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Sequence stratigraphic interpretation of a Late Eocene carbonate platform margin (Mátyás-hegy section, Buda Mountains, Hungary)

by
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Abstract — The Mátyás-hegy section, Buda Mountains (Hungary) was carbonate platform margin during late Eocene (Priabonian) time. The sea-level fluctuation curve of this area was built using benthic foraminifera associations. The geometry of the curve (positive and negative trends, hinge and inflection points) is used to estimate the approximate position of candidates for the systems tracts boundaries. I have been identified the Mátyás-hegy section contains the Priabonian 2 (Pr2) and Priabonian 3 (Pr3) sequence boundaries. The Pr3 boundary can be appointed exactly, while the Pr2 boundary by reason of incomplete exposed can not be exactly marked off.

Keywords — benthic foraminifera, sequence stratigraphy, carbonate platform margin, Priabonian, Hungary.

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Introduction

Sequence stratigraphy was originally developed for passive siliciclastic shelf margins emphasizing temporal-spatial changes in downslope transportation and accumulation as related to changes in sea level, sediment input, and subsidence (VAIL et al. 1977). Later, the concept was more or less successfully extended for use in other environments, mainly for carbonate platforms (e.g., HANDFORD & LOUCKS 1990, 1991, 1993), fluvial system (e.g., WESCOTT 1993) and hemipelagic environments (MANCINI & TEW 1997). The shallow marine deposits, for which the sequence stratigraphic concept was initially defined, commonly exhibit varied lithologies and stratal geometries suitable for sequence stratigraphic interpretation; whereas hemipelagites usually lack features like onlap, downlap, omission surfaces, and cyclic lithofacies changes because of monotonous continuous sedimentation, making application of sequence stratigraphic concepts in hemipelagic settings more problematic (LÜNING et al. 1998). The present study focuses on a carbonate platform margin, i.e. the transition between carbonate platform and the hemipelagic environment.

The Mátyás-hegy profile (Figure 1) is very rich in benthic foraminifers (Table I). On the strength of the quantitative analysis of the benthic foraminifer assemblages could be represent a sea-level fluctuations curve. Geometry of this curve (hinge and inflection points, positive/negative/constant trends) is used to estimate the approximate position of candidates for the systems tract boundaries. In the monotonous succession these horizons do not represent visible physical surfaces (VAIL et al. 1977), but the idealised systems tract boundaries could be correlated with the Cenozoic sequence stratigraphical systems tract boundaries (HARDENBOL et al. 1998).

