THE UGOD LIMESTONE FORMATION (SENONIAN RUDIST LIMESTONE) IN THE BAKONY MOUNTAINS

INTRODUCTION

In Hungary, the work of regular definition and description of most geological formations is being carried out nowadays. This fact enable their relevant distinctive features to be determined on the basis of the same principles.

On a detailed investigation of the *Ugod Limestone Formation,* this study is intended to provide a scope of generalizable and particular considerations for analysing a rock body of complicate makeup, which shows evidence of also original breaks in spatial distribution, and displays a considerably changing chronostratigraphic position.

Besides the definition of formation, the re-interpretation and specification of the knowledge regarding the relationships in space and time of the unit concerned, moreover observations on changes with their trends therein and the examination of the transitions from one lithostratigraphic unit to another, are to be enfocused here.

The knowledge of the laws that hold on the development and variations of rock peculiarities is fundamental in forecasting the presence of economic deposits. By studying the properties relevant to the unit in concern, it is possible to make predictions about the existence of included construction materials, bauxite deposits and even potential reservoir bodies for subsurface waters and hydrocarbons.

POSITION OF THE UGOD LIMESTONE FORMATION IN THE EARTH-HISTORICAL CYCLE

In the western part of the Transdanubian Central Mountains' tectonic belt, a varied sequence of sedimentary rocks was produced by the subsidence that took place at the end of late Cretaceous time (Senonian). On a lithological basis, this succession can be divided into markedly distinguishable units. According to our present-day knowledge, these units can be referred to as settled down in the most characteristic environments of deposition represented by the Senonian sedimentary cycle. Relying upon the traditional understanding but dealing also with genetic points of view, the following lithostratigraphic division can be outlined now:

1. *The Halimba Bauxite Formation.* This unit consists of bauxite and bauxitic clay. The deposition of material of lateritic origin took place in tectonically preformed and karstified carbonate-bottomed depressions of a continental sedimentary basin during the initial phase of a regional subsidence.

2. *The Csehbánya Formation.* The Csehbánya Formation is composed of alternating varicoloured argillaceous, argillaceous-carbonate, silty and finely to coarsely-grained clastic rocks. The accumulation of these beds must have been joined with the beginning of the subsidence of a larger continental sedimentary basin. Periodically and partially, the basin was covered by freshwater and to the area the sedimentary materials were supplied by linear and areal transportation.

3. *The Ajka Coal Formation.* This Formation is built up of a cyclic alternation of brown coal deposits and dark grey to brownish-grey-coloured carbonaceous-argillaceous or argillaceous-carbonate—fine-detrital rock types frequently joined with lumachelle banks. These beds were deposited in freshwater to brackish water coastal swamps of rich vegetation formed, directly or indirectly, by the advancing sea during subsidence.

4. *The Jákó Marl Formation.* Under this name, rock types as grey argillaceous-carbonate (marl) and silty marl are concerned. Lumachelle beds are frequent and characteristic. The lower part of the unit (the *Csingervölgy Marl Member*) shows markedly abundant molluscs and solitary corals, while the higher-situated part displays beds lacking almost entirely in megafossils but others, on the contrary, appear as crowded with rock-building Pycnodonts and Exogyrae ("Gryphaea Marl"). The deposition took place in the brackish water-lagoonal part of the marine sedimentary basin (Csingervölgy Member) or in a shallow neritic shelf (shallow sublittoral) environment of sedimentation.

5. *The Ugod Limestone Formation.* This unit is constituted by limestones deposited in the environment of shelf plateau and continental slope belonging to the marine sedimentary basin.

6. *The Polány Marl Formation.* Light grey marl, silty marl, calcareous marl and argillaceous limestone are dealt with here. The lower part of the sequence is characterizable by higher carbonate content together with clay-covered bedding planes showing, on the whole, evidences of bioturbation and mud slumping. Part of the Polány Formation, made up of limestones, is interfingered with the Ugod Formation, may be treated separately as *Rendek Member*. In some areas a lower-situated member, which contains detritus from the Ugod Limestone and abundant fragments of authigenic *breccia*, is known. In higher parts of the Formation a decrease in carbonate content is joined with the appearance of interbedding sandstones.

The Polány Marl Formation suggests a pelagic basin of epicontinental sea to be the pertinent environment of deposition. Its boundary in areal extent indicates the farthest advance of the marine transgression marked by the maximum achievement of subsidence. The more arenaceous character of the upper part is considered as evidence for regression, however, the increased accumulation of detritus of non-carbonate origin may be explained by climatic change rather than by a presumable regression.

The areal extent on Mesozoic rock surface of each formation occurring in the area of study is presented by the map of Supplement I showing outcrops and stratotypes for the concerned formations with the necessary omission of younger sediments.

With the exception of the Polány Marl, these formations are more restricted in areal extent than the Senonian layers, however, in this peculiarity they show a certain regularity. On a formation-compositional basis, some areally delimited units of the Senonian sequence can be distinguished:

a) A succession in which the Csehbánya and/or Ajka Formation is followed by the Jákó Formation and then by the Polány Formation, is observable.

b) The Ugod Formation rests immediately on rocks older than Senonian and underlies, with an inserted transitional unit, the Polány Formation.

c) Between the above-mentioned two extreme types there is a transitional zone comprising the presence of the lower-situated members of type *a)*, which mostly display, however, a reduced thickness and also somewhat divergent features, together with the Ugod Limestone composed of an interfingering sequence of faciologically peculiar beds.

DEFINITION OF THE FORMATION

The unit Ugod Limestone Formation is demanded to have been defined with the expedient inclusion of the carbonate rock types built largely of rudistid fragments, formed on shelf plateau and slope during the Senonian cycle of the Transdanubian Central Mountains' geological evolution. Upon such a definition, the concerned unit is genetically well interpretable and, additionally, more or less correlable with the "Homokbödöge Beds" described by F. Hauer (1862), moreover with the "Rudista Limestone" or "Hippurites Limestone" by A. Koch (1872 and 1875, respectively). This, after some re-interpretations, was considered as a unit in geological mapping up to the recent past.

The Ugod Limestone Formation is characterizable by the following petrographic properties:

1. Its being limestone-type. The $CaCO_3$ content varies between 85.0 and 99.6% (Fig. 2);

2. Light colour (white, greyish-white, yellowish-white and pale pink colours are commonest);

3. Thick-bedded or bulky character;

4. Rock texture built of prevailingly rudistid-type Bivalvia i.e. of their diversely grained debris (aleurite-rudite);

5. A predominant microscopical texture given by biomicrite and biointramicrite (R. Folk's system) or "wackestone" and "packstone" (R. J. Dunham's system, Table 1).

