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Foraminiferal assemblages as an indicator of foreland basin evolution (Carpathian Foredeep, Czech Republic)

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Abstract. This paper presents a model of depositional history in the Karpatian stage, Lower Miocene of the Carpathian Foredeep based on the study of foraminifers. The paleoecological interpretations, and the data on bioevents and biofacies of the Karpatian deposits were obtained through the statistical evaluation of microfauna. The occurrence of rich faunas alternating with impoverished ones indicates unstable conditions in the depositional area. Euryoxybiont foraminifers such as *Bolivina* div. sp., *Bulimina* div. sp., *Praeglobobulimina* div. sp., and *Uvigerina* div. sp. dominate these faunas. Two biostratigraphical levels containing *Uvigerina* and an overlying one with *Pappina breviformis* (Papp and Turn.) were identified.
Two stages of the development of a transgression can be distinguished. The first stage spread to the eastern part of the Carpathian Foredeep, where the sediments contain agglutinated foraminifers. The second stage reached the present location of the Karpatian deposits. Later shallow-water sediments in the western part of the Carpathian Foredeep have been eroded away.

Key words: Carpathian Foredeep, Moravia, Lower Miocene, foraminifers, paleoecology, biostratigraphy

Introduction

The Carpathian Foredeep is a peripheral foreland basin of the Western Carpathian arc, and is filled with molasse deposits. In the Czech Republic its depositional history began in the Egerian-Eggenburgian (Oligo-Miocene), and proceeded up to the Lower Badenian (Middle Miocene). Paleogeographically, the Carpathian Foredeep is included into the epicontinental basins of the Central Paratethys, with specific paleogeographical and paleobiotic characteristics.

Foraminifers are considered to be the most important fossils of the Karpatian deposits in the Carpathian Foredeep. They have been used as a reliable tool in biostratigraphical and paleoecological research in this depositional area.

The paleoecology and biostratigraphy of the southern part of the Carpathian Foredeep have been studied in publications by Brzobohatý (1980, 1992), Cicha (1995, 2000, 2001), Cicha and Zapletalová (1967, 1974), Jiříček (1983, 1990, 1995), Molčíková (1966), Nehyba and Petrová (2000), and Petrová (1998, 1999, 2003). The conclusions of these previous authors were based on qualitative data, while the present article presents the results of a Ph. D. dissertation based also on quantitative data.

Material and methods

Samples of the pelitic-aleuritic (locally psammitic) sediments in the Lower Karpatian and typical "schliers" (laminated, calcareous, light grey, silty mudstones with silt or very fine sand laminae) of the Upper Karpatian were analysed. Foraminifer assemblages were obtained from boreholes in the area to the south of the Nesvačilka trough. The location of the area and of the boreholes is presented in Fig. 1.

Various kinds of input material were studied, including rocks, the washed residues, and microfossil assemblages (see Tab. 1 for a summary). The type of data influenced the evaluation of results, and it was not possible to correlate all of the values obtained. Data only from the following boreholes were compared: Nosislav-3 (Petrová 1998; Petrová 2003), HV-boreholes (Nehyba and Petrová 2000, Petrová 2003), Cf-4, Znojmo-12, and Pouzdřany-1 (Petrová, 2003).

The rock samples were soaked in sodium carbonate solution for several hours for disaggregation, and then washed under running water through 63 μm mesh sieves. Foraminifers were collected, identified, and counted using a WILD binocular microscope.

Some of the samples were barren of fossils, while others contained impoverished or abundant foraminiferal microfauna. 300 specimens of foraminifers were analysed using statistical methods for comparable results (Petrová 1998; Nehyba and Petrová 2000). Impoverished microfaunas, however, give only qualitative data.

A summary of the studied borehole sections is shown in Fig. 1. In interpreting our results, bioevents and biofacies (Fig. 5) were plotted on the schematic profiles of that boreholes that were amenable to correlation. The example on section by boreholes Zn-12, HV-304, Hy-1, NP-1, NP-2 and Mik-1 borehole is presented in Fig. 2. The evolution of the Carpathian Foredeep in the Karpatian was reconstructed by the present author based on the spatial and stratigraphical distribution of foraminifers. A summary of the statistical methods and data are presented in the author's unpublished Ph. D. dissertation (Petrová 2003).

Results

The foraminifer assemblages considered in this study can be generally characterized as impoverished, with low di-

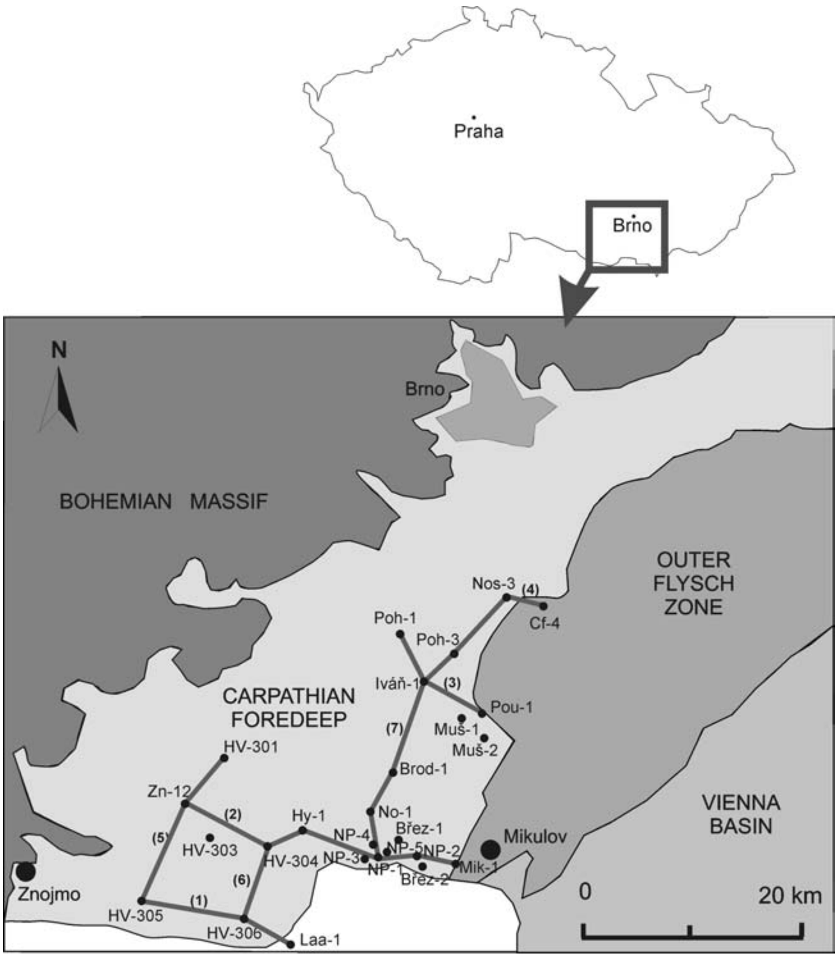

Figure 1. Schematic map of the southern part of the Carpathian Foredeep, showing the location of the studied boreholes and the borehole sections.
Břez – Březí, HV and Hy – Hrušovany nad Jevišovkou, Mik – Mikulov, Muš – Mušov, No – Novosedly, Nos – Nosislav, NP – Nový Přerov, Poh – Pohořelice, Pou – Pouzdřany, Zn – Znojmo

versity, and tests of reduced size and ornamentation. Foraminifers and other microfauna are relatively well preserved, though partly fragmented, while the foraminifer tests are locally rather small. Planktonic foraminifers have small apertures. The assemblages are comprised of foraminifers, local fragments of sponge spicules, fish bone and scale fragments (mainly in the lower part of the sections), fragments of echinoid spines, ostracods, molluscs, bryozoans, radiolarians, and commonly pyritized diatoms.

