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Eocene Bryozoa from Hungary

(part I. Localities and discussions, part II. Systematic palaeontology)

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Preface

During the years 1992 to 1996 we spent many weeks together in the field in Hungary, Slovakia and Italy to find localities with Eocene sediments containing Bryozoa. The investigation of the Hungarian Eocene yielded an exceptionally rich collection of Bryozoa, which seems to be the richest association from the Eocene in the Alpine-Carpathian region. The preparation of samples, determination and description of species took almost next three years. We would like to present results of our study here.

According to personal suggestions of many scientists and to avoid any misinterpretation of priority rule, we have split our results into two parts. The first part describes the localities examined, provides a historical background to the area and deals with the comparison and palaeoecology of Bryozoans. The second part providing detailed descriptions of the species found in systematic order.

These two parts cannot be separated and, therefore, the literature references are common to both parts.

Acknowledgements

This study of Hungarian Bryozoa was initiated by Prof. Milan Mišík (Bratislava) in 1992 to serve as comparative material for the Slovakian faunas, described by Zágoršek earlier. The material found at the Hungarian localities proved to be the richest of the Alpine-Carpathian region and several years were spent on its study.

Many people and organizations supported our work, to whom we owe a great debt. Dr. Dennis Gordon (National Institute of Water and Atmosphere, Wellington, New Zealand) provided helpful comments on an earlier version of the volume and improved the English. Both he and Prof. Giampietro Braga (University of Padova, Italy) offered useful suggestions on taxonomy mostly regarding Cheilostomata. Careful reading and useful remarks and comments were also provided by Prof. Vávra, from the Institute of Palaeontology (Vienna University, Austria). Some important comments were also obtained from Dr. Scholz from the Forschungsinstitut und Naturmuseum Senckenberg, Frankfurt am Main (Germany). We would like to express great thanks to all of them.

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Many thanks also go to Dr. H. Summesberger, who helped the first author to study the original Reuss and Stoliczka material in National History Museum in Vienna.

The final version would not have been possible without kind support of FWF (Fonds zur Förderung der Wissenschaftlichen Forschung, Austria) project M517-GEO to K. Zágoršek, which enabled him to finish the manuscript during his stay at the Institute of Palaeontology (University of Vienna, Austria).

We are grateful also to Prof. Steininger, who offered to publish the presented work in Courier and to Dr. Rich Meyrick who checked carefully the English and greatly improved the style and make it more interesting to read.

We would like to dedicate this research to our families, who have enough courage to help us wherever we need it.

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Eocene Bryozoa from Hungary

(part I. Localities and discussions)

Kamil ZÁGORŠEK & Miklós KÁZMÉR

with 7 figures and 2 tables

Abstract

Upper Eocene (Priabonian) Bryozoa from the Transdanubian Central Range (Hungary) are described. Localities at Mátyáshegy (Budapest), The quarry Lapos-bánya at Üröm and Úrhida yielded 131 species by a new method of dissolving bryozoan marl in concentrated acetic acid. The fauna probably lived in a shallow bathyal environment. The bryozoan assemblage is similar to those from Slovakia, Italy, Austria and Romania.

Keywords: Eocene, Priabonian, Bryozoa, taphonomy, palaeoecology, geology, Hungary.

Introduction

Eocene was a good time for Bryozoa. Family-level global diversity reached its peak (TAYLOR & LARWOOD, 1990:214), new areas, which had never seen mosses before became available for population and billions of colonies grew, eventually to form rocks after their death.

To understand the position of Bryozoa during Eocene and the response of this group to challenges, we started a systematic study of faunas and environments of Late Eocene age (ZÁGORŠEK, 1992–1997; KÁZMÉR et al., 1993; ZÁGORŠEK & KÁZMÉR, in preparation). This monograph presents the richest Eocene bryozoan fauna in the Alpine-Carpathian region [perhaps in the whole of Europe?], which although known to exist for almost 120 years, has lacked proper documentation until now.

New, chemical methods were developed to extract the fragile colonies from the litified marl usually hardly yielding any fossils; bed-by-bed collecting allowed a detailed understanding of environmental evolution; and scanning electron micrography gave aesthetical pleasures.

In the present study we provide a systematic description of the major Upper Eocene bryozoan faunas in Hungary and briefly discuss their environmental and palaeogeographic significance (see also ZÁGORŠEK & KÁZMÉR, 1999). A detailed study of the host rock, the bryozoan marl, will be published elsewhere.

Previous research

The first person described Bryozoa from Buda marls was PERGENS (1887a). who determined 51 species altogether. Most of his species are well known and have also been observed in this study. Some of his determinations, however, seem to be very unusual and in need of revision. Unfortunately his collection cannot be found in the Hungarian Natural History Museum in Budapest, so we cannot revise his determinations. Consequently, we are unable to add his species to the recent study. According to Vávra (pers, com, 2000) a part of his collection is perhaps in Maastricht.

VOGL (1909) has studied the sediments from Úrhida, mentioning 15 Bryozoa species. He did not describe or illustrate any of them, but if we presume that his determinations were correct (in 1909 terms), almost all of them have also been found during this study. He distinguished only two species of “Entalophora”, *E. attenuata* and *E. pulchella*. These two species could be *Mecynoecia proboscidea* (MILNE EDWARDS, 1838). We do not have his original material, so we cannot revise his determinations with certainty.

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DUDICH (1971) described Eocene sediments from a borehole (CSV-18) near the village of Vál in the south-eastern foreland of the Vértes Mountains, mentioning 11 species from 8 genera. All of the genera also occur in the Buda marls, although most of the species are unknown. The most abundant species were *Hornera frondiculata* LAMARCK and *Entalophora attenuata* (STOLICZKA, 1862). *Hornera frondiculata* is a common and cosmopolitan species in the Eocene, but *Entalophora attenuata* (STOLICZKA, 1862) seems to be *Mecynoecia proboscidea* (MILNE EDWARDS, 1838). On the other hand, DUDICH did not describe or illustrate any species, so his determinations remain uncertain.

GHIURCA (1987) revised all Bryozoa taxa from the Palaeogene of Central Europe, 95 species in all. According to his study, 84 of them are determined with certainty, from which 32 were Cyclostomatida and 52 Cheilostomatida species. None of his determinations were described or illustrated. We did not visit his collection and so cannot revise his determinations either.

Stratigraphy

The Hungarian Palaeogene Basin (BÁLDI & BÁLDI-BEKE, 1985) is an elongated, east-west oriented set of sub-basins along the southern, internal side of the Alpine-Carpathian orogen (KÁZMÉR et al., 1996). It is understood to be a retroarc, flexural basin (TARI et al., 1993), where sedimentation started in the west and progressed towards the east. Early Lutetian (Middle Eocene) saw the birth of the westernmost sedimentary basin (western Bakony Hills), the eastern Bakony basins first received marine sediments during the middle Lutetian, whilst the Buda Hills in the east became submerged below sea level as late as the late Priabonian (BÁLDI-BEKE & BÁLDI, 1991). Whilst this eastward progress of sedimentation is only recognizable in shelf sediments, the uppermost, pelagic part of the succession existed without any interruption up until the Priabonian (or later) in all three sectors (BÁLDI-BEKE, 1984; BÁLDI, 1986).

Bryozoans occur in tens of localities as minor faunal elements (SZÖTS, 1956), but there are a few localities where bryozoans occur in rock-forming quantities. This study considers only the latter category.

The biostratigraphy of Hungarian Eocene formations is based on detailed studies of nannoplankton (BÁLDI-BEKE, 1984, also in BÁLDI, 1986) and planktonic foraminifera (HORVÁTH-KOLLÁNYI, 1983), supported by magnetostratigraphy (BERNHARDT et al., 1988). The localities studied in this monograph belong to the top of the NP 19–20 nannoplankton zone (Priabonian, Upper Eocene) (BÁLDI-BEKE, 1972; NAGYMAROSY & BÁLDI-BEKE, 1988).

The best studied sequences of the Hungarian Palaeogene Basin are situated in its eastern sector, namely the Buda Hills (Fig. 1), since they are the 'Hausberge' of both Eötvös University and the University of Technology in Budapest (and of the Hungarian Geological Institute, as well) and have attracted both professionals and students.

Parts of the Buda Hills comprise Middle to Upper Triassic dolomite and limestone. These rocks were deformed during the Cretaceous to form a northwest-southeast trending syncline and were cut by mafic dykes (WEIN 1977, KUBOVICS et al., 1989). A long interval of erosion terminated with the deposition of (Cretaceous?) – Palaeogene bauxite, Middle Eocene coal measures and overlying limestone-marl sequence (SZÖTS, 1956). The whole succession occur mainly in the northwestern Nagykovácsi depression (SZÖTS, 1956; DUDICH, 1959). The early Late Eocene sequence consists of sandstones, conglomerates and breccias of alluvial and shallow marine origin (Fig. 2). Clasts were derived from local basement rocks or have been transported as much as 30 km by rivers or longshore currents (HORVÁTH & TARI, 1987).