The above features are characteristic of the overwhelming part of the rock body distinguishable as Formation. Subordinately i.e. in a restricted distribution in space, there are somewhat diverse properties shown by rocks intercalated in the sequence of rocks of common features. Owing to their being subordinate, they must not be separated as lithostratigraphic units. The commonest divergencies are as follows:

1. In various horizons, notably at the base of the Formation argillaceous limestone of clay-film structure occurs (in the Csabrendek-Gyepükaján area this horizon attains to a more considerable thickness). Some beds of basal situation are composed largely of rock debris originating from older rocks than Senonian as well as, in the known cases, from limestone, dolomite and calcareous marl (Sümeg: Köves-domb and drill Süt-14 at Városerdő, Ajkarendek: drill Ak-6, Tapolcafő: drill T-1). In a few cases, limestone sequence includes beds of marl (Sümeg: Köves-domb).

2. Beside the prevailing light colours, there are darker grey (Gyepükaján—Csabrendek) and dark red, lilac-reddish or greyish-coloured rocks too (Sümeg: Köves-domb, Ugod: Szár-hegy).

3. Thin-bedded argillaceous limestones also occur.

4. In the aphaneritic limestone types (backreef facies) rudistid skeletons or fragments can be found only sporadically.

5. Among the texture types in question the sparite is also present, however, partly as secondary product after micrite, formed by a late diagenetic process of solution to precipitation.

Stratotype

(Type section, borehole Tapolcafő T-1)

Borehole Tapolcafő T-1 has drilled a 223-m-thick Upper Cretaceous sequence that lies on Upper Triassic Dachsteinkalk.

Lithologically, a three-fold division of the Senonian sequence is feasible: *1. The lowermost part (234.0—235.0 m) is constituted by a basal breccia which is found with a small amount of matrix; 2. The middle part (102.0—234.0 m) represents the typical Ugod Limestone; 3. The upper part (11.7—102.0 m) displays Ugod Formation-type biocalcarenite and calcirudite alternating with horizons of aphaneritic argillaceous limestone, which are assignable to the Rendek Member.*

The Senonian part of the section as drilled and tested is shown by Supplements VII and VIII. Here the most important features are to be dealt with.

1. The breccia bed (234.0—235.0 m) that overlies the Dachsteinkalk consists of slightly rounded (K = 1—2) particles ranging in size from 0.5 to 8.0 cm (on the average 3—4 cm), which upwardly turn to be quite angular and unoriented, moreover cemented with a small quantity of reddish-brown marly matrix. The grains are weakly compressed and the surface between them is frequently stylolitic. The detrital material is made up of fragments of pre-existing Triassic rocks, such as typical greyish-white Dachsteinkalk, ochre-coloured argillaceous limestone, furthermore kinds of reddish and dark grey limestone.

It is noteworthy that smaller but more rounded extraclast grains still appear sporadically in bioclastite up to a depth of 233 m.

2. The breccia is immediately overlain by limestone of greyish-white or pinky colour (102.0—234.0 m). This limestone is formed of biogenic debris of changing quantity, grain size and sorting, set generally in aphaneritic matrix (showing rare proofs of sparitic recrystallization). A non-rhythmic alternation of fine calcarenite with small-grained calcirudite and medium-grained to coarse calcarenite with larger rudite grains can be recorded. Beside completely unsorted grain composition, in some cases, two or three comparatively well distinguishable grain size fractions are prevailing (20—60 μ, 0, 2—3 mm and 1—5 cm). Components of rudite size are usually rudistid valves (Hippurites, Radiolites, Praeradiolites, Biradiolites) or skeletal fragments, partly attacked by leaching and partially refilled with secondary coarse spary calcite.

Under microscope, the most common texture-types are biomicrite and bio-intramicrite (wackestone), with 20 to 50% micrite, 30 to 70% biogenic fragments, 0 to 5% intraclasts and, more rarely, with a few per cent lime mud nodules (non-faecal pellets). Primary biosparite (grainstone) is scanty but somewhat more frequent in the lovermost and uppermost quarters of the horizon. The grains are usually angular or weakly rounded (R = 0—1)*, nevertheless, in the "grainstone" portions values of R = 2—3 can also be recorded. Micritic film-like crusts can be observed on rounded grains.

Among the microscopical organic remains molluscan shell fragments (rudistids and others) prevail. Parts of Echinodermata skeletons (Crinoidea and Echinoidea plates and spicules) are quite rare in the lower third part of the horizon but upwardly they become generally distributed, even if not numerous. Ostracods are comparatively common in the lower third part. In an interval of 145 to 158 m the occurrence of Thaumatoporella-type green algae is characteristic. *Pienina oblonga* BORZA—MISIK, which may belong to the Codiaceae algae according to the authors, as microfossil is persistent throughoutly. The appearance of Foraminifera is changing but significant in quantity. Miliolinae (Quinqueloculina, Triloculina, Massilina) are particulary frequent, up to 50 specimens per 1 cubic centimetre. In various horizons, specimens larger than 1 mm occur. Usually small-sized forms of the Textulariidae and Nodosariidae families often appear in large numbers. A larger form by *Dicyclina schlumbergeri* MUNIER-CHALMAS, moreover species of Cuneolina are frequent and typical, while *Rhapydionina liburnica* (STACHE) and *Rhipidionina liburnica* (STACHE), moreover *Accordiella conica* FARINACCI, *Keramosphaerina tergestina* (STACHE) and *Raadshoovenia* sp. are rarer but also characteristic. A mean frequency is peculiar to some smaller but invariably typical skeletons of the species Valvulineria, Valvulammina, Ataxophragmium, Gavelinella, Lituola and Rotalia. *Nummofallotia cretacea* (SCHLUMBERGER) specimens are abundant in the lowermost part of the horizon (up to 216 m).