The frequency with which benthic genera occur in these assemblages is usually between 15–25%. A total of 94 benthic genera were identified in the borehole samples. The consistency of several foraminiferal genera is high: specimens of the genera *Globigerina, Bolivina, Bulimina, Siphonodosaria, Hanzawaia, Heterolepa, Hansenisca*, *Lenticulina, Praeglobobulimina, Elphidium*, and *Uvigerina* occur in 90–100 % of the samples. The number of agglutinated foraminifers reaches up to 2–3%. Occurrences of agglutinated foraminifers coincides with those of euryoxybiont foraminifers (calculations and results presents Petrová 2003).

The following microfaunal taphocoenoses were recognized: 1. fish bones exclusively, 2. impoverished assemblages of foraminifers (often with pyritized tests), 3. abundant and low-diversity foraminiferal assemblages, 4. abundant and diversified foraminiferal assemblages (Petrová 2003).

The succession of the assemblages often varies. Impoverished foraminiferal assemblages alternate with rich ones, and assemblages with predominantly planktonic genera replace benthic ones. This also indicates an unstable environment. The assemblages indicate a suboxic or dysoxic environment, and seldom an oxic one (mostly in the higher parts of the sections) (see Gebhardt 1999 and Kaiho 1994).

Oxygen concentrations at the sediment-water interface control the distribution of benthic foraminifers (Kaiho 1994). It influences the size, wall thickness, porosity, and composition of the assemblages. Kaiho (1994) defined dysoxic, suboxic, and oxic assemblages. Based on his studies, the assemblages of the Carpathian Foredeep can be characterised as follows:

Anoxic assemblages: without foraminifers, comprised only of fish bones, teeth, otoliths, and scales, locally with pyritized centric diatoms.

Dysoxic assemblages: thin-walled, elongate, flattened, high porosity, usually small tests. Examples include the genera *Bolivina*, *Bulimina*, *Cassidulina*, *Chilostomella*, *Dentalina*, *Stilostomella*, and *Praeglobobulimina*. They dwell as infauna. The tests are often pyritized. The local occurrence of only small pyritized globigerinas is also indicative of a dysoxic environment.

Suboxic assemblages: small tests of rounded planispiral, flat ovoid, and spherical forms, such as the genera *Bulimina*, *Cassidulina*, *Fissurina*, *Hansenisca*, *Hoeglundina*, *Lagena*, *Lenticulina*, *Melonis*, *Nonion*, *Oridorsalis*, *Pullenia*, *Uvigerina*, *Valvulineria*, and *Dentalina*.

Oxic assemblages: tests are usually bigger, thick-walled, and of planoconvex, biconvex, rounded trochospiral, and spherical forms. These include the genera *Cibicidoides*, *Quinqueloculina*, and *Triloculina*. They dwell as epifauna.

All studied foraminiferal assemblages came from the Laa Formation (Rögl 1969), including fauna with rare *Globigerinoides bisphericus* Tod in the Upper Karpatian. This latter fauna was documented in the uppermost part of the Pohořelice-3 borehole. Rögl (1994) correlated the foraminiferal assemblages of the Laa Formation with the M4a Foraminifera Zone (Berggren et al. 1995) and the N7 Zone (Blow 1969). Assemblages with rare *Globigerinoides bisphericus* Tod belong to the M4b Foraminifera Zone (after Berggren et al. 1995).

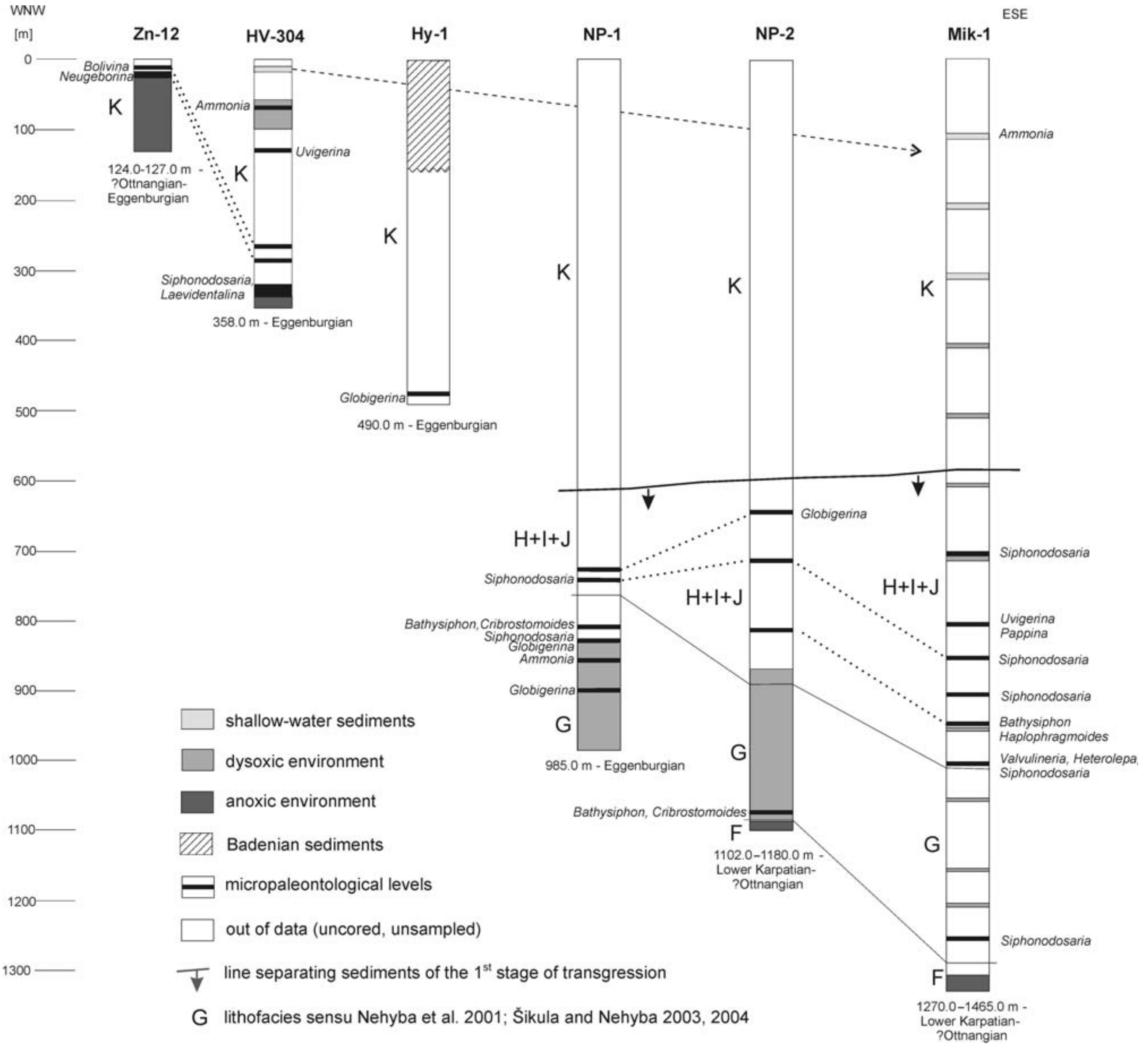

Figure 2. The correlation of boreholes Zn-12, HV-304, Hy-1, NP-1, NP-2, and Mik-1 (Karpatian, Carpathian Foredeep).