This series is overlain by shallow marine limestone containing corallinacean red algae, larger foraminifera (Nummulites, Discocyclina), corals, molluscs and echinoids (MONOSTORI, 1965). These represent varied shallow water carbonate environments associated with moderate subsidence (KÁZMÉR, 1985). The limestones gradually pass into bioclastic calcareous marl, the 'bryozoan marl', the object of the present study. Its fossil content (echinoids, molluscs and particularly bryozoans) suggest a deep neritic to shallow bathyal depositional environment (KÁZMÉR, 1985; SZTRÁKOS, 1987). The bryozoan marl is overlain a thin-bedded marl and a laminated argillaceous marl (Buda Marl). It contains abundant planktonic foraminifera, nannoplankton, bivalves and ostracods of Late Eocene to earliest Oligocene age (BÁLDI-BEKE, 1972; BÁLDI et al., 1984; BÁLDI, 1986; MONOSTORI, 1987, SZTRÁKOS, 1987). These fossils suggest a shallow bathyal origin for the sediments (BODA & MONOSTORI, 1972; BÁLDI, 1986). The Buda Marl is overlain by the laminated Lower Oligocene Tard Clay, which formed in an anoxic environment. This is followed by the fossiliferous pelagic Kiscell Clay of Middle Oligocene age. The shallow marine quartzose Hárshegy sandstone and conglomerate is synchronous with the uppermost Tard Clay and the lower most Kiscell Clay (BÁLDI, 1986). The Lower and Middle Oligocene sequence is capped by neritic Upper Oligocene sandstone followed by Early Miocene coarse clastics, Middle Miocene platform carbonates, Upper Miocene sandstones and freshwater limestones and ultimately Quaternary deposits (WEIN, 1977).

Formal lithostratigraphic subdivision ascribed the name Szépvölgy limestone to the Priabonian algal–*Nummulites* limestone and retained the classical name 'Buda Marl'. For further lithostratigraphic nomenclature see CSÁSZÁR (1997) and KECSKEMÉTI (1998).

The Tertiary sequence has been altered by low-temperature hydrothermal activity along major fault zones (SCHERF, 1928). Silicification (BÁLDI & NAGYMAROSY, 1976) is the major agent, although there have been no

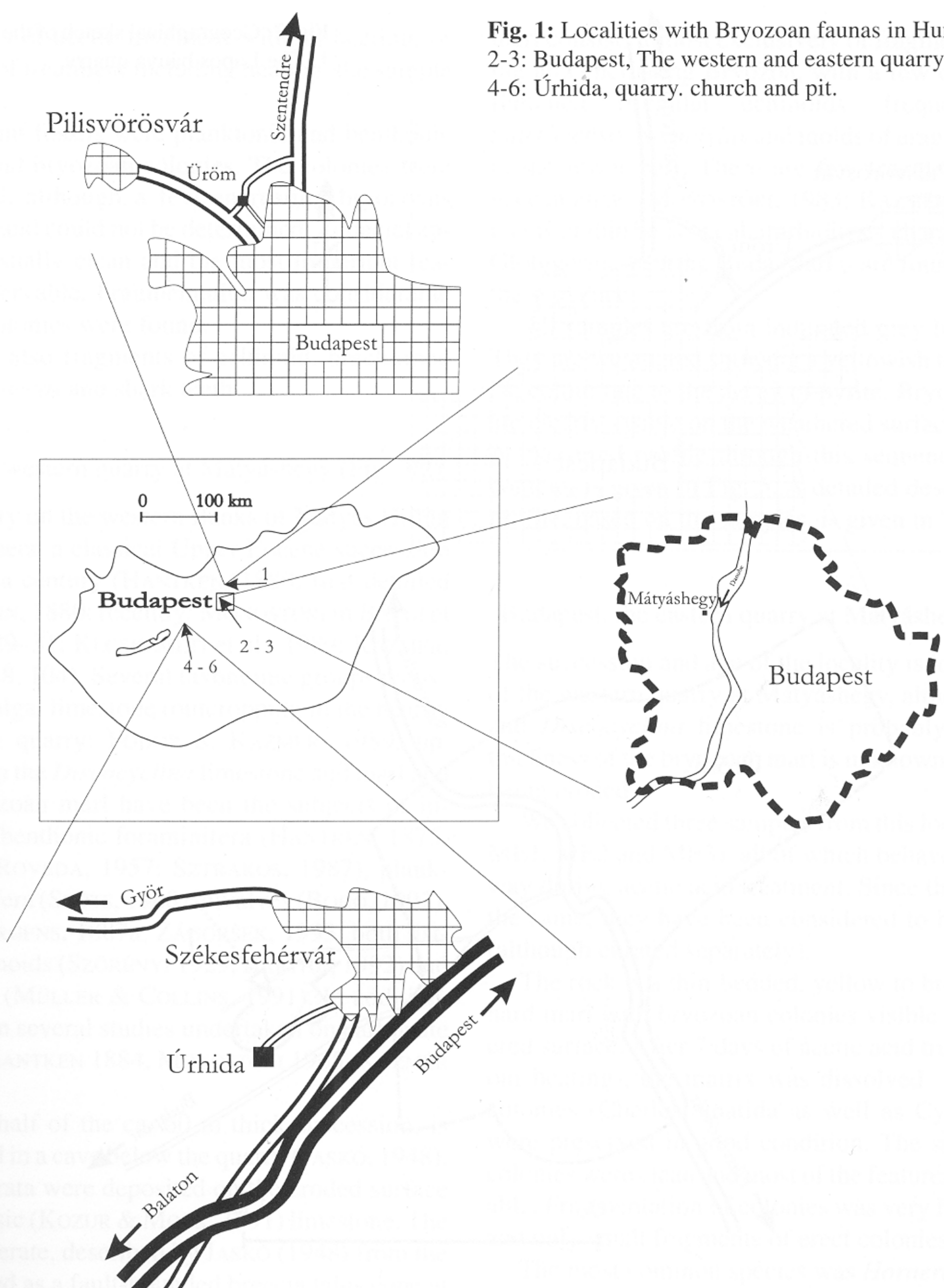

Fig. 1: Localities with Bryozoan faunas in Hungary. 1: Üröm. 2-3: Budapest, The western and eastern quarry at Mátyáshegy. 4-6: Úrhida, quarry. church and pit.

studies on the influence of this process on the preservation of fossils.

Methods

The bryozoan marl, if it contains abundant colonies, is relatively hard and cannot be washed easily. After several trials the following procedure proved to be the most effective in extracting the fossils from the matrix.

1) The samples are cut to 5 cm pieces and cleaned in water.
2) The pieces are dried at about 80 °C in an oven for about 12 to 24 hours to remove any traces of water.
3) The hot samples are covered by glacial acetic acid of technical quality. The samples must be immersed in the acid and the dish has then to be covered to avoid uptake of moisture.
4) The samples are sometimes heated to 80 °C for 12 to 72 hours. Without heating samples can take much longer to disintegrate and the fossils can suffer heavy corrosion.
5) After 2 to 8 weeks of disintegration the acid is decanted and the vessel is filled by cold water. Its content is then washed through a 0.09 mm sieve.
6) The washed sample is kept immersed in clean water for at least 24 hours to remove any trace of the acid.
7) Some of the samples were cleaned in an ultrasonic cleaner before photos could be taken.

