp., *Bacinella irregularis* (RADOIČIĆ) and *Pseudolithocodium carpathicum* (BORZA & MIŠÍK). The rock was qualified by them as Apátvarasd Limestone. As the Apátvarasd Limestone is basically a crinoidal one and it shows a slightly deeper water origin, neither colonial coral nor rudist pelecypods are typical for it. In this way, these two formations must be strictly distinguished. The importance of this distinction is emphasized in detail at the description of the deposition around the volcano. While reconstructing the sedimentary history of the volcanic environment it is worth mentioning the fact that within this environment a thin-section limonitic crust separates laminated mudstone (with a few echinoderm ossicles) from grainstone-type, highly fossiliferous limestone. From this fact we can infer a large-scale sea level rise and related break in sedimentation and then gravitational transportation of platform-type limestone fragments on the slope of the volcano. In borehole Vékény–VI, which is some dozens of metres eastwards from the outcrop (Figure 17), red marl deposited in the basalt-conglomerate and lava-breccia was described by NAGY *et al.* (1977). Stratigraphic intercalation of Vékény Marl into the volcaniclastics is supported by HÁMOR's discovery of a coral colony composed of differently oriented independent bodies and it was found in the volcaniclastic slope into the volcaniclastics (bPlate II: 1–4, p. 66). This is the first Cretaceous reef fragment in the "northern digitation" of the Mecsek Mountains.

According to SIDÓ (1961), the host rock was Cenomanian and she described its rich planktonic foraminifers association. Its age is thought to be Early, Middle Turonian by BALLA & BODROGI (1993). The limestone clasts must be older than the Vékény Marl, which is their host rock. The lack of Globatruncanids and *Rotalipora* species, in spite of the frequent occurrence of *Coxites zubairensis* (SMOUT) in the micritic matrix, suggest Middle Albian or older age. The age of biodetrital limestone is not very well constrained; however it must be younger than the similar rocks at Kisújbánya, Jánosipuszta and the Márévár Valley. It must be taken into consideration, even if there is no analogous data, that volcanic activity, which is similar to Valanginian one, continued in the entire Early Cretaceous, even until the beginning of the middle Cretaceous. In agreement with that, the sedimantation of shallow marine carbonates and deeper-water marl was maintained for a long time heteropically.

CORALS IN THE STUDIED SECTIONS OF THE MECSEK MOUNTAINS

Cretaceous corals of the Mecsek Mountains were first studied by VADÁSZ (1935) and later by KOLOSVÁRY (1954, 1959, 1961). KOLOSVÁRY described 9 species (two of them are new) from 9 genera. A modern revision of these fossils has been made by D. TURNŠEK, who identified 26 coral species in 25 genera, 2 coral, 1 stromatopora and 1 coralline-alga genera in the GIH's collection and in that material collected by the present author and L. BUJTOR (bPlate II: 5, 6, p. 66). A list of the fossils is shown in Table 2. Corals in comparable frequency can only be found in the Schrattenkalk of the Helvetic Zone (BARON-SZABO 1997). The 30 species, described from the Allgäu area, belong to 27 genera, which represents a high diversity. A colonial form of these species represents 98% of the total, while ahermatypic forms amount altogether to 2%. The percentage distribution of the growing forms in Allgäu, is compared with the number of taxa of the Mecsek Mountains (Table 3). A significant difference in their fossil assemblages suggests different palaeogeographic positions of the two studied areas (*i.e.* Mecsek Mountains and Allgäu). Only 5 species from the 30 taxa of the Mecsek Mountains correspond to those from Allgäu. The number of common coral genera of the two regions are 9. However, the total numbers of genera are almost the same (26 in the Mecsek Mountains and 27 in Allgäu). The places of occurrence of the Mecsek Mountains are those mentioned above [Jánosipuszta or Mecsekjánosi (Korhadtfás Valley)], Márévár Valley, and the road-cut at Kisújbánya). The only exception is the Vékény Valley, which has not been described so far. Corals in the list can be found at several localities in the world, thus evidence shows that this area was in connection through the Tethys with the "world ocean", during the Early Cretaceous. Their stratigraphic range comprehend a time interval from the Valanginian until the Cenomanian (Table 2), although the majority of the species are restricted to the Hauterivian–Aptian. Certain species are already present in the Valanginien or in the Albian.

Table 3

Comparison of the coral distribution of the Mecsek and Algäu occurrences according to their shapes. (Algäu in %, Mecsek in number of taxa)

	plocoid	cerioid	hydnoforoid	thamnas-terioid	meandroid	branching	encrusting	solitary
Allgäu (%)	11	21	16	9	22	16	3	2
Mecsek (taxon)	10				4	2		2

According to recent knowledge 5 taxa are restricted for a very short time interval. From among these 3 are present in the Albian only and this seems difficult to explain. Cretaceous coral taxa of the Mecsek Mountains are all hermatypic (reef-builder). Some dendroid and ahermatypic forms are associated with massive forms, which represent the large majority. According to TURNŠEK (CSÁSZÁR & TURNŠEK 1996) corals in the Mecsek are mainly encrusting and nodular and thus they lived in very-shallow sea, where they mostly could only grow in a sideward direction.

Rounded fragments of colonies indicate resettling. A lack of Amphiastraeidae, representing a front-reef environment, implies, that there were no satisfactory conditions (at least at the beginning of the sedimentary cycle) for front reef development. According to TURNŠEK (CSÁSZÁR & TURNŠEK 1996) specimens observed here lived at the inner side of mobile calcarenite sand or a shelf environment (including the protected back reef areas), forming smaller or larger patch reefs/mudmounds. An explanation of this phenomenon will be given later.

EXTENSION OF THE FORMATION

In order to determine the extension of a formation, two factors have to be taken into consideration. According to the recent data — namely, that coral- and rudist-bearing formations occur in little lenses — there is little chance to discover them. The fact, that the potential surface occurrences of the host rocks (*i.e.* Magyaregregy Conglomerate, Hidasivölgy Marl) is restricted to a small part of the eastern Mecsek Mountains further decreases the chance of recognition of this formation. The problem is also expressed in the difficulties related to how to put this formation into formal lithostratigraphic categories, if it is possible at all. Thus we can only outline its potential extension.

The basis of the phenomenon is represented by the marine occurrence of the Mecsekjánosi Basalt, so it is logical to assume the existence of accompanying coral-rudist lenses. Extension of the Mecsekjánosi Basalt is indicated in Figure 20. This formation was found and transected by mapping boreholes in the eastern Mecsek, *e.g.* at Komló (bPlates III: 1–4, IV: 2–4, p. 67–68), Magyaregregy, Kisújbánya, Hosszúhetény and by several hydrocarbon exploratory drillings in the Mecsek Zone at the Alföld (Great Hungarian Plain) However, owing to the sporadical core sampling there is only a little

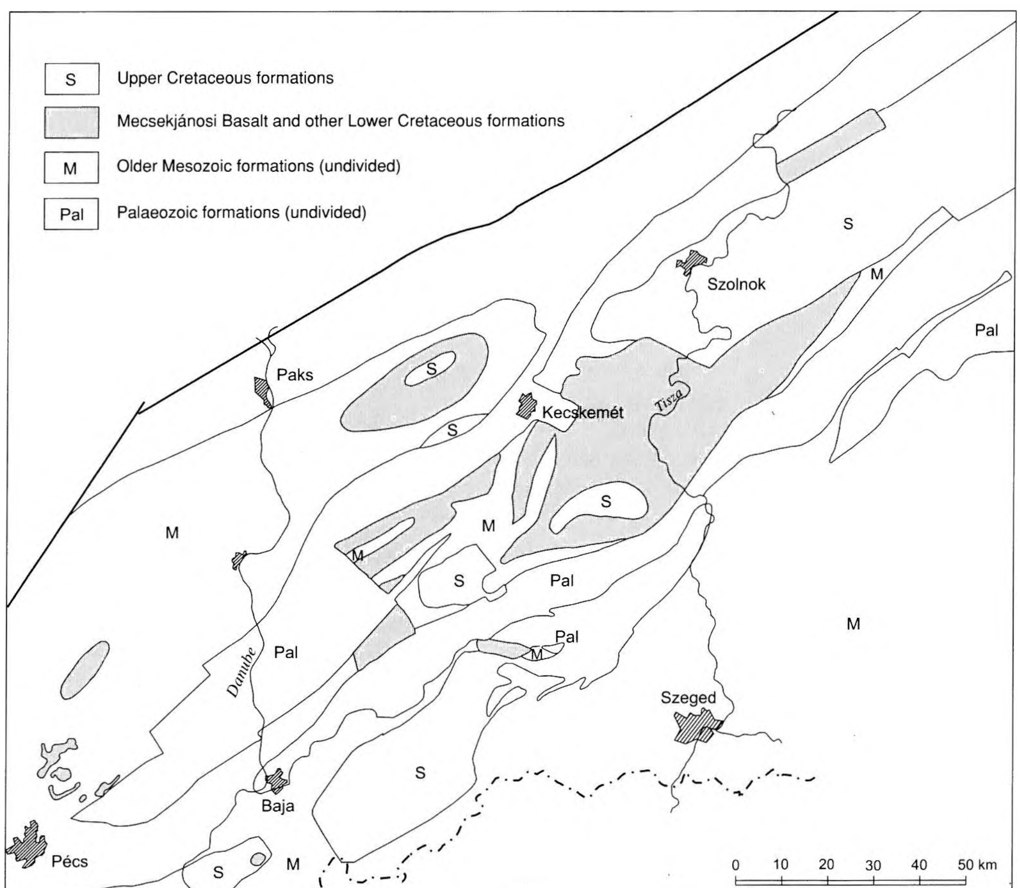


Figure 20. Extent of the Mecsekjánosi Basalt and other Lower Cretaceous formations (after FÜLÖP *et al.* 1987, modified)

chance to find this very special formation. In any case rocks similar to those from the Mecsek Mountains (as far as I know) are not known from the descriptions. Although, the occurrence of the discussed formation and even, real, atoll-like reef, in the basement of the Alföld cannot be excluded (see details later). It seems more likely, by knowing that the southern region of the Mecsek Zone was already shallower and characterized by carbonate facies during the Jurassic (Bérczi-Makk, 1992; Bérczi-Makk *et al.* 1997). Well Martfű–32, in which there is a 40 m thick body of real reef facies with corals and hydrozoans there, could be either a reef at the platform-edge or an atoll, given the recent data.

Age of the formation

The formation, which is called the Magyaregregy Conglomerate, is thought to be Barremian–Aptian by Vadász & Fülöp (1959). In spite of the quite abundant and various assemblages of fossils, the determination of the age of the carbonate platforms is less meaningful than that of the sediments of the pelagic and hemipelagic facies. This is particularly true, in those cases when fragments of the deposit are available for investigation. This is the case at the atoll-like structures of the Mecsek Mountains. In principle it would be an advantage if pelagic fossils were to be found in the slope-sediments composed of rock fragments derived from the volcanic and/or reefal body. This could yield at best the age of the erosion, which could be rather distinct from the age of deposition. This is the reason why I had to use different, (direct or indirect) tools for every outcrop of atolls of the Mecsek Mountains.

The situation is most favourable for the section of Kisújbánya, where pelagic sediments are to be found above and under the slope fan of the volcano. Ammonites indicating the same zone can be found in the floor, in the cover and even in the slope fan. Thus the atoll-like formation cannot be younger than the Late Valanginian Pertransiens Zone based on Bujtor (1993).

This situation is not clear at the Mecsekjánosi sections. Although some ammonites were found, their identification has not been carried out so far. The age of the formation is Valanginian based on *Toucasia carinata* (Matheron), according to Noszky (1948), while its age is Barremian – Early Aptian, based on *Requienia lonsdalii* (Sow.) and gastropods using unpublished data of Czabalay. Görög assumed the existence of a Barremian or younger formation, referring to the (uncontrollable) *Orbitolina* specimens whose place of occurrence is unknown. Taking into consideration the above, the most probable age of section 1 is Valanginian, while section 2 displays a Hauterivian stage, though in the further region the presence of at least Barremian, by chance Aptian formations cannot be excluded.

Unambiguous age information has not been determined so far from the rudist-bearing outcrop of the Márévár Valley. Both Czabalay and Turnšek stated a Barremian–Aptian age of the formation. However, the position in the section could imply Hauterivian, even a Valanginian stage. On the other hand, the second part of the section, whose silty marl level under the lava horizon, contain shells of rudists and other pelecypods, indicates Barremian, or possibly Aptian age of the atoll-like structures.

Shallow marine sedimentation is thought to be Late Albian – Early Cenomanian according to Görög (1996) by identifying *Pseudotextulariella cretosa* (Cushman) in the variously textured limestone fragments at the basis of the Vékény Marl Formation.

Interpretation of the volcanic activity

The petrologic, mineralogic and chemical composition of the volcanoclastic deposit is quite varied (Mauritz 1913; Bilik 1974, 1980, 1983; Kubovics & Bilik 1984; Harangi 1994). Mantle diapirs (mantle ploom) appeared in several places all over the world during the Early Cretaceouos. Based on the composition of the volcaniclastic deposit as well as related atoll-like structures, it is attractive to assume a similar origin for the voluminous volcanism of the Mecsek Zone. However, owing to differences in dimensions direct identification is not possible. According to the authors referred to above and others, the history of the volcanism can be outlined as follows. General submarine volcanic activity started in the Berriasian stage with the production of hyaloclastite. It was followed by several cycles of alternating pyroclasts and lava flows. There are direct evidences of two volcanic cycles, whereas there are indirect ones for only one cycle. Pillow lavas are the products of the initiation of the effusive phase. Few and poorly developed pillow lavas indicate approx. 500 m water depth during the Berriasian and Valanginian.

Magnetic measurements, taking place on the area of the volcanic field were reported by Molnár (1962, 1963, 1964). The most significant forms can be found near Magyaregregy. A system of measurements (50 m distance between points in a given profile, and 200 m between profiles) has created a

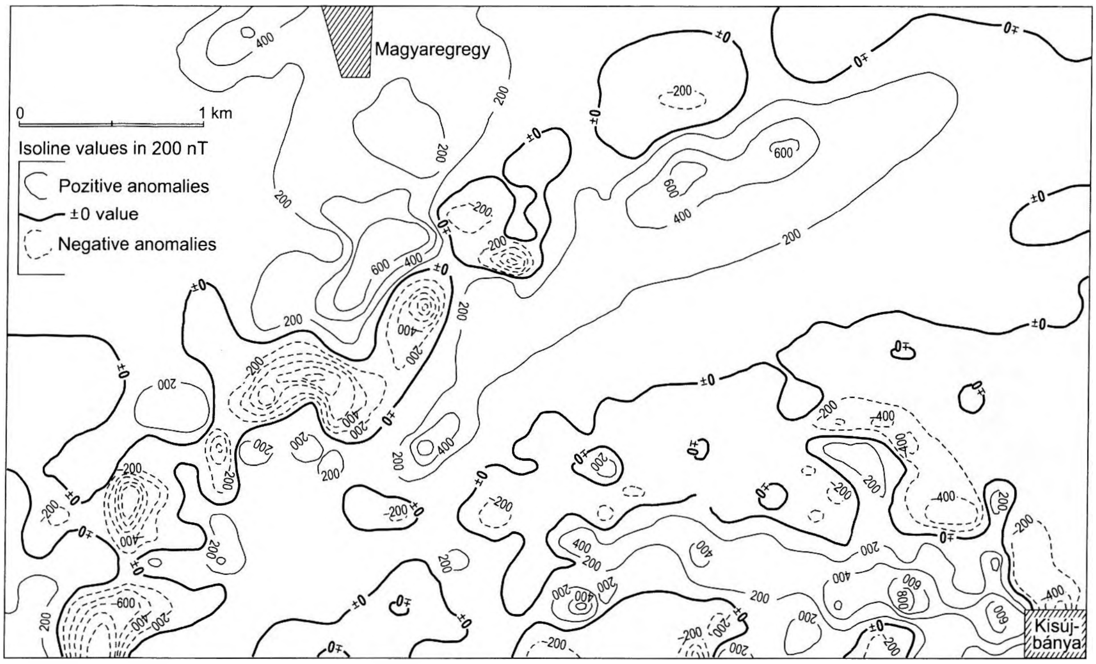


Figure 21. Map of the palaeomagnetic ΔZ anomalies of the Magyaregregy environ (Mapped by MOLNÁR 1962, re-evaluated by KOVÁCSVÖLGYI 1992)

strange pattern of anomalies so that horizontal, vertical and total anomalies are oriented in a E–W direction, while general pictures of the anomalies show a NE–SW direction on the old map. In order to have a chance for real interpretation, these old data were converted by KOVÁCSVÖLGYI (unpublished report; Figure 21). On this map anomalies are more isometric. The distribution of the formations shows anticlines and synclines, in agreement with the magnetic pictures which indicate different degrees of erosion of the Cretaceous, and older formations. The Kisbattyán–Kárász Zone for example, is a syncline, where the various Cretaceous, basaltic volcanic rocks are thicker. On the other hand, the anticline at its southern side is characterized by a thin volcanic and sedimentary sequence that can even be missing. Thus the position, extent and shape of the volcanic edifice can only be assessed with significant uncertainty. The position of the atoll-type volcanic build-up is shown on front cover of this volume.

Approximations, referring to the thickness of the Mecsekjánosi Basalt Formation are more uncertain, taking into consideration the denudation at the end of the Cretaceous and during the Palaeogene. The theory of crack volcanoes proposed by HOFMANN (in VADÁSZ 1932) and BILIK is acceptable, based on the orientation of dykes and if we think of individual volcanoes adjusted to systems of large-scale tectonic structures and not to those similar to oceanic ridges. This is confirmed by the maps of magnetic anomalies. Tectonic phenomena (folds and imbrications) make this notion more complex. Magnetic anomalies, and by chance the volcanoes are NE–SW directed near Magyaregregy, E–W at the "Northern imbrication", and ENE–WSW directed at the "Southern imbrication" owing to folding and remarkable and uneven erosion. Volcanoes see, to be more common on the highly-thinned lithosphere above the mantle diapir, while they are less abundant towards the thicker lithosphere. This is supported by the fact that there are some indications of the volcanic activity in the Villány Zone (Nagybaracska — CSÁSZÁR *et al.* 1983, Babarcszőlős — Fülöp 1966). This model is reflected in a N–S directed simplified palinsplastic section (Figure 22). Initiation and the duration of the volcanic activity is still a subject of discussion. Angular volcanoclasts in the Fonyászó Limestone Formation, and bentonitic clay between the layers of the Kimmeridgean Kisújbánya Limestone Formation could in my opinion, be the first indication of the volcanic activity. BILIK agrees with this idea (personal comm.). K/Ar radiometric ages of basanites and alkaline basalts range from 108.0 ± 4.1 to 134.6 ± 5.1 (HARANGI & ÁRVA-SÓS 1993). This corresponds to the Hauterivian–Albian age. However, the Late Berriasian could also be included, according to the time scale of HARLAND *et al.* (1989). 123.2 ± 5.1 million years average is indicated at the Barremaian–Aptian transition. The whole dataset — at least regarding the first eruptive period — seems to be slightly younger than would be expected by well-known biostratigraphic data (BUJTOR 1993). These lower values can be explained by the K/Ar method, which often provides younger ages due to the weathering processes. Nevertheless the significantly long

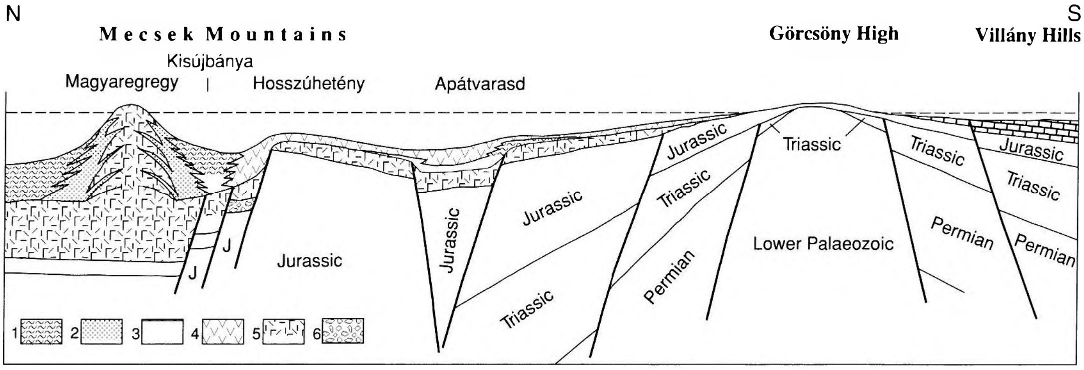


Figure 22. Idealized cross-section through the Eastern Mecsek and Villány Hills during the Early Cretaceous

1 — Hidasivölgy Marl Formation; 2 — Magyaregregy Conglomerate Formation; 3 — Nagyharsány Limestone Formation; 4 — Apátvarasd Limestone Formation; 5 — Mecsekjánosi Basalt Formation; 6 — Márévár Limestone Formation (allodapic limestone)

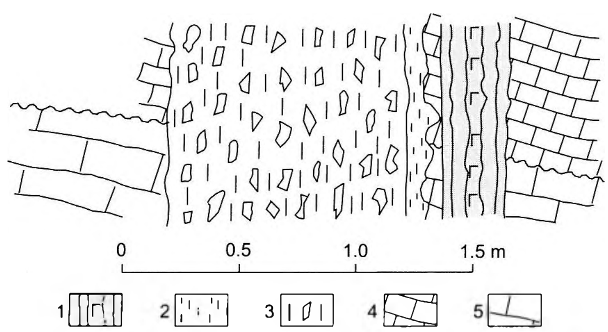


Figure 23. Cretaceous basalt dyke and Miocene fissure fill in the Szabolcs Valley quarry, Villány Hills

1 — Basalt dyke; 2 — Brownish red, brown clay; 3 — Fissure fill (limestone fragments in yellowish-brown clay matrix); 4 — Nagyharsány Limestone Formation; 5 — Szársomlyó Limestone Formation

volcanism cannot be interpreted by the different degrees of alteration. The natural explanation for the phenomena could be the mantle diapir model.

Volcanism in the Mecsek Zone is gets younger towards the NE and continues until the Albian — that is, according to SZEPESHÁZY (1966, 1973). Volcanic sand and silt in limestone fragments from the base of the Vékény Marl seem to be similar to those hosted in coral- and rudist-bearing bodies at Jánosipuszta. Limestone clast from the Vékény Valley is Albian, whereas the occurrence at Jánosipuszta cannot be younger than Neocomian age. No doubt the repeated volcanic activity in the Valanginian–Hauterivian, by chance in the Barremian, could not provide volcaniclastic deposits for the Albian limestones. This idea is supported by the 40 cm thick, altered, vertical dyke which is intruded into the Nagyharsány Limestone of the Villány Hills at the Szabolcsi Valley (Figure 23). K/Ar age of the rock is 64 ± 2.9 Ma (ÁRVA-SÓS 1991). This age excludes a Neogene origin of the formation, and owing to its altered character it rather implies a Cretaceous time for the origin. In spite of the unprecedentedly long volcanic phase, the volcanic activity of the Mecsek and Villány Zone has been proved for up until the Albian and probably up to the Cenomanian. The distribution of radiometric data (HARANGI & ÁRVA-SÓS 1993) confirms the theory of more or less continous and long volcanic activity. However, most of the younger volcanic products have been eroded.

POSITION OF VESTIGES OF THE MECSEK-TYPE ATOLL (CORAL AND RUDIST-BEARING BODIES) IN THE SEQUENCE

In contrast with the model of ANDRI & ROSSI (1993) and the majority of the NW Pacific atolls (GRÖTSCH & FLÜGEL 1992, ARNAUD-VANNEAU *et al.* 1995), abrasion of the volcanic edifice immediatelly began when the volcanoes reached the sea level. Waves continually cut into the body (build-up) of the volcanoes, particulary at sea level. Soft volcaniclastic beds (tuffs and other pyroclastic deposits) were easily removed due to the wave actions and sea level fluctuation near to the edge of the volcanic slopes, while well-rounded pebbles were formed from the lava. Their average diameter is 2-5 cm, though their longer axis could reach 40 cm. Sediment was deposited at the edge of the submarine slopes at first, then was removed to the foot of the volcanic edifice thanks to mass flow, debris flow and sliding during low sea level and stormy periods. Sometimes it could reach the inner part of the continually plainer basin, as can be seen in the section of Kisújbánya (Figure 10: a). Through the progress of the denudation roughly ring-shaped, zoned structures were generated around the volcano.

1995). There are only ruins of the volcanic build-ups in the Mecsek Mountains, though small, nodular appearance of coral colonies suggest that there was not enough room for the development of normal reef bodies. This can be explained by assuming that there was no satisfactory degree of sinking (at least during that period when the volcano raised above the sea level and its abrasion and colonisation had been going on). The intensive production of pebbles in the Mecsek area, — which is not the case with the Pacific atolls — confirms this hypothesis. Thus abrasion-downcutting at sea level is missing from the from the Darwin atolls as opposed the Mecsek-type atoll. Using rather poor data for the Vékény Valley, we can assume here conditions similar to the Pacific atolls in the Albian. As a new phenomenon, the colour of the shallow basinal sediments turned red during the Albian (?), in contrast with the shallow marine facies around the volcanoes. This could be explained as the first step of the two-stage sea level rise. In spite of the insufficient stratigraphic data one can assume that the sea level rise in the Mecsek Mountains temporally coincided with that in the Pacific Ocean. This is explained by GRÖTSCH & FLÜGEL 1992 as global event. In other words, the atolls of the two areas were probably drowned at the same time due to the sea level rise; this is considered to be one of the more significant rises in the Cretaceous period.

THE NAGYHARSÁNY LIMESTONE FORMATION

PLACE OF THE NAGYHARSÁNY LIMESTONE FORMATION IN THE SEQUENCE

The Nagyharsány Limestone is a Lower, (middle) Cretaceous formation. It can be found in the Villány–Bihar Zone (Figures 3 and 26) and settled with debatable and various degrees of erosional discordance on the underlying Upper Jurassic shallow marine formations. In the Villány Hills and the surrounding areas the footwall of the formation is the Szársomlyó Limestone Formation, whereas in the Bihar Mountains and Padurea Craiului its name is Blid Limestone. It has settled on limestone vari-

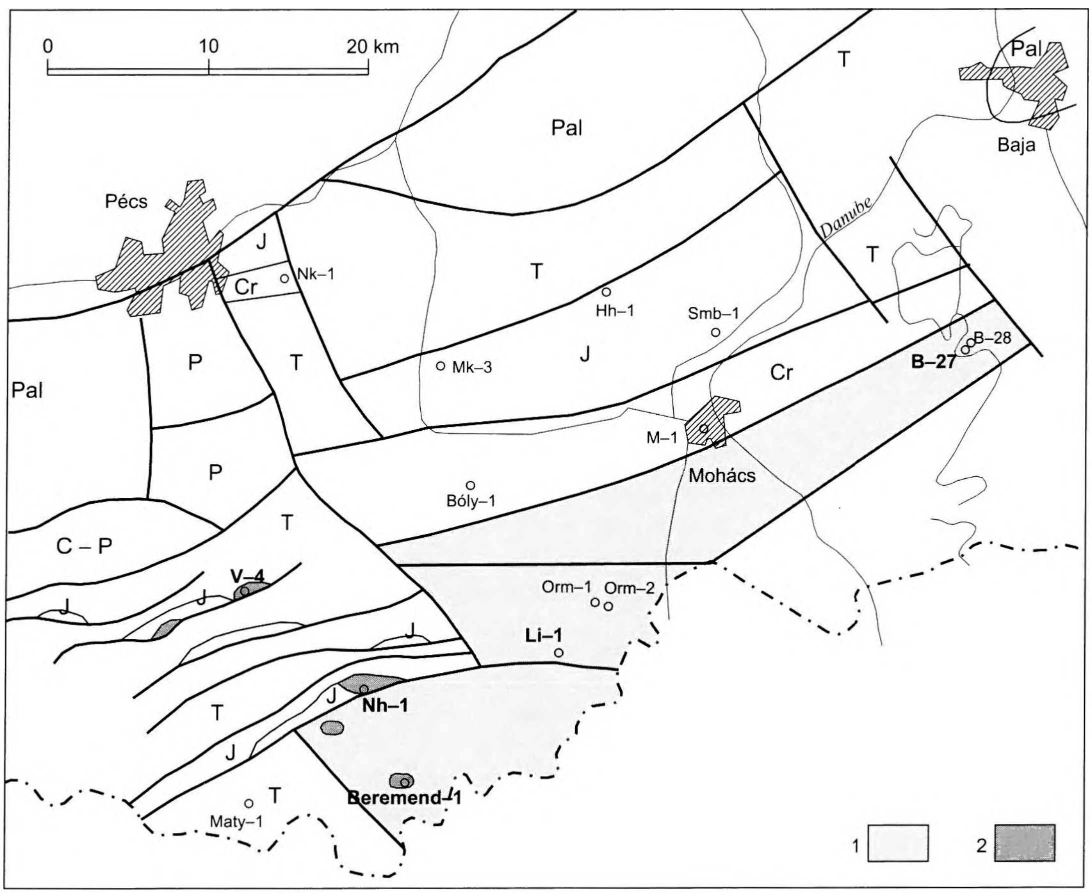


Figure 26. Extent of the Nagyharsány Limestone Formation in South Transdanubia

1 — Nagyharsány Limestone Formation (on the surface); 2 — Nagyharsány Limestone Formation (under Neogene cover); Cr — Other Cretaceous; J — Jurassic; T — Triassic; P — Permian; C–P — Carboniferous-Permian; Pal — Palaeozoic metamorphites; Maty–1 — Borehole without Nagyharsány Limestone; **Nh–1** — Borehole penetrating Nagyharsány Limestone

ants like Albioara, Cornet, and Farcu (DRAGASTAN *et al.* 1986). Bauxite lenses often fill the karstic cavities of the footwall, under the Nagyharsány Limestone and Bild Limestone. These lenses are referred to as Harsányhegy Bauxite in the Villány Hills.

HISTORY OF THE RESEARCH AND GEOLOGICAL SETTING

Rudist bearing limestone was recognized by PETERS (1863), near Beremend and according to him it was Lower Cretaceous; HOFFMAN (1876), recording it as diceras limestone put it and its other occurrences in the Upper Jurassic. SCHAFARZIK (1904) superficially mentioned the formation in association with the mining activity in the Beremend and Nagyharsány quarries. LÓCZY JR. (1912, 1913, 1915) separated the formation into two sub-units. The *Valletia* and foraminifer-bearing limestones of Harsány and "Puszta-tapolca", as *Diceras* limestone was thought to be Upper Jurassic, while the *Requienia* and *Orbitolina*-bearing limestones of Tenkes Hill were accepted by him as Lower Cretaceous. He assumed continuous transition of the two sub-units.

Owing to the discovery of bauxite in the Harsány Hill (TELEGDI-ROTH 1937) after the world war I there were expectations that better knowledge could be obtained of the geological setting, in Hungary that lost most of its area and being poor in raw materials in general. TELEGDI-ROTH (1937) and RAKUSZ (1937) carried out the geological mapping of the area. Nagyharsány Limestone were mentioned as: "South European, reef limestone, of Urgon facies" by the latter author. According to him the bauxite was Berriasian, while its covering limestone was Valanginian–Hauterivian in age. It was detected with a 4-5° difference in angle of dip between the Jurassic footwall and its Cretaceous cover. The Bisse Marl was discovered by STRAUSZ (1941) who found it in the footwall of the rudsitid limestone and considered it to be Barremian in age.

RAKUSZ & STRAUSZ (1953) and NOSZKY (1957, 1959) mainly dealt with providing palaeontologic knowledge of the Nagyharsány Limestone; while this knowledge was broadened concerning the age of its deposition they did not agree. STRAUSZ (1941, 1942, 1952) and ROZLOZSNIK (1936) provided further data of the Cretaceous formations yet without making any fundamental new conclusions. VADÁSZ & FÜLÖP were still writing about Valletia-bearing limestone in 1959.

The knowledge on the geological setting, evolution and regional relationship of the formation was greatly improved by the FÜLÖP's monography which focused on the Cretaceous formation of the Villány Hills and its environs. In this book FÜLÖP (1966) gave the results of a detailed study of the sequences of the quarrics and some exploratory boreholes. According to him the general uplift which took place at the end of the Jurassic was followed by a longer continental period than it had been assumed before. It was terminated by the Barremian transgression. The Lower Cretaceous of the Danube–Tisza Interfluve and the Trans-Tisza Region, especially the Nagyharsány Limestone were examined by BÉRCZI-MAKK (1971, 1985, 1986), who provided fundamental data from there.

The macrofauna of the formation was studied in detail by CZABALAY (1992), whereas modern investigations of the microfauna and -flora have been carried out by the following authors: PEYBERNÈS (1979); PEYBERNÈS & CONRAD (1979); BODROGI (1999); BODROGI & KNAUER (1992); BODROGI *et al.* (1991a, 1991b, 1993); SCHLAGINTWEIT (1990a) and GÖRÖG (1991, 1993, 1996). BODROGI *et al.* (1994) compared the microfauna and microflora assemblages of the Schrattenkalk (Vorarlberg) and the Nagyharsány Limestone, giving special regard to their stratigraphic importance. Their results will be introduced and discussed later. The petrologic and geochemical features of the Harsányhegy Bauxite was reported by BÁRDOSSY *et al.* (1976), DUDICH & MINDSZENTY (1984), D'ARGENIO & MINDSZENTY (1987) and MAXIMOVIĆ *et al.* (1991).

The lithostratigraphic names of the formations were introduced into the literature at the beginning of the 80's, as well as recognition of the new bauxite horizone situated above the Nagyharsány Limestone (CSÁSZÁR & FARKAS 1984). Further lithostratigraphic division, identification of the lofer cycles and the spreading of transgression, the elaboration of the double lagoon palaeographic model, recognition of platform drowning and the fact, that the Bisse Marl extends over the Nagyharsány Limestone are connected to the activity of CSÁSZÁR (1989, 1992) and CSÁSZÁR *et al.* (1994).

The geological setting and fossil content of the formation in the basement of the Danube–Tisza Interfluve and Trans-Tisza Region were described by BÉRCZI-MAKK (1986). Representing its heteropic facies, a pelitic sequence with continental deposits was distinguished as a Biharugra Calcareous Marl Formation in the footwall of the Nagyharsány Formation. The succession of the Danube–Tisza Interfluve was explained as a transitional facies between the carbonate platform and the open shelf (CSÁSZÁR 1992) based on marl beds and planktonic foraminifers (BÉRCZI-MAKK 1986).

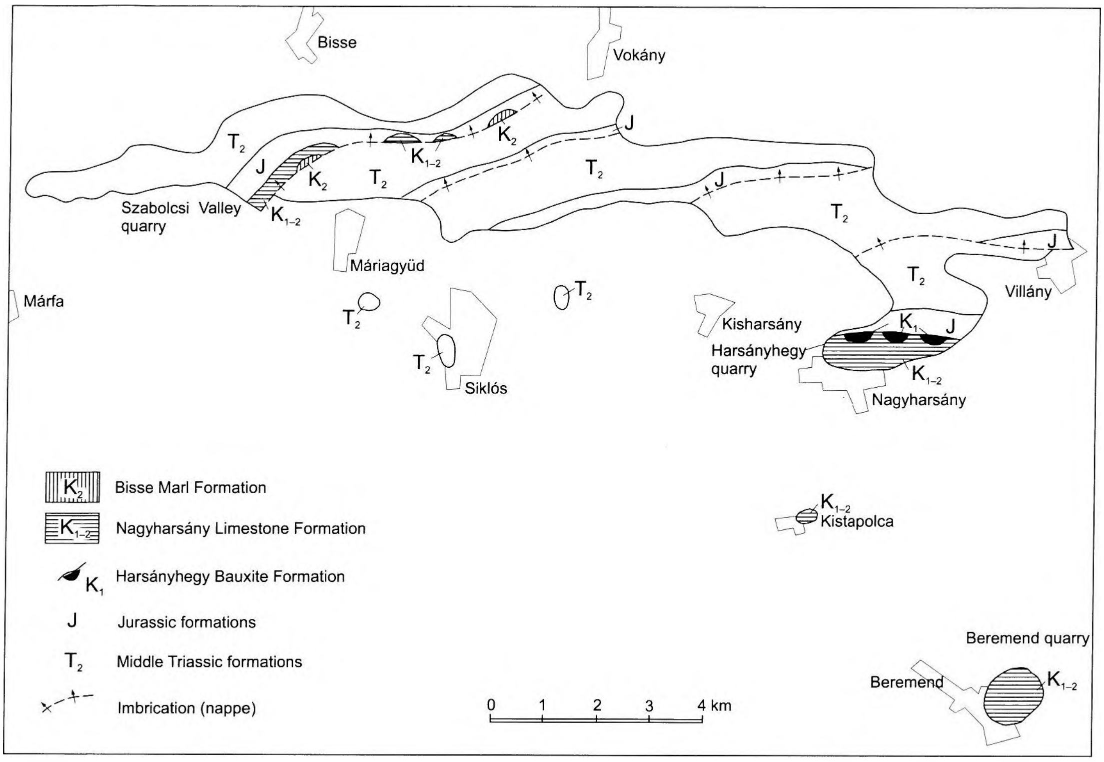


Figure 27. Cretaceous formations on the surface in the environs of the Villány Hills (after FÜLÖP 1966, simplified)

GÖRÖG (1996) has provided the most up-to-date and complex image of the larger foraminifer content of the Nagyharsány Limestone in her Ph. D. thesis. The latter deals with all the occurrences of the formation. Her conclusions are well-founded with regard to both the age of the formation and the faunal province.

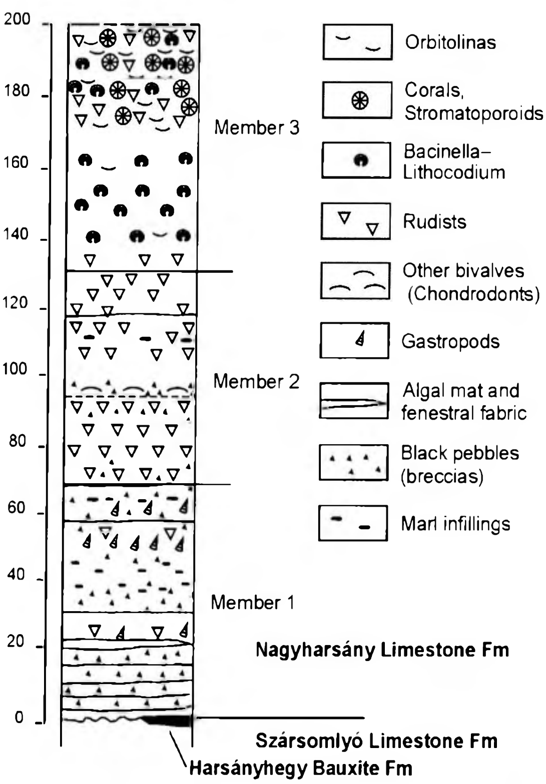


Figure 28. Cumulative stratigraphic column of the Cretaceous formations, Harsány Hill quarry

SECTIONS STUDIED

There are significant differences in facies pattern and thickness between the occurences of the Nagyharsány Limestone due to the imbricated or nappe structures of the Villány Hills. LÓCZY JR. (1912) also noticed of this. The thickness of the Nagyharsány Limestone is only 30 m in the northernmost nappe, while it is at least 200 m in the Nagyharsány Hill Nappe and it exceeds 450 m in the Beremend Nappe. A survey of the occurrences of the Nagyharsány Limestone will be given by below (Figure 27).

The quarry of the Harsány Hill

The most complete exposure (205 m in thickness) of the Nagyharsány Limestone, as a stratotype of the formation can be found, in the Harsány Hill quarry (Figure 28, bPlate V: 1, 4, p. 69) The sequence of the quarry was divided into two member-rank lithostratigraphic units by NOSZKY (1957), three by FÜLÖP (1966) and three by CSÁSZÁR (1989). BODROGI (in BODROGI *et al.* 1994) distinguished five "litho-biostratigraphic" units in the 140 m thick part of the quarry's section.

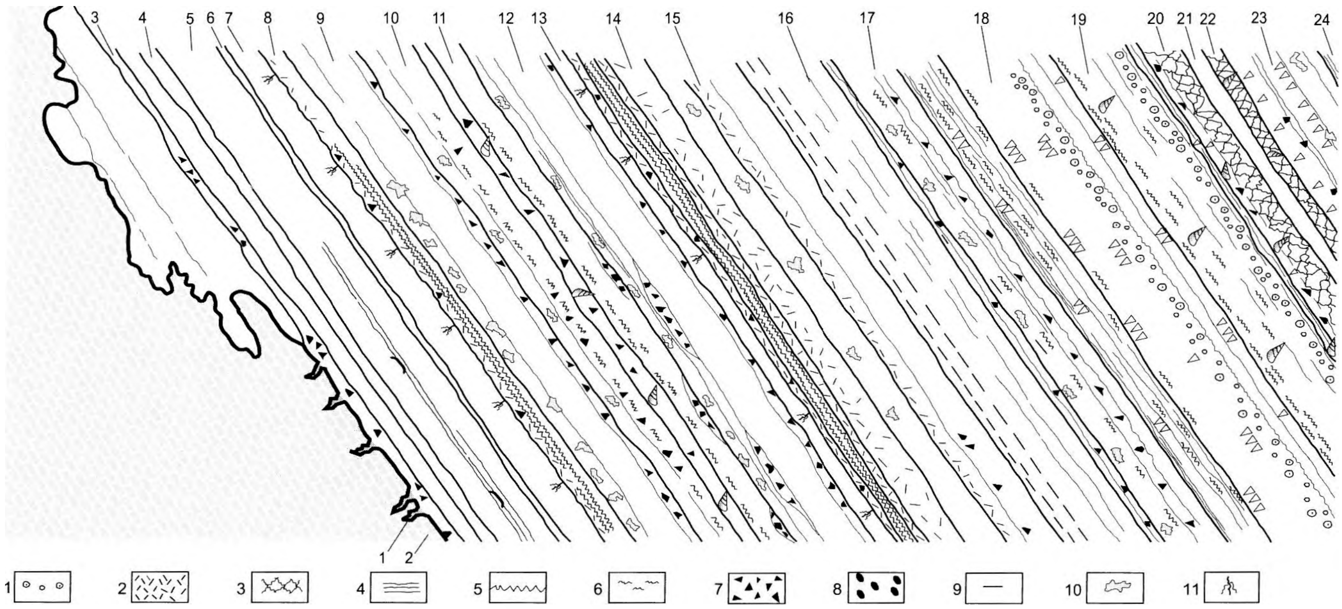


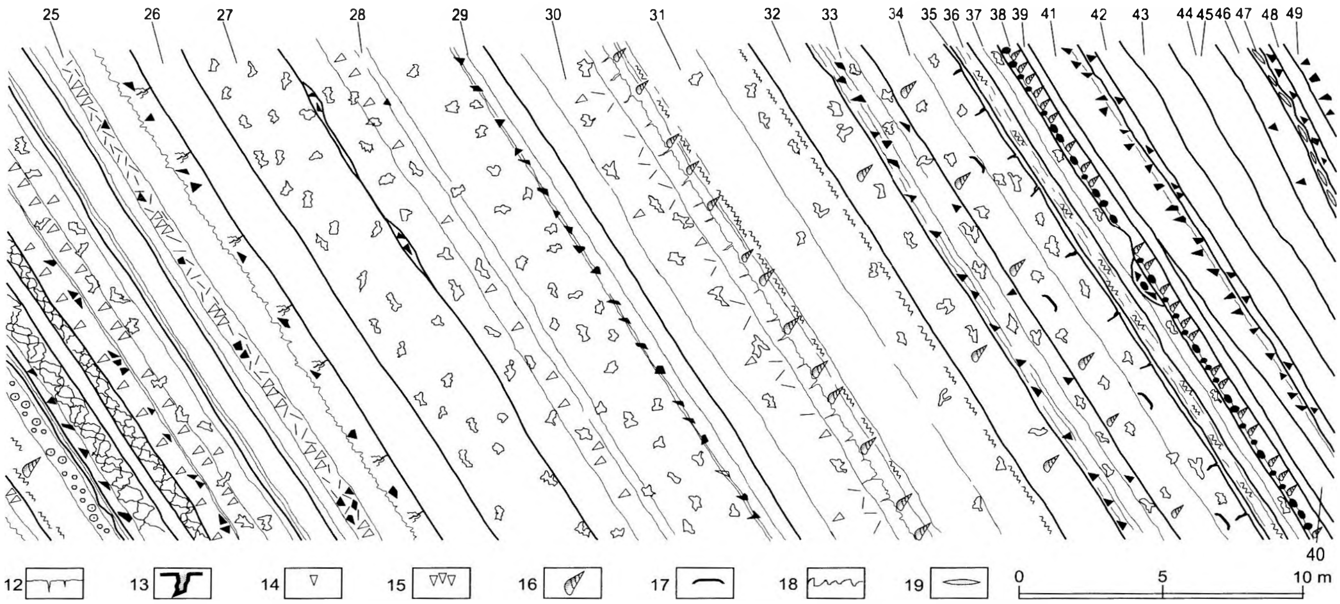
Figure 29. Geological cross-section of the lower part

1 — Oncoidic and peloidal limestone; 2 — Calcareous sand or bioclastic limestones; 3 — Highly stilolithic limestones; 9 — Flat cracks filled by red marl; 10 — Marl and calcareous marl infilling; 11 — Root traces; 12 — Mud crack casts; 18 — Microkarstic surface;

The succession of the quarry has been mapped and depicted in several steps. The recording and mapping was hampered by the fact that sedimentary hiatuses are often difficult to recognize in the sequence because some tectonic movement along these surfaces, together with joint calcitisation, destroyed the original sedimentary patterns. This is enhanced by the feature that, at the most facies-sensitive lower part of the Cretaceous sequence, after some metres progress in excavation, facies and thicknesses are changing and replaced by other facies. The thick-bedded or even massive Szársomlyó Limestone represents the footwall showing a pelbiosparry grainstone, intra-pelbiosparry wackstone and occasionally a boundstone texture, in which most of the pellets were formed via micritization of ooids. Owing to the intensive karstification, the rock displays uneven relief with a 10, perhaps 20 m doline depth. Hard, brownish-red and sometimes pisolithic Nagyharsányhegy Bauxite have settled in some dolines of this limestone (Dudich & Mindszenty 1984). In other cases freshwater versions of the Nagyharsány Limestone fills up the flat dolines. Smaller and bigger fragments of the footwall are also frequently embedded in the doline fill deposit. For the uppermost part of the Szársomlyó Limestone it is characteristic to find crack-like cavities of cm to tens of cm in size with dissolution surfaces filled with variegated pelitic material (Figure 29). X-ray diffraction analysis and thermal analysis of this material have revealed unusual differences in the mineralogical composition; the first one shows 15% vermiculite and 40% chlorite/kaolinite, while the latter shows 45% sudoite. According to the X-ray diffraction analysis the calcite content is 31% while the thermal analysis displays 45% "dolomite" content in which $MgCO_3$ is only 1 mol%. (For more data see Tables 6 and 7, and the origin of the bauxite will be discussed later.)

The lower member of the formation (member 1)

The lowermost 71 m interval of the Cretaceous sequence represents the lower (first) member of the Nagyharsány Limestone Formation. The upper border of this member is closed by the bed indicated by sample number 43 in the 1st section (Figure 29) and by sample number 46 which is considered later (cFigures 2, 3, p. 173–174). The majority of the steeply southward-dipping, mainly grey and thick-bedded layers contain no macrofauna. Its cyclic character is expressed by the alternation of the following features: angular limestone fragments ("black pebbles"— bPlate V: 2, p. 69; VII: 1, p. 71), macroscopically visible fenestral fabric (bPlate V, 6, p. 69) and argillaceous bedding plains of mainly variegated colour. Algal laminite (bPlate VI: 5, p. 70) is also a typical feature of the member — however it is relatively rare. Irregular, variegated (pale green, yellow, pale grey and brownish violet) marl and calcareous marl fillings, formed via bioturbation are frequent. A smaller proportion of the bioturbations in *sensu lato* were made by animals, and their larger portion by plants (cPlate VIII: 3, p. 195). Bigger, dendroid-like fillings



of the Nagyharsány Limestone (larger part of section I), Harsány Hill quarry, Villány Hills
4 — Laminated limestone; 5 — Algal mat; 6 — Fenestral fabric; 7 — "Black pebbles"; 8 — Conglomerate;
13 — Karstic cavity fill; 14 — Rudists; 15 — Rudists in lenses; 16 — Gastropods; 17 — Other bivalves;
19 — Limestone with clay lenses

(bPlate V: 5, 7, p. 69; VI: 4, p. 70) originated from bush like plants. These may correspond to a group of plants which show that their way of life was similar to the nowadays mangrove (CSÁSZÁR *et al.* 1994). Fracture filling materials in some casees are homogenous; elsewhere they display repeated changes in grain size. As rare exceptions, black-crusted cavities are filled with carbonate mud in their lower parts. This carbonate mud — of varied grain sizes and shades — alternates rhythmically, while the upper part of the cavities are filled by calcite (bPlate VI: 3, p. 70; VII: 3, 5, p. 71). Consolidation of the carbonate mud in the two previous cases took place during the lifetime of the plants. Thus after death of the plants the cavities were filled with — more or less homogeneous — material of the next bed. In the second case carbonate mud was semi-consolidated; therefore, simultaneously with the decomposition of roots locks were generated in the channels. Formed by roots, in this way the organic matter could not disappear, so these channels were filled only in part with the carbonate mud of the next layer. Calcite fillings are of late-diagenetic origin.

Occasionally the beds are separated by a few cm thick, black and laminated limestone (bPlate VII: 4, 6, p. 71) or variegated, mainly red clay. This corresponds to a palaeosoil horizon. Slides and calcite veins, which are connected to the formation of nappes are found frequently along bedding planes. These circumstances make the study of palaeosoil horizons unreliable. In spite of bedding planes with frequent variegated clay cover the desiccation cracks are relatively rare.

The significance of these beds lies in the character of the changes in the grade of greyness and the cyclicity having became distinct from these changes. There are three basic types of tonality change of a grey colour: (a) deepening (darkening) upward (b) fading (paling) upward and (c) transition in both directions withouth sharp boundaries. The changes consist of greater cycles, which are dominated by sections showing tint transitions at the sharp, inner boundaries (24.6 m from the 52.0 m total thickness of the section). The upward fading type is composed of three units, with a total length of 18.3 m. The darkening of the upward type is the less frequent, all together 9.1 m.

Angular, storm-originated and mostly black limestone clasts are common (cPlates V: 3, p. 192; VII: 2–5, p. 194; VIII: 1–2, p. 195), though one conglomerate bed can also be observed (cPlate VII: 1, p. 194). It can also be formed on land from red palaeosoil beds (bPlate VI: 6, 7, p. 70).

The member can be subdivided into four sub-units according to macroscopic and microscopic features (CSÁSZÁR 1989). The microscopic texture of the rock is mudstone or pelletal wackstone and (exceptionally) packstone, floatstone and grainstone. In agreement with these textures the matrix is almost everywhere micritic, and exeptionally microsparry or sparry. In addition to biogenic components occurring in low amounts, pellets are also relatively common, while intraclasts appear just at the upper boundary of the sub-unit. Frequent, laminoid-fenestral structures (gas bubbles and shrinkage pores — bPlate VIII:

1, 2, 4, p. 72) and the above-mentioned features indicate extraordinarily quiet, lagunar depostition.The most frequent macrofauna of the member are small sized, sometimes rock-forming gastropods (cPlate VII: 1, p. 194) with thin shells like *Plesioptyxis prefleuriaui* (D'ORBIGNY) and *Plesioplocus essertensis* (P. *et* C.). These are common in bed 38 (CZABALAY 1994). The other group of macrofossils is composed of small-sized occasionally larger rudists (bPlate VII: 2, p. 71) which, exceptionally, can create 10-30 cm thick biostromes based on the identification of the bed 23 according to CZABALAY (1994). The following taxa belong to this group: *Requienia ex. gr. tortilis* MAINFELLI, *Agriopleura marticensis* (D'ORBIGNY), *A. darderi* ASTRE and *Toucasia* sp. These were recognized in this assemblages (bed 23) by CZABLAY (1994).

Foraminifers are the ruling microfossil of member 1 sub-unit in the thin-section.The most abundant taxa are miliolinids and some other general calcareous forms. Ostracods, unidentified fragments of molluscs and microgastropods are also comparatively frequent. Cadosina and Dasycladacea are rarely, but rhythmically returning components (bPlate VIII: 3, 6, p. 72). *Bacinella irregularis* RADOIČIĆ occurs in the middle of the unit, whereas *Cayeuxia* alga can be found here and at the uppermost part of the unit. Characeae — especially oogonium, which is their most suitable part for fossilization — are restricted to the base and beds which are close to the base of the unit (bPlate VIII: 5, p. 72). Based on the distribution pattern and changes of quantity of fossils, the variation curve of the palaeoenvironmental zones, as well as facies-curve rhythmic ranging from marine to freshwater environment, can be outlined (CSÁSZÁR 1989 and cFigures 2, 3, 4, p. 173–175).

BODROGI *et al.* (1994) distinguished three "lithobiostratigraphic" units of member 1 and listed the following foraminifers in them: *Pseudotriloculina, Istriloculina, Qinqueloculina robusta* NEAGU, *Bolivinopsis, Spirillina, Glomospirella, Dorothia, Nautiloculina, Verneuilina cf. polonica* (CUSHMAN & GLAZEWSKY), *Arenobulimina meltae* KOVATCHEVA, *Charenthia cuvillieri* NEUMANN, *Choffatella decipiens* SCHLUMBERGER, *Gaudryina, Pseudotextularia? salvensis* (CHAR., BRÖNN. & ZANINETTI), *Debarina aff. hahounerensis* FOURCADE, RAO & VILA, *Glomospira urgoniana* ARN.-VANN., *Nezzazatinella macovei* NEAGU, *Pfenderina globosa* FOURY, *Trocholina odukpaniensis* DESSAUVAGIE, *T. sagittarita* ARN.-VANN., *Pseudolituonella gavonensis* FOURY, *Lenticulina espitalei* DIENI & MASSARI, *Belorussiella cf. taurica* GORBATCHIK, *Sabaudia minuta* (HOFKER), *S. capitata* ARNAUD-VANNEAU, and also the next algae: *Clypeina? solcani* RADOIČIĆ & CONRAD, *Salpingoporella cf. hispanica* CONRAD & GRABNER, *S. cf. katzeri* CONRAD & RADOIČIĆ, *S. annulata* (CAROZZI), *S. muehlbergi* (LORENZ), *S. cf. geneviensis* (CONRAD), *S. melitae* RADOIČIĆ, *S. urladanasi* CONRAD, RADOIČIĆ & PEY., *Cylindroporella pedunculata* (JAFFR., POISS & AKB.), *Praturlonella aff. danilovae* RADOIČIĆ, and *Actinoporella podolica* (ALTH.). Stratigraphic valuation of the member will be discussed later.

It is important to emphasize that the sequence of the section changed significantly as in excavation progressed. Corresponding to the cavernous, uneven relief of the Szársomlyó Limestone new beds appear, while former ones disappear. To a lesser degree the changeability refers to the upper layers. Newertheless, this would not be enough reason for having essential differences between sections which were either recorded at the top of the Harsány hill, near to the occurrence of bauxite, or recorded on the wall of the quarry. I will return to this question later.

Member 2 (Figures 28, 29, cFigures 4, p. 175)

The thickness of member 2 is 69 m. I marked its lower boundary at an irregularly eroded, erosional surface (at the top of bed 46 of the new record) (cFigure 3, p. 174). This member is terminated at sample 6 of section II. The total thickness of member 1 and 2 is 140 m. Since, there is a 50 m distance between the two sections and most parts of the section II represent a tectonic-breccia zone, the stratigraphic continuation of section I is ambiguous. The thicknesses of the beds can only be approximately determined.

Rudist levels, which were exceptional in section 1, are fundamental features of the grey, limestone unit. The member can be divided into two subunits based on facial properties. The lower part of the member is medium to thick-bedded, while its upper half is characterized by massive development. The frequency of black limestone clasts at the lower part of the second one, is similar to that in member 1, though grain sizes are smaller and more equal, while these clasts are to be found very seldom in the upper portion. Fenestral fabrics — especially in the upper part of the member — are rare. Fillings, associated with bioturbation and dendroid holing, are restricted to some beds. There are also differences in the distribution of macrofauna: the lower portion contains small rudist (*Agriopleura, Eoradiolites* and *Toucasia carinata* (MATHERON) – beds 53 and 64 – cPlate V: 4, p. 192; bPlate VI: 1, 2, p. 70), and in bed 64 small *Chondrodonta, Plesioptyxis* gastropods are present too. The Chondrodonts may form biostrome. The upper part of the member is characterized by *Toucasia* with a dark grey coloured shell, sometimes with a biostrome character. A small-sized *Chondrodonta*-bearing layer is situated on the border of members 1 and 2. Limestone shows dominantly a packstone, and subordinately a wackstone and floatstone texture, while a mudstone type is restricted to the lower part of the member. Grainstone and rudstone textures are very rare.

The diversity of the fossils in thin-sections corresponds to the marine beds of the first member; however, their frequency is higher here. It particularly refers to the Dasycladaeae species (cPlate VI: 6, 7, p. 193). *Orbitolina* (118 m to bed 67) and Alveolinids (from 122 m upward) are new elements of the foraminifers (cPlate VI: 3–5, p. 193). Occasionally there are some smaller *Bacinella* and in connection with that, there are Codiaceae (*Lithocodium*) colonies. The foraminifer and green alga flora of these layers were studied by Bodrogi *et al.* (1994). *Chara* remains from the highest stratigraphic position were found in the lower part of member 2. By modern study of the larger foraminifers Görög (1996) also revised the observations of the previous works concerning the Orbitolinids. She recorded the presence of six species in this member. Czabalay (1994) reported the following rudists and rudist zones from this member: *Agriopleura marticensis – Caprina douvillei* and *Requienia ex. gr. tortilis – Toucasia carinata* Zones.

Member 3

Member 3 can be found in a strongly tectonized part of the quarry (bPlate I: 3, p. 65), where in the thick-bedded, massive sequence it is hard to recognize both the angle and the direction of the stratal dip. Owing to the unknown stratal dip — and ignoring the previous numbering — samples are indicated with measured metres at the foot of the wall of the quarry. For construction of the (columnar section — cFigure 5, p. 176) stratal dips of uncertain measurement were used. These are in harmony with those ones obtained under and above the succession.

The lower boundary of the unit is drawn at the top of the bed and is indicated by 6 m (total thickness: 140 m) in section II, while the upper boundary of the bed is indicated by 54 m (total thickness: 176 m).The thickness of this unit is approximately 40 m. A less tectonized lower part of this member is fractured and intergrown by calcite veins. The upper portion, however, is extremely tectonized and brecciated. Red clay, red calcareous marl or siltstone, and also red or white calcite are the most important bonding agents. In addition limestone blocks and cobbles as constituents of breccia fine-grained sandstone also occur.

Large-sized *Toucasia* pelecypods with dark grey shells are less abundant here than the previous member. However, macroscopic *Bacinella–Lithocodium* (Codiaceae) colonies recognizable by an unaided eye are characteristic in limestone blocks.

Packstone and boundstone are the most common texture types, though wackestone and mudstone also occur. Floatstone and rudstone textures are rare. These types of rocks (together with the fissure fills) can be correlated with those of the section between 60–100 m of the Borehole Nagyharsány Nh–1. These are important marks from a major structural pattern point of view. Thin-section study confirms the presence of *Bacinella–Lithocodium* colonies, whereas coral colonies also can be identified. The content of foraminifers is slightly poorer than in member 2. Orbitolinas are the dominant fossils in most of the beds, however, large sized miliolinas are more significant in those beds where orbitolinas are either subordinate or absent. The lack of Dasycladaceae is conspicuous in beds 69–71 and consequently their fossil assemblages do not belong to this series in spite of the classification of Bodrogi *et al.* (1994). (They are originate from layers which are situated 30 m deeper.)

"Member 4" (Now it is part of member 3; Figure 30)

The uppermost member's thickness is unknown in spite of the fact that the section is incomplete. The section exposes 25 m of the member. The less steeply dipping layers are dissected by an 8 m thick (in its surface projection), vertical fracture filled by Pliocene (sometimes Miocene) sandstone debris. Due to the consequent stratal dipping, numbering was done according to layers (section III/1–12).

The bedded, massive, light-grey limestone is unified by disseminated orbitolinas. Dendroid corals, frequent *Bacinella–Lithocodium* colonies and disseminated. rudists are characteristic for the lower part of the member. These features are only subordinate in the upper part of the section. The textures of the lower part are boundstone and packstone due to the colonies, whereas wackestone is the only texture of the upper portion. In agreement with the above-mentioned each fossil component is under-represented in the upper part. The micritic matrix gets richer in carbonate-silt (composed of fine-grained fragments of fossils) in an upward direction. This is a clear indication of a weakly agitated environment. *Orbitolina* fauna exclusively composed of *Orbitolina (M.) texana* (Roemer) according to Görög (1996).

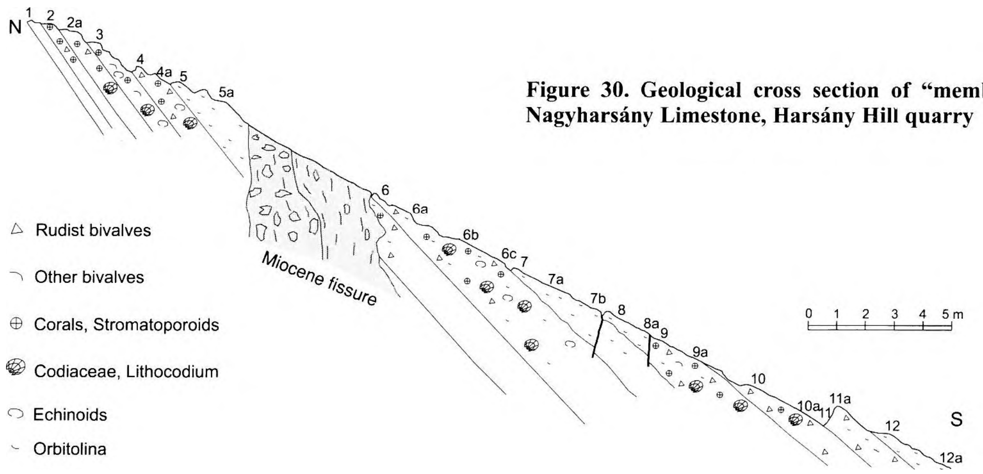


Figure 30. Geological cross section of "member 4" of the Nagyharsány Limestone, Harsány Hill quarry

Partial sections on the surface

The lower and most varied parts of the section were recorded in more detail, (a decade ago) in order to demonstrate the macroscopic textural, structural and sedimentary features. This study also emphasizes the facies-variability and the changes in the author's ability to recognize features (cFigure 2, p. 173). Several partial-sections were recorded in order to identify variability and the particular relationships of beds. The section on the southern slope, next to the bauxite-lense at the top (cPlates V: 1, p. 192; VI: 1, p. 193), is the most distinct one from the above-described type-section (Figure 31). A sketch map shows the relationship of the formations (Figure 32). The speciality of the section is that both the Szársomlyó Limestone and the Harsányhegy Bauxite occur on two occassions. Thin-sections were made — unfortunately — only from the lower part of the section. However, older (Late Jurassic) and younger (Early Cretaceous) cycles can easily be distinguished macroscopically, albeit with a little practice. The results of microscopic studies (cFigures 6, 7, p. 177–178) drew the attention to the need for more detailed fieldwork, especially with respect to the presence of boulders of the Szársomlyó Limestone (sample 15 and 17) in the Harsányhegy Bauxite and Nagyharsány Limestone. Along the section the Szársomlyó Limestone of a grainstone texture is overlain by 4 m-thick mudstone and wackestone type limestone consisting almost exclusively of *Chara* remains (oogoniums, stems and roots) and subordinately of Ostracode shells. Its worth mentioning that miliolinids in bed 11 indicate some marine water influence on freshwater. Dessication cracks and to a certain extent root structures refer to a temporary drying up. Nagyharsány Limestone is followed by an 0.7–1 m thick, red bauxite lens in which the base of the overlying Nagyharsány Limestone 10–30 cm-sized cobbles of the Szársomlyó Limestone can be found. Boulders display in part clastic or karstic surfaces. Boulder, which is 40 cm in diameter and partly sank down into bed 17 plays a significant role in the formation of the sequence. The second bundle

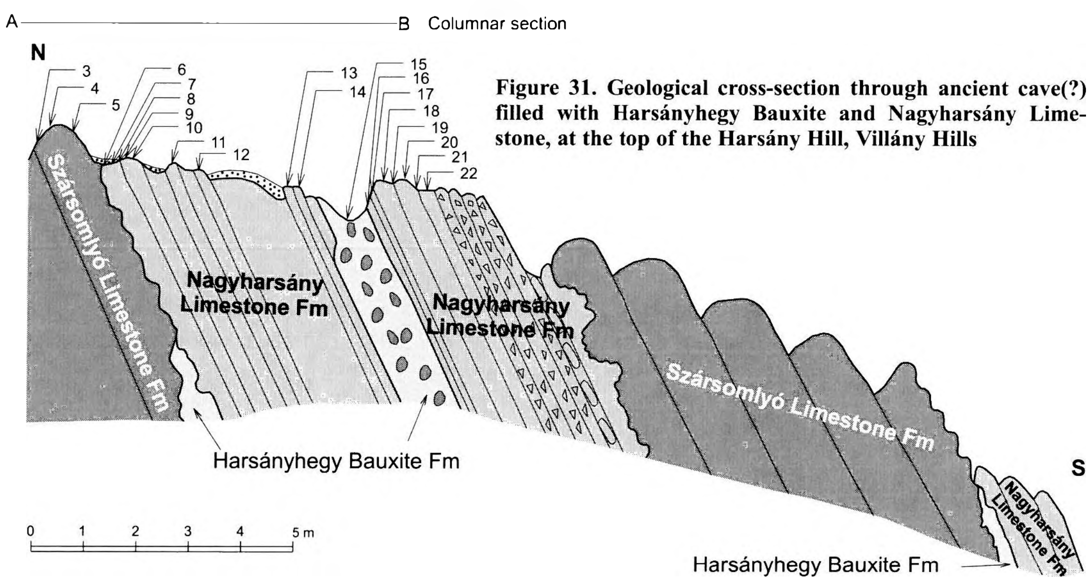


Figure 31. Geological cross-section through ancient cave(?) filled with Harsányhegy Bauxite and Nagyharsány Limestone, at the top of the Harsány Hill, Villány Hills

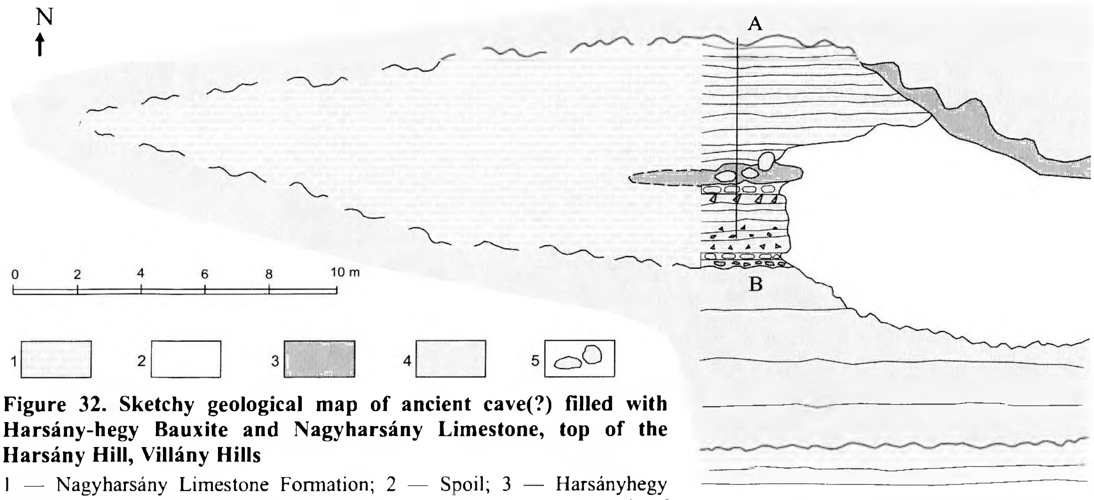


Figure 32. Sketchy geological map of ancient cave(?) filled with Harsány-hegy Bauxite and Nagyharsány Limestone, top of the Harsány Hill, Villány Hills

1 — Nagyharsány Limestone Formation; 2 — Spoil; 3 — Harsányhegy Bauxite Formation; 4 — Szársomlyó Limestone Formation; 5 — Debris of Szársomlyó Limestone

of the Nagyharsány Limestone exceeds 2 m. Apart from the uppermost 25 cm, the upper part of the section is characterized by a nodular intraformational breccia structure. The upper boundary is an uneven "bedding plane" along a significant distance and it gradually turns into a dissolution surface eastwards. It is followed by the Szársomlyó Limestone the thickness of which is 6 m. The customary Cretaceous sequence returns again and in it a small bauxite lens can be found. (In sample 18 *Clypeina jurassica minor* KERČMAR and *Pianella grudii* RADOIČIĆ species were identified by O. PIROS (personal comm.). This bauxite lens corresponds to those in the quarry's wall, while the previously described one can be found 10-14 m under this bauxite body.

The wedge-shaped end of the Nagyharsány Limestone is marked by a dashed line westward on the sketch map (Figure 32). The dashed line is qualified in order to express the fact that there was no exact measurement in the field in this respect simply an estimation. It is obvious from the previous pages that the lowest bauxite level and the directly covering beds of the Nagyharsány Limestone were deposited in a non-marine environment and their thick, repeated appearance can be explained with the help of a model showing a shallow, cave-like hole or at least partly covered doline (Figure 33). Both the interpreted section and the model suggest that the bauxitization was in progress in the background even during that time when the cave-like hole (doline?) was flooded by freshwater and the bauxitic material was redeposited here due to the effect of a considerable amount of precipitation. The probability of this model is supported by the observation of TELEGDI-ROTH (1937) who recognized that isolated bauxite traces also occur in the Upper Jurassic limestone that were considered to be the product of the same bauxite level. At the same time this model also offers a chance to cease the apparent conflict which existsts in the abrupt changes between two types of limestones of the Szársomlyó Formation namely, the fully marine Berriasian grainstone and the freshwater mudstone and wackestone (BODROGI *et al.* (1994). Nevertheless, further investigation is needed to clear up the age and genetic structure of the light-reddish limestone of various grain-sizes which fills small holes and fissures in the Szársomlyó Limestone. This is approximately 10 m below the top of the formation, — that is to say, at the same level at which the cave-like bauxite level is situated.

Section H (cFigure 8, p. 179) is selected in the wall of level 2 counting from the base. It reflects an internal stage of exploitation that may have changed rapidly. In a certain respect the situation resembles that one in cFigure 7, p. 178, because the predominantly grainstone and wackestone fabric of the Szársomlyó Formation alternates with the ostracode- and *Chara*-bearing beds of the Nagyharsány Limestone also without transition. Thanks to the exploitation, the outcropping conditions were extraordinarily good and one could notice (not with an unaidedeye) that "beds" represented by

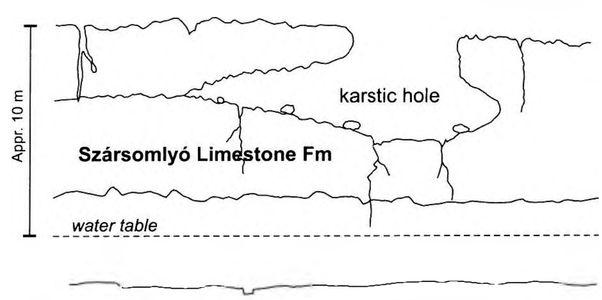


Figure 33. Idealized cross-section of the cave-like sink-hole developed in the Szársomlyó Limestone, Harsány Hill, Villány Hills

Table 5

Green algae in section H of the mining level 2, Harsány Hill quarry (after O. Piros, manuscript)

	6	9	16
Acicularia sp.		+	
Actinoporella maslovi Praturlon		+	
Clypeina jurassica Favre	+		+
Clypeina jurassica minor Kerčmar			+
Pianella grudii Radoičić			+

numbers 6, 7, 9, and 10 were strange bodies pinching out in the Cretaceous sequence. This observation was confirmed by the results of thin-section studies, namely by the texture diagrams and fossil content. Nevertheless, one contradiction has to be mentioned. Contrary to expectations bed 4 also belongs to this (marine) group. The situation might be explained by the non-profound field study. Based on *Clypeina jurassica* Favre, *Suppilulimaella* sp., and *Permocalculus* sp., bed 7 was qualified by Bodrogi *et al.* (1994) as Berriasian, as far as bed 16, using *Clypeina marteli* Emberger, *Clypeina? solcani* Radoičić & Conrad and *Salpingoporella annulata* (Carozzi) were found to be Valanginian. Conrary to these data and the conclusion another algal association (Table 5) was identified by O. Piros (unpublished report) from the same beds.

Nevertheless, the situation is not absolutely clear. In samples 1 and 4, in addition to grainstone fabric, in a few cases wackestone fabric also occurs. Based one these data the occasional marine invasion also cannot be excluded completely. On the basis of dissolution patterns the wackestone type limestone seems to be younger than grainstone. Owing to the progress in exploitation, unfortunately the situation cannot be controlled anymore. At the moment I see two possibilities to explain the situation in the environ of section H. Thanks to the karstification some crags, as an organic part of the basement, might be erected above the water level during the starting phase of sedimentation, or these blocks represent collapsed remnants of small-size karstic towers.

Borehole Nagyharsány–1

The borehole was located at the southern part of the Neogene fracture filling, about 50 m away from the wall of the quarry at the same topographic height as of the office cabin. I had the opportunity to comprehensively describe and sample the upper 100 m part of the 150-m-deep borehole. From the samples, 20 thin-sections were prepared. The borehole intersects fracture fillings of various ages and lithologies. The uppermost 26 m long section exposes a sequence similar to that which can also found on the surface nearby (cFigure 9, p. 180). In the underlying, a grey silty marl bed appears with a minimum thickness of 25 cm. Both its lower and upper contacts are somewhat smudgy as they were torn by the corer The marl dips ca. 15°. The interval between 33 and 45 m is characterized by a network of white calcite veinlets, whereas that from 34 to 43 m is represented by red limestones and calcareous marls. Between 43.5 and 91.7 m red sandstone breccias dominate as the fracture fills, frequently being embedded in red mudstones. This pattern is very significant in the 56.8–58.0 m interval. Dip data measured on the individual sandstone fragments are scattered across a range of 0–70°. Beneath 95.6 m again the white calcite veinlets prevail, and so do the red limestone and calcareous marl fracture fillings below 98.3 m. The discrepancies in the lithologic composition of the core were first detected by the workers doing field description, and also by those processing the material in the laboratoty. Based on palynological, microfaunal and nannoplankton studies (J. Bóna, B. Kerner, M. Gál, respectively; unpublished manuscripts) it was demonstrated that the uppermost marl mass is younger than its overlying sediments. This phenomenon was explained by Bodrogi *et al.* (1994) with reverse fault. They indicated a further thrusting at a depth of 43.7 m, as well. The results of the larger foraminifer studies of Görög (1996) support my conclusions well, drawn from field observations. Namely, that the grey, calcisphaerule-bearing marl is identical to the Bisse Marl Formation and that it was emplaced as a fracture filling. However, fracture fillings made up of red marl and limestone display a wackestone fabric with detrital grains of echinoderms and rudists. Thus these rocks can be paralleled with the fracture filling described by Fülöp (1966). It is probable that the same lithologies are present at about 100 m. Neither this nor the presence of some siliciclastics about 50 m underneath support the idea of the above-mentioned thrust, for the latter is in every respect identical to a Neogene fracture filling in a surface outcrop (Figure 30). Its position is subvertical and it is nearly 4 m thick. The appearance of a zone close the youngest beds of the quarry, characterized by a strong crush, is so a consequence of extensional tectonics. Moreover, its microfacies is comparable to that of the middle third portion of the borehole.

Based on the fossils and facies pattern, from among the Cretaceous fracture fillings I consider the red marl and limestone lithologies to be the older ones. The sediments in question are unequivocally of platform origin no crinoids can be recognized amongst the echinoderm ossicles. The platform drowning is introduced by fracture formation. The lack of fossils however, apart from the aforementioned, still raises some questions. The calcisphaerula-bearing fracture filling reflects deeper marine conditions following the platform drowning and is hence younger than those mentioned earlier.

Beremend quarry

The history of the exploration of the southernmost occurrence of Mesozoic rocks of Hungary is basically similar to that of Nagyharsány (Peters 1863; Hofmann 1876; Schafarzik 1904; Lóczy jr. 1912, 1913; Rakusz & Strausz 1953; Noszky 1957, 1959; Fülöp 1966; Peybernès 1979; Peybernès & Conrad 1979; Császár & Farkas 1984; Császár 1989; Czabalay 1989; Schlagintweit 1990a; Császár 1992; Császár *et al.* 1994; Czabalay 1994; Görög 1996).