One level in the studied area (Fig. 2) contains an assemblage that experienced an abnormally sudden increase in the number of foraminifers of specific genera, and this term is relative and applied for local situation. The levels are comprised of representatives of the genus *Stilostomella*, *Siphonodosaria*, *Neugeborina*, *Laevidentalina*, *Bolivina*, *Bulimina*, *Uvigerina*, *Pappina*, *Ammonia*, *Valvulineria*, *Heterolepa*, *Melonis*, *Globigerina*, and agglutinated foraminifers (*Bathysiphon* sp., *Cibrostomoides* sp., *Haplophragmoides* sp.). They are plotted as bioevents in Fig. 5, and can be used for correlating the sections (Fig. 2).

In the lower parts of the boreholes, containing the Lower Karpatian sediments, assemblages comprised mainly of fish bone fragments (also with scales, teeth, and otoliths) though without foraminifers are observed. Areas comprised purely of the small tests of *Globigerina* div. sp. appear locally. These assemblages become replaced by ones with relatively numerous microfauna. Within the surroundings of the town of Mikulov the tests of agglutinated foraminifers were found (mainly *Haplophragmoides vasiceki* Cicha and Zapl., *Bathysiphon taurinensis* Sacco and *Cribrostomoides columbiensis* Cicha and Zapl.), distinguishing the first developmental stage of the Karpatian transgression (Figs 3, 4A).

Higher in the overlying anoxic sediments of the second developmental stage of the transgression, the following succession of foraminiferal genera is observed: 1. *Siphonodosaria* and *Stilostomella*, 2. *Neugeborina*, 3. *Bolivina*. This succession is especially apparent in boreholes HV-304, HV-305, HV-306, Znojmo-12, and Nosislav-3 (Fig. 5). A more diversified microfauna with the typical Karpatian species *Uvigerina* div. sp. and *Pappina* div. sp. appears in the younger sediments. In several boreholes we identified two positions containing *Uvigerina* sp. (three positions in Nosislav-3), and a higher level with *Pappina breviformis* (Papp and Turn.) and *P. primiformis* (Papp and

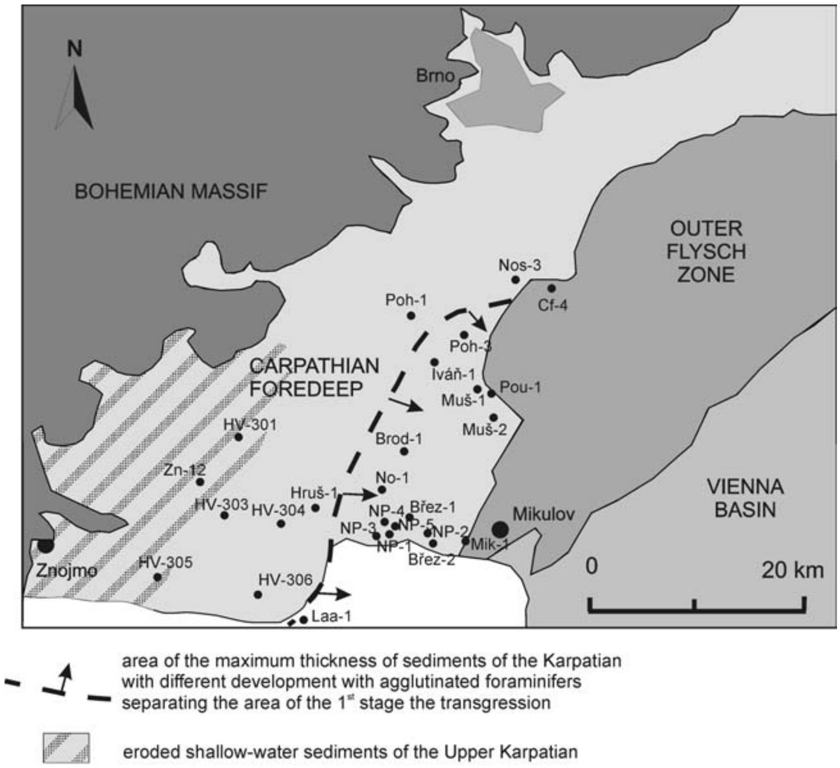

Figure 3. Schematic map showing the area of the first stage of the transgression, and the area in which shallow-water sediments were eroded (Karpatian, Carpathian Foredeep).

Turn.). A barren region containing no fauna occurs between the areas containing *Uvigerina* div. sp. and *Pappina* div. sp. (see Molčíková 1966). The succession of species of the genus *Uvigerina* was observed mainly in borehole Nosislav-3: a lower zone containing *Uvigerina graciliformis* Papp and Turn., *U. peregrina* Cush., *U. multicostata* Le Roy, and a higher one with *Uvigerina acuminata* Hos., *U. pygmoides* Papp and Turn. and *U. semiornata* d'Orb.

A model of the evolution of the basin during the Karpatian is presented in Fig. 4. The zones with anoxic characteristics that develop into dysoxic and suboxic assemblages document both stages of the transgression. Agglutinated assemblages indicate the different development of the eastern part of the Carpathian Foredeep. The two developmental stages were distinguished through sedimentological studies (Nehyba, pers. comm.) and paleontological evidence (Petrová 2003).

Figure 5 shows the succession of the foraminiferal taxa (bioevents) that characterizes these biofacies, and the generalized lithology of the individual facies modified by Šikula and Nehyba (2003). Biofacies-ecostratigraphy characterizes the developmental stages of the transgression based on oxygen concentration and paleobathymetry:

TA – transgressive, anoxic. Fish bones predominate, pyritized diatoms appear, foraminifer tests are rare (small globigerinas in Mikulov-1 borehole).

TD – transgressive, dysoxic. Agglutinated foraminifers occur in the eastern part of the Carpathian Foredeep. Euryoxybiont taxa *Bolivina* div. sp., *Bulimina* div. sp., *Praeglobobulimina* div. sp., *Uvigerina* div. sp. predominate. Some levels contain only globigerinas. Oxygen supply increases. Impoverished and diversified assemblages alternate.

T_BD/TS – transgressive (bathyal) dysoxic – suboxic. Deeper-water assemblages with agglutinated foraminifers were found. Numerous levels with *Siphonodosaria* div. sp. and *Valvulineria complanata* (d'Orb.) were observed.

S – suboxic. Numerous diversified assemblages with *Bulimina* div. sp., *Uvigerina* div. sp., *Pappina* div. sp., *Globocassidulina* div. sp. The percentage of planktonic foraminifers decreases.

MS/MO – shallow-water suboxic – oxic. Numerous and diversified microfauna including *Ammonia vienensis* (d'Orb.), *Elphidium* div. sp., *Hanzawaia bouena* (d'Orb.), *Heterolepa dutemplei* (d'Orb.), *Hansenisca soldanii* (d'Orb.) occur.

Bioevents document the occurrence of foraminiferal positions and the first appearance of stratigraphically important species such as *Uvigerina graciliformis* Papp and Turn. and *Globigerinoides bisphericus* Tod. The model is generally consistent with the quality of the input data.

