

Middle and late Badenian palaeoenvironments in the northern Vienna Basin and their potential link to the Badenian Salinity Crisis

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Abstract: Hydrocarbon exploration in the Bernhardsthal and Bernhardsthal-Sued oil fields documents an up to 2000 m thick succession of middle and upper Badenian deposits in this part of the northern Vienna Basin (Austria). Based on palaeontological analyses of core-samples, well-log data and seismic surveys we propose an integrated stratigraphy and describe the depositional environments. As the middle/late Badenian boundary is correlated with the Langhian/Serravallian boundary, the cores capture the crucial phase of the Middle Miocene Climate Transition. The middle Badenian starts with a major transgression leading to outer neritic to upper bathyal conditions in the northern Vienna Basin, indicated by *Bathysiphon*-assemblages and glass-sponges. A strong palaeo-relief and rapid synsedimentary subsidence accentuated sedimentation during this phase. The middle/late Badenian boundary coincides with a major drop of relative sea level by about 200 m, resulting in a rapid shift from deeper marine depositional environments to coastal and freshwater swamps. In coeval marine settings, a more than 100 m thick unit of anhydrite-bearing clay formed. This is the first evidence of evaporite precipitation during the Badenian Salinity Crisis in the Vienna Basin. Shallow lagoonal environments with diverse and fully marine mollusc and fish assemblages were established during the subsequent late Badenian re-flooding. In composition, the mollusc fauna differs considerably from older ones and is characterized by the sudden appearance of species with eastern Paratethyan affinities.

Keywords: Miocene, Badenian, Paratethys Sea, Vienna Basin, Salinity Crisis, Mollusca, Foraminifera.

Introduction

The Vienna Basin (VB) is a key area for the reconstruction and understanding of the development of the Central Paratethys Sea during the Miocene (Kováč et al. 2004). First attempts to define discrete biostratigraphic units within the sedimentary record of this epicontinental sea were often based on Vienna Basin records (e.g., Suess 1866; Grill 1941, 1943). Difficulties in correlating the middle Miocene strata and faunas of the Paratethys Sea with those from the Mediterranean Sea resulted in the definition of the Badenian as a regional stage by Papp & Steininger (1978) based on the name-giving stratotype locality Baden-Sooß south of Vienna revised by Piller et al. (2007) and Hohenegger et al. (2009).

Despite ongoing controversies about the base and subdivision of the Badenian stage (e.g., Piller et al. 2007 versus Hohenegger et al. 2014), it is generally accepted that the

Badenian stage can be correlated with the entire Langhian stage and the lower part of the Serravallian stage of the Standard Global Chronostratigraphic Scale of Gradstein et al. (2012). This implies that Badenian biota capture the middle Miocene Climatic Optimum (MCO) of the Langhian and pass through the subsequent bottleneck of the Middle Miocene Climate Transition (MMCT) during the late Langhian and Serravallian (Zachos et al. 2001; Billups & Schrag 2002; Shevenell et al. 2004; Hamon et al. 2013).

The impact of this major change in global climate on Paratethyan biota and depositional environments has been variously discussed (De Leeuw et al. 2010; Kováčová et al. 2011; Gebhard & Roetzel 2013; Peryt 2013; Báldi et al. 2017; Holcová 2017; Kováč et al. 2017). An expression of the reorganization of Paratethyan basins and changing hydrology was the formation of evaporites during the Badenian Salinity Crisis (BSC) (De Leeuw et al. 2010). Recently, Báldi et al. (2017)

documented BSC-evaporites also from the Soltvadkert Trough in the Great Hungarian Plain and concluded that this phenomenon was not restricted to the Carpathian Foredeep and the Transylvanian Basin as previously thought (De Leeuw et al. 2010 and references therein). Similarly, the productive halite deposits of Tuzla (Bosnia-Herzegovina) in the Southern Pannonian Basin might be an expression of the BSC (Pezelj et al. 2013).

Stromatolite formation in the Oberpullendorf Basin along the western margin of the Paratethys was interpreted to be related to the BSC (Harzhauser et al. 2014), but clear evidence for the BSC in the VB was missing so far. Nevertheless, a coincidental drop in the diversity of marine biota, mainly accounted for by the loss of thermophilic species, was documented by Harzhauser & Kowalke (2002), Hudáčková et al. (2003), Harzhauser & Piller (2007), Kováčová & Hudáčková (2009) and Landau et al. (2009). All these data were derived from surface outcrops with high resolution but very limited stratigraphic range (e.g., Zuschin et al. 2007; Hyžný et al. 2012). This rather poor data basis — in terms of continuous records — is surprising, given that the VB is among the most important hydrocarbon reservoirs in continental Europe (Hamilton et al. 2000). Due to intense hydrocarbon exploration, data from hundreds of boreholes and information from 2D and 3D seismic surveys have become available since the 1940s. The rather restricted policies of the oil companies made it difficult to access this wealth of data, although general overviews were repeatedly published (e.g., Kreuzer 1986, 1992; Jiříček & Seifert 1990). Larger syntheses combining log data with seismic data were published

later by Kováč et al. (2004) and Strauss et al. (2006), when companies started to open up to science. Herein, we utilize geophysical data in combination with a analysis of the micro- and macropalaeontological content of core samples to describe the changes in depositional environments across the MMCT.

Geological setting and lithostratigraphic framework

The Vienna Basin covers large parts of eastern Austria (Lower Austria, Vienna, and Burgenland) and extends into the Czech Republic in the N and the Slovak Republic in the E. It is about 200 km long and 55 km wide, striking roughly SW–NE from Gloggnitz (Lower Austria) in the SSW to Napajedla (Czech Republic) in the NNE. The VB is subdivided by a morphological high, the Spannberg Ridge, into a northern and a southern part (Wessely 2006). Marine sedimentation was restricted to the N (N of the Danube) during the early Miocene and extended into the S only during the middle Miocene. Due to complex fault systems, the basin was internally subdivided into a series of horst and graben systems (Fig. 1). Herein, we focus only on the oil fields Bernhardsthal and Bernhardsthal-Sued in NE Austria close to the Czech border. There, the Miocene basin fill is in direct vicinity and sphere of influence of the Steinberg fault (Fig. 1), roughly striking in SSW–NNE direction with field Bernhardsthal in the NNE and field Bernhardsthal-Sued in the SSW. The area represents the junction between the Mistelbach Halfgraben in the W with the Steinberg High as boundary, the Zistersdorf Basin in the south and the Moravian Central Basin in the

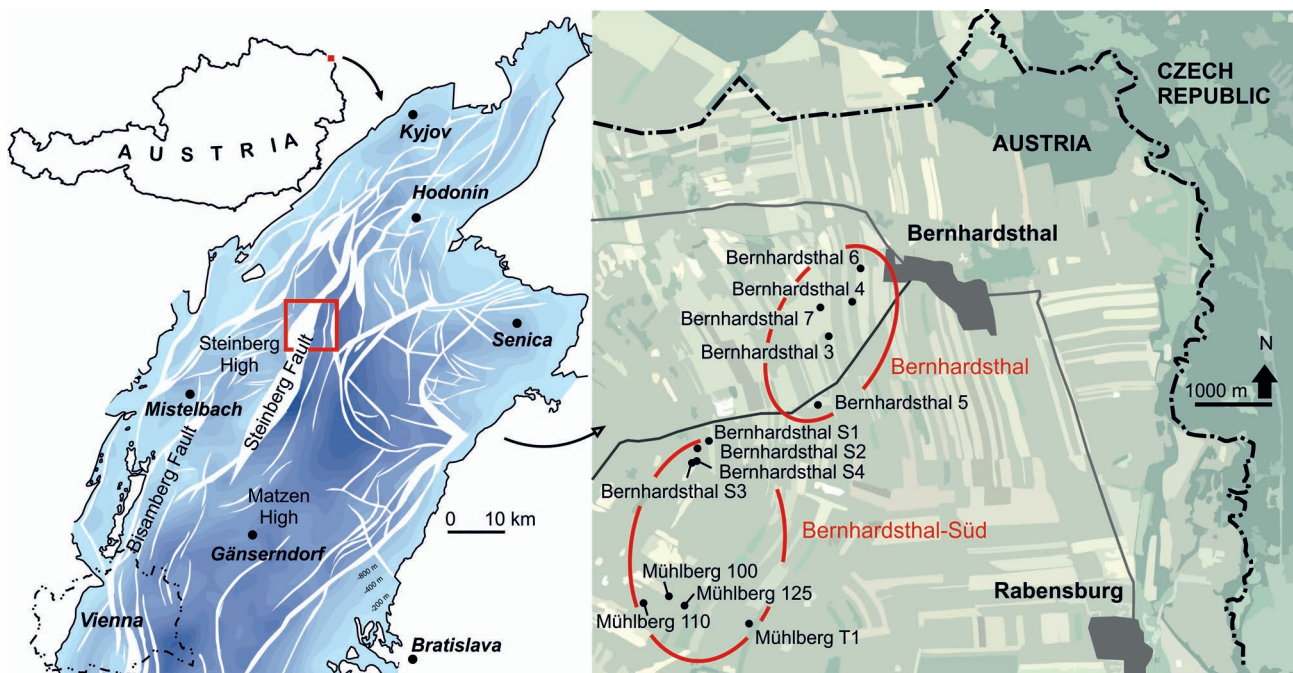


Fig. 1. Structural map of the central and northern Vienna Basin, compiled from Kröll & Wessely (1993), Wessely (2006) and Jiříček (2002). The location of the investigation area is indicated by a square corresponding to the insert on the right showing the position of the wells in north-eastern Austria.

north. To the east, it is bounded by the northern spur of the Eichhorn-Rabensburg High and a complex set of faults. Due to their economic importance, numerous boreholes have penetrated the Neogene deposits in both fields.

In the study area, the Badenian units rest either directly on Rhenodanubian Flysch or on strongly tilted marine Otnangian deposits of the Lužice Formation. The marine Langhian and lower Serravallian (=Badenian) deposits of the VB are united in the Baden Group, which comprises a broad range of lithologies and numerous informal formations (Kováč et al. 2004; Piller 2004) (Fig. 2). Aside from numerous local deltaic and nearshore bodies, the most important and widespread units in the northern VB are the Lanžhot, Jakubov and Studienka formations (Špička 1966; Kováč et al. 2004). In the Bernhardsthal area, deposits of the lower Badenian Lanžhot Formation are not clearly recorded, although their presence cannot be excluded. The lowermost cored Badenian deposits in the region belong to the Jakubov Fm. The predominant lithologies are grey to greenish-grey clays and calcareous clays with subordinate sand layers. A characteristic feature is the frequent occurrence of the agglutinated foraminifer species *Spirorutilus carinatus*. This species, formerly assigned to the genus *Spiroplectamina*, was name-giving for the middle Badenian

ecozone in the Vienna Basin (Grill 1941, 1943). Sediments of the Jakubov Fm. are part of the middle Badenian of most authors. Based on seismic data and sequence stratigraphic interpretations, it comprises the upper parts of the Upper Lagenidae Zone and the entire *Spirorutilus* Zone (Weissenböck 1996) and belongs to nannoplankton zone NN5 (Kováč et al. 2004).

The upper units of the Badenian deposits in the Bernhardsthal area are correlated with the Studienka Fm. Open marine equivalents of this formation, as in the Slovak part of the VB, are represented by dark-grey calcareous clays and sands formed in marine environments with stratified water column and frequent oxygen-depleted bottom conditions (Kováčová & Hudáčková 2009). Characteristic foraminifers are the planktic *Velapertina indigena* and the benthic *Bolivina dilatata maxima* and *Pappina neudorfensis*. The VB *Bulimina-Bolivina* Zone by Grill (1943) was based on the frequent occurrence of these benthic taxa. The nannoplankton is indicative for nannoplankton Zone NN6 (Kováč et al. 2004; Jamrich & Halásová 2010). This classification defines a time window for the deposition of the Studienka Fm. from about 13.6 Ma, marking the extinction of *Sphenolithus heteromorphus*, to 12.7 Ma, which is the onset of the Sarmatian (Harzhauser & Piller 2004a,b).

	Chronostratigr.		Central Paratethys	Eco/bio-zones	Lithostratigraphy	
	Series	Stage	Stage	Foraminifera		
Middle Miocene	11.62	Serravallian	Sarmatian	<i>Porosonion granosum</i> <i>Elphid. hauerinum</i> <i>Elphid. reginum</i> <i>Anomalinoidea</i>	Skalica Fm. Holič Fm.	
			Badenian	upper	<i>Vitta tuberculata</i> (Moll.) <i>Bulimina-Bolivina</i>	Studienka Fm.
				middle	<i>Spirorutilus</i>	Jakubov Fm.
	13.82	Langhian	lower	Upper Lagenidae	Lanžhot Fm.	
				Lower Lagenidae		
Lower Miocene	15.97	Burdigalian	Karpatian	<i>Uvigerina graciliformis</i>	Závod Fm. Lakšary Fm.	
			Otnangian	<i>Cibicides-Elphidium</i> <i>Bathysiphon</i>	Lužice Fm.	

Fig. 2. Lower and Middle Miocene chronostratigraphy and biostratigraphy of the Central Paratethys and major lithostratigraphic units of the Vienna Basin; modified from Harzhauser & Piller (2004a), Kováč et al. (2004), Piller et al. (2007) and Pezelj et al. (2013) (note that stratigraphic gaps between the lithostratigraphic units are not shown).

Material and methods

Thirteen boreholes in the Bernhardsthal and Bernhardsthal-Sued fields (Be3, Be4, Be5, Be6 and Be7, BeS1, BeS2, BeS3, BeS4, MüT1, Mü100, Mü110, Mü125) were chosen (Fig. 1). Although no continuously cored borehole is available, numerous cores from different depth intervals are stored in the OMV core-shed in Gänserndorf (Austria) for sampling. In total, 83 core-samples were taken during two sampling campaigns. The sample names correspond to the names of the core boxes in the OMV core-shed. Typically, each box contains 5 m of core. Samples were taken from about 1-cm-thick slices of undisturbed cores and do not represent mixtures of different levels. All samples were treated with diluted H₂O₂ for several hours and sieved with water through a set of standard sieves (63, 125, 250 µm). Strongly cemented samples were processed with the surfactant Rewoquat® before further treatment. Only foraminifera >250 µm

were picked and counted (note that this leads to a bias against small plankton, which therefore is missing in the palaeoecological discussion). In total, 58775 (often poorly preserved) specimens have been identified and assigned to 219 taxa (Supplementary Table 1). These data have been used for calculating percentages of taxa per sample and Plankton/Benthos ratio as discussed in the Results chapter.

In addition to discrete core samples, foraminifera of 54 drill cuttings from BeS1, an important reference well for the area, have been included in the analyses. The foraminifera of these cuttings were provided by OMV already in microslides; therefore, only presence/absence is indicated in the Supplementary Table 2). All gastropods, bivalves, scaphopods, polychaets, otoliths, bryozoans and coral fragments were collected from the core samples for supplementary palaeoecological information (Supplementary Table 3). 34 of the 83 samples were microsterile but partly contained macrofossils (see Figs. 3–4 for sample positions). The microfossil-bearing samples were qualitatively and partly quantitatively analysed for palaeoecological and biostratigraphic interpretations for the area.

For all wells, resistivity (RES), spontaneous potential (SP) and/or natural radiation (Gr) data, which were logged during the drilling campaigns, were provided by OMV. The data were measured downcore during the drilling with a resolution of ~0.15 m. To remove noise and for an intuitive illustration, all log-data were log-transformed and smoothed by a Gaussian-Filter (Figs. 3–4).

All palaeontological material is stored in the collections of the Natural History Museum Vienna.

Results

Similarities of the well-log patterns in Figs. 3–4 allow a visual correlation of the boreholes. In the following, the samples are united in subsets and the biotic content of the samples is briefly summarized. The composition of foraminiferal assemblages and illustrations of characteristic micro- and macrofossils are shown in Figs. 5–10.

The lowermost middle Miocene units are cored in Mühlberg T1 between 3135 m and 2480 m (Fig. 3). One of the deepest samples MüT1 3127–3132 (Fig. 5) comprises silty sandstone and dark brown silt. The foraminiferal assemblage consists of 43 taxa of which *Heterolepa dutemplei* (Fig. 6Q) is the most abundant foraminifer (32 %) in the benthic assemblage (Fig. 5); *Bathysiphon* sp. (Fig. 6O), *Laevidentalina* spp., *Lenticulina* spp., *Marginulina hirsuta* (Fig. 6I) and *Pseudonodosaria brevis* (Fig. 6H) occur commonly. Planktic foraminifera are absent. MüT1 3132–3135 is similar, containing *Heterolepa dutemplei* and *Laevidentalina* spp. as most abundant benthic foraminifera; *Marginulina hirsuta*, *Spiroplectamina deperdita* and *Bathysiphon* sp. occur commonly. Planktic foraminifera are absent. In MüT1 2937–2942, agglutinated foraminifera, such as *Spirorutilus carinatus*, *Reticulophragmium* spp. and *Cyclamina* spp. dominate the benthic

assemblage, accompanied by common *Psammolingulina papillosa*, *Reophax brevior*, *Spiroplectamina* spp. and *Uvigerina* spp. (including *U. aculeata*, *U. venusta*). Planktic foraminifera are common and include *Globigerina bulloides*, *G. subcretacea* and *G. transsylvanica*. The macrofauna is very poor and comprises only fragments of echinoids (*Brissopsis* sp.) and rare tubes of the polychaete *Ditrupa* sp. MüT1 2737–2742 (Fig. 5) represents lignitic sandstone with a diverse microfauna of 61 species; *Ammonia* spp. (14 %) (Fig. 6P) is the most abundant benthic foraminifer in the sample, *Lenticulina* spp. and the agglutinated foraminifera *Spirorutilus carinatus*, *Reophax* ssp. (Fig. 6K) and *Adelosina schreibersi* (Fig. 6L) occur commonly. Planktic foraminifera are abundant (13 %); plankton/benthos ratio (P/B)=0.15. MüT1 2480–2485 (Fig. 5) comprises mica-rich lignitic sandstone; the foraminiferal assemblage of 26 taxa is strongly dominated by *Ammonia* spp. (87 %), *Reophax scorpiurus* occurs commonly. Miliolid benthic foraminifera are absent, planktic foraminifera are very rare (0.5%), (P/B=0.01). A mass occurrence of the ostracod *Cytheridea acuminata* is characteristic for the sample.