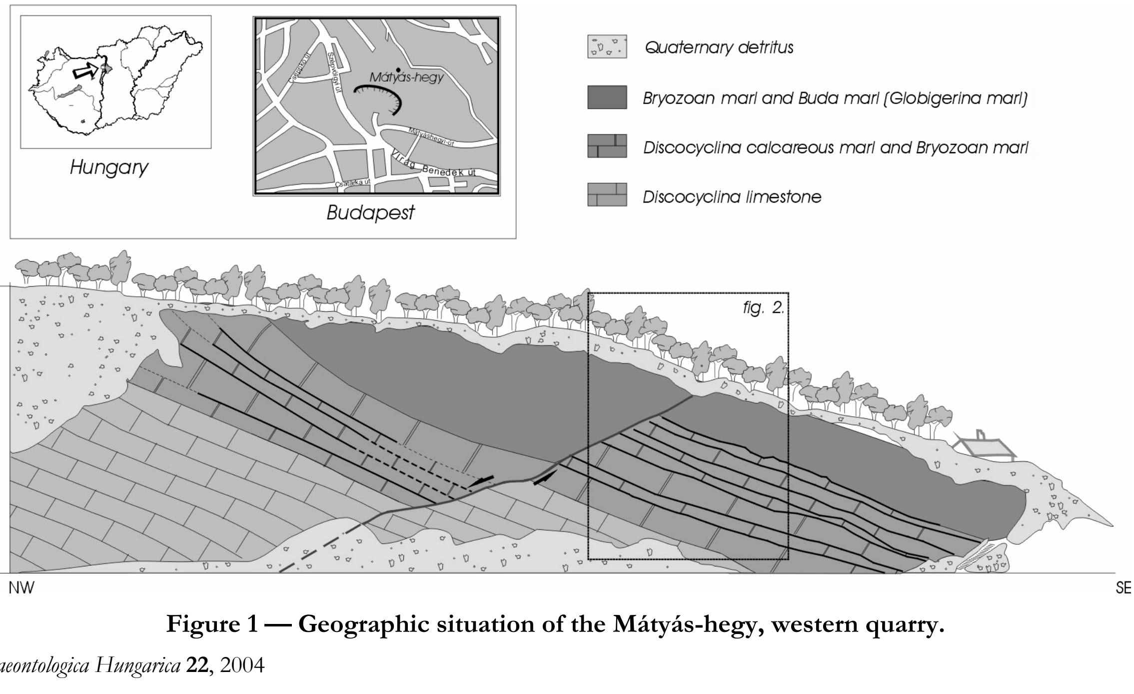

Figure 1 — Geographic situation of the Mátyás-hegy, western quarry.

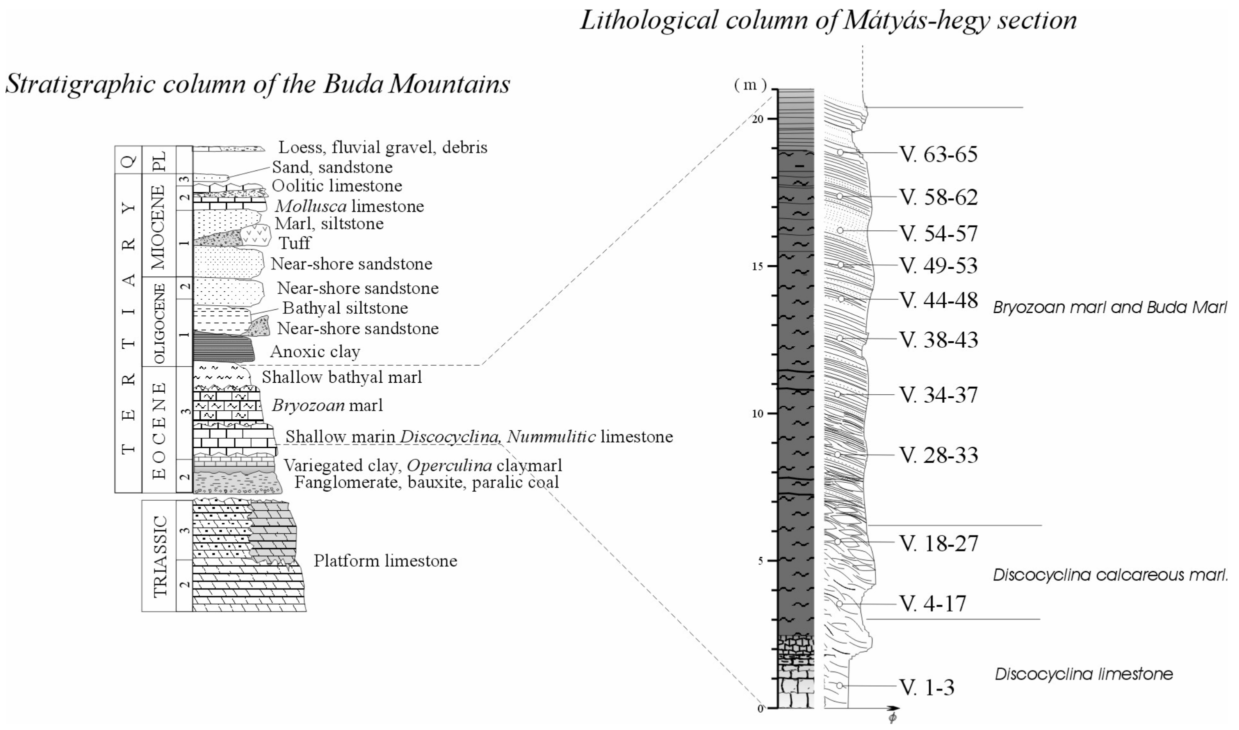

Figure 2 — Stratigraphy of Buda Mountains (after WEIN 1977 and FODOR et al. 1994) and lithology of the studied section (MAGYARI et al. 1995) with the indication of the samples.