Paleoecological interpretation

The transgression of the Karpatian sea entered the southern part of the Carpathian Foredeep from the Mediterranean area (Rögl and Steininger 1984). The first stage of the transgression expanded to the current area of Mikulov, where the NP-boreholes and the Pohořelice-3 borehole were drilled (Figs 3, 4A). These sediments are typical of the maximum thickness of Karpatian sediments that bear on the Savian movements (Nehyba and Petrová 2000). They are usually barren (biofacies TA – see Fig. 5). Positions with small pyritized globigerinas appear in the anoxic sediments. The sediments locally contain microfauna with euryoxybiont siphonodosarias, stilostomelas, and bolivinas developed from the anoxic and dysoxic positions in higher segments. Assemblages with agglutinated foraminifers indicate that an environment ranging from deeper littoral to upper bathyal existed in this area. These were cold water assemblages (Murray 1991; biofacies TD – see Plate I, fig. 1).

During the second stage, the transgression proceeded to the western part of the Carpathian Foredeep. There occurred an onlap onto the Eggenburgian and the Ottnangian sediments (Fig. 4), just as in the eastern part. Depressions in the southwest and western part of the Carpathian Foredeep were filled partly as separate basins under anoxic conditions (biofacies TA). These basins gradually became a shallow-water dysoxic sea (biofacies TD). These deposits are formed by muds and mudstones, with the exception of some sediments in borehole Znojmo-12. This borehole contained sands with plant debris, indicating the proximity of the shore (Zdražílková in Pálenský et al. 1991 – unpublished report).

Microfauna with fish bone fragments, locally pyritized foraminifer tests, and with levels comprised only of *Globigerina* sp. (biofacies TD – see Plate I, fig. 2) are replaced by more diversified fauna. This indicates a paleoenvironmental change from anoxic to dysoxic, documenting the improvement of environmental conditions and the stability of the oxygen supply. Higher successions of deeper water deposits with taxa the *Siphonodosaria, Neugeborina,*and *Bolivina* are also present (biofacies TD – see Plate I, fig. 4).

Euryoxybiont taxa such as *Bolivina* div. sp., *Bulimina* div. sp., *Praeglobobulimina* div. sp., and *Uvigerina* div sp. predominate (biofacies S – see Plate I, fig. 3). They are followed by numerous planktonic, often pyritized specimens, such as *Globigerina* sp. and the pyritized cores of centric diatoms. Local lithological indications of the anoxic environment are also observed (as lamination, and the occurrence of the organic matter). Muds and mudstones with sandy siltstones and sandy mudstones (and silty, muddy sands and sandstones in the HV-boreholes) dominate during the second stage of the transgression. The number of horizons with impoverished fauna decreases upwards, and euryoxybiont foraminifers alternate with numerous planktonic specimens. Numerous sudden alternations of impoverished and diverse levels are typical of the Nosislav-3 borehole.

Table 1. Summary of studied material

Borehole	Abbreviation	Type of borehole	Number of sample	Type of sample
Nosislav-3	N-3	CC	80	WR
Cf-4 Židlochovice	Cf-4	CC	21	WR
HV-301 Čejkovice	HV-301	NCC	5	rock
HV-303 Božice	HV-303	NCC	2	rock
HV-304 Hrušovany nad Jevišovkou	HV-304	NCC	18	rock
HV-305 Slup	HV-305	NCC	10	rock
HV-306 Hevlín	HV-306	NCC	13	rock
Znojmo-12	Zn-12	NCC	16	rock
Nový Přerov-1	NP-1	NCC	5	rock
Nový Přerov-2	NP-2	NCC	2	rock
Nový Přerov-3	NP-3	NCC	2	rock
Nový Přerov-4	NP-4	NCC	3	rock
Nový Přerov-5	NP-5	NCC	2	rock
Březí-1	Břez-1	NCC	7	rock
Březí-2	Břez-2	NCC	8	rock
Hrušovany-1	Hy-1	NCC	1	rock
Novosedly-1	No-1	NCC	3	rock
Brod-1	Brod-1	NCC	4	rock
Mušov-1	Muš-1	NCC	2	rock
Mušov-2	Muš-2	NCC	2	rock
Pouzdřany-1	Pou-1	NCC	7	rock
Ivaň-1	Ivaň-1	NCC	3	rock
Pohořelice-1	Poh-1	NCC	6	rock
Pohořelice-3	Poh-3	NCC	4	rock
Mikulov-1	Mik-1	NCC	31	MA

Legend: CC – continuous core; NCC – non continuous core; WR – washed residues; MA – microfossil assemblages (revision Holzknecht 1965 – unpublished data).

Positions with numerous fish bone fragments, pyritized diatoms and foraminifer tests (*Globigerina* div. sp.) indicate the brief deterioration of the environment in the Upper Karpatian, mainly in boreholes Nosislav-3 and Cf-4 Židlochovice. The foraminiferal fauna is impoverished, and shallow-water foraminifers predominate in the upper parts of most borehole sections. The sudden alternation of impoverished zones with the occurrence of the euryoxybiont foraminifers can be explained by the upwelling and oscillation of the sea level. Lithological considerations also support this interpretation (laminated muds and silts of reduced facies are typical of seasonal changes, such as in Nosislav-3).

The depositional conditions became those of a shallow-water environment (infralittoral, biofacies MS/MO – see Plate 1, figs 5, 6, Fig. 4C) in the uppermost parts of the borehole sections. The oxygen concentration is higher. Euryoxybiont taxa show the following succession: 1. *Pappina;* 2. *Bulimina;* 3. *Bolivina* (comp. Holcová-Šutovská 1996). The activity of a normal fault was connected with Styrian movements that occurred during and mostly after the shallow-water sedimentation of the Karpatian deposits in the southern part of the Carpathian Foredeep (Čtyroký 1992). The Karpatian sediments in the eastern part of the Carpathian Foredeep dipped. These sediments could have been affected by thrust faulting connected with the movement of nappes. In the western part the shallow-water sediments of the Upper Karpatian became eroded, as evinced in boreholes HV-301, HV-305, and Znojmo-12 (Figs 3, 4D). This is further documented by the absence of shallow-water assemblages in the higher sections of the boreholes (Fig. 2). They were subsequently overlain by the Lower Badenian and Quaternary sediments.

Discussion and conclusions

At the beginning of the Karpatian, in the southern part of the Carpathian Foredeep, deposition began under anoxic conditions (Brzobohatý 1992). Impoverished and more abundant microfauna later began to alternate. Euryoxybiont taxa predominate and represent a sublittoral or locally upper bathyal environment (eastern part of the Carpathian Foredeep). The oxygen supply gradually increased. These