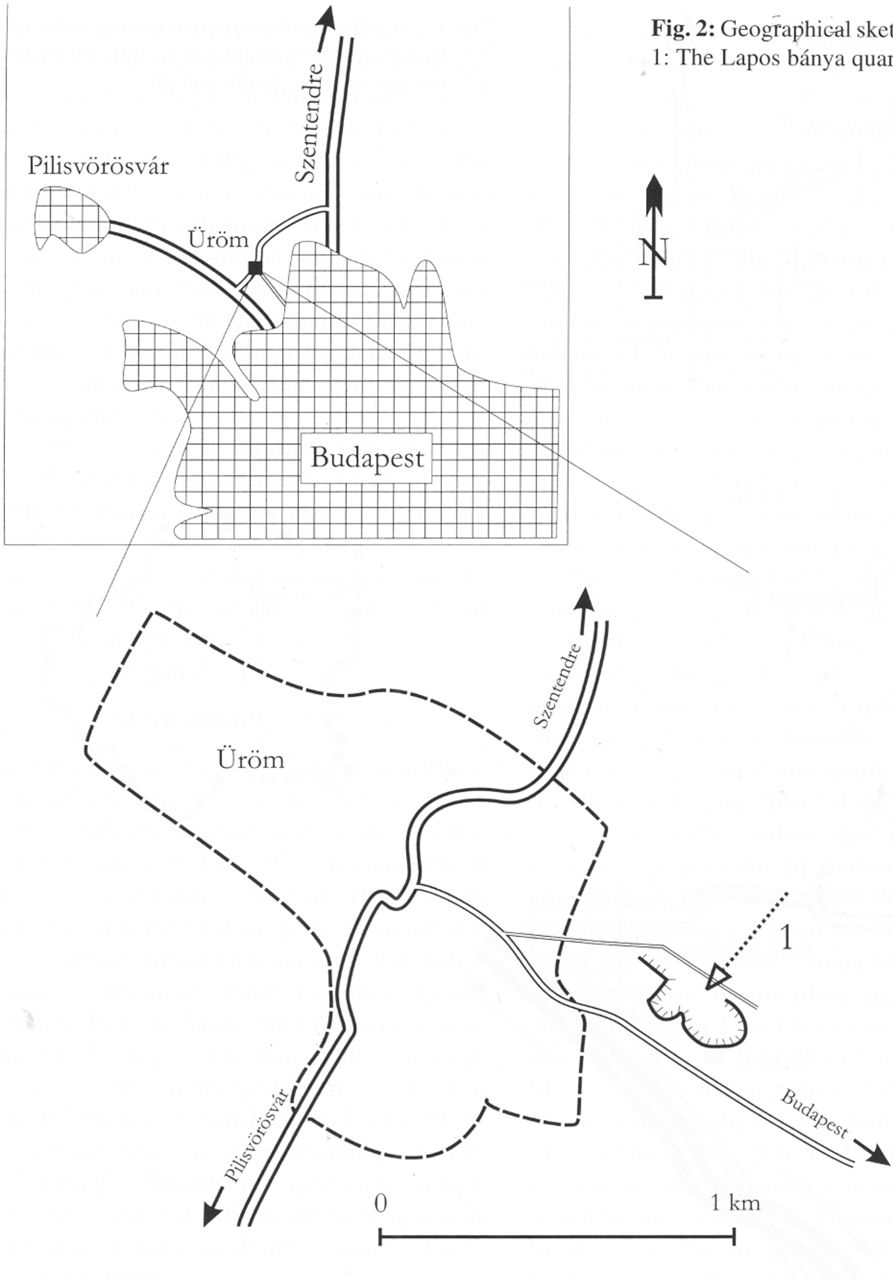

Fig. 2: Geographical sketch of the locality at Üröm 1: The Lapos bánya quarry.

Localities and samples

Bryozoan-rich samples were collected at six localities (Fig. 1):

- The quarry Lapos-bánya at Üröm
- Budapest, the western quarry at Mátyáshegy
- Budapest, the eastern quarry at Mátyáshegy
- The quarry at Úrhida
- The church at Úrhida
- The pit at Úrhida

The classical locality at Budapest, the western quarry at Mátyáshegy – exposing the thickest profile – is the major source of bryozoan specimens published here. We examined several further localities for bryozoans and found five more with rich faunas (Tab. 1).

The quarry Lapos-bánya at Üröm (Fig. 2/1)

Lapos-bánya east of Üröm village is the largest active quarry exposing a particular facies of the Upper Eocene of Buda Hills. The partly siliceous bioclastic limestone and calcareous marl was probably deposited in a toe-of-slope environment.

It is generally believed that the slabs quarried at Lapos-bánya are made of bryozoan marl. It is very difficult, however, to find colonies in the quarry although we managed to sample a rock surface along the southwestern edge of the pit.

The sample was a yellowish to brownish hard marl, with large bioclasts. The fauna visible on the surface consisted of bivalve shells, echinoid fragments and bryozoan colonies.

After 7 days of acetic treatment without heating, or after 3-4 days of treatment including heating, the sample disintegrated.

The dominant fossils were planktonic and benthonic foraminifera and bryozoan colonies. The colonies were well preserved, although a few encrusting bryozoans were corroded and could not be determined. Zooecial apertures were usually clean and the most important features were observable. Fragmentation was considerable and no large colonies were found.

There were also fragments of echinoid, brachiopod shells *(Argyrotheca)* and shark teeth.

Budapest, the western quarry at Mátyáshegy (Fig. 3/2)

The large quarry on the western flanks of Mátyás Hill in Budapest has been a classical Upper Eocene succession for more than a century (HANTKEN, 1880; first detailed study: HOFMANN, 1880; recently: MONOSTORI in BÁLDI et al., 1983, pp. 29–31; KECSKEMÉTI et al., 1989; KÁZMÉR, 1993, pp. 71–78, 104). Several taxonomic groups recovered from the algal limestone (outcropping in the nearby Fenyögyöngye quarry: FODOR & KÁZMÉR, 1989, pp. 239–241), from the *Discocyclina* limestone and marl and from the bryozoan marl have been the subjects of in-depth studies: benthonic foraminifera (HANTKEN, 1875; LANTERNO & ROVEDA, 1957; SZTRÁKOS, 1987), planktonic foraminifera (SZÖTS, 1968), bivalves (BODÓ, 1992), bryozoans (PERGENS, 1887a; ZÁGORŠEK, 1993: both listing only), echinoids (SZÖRÉNYI 1929, BARTHA, 1992) and decapod crabs (MÜLLER & COLLINS, 1991). In addition, there have been several studies undertaken on carbonate microfacies (HANTKEN 1884, MONOSTORI 1965, KÁZMÉR 1985).

The lower half of the ca. 60 m thick succession, is poorly exposed in a cave below the quarry (JASKÓ, 1948). The Eocene strata were deposited on the eroded surface of Upper Triassic (KOZUR & MOCK, 1991) limestone. The basal conglomerate, described by JASKÓ (1948) from the cave, is exposed as a fault-bounded breccia talus cone at the northern end of the quarry (FODOR & KÁZMÉR, 1989; FODOR et al., 1992, their fig. 6; FODOR et al., 1994, their fig. 44), indicating synsedimentary fault activity. The basal beds are overlain either by *Nummulites* limestone (JASKÓ, 1948) or by *Discocyclina* limestone (FODOR et al., 1992; KÁZMÉR, 1985). To resolve this contradiction a microfacies study of the strata exposed in the cave is necessary.

The *Discocyclina* limestone consists almost exclusively of *Discocyclina, Orbitoclypeus, Asterocyclina* and a few *Nummulites fabianii* (with some *Chlamys biarritzensis* and *Amussium corneum* bivalves) in a micrite and sparite matrix (MONOSTORI, 1983; KECSKEMÉTI et al., 1989). The ratio of discocyclinids decreases upwards, while the amount of bryozoans increases. There is no sharp boundary between the Discocyclina limestone and the bryozoan marl (KÁZMÉR 1985). The typical bryozoan marl consists almost exclusively of fragments of branching and encrusting Bryozoa, with a few discocyclinids, flattened irregular echinoids, frequent *Chlamys biarritzensis, Spondylus* and molds of aragonitic bivalves in the lower part. There are few fragments of corallinacean algae (MONOSTORI, 1983; KÁZMÉR, 1985). Fragments of thin beds of calciturbidites – characteristic of the Globigerina-bearing Buda Marl – are found at the top of the sequence.

All samples are from indurated grey bryozoan marl. They are weathered showing a yellowish to grey-brownish colour due to the decay of pyrite. Bryozoan colonies are clearly visible on the weathered surface of the rocks. A measured profile through this sequence, with fossil content, is given in Fig. 5. A detailed description of the profile, based on the samples, is given in Tab. 2.

Budapest, the eastern quarry at Mátyáshegy (Fig. 3/3)

The succession and age of the locality is identical to that of the western quarry at Mátyáshegy, although the algal and *Discocyclina* limestone is probably thinner. The thickness of the bryozoan marl is unknown, its upper part being eroded.

We collected three samples from this locality (Sample ME1, ME2 and ME3), all of which behaved in the same way during acetic acid treatment. Since the faunas were the same, they have been considered to be one sample (although curated separately).

The rock is a thin-bedded, yellow to brownish, semi-hard marl with bryozoan colonies visible on the weathered surface. After 7 days of acetic acid treatment (without heating), the matrix was dissolved. The bryozoan colonies (Cheilostomatida as well as Cyclostomatida) were preserved in good condition. The surfaces of the colonies were clean and most of the features were observable. Fragmentation of colonies was very high, however, and only small fragments of erect colonies were found.

The most common species was *Hornera frondiculata* Auct. There were also fragments of bivalve shell (probably *Chlamys*), tests of planktonic foraminifera and brachiopods *(Argyrotheca)*.

Úrhida

The village Úrhida (Fig. 1) is situated on a low hill of Eocene limestone and marl. This hill is an isolated occurrence of the Transdanubian Eocene basin, separated by strike-slip displacements during the Miocene (DUDKO, 1988; BALLA & DUDKO, 1989). A borehole (Úrhida-1) yielded 340 m of Upper Lutetian to Priabonian sediments in tectonic contact above a metamorphic Palaeozoic basement. The Priabonian part is 267 m thick and is composed of andesite pyroclastics, corallinacean limestone, sandstone and bryozoan marl (KECSKEMÉTI & VÖRÖS, 1983 and KÓKAY, 1989).