In slightly shallower borehole depth, follow samples from the boreholes Bernhardsthal 4, 5 and 6 (Fig. 4). Be5 2338–2343 reveals light grey fine sandstone with numerous fragments of *Anomia ephippium* and *Ostrea digitalina*, but lacks any microfauna. The brownish-grey fine to medium sandstone of Be4 2134–2141 (Fig. 5) is rich in macrofauna, comprising balanid plates, cardiid bivalves and shell fragments of *Anomia ephippium*. The microfauna consists of ostracods and a rich foraminiferal assemblage of about 28 taxa. *Ammonia* species account for 77 % of the total assemblage with *Ammonia viennensis* as dominant species. Planktic species, represented by *Trilobatus trilobus*, are very rare (<1.7 %) (P/B=0.002). A comparable composition was detected in Be6 2124–2131. Samples Be4 2100–2109 and Be4 2134–2141 comprise green to grey sand and silt with coralline debris, bivalves, such as *Anadara diluvii*, *Ostrea digitalina*, *Anomia ephippium*, *Perna aquitanica* and *Aequipecten* sp. along with the echinoderm *Brissopsis* sp. Laterally, cuttings from BeS1 2130–2140 document the presence of anhydrite in this horizon.

The grey sandy siltstone of sample Be6 2082–2091 is rich in fragments of *Anomia ephippium* and *Ostrea digitalina*. A claw of an Alpheidae decapod indicates the presence of snapping shrimps (Fig. 7G). The most striking feature is the mass occurrence of the ostracod *Cytheridea acuminata* (Fig. 7E–F). The foraminiferal assemblage is moderately diverse with 26 taxa. *Ammonia* spp. strongly dominate along with *Elphidium* spp.; planktic species account for less than 0.5 % of the assemblage (P/B=0.005). Be4 2070–2078 (Fig. 5) has a comparable lithology and macrofauna. Its rich fish assemblage is represented by stingrays of the genus *Dasyatis* (Fig. 8K), juvenile individuals of the seabream *Spondyliosoma* sp. (Fig. 8A–B) and numerous representatives of the family Gobiidae (Fig. 8C), including *Lesuerigobius vicinalis* (Fig. 8E–H). The foraminiferal assemblage comprises 17 taxa and is strongly dominated by *Ammobaculites agglutinans* and *Ammonia* spp. No planktic species have been detected.

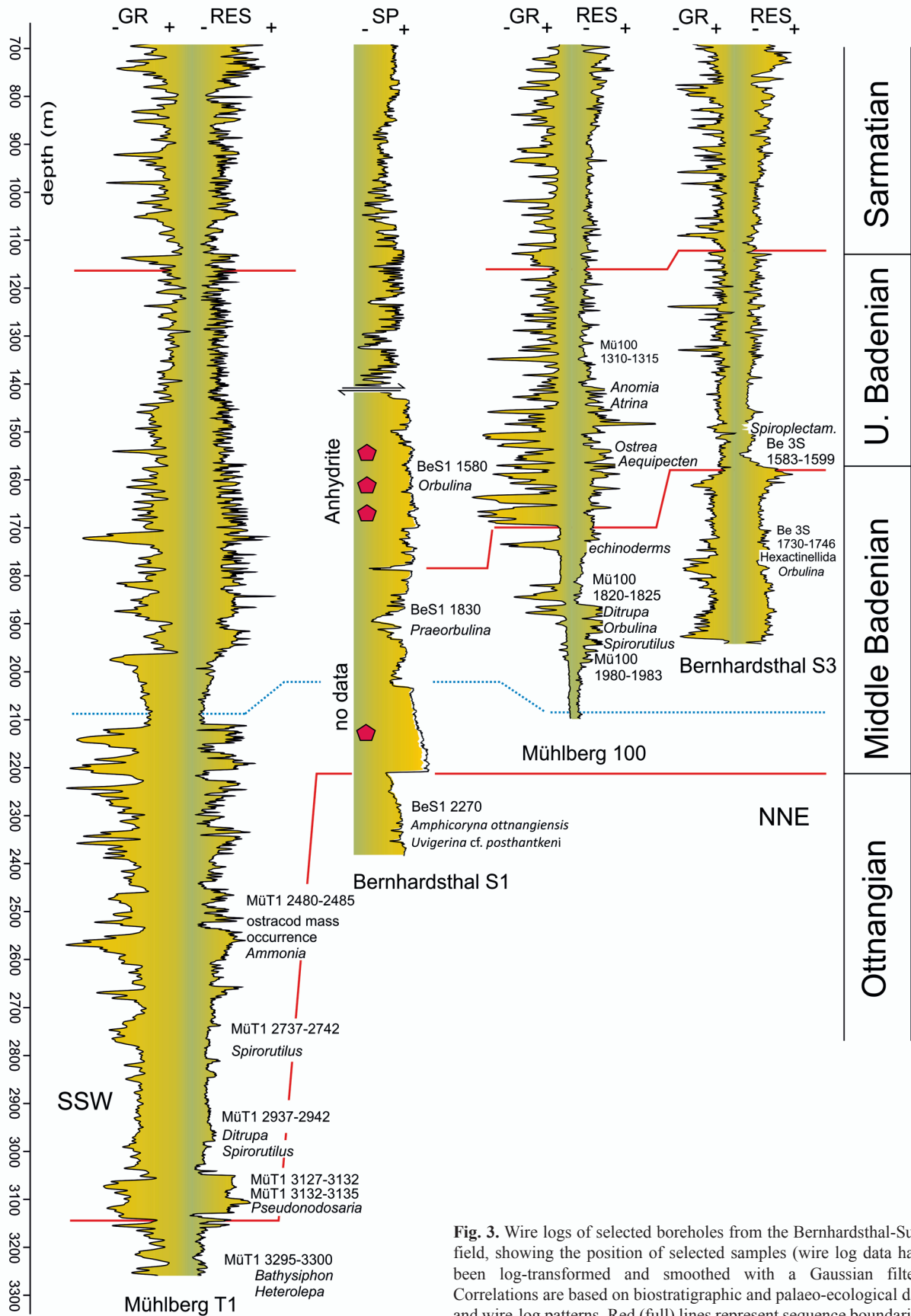


Fig. 3. Wire logs of selected boreholes from the Bernhardsthal-Sued field, showing the position of selected samples (wire log data have been log-transformed and smoothed with a Gaussian filter). Correlations are based on biostratigraphic and palaeo-ecological data and wire-log patterns. Red (full) lines represent sequence boundaries; blue (dotted) lines are flooding surfaces.

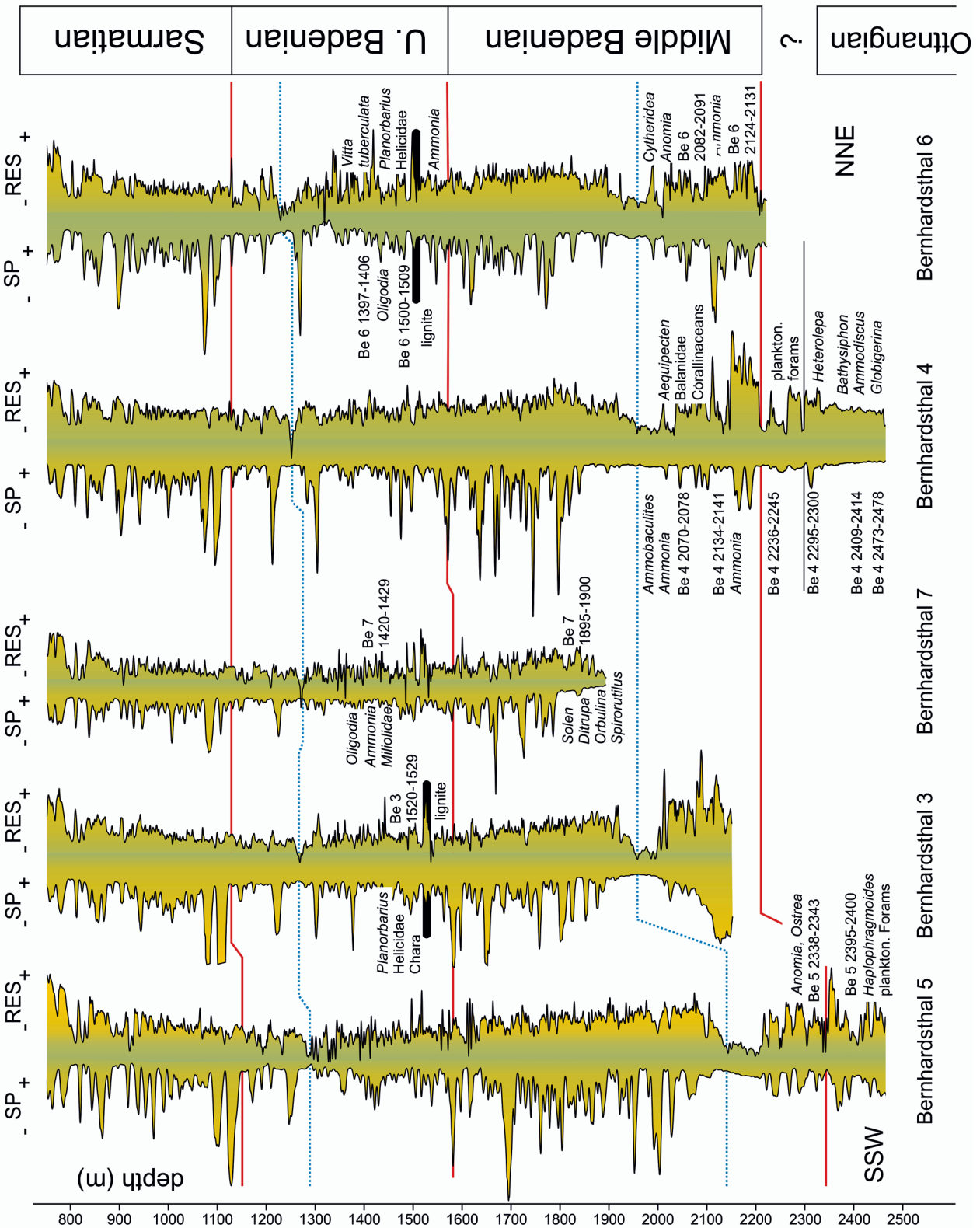


Fig. 4. Wire logs of selected boreholes from the Bernhardtsthal field (see Fig. 3 for captions).

The next samples are separated from the samples below by a conspicuous shale line interval in all wells and start with the Mü100 1980–1983 (Fig. 5), which yields a highly diverse microfauna with 66 taxa; *Lenticulina clypeiformis* (50 %) predominates in the assemblage and *Adelosina schreibersi* is

common. Other benthic species and planktic foraminifera (3.6 %) are rare (P/B=0.04). Be7 1895–1900 (Fig. 5) yields brownish-grey bioturbated silty clay with rare molluscs. *Solen marginatus* occurs with disarticulated valves parallel to the bedding plane. *Striarca lactea*, *Tritia schoenni* and *Ditrupa* sp.

are frequent. The microfauna is highly diverse with 60 taxa. Typical taxa are *Gaudryinopsis* ssp., *Heterolepa dutemplei*, *Praeglobulimina pupoides*, *Spirorutilus carinatus*, *Textularia gramen* and *Sphaeroidina bulloides*. No planktic species have been detected. Sample Mü100 1820–1825 (Fig. 5) comprises a diverse microfauna with 58 taxa; *Spirorutilus carinatus* (26 %) (Fig. 6M–N) and *Uvigerina semiornata* (Fig. 6B) are the most abundant benthic species in this assemblage, *Uvigerina pygmaea* (Fig. 6G), *Nonion commune*, *Cibicidoides* spp. and *Heterolepa dutemplei* occur commonly. Planktic foraminifera, such as *Orbulina* sp., are rare (6.7 %), (P/B=0.07). Tubes of the polychaete worm *Ditrupa* are common. Benthic assemblages from BeS1 1980 to BeS1 1810 regularly contain *Cibicidoides* spp. and *Elphidium* spp. Sample BeS1 1830 yielded a poorly preserved specimen tentatively identified as *Praeorbulina circularis* (Fig. 6R).

Mü110 1798–1803 and Mü100 1740–1745 (Fig. 5) yield microfaunas of low diversity predominated by *Ammonia* spp. (66 %) and *Elphidium* spp. (29 %) or by *Quinqueloculina* spp. and *Ammonia* spp., respectively; planktic foraminifera are absent. The mica-rich, greenish grey silty fine sand of BeS3 1730–1746 (Fig. 5) is poor in macrofossils but yielded articulated parts of glass sponges of the family Craticulariidae (Fig. 7A–C), which are otherwise extremely rare in the fossil record. The foraminiferal assemblage consists of 25 taxa; *Uvigerina venusta* (Fig. 6D–E), *Uvigerina aculeata* (Fig. 6A), *Elphidium* spp. and *Spiroplectammina deperdita* are abundant in the foraminiferal assemblage, *Cibicidoides* spp., *Lenticulina* spp. and *Nonion commune* occur commonly. Planktic foraminifera are rare (5.6 %), (P/B=0.6). BeS2 1697–1706 yields a moderately diverse microfauna with 14 taxa; agglutinated foraminifera including *Textularia* spp., *Haplophragmoides* spp., *Alveolophragmium crassum* and *Spiroplectammina deperdita* dominate the benthic foraminiferal assemblages, while *Nonion commune* occurs frequently. Planktic foraminifera are absent. At BeS1, samples from BeS1 1790 to BeS1 1720 regularly contain *Heterolepa dutemplei*, *Pullenia bulloides*, *Lenticulina* spp., *Uvigerina* spp. (including *U. semiornata*) and *Elphidium* spp. Amongst planktic foraminifera, a poorly preserved specimen tentatively identified as *Praeorbulina circularis* occurs in cutting sample BeS1 1720.

Anhydrite-bearing greenish to brownish clay is documented from BeS1 by cuttings starting from downcore ~1535 m culminating in a characteristic interval of reddish clay with abundant anhydrite from 1640 to 1680 m (Fig. 3). Cutting samples from this interval (BeS1 1680–BeS1 1540) yielded various planktic foraminifers including *Orbulina suturalis* (Fig. 6S), *Globorotalia bykovae* and *Paragloborotalia mayeri*. Amongst benthic taxa, *Heterolepa dutemplei*, *Uvigerina semiornata*, *Lenticulina* spp., *Cibicidoides* spp. and *Pullenia* spp. are the most abundant for the entire interval from BeS1 1830 to BeS1 1540.

A characteristic lignite bed, detected in the wells Bernhardsthal Be3, Be6 and BeS3, allows a separation of the uppermost subset of samples. The lignite is drilled in Be3 1520–1529 and Be6 1500–1509. Reddish, mottled siltstone

with numerous shells of the terrestrial gastropods *Megalotachea* sp. and lignite with *Planorbarius mantelli* coquinas are typical for Be3 1520–1529 (Fig. 9A–B). A single vertebrate bone might represent a frog (*Rana* sp.). A subsample of Be3 1520–1529 yielded rare *Ammonia* sp. and fragments of the thin-shelled cardiid *Plicatiforma parvissima*. The assemblages in Be6 1500–1509 (Fig. 5) are nearly identical with rare fragments of the thin-shelled cardiid *Plicatiforma parvissima* and scattered shells of the pea clam *Pisidium* sp. (Fig. 9D), the freshwater snail *Bithynia* sp. (Fig. 9C), the planorbid *Planorbarius mantelli* (Fig. 9E) and the tiny hydrobiid *Martinietta?* sp. (Fig. 9F). Terrestrial taxa are represented by fragments of the helcid *Megalotachea* sp. The low diverse microfauna comprises 10 taxa and is strongly dominated by *Ammonia falsobeccarii* (~85 %). Planktic foraminifera are absent.