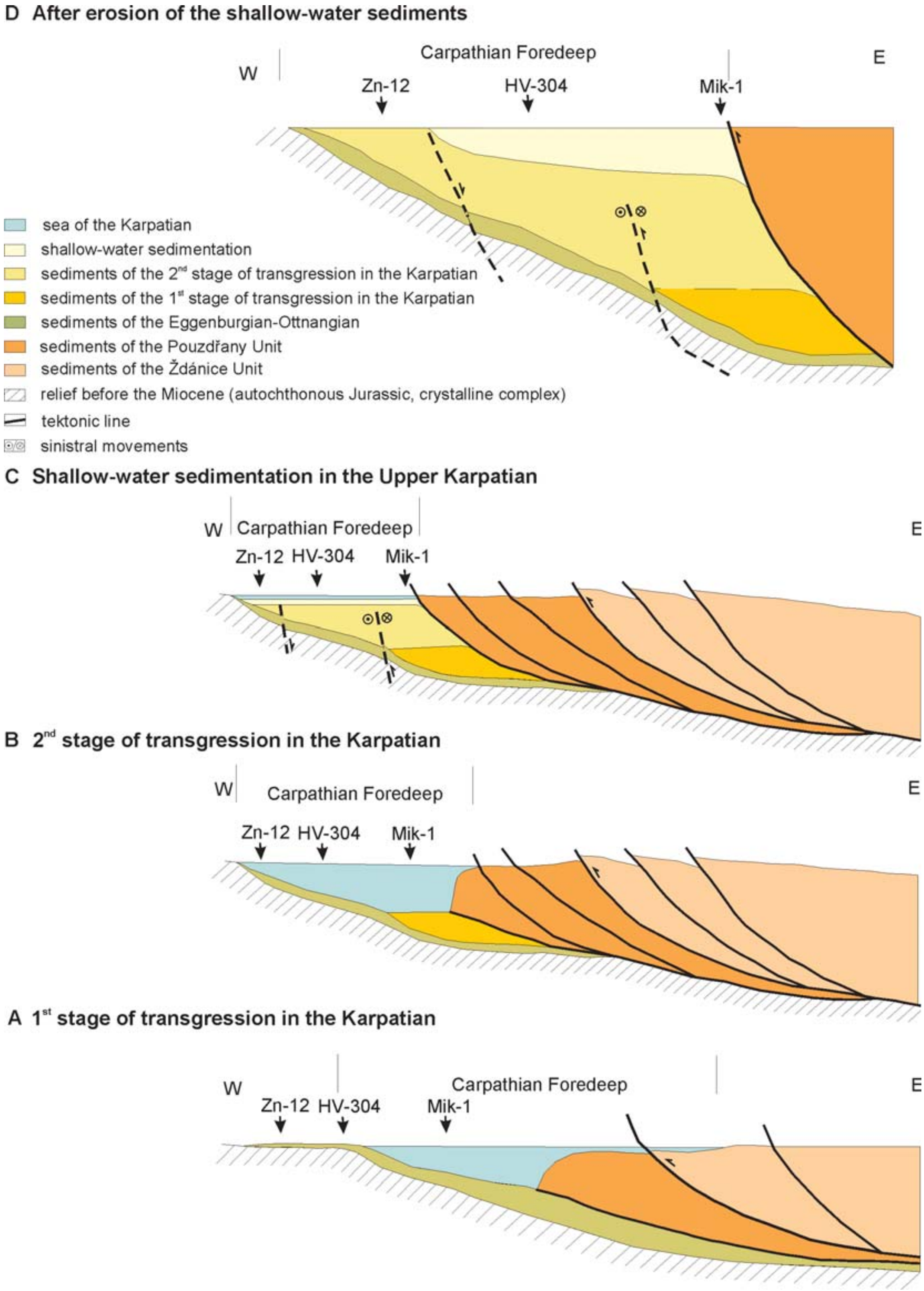

Figure 4. Model of the development of the southern part of the Carpathian Foredeep based on the occurrence of foraminifers (Karpatian).

data are in agreement with the conclusions reached by the sedimentological studies of Adamová et al. (1992), and Nehyba and Petrová (2000), all of whom found evidence of intense circulation in the depositional area.

Three stratigraphically important levels containing *Uvigerina* div. sp. (lower with *U. graciliformis* Papp and Turn., *U. peregrina* Cush., *U. multicostata* LeRoy, and upper with *U. acuminata* Hos., *U. pygmoides* Papp and Turn. and *U. semiornata* d'Orb.) have been identified. Higher levels with *Pappina breviformis* (Papp and Turn.) correspond to the Upper Karpatian. Shallow-water assemblages are observed in the uppermost part of most sections.

The model of basin evolution (Fig. 4) in the southern part of the Carpathian Foredeep is based mainly on foraminiferal studies. The present author distinguishes two developmental stages of the transgression based on microfaunal data: 1. the first stage extended to the eastern part of the Carpathian Foredeep, where deposits containing agglutinated foraminifers occur, which we consider to be the paleoecological equivalents of the agglutinated assemblages from the initial transgressive Karpatian sediments in the Bánov fold and the Blatnice depression of the Danube Basin (Kováč et al. 1999); 2. the second stage reached present extent of the Karpatian deposits on the eastern margins of the Bohemian Massif. Later, after the Lower Badenian, shallow-water Karpatian sediments in the western part of the Carpathian Foredeep were eroded (Fig. 3). Lithostratigraphy, lithofacies, lithology, biofacies, ecostratigraphy, and bioevents are summarised in Fig. 5.

Our model shows some similarities and differences between our study area and other partial Western Carpathian basins. The beginning of marine sedimentation with rapid subsidence and usually anoxic and relatively deepwater conditions is a characteristic feature of all Western Carpathian basins. The final shallowing during the last stage of sedimentation is concordant between the part of the Carpathian Foredeep considered here and the entire Carpathian-Pannonian area. The Ottnangian-Karpatian cycle culminated with a global slowing of subsidence (Kováč 2000).

Similarities in the development of the southern part of the Carpathian Foredeep in Moravia and the northern part of the Lower Austrian molasse were identified. The maximum water depth along the front of flysch nappes fluctuated between neritic and upper bathyal. Sediments with high quantities of organic matter were deposited in suboxic and dysoxic environments. Marginal sediments show fluctuating salinity. Sediments in the higher parts of the borehole sections were deposited in more oxygen-rich environments (Spezaferri and Coric 2001). The lithology of all the studied sediments can be assigned to the Laa Formation (Rögl 1969).

We also found similarities with the development under the Flysch nappes of the Western Carpathians in the surroundings of the town of Zlín. These sediments contain rich organic matter, though foraminifer tests are rare. The deposits originated in a lagoonal environment with low oxygen supply, as indicated by the occurrence of euryoxybiont species. Oxygen concentrations gradually increased, just as in the southern part of the Carpathian Foredeep. Karpatian sediments are correlated with the first stage of the transgression, whereas the sediments of the second stage of the transgression were not identified (Thonová et al. 1987). According to the model presented here, the absence of these latter deposits is a primary feature. Accordingly, the first stage of the Karpatian transgression was terminated by the thrusting of the Flysch nappes over the Zlín area. The tectonic rabotage of the upper sections of the Karpatian sediments in the area around Mikulov should also be considered (Čtyroká et al. 1989).

The changes caused by coastal onlap in the southern part of the Carpathian Foredeep correspond to the coastal onlap curve by Kováč and Hudáčková (1997). This curve was constructed for the part of the Vienna Basin that exists in Slovakia, and differs from the coastal onlap curve of Haqa et al. (1988) by low shallowing of the Upper Karpatian.

Assemblages containing rare *Globigerinoides bisphericus* Todd indicate the long continuation of sedimentation in the Carpathian Foredeep on the Karpatian-Badenian boundary. These assemblages are missing in the East Slovakian Basin (Kováč and Zlinská 1998), Danube basin, Novohrad Basin, and in the Slovakian part of the Vienna Basin (Kováč and Hudáčková 1997). They are, however, documented in the Styrian Basin, and the western part of the Vienna Basin in connection with molasse and Lower Austrian molasse in surroundings of Laa an der Thaya (Rögl et al. 2002).