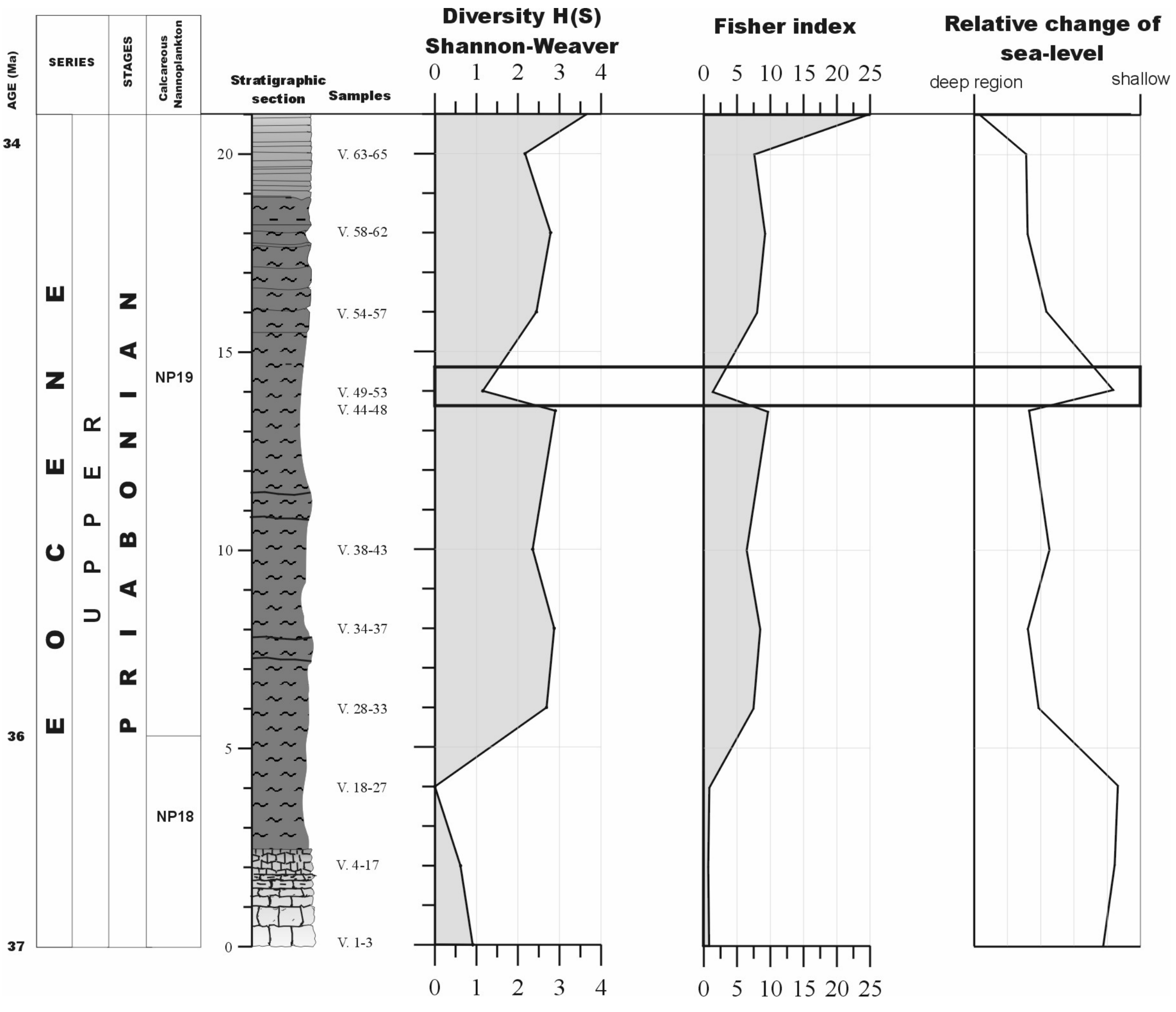

Figure 3 — The H(S), Fisher index and the relative change of sea-level curves based on quantitative analysis of benthic foraminifera assemblage of Mátyás-hegy section.