Above the lignitic level, brownish-grey fine sandstone with *Textularia gramen*, *Textularia* spp., *Spiroplectammina deperdita*, *Ammonia* spp. and *Nonion commune* occurs in BeS3 1583–1599 (Fig. 5). A very low diversity is evident for Mü100 1565–1570 (Fig. 4), which yielded only a few specimens of *Ammonia* spp. and 1 specimen of *Elphidium* sp. Agglutinated, miliolid and planktic foraminifera are absent. Rare fragments of *Aequipecten* sp. occur. Up-core follows brownish-grey silty fine sandstone with numerous molluscs in Be7 1429–1434 (Fig. 4), Be7 1420–1429 (Fig. 5) and Be6 1397–1406 (Fig. 10). Turritellid coquinas with *Oligodia pythagoraica* (Fig. 10G–H) are very frequent; the diverse mollusc assemblages comprise taxa such as *Potamides schaueri* (Fig. 10I–K), *Vitta tuberculata* (Fig. 10A–D), *Tritia longitesta* (Fig. 10L), *Tritia schoeni* (Fig. 10M), *Gibborissoia varicosa* (Fig. 10N), *Alvania oceani* (Fig. 10N), *Tornus kuemeli* (Fig. 10E–F), *Favriella* sp. (Fig. 10P), *Tragula fenestrata* (Fig. 10R), *Chemnitzia* sp. (Fig. 10S), *Turbonilla* ssp. (Fig. 10Q), *Acteocina heraclitica* (Fig. 10T), *Retusa truncatula* (Fig. 10U), *Striarca lactea* (Fig. 10W–X), *Papillicardium papillosum* (Fig. 10AB), *Plicatiforma parvissima* (Fig. 10Z–AA), *Mioerycina letochai* (Fig. 10Y), *Microlophos dentatus* (Fig. 10AC) and *Solen marginatus*. Prismatic crystals of shells from pen shells (Pinnidae indet.) are frequent. In addition, tubes of the polychaete *Ditrupa* sp., elements of astropectenids and colonies of the bryozoan *Schizostomella grinzinensis* (Fig. 7D) occur. The mainly epifaunal microfauna of Be7 1429–1434 comprises 12 taxa and is dominated by miliolids, *Cycloforina contorta* and *Elphidium* ssp. Planktic species account for less than 1.7 % of the assemblage (P/B=0.02). Be7 1420–1429 yields 18 taxa and is strongly dominated by *Ammonia viennensis*, *Quinqueloculina boueana* and *Elphidium crispum*. No planktic species were detected in the sample. In addition, octocorals, seastars (*Astropecten* sp.) and the scaphopod *Antalis* cf. *mutabilis* (Fig. 10V) were found in sample Be6 1397–1406. The rich fish assemblage comprises various myliobatiform batoids (Fig. 8L–M), juvenile seabreams (*Spondyliosoma* sp.), croakers (*Umbrina* sp.) (Fig. 8I–J) and numerous Gobiidae (Fig. 8D), such as *Lesuerigobius vicinialis*. The moderately diverse foraminiferal

assemblage with 17 taxa is strongly dominated by *Ammonia viennensis* and *Porosonion granosum*. Planktic species account only for 1 % of the assemblage (P/B=0.01). The uppermost sample Mü100 1330–1335 is microsterile; its mollusc

fauna consists only of calcitic shells of *Ostrea* sp., *Anomia ephippium* and *Pinna* sp.

At BeS1, assemblages from BeS1 1550 to BeS1 1430 frequently contain the benthic taxa *Sphaeroidina bulloides*,

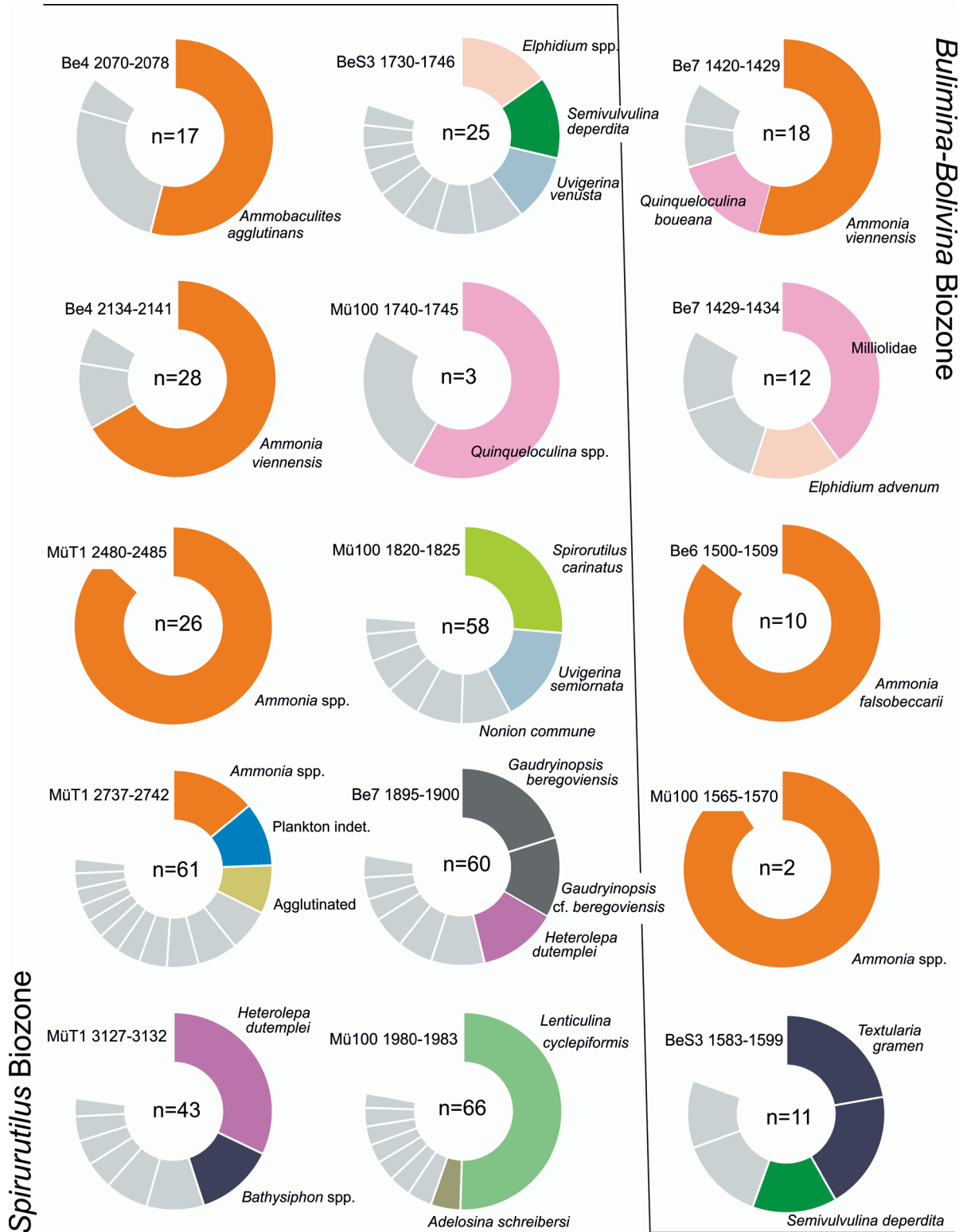


Fig. 5. Composition of representative foraminiferal assemblages with indication of the most important taxa in %; (in stratigraphical order from bottom to top); n=number of taxa (based on data in Supplementary Table 1).



Fig. 6. Foraminifers from the Berhardsthal boreholes: **A** — *Uvigerina aculeata* d'Orbigny, 1846, BeS3 1730–1746; **B** — *Uvigerina semiornata* d'Orbigny, 1846, Mü100 1820–1825; **C** — *Uvigerina grilli* Schmid, 1971, Mü100 1820–1825; **D** — *Uvigerina* cf. *venusta* (Franzenau, 1894), Mü100 1980–1983; **E** — *Uvigerina* cf. *venusta* (Franzenau, 1894), BeS3 1730–1746; **F** — *Uvigerina* cf. *multistriata* Hantken, 1871, MüT1 3295–3300; **G** — *Uvigerina pygmoides* Papp & Turnovsky, 1953, Mü100 1820–1825; **H** — *Pseudonodosaria brevis* (d'Orbigny, 1846), MüT1 3127–3132; **I** — *Marginulina hirsuta* d'Orbigny, 1826, MüT1 3127–3132; **J** — *Pleurostomella alternans* Schwager, 1866, MüT1 3295–3300; **K** — *Reophax nodulosa brevior* Lomnicki, 1899, MüT1 2737–2742; **L** — *Adelosina schreibersi* d'Orbigny, 1846, MüT1 2737–2742; **M** — *Spiroretulus carinatus* (d'Orbigny, 1846), Mü100 1820–1825; **N** — *Spiroretulus carinatus* (d'Orbigny, 1846), Mü100 1820–1825; **O** — *Bathysiphon* sp., MüT1 3127–3132; **P** — *Ammonia viennensis* (d'Orbigny, 1846), MüT1 2737–2742; **Q** — *Heterolepa dutemplei* (d'Orbigny, 1846), MüT1 3127–3132; **R** — *Praeorbulina circularis* (Blow, 1956), BeS1 1830; **S** — *Orbulina suturalis* Brönnimann, 1951, BeS1 1570. all scale bars=100 µm.

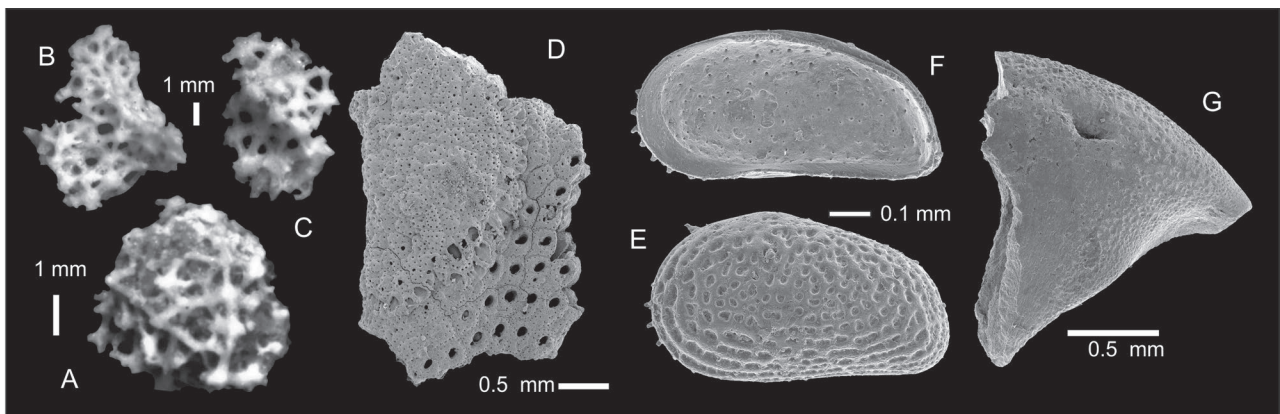


Fig. 7. Micro and meso-fossils from the Bernhardsthal boreholes: **A, B, C** — glass sponges (Hexactinosida; Craticulariidae), BeS3 1730–1746; **D** — *Schizostomella grinzingensis* David & Pouyet, 1974, (Bryozoa), Be7 1420–1429; **E, F** — *Cytheridea acuminata* Bosquet, 1852 (Ostracoda), Be6 2082–2091; **G** — tip of Alpheidae claw (Decapoda), Be6 2082–2091.

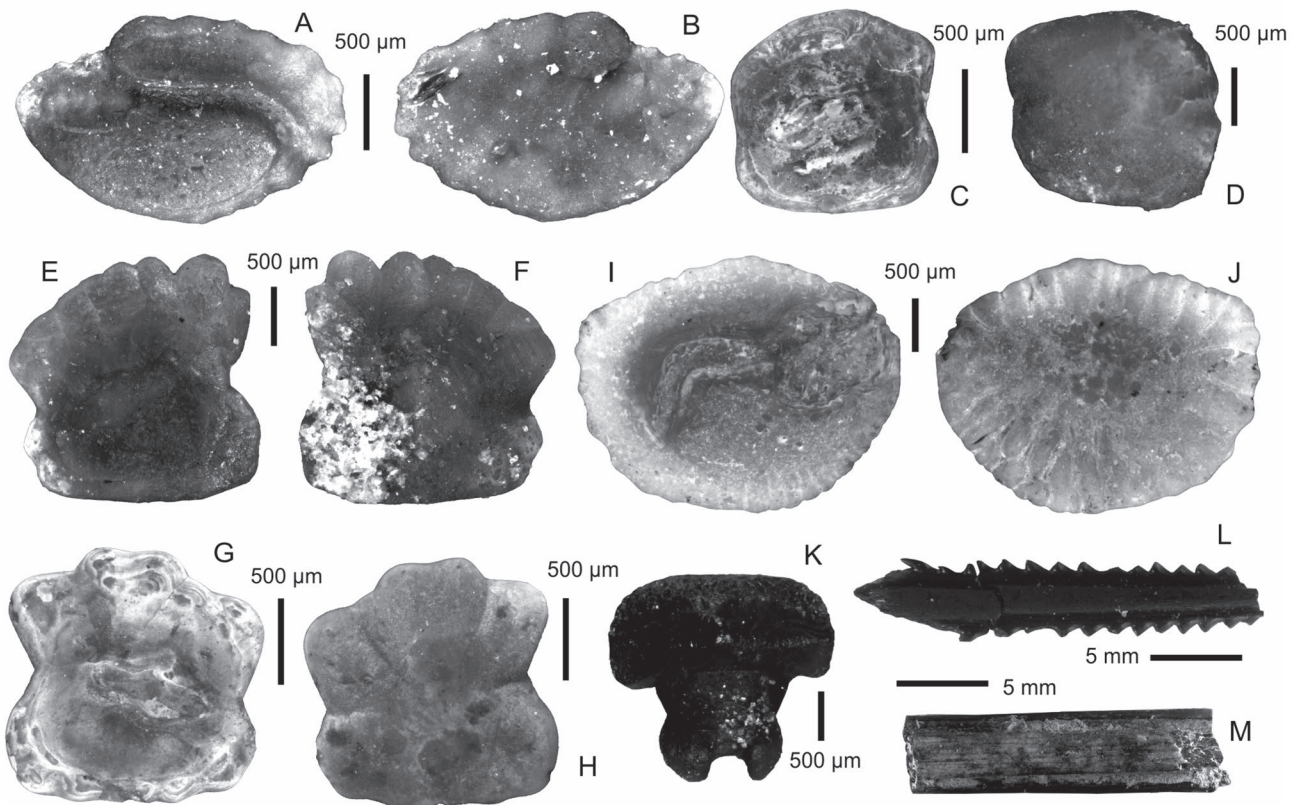


Fig. 8. Vertebrates from the Bernhardsthal boreholes: **A–B** — *Spondyliosoma* sp. (Sparidae), Be4 2070–2078; **C** — Gobiidae, Be4 2070–2078; **D** — Gobiidae, Be4 1397–1406; **E–F, G–H** — *Lesueurigobius vicinalis* (Koken, 1891) (Gobiidae), Be4 2070–2078; **I–J** — *Umbrina* sp. (Sciaenidae), Be4 1397–1406; **K** — *Dasyatis* sp., Be4 2070–2078; **L, M** — Myliobatiformes indet., Be4 1397–1406.

Melonis pompilioides, *Cibicidoides* spp. and uvigerinids including *Uvigerina macrocarinata* and *U. semiornata*; shelf taxa such as *Ammonia* and *Elphidium* are rare. Amongst planktic foraminifera, *Orbulina suturalis* occurs frequently. Above this interval (BeS1 1420–BeS1 1380), assemblages show very low diversity and are composed almost exclusively of species of *Ammonia*, *Elphidium*, *Nonion* and *Porosonion*.

Biostratigraphy and lithostratigraphy

Middle Badenian (*Spirorutilus carinatus* Ecozone, Jakubov Fm.): Occurrences of *Amphistegina mammilla*, *Psammolingulina papillosa*, *Pseudonodosaria brevis*, *Schlumbergerina transilvaniae*, *Uvigerina grilli* and *Uvigerina semiornata* in samples Be4 2134–2141, Be7 1895–1900, MüT1 3127–3132,

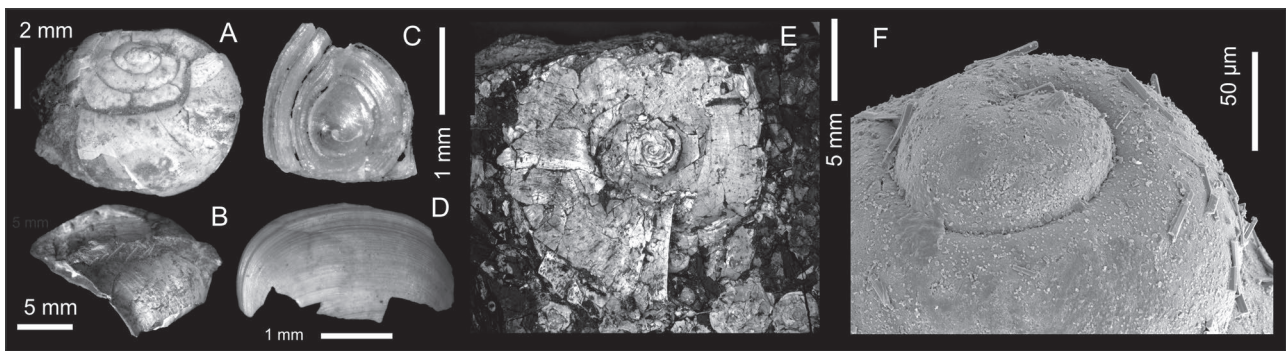


Fig. 9. Terrestrial and freshwater indicators from the Bernhardsthal boreholes: **A, B** — *Megalotachea* sp., Be3 1520–1529; **C** — operculum of *Bithynia* sp., Be6 1500–1509; **D** — *Pisidium* sp., Be6 1500–1509; **E** — *Planorbis mantelli* (Dunker, 1848), Be3 1520–1529; **F** — protoconchs of a hydrobiid (*Martinietta?* sp.) with calcite rods, Be6 1500–1509.

MüT1 2937–2942, MüT1 2737–2742, Mü100 1980–1983, BeS1 1790 and BeS1 1780 generally suggest an early to middle Badenian age (sensu Kováč et al. 2004 and Piller et al. 2007). The co-occurrence of the planktic foraminifers *Globigerina subcretacea* (middle to late Badenian) and *Globorotalia transsylvanica* (early to middle Badenian) in sample MüT1 2937–2942 indicates a middle Badenian age (Cicha et al. 1998). This correlation with the *Spirorutilus carinatus* Biozone is also supported by the rich assemblage of agglutinated foraminifera including the name giving species *Spirorutilus carinatus* in samples MüT1 2937–2942, Mü100 1820–1825 and Be7 1895–1900. Other typical middle Badenian taxa are *Reophax brevior*, *U. aculeata* and *U. venusta*, which are all rare or already extinct in the late Badenian (Haunold 1995; Cicha et al. 1998).