3. It has already been revealed by the microscopical study that the bioclastic beds (calcarenite, calcirudite) of the upper part of the drilled section (above 101 m) are interbedded with calcipelitic layers at various levels. Moreover, it has also been recorded that there is a regularity observable in the succession of calcipelite, calcarenite and calcirudite subhorizons. Minor horizons or cyclic unit members distinguished megascopically are denoted in Supplements VII and VIII as follows: *A* = calcipelite, *B* = finely to medium-grained calcarenite, *C* = coarse calcarenite-calcirudite. According to such a marking, from 110 m upwards the series of changes can be made appreciable by the following succession: *C—B—A—B—C—B—A—C—B—C—B—A.*

The diagnostic features of the individual members of cycle are treated below:

A) Light brown and thin-bedded (5—25 cm) aphaneritic limestone. The bedding planes are covered with clay film showing, at places, filling materials in surface irregularities after worm tracks, which can be detected by their unlike shade of colour (yellowish-pink, brown).

The matrix is pelletal biomicrite (packstone) formed by grains of calcaleurite or fine calcarenite. The rock is made up of 60—70% biogenic detritus, i.e. fragments of Mollusca and Echinodermata skeletons showing angular grains sized from 20 to 100 μ, in company of microfossils (Calcisphaerulidae

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* R (on the Figs. marked in Hungarian: K) = roundness — after RUHIN's definition.

with subordinate Foraminifera). The micrite matrix takes up 20—30%. Beside these, 5 to 10% pellet and small intraclasts (mud lumps) can also be found.

In the fauna assemblage planktonic Calcisphaerulidae (Table I: 2) prevail, as well as species like Stomiosphaera, Pithonella, Cadosina, moreover a conspicuous cone-shaped remain of fibrous test which has been described by us as *Conocella ugodensis* n. sp. (J. HAAS, 1978). The Foraminifera assemblage is poor: both planktonic (Globotruncana, Hedbergella) and benthonic forms (Bulimina, Stensiöina, Dorothia) occur.

B) Greyish-white to yellowish-white limestone, fine to medium-grained calcarenite. Rudite-sized bioclasts are very rare. Stratification is observable. The rock is partly leached out to a considerable extent: the porosity of such parts is striking.

The typical texture is constituted by biomicrite (packstone) or, less frequently, bioclastite that contains a quite small proportion of matrix (micrite). Skeletal fragments take up 60—90%. Intraclasts are seldom observable and by small proportions. The particle size is ranging from 20 μ to 1 mm. Between calcaleurite (20—60 μ) and the coarser-grained arenite fraction, no transition given by a distinct grain-size category can be recorded. The particles are usually angular and free of any crust.

The prevailingly biogenic components are molluscan fragments (often rudistids). Particles after Echinodermata skeletons are numerous in certain portions. Foraminifers are absent almost completely: from a depth interval of 47.0 to 80.5 m only 3 foraminifers could be detected by means of a sample collecting interval of 0.5 m.

C) Greyish-white, yellowish-white, at places pinky limestone. The rock is calcarenite-grained bioclastite (1—2 mm) with varying proportions (10—40%) of rudite-sized components (3—15 cm). The rudite particles are mostly formed of Rudista valves (Hippurites, Radiolites, Praeradiolites, Biradiolites and Lapeirousia, according to L. CZABALAY). Their fragments often show a high-degree roundness. In the upper part of the section, this rock type includes also 1-to-6-cm-sized grains of aphaneritic limestone (authigenic breccia).

The porosity upon leaching of the rock here also is extensive. Solution tracks can well be appreciated on the individual fragments of coarse bioclastite.

Under microscope, the rock texture seems to be composed dominantly of material of biomicrite (wackestone, packstone) with comparatively frequent biosparite (grainstone).

Bioclasts amount to 30—70% and are associated with pellets or intraclasts (0—15%). The grain-size is changing on a broader scale, the particles are here well-sorted and there even unsorted. The grains belonging to arenite are the best-rounded ones in this type (up to 3). Encrustations by micritic film are widespread. The biogenic components are composed of elements of Rudista and Echinodermata skeletons. Foraminifers are poor in species and very scanty.

For a better environmental reconstruction, the mineral composition and trace elements content of the individual rock types have been analysed.

According to X-ray diffractometry, the only mineral of $CaCO_3$ composition is calcite. Values of the Sr content (610—270 p.p.m), fall into an interval between recent aragonite and calcite. Accordingly, an originally mixed deposit is dealt with.

CHARACTERIZATION OF THE AREAL UNITS STUDIED

Tapolcafő

The position and extent of the Ugod Formation in the neighbourhood of Tapolcafő are shown on map and sections which have furnished data on field observations and examinations (Supplement II: map and section lines A—B, C—D, E—F and G—H; Figs. 4, 7 and 8: sections).

The relevant statements are as follows:

1. Typical Ugod Limestone cropping out at the NW part of Tevel-hegy (Fig. 4), which has been drilled through by borehole Tapolcafő-1, can be detected in an about 5-km-broad zone as resting on the Triassic directly or after a very thick bed of basal breccia.

2. Towards NW and SE, between the occurrences of Ugod Limestone and Polány Formation, there is a vertically and also laterally developed zone of interfingering transitional beds (Fig. 7: section A—B).

3. Vertically, the typical Ugod Formation is overlain by a group showing rhythmic alternation of fine-grained, thin-bedded, pelagic-type fossils containing argillaceous limestone and other kind of limestone richer in fine to coarse bioclasts originating, to a considerable extent, from rudistids. The latter rock is poor in foraminifers and other microskeletons (borehole T-1, quarries of "Kőhányás", Fig. 3). This transitional unit includes also beds of local extension packed with chert nodules and sponge spicules (Fig. 5).

4. In the zone of the lateral transition, brecciated beds (breccia member) including also fragments of rocks belonging to the Ugod Formation can be detected on the surface or by drills in the direction of Bakonyjákó.

5. SW of Tevel-hegy, beds of the Ugod Formation (Attya-major) and the Ugod—Polány transitional unit (Tapolcafő, Bótakő, Fig. 6) appear by a few uplifted blocks amongst rocks pertaining to the Polány Formation (Fig. 8: section E—F).