The quarry has been operating since the 19th century. Back in the times of my field works, there were three levels working (Figure 34). These levels expose a 46 m thick section of the Nagyharsány Limestone Formation. In spite of the gentle dip, there are missing intervals of strata between the respective levels, which are 6 and 16 m thickness, respectively. The limestone is thick-bedded to massive, medium grey in colour and it often smells of bitumen. Arranged to certain levels, pale grey intraclasts or onkoids of a faint, obscure contour may be present. The macrofauna (Czabalay 1994) consists predominantly of rudists: *Toucasia carinata* (Matheron), *Caprina douvillei* (Paquier), *Requienia ex. gr. tortilis* Mainelli, *Praecaprina* sp., *Monopleura* sp. and *Agriopleura* sp. On the other hand, *Chondrodonta* sp. and gastropods, such as *Plesioptyxis prefleuriaui* (d'Orbigny), *P. fleuriaui* (d'Orbigny) and *P. cretacea* (Conrad) are also abundant. A part of the microfauna can off and on be even macroscopically observed; a darker tone of orbitolines and a lighter hue of the miliolids are more or less discernible. The rock matrix is usually micritic and the most abundant allochems are bioclasts and pellets. However, their frequency varies within a narrow range. Dominant fabric types are wackestone and packstone; mudstone and floatstone occur only occasionally, whereas grainstone and boundstone have been proved to be exceptions. In thin-sections, the fossil assemblage appears to be rather scanty; the most abundant are benthic foraminifers being rich in both calcareous and arenaceous forms. The most common benthic foraminifers are the miliolids, including some large-sized forms as well. The orbitolines, which are of outstanding stratigraphic importance, occur only sporadically although in a couple of samples they may exceptionally be more abundant. The following biogene constituents are still common but occur in lesser proportions: Cadosina, ostracods, fragments of echinoderm ossicles and pelecypod shells. *Bacinella irregularis* Radoičić and *Lithocodium* sp. are only rarely found in colonies of significant size. Dasycladaceans are an apparent rarity, whereas spicules occur in only one bed in a frequency worth mentioning. A detailed description of the foraminifer assemblage of the section is found in Bodrogi (in Császár *et al.* 1988). A modern investigation of orbitolines is thanks to Görög (1996). This assemblage — which consists of two species [*Orbitolina (M.) texana* (Roemer) and *Dictyoconus pachymarginalis* Schroeder] — differs significantly from the taxonomical listings of other specialists, whereas it bears good resemblance to the data of Schlagintweit (1990a).

A detailed description of the 424-m-long upper part of the 850-m-deep Borehole Beremend–1, drilled in the yard of the Beremend quarry, is found in the monograph of Fülöp (1966). Unfortunately, the re-examination of those numerous thin-sections turned out to be unattainable. Therefore, a brief summary hereunder is entirely based on Fülöp's work.

The Nagyharsány Limestone, overlying the Szársomlyó Limestone, may appreciably be paralelled with that observed in the Harsány Hill section. A sequence 424 m thick was split into four parts of a nearly identical thickness. The three lower units exhibit similarities to a certain degree with those in the surface section of Nagyharsány which was subdivided by me. In contrast, the spicule-bearing facies is within Fülöp's 2nd unit, whereas in the Nagyharsány section they first appear in the uppermost beds of the member 3. The youngest beds of both columns are confined to the Gargasian stage by Görög (1996). Hence the thickness of the Beremend section is twice as large as that of the Harsány Hill; sedimentation at the Beremend area must have commenced earlier. I shall come back to this point later — that is namely, when the palaeogeographical circumstances are outlined.

With respect to the lower part of the Borehole Beremend–1, neither Fülöp's monograph (1966) nor the data available at the archive provide reliable information. As the downward continuation of the borehole is considered to be Cretaceous in age, I made an attempt to do additional samplings in the

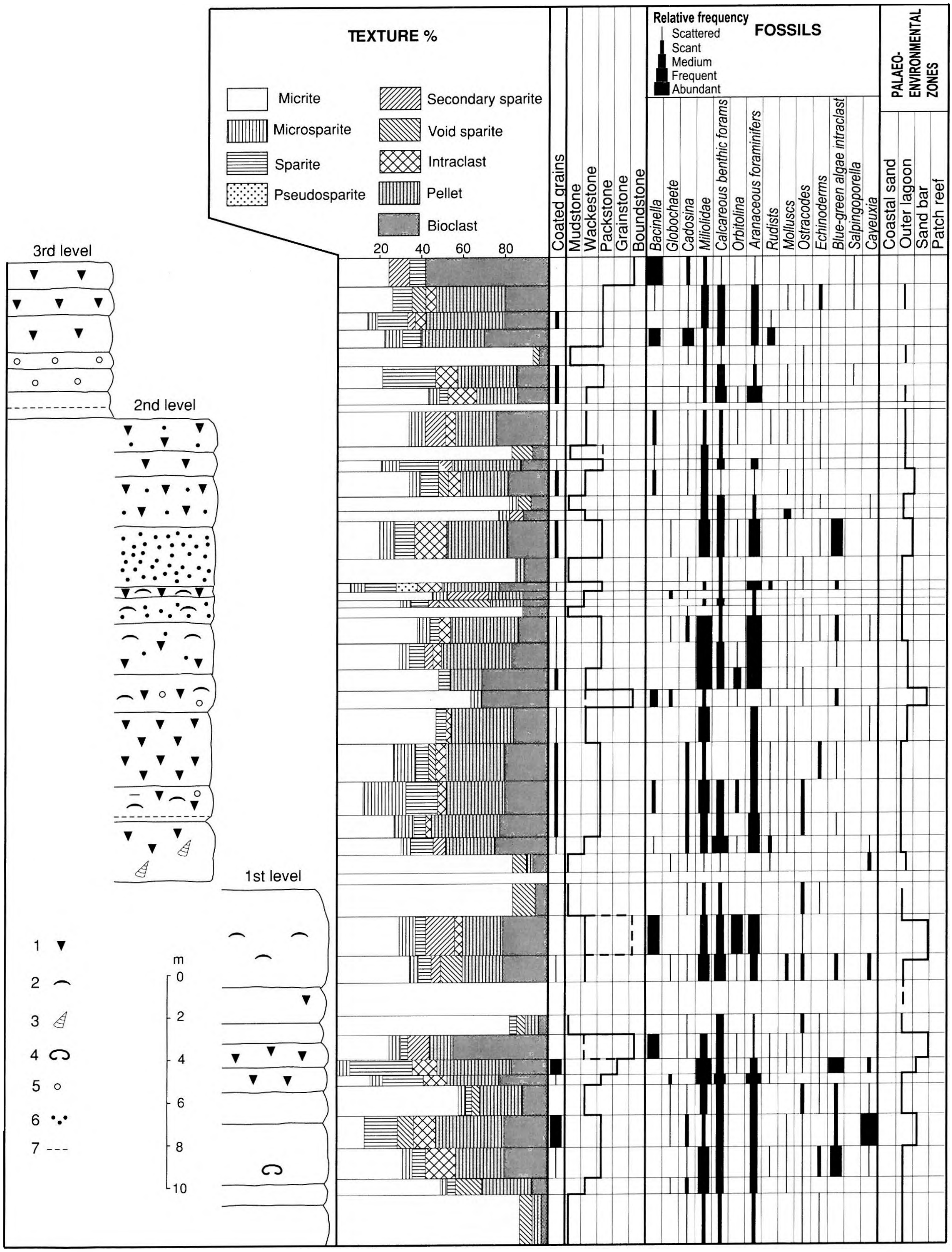


Figure 34. Columnar section of the exploitation levels, results of thin-section studies and sedimentary environments of the Beremend quarry, South Transdanubia

1 — Rudist bivalves; 2 — Other bivalves; 3 — Gastropods; 4 — Sea urchins; 5 — Oncoids; 6 — Miliolids; 7 — Argillaceous horizon

Somogy core storehouse of the Geological Institute of Hungary. The samples originating from the interval 424.0–508.9 m could not be dug out. On the contrary, those accessible were from 508.9–850.0 m, thus I acquired 32 samples for thin-sections. Both the defective wrapping of the cores and the modest number of the thin-sections hindered the reconstruction of this part of the sequence to a deeply level. The most important results and the interpretation thereof, coming from thin-section studies, are demonstrated in Figure 35. A greater part of the respective interval proved to be Szársomlyó Limestone with packstone fabrics which, in the downsection, gradationally pass into grainstone. Simple ooids occur at 553 m, transforming the downsection step-by-step to sincere ooids. Almost contemporaneously, Saccocoma appears, and in turn, becomes more and more abundant. The observed and inferred contacts between the Jurassic/Cretaceous formations are indicated in the sketch of the column by solid and dashed lines, respectively. I cannot determine the style of those contacts between Jurassic and Cretaceous slices but the recurrent repetition suggests tectonic juxtaposition. The first occurrence of the Nagyharsány Limestone of mudstone fabric and containing detrital pelecypod and gastropod shells is at a depth of 568.5 m. The next limestone unit, also containing intercalations of the Szársomlyó Limestone, is found between 637.0–646.0 m. This is a freshwater facies, accommodating only characeans and ostracods. The two individually intervening units at 693.0 and 726.0 m are marine facies with smaller foraminiferal-pelmicritic mudstone and wackestone fabrics. With the exception of two samples, every sample belongs to the marine facies of the Nagyharsány Limestone and they display wackestone and packstone textures. However, there are some smaller foraminiferal mudstones and bacinellid wackestone, too. Rudistid and dasycladacean facies are here subordinate. Similarly, miliolinids are rare, too. A facies which may be denoted as orbitolinid, occurs only close to and at the base of the borehole (846.5–848.5 m; 849.5–850 m. GÖRÖG (1996) discovered a form of stratigraphic value herein, namely *Orbitolina (M.) texana* (ROEMER). From the Szársomlyó Limestone, O. PIROS (1997, unpublished report) determined the species *Pianella grudii* RADOIČIĆ (at 649.5 m and between 803.0–804.5 m) and *Clypeina jurassica minor* KERČMAR.

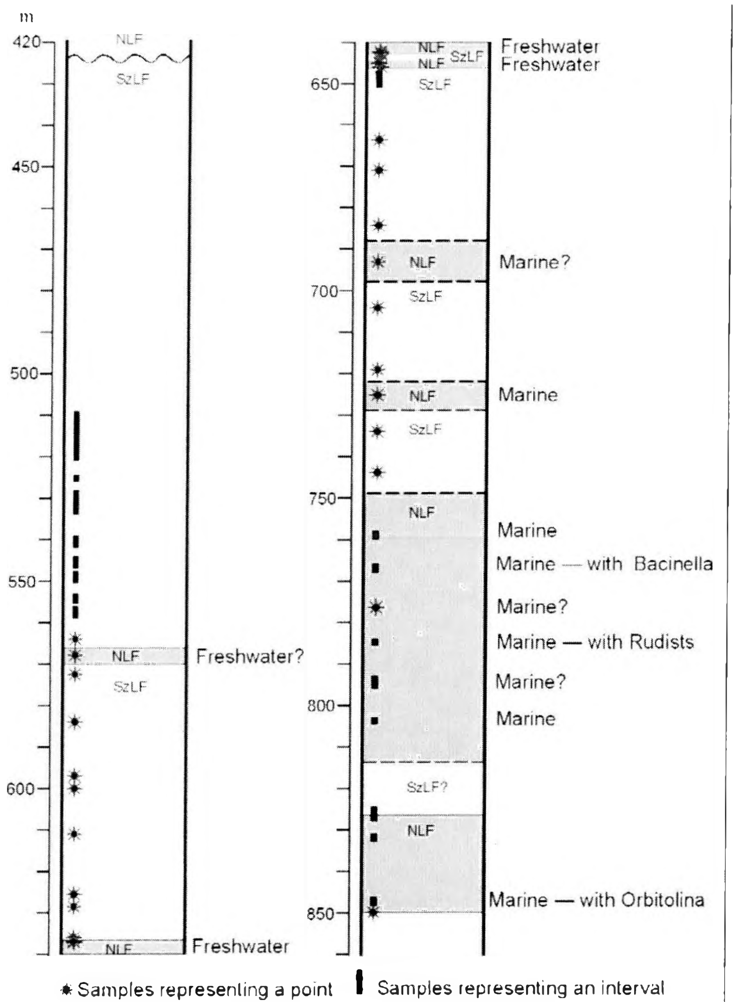


Figure 35. Sketchy column of the lower part of Borehole Beremend–1, located in the Beremend limestone quarry. Its lithostratigraphic subdivision based on thin-section data

NLF — Nagyharsány Limestone Formation; SzLF — Szársomlyó Limestone Formation

The alternations of the Szársomlyó Limestone and the Nagyharsány Limestone in the borehole section indicate thrusting movements. A principle drawn from a limited number of data is somewhat contradictory — that is, Saccocoma appears to be in the upsection less abundant. This reflects normal stratigraphic ageing. In contrast, with respect to the Nagyharsány Limestone, non-marine characean facies occur in higher horizons whereas the orbitolinid strata appear at the base of the borehole. For these reasons, downsection the Createaceous appears to be younger but on the other hand the Jurassic seems to be older.

While I was carrying out the profiling at the lower and upper working levels of the quarry, I observed bauxitic clay as fracture filling (cPlate VI: 2, p. 193) and as doline fill (cPlate V: 2, p. 192), too. The analysis of the samples collected verified that they pertain to the second bauxite horizon of the Villány Zone (CSÁSZÁR & FARKAS 1984); the exlusive mineral phase thereof is gibbsite, whereas boehmite prevails, accompanied by a minor proportion of diaspore, in the Harsányhegy Bauxite overlying the Szársomlyó Limestone.

Occurrences at Tenkes Hill

Cretaceous formations of the Tenkes Hill were formerly mentioned as Jurassic (HOFMANN 1876; SCHAFARZIK 1904). LÓCZY JR. (1912) was the first to discover that these rocks were of Cretaceous age, and he separated them from those on the Harsány Hill, describing them as Tenkes facies. Following many bauxite prospects carried out by TELEGDI ROTH (1937); RAKUSZ (1937); STRAUSZ (1941) and NOSZKY (1957), the first detailed investigations on the formations of the Tenkes Hill (Figure 27) were performed by FÜLÖP (1966). He exhaustively portrayed the essential palaeontological and lithological features of the sections of the trenches atop the Tenkes Hill and that in the Szabolcs Valley quarry (bPlate I: 4, p. 65). Based on joint facial features, FÜLÖP distinguished four groups of strata within the "lower Albian pachyodontid-orbitolinid limestone beds" on top of the Tenkes Hill: (a) "packed and with crumbs of lime mud", which is more or less equal to the term 'pelletal', (b) "comprising minute shell fragments", (c) "orbitolinid", (d) "pseudo-oolithic to orbitolinid". Among other things, he pioneered the recognition of the red, crinoidal, limestone fracture fillings pervading as deep as to the Kimmeridgian limestones. He considered the material of the fill to be the result of a sort of short-lived but pronounced facial change triggered by crustal movements. The contact of the Nagyharsány Limestone and the Bisse Marl was trenched such as to be exposed. FÜLÖP established the "abrupt, sudden change with respect to the lithofacies" of the two formations. He reported the fauna and flora contents and the chemical and petrographical compositions of the Bisse Marl very extensively. For the purpose of the refinement of the relations between the Nagyharsány Limestone and the Bisse Marl, and because the older trenches were already collapsed, we created a new one (Figure 36). The new trench is located near the former hunting lodge, just next to the artificial outcrop trenched in the early 1960s. After we had removed a thick loess cover, we succeeded in cropping out the contact of the two formations. Indeed, it was found to be abrupt, the boundary surface being slightly uneven. The sequence here lacks the red, crinoid-, and planktonic foraminifer-bearing limestones, which appear in the area in the form of fracture fills. A probable explanation of this is that the vacuum generated by the fracture opening drew in the yet unconsolidated mud to the voids. The underlying fine-grained limestones are grey in colour, display a grainstone fabric and contain many tiny pellets and bioclasts (chiefly echinoderms). Nevertheless, orbitolines are abundant, too. In the thin-section of sample 1 it can be recognized that the marl is infilling the surface roughnesses of the limestone. The discontinuty plane is covered with a limonitic crust; however, in the light of the macroscopic observations this phenomenon cannot regarded as being for regular. Some tiny planktonic foraminifers and quartz grains occur in the marl.

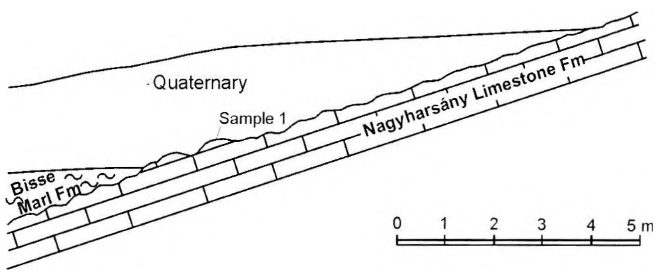


Figure 36. Stratigraphic contact between the Nagyharsány Limestone and Bisse Marl near the Hunting hut, Tenkes Hill

From the Szabolcs Valley quarry situated at the foot of the southern flank of the Tenkes Hill, operating on and off and was renamed several times during the last decades, FÜLÖP (1966) gives an account of the investigation of a very fossiliferous bed of mere 2 m thickness. He lists large-sized rudists, *Lamellotis* (*Chondrodonta* today), gastropods, solitary corals and numerous microfossils. As the excavation progressed, within the scope of my profiling works I had the opportunity to document a succession of 18 m thickness (cFigure 10, p. 181) in a sequence appearing underneath the Middle Triassic dolomite at the eastern margin of the quarry.

The limestone is white to pinkish in colour, and on rare occasions it displays red patches. Its size is thick-bedded to massive. According to thin-section studies, the Szársomlyó Limestone is of Saccocoma-bearing oopelsparitic grainstone texture. The Szársomlyó Limestone, cut by an erosional surface, is unconformably overlain by the Nagyharsány Limestone (bPlate I: 4, p. 65). The most common fossils of the latter are the nearly omnipresent rudists. The most striking among them is the large-sized *Toucasia carinata* (MATHERON), but species of *Agriopleura* may also be present. In the middle part of the section, within three distinct horizons, corals occur in an upright position. Contemporanously, a 20-cm-thick lensoid rock mass of coarse sandstone consisting of detritic orbitolines is deposited. The bivalves *Agriopleura* oriented upright are infilled with red marl. A sort of similar marl can occasionally be observed in other horizons, too. The column is capped by a gastropod-bearing limestone bank.

The thin-section pattern is similar to that described by FÜLÖP (1966), but it appears to be somewhat more varied. The lowermost bank (samples 1 to 7) is dominated by wackestone fabrics, reflecting normal saline conditions. The orbitolines and rudist pelecypods are already present in the lowermost sample. The second part (samples 8 to 13) is characterized by packstone, grainstone and floatstone textures, with significant masses of rudist shells and orbitolines. Various textures are typical for the third interval (samples 14 to 21); from wackestone to grainstone, moreover, micritic or sparry floatstone is also found. In contrast, orbitolines are missing or nearly missing and the proportion of the shell fragments of the rudists markedly decreases, too. However, colonies of *Ethelia alba* PFENDER are seemingly frequent and well-developed. Among the reduced number of biogene constituents the increased amount of foraminifers is the only striking feature of the wackestone to packstone-type limestones in the fourth part of the section (samples 22–25).

I found many examples of the appearance of clasts, sands to pebbles of grain size, and of subjacent limestone, partly forming a section of the base of the Nagyharsány limestone, being which is embedded in its material. These samples are from fallen boulders and are not found in bedrocks at all. Several generations of cements can be distinguished. The oldest is probably of freshwater origin; it contains only a few ostracods and is of mudstone fabric. This may be present in the form of limestone clasts in a normal marine limestone. Furthermore, in the crevices of this freshwater limestone, mudstone with rudist fragments occur. This may even again be intersected by microsparry crack fillings. Elsewhere rudistid wackestone or pelbiosparitic grainstone as cements may also appear. All these mean that the decisive transgression event might have been preceded by a freshwater period even intermittently interrupted by marine phases.

Having re-examined the fracture fill described from the top of the Tenkes Hill by FÜLÖP (1966), I came to the conclusion that it consists partly of planktonic foraminiferal, crinoidal packstone, and on the other hand, of planktonic foraminiferal and ostracodal wackestone. Both rock types contain subordinate rudist fragments. Mention must be made of some quartz and glauconite grains, too.

On the western side of the Szabolcs Valley (nowadays Water Conservation) quarry a volcanic dyke intruded the sequence including the Nagyharsány Limestone (Figure 23). There is no remarkable alteration at the contact zone, apart from an insignificant change in colour into grey. However, the development of an expressive micritization, which cannot be always distinguished from the pits and voids filled by silt, might be confined to the effects of the intrusion. In the rock, rich in *Acicularia*, apparently large and euhedral feldspar and subordinately situated quartz grains occur. These are laced with calcite.

The microfauna evaluation of the thin-sections acquired from the section was performed by GÖRÖG (1996). Among others, she reported the following fossils to be of biostratigraphic interest: *Simplorbitolina manasi* CIRY *et* RAT, *Orbitolina (M.) texana* (ROEMER), *Paracoscinolina sunnilandensis* (MAYNC) and A*rchalveolina reicheli* (DE CASTRO). These suggested an age of formation as Late Aptian (Clansayesian) to Early Albian, although this needs further investigation.

From the sedimentological point of view, the most striking phenomena are the large bio- and intraclasts with dogtooth cement rinds, indicating that the formation of meteoric cement points to a period of formation took place (withouth micrite), prior to the precipitation of pore-filling micrite.

MINERALOGICAL AND GEOCHEMICAL INVESTIGATIONS ON THE NAGYHARSÁNY LIMESTONE

Investigations described in the passage below (Tables 6 and 7) were carried out between 1984 and 1996; this is, to some extent, mirrored in the results. Nevertheless, the restriction of bauxite minerals to pregnant hiatuses is considered to be a striking feature of the stratigraphic succession. According to X-ray powder diffractometry (Table 6) and thermal analysis (Table 7) the diaspore content of a fracture-filling of the Szársomlyó Limestone and the gibbsite content of the Miocene fracture filling was 6-7% and <1%, respectively. P. KOVÁCS-PÁLFY has demonstrated that in the diaspore-bearing (that is, the Lower Cretaceous) sample the only accompanying clay mineral is sudoite (45%) which is made up of a probably regularly alternating interlayering of chlorite-like and smectite-like laminae. It is presumably a product of subaerial weathering of basic volcanic rocks. The thermal analysis carried out by M. FÖLDVÁRI has shown that the proportion of chlorite+kaolininte in this sample is 40%, and that it is accompanied by vermiculite to a degree of 15%. A similar clay mineral (tosudite) from the Lower Createaceous limestones of the borehole Doboz–1 was detected by VICZIÁN (1987, 1992). He explained its formation by the diagenetic alteration of clay minerals (kaolinic in composition) at a temperature of around 200 °C. On the contrary, the pelitic fractions of both the pelitic palaeosols of short-lived ter-

Table 6

X-ray diffraction analysis of the Cretaceous sequence, Harsány Hill quarry, analysed by L. BOGNÁR (1st sample), G. RISCHÁK (marked by ^), L. FARKAS (57.2 m) and P. KOVÁCS-PÁLFFY (the rest)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Fissure fill in SzLF					45		6	1				41*		1	4	1	1	
Level 2, bauxite 2		12	5			4				56			18	5				
Bed	4^		47^	4						49					15			
	6^	t						t		99				1				
	11^	4	51	9						36								
	12^	2	11							86						1		
	13^		18^							82								
	15^	3	20							77								
	17^		58^			4				23					14			
	17a^		45^	8						17			30		10			
	20^	3	43	t		11				28					16			
	22^	3	16							74					6			1
	30^		8			1				90				1				
	33^		9					t		91								
	38^	5	12							78				3	3	2		
	44^	6	35							56					5	3		
57.2 m		8	22	14				49	3	2		1						1
Miocene fissure fill		9	36	12		4		6					3		4			
Rudist shells, Márévár Valley								2	1	96	1							
Toucasia shell fragments		2						1		97	t	t						
Treated with HCl																		
Bed	4^	5	78	5				6							20	6		
	6^		35^	22				30						13				
	12^	11	55	11				4					16		15	?3		
	17^		54^	7									33		15	6		
	30^		74^	9				4						6	15	7		
	33^		75^	?8				17							10			
	38^		56^	9				6						20	8	9		
	44^		84^	8											10	8		
Beremend quarry																		
Red calcareous marl				3														

1 — Montmorillonite; 2 — Illite; (+ illite-montmorillonite when marked by sign ^); 3 — Kaolinite; 4 — Sudoite; 5 — Chlorite; 6 — Diaspore; 7 — Quartz; 8 — Feldspar; 9 — Calcite; 10 — Aragonite; 11 — Dolomite (calcite containing 1 mol dolomite when marked by *); 12 — Goethite; 13 — Hematite; 14 — Amorphous; 15 — Anatase; 16 — Rutile; 17 — Pyrite; SzLF — Szársomlyó Limestone Formation; t — in traces.

restrial periods, and the freshwater to marine limestone varieties of the Nagyharsány Limestone at Harsány Hill, are composed of chiefly illite and interlayerings of illite-montmorillonite. Besides the Miocene samples, the accidental occurrence of kaolinite is striking; in the case of untreated samples and insoluble residues its maxima are 14% and 22%, respectively. Chlorite rarely occurs and a maximum of 11 percent weight was determined. The strata contain a significant fraction of X-ray amorphous minerals; it is 14% for untreated samples and 20% for the insoluble residue.

Layered or void-filling variegated marls and clay marls are discoloured by goethite and hematite. The former concentrates up to 30% in untreated samples, whereas the latter one only up to 3%. Their maximum concentrations in the insoluble residue are 33% and 20%, respectively. Pyrite is markedly scarce; only two samples contained it in concentrations of 1%.

Table 7

Thermal analysis of the Cretaceous sequence, Harsány Hill quarry, analysed by M. FÖLDVÁRI

	1	2	3	4	5	6	7	8	9	10	11
Fissure fill in SzLF			15	40		7		31			
Level 2, bauxite 2	11	9			6			56			17
Miocene fissure fill	14	28		14			<1				5
Toucasia shell								96	t	1	
Rudist shell (Márévár Valley)								93			

1 — Montmorillonite, 2 — Illite, 3 — Vermiculite, 4 — Chlorit/kaolinite, 5 — Chlorite, 6 — Diaspore, 7 — Gibbsite, 8 — Calcite, 9 — Aragonite, 10 — Dolomite, 11 — Goethite.

Table 8

Spectral analysis of the Cretaceous sequence, Harsány Hill quarry, analysed by Spectral Analytical Laboratory of the Geological Institute of Hungary

Bed	B	Ba	Be	Co	Cr	Cu	Ga	Mo	Ni	Pb	Sn	Sr	V	Y	Zr
1	60	<40	16	<4	25	40	25	<6	60	25	<6	250	40	100	400
2	60	<40	16	60	40	40	40	16	100	60	<6	60	100	<60	250
3	60	<40	10	<4	25	25	16	10	60	40	<6	100	60	60	<100
4	<16	40	<6	<4	10	10	4	<6	4	<6	<6	160	16	<60	<100
10	<16	40	<6	<4	<4	6	<6	<6	6	<6	<6	100	10	<60	<100
11	60	400	<6	<4	25	10	10	<6	100	16	<6	250	100	<60	600
13	<16	100	<6	25	16	10	10	<6	16	10	<6	600	25	<60	<100
15	<16	100	<6	6	25	16	16	<6	40	10	<6	1000	25	<60	<100
17	100	100	<6	<4	4	10	10	<6	40	<6	<6	100	40	<60	1000
20	60	100	10	<4	10	16	16	<6	25	10	16	100	25	<60	1000
22	16	60	<6	<4	16	10	16	<6	4	<6	<6	600	25	<60	<100
Variegated lms	25	160	<6	<4	100	16	25	<6	40	25	<6	400	60	<60	<100

The carbonate mineral phase of the limestone strata is almost exclusively calcite. Only the latest X-ray diffraction study was able to demonstrate that the marl, filling the voids of the Szársomlyó Limestone, contains 1 mol% dolomite. Measurements of rudist shells yielded 1% or rather trace concentration values for aragonite, both by X-ray diffraction and thermal analysis. This is in accordance with the occurrence of botryoidal aragonite in 2-3 thin-sections. Surprisingly, the thermal analysis indicated 1% dolomite in *Toucasia* shells.

Generally, the amount of detrital mineral grains is negligible. The amount of quartz is generally lower than the limit of detection, but in a single sample we measured an excessive proportion (49%). Furthermore, it does not exceed 30% in the insoluble residue of the samples. For feldspars, which are quite uncommon constituents, a maximum of 3% was measured. The concentration of anatase, even in the case of untreated samples, sometimes exceeds the limit of detection (3%) and it may reach 9% in the insoluble residue.

The bauxite minerals detected in the fractures and dolines of the Beremend quarry (Császár & Farkas 1984) fundamentally differ from those recognized in the subjacent beds of the Nagyharsány Limestone. This was also corroborated by the analyses of Rischák & Énekes (1987). Accordingly, the red calcareous marl contains 93% calcite, as well as 3% gibbsite, 3% kaolinite and 1% hematite; on the other hand, the red clay with calcite lenses is made up of 10% calcite, 41% gibbsite, 19% chlorite, 17% goethite and 13% hematite.

In general, the microelement content of the Nagyharsány Limestone is rather scanty (Table 8). The samples 1 and 2 of the Szársomlyó Limestone differ in their relatively higher element concentration from those of the Nagyharsány Limestone. B, Ba and Sr are seemingly uncorrelated although it could be expected. The microelement content of the Harsányhegy Bauxite (Maximović *et al.* 1991) exceeds the values above (Table 8), with the exception of Sr and Ba. Rare earth element studies have only been done on the Nagyharsány Bauxite. These elements, according to Bárdossy *et al.* (1976), are harboured partly by clastic phases (*e.g.* monazite) and partly by authigenic minerals. In contrast to all of our expectations, iron and sulphur investigations carried out in the laboratory of the Geological Institute of Hungary by K. Soha and É. Bertalan did not reveal any relationship between the quantity or ratio of Fe^{2+}/Fe^{3+} and the degree of grey tone (Table 9). In limestones of little or medium iron content a substantial fraction of the iron is yielded by Fe^{3+} (the difference is about an order of magnitude), in spite of the predominantly greyish colour of these rocks. In case of the rocks which are yellowish to pale pink in colour this discrepancy increases to be two orders of magnitude. In the cases of six other samples the concentrations of the bivalent and trivalent states of the iron are in the same order of magnitude. However, a slight dominance of Fe^{3+} occurs. Surprisingly, not only the limestones which are greyish beige in colour pertain to this group but also those of red colour. In the case of only three samples do concentrations of bivalent iron exceed the concentrations of the trivalent one, within the same order of magnitude. One of these samples is a dark grey *Toucasia* shell; the other two provide an expected result: namely, grey limestones. So the greyish tone is an essential but not sufficient requirement for the excess Fe^{2+}. In other words, "gel pyrite" grains of disperse distribution cannot be regarded as a primary cause for the various sorts of grey scales.

Following the assumption of Strasser (1984), based on their observations and experiments Shinn & Lidz (1989) have demonstrated that angular, black limestone clasts found in stratigraphic successions can be attributed to forest-fires and they are often autochthonous and pedogenous. These exper-

Table 9

FeO, Fe²O³, SO⁴ and S content of selected samples of the Harsány Hill sequence (analysed by SOHA, K. BERTALAN, É.)

Sample	FeO	Fe_2O_3	SO_4	S
Harsány Hill				
Grey limestone above bauxite lense	0.08	<0.02		0.020
Base 1 of bed 3	0.026	0.201	0.098	
Base 2 of bed 3	0.071	0.331	0.098	
Base 3 of bed 3	0.043	0.163	0.130	
Base 4 of bed 3	0.026	0.234	0.041	
Middle1 of bed 3	0.026	0.161	0.218	0.003
Middle 2 of bed 3	0.025	0.379	0.070	
Top of bed 3 (pale grey)	0.089	0.210	0156	0.073
1.3 m above bauxite (fissure fill 1)	0.089	0.191	0.115	
1.3 m above bauxite (fissure fill 2)	0.040	0.150	0.082	
Bed 9 (black)	0.100	0.130		0.010
Bed 9 (greyish beige)	0.200	0.390		<0.010
Bed 29 (red limestone)	0.180	0.280		0.020
30.05 m (grey breccia)	0.044	0.970	0.065	
30.05 m (above breccia)	0.026	0.081	0.028	
Bed 38 (yellow with gastropods)	0.089	2.140	0.119	
48.35 m (grey)	0.026	0.240	0.218	0.018
48.35 m (white)	0.044	0.320	0.086	
76.2 m (grey)	0.085	0.031	0.065	
76.8 m	0.043	0.083	0.016	
82.2 m (grey)	0.043	0.120	0.074	
82.2 m	0.025	0.113	0.053	
Dropped limestone (above)	0.043	0.410	0.189	<0.020
Dropped limestone	0.026	0.371	0.230	0.018
Beremend				
Rudist shell (dark grey)	0.042	0.034	0.255	0.007
Rudist limestone	0.026	0.041	0.102	

FeO < Fe_2O_3 (with 2 order)
FeO < Fe_2O_3 (with 1 order)
FeO < Fe_2O_3 (within the same order)
FeO > Fe_2O_3 (within the same order)

iments have revealed that the blackening occurs at temperatures of 400 to 500 °C and it probably lasted 0.5–3 hours depending on the grain composition.

A major fraction of the clastic limestone grains which appear very commonly in the lower third of the Nagyharsány section is confined to subaerial hardground formation of shorter or longer periods. Because chemical investigations did not show any considerable amounts of organic matter nor disperse pyrite, the most obvious implication for the formation of the black grains might deal with forest- or scrub-fire events. Nevertheless, the clasts may have sizes up to tens of centimetres, exhibit visible positions within a certain bed and be of a frequent lensoid appearance; in rare cases there is a joint occurrence with gravels, which then suggests a possible short-distance transport related to storms. In a few exceptional cases, there are protected bedding planes, where the 1-to-2-cm-thick uppermost parts of the beds are progressively blackened and this crust has preserved their pristine position. Thin-section studies have demonstrated that a part of these planes have a laminated and crumpled palaeosoil horizon.

The role of the aforementioned thermal effect is confirmed by the contact effect along the basalt dyke in the Szabolcs Valley quarry. As mentioned, this is reflected in a darkening hue of the limestone towards the dyke, yet with the degree of crystallinity imperceptible under the microscope.

Some limestone beds of various greynesses — many tens of cm or even one m thick — recognized in the stratigraphic column should, however, by no means be regarded as of forest-, or scrub-fire origin. For a spectacular example of these phenomena in the case of paling-upward beds, see the 0.5–3.0 m and 10.0–16.0 m intervals in cFigure 2, p. 173. Many researchers observed a blackening of Holocene fossils and the host rocks of the intertidal or subtidal zone (GINSBURGH 1957; WAGNER & VAN DER TOGT 1973, *etc.*). These phenomena, however, were always explained by the organic matter or manganese sulphide content of the rocks. Many experiments of PILKEY *et al.* (1969) have proved that for this a reductive milieu is needed. Since there were no quantifiable investigations on organic matter nor on manganese sulphide, it cannot be ruled out that any of the two factors could be responsible for the changes in grey tones. Nonetheless, on the basis of tone discrepancies, organic matter as a factor seems more possibly to be precluded.

As it turned out in the foregoing, based even on the feature interconnections compiled by SHINN & LINN (1989), the two different sorts of blackening frequently can only be doubtfully distinguished.

GEOGRAPHICAL EXTENT OF THE NAGYHARSÁNY LIMESTONE

Apart from those described above and the small outcrops in the valleys of the Terentás Hill — Csukma Hill range, we only know one noteworthy surface outcrop of the Nagyharsány Limestone — namely, at the north-easterly border of the village of Kistapolca (FÜLÖP 1966). Furthermore, it was also cored below the Neogene formations in numerous boreholes in Transdanubia (Figure 26). In what follows, I provide a synopsis of the hydrologic and structure wells of Trandanubia, going from the north to the south, possibly nappe by nappe.

According to the field documentation of Á. JÁMBOR, the Borehole Nagykozár Nk–2 traversed Cretaceous limestones (Nagyharsány Formation) of 458.0 and 578.8 m. There are orbitolines recorded by photographs at 514.8 m in the report of Á. BARABÁS-STUHL (1988). Later, GÖRÖG (1996) assigned these to the genus *Orbitolina (Mesorbitolina)*. BODROGI *et al.* (1994) recognized the Szársomlyó Formation in the section between 579.6 and 663.8 m. A rapid macroscopic check of the strongly tectonized stratigraphic succession in this borehole did not allow me to distinguish the aforementioned formations. thin-sections have revealed that a majority of the samples collected from the interval 463.0–508.0 m are of fine-grained pelbiosparitic, subordinately even oosparitic grainstone facies, whereas the age of the formation is supposed to be Late Jurassic. Exceptionally, sample 4 has a poor fauna and is of mudstone texture, hence its biostratigraphic position is unclear. However, its Jurassic age might with good reason be precluded, and either Triassic or Cretaceous are considered as possible periods of formation. Furthermore, a Triassic age would be supported by the fact that there is more than a 10-m-thick calcitized or dolomitized limestone interbedding. To complicate matters, variegated, fine-grained, siliciclastic fracture fillings of a maximum thickness of 1.3 m also occur. Macroscopically, typical formations of Urgon facies (*e.g.* Nagyharsány Limestone) are missing in this borehole. thin-sections prepared from the depth interval 509.3–521.0 m show that between 515.5 and 518.7 m Cretaceous limestones do occur but their age is constrained by orbitolines. They are characterized mostly by grainstone textures but, subordinately, packstones and wackestones are also present. Spiculitic or carbonate-clastic rock types suggest deposition in the slope facies. Clastic and crinoidal samples from the portion extending down to 521.0 m are probably Cretaceous, too. Thus they might pertain to the Apátvarasd Limestone, representing its shallower facies. This is confirmed by the fact that in the Borehole Bóly–1, situated more south-eastearly, there is a direct deposition of the Bisse Marl onto the Szársomlyó Limestone. The primary thickness of the Nagyharsány Limestone (Borehole Vokány–3) does not exceed 20 m, even in the Tenkes nappe overridden by middle Triassic dolomites. FÜLÖP (1966) has demonstrated that the distinctive features of this succession are identical to those of the Tenkes Hill section (I shall come back to the reasons later). The drilling Vokány–2 was stopped within the Bisse Marl just beneath the nappe, whereas Vokány–4 was stopped just after it first hit the Nagyharsány Limestone.

There were two additional boreholes upon the Nagyharsány Nappe which intersect the eponymous formation of identical facies in contrast to what was described earlier. Moreover, another borehole (Majs–1) traversed the Nagyharsány Limestone between 244.1 and 350.0 m, but did not reach the subjacent thereof. The formation here was placed in the Barremian stage by FÜLÖP (1966).

In the central unit (NAGY & NAGY 1976) of Transdanubia there was a comparatively slight number of boreholes traversing the Nagyharsány Limestone. For instance, the Lippó–1 borehole intersected it to a thickness of about 1649 m, but the style of stratification could not be recognized. These features imply a subvertical arrangement of the unit. Microfaunal investigations of BODROGI (1988, 1999) provided evidence for an overturned structure. The following orbitoline assemblage-zones were determined: *Palorbitolina (E.) lenticularis – Palorbitolina (E.) charollaisi, Orbitolina (M.) parva – Orbitolina (M.) texana, Orbitolina (M.) texana – Orbitolina (M.) subconcava* and *Orbitolina (M.) parva – Orbitolina (M.) texana – Sabaudia auruncensis*. The uppermost 20 m section of the borehole is equivalent to the characean, freshwater beds and intertidal to shallow subtidal, brackish water beds with the fenestral fabric of the Harsány Hill section. From samples collected by I. BODROGI, the following macrofauna were determined by CZABALAY (1987): *Toucasia carinata* (MATHERON), *Toucasia lonsdalei* (D'ORBIGNY), *Agriopleura marticensis* (D'ORBIGNY), *Agriopleura darderi* ASTRE, *Eoradiolites murgensis* TORRE, *Liostrea couloni* (D'ORBIGNY), *Plesioptyxis fleuriaui* (D'ORBIGNY), *Tritonalia urgonense* P. *et* C., *Nerinea* sp., *Pseudonerinea* sp., *Pseudomelania* sp., *Astrocoenia* sp. and *Favia* sp.

She split the fauna into the following assemblages:

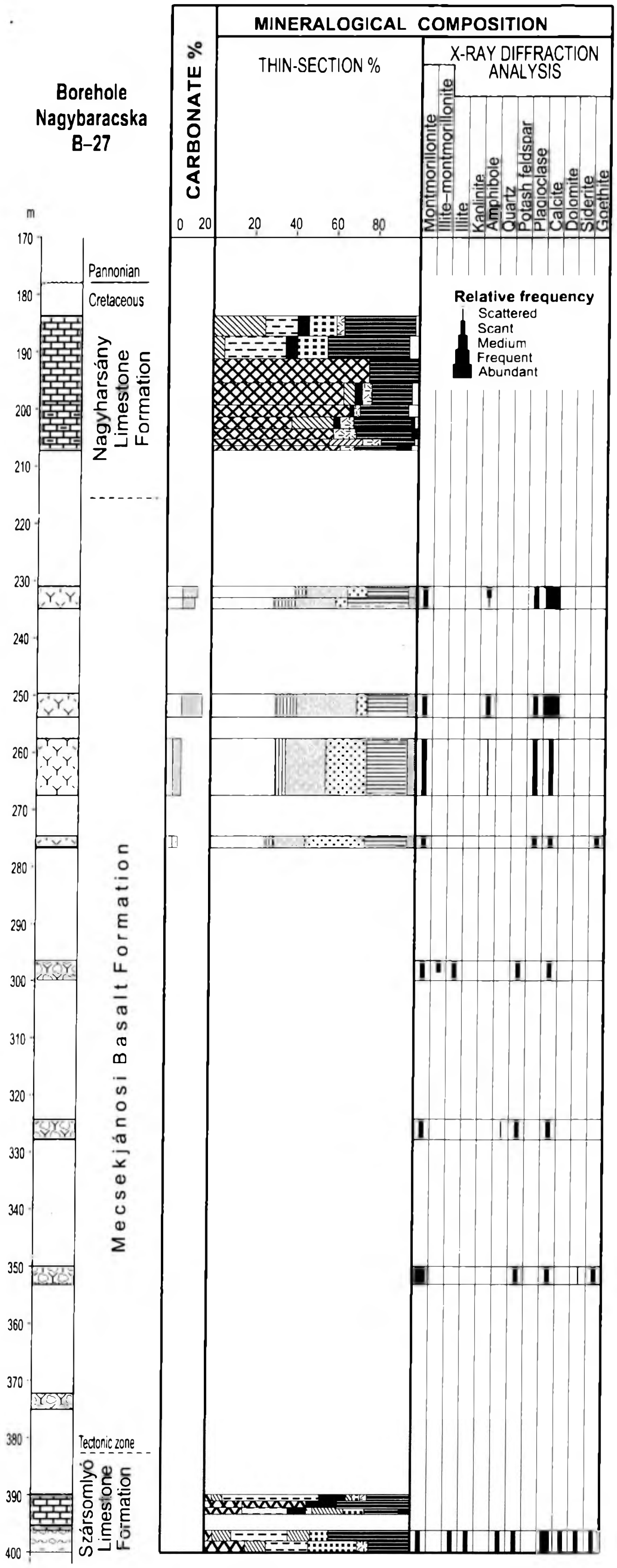
— *Toucasia* assemblage (817.7 m),

— *Agriopleura+Toucasia*+tiny gastropods assemblage (911.5–942.2 m),

— *Agriopleura* assemblage (1297.1–1714.7 m),

— *Toucasia+Liostrea+Nerinea* assemblage.

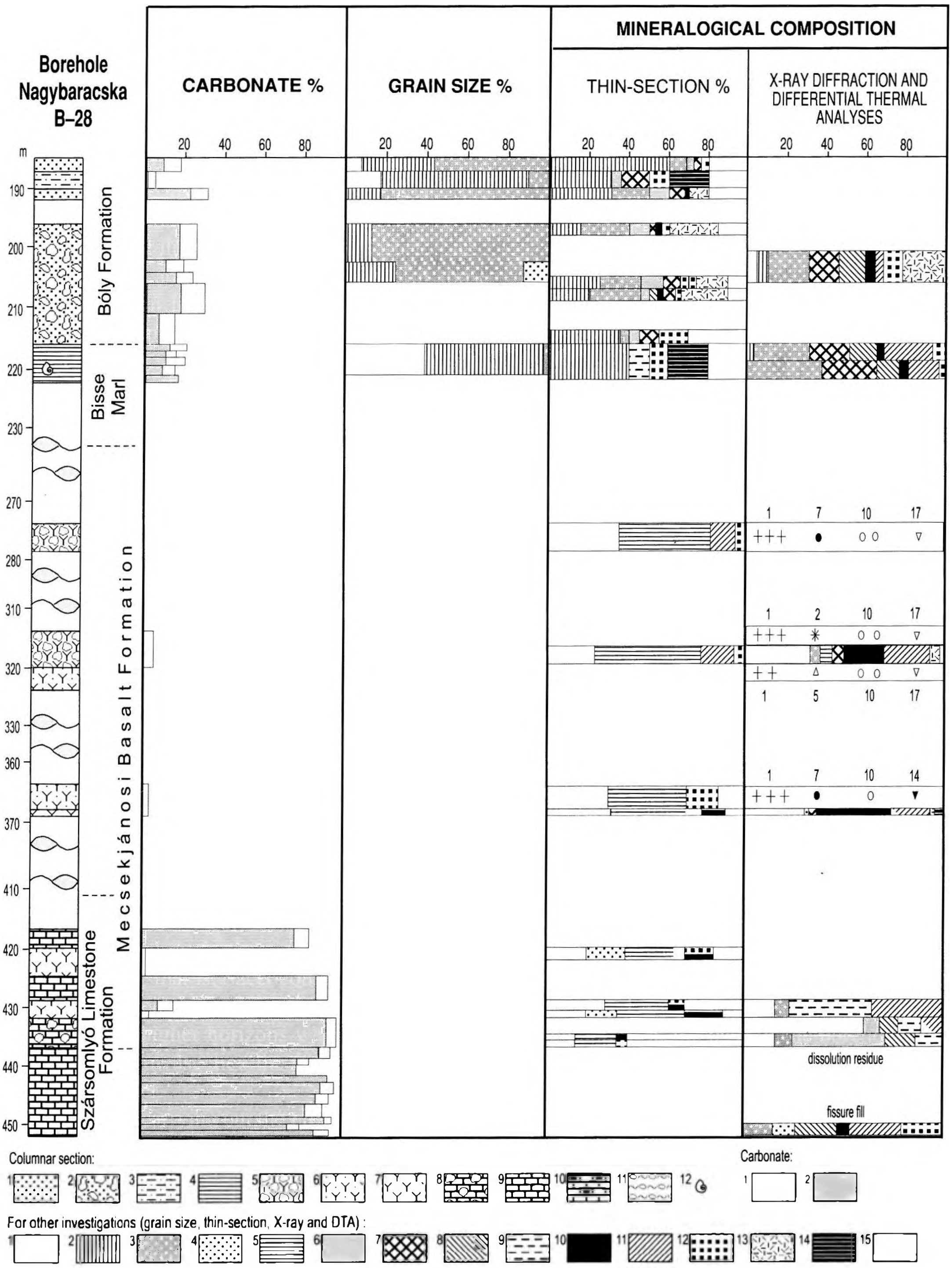
In the 1970s two hydrologic wells were drilled in Nagybaracska. It is still unclear how this area relates to the Villány Nappes. Even though Mesozoic formations occur here at a relatively shallow depth, the area itself falls within the Danube–Tisza Interfluve tract of the Villány Zone. However, the stratigraphic column differs in many respects from those formations developed in the Danube–Tisza Interfluve. A joint feature of the periodically cored Boreholes B–27 and B–28 is that they contain lavas and pyroclastics trachytic and basaltic in composition. These can thus be assigned to the Mecsekjánosi Basalt Formation (CSÁSZÁR *et al.* 1983). In the Borehole B–27 (Figure 37) the volcanics are overlain by limestones, covering an interval of 178.0–216.0 m. However, coring was realized here only between 183.5–206.76 m. The upper section extending up to 190.0 m is of orbitolinid biointrasparitic grainstone fabric and is therefore attributed to the Nagyharsány Limestone. Orbitolines were determined to be *Palorbitolina lenticularis* (BLUMENBACH) and *Orbitolina (M.) beremendensis* MÉHES by MÉHES (in CSÁSZÁR *et al.* 1983). The lower section is made up of biomicritic wackestone containing echinoderms, *Globochaete* sp., radiolarians as well as the species *?Nannoconus bermudezi* BRÖNNIMANN and *?Cadosina lapidosa* VOGLER. According to the above, the latter rock mass, being slightly silicified, can perhaps be classified as a new formation. However, it may be an unrecognized facies of the Nagyharsány Limestone. Nevertheless, all we can state about it is that it is probably early Early Cretaceous in age. The Mecsekjánosi Basalt Formation is underlain by a calpionellid-rich, slightly siliceous limestone (TARDI-FILÁCZ in CSÁSZÁR *et al.* 1983), which is Berriasian in age. This rock mass is macroscopically similar to that overlying the volcanics.



In the Borehole B–28, between 185 and 237 m, the Bóly Formation and the Bisse Marl Formation appear (Figure 37). The well log reveals that they are directly underlain by the Mecsekjánosi Basalt and hence the Nagyharsány Limestone fails to appear between them. The basaltic sequence seems to alternate with the limestones at the 411–437 m interval, which in turn permanently underly the volcanics. Based on its macroscopic features and thin-section studies by LÉNARD (in CSÁSZÁR *et al.* 1983), this limestone, containing also some volcaniclastics, was assigned to the Szársomlyó Limestone Formation. From between 449.5 and 461.0 m he described the following fossils as beeing indicative of Late Tithonian age: *Calpionella alpina* LORENZ,

Figure 37. Columnar sections and results of thin-section studies, X-ray diffraction analysis and Differential thermal analysis (DTA), Boreholes Nagybaracska B–27 and B–28

Legend of columnar sections: 1 — Sandstone; 2 — Pebbly sandstone; 3 — Siltstone; 4 — Claystone; 5 — Volcanic and pyroclastic breccia; 6 — Tuff; 7 — Basalt lava; 8 — Limestone with volcaniclasts; 9 — Limestone; 10 — Cherty limestone; 11 — Marl, calcareous marl; 12 — Ammonite. *Carbonate:* 1 — Dolomite; 2 — Calcite; **B–27** *Thin-section:* 1 — Glass; 2 — Plagioclase; 3 — Mafic constituent; 4 — Chlorite; 5 — Carbonate; 6 — Opac minerals; 7 — Micrite; 8 — Microsparite; 9 — Sparite; 10 — Block calcite; 11 — Silicification; 12 — Intraclasts; 13 — Pelletal grains; 14 — Bioclasts; 15 — Extraclasts; **B–28** *Grain size: 1* — Clay; 2 — Silt; 3 — Sand; 4 — Pebble; *Thin-secftion:* 1 — Glass; 2 — Quartz; 3 — Quartzite; 4 — Silica; 5 — Plagioclase; 6 — Feldspar; 7 — Mica; 8 — Biotite; 9 — Muscovite; 10 — Garnet, zircon; 11 — Mafic constituent: — Opaque minerals; 13 — Limestone pebbles; 14 — Clay minerals; 15 — Carbonate (calcite); *X-ray and DTA:* 1 — Montmorillonite; 2 — Illite-montmorillonite; 3 — Illite; 4 — Biotite; 5 — Hornblende; 6 — Kaolinite; 7 — Chlorite; 8 — Quartz; 9 — Potash feldspar; 10 — Plagioclase; 11 — Calcite; 12 — Dolomite; 13 — Siderite; 14 — Goethite; Crosses, circles *etc.* indicate relative frequency



Crassicollaria brevis REMANE, and *C. intermedia* (DURAND-DELGA). Further-more, he correlated the cherty limestones intersected at the lower section of the borehole with the Oxfordian crinoidal beds of the Mecsek Mountains. An unpublished report of SIDÓ (1978) which came to light only in the recent times, comprises a description of 6 thin-sections from the 417.0 to 697.0 m interval of a 708.0-m-deep borehole. To paraphrase SIDÓ, the succession under discussion is characterized by a "pachyodontid/echinodermate/foraminiferal/calcareous algal nearshore reef facies". Although she placed the entire sequence in the Albian stage, the lower two samples (565.0 to 565.2 m and 697.0 to 697.2 m) — which contain an assemblage with *Orbitolinopsis* and an increased amount of calpionellid and radiolarian extraclasts — allowed a more precise stratigraphic placement, namely, a deeper horizon within the Albian. A marked peculiarity of this column is provided by the uppermost thin-section where radiolarians and *Pithonella* contemporaneously occur. It is difficult to explain why dasycladaceans coupled with characeans appear in a repetitive manner in the otherwise rich fossil assemblage. This suggests either a possible reworking of the lower member of the Nagyharsány Limestone or tectonic movements related to imbrication. Basically, the fact that Jurassic rocks are now superimposed on those of Cretaceous age is in any case suggestive of thrusting (or nappe tectonics), or perhaps mixing of the still soft, unconsolidated materials. It is therefore of particular interest to reconcile this contradiction and to clarify the real connection between the Mecsekjánosi Basalt and its subjacent limestones with respect to their palaeoenvironment and evolution.

It remains an unachievable task to split the Neogene basement east of the river Danube into sincere nappes, although it is intersected by a number of boreholes. These also involve many various facies of Urgon (BÉRCZI-MAKK 1971, 1985, 1986). Since these wells were drilled for hydrocarbon exploration, corings rarely took place. This limits the reliability of the stratigraphic columns composed in this area. Based on the data available up until then, BÉRCZI-MAKK (1985, 1986) subdivided the Villány Zone into Bácska and Körös facies zones. In the Bácska area, in the vicinity of Kiskunmajsa, there is an 80-m-thick sequence of dark grey ooidal limestones at the base of the Cretaceous system which is thought to have developed progressively from the Jurassic. It is overlain by a sediment pile composed of dark to light grey limestone, calcareous marl and marl. Its apparent thickness is more than 600 m. The latter formations were drilled in the neighborhood of S and NE Kiskunhalas, S Kiskunmajsa and Üllés and contain the following important taxa: *Tintinnopsella* sp., *Globochaete alpina* LOMBARD, *Campanulia carpatica* MIŠÍK and *Pieninia oblonga* BORZA *et* MIŠÍK. This assemblage indicates a Neocomian age. These rocks are then overlain by the Nagyharsány Limestone which exhibits dark to light grey limestone, calcareous marl and calcareous sandstone lithologies. Distinctive fossils of the formation are: *Agriopleura blumenbachi* (STUDER), *Spiroplectammina* sp., *Miliolidae div.* sp., orbitolines, as well as a number of planktonic foraminifers (*Globigerinelloides* sp., *Hedbergella* sp.). There are numerous boreholes intersecting such limestones in this zone (at the localities of Eresztő, Érsekcsanád, Kiskunhalas, Kiskunmajsa, Öttömös, Pusztamérges, Kiskunszállás, Tompa and Üllés). The maximum apparent thickness of the formation is 654 m. Mention should be made of the description of tuffite and silty marl beds at Csávoly. In my view, the ooidal limestone pertains to the Szársomlyó Limestone Formation. However, the sequence comprising patchy limestones, calcareous marls and marls is worthy of lithostratigraphic distinction, namely, a new formation is supposed hereby.

In the Körös Zone a likewise trimerous Lower-to-middle Cretaceous succession overlies Liassic limestones thus exhibiting a considerable hiatus. In the area of Biharugra and Doboz brownish red, conglomerate-bearing claystones and sandstones occur in a maximum apparent thickness of 110 m (BÉRCZI-MAKK 1986). This is overlain by a sequence, about 200 m in thickness, which consists of dark grey limestone and calcareous marl, with ooliths and saccocoma limestone clasts at their base (Biharugra Formation). They are capped by terrestrial sediments and then overlain by, as revealed by the Biharugra and Sarkadkeresztúr boreholes, the Nagyharsány Limestone (of 1081 m apparent thickness) which contains remains of *Spiroplectammina* sp., *Miliolidae div.* sp., orbitolines, sponge spicules and algae. BÉRCZI-MAKK (1986) correlated this orbitolinid sequence with the Nagyharsány Limestone and with the Ecleja Formation of both the Bihor Autochtonous and Vălani Nappe. Strangely, the rudists in this vast column have not received any attention.

We do not have enough precise knowledge to make it possible to determine the problem of the lithostratigraphic terminology of the Cretaceous formations in the Trans-Tisza Region.

Given the above, the question of the age of Nagyharsány Limestone has been the subject of a serious debate ever since. This is partly because in the two outcrops (which also expose the basal strata) the respective commencements of sedimentation, as argued by Fülöp (1966), markedly differ from each other. On the other hand, certain objective difficulties pose a major obstacle to a reliable dating of the lowermost, at times considerably thick, non-marine beds.

In bed no. 7 of my profile H at Harsány Hill Bodrogi *et al.* (1994) found the following microfossils: *Clypeina jurassica* Favre, *Suppilulimaella* sp. and *Permocalculus* sp., whereas *Clypeina marteli* Emberger, *?Clypeina solkani* Radoičić and *Salpingoporella annulata* (Carozzi) appear in bed no. 16, reflecting Berriasian and Valanginian ages of these beds, respectively. Field relations suggest thatthe sampled part of bed no. 7 is a foreign body therein, namely, a rock mass among the non-marine beds of a new sedimentary cycle. It is therefore not possible to date the beginning of the new cycle. However, I must add that the upper part of bed no. 7 and the lower part of bed no. 9 in a previously created section proved to be also marine but the both cases a micritic matrix occurred (that is, pelmicritic and biomicritic, respectively). The results of thin-section studies on the Borehole Nagybaracska B–28 give strength to the view that formation of the Szársomlyó Limestone at the margins of the rise (considered as the Villány Zone itself) might reach up into the Berriasian. Although Late Berriasian as the time of beginning of the new sedimentary cycle should not be exluded, it is far more reasonable that, based on bed 16, the transgression is accepted to be of Valanginian. Due to many short-lived floodings at times of sea level fluctuations it may have been a diachronous event. Consequently, a possible time span for bauxite formation could have been Late Berriasian to Early Valanginian. During Early Cretaceous, basaltic volcanism of the Mecsek became intense and adjoining pyroclastics were subsequent to accumulate in dolines resulting in just the early stages of karsitification. Allite formation has also taken place. It should be emphasized that section H is the only one in the area to display blocks of collapsed karstified cliffs of Szársomlyó Limestone. Neither the primary nor the more recent additional sampling provided such features.

As seen earlier, the lower 70-m-thick part of the succession contains numerous minor hiatuses. Bodrogi *et al.* (1994) report however, an unusual "condensation" solely in the lowermost 8 m and denote it as Berriasian to Valanginian in age. *Protopeneropolis trochangulata* Septfontaine, which is derived from section I — located at the hill-top — is not characteristic for the local geological situation nor for the available results of the investigation and it is only obscurely projected into the stratotype section.This rock is probably also a dropped block within the Nagyharsány Limestone, resulting from a similar situation to that described for the cave section. A Late Hauterivian to Early Barremian age is constrained by the species *?Orbitolinopsis capuensis* de Castro (Bodrogi *et al.* 1994). This taxon is also absent from the stratotype section since it is recorded solely in sections R and N and is of obscure stratigraphy. According to the above, the occurrences of not only Valangian but even Hauterivian, as reflected by the literature, do not seem to be well-constrained. Although this is not quite the most well-estabilished method, if postulating a widely uniform rate of sedimentation then the commencement of the sedimentation in the Nagyharsány Nappe would most probably be put to the end of the Late Valanginian, or to the beginning of the Early Hauterivian.

The southward dipping ramp of the slightly accentuated surface was progressively flooded by the northward transgressing sea. The area of the Tenkes Nappe, for instance, was first veneered in the Late Aptian only.

Platform drowning is very likely due to tectonism — namely, it dates to Early Albian when this flexural basin was formed.

Depositional environment of the Nagyharsány Limestone

As contrasted by the facies change in the neighbouring Mecsek Mountains, the Late Jurassic (to Berriasian) of the Villány Zone is characterized by subaerial events as the carbonate platform emerged above the base level; thus marine sedimentation was succeeded by erosion. Karsitification recorded in two surface outcrops in the Villány Hills reveal that the amplitude of the relative sea level change was not greater than several tens of metres. This is in accordance with the concept of Bárdossy (1994) — that is, to realize that the distribution of bauxite accumulations are linked to islands or coastal plains dominated by shallow-marine environments. Bauxite formation took place adjacent to the ground water table, under semi phreatic conditions (Maximović *et al.* 1991). Sedimentological investigations of DUDICH & MINDSZENTY (1984) point to a hemiautochtonous origin of the bauxite. BÁRDOSSY *et al.* (1976) reported however, green and iron-rich bauxite pebbles indicative of reworking. Although the emersion was little, it resulted not only in a rugged topography but also in the formation of near-surface caves. From both the north and the south, the Villány Zone was neighboured by deep-marine realms; therefore, the initial material of bauxite formation would have been derived either from aeolian transportation or erosion of smaller volcanics of the Villány Zone. According to MAXIMOVIĆ *et al.* (1991) and MAXIMOVIĆ & PANTÓ (1996), rare-earth elements in Bosnian and Greek samples originate from ultrabasic rocks. Rare-earth element enrichment in the Harsányhegy Bauxite however, is explained by the clastic input of the "anatexitic granite of the Mecsek" containing also the bastnaesite group. Nevertheless, the most recent studies (VASKÓ-DÁVID 1997) have proved that the Mórágy Granite Formation was almost without doubt, not exposed before the Albian. HARANGI (1994) and HARANGI *et al.* (1996) measured noticeable concentrations of Ce (244 ppm), La (145 ppm) and Nd (85 ppm) in the Mecsek volcanics, and in particular in the phonolites. Thus there is an obvious source for synchysite and bastnaesite.

The time gap recorded by the hiatus varies significantly from place to place; hitherto no exact timing has been available. It is to be feared that the timing of the commencement of sedimentation in the Harsány Hill section remains unclear since the new cycle that sits upon the bauxites consists of non-marine beds at its base. The first true marine intercalation is first represented by bed no. 7, followed by no. 9a, 9b and 15. According to what was stated earlier, sedimentation herein began in the Valanginian age. Apart from infrequent exceptions, the section as a whole is characterized by micritic matrices, irrespective of variations in salinity (freshwater or full marine). It is suggested therefore, that this permanently tranquil sedimentary basin must have been bound to a sort of swell to separate it from the sea. More elevated tracts of the rise could then have formed an archipelago.

The sea of the separated or almost separated, small basin could have been lashed into fury by storms only. Many storm events resulted in altogether 36 breccia horizons, which hardly appear in the second member. They consist of black to dark grey limestone clasts and often occur as lensoid bodies. They are widely accepted as products of carbonate sedimentation in the intertidal zone (FISHER 1964; HAAS 1982; STRASSER & DAVAUD 1983; DURINGER 1987; CSÁSZÁR 1989 and HAAS & BALOG 1995). They range in size from 1-2 cm to several tens of cm, the former being more abundanant. The clastic material characteristics suggest sedimentation in freshwater ponds; however, pieces of intertidal or shallow subtidal origin (fenestral fabric) may also occur, albeit rarely. Breccias can, to a certain degree, be accompanied by well-rounded pebbles of the Nagyharsány Limestone which occur in tidal channels. Their presence reflects a longer transport compared to that of breccias.

Variegated clay often comes with breccia horizons. This and especially the red clay horizons, indicate short-lived subaerial events. After the pause, the sedimentation commonly starts with freshwater to brackish water sediments. The surface of the limestone below the clay horizons are, to various degrees, indented and they are apt to behave as sliding surfaces, too. Calcite mineralization is common here.

Algal mats, which are so typical of the intertidal zone, are however, very rare here. If any, they are difficult to distinguish from grey (water-saturated) palaeosoil horizons. Subaerial exposure is indicated by desiccation cracks on a microscopic to mm-scale, appearing chiefly in the lower member but ocassionally even in the second member, too. Microcarstic subaerial surfaces are also common (bPlate V: 3, p. 69).

The most striking features of the lower two members are polyphase void fillings, described earlier as "bioturbation". They are of various sizes and branched in appearance. Based on these aspects, I interpret them as colmatages of root holes of trees or sizable bushes. An alternative interpretation was raised earlier which dealt with crab burrows. However, taking into account their various shapes and sizes, this explanation has been rejected. These fills occur mostly in brackish water sediments and they are not uncommon in marine beds, either. They reflect shallow, subtidal zone circumstances.

Fenestral fabrics are also a common feature of the two lower members. They mainly have laminoid fenestral fabric but may display disordered arrangements as well. A certain type of this group is represented by shrinkage pores, indicative of sublittoral milieu.

The energy level of the sedimentary agent and variations thereof are mirrored in the diagram showing the grade of greyness, obtained from the lower 52-m-thick part of the Harsány Hill section (cFigure 2, p. 173). The diagram provides evidence for a tranquil to slightly agitated flow regime, which bears sound resemblance to the prevailing micritic matrices.

In general, in addition to sedimentary structures, a certain sedimentary environment appears to have left another source of evidence in the form of a fossil assemblage. In the terrestrial environment, the only sort of structures found are some infilled root holes. Freshwater sediments exhibit a myriad of characeans and ostracod valves and they may be accompanied by tiny, thin-shelled gastropods.

In addition to ostracods, the brackish environment is inhabited by calcareous smaller foraminifers such as *Ophtalmidium* and miliolinids. The algae are reminiscent of *Cayeuxia* but these of course, many gastropods and pelecypods. In the intertidal zone, the fauna content may vary with fluctuating salinity but is usually of rather moderate abundance. The marine lagoonal environment contains a diverse and abundant fossil assemblage. The most conspicious among these are calcareous and arenaceous foraminifers and echinoderm ossicles, various molluscs (rudists in this particular case), assorted algae, especially green algae. Green algae are also very common in the microflora of similar facies in the neighbouring countries. Interestingly, this provided an earlier basis for the correspondence of the Nagyharsány Limestone with the platform carbonates of the Dinarides and the Adriatic Karst.

By assimilating the results of a detailed analysis by Sokač (1996) and investigations of Bodrogi *et al.* (1994), it was disclosed that there are altogether 9 identical and 12 different species in the formations under discussion. According to Wray (1977) the mass occurrence of dasycladaceans can be found in the modern tropical and subtropical seas, at water depths shallower than 5 m. However, they may have dwelt even as deep as 30 m on a sandy or muddy seafloor. Palaeoecological considerations suggest that they occupied a similar habitat during Cretaceous times.

Fossils in the sand shoal are unequivocally derived from the adjacent zones. Colonial organisms, such as corals, hydrozoans, algae (in this particular case *Lithocodium, Ethelia, etc.*) and *Bacinella inc. sed.* might have occured in the marine lagoon but their sincere habitat is at patch reefs or in mud mounds.

With respect to the Nagyharsány Limestone, to date there are only three occurrences of sand shoals. Nevertheless, making sampling sites more dense would certainly result doubling this number. Only the upper third of the section displays patch reef/mud mound sedimentary environments.

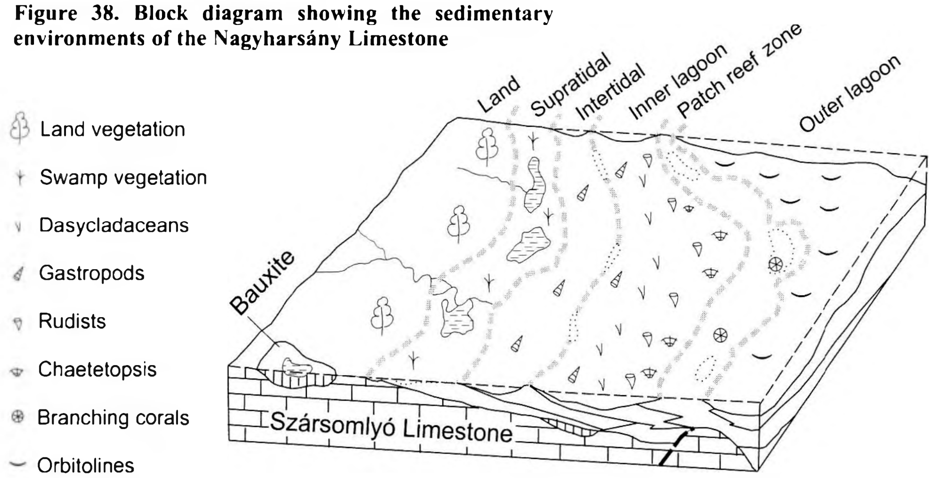
In the Harsány Hill quarry section, traces of terrestrial sedimentation are recognizable from the lower 94-m-thick portion. Their distribution up to 74 m is rather uniform. Freshwater sediments, though, which occur along with the terrestrial sediments, can be traced up to 102 m, with a tendency of upward-decreasing frequency. I indicated well-developed fenestral structures this time right at the intertidal zone (cFigure 4, p. 175). The uppermost occurrence of fenestral structures is found at 120 m. In the lower part of the section brackish water sediments prevail. However, it is likely that a number of vague occurrences exist at higher levels.

In accordance with the alternations of the sedimentary environment, frequent and apparent excursions of the sea level curve are experienced in the lower 80 m of the section (cFigures 2, 3, p. 173–174). This is explained by the deepening of the basin; after the deepening a sea level change of 1-2 m amplitude is no longer discernible, whereas prior to deepening a similar, or even, more moderate (smaller than 1 m) event causes a marked excursion with respect to the curve. Unfortunately, the lack of precise and reliable dating upsets the performance of the calculation concerning the time interval of sea level changes which occur on average every half metre. The detectable frequency and apparent amplitude of the sea level change decrease upsection.

EARLY TO MIDDLE CRETACEOUS EVOLUTION OF THE TISZA UNIT AS REFLECTED BY THE FORMATIONS OF URGON FACIES: AN OVERVIEW

Formations of Urgon facies occur in two structural zones of the Tisza Unit. Mantle diapirism beneath the Mecsek Zone commenced in the Late Jurassic and was followed by the formation of volcanic breccias and thin tuffite measures. Basin floor differentiation continued during the Tithonian age (Nagy 1986a, 1986b). In the Mecsek Zone, an intensive and widespread volcanism started in the Berriasian. Since the Villány Zone was subaerially exposed during the Berriasian, facies differences between the Mecsek and Villány Zones are most apparent within this time span. That is to say, a submarine, then slowly emerging volcanic edifice was formed by the volcanic activity in the Mecsek Zone, while the Villány–Bihar Zone was dominated by karstification and the allitisation of pyroclastics. The southern part of the latter zone was again encroached by the sea during the Valanginian to Hauterivian (Császár 1992). This belt was initially separated from the open marine region and probably resulted in extensive freshwater conditions in the basin. Owing to frequent sea level fluctuations, seawater increasingly invaded through straits resulting in a more and more saline basin. This was, synchronously, transformed from a lake to a lagoon (Figure 38). Due to the shallow water depth the area

Figure 38. Block diagram showing the sedimentary environments of the Nagyharsány Limestone



was often exposed to subaerial conditions as a consequence of sea level fluctuations. Frequent and intense storms are indicated by the very common "black pebbles". Reflecting by chance freshwater brackish water conditions, they reveal high rain yields, whereas desiccation cracks witness an uneven precipitation distribution. That dry seasons were short is suggested also by the lack of hypersaline sediments (X-ray powder diffraction studies by G. RISCHÁK in the laboratory of the GIH indicated only 1% dolomite in just one sample). Hence the barrier was temporarily covered by seawater, and freshwater intercalations thus ceased. However, occasionally a slight decrease in salinity is detectable. The development of a poorly evolved patch reef or a mud-mound crest resulted in the differentiation of the lagoon to form an internal and external tract, being restricted and open, respectively. Spicules and sponges appear in the external part. The prolonged restriction is mirrored in the various grey tones of the limestone, its predominant micritic matrix and the remarkably scarce appearance of the calcareous sand facies.

Data derived from the Szabolcs Valley quarry reveal that in the Tenkes Nappe, sedimentation of Urgon facies began in the Late Aptian. The column in this section indicates a more agitated environment. The alternating occurrence of reefal, marine lagoon and calcareous sand facies, as well as a subaerial environment, suggests that the sea level fluctuations based on the features of the lower part of the Harsány Hill section carried on. In the Villány–Bihar Zone, the transition of spiculitic and pelitic facies in to hemi-pelagic facies occur only in the area of the Danube–Tisza Interfluve. In the Apuseni Mountains however, the Ecleja Marl intercalating the Urgon facies represents a true hemi-pelagic sediment which, at the same time, attests that a change in formations should by no means directly and exclusively be assigned to changes of the sea level.

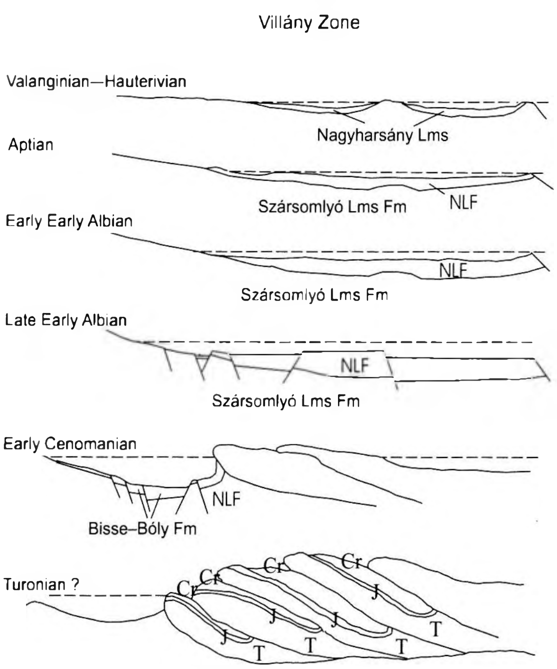


Figure 39. Simplified cross section showing the stages of the geological history of the Villány Zone and its adjacent areas

NLF — Nagyharsány Limestone Formation; Cr — Cretaceous; J — Jurassic; T — Triassic

The platform drowning was a two-stage event and it took place during the Early Albian. The first step is confined to fracture fillings consisting of crinoidal, planktonic foraminiferal marl (FÜLÖP 1966). Strangely, its stratigraphic record is missing only in borehole Vokány–4. The abrupt transgression on the platform was adjoined by a short-lived condensation period, as reflected also by limonitic crusts in some places. The transgression is most probably consequence of the compressional movement started already in the southern areas (Vojvodina and Srem) that time. On the effect of peak of wave and trough of wave were formed and in the trough part of the sinusoidal form deeper water environment came into being (Figure 39; CSÁSZÁR 1992).

Both the thicknesses of the Nagyharsány Limestone (reaching a few hundred metres) and the progressive northward propagation of sediments of Urgon facies on a subhorizontal landscape draw attention to a considerable shortening. There is still debate on whether these resulted from a mere imbrication or nappe thrusting. However, it should be borne in mind that the limestone, at least 500 m thick, pinches out non-erosionally northward to a distance of 20 km (Figure 40). Thus it means that the discrete slivers are detached from their root regions and they need to be considered as nappes (CSÁSZÁR 1992). By adding that Jurassic and Cretaceous facies differences between the Mecsek and Villány Hills would require a remarkably larger distance than it is at present; the Villány Zone as a whole should be interpreted as a nappe pile. This is consistent with the old-established concepts on the structural situations in the Apuseni Mountains. The area therefore, originates from the zone of crystalline basement south of the national boundary.

During the times the events described above were taking place, in the Mecsek Zone there was volcanism of various intensity at different places. According to SZEPESHÁZY (1966, 1973) the volcanic activity gets younger eastwards within the Mecsek Zone.

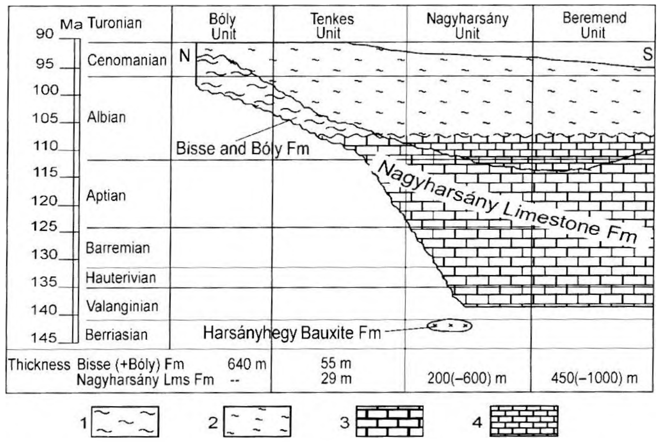


Figure 40. Changes of ages and thicknesses of the Nagyharsány Limestone, Bisse Marl and Bóly Formations along a N–S oriented section

1 — Bisse and Bóly Fms (preserved); 2 — Bisse and Bóly Fms (eroded); 3 — Nagyharsány Limestone Fm (preserved); 4 — Nagyharsány Limestone Fm (eroded)

Just after the volcano emerged above the sea level, its erosion started immediately. In the coastal region wave-cut notches were formed, thus enabling the settlement of shallow-marine organisms with the formation a respective near-shore zonation. As a result of minor sea level fluctuations and/or storms, both the bioproduction and the continuously eroding volcanic material were gravitationally transported to the foot-slope of the volcano or into the permanently existing intravolcanic basins, furthermore, they were contemporaneously mixed with pelagic sediments and fossils. These processes were probably off and on repeated, at least up to the end of the Albian age. All the volcanic edifices suffered serious, either partial or complete erosion not later than during the Early Tertiary. This is why they are rather difficult to investigate.