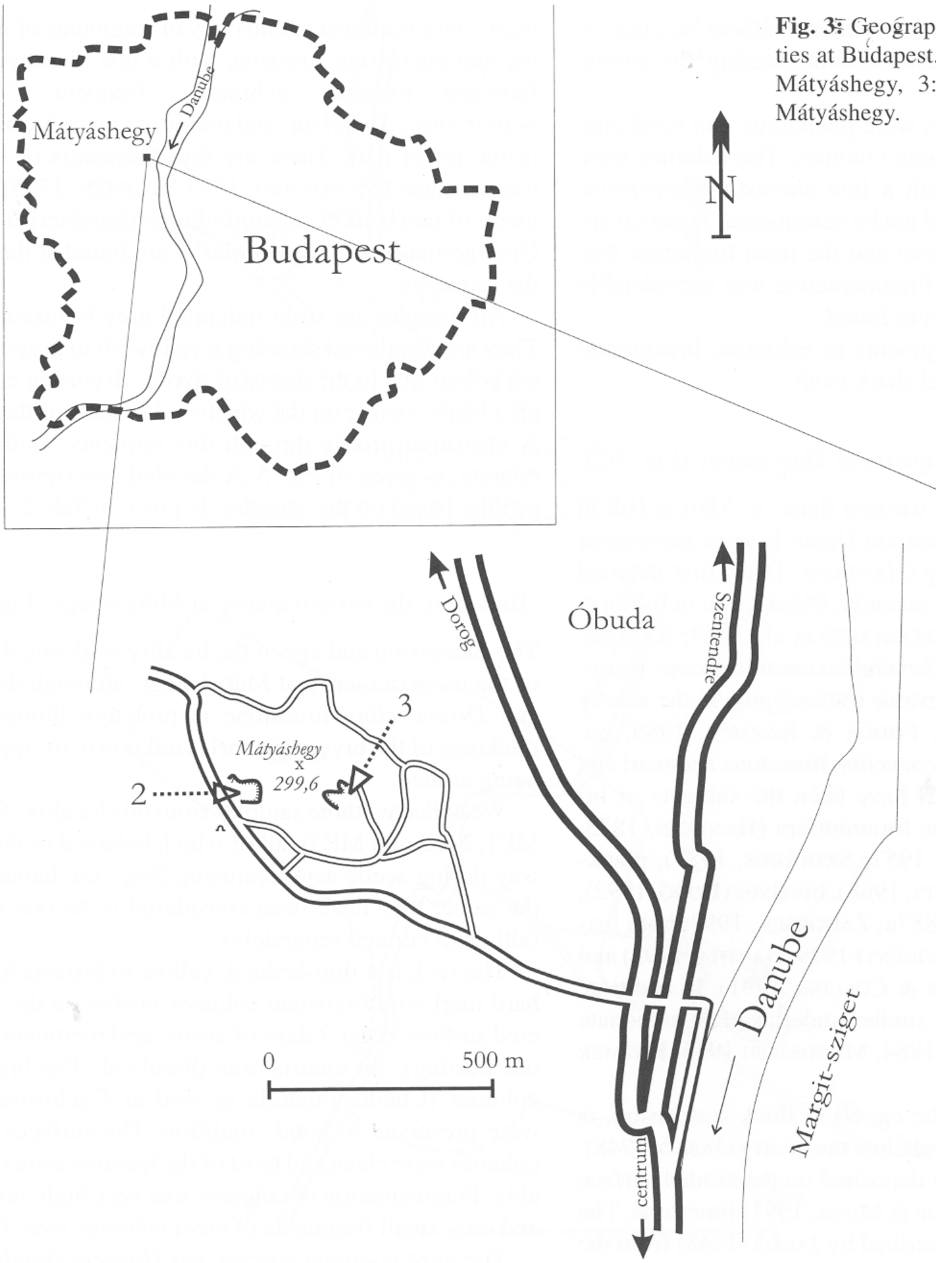

Fig. 3: Geographical sketch of the localities at Budapest. 2: The western quarry at Mátyáshegy, 3: The eastern quarry at Mátyáshegy.

There are numerous abandoned quarries within and around the village. We found a bryozoan fauna in three of them.

The quarry at Úrhida (Fig. 4/4)

This abandoned quarry yielded numerous and well preserved associations of bryozoans, second only to the western quarry at Mátyáshegy. The rock consists of a bedded, yellow to brownish, hard marl. Fragments of colonies and worm tubes were already visible on the surface.

The sample was disintegrated after three days of acetic acid treatment (including 24 hours of heating). The washed sample was very rich in well-preserved bryozoan colonies. Most of the colony surfaces were clean and features in the apertures were easily observed. A few encrusting bryozoans were corroded and could not be determined. No large colonies were found, due to the high degree of fragmentation.

Fragments of echinoids, mostly spines and isolated plates of asteroids, tests of planktonic foraminifera and serpulid tubes were frequent. There were also a few crab fingers and shark teeth.

The church at Úrhida (Fig. 4/5)

This temporary locality was situated in a pipeline trench next to the church. We collected a yellowish to white, less lithified marl. No fauna was visible on the sample surface.

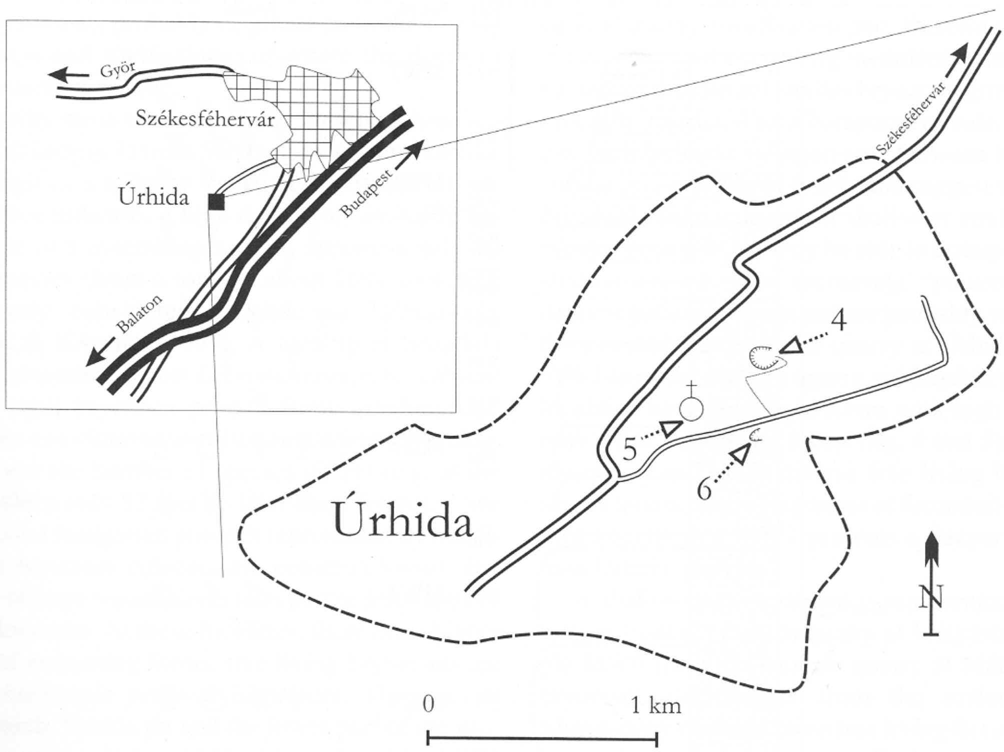

Fig. 4: Geographical sketch of the localities at Úrhida. 4:The quarry, 5: The church, 6: The pit.

The sample disintegrated after 24 hours of acetic treatment (without heating).

The rock was poor in fossils. The most abundant fragments were planktonic foraminifera and fragments of bryozoan colonies. The preservation of the colonies was good and their surfaces were clean, although somewhat corroded. The most important features could be observed and almost all specimens could be determined. Fragmentation of colonies was high, usually only 4–5 zooecia were preserved from the whole colony.

Other fossils included fragmented bivalve shells and echinoids (mostly parts of Aristotle's lantern). There were also a few ostracods and brachiopod shells *(Argyrotheca).*

The pit at Úrhida (Fig. 4/6)

The pit locality at Úrhida is situated in a small quarry, being filled up by rubbish.

The sample was brownish marl, naturally disintegrated into small pieces. No macrofauna was visible.

Less than 24 hours of acetic treatment (without heating) was sufficient to dissolve the sample.

The preservation of colonies was good, although some of the specimens were very corroded and could not be identified. Most of the apertures were clean and the important taxonomic features could be observed. The fragmentation of fossils was considerable such that only small pieces of colony were found.

The washed samples also contained planktonic foraminifera, echinoid fragments, brachiopod shells *(Argyrotheca)* and fragments of bivalve shell *(Pecten).*

Discussion

Similarities among studied localities and other known regions

Two groups can discussed in Hungarian Bryozoa faunas. The first group represented by localities where bryozoan colonies are embedded in typical bryozoan marl. Bryozoan marl is a sediment where Bryozoans form more than 90% of all fossils. The second group of localities is characterized by other fossils (foraminifera and/or fragments of corallinacean algae). These sediments are usually marls or sandstones.