Ugod

The most important outcrops of the Ugod Limestone are known at the localities Szár-hegy and Durrogós-tető near Ugod. In this zone some hundred metres wide, close to the boundary of the NW extent of Senonian beds, the Dachsteinkalk is directly overlain by layers of the Ugod Limestone of a poorly argillaceous and fine-bioclastic constitution (Fig. 9: A). Upwardly the Ugod Limestone is followed by bulky to thick-bedded limestone made up of coarse-grained bioclastic material, which includes colony-like Rudista assemblages preserved in a state resembling the life-position of these organisms. This member of sequence is supposed to be 80—100 m thick. It forms, essentially, the south-eastern third part of these ranges, showing a quite close similarity to the type section part of the sequence penetrated by drill Tapolcafő-1. South-eastwardly, between the Dachsteinkalk and the Ugod Limestone, grey-coloured beds of argillaceous limestone are intercalated (Fig. 9: B). These beds consist of non-carbonate detrital material, and they are presumed to have been developed more thicker in a south-east direction. Farther in the same direction, towards the central zone of the ranges, rocks of another sequence break surface: bioclastic limestone grained as calcarenite and calcirudite alternating with quite finely grained argillaceous limestone which contains pelagic-type fossils (Fig. 11). This transitional sequence between the Ugod and Polány Formations is correlable with the upper part of the section drilled (Tapolcafő-1). The transition between the two Formations is continuous in both horizontal and vertical directions.

In the SE zone of the ranges rocks of the Polány Formation are cropping out at the surface. At Szár-hegy brecciated beds are also observable, which can be assigned to the breccia member.

The position in space and interrelation of the lithostratigraphic units are shown on the map included by Supplement III. Furthermore, two geological sections (NW—SE and NE—SW) set up through the whole area of study are also illustrative in this respect (Fig. 12).

Bakonyjákó

This area offers us the possibility to study a some-metres-thick layer of the Ugod Formation as intercalation in the breccia member. Upon the testimony by geological profiles (Fig. 13), the breccia member is 90—100 m thick, and it is overlain by rocks characteristic of the Polány Formation. Similar rocks are found as interbedded in the breccia sequence (Supplement III.).

Matrix material in the brecciated beds is mostly a very fine-grained bioclastite (calcaleurite), which contain fossils derivable from a pelagic environment of deposition, accompanied sporadically by skeletal fragments characteristic of the Ugod Formation. The detritus itself originates from the Ugod Limestone, and likewise from rocks of transitional type developed between the Ugod and Polány Formations, moreover the Polány Formation also is a source of detrital accumulation. These rocks had been consolidated well before their wearing away. The size of the fragments is extremely varied. A few blocks may attain to 1 m.

In the breccia member there are banks in which detritus is scanty or absent. This rock type is predominantly arenite formed frequently of bioclastite derived from rudistids. According to their lithological features, these rocks can be assigned to the Ugod Formation.

As it has been attested to by drilling, the breccia member is stretching farther towards SW. Several boreholes sunk in the Magyarpolány area (Mp-1, Mp-2 and Mp-38, the latter's section and diagrams are seen in Fig. 14), moreover Devecser Dv-3 (Fig. 14) have drilled these rocks between breccia-free portions of the Polány Formation. Drill cores testify to the presence of bioclast-bearing limestones some metres thick, however, it is not known whether these are transported blocks or stand-up "tongues" of the Ugod Formation.

Ajka—Padragkút

In the Ajka Coal Basin only minor erosional remnants of the Ugod Formation are sporadically exposed at the surface or drilled frequently below it. Upon drilling data, a major and coherent but also thinner occurrence is presumed to exist north of Gyűr-hegy. The areal extent of the Formation, together with well logs and the lines of summarizing profiles are found in Supplement IV: subsurface map of the Mesozoic formations.

Comparatively well studiable outcrops come into our focus at Gyűr-hegy, 1 km north of Padragkút. On the northern hillside the Ugod Limestone, with a thinner bed of basal conglomerate built of well-rounded dolomite detritus, is seen to rest immediately on the Upper Triassic dolomite.

There is an about 1-km-broad belt in the Ajka Coal Basin where exploration drills have recovered rocks assignable to the Ugod Formation showing here a thickness of a few metres. Towards SE, the Formation was obviously eroded off.

The distribution of the erosional remnants of the Ugod Formation, which are bound to fault blocks of extremely restricted areal extent, is shown by the geological section A—B in Fig. 15.

Section C—D in Fig. 15 illustrates a north-westward pinching out of the Ajka and Jákó Formations lying under the Ugod Limestone. The situation presented is very similar to that experienced on the SE side of Szár-hegy.

Sümeg

The most excellent and best-studied exposures of the Ugod Limestone are known in the vicinity of Sümeg (Supplement V). Southwardly from the town, on the northern side of Köves-domb, the Ugod Formation rests on the Csingervölgy Marl Member (borehole Süt-16, Fig. 30). In the middle part of the area, represented by the well-defined close surroundings of the Sintérlap quarry, however, the Formation is overlying directly the pre-Senonian basement (Supplement VI).

In the quarry of Sintérlap, a 10-metre-thick sequence can be found over the Aptian Tata Limestone (Fig. 21). This sequence of bioclastic limestone includes colony-like crowds of vertically oriented Hippurites valves. Its outcrops are detectable farther towards the south. In borehole S-7 and various exposures, the underlying Ugod Formation is thicker (up to 70 m). Similarly, the Hippurites-bearing bioclastic limestone too is thicker here, and this rock passes downwards at first into aphaneritic limestone and then into an extraclast-bearing one (Figs. 16—20). The last-mentioned rock resembles a southward-stretching mantle, which borders the Aptian Tata Limestone cliff. The latter, in its turn, is covered by bioclastic limestone some metres thick only. The setting and interrelation in space of the concerned lithostratigraphic units are shown by the section in Supplement VI.

In the extreme part of Városi-erdő, 2 km south-east of Sümeg, the Ugod Formation was recovered by survey drilling Süt-14. and several bauxite exploration wells (Supplement IX). The facial features of these rocks show a resemblance with those of the Köves-domb area.

In a range stretching east of Sümeg, the position and character of the Ugod Formation show a strong change in no distance. NW—SE directed changes in the formation's setting in general and position inside the Senonian complex can be estimated by the section of Fig. 27. As for the changes, they can be resumed as follows:

In the SE outermost belt of the areal distribution of the Ugod Limestone, the typical formation is a coarse bioclastic limestone containing giant rudistids grouped in colony-like assemblages, which usually overlies immediately the Triassic dolomite basement (Fig. 23).

Towards NE, in the lower part of the Ugod Formation or under it, a marginal sort of the Csingervölgy Member appears. As having been compared with the main type, this rock variety is less thick and contains more carbonate (Fig. 24). In this zone the Ugod Limestone is usually of a finer bioclastic-type with rudite-sized grains in various parts. In the middle of sequence the interfingering-type joining-in of the Rendek Member is observable.