In terms of lithostratigraphy, the greenish-grey clays and siltstones belong to the Jakubov Fm. (Špička 1966; Kováč et al. 2004), which is part of the Baden Tegel Series of Papp et al. (1968). Although lower parts of the formation comprise parts of the Upper Lagenidae Biozone, the majority of the deposits belong to the *Spirorutilus carinatus* Biozone (Weissenböck 1996). In the Bernhardsthal and Bernhardsthal-Sued boreholes, this formation seems to cover only the *Spirorutilus carinatus* Biozone.

Upper Badenian (*Bulimina-Bolivina* Biozone & *Vitta tuberculata* Biozone, Studienka Fm.): The microfaunas of the samples Be7 1429–1434, Be7 1420–1429, Be6 1500–1509, Be6 1397–1406, BeS3 1583–1599 and MüH100 1565–1570 lack biostratigraphic index fossils and their correlation with the *Bulimina-Bolivina* Biozone is tentative. Nevertheless, high percentages of *Ammonia viennensis* and *Porosonion granosum* with various miliolid foraminifera are highly characteristic for inner shelf environments of the late Badenian (Papp et al. 1968; Cicha et al. 1998). A more reliable biostratigraphic tool for these samples is the mollusc fauna, which is characterized by frequent occurrences of *Vitta tuberculata*, *Oligodia pythagoraica*, *Papillicardium papillosum* and *Potamidites schaueri* (Fig. 10). This assemblage type is restricted to the late Badenian of the Central Paratethys. It has variously been documented from the VB, the Danube Basin and

the Pannonian Basin (Švagrovský 1964; Hladilová & Fordinál 2013). *Vitta tuberculata* (sometimes referred to as “*Nerita picta*” in the older literature) is restricted to the late Badenian of the Central Paratethys (Švagrovský 1964, 1982). For the VB, Grill (1941) already recognized its biostratigraphic value and proposed the “Zone with *Rotalia beccarii* and *Nerita picta*” for the upper Badenian.

In the VB, the dark-grey clays and brownish siltstones containing assemblages of the *Bulimina-Bolivina* Biozone are united in the Studienka Fm. (Špička 1966; Kováč et al. 2004). In basal parts with open marine conditions, a stratified water column and frequent oxygen-depleted bottom conditions prevailed (Kováčová & Hudáčková 2009). The correlative samples from the Bernhardsthal and Bernhardsthal-Sued boreholes document shallow sublittoral and lagoonal equivalents of this offshore facies.

Discussion

Palaeoecology and depositional environment

The transgression of the Paratethys Sea in the northern VB flooded a strongly accentuated palaeorelief. This is documented by the strongly varying depth of the Ottnangian/Badenian boundary in the boreholes (note that post-Badenian tectonics is not responsible for this pattern as can be seen from seismics). Samples BeS1 2210, BeS1 2179.6, Be4 2473–2478, Be4 2409–2414, Be4 2344–2347.5, Be5 2395–2400 and MüT1 3295–3300 all yielded Ottnangian assemblages of the Lužice Formation corresponding to the regional benthic *Bathysiphon-Cyclammina* Biozone of Grill (1941, 1943, 1968), Kapounek et al. (1965), Cicha & Rögl (1973) and Cicha et al. (1998). A typical early Miocene (Ottnangian) assemblage is detected in MüT1 3295–3300 (4/5) with *Globigerinoides subquadratus*, *Pleurostomella alternans* (Fig. 6J), *Uvigerina mantaensis* and *Uvigerina* cf. *multistriata* (Fig. 6F). Of these, *Pleurostomella alternans* displays its Last Occurrence (LO) in the Karpatian, and *Uvigerina mantaensis* and *Uvigerina* cf. *multistriata* are restricted to the Egerian to

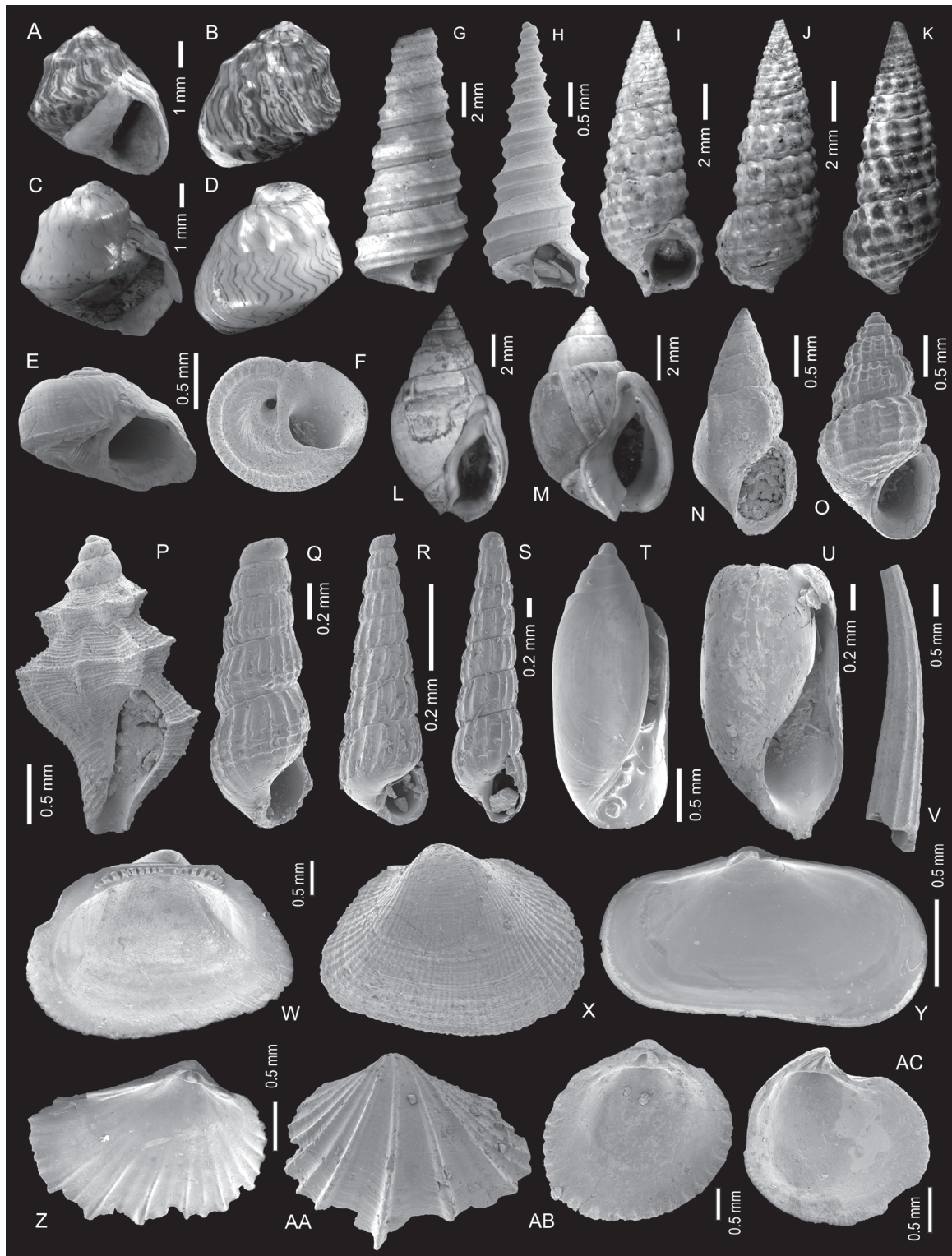


Fig. 10. Marine molluscs from the Bernhardsthal boreholes: **A–B, C–D** — *Vitta tuberculata* (Schréter in Horusitzky, 1915), Be6 1397–1406; **E, F** — *Tornus kuemeli* Harzhauser, 2002, Be6 1397–1406; **G, H** — *Oligodia pythagoraica* (Hilber, 1882), Be6 1397–1406; **I, J–K** — *Potamides schaueri* (Hilber, 1882), Be7 1429–1434; **L** — *Tritia longitesta* (Beer-Bistrický, 1958), Be6 1397–1406; **M** — *Tritia schoenni* (Hoernes & Auinger, 1882), Be6 1397–1406; **N** — *Gibborissoia varicosa* (de Basterot, 1825), Be6 1397–1406; **O** — *Alvania oceani* (d'Orbigny, 1852), Be6 1397–1406; **P** — *Favriella* sp., Be7 1420–1429; **Q** — *Turbonilla* sp., Be7 1420–1429; **R** — *Tragula fenestrata* (Jeffreys, 1848), Be7 1429–1434; **S** — *Chemnitzia* sp., Be7 1429–1434; **T** — *Acteocina heraclitica* Berger, 1949, Be7 1420–1429; **U** — *Retusa truncatula* (Bruguière, 1792), Be6 1397–1406; **V** — *Antalis* cf. *mutabilis* (Hörnes, 1856), Be6 1397–1406; **W, X** — *Striarca lactea* (Linnaeus, 1758), Be6 1397; **Y** — *Mioerycina letochaj* (Hörnes, 1865), Be6 1397–1406; **Z, AA** — *Plicatifforma parvissima* (Švagrovský, 1960), Be6 1397–1406; **AB** — *Papillicardium papillosum* (Poli, 1791), Be7 1420–1429; **AC** — *Microloripes dentatus* (Defrance, 1823), Be6 1397–1406.

Ottangian; *Globigerinoides subquadratus* has its First Occurrence (FO) during the early Burdigalian (Postuma 1971; Cicha et al. 1998). Typical Ottangian assemblages also appear in BeS1 2179.6 and BeS1 2210 with the marker species *Amphicoryna ottangiensis* and *Uvigerina cf. posthantkeni*.

Consequently, MüT1 3132–3135 and MüT1 3127–3132 are the lowermost Badenian samples available from the Bernhardsthal field. Based on the high abundance of *Heterolepa dutemplei* and frequent occurrences of *Bathysiphon*, *Laevidentalina* and Chrysalogoniidae, an outer neritic to upper bathyal depositional environment can be deduced (Leckie & Olson 2003; Murray 2006; Hayward et al. 2012; Grunert et al. 2013). *Bathysiphon* is adapted to high sediment flux in unstable environments with frequent deposition of turbidites (Grunert et al. 2013). The high abundances of uniserial hyaline foraminifera indicate high export productivity (Roetzel et al. 2006; Grunert et al. 2010; Hayward et al. 2012). Due to the presence of Badenian marker species such as *Pseudonodosaria brevis* and the homogenous state of preservation, the assemblage can be considered parautochthonous (e.g., not reworked from Ottangian strata). Outer neritic to upper bathyal conditions also prevail in MüT1 2937–2942 based on the high abundances of *Reophax*, *Reticulophragmium*, *Cyclammina* and *Spirorutilus* (Van Morkhoven et al. 1986; Holbourn et al. 2013). Influx from inner to middle neritic environments is indicated for MüT1 2737–2742 and MüT1 2480–2485 by frequent occurrences of *Ammonia* spp. and *Lenticulina* spp. (Leckie & Olson 2003; Murray 2006).

Upsection, the following sample set suggests inner neritic depositional environments in the shallow sublittoral. *Anomia*, *Ostrea* and the balanids in Be5 2338–2343 and Be4 2134–2141 were all attached to rocks or other shells and are found from the intertidal down to sublittoral environments (Bernard et al. 1993). The first evaporite formation is indicated by anhydrite cuttings in BeS1 2130–2140.

Similarly, Be4 2100–2109 formed under fully marine conditions in coastal to inner neritic environments as indicated by the echinoderm assemblage and the pectinids. The frequent abundance of the ostracod *Cytheridea acuminata* in Be6 2082–2091 also suggests a shallow sublittoral environment <60 m (Zorn 2003; Opreanu 2003). The *Ammonia–Elphidium* dominated foraminiferal assemblage supports this interpretation (Murray 2006). Similar conditions are documented for sample Be4 2070–2078; juvenile sea breams and gobies of the genus *Lesuerigobius* prefer coastal waters and occur over sea-grass beds and sandy bottoms to about 300 m depth (e.g., Bauchot & Hureau 1986; Miller 1986). The *Ammobaculites–Ammonia* dominated microfauna is typical for lagoons (Murray 2006). The scarceness of planktic foraminifers also points to very shallow settings.

The samples above the shale line interval document a deeper marine environment. The predominance of *Lenticulina* spp. and common occurrences of *Adelosina schreibersi* indicate a middle to outer neritic environment for Mü100 1980–1983 (Jones 1994; Murray 2006). Be7 1895–1900 with a rich foraminiferal assemblage with *Gaudryinopsis*, *Heterolepa*,

Praeglobobulimina and *Sphaeroidina* likely also formed in middle neritic environments (Rupp 1986; Kaiho 1994; Rögl & Spezzaferri 2003; Pezelj et al. 2007; Spezzaferri & Tamburini 2007; Grunert et al. 2012). The mollusc fauna, however, derives from shallow sublittoral environments: The extant *Solen marginatus* prefers sandy to muddy bottoms from 0.5 to 3 m water depth (Milišić 1991). *Tritia schoenni* is known mainly from protected lagoonal environments (Harzhauser 2002; Zuschin et al. 2014). This contradiction might be explained by occasional transport from coastal environments into deeper settings, which would account for the preservation of the solenids with valves parallel to the bedding plane. Middle to outer neritic conditions are also documented for Mü100 1820–1825, based on the frequent occurrences of *Spirorutilus carinatus*, *Uvigerina semiornata*, *Nonion commune*, *Cibicidoides* spp., and *Heterolepa dutemplei* (Van Morkhoven et al. 1986; Jones 1994; Murray 2006; Pezelj et al. 2007; Holbourn et al. 2013). BeS3 1730–1746 formed under similar conditions based on foraminiferal assemblages with *Uvigerina venusta*, *Elphidium* spp., and *Spiroplectammina deperdita*, *Cibicidoides* spp., and *Lenticulina* spp. Deep water conditions are also indicated by the presence of hexactinoid glass sponges (Tabachnick 1994; Chu et al. 2011). Up to the level of BeS2 1697–1706, benthic foraminiferal assemblages with *Textularia* spp., *Haplophragmoides* spp., *Alveolophragmium crassum*, *Spiroplectammina deperdita* and *Nonion commune* point to middle neritic environments. A lateral equivalent of this interval is drilled in BeS1 where a more than 100-m-thick unit of anhydrite-bearing greenish to reddish clay (BeS1 1535–1680) points to high evaporation (Fig. 11). These evaporites, however, are only documented by cuttings. Therefore, their depositional architecture is unknown. The presence of planktic foraminifera such as *Orbulina suturalis* and a diverse benthic fauna clearly indicate a marine environment during the formation of the evaporites.

The widespread lignite interval sampled in Be3 1520–1529 and Be6 1500–1509 comprises several sub-environments. The mottled colour of the siltstone and the presence of frequent terrestrial gastropods indicate palaeosol formation. This palaeosol is followed by a very shallow, vegetated freshwater swamp with planorbids and *Pisidium*; close to the lignite a thin marl layer of characean oogonia occurs, supporting the interpretation as freshwater swamp (John et al. 2011). Above follows lignitic clay of a paralic swamp, as indicated by the rare presence of the cardiid *Plicatiforma* and the foraminifer *Ammonia*, which stands lowered salinities in marshes (Murray 2006). Shallow marine conditions were re-established in the interval represented by BeS3 1583–1599, based on the benthic foraminiferal assemblage with *Textularia gramen*, *Textularia* spp., *Ammonia* spp., *Spiroplectammina deperdita*, *Nonion commune* and *Elphidium* spp. (Leckie & Olson 2003; Murray 2006). Shallow marine environments are also documented by the impoverished *Ammonia/Elphidium* assemblage of Mü100 1565–1570 (Murray 2006).

Coastal marine environments became established around sample Be7 1429–1434. The frequent occurrence of

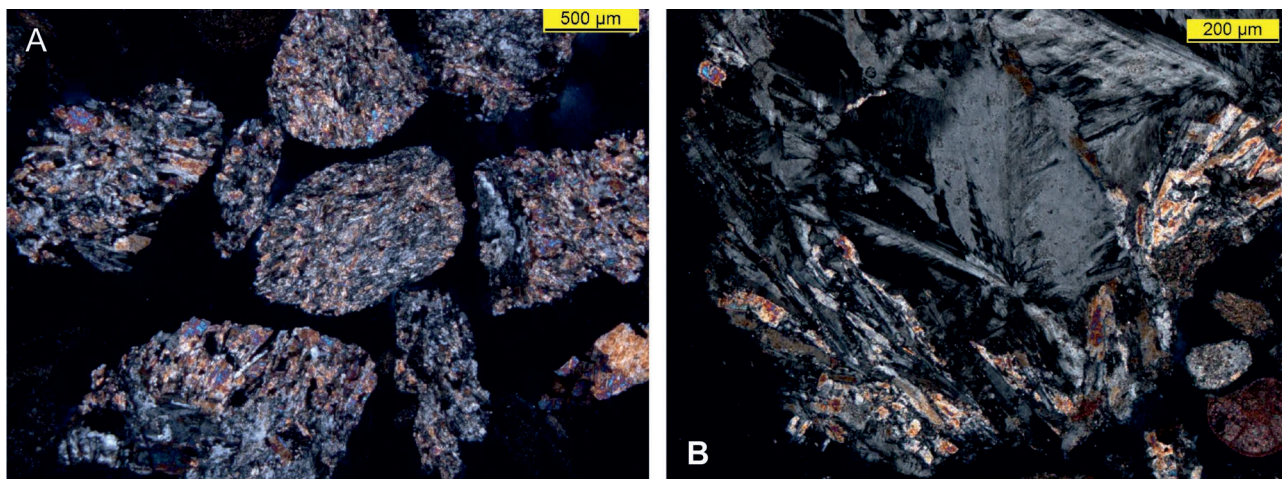


Fig. 11. Anhydrite-bearing cutting samples from Bernhardsthal S1: **A** — BeS1 1580 m, **B** — BeS1 1600 m (crossed Nikols).

potamidids and the neritid *Vitta tuberculata* indicates tidal mudflats (Reid et al. 2008; Petuch & Myers 2014); especially the batillariid *Granulolabium binctum* settled mudflats (Lozouet et al. 2001; Harzhauser 2002; Zuschin et al. 2014), and the microgastropods point to a vegetated shallow subtidal setting. *Tornus kuemeli* was documented by Harzhauser (2002) from brachyhaline littoral to shallow sublittoral assemblages of an estuary in the Korneuburg Basin. Adjacent littoral to very shallow sublittoral settings were settled by large turrillid populations. These conditions prevailed in the interval represented by Be7 1420–1429 and Be6 1397–1406; shallow sublittoral sandflats were settled by large populations of the turrillid *Oligodia pythagoraica*. Rissoids indicate the presence of algae and/or seagrass, which was settled by bryozoans. Seagrass is also indicated by the presence of pen shells (Milišić 1991). The uppermost sample available is Mü100 1330–1335. Although the aragonitic mollusc fauna is dissolved, the remaining calcitic taxa, such as *Ostrea*, *Anomia* and Pinnidae, indicate shallow marine conditions.