Bryozoan marl is a widely distributed facies within the Alpine-Carpathian region (Zágoršek & Kázmér, 1999). More than 30 % (by weight) of bryozoan marl is made of colonies. The fauna is highly diversified, with more than a hundred bryozoan species often occurring. Besides Bryozoa, the sediment also contains low numbers of echinoid fragments, planktonic foraminifera and, typically, small shells of the brachiopod *Argyrotheca.* Bryozoan marl is exposed at localities in the eastern quarry at Mátyáshegy, in samples MW6 and MW7 from the upper part of the profile from the western quarry at Mátyáshegy and also in the quarry at Úrhida. In addition, bryozoan marl has been found in parts of the quarry

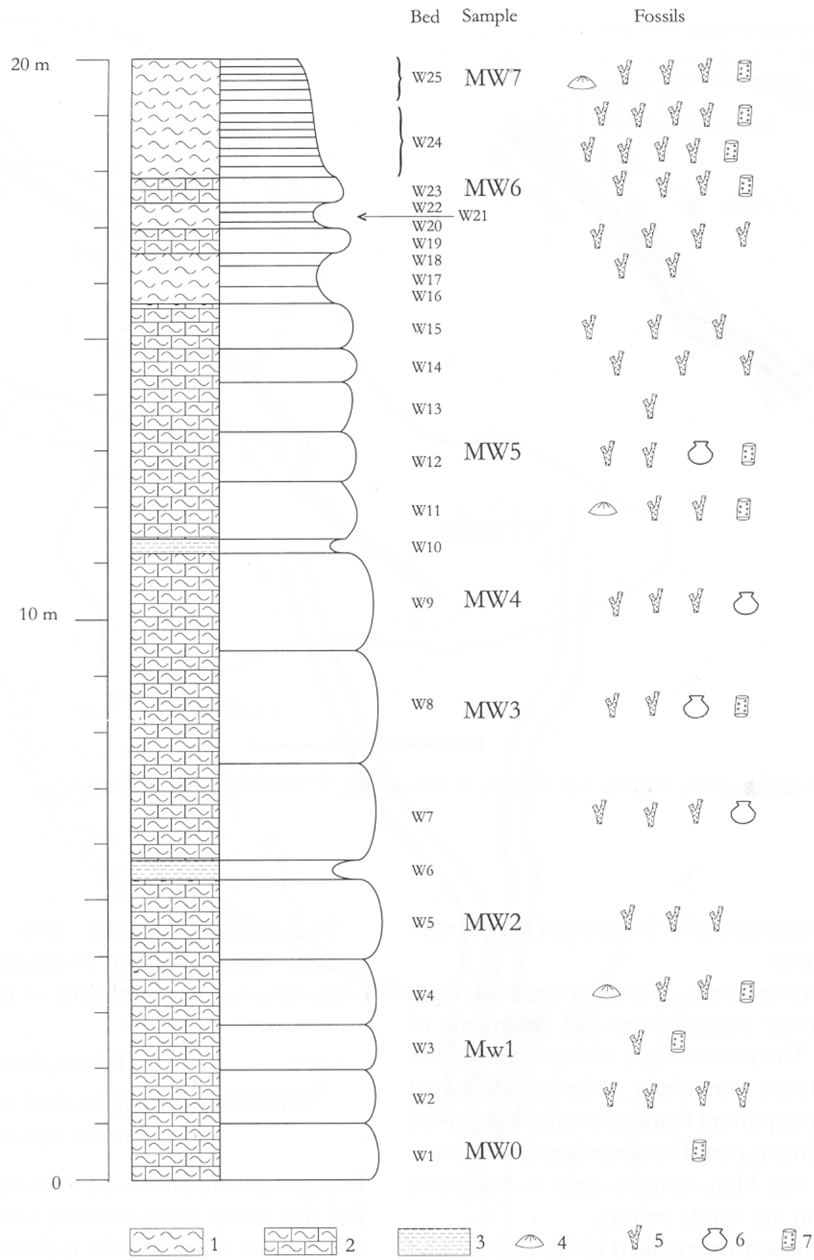

Fig. 5: Budapest, Mátyáshegy, western quarry: stratigraphic column and fossil content. 1: marl. 2: marly limestone. 3: claystone. 4: echinoids. 5: erect Bryozoa. 6: bivalves. 7: *Vicariopora chelys* (very large bryozoan colony). Description see Tab. 2.

Lapos-bánya at Üröm locality. These sites are characterized by the predominance of erect rigid bryozoan growth forms (mostly Cheilostomatous), the rare occurrence of free living colonies, the presence of *Hornera frondiculata* and *Mecynoecia proboscidea* and the absence of *Lacrimula perfecta*. According to BRAGA & BARBIN (1988) *Lacrimula perfecta* only lives in water depth of less than 50 m, so the presence or absence of *Lacrimula* seems to be a good palaeoenvironmental indicator.

Other localities of Eocene age similar to those of the first group are known from Slovakia (Hybica and Štrba: ZÁGORŠEK, 1992, 1994, 1997), Italy (Brendola and Possagno: BRAGA, 1963, 1965), Romania (Cluj-Napoca - not yet published) and Austria (borehole Helmberg-1, Salzburg: ZÁGORŠEK, in press).

Bryozoans marl mostly occurs in a typical succession, which can be observed in most of these localities. The succession begins with bioclastic limestone (corallinacean algae, larger foraminifera). These layers are up to hundred metres thick and usually terminate with *Discocyclina* limestone and/or marl. this is overlain by bryozoan marl of between 6 m to 20 m in thickness. The uppermost part of the succession is usually formed by *Globigerina* marl.

These sediments probably originate from the margin of the continental shelf, slope, or where the depth of water increased over time.

The locality most similar to those presented here is a borehole (Helmberg 1) from Salzburg in western Austria. A Kojumdgieva similarity coefficient (BRAGA et al., 1996) of 66.4 indicates a high degree of similarity between these two assemblages, with approximately 80 common species (from a total of about 160), including five formerly considered endemic to Mátyáshegy (ZÁGORŠEK & KÁZMÉR, 1999). A locality at Brendola (Italy) is also similar, in that *Lacrimula perfecta* is absent and erect rigid bryozoan growth forms predominate. Comparable associations are also known from Slovakia, although here the number of species differs (e.g. at the locality Hybica only 57 species have been found).

The second Hungarian group is represented by localities where bryozoan colonies are common fossils, but fragments of large foraminifera tests and/or fragments of algae predominate. At these localities, there are a higher diversity of encrusting forms, free living bryozoans are common *Lacrimula perfecta* is present. The sites at Úrhida church, Úrhida pit and the lower part of the profile in the western quarry at Mátyáshegy (samples MW1 to MW5) belong to this group.

Assemblages similar to this second group can be observed at Partizánska Lupča in Slovakia (ZÁGORŠEK, 1992, 1994, 1997), Pannone and Brentonico in Italy (BRAGA, 1980) and Reingruberhöhe in Austria (Waschberg zone, ZÁGORŠEK, in prep.). Of these, the best correlation is with Partizánska Lupča, where *Discocyclina* tests are rock-forming fossils. Reingruberhöhe, which includes some rare species, is also very similar, but here dominated corallinacean algae instead of larger foraminifera. The Italian localities are also comparable, since they include various free living bryozoans as well as large foraminifera.

These sediments and their associated assemblages probably originate from the middle part of the continental shelf, in some cases from very shallow water (ZÁGORŠEK, 1996).

Some thoughts concerning bryozoan palaeoecology

According to MCKINNEY & JACKSON (1989), in a study of recent Atlantic Bryozoans, the diversity and number of specimens of Bryozoa with erect rigid colonies increases with depth. On the other hand, the diversity and number of specimens of encrusting bryozoan colonies decreases with depth. At a depth of about 50 m, more than 65% of all Bryozoa form encrusting colonies, whilst at a depth of about 1500 m only 10% are encrusting. Conversely, only 15% of all Bryozoa living at a depth of 50 m exhibit erect rigid colonies, but at a depth of 1500 m such colonies represent more than 50% of the population.

In fossil material we also have to take preservation into consideration. Encrusting species are very often destroyed during fossilisation and, therefore, the ratio between erect and encrusting is shifted. Consequently, in palaeoenvironmental studies bryozoan growth forms are probably restricted to a comparative role, such that we can perhaps make comparisons between localities with similar preservation of fossils and suggest which of them originates from a deeper or shallower environment. Using this principle, we may be able to arrange all localities studied according to increasing "palaeo-depth". The deepest palaeoenvironment are probably represented by the assemblages from the quarry at Úrhida and sample MW7 from the western quarry at Mátyáshegy. Both these localities have erect rigid forms with high diversity and only a few encrusting forms (fig. 4 and 5). However, at the quarry at Úrhida diverse free living bryozoans are also common, as are fragments of foraminifera. We therefore assume that MW7 presents a deeper environment than Úrhida quarry.

A shallower environment is represented by the association from the eastern quarry at Mátyáshegy and sample MW6 from the western quarry at Mátyáshegy. The bryozoan assemblages from the eastern quarry at Mátyáshegy contains more free living Bryozoa and more encrusting growth forms, most likely representing a shallower environment than association from sample MW6.

The original palaeoenvironment at these localities was probably the margin of the continental shelf, perhaps even the continental slope with upwelling cool water, at a depth of at least 200 m and perhaps as much as 500 m (ZÁGORŠEK, 1996).