The Priabonian depositional sequences

The Mátyás-hegy, western quarry has been considered a classical section of Upper Eocene carbonate and marl succession studies for more than a century. HANTKEN, M. founder of the Department of Palaeontology, Pázmány Péter University, Budapest (actually Eötvös Loránd University) investigated the sequence and the fauna the first time in the 1870s. Based on the analysis of calcareous nannoplankton (BÁLDI–BEKE 1972) and planktonic foraminifers (SZTRÁKOS 1987), the initiation and process of subsidence of the area occurred in Priabonian time (KÁZMÉR et al. 1993).

An almost complete Upper Priabonian sequence is exposed in this quarry: palaeoenvironments range from transgressive conglomerate through neritic limestone and bryozoan marl to shallow bathyal marl.

The sequence is subdivided into three units:

3 m *Discocyclina limestone* — hard, compact limestone (0–3 m). Besides *Orthophragmina*, there are rare *Nummulites, Operculina, Heterostegina, Asterigerina* and *Miliolina* as well as other benthic smaller foraminifers. There are corallinacean algae in considerable quantity. Other accessory elements are bryozoan and echinoid fragments.

3 m marly limestone — *Discocyclina calcareous marl* (3–6 m). Apart from the "*Orthophragmina*" the bryozoans are accumulated in rock-forming quantity, and the number of echinoid fragments is significantly increased as well. A few *Sphaerogypsina*, agglutinated foraminifers and *Ditrupa* sections represent new elements in the fauna. The corallinaceans are accessory elements of the assemblage.

14 m marl — *Bryozoan marl* and *Buda Marl* (6–20 m). In the section above 15 m there are angular extraclasts. These are micrite clasts without *"Orthophragmina"* and other bioclasts, and fine grained clasts with some *"Orthophragmina"* clasts. The rock-forming fossils are the bryozoans. These are represented almost exclusively by branching and encrusting species. There are subordinate "*Orthophragmina*", *Heterostegina, Miliolina,* and echinoids. In the argillaceous facies, mainly in the uppermost part of the section, there are benthic and planktonic foraminifers (Figure 3), as well as sponge spicules.

Quantitative analysis of benthic foraminifer assemblages

Productivity of benthic foraminifer is influenced by numerous water mass properties, such as temperature, oxygen, salinity, pressure, density, nutrients, light penetration, fluctuations in the curves of quantitative rate of benthic foraminifer may be caused by a number of palaeooceanographic events. The most important processes are changes in sea-level and in nutrient-related palaeoproductivity.

If water mass properties are mainly controlled by water depth, physicobiochemical parameters, and therefore the distribution patterns of quantitative rate of benthic foraminifer, may vary predictably along a depth gradient. Hence, the quantitative rate of benthic foraminifer provides no numerical depth information and should be used only as an indicator of relative palaeobathymetric changes. The two statistical methods, which was used are the Species richness and Heterogenity.

Species richness — The most frequently used measure is the α (or Fisher) index:

$$\alpha = \frac{n^1}{x}$$

where x is a constant having a value < 1, and n^1 can be calculated from $N(1\text{-}x)$, N being the size of the sample (number of individuals).

Heterogenity — Indices of heterogeneity take into account both the number of species and the distribution of individuals between species (equability). The most commonly used measure is based on information theory (H) and on use the Shannon-Weaver formulation:

$$H(S) = -\sum_{i=1}^{n} p_i \ln p_i$$

where S is the number of species and p_i the proportion of the ith species (p = percent divided by 100).

The samples were collected by MONOSTORI, M. from the whole section. The foraminifers were selected from the appropriate samples (V.28–33 – V.63–65) by standard processing methods, while the carbonate rocks (V.1–3 –- V.18–27) were opened up by concentrated acetic acid.

On the basis of the above-mentioned statistical methods could be sketched relative sea-level fluctuation curve sample by sample. As it can be seen in Figure 3 from the sample No. V.18–27 starts a very strong shift towards the deeper region. The maximum shift (the relative most deeply environment) is at the sample No. V.44–48. At the sample No. V.49–53 a sea-level fall is visible, while on the relative sea-level fluctuation curves a strong shift towards the shallow region has been recognized. Above this locally minimum shift there is again the fluctuation towards the deeper region.

The aforementioned statistical methods work only the diagnose of relative sea-level change. Real depth could not establish with these methods, but many authors gave evaluation on the absolute depth in the Mátyás-hegy section. ZÁGORSEK, K. (1993) suggested 1200–1300 m deep depositional environment, posteriorly he revised his estimate 500–600 m deep. OZSVÁRT (2000) suggested 300–500 m deep environment by quantitative analysis of the benthic foraminifer assemblages.