With respect to the above, the exact timing of the drowning of these atoll-type build-ups cannot be calculated. However, it is certain that the phenomenon took place sometime in the Albian. Some commentators point out that this must have been contemporaneous with atoll drownings in the north-western Pacific, as documented by GRÖTSCH *et al.* (1993). which is, interestingly, coeval with that of the platform of Zirc Limestone in the Transdanubian Range. The contemporary nature of the events above need not be regarded as accidental, but it provides us with a good reason to suspect a global sea level rise.

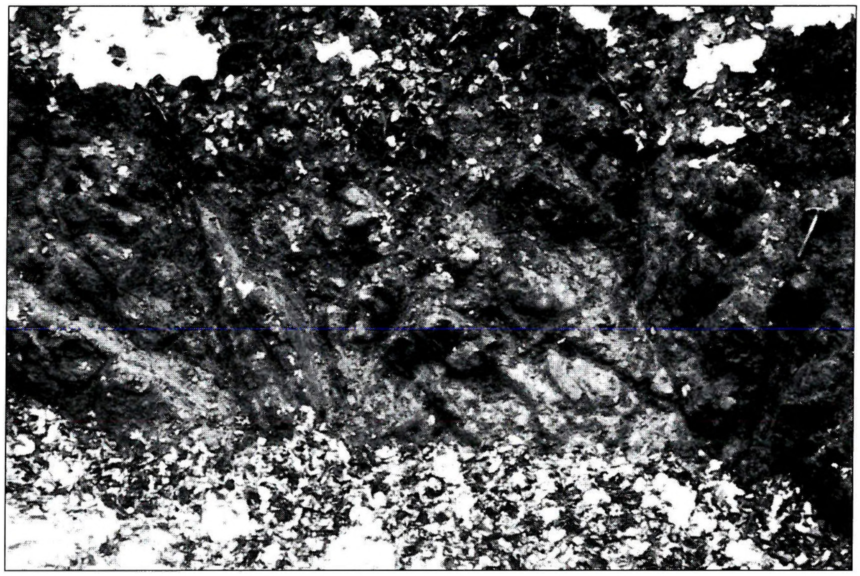
BLACK AND WHITE PHOTOGRAPH PLATES OF THE TISZA UNIT (I–VIII)

MECSEK–VILLÁNY — PLATES: I

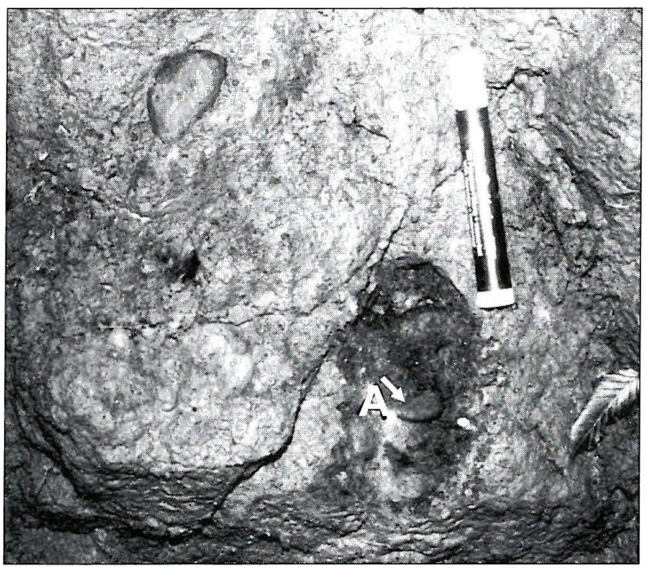
MECSEK — PLATES: II–IV

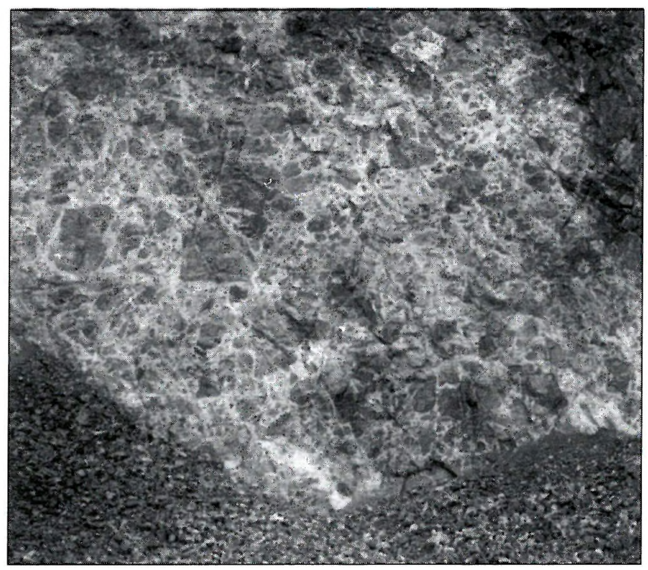
VILLÁNY — PLATES: V–VIII

1. Reference section of the Magyaregregy Conglomerate, Korhadtfás Valley, Mecsekjánosi. The general deep is 30° which are dissected by tectonic lines



2. Pebbles and ammonites (A) in the volcaniclastic of various grain-size in the Magyaregregy Conglomerate, Korhadtfás Valley, Mecsekjánosi

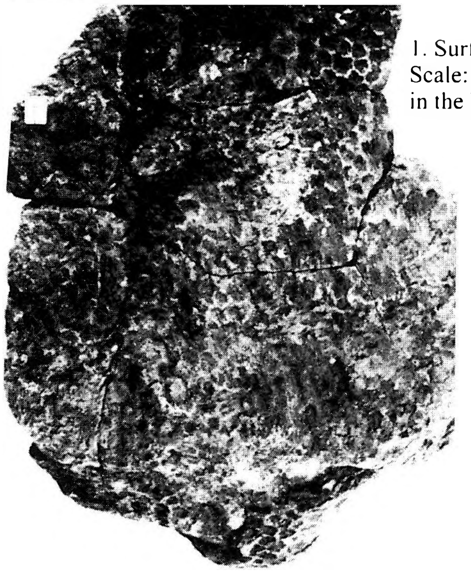




3. Megabreccia of maximum 5 m sized boulders of the Nagyharsány Limestone in a Neptunian (?) dyke within Szársomlyó Limestone, Harsány Hill quarry

4. Jurassic/Cretaceous boundary marked with arrow in the Szabolcs Valley quarry (Szársomlyó Limestone/Nagyharsány Limestone)

Coral colonies from the Magyaregregy Conglomerate



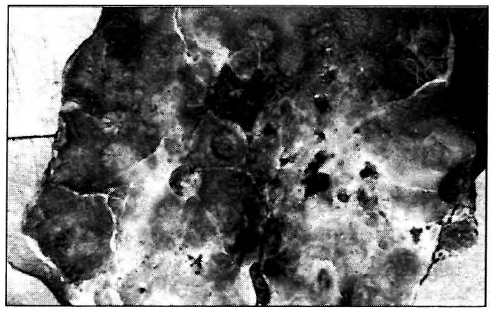
1. Surface of an encrusting coral colony. Scale: 1.5 cm. (Collected by G. HÁMOR in the Vékény Valley)

2. Fragment of a coral colony under the encrusting colony of the previous picture (magnification of picture 3). Dark shade of circular shape represents volcaniclastics in boring hole Scale: 1.5 cm. (Collected by G. HÁMOR in the Vékény Valley)

3. Reworked, fragmented coral colonies serving as substratum for the colony seen in picture 1 (collected by G. HÁMOR in the Vékény Valley)

4. Side view of picture 1. The encrusting colony is on the right side (collected by G. HÁMOR in the Vékény Valley)

5. Recrystallized coral colony with traces of boring bivalve (natural size). (Collected by L. BUJTOR, Kisújbánya)



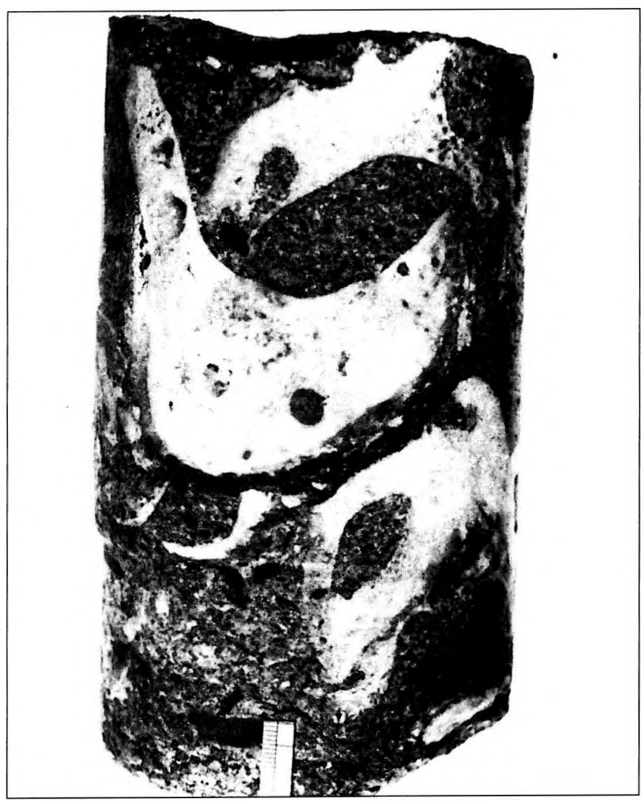
6. Coral colony with primary holes (natural size). (Collected by L. BUJTOR, Kisújbánya)

Rudist bivalves and colonial organisms embedded into volcaniclastics
Borehole Komló–XIV

1. Cross-sections of rudist bivalves (42.5–43.0 m)

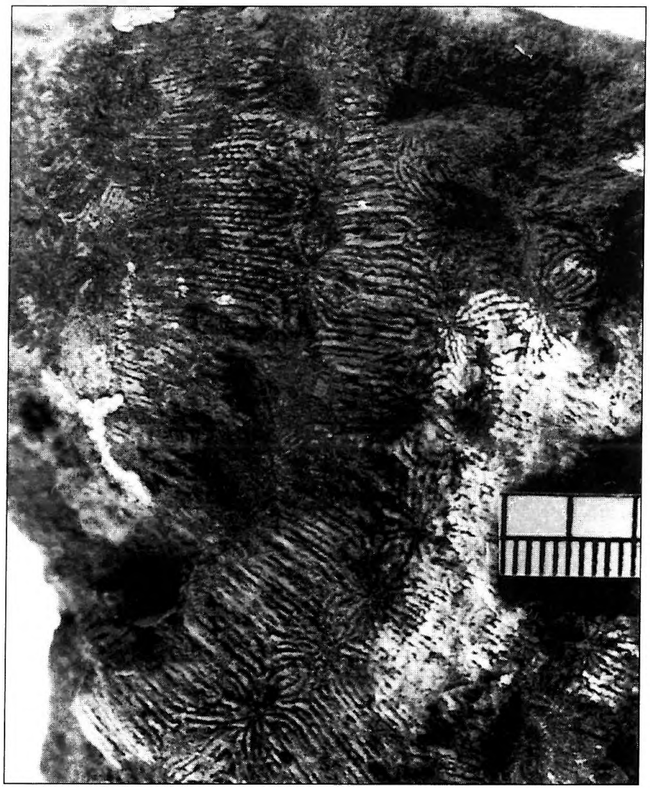
2. Fragments of bored colonies and rudist shells (43.5–44.0 m)

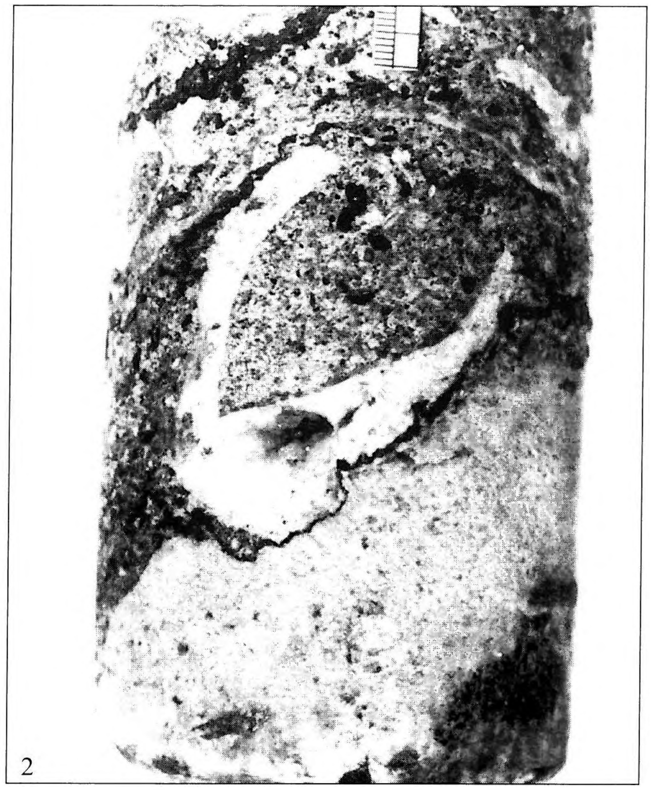
3. Bored fragments of rudist shells (42.5–43.0 m)



4. Bored fragments of rudist shells (42.5–43.0 m)

Coral colonies and rudist bivalves from Márévár Valley (1) and Borehole Komló–XIV (2–4)



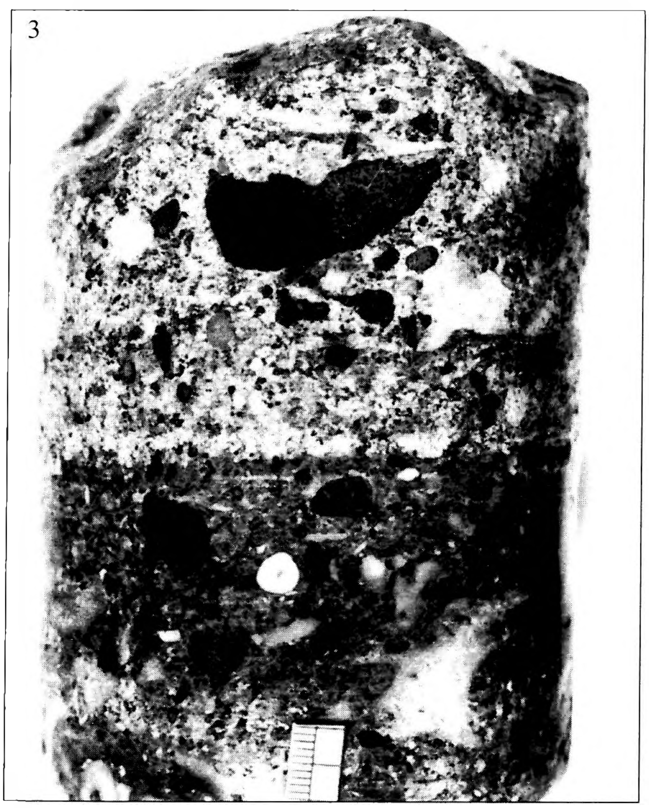


2

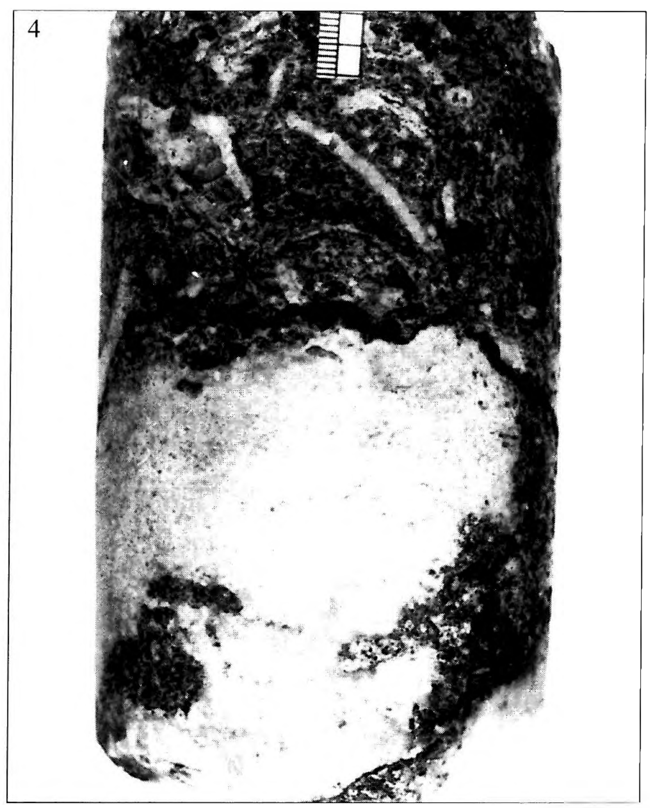
1. Coral colony from the Hidasivölgy Marl. Key section of the Magyaregregy Conglomerate behind the swimming pool

2–4. Fragments of coral colony and rudist bivalves from the interval 43.5–44.0 m (2, 4) and 46.5–47.5 m (3) consisting of volcaniclastics of varied graine size and roundness. Note the pressure solution between rudist coquina and coral colony

3

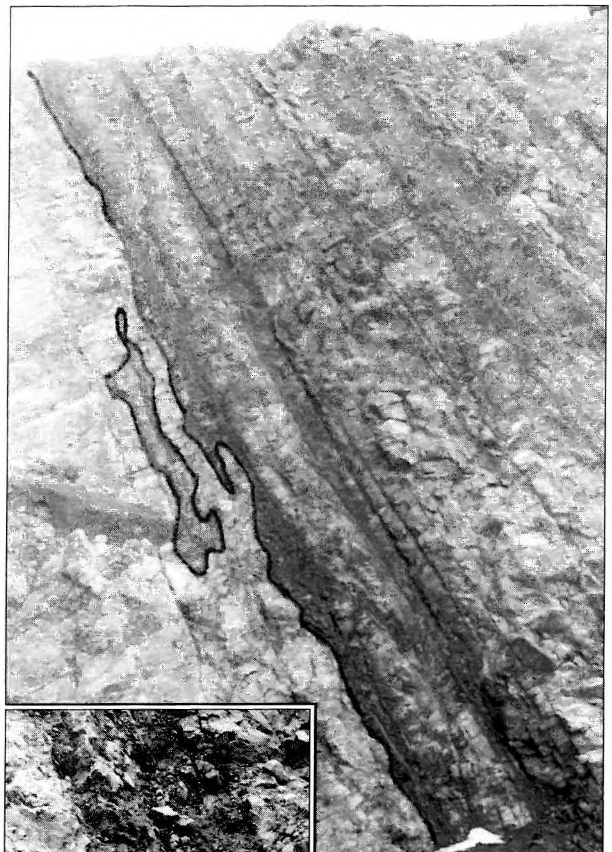


4



Sedimentary patterns of member 1 of the Nagyharsány Limestone, Harsány Hill quarry

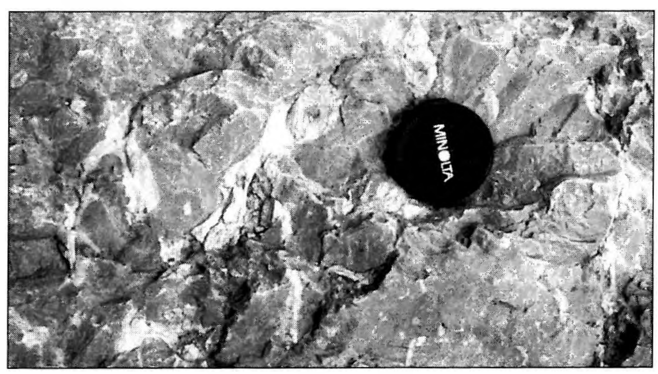
1. Contact of the Szársomlyó Limestone and Nagyharsány Limestone with infilled karstic hole



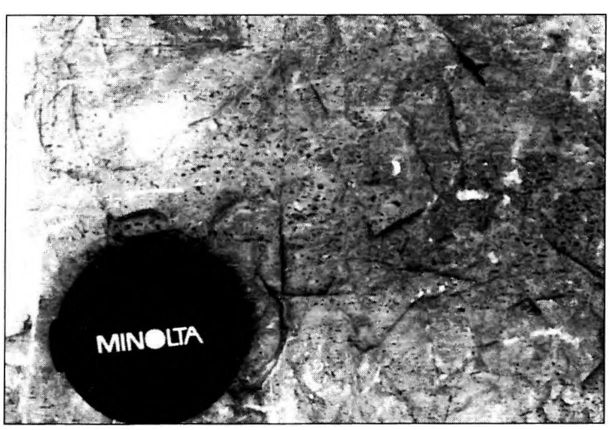
2. "Black pebble" horizon

3. Erosional karstic hardground

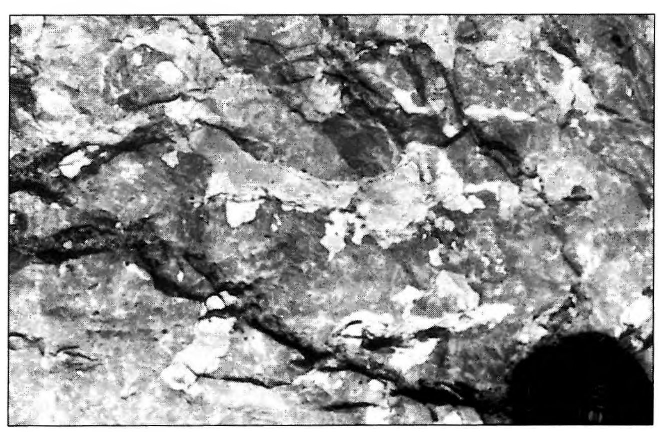
4. Detail from the contact of the Szársomlyó Limestone and the Nagyharsány Limestone (Jurassic/Cretaceous)



5. Mould of one-time rootlet (light grey micrite) in grey micritic limestone

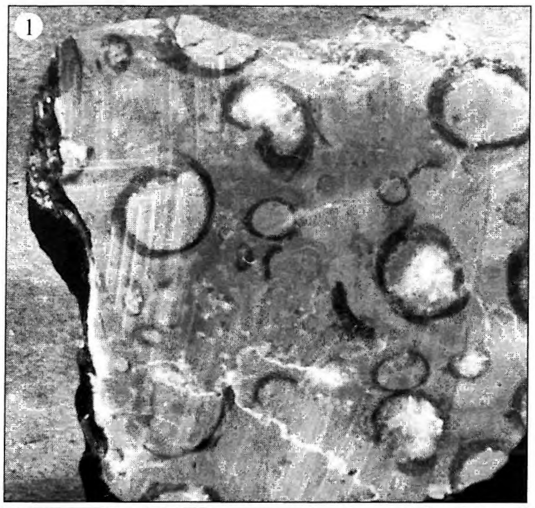


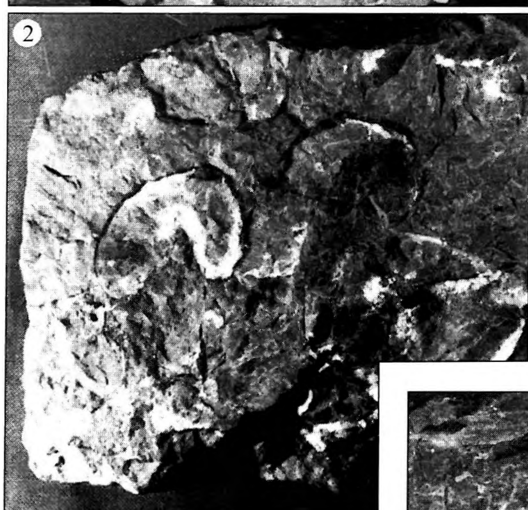
6. Layer of large scale laminoid fenestral fabric



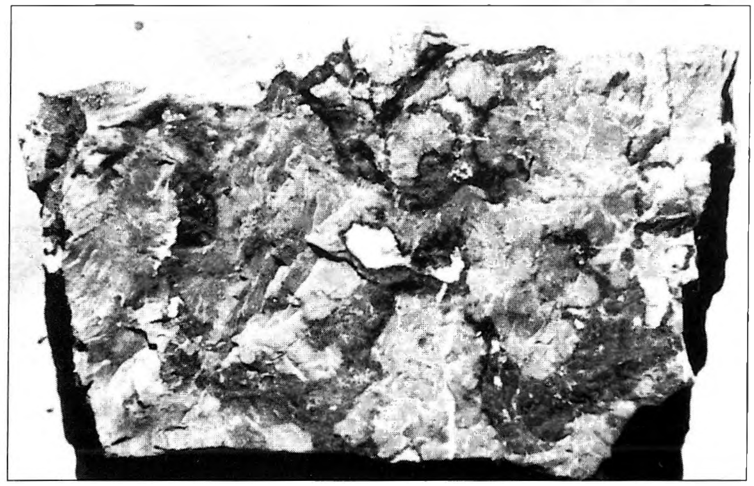
7. Mould of one-time rootlet (light grey, yellowish violet marl) in grey limestone

Sedimentary patterns and fossils of the Nagyharsány Limestone, Harsány Hill quarry



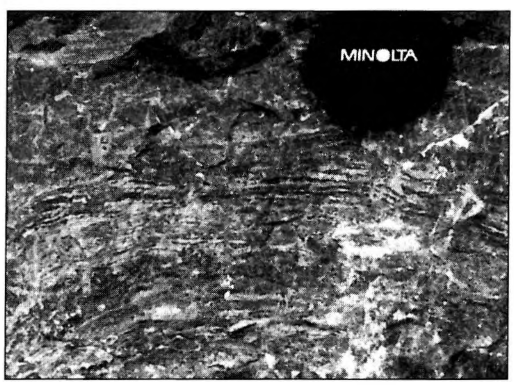


1–2. Rudist coquinas from member 2

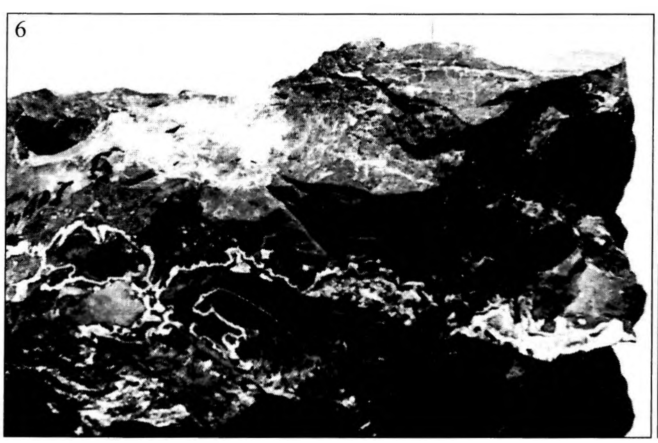


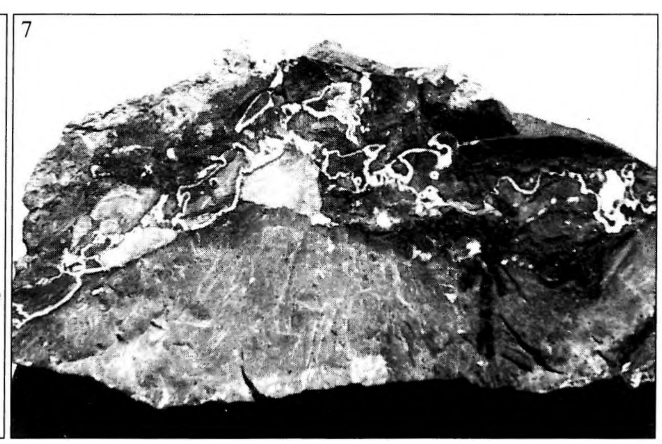
3. Two generations (dark grey limestone and white calcite) infilling of karstic holees in member 1

4. Mould of one-time rootlet in member 1

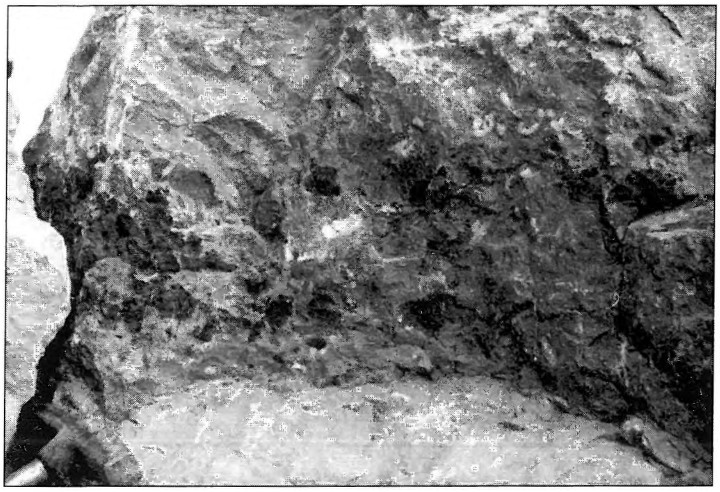


5. Algal mat in member 1





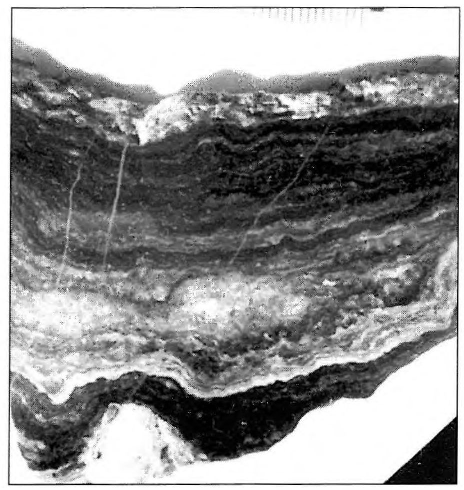
6–7. Breccia of red calcareous marl composition with white calcite crust and infilling of hole above an erosional surface in member 1



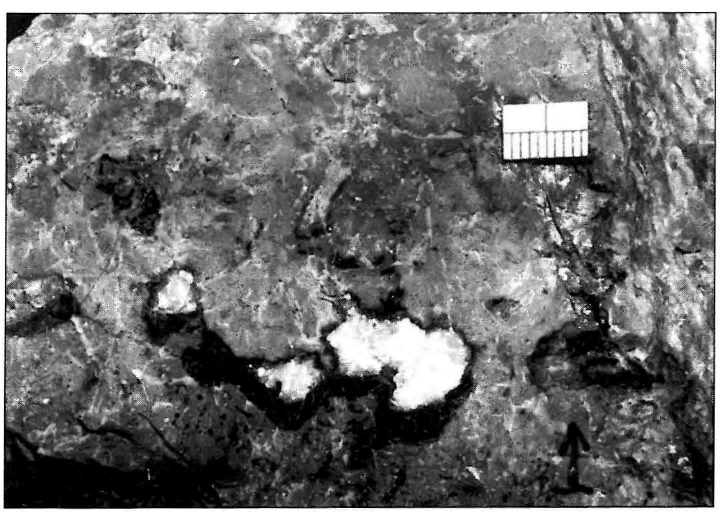
1. "Black pebble" horizon in member 1

2. Surface of a *Toucasia*-bearing bank in member1

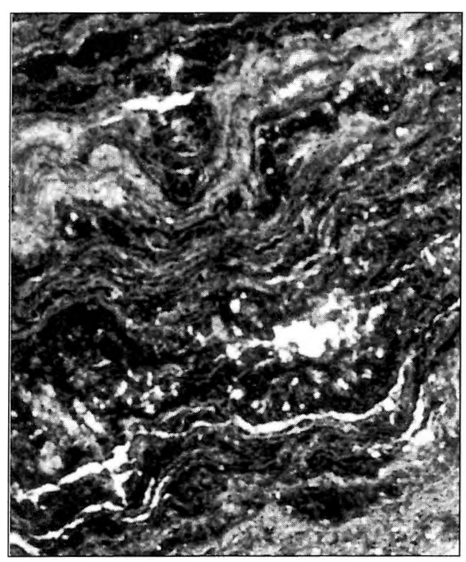
3. Multi-generation infilling of a hole system indicating various sedimentary environment in member 1



4. Algal mat-like palaeosoil bed deposited on layer of uneven surface from member 1

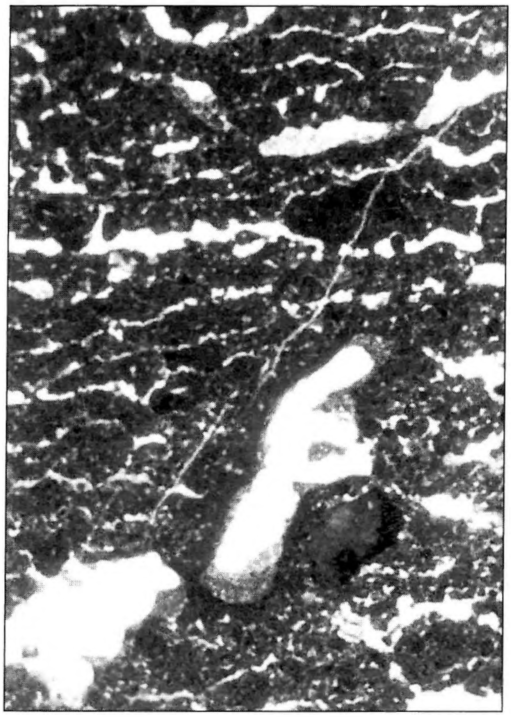


5. Three generation infilling of karstic hole from member 1.
The 1st generation is a laminar black, micritic limestone which — as a fine crust — everywhere covers the wall of the hole. The 2nd generation is blocky calcite, the 3rd one is light grey, micritic limestone.

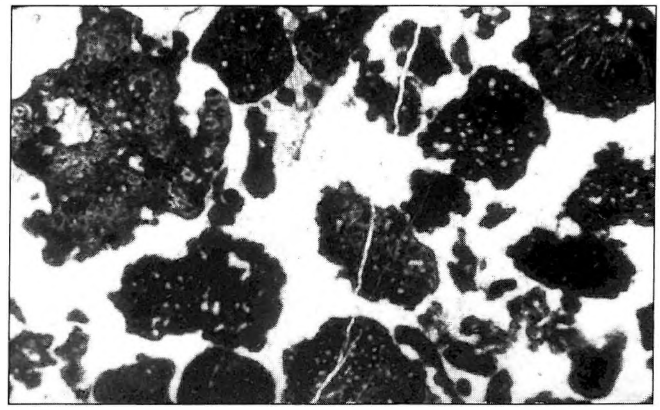


6. Micrograph of the palaeosoil shown in picture 4 (M: 34×)

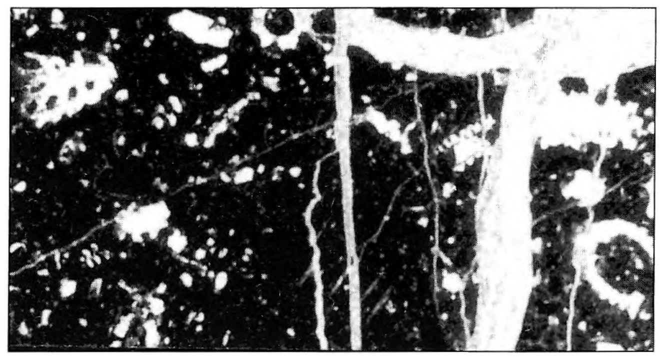
 Micrographs from member 1 of the Nagyharsány Limestone, Harsány Hill quarry



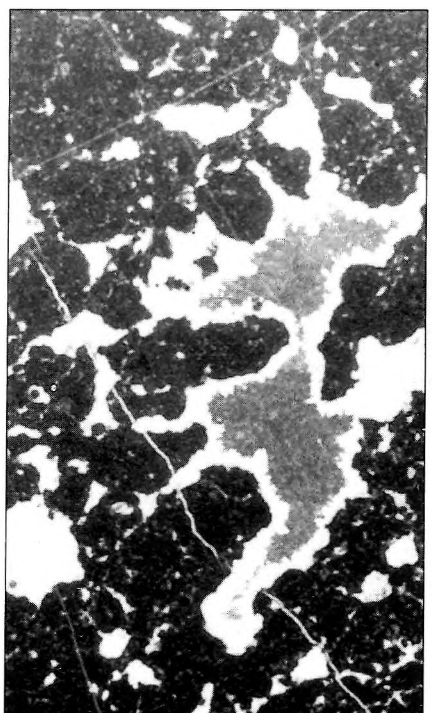
1. Laminoid fenestral fabric and filling of gas bubbles (M: 30×)



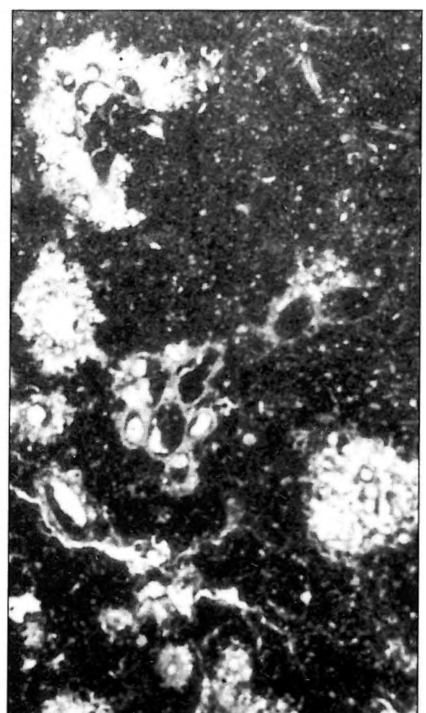
2. Limestone of pseudograinstone fabric. The aggregates cemented by cyanobacteria represent extreem state of development of fenestral fabric (M: 34×)



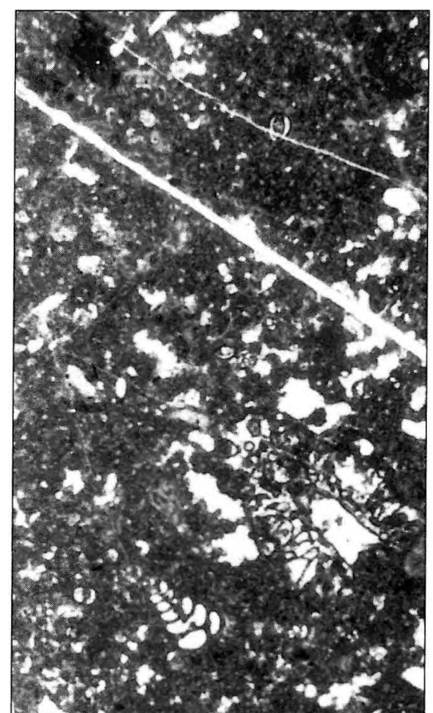
3. Dasycladacean marine microfacies (M: 30×)



4. Shrinkage pores with dog-tooth calcite and vadose silt (M: 34×)



5. Characean freshwater microfacies (M: 34×)



6. Dasycladacean, foraminifera-bearing microfacies (M: 30×)

Pelso Unit

Contrary to the Tisza Unit, where formations of Urgon facies are already apparent in the early Early Cretaceous and may well be traced up to the middle Cretaceous, in the Pelso Unit this peculiar kind of facies first occurs only in Albian beds. With respect to Urgon, the only thing that the two structural units have in common is that they comprise formations which have been entirely eroded and can now only be found as transported remnants. The pristine arrangement and spatial distribution of these formations, therefore, might be deduced merely from the remains in question. Consequently, no separate lithostratigraphic term is attributed to them.

Urgon limestones occurring as olistoliths are found in the uppermost beds of the Lábatlan Sandstone, whereas the Környe Limestone Formation and Zirc Limestone Formation, both being Albian in age, appear autochtonously and relatively extensively in the area of the Pelso Unit.

A CORALLINE, RUDISTID FORMATION IN THE GERECSE MOUNTAINS

Position of the Köszörükőbánya Conglomerate within the sequence

The Köszörükőbánya Conglomerate Member (Figure 41) represents the uppermost bed of the Lábatlan Sandstone Formation (Császár 1996). With respect to the Cretaceous formations of Hungary it is considered to be an extraordinary facies. Its occurrence is restricted to a narrow strip on the northern flanks of the Gerecse Mountains and the Tatabánya Basin (Figure 42). The Triassic to Jurassic sequence of the Eastern Gerecse was abruptly interrupted in the Berriasian (or Early Valanginian) by a pelitic sequence with sandstone interbeddings (Bersek Marl Formation); this is then rapidly overlain by the Lábatlan Sandstone. In the Western Gerecse however, this sandstone is directly superimposed on the beds of the Szentivánhegy Limestone, which here is slight-

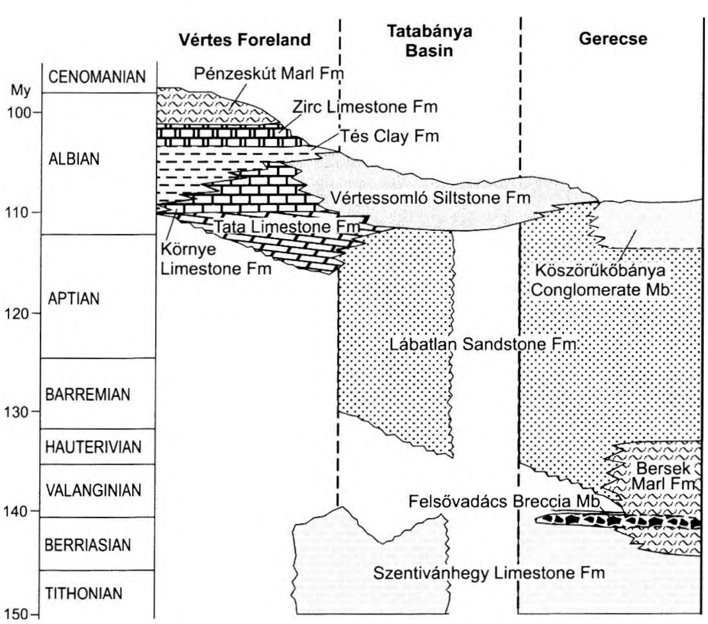


Figure 41. Relation of the Cretaceous formations in the Vértes Foreland and the Gerecse Mountains

ly younger. That is to say, the Bersek Marl is missing from the sequence in the Western Gerecse. The facies change between the two areas is well-documented by the synchronous Felsővadács Breccia Member since it appears within the Bersek Marl in the east and within the Szentivánhegy Limestone in the west (CSÁSZÁR 1995).

In contrast to FÜLÖP's opinion (1958), the Lábatlan Sandstone and its Köszörűkőbánya Member (of bathial slope origin) reveal that this formation is by no means a nearshore facies at the top of a cycle. It is highly probable that a sort of sequence is to be assumed. This is of an unknown spatio-temporal extent but it had certainly been eroded as a result of forceful and extensive Subhercynian or Laramide movements. Actually, the Köszörűkőbánya Member would inevitably be a fortunate remnant from the base of the eroded sequence which is of an unknown range.

PREVIOUS WORKS AND THE GEOLOGICAL SETTING

In the Gerecse Mountains rocks assignable to Urgon facies as such, occur in the hitherto discovered uppermost beds of the Lábatlan Sandstone — namely, the Köszörűkőbánya Conglomerate. They appear as randomly scattered clasts and, on the other hand, as two separate horizons of limestone megabreccia (olisthostrome) (bPlates IX: 1–4, 6, p. 112; X: 1–4, p. 113).

The eponymous outcrop which is yielded by the quarry itself was first recorded by HANTKEN (1868, 1878). The first mention of the limestone clasts therein is found in the work of VÍGH (1925) who regarded them as boulders consisting of Triassic and Jurassic rocks. A pioneering biostratigraphic investigation was performed by FÜLÖP (1958) and VADÁSZ & FÜLÖP (1959), providing evidence that these clasts are without exception of Cretaceous origin, based on the corals, hydrozoans, calcareous algae, bryozoans and pelecypods found in them. Ancient traces of boring clams were also recognized. To borrow the previous authors' description, a major fraction of the limestone boulders "was formed by attrition due to wave action and then swept away from its primary position". However, FÜLÖP (1958) qualified a part of the limestone masses as bioherms and considered the conglomerates to be a whole as of shallow-marine and partly near-shore origin. From the limestone boulders KOLOSVÁRY (1954a, 1954b) described 35 coral taxa. A greater part of these even have specific names. Surprisingly, orbitolines were discovered only in one sandstone bank. SIDÓ (in FÜLÖP 1958) succeeded in recognizing four species in this faunula.

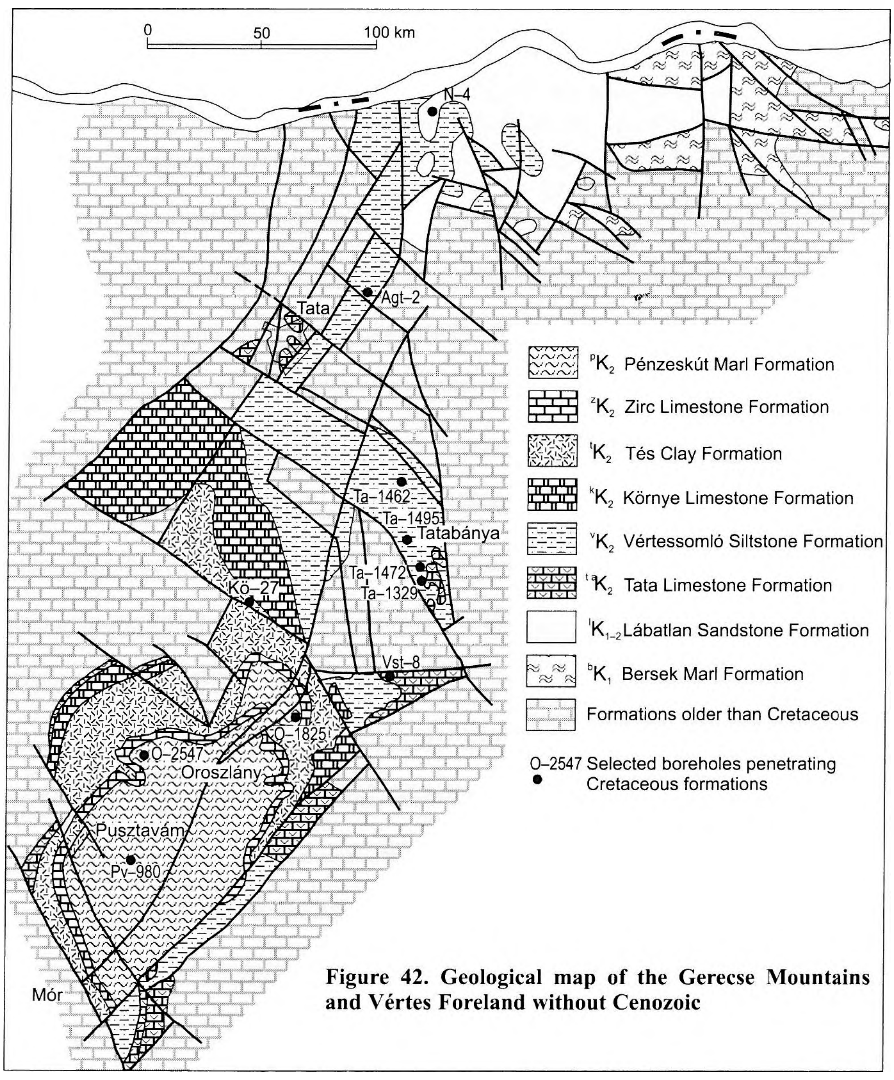


Figure 42. Geological map of the Gerecse Mountains and Vértes Foreland without Cenozoic

A turbiditic origin of the siliciclastic sequence of the Gerecse Mountains was first suggested by CSÁSZÁR & HAAS (1979, 1984). However, the term 'submarine fan' itself was first employed by KÁZMÉR (1987). The landmark works of SZTANÓ (1990a, 1990b) have unambiguously proved that the limestone clasts had been transported to a deep-sea slope. Furthermore, the sequence as such had originated due to gravity movements and formed a fan.

On the top of the Bersek Hill, among the uppermost beds of the column FÜLÖP (1958) described a "50-cm-thick bioclastic limestone bed with flint pebbles" or, elsewhere, a "limestone breccia bank". He mentioned similar limestone breccias with flint pebbles from the top of Szágodó Hill and the western foothills of the Nagy-Eménkes.

SECTIONS STUDIED

Lábatlan, Köszörűkőbánya quarry

In the Köszörűkőbánya Member of the abandoned quarry, platform-derived limestones accompany the flint breccia, either in the form of random disseminations or as separate (off and on even predominant) limestone breccia banks. Limestone clasts exhibit a wide range of sizes: scattered and subangular forms vary between 5 and 35 cm whereas it is possible to find much worse sorting in the megabreccia bank. Figure 43 shows the size distribution of the limestone fragments dispersed in the predominantly flinty clastics at the northern end of the quarry scarp. The flint breccia mass in question overlies a clayey siltstone bed of 20-30 cm thickness, whose surface exhbits current ripples. Thin-section studies have proved that a significant portion of the limestone clasts consists of reef-builder organisms — that is, mainly corals, hydrozoans, sponges, *Chaetetopsis, Bacinella* (cPlate IX: 2–5, p. 196) and subordinately red algae. Colonies of corals and hydrozoans suffered a marked recrystallization; this makes their taxonomic determination rather uncertain. Among the algae, two species can be recognized: *Marinella lugeoni* PFENDER and *Ethelia alba* PFENDER. In sample 9 monaxon spicules do also occur. These rocks are not exclusively made up of colonial organisms but do comprise a remarkable amount of rudist-shell fragments, bryozoan colonies as well as ossicles of echinoderms, pelecypods and gastropods. Foraminifers, for example, are also present but in lesser quantities. They consist of both calcareous and arenaceous forms (the latter includes orbitolines and, even, one planktonic form was also found). Boundstone and subsidiarily packstone textures characterize these rocks. Even if of infrequent occurence, all breccia horizons of the Köszörűkőbánya Conglomerate contain shallow-marine limestone clasts.

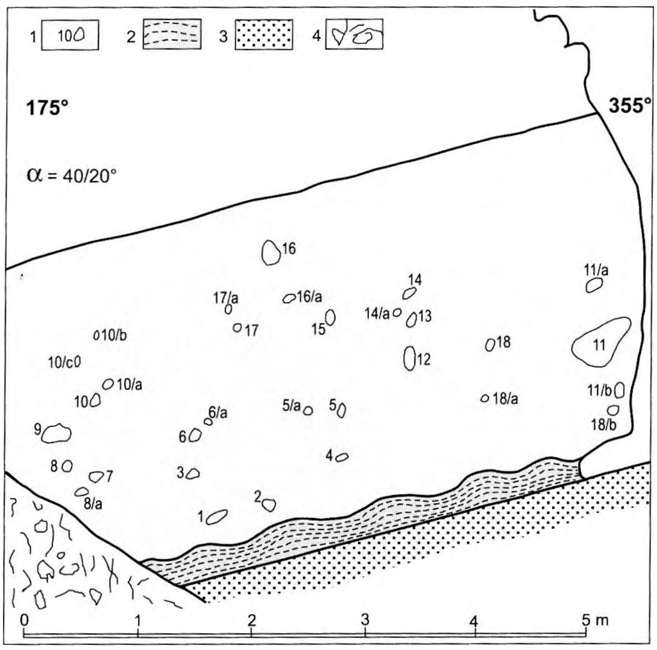


Figure 43. Scattered limestone debris derived from carbonate platform. Northern end of the Köszörűkőbánya quarry, Lábatlan, Gerecse Mountains

1 — Limestone debris in chert breccia; 2 — Siltstone; 3 — Sandstone; 4 — Scree

However, occurrences of limestone olisthostromes are restricted to merely two individual horizons (Figure 44). In the lower horizon, limestone clasts vary in size from 1 to 5 cm, having a slightly lower abundance than that of the flint grains. The internal structure of the bed does not display any obvious regularity. The upper breccia horizon contains far less rounded limestone grains; the average size of these is between 5 and 15 cm. Exceptionally, a boulder 40 cm in diameter was also found. This group of beds is capped by a bioclastic, sandy, lime-mud derived limestone, or calcareous marl.

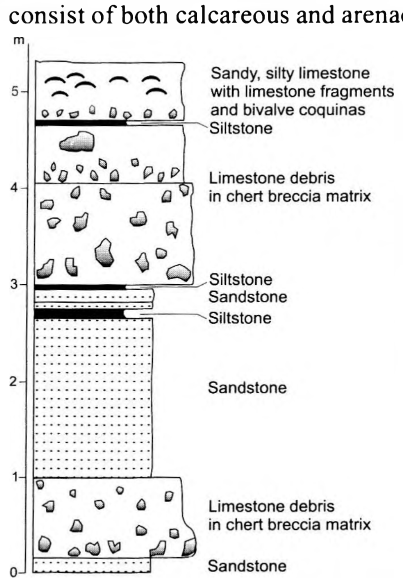


Figure 44. Columnar section with olisthostrome horizons, Köszörűkőbánya Conglomerate Member, Köszörűkőbánya quarry, Lábatlan

Samples collected for thin-section studies exhibit a wide variety of textural patterns; wackestone, packstone, grainstone, boundstone, floatstone and rudstone occur, indicating of diverse sedimentary environments. Fossils are very abundant, and if fragmented, much more pronouncedly coated. Even macroscopically, the following fossils can be recognized in the limestone clasts: corals, hydrozoans, rudist pelecypods and those of the genera *Ostrea* and *Alectryonia* (bPlate IX: 6, p. 112), as well as a couple of gastropods and orbitolines which are occasionally quite frequent. CZABALAY (1983b, 1989, 1995) determined therefrom 11 pelecypod taxa including the rudists *Agriopleura marticensis* (D'ORBIGNY), *A. darderi* ASTRE, *Toucasia carinata* MATHERON, *Pseudotoucasia santanderensis* (DOUV.) and *Eoradiolites murgensis* TORRE; there are also 9 gastropod taxa present, most of them being nerineid.

In accordance with the numerous fabrics, the microfossil content is also varied. In addition to those mentioned in the discussion of the scattered limestone clasts, the following fossils have been found: *Bacinella irregularis* RADOIČIĆ, encrusting foraminifers, *Pieninia* sp., Calcisphaerulidae as well as *Colomiella* sp. Among red algae, also *Paraphyllum* sp. can be recognized. SCHLAGINTWEIT (1990) reported a rich fauna from different horizons containing limestone clasts. The most important taxa thereof are as follows: *Orbitolina (M.) texana* (ROEMER), *?Valvulineria n.* sp. 2 ARNAUD-VANNEAU, *Solenopora urgoniana* PFENDER. BODROGI (unpublished report) detected *Conicorbitolina conica* D'ARCHIAC. In her Ph. D. thesis, GÖRÖG (1996) studied the larger foraminiferal assemblage from the limestone clasts and a ripped-up sandstone boulder (bPlate IX: 5, p. 112), as minutely as never had been done before.

Top of the Bersek Hill

In Figure 45 the position of the limestone breccia bed (FÜLÖP 1958) is shown, as observed at the top of the marl quarry of Bersek Hill. The limestones display various textural patterns since packstone, floatstone, grainstone, rudstone as well as boundstone may occur. Average values for textural components, derived from 8 thin-section samples, are shown in Figure 46. Extraclasts of 15–40% are predominantly composed of quartz, flint, volcaniclasts and well-rounded limestone grains. The origin of the limestones is twofold: besides Late Jurassic or Early Cretaceous ones (accomodating *Clypeina jurassica* FAVRE) there also occur clasts probably derived from the Dachstein Limestone. The percentage of bioclasts is around 30–40% with a substantial admixture of ossicles of echinoderms. Fragments of pelecypod shells are sometimes quite abundant; however, those of rudists and *Lithocodium* are negligible. Remains of orbitolines, *Ethelia alba* PFENDER, bryozoans and fragmented *Inozoa* are uninterruptedly present but always in minor amounts. Sponges, sponge spicules, green algae, vermicular structures, and benthic arenaceous foraminifers are accidental and various degrees of abundance. Also accidental are the encrusting foraminifers, calcareous benthic foraminifers, corals, gastropods and colonies of *Bacinella*. Their average distribution is demonstrated in Figure 46.

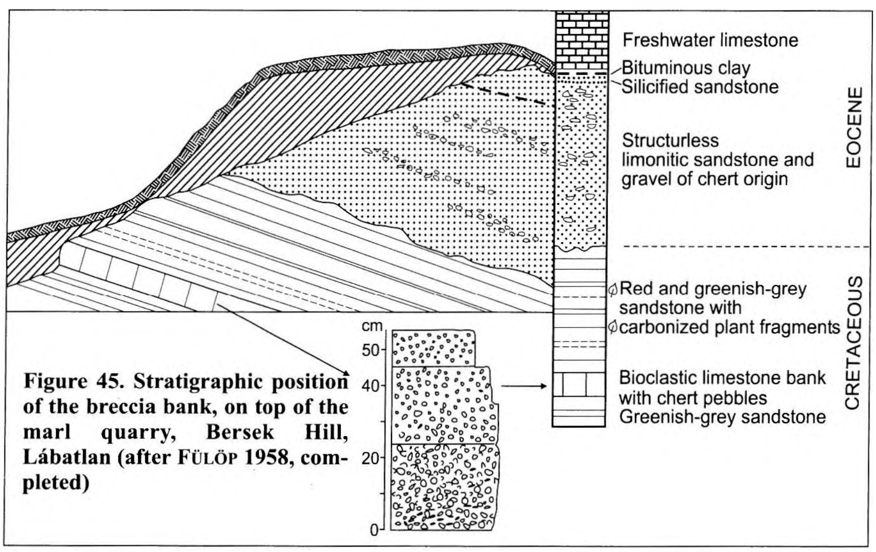


Figure 45. Stratigraphic position of the breccia bank, on top of the marl quarry, Bersek Hill, Lábatlan (after FÜLÖP 1958, completed)

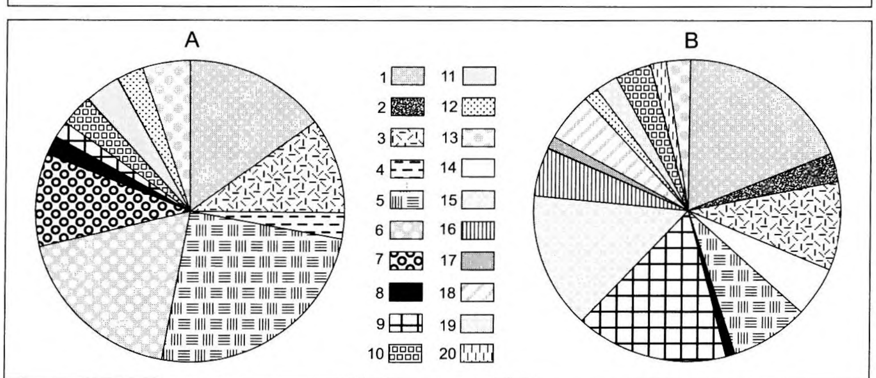


Figure 46. Mean texture composition and fossil content measured in thin-sections of the breccia bank, marl quarry, Bersek Hill, Lábatlan

1 — Micrite; 2 — Microsparite; 3 — Neomorphic calcite; 4 — Echinoderm; 5 — Packstone limestone (pebble); 6 — *Clypeina* limestone pebble; 7 — Inozoa limestone (pebble); 8 — Sandstone; 9 — Chert; 10 — *Lithocodium;* 11 — *Orbitolina;* 12 — Rudist bivalve; 13 — Other fossils; 14 — Quartz, chert; 15 — Other limestone; 16 — Volcaniclastics; 17 — Sponges; 18 — Corals; 19 — Other bivalves; 20 — Foraminifers

Off the vicinity of the quarry there are formations also probably assignable to the Köszörűkőbánya Conglomerate Member, even if they are of a slightly different stratigraphic position (Figure 47). Cretaceous, shallow marine faunal limestone clasts, similar to those in the Köszörűkőbánya quarry, are found at the eastern flanks of the middle sector of the Nyagda Valley. There, due to the findings of a myriad of limestone clasts on the slope I have arrived at the conclusion that the actual limestone breccia-bearing clastics cannot be derived from the youngest strata present there because the breccia banks at the top of the slope are composed overwhelmingly of flint fragments. A pebbly sandstone sequence just beneath the Eocene beds at the top of the Bersek Hill was correlated with the sequence made up of an alternating succession of breccias and sandstones in the Köszörűkőbánya cliff (FÜLÖP 1958). However, the borehole Lábatlan–36 drilled in the yard of the Köszörűkőbánya quarry reveals that the beds at the top of Bersek Hill are at least of a 100 m deeper stratigraphic position than these. Careful studies may, in addition, even ascertain lithological discrepancies between them. Limestone clasts derived from a syngenetic carbonate platform are angular and of low roundness, whereas those appearing in deeper horizons are of high- to medium roundness. Studies of Borehole Neszmély N–4 have made it clear that limestone pebbles of Triassic to Jurassic age are typical of the lower half of the Lábatlan Sandstone (257.4–354.9 m).

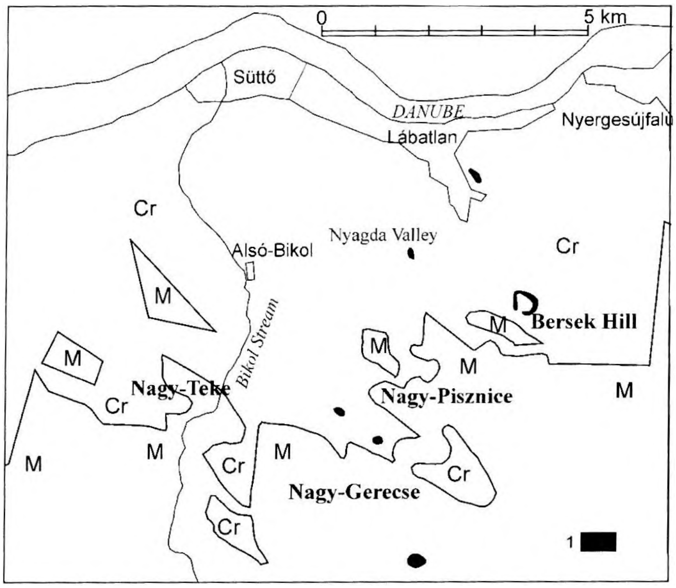


Figure 47. Surface occurrences of the Köszörűkőbánya Conglomerate Member of the Lábatlan Sandstone Formation, Gerecse Mountains

1 — Köszörűkőbánya Conglomerate Member; C — Other Cretaceous formations; M — Jurassic and Triassic formations

Conglomerate and breccia banks pertaining to the Lábatlan Sandstone appear on the northeastern flanks of the Kis-Gerecse as well as to the west of Nagy-Pisznice, too. There, interestingly, the dominant flint pebbles are supplemented by quartz, quartzite, and metamorphite pebbles, often in percentages similar to those of the flints. However, I have not found any limestone pebbles at all. (Based on its composition, the possibility of assigning the pebbles to the Eocene has also been raised.) In sum, among the surface appearances of the Köszörűkőbánya Conglomerate, which are otherwise areally very restricted, those at the Köszörűkőbánya quarry and in the Nyagda Valley are to be regarded as of outstanding interest since the limestone clasts therein, as a part of the youngest member of the Cretaceous succession, carry information about the one-time carbonate platform.

AGE OF THE KÖSZÖRŰKŐBÁNYA CONGLOMERATE

As seen earlier, opinion is divided with respect to the age of the formation. From intercalated siltstone and clay marl among sandstones and breccias beds, GÓCZÁN (in FÜLÖP 1958) reported angiosperm palynomorphs. However, in those times no significance was yet attached to this observation. Nevertheless, based on data from Hungary, there is no pre-Albian formation at all to contain such remains of angiosperms. Nannoplankton studies of SZTANÓ & BÁLDI-BEKE (1992) indicate an Aptian/Albian transitional age of the beds under discussion. FÉLEGYHÁZI & NAGYMAROSY (1991, 1992) argued that these beds are by no means older than Albian. Moreover, the species *Eiffellithus turriseiffeli* DEFLANDRE stemming from the base of the Borehole Lábatlan Lbt–36, evidences an age certainly not older than Middle Albian. Orbitoline investigations by SCHLAGINTWEIT (1990a, 1990b) marked Late Aptian as the age of formation. Based on the occurrence of *Orbitolina (M.) texana* (ROEMER) in a siliciclastic bed, GÖRÖG (1996) considers this bed as having formed in Late Aptian/Early Albian. However, she suggested a Late Aptian age of the limestone clasts given that they contain the *O. (M.) texana – O. (M.) cf. lotzei* assemblage. Molluscs accommodated by the limestone boulders and the matrix of the megabreccia were studied by CZABALAY (1995) and they suggested an Early to Middle Albian age. To summarize the above, the most probable age of formation may be Early Albian. (I shall come back to its expalantion later).

DEPOSITIONAL ENVIRONMENT OF THE KÖSZÖRŰKŐBÁNYA CONGLOMERATE

The marginal slope of the Gerecse Basin, which is now indicated by the Köszörűkőbánya quarry, was rimmed by a unique carbonate platform (Figure 48). Peculiarities of the platform involve many aspects. Contrasting other Urgon formations in Hungary, the remarkably abundant fauna of the platform — comprising corals, hydrozoans and further colonial organisms — provides a good basis to suggest that the platform was rimmed by front reefs. The thick clastic sequence containing chiefly subangular pebbles is indicative of a vast clastic input from a relatively close source. This is also reflected in the sedimentary record by the co-occurrence of basic rock fragments. The width of the land was predestined by the continentward drift of the island arc shown by BALLA (1981) and by the formation of a foreland basin as a result of oceanic basement obduction. Resulting from Late Jurassic compression, complementary tectonic units, namely, positive landforms were formed in the foreland of the Vértes Mountains (Figure 49). This high point might have been subareally exposed in the late Early Createaceous, to separate a siliciclastic and a Maiolica-type basin at the northeastern and southwestern parts of the Transdanubian Range, respectively.

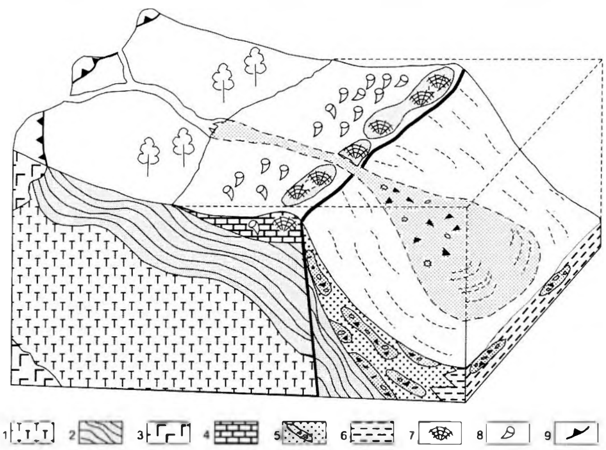


Figure 48. Block diagram showing the relation of the carbonate platform with the front reef and the siliciclastic basin

1 — Triassic and older formations; 2 — Jurassic; 3 — Obducted oceanic basement (basalt); 4 — Cretaceous platform carbonate; 5 — Slope deposit; 6 — Basin sediment; 7 — Corals; 8 — Rudist bivalve; 9 — Obduction surface

The front reef was dissected by distributary channels whose load occasionally might have partially veneered the reef edifice. This is suggested by flint grains found in reefal limestones (FÜLÖP 1958). Clastics of grainstone and rudstone fabrics indicate the presence of heavily agitated intra-, or back-reef zones. Various fossils and textural types (wackestone, packstone and floatstone) however, reflect a more compound energetic pattern at the back-reef zone. CZABALAY (1995) established that a vast majority of the pelecypods was fixosessile (rudists and ostreids); the rest (*Arca, Lima, Astarte*) are slightly burrowed into the lime mud. Some of the gastropods occupied reef or back-reef habitats, whereas a minor portion of theirs lived in the tranquil water of the lagoon.

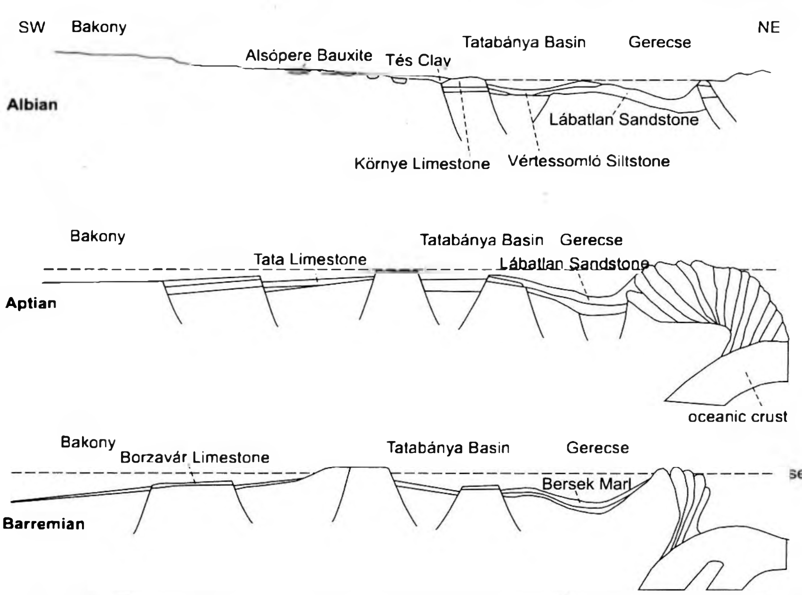


Figure 49. Sinusoidal form of the surface developed during the Early and middle Cretaceous due to the compressional forces of subduction and obduction in the northern part of the Transdanubian Range

The fact that clasts of Cretaceous (rudistid-coralline) limestones are found exclusively in the Köszörűkőbánya Conglomerate appears to support the concept which is as follows: Urgon facies in the area was first developed in the Early Albian, when its clasts were initially represented only by randomly scattered cobbles and boulders and then, in a few metres upsection, by two distinct breccia (olisthostromc) horizons. These two highstand levels can be interpreted as a consequence of storms battering the reef mass as well as other zones of the platform. The upper breccia horizon is overlain by a moderately fining-upward sequence of sandy limestone. This is explained by the sieving-out of lime mud which had been previously whipped up and then transported into the depositional area.

At Bersek Hill, the so-called "limestone breccia" is often conglomeratic in character and, in addition, the composition of the clastics is fundamentally different from that of the constituents of the olisthostromes at the Köszörűkőbánya quarry. A further discrepancy is yielded by the lack of the thick gravel horizon beneath the "limestone breccia" in the Bersek Hill section, otherwise so universal in the Köszörűkőbánya quarry. Unfortunately, there are no reliable palaeontological data available from the Bersek Hill section. On the basis of the above, one may rightly assume that the "limestone breccia" horizons of the two occurrences are not assignable to the same rock mass. In my opinion, the occurrence at Bersek Hill is somewhat older than that in the Köszörűkőbánya quarry.

KÖRNYE LIMESTONE FORMATION

The Környe Limestone Formation (Császár 1996) is defined as a "light grey to yellowish pale brown organogenic limestone that overlies the Tata Limestone directly or without expressive hiatus and goes beyond it in extent, and which is directly overlain or progressively intercalated by the Tés Clay Formation. Within a narrow strip, it is interfingered also with the Vértessomló Siltstone. It is subdivided into two member rank units". Its thicker, and lower part is called the Kecskéd Limestone Member which is a thick-bedded bioarenite chiefly of grainstone texture and usually lacking macrofauna. Exceptionally, it may contain echinids and rudists; however, orbitolines are relatively abundant. The upper part of the formation, making up only the one-third or one-fourth of the total thickness, is described as the Kocs Limestone Member. It consists of a micritic limestone generally grey in colour. It may contain a remarkable macrofauna, which may even attain a rock-forming quantity. The most noteworthy groups (Czabalay 1995; Bartha 1995) are represented by rudists (*Agriopleura, Toucasia, Eoradiolites, Pseudotoucasia*), chondrodontid and other pelecypods, *Nerinea* sp. and other gastropods, colonial corals, stromatoporoids and orbitolines.

Position of the Környe Limestone Formation in the succession

From the southwest, Környe Limestone borders the Gerecse Basin filled by siliciclastic formations of deep-water facies. It is of a platform, or platform-derived deposit. It represents a transition between the deep sublittoral/shallow bathyal facies and the fluvial/lacustrine facies in space and between the shallow (sublittoral) basin and the fluvial/lacustrine environments. Correspondingly, it is underlain by the Tata Limestone, or, if left out, by various Jurassic formations as well as the Dachstein Limestone. It is interfingered with the Vértessomló Siltstone Formation towards the Gerecse Basin and with the Tés Clay to the south-west (Figure 41).

Previous works and the geological setting

The formation is restricted spatially to the northwestern and western forelands of the Vértes and Gerecse Mountains, respectively (Figure 42). Since studies of this formation began, it has been a decisive circumstance that no surface outcrop has ever been found. However, the first one was actually discovered in the course of this work, and was thus unknown even to the specialists. All this reflected our poor knowledge of the Vértes Mountains and signalled an urgent necessity for mapping. The first recognition of the formation itself was due to the dynamic Eocene coal exploration in the 1950s and especially in the 1960s. Although doing their best, geologists preparing the drill-core protocol identified the formation with those later designated either as Zirc Limestone or Tata Limestone. It became an individually treated formation in the late 1960s, when coal prospecting required in-depth knowledge of the rocks subjacent to the Eocene. The crucial step towards becoming acquainted with the Környe Limestone was the implementation of the Borehole Oroszlány–1825 to core the Mesozoic sequence as a whole. While preparing field descriptions, this was the time when I became totally convinced that this formation makes up a distinct lithostratigraphic unit. However, there arose some problems about delimiting it from the underlying formation, known today as Tata Limestone. The Borehole Környe–27 was drilled among others to reconcile this uncertainty; it then became the eponym as well as the stratotype section of the formation. Nevertheless, it should be added that the description of Vértessomló Siltstone as a distinct lithostratigraphic unit to replace the former term 'Turrilites marl' progressed in a similar fashion, although, there had been relative early signs relating to the wrong terminology in former borehole successions.

The lithostratigraphic term 'Környe Limestone' was first published in 1983 in the tables of the 'Lithostratigraphic Units of Hungary' [in Hungarian, CSÁSZÁR & HAAS (eds) 1983]. Unfortunately, the majority of the results of the exhaustive investigations have not yet been published. Following a few brief reports, CZABALAY (1989) provided a summary of the composition and descendence relationships of the mollusc fauna. She recognized the alternation of fore-reef and back-reef assemblages in the formation (CZABALAY 1995). In spite of this alternation, she demonstrated that the fauna composition is nearly the same as that of the Köszörűkőbánya Conglomerate. However, she found the latter to be, a bit older than the Környe Limestone. A comprehensive macrofauna evaluation was performed by BARTHA (1995) who described 25 pelecypod genera with 11 species and 15 gastropod genera with 14 species. With reference to the Környe Limestone and Tés Clay, mainly on the basis of their occurrence in the Borehole Oroszlány–2301, BARTHA actualized the system of KAUFFMAN & SOHL (1974) and worked it out for rudist assemblages. Correspondingly, 7 assemblages, also refelecting distinct evolutionary stages, were distinguished: individuals, associations, meshes, bushes, scrubs and biostromes. These and other accompanying molluscs provided them with a basis to distinguish between the following sorts of environments: fore-reef, carbonate platform, rudistid high, back-reef, lagoon, lagoon slope and coastal/paludal/delta. On the basis of the Borehole Oroszlány–2301, BARTHA (1995) created a sea level curve.

CSÁSZÁR (1995) subdivided the formation into an allochtonous-biodetrital and an autochtonous-organogenic members; moreover, he managed to outline its rather difficult facies connections. An attempt was made to evaluate the sequences of the Gerecse and the Vértes Foreland by means of sequence stratigraphy.

In most cases, the core documentation proved to be unsuitable for avoiding recognition of the uncertainties depicted above. My knowledge on the Boreholes Oroszlány Op–1, Oroszlány (Bokod)–1317, Mór–15, Pusztavám–820 and Vértessomló Vst–2 comes from the study of selected drillcores and thin-sections. In possession of these samples, I made repeated attempts to re-evaluate the drilling documentation.

SECTIONS STUDIED IN DETAIL

Borehole Környe–27

This borehole was selected to be the stratotype section of the formation. At its base, it exposes the Dachstein Limestone Formation which is overlain (471.2–483.7 m) by the Tata Limestone, 12.5 m in thickness (Figures 50). It is light- to dark grey in colour, medium-grained, bioclastic and occasionally of nodular structure or of flaser bedding. The poor macrofauna is only represented by a couple of belemnites and brachiopods. Silicified biomicrosparitic wackestone/packstones are the most significant fabrics. Sparse cement becomes important only at the upper 2-m-thick part of the interval. Scarce extraclasts are derived from the subjacent rocks, namely Mesozoic (among others calpionella-bearing) limestones, quartz and flint grains. Limestone fragments however, appear only in the lower half of the interval. The fossils are often replaced by glauconite.