Farther towards NW, the Ugod Formation turns to be underlain by the Ajka and Jákó Formations and even by the Rendek Member of the Polány Formation (borehole Ck-168, Fig. 26). The trend of moderate decrease in the grain-size of bioclasts continues to be perceptible, and semi-authigenic breccias also appear is various beds.

Regarding a NW zone (about 1 km wide) of the range, the Ugod Limestone practically disappears from the geological setting so that solely its thin and fine bioclastic beds are stretching into the partially brecciated part of the isochronous Polány Formation. According to a profilage based on sections of boreholes set in the zone of the north-western hill edge there the breccia member also is absent, and the Jákó Formation is overlain by the Polány Formation.

Csabrendek—Gyepükaján

Regularities in the geological occurrence of the Ugod Formation encountered between the villages of Csabrendek and Gyepükaján generally recall those recorded in the range situated east of Sümeg, however, there are differences observable in facies pattern (Fig. 28). It is a common peculiarity that in the SE marginal zone the Ugod Limestone rests directly on a pre-Senonian basement. On the other hand, these beds are composed of coarse bioclasts in the Sümeg area, while here an argillaceous, aphaneritic limestone is predominant. A similarity is given again by the fact that in a NW direction firstly the Jákó Formation and then the Ajka Formation too appear between the pre-Senonian beds and the Ugod Limestone. A difference is given by the fact that the rocks that underlie the Ugod Formation belong to a thicker Rendek Member in Sümeg and here, in turn, to the Jákó Marl. On the other hand, a thinner sequence of beds standing closer to the characteristics of the Rendek Member, is situated by 60—80 m above the base of the Ugod Formation (zone 4). Below this zone, the Formation is composed of a variate and not completely typical Ugod Limestone, which is greyish to brownish and frequently argillaceous (zones 1, 2 and 3). The genuinely developed Formation can be encountered over the 4th horizon (Fig. 29).

Similarly to the Sümeg area, here also the Ugod Limestone is likely to be pinched out rapidly towards NW.

The northern foreland of Bakony

In the northern foreland of the Bakony Mountains only a few drills could hit Senonian formations. Out of these, only the petroleum exploratory boreholes Ukk-1 and 2, moreover Dabrony-1 have penetrated rocks of the Ugod Formation.

These holes drilled by coring and reaming have yielded fairly uncertain data which are inadequate for a detailed facies analysis.

CHRONOSTRATIGRAPHIC CORRELATION

The stratigrapher has a theoretically and practically complex problem in attempting to precisely establish the chronostratigraphic age of the Ugod Formation on the basis of up-to-date principles and methods.

The most difficult general problem has emerged from the inadequacy of type sections chosen to be a standard for comparison of stratigraphic stages and, in addition, from the lack of suitable boundary stratotypes.

For a solution, our approach was supported by taking as a basis for correlation the section (Devecser Dv-3) drilled through a depth interval ranging from 244.4 m to 1035.8 m. This marine-pelagic Senonian sequence with an unbroken succession, for its better part, is so far best studied and documented due to a manysided investigation. Accordingly, the stage boundary traced on a biostratigraphic basis (regional chronostratotype) in borehole Dv-3, has served as standard to which other sections have been compared in line with the use of different methods of correlation.

The litho-, bio- and chronostratigraphic division of the sequence drilled by borehole Dv-3 is shown in Fig. 30. The palynological investigations made by F. Góczán have led to the setting up of biozones based upon the conditions of dominance. The plant life evolution had accelerated in Late Cretaceous time. Thus the investigation of the fossil spore and pollen assemblages of rocks in the pertinent geological units offers us a disposable key to solution. Consequently, *the palynological zonation was chosen as main tool of correlation.*

For the time being, the most widely accepted and used instrument for a long-distance correlation of the Senonian strata is secured by planktonic Foraminifera. An attempt has been made to find out how the most generally used Foraminifera zones correlate with old stage stratotypes and even with chronozones based on Cephalopoda (J. E. Van Hinte, 1972). In consequence, it seemed purposeful *to designate stage boundaries in the local chronostratotype section on the basis of Foraminifera (Globotruncana).*

A detailed study on the foraminifers collected from borehole Dv-3 was carried out by M. Kurucz-Sidó.

Focusing attention on the evaluation of chronostratigraphic data (Fig. 31), it can be stated that the deposition of the Ugod Formation must have been started as early as the Early Campanian in various tectonically preformed areas and belts of the Bakony Mountains. With the main phase in the Late Campanian, the deposition persisted during the Early Maastrichtian too, however, the settling down of the cyclic sequences of the Polány and Ugod Formations and their transitional rock types is characteristic of the zones known. Parallelly, and partially (mainly in the northern Bakony), in the sequence of pelagic basin deposits the accumulation of the breccia member belonging to the Polány Formation took place, with the embedding of detrital materials derived from the Ugod Limestone. During Late Maastrichtian time, the deposition of the pelagic Polány Formation became quite widespread in the actual area of study.

Facies zones

According to evidences by a palaeomorphological study, the division of the environment that had existed at the beginning of deposition of the Ugod Limestone encompasses three principal areal units: *1.* the basin with sedimentation from as early as the Santonian, displaying a neritic marine facies prior to the introduction of the Ugod Formation, *2.* the marginal slope of the basin and *3.* an uplifted karst plateau. About the beginning of the Campanian, with the advance of transgression the situation was modified: *1.* parallel with the deepening of sea pelagic mud began to settle down, *2.* the marginal slope was changed into submarine shelf slope and *3.* the karst plateau was converted into a submarine plateau inundated by shallow sea with biogenic carbonate deposition. Basically, this configuration agrees with WILSON's facies pattern (1975) generalized for shelf regions (Fig. 32). Consequently, our more detailed facies classification should also be based on WILSON's categories used here with unessential modifications.

1. *Basin facies.* Rocks of the Polány Formation may be interpreted to have formed from nannoplanktonic mud containing a good many skeletons of planktonic Foraminifera and Calcisphaerulidae accompanied by merely subordinate benthonic forms, which had been deposited in a reductive environment of the typical basin facies.

The environment of deposition may have been the pelagic belt (deeper than 100—200 m) of an epicontinental sea.