Sequence stratigraphic interpretation

Sea level reconstruction in this work is based on quantitative analysis of the benthic foraminifer assemblages. As it has been discussed above, the quantitative benthic ratio is employed as a palaeobathymetric proxy, allowing the reconstruction of the relative sea-level changing sample by sample. Geometry of the benthic ratio curve is used to estimate the approximate position of candidates for the systems tract boundaries. Because in the hemipelagic environment these horizons do not represent physical surfaces but "correlative conformities" (VAIL et al. 1977) only boundary intervals rather then discrete surfaces can be reconstructed.

The position of the systems tracts boundaries on the sea level curve based on benthic foraminifera ratio (see Figure 4) follows concepts established for eustatic sea-level curves used by many authors (e.g. MANCINI & TEW 1997). In this study I have made an eustatic sea-level curve from the benthic ratio curve. The Mátyás-hegy section contains the Pr2 and Pr3 intersequence boundary systems tracts. From the sample No. V.1–3 to № V.18–27 is a lowstand condition (LST), boundary Pr2 could be under the sample № V.1–3 because in the outcrop could not be observe the whole section. From the sample № V.18–27 to V.38–43 is a transgressive condition (TST) and from the sample № V.38–43 to above (the inflection point of the curve) sample № V.44–48 is a highstand condition (HST). There is the Pr3 sequence boundary, simultaneously. From this boundary to above (the inflection point of the curve) sample № V.49–53. is a lowstand condition (LST) again and from there start to top of the section a transgression condition (Figure 5).

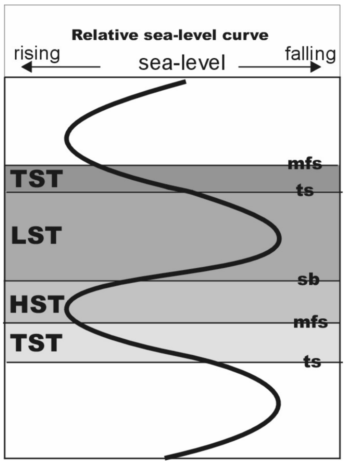

Figure 4 — Approximate location of systems tracts boundaries in idealized, palaeobathymetrically significant benthic foraminiferal rates curve from the hemipelagical environment (after MANCINI & TEW 1997). — The terms are: —**mfs** (maximum flooding surface) — **ts** (transgressive surface) — **sb** (sequence boundary) — **TST** (transgressive systems tract) — **LST** (lowstand systems tract) — **HST** (highstand systems tract).