The sediments from the Úrhida church, Úrhida pit and Üröm represent very similar environments. The number of free-living Bryozoa suggests a shelf environment, the presence of *Lacrimula perfecta* indicating very shallow water depth. However the specimens of *Lacrimula perfecta* however, could have been transported across a long distance without major damage. We suppose, therefore, that the original environment could have been near the margin of the continental shelf, at a depth of about 100 m. This idea is supported by the abundance of *Mecynoecia proboscidea,* which lives in depths of about 70 - 100 m (MOISSETTE, 1988).

The lower part of the profile in the western quarry at Mátyáshegy probably represents shelf sediments. Among the bryozoan specimens, a wide diversity of encrusting forms have been found. However, the main problem in the interpretation of this part of the profile is the poor preservation of fossils.

It seems that samples MW3, MW4 and MW5 from the western quarry at Mátyáshegy represent the shallowest (or warmest) environment, while samples MW0, MW1 and MW2 represent deeper (or cooler) environments. The apperance of deep-water faunas in continental shelf successions has been explained by the upwelling of cold water during global climatic deterioration (ZÁGORŠEK, 1996) and/or by the filling of ecological niches vacated by decimated larger foraminifera faunas in these area.

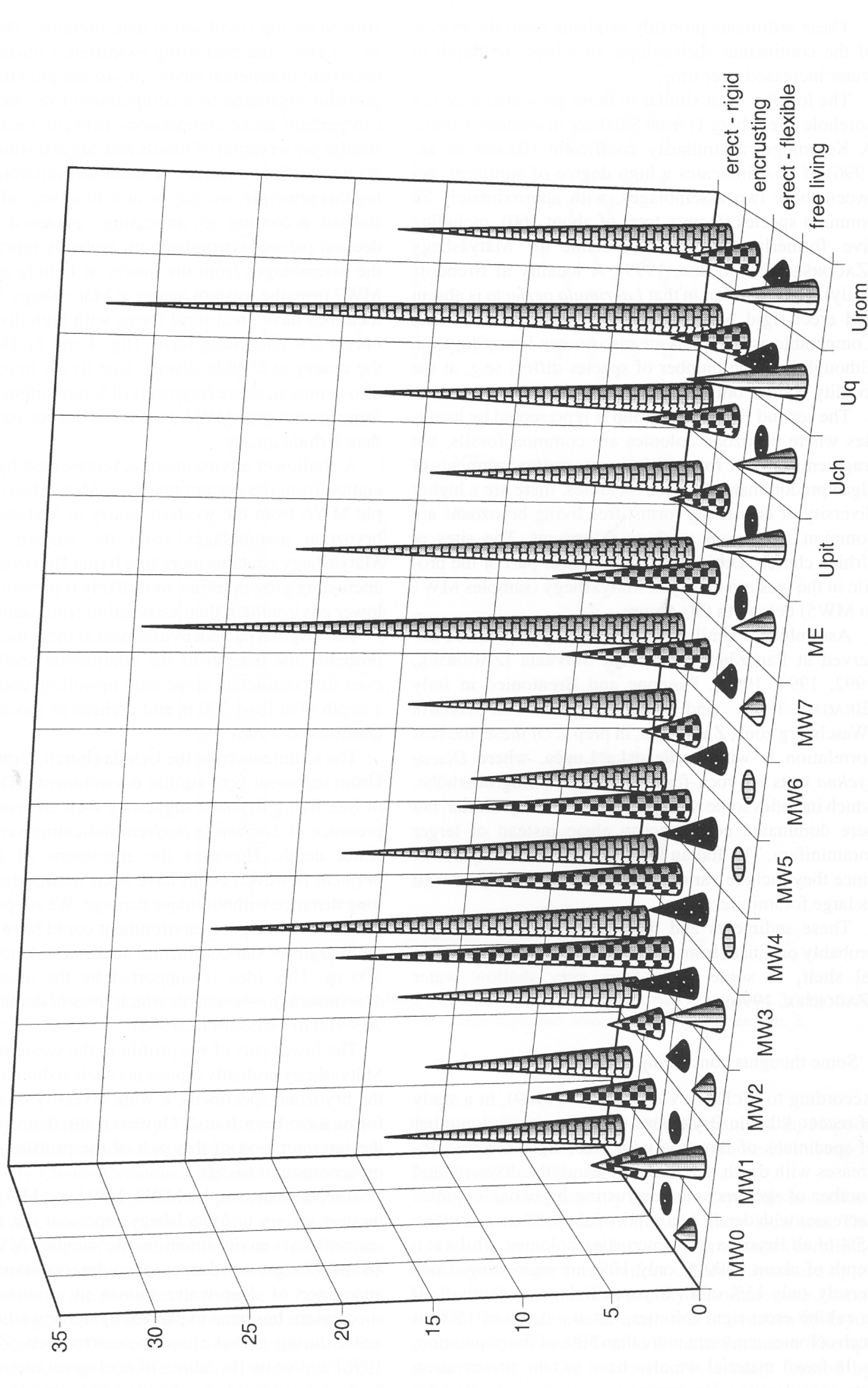

Fig. 6: Distribution of bryozoan growth forms in studied localities. (abbreviations used: MW0 - MW7: samples from Mátyáshegy, western quarry locality, ME: Mátyáshegy, eastern quarry, Upit: Úrhida pit, Uch: Úrhida church, Uq: Úrhida quarry, Urom: Üröm).

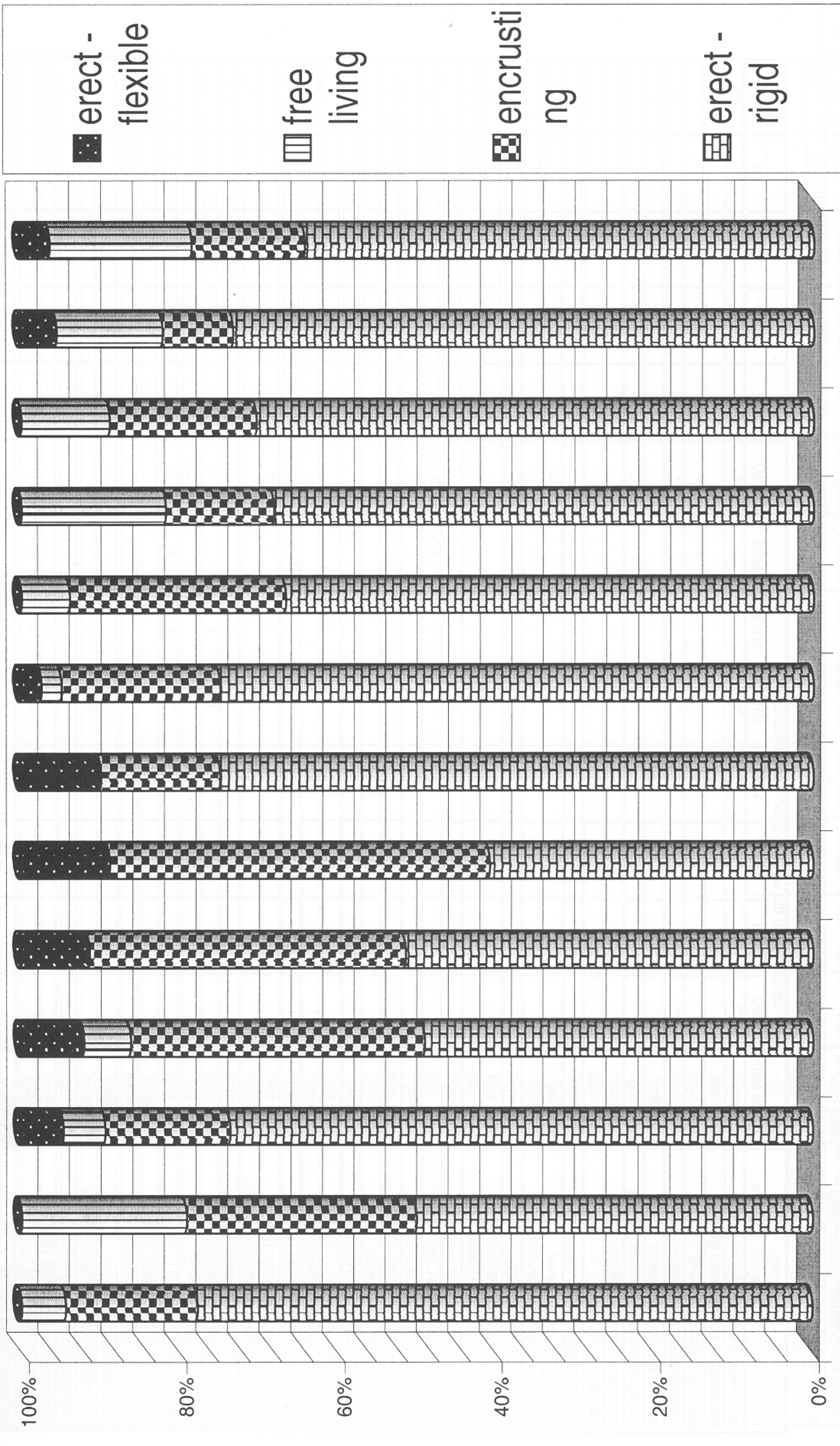

Fig. 7: Ratio of erect, encrusting and free living bryozoan growth forms in studied localities. (abbreviations see Fig. 6).