The rich fossil assemblage of the Tata Limestone consists of the following taxa (in a descending order of importance): echinoderm ossicles, red algae, sponge spicules, planktonic and arenaceous benthic foraminifers, bryozoans, fragments of pelecypods and brachyopods, as well as calcareous benthic formainifers. *Pieninia, Cadosina, Colomiella* and ostracods, however, may also appear accidentally.

The lower, or, Kecskéd Member of the Környe Limestone Formation (389.6–471.2 m) sharply overlies the Tata Limestone. More subtly, their boundary corresponds to a submarine erosional unconformity. At the base of the formation, there is a 10-cm-thick bed of glauconitic limestone clasts cemented by greenish-grey mudstone. The X-ray powder diffractometry of the embedding material, carried out in the laboratory of the Geological Institute of Hungary (GIH) by I. FARKAS, displayed siderite to a degree of 21%. Macroscopically, the rock can be easily mixed up with the Tata Limestone. Its colour varies between light brown and light grey. The size of the bioclasts shows an increasing-upward tendency. In fact, in the uppermost 14 m of the member, there are also fossils that are well-preserved enough to be determined. The textural pattern exhibits intraclast-bearing/pelletal, biosparitic grainstone/rudstone and pelletal and intraclast-bearing biomicrosparitic packstone types.

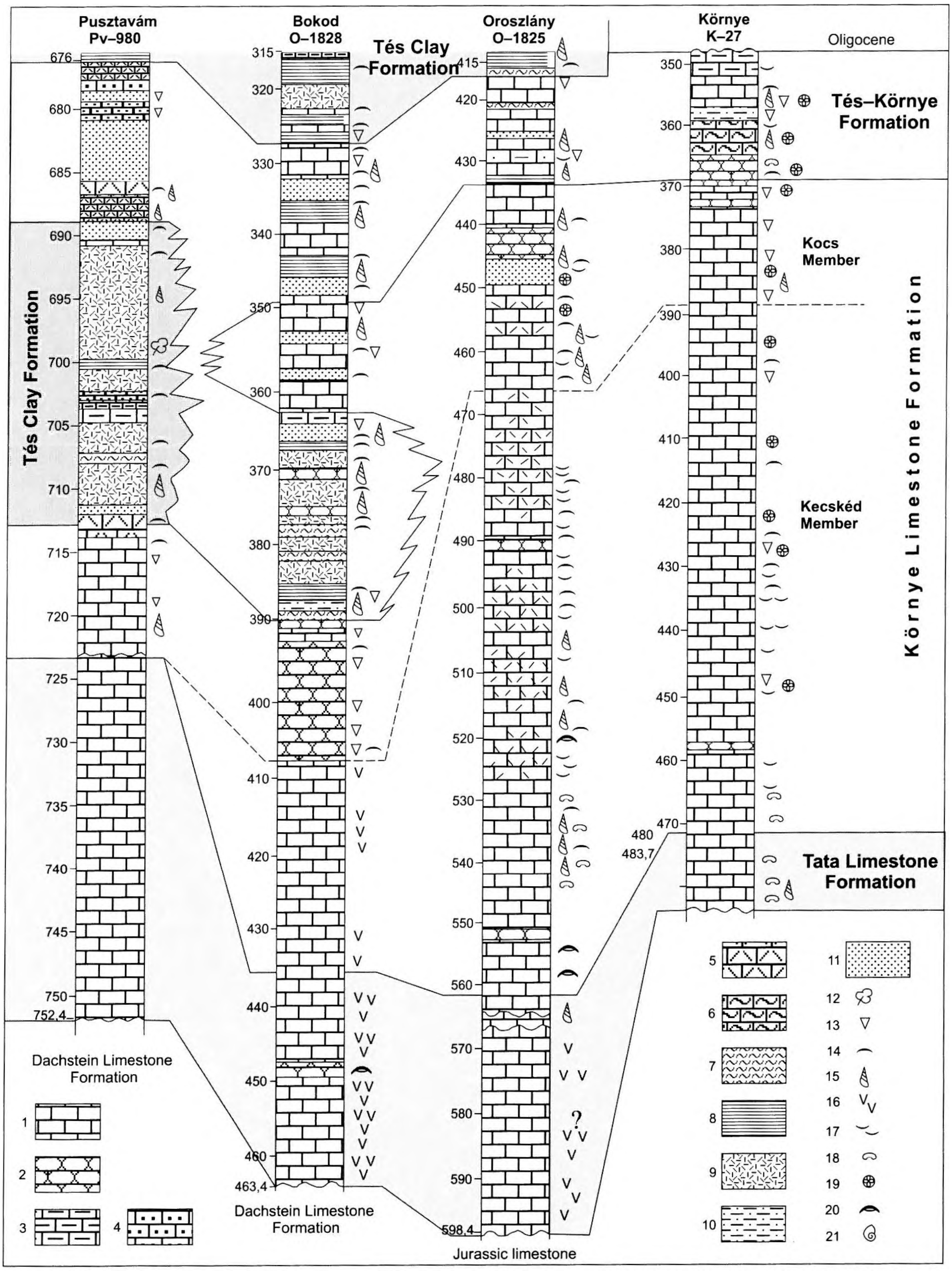


Figure 50. Relation of the Környe Limestone to the Tata Limestone and the Tés Clay in a few boreholes in the Vértes Foreland

1 — Thick-bedded limestone; 2 — Nodular limestone; 3 — Limestone with argillaceous intercalations; 4 — Sandy limestones; 5 — Bioclastic limestones; 6 — Limestone with calcareous marl intercalations; 7 — Marl; 8 — Clay; 9 — Variegated clay; 10 — Siltstone; 11 — Sandstone; 12 — Plant remains; 13 — Rudist bivalves; 14 — Other bivalves; 15 — Gastropods; 16 — Echinoderm fragments; 17 — *Orbitolina;* 18 — Echinoids, 19 — Corals; 20 — Brachiopods, 21 — Ammonite

The increased abundance of coated grains also indicates more intense water agitation relative to that of the Tata Limestone. The quantity of glauconite grains diminshes and, in turn, is reduced to zero around the half of the unit. Although the echinoderm ossicles also occur in the Környe Limestone, the most significant feature of the formation is the increasing upwards occurrence of rudist shell fragments up to rock-forming masses, from the base of the formation. Orbitolines, the other typical Urgon fossil group is all the time present in the member and may from place to place reach up to rock-forming quantity as well. In addition to *Orbitolina* the other important difference between the Tata Limestone and the Környe Limestone is that there are almost no sponge spicules and red algae in the latter and here there is a pronounced reduction of planktonic foraminifers. Although in minor volumes, *Pieninia oblonga* MIŠÍK is generally widespread. There are no other fossils to show major differences between the two formations. Corals and worm tubes however, represent a rare and novel component.

Table 10

Mollusc distribution in the Környe Limestone of Boreholes Környe–27, Oroszlány–1825, Pusztavám–980, Vértes Foreland (after CZABALAY 1983a, 1992)

	Környe–27			O–1825	Pv–980
	Kör. 1	Kör. 2	Kö–Té		
Agriopleura darderi ASTRE		+		+	+
Agriopleura sp.	+				
Monopleura sp.				+	
Eoradiolites murgensis TORRE,	+	+			
Eoradiolites davidsoni (HILL) DOUV.		+			
Toucasia carinata (MATH.)		+		+	+
Chondrodonta hantkeni (HORVÁTH)	+	+			
Ch. cretacea (HORVÁTH)		+		+	
Liostrea delettrei (COQ.)		+			+
Lopha rectangularis (ROEM.)			+	+	
Lopha sp.				+	
Neithea quadricostata (SOW.)			+		
Neithea sp.				+	
Chlamys sp.				+	
Nucula sp.				+	+
Cardium sp.					+
Arca marullensis D'ORB.				+	
Astarte obovata COQUAND					+
Corbula sp.				+	
Tellina sp.					+
Mytilus sp.				+	
Gervilleia tenuicostata P. et C.			+		
Gervilleia sp				+	
Lima cottoldiana (D'ORB.)			+		
Panopea sp.				+	
Crassatella sp.				+	
Opis sp				+	
Ampullina laevigata (D'ORB.)		+			
Cryptaulax angustatum D'ORB.		+			
Pyrasus michaillensis P.et C.		+			
Nerinea titan SHARPE					
Nerinea (Eunerinea) sp.					+
Plesioptyxis fleuriaui (D'ORB.)	+	+		+	
P. baconica (CZABALAY)	+	+			
P. dayi (BLANKH.)		+			
P. cretacea (CONRAD)		+			
P. prefleuriaui rengarteni (CZAB.)		+			
Plesioptyxis sp.				+	
Nerinella utrillasensis VERN. et LOR.	+	+		+	
Metacerithium trimonile (MICH.).	+	+			
Metacerithium sp.				+	
Cerithiella sp.				+	
Tritonalia urgonensis P. et C.		+			
Haustator vibrayeanum (D'ORB.)			+	+	
Haustator sp.				+	
Delphinula valfinensis ETALLON			+		

Kör. 1 = Környe Limestone: Kecskéd Member, Kör. 2 = Környe Limestone: Kocs Member, Kö–Té = Környe–Tés Formation.

The upper part of the formation, or, Kocs Member (396.0–389.6 m) is regarded as a definitive limestone of Urgon facies. It develops gradually within a transitional zone of a few metres thickness from the underlying allochtonous-type limestone (Figure 50). The change is manifested in the prompt embedding of the fossils — that is, without no remarkable transportation. The member is characteristic of its ample and diverse macrofauna assemblage where rudists and *Chondrodonta* pelecypods play an important role. They are accompanied by corals and stromatoporoids which may again be of rock-forming importance. For the distribution of the macrofauna by member rank units, see Table 10 (CZABALAY 1983a, 1992).

The upper member shows a variety of different textures; these textures are mainly biomicritic, intrabiomicritic or pelbiomicritic wackestones, packstones and boundstones; however, floatstones may be present as well. Foraminifers are the most frequent biogenic constituents (KOVÁCS-BODROGI in CSÁSZÁR *et al.* 1985), especially those that are calcareous and benthic ones, miliolinids in particular. Among a number of benthic forms, orbitolines may often appear but in varying degrees of abundance. Fragments of rudists and other pelecypods are comparatively scarce. However, cadosina becomes more abundant and some green algae and colomiella are also present (NAGY 1987a).

The uppermost portion of the Borehole Környe–27 (347.0–369.0 m) can easily be distinguished from the member to which it is superjacent. These beds are made up of bioclastic, argillaceous and nodular limestones and calcareous marls. Siltstones may however, be intercalated, too. Though subordinately, glauconite is again present. In spite of terrigenous effects, in these beds the macrofauna remains almost unchanged; only the gastropods increase, both in abundance and diversity (Table 10). Contrasting the micrite-dominated textural types of the previous unit, the most characteristic fabrics here are bioextrasparitic/biopelsparitic grainstones. Quartz grains, being silt in grain size, bulk to 6000/cm^2. The foraminifer content, especially in terms of miliolinids, is scanty. Orbitolines however, are exceptional since in certain beds they may be of rock-forming importance. Nevertheless, planktonic foraminifers may also appear on and off. Shell fragments of molluscs, including that of rudists as well as bryozoans, ostracods and echinoderm ossicles are of somewhat increased proportion. Many small coral colonies are rather typical of this unit.

On the basis of the silt and clay content and the dominance of shallow-marine fossil elements I assign the above sequence to the Tés–Környe Formation, However, on account of the planktonic foraminifers the Vértessomló–Környe Formation cannot be exluded, either.

Owing to the deficient coring, the lower part of the Cretaceous portion of the borehole can only be concerned with uncertainties (Table 11). The fine-grained, heavily pelletal, intraclast-bearing Tata Limestone is basically micritic in matrix. However, it is to a great extent recrystallized. In its predominant wackestone fabric, red algae and echinoderms occur in approximately the same quantities. Also characteristic but not so dominant are planktonic foraminifers and a few sponge spicules. There is almost a complete lack of coated grains. The thickness of the Tata Limestone is estimated to be not more than 1.5 m. The contact between the Környe Limestone and Tata Limestone cannot be laid out precisely. Thus, based merely on its macroscopic features, the 4-m-thick, fine- to medium-grained biodetritic limestone is denoted as the transitional Tata–Környe Formation. However, its textural pattern bears good resemblance to that of the Kecskéd Member of the Környe Formation (683.7–699.5 m). They have the following textural features in common: subordinate echinoderms (without a customary decreasing upward pattern), outstandingly abundant (sometimes rock-forming) fragments of rudist shells and high frequencies of both orbitolines and coated grains. In general, the texture of these rocks is intrapelbiosparitic. However, the frequencies of intraclasts and pelletal grains are high and the texture of the Tata–Környe Limestone may vary between intrapelbiomicritic and intrapelbiosparitic; thus any of the transitional types can there be found. Another striking feature of this portion is that in the upper part there are cross-cuts of rudists embedded in biodetritic material. Moreover, in the uppermost section, there is a *Chondrodonta* colony in life position. All these features indicate alternation of features characteristic either for the lower or the upper members of the Környe Limestone.

The Kocs Member is grey or rarely brownish-grey in colour and it is of aphaneritic texture. It contains a well-preserved, diverse and rich gastropod and pelecypod fauna. It is separated from the lower member by a thin, black claystone intercalation which is underlain by a transitional bed of 40 cm thickness that is upward less and less biodetritic. Czabalay (1995) distinguished between a lower and an upper faunal assemblage — namely, the *Chondrodonta–Toucasia–Nerinella* and the *Toucasia–Agriopleura*, respectively within the Kocs Member. Thin-sections reveal that the rocks, apart from the uppermost 2.5-m-thick portion, are biomicritic/biopelmicritic wackestones/floatstones/packstones in fabric. Its most common and abundant fossils are miliolinids, which are off and on accompanied by a significant amount of orbitolines.

Macroscopically, the uppermost 2.5-m-thick part of the borehole is somewhat similar to the lower member. Under the microscope, this limestone is of intrabiosparitic texture. Intraclasts are considerably increased here. Miliolinids are almost entirely missing. However, the abundance of coated grains increases is perceptibly and, in addition, this is the first time that such fragments of pelecypod shells other than rudists are quite abundant.

The Borehole Oroszlány–1825 traversed a thicker and more complete Cretaceous sequence than did Borehole Környe–27. In many respects it is similar to the latter. However, there are some important discrepancies as well. To mention the most important, whereas in the Borehole Környe–27 there is only one unconformity accompanied by breccias as well as conglomerates going with the boundary to the Tata Limestone, there are two of them in Borehole Oroszlány–1825 (Figure 50). These are at the 564.6–564.9 m interval (cPlate X: 5, p. 197) as well as at 566.2–566.6 m. With respect to lithology however, there is no marked difference between the limestones overlying and underlying these horizons. The deeper-situated breccia level is joined by belemnites, orbitolines and poorly preserved ammonites. The slow and gradual shift in the proportions of fragments of rudists and echinoderms would provide a tool to reconcile the difficulties of making distinction between the two formations. The typical Tata Limestone (566.6–598.4 m) is devoid of shell fragments of rudists, whereas very fine- to fine-grained ossicles of echinoderms as well as the likewise fine-grained red algae prevail in the biodetritus. I drew the line at about 561 m, where rudist fragments become predominant at the expense of ossicles of echinoderms. It is reasonable to assign the term Tata–Környe Formation to an interval between 561.0-566.6 m. In the broad sense however, I would rather attach this transitional interval to the Környe Limestone as well, since the appearance of rudists indicate the appearance of a new environmental type. This is supported by the circumstance that no specialist would ever be expected to recognize macroscopically the upper boundary of this section since a reliable estimation of the bioclast proportions requires microscopic studies. The use of a hand lens however, may be useful; however because it is still also a matter of thorough practice, drawing the line remains to a certain extent subjective. Therefore I repeatedly argue that recognizing the Tata–Környe Formation as a distinct lithostratigraphic unit is certainly advisable.

Cytherella, the genus typical of euhaline and low-agitated water becomes predominant. At shallower water depths, terrestrial signals occur in the stratigraphic record.

Borehole Oroszlány O–1828

With respect to the formations under discussion, this is the westernmost located borehole, and it exhibits the widest lithological variety in terms of the interfingering of the upper member of the Környe Limestone and the Tés Clay (Figure 50).

The fine- to medium-grained, crinoidal Tata Limestone (435.7–463.4 m) displays a range of colours, — that is, whitish, yellow, dark grey and light red as well. It is thin-bedded and nodular and flaser bedding may occasionally appear. Its macrofauna is rather scarce; there might be a few brachiopods or pelecypods present.

One can tell the Kecskéd Member of the Környe Limestone (408.4–435.7 m) from the underlying Tata Limestone only by means of thin-section investigations; thus there is a continuous transition between the two formations. A 10-cm-thick ostreid coquinite embedded in orange-brown claystone, forming the base of the Kocs Member of the Környe Limestone veneers the irregular and pronouncedly eroded surface of the Kecskéd Member. The Kocs member is then interrupted by the 25.9-m-thick Tés–Környe Formation and is therefore cut it into two. Its lower part (389.8–408.4 m) displays an aphaneritic texture, is somewhat nodular and contains shells of rudists and, subordinately, chondrodonts. In addition, there are a plenty of miliolinids in this member. The upper part (348.7–363.9 m) is characterized by thin sandstone intercalations and comprises the species *Toucasia carinata* (Matheron) and *Agriopleura darderi* Astre, but also a number of the genus *Cerithium* and a few of *Nerinea*, (Czabalay 1983a). These generally biodetritic limestones are dark grey in colour, thin-bedded and often, to some extent, sandy. Flaser and filmy clay layers often appear occasionally with plenty of carbonised plant remains on the bedding plains.

As a consequence of the above, the Tés–Környe Formation also appears to be of two different facies and intervals. In the lower part (363.9–389.8 m) there are alternately appearing beds made up of grey and variegated clays, siltstones, marls, limestones and, at the top, sandstones. The macrofauna content is extremely varied; nevertheless, ostreids are the most abundant macrofossils which often form coquinite accumulations. Sometimes, gastropods and pelecypods with a friable, aragonitic shell may also be frequent. *Cerithium* and *Nerinea* (or any *Nerinella*-like) gastropods are rather subordinate. Rudists occur chiefly in the lower part of the unit. Miliolinids are very common.

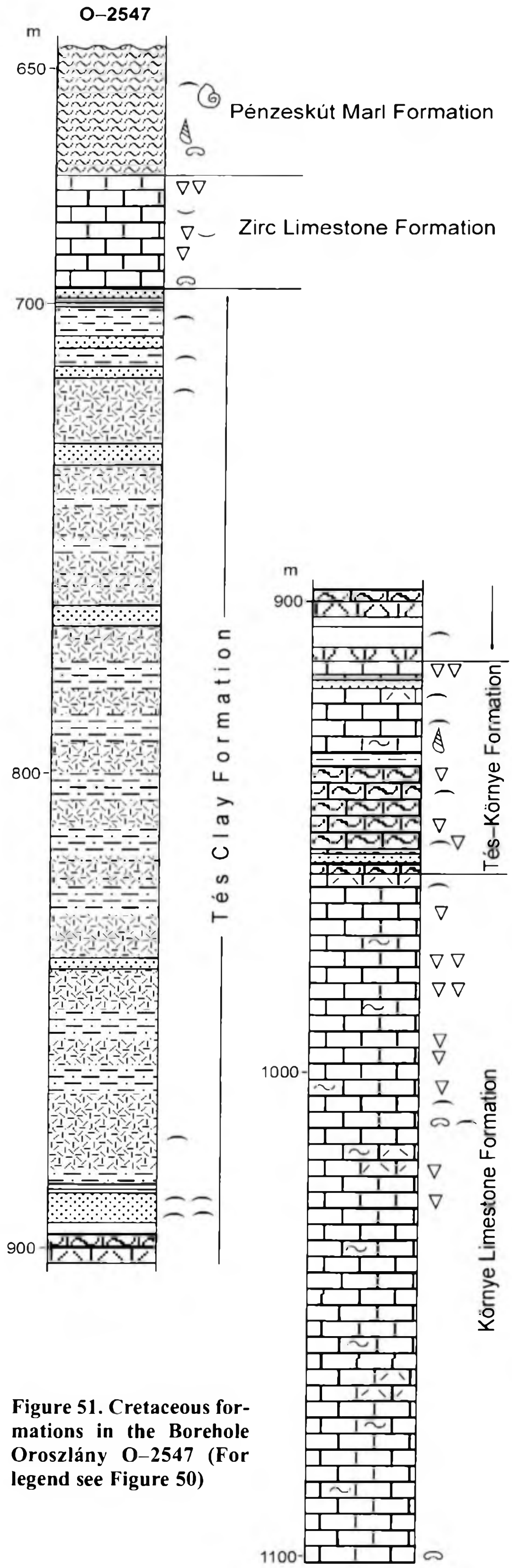


Figure 51. Cretaceous formations in the Borehole Oroszlány O–2547 (For legend see Figure 50)

Apart from some beds that are variegated in colour, the upper part of the Tés–Környe Formation (327.0–348.7) is very similar to the lower part, although the proportion of sandstones (including variants that are also cross-stratified) and rudist shells are more frequent. The shells of rudist and other pelecypods, as well as gastropods, are often fragmented and form coquinite accumulations. In spite of these facts, the colour of the rocks is grey, or even, dark grey. The ostreid shells show particularly great variations in size and shell thickness (bPlate XI: 1, p 114).

Borehole Kocs–5

The Tata Limestone, which is only 3 m thick, overlies the Jurassic Tűzkövesárok Limestone in the borehole. It comprises brachiopods, lithoclasts, echinoderm ossicles, bryozoans, globochaetes as well as planktonic and calcareous benthic foraminifers. An abrupt hardground surface associated with clay lenses is developed at its top and this then passes into the lower member of the Környe Limestone (440.8–465.3 m). It is organodetritus-dominated and somewhat uniform in facies. Its lower part is characterized by packstone and grainstone fabrics whereas the upper part is dominated by a grainstone texture. Coated grains are rather prevalent throughout the formation. Although these beds are devoid of a sincere macrofauna. However, their fragments, such as biodetrital components, are very common and especially those of rudist shells and echinoderm ossicles. Arenaceous benthic foraminifers, including orbitolines, are quite frequent in their occurence.

Borehole Pusztavám–980

The most striking feature of this borehole is the lack of the Kecskéd Member. It is likewise important that the rudistid intercalation, which is so typical of the Környe Limestone, is underlain by the Tés Clay of more than 20 m thickness (Figure 50). In the basal part of the borehole Tata Limestone occurs. It is very fine- to fine-grained and contains echinoderm ossicles, shark teeth and belemnites. An eroded surface appears at 723.4 m and this is covered by a dark grey claystone layer of 0.5 to 1.0 cm thickness with pelecypod shell fragments. It is superimposed upon by the Környe Limestone which is 10.3 m in thickness (at a depth of 713.1–723.4 m), medium- to dark grey in colour and biomicritic wackestone in fabric. However, mudstone and packstone fabrics may also have developed. The macrofauna of the Környe Limestone is scarce; the rudist assemblage comprises merely two species and the individuals are small in size. In addition to the rudists the apparent macroscopic occurrence of miliolinids and the absolute lack of orbitolines both indicate the mixing-in of freshwater. The exclusive appearance of *Muneria* with a relative frequency of 4 within the rudistid limestones, corroborated the highly decreased salinity.

A rudistid facies occurs again in the Tés–Környe Formation, above the Tés Clay intercalation (Figure 50). It is heavily sandy, and the fauna therein is very much fragmented, too. In the sandy limestone, calcareous sandstone lithologies and sparitic or micritic cements also prevail. Although a couple of *Munieria* can also be observed here, their mass occurrence is restricted to the more typical Tés Clay underneath. It is exactly here, and also in the upper part of the Tés–Környe Formation, floral remnants are present.

Further important boreholes transecting the Környe Limestone

The Borehole Oroszlány–1884 traversed the Tata Limestone between 275.4 and 357.7 m. Its basal part contains limestone pebbles of Jurassic age throughout a 6-m-thick interval. Higher (at 309.7 and 311.0–311.6 m), the sand fraction is accompanied by pebbles made up of Dachstein Limestone, Hauptdolomit as well as lydite and marl. The upper boundary of the formation is marked by a glaukonitic unconformity surface. Upsection it is followed by a limestone sequence of 25 m thickness (~250.0–275.4 m) The lower part of which is also glauconitic (cPlates XI: 4, p. 198; XII: 2, p. 199). This is characterized by equal proportions of fragments of echinoids and rudists whose quantities are, however, of low or medium frequency. These circumstances give grounds for assigning this sequence to the Tata–Környe Formation. Of the Környe Limestone, in the area under discussion only the Kecskéd Member has been preserved. At certain levels there are breccia intercalations that veneer irregular hargrounds. Although two of the breccia horizons are of unclear origin, that at 259.0 m is, no doubt, intraformational. The macroscopically observed fossils here are as follows: orbitolines, a couple of small-sized rudists (right at 246.6 m), and rarely, other pelecypods and brachiopods. In the uppermost 15 m there are tiny colonies of hydrozoans, corals and algae (cPlate XII: 3, p. 199).The Borehole Oroszlány–1822 falls within the transitional zone of the Környe and Vértessomló Formations. There is a 7-m-thick transitional portion where the Tata Formation grades up into the Környe Formation.Contrary to the thick, typical Kecskéd Member, the Kocs Member of the Környe Limestone has been developed here, with a thickness of 5.3 m. The rudists in it occur along with hydrozoan colonies. As is normal in the transition zone, the Kocs Member is overlain by a 26.7-m-thick sequence of the Vértessomló Siltstone. This is a bit more sandy and calcareous than usual. The Vértessomló–Környe Formation, remarkable for its thickness, is made up of an alternation of fossiliferous limestone (bPlate XII: 1–4, p. 115) grainstone and packstone fabrics, with silty, fossiliferous marl beds which are more calcareous and often sandy. The introduction of true paludial conditions are reflected in the occurrence of the Tés–Vértessomló Formation of which reaches a thickness of 26 m.

In contrast to the previous borehole, but similar to the Borehole Pusztavám–980 only the Kocs Member of the Környe Limestone represents in the Borehole Pusztavám–820 with a thickness of 7.5 m. The fine-grained Tata Limestone is overlain by rudistid limestone and then by a limestone containing lots of *Sabaudia* and, occasionally, orbitolines (cPlate XI: 5, p. 198). The formation is capped by a limestone characterized by large miliolinids. The sedimentation of the Tés Clay, as proof of the rapid decrease in salinity, commences with the formation of *Munieria* limestones.

Borehole Pusztavám Pvt–4 is worth mentioning because of its several problems. There were a few thin-sections and cores to turn up and these support the idea of the following fragmented sequence: between 48.2 and 52.4 m there is the rudist fragment-bearing, orbitoline-rich Környe Limestone which has a grainstone texture. Some samples derived from its lower part however, display transitional characteristics in connection with Tata Limestone. Between 82.8 and 86.0 m glauconite-rich Pénzeskút Marl occurs. The interval between 52.4 and 82.6 m has still not been revealed. This phenomenon might be explained either by brittle tectonics (overthrust or horizontal displacement) or an erroneous sampling technique.

The abandoned quarry south of the wood-yard at Pusztavám

In the upper quarter of the southwestern wall of the quarry, which has been abandoned for a couple of decades, a Cretaceous succession is exposed which is in tectonic contact with the Dachstein Limestone (Figure 52; cPlate X: 1–2, p. 197). The fault plane dips steeply to the south-west. There is a 2-m-thick bundle of *Toucasia* beds which can be split into three individual beds. Both their overlying and underlying beds are made up of variegated clay and, thus, can be assigned to the Tés Clay Formation. The lower part of the Tés Clay contains irregularly-shaped limestone nodules, 3 to 15 cm in diameter. Although covered by scree, the variegated clay continues upsection. The lower rudistid limestone is rich in well-preserved shells of *Toucasia* (cPlate X: 3, p. 197) and occasionally small-sized chondrodonts. They are hosted by a red to yellowish-grey limestone which is aphaneritic or, rarely, of disseminated bioclasts. Basically, the upper limestone bank is similar to the lower one. However, the quantity of rudist shells is much lower which, moreover, tends to keep decreasing upsection. The two banks are separated by a nodular bed with red clay in its base divides. In a brackish water marl bed of a nearby outcrop of the Tés Clay, stratigraphically above the bundle of the Környe Limestone root structures are found. They indicate a brackish water marsh environment with forest-type vegetation which is situated close to the sea. Similar structure can be seen in a core of the Borehole Oroszlány–1317 (cPlate X: 4, p. 197).

Based on its *Chondrodonta* and predominant *Toucasia* content, this sequence is to be assigned to the Környe Limestone, even if both its subjacent and superjacent rocks are untypical.

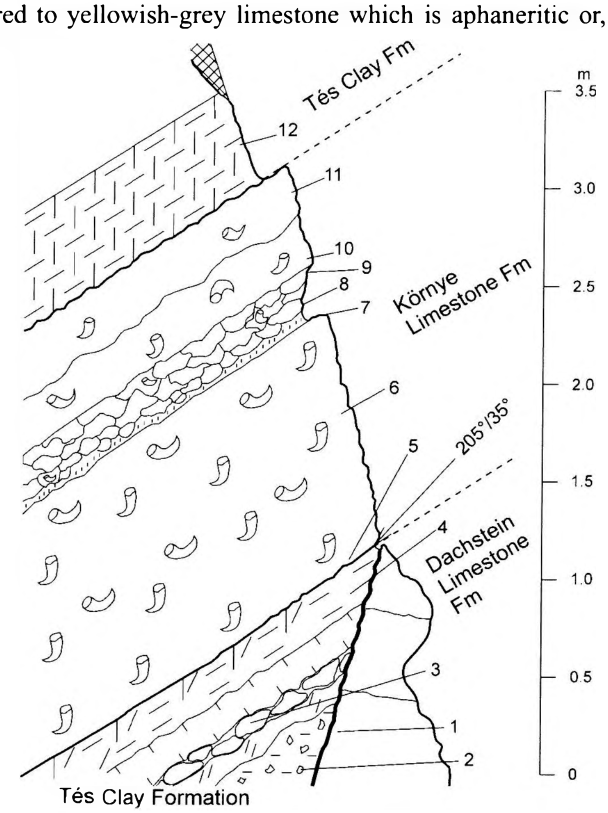


Figure 52. Környe Limestone Formation intercalated within the Tés Clay Formation in a quarry south of the Pusztavám wood-yard, Vértes Mountains

The data from the Környe and Vértessomló Formations are tabulated (Tables 12, 13). The two upper samples of Borehole Vértessomló–8 are derived from above the basin floor fan sediments, whereas the lower sample is obtained from right below the fan. The surface samples from Pusztavám, the upper two samples of the Borehole Oroszlány–2547 and each sample of the Borehole Oroszlány–1828 were taken from the underlying rocks of the Toucasia-bearing biostrome, the Tés–Környe Formation and the Tés Clay, respectively. The rest originate from the Környe Formation.

Most typically, in the Vértessomló Formation there are equal proportions of montmorillonite and other clay minerals. Kaolinite is completely absent. Subordinate amounts of quartz and feldspar and, in the lowermost sample, siderite and interestingly, dolomite are present. The samples of the Tés Clay and Környe Limestone derived from the boreholes at Bokod and Oroszlány, respectively, reveal comparable clay mineralogy compositions: the predominant phase is illite

Table 12

X-ray diffraction analysis of the Környe Limestone Formation and its stratigraphically connected formations (analysed by L. Bognár, and in case of Pusztavám quarry by P. Kovács-Pálffy)

Sites	m	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Borehole Vst–8	132.5	10		8		7	23	3	47					2	
	133.2	12		4		10	20	2	51					1	
	169.0	10	8	10		5	22		37	2	5			1	
Pusztavám quarry, base		8		4	6		60		13			5*			4
Borehole O–2547	911.0	4	6	23	8	11	28	4	14					1	
	938.0		5	11	2	3	54	4	10			11			
	943.0	2	5	12	3	3	21		52					1	
	1027.0	7	7	11	7	4	46		14			4			
	1041.5	8	6	13	7	3	34		22			7			
Borehole O–1828	272.0	2	4	16	9	3	56	4					6		
	272.5	4	5	18	9	1	49	5					9		
	278.0		6	21	8	2	51	3					9		
	281.0		3	10	10		71						6		

1 — Montmorillonite; 2 — Illite-montmorillonite; 3 — Illite; 4 — Kaolinite; 5 — Chlorite; 6 — Quartz; 7 — Plagioclase; 8 — Calcite; 9 — Dolomite; 10 — Siderite; 11 — Goethite (alumogoethit when marked by *); 12 — Hematite; 13 — Pyrite; 14 — Amorphous material.

which is accompanied by kaolinite. Montmorillonite and illite/montmorrilonite may occasionally occur with it. The quartz content is consistently high. In the carbonate-free, variegated beds of the Borehole O–1828, the discolouring agent is hematite (9%) whereas it is mainly goethite in the case of the somewhat calcareous samples from Oroszlány. The surface sample from Pusztavám quarry is in every respect of a transitional character between the Vértessomló and Bokod–Oroszlány sets of samples.

Heavy mineral studies of the Tés Clay, the Környe Limestone and Tés–Környe Formation of the Borehole Oroszlány–2547 were carried out by Vaskó-Dávid (1991a, 1991b). The results are as follows (data in percentages): basic to ultrabasic magmatic group 29.02 (3.30 thereof volcanogenous), acidic magmatic 4.12, epimetamorphic 2.88, the rest (of mixed origin) 63.99. The float fraction contains a 48.89% microcrystalline lithic fragment which is considered to be of volcanic origin. Below the 904 m level of the borehole, namely, in the Tés–Környe Formation and Környe Formation, the proportion of the float fraction increases as high as the mean proportion, exceeding 81%. It is strange that the heavy mineral composition of the lowermost (1041.5 m) sample is 100 grains of ilmenite as well as 56 of garnet, 2 of zircon and 1 of tourmaline.

Just below this interval "heavy minerals suggesting a coeval, basic calc-alkaline volcanism" also occur. In the Tatabánya Basin the pelitic fraction of the Vértessomló Siltstone nearly contemporaneous with the Környe Limestone. It is dominated by swelling clay minerals (Ca-montmorillonite and with a structure of mixed clay minerals) and subordinately, there are chlorite and vermiculite as well

Table 13

Mineral composition of the Vértessomló Siltstone in Borehole Vst–8 based on thermal analysis (by M. Földvári)

m	Montm.	Illite	Chlorite	Calcite	Siderite	Pyrite
132.5	13	5	5	47		1
133.2	12	4	12	50		1
169.0	11	11	5	42*	2	1

Sample marked by * contains also dolomite.

(FÖLDVÁRI *et al.* 1973). Based on these features and on glass characteristics a neutral to acidic volcanism is suggested, whereas enhanced concentrations of Co, Cr, Ni, and V would rather be consistent with the idea of basic volcanic activity (FÖLDVÁRI *et al.* 1973).

Geographical extent of the Környe Limestone

In spite of its complicated facies relationships in all directions, the area of extent of the Környe Limestone can (comparatively) be estabilished (Figure 53). To the west of Bokod, the western boundary of the formation is given by a pinching-out line partially of denudational origin. To the north of Bokod, the recent extent is bounded by NW–SE and NE–SW-trending Neogene faults. The original boundaries of extent are marked by its interfingering with the Vértessomló Siltstone in the east and its wedging below, in or at the base of the Tés Clay in the south-west. In the Borehole Pusztavám–980 the thickness of the Környe Limestone is 23 m. In terms of the facies, this interval is far from being typical since it also comprises the facies which are in, and exhibits many of the features of the Tés Clay. This statement is much more valid for the Borehole Pusztavám–820 since the rudistid limestone therein is merely 2 m in thickness. The Környe Formation, exclusively represented here by its Kocs Member, which is only 7.5 m thick. Even the Borehole Mór–15 yielded not more than one sample containing rudists (at 235.0 m). However, the overlying sequence of 30 m thickness, partly micritic, partly bioclastic in fabric is, even in spite of its untypical facies, most reasonably to be attached to the Környe Limestone. Based on both the above and the similar facies at the wood-yard near Pusztavám it is very likely that this peculiar carbonate platform environment might not have gone far beyond the area in which the boreholes under discussion were drilled. This can be explained by the fact that a sincere marine, rudistid environment was also developed in this area due to a short-lived relative sea level rise. Marine limestones here signal a moderate terrigenous sediment input, in contrast to their surroundings. A rapid recursion of the similar sedimentary milieu is reflected 12 m higher by the occurrence of rudists in a sandy bed of 20 cm thickness. The transitional facies is also demonstrated in several boreholes cPlate XI: 1–3, p. 198.

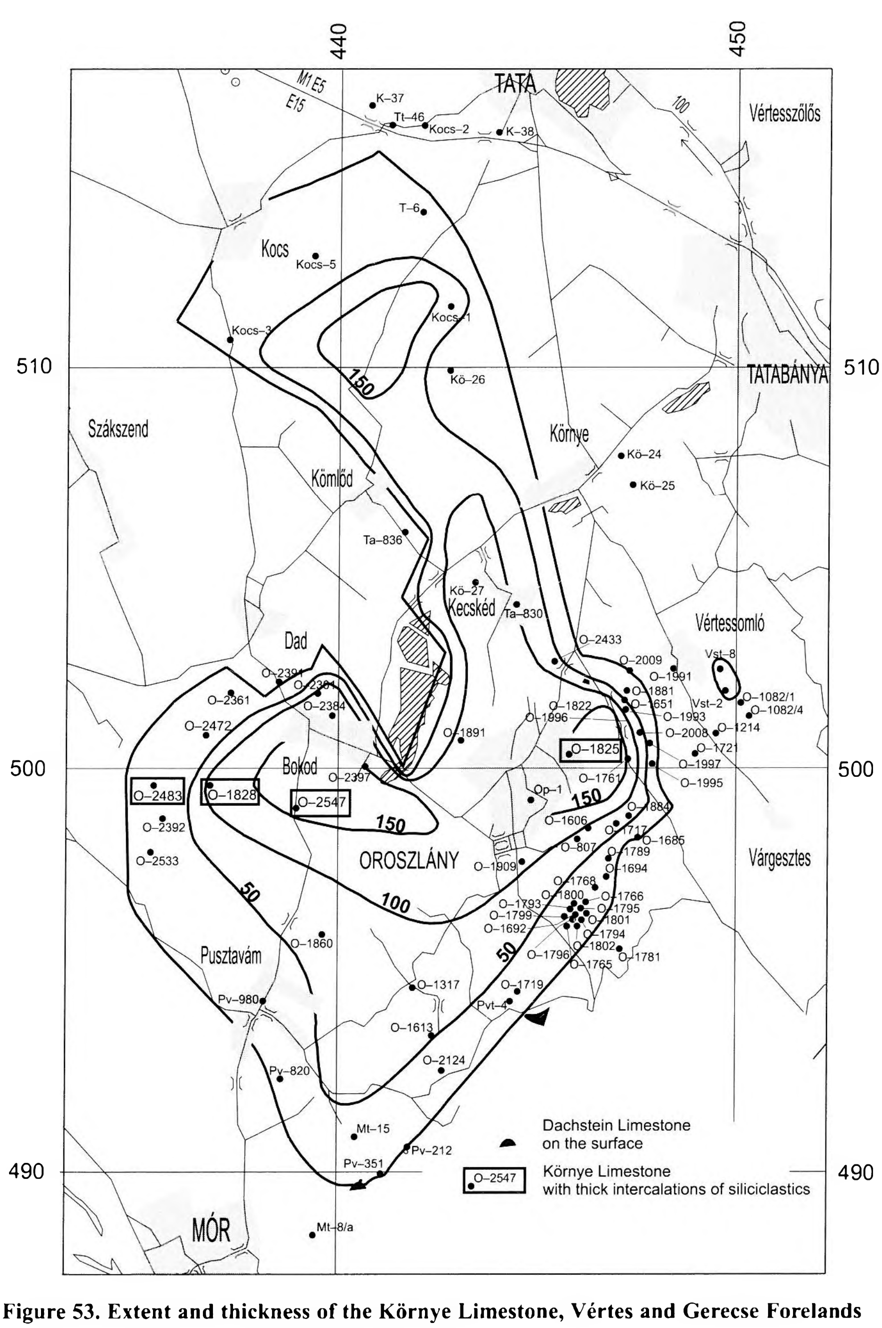


Figure 53. Extent and thickness of the Környe Limestone, Vértes and Gerecse Forelands

The south-eastward extent of the Környe Formation is clearly indicated by a NE–SW-trending fault line and in part by its zone of interfingering with the Tata Limestone. Although it is simply a line near Oroszlány which draws its eastern boundary, actually there is a well-established gradual decrease in its carbonate content as well as in the size and frequency of bioclasts. The thick sequence of the

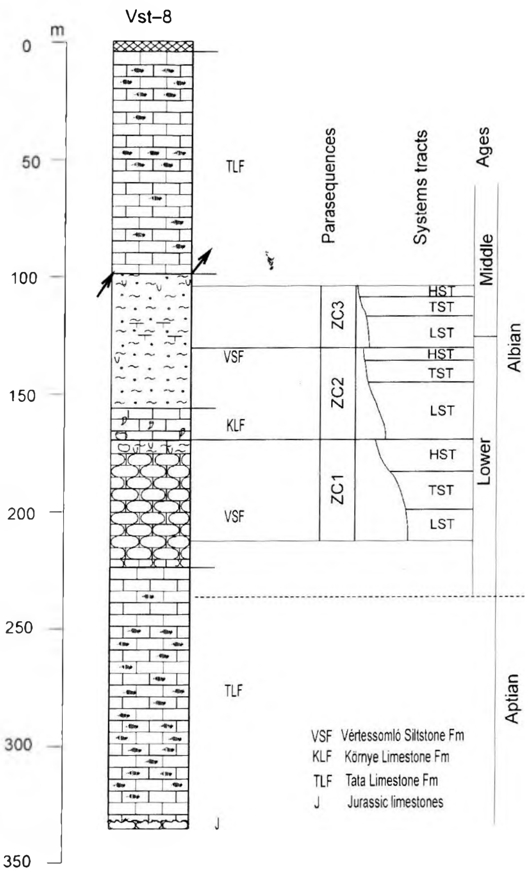


Figure 54. Columnar section and sequence stratigraphic interpretation of the Borehole Vértessomló Vst–8 based on dinocyst studies made by H. Leereveld (1992)

Borehole Oroszlány–1822 document perfectly the transitional character of the facies. That is to say, the Kocs Member of minimal thickness is overlain by the Vértessomló Siltstone and, in turn, by an alternating sequence of different bundles of the Vértessomló–Környe Formation. The key aspect of this interval is that the features of the limestone are typical of the Kecskéd Member, rather than the Kocs Member. The sandy to silty, rarely pelitic, limestones of the Borehole Oroszlány–1881 display transitional features macroscopically; the composition of the bioclast content, so typical of the Környe Limestone, cannot be recognized. However, the carbonate content is much higher than the average values for the Vértessomló Formation. In the Borehole Vértessomló Vst–2 the Vértessomló–Környe Formation occurs with a thickness of at least 3.6 m, what is more, it also contains rudists. In addition, the Kecskéd Limestone Member appearing as a basin-floor fan (or shelf margin wedge) in the Vértessomló Basin, is traversed by the Borehole Vst–8 (Figure 54). It may also appear elsewhere within the Vértessomló Siltstone (cPlate XI: 2, p. 198). In other words, the transitional zone here may reach a few kilometres. It is worth assuming a comparable transitional zone north of this area, in spite of the infrequent data.

Age of the Környe Limestone

There are direct and indirect approaches for determining the age of the formation. Since its first description and classification, its Albian age of the formation has never been a matter of debate. Based on the formation itself, opinion is somewhat divided on the exact intra-Albian position of the Környe Limestone. The indirect approach involving the fossils derived from the formation itself, was first employed by Czabalay (1983a, 1989, 1995). As appropriate, her investigations could only apply to the Kocs Member. On the basis of rudists and gastropods (species of *Nerinella* and *Nerinea*) a late Early Albian to early Middle Albian age was suggested. Bodrogi (1992) allocated the Tata Limestone in the uppermost Aptian (*Ticinella bejauensis* Zone), the Vértessomló Siltstone in the Lower Albian (*Ticinella primula* Zone), the Környe Limestone in the Lower Albian, and the Tés Clay and the Tés–Környe Formation in the Middle Albian. In the Környe Limestone (Boreholes Kocs–5; Környe–26, –27), Nagy (1987a), besides *Cadosina* sp., described *Colomiella recta* Bonet, *C. aff. tunesiana* Bonet, *?C. mexicana* Bonet and *?C. semiloricata* Trejo. Accordingly, possibly an Early Albian, but more probably a Middle Albian age of formation is proposed. On the basis of colomiellids and cadosinids which also occur in the Tata Limestone, the Aptian/Albian boundary was drawn by Nagy within the Tata Limestone. In the case of Borehole O–1825 the boundary was estabilished to be at 575.0 m (Nagy 1987c), about 10 m below the contact of the Tata and Környe Limestones (Table 14).

Based on the above forms and, in addition to them, the *Calpionellopsella maldonadoi* Trejo found in the Borehole Pusztavám–980, the Tata Limestone was placed, up to the 735 m level, unequivocally by Nagy (1987b) in the Lower Albian substage. However, owing to the lack of key fossils, the underlying section of this formation could only be doubtfully placed in the Upper Aptian.

Ostracod studies by Monostori (1990) on the Környe Limestone Formation and the marine beds of the Tés Clay indicate an Early Albian age, as indicated by the occurrence of *Cythereis bartensteini* Oertli and *Centrocythere denticulata* Mertens.

Table 14

***Cadosina* and *Colomiella* species in the Cretaceous part of the Borehole Oroszlány–1825 (after NAGY 1987c)**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
566.0																	+							
566.3–566.4				+	+																			
566.4–566.6		+																						
567.5–567.6																			+					
568.0	+																						+	
569.8																			+					
570.0						+	+								+			+	+					
571.0	+																							
573.0																		+	+					
574.0									+						+			+	+		+			
575.0																		+					+	
576.0								+			+								+					
578.0													+											
579.0																								a
580.0																								b
581.0									+							+								c
582.0																						+		d
583.0																				+				
586.0										+	+													
587.0	+														+									
590.0	+													+										
592.0	+		+																					
593.0	+										+													
594.0																								e
595.0															+									
596.0	+									+	+	+												b
597.0	+										+								+					a.b

1 — Circular section of Calpionellidea; 2 — *Colomiella semiloricata* TREJO; 3 — *?Colomiella mexicana* BONET; 4 — *Colomiella aff. tunesiana* COLOM. *et* SIGAL.; 5 — *Colomiella recta* BONET; 6 — *Cadosina* sp. *1.*; 7 — *Cadosina* sp. *2.*; 8 — *Cadosina* sp. *3.*; 9 — *Cadosina* sp. *4.*; 10 — *Cadosina fusca nov. var. crassa* NAGY; 11 — *Cadosina fusca nov. var. ovalis* NAGY; 12 — *Cadosina aff. oraviensis* BORZA; 13 — *Cadosina aff. carpathica* (BORZA); 14 — *Cadosina aff. vogleri* BORZA; 15 — *Cadosina aff. fusca* WANNER; 16 — *Cadosina aff. spinosa* BORZA; 17 — *Cadosina heliosphaera* VOGLER; 18 — *Cadosina lapidosa* VOGLER; 19 — *Cadosina semiradiata olzae* NOWAK; 20 — *? Stomiosphaera*; 21 — *Stomiosphaera aff. wanneri* BORZA; 22 — *Gemeridella minuta* BORZA *et* MIŠÍK; 23 — ?Reptile bone; 24 — Reworked fragments: a — Middle Jurassic; b — Upper Jurassic–Berriasian; c — Kimmeridgian–Tithonian; d — Tithonian; e — Berriasian.

GÖRÖG (1995), by means of foraminifer investigations, has demonstrated that samples collected from the lower part of the Környe Limestone (or even, from the Tata Limestone itself) reflect an Early to Middle Albian age, whereas those from the upper part of the section are indicative of Middle to Late Albian.

Regarding information on indirect age, palynological data are the first that should be mentioned. The Vértessomló Siltstone, a heteropic facies of the Környe Limestone, was determined to have been formed in the Early Albian given that primitive pollen grains of angiosperms are not present (JUHÁSZ 1983). JUHÁSZ (1978) was a pioneer in recognizing that there are present-day outcrops of the Vértessomló Siltstone in the western part of the Gerecse Mountains (Figure 55).

According to the detailed dinocyst analysis of the Borehole Vértessomló Vst–8 by LEEREVELD (1992a, 1992b), the formation of the Vértessomló Siltstone and the uppermost part of the Tata Limestone took place in the Early to Middle Albian (?). Based on his own nannoplankton studies, FOGARASI (in CSÁSZÁR *et al.* 1995) confirmed the statement of NAGY (1987a, 1987b) — namely, that the Aptian/Albian boundary is within the lower portion of the Tata Limestone. On the other hand, he has not exluded the assumption that the Tata Formation as a whole takes place in the Albian stage.

GÖRÖG (1995) has discovered that among the common orbitolines there are two species which occur in both formations: *Orbitolina (M.) texana* (ROEMER) and *O. (M.) subconcava* LEYMERIE. This fairly supports the idea that the uppermost part of the Vértessomló Siltstone and the upper half of the Környe Limestone would be contemporaneous, that is to say, Early to Middle Albian. In contrast, from the Tés Clay she reported an assemblage consisting of three species, namely, *Orbitolina (M.) subconcava* LEYMERIE, *O. (O.) sefini* LEYMERIE and *O. (Conicorbitolina) baconica* MÉHES, which indicate a Late Albian age.

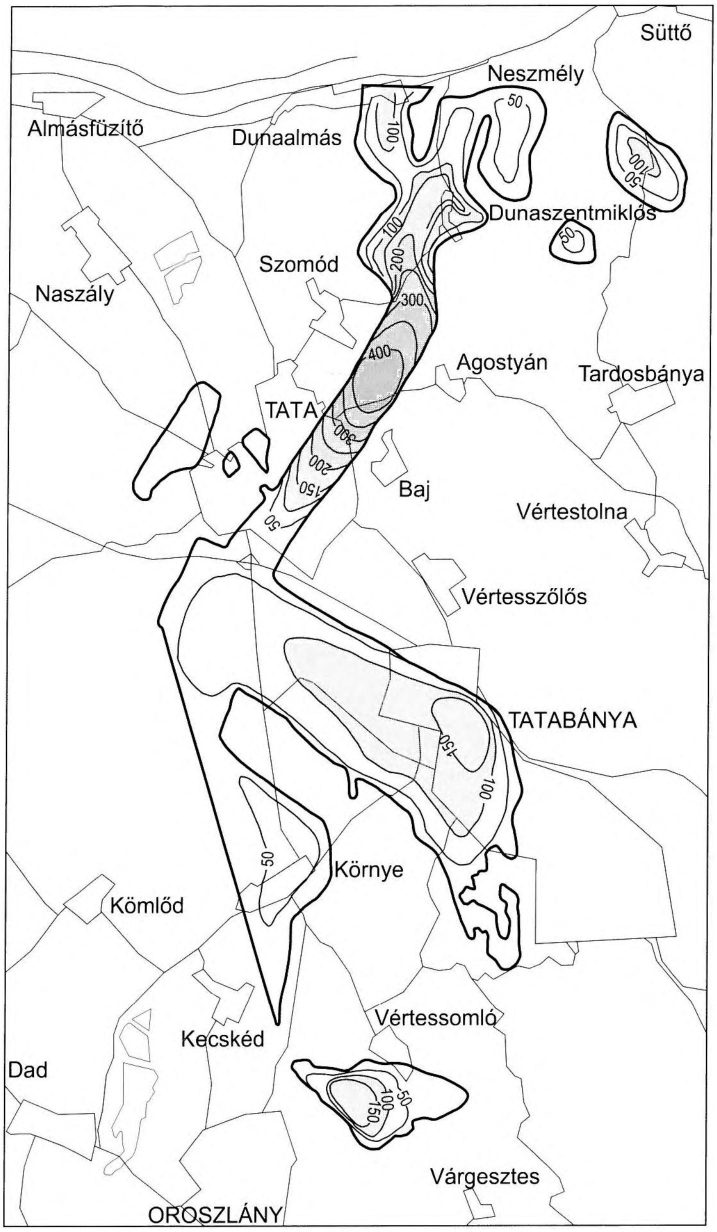


Figure 55. Recent extent and thickness distribution of the Vértessomló Siltstone Formation

To summarize the results of all these investigations, the Környe Limestone was, in my view, most probably formed at the turn of the Early and Middle Albian. My conclusion is to some extent corroborated by the biostratigraphic work of SZIVES (1999b) focusing on the Creta-ceous section of Kálvária Hill at Tata. She managed to show that, in the condensed material filling the casts ("pockets") at the base of the Tata Limestone, besides ammonites indicative of the biozones of the Upper Aptian, those of the lowermost Albian zone also occur. Therefore, it is suggested that, following a longstanding submarine hiatus, the formation of the Tata Limestone might have first commenced in the Early Albian.

DEPOSITIONAL ENVIRONMENT OF THE KÖRNYE LIMESTONE

Each member of the Környe Limestone manifests different sedimentary environments. Rocks in the lower member were deposited in a hemipelagic environment (at least, in a relatively shallow basin). This is reflected in the microfaunal assemblage which consists of planktonic foraminifers (in some places very abundant and occasionally of smaller size), various cadosinids and colomiellids (NAGY 1987a, 1987b, 1987c) and, off and on, sponge spicules and brachiopods. Near the base of the formation as well as on the basinward side (where it interfingers with the Vértessomló Siltstone), glauconite, fragmented *Lithophyllum* and other red algae become abundant. Within the Kecskéd Member itself, echinoderm ossicles tend to decrease upsection and the crinoids disappear relatively early. On the contrary, reworked, winnowed edge sand sand-derived fossils, or minute fragments thereof, make more and more common constituents. Shells of rudists, characteristic fossils of the formation, appear as small fragmentaraine and are remarkably abundant.

The textural pattern of the limestone is dominated by grainstones and packstones. Thus it is mainly sparitic cement which is to be encountered and this shows relatively high energy in the depositional environment. This resulted in the transportation of lime mud into the basin. From the distribution of bioproduction of the carbonate platform — from a source area point of view — the dip and the shore of the slope is very important. Here it probably had an areal variability. In the Borehole Környe–27, the lower member of the formation occasionally contains slightly moved rudist shells and colonies of corals and hydrozoans which indicate a ramp-type sedimentation. However, boreholes drilled at the eastern periphery of Oroszlány indicate that the lower part of the section, *i.e.* the transitional zone of the Tata Limestone into Környe Limestone, is rich in planktonic foraminifers, fragments of red algae, and, glauconite. This implies a more pelagic facies and sedimentation in a basin-like hemipelagic environment. The lower member in *sensu stricto* typically contains red algae and, in upward-decreasing amounts, glauconite. In some of the boreholes the toe of slope sediments occur in the form of corals and chaetetopses bored by clams (bPlate XI: 2, 3, p. 114). This points to a slope-top facies on a rather steep slope.

Representing a special facies and, at the same time, signifying likewise a steep slope, the Borehole Vértessomló Vst–8 (Figure 54) reveals that in the basin, 2 km away from the platform margin, there is a 13.5-m-thick allodapic limestone bed of platform-derived biodetritic material. From the lithostratigraphic point of view, this bed is situated in the lower part of the Vértessomló Siltstone, near the Tata Limestone. It is overlain by an ammonite-rich, heavily glauconitic silty marl, and thus the whole rock mass can be interpreted as a basin-floor fan. The results of Szives (1999b) however, draw our attention to another possibility which should not be overlooked. Accordingly, it is very likely that coeval sedimentation took place on a rudistid and coralline carbonate platform as well as on crinoid meadows situated between the carbonate platform and the basin as transitional step.

In a 3-to-6-m-thick interval the Kecskéd Member passes gradually into the Kocs Member. At least this is the case in the boreholes near Környe as reflected by the decrease in the grain size and the frequency of clastic grains as well as the replacement of sparitic cement by micritic matrix. These phenomena provide evidence for a change in sedimentation — *i.e.* deposition on the ramp was replaced by a lagoonal facies and other subfacies on a moderately uneven platform, where rudistid (cPlate XII: 1, p. 199), *Chondrodonta* beds and, depending on sea level fluctuations and salinity, gastropodal beds are alternating. Minor colonies of corals and chaetetopses may also appear. Interestingly, the progradational tract, (the lower member) is devoid of or deficient in extrabasinal siliciclastics, whereas in the aggradational tract this feature is quite common, appearing mainly in the form of silts. A seaward continuation of a deltaic input may be discerned in the vicinity of Oroszlány and Bokod (Figure 53) where sandstone intercalations containing full-marine fauna are found within a typical Urgon sequence represented by the Kocs Member (Boreholes O–2483: 370.2–371.8 m; and O–1825: 445.5–450.0 m). In most cases, sandstone banks are found in the Tés–Környe Formation (Boreholes O–2547: 917.4–918.2 m; 921.5–921.9 m and 955.7–956.9 m, O–1825: 425.5–426.4 m), and, of course, mainly in the Tés Clay. In this respect, Borehole O–1828 is very special because there is a rock mass of Környe Limestone (348.7–363.9 m) in which it is sandwiched by two rock masses of the Tés–Környe Formation. It should be added that between 332.2 and 366.6 m there are 11 horizons of sandstone intercalation, of which the most voluminous is 2.6 m in thickness. The effect of a freshwater influence due to a fluvial inlet appears to be comparable in the respective cases of Boreholes O–1828 and O–2547, even if it is less obvious in the case of the latter one, as it is situated more basinward. However, we do not have enough knowledge to reliably interpret the 308.0–308.8 m interval of Borehole O–2011, where the sandstone appears as early as in the Kecskéd Member. In accordance with the idea of a poorly-developed delta system, sandstone bodies of a few tens of cm thickness are overall present already in the Kocs Member. Thus, for instance, they can be found in the southernmost-situated Borehole O–2124 (20 cm), and in the Borehole Ta–835 (100 cm) close to the northern margin. On the other hand, it is strange that there is no mention of sandstone in the Borehole Kocs–1, located just next to the latter one, although it traverses the entire formation.

In more southerly areas (*e.g.* Pusztavám), omitting the Kecskéd Member, the Kocs Member directly overlies the Tata Limestone (Borehole Pv–980) or is developed within the Tés Clay (Borehole Pv–820 and surface outcrops — wood-yard, south of Pusztavám). The implications on sea level changes will be examined later.

It is apparent that the boreholes which contain sandstone banks are aligned in an E–W-stretching zone. This strike would correspond to the flow directions of the marine continuation of the river providing the basin with clastics. It is rather odd that, this direction is, in spite of the paucity of data, very coincident with the anomalously thick facies zone of the Környe Limestone (Figure 53). The total thickness of the Környe Limestone there may even reach 150 m. This can be explained by the fact that this strip was characterized by higher subsidence rates at the times of formation of the Környe Limestone. North of this zone, sandstone banks of considerable thicknesses and of coarse grain size are not found. Therefore, the latter area is most probably interpreted as being somewhat emerged relative to its environs; thus the thicknesses of the Környe Limestone are not so significant here. It seems to be reasonable to assume that this rise would have been the origin of the thickening mass of the Kecskéd Member situated both to the north and to the south of the rise. Curiously, this rise appears to coincide with the recent block which apparently lacks Cretaceous rocks.

As a result of careful analysis facilitated by a number of boreholes, it is possible to draw more reliable contacts between the Környe Limestone and Vértessomló Siltstone, as well as between the Tés

Clay and the Vértessomló Siltstone. At the southern part of the Vértessomló Basin the boreholes did not traverse this crucial sequence. However, further to the north there are some boreholes which have intersected at least two of the Cretaceous formations. So, based on their stratigraphic records, a 1-km-wide transition zone has been estabilished between the Környe Limestone and Vértesssomló Siltstone in terms of the amounts of carbonate-, biogenic- and siliciclastic detritus. Such a transitional formation can be observed in the following boreholes: O–1761, O–1822, O–2008 and perhaps Kö–27. Thereupon, it is no longer surprising to recognize that at the same place the Környe Limestone is overlain by the Vértessomló Siltstone and this is of a remarkable thickness [10 m in Borehole O–1673; and 162 m (?) in the Borehole O–1881]. Consequently, another transitional zone, namely between the Tés Clay and the Vértessomló Siltstone, should also have existed. This assumption is supported by the occurrence of variegated beds in the Vértessomló Siltstone (Borehole Vst–6) and also by the fact that there are some boreholes at the western margin of the Vértessomló Basin (O–1822, for example) in which the typical Kocs Member of the Környe Limestone is missing. At the margin of the basin, it is difficult to distinguish between the marine portion of the Tés Clay and the Vértessomló Siltstone. For instance, in Borehole O–2011 it is only the Tés–Környe Formation which contains limestones with thin-shelled rudists. The increased terrigenous sediment input thus obstructed further production of the carbonate factory. However, this could initially have occured after the delta system — rather than operating in a narrow zone — had sprawled the large volume of its transported siliciclastics all over the one-time carbonate platform. This suggests an enhanced production of clastics, which can be traced back to a change, at least seasonally, to a more humid climate in the hinterland. Nevertheless, a good part of the Vértessomló Basin remained unaffected since no disturbance can be observed with respect to the lithological buildup of the Vértessomló Siltstone. The changes depicted above have modified the marginal facies only.

ZIRC LIMESTONE FORMATION

By definition (Császár 1986, 1996) "The Zirc Limestone is a set of variations of mostly pure limestones, deposited during the middle Cretaceous sedimentary cycle, situated between the Tés Clay Formation and Pénzeskút Marl Formation, consisting of diverse biogenic constituents (rudists and other thick-shelled bivalves, *Nerinea*-type gastropods, Orbitolinas, *etc.*), or their detritus. They either can be vertically divided into some member rank units (Nothern Bakony and Vértes Foreland), or its main character is the rhythmic alternation of various fossiliferous rock types (Úrkút region)".

Position of the Zirc Limestone Formation in the sequence

Conventionally both the basal part of the formation and the uppermost bedding plane are chronohorizons where the formation appears and disappears abruptly between the above-mentioned formations in accordance with the definition. The real situation, as we can see later, is more complex. In the south-western part of the occurrence, near Padragkút, the formation overlaps the underlying Tés Clay Formation and interfingers with the erstwhile overwhelmed and just rarely preserved Alsópere Bauxite. This can frequently be found between the limestone layers of the Úrkút Member because the bauxite was washed into the marginal part of the basin (Császár 1981). The thickness of the formation in the Úrkút area is significant, although it has no continuous or semi-continuous overlying bed, hence the original stratigraphic connection can only be assumed. Towards the NE in the Northern Bakony and the Vértes Foreland the hiatus becomes larger and larger and then the whole part of the entire upper member is missing, and in the Vértes Foreland even the middle member is truncated.

Research precedent and the geological setting

This is one of the oldest known formations to have been denoted this way and the earliest to be described. Among the names suggested by Hauer (1862b) for the units, we have been using just one (Schichten von Zirc) for two decades for the whole formation. In 1986 I could distinguish three periods in the history of knowledge about it. These are as follows: the 1st is the recognition period of the formation (1861–1878), signed by Schwabenau (in: Hauer 1862a), Hauer (1861–1862a, 1861–1862b, 1862b), Stache (1861–1862, 1867), Böckh (1874, 1875–1878), Hantken (1878).

The 2nd is the period of modification of depositional time (redating), PRINZ (1904), STAFF (1906–1907), TAEGER (1911, 1912a,1912b, 1914, 1915) and LÓCZY JR (1913) deserve attention. The 3rd period is the time of the comprehensive cognition which is still going on. Many research workers have added fur-ther details to the previous knowledge: *e.g.* DOUVILLÉ (1933), NOSZKY (1934, 1953), TELEGDI ROTH (1935), TAEGER (1936), TELEKI (1936), VADÁSZ (1953), VADÁSZ, FÜLÖP (1959), SZÖRÉNYI (1961), CZABALAY (1962, 1965, 1985), MÉHES (1964), HORVÁTH (1966), KNAUER (1966), MÉSZÁROS (1968), GELLAI (1973), PEYBERNÈS (1977), PEYBERNÈS & CONRAD (1979), CSÁSZÁR (1981, 1985, 1986, 1995), CSÁSZÁR & HAAS (1989), KNAUER & GELLAI (1983, 1989), KNAUER *et al.* (1991), BODROGI (1993), GÖRÖG (1993, 1995, 1996).

I produced a monographic summary approximately fifteen years ago about the formation in the Bakony Mountains (CSÁSZÁR 1986). Therefore in the following I shall only refer to those discussed in that summary with respect to research history and geological setting. However, the sequence of the Vértes Foreland, will be dealt with in more detail because it was not considered in that summary. This is the case with the the Úrkút Member of the Zirc Limestone Formation as well. At the same time I attempt to present the environmental condition and evolution history for its entire depositional area.

The macrofaunistical description of the formation has been discussed by CZABALAY (1982, 1985). According to her, for the Northern Bakony the fore-reef derived *Agriopleura–Toucasia–Nerinea* community is typical; to this community the *Liostrea–Lopha–Chondrodonta* association is occasionally connected Coral (bPlate XXI: 1, p. 124) may occur very rarely. Five associations were distinguished by her in the Southern Bakony. *Nerinea* and *Nerinella* are the most important constituents in that region and either *Chondrodonta* and/or *Toucasia* are associated with them. Another group is characterised by the *Liostrea–Lopha* association. Among those associations both fore-reef and back-reef ones are regarded as typical. In the Pénzesgyőr environ fossils typical for the transitional zone between the Southern and the Northern Bakony were reported.

The Eperkéshegy Member, which occurrs also in the Vértes Foreland, does not contain orbitolines suitable for identification (GÖRÖG 1995). Its scarce microfossil assemblage is dominated by primitive algae — *e.g. Marinella lugeoni* PFENDER as well as the foraminifer taxa *Miliolidae, Textulariidae* and *Glomospira* (GÖRÖG 1995). In addition to these, *Dicyclina schlumbergeri* (MUN.-CHALM.) and *Cuneolina pavonia parva* HENSON can also be found. From the Eperkéshegy Member in the Bakony Mountains, GÖRÖG (1993) determined the following species: *Orbitolina (M.) aperta* ERMAN (bPlate XXII: 2, p. 125), *O. (Conicorbitolina) baconica* MÉHES and *O. (O.) sefini* LEYMERIE; *O. (O.) concava* (LAM.) is present in the Úrkút Member.

The Zirc Limestone displays a variety in both thicknesses and facies along the axis of the Transdanubian Range syncline (CSÁSZÁR 1986, 1995). In the Southern Bakony however, the sequence can neither lithologically nor faunistically subdivided. Its thickness exceeds 200 m, despite the lack of continuous stratigraphic cover. In the Northern Bakony, the Zirc Formation which is of a quasi-continuous stratigraphic cover as a whole, is not thicker than 50 m. Based on its facies characteristics, it was split into three members: the Eperkéshegy, the Mesterhajag and the Úrkút Members. Owing to the Albian emersion and associated subaerial erosion, the upper member as a whole and a substantial portion of the middle member are preserved neither in the Balinka area (KNAUER 1966) nor in the Vértes Foreland (CSÁSZÁR 1995). Karstic holes filled by glauconitic marl, as KNAUER (1966) observed, are found down to a depth of 10 m. In some places the facies which represent the Mesterhajag Member is capped by patch-reef followed by a short-lived subaerial erosion east of Pénzesgyőr (CSÁSZÁR 1986, 1995). The time span of the subaerial period, associated with karstification, was estimated by KNAUER *et al.* (1991) to be about 1 My at Pénzesgyőr, and less at Alsópere. The Gajavölgy Limestone, following the hiatus, is not an Urgon facies but a sandy open shelf limestone with a considerable amount of fragmented echinoderm ossicles, and glauconite at its base (CSÁSZÁR 1986, 1995).

There is only one succession apparently lacking in rudists: that of the Borehole Pénzesgyőr Pgy–5 (CSÁSZÁR 1986, 1995). An unusual accumulation of orbitolines was first reported by KNAUER & GELLAI (1983, 1989) from the base of the Zirc Limestone in the Borehole Csetény Cs–25.

The first attempt at a cycle-stratigraphic interpretation of the formation was performed by CSÁSZÁR (1986, 1995). According to this the lower two members of the Zirc Limestone are confined to a transgressive systems tract whereas the Gajavölgy Member is part of a highstand systems tract. Maximum flooding occurred just at the base of the Pénzeskút Marl, preceded by a transient subaerial exposure event around the end of the formation of the Zirc Limestone.

In reliably documented boreholes the total thickness of this formation was measured to be 23 to 25 m (Table 15). In many of these boreholes, one could clearly distinguish between the Eperkéshegy and Mesterhajag Members. The thickness of the latter varies between 2:4 and 7.5 m. Exceptionally, 10.9 m and 12.1 m thicknesses were measured for the Mesterhajag Member in Boreholes O–1317 and O–2200, respectively. The thickness of the Zirc Limestone in such boreholes with drillcore documentations of lesser value, with Pénzeskút Marl cover, proved to be between 23 m and 26 m; the exceptions were the Boreholes O–1889 and O–1613, which are 31.1 m and 36.0 m thick, respectively.

The subjacent rocks of the Zirc Limestone are made up of a few metres thick bioclastic, sandy limestone. Drawing the exact line between the two lithostratigraphic units is in some cases quite problematic. Should any of these beds contain rudist fragments, it is neccessarily regarded as pertaining to the Zirc Limestone. Very rarely, the Tés Clay may be capped by a glauconitic sand body, as is the case in borehole Mt–15. In two cases beds rich in orbitolines were found at the very base of the formation: in Boreholes Oroszlány–1317 (272.0–277.1 m) and O–2200/a (638.1–638.3 m). In a single borehole (O–2190) the lowermost 1-m-thick part consists of "conglobreccia".

Glauconitic fills in karstic holes were found in the following boreholes: Ba–246 (bPlate XVIII: 1, 2, p. 121), Ba–284, O–1825 (cPlate X: 6, p. 197; XV: 4–5, p. 202), O–1889, O–2348, O–2547 and Pv–820. From all these, in the case of O–2348 the filling could be traced as deep as 3.3 m.

Textural patterns in thin-section with respect to the two members show marked differences. That of the Eperkéshegy Member is more various: floatstone, wackestone and packstone fabric occur commonly. In both the lower and upper transitional bed(s) of the formation packstone fabrics may be accompanied by fine-grained grainstones. The most typical allochems are rudists, or fragments of these, throughout the entire section. A small quantity of foraminifers is common through out the column. However, *Orbitolina* and *Dicyclina* may also appear, particularly at the transitional zones. The only non-biogene constituents are pellets and these usually appear along with packstone and the somewhat rarely-occurring grainstone fabrics.

The Mesterhajag Member is usually of sparitic cement with various biogenic as well as non-biogenic constituents. Among the well-rounded and often coated grains rudists might be found but mainly in the lower, that is, transitional part between the Eperkéshegy and Mesterhajag Members. The foraminifers display a wide variety of taxa, however, with green- and red algae appearing only accidentally. The higher water agitation is indicated by the common pellets and the abundant intraclasts. Accordingly, biopelsparitic, intrabiopelsparitic and bioclastic intrapelsparitic grainstones are the most typical texture types.

THE SOUTHERN BAKONY FACIES: ÚRKÚT LIMESTONE MEMBER

In this chapter three small surface outcrops as well as two borehole sequences will be discussed; these were only synoptically introduced in an earlier monograph. In addition to this, some typical fossils coming from various other outcrops of the Southern Bakony facies area are also shown here (bPlates XIX: 1–2, 5, p. 122; XX: 1–2, 4, p. 123).

Sections at the Manganese slurry reservoir, Úrkút

There are two continuous sections at this locality, of which the eastern one (cFigure 11, p. 182) comprises a transitional zone between the Tés Clay (CSÁSZÁR 1978) and the Úrkút Member of the Zirc Limestone. The manganese-bearing Tés Clay and the transitional beds themselves, made up of calcareous marl and clayey limestone and being devoid of macrofauna or containing just a few gastropod shells, all indicate sedimentation in the fore-slope zone. A strong argument for this is yielded by a considerable quantity of spicules and by the dominance of arenaceous forms amongst the foraminifers. Furthermore, the upper portion of the section is dominated by two monogeneric beds — that is, one containing *Toucasia* and the other accommodating *Eoradiolites* (bPlates XV: 1, p. 118; XVI: 4, p. 119). The beds of the third type are abundant in gastropod shells, being rich in both species and specimens. Table 16, a taxonomic list, summarizes the forms in the section that were described by CZABALAY (1989 unpublished report). Apparently, in addition to the appearance of the genera *Nerinea* and *Nerinella*, the euryhaline genus *Cerithium* also occurs and what is more, in rock-forming masses (bPlate XVII: 4, p. 120).

Table 15

Lithostratigraphic subdivision of the Zirc Limestone Formation in the boreholes of the Vértes Foreland and the connected part of the Northern Bakony

Borehole	Roof	Mesterhajag Member	Eperkéshegy Member		Undivided Zirc Limestone
				with orbitolinids	
Balinka–28	Pénzeskút Fm				98.2–99.8
Balinka–33	Pénzeskút Fm				185.5–194.4
Balinka–42	Eocene				111.0–116.5
Balinka–47	"				79.8–85.0
Balinka–51	"		76.0–79.9		
Balinka–83	"	67.0–70.1			
Balinka–138	Pénzeskút Fm				126.7–131.5
Balinka–284	Pénzeskút Fm	614.2–617.8			
Balinka–288	Eocene		579.2–591.5		
Balinka–289	"		604.2–618.1		
Balinka–302	?	498.1–601.0			
Balinka–320	Pénzeskút Fm	faulted at the top	539.7–560.8		
Balinka–321	"	589.4–597.7	597.7–610.7		
Balinka–322	"	582.7–587.7	587.7–588.7		
Balinka–323	"	596.9–597.7			
Balinka–324	"	593.6–600.7			
Balinka–325	"	580.8–590.0	590.0–602.3		
Balinka–326	"	607.5–609.3			
Balinka–327	"	583.2–584.2			
Balinka–328	"	585.5–591.0			
Balinka–329	"	581.0–583.0			
Balinka–330	"	620.0–621.1			
Balinka–331	"	572.4–580.0	580.0–595.5		
Balinka–333	Eocene		624.0–635.0		
Balinka–334	Eocene				581.8–603.4
Balinka–335	Pénzeskút Fm	613.6–616.7			
Balinka–338	"	597.3–606.0	606.0–621.0		
Balinka–339	"	524.4–533.4	533.4–547.0		
Balinka–340	"	575.0–582.0	582.0–596.0		
Balinka–341	"	564.0–567.2			
Balinka–342	Eocene		632.5–636.6		
Balinka–347	" (faulted)		539.3–540.9		
Balinka–353	"		625.4–630.9		
Bakonycsernye–24	Pénzeskút Fm				626.2–646.6
Bakonycsernye–28	" (faulted)		627.2–629.2		
Bokod–1317	"	252.1–263.0	263.0–277.1	272.0–277.1	
Dudar D–98	Eocene				280.0–313.9
Dudar D–98b	"				91.0–104.8
Dudar D–179	Pénzeskút Fm				281.0–307.9
Dudar D–188	Pénzeskút Fm	faulted	369.2–369.5		
Dudar D–195	Eocene				289.3–295.7
Dudar D –235	"				274.8–277.0
Dudar D–245	Pénzeskút Fm	289.4–321.0?	321.0–327.6		
Dudar D–248	"	284.3–303.8	303.8–335.8		
Dudar D–263	"				236.3–236.9?
Dudar D–302	" (faulted?)		498.1–501.0		
Dudar D–303	"	640.8–642.5			
Dudar D–304	"				305.2–340.2
Dudar D–306	" (faulted)		434.0–446.5		
Mór Mt–6	?				7.2–24.2
Mór Mt–10	?	12.4–18.0	18.0–26.2		
Mór Mt–15	Pénzeskút Fm	65.7–71.5	71.5–86.1		
Oroszlány O–1613	"				206.0–242.0
Oroszlány O–1825	"	221.5–229.0?	229.0? –245.0		
Oroszlány O–1889	"				255.5–286.6
Oroszlány O–1909	"				181.8–205.0
Oroszlány O–1860	"				411.0–437.5
Oroszlány O–2179	" (faulted)				648.6–659.1
Oroszlány O–2190	"				654.2–679.0
O–2200/a	Eocene?	615.4–627.5?	627.5–638.6	638.1–638.3	
Oroszlány O–2210	"		577.3–583.6		
Oroszlány O–2338	"		389.6–391.8		

Table 15 (continuation)

Borehole	Roof	Mesterhajag Member	Eperkéshegy Member		Undivided Zirc Limestone
				with orbitolinids	
Oroszlány O–2348	Pénzeskút Fm	471.5–479.0	479.0–495.0?		
Oroszlány O–2396	Oligocene		433.1–450.9		
Oroszlány O–2521	Eocene?		251.8–258.3		
Oroszlány O–2524	Oligocene		231.5–242.5		
Oroszlány O–2525	"	233.9–243.9	243.9–250.0		
Oroszlány O–2547	?	673.0–679.1	679.1–697.2		
Oroszlány O–2550	Eocene	573.1–578.6			
Op–1					
Pusztavám Pv–3	Pénzeskút Fm				428.5–429.95
Pusztavám Pv–632	"				424.1–435.1
Pusztavám Pv–793	"				277.6–301.1
Pusztavám Pv–803	"	804.5? –816.0	816.0–831.0		
Pusztavám Pv–820	"	519.1–521.5	521.5–544.0 v.531.9?		
Pusztavám Pv–888	"				229.6-255.4
Pvt–2	"	91.0–100.1	100.1–116.5		

Remains of characeans and the lack of marine fossils suggest intercalations of two beds of freshwater origin, whereas the scanty occurrence of tiny foraminifers and the simultaneous lack of other marine organisms point to the development of two other beds, brackish-water in origin. The microfacies is almost exclusively restricted to pelletal biomicrites (mudstones and wackestones). Grainstone fabric was found in merely one particular part of a bed. It is highly possible therefore, that sedimentation took place basically in shallow, marine to brackish water nearly, tranquil lagoon, turned into freshwater environment at least two times. The alternations of the frequency of various fossil groups allude to some further decreases in salinity, that is, increased rates of fluvial inlet.