Model complements the general view of partial Western Carpathian basins (Kováč 2000) in the Karpatian. It demonstrates that the southern part of the Carpathian Foredeep shares generally identical paleoecological features with the Vienna, northern Danube, Novohrad, and East Slovak basins. During the Karpatian the circular system of the Central Paratethys was of an estuarine type (Brzobohatý 1987, Kováč 2000). The basins differed mainly during the initial and final stages of Karpatian sedimentation.

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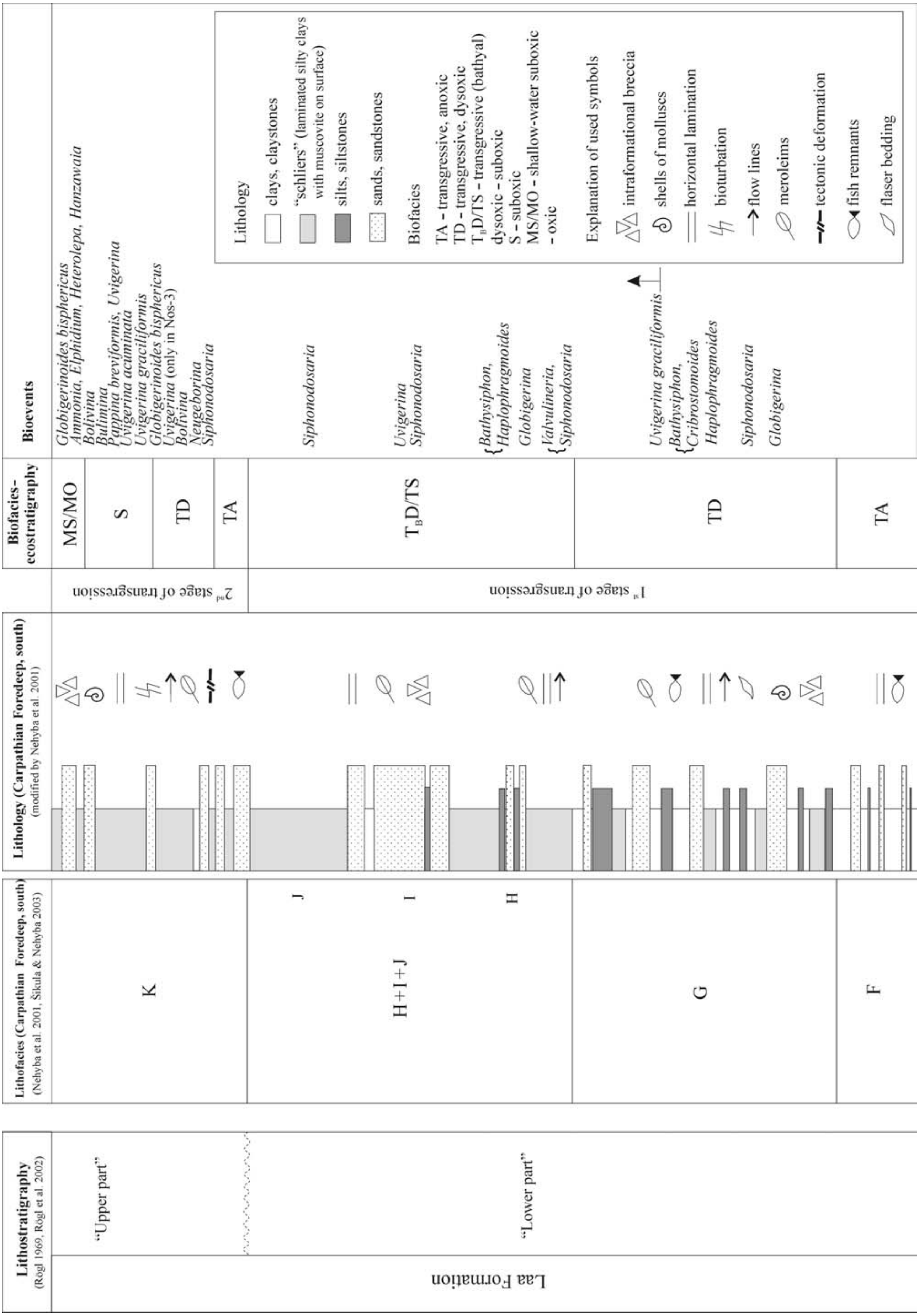
Lithostratigraphy
(Rögl 1969, Rögl et al. 2002)
Laa Formation
"Upper part"
"Lower part"
Lithofacies (Carpathian Foredeep, south)
(Nehyba et al. 2001, Šikula & Nehyba 2003)
K
H+I+J
J
I
H
G
F
Lithology (Carpathian Foredeep, south)
(modified by Nehyba et al. 2001)
2nd stage of transgression
1st stage of transgression
Biofacies-ecostratigraphy
MS/MO
S
TD
TA
TBD/TS
TD
TA
Bioevents
Globigerinoides bisphericus
Ammonia, Elphidium, Heterolepa, Hanzawaia
Bolivina
Bulimina
Pappina breviformis, Uvigerina
Uvigerina acuminata
Uvigerina graciliformis
Globigerinoides bisphericus
Uvigerina (only in Nos-3)
Bolivina
Neugeborina
Siphonodosaria
Siphonodosaria
Uvigerina
Siphonodosaria
Bathysiphon,
Haplophragmoides
Globigerina
Valvulineria,
Siphonodosaria
Uvigerina graciliformis
Bathysiphon,
Cribrostomoides
Haplophragmoides
Siphonodosaria
Globigerina
Lithology
clays, claystones
"schliers" (laminated silty clays with muscovite on surface)
silts, siltstones
sands, sandstones
Biofacies
TA - transgressive, anoxic
TD - transgressive, dysoxic
TBD/TS - transgressive (bathyal) dysoxic - suboxic
S - suboxic
MS/MO - shallow-water suboxic - oxic
Explanation of used symbols
intraformational breccia
shells of molluscs
horizontal lamination
bioturbation
flow lines
meroleims
tectonic deformation
fish remnants
flaser bedding

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Figure 5. Summary of the lithostratigraphy, lithofacies, lithology, biofacies, ecostratigraphy and bioevents (Nehyba et al. 2001; internal report for Czech Geological Survey).