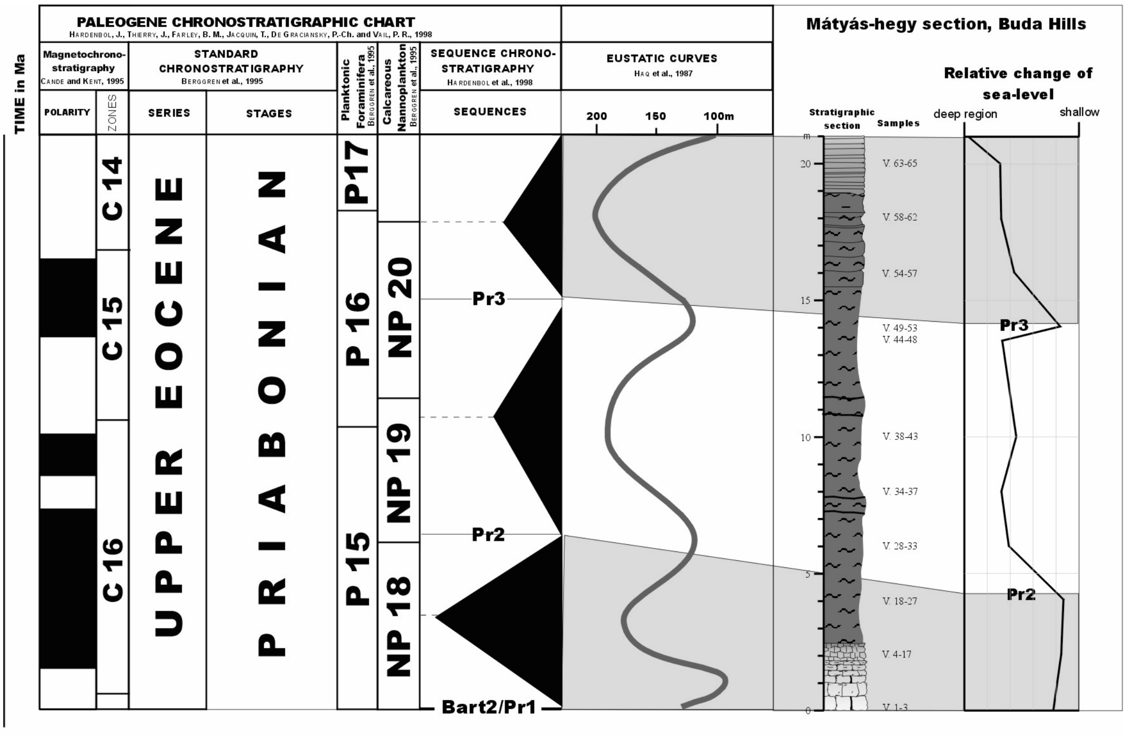

Figure 5 — Sequence stratigraphy interpretation and correlation of the Mátyás-hegy.

Conclusion

The spatial position, the environment migration and the sequence stratigraphic interpretation of Mátyás-hegy during Priabonian time can be seen on Figure 6. Counting of benthic foraminifer assemblages, coupled with sequence stratigraphical data from "European basins" (by HARDENBOL et al. 1998) has shown how such data can identify sequence boundaries and systems tracts. The quantitative analyses of benthic foraminifer do show distinctive distribution, which can help to draw a relative sea-level curve for the Mátyás-hegy section. Using this curve it is possible to correlate these sequences and sequence boundaries with the standard sequence boundaries in the "European basins" by HARDENBOL et al. 1998. The Mátyás-hegy section contains the Pr2 and Pr3 sequence boundaries.

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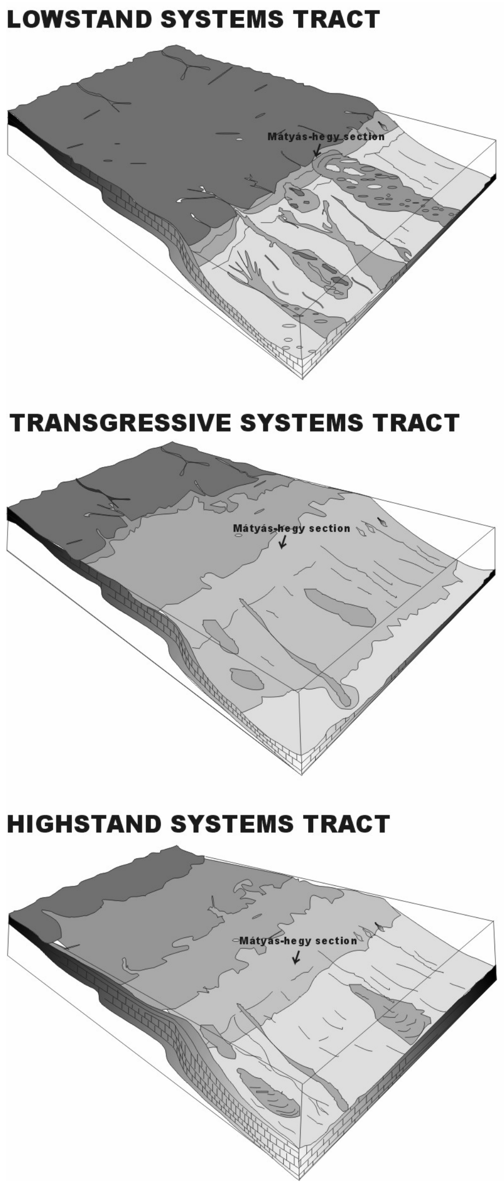

Figure 6. — Depositional sequence model of carbonate platforms, shelves and platforms margins (after Handford & Loucks 1993).

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Table I. — Benthic foraminifera fauna of the Mátyás-hegy (OZSVÁRT 2000).