In general, the curve indicating changes in sea level (cFigure 11, p. 182) suggests moderate fluctuations; the reasons for this will be discussed later.

The section at the western side (cPlate XIII: 1, p. 200; XV: 1, p. 202; cFigure 12, p. 183) of the Manganese slurry reservoir (at an earlier stage this was an open pit), is the continuation of its eastern counterpart, with slight overlapping. The macrofauna content of its lower part (Table 16) resembles well that of the eastern section. As is reflected in the section (cFigure 12, p. 183) some of the beds contain monogeneric, or even, monospecific fossil assemblages concentrating up to rock-forming masses in many cases (bPlates XIII: 1–4, p. 116; XV: 3, p. 118; XVI: 4, p. 119; cPlate XIII: 3, p. 200; XIV: 1, p. 201; XV: 2, p. 202). Appearing as a new form in the section (cPlate XIV: 2, p. 201), the giant gastropod *Adiozoptyxis coquandiana* (D'ORBIGNY) is found in the upper part of the section, being the only taxon in a few of those beds (bPlate XVII: 3, p. 120).

A few storm-related breccia horizons intercalate in the section, cemented by red clay, and this suggests palaeosoil formation (bPlates XV: 4, p. 118; XVI: 2, p. 119). Two of these intercalations are qualified to be of brackish-water and one of them freshwater origin even, if in all cases scattered tiny foraminifers were encountered. Our hypothesis for the deposition in the intertidal shallow subtidal and supratidal zones is supported by the occurrence of root traces (bPlate XV: 2, p. 118; cPlate XIV: 3, p. 201), too, the most of which can be measured in cm (bPlates XVI: 1, p. 119; XVII: 1, 2, p. 120). To sum up, mostly based on the predominant biomicritic to biopelmicritic wackestone microfacies, these rocks are interpreted as having been formed in a gentle-agitated lagoon, which, apart from the storm sediments (bPlate: XV: 4, p. 118; cPlate XIII: 4, p. 200, XV: 3, p. 202) discussed above, display no signs of a more intense water agitation. In harmony with the narrow range of the sedimentary environment the respective portion of the sea level curve is also equalized.

Table 16

Bivalves and gastropods of the Úrkút Member of the Zirc Limestone in the quarries at Úrkút, Bakony

	1	2	3
Actaeonella baconica CZABALAY			+
Actaeonella sp.	+		
Cryptoptyxis sp.		+	+
Dimorphotectus sp.	+		
Metacerithium trimonile (MICH.)	+	+	
M. michaillensis (D'ORBIGNY)	+		
Nerinella sp.	+	+	+
Plesioplocus sp.	+		
Plesioptyxis cretacea (CONRAD)	+	+	
P. fleuriaui (D'ORBIGNY)	+	+	
P. prefleuriaui (D'ORBIGNY)			+
Plesioptyxis sp.			+
Pseudomelania urgonensis COSSM.	+	+	+
Chondrodonta sp.			+
Eoradiolites sp.	+	+	
Pseudotoucasia santanderensis (DOUVILLE)	+		
Toucasia carinata (MATHERON)	+		+

1 — Eastern part of the quarry of Manganese slurry reservoir; 2 — Western part of the quarry of Manganese slurry reservoir; 3 — Ouarry close to the road between Ajka and Úrkút

The quarry near the road between Ajka and Úrkút

The formations exposed in a string of quarries at the south-western flank of the valley were first examined by DOSZTÁLY (1985). The most exciting feature in that part of the string where the southern quarry (bPlate XVIII: 3, p. 121) lies, is represented by two *Chondrodonta* biostromes, with several generations in life positions progressively superimposed upon themselves (cFigure 13, p. 184, bPlate XVI: 3, 5–6, p. 119). The development of the lower biostrome was ended by a relative fall in sea level. During the exposure period the consolidation of lime-mud proceeded "immediately" so that the sea encroaching the hardground surfaces produced a uniform sea-floor morphology. This process inevitably resulted in pelecypod shells sticking out of the sea-floor being entirely cut off, some of the fragments of which exlusively make up the basal clastics of the next bed.

Another peculiarity of this section is that it fails to contain any rudist shells being perfectly well-preserved. The beds, lacking in chondrodonts, also contain a monotonous macrofauna, composed chiefly of the gastropod species *Actaeonella baconica* CZABALAY. The rock texture is dominated by biomicritic to biopelmicritic wackestone, occasionally mudstone, and albeit rarely, floatstone — similarly to the previous cases the sequence exposed in the quarry reflects formation in a tranquil, shallow lagoon. This, according to the occurrence of characeans this was succeeded by freshwater-lacustrine environments on three occasions. The decrease in salinity attained brackish water conditions three other times. An intertidal environment is evidenced by shrinkage pores that usually appear in brackish-water and freshwater beds. Based on these observations, in this 10-m-thick portion of the section the evidence of somewhat frequent sea level fluctuations are to be encountered.

Borehole Padrag Pa–7

Focusing mainly on bauxite generation, a description of this borehole is found in CSÁSZÁR (1981, 1986). The re-evaluation of some thin-sections has given rise to a recompilation of the lithologic column and its combination it with the appearance of the palaeoecologically most important fossils (Figure 56). By integrating these data with those collected in the field, I re-evaluated the ideas about the sedimentary environments and completed this figure with the sea level change curve.

Due to strike-slip faulting in the affected area, an Upper Cretaceous rock slice of about 10 m thickness occurs within the column thus dramatically spoiling the chances of evaluating the sequence. In spite of the fact that macrofauna, including rudists, is rather abundant, freshwater/lacustrine environments predominate even in the uppermost part of the column. There is a definitive tendency in the changing of several of the factors, as follows: rock colour, thicknesses and frequencies of the pelitic intercalations as well as the average bed thicknesses. That is to say, on the lower part of the column red and violet-red colours prevail; upsection these then progressively turn into lighter hues. In accordance with this, the terrestrial bauxitic clay intercalations (bPlate XX: 3, p. 123) tend to be less and less frequent, as does their average thickness. In accordance with the drying up of the freshwater environment the shrinkage pores, root traces or rhizolites, desiccation cracks and black pebbles are very frequent. However, the most striking evidence of freshwater conditions is yielded by the presence of fragments of characeans (fruits, stems and roots) as well as the alga *Munieria*. Intercalations of bauxitic red clays or marls are accompanied mostly by freshwater limestones. As a rare example, they may overlie, or just underlie marine lagoon sediments. This implies that the bulk of the sea level changes that occurred at this time could have been on a modest scale — that is, with a maximum amplitude of 1-2 m. Nevertheless, the 1:500 scale (Figure 56) is not suitable for providing a complete reflection of all the environmental changes that might have come about in an extremely sensitive zone of paludial, flat coastal environments. This may be the reason why red clays, as indicated in the figure, do not reflect that actually there is a brackish-water bed of a few cm thickness within this layer. According to the X-ray diffraction and thermal analyses of L. FARKAS and M. FÖLDVÁRI, respectively, almost every sample from red clay or marl horizons contains bauxite minerals, mainly boehmite, and subordinately, gibbsite (cFigure 14, p. 185; CSÁSZÁR 1981). The insoluble residue of the limestone tends to contain more or less boehmite, too. The mineralogic composition of the pelitic fraction is dominated by kaolinite, and, on some occasions, kaolinite-chlorite. The reddish colour of these sediments is caused either by goethite or by haematite.

Brackish water environments are found relatively rarely. I only classified a given bed in this way if freshwater forms were accompanied by a small number of fully marine taxa, where the foraminifers are usually smaller in size. The principal forms of the characteristic marine assemblages are the rudist pelecypods and gastropods (bPlate XIX: 3, 4, p. 122), various foraminifers (but barren of orbitolines), dasycladaceans, the encrusting taxon *Ethelia alba* PFENDER, and a few sponge spicules and fragments of echinoids. Examples of calcareous sand facies were encountered on only four occasions, and a mud

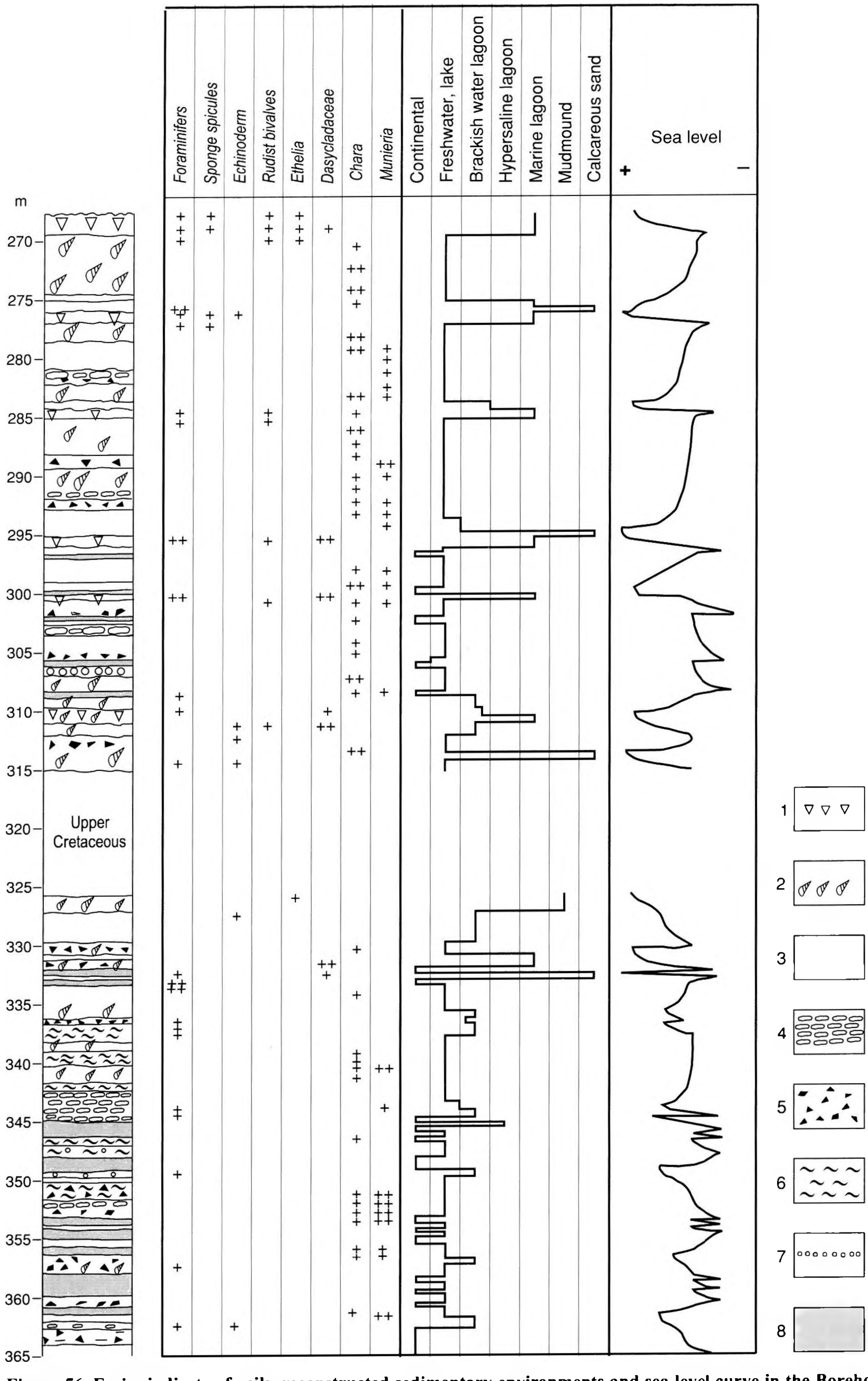


Figure 56. Facies indicator fossils, reconstructed sedimentary environments and sea level curve in the Borehole Padrag–7, Bakony Mts

1 — Rudistid limestone (*Toucasia, Eoradiolarites, Agriopleura*); 2 — Gastropod limestone; 3 — Micritic limestone (barren of macrofossils); 4 — Nodular, argillaceous limestone, limestone nodules; 5 — Limestone debris including a few "black pebbles"; 6 — Marl, clayey marl (reddish); 7 — Conglomerate; 8 — Bauxite, bauxitic clay

mound built up of *Solenopora* colonies on merely one occasion. The bed from which a sample consisiting of rhombohedrons of dolomite is derived, was classified as being a hypersaline environment.

According to this it is not surprising that in this section the typical texture of mudstone and wackestone is restricted. The other types (packstone, grainstone, floatstone, boundstone) all play a secondary role. Rudstone does not occur at all. The most typical allochems are bioclasts and pellets, but intraclasts are inconsiderable with only one occurrence. It is hard to explain the existence of the ooids in two beds. Their quantity almost reaches 23%.

The sea level curve can be split into 4 parts. The lowermost section of the column (from the base to 345 metres) reveals a permanent struggle of intermittent and continuous water cover of prevailingly freshwater. Between 345 and 308 metres the section demonstrates an alternation of fresh and marine water influences but with decreased intensity. The third (308 to 297m) part of the section is similar to the first one but characterized by less thick rhythm. The fourth part is situates above 297 metres and has similarites with of the second part, but the change of the sea level greatly exceeds those prior to it. Unfortunately the biostratigraphical subdivison of the sequence cannot allow us to assess the time intervals of the sea level changes, even for the previous united periods.

Borehole Úrkút Ú–421

The 200 m thick succession of Urgon facies rocks drilled in the Borehole Úrkút–421 is located just 2 km away from Borehole Pa–7. However, the rocks differ in many ways from each other: *e.g.* colour, thickness, volumetric proportion and mineralogic composition of the pelite fraction, fossil content, and as a consequence the sedimentary environments. The results of a studies such as: carbonate content, mineralogic composition and the percentage of textural constituents, relative frequency of various elements to be recognised in thin-sections, and the complete makrofossil content have already been published (Császár 1986). Hence, the focus is now on the interpretation of sedimentary environments as well as on further phenomena related to global sea level changes (cFigure 15, p. 186).

Similarly to that recognized in Borehole Pa–7, the limestones here are also micritic in texture. However, in certain parts of the sequence — that is, in the second quarter from the base — an apparent increase in the percentage of sparitic matrix was observed. Moreover, in four particular cases the sparitic matrix proved to be predominant. Ooids appear in many of the thin sections though, strangely, they never exceed 4%. The ratio of intraclasts nearly equals those of pellets and these occur along with ooids, indicating a relatively high water agitation.

The dominant part of the succession was formed in a marine lagoonal environment with a few benthic forams (bPlate XXII: 3, p. 125). Gastropods prevail both in species and specimens, at the expense of pelecypods. By contrast, orbitolines occur only scarcely. From these data it is obvious that the lagoon was very shallow, even if chondrodonts are sometimes concentrated such as to be rock-forming (cPlate XIII: 2, p. 200). This gives rise to an even more subtle subdivision of the sedimentary environment.

A brackish-water environment is recorded in the lowermost as well as the third quarter of the succession but, with the exception of one particular bed, such beds occur only as intercalations of moderate thicknesses between the fully (or nearly fully) marine strata. A couple of small beds ("bedlets") formed under freshwater conditions, occurring at the base, and, in the upper part of the formation represent an even shorter time interval. The identification of freshwater beds was based again on characeans and *Munieria* algae, although the number of specimens is less than in Borehole Padrag–7.

In contrast with Borehole Pa–7, Borehole Ú–421 displays very little sedimentological evidence of subaerial periods. Only six horizons could be discerned with confidence, four of which fall within the lower third of the section studied. Studies on clay mineralogy of the more pelitic beds in these and also other environments (Farkas in Császár 1986) have revealed that allitic species are entirely absent and the prevailing kaolinite is accompanied by varied but more subordinate amounts of montmorrillonite and illite/ montmorrillonite. It is worth repeating that in the Zirc Basin illite/montmorillonite is the predominant mineral.

A common field description of the succession does not make it possible to distinguish macroscopically between brackish-water and freshwater environments. Root traces, oncoids and shrinkage pores may well be quite common in both environments. To complicate matters, oncoids and shrinkage pores also occur in marine environments. Shrinkage pores, however, only indicate intertidal or very shallow subtidal circumstances. Desiccation cracks tend to be linked mainly to freshwater for-mations, but occur within those of brackish water if the emersion was definitely short-lived. Freshwater beds usually lack macrofauna, but some gastropods and pelecypods might be present. Brackish-water beds tend to share this feature but the gastropods, if any, are smaller in size and thefossils may occasionally be rather abundant. The erosional surfaces related to subaerial exposure are filmed with a few mm thick red clay, that often followed the unevenly eroded karstic surfaces with pits and holes of a couple of cm in size. Smaller karstic holes and bigger root traces cannot be distinguished at a smaller diameter in the cores — after all, in some cases the two phenomena my be combined.

The borehole documentation I carried out in the 1980s contains twenty-six breccia horizons produced by storm activities. The maximum clast size is about 5 cm. Although the majority of the breccia horizons is found in a marine environment (14), their number relative to the thickness in the sequence is greater in both the brackish water (9) and freshwater environments (3). This phenomenon can obviously be explained by the fact that the increased water depth retarded the breccia formation (At shallower water depths weaker storms can also produce breccia.). Grey limestone clasts occurring along with the breccia are probably indicative of little ponds with no water circulation but occupied by vegetation, similar to those inferred under the subheading "Nagyharsány Limestone Formation" (Sedimentary environment....).

It is sure that the relative sea level curve (cFigure 15, p. 186), compiled for Borehole Ú–421 is actually much more complicated than is indicated in this figure. Thus a more detailed evaluation of the macrofauna would be needed and the present scale of 1:1000 has proved to be insufficient for such an evaluation. The density of the stratigraphic data however, is not enough even for an evaluation which could be expected from the present curve. The curves of the Padrag and Úrkút sections are strikingly different, even at first sight. Whereas marine incursions in the Padrag curve are of small thicknesses or, representing a short time span, due to the predominance of the freshwater milieu, in the Úrkút section the freshwater to subaerial intercalations are thinner (shorter in time). The only common feature of these two neighbouring borehole successions is that they both record a sedimentation which has kept pace with the subsidence.

The curve from Úrkút indicates four marked sea level falls and many others albeit on a smaller scale. But even those major excursions cannot be assigned to any of the known third order events. According to some forceful arguments put forward by LUPERTO SINNI — who had an opportunity to study all thin-sections of Borehole Úrkút–421 — the sequence reaches up to the Cenomanian (personal communication). This opinion is based on her observations of some *Ovalveolina* species. If her assertion is valid, the maximum flooding surface, related to the Late Albian transgression, ought to be detected in this succession, with respect to both lithology and faunal characteristics. This is due to the fact that this event is well manifested itself in the closely-located Northern Bakony and Vértes Foreland sequences.

MINERALOGICAL, PETROGRAPHICAL AND GEOCHEMICAL INVESTIGATIONS ON THE ZIRC LIMESTONE

There are clay intercalations between the uppermost highly calcareous beds of the Tés Clay and the lowermost beds of the Zirc Limestone at Úrkút. At this level, small karstic holes are also filled by clay. The results of both the X-ray diffractometric (Table 17) and thermal analyses (Table 18) elucidate a ten-

Table 17

Results of X-ray diffraction analysis in weight percentage from the eastern and western sections of the Manganese slurry reservoir, Úrkút (after BOGNÁR 1993, except sample marked by *, which was made by KOVÁCS-PÁLFFY & BARÁTH 1996)

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Úrkút E														
1	50	8	7		14		18				3			
4	53	5			6		23				3	10		
4	46			4	14		4	4	3		20			5
8	37				5		32			9	17			
10	42				6		19			5	26	2		
12	18		3		3		2				68	6		
17	25				11						57	7		
Úrkút W														
5	50	10		6	10		7				15		2	
11	11				5		1				83			
13/a	3										97			
17/a *			5			1					94			

1 — Montmorillonite; 2 — Illite-montmorillonite; 3 — Illite; 4 — Kaolinite; 5 — Chlorite; 6 — Boehmite; 7 — Quartz; 8 — Potassium feldspar; 9 — Plagioclase; 10 — Aragonite; 11 — Calcite; 12 — Goethite; 13 — Anatase; 14 — Amorphous.

dency which is as follows. The clay is free or short of carbonates and made up chiefly of montmorillonite (bPlate XVI: 1, p. 119). In spite of having been covered almost permanently by water during its formation, the montmorillonites are of relatively high purity. Therefore, they are interpreted as ash-layers which can be attributed to the pyroclastic activity of a distant volcanic source. In both sections the proportion of chlorite increases upwards at the expense of montmorillonite. This is accompanied by a synchronous increase of calcite. Kaolinite was signalled by X-ray diffraction in only two samples of the transitional beds, although it was shown by earlier studies that at higher levels of the Zirc Formation kaolinite dominates its pelitic fraction. Likewise, boehmite appears only in section II, but with high calcite proportions. This indicates that boehmite is the marker mineral phase of the pelite fraction of the section.

The quartz content is relatively low even in carbonate-free beds, and it tends to decrease upsection so as to be beyond the limit of detection. In contrast to the environs of the Nagyharsány Limestone and Környe Limestone, the cementing and discolouring iron mineral phase here is exlusively goethite.

Table 18

Results of thermal analysis in weight percentage from the eastern and western sections of the Manganese slurry reservoir, Úrkút (Földvári 1993, 1996)

Sample	1	2	3	4	5	6
Úrkút E						
1	60	13	13		2	
4	65	3	8		1	10
4	46	1	28		19	
8	37	5	9		26*	
10	38		13		32*	5
12	15	4	8		68	6
.17	24	4	8		56	5
Úrkút W						
5	47	10	22*		14	
11	6		7		84	
13/a	4		2		94	
17/a		4		1	91	

1 — Montmorillonite; 2 — Illite; 3 — Chlorite (+ kaolinite when marked by *); 4 — Boehmite; 5 — Calcite (+ aragonite when marked by *); 6 — Goethite.

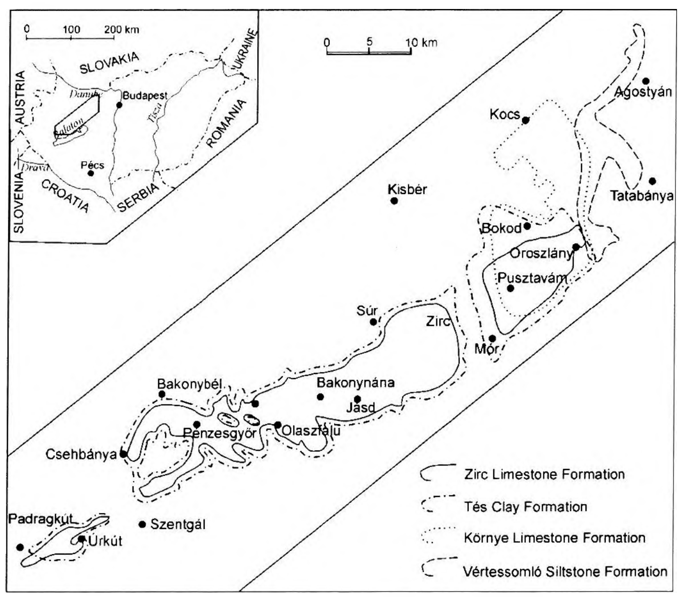


Figure 57. Extent of the mid-Cretaceous formations in the Transdanubian Range

Geographic extent of the Zirc Limestone

The recent study of the Zirc Limestone is restricted to the axial zone of the syncline of the Transdanubian Range (Figure 57) between Padrag to the south-west and Oroszlány–Bokod to the north-east. The width ranges between a few hundred metres and 15 km. It is continuous in its extent but is interrupted at Szentgál and in the Mór Trough (Figure 57). It has two different facies: the Southern Bakony and the Northern Bakony. A transitional facies is found between the two facies zones in and, mainly, to the west of the Hajag Hills (Császár 1986). This is indicated by the re-appearance of rudists in the transitional zone, within the Mesterhajag Member.

Age of the Zirc Limestone

In spite of controversial biostratigraphic data Császár (1986) assigned the Zirc Limestone to the Late Albian. This was corroborated by the revisionary studies on foraminifers and calcareous algae by Bodrogi (1993). The most recent and most reliable data were provided by Görög (1995). From the Eperkéshegy Member of the Zirc Limestone, occurring in the Bakony Mountains, she determined thefollowing species: *Orbitolina (M.) aperta* Erman, *Orbitolina (Conicorbitolina) baconica* Méhes and *Orbitolina (O.) sefini* Leymerie. On the basis of these taxa, a Late Albian age was determined. The assemblage *Dicyclina schlumbergeri* MUN.-CHALM. and *Cuneolina pavonia parva* HENSON — which was collected from the boreholes drilled in the Vértes Foreland — is indicative of the Late Albian age, too. *Orbitolina (M.) concava* (LAM.), which appears in the Úrkút member also supports a Late Albian age but the range of this species extends up to the Middle Cenomanian. These data are more or less in accordance with the results of further biostratigraphic studies such as macrofaunal investigations (CZABALAY 1981a, 1981b), ostracod studies (ORAVECZ-SCHEFFER in CSÁSZÁR 1986) and palynological analysis from the rocks directly underlying the Zirc Limestone (JUHÁSZ 1979, 1983). A co-occurrence of *Stoliczkaia dispar* (D'ORBIGNY) and *S. dispar blanchetti* (D'ORBIGNY) (HORVÁTH 1985), *Rotalipora appenninica* (RENZ) (BODROGI 1985) as well as *Eiffellithus turriseiffeli* within the Gajavölgy Member of the Zirc Formation proves unambiguously that the formation as a whole is of Late Albian origin. The results of investigations on glauconites derived from the base and top of the Gajavölgy Member (FÖLDVÁRI & BALOGH 1984, CSÁSZÁR 1986) are, with some provisoes however, in accordance with the biostratigraphic data. In contrast to the few specimens *Cadosina* has a rather big variety in species (bPlate XXV: 1–30, p. 128) but without a detailed study their stratigraphic importance is unknown.

Concerning the microfauna of the Southern Bakony facies zone of the formation, there has, unfortunately been no significant work published in the past decade. According to LUPERTO SINNI (pers. comm.) the quarry near the road between Ajka and Úrkút exposes a sequence which, based on some species of *Ovalveolina,* would extend up to the Cenomanian. Yet given what has been above said this seems to be very unlikely.

DEPOSITIONAL ENVIRONMENT OF THE ZIRC LIMESTONE

Each member in this formation reflects different sedimentary regimes. The results of their detailed investigation (CSÁSZÁR 1986) call for a slight revision. A sequence 1 to 3 m in thickness, representing a transition between the Tés Clay Formation and the Eperkéshegy Member but pertaining lithostratigraphically to the latter, is classified as a coastal sand facies, especially in the Vértes Foreland. The sand fraction is to various degrees sorted and consists chiefly of the ground material of rudist shells. It contains however, a remarkable but upsection decreasing amount of terrigenous quartz and flint grains. These grains were transported into the basin by a fluvial system which broke through the extensive swamps in the background. In the Southern Bakony, this facies is not found (see Manganese slurry pond, eastern section). Inasmuch as the entry of the river was situated too far from this area, the sediments reaching here were of little volume and finer in grain size. As a consquence, a slightly deeper and more hemipelagic basin formed here at the end of the sedimentation of the Tés Clay.

I classified earlier the Eperkéshegy Member as a reef or organic buildup facies (CSÁSZÁR 1986), according to the facies systematics of WILSON (1975). However, on the basis of what follows, I argue that a re-classification is needed: namely, I assign the Eperkéshegy Member to Wilson's shelf lagoon facies zone with open circulation. Because these sedimentary realms were a bit deeper than their adjacent zone, I do not agree with BARTHA (1995) when applying the term 'rudistid ridge' to this area; this was employed originally (and correctly) to the Környe Limestone. In the micritic matrix, cementing algae are completely missing. A part of the rudists was more or less immersed into the muddy seafloor, and what is more, Agriopleurids (bPlates XIII: 5–6, p. 116; XIV: 2–4, p. 117) were not real reef-constructing organisms, either. They required water agitation, but only on a moderate scale. It is characteristic that all of the clusters and the majority of the individual species, are found in a recumbent or strongly tilted position (bPlate XIV: 3, p. 117), in spite of the fact that the degree of agitation was not as heavy. Green and other algae (bPlate XXIV: 1–7, p. 127) are also found but in subordinate quantities. It remains a puzzling question as to why these subordinates are ground into, and found as, fine grained fragments. Typical microfossils of the Eperjeshegy Member are shown in bPlates XXI: 2–3, p. 124; XXII: 1–2, 4–6, p. 125; XXIII: 1–2, 4, 6–8, p. 126.

The Mesterhajag Member, 5 to 19 m in thickness, is typical of its grainstone texture, corresponding to WILSON's winnowed edge sands facies zone. The peculiarity of this facies is given by the almost complete lack of macrofauna-derived grains (bPlate XIV: 1, p. 117) as well as by the relative abundance of red algae of 'Vimport facies' (PEYBERNÈS 1977, 1979). For further details, see the description of CSÁSZÁR (1986).

The Gajavölgy Member was formed in WILSON's deep shelf margin zone as a hemipelagic sediment. Here, the common rock types are the very fine to fine grained (bPlate XVIII: 1–2, p. 121), well-sorted bioclastic limestone of wackestone to packstone fabric, with characteristic forams (bPlate XXII: 2, 5, p. 125) containing some reworked clasts of Triassic limestone and dolomite as well. In its fauna

Table 19

Distribution of bivalve and gastropod taxa according to the salt content in the Urgon facies the Southern Bakony (Úrkút U–421, Padrag Pa–7), and the Northern Bakony (Pénzesgyőr Pgy—5, Olaszfalu Ot–84) Eperjes Hill, Olaszfalu and Jásd)

	North Bakony		South Bakony	
	Bivalve	Gastropod	Bivalve	Gastropod
Stenohaline	12	8	7	9
Euryhaline	11	2	4	21
Brackish water	7	4	7	9
Σ	30	14	18	39

fragmented echinids, planktonic foraminifers (bPlate XXIII: 5, p. 126) and calcisphaerulids prevail. Glauconite grains are also an important component in these rocks (bPlate XIV: 5, p. 117).

The Úrkút Member represents a distinctive sedimentary environment, as it was formed on a shelf lagoon, with open circulation and restricted circulation in the shelf zones. The latter area was characterized by moderate agitation, or even, no water circulation and therefore, included environments such as lagoons with gentle or no agitation and coastal, parching swamps. The prevailing sorts of textures are bioclastic mudstone and often dolomitic limestone. Exceptionally, calcareous dolomite may appear, too. However, storm-related breccias of various grain sizes and intraclasts encrusted by algae are quite common constituents of these rocks. A further attribute of this member is that the proportion of the gastropods to the molluscs as a whole is conspicuously high. From the boreholes Ú–421 and Pa–7, a total of 39 gastropod taxa was listed by Czabalay (1982, 1985 — Table 19). There are 9 taxa restricted either to the stenohaline or to the pronouncedly brackish water sedimentary environments. The remainder of these taxa (21 altogether) pertain to the euhaline group. Consequently, it can be estabilished that there are brackish water, freshwater (*Chara, Muneria*) and even, terrestrial sediments in the Úrkút sequence. The palaeosoil horizons are of terrestrial origin, as are the bauxitic clay and clayey bauxite masses. A marked indication of the subaerial exposure is given by dessication cracks and the shell fragments derived from such chondrodonts that were truncated while still in their upright, living positions. As a consequence of the mainly shallow water-depth on the substrate, (which is slightly irregular), even minor sea level falls gave rise to the formation of decreasingly salty lagoons or lakes (indicated by Characea, *Munieria* and *Girvanella*). The vegetation was not restricted to the shallow seafloor which was inhabited by many herbivorous gastropods, and it can be assumed that certain kinds of bushes or trees bordered this archipelago-like lagoon and the intra-lake realm, too. This is indicated both by traces of roots and by limonitized remains of thicker stems or trunks.

It is exceptional that limestones of ooidic grainstone texture are evident and these indicate an open platform, because the Padrag area under discussion is dominated rather by nearshore facies.

In terms of the sedimentary environment, there are certain changes which can be noticed in the Padrag and Úrkút sections. These indicate the decrease of the duration and frequency of the subaerial periods. In contrast, it cannot be observed in any of these sections that a seaward, *i.e.* towards the more pelagic facies — took place, although it would be expected. In the Padrag section the freshwater environment is the most decisive factor throughout the entire sequence (time span). Likewise, in the borehole at Úrkút a bundle of beds reflecting higher energy is eventually overlain by less agitated, lagoonal sediments. These, in turn, prevail throughout the borehole.

THE MIDDLE CRETACEOUS EVOLUTION OF THE PELSO UNIT IN THE LIGHT OF THE URGON FORMATIONS

In order to outline the evolution of Urgon formations it is necessary to take a brief look at other formations which were formed contemporaneously and were interfingered with them. Therefore, in the following several different formations are considered.

The first crucial step towards the modern understanding of the formation and palaeogeographic connections of the Cretaceous sequence in the Gerecse Mountains was the recognition of the chromium spinel content of the heavy mineral spectra (Vaskó-Dávid in Fülöp 1975; 1991). Equally important was the next step, when the Gerecse sediments turned out to be true flysch (Császár & Haas 1979, 1984). Balla (1981) proposed an island arc to the north-west of the Gerecse to be the sediment provenance. The Transdanubian Range, as Haas & Császár (1987) argued, was situated at the margin of the oceanic basin during the Early Cretaceous. The Gerecse basin of the TR was correlated with the Belluno Trough by Kázmér (1987). The palaeogeographic position of the Gerecse and Rossfeld basins, relative to the suture zone, played a key role in sediment supply, as attested by many authors (Pober & Faupl 1988; Faupl & Wagreich 1992;

SCHLAGINTWEIT 1990b; CSÁSZÁR & ÁRGYELÁN 1994). A thorough sedimentological analysis focusing on sediment gravity flows was carried out first by SZTANÓ (1990a, 1990b), and then by FOGARASI (1995a, 1995b). An attempt to explain the variations in palaeoflow directions was performed by the latter author, who assumed rigid block-rotations induced by right-lateral strike-slip displacements cut off from the shelf margins.

According to CSÁSZÁR & ÁRGYELÁN (1994) the oceanic basement might have been, at least partially, obducted by the Late Jurassic. The most important implication of the relevant works of ÁRGYELÁN (1989, 1992, 1993, 1995) is that the clastic material of the Cretaceous sequence in the Gerecse Mountains is derived from oceanic island arc(s), oceanic ophiolites, deep-sea sediments and slices of the overthrusted continental crust, resulting from a polyphase collision event. With respect to both the Gerecse and Rossfeld Basins, the ophiolithic mass supplying detrital spinels indicate a similar sediment source, namely the harzburgitic subprovince. However, serpentinite fragments do occur in the Gerecse Basin but not in its Alpine counterpart. Therefore, it is assumed that the provenance area was situated much closer to the Gerecse Basin than to Rossfeld. From a palaeotectonic point of view, the Gerecse sequence was accumulated in a foreland basin developed in front of the obduction zone.

In the Western Gerecse, there is a submarine hiatus at the base of the Cretaceous sequence, increasing westward in its extent (CSÁSZÁR 1995). This means that a significant pause in sedimentation took place both on the Gorba High, becoming morphologically less and less important, and on the slopes adjacent to that high. At Tata for example, after the Valanginian, the sedimentation commenced again in the late Late Aptian or, as SZIVES (1999b) has recently demonstrated practically, in the Early Albian. This means that the relatively steep western slope of the trough-like foreland basin of the Gerecse acted as a by-pass zone for a long period of time. (It has to be added, that there is substantial merit in the arguments of many researchers who state that the by-pass period was preceded by a short-lived subaerial event in the middle sector of the Transdanubian Range. This provides an obvious explanation for the uneven erosion of the subjacent rocks. However, these arguments should not be taken too far since in allusion to the pre-Early Albian and Early Albian palaeotopographic conditions this appears to be very unlikely. I should add that the general occurrence of basal clastics in both the Northern Bakony and the Vértes Foreland, as well as the considerable temporal variability of the formations which underlie the Tata Limestone, provide evidence for a subaerial exposure.) High-energy bottom currents are often indicated by the development of deep-water stromatolite encrustings. Here, a case in point may be the nature conservation area at Tata where the encrustings are found, forming a thick crust at the base of the Tata Limestone and overlying different horizons of the Jurassic.

The limestone cobbles of the Köszörűkőbánya Conglomerate retain evidence of a carbonate platform. However, this is not unprecedented in the area because some pebbles — to be precise, the microfossils therein — can be recognized at the top of the Bersek Hill quarry and they indicate a carbonate platform that already existed in the Late Jurassic [*Clypeina jurassica minor* KERČMAR, *Actinoporella podolica* (ALTH.), *Salpingoporella annulata* (CAROZZI), *Gryphoporella* sp. and *Teutloporella* sp. — det.: O. PIROS; see also SCHLAGINTWEIT 1990a). As a consequence of the obduction of the oceanic basement and island arc a foreland basin was formed which, at the same time, resulted in the formation of a shoreline within the former open sea. An undisturbed lagoon might have been formed along this shoreline between the adjoining ridges thus providing algae with a favourable habitat. The study recently made of the northernmost situated Borehole Štúrovo–1 has revealed that both the algal and calpionellid limestones were transported to the slope of the Gerecse Basin at a relatively early stage of the

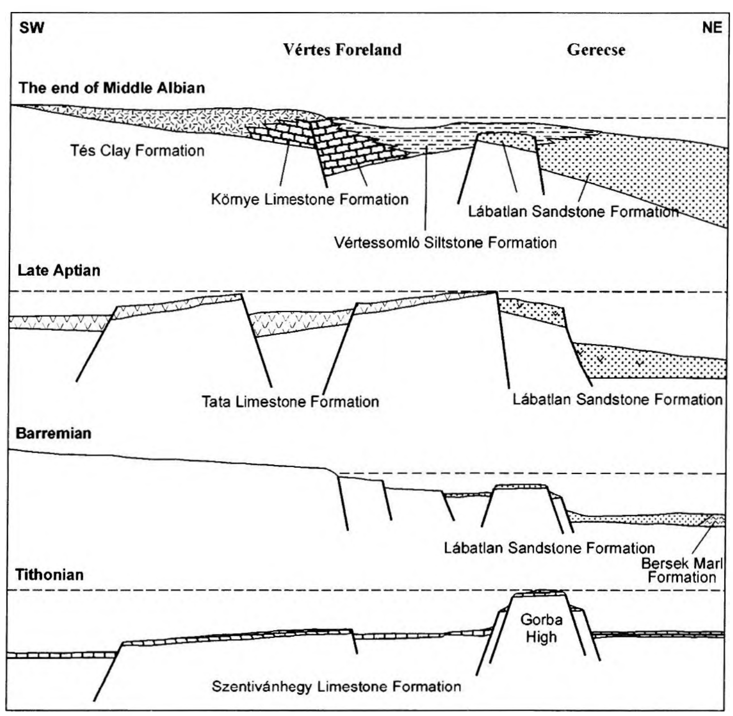


Figure 58. Idealized cross sections showing the development of the sedimentary environments in the Gerecse Mountains and Vértes Foreland during the Early and middle Cretaceous

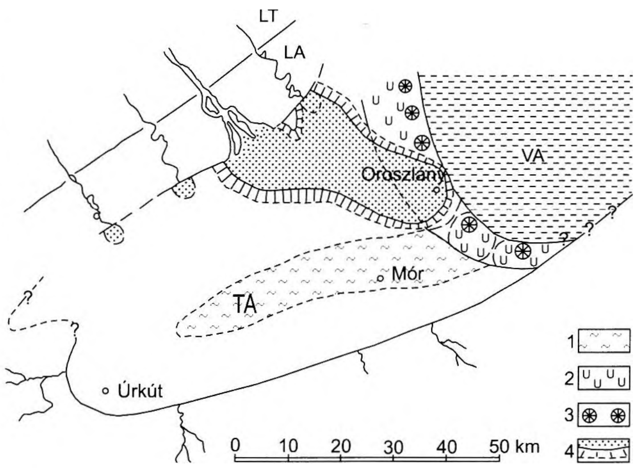


Figure 59. Palaeogeographic sketch-map of the Transdanubian Range at the turn of the Early and Middle Albian

1 — Deepest part of the sedimentary basin during sedimentation of the Tés Clay; 2 — Rudistid zone of the Környe Limestone; 3 — Reefal zone of the Környe Limestone; 4 — Fan delta; TA — Tés Clay Formation; LA — Transitional zone between the erosion and accumulation; LT — Dissected erosional area; VA — Vértessomló Siltstone Formation

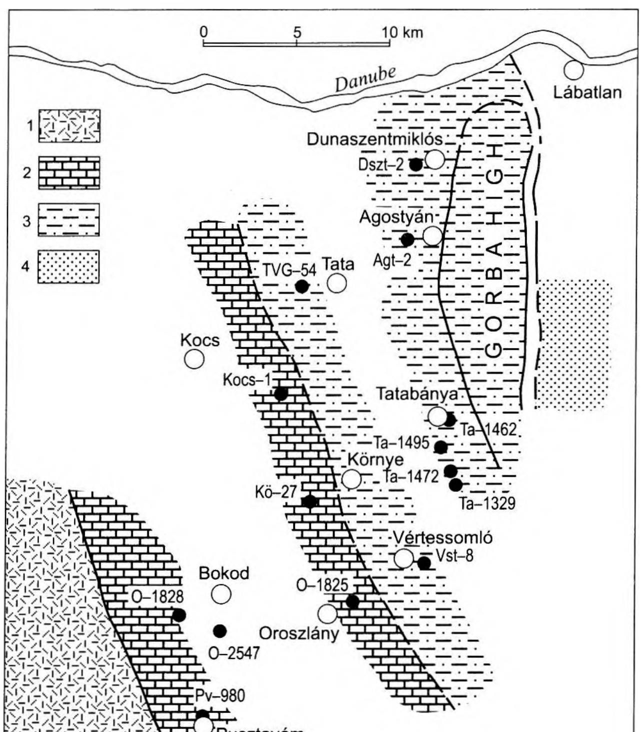


Figure 60. Sedimentary zones in the Gerecse and the Vértes Foreland in the Middle Albian

1 — Tés Clay Formation; 2 — Környe Limestone Formation; 3 — Vértessomló Siltstone Formation; 4 — Lábatlan Sandstone Formation

basin evolution and in the form of sizable clasts. It was precisely here, the calpionellid limestones are rich in terrigenous siliciclastics of silt grain size.

In addition to our knowledge about the platform with green algae which existed in the Late Jurassic and the rudistid one in the Early Albian, a different algal assemblage, cropping up in the Borehole Šturovo–1, alludes to a further sort of platform probably of an in-between stage.

On the basis of the Borehole Tatabánya–1472 we may rightly assume a lateral, one-time facies transition between the Lábatlan Sandstone and Tata Limestone in the Tatabánya Basin. The former formation is indicative of bathyal conditions whereas the latter one reflects origin which are shallow- to deep sublittoral. The Tata Limestone itself represents a distinctive period of the evolution of the Transdanubian Range because the sedimentation, separated during the Early Cretaceous to form independent basins of the Bakony and Gerecse, reunited at this time (Figure 58). These phenomena can most probably be connected to a significant relative sea level rise and a subsequent sea level drop. This might serve to explain why a considerable hiatus is evident at the base of the Tata Limestone. This, in turn, starts directly with sediments of a deeper sublittoral environment with no or merely a few clastics at the base. Therefore, in order to recognize different kinds of hiatuses and draw the eastern boundary of the subaerial hiatus, it is apparent that further studies are needed.

Coincident with, or even, at certain places prior to the formation of the Köszörűkőbánya Conglomerate, a carbonate platform of Urgon facies developed to the north of the Gerecse Basin (Császár & Árgyelán 1994, Figure 48). It was attached to the southern part of the accretionary zone of the obducted oceanic basement. Horizons of zoogenic limestone clasts, rich in macrofossils, were formed due to sediment gravity flows (in part by debris flow and in part by turbidity currents) which were provoked by sea level changes and/or storms.

The study of the middle Cretaceous palaeogeographic restoration of the Vértes Foreland and it connections with the Bakony (Figure 59), was carried out by Császár (1986). Uplift in the late Early Cretaceous resulted in the formations of lowermost Cretaceous and the otherwise often discontinuous Jurassic being preserved only as erosional remnants. The Vértessomló area is an exception to this. The Vértessomló Siltstone has either been developed continuously from the Tata Limestone or, at some places, directly overlies the Jurassic. It was deposited in a NNW–SSE stretching shallow, hemipelagic trough, or rather, a progressively shallow, oxygen-depleted basin characterized by low-energy currents. At higher stratigraphic horizons, these deposits are also found in the Western Gerecse (Figure 60). The basin was bounded from the west by a gradually shallowing platform, first of Tata Limestone, and later of Környe Limestone (Figure 58). After the basin had been filled up, the platform prograded on to the basin sediments.

Although several limestone types which were formed on the Urgon platforms in the Gerecse and in the Vértes Foreland are very similar, there are fundamental differences in terms of their palaeogeographic conditions. The Gerecse platform was rimmed by a front reef which sheltered an orbitolinid calcareous sand facies as well as a rudistid lagoon beyond. In contrast, more gently-dipping slopes were attached to the platform as well as patch-reefs in the Vértes Foreland; the front reef and a semi-restricted hemipelagic basin were adjacent to the platform. As a consequence of intensive bioproduction in the shallow water, crinoids on the fore-reef slope and deeper platform were gradually replaced by the increasingly coarsening clastics of the prograding Urgon platform. Finally, this zone has converted into a carbonate factory, too. If the two platforms under discussion, which are of different origin, had existed contemporaneously, they could have been connected only in the west. As a consequence of the above, the concept of CSÁSZÁR (1986) needs to be adjusted. (This dealt with a front-like eastern rim with respect to the platform of the Környe Limestone.)

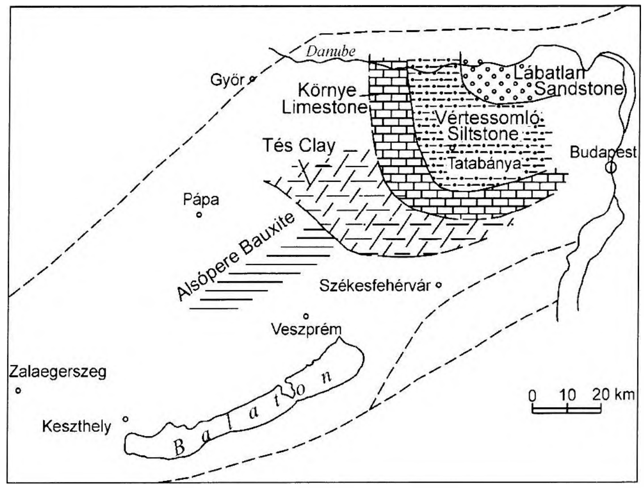


Figure 61. Zones of sedimentary environments in the Transdanubian Range in the early Middle Albian

By the end of the formation of the Környe Limestone another siliciclastic basin was formed in the Transdanubian Range. However, in contrast to the Gerecse Basin, the style of sedimentation was fundamentally different here given that terrestrial sediments were deposited. The siliciclastics were transported from the north-west. Prior to alluvial sedimentation, the borehole Pv–980 indicates that, the platform of the Környe Limestone underwent a soutwestward transgression (retrogression). It is mainly climatic factors which influenced the commencement and progradation of fluvial, and freshwater swamp sedimentation behind the Urgon type platform (Figures 58 and 60). However, brackish water swamps were also formed. Thus, the formation of platform carbonates was broken off by the enhanced clastic input, even though shallow-water circumstances persisted. The Környe Limestone is overlain by, or heteropically intercalated with, the Tés Clay. Its deltaic beds are, in turn, interfingering with the Vértessomló Siltstone for a short stratigraphic interval. The Early and middle Cretaceous evolution of the sedimentary environments in the Gerecse and the Vértes Foreland are demonstrated schematically in Figure 58. The arrangement of various depositional zones in the early Middle Albian are shown in a palaeogeographic sketch map (Figures 60 and 61). The most decisive factor affecting the facies relations of the Transdanubian Range as a whole is the NE-deepening periplatform trough, directly connencted to the pelagic region off the ocean. Equally important is the subaerially exposed landmass as a site of bauxite accumulation (Figure 61). The facies connection — in the light of sequence stratigraphy — between the semi-restricted (oxygen-depleted) basin of the Vértessomló Siltstone and the terrestrial basin with its fluvial to paludal sediments, is shown in Figure 62.

As soon as the sediment supply ceased, the area became a venue for the formation of the second Urgon platform as evidenced in the Zirc Limestone Formation. Facies of member rank units in the Northern Bakony and the Vértes Foreland are very likely heteropic facies of each other rather than time horizons. However, this has not been corroborated yet by means of biostratigraphy. Evidently, with respect to a carbonate platform, the number of tools that we have is too meagre and not sufficient to permit exact detections of short time events, and even less adequate for detecting constraints on their timing. From this point of view, that the terrigenous input has failed to come because of a relative sea level rise, rather than being due to certain changes in the climate. As the transgression advanced or, as the platform retrograded, more and more subaerial areas were converted into sites of carbonate deposition. The Zirc Limestone is incompletely developed in the Vértes Foreland and, in a subsidiary way, in the Northern Bakony. That is to say, in these areas the upper part of the Mesterhajag Member and the entire Gajavölgy Member is missing. This phenomenon can unequivocally explained by subaerial erosion (CSÁSZÁR 1986). CSÁSZÁR's arguments were based on the recognition that the glauconitic basal beds of the Pénzeskút Marl Formation, overlying the Zirc Limestone, fill in karstic holes and caverns of the latter. In fact, the karstification was corroborated by a number of new

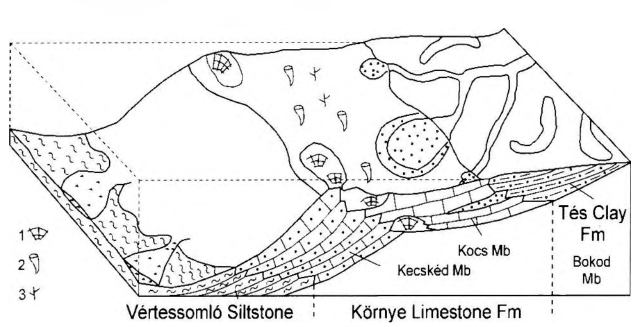


Figure 62. Block diagram showing prograding carbonate platform and related facies at high stand with decreasing water level in the Vértes Foreland during the Middle Albian

1 — Patch-reef (corals and stromatoporoids); 2 — Rudists; 3 — Dasycladaceans

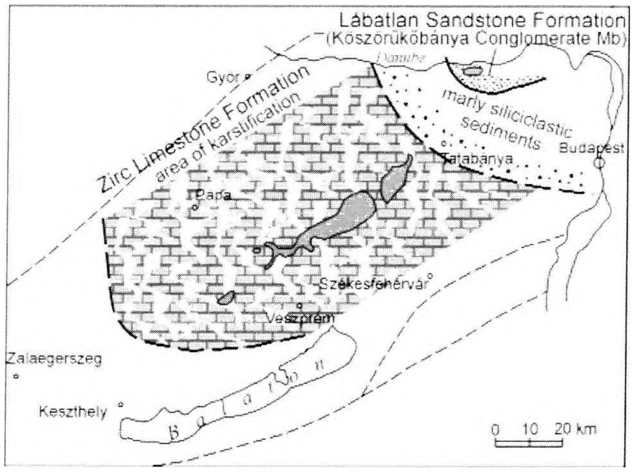


Figure 63. The assumed coast line during the short term sea level drop in the early Late Albian just before the flooding of the Pénzeskút Marl

borehole data. The exact depth of karstification is approximately 10 m and the magnitude of uplift relative to the groundwater table, could be 40-50 m. The palaeogeographic situation is shown on Figure 63. The sequence stratigraphic model provides us with a novel understanding of the fact that the rate of hiatus increases in an opposite direction relative to that in which the transgression (or, retrogradation) is advancing. The hiatus was explained exclusively by karstification just before the formation of the Pénzeskút Marl. In this way contradiction arose from the situation that the connection towards the ocean coincides with the direction of the increasing hiatus. It is obvious therefore, that most of the hiatuses are a consequence of the lacuna which occured during maximum floodings. However, hitherto it has not been possible to distinguish between the two, temporally very closely related maximum flooding surfaces in the Vértes Foreland (*i.e.* one above the Mesterhajag Member and the other one at the base of the Pénzeskút Marl, indicated by glauconite horizons).

As depicted earlier, the two facies areas of the Zirc Limestone which interfinger with each other most likely represent the transition between the Southern and Northern Bakony. Seemingly in the northern area, the rate of subsidence owing to abrupt tectonic movement exceeded the rate of sedimentation (see Mesterhajag Member and especially the Gajavölgy Member) while, in the Southern Bakony the sedimentation kept pace with subsidence. (A couple of short term hiatuses as well as subaerial sediments indicate that the carbonate sedimentation potential is not absolutely utilized). The early Late Cretaceous erosion might account for the effect of a remarkable transgression (forming the Pénzeskút Marl) on the Southern Bakony sequence, but this remains something of a mystery. The transgression could be an outcome of an abrupt and considerable (certainly more than 100 m in amplitude or even more) sea level rise. An unusual subsidence may also have contributed to the effect of this sea level rise. This resulted in a broadening of the depositional area of the Pénzeskút Marl and reached the Gerecse area; its original features have not been changed fundamentally. Some incipient stage of this scenario is presented in Figure 63. Based on the data from the Bakony Mountains, the formation, whose thickness might have exceeded 500 m, was most probably connected to the remnant of the former Vardar Ocean. This is reflected in the late Early Cretaceous to middle Cretaceous retrogradation and facies arrangement in the Transdanubian Range (Figure 64).

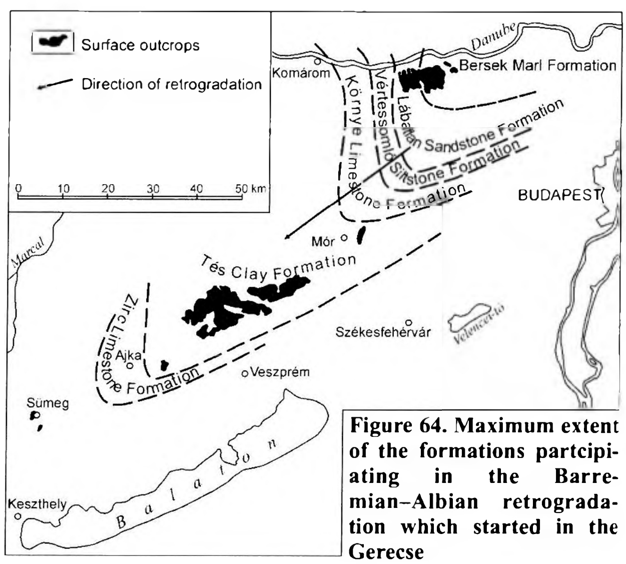


Figure 64. Maximum extent of the formations partcipiating in the Barremian–Albian retrogradation which started in the Gerecse

BLACK AND WHITE PHOTOGRAPH PLATES OF THE PELSO UNIT (IX–XXV)

GERECSE: IX–X

VÉRTES FORELAND: XI–XII

BAKONY: XIII–XXIV

BAKONY, VÉRTES FORELAND: XXV

Limestone breccia (olisthostrome) horizon in the Köszörűkőbánya Conglomerate Member, Lábatlan Sandstone, Köszörűkőbánya quarry, Lábatlan

1. Sandstone and siltstone cemented by lime mud of platform origin with limestone fragments

2. Sandy, pebbly limestone of platform derived lime mud with fossil fragments, top of the uppermost bank

3. Limestone debrit of prevailingly platform carbonate origin, upper limestone breccia horizon

4. Bundle of graded sandstone and breccia consisting of cherts and limestone fragments of carbonate platform origin

5. *Orbitolina*-bearing, pebbly sandstone in limestone fragment-bearing chert–conglomerate between two limestone breccia bank

6. Platform derived limestone cobbles in the upper limestone breccia bank with *Alectryonia* coquina

The upper limestone breccia horizone in Köszörűkőbánya Member, Lábatlan Sandstone Formation, Köszörűkőbánya quarry

1. Sandstone of Radiolaria-bearing chert with a horizon of platform derived limestone fragments (top of the lower third), and sandy limestone bank of platform derived lime mud (upper part)

2. Debrit of Radiolarian chert with unsorted limestone fragments of platform origin

3. Platform derived limestone cobbles in chert debrit

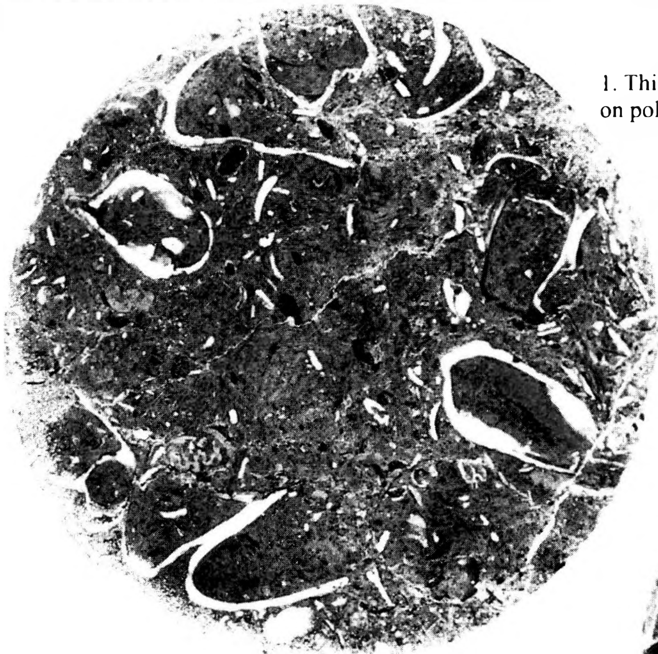
4. Platform derived limestone clasts of chert fragments in matrix

Photographs of borehole cores, Környe Limestone and Tés–Környe Formation

1. *Lopha rectangularis* (ROEMER) in siltstone marl of Tés–Környe Formation, Borehole Oroszlány–1828

2–3. Fragments of colonial organisms and other fossils in sandy flaser-type limestone of the Kecskéd Member, Borehole Oroszlány–1995 (234.1–234.3 m)

Fossils from the Vértessomló–Környe Fm, Borehole Oroszlány–1822 (Det.: L. CZABALAY, Photo: M. PELLÉRDY)

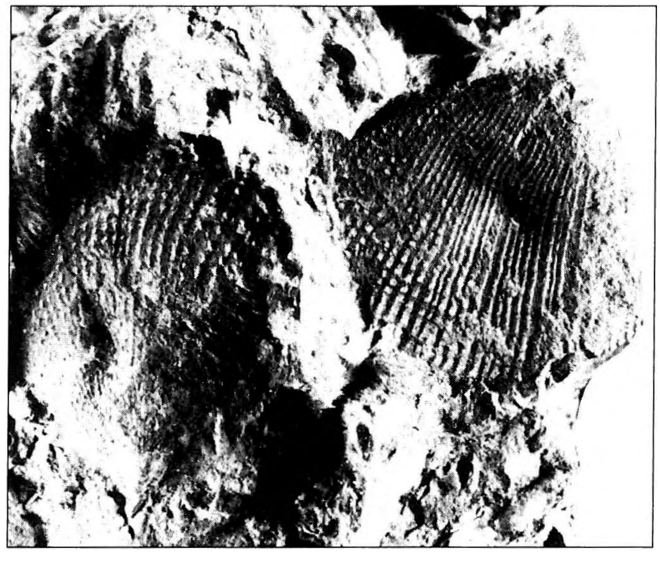


1. Thin shells of rudist bivalves on polished surface (365.5–366.0 m)

2

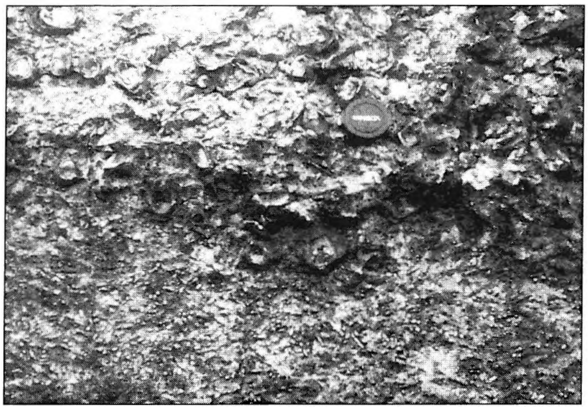
3

2–3. *Nerinea (Adiozoptyxsis) coquandiana* D'ORB. (365.5–366.0 m)



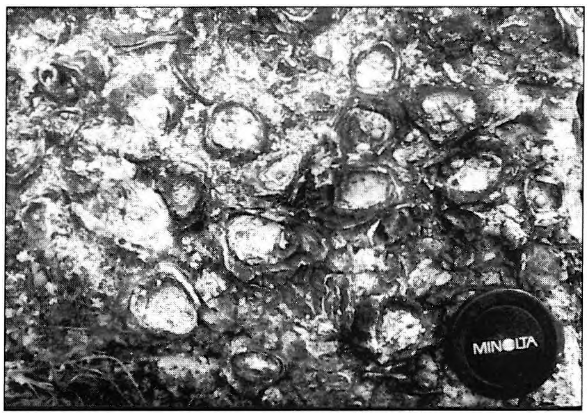
4. *Chlamys robauldianus* DE LOR. (423.5 m)

Zirc Limestone in surface outcrops



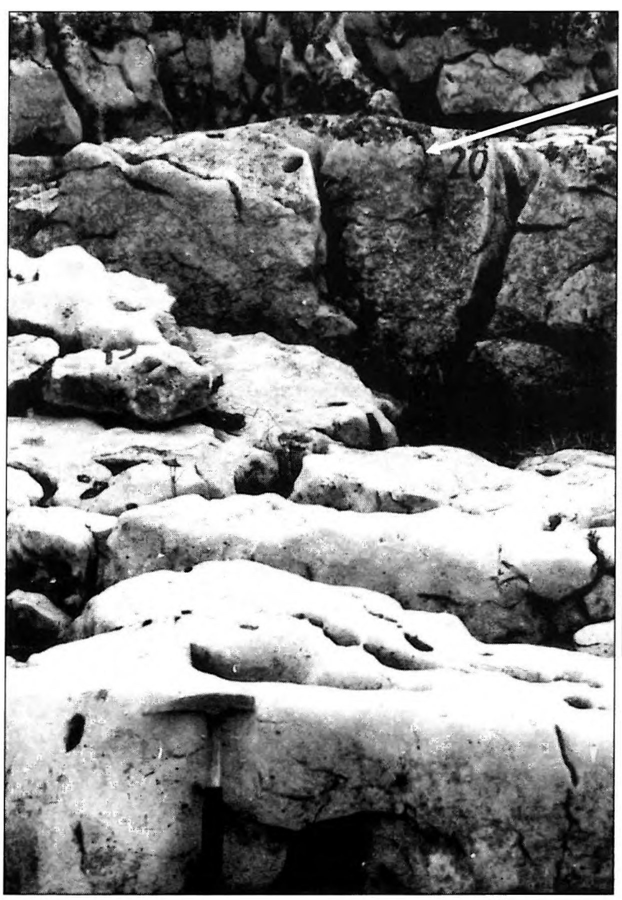
1. Abrupt change in fossil community without any change in matrix, in a bank of *Nerinella* limestone (lower part) and *Eoradiolites* limestone (upper part). Úrkút Member, Manganese slurry reservoire (abandoned manganese mine), Úrkút

2. Detail from the lower part of the previous photograph



3. Bedding plane of an *Eoradiolites* bank with well prepared rudists in life position. Manganese slurry reservoire (abandoned manganese mine), Úrkút

4. *Nerinea* limestone, Manganese slurry reservoire (abandoned manganese mine), Úrkút



6. Uppermost *Agriopleura* limestone bed, top of Eperjes Hill, Olaszfalu

5. Tectonic and stratigraphic contact between Eperkéshegy and Mesterhajag Members, top of Eperjes Hill, Olaszfalu

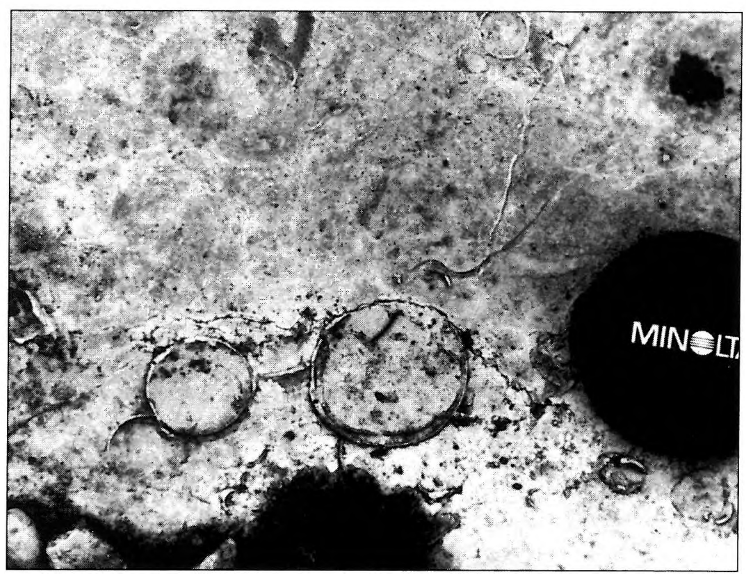
Eperkéshegy Member of the Zirc Limestone, Eperjes Hill, Olaszfalu (1–4), Mesterhajag and Gajavölgy Members, Jásd (5)

1. Karstic limestone

2. *Agriopleura* bivalves in tilted position

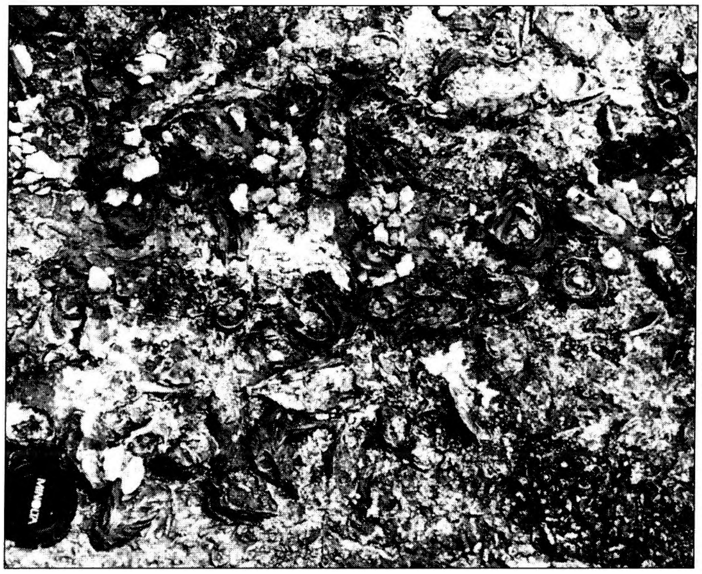
3. *Agriopleura* cluster

5. Erosional contact between
the two members
the darker upper one (Gajavölgy Mb) is glauconitic

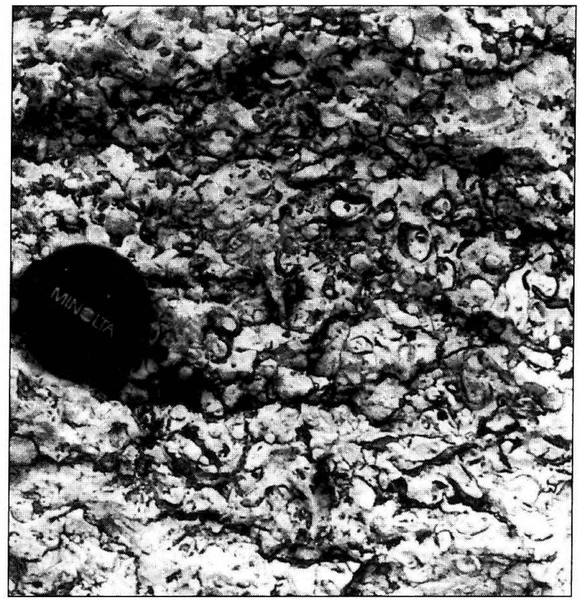


4. Cross section of fine shell rudists ("lorgnette")

Úrkút Member of the Zirc Limestone in the quarry of Manganese slurry reservoir, Úrkút



1. *Eoradiolites* limestone



3. Limestone with moulds of small size rudists

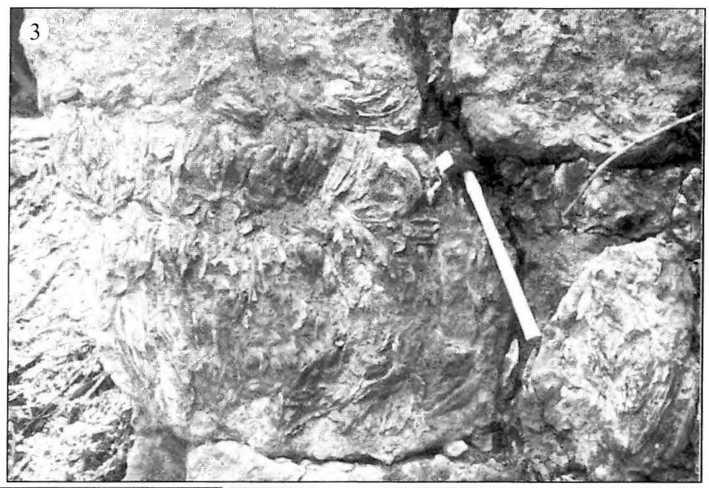
2. Limestone with traces of root structure, capped by tempestite

4. Red tempestite of palaeosoil character with limestone cover

2. Tempestite breccia of palaeosoil character, Manganese slurry reservoir, Úrkút

1. Karstified small cavities after plant roots filled by bentonitic clay of probably tuff origin, covered by gastropod limestone, Manganese slurry reservoir, Úrkút

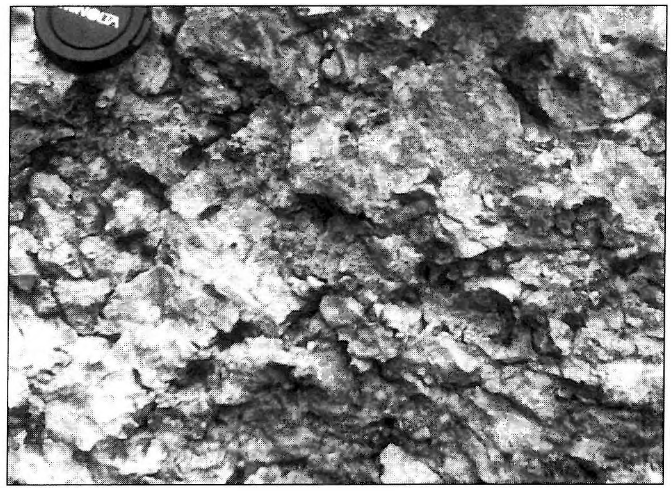
4. *Eoradiolites* bivalves in random distribution, Manganese slurry reservoir, Úrkút



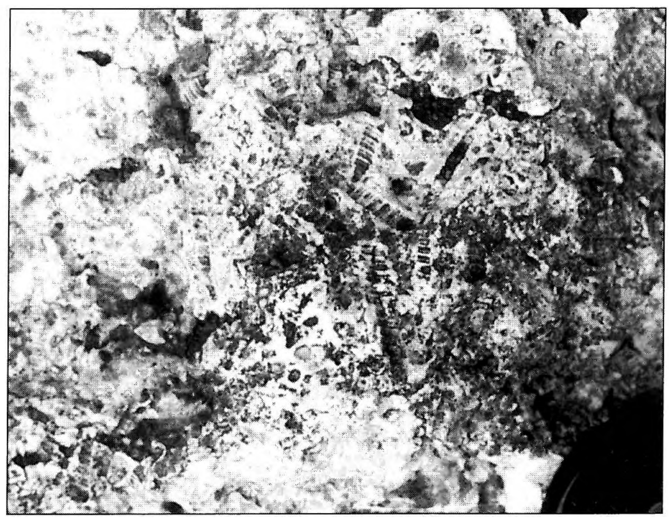
3, 5, 6. *Chondrodonta* bivalve generations in the quarry on the west side of the Ajka–Úrkút road

Úrkút Member of the Zirc Limestone in the quarry of Manganese slurry reservoir, Úrkút

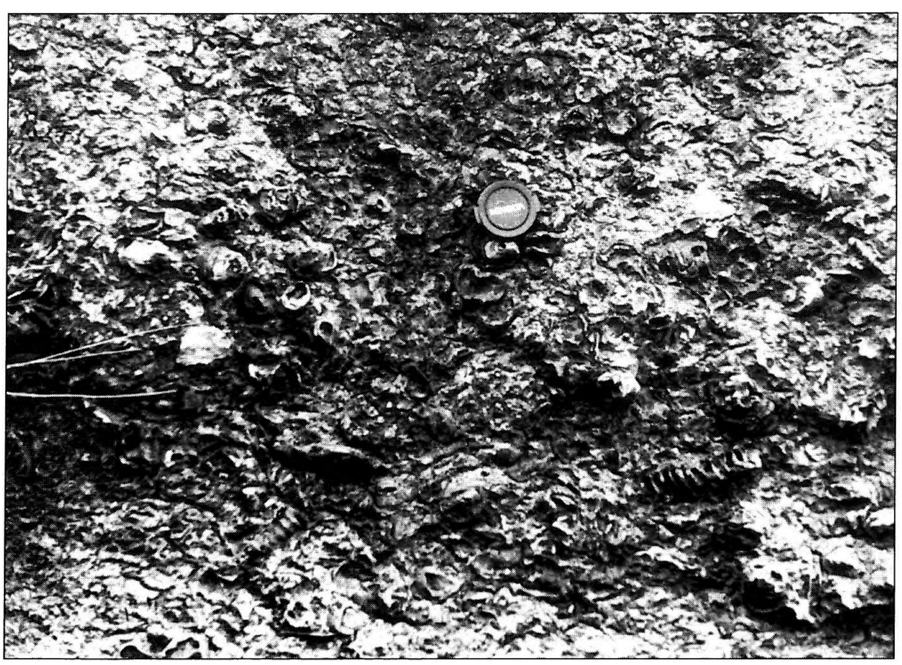
1. Rudistid (lower part) and cavernous limestone after plant roots and *Chondrodonta* coquina (upper part)



2. Limestone bank with cavities of irregular shape, in part after plant roots



4. *Cerithium* limestone

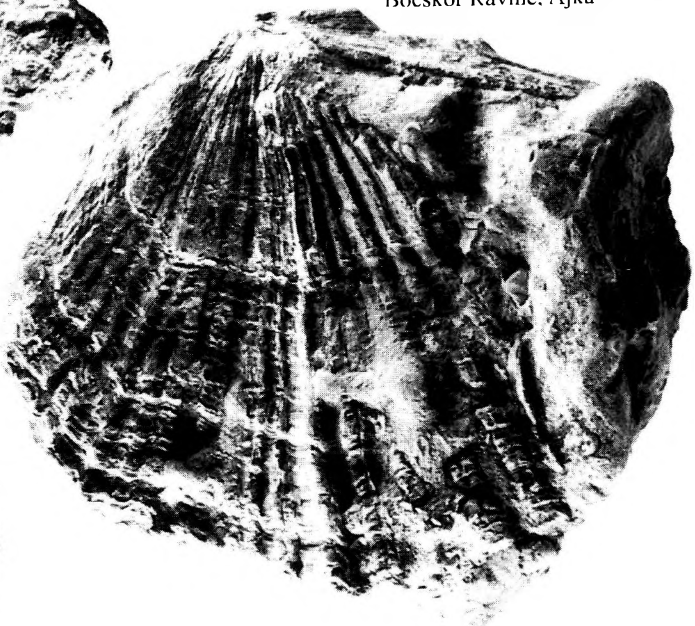


3. Limestone bank consisiting of *Nerinea* gastropod

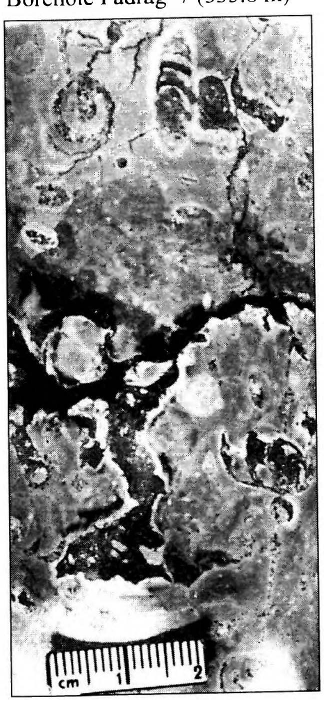
Typical fossils of the Zirc Limestone Formation
(Determination: L. CZABALAY, photograph: M. PELLÉRDY)