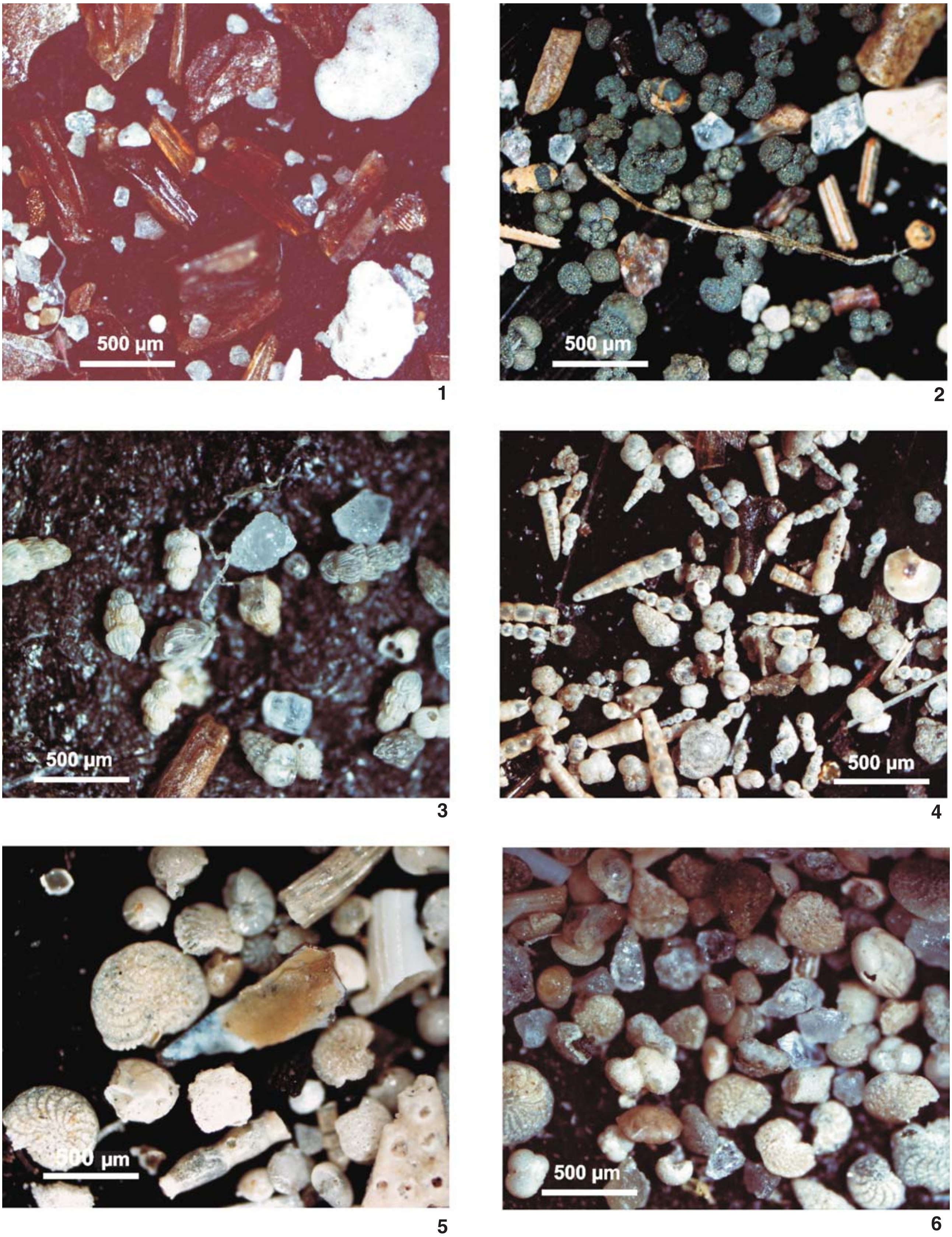

Plate I
Examples of several paleoecologically significant assemblages.
1 – NP-4 (919–923 m) – assemblage with numerous fragments of teleostei and agglutinated foraminifers; 2 – Nosislav-3 (267.5–267.6 m) – assemblage with pyritized tests of globigerinas; 3 – Nosislav-3 (232.2 m) – assemblage with uvigerinas; 4 – HV-306 (380.2–380.4 m) – assemblage with siphonodosarias and stillostomelas; 5 – Mikulov-1 (201–206 m) – shallow-water assemblage with *Elphidium* div. sp.; 6 – Cf-4 Židlochovice (81.0–83.0 m) – shallow-water assemblage with *Elphidium* div. sp.