Tab.1: Distribution of determined Bryozoa with growth forms. Abbreviations used: ME = the eastern quarry at Mátyáshegy, Upit = the pit at Úrhida, Uch = the church at Úrhida, Uq = the quarry at Úrhida, Urom : the Lapos-bánya quarry at Üröm. The quantity of species present in each locality is estimated: * = present, ** = common, *** = abundant, **** = predominant.

taxa	growth form	samples from the western quarry at Matyashegy								ME	Upit	Uch	Uq	Urom
		MW0	MW1	MW2	MW3	MW4	MW5	MW6	MW7					
Adeonella minor (Reuss)	erect - rigid	***		***	***	***			*	*		**	**	***
Adeonellopsis coscinophora (Reuss)	erect - rigid												*	*
Adeonellopsis giampietroi sp.n.	erect - rigid				*			*	*				*	
Adeonellopsis porina (Romer)	erect - rigid	**	**	**	**	**			*	*			*	*
Alderina subtilimargo (Reuss)	encrusting	*	*		*					*	*	*	*	
Amphiblestrum appendiculata (Reuss)	encrusting				*					*			*	
Arthropoma sparsipora (Reuss)	encrusting		*											
Aviculiera hungarii sp.n.	erect - rigid												*	
Bactridium hagenowi Reuss	erect - rigid				*					*	*		*	
Batopora multiradiata Reuss	free living		*										*	*
Batopora scrobiculata Koschinsky	free living												*	
Biflustra clathrata (Philippi)	erect - rigid	*	*									*		
Biflustra savartii texturata (Reuss)	erect - rigid										***	*	*	***
Bobiesipora fasciculata (Reuss)	erect - rigid					*	*					*		
Bryochaperia spinella (Zágoršek)	erect - rigid				*	*				*	*			
Caberoides canaliculata Canu	erect - rigid							*	*	*				*
Caberoides cf. grignonensis Canu	erect - rigid								*					
Calpensia gracilis (Munster)	erect - rigid				*									
Calpensia polysticha (Reuss)	erect - rigid												*	
Castanopora calomorpha (Reuss)	encrusting						*							
Cellaria reussi d'Orbigny	erect - flex.												*	*
Celleporaria globularis (Bronn)	free living	*	*		*?					*	*		*	*
Cheilopora orbifera Canu & Bassler	encrusting				*									
Chlidoniopsis vindobonensis (Reuss)	erect - flex.						*	*	*				*	
Crassimarginatella macrostoma (Reuss)	encrusting				*					*	*	**		*
Crisia cf. eburnea (Linnaeus)	erect - flex.				*	*								
Crisia elongata Milne Edwards	erect - flex.				*	*	*							
Crisia haueri Reuss	erect - flex.			*	*									
Crisia hoernesii Reuss	erect - flex.					*	*	*						
Cyclicopora laticella Canu & Bassler	encrusting		*									*		
Cyphonella nodosa Koschinsky	erect - rigid										*			
Disporella coronula (Reuss)	encrusting					*								
Disporella grignonensis Milne Edwards	encrusting				*	***	*						***	
Disporella radiata (Savigny-Audouin)	encrusting								*					*
Ditaxiporina septentrionalis (Waters)	erect - rigid						*						*	
Escharella grotriani (Stoliczka)	encrusting					*	*	*						
Escharella tenera (Reuss)	encrusting						*		*					
Escharoides aliferus (Reuss)	encrusting				*	*				*				*
Escharoides coccinea (Abildgaard)	encrusting				*									
Escharoides crenilabris (Reuss)	encrusting						*							
Escharoides sp.	encrusting								*					
Exidmonea atlantica Forbes in Johnston	erect - rigid	**	**	**	*	*	*	*	**	**	*	***	*	*
Exidmonea giebeli (Stoliczka)	erect - rigid							*	*	*				
Exidmonea hoernesi (Stoliczka)	erect - rigid								*	*				

Tab. 1 (continued):

taxa	growth form	samples from the western quarry at Matyashegy MW0	MW1	MW2	MW3	MW4	MW5	MW6	MW7	ME	Upit	Uch	Uq	Urom
Exidmonea villaltae (Reguant)	erect - rigid						*		**	*				
Exochella? labiosa (Reuss)	encrusting					*	*							
Exochoecia compressa (Reuss)	erect - rigid	*												
Fedora ? sp. [bidentata (Reuss)	free living								*					
Foveolaria vibraculata sp.n.	encrusting	*			*									
Gephyrotes convexa Canu & Bassler	encrusting						*							
Gigantopora duplicata (Reuss)	erect - rigid				*									
Gigantopora lyratostoma (Reuss)	erect - rigid					*	*							
Gordoniella budai sp.n.	encrusting				*									
Gordoniella diporica sp.n.	encrusting				*	*								
Herentia hyndmanni (Johnston)	encrusting			*										
Heteropora subreticulata Reuss	erect - rigid				*									
Hippomonavella exarata (Reuss)	erect - rigid								**					
Hippomonavella stenosticha (Reuss)	erect - rigid					*	*					*		
Hornera frondiculata frondiculata Mong.	erect - rigid	**	**	***	**				*	**				*
Houzeauina parallela (Reuss)	erect - rigid												*	
Iodictyum labellatum sp.n.	erect - rigid								*					
Iodictyum rubeschi (Reuss)	erect - rigid								*				*	
Kionidella excelsa Koschinsky	erect - rigid													*
Labioporella? dartevellei Cheetham	erect - rigid						*						*	
Lacrimula perfecta (Accordi)	free living		*?								*	*		
Lunulites cf. quadrata (Reuss)	free living											*		
Margaretta cereoides (Ellis-Solander)	erect - rigid		*		*	*				*	*			
Matyashegyella aubrechti sp.n.	encrusting							*	*					
Mecynoecia proboscidea (Milne Edwards)	erect - rigid			**	**					*	*	**	**	*
Meniscopora syringopora (Reuss)	erect - rigid	*			*	*		*	*				*	
Metrarabdotos maleckii Cheetham	erect - rigid											*		
Micropora hexagona (Zágoršek)	encrusting			*	*								*	
Micropora urhidensis sp.n.	erect - rigid										*		*	
Nematifera susannae Zágoršek	erect - rigid						*	*				*	*	
Notoplites sp.	erect - rigid								*					
Odontoporella sp.	encrusting													*
Ogivalina cf. dimorpha (Canu)	erect - rigid					*							*	
Oncousoecia biloba (Reuss)	erect - rigid					*	*					*		
Onychocella subpyriformis (d'Archiac)	erect - rigid			***	***				*		*	*	*	**
Opaeomorpha michaliki sp.n.	encrusting		*		*	*	*							
Orbitulipora petiolus Lonsdale	erect - rigid												*	*
Parasmittina saccoi (Canu)	erect - rigid								*	*				
Parasmittina telum (Canu & Bassler)	erect - rigid				*									
Perigastrella granulata Zágoršek	encrusting				*	*	*							
Plagioecia cf. concreta Canu & Bassler	encrusting		*											
Pleuronea fenestrata (Busk)	erect - rigid		*											
Polyascosoecia coronopus (Canu & Bassler)	erect - rigid	*	*									*	*	
Porella clavula (Canu & Bassler)	encrusting								*					
Poricellaria complicata (Reuss, 1869)	erect - flex.				*									

Tab. 1 (continued):

taxa	growth form	samples from the western quarry at Matyashegy								ME	Upit	Uch	Uq	Urom
		MW0	MW1	MW2	MW3	MW4	MW5	MW6	MW7					
Porina coronata (Reuss)	erect - rigid	*	*		***	***		**	**	*	*	*	*	*
Porina duplicata (Reuss)	erect - rigid								*					
Porina labrosa (Reuss)	erect - rigid				*			*	*	*				*
Porina peristomica sp.n.	erect - rigid							*	*					
Prenantia phymatopora (Reuss)	erect - rigid						*	*			*		*	
Puellina (Cribrilaria) haueri (Reuss)	encrusting	*			**	*				*				
Puellina (Cribrilaria) radiata (Moll)	encrusting				*					*				
Reteporella simplex (Busk)	erect - rigid							*		*			*	
Reteporella subovata (Stoliczka)	erect - rigid											*	*	
Reteporella tuberculata (Reuss)	erect - rigid	*	*		*					*	*	*	*	
Reussia (Smittina) regularis (Reuss)	erect - rigid							*	*	*			*	
Rosseliana rosselii (Audouin)	encrusting				*	*						*		
Schizolepralia fissimargo (Reuss)	erect - rigid								*	*				
Schizolepralia scrobiculata (Reuss)	erect - rigid	*	*		*	*		*	*	*				
Schizomavella larva (Reuss)	erect - rigid								*					
Schizoporella dunkeri (Reuss)	encrusting								*					
Schizosmittina ovicellata sp.n.	erect - rigid	**										*		
Scrupocellaria brendolensis Waters	erect - rigid					*	*						*	
Smittina cervicornis (Pallas)	erect - rigid			**	***	****		**	***		*	*		
Smittina porelloides Canu & Bassler	erect - rigid								*					
Smittoidea angulata (Bronn)	encrusting					*	*							
Smittoidea circumornata (Reuss)	encrusting								*	*				
Smittoidea excentrica (Reuss)	erect - rigid			*	*	*			*					
Sparsiporina elegans (Reuss)	erect - rigid			*									*	
Steginoporella cucullata (Reuss)	erect - rigid											*		*
Steginoporella elegans chattiensis P.& D.	erect - rigid								*					
Steginoporella haidingeri (Reuss)	erect - rigid			***	***	***			*		*		*	*
Stenosipora aviculifera sp.n.	free living			*	*									
Stenosipora reussi (Stoliczka)	free living		*										*	*
Stenosipora simplex (Koschinsky)	free living										*		*	*
Stephanollona otophora (Reuss)	encrusting				*	*	*							
Tervia serrata (Reuss)	erect - rigid	*		*				*	*	*	*	*	*	
Thalamoporella cf. neogenica Buge	encrusting							*	*	*				
Trochiliopora beyrichii (Reuss)	erect - rigid				*									*
Tubucella mammillaris (Milne Edwards)	erect - rigid		*	*	*	*				*	*		*	*
Tubucella papillosa (Reuss)	erect - rigid	*	*	*	*					*				*
Tubulipora flabellaris (Fabricius)	encrusting		*									*		
Tychinella schreibersi (Reuss)	erect - rigid				*								*	
Umbonula monoceros (Reuss)	encrusting					*								
Vavropora pupuliformis sp.n.	encrusting						*							
Vibracella trapezoidea (Reuss)	free living		*		*					*	*	*	*	*
Vicariopora chelys (Koschinsky)	encrusting		*	*	*	*	*							
		total number of taxa from the western quarry at Matyashegy : 113												
Total number of taxa 131		18	24	18	51	35	27	20	41	33	22	27	45	28