1. *Pseudotoucasia santanderensis* (DOUVILLE),
Bocskor Ravine, Ajka

2. *Neithea stephanoi* (CHOFFAT),
Bocskor Ravine, Ajka



3. Karstic cavity filled
by bauxitic clay,
Borehole Padrag-7 (335.8 m)

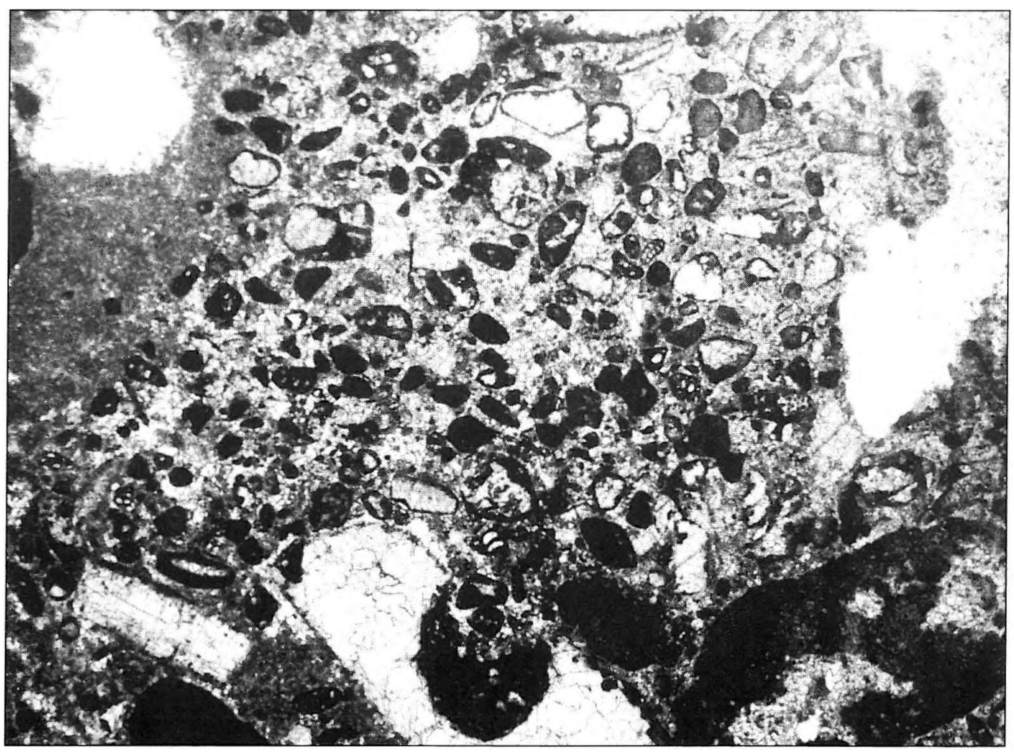


4. *Neithea stephanoi* (CHOFFAT),
Bocskor Ravine, Ajka

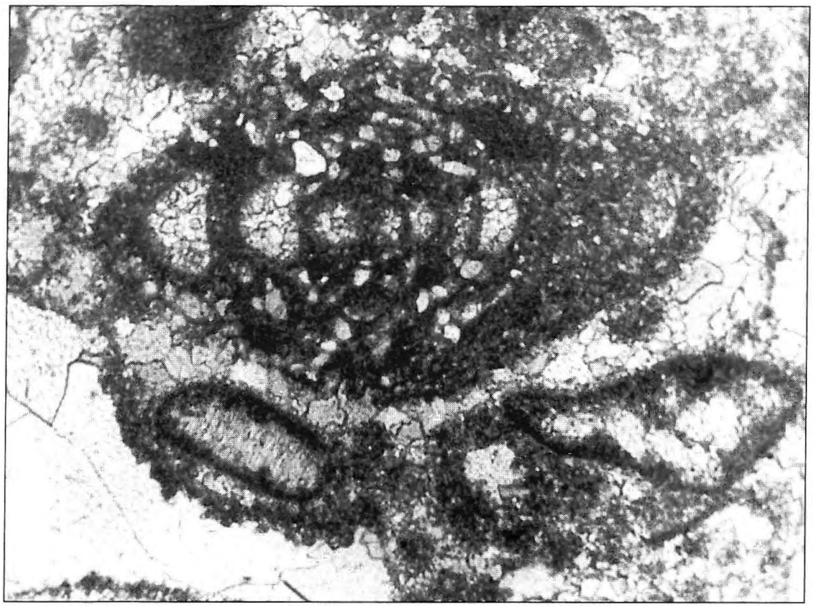
Photomicrographs of the Zirc Limestone Formation, Eperjes Hill, Olaszfalu

1. Coral(?) colony, base of the Mesterhajag Member

2. *Dicyclina schlumbergeri* MUNIER-CHALMAS with *Salpingoporella* fragments, Bed 1, Eperkéshegy Member

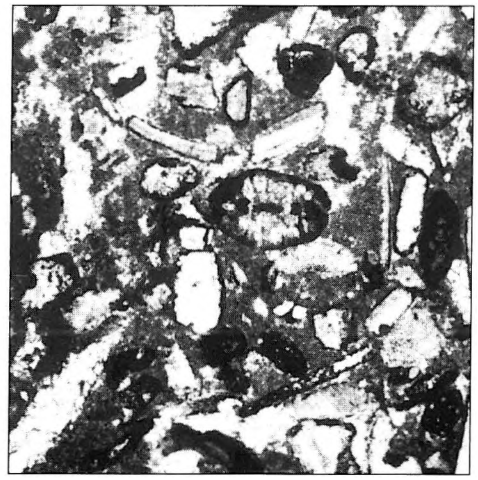


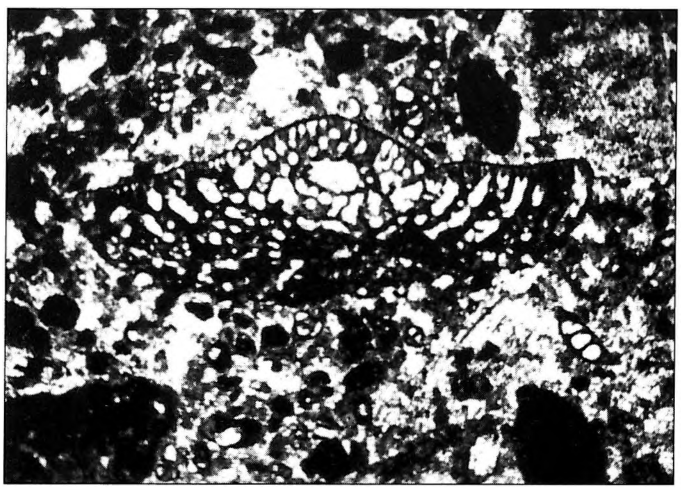
3. Grainstone lens with bored rudist coquina, Eperkéshegy Member



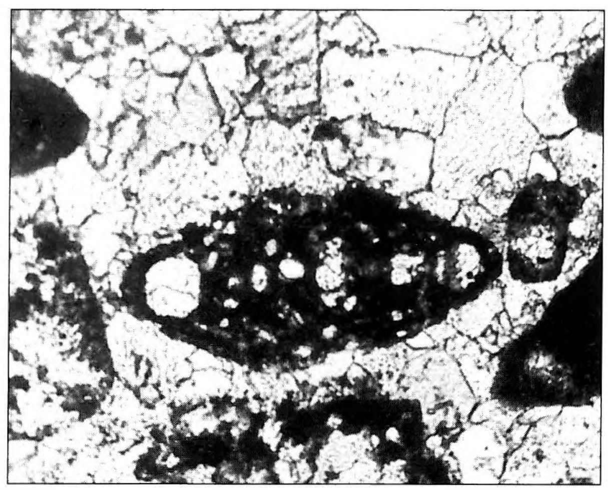
1. *Charentia* sp., Bed 8, Eperjes Hill, 70×

4. *Involutina hungarica* Sidó, Borehole Zirc–61 (20.3 m), 43×

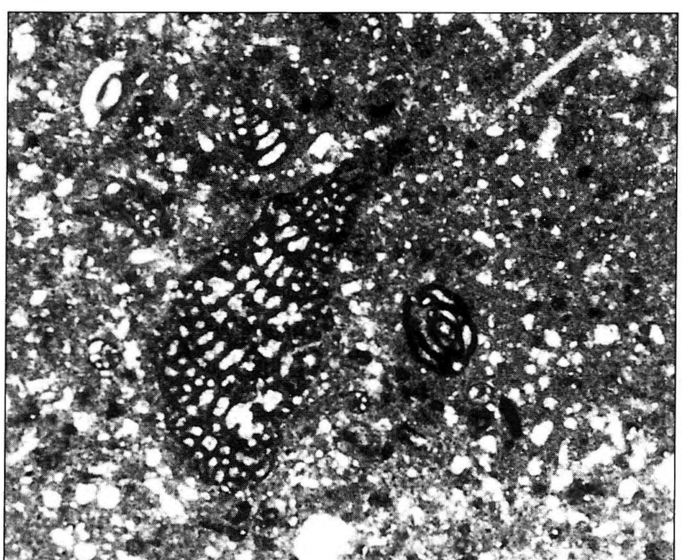




2. *Orbitolina (M.) aperta* (Erman), Borehole Pénzesgyőr–5 (49.0 m), 50×

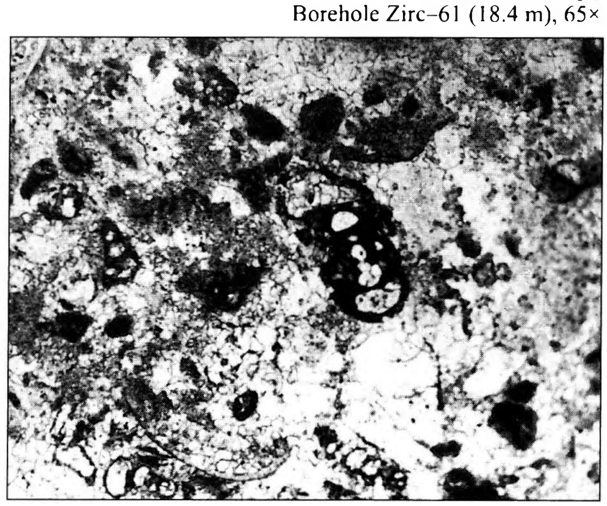


5. *Charentia* sp., Bed 22b, Eperjes Hill, Olaszfalu, 70×

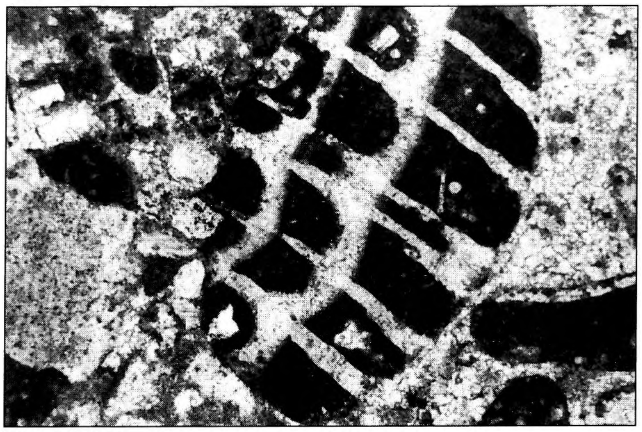


3. *?Cuneolina* sp., Borehole Úrkút–421 (301.8 m), 20×

6. *?Charentia* sp., Borehole Zirc–61 (18.4 m), 65×

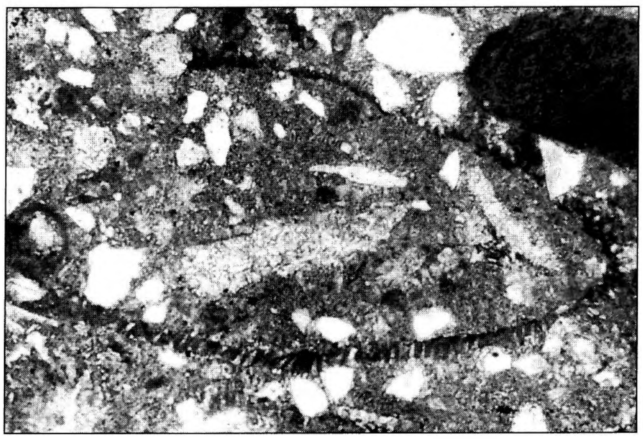


Textural fabric and microfossils of the Zirc Limestone

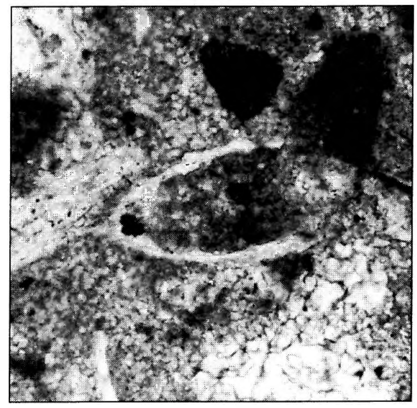


1. Rounded rudist shell fragment, Borehole Zirc–61 (20.0 m), 50×

2. Packstone with rudist shell fragments and *Pieninia oblonga* BORZA *et* MIŠÍK, Borehole Zirc–61 (19.8 m), 65×

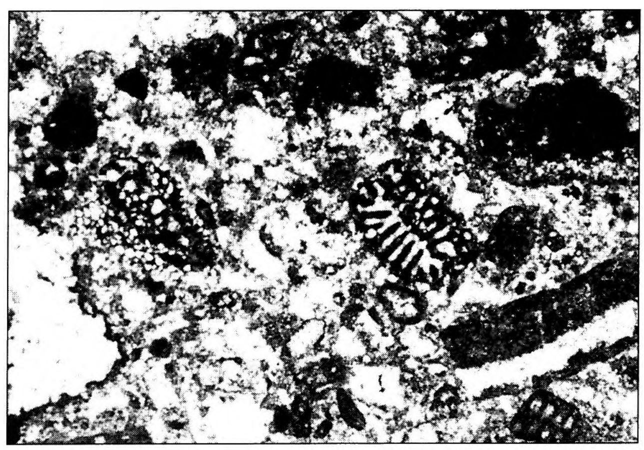


3. Calcareous sandstone with green alga, Tés Clay, Borehole Zirc–61 (31.3 m), 50×

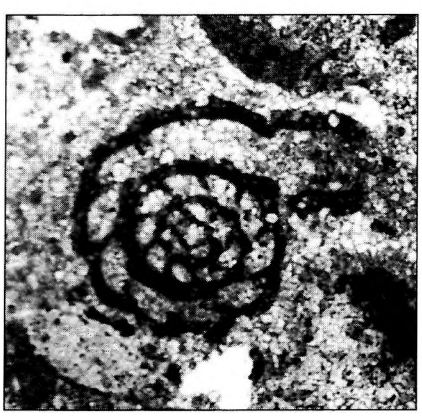


4. *Colomiella* sp., Borehole Zirc–61 (19.0 m), 164×

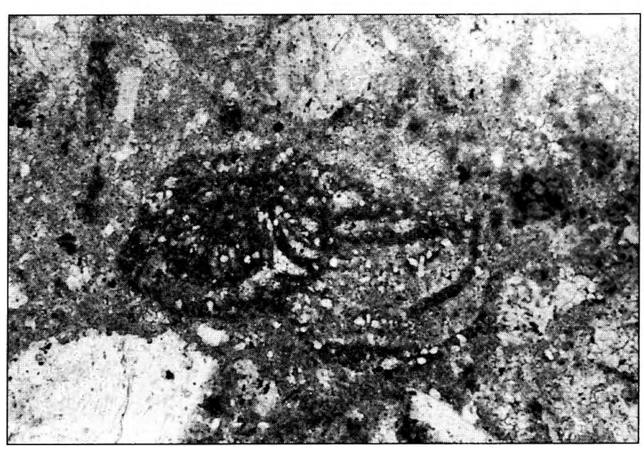
5. Packstone with *Favusella* sp., Bed 17, section 1, Bakonynána, 100×



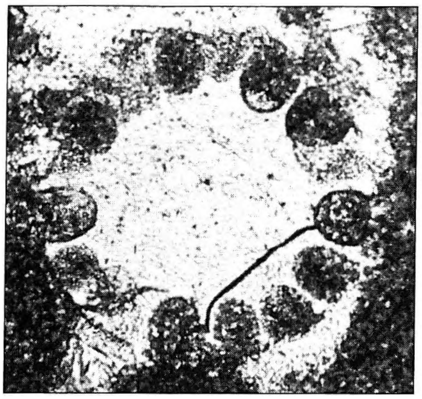
6. *Cuneolina* sp. and *Charentia* sp., Borehole Olaszfalu–83 (6.0 m), 41×



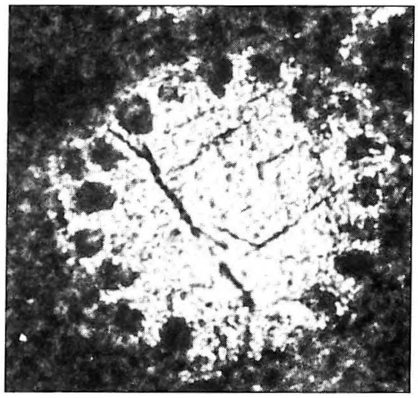
7. *Choffatella* sp., Borehole Olaszfalu–84 (70.0 m), 50×



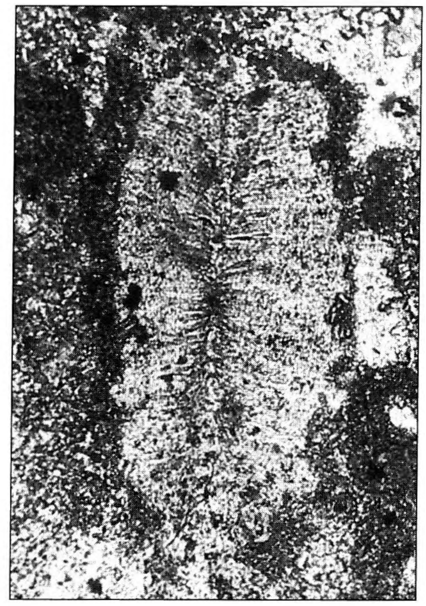
8. *Nezzazata simplex* ?, Borehole Olaszfalu–84 (70.0 m), 50×



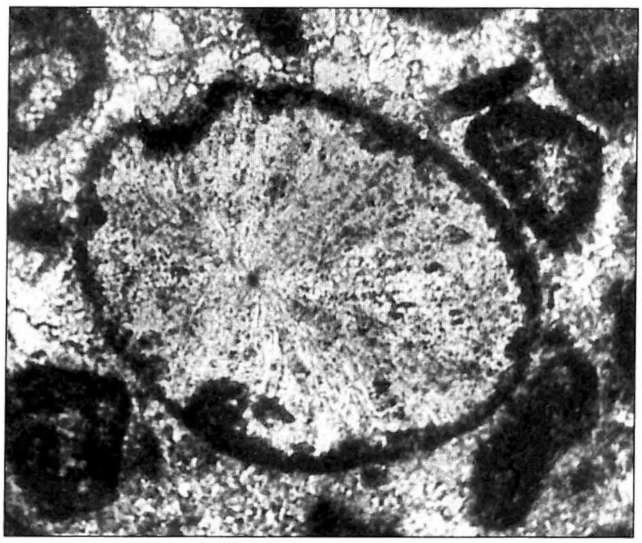
1. *Acicularia* sp., Bed 22a, Eperkés Hill, Olaszfalu



2. *Acicularia* sp., Borehole Olaszfalu–84 (54.0 m), 50×



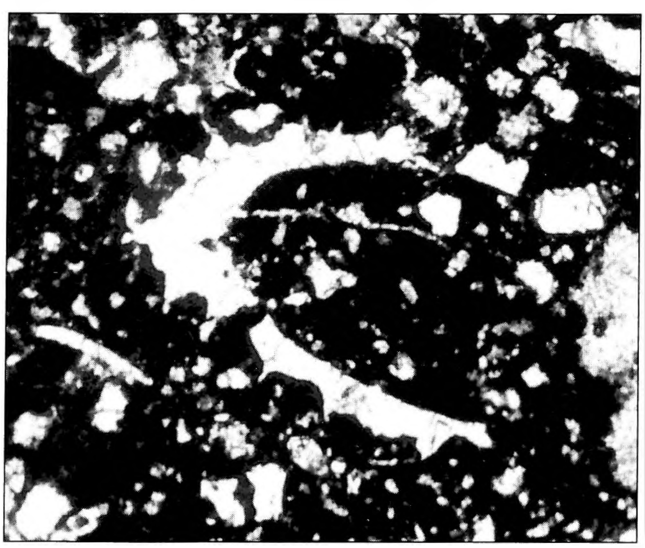
3. *Pieninia oblonga* BORZA *et* MIŠÍK, Bed 21b, Eperkés Hill, Olaszfalu



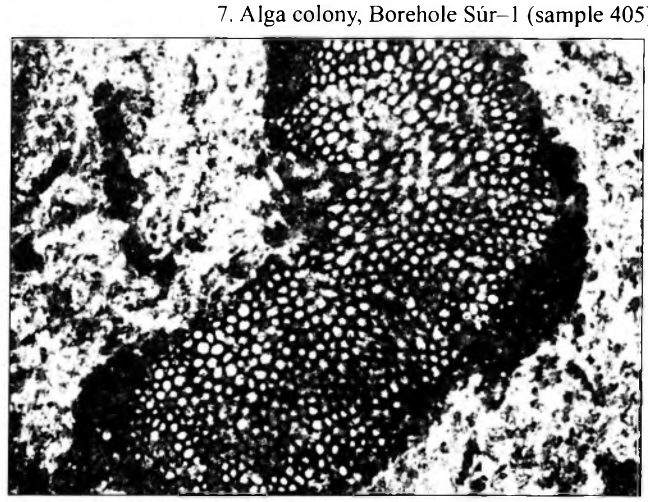
5. *Pieninia oblonga* BORZA *et* MIŠÍK, Bed 19b, Eperkés Hill, Olaszfalu

4. *Pieninia oblonga* BORZA *et* MIŠÍK, Borehole Olaszfalu–84 (79.6 m), 50×

6. *Salpingoporella* sp., Bed 15, Eperkés Hill, Olaszfalu



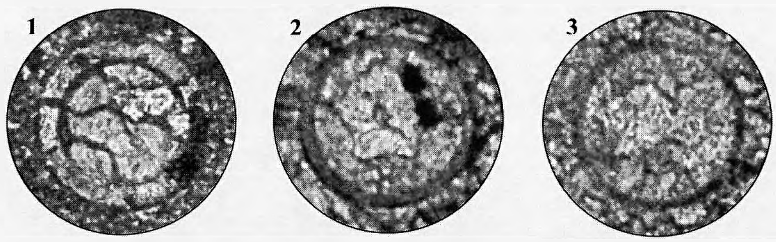
7. Alga colony, Borehole Súr–1 (sample 405)

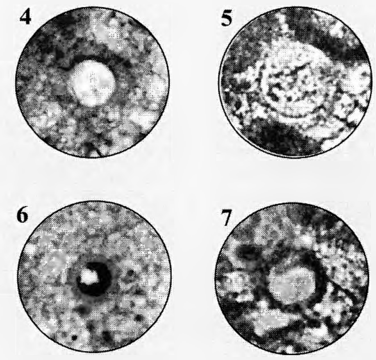


Cadosina varieties
(Determined by K. Borza)

Pénzeskúti Marl Formation (surface outcrop at Bakonynána)

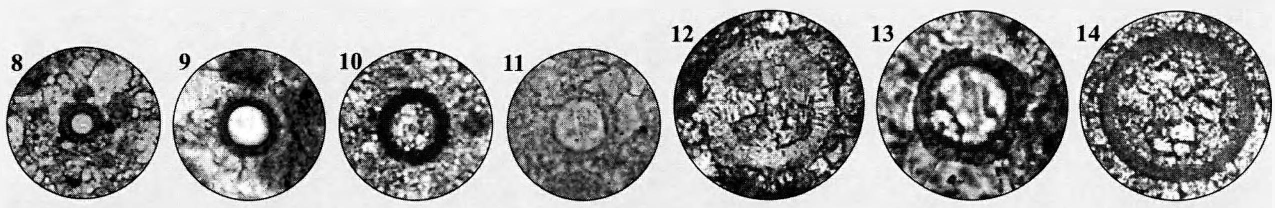
1 — Bed no 12; **2**–**3** — Bed no 1/b

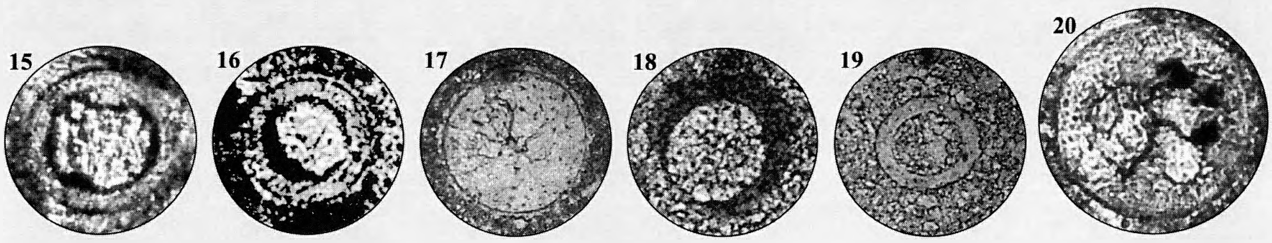


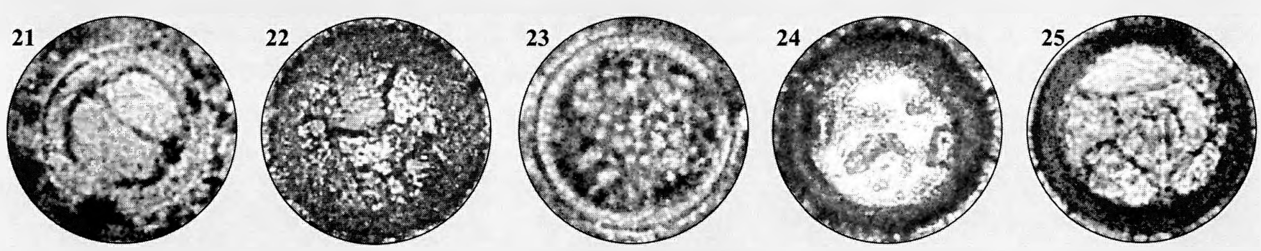


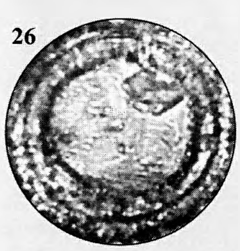
Zirc Limestone Formation. Order of data: — borehole (Pgy–5), depht (51.5 m), magnification (63×)

4 — Pgy–5, 51.5, 63×; **5** — Pgy–5, 52.0, 25×; **6** — Ot–84, 70.7, 128×; **7** — ?*Stomiosphaera moluccana?* Wanner, Pgy–5, 52.0, 63×; **8** — Zt–61, ?; **9** — Zt–61, 19.0/a, 164×; **10** — Zt–61, 20.5, 164×; **11** — *Cad. cf. tenuis* Nagy, Ot–84, 68.0, 200×; **12** — Pgy–5, 52.5, 25×; **13** — Pgy–5, 53.5, 63×; **14** — Bakonynána, bed no 16, 25×; **15** — Ot–84, 33.5/1, 25×; **16** — Ot–84, 44.5, 25×; **17** — U–421, 289.0, 170×; **18** — U–421, 301.8, 266×; **19** — U–421, 301.8, 266×; **20** — Ot–84, 38.0, 25×; **21** — Ot–84, 44.5, 25×; **22** — Ot–84, 26.5, 25×; **23** — Ot–84, 33.5, 25×; **24** — Ot–84, 33.5/1, 25×; **25** — Ot–84, 38.0, 25×; **26** — Ot–84, 31.5, 25×
(Abbreviation of boreholes: Ot = Olaszfalu, Pgy = Pénzesgyőr, U = Úrkút, Zt = Zirc)



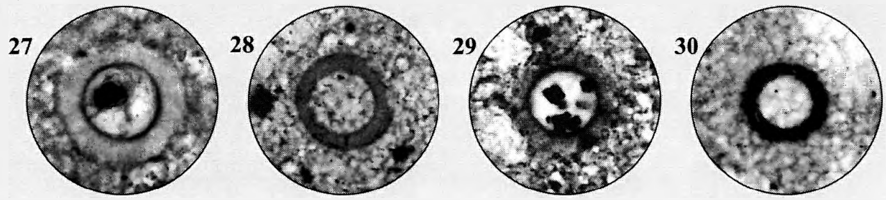






Tés Clay Formation (Boreholes: Súr–1 and Olaszfalu Ot–84)

27 — *Cad. cf. heliosphaera,* Súr–1, 338.5–341.0, 320×; **28** — *Cad. cf. semiradiata* Wanner, Ot–84, **29** — *Cad. cf. heliosphaera,* Ot–84, 79.6, 320×; **30** — *Cad. fusca* Wanner, Ot–84, 79.6, 200×



Carbon and oxygen isotope studies

Oxygen and carbon isotope ratios differ significantly depending on the media in which they are measured, *e.g.* air, or aqueous solutions such as those of depositional systems. These also display a temporal variability, especially with respect to carbon isotopes (VEIZER & HOEFS 1976; FÖLLMI *et al.* 1994; JENKYNS *et al.* 1994; VAHRENKAMP 1996 *etc.*). Although isotope ratio variations in the sedimentary record are in general not more than just a few per mils (owing to the high precision that the measurements yield) the results give a good indication of the many parameters of the formation or alteration of the rocks. However, since there are a number of factors to control the isotope ratio of a given rock or mineral — such as temperature, salinity and in some cases, further chemical features — it is not possible to evaluate mechanically and, particularly, interpret the raw data. The distribution of carbon isotope ratios is, furthermore, influenced by external factors (volcanic activity, climate) and internal factors (weathering, nutrient mobilization, productivity and burial organic matter) (FÖLLMI *et al.* 1994). However, FÖLLMI *et al.* (1994) managed to demonstrate that a relationship does exist between the distribution of $\delta^{13}C$, the sea level changes and the style of sediment accumulation. VALLADARES *et al.* (1996) argue that isotope measurements can contribute to sequence stratigraphic studies, too. VAHRENKAMP (1996) is of the same opinion and he states that the study of the patterns of $\delta^{13}C$ distribution curves from different sedimentary settings can provide new avenues for the comparison of platform and basinal carbonate sequences. To date, it has proved impossible to correlate these precisely by any other means.

It was in the 1970s when the first oxygen isotope measurements were carried out in Hungary (CORNIDES *et al.* 1979), in order to determine seawater temperature, *i.e.* to unravel tendencies in climate change. At that time, investigations were focused on rocks formed in neritic and bathyal environments. In contrast recent $\delta^{13}C$ and $\delta^{18}O$ studies concentrate exclusively on platform formations, especially on the Nagyharsány Limestone. Within the scope of these studies, for example, isotopic curves were obtained for the Harsány Hill section. Furthermore, there were individual analyses of the atoll-type structures in the Mecsek Mountains (at Mecsekjánosi, Korhadtfás Gorge, Vékény Valley) and on various facies of the Zirc Limestone (at Bakonynána and Zsidó Hill in the Northern Bakony; at Úrkút in the Southern Bakony). This is why it seems reasonable to discuss the results of the isotope studies in a separate chapter here rather than alongside the respective formations.

Stable isotope measurements were carried out in the Nuclear Research Institute in Debrecen, Hungary (HERTELENDI *et al.* 1992; Figure 65). For a description of the methods and analytical techniques applied, see HERTELENDI *et al.* 1986.

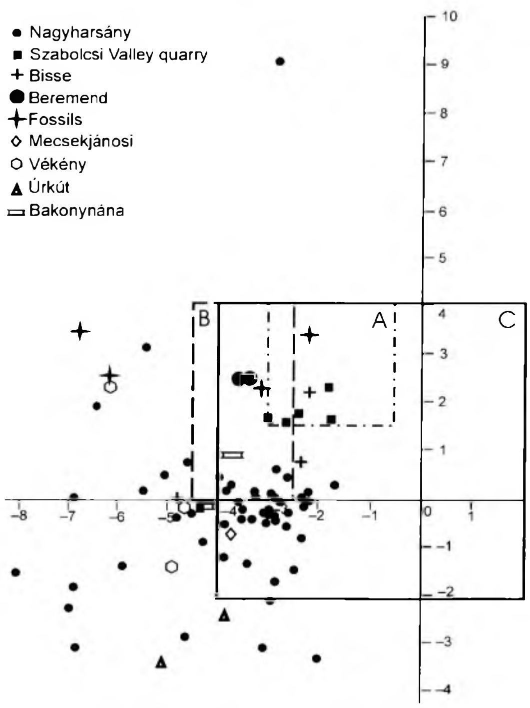


Figure 65. Scatter diagram of $\delta^{13}C$ versus $\delta^{18}O$ for Urgon formations of Hungary

A — Precipitation of $\delta^{13}C$ and $\delta^{18}O$ isotopes in equilibrium (WOO *et al.* 1993); B — Precipitation of $\delta^{13}C$ and $\delta^{18}O$ isotopes in disequilibrium (WOO *et al.* 1993); C — normal marine isotope ratio (MILLIMAN 1974)

Table 20

Distribution of carbon and oxigen isotopes and strontium in the Early and middle Cretaceous platform carbonates of the Villány Hills, the Mecsek and the Bakony Mountains

Sample	Rock characteristics	Environment	$\delta^{13}C(PDB)$	$\delta^{18}O(PDB)$	Sr (ppm)
Nagyharsány Limestone Formation					
Harsány Hill quarry					
0	Variegated marl (fissure fill)	terrestrial	inmeasurable	inmeasurable	77±2
1	Bioclastic (Jurassic)	lagoon	–1.40	–5.88	82±2
2	Bioclastic (Jurassic)	lagoon	–2.26	–6.95	
3a	Medium grey	Freshwater lake	–2.10	–2.97	
3b	Dark grey	Freshwater lake	–1.49	–2.45	155±3
4	Micritic		–3.12	–3.01	109±3
5	Micritic, slightly variegated		–0.30	–4.48	
6	Micritic, slightly variegated		–3.34	–2.00	
7	Micritic, slightly variegated		–0.26	–2.99	
8	Micritic, slightly variegated		0.14	–3.80	
9	Micritic, slightly variegated		–0.41	–4.81	
10	Red, pelitic		–1.53	–8.04	
11	Micritic		–0.70	–3.58	
12	Micritic		0.03	–2.33	
13	Bioclastic		0.43	–3.99	149±3
14	Laminoid fenestral fabric		0.24	–3.74	128±3
15	Grey with shells		9.10	–2.84	
16	Grey with shells (fragment)		0.56	–2.82	
17	Bird's-eye fabric		–0.61	–2.61	
18	Microstylolitic, pelitic levels		–0.85	–2.30	
19	Micritic		–1.74	–2.84	
20	Micritic		–0.46	–3.99	
21	Micritic, bioclastic		–0.33	–2.59	
22	Pelitic, bird's-eye fabric		–0.55	–3.02	117±3
23	Variegated marl, limestone lenses		–0.38	–2.84	
24	Brownish-yellow, bird's-eye fabric		0.27	–1.66	
25	Dark grey, small rudists		–0.05	–2.15	
26	Micritic		0.05	–2.87	
27	Micritic, bioclastic		0.04	–3.20	
28	Rudistid		–0.33	–3.07	175±3
29	Bioturbated		–0.56	–3.81	
30	Pale-yellow marl infilling		0.14	–5.46	75±3
31	Calcareous sand		–1.35	–3.88	
31a			–0.44	–3.29	
32	Pale-yellow marl infilling		0.04	–6.89	
33	Calcareous sand		–1.25	–3.85	
34	Micritic		–0.47	–3.50	
35	Micritic (fragment)		0.40	–2.60	
36	Brownish-yellow, bird's-eye fabric		–0.37	–2.98	
37	Greyish-yellow, bird's-eye fabric		–0.48	–2.82	
38	Small bird's-eye fabric		–0.24	–2.98	
39	"Black pebble"		–3.14	–6.83	217±4
40	"Black pebble"		0.09	–2.94	
41	Stromatoporoidea		2.51	–6.18	
42	Ostreidae		3.44	–6.77	256±4
Nagyharsány section II					
?m			3.13	–5.44	
30.0 m			–0.21	–2.26	
42.0 m			0.48	–5.04	
43.8 m			–0.26	–3.50	
52.0 m			–0.07	–2.77	
56.0 m			–0.92	–4.27	
64.5 m			–1.88	–6.86	
84.0 m			0.75	–4.60	
Nagyharsány section III					
?			1.89	–6.42	
?			–2.89	–4.63	
?			–0.11	–2.23	
Mean			**–0.37**	**–3.00**	

Sample	Rock characteristics	Environment	δ¹³C(PDB)	δ¹⁸O(PDB)	Sr (ppm)
Nagyharsány Limestone Formation					
Szabolcs Valley quarry					
43	Bioclastic (Jurassic)		1.66	−2.97	
44	Fine bioclastic (Cretaceous)		1.56	−1.78	
45	Red pelitic, nodular		1.63	−2.63	
46	Orbitolinit		0.11	−3.24	
47	Red calcareous marl		2.28	−1.69	
48	*Toucasia* shell		2.27	−3.13	750±8
49	*Chondrodonta* shell		3.40	−2.19	492±6
(23)			−0.16	−4.38	
(24)			1.75	−2.46	
Mean			**1.61**	**−2.72**	
Hunter's hut, Bisse					
(1)			0.015	−4.72	
(4)			2.18	−2.17	
(8)			0.74	−2.38	
Mean			**0.98**	**−3.09**	
Beremend quarry					
(17)			2.50	−3.62	
(18)			2.47	−3.38	
Mean			**2.49**	**−3.50**	
Atoll-type structure					
Mecsekjánosi					
(19)			−0.76	−3.68	
Vékény Valley					
(20)			2.28	−6.14	
(21)			−0.24	−4.64	
(22)			−1.45	−4.89	
Mean			**0.20**	**−5.22**	
Zirc Limestone Formation					
Manganese slurry reservoir, Úrkút					
(6)			−3.43	−5.10	
(7)			−2.47	−3.83	
Mean			**−2.95**	**−4.47**	
Zsidó Hill, Bakonynána					
(25)			0.89	−3.69	
(26)			−0.17	−4.27	
Mean			**0.36**	**−3.98**	

Samples withouth lithologic names are limestones. Exceptions are marked separately. Curves of δ¹³C és a δ¹⁸O are runing mainly opposing.

The isotopic data obtained (Table 20) are plotted in Figure 65. The values, especially those of the δ¹³C, are rather scattered. The bulk of the δ¹³C-values falls within +9.1 and −3.43‰ although there is only one case where the value is greater then +3.44. Negative values point most commonly to the bacterial degradation of organic matter (Bellance *et al.* 1996). Therefore, it can be assumed that enhanced bacterial activity took place at the base of the formation given that most of the negative values appear in that position. Progressing upsection, δ¹³C values are close to zero indicating more moderate bacterial degradation. Although somewhat fluctuating, in the lowermost 4-m-thick section there is an increasing tendency with respect to the isotopically heavy carbon (¹³C). Above this there is no significant excursion in the δ¹³C-values. Our results compromise the opinion of Rasmussen *et al.* (1990) who stated that the δ¹³C distribution fairly facilitates the reconstruction of sedimentary environments (*i.e.* biofacies and lithofacies), provided that both the sampling site selection and sampling density had been appropriate. The δ¹³CPDB-values of soil-derived, dissolved bicarbonate in the Upper Albian Caniego Limestone are restricted to an interval bracketed by +2‰ and −12‰ (Fernández-Mendiola & Garcia-Mondéjar 1997). Apart from a few exceptions, curves of δ¹³C and δ¹⁸O are in anti-correlation with each other.

Similary to those of carbon, δ¹⁸O -values also have significant deviations — the extremes are −1.66 and −8.04‰. In general, heavier oxygen isotopes (¹⁸O) are subordinate; this is rather characteristic of the typical platform carbonates of the Szársomlyó Limestone, where the measurement of two samples yielded an average of −6.42‰. Corresponding to the carbon isotope values, the most powerful fluctuations of $\delta^{18}O$ are found within the lowermost 4 m; however, the shape of the curve does not reflect any tendency.

The isotopic distribution pattern described above bears a good resemblance, especially in terms of oxygen, to that of the Aptian to Cenomanian sequence in Beotia, Greece (STEUBER *et al.* 1993). They experienced a coincidence of low $\delta^{18}O$ and $\delta^{13}C$-values. As they demonstrated, this is typical of the mixing zone at the contact of the meteoric and marine zones. The weaker the terrigenous influence recorded by the sequence, the more positive the isotopic ratios. This interpretation may well be adopted for the Harsány Hill section with the only exception that the latter was uninterruptedly influenced, even if decreasingly, by terrigenous materials throughout the entire time span of the studied part of the section (cFigure 16, p. 187). By comparing the ^{18}O-content ($\delta^{18}O$: –3.8 to –8.4‰) of the Cretaceous successions in Spain (VALLADARES *et al.* 1996) to the values measured in recent oceans (MILLIMAN 1974) it turns out that the recent values are higher. This discrepancy is explained by these authors by the isotopic re-equilibration owing to either meteoric or burial diagenetic fluids. In the view of JENKYNS *et al.* (1994) however, the concept of diagenetic alteration should be ignored given that, with the increasing depth, no tendency of light isotope enrichment can be observed. Nevertheless, the meteoric alteration in the Harsány Hill section is not quite well-constrained by the $\delta^{13}C$-values. The $\delta^{18}O$-values obtained for the Nagyharsány Limestone agree well with those measured on samples from Barremian to Aptian shallow-marine successions in the Gulf of Persia (–2 to –8‰ — VAHRENKAMP 1996), whereas the $\delta^{13}C$-values are remarkably higher (0.5–7‰ PDB) than those of the Nagyharsány Limestone.

Exhaustive investigations have been carried out with respect to the isotope- and element distribution of the varietis of the middle Cretaceous limestones in Texas, Arizona and Mexico in order to decipher their origin and diagenetic history (WOO *et al.* 1993). The equant and radiaxial fibrous calcite (RFC) crystals of each formation were analysed separately, in terms of their $\delta^{18}O$ and $\delta^{13}C$-values. It was concluded that the equant calcite cements, displaying $\delta^{18}O$-values between –1.1 and –10.4‰ were formed under shallow meteoric to phreatic conditions, whereas those of $\delta^{18}O$-values varying between +11.0 and –7.0‰ indicate diagenesis in a shallow meteoric zone (because these rocks have never been deeply buried). $\delta^{18}O$-measurements of radiaxial fibrous calcite yielded values in the range –0.5 to –7.5‰. Within the RFC group, values for the non-luminescent samples average about –0.5 to –2.6‰, whereas those for luminescent ones vary between –1.1 and –7.7‰. Interestingly, the latter interval overlaps with that of the equant calcites, showing that diagenetic alteration most probably took place under similar circumstances. However, the formation of the former group of calcites came about, as they interpreted, in shallow marine environment, whereas the characteristics of the latter ones suggest shallow meteoric diagenesis.

In the Cretaceous, the surface temperature of the seawater at relatively high latitudes was equal to, or higher than recent temperatures (*e.g.* SAITO & VAN DONK 1976). As a consequence, it was non-luminescent. This is to say that, original textural components may reflect higher salinities with respect to the surface waters of the Tethys, probably because of enhanced evaporation (BRASS *et al.* 1982). Although there have not been as detailed investigations separately by cement types on the Hungarian samples as there were on the American ones, the range of $\delta^{18}O$-values (–1.66 to –8.04‰) is practically consistent with that of the American samples. This would suggests that the values of the shallow-marine samples and the shallow meteoric samples are similar in both sets of samples.

Several measurements were carried out by HERTELENDI (unpublished report) on single shells of fossils. These data and those derived similarly by WOO *et al.* (1993) are compiled in Table 21.

The texturally well-preserved rudists, chondrodonts, pectinides and most of the ostreids of the American and Mexican samples display $\delta^{18}O$-values between –0.5 and –4.0‰ (WOO *et al.* 1993). With the exception of rudists, all of them fall within in the range of the non-luminescent RFC [–0.5 to –3.0‰ (domain A)]. This indicates an isotopic equilibrium with that of seawater and calcite during the formation of carbonates. It is assumed therefore that a similar scenario also applies to the Hungarian rudists and chondrodonts. Among the samples of WOO *et al.* (1993), however, there are some well-preserved rudists and ostreids, the shells of which are primarily calcitic and they display somewhat lower $\delta^{18}O$-values (–2.5 to –4.1‰) than the RFC range (domain B). According to these authors, a possible explanation might be that these shell-secreting organisms did not precipitate their carbonates in equilibrium with their environment but selected among isotopes. Among the few samples acquired during research in Hungary, no similar phenomenon was observed. WOO *et al.* (1993) have found that neomorphous rudists (requienids and caprinids) of altered texture, and some ostreid shells are depleted in ^{18}O by at least 1‰ relative to the unaltered shells and RFC cements. Sr concentrations vary in the same manner. These led them to the conclusion that the system, in terms of cations, may have been open during the diagenetic alterations. In other words, $\delta^{18}O$-values reflect the palaeotemperatures of the diagenetic fluids. With respect to the ostreid shell sample from the Nagyharsány section, the remarkably low values of $\delta^{18}O$ and Sr, also, might be explained in several different ways. In principle, a sequestration of isotopically heavy oxygens due to diagenetic alteration or the ability of isotope fractionation of fossils (metabolic fractionation) cannot be excluded. It seems more likely however, that the freshwater influence which is wide spread in the section is responsible for the low values of $\delta^{18}O$ and Sr. In general, Sr concentrations in the Hungarian samples, including shells of carbonate-secreting fossils, are much lower (77–750 ppm) than those measured in recent aragonitic shells, yielding 700–9400 ppm (VEIZER 1983) or 1300–3200 ppm (MILLIMAN 1974). The low values, and intense fluctuations thereof, are a result first of all, of the depositional media themselves (freshwater to brackish water), but also of diagenetic alterations under meteoric circumstances.

Table 21

Carbon and oxygene isotope composition of some fossil shells and sceletons

Fossil	$\delta^{18}O$		$\delta^{13}C$	
	WOO *et al.* 1993	HERTELENDI *et al.* 1986, 1992	WOO *et al.* 1993	HERTELENDI *et al.* 1986, 1992
Rudists with original shells	−4.1 — −3.0	−3.1	0.2 — 3.3	2.3
Other bivalves with calcite shells	−3.0 — −0.5	−2.2 (Chondr.)	0.5 — 3.7	3.4
Rudists with neomorphic shells	−5.9 — −2.3		−4.8 — −0.5	
Ostrea		−6.8		3.4
Stromatoporoidea		−6.2		2.5

The $\delta^{18}O$-values of stromatoporoids measured in the framework of this research are similar to those derived from the shells of ostreids. This strongly suggests that a diagenetic alteration should be encountered. $\delta^{13}C$-measurements (between +2.27‰ and +3.44‰) have revealed that the isotopically heavy carbon tends to enrich in the shells of fossils — *e.g.* ostreids, chondrodonts, *Toucasia* and Stromatopora.

Sequence stratigraphic interpretation of the Urgon-type formations

The revolutionary new approach of sequence stratigraphy has resulted in major advances in several disciplines central to basin analysis. The past 20 years, therefore, have been undoubtedly the golden age of the stratigraphy, and especially sedimentology. Sequence stratigraphy, introduced as 'seismic stratigraphy' by VAIL *et al.* (1977), early on proved to be a very powerful tool for carrying out field (and lab) sedimentology. These breaktroughs have substantially altered the view of many sedimentologists. In fact, sequence stratigraphy has become a true science with a shift of the focus of research from a geophysically-oriented approach to the development of testable, thus critical, actual geologic models based on a combination of theory and field observation with respect to different sedimentary settings. Besides eustatic changes, more and more factors controlling the formations of, or in some way affecting the sequences have been recognized: tectonic, sedimentary and environmental factors (*e.g.* interbedding of clastics in a carbonate succession), temperature, light, the current's conditions, wind direction, inherited basin-floor morphology and nutrient supply, water agitation, to name just a few. However, the number of contradictions have been likewise been increasing (*e.g.* POSAMENTIER & VAIL 1988; TUCKER & WRIGHT 1990; SCHLAGER 1991). In particular, a range of valuable papers have been published concerning the discrepancies in the characteristics of sedimentation of siliciclastic vs. carbonate rocks. This has resulted in estabilishing different models on the origin and development of these two distinct major rocks types, including the various types of carbonate platforms where they were formed (*e.g.* SARG 1988; CALVET *et al.* 1990; TUCKER 1991; TUCKER *et al.* 1993). More recently, biota has not only been regarded as a mere rock-forming constituent or a decisive record for the sake of chronostratigraphy but, in some cases, also as a powerful tool for recognizing such sedimentary units as sequences, parasequences and systems tracts (HOEDEMAEKER & LEEREVELD 1995; LEEREVELD 1995; SIMMONS & WILLIAMS 1992). A convincing example is provided here by the results of a detailed testing of materials on Borehole Vst–8 (LEEREVELD 1992a) and, based on this work, by the sequence stratigraphic evaluation (Figure 54).

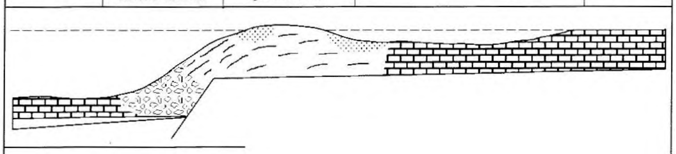
Water depth is a dominant factor for controlling carbonate sedimentation, but it also has a substantial effect on water temperature. The productivity is most intense at water depths shallower than 10 m. Beneath this, productivity rapidly decreases (HUNT AND TUCKER 1993). The energy of the environment is highest at the inner ramp and the shelf margin and, in turn, the rate of sedimentation decreases with increasing distances from these areas. Wind-generated currents have similar effects on sedimentation; a reef has developed on the windward side of the platform margin with a steep slope and associated sediment trasport (by-pass), whereas the leeward margin dips gently and, in fact, forms an accretionary sand apron.

Platform progradation is caused mainly by sediment gravity flow. Slopes were subdivided into accretionary, by-pass and erosional types by SCHLAGER & GINSBURG (1981).

TUCKER & WRIGHT (1990) distinguished shelves of the following types: rimmed, aggrading and drowning shelves. An example of the former two is given in Figure 66 (taken from HUNT & TUCKER 1993, p. 310). A rimmed shelf develops when sea level fluctuations of a high magnitude take place, namely, in icehouse periods. In contrast, aggrading shelves form under greenhouse circumstances

a)

BASIN		SLOPE	CARBONATE RIMMED SHELF		
Below fair weather wave base			Maximum wave action	Protected	Subaerial
Shales/ pelagic	Re-sedimented carbonates		Reefs and carbonate sand bodies	Lagoonal and tidal flat carbonates	Supratidal carbonates
Mudstones	Grain/rud/float/ wacke-stones		Boundstones/ grainstones	Wackestones–mudstones	Mudstones



b)

BASIN	SLOPE	CARBONATE AGGREGATED SHELF	
Below fair weather wave base		Maximum wave action	Near-uniform shallow-water conditions across shelf
Shales/ pelagic limestones	Resedimented carbonates	Reefs and carbonate sand bodies	Parasequences of shallow subtidal to supratidal facies

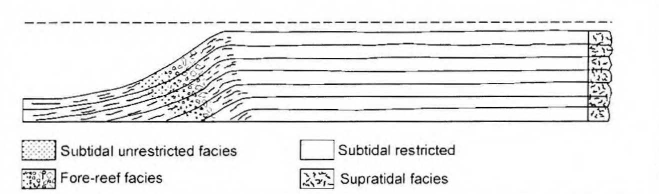


Figure 66. Types of carbonate shelfs, after Tucker & Wright (1990)

when sea level fluctuations come about on a much smaller scale (Tucker 1992). It has been known for a long time that platform carbonates occur as bundles of a few m thickness. Theoretically, such a bundle is built up as follows: at its base, carbonate mudstones occur, formed under the wave base. They are overlain by intertidal mudstones of a fenestral structure or grainstones of keystone character. On their top, indications of subaerial exposure may sometimes occur. Such regressive minor cycles are called parasequences and are considered as having formed as a consequence of fourth- or fifth-order sea level fluctuations (10^4 and 10^5 years).

The composition of a parasequence is a function of many factors such as its position on the shelf, the amplitude of the sea level change, bathymetry relative to the sea level change and the rate of sedimentation. Nevertheless, any systems tract is characterized by a given style of superposition of parasequence sets, and, after all, this pattern may be attributed to the second- and third-order cycles (10^6 and 10^7 years).

Sequence boundaries are formed due to sea level fall and are characterized by a pronounced basinward facies shift. There are two different sorts of sequence boundaries. A type 1 sequence boundary is a result of a considerable sea level fall. As a consequence, the actual sea level will be beneath the offlap point and this results in the absolute surface exposure of the shelf. A type 2 sequence boundary is formed when the sea level fall does not exceed the offlap point. In other words, the increase of the accommodation space is reduced to a minimum and a slow relative sea level rise takes place. As pointed out by Hunt & Tucker (1993), carbonate shelves mainly involve type 1 sequence boundaries — that is to say, shelf margin wedges are very uncommon. According to Tucker *et al.* (1993) and especially Hunt & Tucker (1993) Type 2 sequence boundaries form chiefly on homoclinal ramps. However, they argued that not every sea level fall resulting in the subaerial exposure of the shelf can be considered as a sequence boundary. Any similar but much shorter event may account for the formation of a parasequence boundary. In my opinion, the detailed informations that has accumulated represents an enormous literature. Thus, more and more uncertainties have arisen with respect to the typification of the boundaries. Furthermore, this is hampered by the fact that boundaries indicating subaerial periods are too frequent in some sections and it is not possible to look into their areal extent. Here, the Nagyharsány Limestone or the Úrkút Member of the Zirc Limestone serve as good examples, because the respective variations therein are not characteristic enough to be able to classify them even as parasequence boundaries. Furthermore, the number of sequences and parasequences, hitherto defined by several authors, is remarkably larger than it was a decade ago. This controversy arises partly due to the fact that is no possible specify exactly the cause(s) of the higher order sea level changes. On the other hand, on such scales many further factors, causing relative sea level falls, are inevitably encountered. As a consequence, doubts continue to accumulate as to whether these sea level changes are indeed global. In contrast to earlier attempts, in the present work I will endeavour to avoid the terms 'sequence' and 'parasequence' because distinguishing these terms in small outcrops we have is uncertain and because their statigraphic subdivision has no firm base to use the curves of Vail *et al.* (1977), Haq *et al.* (1988) Hardenbol *et al.* (1995), or any other versions. Events on carbonate shelves driven by sea level changes will be briefly discussed here, largely following Hunt & Tucker (1993).

Carbonate shelves are dominated by chemical erosion, in contrast to the siliciclastic shelves, where physical erosion is the most decisive factor. The rate of chemical erosion is a function of climate and precipitation. At lowstand conditions the rate of pelagic sedimentation drastically decreases since the formation of carbonate mud ceases on the shelves (Crevello & Schlager 1980; Wilber *et al.* 1990). Hence, condensed sediments are formed in the basin. However, during sea level falls and under lowstand conditions two different kinds of sediments may form. Allochthonous matter is derived from the mechanical transportation of the sediments produced during the previous highstand whereas autochthonous sediments are newly-formed on the fore-slope (Sarg 1988).

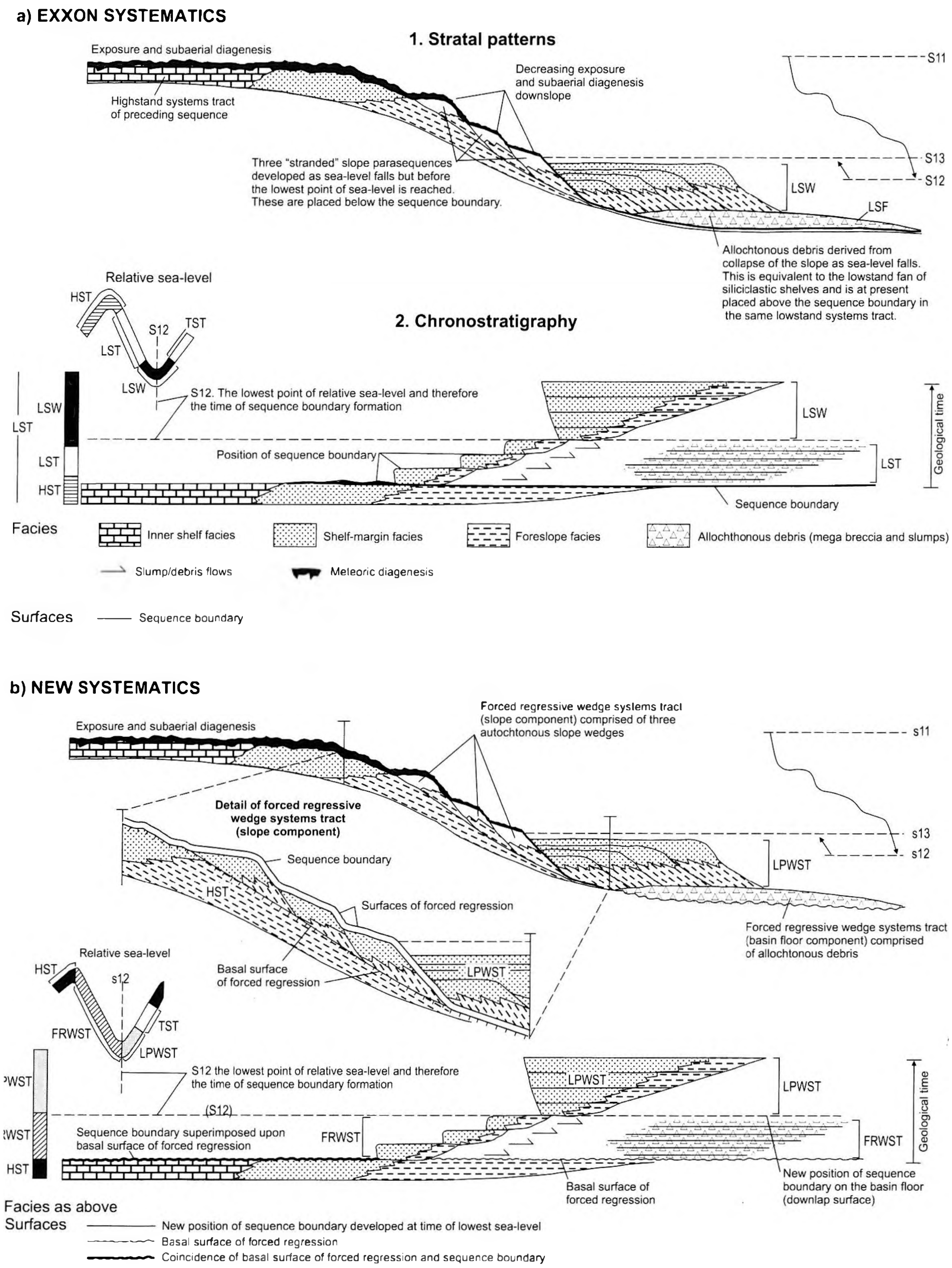


Figure 67. Cross-section of carbonate sand-shoal rimmed shelf showing facies, stratal pattern, chronostratigraphy and relationship to relative sea level, after Hunt & Tucker (1993)

autochthonous sediments are newly-formed on the fore-slope (Sarg 1988).

The allochthonous sediments, similar to the siliciclastics, rarely accumulate to form a slope fan or apron (Wright & Wilson 1984) of turbiditic origin; more often, they occur as slumps or megabreccias derived from the sediments of a given highstand systems tract. The rock mass which is interbedded in the Vértessomló Siltstone of Borehole Vst–8 and made up of platform-derived biodetritus can be regarded as such an allochthonous sediment (Figure 54). By defining the basin-floor fan sequence boundary, Hunt & Tucker (1993) appear to be inconsistent since in their Figure 5 it is drawn below, but in Figure 6 above the outer fan; thereby they introduce the term "forced regressional wedge sys-

With respect to mixed siliciclastic/carbonate sediments, the principles of siliciclastic sedimentation need to be applied. For this reason, the occurrence of the Tés Clay above the Környe Limestone is, at least partially, a consquence of a fall in the sea level.

An allochtonous lowstand wedge developed on a platform fundamentally differs in terms of its size and extent from that formed on a ramp. This is beacause of the different potentials of the respective carbonate factories. A considerable progradation can be encountered on a ramp-type depositional area and if the slope angle is steeper then secondary basin-floor sediments will also be produced.

The conditions prevailing when a forced regressional systems tract (FRWST) is formed are considered to be special by HUNT & TUCKER (1993). In other words, the geometry, place and even, the occurrence itself of the sedimentation during a sea level fall of a third-order are markedly influenced by a higher order sea level change (Figure 67; taken from HUNT & TUCKER 1993, Figure 6, lower part). However, I have not been able to demonstrate this phenomenon because it was not present in the sections I studied. It is for this reason that the relevant conditions of the formation are not discussed here.

To sum up, in the carbonate sedimentary systems during a sea level fall and during lowstand situations the volume of sediments formed tends to decrease and may even be reduced to zero. In contrast to this, the siliciclastic systems do not share this feature.

The beginning of the transgressive systems tract (TST) is coeval with the first backstepping parasequence given that the accommodation space on the shelf increases relative to sediment supply (VAIL *et al.* 1977, VAN WAGONER *et al.* 1990). This is exactly what happens at the base of the Tata Limestone, and, in marginal areas (*e.g.* Borehole Pv–980), also at the base of the Környe Limestone. This, unconformably, overlies a hardground surface. Furthermore, I include both the Eperkéshegy and Mesterhajag Members of the Zirc Limestone in this group. Even though the Nagyharsány Limestone as a whole cannot be interpreted yet, a major part of its succession can be assigned beyond doubt to several transgressive systems tracts.

On the basis of the relationship between relative sea level rise and the rate of sedimentation, HUNT & TUCKER (1993) defined two archetypes of sediment geometry. Archetype 1 reveals that sea level rise exceeds the rate of sedimentation whereas archetype 2 indicates a sea level rise that does not exceed the rate of sedimentation (see Figure 68; taken from HUNT & TUCKER 1993, Fig. 7). In the case of carbonate systems, they subdivided these archetypes into a couple of subtypes, based on local rates of sedimentation and relationships to mean wind direction. Within archetype 2, the accretionary shelf margin may grade vertically into a by-pass-, or even erosional-type shelf margin, resulting in the occurrence of the allochthonous toe-of-slope and outer fan deposits. This is, in particular, typical of shelf margins with associated reef buildups. We can assume that this may be the point for the upper limestone megabreccia level in the Köszörűkőbánya quarry at Lábatlan, whose formation is most probably explained by a catastrophic rock fall.

SCHLAGER (1981) has shown that in the case of type 2 transgressive systems tracts, sea level rise could not have been driven by glaciation-induced sea level changes because this would have involved platform drowning. However, the changes in the geometry of the sediment cannot be traced back simply to the changes in the rate of sea level rise because the rate of sedimentation is far from being constant (VAIL 1987; SARG 1988) as it is a direct function of the sedimentary environments. This circumstance confirms my scepticism, mentioned also earlier, about whether the sea level changes resulting in the formation of sequences and parasequences are really due to a global effect.

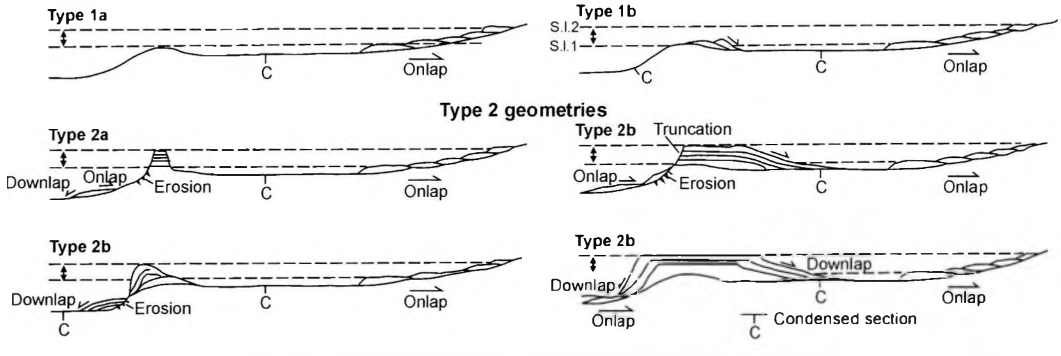


Figure 68. Geometric standard types determined on the basis of relation between sea level rise and sediment accumulation, after HUNT & TUCKER (1993)

In the case of type 2 transgressive systems tracts the lagoon becomes too deep and this has given rise to the accumulation of muds rich in organic matter. A striking example is provided by the relative sea level rises of a second order which have led to the formation of successions that reserve 70% of the known carbonate-hosted hydrocarbons of the world (GREENLEE & LEHMANN 1990).

By definition, highstand systems tracts overlie the maximum flooding surfaces. They are formed when the rate of sedimentation exceeds the rate of relative sea level rise at both the outer and inner shelves. A highstand systems tract represents a period within a sequence that is characterized by maximum carbonate productivity (MULLINS 1983) given that shallow marine conditions extend areally to their maxima. This is accompanied by the progradation of the clinoform. There are two types known: one is the 'slope apron' and the other is 'toe of slope apron'. This so-called "highstand shedding" could be the cause of the shallowing of the basins, and, in the case of Környe Limestone, also its filling up. In this context, the Kecskéd Member, as a succession of slope apron sediments, and the topmost beds of the Kocs Member seem to record this event.

The actual sedimentary character of a distinct unit defined as the Tés–Környe Formation and overlying the Környe Limestone, was controlled during sedimentation by the interplay between eustatic sea level changes and the increasingly dominant delta system. Basically, this succession can be confined to a lowstand systems tract. However, there are intercalations of Urgon facies, yet with an upward decreasing Urgon character, along with an upward-decreasing tendency in salinity in the Tés Clay. These are interpreted as the products of minor sea level rises driven by cycles of a higher order. Depending on the rate of sea level rise, the consequences of maximum flooding may show significant contrast. If the transgression is rapid and powerful enough then the sedimentation cannot keep pace with subsidence and the platform drowns. The drowning of the Zirc Limestone platform progressed in such a manner and there is evidence that this was a stepwise event; two stages of platform drowning could be distinguished. The formation of the Gajavölgy Member of the Zirc Limestone was preceded by a short-lived sea level fall which also resulted in a moderate "micro"karstification. This was then followed by a rapid transgression which formed the Gajavölgy Member. This is in all likelihood a highstand, rather than a transgressive systems tract. The following sea level fall was again be accompanied by karstification. Subsequently, an even more rapid and largish sea level rise occurred and this was responsible for the most important condensation event in the Albian. It is assumed that a similar process affected the atolls at the Mecsek Mountains but the record there is too obscure to be analysed with confidence. The "untimely" (pre-Vraconian) drowning of the Nagyharsány Limestone can be traced back to the formation of a flexural basin (for details, see Chapter: Early to middle Cretaceous evolution of the Tisza Unit...). A perusal of the literature provides evidence of a number of contributions to the phenomenon in which an enormous sea level rise is preceded by such a sea level fall. This results in the abrupt superposition of pelagic or hemipelagic sediments — indicating maximum flooding — onto the karstified surface of the shallow marine sediments of the highstand systems tracts (ARNAUD-VANNEAU *et al.* 1995). The example provided by the contact between the Zirc Limestone and Pénzeskút Marl is just as clear and pleasing to observe as those at the Pacific atolls.

There is a great number of works concerning the carbonate platform drowning which occured within the *Rotalipora appenninica* Zone. Based on their observations in the Tethyan, Pacific and Atlantic regions, GRÖTSCH *et al.* (1993), in spite of local stratigraphic uncertainties, have arrived at the conclusion that in the Late Albian a sea level rise of 50 to 150 m amplitude took place. FERNÁNDEZ-MENDIOLA & GARCIA MONDEJAR (1997) give a description of 14 occurrences from all over Europe and South and Central America, on the bases of their own field observations and the work of others. This comprehensive study includes many assorted sedimentary settings. Excluded however, were the aforementioned data from the Pacific.

Having captured the essence of that study, I compiled this short list:

Number of cases	Sediment inferior to unconformity	Sediment superior to unconformity
6	carbonate platform	a variety of deep-sea sediments
1	carbonate platform	shallow-marine, siliciclastic
1	carbonate platform	carbonate platform (followed by karstification)
5	siliciclastic	hardground surface, sequence boundary
1	siliciclastic	siliciclastic

Based on the above, I would like to emphasize again that there is not total confidence in the possibility of identifying single sequence stratigraphic units, nor in the distinguishing of sequences and parasequences. Similarly, the full global character of the sea level fluctuations has also been questioned. Notwithstanding this, the study of formation exchanges in the Transdanubian Range (Zirc Limestone and Pénzeskút Marl) and in the Mecsek Mountains (Magyaregregy Conglomerate and Vékény Marl), as well as the assimilation of the above literature, have led me to the conclusion that sequence stratigraphy is not only the most powerful tool for interpreting sedimentary history on both local and regional scales but it also facilitates correlation among the third-order units. Furthermore, it assists the progress of correlating global events when applied to units of a lower order. However, one should be very careful because employing the term'global' without qualifying that term only gives rise to the discrediting of this technique. After all, sequence stratigraphy cannot be treated as a nostrum.

Significant Urgon formations in the neighbouring areas

WESTERN CARPATHIANS

Formations of Urgon facies are known in the Western Carpathians both in the territory of the Slovak Republic (MIŠÍK & SYKORA 1981; MIŠÍK 1990; MICHALIK 1994) and Poland (LEFELD 1968, 1974, 1988; LEFELD *et al.* 1985). The following discussion is mainly based on the comprehensive review of MICHALIK (1994) and to some extent, on my own observations (CSÁSZÁR *et al.* 1989). According to MICHALIK (1994), the Penninic Trough was bordered from both north and south by a carbonate platform. The Urgon platform to the NNW of the trough corresponds to the Outer Carpathians and can be related to the Schrattenkalk of the Helvetic Zone as well as the Máramaros Block of the Eastern Carpathians. In the Western Carpathians the formation is developed on the obducted slices of the accretionary wedge known as the Andrusov Ridge (BIRKENMAJER 1988). In this area however, the Urgon formations have been entirely eroded but have only recently been found only as cobbles (Upohlav, Proč and Strihovec Conglomerates) and as transported clastics in olistostrome and flysch successions (BIRKENMAJER & LEFELD 1969; JABLONSKÝ & MARSCHALKO 1992). The Urgon limestone cobbles contain a remarkable amount of detrital chromium spinel which reveals that ultrabasic units were obducted onto the Andrusov Ridge. Based on the coexistence of Archalveolina (BASSOULET *et al.* 1985) in this area, as well as in the Dinarides and Villány Hills, it can be regarded as a South Tethyan faunal element. However, it is intriguing that MICHALIK (1994) alludes to some anonymous workers proposing to connect these areas palaeogeographically.

In the Inner Carpathians there are several surface outcrops that expose Urgon limestones. The Late Barremian to Early Albian (MASSE & UCHMAN 1997) Wysoka Turnia Formation in the Higher Tatras, LEFELD *et al.* (1985), exhibits various facies, such as a sincere reef as well as a fore-reef and slope sediments. As reflected by the sections, the time span represented by the hiatus may range from Late Aptian to Early Albian. The Tatra Platform containing both autochthonous and allochthonous facies (MASSE & UCHMAN 1997) is separated by the Križna Basin in the south and the Osobita Basin in the north. In the Tatras, the Urgon limestones are capped by a glauconitic and phosphoritic marl unit of Middle Albian age (Zabijak Formation).

The Tatra Platform, which has recently been found to have the northernmost setting (49° N), could have been situated at the same latitude as the Provence facies, that is, at 28° N (MASSE & UCHMAN). This position corresponds to the Pre-Apulian Zone

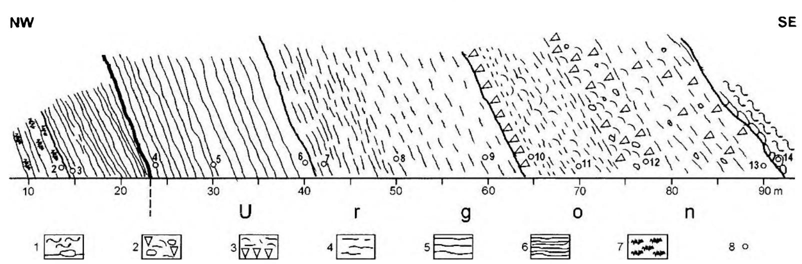


Figure 69. Coarsening upward sequence of platform derived material accumulated on the slope, Manín Gorge, Slovakia (CSÁSZÁR *et al.* 1989)

1 — Dark grey marl with calcareous marl and limestone nodules at the base; 2 — Bioclastic limestone with rudist fragments and rudist pebbles; 3 — Coarse-grained bioclastic limestone with rudist shells; 4 — Weakly bedded limestone with tiny clay lenses; 5 — Thin- and thick-bedded limestone and limestone banks; 6 — Laminoid and thin-bedded limestone; 7 — Cherty limestone; 8 — Sampling sites

defined by Tollmann (1990), which is in fact a realm between the Apulian and European plates of the Tethys Ocean. The algal assemblage of the Tatra Platform has similarities with that of the Carpathian–Balkan Region, allowing Masse & Uchman (1997) to classify this domain as belonging to the Pre-Apulian area.

The well-exposed, upward-coarsening clastic sequence at the Manín Gorge is capped by the Manín Formation of Urgon facies (Figure 69; cPlate XVI: 1–4, p. 203). It exhibits a hardground surface which is overlain by Upper Albian marl beds (Butkov Marl). Birkenmajer & Lefeld (1969) reported a similar column near Haligovce. Michalik (1994) argued that there are many late Early Cretaceous distal turbidites which could also be assigned to this group.

EASTERN ALPS

There are two structural units in the Eastern Alps where formations of Urgon facies are found. In the Helvetic Zone, which was a part of the European margin, there are many excellent outcrops of the Schrattenkalk which are Late Barremian to Early Aptian in age (Heim & Baumgartner 1933; Zacher 1973; Scholz 1984; Funk & Briegel 1979; Császár *et al.* 1989, 1994). With respect to its age and facies, the most closely related formation to Schrattenkalk is the Nagyharsány Limestone although there are still some noticeable discrepancies (Császár *et al.* 1994). The Schrattenkalk (cPlates XVII: 1–4, XVIII: 1–3, XIX: 1–4; p. 204–206) consists of both autochtonous beds [containing rudists, coral colonies of patch-reef type, orbitolines (bPlate XXVI, 1–12, p. 147), dasycladaceans, *etc.*] as well as allochthonous sediments comprising calcareous sand beds made up of biodetritic material. These were formed on the fore-slope and in the basin. It is underlain by the Drusberg Formation of basinal facies and underlies the hemipelagic Garschella Formation. Further to the south it passes laterally into the Drusberg Formation and in this basin it is followed by the Mittagspitz Formation. In addition to its similarities with the Nagyharsány Limestone, its remarkable coral content is comparable to that of the atoll environment in the Mecsek Mountains (Baron-Szabo 1997). The E–W stretch of the Helvetic platform is estimated to be 1500 km by Funk *et al.* (1993), whereas its width may range up to 100 km. According to Baron-Szabo (1997), the western termination of the zone is in Provence whereas it can be traced as far as to the Western Carpathians in the east. The original position of the platform was at the southern continental margin of Europe, that is, at the northernmost zone of the Tethys at about 35° N (Barron 1987). According to the coral investigations of Fabricius (1977), Baron-Szabo (1997) has demonstrated that sea level temperature could not have fallen below 20 °C even in the cold season.