Integrated stratigraphy

Tracing the lower/middle Miocene boundary

The deepest parts of the boreholes represent the lower parts of the Lužice Formation and are correlated with the *Bathysiphon–Cyclammina* Biozone (Cicha et al. 1998). Assemblages of the *Cibicides–Elphidium* Biozone, representative for the upper Lužice Fm., or from the Karpatian have not been detected. In Bernhardsthal 4 and 5 and in Mühlberg T1, the Lužice Fm. is overlain by Badenian deposits. Lower Badenian deposits of the Lagenidae zone might be present in basal parts as relics but have not been reliably documented by our samples (e.g., Be4 2236–2245). The first samples with significant fauna yield assemblages characteristic for the *Spirorutilus carinatus* Biozone. This depositional gap indicates at least one hiatus. The hiatus coincides with a phase of erosion and non-deposition after the tectonic tilting of the

lower Miocene deposits in large parts of the (later) Vienna Basin during the Styrian tectonic phase (Stille 1924; Rögl et al. 2007).

Due to the spotty core recovery and limited number of samples, the boundary between the lower Miocene Lužice Fm. and the middle Miocene Jakobov Fm. cannot be identified precisely. In Bernhardsthal 4, the boundary lies between samples B4 2295–2300 and B4 2134–2141, coinciding with a shift from outer shelf environments to coastal settings with hardgrounds (e.g., rocky shore with balanids and oysters) (note that the intervening sample Be4 2236–2245 does not contain biostratigraphic markers). Given the abrupt change in wire-log patterns, from low to very high RES-values and the opposite trend in SP-values, the boundary might be expected at ~2207 m. In Bernhardsthal 5, the boundary lies between samples Be5 2395–2400 and Be5 2338–2343, indicated by the same shift in depositional environments and faunas as in Be4. The boundary may be expected at ~2347 m, where a change in wire-log patterns like that in Be4 occurs. In Mühlberg T1, the boundary is located between samples MüT1 3295–3300 and MüT1 3132–3135 and might be placed at ~3140 m based on the considerable change in well-log patterns (Fig. 2). Hence, the basal part of the Middle Miocene succession is represented in all three boreholes by a thick unit with blocky or strongly serrated high amplitude RES- and SP-values, ranging from 3140–3058 m in Mühlberg T1, from 2207–2149 m in Bernhardsthal 4 and from 2347–2208 m in Bernhardsthal 5.

The middle Badenian depositional cycle — severe flooding of the basin

Middle Badenian samples of the *Spirorutilus carinatus* Biozone are recorded in Bernhardsthal 4, 5, 6, 7, S3 and Mühlberg MüT1 and Mü100, partly yielding abundant *Orbulina suturalis*. The stratigraphically lowest samples of the Biozone in the Bernhardsthal field indicate very shallow marine, nearshore environments partly with close by rocky

shores with sessile taxa such as balanids, oysters, mytilids and *Anomia* (Be4 2134–2141, Be5 2338–2343 (2/4) or lagoonal conditions (Be6 2124–2131). Subsequent samples (Be4 2070–2078.5, Be4 2100–2109, Be6 2082–2091) do not show a major environmental change. Shallow marine sublittoral conditions of <100 m water depth were established with *Ammonia*–*Elphidium* dominated foraminiferal assemblages. These samples from the Bernhardsthal field all come from an ~120 m thick interval of moderately serrated RES- and SP-log patterns, which passes into an ~60–80 m thick shale-line interval. In terms of sequence stratigraphy, this interval can be interpreted as a transgressive systems tract culminating in a maximum flooding surface at ~1960 m in Be3, Be4 and Be6 and at ~2150 m in Be5. Sample Be7 1895–1900 lies only slightly above the maximum flooding surface (mfs) and consequently represents the deepest environment recorded by the available samples, indicating deeper inner shelf or even outer shelf settings. The subsequent high-stand systems tract (HST) might be heralded in this sample by the presence of molluscs, which seem to have been transported from nearshore environments. In RES-, GR- and SP-logs, the HST is expressed as a 300–500-m-thick unit with strongly serrated, barrel to funnel-shaped wire-log patterns. No samples are available from this interval and therefore the exact thickness of the Jakobov Fm. cannot be defined in the wells.

At the Mühlberg T1 drill site, the TST is represented by a deeper, middle to outer neritic (or even upper bathyal in the deepest sample) environment indicated by the faunal content of samples MüT1 3127–3132 and MüT1 2937–2942. Except for the lowermost interval, GR- and SP-logs are only a little serrated in this ~400 m thick interval. A progressive shallowing of the environment, probably the result of high sedimentation rates suggested by the presence of *Bathysiphon* in the lower part, is indicated by increasing predominance of *Ammonia* in the lignitic sandstones of samples MüT1 2737–2742 and MüT1 2480–2485. Well-log data in this interval show a clearly serrated pattern, indicating that inner to middle neritic conditions prevail up to ca. 2000 m in MüT1 where the mfs is tentatively placed (Fig. 12). Samples of the HST are available from drill-site Mühlberg 100. Samples Mü100 1980–1983, Mü100 1820–1825 and BeS3 1730–1746.8 indicate deeper, middle to outer neritic conditions than below the mfs, thus supporting the sequence stratigraphic interpretation from the Bernhardsthal field, where identical outer neritic depositional environments are indicated, for example, by sample Be7 1895–1900. The shallowing during the middle Badenian HST is also indicated in seismic data by prograding clinoforms (Fig. 12).

The upper Badenian depositional cycle — from swamps and evaporites to lagoons

The next samples, reflecting a major change in depositional environments, derived from Bernhardsthal 3 and Bernhardsthal 6, which penetrated lignites and lignitic clay roughly at the same depth between 1500 m and 1530 m. The faunal content

in both boreholes is identical and represents basically three palaeoenvironments:

1. Paralic swamps with species adapted to brackish water conditions, such as *Ammonia* among the foraminifera and *Plicatiforma parvissima* among the bivalves.
2. Pure freshwater swamps with freshwater molluscs such as *Planorbarius mantelli*, *Pisidium* sp. and *Bithynia* sp. None of these taxa can stand polyhaline conditions. Moreover, thin marl layers were formed in these swamps by the charophyte green algae *Chara*, which is a freshwater genus. Microscopic calcite rods within the lignites and especially on mollusc shells were precipitated in the vadose zone by fungal mycelial strands (Reuter et al. 2009).
3. Terrestrial environments within the swamps settled by terrestrial gastropods, such as the helcid *Megaotachea* sp. Palaeosols are intensively mottled and often show traces of roots.

An additional exceptional palaeoenvironment is represented by the anhydrite-bearing marine clays in BeS1. In shallow marine settings, connected to the Paratethys Sea as indicated by the presence of planktic foraminifers, evaporation occasionally increased and gypsum was precipitated.

No comparable palaeoenvironments have been described so far from the Badenian of the VB. The lignites overlay marine deposits of the *Spirorutilus carinatus* Biozone and underlay marine deposits of the *Bulimina–Bolivina* Biozone (and *Vitta tuberculata* Zone). Thus, they are close to the middle/upper Badenian boundary. The occurrence of the marine-derived cardiid *Plicatiforma parvissima* in samples Be3 1520–1529 and Be6 1500–1509 allows a correlation with the late Badenian *Vitta tuberculata* Zone, as this species has never been documented so far in lower and middle Badenian strata. Consequently, the lignites in Bernhardsthal 3 and 6 are interpreted as representing terrestrial and paralic environments of the low-stand systems tract (LST) of the late Badenian rather than to have formed during the late HST of the middle Badenian.

The sequence boundary between the middle Badenian HST and the late Badenian LST is difficult to detect in the wire-logs. Tentatively it may be placed around 1580 m Be3, Be4 and Be5 and ~1600 m in Be6 and Be7, coinciding with the last high amplitude peaks in the SP-logs, which characterize the SP-logs of the middle Badenian HST (Fig. 4). The late Badenian LST and TST are well reflected in the wire logs by strongly serrated but overall clearly bell-shaped patterns, reflecting a fining upward trend culminating in the maximum flooding surface at ~1260–1270 m in Be3, Be4 and Be7 and ~1290 m and ~1320 m in Be5 and Be6. Hence, samples Be6 1397–1406 and Be7 1420–1429 and Be7 1429–1434 all derive from the late Badenian TST. All these samples are strikingly similar in faunal content. Coquinas formed by turritellids and *Anomia ephippium* were wide spread. Fully marine conditions are clearly indicated by various echinoderms, bryozoans, octocorals and rays. The mollusc assemblages lived in very shallow sublittoral environments in a lagoonal setting with sandy to muddy soft bottom with patches of sea grass and

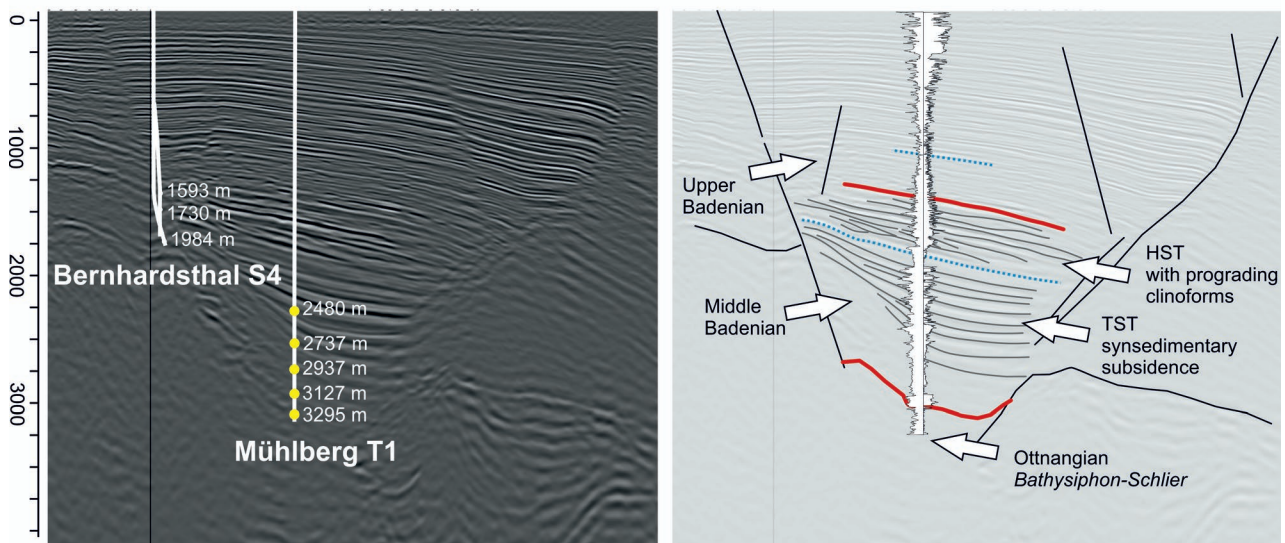


Fig. 12. Sequence stratigraphic interpretation of the middle Badenian cycle in the Bernhardsthal-Sued field (with Mühlberg T1). **Left:** seismic survey with indication of the wells Bernhardsthal S4 and Mühlberg T1. **Right:** Interpretation and wire logs of MüT1; blue (dotted): flooding surfaces, red (full): sequence boundary.

algae. The coast was formed by tidal mudflats, which were settled by potamidid gastropods and hydrobiids. Very shallow water depths of less than 50 m are also indicated by the foraminiferan faunas with *Ammonia*-dominated assemblages, which are nearly devoid of planktic species, and by the diverse fish fauna with numerous gobiids, seabreams and croakers.

Shallow conditions are also indicated between samples Mü100 1820–1825, Mü100 1740–1745, Mü110 (1798–1803, 1850–1855) and BeS3 1730–1746 and BeS3 1583–1599, which we correlate with the late Badenian LST. These conditions <100 m prevail at least until sample Mü100 1565–1570.

The subsequent HST was not sampled within this project. In all Bernhardsthal boreholes, it seems to be strongly truncated at around 1100 m due to erosion by Sarmatian channels [note that the placement of the Badenian/Sarmatian boundary in Figs. 3–4 is based only on comparison with characteristic wire-log patterns of the Sarmatian as discussed by Harzhauser & Piller (2004a, b)].

The Langhian/Serravallian boundary in the Vienna Basin and biogeographic considerations

The Bernhardsthal boreholes capture the middle/upper Badenian boundary, which correlates with the Langhian/Serravallian boundary at 13.82 Ma (Kováč et al. 2004; Hohenegger et al. 2014). The Langhian/Serravallian boundary is characterized by a major drop of global temperatures and sea level (TB2.5 of Hardenbol et al. 1998; Hilgen et al. 2009), which also affected Paratethyan basins. De Leeuw et al. (2010) showed that the onset of the BSC in the Carpathian Foredeep and the Transylvanian Basin coincided with the onset of the MMCT. The sea level drop resulted in exposure of middle Badenian coralline shoals in the southern VB (Strauss et al. 2006), the Carpathian Foredeep (Nehyba et al. 2016) and

in the southern Pannonian Basin a distinct shallowing is observed (Bakrač et al. 2010; Pezelj et al. 2013). Incised valleys were formed in the Alpine–Carpathian Foredeep (Gebhard & Roetzel 2013). In addition, this phase coincided with considerable tectonic activity in the vicinity of the Vienna Basin. For instance, the opening of the Danube Basin and the new connections to the southern Vienna Basin are reflected in a major change from biologically to hydrodynamically controlled sedimentation in the coralline shoals (Wiedl et al. 2014).

In the northern Vienna Basin, this boundary was not well understood so far. There, the sequence boundary between middle and upper Badenian was recognized in the Slovak part of the basin as an unconformity by Kováč et al. (2004), who described a shift from offshore environments to littoral or sublittoral shore face sands in the Slovak part of the basin. Now, the data from the Bernhardsthal and Mühlberg boreholes prove a major drop of relative sea level around the Langhian/Serravallian boundary in the VB. The uppermost Langhian (middle Badenian) samples available from the boreholes (e.g., Mü100 1980–1983, Mü100 1820–1825, BeS3 1730–1746, Be7 1895–1900) indicate deeper, middle to outer neritic conditions. The lowermost Serravallian samples (upper Badenian) (e.g., Be3 1520–1529, Be6 1500–1509) reflect palaeosols, freshwater swamps and paralic swamps. This suggests a rapid drop of the relative sea level by around ~200 m in the investigated area and probably in the entire VB. This drop clearly exceeds estimates for a global sea level drop of about 50 m at the Langhian/Serravallian boundary (John et al. 2004; Westerhold et al. 2005), but is in line with estimates for the southern Pannonian Basin calculated by Pezelj et al. (2013). Therefore, the sea level of the Paratethys might have been influenced by additional factors, such as tectonics and/or evaporation. The latter assumption is in line with

the presence of evaporites in BeS1 (1535–1680 m), which are documented here for the first time from the VB. The additional presence of BSC-evaporites in the Pannonian Basin (Pezelj et al. 2013; Báldi et al. 2017) shows that the BSC affected the entire Central Paratethys, which thus explains the dramatic Paratethyan sea level drop. The more or less coeval formation of lignites and evaporites seems to be a contradiction due to the different climatic regimes, which are commonly associated with these deposits. Nevertheless, peat bogs, coastal forest swamps and open marshes, which formed laterally to Badenian evaporites, were also documented from the Polish part of the Carpathian Foredeep by Wagner et al. (2008, 2010).

In the Southern Pannonian Basin of NW Croatia, the upper Badenian LST is also represented by a paralic coal facies (Bakrač et al. 2010).

The subsequent flooding was rather moderate in the investigated area and shallow water depths of a lagoonal to inner neritic environment were established. The immediate appearance of new and endemic molluscs, however, suggests that this flooding allowed immigration from the eastern Paratethyan region. Species such as *Vitta tuberculata*, *Oligodia pythagoica*, *Papillicardium papillosum* and *Potamides schaueri* are unknown from coeval Serravallian proto-Mediterranean faunas (Landau et al. 2013). Therefore, the sea-level drop might also have resulted in a biogeographic separation from the proto-Mediterranean Sea as discussed also by Studencka & Jasionowski (2011). Similarly, Bartol et al. (2014) discussed influence from the Eastern Paratethys during the late Badenian based on nannoplankton assemblages.