The sediments of pelagic basin facies appeared in Late Campanian time, first in narrow sub-basins formed between elevated ridges (boreholes Sümeg Sp-2, -3, Devecser Dv-3, Magyarpolány Mp-1, -2 and -38, outcrops of Bakonyjákó, S Tevel-hegy, S Szár-hegy, borehole Pápa Pa-2 etc.). From the Late Maastrichtian on, they have been widely spread all over the carbonate-platforms too.

2. *Open shelf facies.* This belt of sedimentation is represented by the Rendek Member. The pertaining rocks are grey-coloured, thin-bedded argillaceous limestones of calcarenitic-micritic texture (wackestone, mudstone) with sporadically contained arenite-sized fragments of Echinodermata and Mollusca. Sole markings are frequently seen in beds and on the uneven and clay-film-covered top and bottom of strata. Structures such as bioturbation and nodular, plastic or mud slumping phenomena are common in some layers. Calcisphaerulidae are generally frequent, while benthonic and planktonic Foraminifera have an equal share (Plates I and II).

The site of deposition must have been in a zone considered still pelagic, with a bottom sloping at quite low angles between the basin and the shelf plateau. The depth may have changed between 40 m and 100 m under the zone of waves.

The pelagic slope facies can be recognized by deposits interfingered with those of the Ugod Limestone in the vicinity of Sümeg, above the Campanian Ugod Limestone at Köves-domb. Easterly from Sümeg, such rocks are covered with a rudistid-bearing unit of Late Campanian to Early Maastrichtian age.

The transition towards both the basin and the foreground to the rudistid-bearing plateau environment is quite continuous and detectable on the basis of the rock sequences (Fig. 27).

Rocks of similar composition and, obviously, facies are seen in the surroundings of Tevel-hegy, moreover on the SE slopes of Szár-hegy and Durrogós-tető.

3. *Foreslope facies of carbonate platform.* A more inclined upper zone of the slope connecting the epicontinental basin with the elevated shallow plateau is to be dealt with here, since the concerned sedimentation is characterizable by the accumulation of carbonate detritus proceeding from the rocks of the plateau. The detritus in question can be divided into two principal groups: *a)* bioclasts and *b)* lithoclasts ranging in size from arenite to metre-sized boulders, formed from carbonate rocks and lithified deposits of pre-existing slope zones. The two types may occur together or separately and, in some places, they form an alternating sequence. Both the bioclastic and lithoclastic types are interfingered with pelagic beds (outer shelf, basin). Despite their fairly close relationship, they should be assigned to separate lithostratigraphic units owing to the significant lithological differences recognized between them. In consequence, deposits of the bioclastite facies have to be classified, upon the formations' criteria, into the Ugod Formation, while lithoclasts, embedded in a matrix showing diagnostic features of the Polány Formation, are to be included in the breccia member of the Polány Formation.

a) The accumulation of lithoclasts. The material, size and proportion of detritus in te concerned lithoclastic rocks are highly diversified. As for the material, fragments from widely different facies of the Ugod Formation (foreslope, atform and backreef) prevail, however, authigenic breccia derived from local or quasi-local tearing up of mud, is also observable. The detrital material is usually quite unsorted. The particles are angular or, at the most, poorly rounded. The embedding material show features indicative of the Polány Formation or the Rendek Member. Undulating and clay-covered bed surfaces, beside evidences for mud slumping, are seen (Plate III).

During local uplifts and owing to episodes like stormy surf and earthquake, the once consolidated carbonate material may have been broken down, then removed on a steep path and finally accumulated at the foot of slope. The rapid duration and very episodic character of such an action can be verified here by the repetitive interstratification of common pelagic sediments. In the foreground of carbonate buildups it is common the accumulation of consolidated carbonate detritus, and this is always indicative of steep slopes. According to Wilson (1975), in modern cases this slope angle may attain to 30°. Hence, the accumulation of lithoclasts indicates the basal zone of steep slopes.

The one-time existence of such slope can be assumed on the basis of a thick accumulation of the breccia member along a line marked by Szár-hegy, Tevel-hegy, Bakonyjákó, Magyarpolány and Devecser. The lithoclastic accumulation can be recognized also near Sümeg, however, here the detritus of platform facies is less common and authigenic breccia-type detritus prevails instead. This is indicative of a less steep slope.

The presence of the breccia member is connected with well defined areas and chronostratigraphic periods (Early Maastrichtian). On this recognition it can be stated that the necessary conditions (slope steepness, storm-waves) had existed in definite areas and in certain phases of transgression. Subordinate proportions of lithoclasts, nevertheless, could have formed elsewhere and in other periods, too.

At base of the Ugod Formation accumulations of detritus from older rocks (extraclast) can be recorded as having been restricted to minor areas (Sümeg: Köves-domb, Városi-erdő, borehole Cn-211 etc.). According to observations done till now, these are bound to the backreef facies instead of the foreslope one. Their material is derivable from rocks of older geological cycles, thus they cannot be correlated genetically with the lithoclast accumulations treated here.

b) Bioclast accumulation. A group of rocks embraced by the Ugod Formation can be interpreted as formed on the foreslope, on the basis of the following features: biomicrite, more rarely bio-intramicrite (wackestone, packstone) with 60—80% allochemical components by predominant organic fragments. The particle size distribution of the latter occupy an extraordinarily wide scale from 20 μ to 10 cm. The material is unsorted i.e. frequently separated into various grain-size fractions (calcaleurite 20—60 μ, calcarenite 0.06—2.0 mm and rudite 2—10 cm). The smaller grains are angular and the rudite-sized particles subangular. Encrustations are seldom seen.

The majority of the rock-forming skeletal components are derived from the rudist buildup (Rudista plus other Mollusca), while the life environment of other organisms may have been identical with the site of accumulation (presumably, part of Echinodermata). The Foraminifera assemblage is poor in species and frequency, too. Benthonic forms (Textulariidae) prevail; part of them (Dicyclina, Cuneolina etc.) may be originating from the platform. Planktonic fossils are rarely observable.

On a main basis by grain-size distribution, sediments of the foreground slope can be subdivided into two additional groups.

On the uppermost part of the slope, which constituted the immediate foreground to the carbonate buildup, the most coarsely-grained part of the bioclastic material that had been removed from the platform by waves, accumulated. Then they must have been submerged under the zone of waves. A low degree of shattering force of the waves is indicated by non-rounded fragments and the presence of lime mud (micrite) matrix. The water depth may have been 15—30 m. Light conditions in the otherwise photic zone were very poor on account of shadowing by detrital inflows, thus this environment could not meet the requirements for life of the sessile benthonic organisms.