The evidence of the sometime existence of Urgon formations in the Northern Calcareous Alps is retained by limestone pebbles that suggest a substantial spatio-temporal extent of the platform (Allersmeier 1981 in: Schlagintweit 1990b; Hagn 1982, 1983; Weidich 1984; Schlagintweit 1987; Wagreich & Schlagintweit 1990). The pebbles are found in a variety of settings: *i.e.* in six stratigraphic horizons of three different structural units. Within the Tirolicum in the south, it is only the Eocene Kohlenbach Conglomerate which contains Urgon limestone clasts (Allersmeier 1981), and similarly, the Miocene Wachtberg Gravel (Hagn 1983) in the Sub-Alpine Molasse Zone in the north. In contrast, the occurrences in the Lechtal Nappe of the Bajuvaric Nappe System have a much more plentiful supply of Urgon pebbles. Equally abundant is the easternmost occurrence which is represented by the Gosau Basin resting upon the Lunz Nappe. At these localities the pebbles are found in the following stratigraphic horizons: Barremian, Aptian, Cenomanian, Senonian and Eocene (Hagn 1982; Schlagintweit 1987; Wagreich 1986; Wagreich & Schlagintweit 1990). Innumerable studies have demonstrated that these Urgon limestones had been formed during a time interval between Barremian and Cenomanian, in contrast to their Late Barremian to Early Aptian counterparts at the European margin. Pebbles of different ages reflect various facies. However, so far no typical Urgon facies has been discovered amongst Barremian pebbles; there is only a variant pertaining to the bioclastic calcareous sand facies. The most manifold facies types stem from the Aptian stage, and also from the Albian; however, this is difficult to distinguish from the former one. By this time not only had the internal or open platform or lagoonal area was developed (indicated by rudists, green algae, primitive red algae and miliolinids) but also a freshwater or brackish waterlagoon or a separated lacustrine swamp, as mirrored by the appearance of *Munieria* and characeans. In addition, microfacies analyses have demonstrated that also further facies are present. These are in evidence around the patch-reef (orbitolinid grainstones and rudists and various rudstones with fragments of algae) and the sand shoal (ooidal grainstone), and they are also indicated in the outer slope zone (a grainstone with arenaceous foraminifers, red algae of 'Vimport facies', and platform foraminifers).

With regard to the palaeogeographic pattern of the pebbles of the Urgon facies, there are currently two models, both of which deal with their origins and palaeotransport direction. The first model, presented by ALLERSMEIER (1981), WAGREICH (1986) and TOLLMANN (1987), proposes that these pebbles, together with quartz porphyry pebbles, were transported into the basin from the north. The second model, though, comes up with the idea that the material is derived from the erosion of the platforms developed on the northward-migrating nappe fronts, probably at the southern part of the Bajuvaric Nappe or at the northern rim of the Tirolic Nappe (HAGN 1982; WEIDICH 1984; SCHLAGINTWEIT 1990).

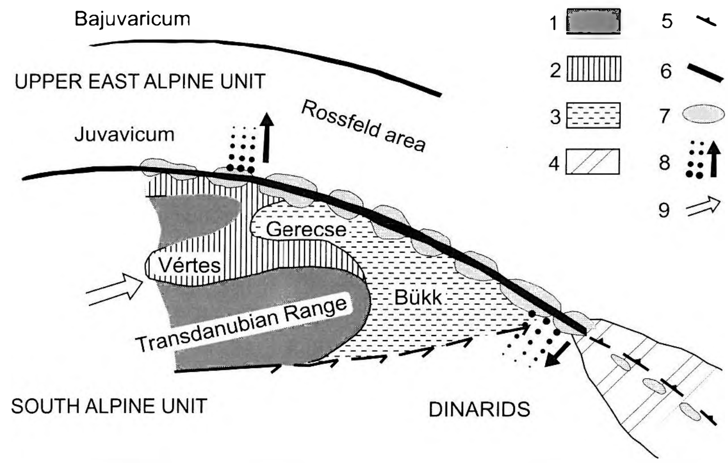


Figure 70. Palaeogeographic sketch map of the northern part of the Transdanubian Range and surrounding areas in the Early Albian

1 — Land, 2 — Carbonate platform; 3 — Hemipelagic and pelagic basin; 4 — Oceanic basement; 5 — Subduction zone; 6 — Obduction zone; 7 — Island arc; 8 — Transport direction; 9 — Escape direction

The facies and the fossil assemblage of the Urgon of the Northern Calcareous Alps is rather similar to those of the Pelso Unit. In his reconstruction, SCHLAGINTWEIT (1990), mostly on the basis of the palaeogeographic sketch maps of TOLLMANN (1987) and HAAS & CSÁSZÁR (1987), outlined the probable Early Cretaceous arrangement of the domains under discussion. Accordingly, on both sides of the obducted portion of the basement of the Vardar Ocean there was a basin; the basin where the Rossfeld Formation was accumulated was situated to the north, and the Gerecse siliciclastic basin to the south, with the momentous appearance of chromium spinel in both depositional areas.

CSÁSZÁR & ÁRGYELÁN (1994) presented a similar map but with more datails with respect to the Transdanubian Range (Figure 70). Agreeing with TOLLMANN (1987), it is suggested that there was a left-lateral strike-slip displacement contemporaneously with, and most probably induced by, the collision-related uplift in the Drau Range. This was much more intense during the Late Cretaceous movements. This movement rejuvenated in the Palaeogene and ended for the Early Miocene.

APUSENI MOUNTAINS

Because it is also a part of the Tisza Unit, formations of the Urgon facies of the Apuseni Mountains are nearly the same as those encountered in the Hungarian territory. A direct connection between them was proposed as early as by FÜLÖP (1966) and PATRULIUS & BLEAHU (1967). On the other hand, the term 'Villány–Bihar Zone' also seems to be appropriate.

The Apuseni Mountains characterized by north-vergency is built up of two facies-structural units: a northern domain which contains chiefly continental shelf elements and a southern unit comprising an oceanic basement. The principal subunits of the northern unit are: Bihar Autochthonous, Codru Nappe System and the Biharia Nappe System (IANOVICI *et al.* 1976). Formations of Urgon facies are known from the northern unit, namely, the Bihar Autochthonous. This is a part of the Villány–Bihar Zone and is exposed in the Bihar Mountains and Pădurea Craiului Mountains. Another occurrence is in one of the nappes of the Codru Nappe System. The subjacent rocks show slight variations in facies at different places and have, therefore, different names (*i.e.* Farcu, Cornet, Albioara and Criş Formations). Besides this, all of them can be compared with the Szársomlyó Limestone. All these formations were subject to a minor uplift and, thus, to karstification during the Late Jurassic and earliest Cretaceous. As a consequence, dolines of various sizes were formed and in these traps bauxite has accumulated. The bauxites are similar in character to those in the Villány Hills, but much more voluminous. The Cretaceous sequence, which appears as a distinct sedimentary cycle, shows serious discrepancies from area to area, in terms of both facies and age.

The shortest hiatus between the Jurassic and Cretaceous rocks was found in the Bihar Mountains (DRAGASTAN *et al.* 1986). The point is that the Criş or Albioara Formations were overlain by the Glăvolui or Hodobana Formations as early as the Early Berriasian. At the base of the 100-m-thick Glăvolui Formation there are limestone clasts which contain calpionellids and green algae as well as bauxite clasts. These are embedded in red clay. However, the main mass of the formation is built up of green algal intrasparitic and pelsparitic limestones. The oosparitic Hodobana Limestone, which is contemporaneous with the Glăvolui Formation, contains bauxite boulders at its base, too. The Hodobana Limestone is, in contrast, a maximum 50 m in thickness, dark grey in colour, micritic in its matrix, and contains calpionellids indicating the *Calpionellopsis* and *Calpionellites* biozones (Dragastan *et al.* 1986). Superjacent to the Glăvolui Formation a further bauxite horizon can be observed. In contrast with the two former formations, the only true limestone of the Urgon facies in the Bihar Mountains is the Blid Limestone Formation, which is of Barremian to Aptian in age. It unconformably overlies the previous formations or the bauxite. The lowermost, ostracod-bearing beds of the Blid Limestone are freshwater to brackish water in their origin. These are overlain first by oncoidic, miliolinid limestones and then by rudistid, orbitolinid limestones (Mantea 1985; Bucur *et al.* 1993). The Urgon facies is followed by the hemipelagic Ecleja Marl in the Aptian. Within this, the second Urgon limestone horizon has developed. The third horizon (of merely 10 m thickness) is found as an interbedding in the Albian glauconitic sandstone beds. Besides the rudists therein, it is characterized by an unprecedented richness of corals.

In the Pădurea Craiului Mountains there is a 4-m-thick, characean, ostracod-bearing limestone succession also containing tiny gastropods. In fact, this unit is the base of the lower member of the Blid Limestone whose maximum thickness is about 500 m. This member is broadly identical to the aforementioned facies in the Bihar Mountains. However, the age of these rocks is Hauterivian to Early Barremian. In this area, the Late Bedoulian to Gargasian Ecleja Marl starts with the Gugu Breccia (Bordea & Istocescu 1970; Patrulius *et al.* 1982). The thickness of the second member of the Blid Limestone may reach 50 to 150 m. The most spectacular outcrop of the third Urgon horizon is found in the Pietroaca Valley.

In the Vălani Nappe, which is a part of the Codru Nappe System, there are Urgon limestones with small patch reefs in them. At their base, characean, freshwater limestones are interbedded. The age of these Urgon limestones is reckoned to be Barremian to Early Aptian. Ecleja Marl also occurs in this area. A few allochthonous limestone lenses consisting of biodetritic material appear within it. These lenses are composed of fragments of corals, echinids, rudists, foraminifers and rivulacean algae. Sedimentological analysis of the limestone bodies has not yet been carried out. There do not appear to be any notes in the literature about the occurrence of the third Urgon horizon within the Vălani Nappe.

In conclusion, during the Jurassic and Cretaceous the Transdanubian Range and, as its parts, the Vértes and Gerecse areas were situated at, or in the vicinity of the southern (southwestern) margin of the Vardar Ocean (Figure 71). Formations of Urgon facies were first developed here only in the Albian or, perhaps, in the Late Aptian. Progressing to the west, the oceanic realm was wedged out and succeeded by a shelf characterized by various water depths. This was also a venue for the development of Urgon formations — commencing in the Aptian, or, perhaps, in the Barremian — in the Northern Calcareous Alps. This facies endured withouth interruption up to the Middle Albian. It is possible that the diachronous eastward closure of the Vardar Ocean was accompanied by a corresponding shift of the Urgon formations along the suture zone. It is assumed that the astonishingly similar facies in the Transdanubian Range and that reconstructed on the bases of pebbles in the Northern Calcareous Alps could have been linked by this very zone.

In the Inner Western Carpathians, which is actually an eastward continuation of the Northern Calcareous Alps, there were certain environments enabling the formation of Urgon rocks. The Tatra sequence and the

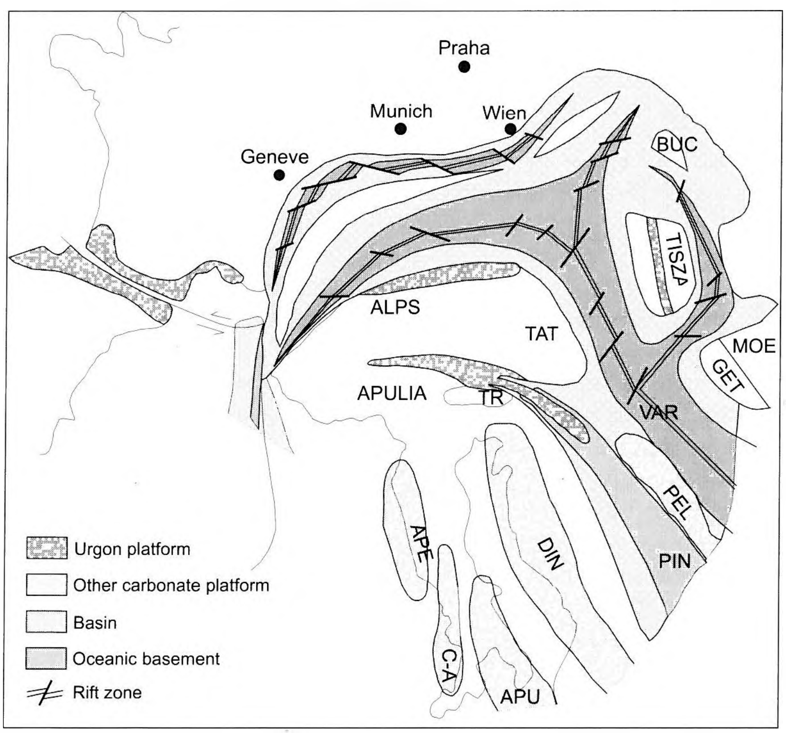


Figure 71. Palaeogeographic position of the Pelso and Tisza units and extent of Urgon platform in the north-western corner of the Tethys in the Early Albian

APE — Appenine Platform; APU — Apulian Platform; BUC — Bucovinian Unit; C-A — Campania–Abruzzi Platform; DIN — Dinaric Platform; GET — Geticum; MOE — Moesian Plate; PEL — Pelagonian Platform; PIN — Pindus Ocean; TAT — Tatricum; TR — Transdanubian Range (Pelso Unit); VAR — Vardar Ocean

Manín sequence, also assigned to the Tatricum, were formed at the southern margin of the Southern Penninic oceanic branch (the northern rim of the Inner Western Carpathians). However, in terms of its age (Barremian to Early Albian) and faunal content (*Offneria* sp.) it differs considerably from the Urgon formations of the Transdanubian Range. Nevertheless, the regressive character of its formation and the cessation of platform sedimentation by drowning are such features that might well be paralleled with those of the origins of the Környe Limestone and the cessation of the Zirc Limestone. The facies characteristics in the Northern Calcareous Alps seem to be of an intermediary setting between those in the Transdanubian Range and the Inner Western Carpathians.

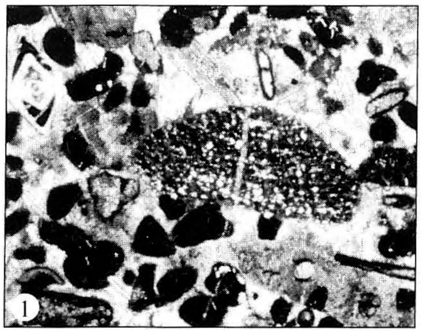
An Urgon formation now retained only as pebbles, which was developed on the obducted Andrusov Ridge, can be fairly paralleled with the Schrattenkalk of the Helvetic Zone at the northern margin of the South Penninic oceanic branch. The only difference between them is manifested in the heavy mineral grains that occur in the former one, witnessing a synchronous oceanic basement obduction.

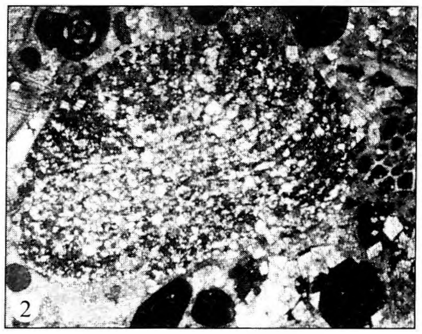
There is a trend in terms of the age distribution of the Urgon formations: at the European margin from the Western Alps to Bulgaria they are Late Barremian to Early Aptian; at the northern margin of the South Penninic realm they are Barremian to Early Albian; and Early(?) Albian to Late Albian ages are encountered in the Transdanubian Range, that is, at the southern margin of the Vardar Ocean.

Facies characteristics strongly suggest that in the Early Cretaceous the Tisza Unit was no longer an integral part of the European Plate but was not yet amalgamated with the Apulian Plate, either. This is clearly reflected, for instance, in the ages of the formations of Urgon facies developed in this zone, yielding the widest time interval, namely, Valanginian to Early Albian. The timing of the formation of the Urgon sequence in the Apuseni Mountains is basically similar to that in the territory of Hungary. However, in a couple of particular cases, there are considerable differences in certain facies-structural zones. More important discrepancies arise, though, when considering facies characteristics; marl, and subsidiarily, sandstone beds are interbedded in the limestone sequence of the Apuseni Mountains. This is atypical of the Hungarian area, where only minor signs of this phenomenon occur in the boreholes drilled near Öttömös and Biharugra.

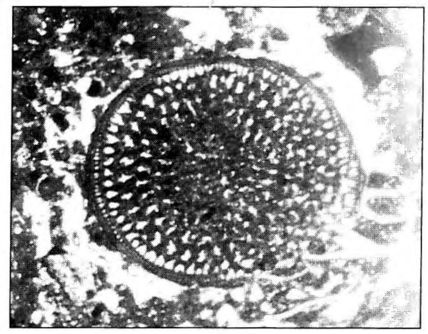
BLACK AND WHITE PHOTOGRAPH PLATES OF THE ALPINE–CARPATHIAN URGON (XXVI)

Orbitolinids (Identification and photograph by E. KÖHLER)

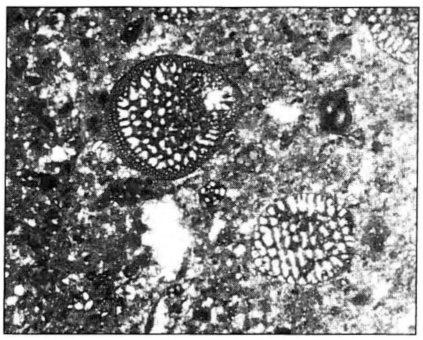




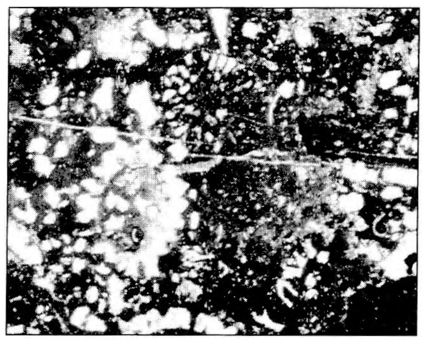
1–2. *Palorbitolina lenticularis* (BLUMENBACH), Hintere Illschlucht, Feldkirch



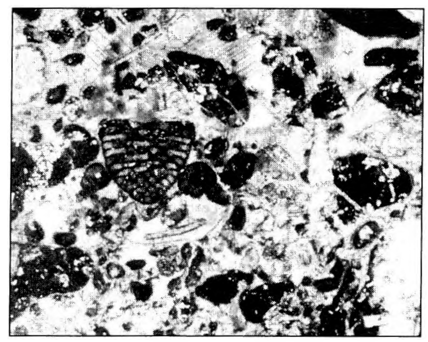
3. *Palorbitolina lenticularis* (BLUMENBACH), Rhomberg quarry, Unterklien



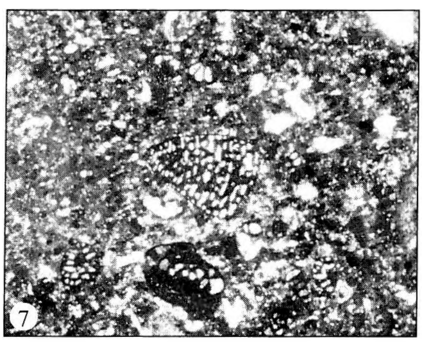
4. *Palorbitolina lenticularis* (BLUMENBACH), *Paracoscinolina* sp., Rhomberg quarry, Unterklien

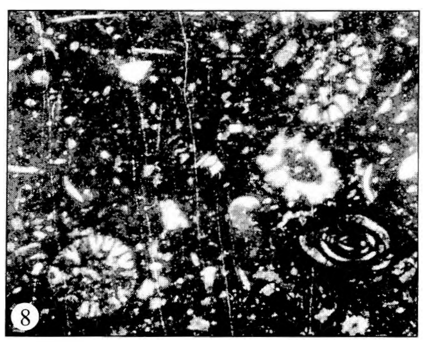


5. *Orbitolinopsis cuvillieri* MOULLADE, *Orbitolinopsis pygmaea* ARNAUD-VANNEAU, *Salpingoporella* sp., Rhomberg quarry, Unterklien

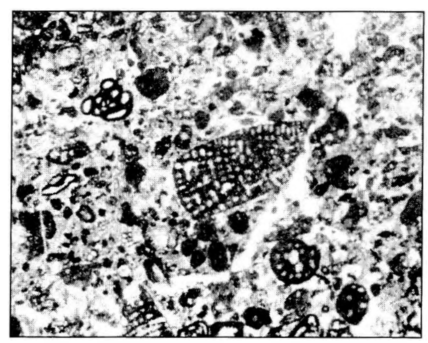


6. *Orbitolinopsis cuvillieri* MOULLADE, Hintere Illschlucht, Feldkirch



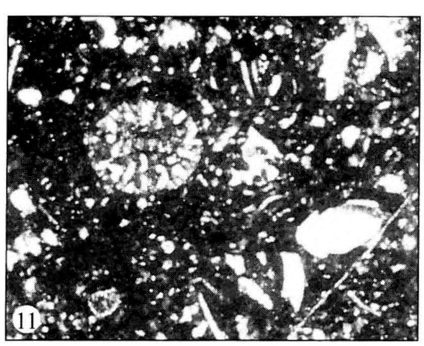


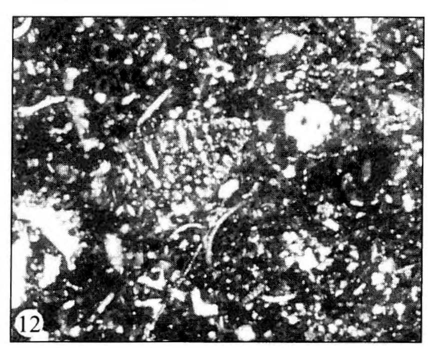
7–8. *Paracoscinolina sunnilandensis* MAYC, Rhomberg quarry, Unterklien



9. *Paracoscinolina mayci* (CHEVALIER), *Orbitolinopsis cuvillieri* MOULLADE, *Sabaudia auruncensis* (CHIOCCHINI *et* DI NAPOLI ALLIATA), Rhomberg quarry, Unterklien

10. *Paracoscinolina mayci* (CHEVALIER), Hintere Illschlucht, Feldkirch





11–12. *Orbitolinopsis debelmasi* MOULLADE *et* THIEULOY, Rhomberg quarry, Unterklien

Geological natural values (key and reference sections)

AIM AND IMPORTANCE OF GEOLOGICAL NATURAL PROTECTION

The basic aim of natural protection is to protect living and non-living products of nature from damage and to save their endangered elements from annihilation. With regard to the living world, the point now is the maintenance of the varieties of life which still exist, and the prevention of the overturning of the biological balance. However, it is also a very important standpoint to create the right conditions to be able to identify the total gene stock developed over millions of years and also to enable their possible utilisation for scientific purposes. Nevertheless, other natural values also cannot be disregarded. In addition to discovering fundamental identity, the arguments of the geological natural protection in certain respects differ from those mentioned above. Though taking delight in the products of the Earth's history and other common elements in the living world, it should not be neglected that at same time the protected geological objects make it possible to recognize and reconstruct milestones in the development of the Earth and also in the development of the life which has evolved on it. This knowledge makes it possible to draw conclusions that are useful from the actual life point of view. Unfortunately, in the lack of protection for geological objects decreases the chance to take advantage of what these objects may offer. There is no doubt that scientific research will concentrate on these protected objects in the future and thus they will become demonstrative sites of knowledge, with an inherent value discovered in the course of research for all those people interested in nature, especially in the earth sciences.

It can be concluded from the paragraph above that the tight interaction of the development of the living and non-living worlds manifests itself in geological objects, especially in certain selected objects. Therefore, these objects can most effectively promote an understanding of the scientific way of looking at natural sciences for a broad circle of the population. The geological monuments (key sections) will also promote the acceptance of this kind of approach, which is based on firm ground. This topic must be kept on the agenda because unscientific views concerning life and earth history are presented on the television screen and also in other media day by day.

THE "KEY SECTION" PROJECT OF HUNGARY

A "key section" project was launched by the Geological Institute of Hungary and the Hungarian Stratigraphic Commission in order to serve as a base for controlling the validity of the lithostratigraphic units found in the territory of Hungary. This activity coincided with the separation of lithostratigraphic units subdividing the earth's crust under our feet in the late 1970s. This selection required great effort from geologists interested in lithostratigraphy (which was a new branch in stratigraphy at that time). In spite of restricted occurrences of surface outcrops, key sections were found on the surface, representing a majority of the lithostratigraphic units. Due to the hard rocks of platform carbonates the formations described in this monograph have relatively better outcrops than the less hard types of rocks.

The aim is to select key sections on the surface in order to assure that every interested person has the opportunity to get his/her own impression and can carry out sampling for special additional investigations.

PLATFORM CARBONATE AND URGON FACIES

This volume is primarily concerned with to the formations which developed in a particular sedimentary environment of the Early and mid-Cretaceous epochs. The environment in which these geological formations were formed is characterised by a warm, tropical, shallow sea with a maximum of a few-tens-of-metre water depth. This environment is the homeland of the "carbonate factory" where, on huge areas, thick platform carbonates were formed at many times and in many places during the Phanerozoic eon. Well-known ones developed in the Devonian, Triassic, Jurassic, Cretaceous, Eocene and Miocene periods.

The special feature of the Lower to mid-Cretaceous carbonate platforms — distinguishing them from others — is their peculiar fossil assemblage. The ruling fossil group of this assemblage are the rudist bivalves such as diceratids, requienids, *Toucasia* varieties, agriopleurids and radiolitids, *etc.* Formations characterised by rudists have a common facies referred to as Urgon, after the small town of Orgon, the type locality of this facies, situated in South France. The other typical fossil group comprises the larger foraminifers — that is to say, orbitolinids; these are the most important fossils of the Urgon formations from a stratigraphic point of view. The Urgon limestones are extremely rich in fossils both in taxa and specimens. Depending on the varieties of the subfacies of the Urgon, the fossil community is changeable.

THE SIGNIFICANSE OF URGON LIMESTONES IN HUNGARY

Urgon formations developed in both major tectonic units of Hungary, and all of them have surface outcrops as well (Figure 72). Although a few of them are either in a very bad condition or do not really well representing the entire succession we were able to find key or at least reference sections among them. The age of the Urgon-type formations ranges between Valanginian and Albian. The peculiarity of their age distribution is that the oldest (Valanginian) Urgon type formations are restricted to the Tisza Unit,which was separated from the European Plate in the Middle Jurassic and shifted southward continuously. The deposition of the Urgon facies lasted in the Tisza Unit for as long as the Early Albian. On the other hand, the first occurrence of the Urgon facies in the Pelso Unit can be put in the Early Albian.

Two fundamentally different types of Urgon facies developed in the tectonic zones of the Tisza Unit, namely in the Mecsek and the Villány Zones. The Nagyharsány Limestone of Urgon facies in the Villány Zone is considered to be a typical ramp-type platform carbonate, the deposition of which started developing as a new sedimentary cycle with *Chara*-bearing freswater limestone (after a short break in sedimentation in the early Early Cretaceous). It contains plenty of black pebble horizons, many hardgrounds and traces of root stuctures of onetime vegetation in its lower 70 m-thick section. Marine conditions stabilised higher up in the succession where rudists prevail but colonies of *Bacinella* and branching corals, moreover green algae and orbitolines are also common. The total thickness of the formation exceeds 1000 m. It continues in the basement of the Alföld as far as the Pădurea Crailui and Bihar Mountains in the Apuseni Mountains in Transylvania.

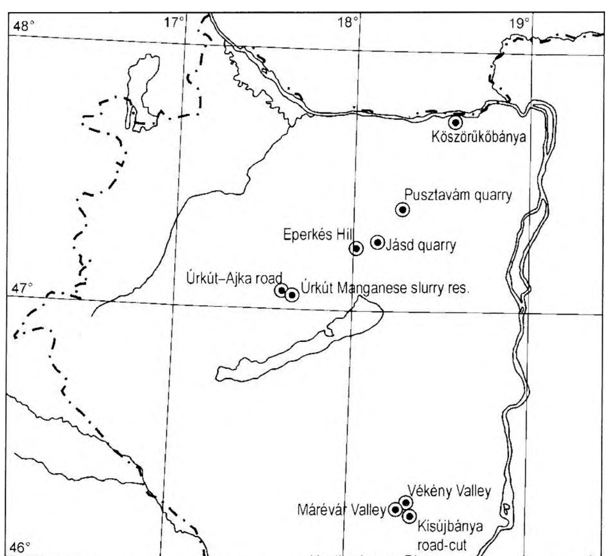


Figure 72. Surface outcrops of key sections of the Urgon in Hungary

The Mecsek Zone had a thinned crust with a deep-water environment in the Late

Jurassic and turned into a rift zone at the beginning of the Early Cretaceous when basaltic volcanoes erupted. Hyaloclastics were the products of the first eruptions. When the hot lava came up to the bottom of the sea and came in contact with the seawater, it soon exploded and broke into small pieces. Later, giant volcanoes grew above the sea level. Since the subsidence of the basement slowed down or maybe even stopped (instead of the settling of colonial organisms such as corals, chaetetopsis, and stromatoporoids) erosion started at the sea level around the volcanoes. This peculiarity of the Mecsek volcanoes distinguishes them from those which occured in the Pacific ocean in the Early Cretaceous. As the oceanic basement of the latter volcanoes subsided continuously there was no notable erosion. Therefore, colonial organisms settled down, and keeping pace with the subsidence, they formed atollrings around and above the subsided volcanoes. This phenomenon is called, after Darwin, who was its discoverer, Darwin's atoll. In contrast to the Darwin's atoll in the Mecsek Zone, after a considerable incision into the body of the volcanic build-ups, first a customary clastic sedimentary zonation was formed around the volcanoes (starting with a cobble and pebble zone) and this was followed by a zone of sand and silt fractions. Later on small colonies developed at the margin of the volcano and these were saved temporarily from the erosion under sea cover. Since there was no notable subsidence, colonies were not able to continue growing and they were destroyed and, together with bivalves (among others rudists), gastropods, echinoids and lived in the lagoon in between the reef and coastal zones (Figure 24). There were also products of weathering (pebbles, sand and silt fractions) which were transported to the submarine margin of the volcano. From here they were transported gravitationally to the lower part of its slope and into the basin where they existed among volcanoes continuously.

The state of preservation of the Urgon-type formation is different in the Pelso unit from those in the Tisza Unit. The oldest Urgon limestone is preserved as rock fragments (breccias, pebbles and boulders) on the slope of a foreland basin in the Gerecse Mountains. The platform, which serves as source area of these rock fragments, developed on an island arc on which basalt, the oceanic basement rock was obducted. On the basis of the lithologic and fossil composition of the limestone fragments one can conclude that the platform consists of zones of well-developed patch reefs with various reefal organisms and a lagoon with rudists and other bivalves. These olisthostrome-like horizons, as events, are found only as a few intercalations within the Köszörűkőbánya Conglomerate. As member of the Lábatlan Sandstone Formation the Köszörűkőbánya Conglomerate also consists mainly of chert pebbles and breccias.

The extent of the Környe Limestone is restricted to the northwestern foreland of the Vértes Mountains and western foreland of the Gerecse. This Urgon-type formation has been developed from the hemipelagic crinoidal limestone — namely, the Tata Limestone Formation. The Környe Limestone forms a narrow belt and interfingers westwards with the non-marine Tés Clay Formation; eastwards and upwards it interfingers with the hemipelagic, oxygen-depleted Vértessomló Siltsone. The Környe Limestone is subdivided into two member rank units. The lower part is an allodapic limestone composed of platform-derived shells, various fossils (rudist bivalves, chondrodonts, a few colonial organisms and also larger foraminifers (such as Orbitolinas) and rock fragments. The thinner upper member is an autochtonous true Urgon limestone. The age of the formation is late Early Albian and early Middle Albian.

The third Urgon-type limestone is the Zirc Limestone which developed in both the Bakony Mountains and the Vértes Foreland. The 50 m thick succession in the Northern Bakony and in the Vértes Foreland consists of three members. The lowest member is a typical Urgon limestone of rock forming rudist bivalves (mainly agriopleurids); the middle member is characterised by foraminifers — among others several species of orbitolinids. These indicate a slightly stronger water agitation than the rudist limestone. In reality the upper member is not an Urgon facies but a biodetrital, sandy limestone of hemipelagic facies with planktonic foraminifers and some glauconite. The sedimentation was stopped because of a short period of sea level fall which was followed by a rapid and worldwide (?) sea level rise of some 150 m in magnitude in the Late Albian. The thickness of the Zirc Limestone in the Southern Bakony exceeds 200 m, without continuous sediments above it. It is a unique type of Urgon facies, characterised by a great variety of various sized gastropods, eoradiolitid rudists and chondrodonts which are in their original life positions. These fossils alternate bed by bed, while a majority of the beds are composed of monogeneric or even monospecific fossils. Another characteristic feature of the formation is the regular intercalations of hardgrounds and bauxitic clay horizons.

Nagyharsány Limestone

The key section of the formation and the most characteristic and thickest surface outcrop is situated at the beautiful Harsány Hill (see photograph on back cover) in the Villány Hills. This Hill is valuable not only because of the Nagyharsány Limestone but also because of its east-west oriented, elongated, narrow form and also its precious relict flora and fauna. It has an abandoned quarry known as the Statue quarry at its eastern end with many of statues constructed by sculptors from all over Europe. At the other end of the Harsány Hill there is a larger quarry still being worked but it is prohibited to continue exploitation eastwards; thus quarrying takes place in a downwards direction only. The thickness of the formation in the Harsány Hill is 200 m (Figures 28 and 29), albeit this is only a part of its total thickness. Close to the crest of the hill there is an open pit of bauxite and an old shaft on the southern slope. The hill itself and both quarries expose the massive Upper Jurassic limestone in which only a few macrofossils can be recognised (*i.e.* brachiopods, ammonites, belemnites and small colonies of varied fossils). The Nagyharsány Limestone started its development with *Chara*-bearing freshwater limestone often of a dark grey colour. "Black pebble" horizons and hard grounds with holes of plant roots are also typical for the lower part of the section. Its beds dip steeply to the south. After temporal marine intercalations thick-bedded rudistid limestone became dominant in the section, although small pathes of *Bacinella* colonies and a coral colonyare also present. Due to a decision of the Environmental Ministry there is now a guarantee of the protection, both for the geological phenomena and for the elements of the living world.

The total thickness of the Nagyharsány Limestone in the Szabolcs Valley quarry is only 18 m (cFigure 10, p. 181) these beds are of a younger age (Late Aptian – Early Albian) than those of the Harsány Hill quarry. This quarry is not abandoned although the exploitation is occasional only. The age of the underlying rock is Late Jurassic. In spite of the long depositional break, the contact between the two formations is paraconform. It can be seen on the eastern side of the quarry, on the lower exploitation level and at the top on the western side.

At present there is only one outcrop where the upper contact of the Nagyharsány Limestone can be seen. This is an artificial trench close to the top of the Tenkes Hill, not far from former hunting hut, where the Bisse Marl covers the Nagyharsány Limestone (Figure 36). This contact bears witness to an abrupt sea level rise, the consequence of which has been the drowning of the carbonate platform. Unfortunately, the narrow trench needs frequent and regular cleaning, otherwise the contact is covered by scree.

The production of limestone in the giant Beremend quarry (Figure 34) is continuous. Due to a cave system its close environment has been declared natural monument. In accordance with the progress of the exploitation, the height of the cliff associated with the cave system increases gradually but permanently. The age of the thick-bedded Nagyharsány Limestone is Late Aptian, but in contrast with the Nagyharsány succession the total thickness of the formation exceeds 400 m. This is clear evidence that the sedimentation started here earlier than in the Nagyharsány environs. In addition to the cave there are karstic holes and fissures filled with red bauxitic clay (cPlates V: 2, VI: 2; p. 192–193) in the block of the natural monument. These represent the second bauxitic horizon in the Hungarian part of the Villány–Bihar Zone.

Magyaregregy Conglomerate

In contrast to the Nagyharsány Limestone, unfortunately the Magyaregregy Conglomerate (which contains rock and fossil fragments of the onetime Mecsek type atolls in the Mecsek Zone) has no good outcrops which are easily accessible. In spite of the unpleasent situation it is worth maintaining a few otcrops as key sections because they represent unique geological features of the atoll-type stucture. The only accessible outcrop is situated behind the swimming pool at the entrance of the Márévár Valley (Figure 16). The long section reveals the upper slope of a volcano with the following rock types: conglomerate consisting exclusively of basalt pebbles, highly weathered pyroclastics and lava fragments, sandstones, sandy siltstones and lava flow. The weathered pyroclastics, sandstones and sandy siltstones contain various megafossils derived from different environmental zones of the atoll ring as follows: rudist and other bivalves, gastropods (species of *Nerinea* and *Purpuroidea* — lagoon), corals (reef) and brachiopods (slope). It is remarkable that no ammonites have been reported from this outcrop and this is evidence that the outcrop must have been situated on the higher part of the volcanic slope.

Unfortunately an artificial outcrop (a road-cut) south-west of Kisújbánya has been almost completely destroyed (Figure 10a). I hope it can be reconstructed because it is the only outcrop in which a half-metre thick breccia of slump/fan origin intercalates into a basinal succession (sandy siltstone and marl). The breccia tongue practically consists of a great variety of megafossils such as rudists and other bivalves, gastropods, corals and a few ammonites. From the host rocks (siltstone, sandstone and marls) lots of ammonites and a few bivalves and gastropods of shallow marine origin have been reported. The breccia tongue shows a prevalence of shallow marine fossils in this basinal succession of 400–500 m water depth. This is clear evidence of a submarine slump, the driving force of which was gravitation.

In the 3rd outcrop, situated in the Vékény Valley, a non-typical Magyaregregy Conglomerate and the stratotype of the Vékény Marl are known to be present. The first one consists of weathered pyroclastics and fragments of basalt lava in which a fragmented coral colony has been discovered. The latter seems to be intercalated within the Magyaregregy Conglomerate with limestone debris at the base. (Figure 18) They are derived in part from a very shallow, hemipelagic environment. In addition to the bioclasts, the first group of limestone debris contains the same volcaniclast grains as those in the previous outcrops. The age of this type of limestone is probaly Middle Albian, that of the hemipelagic one is Late Albian to Early Cenomanian, while that of the host rock is Early to Middle Turonian. These limestone debris provide evidence that the atoll drowned in two steps; the first one took place in the Middle Albian while the 2nd one probably in the Late Albian. The other important conclusion is that the volcanic activity lasted an incredibly long time: from the Early Berriasian until the Middle Albian. Unfortunately this precious section is in an appalling condition.

While visiting Cretaceous key sections in the Mecsek Mountains careful attention has to paid to what is actually being observed. In the rift zone volcanoes grew above the sea level and, with a lack of notable subsidence, an erosional incision came about; a complete sedimentary zonation then developed around the volcanoes, including atoll rings. The colonial organisms of the rings have been destroyed from time to time and transported to the slope of the volcanoes. Unfortunately the volcanic build-ups have been almost completely eroded, but thanks to the fossils and limestone fragments that have been preserved on the slope it is possible to reconstruct the events that have taken place.

Köszörűkőbánya Conglomerate

The oldest Urgon limestone of the Pelso Unit is found in the Gerecse Mountains as reworked rock fragments. Among the few outcrops, the Köszörűkőbánya quarry (köszörűkő means grindstone) is the only one which functions as a key section. The succession of this quarry is the stratotype of the Köszörűkőbánya Conglomerate Member of the Lábatlan Sandstone. In this Member can be found limestone boulders, cobbles and smaller fragments, either in a randomly scattered way or concentrated in two breccia (olisthostrome) horizons (Figures 43 and 44, cPlate IX: 1, p. 196; bPlates IX: 1–4; X: 1–4, p. 112–113), the matrix of which is smaller grain-sized chert breccia or sandstone. These beds are either pruducts of debris flow (*i.e.* random distribution of fragments) or turbidity currents (in the case of graded bedding cPlate: IX: 1, p. 196). In addition to chert and limestone fragments a few metamorphite, even small sized mafic and ultramafic rocks also occur. Together they represent a complicated history of events, namely the obduction of oceanic basement on an island arc, on which a carbonate platform has developed. In front of it a foreland basin was formed from the inherited Jurassic basin and the rocks listed above were transported gravitationally on the slope between the platform and basin.

Környe Limestone

The other platform carbonates of the Urgon facies were deposited in a narrow belt, west of the Gerecse Mountains and in the Vértes Foreland. It is called Környe Limestone and it has only one surface outcrop in an abandoned quarry, south of the village of Pusztavám. The succession of the formation is represented by two beds of 2 metre total thickness only (Figure 52, cPlate X: 1–3, p. 197). These are rudistid limestones intercalating within the Tés Clay Formation. Here, the Tés Clay consists of variegated, mainly reddish and ochre clay and clay marl of freshwater origin. This intercalation indicates a transitional interval between the two formations where the Környe Limestone is a product of a short-lived sea level rise. After this rise the fluvial and lacustrine sedimentation continued for a long period. The probable age of the Környe Limestone is late Early Albian to early Middle Albian.

Zirc Limestone

The 3rd Urgon-type limestone is the Zirc Limestone which is a product of a sea level rise that followed the sedimentation of the Tés Clay. Its areal extension is much larger than the other Urgon formations of the Pelso Unit because it is found in the Bakony Mountains and the Vértes Foreland as well. It has many surface outcrops which are almost exclusively in the Bakony Mountains. The formation has two facies-type areas, called the Northern Bakony and the Southern Bakony facies. The thickness of the first one is a maximum of 50 metres and consists of three member-rank units with regard to the water depth, while the thickness of the latter is at least 200 m and its succession cannot be subdivided it into memeber-rank units vertically.

Three surface outcrops were selected as key sections from among the many in the Northern Bakony facies-type area. The stratotype section of the formation is situated on the Eperjes Hill (*i.e.* the right side of the Veszprém–Zirc road) where Agriopleura (rudist bivalves) are found in rock-forming quantities (bPlate XIII: 5–6) in an impressive cliff of massive or thick-bedded, strongly karstified limestone of the lower member (Eperkéshegy Member). The upper part of the section represents the middle member of the formation. This comprises thick-bedded limestone, almost without macrofossils but rich in microfossils; in the larger foraminifers these can be seen with an unaided eye.

The other outcrop is an abandoned quarry, south-west of the village of Jásd. The disadvantage of the quarry is that it is accessible by field car only. The lower part of the succession shows that the middle member of the formation is scattered with giant *Orbitolina texana* (Roemer) (larger foraminifer); in the upper part the 3rd member can be seen. The two members are separated by an unevenly eroded hardground (or erosional surface) above which lies glauconitic limestone. The 3rd member consists of limestone of coarse-grained echinoderm ossicles with fine-grained Triassic dolomite sand. This section of the cliff is capped by an ammonite-bearing, highly glauconitic, phosphatic silty marl horizon of the Pénzeskút Marl Formation. The ammonitic marl represents a condense horizon of maximum flooding of a world-wide sea level rise in the Late Albian.

The 3rd key section of the formation is selected at the southern bank of Gaja brook (cPlate XIV: 4, p. 201). In the forest road-cut there is an outcrop of the upper member and the Pénzeskút Marl. This is includes the ammonite-rich glauconitic condensed horizons with fragments of an omission surface.

The best outcrops of the Southern Bakony facies are exposed in the Úrkút area. In the former manganese mine (later a manganese slurry reservoir), the lower part of the formation can be seen and studied (cFigures 11, 12, p. 182–183; cPlates XIII: 1, p. 200, XV: 1, p. 202). In many respects this succession is unique. It develops from the Tés Clay without a break in sedimentation and consists of fossiliferous limestone beds, where a monogeneric, even monospecific composition is charactristic (cPlates XIII: 3, XIV: 1–2; XV: 1, p. 200–202). The major macrofossils are as followes: gastropods (*Nerinea coquandiana* d'Orbigny, *Nerinella, Nododelphinula, etc.*) *Eoradiolites* (rudist bivalve) and a few *Chondrodonta.* There are tempestite (cPlates XIII: 4, XIV: 3, XV: 3, p. 200–202) palaeosoil, microckarstic holes, thin tuff intercalations and many other interesting features.

A higher part of the succession crops out in a few quarries in the forest, on the south-west side of the Úrkút–Ajka road. The most important quarry is that in which several *Chondrodonta* generations are found above each other in a life position (cFigure 13, p. 184; bPlate XVI: 3, 5–6, p. 119). This phenomenon appears in two horizons. At the top of the lower one *Chondrodonta* coquinas are "shaved off" at the halfway point, giving evidence of the very rapid consolidation of the muddy matrix after emerging above the sea level; when the sea returned it could only cut them instead of overturning them.

Of course, this short survey of key sections and reference sections of the Urgon-type formations in Hungary can be considered as an introduction to the great variety of features and events that can be gathered from them. I did not want to be rigorously scientific in this study — rather I have tried to adopt simple methods in order to promote a better undersanding of the relevant history of the area. Thus this example should help with the investigation of key section. The main aim is to convince as many people as possible that it is worth protecting geological key sections and thus encourage them to visit these sections.

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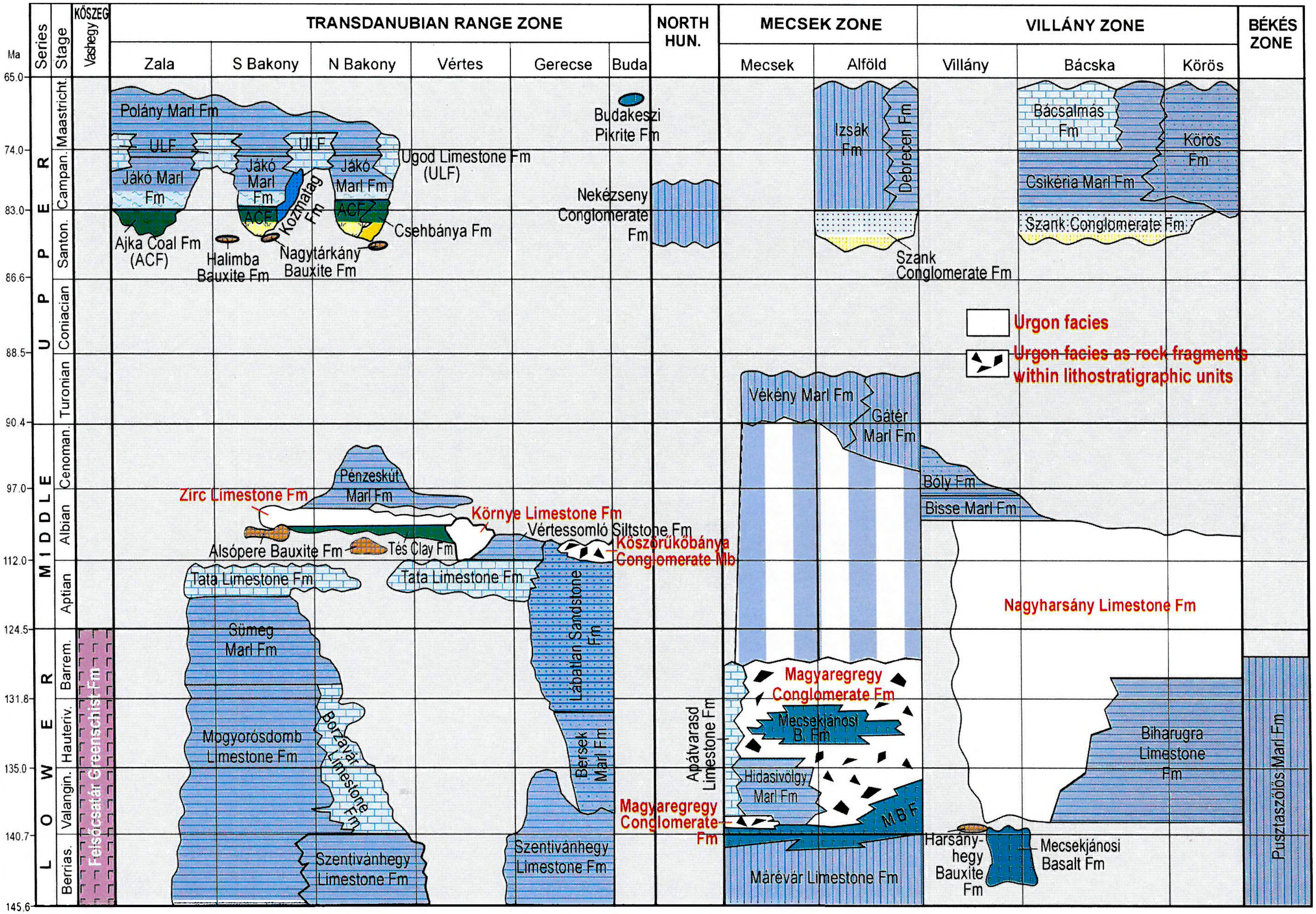
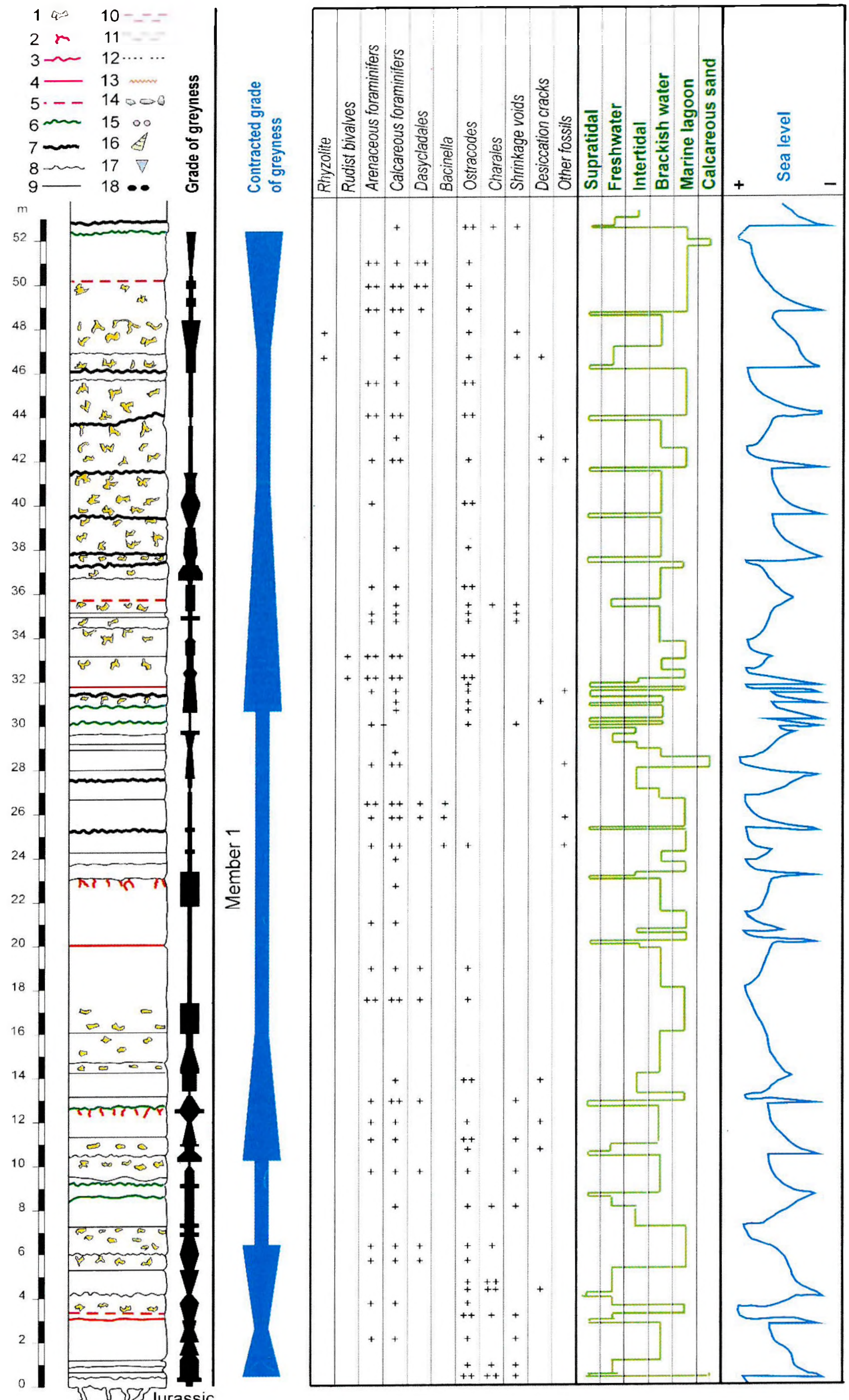
Colour Figures and Plates

LEGEND FOR cFIGURES 4, 5, 6, 8, 10, 11, 12, 13, 16

- *Toucasia* limestone
- *Agriopleura* limestone
- *Toucasia* and *Agriopleura*-bearing limestone
- Rudistid, bioclastic limestone
- Rudistid limestone with limestone fragments
- Limestone with *Toucasia* and other bivalves
- Limestone with *Agriopleura* and/or *Eoradiolites* and other bivalves
- *Toucasia* and gastropoda-bearing limestone
- Rudistid and *Orbitolina*-bearing limestone
- Gastropoda and *Agriopleura*-bearing limestone
- A B — A) Limestone with branching corals and *Toucasia* B) *Toucasia* limestone with solitary corals
- Rudistid and *Bacinella*-bearing limestone
- *Bacinella Lithocodium* limestone with *Toucasia*
- *Chrondrodonta* limestone
- A B — A) Bivalve coquina-bearing limestone B) Bivalve coquina-bearing sandstone with limestone fragments
- Brackish water limestone with bivalves
- Bivalve coquina and gastropoda-bearing limestone
- Gastropoda limestone
- *Orbitolina* limestone
- A B — A) Bioclastic limestone B) Bio- and intraclastic (breccia-bearing) limestone
- Marine limestone barren of macrofossils
- Mudstone type limestone
- Limestone with fenestral fabric
- Freshwater and brackish water limestone
- Nodular limestone
- Limestone breccia
- Chert breccia with limestone fragments
- Sandstone
- Marl
- Siltstone, claystone
- A B — A) Grey clay B) Grey clay with limestone fragments
- Green clay
- Greyish-brown clay
- Variegated clay (palaeosoil) with limestone fragments
- Violet-dominated variegated clay
- Red-dominated variegated clay
- Black pebbles
- Oncoids
- Bioturbation incl. root structures
- White patches
- Root traces
- Plant remains
- Sea urchins
- Brachiopods
- *Orbitolina*
- Bivalve coquinas
- Gastropods

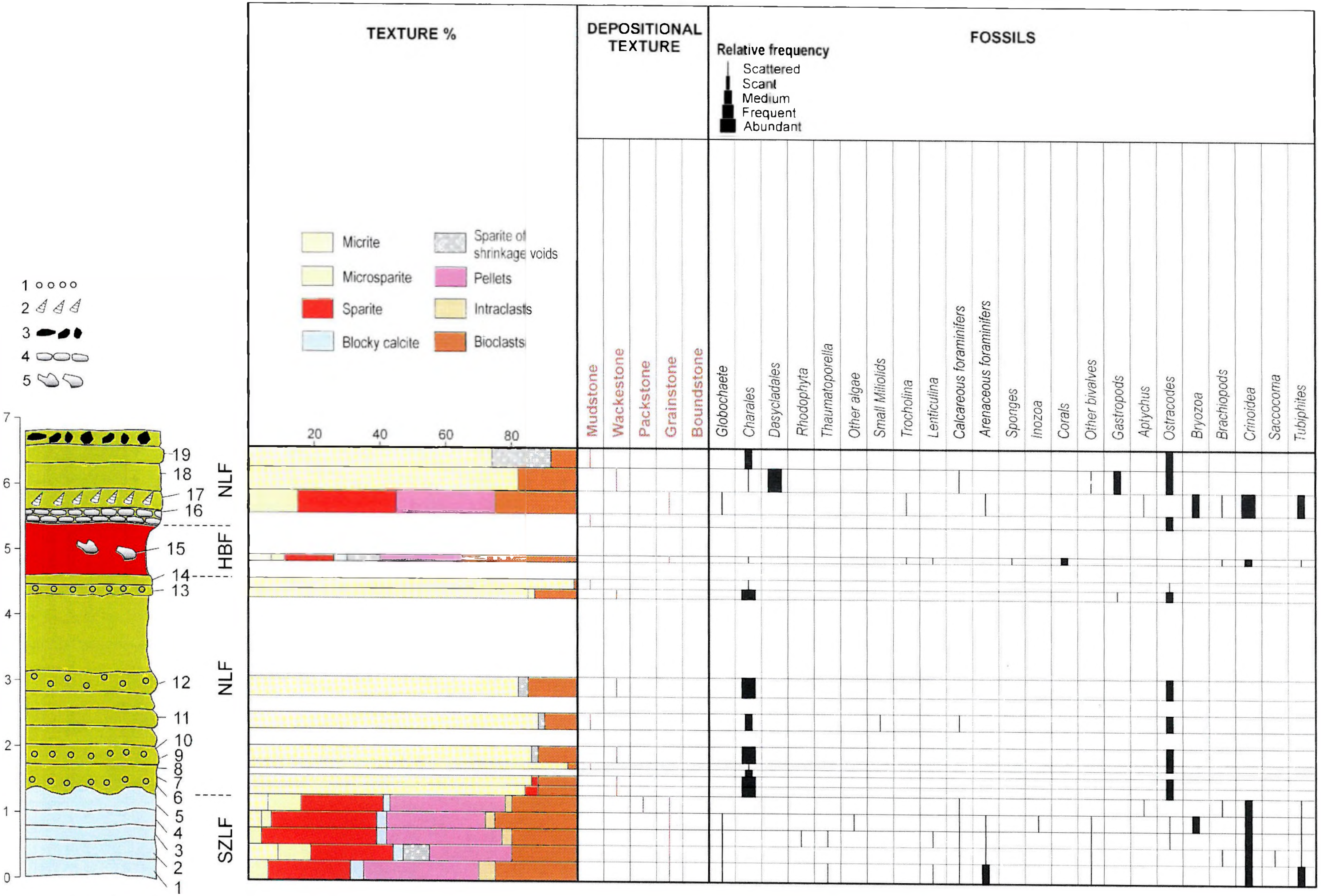


cFigure 1. Basic Cretaceous lithostratigraphic units of Hungary with indication of the formations of the Urgon facies



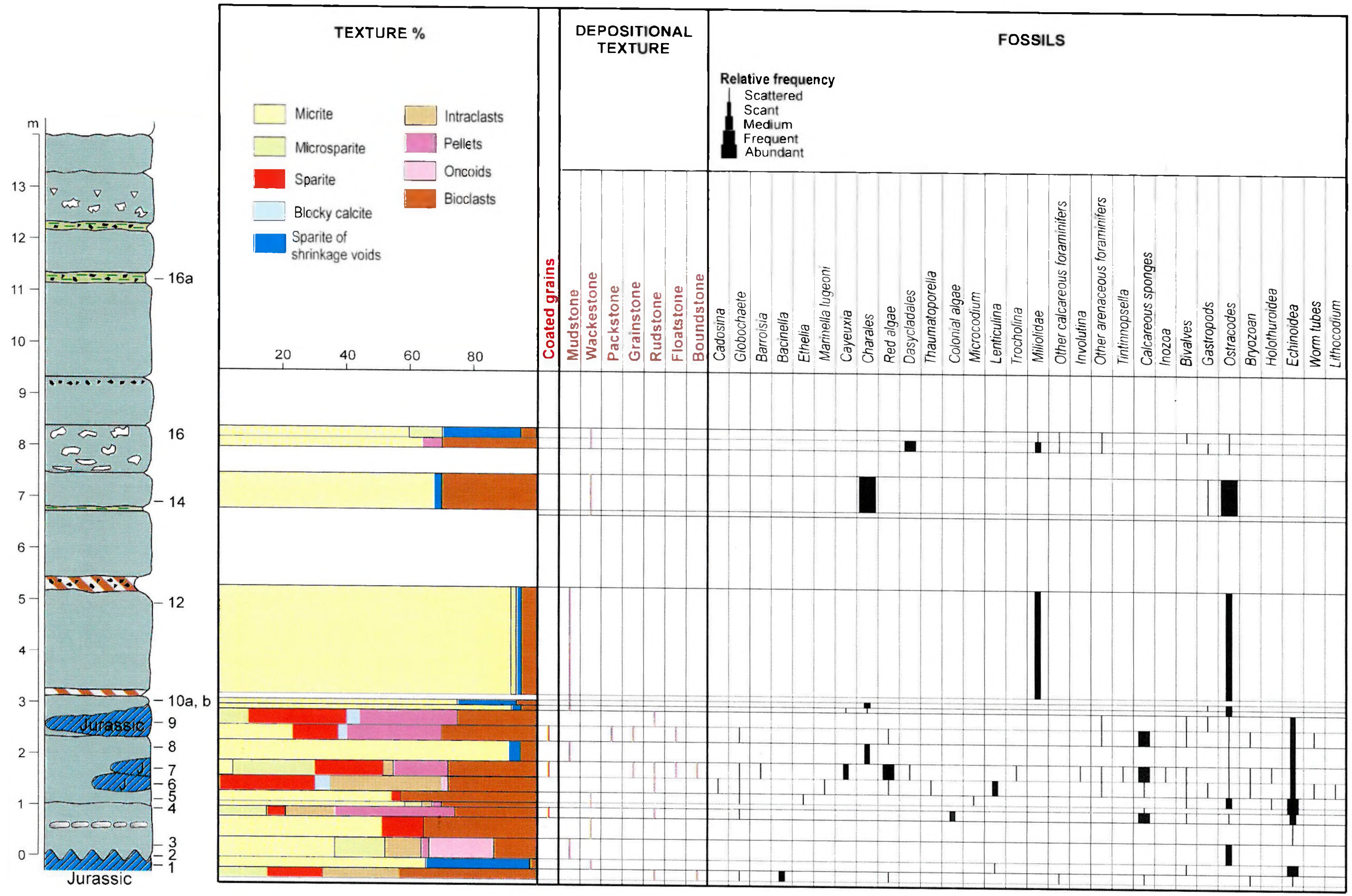
cFigure 2. Columnar section of the lower part of member 1 of the Nagyharsány Limestone, its selected fossil content and environmental interpretation. Section I, Harsány Hill quarry

1 — Infilling after bioturbation; 2 — Root traces; 3 — Erosional bedding planes with reddish variegated clay; 4 — Microkarstic bedding planes with red clay; 5 — Uncertain bedding planes with red clay; 6 — Erosional bedding planes with greenish clay; 7 — Uneven bedding planes without clay; 8 — Slightly uneven bedding planes; 9 — Even bedding planes; 10 — Uncertain bedding planes; 11 — Clay intercalation of reddish variegated colour; 12 — Grey clay; 13 — Fenestral structures; 14 — "Black pebbles" ; 15 — Oncoids; 16 — Gastropods; 17 — Rudist bivalves; 18 — Conglomerate

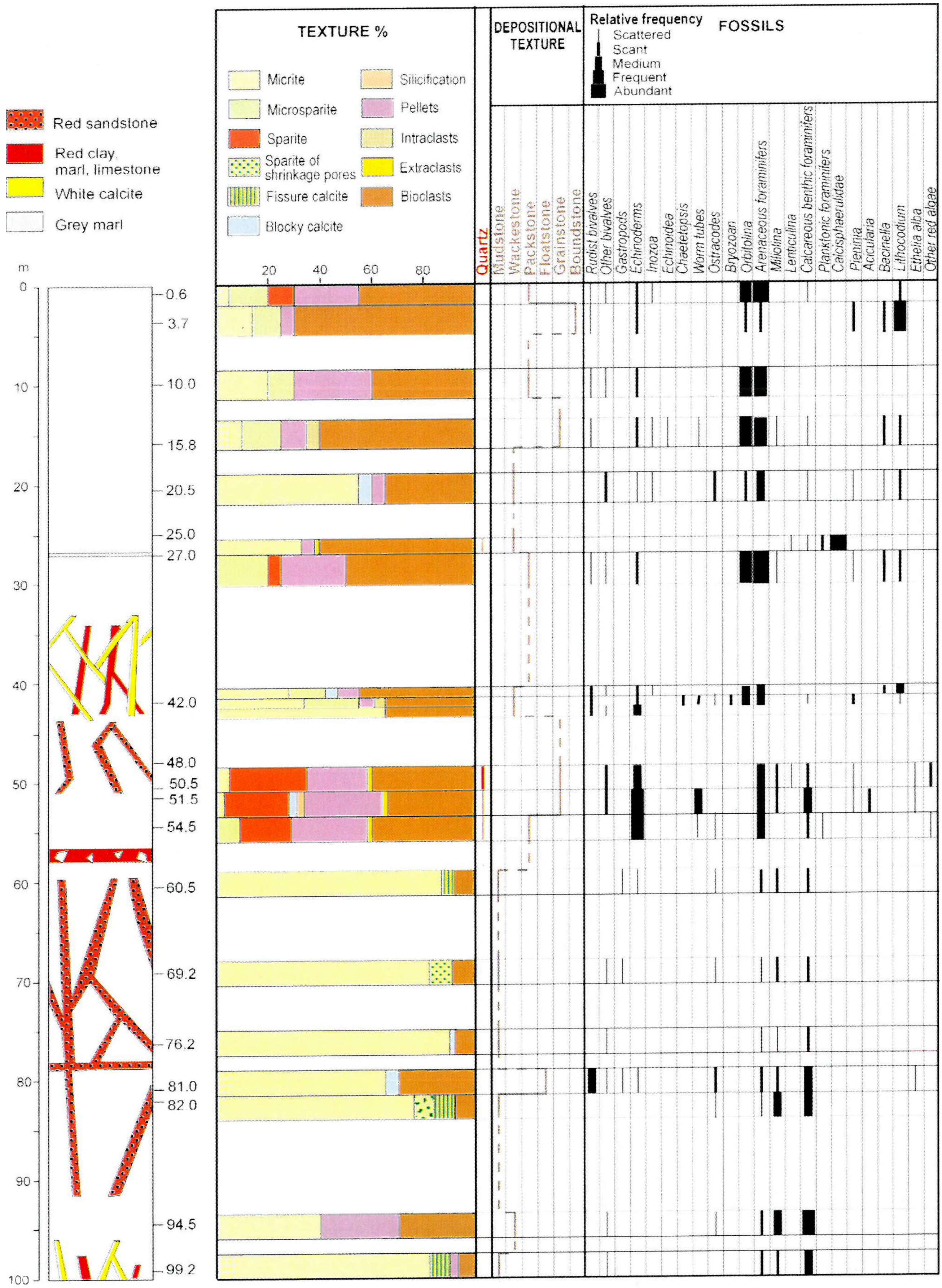


cFigure 7. Results of thin-section studies of the Cretaceous cave(?) fillings and the host rock. Top of the Harsány Hill, Villány Hills

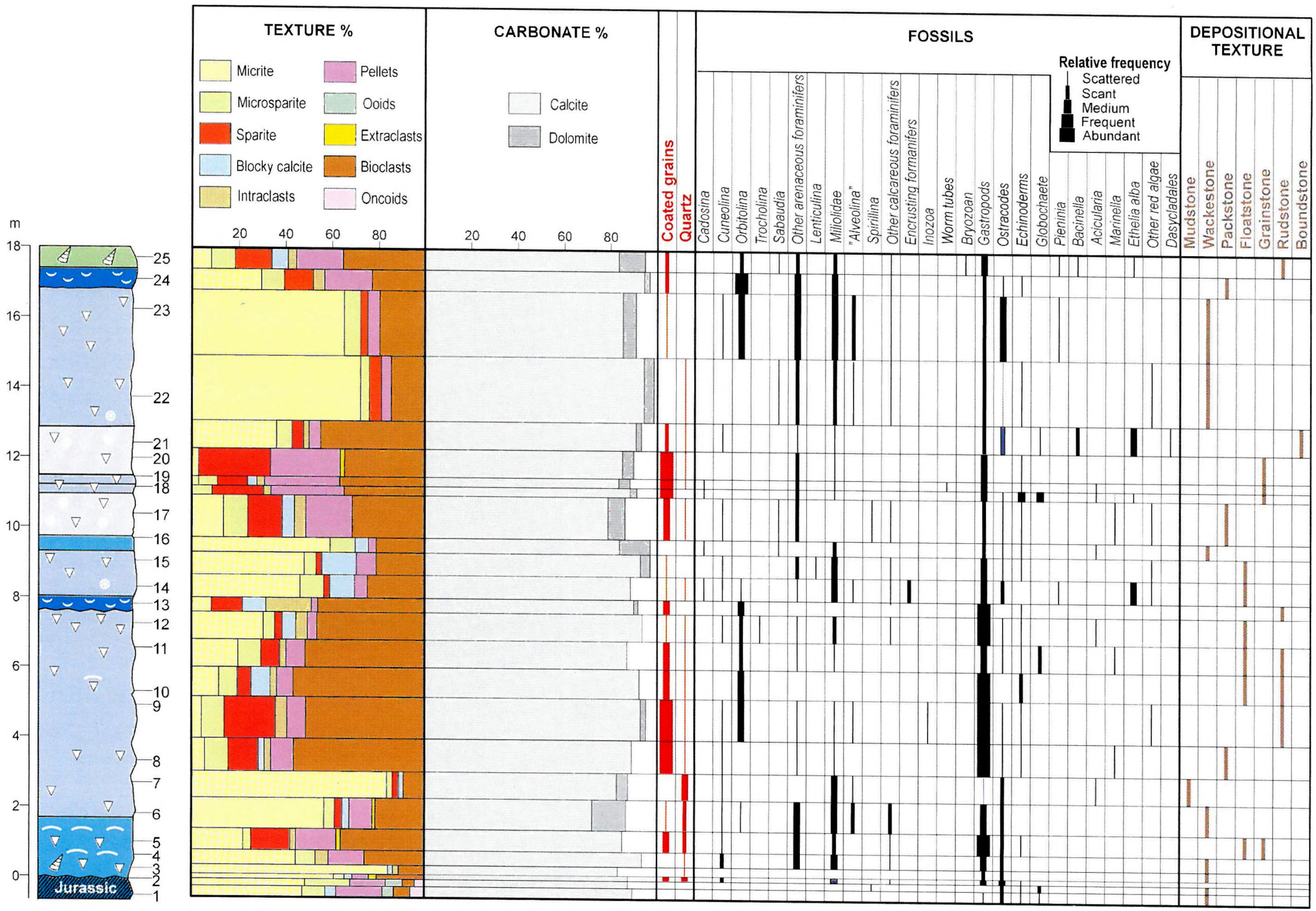
1 — *Chara* oogoniums, 2 — Gastropods; 3 — Breccia grains (intraformational rock fragments); 4 — Nodular structures; 5 — Upper Jurassic rock fragments



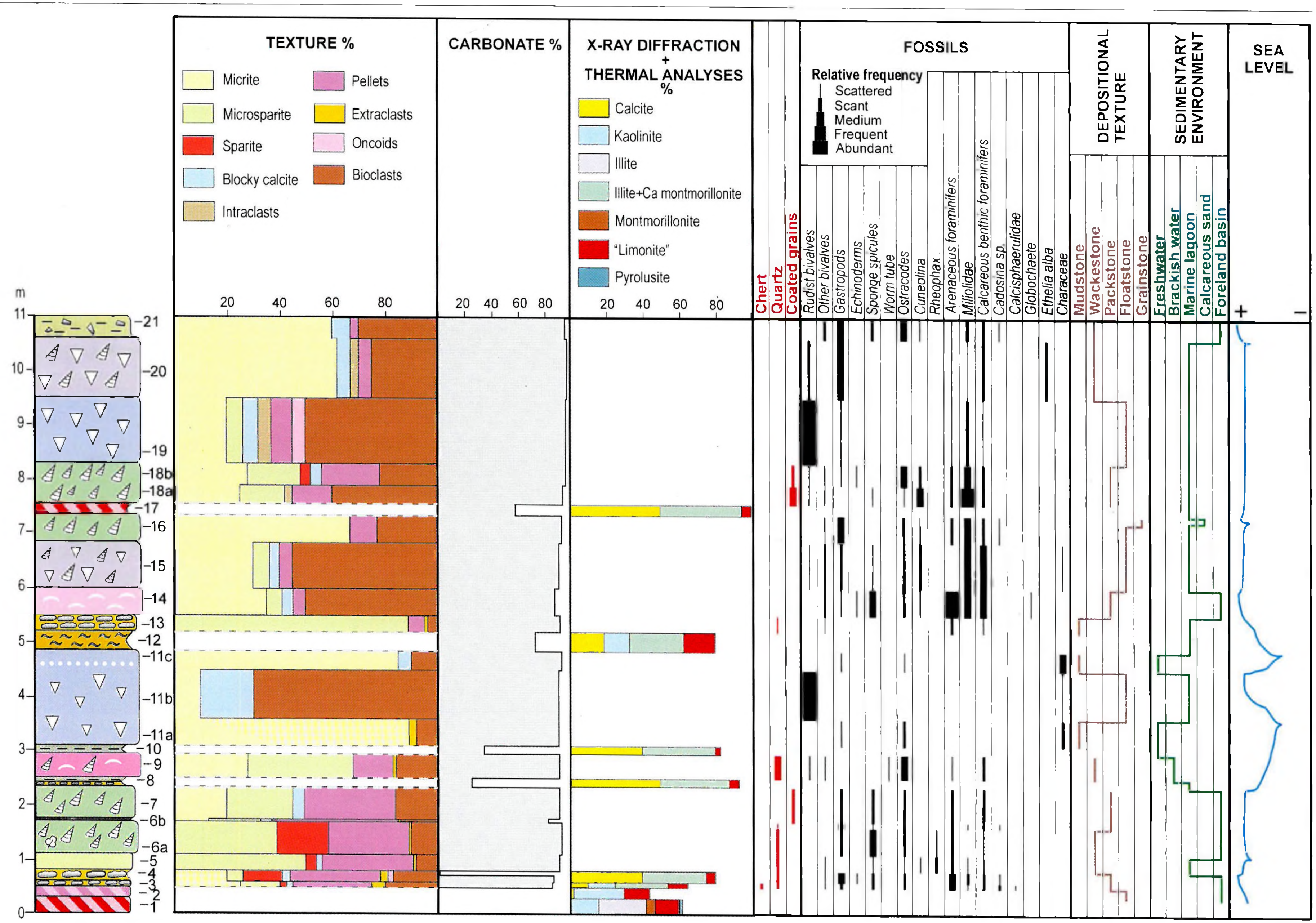
cFigure 8. Columnar section and results of thin-section studies of the basal beds of the Nagyharsány Limestone. Mining level 2, Harsány Hill quarry. For legend of columnar section see p. 171



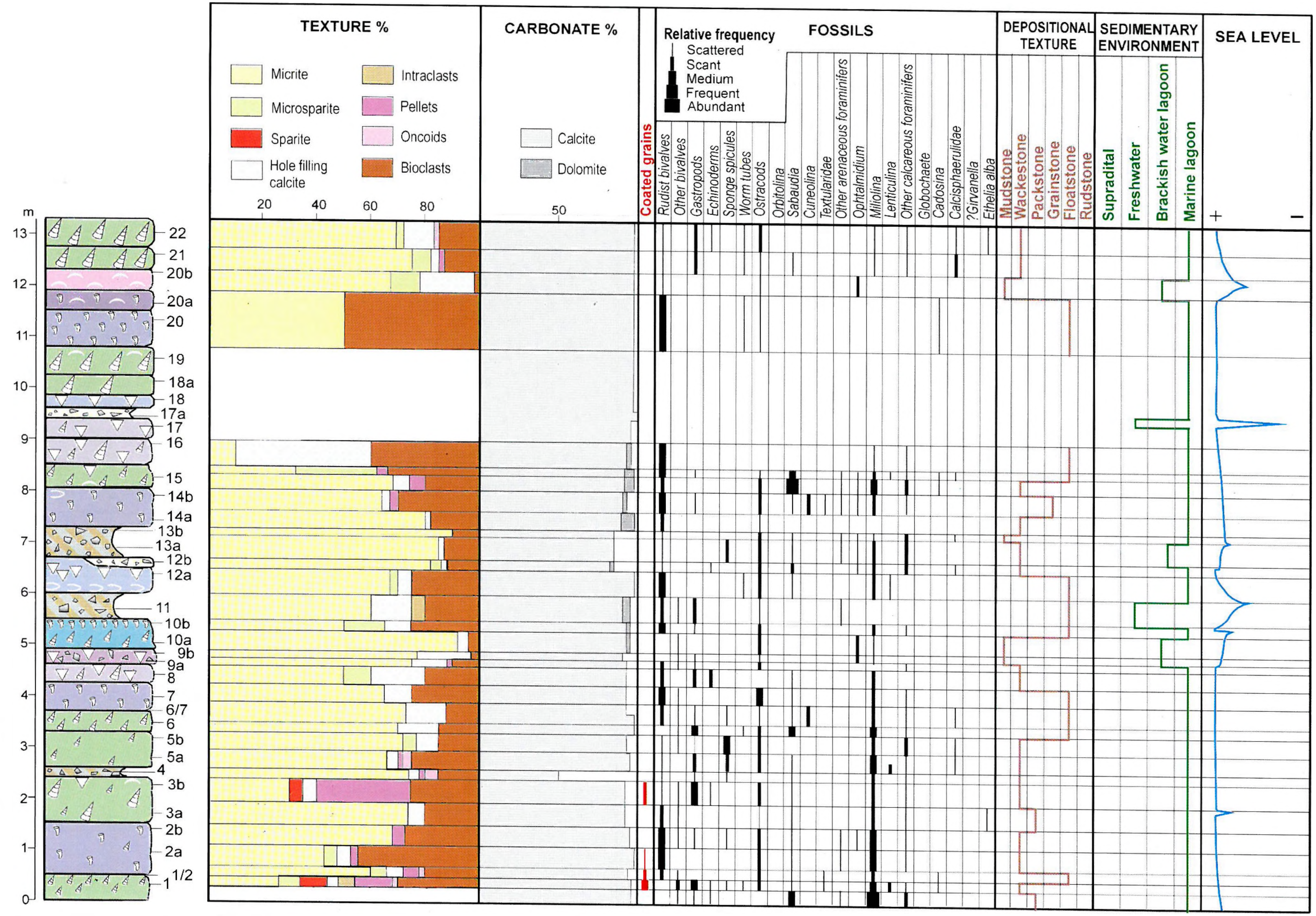
cFigure 9. Columnar section of the Borehole Nagyharsány–1 and results of investigation focusing on fissure fills