Tab. 2 (next pages continued): The western quarry at Mátyáshegy, description of the profile. ("bed/sample" relates to Fig. 3, the "description" concerns structures visible in the field, "acid residue" describes how the samples behaved in acetic acid and "taphonomy" describes each sample after acetic acid treatment)

Bed / Sample	Description	Acid residue	Taphonomy
	Buda Marl (globigerina marl)		
W25 70 cm **Sample MW7**	A thin beds on top of the vertical quarry face, disintegrated by frost. Bryozoan marl, rich in large columnar colonies, in erect, rigid Bryozoans and Echinoids.	Lots of colonies were already visible after washing. The dry sample reacted with the acetic acid within 6–8 hours producing a whitish precipitate. The washed sample was very rich in colonies. Almost no other fossils were found.	The best preserved assemblage of all studied material: most of the photographed specimens were taken from this sample. The colony surfaces were clean, and very rarely corroded by acid. Internal structures are mostly visible, apertures are usually clean. Fragmentation of colonies is very slight, reteporiform colonies are well preserved.
W24 100 cm	Thin bedded bryozoan marl, with a few large columnar and many erect, rigid Bryozoan colonies.		
W23 45 cm **Sample MW6**	Bedded bryozoan marl, very rich in erect, rigid bryozoans colonies.	The bryozoan colonies and molluscs fragments were visible on the sample surface. After 48 hours of acid treatment all apertures were still covered by sediment. After further 24 hours in acetic acid (including 8 hours of heating) most of the specimens were in identifiable condition.	The colony surfaces were clean of sediments; some specimens of Cyclostomatida were corroded by acid. Apertures were mostly clean, internal features could be determined. Fragmentation of colonies was low: large colonies of reteporiform Bryozoa could be found.
W22 38 cm	Bedded bryozoan marl, rich in erect bryozoans. The large, columnar colonies were more common than in the layer W21. Molluscs and echinoids also occurred.		
W21 18 cm	Bryozoan marl very rich in erect forms and seldom large, columnar colonies.		
W20 12 cm	Bryozoan marl very rich in erect forms; but without large, columnar colonies.		
W19 40 cm	Bryozoan marl very rich in erect forms; but without large, columnar colonies.		
W18 20 cm	Bryozoan marl rich in erect forms; but without large, columnar colonies.		
W17 30 cm	Bedded bryozoan marl rich in erect forms and with a few large columnar colonies.		
W16	Soft marl without any macrofossils.		

Bed / Sample	Description	Acid residue	Taphonomy
30 cm			
W15 70 cm **Sample MW5**	Bedded bryozoan marl rich in erect forms and with a few large columnar colonies. On the rock surface, there were many colonies, mostly erect, rigid growth forms (e.g. *Porina coronata, Tubucella mammillaris* and *Schizolepralia scrobiculata*).	48 hours of acid treatment, including 14 hours heating made the sample disintegrate. The precipitate was dissolved in water and after further 24 hours hydrogen peroxide treatment yielded very well preserved colonies. Besides colonies, fragments of echinoderms and planktonic foraminifera were occasionally also found.	Most of the encrusting colonies could be identified. A number of erect colonies had poorly preserved external surfaces and could not be determined. This sample was dominated by large, columnar colonies of *Vicariopora chelys*. These colonies were less fragmented, than others. A number of erect colonies were encrusted by other bryozoans.
W14 50 cm	Bryozoan marl rich in erect, rigid forms, but without any columnar colonies.		
W13 80 cm	Bryozoan marl with common erect, rigid forms and without large, columnar colonies.		
W12 80 cm	Bryozoan marl with large, columnar colonies and bivalve shells.		
W11 100 cm	Bryozoan marl rich in erect, rigid forms and in large, columnar colonies. Fragments of Echinoids also occurred.		
W10 20 cm	Soft marl without any recognisable fauna.		
W9 140 cm	Massive bryozoan marl with fragments of bivalve shells.		
W8 180 cm	Massive bryozoan marl with erect, rigid and large, columnar colonies and fragments of Bivalve shells.		
W7 140 cm **Sample MW4**	Massive bryozoan marl rich in erect forms and bivalve shells.	After 48 hours of acid treatment the sample disintegrated. The zooecial apertures were clean and the surface of Cheilostomatida and Cyclostomatida colonies were not corroded. A further 72 hours of acid treatment combined with heating corroded the surface of cyclostomatous colonies. No other fossils were found.	The colonies were preserved in good condition. However, when colony surfaces were corroded by acid most of the external features could not be seen. Sediment rarely covered the surfaces of colonies such that only a small part of them could be observed. Nevertheless, most of the colonies could be identified. Fragmentation of colonies was very high; sometimes only one or two zooecia remained from whole colonies.

Bed / Sample	Description	Acid residue	Taphonomy
W6 30 cm	Soft marl with no visible fauna.		
W5 240 cm **Sample MW3**	Massive bryozoan marl very rich in erect, rigid forms. No large, columnar colonies were observed. The colonies (mostly *Porina coronata* and *Schizolepralia scrobiculata*) were visible on the surface.	The sample was heated in acetic acid for about 24 hours, then washed in water and dried for 15 hour. A further 48 hours treatment in cold acetic acid and final washing in water yielded well preserved colonies. The sample contained echinoderm fragments, brachiopods (probably *Argyrotheca*) and bivalve fragments.	The colony surfaces of Cyclostomatida and Cheilostomatida were less corroded and largely clean. Important taxonomical features could be observed without any problems. Colony apertures were clean, internal structures were observable. This sample yielded the best-preserved Bryozoans in the lower part of Mátyáshegy western quarry profile. Fragmentation of colonies was lower than in samples MW1 and MW2.
W4 230 cm	Bryozoan marl rich in large, columnar colonies, poor in erect, rigid forms and with abundant echinoids.		
W3 90 cm	Massive bryozoan marl rich in large, columnar colonies and poor in erect, rigid forms. The orthophragminid foraminifera were rare.		
W2 90 cm **Sample MW2**	Bedded bryozoan marl, very rich in small, erect, rigid forms. The colonies (mostly *Vicariopora chelys*) were visible on the surface of the sample.	The disintegration took 14 days. Besides Bryozoa, the washed sample contained fragments of echinoderms and of larger foraminifera tests.	The preservation was quite good compared with samples MW0 an MW1. The colony surfaces were clean, zooecial apertures partly filled by marl, but after ultrasonic cleaning Bryozoa could be determined. Most of the encrusting colonies had been destroyed. Large colonies were less fragmented than smaller ones.
W1 100 cm **Sample MW1**	Massive bryozoan marl with common large, columnar colonies. The orthophragminid foraminifera tests were abundant. Some tests of large foraminifera could be seen also on the rock surface.	The sample was not disintegrated after 24 hours in cold concentrated acetic acid. The process was very slow taking 35 days. The washed sample contained fragments of larger foraminifera tests, bivalve shells, corallinacean algae and bryozoan colonies.	Sample MW1 was very similar in preservation to sample MW0. Colony surfaces were mostly covered by sediment and lightly corroded, but the surface of Cyclostomatous colonies were destroyed. Zooecial apertures were filled by marl. Fragmentation of colonies was very high.
W0 **Sample MW0**	Massive Orthophragmina marl with no Bryozoa visible on the surface.	Sample MW0 was hard limestone and the extraction method was not successful.	The preservation of colonies was very bad: no important taxonomical features could be recognised. Fragmentation of Bryozoa was high.

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