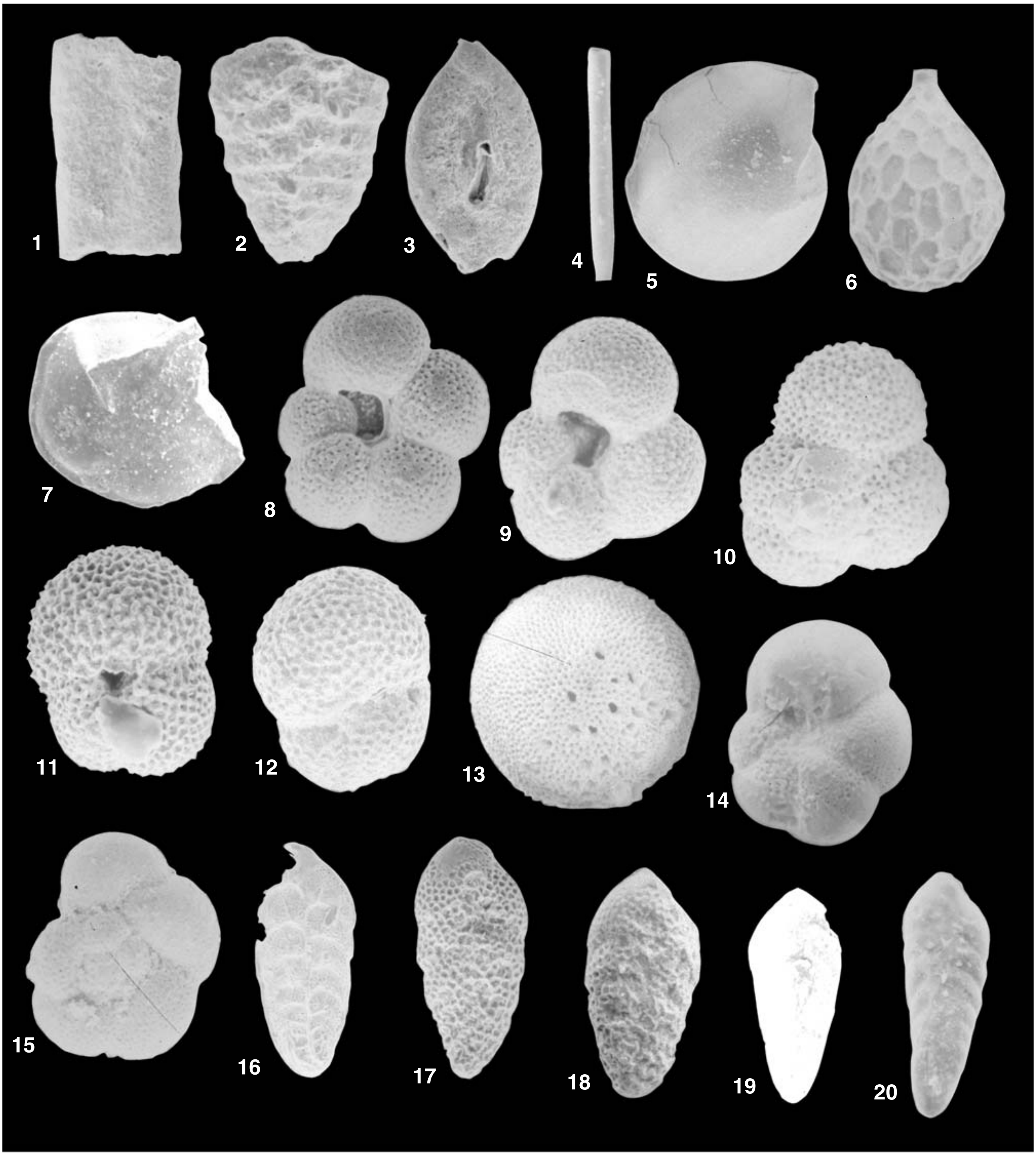

Plate II

1 – *Bathysiphon taurinensis* Sacco, Nosislav-3 borehole, 280.0–280.3 m (90×). 2 – *Textularia* sp., Nosislav-3 borehole, 71.4 m (160×). 3 – *Sigmoilinita tenuis* (Czjzek), Nosislav-3 borehole, 147.3 m (120×). 4 – *Neugeborina longiscata* (d'Orbigny), Znojmo-12 borehole, 25.5 m (45×). 5 – *Lenticulina inornata* (d'Orbigny), Cf-4 Židlochovice borehole, 180.0–182.0 m (48×). 6 – *Favulina hexagona* (Williamson), Nosislav-3 borehole, 107.4 m (260×). 7 – *Lenticulina* aff. *melvilli* (Cushman & Renz), Cf-4 Židlochovice borehole, 180.0–182.0 m (110×). 8 – *Globigerina ottnangiensis* Rögl, Pohořelice-1 borehole, 500.0–505.0 m (240×). 9, 10 – *Globigerina bulloides* d'Orbigny, Nosislav-3 borehole, 237.8 m (200×). 11 – *Globigerinoides trilobus* (Reuss), Hrušovany-1 borehole, 500.0–505.0 m (150×). 12 – *Globigerinoides bisphericus* Todd, Pohořelice-1 borehole, 400.0–405.0 m (100×). 13 – *Orbulina suturalis* Brönnimann, Troskotovice locality, sample F (90×). 14, 15 – *Globorotalia* sp., Troskotovice locality, sample H (170×). 16 – *Bolivina fastigia* Cushman, Nosislav-3 borehole, 200.8 m (100×). 17 – *Bolivina hebes* Macfadyen, Nosislav-3 borehole, 83.1 m (150×). 18 – *Bolivina plicatella* Cushman, Nosislav-3 borehole, 83.1 m (150×). 19 – *Bolivina dilatata* Reuss, Nosislav locality, sample B (120×). 20 – *Bolivina antiqua* d'Orbigny, HV-304 borehole, 136.0–136.2 m (120×).

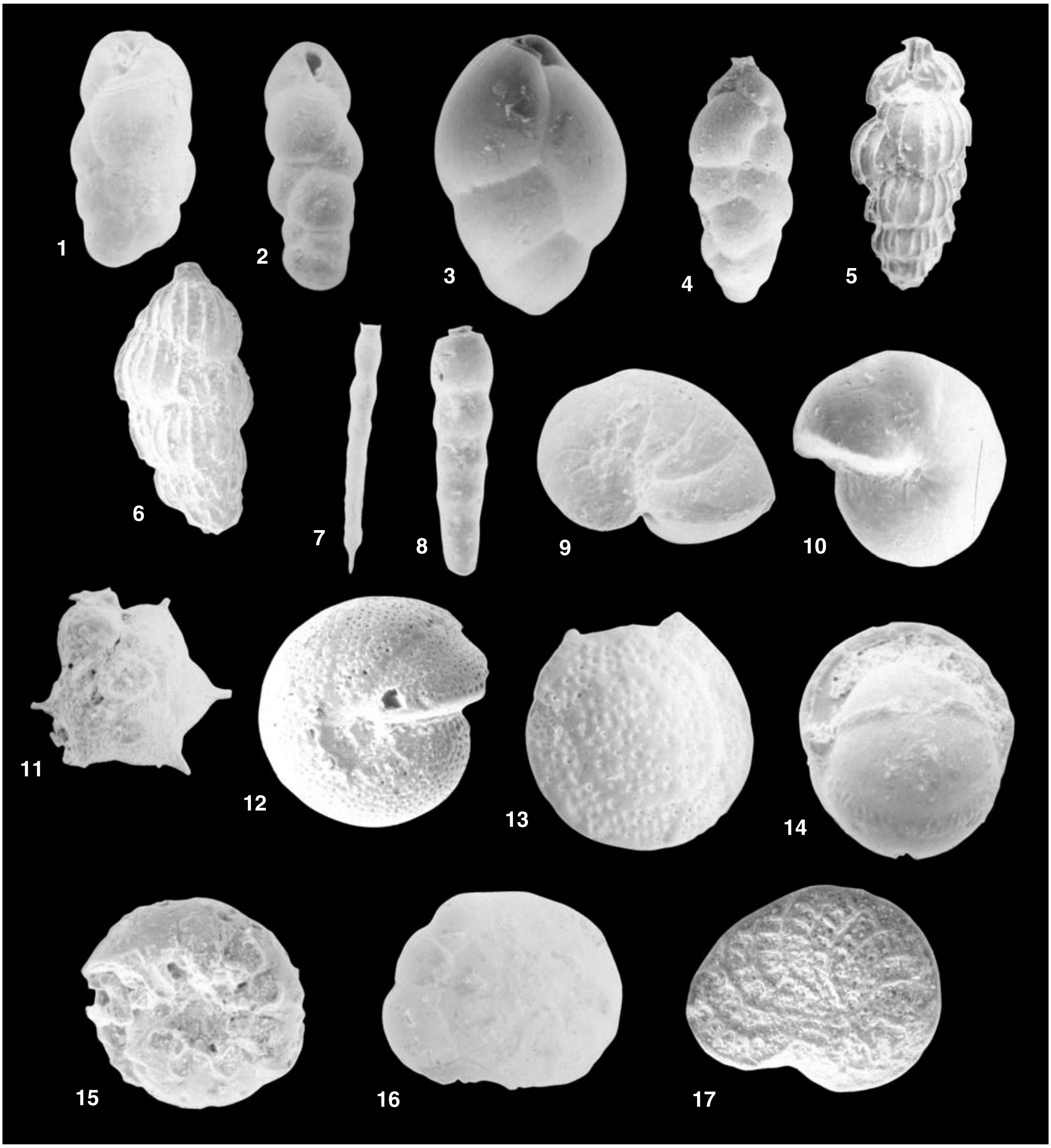

Plate III
1 – *Bulimina schischinskayae* Samoylova, Nosislav-3 borehole, 83.1 m (160×). 2 – *Bulimina elongata* d'Orbigny, Nosislav-3 borehole, 107.4 m (90×). 3 – *Praeglobobulimina pupoides* (d'Orbigny), Pouzdřany-1 borehole, 650.0–655.0 m (100×). 4 – *Pappina breviformis* (Papp & Turnovsky), Nosislav locality, sample B (100×). 5 – *Uvigerina graciliformis* Papp & Turnovsky, Cf-4 Židlochovice borehole, 241.0–243.0 m (100×). 6 – *Uvigerina acuminata* Hosius, Cf-4 Židlochovice borehole, 198.0–200.0 m (110×). 7 – *Siphonodosaria* cf. *consobrina* (d'Orbigny), HV-304 borehole, 136.0–136.2 m (45×). 8 – *Siphonodosaria scabra* (Reuss), Nosislav-3 borehole, 82.6 m (120×). 9 – *Nonion commune* (d'Orbigny), Cf-4 Židlochovice borehole, 241.0–243.0 m (160×). 10 – *Hansenisca soldanii* (d'Orbigny), Nosislav-3 borehole, 80.1 m (200×). 11 – *Pararotalia canui* (Cushman), Nosislav-3 borehole, 67.6 m (150×). 12, 13 – *Heterolepa dutemplei* (d'Orbigny), Nosislav-3 borehole; 80.1 m (200×). 14 – *Pullenia bulloides* (d'Orbigny), Cf-4 Židlochovice borehole, 241.0–243.0 m (190×). 15, 16 – *Ammonia vienensis* (d'Orbigny), Brod-1 borehole, 612.0–617.0 m (120×). 17 – *Elphidium fichtelianum* (d'Orbigny), Cf-4 Židlochovice borehole 212.0–215.0 m (110×).