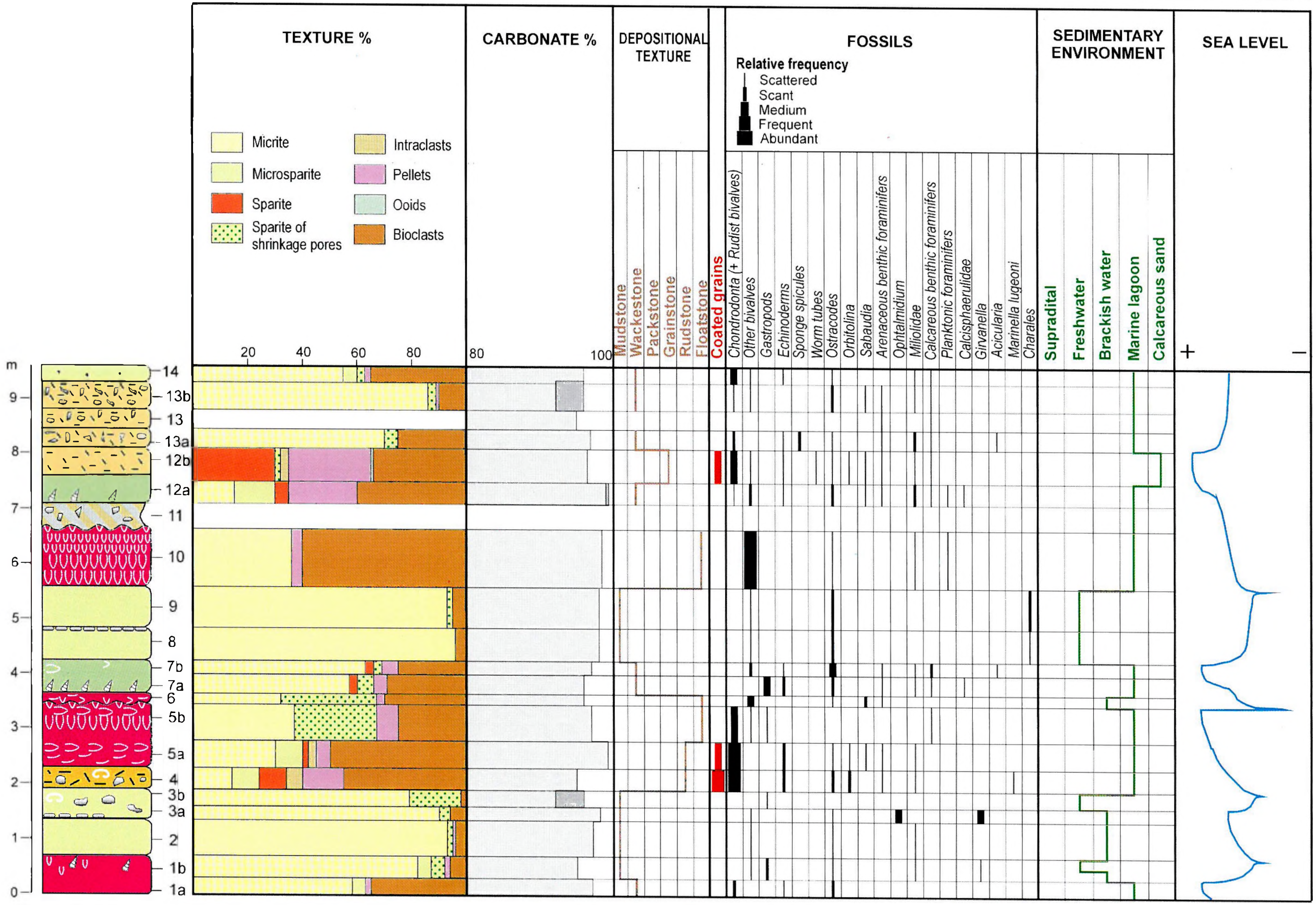
cFigure 10. Columnar section and results of investigations, Szabolcs Valley quarry, Villány Hills. For legend of columnar section see p. 171



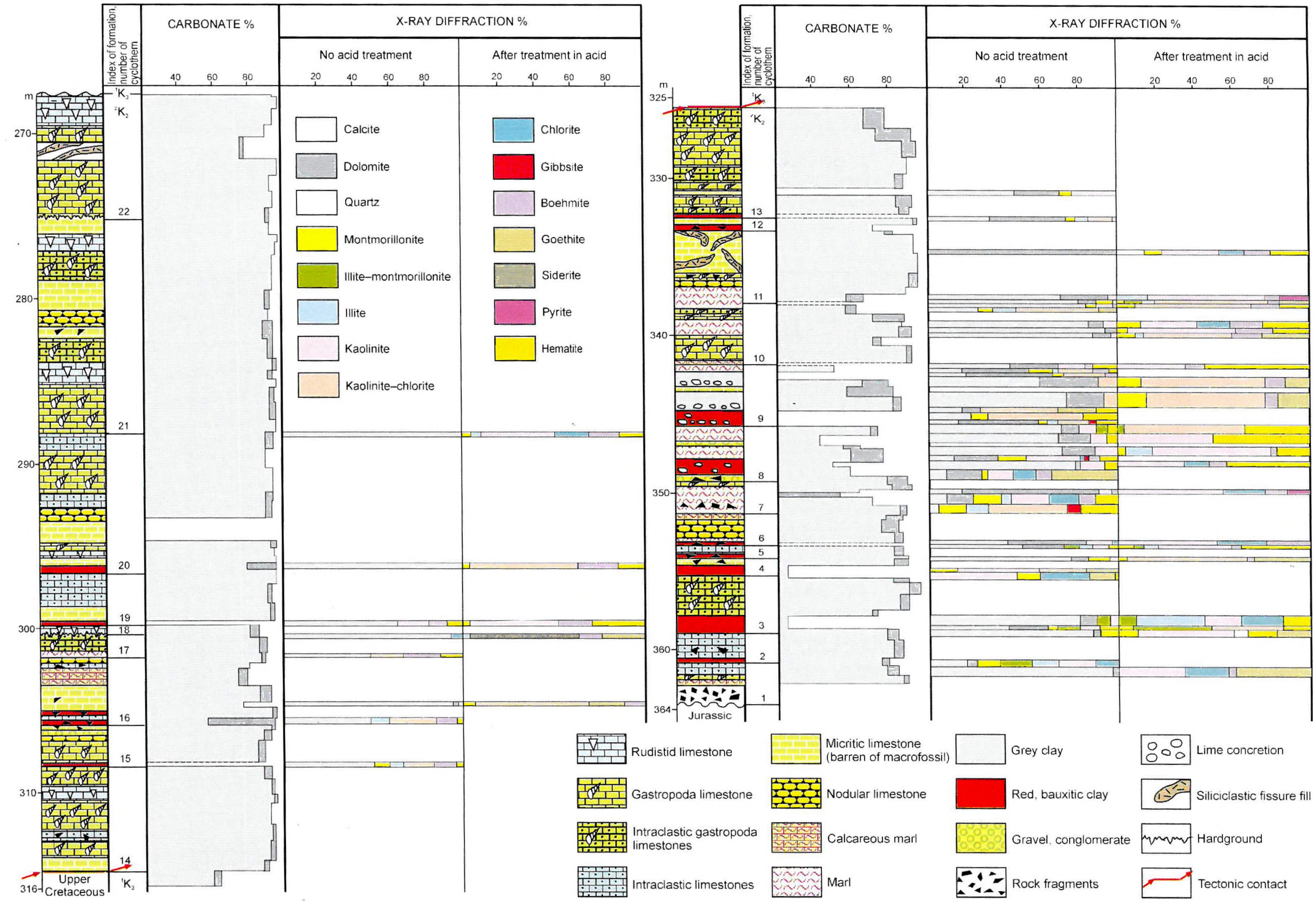
cFigure 11. Transitional beds between the Tés Clay and Zirc Limestone and results of their investigations, Manganese slurry reservoir, Úrkút. For legend of columnar section see p. 171



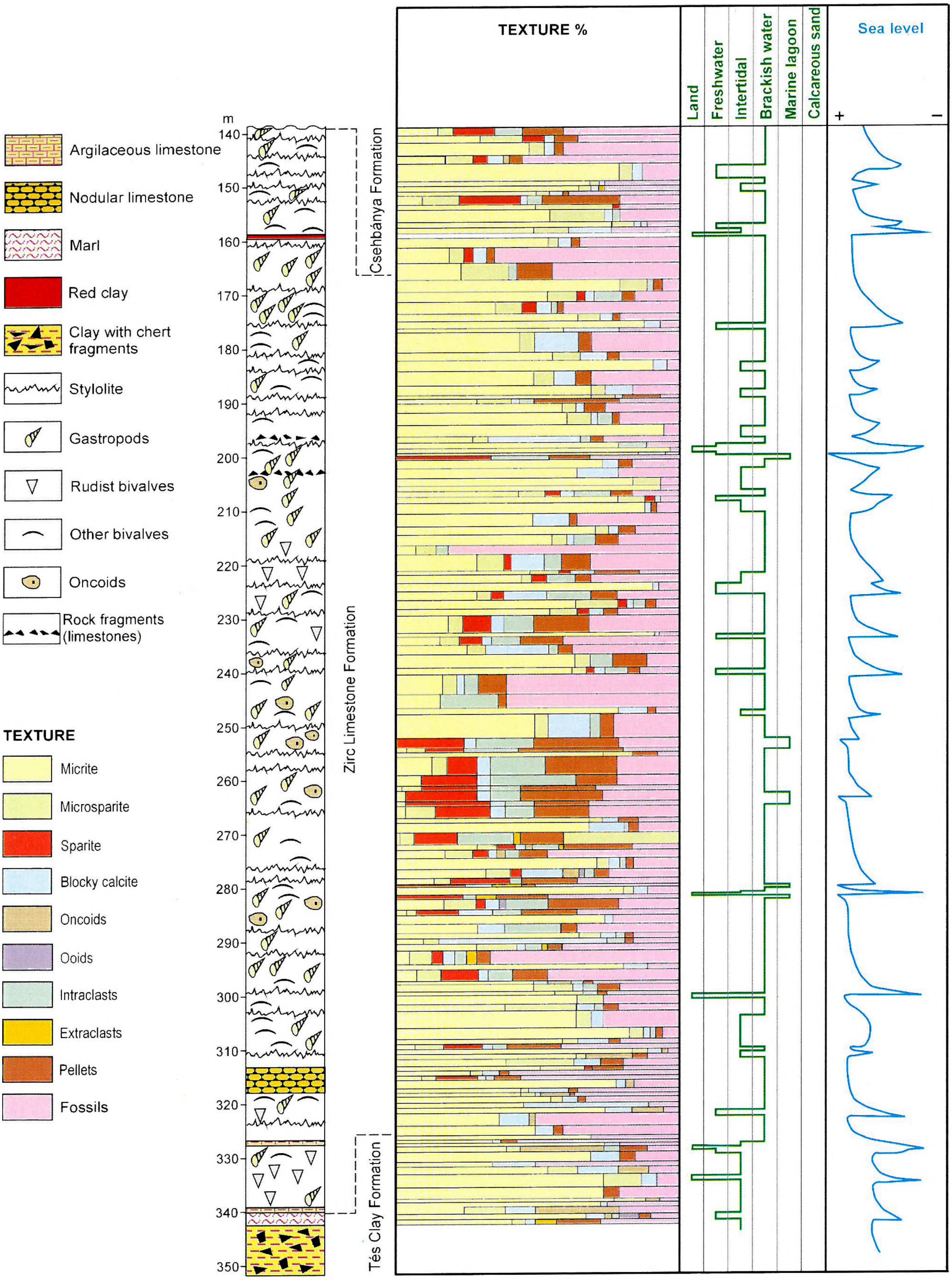
cFigure 12. Lower part of the Zirc Limestone with results of investigations in the Manganese slurry reservoir, Úrkút. For legend of columnar section see p. 171



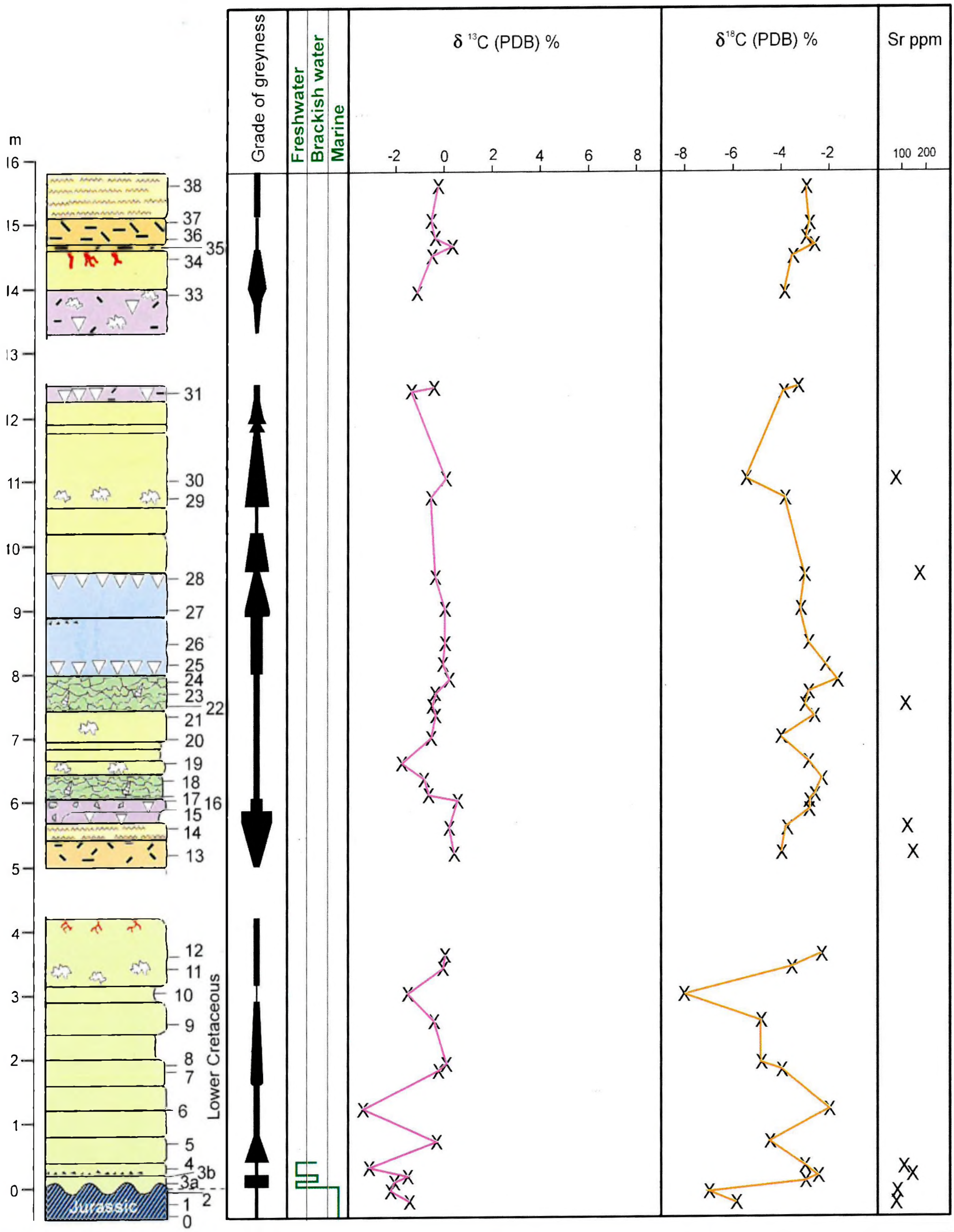
cFigure 13. Columnar section with results of investigations and interpretation of results. A quarry close to the Ajka–Úrkút road. For legend see p. 171



cFigure 14. Columnar section and mineral composition of the Zirc Limestone Formation, Borehole Padrag–7 (measurements made by L. Farkas and M. Földvári)

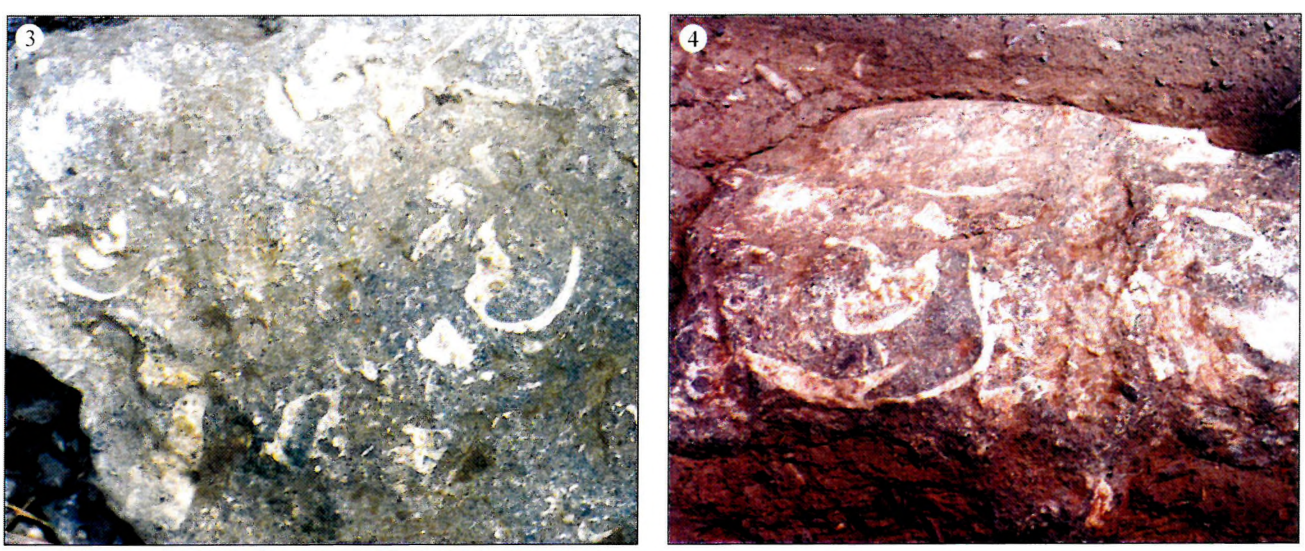


cFigure 15. Selected results of thin-section studies, reconstructed sedimentary environments and curves of sea-level fluctuations of the Zirc Limestone, Borehole Úrkút–421, South Bakony



cFigure 16. Distribution of carbon and oxygen isotopes and stroncium in the basal beds of the Nagyharsány Limestone, Harsány Hill quarry, Villány Hills. For legend of columnar section see p. 171

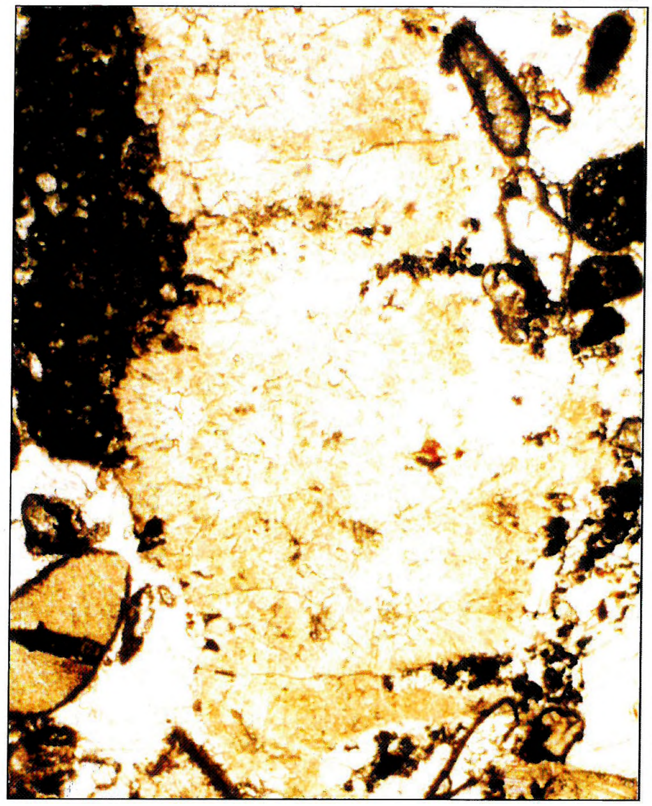
1–2. Southern (ph. 1) and northern (ph. 2) parts of the reference section of the formation in the Korhadtfás Valley



3–4. Rudist shell and other fossils in the rocks on the road at Jánosipuszta derived a nearby outcrop

Micrographs of limestone fragments derived from the base of the Vékény Marl, Vékény Valley

1. Coated grains, fragments of fossil skeleton of shallow marine origin in biointrasparitic grainstone/rudstone limestone with early diagenetic cement (faser A) (M: 65×)



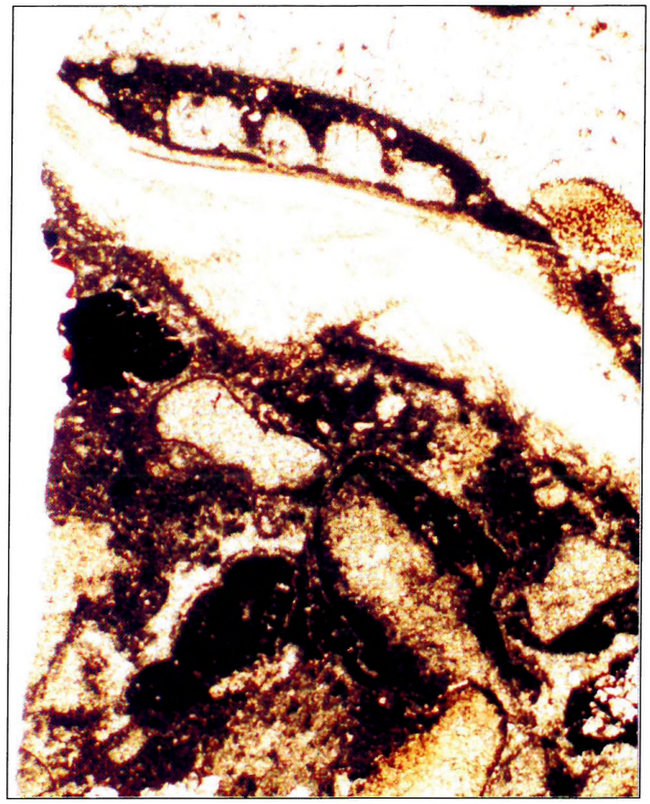
2. Microcodium-like algal colony (M: 65×) || N

3. Packstone fabric with *Neotrocholina* sp. and volcaniclastics (M: 65×)

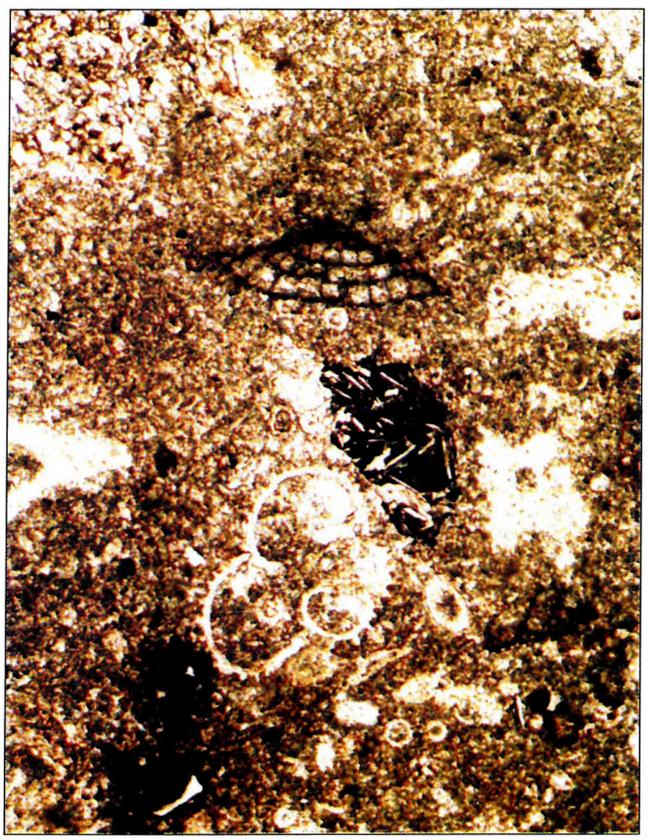
4. Same as picture 2 but # N

Micrographs of limestone fragments from the base of the Vékény Marl, Vékény Valley

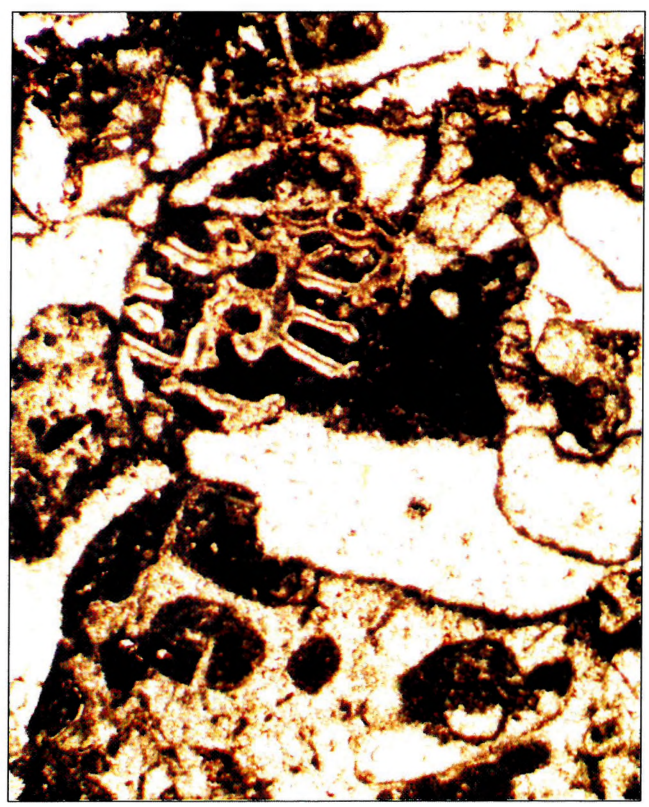
1. ?Stromatoporoidea colony (M: 65×)



2. Encrusting (nubecularid) foraminifer on the shell fragments (M: 65×)

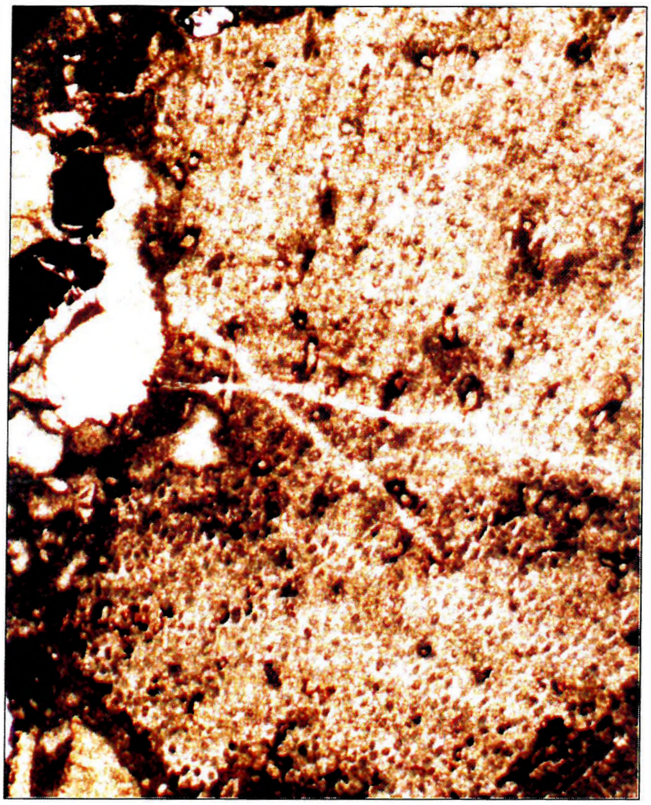


3. Volcaniclastics, *Favusella washitensis* (CARSEY) and *Pseudotextulariella* sp. in wackestone type limestone (M: 125×)



4. Intrabiosparite with coated bioclasts

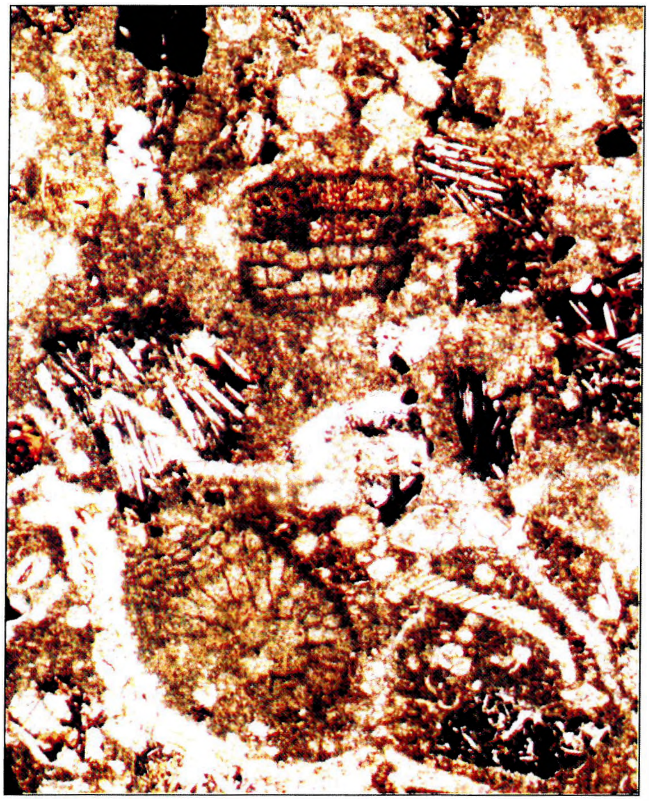
Micrographs of limestone fragments from the base of the Vékény Marl, Vékény Valley



1. *Chaetetopsis* colony (M: 65×)

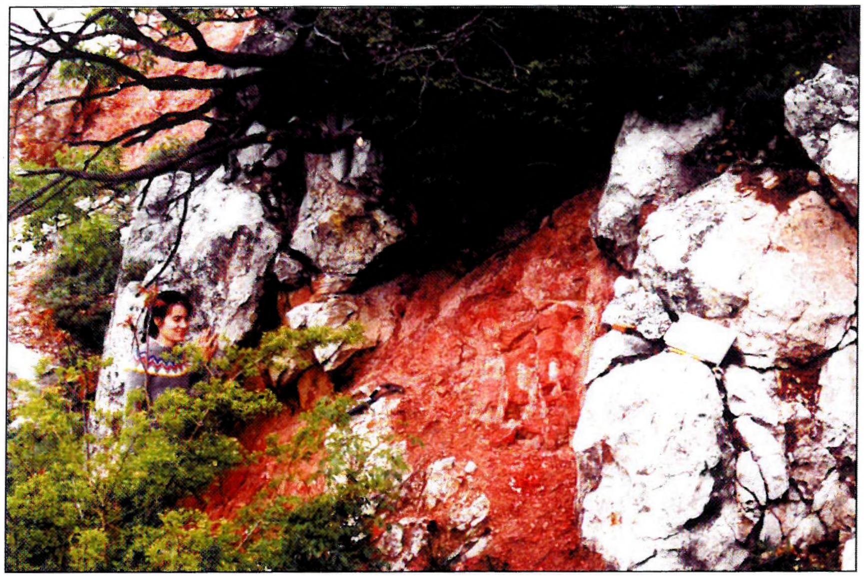
2. Intraclastic limestone of rudstone fabric with fragments of unknown colony (M: 65×) # N

3. Foraminifera wackestone with *Pseudotextulariella* sp. and small size weathered volcaniclastics (M: 125×)



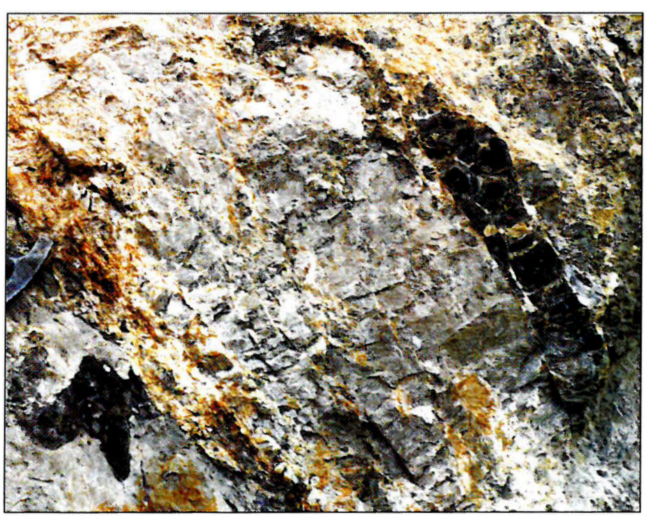
4. Bioclastic packstone with basalt fragments and *Pseudotextulariella* sp.

Nagyharsány Limestone in the Harsány Hill quarry (phs 1, 3, 4) and the Beremend quarry (ph. 2)

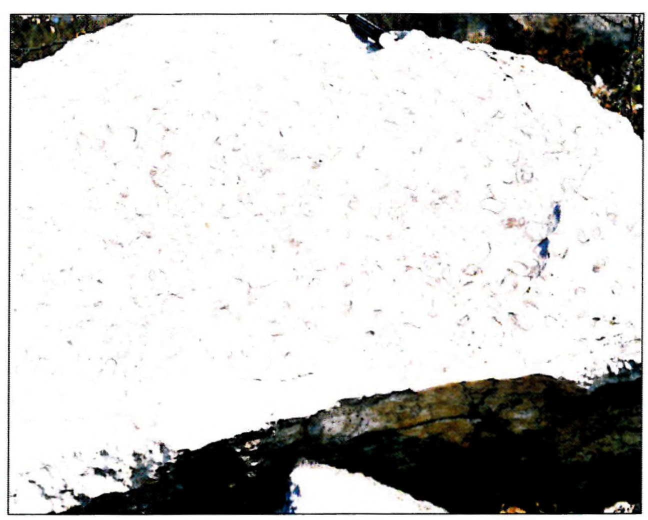


1. Small deposit of Harsányhegy Bauxite between Szársomlyó and Nagyharsány Limestones

2. Fissures and holes filled by bauxitic clay indicating a new bauxite level in the uppermost beds of the quarry. Beremend quarry, South Transdanubia



3. Dark-grey limestone fragments ("black pebbles") from the layers close to the base of the sequence. Harsány Hill

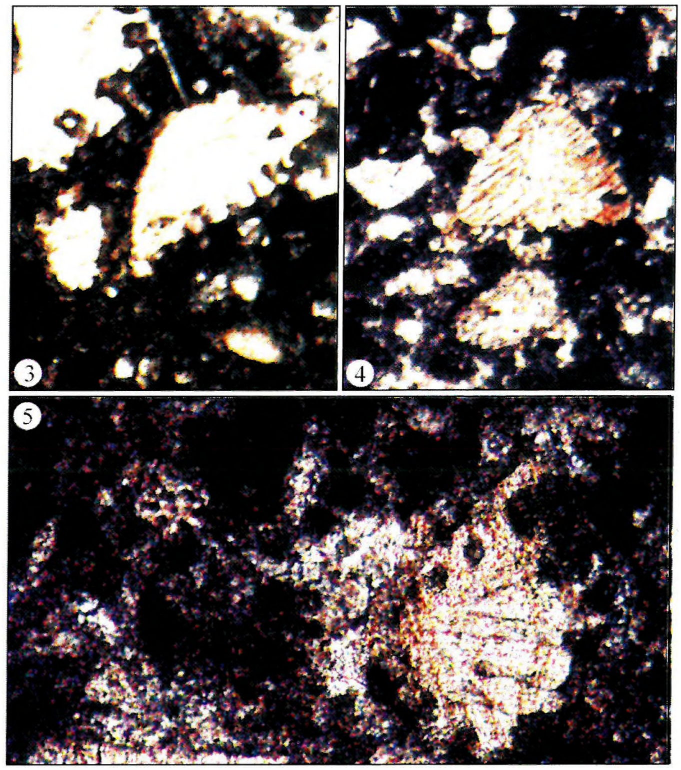


4. Limestone bank with full of small-sized rudist bivalves

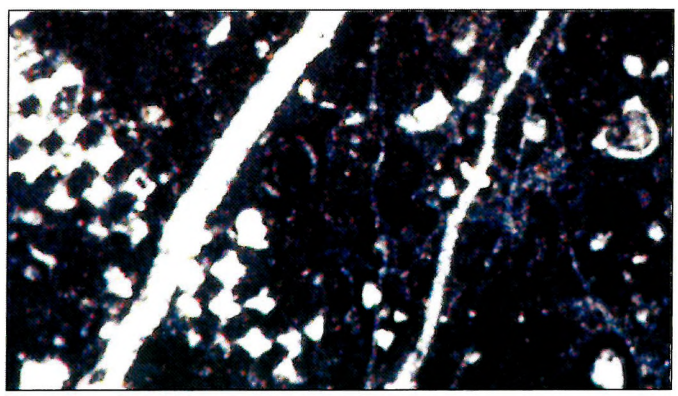
Nagyharsány Limestone in the Harsány Hill (phs 1, 3–7) and Beremend (ph. 2). Phs 3–7 are micrographs

1. Steeply dipping Upper Jurassic/Lower Cretaceous sequence in the Nagyharsány quarry: Szársomlyó Limestone (left side), Harsányhegy Bauxite (in the middle), Nagyharsány Limestone (right side)

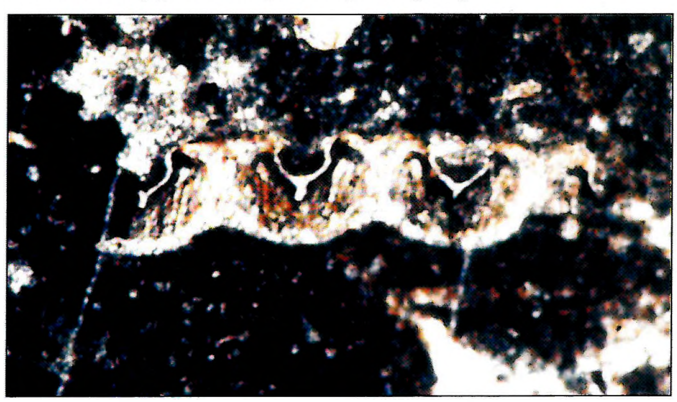
2. Bauxitic fissure fill in the topmost beds of the quarry (the younger bauxite level), Beremend quarry



3–5. *Neotrocholina div.* sp., Sample 10, section II, Harsány Hill quarry

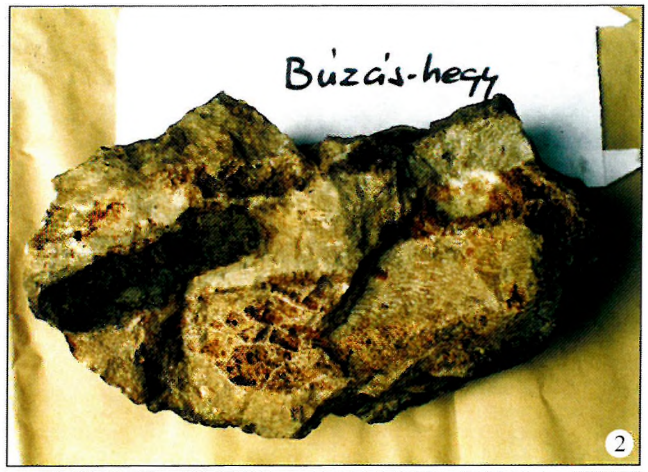


6. Dasycladacean algae (chessboard) and an embryonal chamber of *Sabaudia* sp., Section II, Harsány Hill quarry



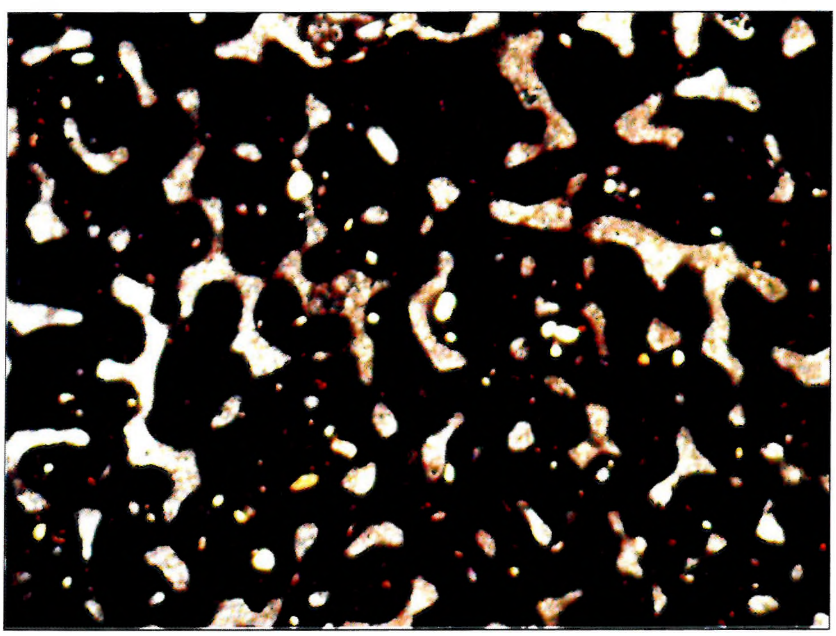
7. Dasycladacean fragment with sporangium, section II, Harsány Hill quarry

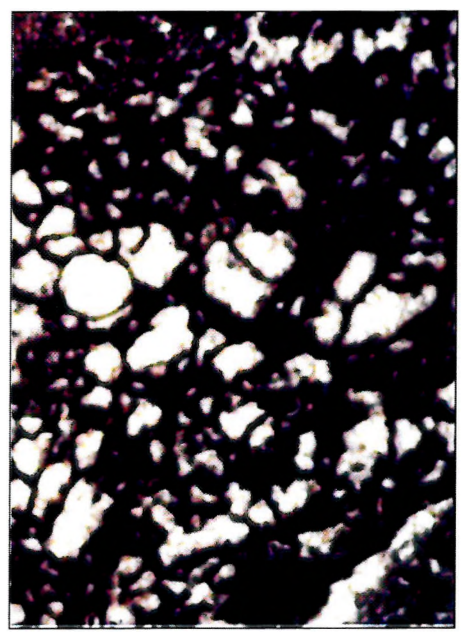
Lábatlan Sandstone and reworked fossils from its upper layers



1. Graded limestone fragments of reefal origin with chert debris in the Köszörűkőbánya Conglomerate, Köszörűkőbánya quarry, Lábatlan

2–3. Bored *Chaetetopsis* (?) colony from the Lábatlan Sandstone, Búzás Hill, Lábatlan (collected by J. FÜLÖP)

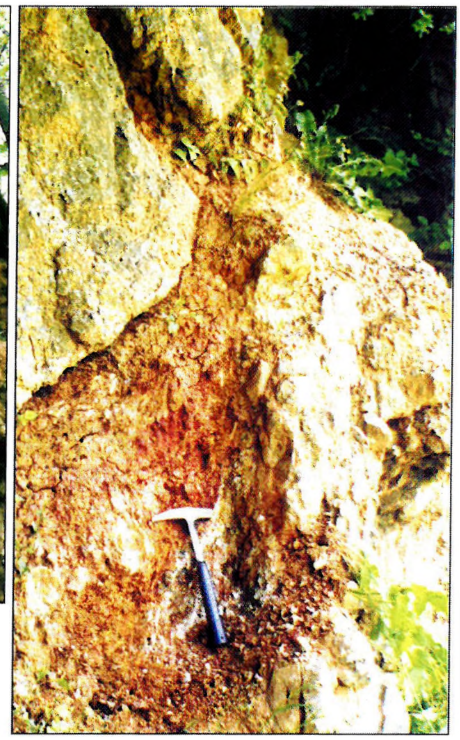




4. Micrograph of a sponge colony in a limestone fragment derived from the lower olisthostrome, Köszörűkőbánya quarry, Lábatlan (M: 41×)

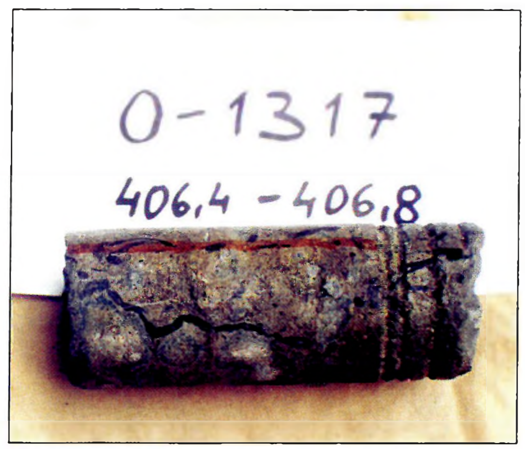
5. Micrograph of a *Bacinella* colony in a limestone fragment, Borehole Sturovo–1, Slovakia

1. Dachstein Limestone (right lower corner) and the faulted Tés Clay (with notebook) and the Környe Limestone intercalated into the latter one, an abandoned quarry, south of wooden deposit, Pusztavám, Vértes Mountains



2. Detail of the previous photograph

3. Bedding plane of a Toucasia-bank of the Környe Limestone, abandoned quarry south of the wood-yard, Pusztavám



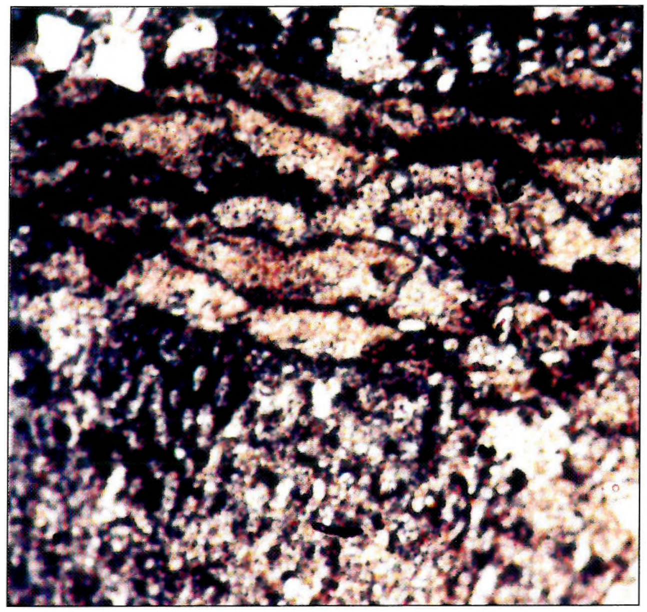
4. Root structure in the Tés–Környe Formation, Borehole Oroszlány O–1317

5. Intraformational conglomerate (breccia) in the uppermost layer of the Tata Limestone, Borehole Oroszlány–1825. Note the pressure solution surfaces of the pebbles

6. Erosional contact between the Zirc Limestone and the Pénzeskút Marl, Borehole Oroszlány–1825

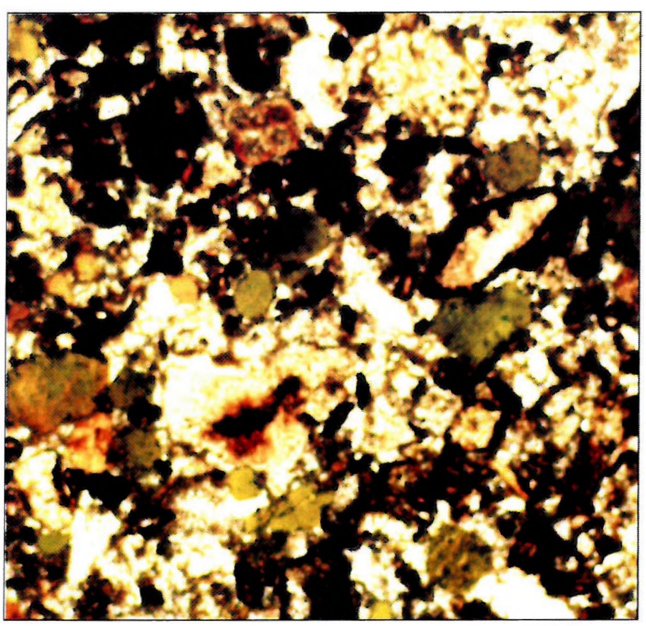
Környe Limestone and its neighbouring (transitional) formations

1. Argillaceous. *Toucasia* limestone of the Tés–Környe Formation. Borehole Oroszlány–2392. Vértes Foreland

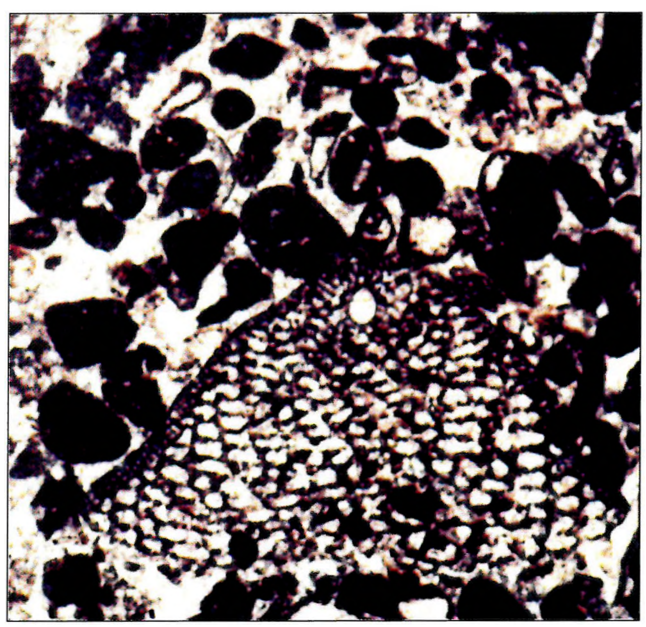


3. Micrograph showing the encrusting *Ethelia alba.* Vértessomló–Környe Formation. Borehole Oroszlány–1822 (377 m)

2. Limestone fragments of the Környe Formation in the Vértessomló Siltstone. Platform foreslope environment. Borehole Oroszlány–2370

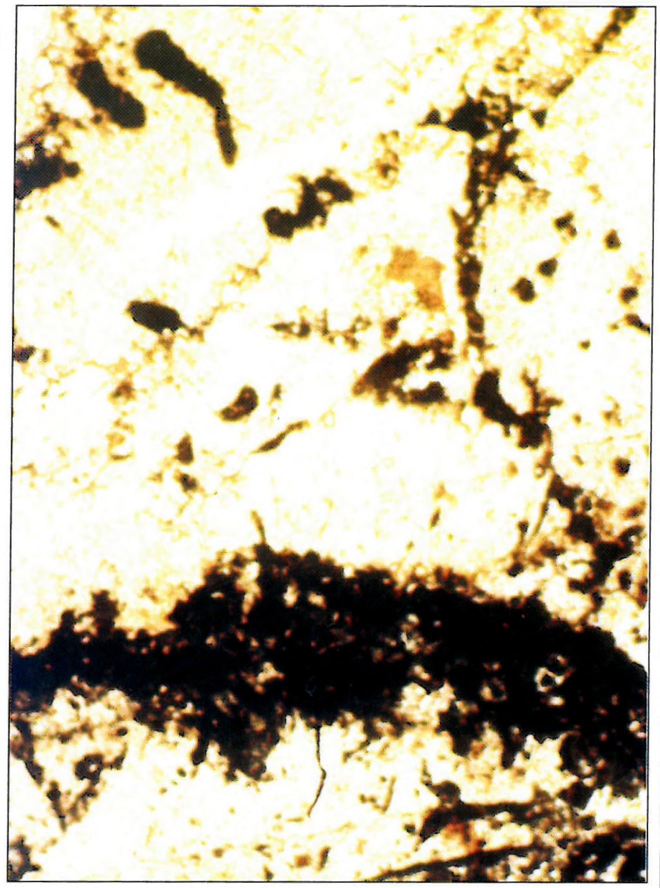


4. Micrograph showing glauconitic, planktonic foraminifera and rudist shell-bearing limestone. Uppermost bed of the Tata Limestone. Borehole Oroszlány–1884

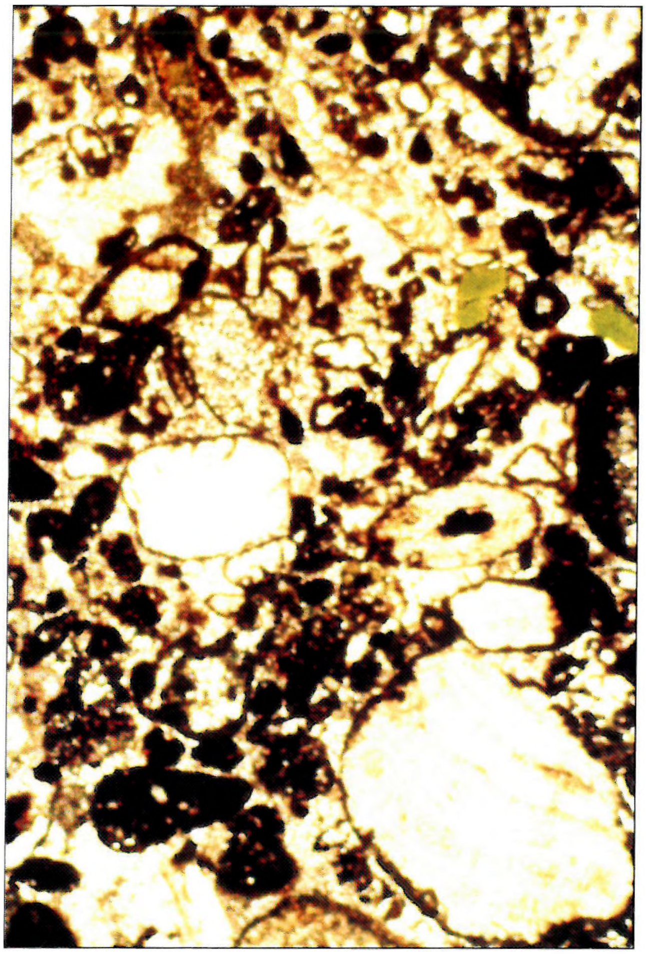


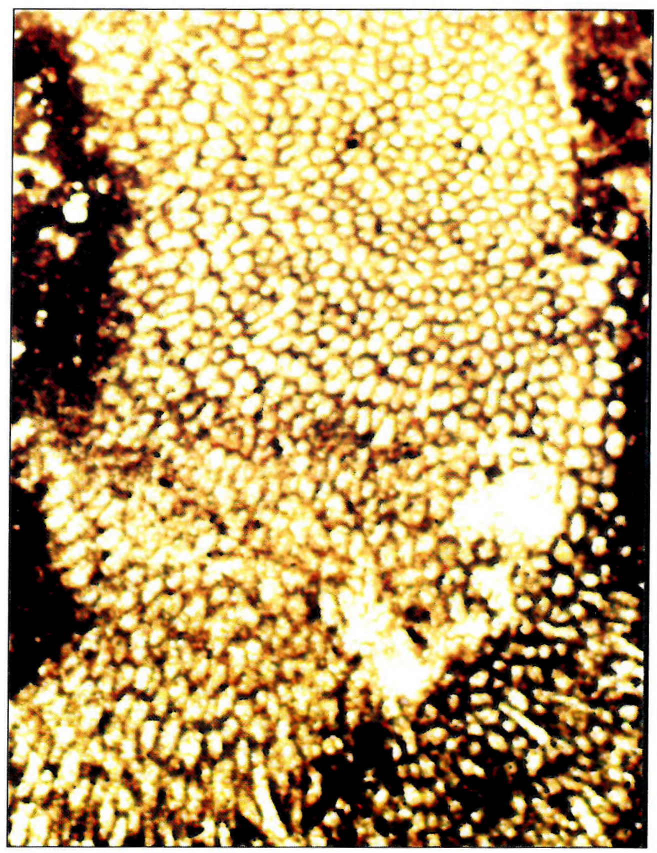
5. Micrograph of an *Orbitolina* grainstone in the Kocs Member of the Környe Limestone Formation. Borehole Pusztavám–820

1. Micrograph of micritizing rudist shell,
Borehole Mór Mt–6
(7.2 m)

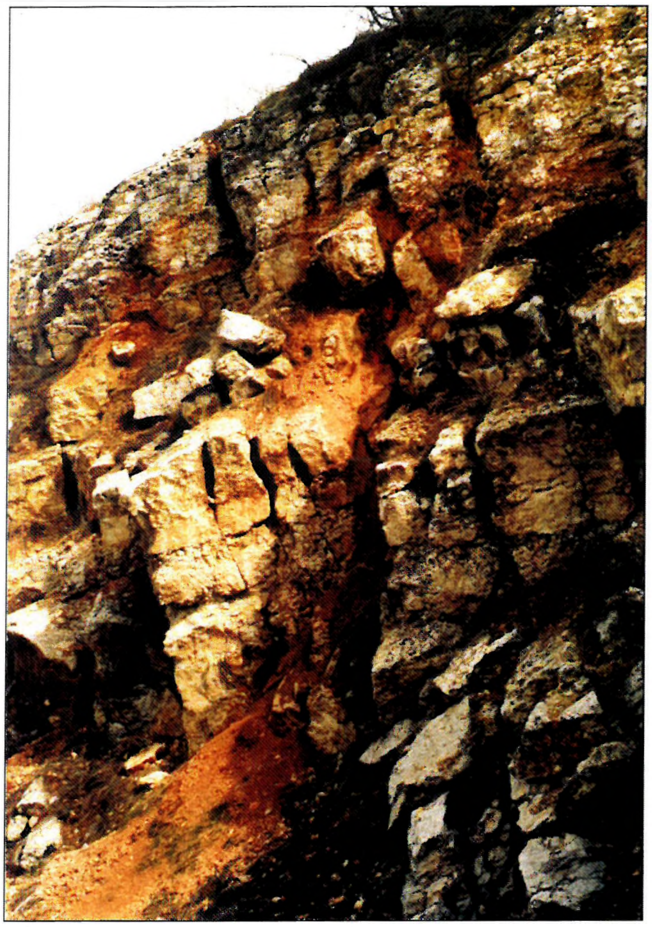


2. Micrograph of rudist biopelsparry grainstone
with glauconite,
Borehole Oroszlány–1884 (275 m)

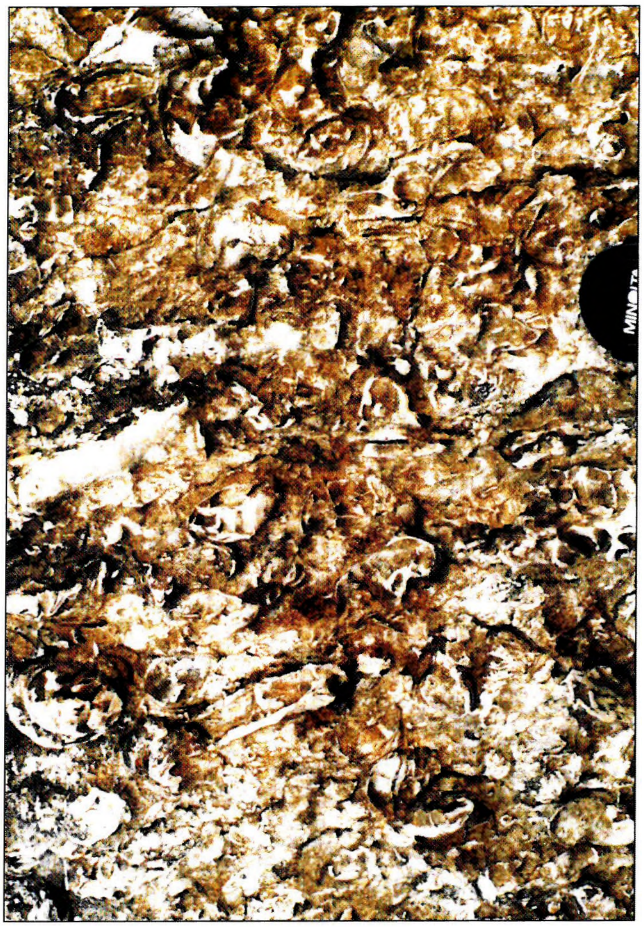




3. Micrograph of algal colony,
Borehole Oroszlány–1884
(221.0–221.5 m)



1. Palaeosoil horizons in the western wall of the abandoned manganese mine, Úrkút



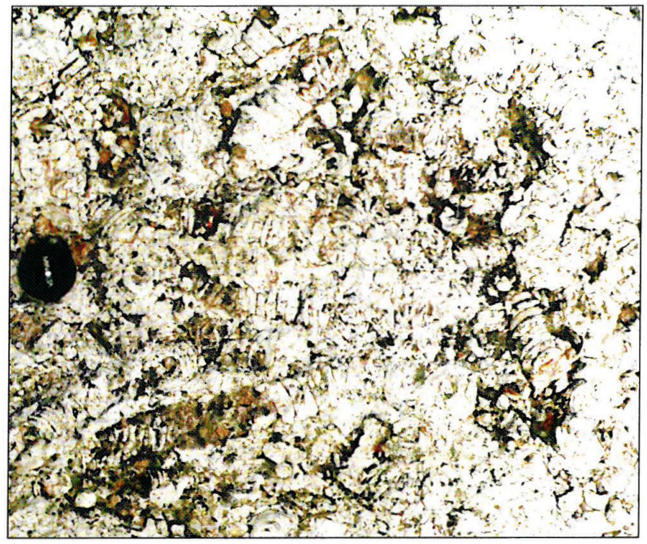
3. Rudist coquinas from the abandoned manganese mine, Úrkút

2. Chondrodonts in life position in the Borehole Úrkút–421 (124.2–124.5 m)

4. Tempestite consisting of limestone debris of 1–5 cm in diameter, abandoned manganese mine

Úrkút Member of the Zirc Limestone Formation from the abandoned manganese mine (phs 1–3)

1. Abrupt change of fauna: small gastropods (mainly *Nerinella*) below (at the base). *Eoradiolites* above them



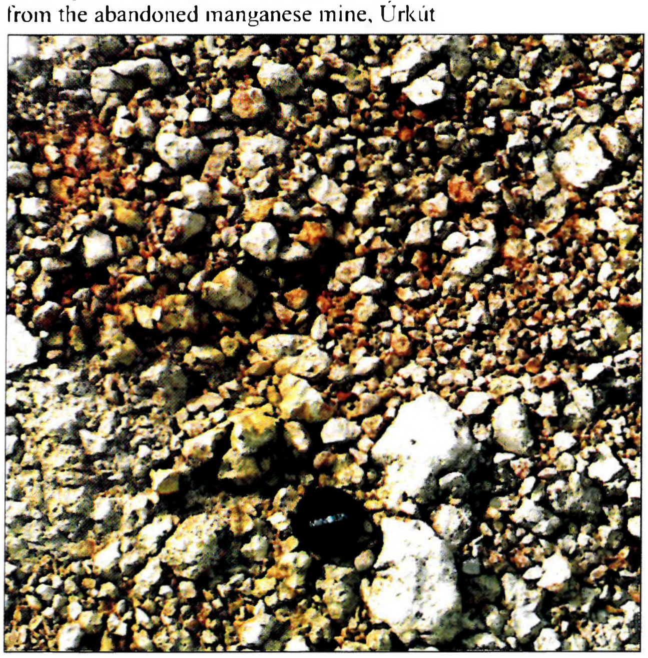
2. Limestone bank consisting of *Nerinea*

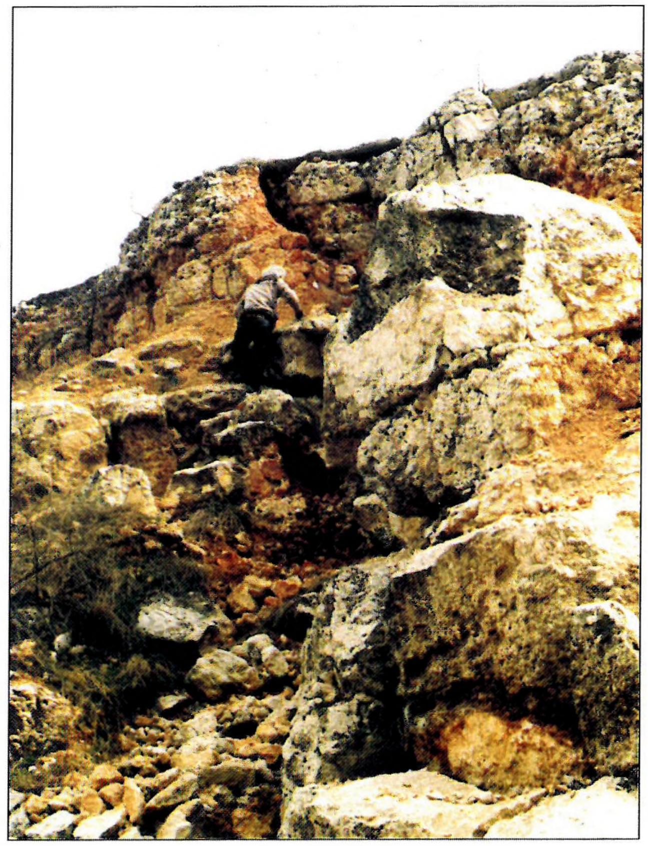
3. Limestone with root structure (lower half) and tempestite (upper half)

4. Gajavölgy Member of the Zirc Limestone (lower part). Pénzeskút Marl with the glauconitic, ammonite-rich Nána Bed at its base. Road-cut, Zsidó Hill, Bakonynána

2. Abrupt change of fossils withouth lithologic change; small gastropods (mainly *Nerinella*) in the lower half and *Eoradiolites* in the upper half. Úrkút Member from the abandoned manganese mine, Úrkút

3. Tempestite bank; Úrkút Member from the abandoned manganese mine, Úrkút





1. Thick-bedded limestone with argillaceous hardgrounds. Úrkút Member from the abandoned manganese mine, Úrkút

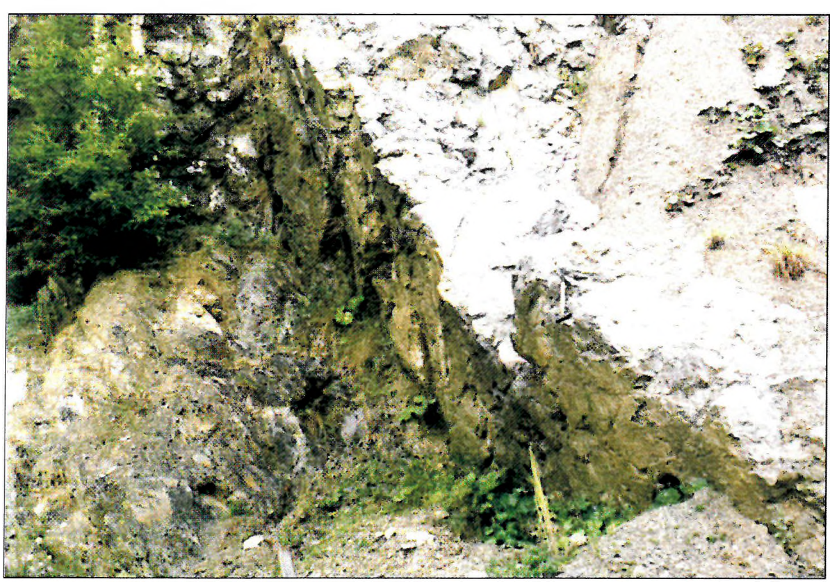
4. Karstic holes in the Zirc Limestone filled by glauconitic marl. Borehole Balinka–246 (479.6–482.6 m, collected by J. KNAUER)

5. Karstic holes filled by glauconitic marl with limestone fragments. Sample as Figure 4 (collected by J. KNAUER)

1. Urgon limestone and its footwall in the Manín Gorge

2. Slope facies limestone with rudist fragments and limestone breccia in the Manín Gorge

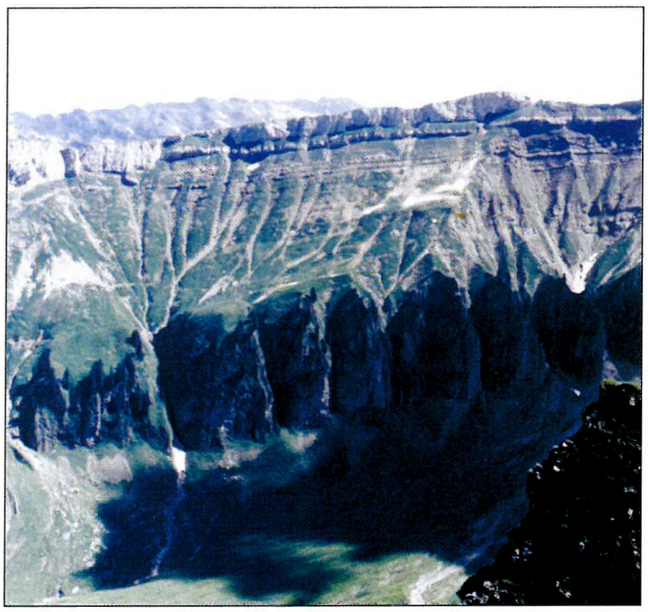
4. Traces of boring bivalves (?) in the bedding plane of the uppermost bed of the Urgon limestone, Butkov quarry



3. Contact of Urgon limestone and the Albian marl nearly vertical position, Butkov quarry

1. Cliff of the Drusberg Formation, capped by the plate of the Schrattenkalk, Voralberg

2. Schrattenkalk as a cap above the Drusberg Formation, Voralberg

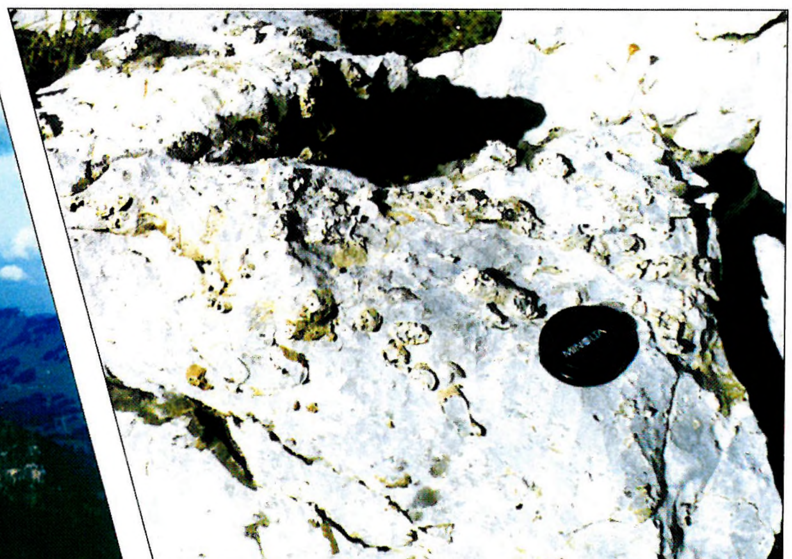


3. Transitional beds between the Drusberg and the Schrattenkalk Formations, western corner of Hoher Ifen

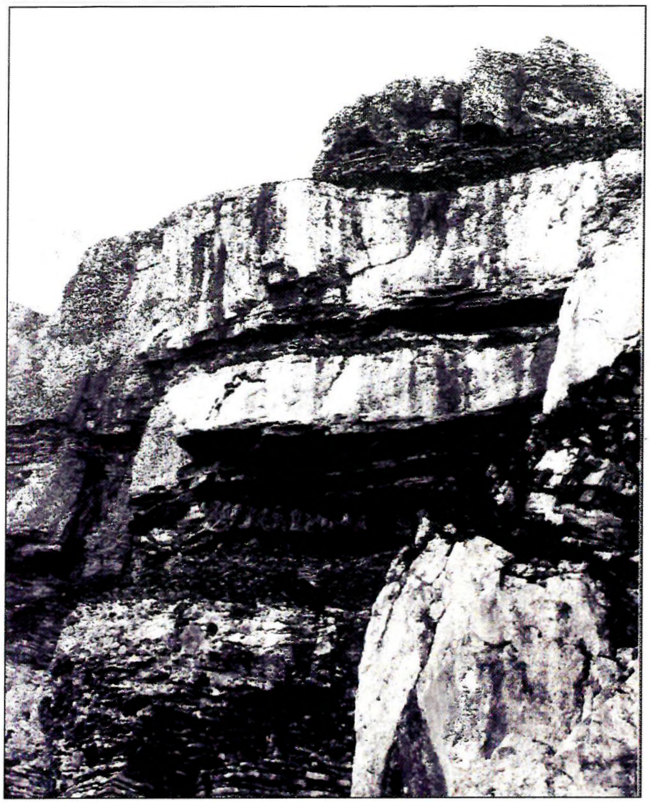
4. Schrattenkalk with the Garschella Formation above it on the top of a mount (left side). South of Chäserrug, Churfirsten

2. Plato of the massive Schrattenkalk to the south of Chäserrugg, Churfirsten, Switzerland

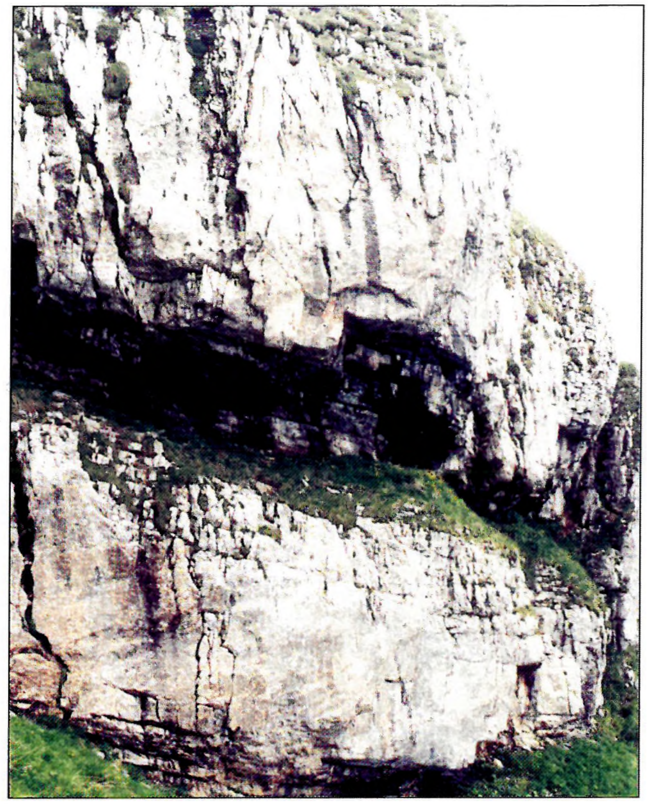
1. Transitional beds from the Drusberg Formation



3. Sponges in the Schrattenkalk to the south of Chäserrug, Churfirsten, Switzerland

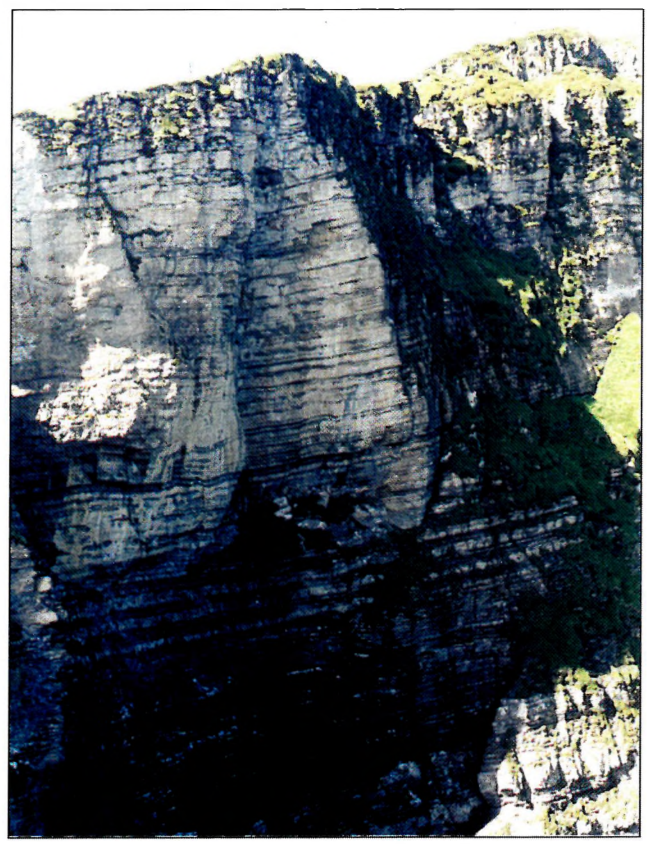


1. Below the peak of Hoher Ifen looking at from the west



2. Thin intercalation of the Drusberg Formation

3. Drusberg Formation with Schrattenkalk at the top



4. Drusberg Formation and the Schrattenkalk thinning towards the basin, upper part of Pellinger Köpfle

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