Conclusions

For the first time an integrated stratigraphy of the Neogene deposits of the Bernhardsthal and Bernhardsthal-Sued fields is proposed. Micropalaeontological and seismic data document middle Badenian units unconformably overlying tilted Ottmangian deposits. No Karpatian or lower Badenian deposits could be verified based on the available samples (although the presence of such deposits cannot be excluded). Based on the foraminifers, the lowermost cored Badenian deposits covered by the boreholes can be correlated with the middle Badenian *Spirorutilus carinatus* Biozone (although we do not exclude the presence of deposits correlative with the Lagenidae Zone in basal parts). This dating reveals a major hiatus in this part of the Vienna Basin due to non-deposition or erosion.

The middle Badenian units display a considerable difference in thickness between Bernhardsthal and Bernhardsthal-Sued. This difference is mainly reflected in the deposits interpreted here as TST, whereas the position of the maximum flooding surface and the thickness of the HST are roughly similar across both fields. This pattern points to considerable syndepositional tectonics in the Bernhardsthal-Sued field with rapid subsidence. In addition, some palaeo-relief may have provided higher accommodation space in the Bernhardsthal-Sued area.

This assumption is supported by the fact that the deepest Badenian samples in the Bernhardsthal field yield mollusc faunas indicative for close-by rocky coast and/or shallow sublittoral environments, whereas the coeval samples in Mühlberg T1 indicate deeper marine conditions. Outer to middle neritic conditions prevailed throughout the middle Badenian in the region indicated by outer shelf foraminifer assemblages and deep water glass sponges in the HST deposits. The marine middle Badenian units are abruptly overlain by lignites, which are interpreted here as LST of the late Badenian cycle. Palaeosol and paralic swamps developed in the region. Laterally, evaporation took place in shallow marine settings, resulting in deposition of anhydrite-bearing clay, being probably equivalent of the BSC-evaporites of other Paratethyan basins.

Samples from the subsequent late Badenian TST are extraordinarily rich in molluscs, bryozoans, teleost fish and sharks indicating the re-flooding of the northern VB. At that time, shallow marine lagoonal conditions, partly with sea grass patches, prevailed. The associated mfs can be traced easily in wire-log patterns across both fields. The upper Badenian HST was not studied here, but is obviously strongly truncated by erosion by Sarmatian strata.

In conclusion, a rapid sea-level drop marked the boundary between middle and late Badenian, coinciding with the Langhian/Serravallian boundary. This global event was amplified in magnitude in some Paratethyan basins by local tectonics. In the northern VB it led to a shift from outer neritic environments to palaeosols and freshwater swamps. This implies a drop of relative sea level of up to 200 m. The coastal marine mollusc fauna of the late Badenian yields several new immigrants from the eastern Paratethys. This partly endemic character might suggest that connections to the proto-Mediterranean Sea were already partly restricted during the early Serravallian.

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References

- Bakrač K., Hajek-Tadesse V., Mikinić M., Grizelj A., Hećimović I. & Kovačić M. 2010: Evidence for Badenian local sea level changes in the proximal area of the North Croatian Basin. *Geologia Croatica* 63, 259–269.

- Báldi K., Velledits F., Čorić S., Lemberkovics V., Lőrincz K. & Shevelev M. 2017: Discovery of the Badenian evaporites inside the Carpathian Arc: implications for global climate change and Paratethys salinity. *Geol. Carpath.* 68, 193–206.
- Bauchot M.L. & Hureau J.C. 1986: Sparidae. In: Whitehead P.J.P. et al. (Eds): Fishes of the North-Eastern Atlantic and the Mediterranean. Volume II. *UNESCO*, Paris, 883–907.
- Bernard F.R., Cai Y.Y. & Morton B. 1993: Catalogue of the living marine bivalve molluscs of China. *Hong Kong University Press*, Hong Kong, 1–121.
- Billups K. & Schrag D. 2002: Paleotemperatures and ice volume of the past 27 Myr revisited with paired Mg/Ca and 18O/16O measurements on benthic foraminifera. *Paleoceanography* 17, 1003.
- Chu J.W.F., Maldonado M., Yahel G. & Leys S.P. 2011: Glass sponge reefs as a silicon sink. *Mar. Ecol. Prog. Ser.* 441, 1–14.
- Cicha I. & Rögl F. 1973: Die Foraminiferen des Ottnangien. In: Papp A., Rögl F. & Seneš J. (Eds): Chronostratigraphie und Neostatotypen. Miozän der Zentralen Paratethys. Band III: M2 Ottnangien. Die Innviertler, Salgótarján, Bántapusztaer Schichtengruppe und die Rzehakia Formation. *Verlag der Slowakischen Akademie der Wissenschaften VEDA*, Bratislava, 297–355.
- Cicha I., Rögl F., Rupp C. & Čtyrská J. 1998: Oligocene–Miocene foraminifera of the Central Paratethys. *Abhandlungen der senckenbergischen naturforschenden Gesellschaft* 549, 1–325.
- De Leeuw A., Bukowski K., Krijgsman W. & Kuiper K.F. 2010: Age of the Badenian salinity crisis; impact of Miocene climate variability on the circum Mediterranean region, *Geology* 38, 715–718.
- Gebhard H. & Roetzel R. 2013: The Antarctic viewpoint of the Central Paratethys: cause, timing, and duration of a deep valley incision in the Middle Miocene Alpine–Carpathian Foredeep of Lower Austria. *Int. J. Earth Sci.* 102, 977–987.
- Gradstein F.M., Ogg J.G., Schmitz M.D. & Ogg G.M. 2012: The Geologic Time Scale 2012. *Elsevier*, Amsterdam. 2 vols., 1–1144.
- Grill R. 1941: Stratigraphische Untersuchungen mit Hilfe von Mikrofaunen im Wiener Becken und den benachbarten Molasse-Anteilen. *Oel und Kohle* 37, 595–602.
- Grill R. 1943: Über mikropaläontologische Gliederungsmöglichkeiten im Miozän des Wiener Beckens. *Mitteilungen der Reichsanstalt für Bodenforschung* 6, 33–44.
- Grill R. 1968: Erläuterungen zur Geologischen Karte des nordöstlichen Weinviertels und zu Blatt Gänserndorf. Flyschausläufer, Waschbergzone mit angrenzenden Teilen der flachlagernden Molasse, Korneuburger Becken, Inneralpines Wiener Becken nördlich der Donau. *Geologische Bundesanstalt*, Wien, 1–155.
- Grunert P., Hinsch R., Sachsenhofer R.F., Bechtel A., Čorić S., Harzhauser M., Piller W.E. & Sperl H. 2013: Early Burdigalian infill of the Puchkirchen Trough (North Alpine Foreland Basin, Central Paratethys): Facies development and sequence stratigraphy. *Mar. Petrol. Geol.* 39, 164–186.
- Grunert P., Soliman A., Čorić S., Roetzel R., Harzhauser M. & Piller W.E. 2012: Facies development along the tide-influenced shelf of the Burdigalian Seaway: An example from the Ottnangian stratotype (Early Miocene, middle Burdigalian). *Mar. Micropaleontol.* 84–85, 14–36.
- Grunert P., Soliman A., Harzhauser M., Müllegger S., Piller W.E., Roetzel R. & Rögl F. 2010: Upwelling conditions in the Early Miocene Central Paratethys Sea. *Geol. Carpath.* 61, 129–145.
- Hamilton W., Wagner L. & Wessely G. 2000: Oil and gas in Austria. *Mitteilungen der Österreichischen Geologischen Gesellschaft* 92, 235–262.
- Hamon N., Sepulchre P., Lefebvre V. & Ramstein G. 2013: The role of eastern Tethys seaway closure in the Middle Miocene Climatic Transition (ca. 14 Ma). *Climate of the Past* 9, 2687–2702.
- Hardenbol J., Thierry J., Farley M.B., Jacquin T., Graciansky P.-C. & Vail P.R. 1998: Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins. In: Graciansky P.-C., Hardenbol J., Jacquin T. & Vail P.R. (Eds): Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. *SEPM Spec. Publ.* 60, 3–13.
- Harzhauser M. 2002: Marine und brachyhaline Gastropoden aus dem Karpatium des Korneuburger Beckens und der Kreuzstettener Bucht (Österreich, Untermiozän). *Beiträge zur Paläontologie* 27, 61–159.
- Harzhauser M. & Kowalke T. 2004: Survey of the Nassariid Gastropods in the Neogene Paratethys. *Archiv für Molluskenkunde* 133, 1–63.
- Harzhauser M. & Piller, W.E. 2004a: Integrated stratigraphy of the Sarmatian (Upper Middle Miocene) in the western Central Paratethys. *Stratigraphy* 1, 65–86.
- Harzhauser M. & Piller W.E. 2004b: The Early Sarmatian — hidden seesaw changes. *Courier Forschungsinstitut Senckenberg* 246, 89–111.
- Harzhauser M. & Piller W.E. 2007: Benchmark data of a changing sea — Palaeogeography, palaeobiogeography and events in the Central Paratethys during the Miocene. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 253, 8–31.
- Harzhauser M., Peckmann J., Birgel D., Draganits E., Mandic O., Theobald D. & Huemer J. 2014: Stromatolites in the Paratethys Sea during the Middle Miocene Climate Transition as witness of the Badenian Salinity Crisis. *Facies* 60, 429–444.
- Haunold T.G. 1995: Zur Taxonomie, Systematik und stratigraphischen Bedeutung uviginerider Foraminiferen im Neogen des Wiener Beckens und benachbarter Gebiete — 40 Jahre nach Papp & Turnovsky (1953). *Jahrb. Geol. Bundesanst.* 138, 67–87.
- Hayward B.W., Kawagata S., Sabaa A.T., Grenfell H.R., van Kerckhoven L., Johnson K. & Thomas E. 2012: The Last Global Extinction (Mid-Pleistocene) of Deep-Sea Benthic Foraminifera (Chrysalogoniidae, Ellipsoidinidae, Glandulonodosariidae, Plectofrondiculariidae, Pleurostomellidae, Stilostomellidae), their Late Cretaceous–Cenozoic History and Taxonomy. *Cushman Found. Foraminiferal Res. Spec. Pap.* 43, 1–408.
- Hilgen F.J., Abels H.A., Iaccarino S., Krijgsman W., Raffi I., Sprovieri R., Turco E. & Zachariasse W.J. 2009: The Global Stratotype Section and Point (GSSP) of the Serravallian Stage (Middle Miocene). *Episodes* 32, 152–166.
- Hladilová Š. & Fordinál F. 2013: Upper Badenian Molluscs (Gastropoda, Bivalvia, Scaphopoda) from the Modra-Kráľová locality (Danube Basin, Slovakia). *Mineralia Slovaca* 45, 35–44.
- Hohenegger J., Čorić S. & Wagreich M. 2014: Timing of the Middle Miocene Badenian Stage of the Central Paratethys. *Geol. Carpath.* 65, 55–66.
- Hohenegger J., Čorić S., Khatun M., Pervesler P., Rögl F., Rupp C., Selge A., Uchman A. & Wagreich M. 2009: Cyclostratigraphic dating in the Lower Badenian (Middle Miocene) of the Vienna Basin (Austria): the Baden-Sooss core. *Int. J. Earth Sci.* 98, 915–930.
- Holbourn A., Henderson A.S. & MacLeod N. 2013: Atlas of Benthic Foraminifera. *Wiley-Blackwell & Natural History Museum*, 1–642.
- Holcová K. 2017: Calcareous nannoplankton and foraminiferal response to global Oligocene and Miocene climatic oscillations: a case study from the Western Carpathian segment of the Central Paratethys. *Geol. Carpath.* 68, 207–228.
- Hudáčková N., Halásová E., Fordinál K., Sabol M., Joniak P. & Král J. 2003: Biostratigraphy and radiometric dating in the Vienna Basin Neogene (Slovak part). *Slovak Geological Magazine* 9, 233–236.

- Hyžný M., Hudáčková N., Biskupič R., Rybár S., Fuksi T., Halásová E., Zágorský K., Jamrich M. & Ledvák P. 2012: Devínska Kobyla — a window into the Middle Miocene shallow-water marine environments of the Central Paratethys (Vienna Basin, Slovakia). *Acta Geologica Slovaca* 4, 5–21.
- Jamrich M. & Halásová E. 2010: The evolution of the Late Badenian calcareous nannofossil assemblages as a reflexion of the palaeo-environmental changes of the Vienna Basin (Devínska Nová Ves — clay pit). *Acta Geologica Slovaca* 2, 123–140.
- Jiríček R. 2002: The evolution of the Molasse in the Alpine–Carpathian Foredeep and the Vienna Basin. *Exploration Geophysics, Remote sensing and environment* 9, 1–179.
- Jiríček R. & Seifert P. 1990: Paleogeography of the Neogene in the Vienna Basin and the adjacent part of the foredeep. In: Minaříková D. & Lobitzer H. (Eds): Thirty Years of Geological Cooperation between Austria and Czechoslovakia. *ÚÚG, Praha*, 89–104.
- John C.M., Karner G.D. & Mutti M. 2004: $\delta^{18}\text{O}$ and Marion Plateau backstripping: Combining two approaches to constrain late middle Miocene eustatic amplitude. *Geology* 32, 829–832.
- John D.M., Whitton B.A. & Brook A.J. 2011: The Freshwater Algal Flora of the British Isles. *Cambridge University Press*, London. 2nd Edition, 1–896.
- Jones R.W. 1994: The Challenger Foraminifera. *Oxford University Press*, New York, 1–149.
- Kaiho K. 1994: Benthic foraminiferal dissolved-oxygen index and dissolved-oxygen levels in the modern ocean. *Geology* 22, 719–722.
- Kapounek J., Kröll A., Papp A. & Turnovsky K. 1965: Die Verbreitung von Oligozän, Unter- und Mittelmiozän in Niederösterreich. *Erdoel-Erdgas-Zeitschrift* 81, 109–115.
- Kováč M., Baráth I., Harzhauser M., Hlavatý I. & Hudáčková N. 2004: Miocene depositional systems and sequence stratigraphy of the Vienna Basin. *Courier des Recherches-Instytut Senckenberg* 246, 187–212.
- Kováč M., Hudáčková N., Halásová E., Kováčová M., Holcová K., Oszczytko-Clowes M., Báldi K., Less G., Nagymarosy A., Ruman A., Klučiar T. & Jamrich M. 2017: The Central Paratethys palaeoceanography: a water circulation model based on microfossil proxies, climate, and changes of depositional environment. *Acta Geologica Slovaca* 9/2, 75–114.
- Kováčová M., Doláková N. & Kováč M. 2011: Miocene vegetation pattern and climate change in the northwestern Central Paratethys domain (Czech and Slovak Republic). *Geol. Carpath.* 62, 251–266.
- Kováčová P. & Hudáčková N. 2009: Late Badenian foraminifera from the Vienna Basin (Central Paratethys): Stable isotope study and paleoecological implications. *Geol. Carpath.* 60, 59–70.
- Kreutzer N. 1986: Die Ablagerungssequenzen der miozänen Badener Serie im Feld Matzen und im zentralen Wiener Becken. *Erdoel-Erdgas-Zeitschrift* 102, 492–503.
- Kreutzer N. 1992: Matzen Field — Austria, Vienna Basin. *AAPG, Treatise-Atlas, Structural Traps* 7, 57–93.
- Kröll A. & Wessely G. 1993: Strukturkarte — Basis der tertiären Beckenfüllung 1:200,000. Erläuterung zu den Karten über den Untergrund des Wiener Beckens und der angrenzenden Gebiete. *Geologische Bundesanstalt*, Wien.
- Landau B., Harzhauser M. & Beu A.G. 2009: A revision of the Tonnoidea (Caenogastropoda, Gastropoda) from the Miocene Paratethys and their palaeobiogeographic implications. *Jahrb. Geol. Bundesanst.* 149, 61–109.
- Landau B.M., Harzhauser M., İslamoğlu Y. & da Silva C.M. 2013: Systematics and palaeobiogeography of the gastropods of the middle Miocene (Serravallian) Karaman Basin, Turkey. *Cainozoic Res.* 11–13, 11–584.
- Leckie R.M. & Olson H.C. 2003: Foraminifera as proxies for sea-level change on siliciclastic margins. In: Olson H.C. & Leckie R.M. (Eds): *Micropaleontologic Proxies for Sea-Level Change and Stratigraphic Discontinuities. Society for Sedimentary Geology Special Publication* 75, 5–19.
- Lozouet P., Lesport J.F. & Renard P. 2001: Révision des Gastropoda (Mollusca) du stratotype de l'Aquitainien (Miocène inf.): site de Saucats 'Larrey', Gironde, France. *Cossmanniana, Hors série* 3, 1–189.
- Milišić N. 1991: Bivalves and Gastropods of the Adriatic Sea. *Logos, Split*, 1–302.
- Miller P.J. 1986: Gobiidae. In: Whitehead P.J.P. et al. (Eds): *Fishes of the North-Eastern Atlantic and the Mediterranean. Volume III. UNESCO, Paris*, 1019–1085.
- Murray J.W. 2006: Ecology and Applications of Benthic Foraminifera. *Cambridge University Press*, Cambridge, 1–426.
- Nehyba S., Holcová K., Gedl P. & Doláková N. 2016: The Lower Badenian transgressive-regressive cycles — a case study from Oslavany (Carpathian Foredeep, Czech Republic). *Neues Jahrb. Geol. Paläontol.* 279, 209–238.
- Opreanu P. 2003: Some data on the recent ostracod fauna from the continental shelf of the black sea in the Crimea and Sinop Areas. *Geo-Eco-Marina* 9–10, 1–4.
- Papp A. & Steininger F. 1978: Holostratotypus des Badenien. Holostratotypus: Baden-Sooss (südlich von Wien), Niederösterreich, Österreich. Badener Tegel–Keferstein, 1828 (Unterbaden; M4b; Obere Lagenidenzzone). In: Papp A., Cicha I., Seneš J. & Steininger F. (Eds): *Chronostratigraphie und Neostratotypen. Miozän der Zentralen Paratethys. Band VI: M4 Badenien (Moravien, Wielicien, Kosovien). Verlag der Slowakischen Akademie der Wissenschaften VEDA, Bratislava*, 138–145.
- Papp A., Grill R., Janoschek R., Kapounek J., Kollmann K. & Turnovsky K. 1968: Zur Nomenklatur des Neogens in Österreich — Nomenclature of the Neogene of Austria. *Verh. Geol. Bundesanst.* 1968, 9–27
- Peryt D. 2013: Foraminiferal record of the Middle Miocene climate transition prior to the Badenian salinity crisis in the Polish Carpathian Foredeep Basin (Central Paratethys). *Geol. Quarterly* 57, 141–164.
- Petuch E.J. & Myers R.F. 2014: Molluscan communities of the Florida Keys and adjacent areas: their ecology and biodiversity. *CRC Press*, Florida, 1–320.
- Pezelj D., Mandić O. & Čorić C. 2013: Palaeoenvironmental dynamics in the southern Pannonian basin during initial middle Miocene marine flooding. *Geol. Carpath.* 64, 81–100.
- Pezelj D., Sremac J. & Sokač A. 2007: Palaeoecology of the Late Badenian foraminifera and ostracoda from the SW Central Paratethys (Medvednica Mt., Croatia). *Geologia Croatica* 60, 139–150.
- Piller W.E. 2004 (Ed.): Die stratigraphische Tabelle von Österreich (sedimentäre Schichtfolgen). *Kommission für die paläontologische und stratigraphische Erforschung Österreichs der Österreichischen Akademie der Wissenschaften und Österreichische Stratigraphische Kommission*, Wien.
- Piller W.E., Harzhauser M. & Mandić O. 2007: Miocene Central Paratethys stratigraphy — current status and future directions. *Stratigraphy* 4, 151–168.
- Postuma J.A. 1971: Manual of planktonic foraminifera. *Elsevier*, Amsterdam, London, New York, 1–420.
- Reid D.G., Dyal P., Lozouet P., Glaubrecht M. & Williams S.T. 2008: Mudwhelks and mangroves: The evolutionary history of an ecological association (Gastropoda: Potamididae). *Molecular Phylogenetics and Evolution* 47, 680–699.
- Reuter M., Piller W.E., Harzhauser M., Kroh A. & Berning B. 2009: A fossil Everglades-type marl prairie and its palaeoenvironmental significance. *Palaios* 24, 747–755.