In a more lower-situated part of the slope a quick deposition of fine-grained bioclasts took place on a bottom 30—50 m deep. The light that penetrated down to the bottom was very weak and the water temperature also somewhat reduced, presumably to 24—26 centigrades in case of a surface temperature of 30 °C. These conditions were no longer suitable for the typical benthonic life community of the shallow plateau.

In the case of the existence of steep slopes or slope zones, an episodic accumulation of coarse lithoclasts and bioclasts took place at the foot of slopes, beside a common basin, shelf or slope sedimentation. Low-angle slopeness implies the reduction of the role played by gravity transport, and the foreslope must have passed into the open shelf area without any essential change in slope angle.

The type of moderate slopes is exemplified by the facies distribution shown by the Sümeg range.

On the other hand, the immediate plateau foreground of the Campanian formations at Szár-hegy must have been markedly steeper, since the bioclastic foreslope facies are very reduced in areal extent.

In the vicinity of Tapolcafő, the Lower Maastrichtian sequence shows a succession of open-shelf-facies rocks alternating with beds of the bioclastic-type foreslope. This is indicative of the pre-existence of extensive foreslopes, presumably formed after the building up of the biogenic accumulation when the balance of sedimentation was shifted from a biogenic primary precipitation towards the splitting up of previously lithified rocks.

4. *Platform margin facies.* Rock types holding "in situ" embedded colony-like close assemblages of rudistid valves are considered to represent a platform margin facies of the Ugod Limestone. Typical accessory skeletons are colonial coral, hydrozoans, red algae and larger Ostrea. On these skeletons solution markings after sponges are seen. Beside complete skeletons, proportions of bioclasts of rudite to arenite size are also significant. The rudite particles are poorly rounded, while those of arenite size show a diversified state of roundness, as far as they are angular but covered with micritic film in a micrite matrix, while the constituents of biosparite texture are well-rounded (Plates V and VI).

The environment of deposition comprises the edge of the surf zone adjacent to the plateau (natural breakwater front). The water may have reached a few metres in depth (at low tide some centimetres). Upward-moving currents could carry water rich in CO_2, organic nourishing materials and also in oxygen owing to the breaking of waves. Optimum conditions for the chemical precipitation of carbonate materials were assured together with the existence of giant Mollusca of cellular-type shell adapted for heavily rolling sea. Rudistids as reef builders, however, could not form a "breakwater" so highly compact and protective than the coralline-algal edge of modern coral reefs. Nevertheless, they were able to slow down anyhow the waves breaking against them. Steep i.e. quasi-vertical walls characteristic of coral reefs could not be formed here, however, a kind of morphological elevation must have been erected by the quickly growing giant organisms. The foreground sloping of these masses may have been gentler than that of the modern coral reefs, but it was surely steeper than the common slanting of the continental shelf. This organic barrier was formed on the only condition that the controlling morphological and other factors were favourable in full. It is also imaginable that during the formation of the Ugod Limestone no sharp plateau edge could support the development of the marginal facies. In such a case, the marginal facies and the pertinent zones behind the breakwater front cannot have been formed i.e. separated.

The preservation of these narrow marginal facies zone of the plateau can hardly be secured, since they are formed in a belt of the most intensive water movement. Consequently, their building up is soon followed by their destruction. Thus, the environment-controlling role of the marginal facies is much more greater than expected upon the frequency of the pertaining fossils to be found. Their one-time existence can be detected, in many cases, only by the reconnaissance of joint facies (backreef lagoon facies).

The best-recovered, even if somewhat peculiar occurrence of the platform margin facies is likely to be encountered at Köves-domb near Sümeg. Rudistids, embedded "in situ" in colony-like groups, are seen in the upper zone of the Csabrendek—Gyepükaján sections (boreholes Gy-3 and Cn-299).

A fine example of the vertical succession of more Hippurites populations is found on the western side of Szár-hegy (Supplement III, point 4).

5. *Unstable sand facies of the platform.* Some light-coloured kinds of limestone of the Ugod Formation have been assigned to this facies type on the basis of the following textural features: biosparite to bio-intrasparite (grainstone) consisted of well-sorted, medium to coarse-grained and well-rounded particles of calcarenite size, frequently encrusted with micritic film. Bioclastic i.e. skeletal fragments (mainly rudistids, less frequently molluscs and crinoids) take up 70—80%. Out of algae, the presence of *Pienina oblonga* Borza—Misik is striking. The rarely occurring foraminifers are benthonic forms. There is, however, a biosparite-texture type the grains of which are almost exclusively foraminifers (species of Textularia, Dorothia, Nodosaria and Miliolina). From the allochemical components, arenite-sized and well-rounded intraclasts (0—20%) are mentionable. The proportion of pore-filling sparite ranges from 10 to 20% (Plates VII and VIII).

The deposition must have taken place in shallow and wave-shattered parts of the plateau, where the bioclastic grains are subjected to abrasive effects by the action of waves resulting in the winnowing out of lime mud. During such a sedimentation, in the intertidal zone lime sands are piled into mounds or dunes and, respectively, smoothed down into flat, sandy beach according to the changing features of the pattern of tidal currents and waves.

Rocks interpretable as belonging to the moving sand facies are frequent in the upper part of the Köves-domb sequence (e.g. cut by drill S-7 from 20 m upwards), moreover at various levels in the Csabrendek—Gyepükaján section, mainly in the upper parts of the sequences.

6. *Backreef facies.* Quite finely crystalline, generally aphaneritic, white or yellowish to pinky limestones of the Ugod Formation may belong to the backreef facies. Their texture is micrite or pelmicrite or biomicrite with angular to subangular particles and a grain-size ranging from aleurite to rudite. The assemblage of megafossils is composed of small rudistids (Agria, Biradiolites, Praeradiolites) and species of Nerinea, moreover Decapoda scissors. For microfossils, first of all benthonic foraminifers are worthy of note, mainly the frequent appearing of langer Miliolina. Large-sized Porcellanea types are also characteristic: Dicyclina, Cuneolina, Rhipidionina. Among other microfossils ostracods and green algae are typical but not generally frequent (Plates IX, X and XI).