- Roetzel R., Ćorić S., Galović I. & Rögl F. 2006: Early Miocene (Ottangien) coastal upwelling conditions along the southeastern scarp of the Bohemian Massif (Parisdorf, Lower Austria, Central Paratethys). *Beiträge zur Paläontologie* 30, 387–413.
- Rögl F. & Spezzaferri S. 2003: Foraminiferal paleoecology and biostratigraphy of the Mühlbach section (Gaindorf Formation, Lower Badenian), Lower Austria. *Annalen des Naturhistorischen Museums Wien* 104A, 23–75.
- Rögl F., Ćorić S., Hohenegger J., Pervesler P., Roetzel R., Scholger R., Spezzaferri S. & Stingl K. 2007: The Styrian tectonic Phase — a series of events at the Early/Middle Miocene boundary revised and stratified (Styrian Basin, Central Paratethys). *Joannea Geologie und Paläontologie* 9, 89–91.
- Rupp C. 1986: Paläoökologie der Foraminiferen in der Sandschalerzone (Badenien, Miozän) des Wiener Beckens. *Beiträge zur Paläontologie von Österreich* 12, 1–180.
- Shevenell A.E., Kennett J.P. & Lea, D.W. 2004: Middle Miocene southern ocean cooling and Antarctic cryosphere expansion. *Science* 305, 1766–1770.
- Spezzaferri S. & Tamburini F. 2007: Paleodepth variations on the Eratosthenes Seamount (Eastern Mediterranean): sea-level changes or subsidence? *eEarth Discuss* 2, 115–132.
- Špička V. 1966: Palaeogeography and tectonogenesis of the Vienna Basin and a contribution to its oil-geological problems [Palaeogeografie a tektonogeneze Vídeňské pánve a příspěvek k její naftově-geologické problematice]. *Rozpravy Československé akademie věd, Řada matematických přírodopisných věd* 76, 1–118.
- Stille H. 1924: Grundfragen der vergleichenden Tektonik. *Gebrüder Bornträger*, Berlin, 1–443.
- Strauss P., Harzhauser M., Hinsch R. & Wagreeich M. 2006: Sequence stratigraphy in a classic pull-apart basin (Neogene, Vienna Basin). A 3D seismic based integrated approach. *Geol. Carpath.* 57, 185–197.
- Studencka B. & Jasionowski M. 2011: Bivalves from the Middle Miocene reefs of Poland and Ukraine: a new approach to Badenian/Sarmatian boundary in the Paratethys. *Acta Geol. Pol.* 61, 79–114.
- Suess E. 1866: Untersuchungen über den Charakter der österreichischen Tertiärablagerungen, II. Über die Bedeutung der sogenannten brackischen Stufe oder der Cerithienschichten. *Sitzungsberichte der kaiserlichen Akademie der Wissenschaften* 54, 1–40.
- Švagrovský J. 1964: Zur Torton-Sarmat Grenze im ostslowakischen Neogen. *Geologický Sborník* 15, 79–86.
- Švagrovský J. 1982: Gastropoda, Prosobranchia, 1. Archaeogastropoda und Mesogastropoda des oberen Badenians von Borský Mikuláš (NO-Teil des Wiener Beckens) und ihre stratigraphische Bedeutung. *Geologický Zborník — Geol. Carpath.* 33, 3–50.
- Tabachnick K.R. 1994: Distribution of recent Hexactinellida. In: van Soest R.W.M., van Kempen B. & Braekman G. (Eds): Sponges in time and space. *Balkema*, Rotterdam, 225–232.
- Van Morkhoven F.P.C.M., Berggren W.A. & Edwards A.S. 1986: Cenozoic cosmopolitan deep-sea benthic foraminifera. *Bulletin des Centres des Recherches Exploration-Production Elf-Aquitaine, Mémoire* 11, 1–421.
- Wagner M., Bukowski K. & Przybyło J. 2008. Petrographic character of the coal substance from the Wieliczka salt sediments [Charakter petrograficzny substancji węglowej z osadów solnych Wieliczki]. *Gospodarka Surowcami Mineralnymi* 24, 225–239 (in Polish).
- Wagner M., Bukowski K. & Stochel B. 2010. Petrologic character of lignite (brown coal) from Badenian salts in the Bochnia Mine (Southern Poland). *Geol. Quarterly* 54, 439–448.
- Weissenböck M. 1996: Lower to Middle Miocene sedimentation model of the central Vienna Basin. In: Wessely G. & Liebl W. (Eds): Oil and Gas in alpidic thrustbelts and basins of Central and Eastern Europe. *European Association of Geoscientists and Engineers (EAGE), Special Publications* 5, 355–363.
- Wessely G. 2006 (Ed): Niederösterreich. Geologie der Österreichischen Bundesländer. *Geologische Bundesanstalt, Wien*, 1–416.
- Westerhold T., Bickert T. & Röhl U. 2005: Middle to late Miocene oxygen isotope stratigraphy of ODP Site 1085 (SE Atlantic): New constrains on Miocene climate variability and sea-level fluctuations. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 217, 205–222.
- Wiedl T., Harzhauser M., Kroh A., Ćorić S. & Piller W.E. 2014: From biologically to hydrodynamically controlled carbonate production by tectonically induced palaeogeographic rearrangement (Middle Miocene, Pannonian Basin). *Facies* 60, 865–881.
- Zachos J., Pagani M., Sloan L., Thomas E. & Billups K. 2001: Trends, rhythms, and aberrations in global climate 65 Ma to present. *Science* 292, 686–693.
- Zorn I. 2003: Ostracoda from the Gaindorf Formation (Middle Miocene, Lower Badenian) of Mühlbach (Molasse Basin, Lower Austria). *Annalen des Naturhistorischen Museums in Wien* 104A, 77–84.
- Zuschin M., Harzhauser M. & Mandic O. 2007: The stratigraphic and sedimentologic framework of fine-scale faunal replacements in the Middle Miocene of the Vienna Basin (Austria). *Palaios* 22, 285–295.
- Zuschin M., Harzhauser M., Hengst B., Mandic O. & Roetzel R. 2014: Long-term ecosystem stability in an Early Miocene estuary. *Geology* 42, 1–4.

Supplementum

Supplementary Table 1: List of foraminifers identified from quantitatively analysed samples.

Taxa	Be4 2070-2078,5	Be4 2134-2141	Be6 1397-1406	Be6 1500-1509	Be6 2082-2091	Be7 1420-1429	Be7 1429-1434,5	Be7 1895-1900	Mü100 1565-1570	Mü100 1740-1745	Mü100 1820-1825	Mü100 1980-1983	MüT1 2480-2485	MüT1 2737-2742	MüT1 3127-3132	Mü110 1798-1803	Mü110 1850-1855	BeS2 1697-1706	BeS3 1583-1599,5	BeS3 1730-1746,8
<i>Adelosina longirosta</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	9	0	0	0	0	0	0	8	0	0	0	0	0
<i>Adelosina schreibersi</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	8	0	0	100	113	0	106	2	0	0	0	0	0
<i>Adelosina</i> spp.	0	0	0	0	0	0	0	1	0	0	0	72	0	0	0	0	0	0	0	0
Agglutinated indet.	0	0	0	0	0	1	0	1	0	0	477	78	32	653	44	0	0	258	0	0
Agglutinated indet. - biserial	16	0	0	0	0	0	0	2	0	0	0	0	0	0	12	0	0	0	0	0
Agglutinated indet. - spiral	0	0	0	0	0	0	0	0	0	0	0	0	16	32	6	0	0	0	0	64
Agglutinated indet. - uniserial/tube	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0
<i>Allomorphina trigona</i> Reuss, 1850	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
? <i>Ammobaculites agglutinans</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	4	32	224	0	0	0	0	0	0
<i>Ammobaculites agglutinans</i> (d'Orbigny, 1846)	292	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0
<i>Ammodiscus</i> cf. <i>peruvianus</i> Berry, 1928	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammodiscus</i> cf. <i>tenuissimus</i> Grzybowski, 1896	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammodiscus miocenicus</i> Karrer, 1877	0	0	0	0	0	0	0	2	0	0	0	1	0	1	1	0	0	0	0	0
<i>Ammodiscus</i> spp.	0	0	0	0	0	0	0	4	0	0	5	5	0	0	0	0	0	0	0	0
<i>Ammomarginulina</i> sp. 1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammomassilina</i> sp.	0	0	0	0	0	0	0	0	0	0	16	8	0	0	0	0	0	0	0	0
<i>Ammonia convexa</i> Collins, 1958	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammonia falsobeccarii</i> (Rouvillois, 1974)	138	37	4	210	4	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammonia inflata</i> (Seguenza, 1862)	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammonia</i> sp. 1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammonia</i> spp.	8	0	0	1	5	0	0	0	640	3	0	0	17780	1143	0	5440	849	0	80	0
<i>Ammonia tepida</i> (Cushman, 1926)	14	24	8	16	101	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammonia viennensis</i> (d'Orbigny, 1846)	30	399	227	2	210	188	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Amphicoryna badenensis</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	1	0	32	0	0	0	0	0	0
<i>Amphicoryna hispida</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Amphistegina mamilla</i> (Fichtel & Moll, 1798)	0	10	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Amphistegina</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>Anastomosa</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Anomalina badensis</i> (d'Orbigny, 1846)	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Asterigina</i> sp. 1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Asterigina</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	448	0	0	0
<i>Bathysiphon</i> sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	70	0	0	0	0	0
<i>Bathysiphon</i> spp.	0	0	0	0	0	0	0	7	0	0	0	0	0	3	223	0	0	0	0	0

Taxa	Be4 2070-2078,5	Be4 2134-2141	Be6 1397-1406	Be6 1500-1509	Be6 2082-2091	Be7 1420-1429	Be7 1429-1434,5	Be7 1895-1900	Mü100 1565-1570	Mü100 1740-1745	Mü100 1820-1825	Mü100 1980-1983	Mü100 2480-2485	Mü100 2737-2742	Mü100 3127-3132	Mü110 1798-1803	Mü110 1850-1855	BeS2 1697-1706	BeS3 1583-1599,5	BeS3 1730-1746,8
<i>Biasterigerina planorbis</i> (d'Orbigny, 1846)	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bigenerina nodosaria</i> d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0
<i>Bolivina antiqua</i> d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Bolivina</i> sp. 1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Budashevaella multicamerata</i> (Voloshinova, 1961)	0	0	0	0	0	0	0	0	0	0	64	0	0	0	2	0	0	0	0	0
<i>Bulimina striata</i> d'Orbigny, 1826 gr.	0	0	1	0	0	0	0	13	0	0	0	0	0	32	0	0	0	0	0	0
<i>Bulimina subulata</i> Cushman & Parker, 1947	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	32	16	16	0
<i>Cassidulina laevigata</i> d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0
Chrysalogoniidae indet.	0	0	0	0	0	0	0	0	0	0	12	0	0	78	0	0	0	0	0	0
<i>Cibicoides</i> cf. <i>lopjanicus</i> (Myatlyuk, 1850)	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0
<i>Cibicoides lobatulus</i> (Walker & Jacob, 1798)	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	24
<i>Cibicides</i> sp. 1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
<i>Cibicoides</i> cf. <i>austriacus</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2	0	0	0	0	0
<i>Cibicoides</i> cf. <i>ungerianus</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
<i>Cibicoides pachyderma</i> (Rzehak, 1886)	0	0	0	0	1	0	0	0	0	0	0	1	16	0	16	0	0	0	0	0
<i>Cibicoides</i> spp.	0	0	0	1	0	0	0	0	0	0	618	30	0	64	0	256	160	0	16	152
<i>Cyclammina</i> spp.	0	0	0	0	0	0	0	0	0	0	4	0	32	0	0	0	0	0	0	0
<i>Cyclammina vulchoviensis</i> Venglinskyi, 1953	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
<i>Cycloforina nussdorfensis</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
<i>Cycloforina</i> sp. 1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cycloforina</i> sp. 2	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cycloforina</i> sp. 3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
? <i>Cycloformia badensis</i> (d'Orbigny, 1846)	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cycloformia badensis</i> (d'Orbigny, 1846)	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cycloformia contorta</i> (d'Orbigny, 1846)	0	1	1	0	0	5	9	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cycloformia</i> spp.	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Cymbaloporetta</i> sp. 1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dentalina elegans</i> d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0
<i>Dentalina scripta</i> d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Dentalina</i> spp.	0	0	0	0	0	0	0	0	0	0	96	2	0	0	0	0	0	0	16	0
<i>Discorbina planorbis</i> (d'Orbigny, 1846)	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ellipsoidella</i> sp.	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
<i>Elphidella minuta</i> (Reuss, 1865)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Elphidium advenum</i> (Cushman, 1922)	2	4	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> cf. <i>angulatum</i> (Egger, 1857)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> cf. <i>flexuosum</i> (d'Orbigny, 1846)	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> cf. <i>subnodosum</i> (Münster, 1838)	10	0	2	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> cf. <i>ungeri</i> (Reuss, 1850)	12	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxa	Be4 2070-2078,5	Be4 2134-2141	Be6 1397-1406	Be6 1500-1509	Be6 2082-2091	Be7 1420-1429	Be7 1429-1434,5	Be7 1895-1900	Mü100 1565-1570	Mü100 1740-1745	Mü100 1820-1825	Mü100 1980-1983	MüT1 2480-2485	MüT1 2737-2742	MüT1 3127-3132	Mü110 1798-1803	Mü110 1850-1855	BeS2 1697-1706	BeS3 1583-1599,5	BeS3 1730-1746,8
<i>Elphidium crispum</i> (Linnaeus, 1758)	0	65	0	0	4	25	8	0	0	0	0	0	48	96	0	0	0	0	0	0
<i>Elphidium fichtelianum</i> (d'Orbigny, 1846)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
<i>Elphidium hauerinum</i> (Linnaeus, 1758)	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> sp. 1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> sp. 2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> sp. 3	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> sp. 4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> sp. 5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> spp.	2	1	0	1	5	3	1	0	64	2	0	0	0	3	0	2400	293	16	32	288
<i>Eponides repandus</i> (Fichtel & Moll, 1798)	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
<i>Fissurina obtusa</i> Egger, 1857	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Fissurina</i> sp. 1	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0
<i>Fursenkoina acuta</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
? <i>Gaudryinopsis beregoviensis</i> (Vengliński, 1958)	0	0	0	0	0	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gaudryinopsis beregoviensis</i> (Vengliński, 1958)	0	0	0	0	0	0	0	122	0	0	42	0	0	0	0	0	0	0	0	0
<i>Glandulina ovula</i> d'Orbigny, 1846	0	0	0	0	0	0	0	4	0	0	33	16	0	0	0	0	0	0	0	16
<i>Globigerina bulloides</i> d'Orbigny, 1826	0	0	0	1	0	0	0	0	0	0	48	8	16	32	0	0	0	0	0	0
<i>Globigerina</i> cf. <i>praebulloides</i> Blow, 1959	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globigerinella aequilateris</i> (Brady, 1879)	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0
<i>Globigerinella</i> sp. 1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Globigerinoides apertasuturalis</i> Jenkins, 1960	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Globigerinoides</i> cf. <i>apertasuturalis</i> Jenkins, 1960	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globigerinoides quadrilobatus</i> d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Globobulimina</i> sp.	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
<i>Globoquadrina altispira</i> (Cushman & Jarvis, 1936)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Globulina gibba</i> (d'Orbigny in Deshayes, 1832)	0	0	0	0	0	0	0	1	0	0	1	1	0	32	0	0	0	0	0	0
<i>Grigelis</i> sp.	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0
<i>Guttulina communis</i> (d'Orbigny, 1826)	0	0	0	0	0	0	0	2	0	0	16	0	0	0	0	0	0	0	0	0
<i>Guttulina</i> sp. 1	0	0	0	0	0	0	0	1	0	0	16	0	0	0	0	0	0	0	0	0
<i>Hansenisca soldanii</i> (d'Orbigny, 1826)	0	0	0	0	0	0	0	5	0	0	32	0	0	0	0	0	0	0	0	0
<i>Hanzawaia crassiseptata</i> (Łuczowska, 1964)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hanzawaia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Haplophragmoides carinatum</i> Cushman & Renz, 1941	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
<i>Haplophragmoides</i> sp. 1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Haplophragmoides</i> sp. 2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
? <i>Haplophragmoides</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
<i>Haplophragmoides</i> spp.	0	0	0	0	0	0	0	0	0	0	174	2	16	0	0	0	0	173	0	80
<i>Haplophragmoides</i> cf. <i>advenum</i> Cushman, 1925	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0

Taxa	Be4 2070-2078,5	Be4 2134-2141	Be6 1397-1406	Be6 1500-1509	Be6 2082-2091	Be7 1420-1429	Be7 1429-1434,5	Be7 1895-1900	Mü100 1565-1570	Mü100 1740-1745	Mü100 1820-1825	Mü100 1980-1983	Mü11 2480-2485	Mü11 2737-2742	Mü11 3127-3132	Mü110 1798-1803	Mü110 1850-1855	BeS2 1697-1706	BeS3 1583-1599,5	BeS3 1730-1746,8
<i>Heterolepa cf. dutemplei</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	72	0	227	0	0	0	96	0	0
<i>Heterolepa dutemplei</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	78	0	0	451	0	64	193	553	0	0	4	16	56
<i>Heterolepa</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Hoeglundina elegans</i> (d'Orbigny, 1826)	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Hyaline indet.	1	1	0	0	0	0	2	1	0	0	16	0	192	135	36	0	0	0	0	8
<i>Hyalinea</i> sp. 1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hyperammina elongata</i> Brady, 1878	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Karrerella</i> sp. 1	0	0	0	0	0	0	0	5	0	0	0	3	0	0	0	0	0	0	0	0
<i>Laevidentalina</i> spp.	0	0	0	0	0	0	0	0	0	0	24	96	96	1	122	0	0	0	0	72
<i>Lagena striata</i> (d'Orbigny, 1839)	0	0	0	0	0	0	0	2	0	0	8	0	0	0	0	0	0	0	0	32
<i>Lenticulina calcar</i> (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	0	13	0	116	5	0	0	0	0	0
<i>Lenticulina cf. limbosa</i> (Reuss, 1863)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
<i>Lenticulina cf. melvilli</i> (Cushman & Renz, 1941)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lenticulina convergens</i> (Bornemann, 1855)	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
<i>Lenticulina cyclepiformis</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	1184	0	0	0	0	0	2	0	0
<i>Lenticulina gibba</i> (d'Orbigny, 1839)	0	0	0	0	0	0	0	0	0	0	16	4	0	0	0	0	0	0	0	0
<i>Lenticulina inornata</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	16	0	210	3	0	0	0	0	0
<i>Lenticulina iota</i> (Cushman, 1923)	0	0	0	0	0	0	0	0	0	0	30	24	0	0	0	0	0	0	0	0
<i>Lenticulina</i> spp.	0	0	0	0	0	0	0	0	0	0	16	85	48	564	162	0	17	5	16	128
<i>Lenticulina vortex</i> (Fichtel & Moll, 1798)	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
<i>Marginulina hirsuta</i> d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	15	16	128	70	0	0	0	0	0
<i>Marginulina obesa</i> Terquem, 1866	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
<i>Marginulina</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0
<i>Martinottiella communis</i> (d'Orbigny, 1826)	0	0	0	0	0	0	0	5	0	0	224	1	0	0	0	0	0	0	0	0
<i>Martinottiella karreri</i> (Cushman, 1936)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Melonis pompilioides</i> Fichtel & Moll, 1798	0	0	0	4	0	0	0	3	0	0	160	1	32	32	34	0	32	0	0	0
<i>Melonis</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
<i>Melonis</i> sp. 1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	32	0	0	0	0
Miliolidae indet. sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
Miliolidae indet. sp. 2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Miliolidae indet. sp. 3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Miliolidae indet.	0	0	0	0	0	12	24	7	0	0	0	24	0	0	9	0	0	0	0	24
<i>Neolenticulina variabilis</i> (Reuss, 1850)	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
<i>Neugeborina longiscata</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Nodosaria?</i> sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	42	0	0	0	0	0
<i>Nonion commune</i> (d'Orbigny, 1846)	0	0	0	0	2	0	0	2	0	0	680	13	16	288	2	0	0	304	64	96
<i>Nonion tumidulus</i> Pishvanova, 1960	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Oolina globosa</i> (Montagu, 1803)	0	0	0	0	0	0	0	1	0	0	8	0	0	0	0	0	0	0	0	24

Taxa	Be4 2070-2078,5	Be4 2134-2141	Be6 1397-1406	Be6 1500-1509	Be6 2082-2091	Be7 1420-1429	Be7 1429-1434,5	Be7 1895-1900	Mü100 1565-1570	Mü100 1740-1745	Mü100 1820-1825	Mü100 1980-1983	MüT1 2480-2485	MüT1 2737-2742	MüT1 3127-3132	Mü110 1798-1803	Mü110 1850-1855	BeS2 1697-1706	BeS3 1583-1599.5	BeS3 1730-1746.8
<i>Orbulina suturalis</i> Brönnimann, 1951	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Oridorsalis umbonatus</i> (Reuss, 1851)	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Orthomorphina</i> spp.	0	0	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	0
<i>Paragloborotalia</i> sp. 1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Planularia</i> sp.	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Porosonion granosum</i> (d'Orbigny, 1846)	0	7	36	2	16	0	0	0	0	0	0	0	0	96	0	0	0	0	0	0
<i>Praeglobbulimina pupoides</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	53	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pseudonodosaria brevis</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	10	0	0	0	0	0
<i>Pullenia bulloides</i> (d'Orbigny, 1846)	0	1	0	0	0	0	0	0	0	0	64	5	0	0	24	0	0	0	0	0
<i>Pyrgo lunula</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	16	17	0	0	0	0	0	0	0	0
<i>Quinqueloculina akneriana</i> d'Orbigny, 1846	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Quinqueloculina auberiana</i> d'Orbigny, 1839	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Quinqueloculina boueana</i> d'Orbigny, 1846	0	0	0	0	0	55	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Quinqueloculina contorta</i> d'Orbigny, 1846	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Quinqueloculina haidingeri</i> d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Quinqueloculina seminula</i> (Linnaeus, 1758)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Quinqueloculina</i> sp. 2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Quinqueloculina</i> spp.	4	1	0	0	0	0	0	0	0	7	17	22	0	381	0	0	0	0	0	0
<i>Quinqueloculina triangularis</i> (d'Orbigny, 1846)	0	3	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
<i>Recurvoides</i> sp. 1	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
<i>Reophax nodulosa breviar</i> Lmnicki, 1900	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Reophax scorpiurus</i> Montfort, 1808	0	0	0	0	0	0	0	0	0	0	24	0	1536	426	0	0	0	0	0	0
<i>Reophax</i> spp.	0	0	0	0	0	0	0	0	0	0	0	2	208	0	0	0	0	0	0	0
<i>Reticulophragmium venezuelanum</i> (Maync, 1952)	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0
<i>Reussella spinulosa</i> (Reuss, 1850)	0	0	0	0	0	0	0	0	0	0	8	0	0	0	2	0	0	0	0	0
<i>Rosalina</i> sp. 1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sigmoilopsis schlumbergeri</i> (Silvestri, 1904)	0	0	0	0	0	0	0	5	0	0	97	8	0	0	4	0	0	32	0	48
<i>Sigmoilopsis</i> sp. 1	0	0	0	0	0	0	0	0	0	0	0	2	0	321	6	0	0	0	0	0
<i>Sinuloculina consobrina</i> (d'Orbigny, 1846)	2	0	5	8	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sphaeroidina bulloides</i> d'Orbigny, 1826	0	0	0	0	0	0	0	32	0	0	104	0	0	0	0	0	0	0	0	0
<i>Spiroloculina tenuis</i> (Cžjžek, 1848)	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
<i>Spiroplectamina pectinata</i> (Reuss, 1850)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
<i>Spiroplectamina deperdita</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	64	0	0	0	38	0	0	240	80	256
<i>Spiroplectamina</i> sp. 1	0	0	0	0	0	0	0	5	0	0	0	7	0	0	0	0	0	0	0	0
<i>Spiroplectinella cf. wrighti</i> (Silvestri, 1903)	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0	0	0
<i>Spiroplectinella</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Spirorutilus carinatus</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	35	0	0	2186	56	0	544	6	0	0	0	0	48
<i>Stilostomella adolphina</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Taxa	Be4 2070-2078,5	Be4 2134-2141	Be6 1397-1406	Be6 1500-1509	Be6 2082-2091	Be7 1420-1429	Be7 1429-1434,5	Be7 1895-1900	Mü100 1565-1570	Mü100 1740-1745	Mü100 1820-1825	Mü100 1980-1983	Mü11 2480-2485	Mü11 2737-2742	Mü11 3127-3132	Mü110 1798-1803	Mü110 1850-1855	BeS2 1697-1706	BeS3 1583-1599,5	BeS3 1730-1746,8
<i>Stilostomellidae</i> indet.	0	0	0	0	0	0	0	0	0	0	0	33	0	160	51	0	0	0	0	0
<i>Textularia</i> cf. <i>laevigata</i> d'Orbigny, 1826	0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0
<i>Textularia gramen gramen</i> d'Orbigny, 1846	0	0	0	0	0	0	0	22	0	0	40	23	0	4	3	0	0	2	128	32
<i>Textularia gramen maxima</i> Cicha & Zapletalova, 1965	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Textularia laevigata</i> d'Orbigny, 1826	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
<i>Textularia mariae</i> d'Orbigny, 1846	0	0	0	0	0	0	0	6	0	0	96	4	0	0	0	0	0	0	0	0
<i>Textularia pala</i> Czjžek, 1848	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
<i>Textularia</i> spp.	0	0	0	0	0	0	0	7	0	0	100	44	0	256	21	0	32	94	112	24
<i>Trilobatus</i> cf. <i>bisphericus</i> (Todd, 1954)	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Trilobatus trilobus</i> (Reuss, 1850)	0	1	1	0	0	0	0	0	0	0	96	42	16	64	0	0	0	0	0	0
<i>Triloculina gibba</i> d'Orbigny, 1826	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Triloculina</i> spp.	0	0	0	0	0	0	0	1	0	0	48	72	0	0	0	0	0	0	0	0
<i>Triloculina trigonula</i> (Lamarck, 1804)	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trochammina</i> sp. 1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Uvigerina aculeata</i> d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72
<i>Uvigerina</i> cf. <i>aculeata</i> d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	8
<i>Uvigerina</i> cf. <i>grilli</i> Schmid, 1971	0	0	0	0	0	0	0	4	0	0	8	0	0	0	0	0	0	0	0	0
<i>Uvigerina</i> cf. <i>multistriata</i> Hantken, 1871	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0
<i>Uvigerina</i> cf. <i>venusta</i> Franzenau, 1894	0	0	0	0	0	0	0	0	0	0	8	0	16	0	0	0	0	0	0	0
<i>Uvigerina grilli</i> Schmid, 1971	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Uvigerina pygmaoides</i> Papp & Turnovsky, 1953	0	0	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0	0	0	0
<i>Uvigerina semiornata</i> d'Orbigny, 1846	0	0	0	0	0	0	0	0	0	0	1328	0	0	0	0	0	0	0	0	0
<i>Uvigerina</i> spp.	0	0	0	0	0	0	0	1	0	0	0	5	64	32	0	0	0	0	0	0
<i>Uvigerina urnula</i> d'Orbigny, 1846 gr.	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0	0	0	0
<i>Uvigerina venusta</i> Franzenau, 1894	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	208
<i>Vaginulinopsis hauerina</i> (d'Orbigny, 1846)	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Vaginulopsis</i> sp.	0	0	0	0	0	0	0	0	0	0	8	0	0	0	2	0	0	0	0	0
<i>Valvulineria complanata</i> (d'Orbigny, 1846)	0	2	0	0	1	0	0	6	0	0	0	0	0	32	0	0	0	0	0	0
<i>Valvulineria</i> sp. 1	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0
<i>Valvulineria</i> spp.	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Vulvulina pennatula</i> (Batsch, 1791)	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
Plankton indet.	0	0	0	0	0	0	0	0	0	0	376	34	80	864	0	0	16	0	0	104
Benthos indet.	0	0	7	0	11	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0

	Species/Genus/Family	Be S1 2362-2367 (2/2)	Be S3 1730-1746 (2/2)	Mü 100 1740-1745 (3/14)	Mü 100 1450-1455 (2/4)	Be 3 1520-1529 (1/3)	Be 3 1520-1529 (5)	Be 4 2134-2141 (3/5)	Be 4 2134-2141 (3/2)	Be 4 2100-2109 (2/9)	Be 4 2100-2109 (2/4)	Be 5 2070-2078.5 (1/1)	Be 5 2338-2343 (2/4)	Be 6 2082-2091 (3/1)	Be 6 1500-1509 (2/5)	Be 6 1500-1509 (2/1)	Be 6 1397-1406 (1/7)	Be 6 1397-1406 (1/8)	Be 6 1397-1406 (1/5)	Be 6 1397-1406 (1/2)	Be 7 1895-1900 (3/2)	Be 7 1420-1429 (1/5)	Be 7 1420-1429 (1/2)	Be 7 1429-1434.5 (2/4)	Be 7 1429-1434.5 (2/3)	Be 7 1429-1434.5 (2/7)
Gastropoda	<i>Alvania oceani</i> (d'Orbigny, 1852)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Gastropoda	<i>Tornus kuemeli</i> Harzhauser, 2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1	0
Gastropoda	<i>Idirophe defrancei</i> (de Basterot, 1825)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Gastropoda	<i>Tritia longitesta</i> (Beer-Bistrický, 1958)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	0	1
Gastropoda	<i>Tritia schoenni</i> (Hoernes & Auinger, 1882)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0
Gastropoda	<i>Cyllenina ancillariaeformis</i> (Gratelop, 1834)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Gastropoda	<i>Epitonium</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gastropoda	<i>Favriella</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0
Gastropoda	<i>Mangelia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Gastropoda	<i>Bela</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gastropoda	<i>Perrona</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Gastropoda	<i>Chemnitzia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Gastropoda	<i>Turbonilla</i> sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Gastropoda	<i>Tragula fenestrata</i> (Jeffreys, 1848)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Gastropoda	<i>Turbonilla gastaldi</i> auct.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0
Gastropoda	<i>Odostomia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0
Gastropoda	<i>Acteocina heraclitica</i> Berger, 1949	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0
Gastropoda	<i>Retusa truncatula</i> (Bruguière, 1792)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Gastropoda	<i>Ringicula</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Gastropoda	<i>Bithynia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Gastropoda	<i>Planorbarius mantelli</i> (Dunker, 1848)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Gastropoda	<i>Megalotachea</i> sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Scaphopoda	<i>Antalis cf. mutabilis</i> (Hörnes, 1856)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Polychaeta	<i>Ditrupa</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Bryozoa	<i>Schizostomella grinzigenensis</i> David & Pouyet, 1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Cirripedia	<i>Balanidae</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	<i>Cytheridea acuminata</i> Bosquet, 1852	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Asteroidea	<i>Astropecten</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0
Echinodea	<i>Brissopsis</i> sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthozoa	Octocorallia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
Amphibia	<i>Rana?</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chondrichthyes	<i>Dasyatis</i> sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chondrichthyes	Myliobatiformes 1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0

	Species/Genus/Family	Be S1 2362-2367 (2/2)	Be S3 1730-1746 (2/2)	Mü 100 1740-1745 (3/14)	Mü 100 1450-1455 (2/4)	Be 3 1520-1529 (1/3)	Be 3 1520-1529 (5)	Be 4 2134-2141 (3/5)	Be 4 2134-2141 (3/2)	Be 4 2100-2109 (2/9)	Be 4 2100-2109 (2/4)	Be 5 2070-2078,5 (1/1)	Be 5 2338-2343 (2/4)	Be 6 2082-2091 (3/1)	Be 6 1500-1509 (2/5)	Be 6 1500-1509 (2/1)	Be 6 1397-1406 (1/7)	Be 6 1397-1406 (1/8)	Be 6 1397-1406 (1/5)	Be 6 1397-1406 (1/2)	Be 7 1895-1900 (3/2)	Be 7 1420-1429 (1/5)	Be 7 1420-1429 (1/2)	Be 7 1429-1434,5 (2/4)	Be 7 1429-1434,5 (2/3)	Be 7 1429-1434,5 (2/7)		
Chondrichthyes	Myliobatiformes 2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Decapoda	Alpheidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Osteichthyes	Gobiidae	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Osteichthyes	<i>Spondylisoma</i> sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Osteichthyes	<i>Lesueurigobius vicinalis</i> (Koken, 1891)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Osteichthyes	<i>Umbrina</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0