The site of deposition of this facies is considered to occupy a zone protected against waves behind dunes or platform margin where the lime mud winnowed out from the zone of waves can be settled down. In case of storms, however, coarser bioclastic material can also reach the backreef zone. As not having been subjected to further wearing effects by waves the particles of this sedimentary material should be left angular. The depth of the backreef lagoons may be estimated at 10—20 m. The bottom was surely situated under the normal wave base, well inside the photic zone (presence of green algae, algal symbionts). Due to a poor circulation, the water temperature must have been risen up to as high as 30—32 °C, according to actuogeological data (Riera 1972) and palaeotemperature estimations. The salt content of water was generally normal but in some zones and certain periods a slight freshening took place, at least according to the presence of locally dominant Miliolina skeletons associated with *Nummofallotia cretacea* (Schlumberger) at the base of the concerned sequences. The appearance of this last-mentioned form is particularly striking in the upper part of the Csingervölgy Marl succession. Here the animal life was much less rich than in the platform margin zone, but rudists were presumably able to adapt themselves for the life conditions displayed by backreef lagoons.

Most typical examples of the backreef facies can be studied at Kövesdomb near Sümeg and in the drilled section Süt-14. The same facies can frequently be found also in the sequence of the Csabrendek—Gyepükaján area, however, in a less typical form which is indicative of a less markedly developed protective zone against waves. Borehole Tapolcafő T-1 has drilled a section the lower half of which represents, for the most part, the backreef facies.

EVOLUTION HISTORY

In reconstructing the evolution history of the Ugod Formation, our approach should obviously be based on an analysis of the distribution in space and time of the facies combinations that show a close interrelationship with the palaeomorphological conditions.

It should now be clear that the development of the early Mesozoic synclinal structure of the Transdanubian Central Mountains was opened as early as the Jurassic. The main course of its formation, however, was bound to the mid-Cretaceous Austrian phase of orogeny. In the NW part of this structural zone a process of epeirogenic subsidence and uplift involving marine sedimentation took place during the Albian – Cenomanian. Thereafter, up to as late as Santonian time, the zone was on the whole subjected to denudation.

Triassic carbonate formations and older crystalline metamorphic rocks were exposed to the surface in the middle of the region and on the limbs of syncline, respectively. In the central zone of the syncline there was a fairly rugged morphology preformed tectonically (Fig. 33). During Santonian time the region was dropped by subsidence. In the deepest-situated part this subsidence resulted in the formation of continental sedimentary basin. Then the filling up by a fluviatile to swamp sedimentation of this basin began (Csehbánya Formation). In the following period of subsidence, about the end of late Santonian time, the southward-situated zones were inundated by freshwater. This involved a lacustrine to swamp deposition of sediments (Ajka Coal Formation). At the beginning of the Early Campanian, in a SW–NE direction a gradually developing contact with the sea brought about the formation of brackish-water lagoons and swamps (upper part of the Ajka Formation) together with a shallow-basin sublittoral deposition of marls (Csingervölgy Member). At the same time, on basin-dividing ridges and marginal plateaus a characteristic pattern of karst scenery was being formed. This layout is shown by the palaeogeographic sketch of Fig. 34a. Farthest towards the west (Sümeg), the earlier appearence of the sea left the area covered by normal saline water able to create life environment for rudistids (Köves-domb).

Between the Early and Late Campanian, waters of normal salinity turned to be prevailing over the region inundated by sea. This was a significant factor for the life environment of the rudistid lamellibranchs. These environments were really formed in the marginal shallow waters (0–20 m) but in a limited areal extent due to the predominant morphological conditions. On account of the relevant controlling factor given by the gradual inundation of steeper slopes, the areal distribution of the rudistid-bearing marine environment was restricted to the mostly narrow areas of the upper slope zones and cliffs

(Fig. 34b). In the shallow-sublittoral environment of basin marly mud was being deposited (Jákó Marl Formation).

In late Campanian time the basin subsidence continued, and in deeper-sunk zones an open epicontinental basin sedimentation took place (lower part of the Polány Formation). During subsidence, the flat ridges and karst plateaus of the southern basin edge were gradually inundated by the advancing sea. These former karst plateau zones were turned into submarine platform representing optimum conditions for the life of rudistids. The former coastal slopes became foreslopes of the platform suitable for bioclastic accumulation. During this, the former basin deposits also were getting buried with foreslope sediments. On the plateau margins breakwater front facies or rows of travelling dunes were formed, in depedence on the steepness of the slope/platform transition. Behind the fronts backreef facies was deposited. Areas and depth conditions of this deposition are shown in Fig. 35.

According to observations done in the northern Bakony, the subsidence/filling up balance turned to be upset on the plateau between the NW and SE sub-basins at the end of Late Campanian. Life-environment of the rudistids that are generally depth-sensible, disappeared and the former plateau became subject to receive deposits settled down in an open shelf-slope environment of sedimentation (Rendek Member). Evidences of a succession of alternating transgressions and regressions have been recognised in the Lower Campanian sequence. Regressive periods seem to imply subaerial conditions for various parts of the carbonate platform together with the involvement of the consolidation of carbonate deposits. Then the latter were gradually splitted up as battered by erosional forces, and their fragments were accumulated in zones adjacent to the foot of slopes (breccia member).

On the southern margin being less steeply inclined between the platform and the sedimentary basin, the face of the partinent environments was more changing. In the vicinity of Sümeg, the end of Late Campanian is marked by evidences of the transgression that was responsible for disappearance of the rudistids (e.g. Köves-domb). This transgression was followed by regression (east of Sümeg there is a belt a few kilometres wide in which the foreslope facies of the Ugod Limestone is overlapping the open shelf facies). The same tendency can be detected in the Csabrendek—Gyepükaján area (see the facies curve plotted for the drilled section Gy-7: sequence of the facies, backreef—foreslope—open shelf and platform). All by this the deposition was hardly influenced, for the unbroken appearance of platform to near-platform facies can be recorded as starting from the lowermost Upper Campanian and passing into the Lower Maastrichtian.

By the beginning of late Maastrichtian time, the preservation conditions for the rudistid-bearing shallow plateaus became definitively unfavourable (with the maximum of transgression) and an argillaceous to calcareous (nannoplanktonic lime mud) sedimentation of open epicontinental character was introduced all over the area investigated (Polány Formation).

The Cretaceous period ended with the general elevation of the sea-floor into a land of widespread denudation responsible for the wearing away of the Polány Formation principally in the Bakony Mountains and their nearby foreland. Consequently, the Ugod Limestone was exposed to the surface as early as the pre-Eocene times, however, it was later eroded off to a diverse extent and covered by Eocene beds.

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