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The Middle Miocene Badenian stratotype at Baden-Sooss (Lower Austria)

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Abstract: The brickyard of Baden-Sooss, in the Austrian part of the Vienna Basin was selected as the stratotype of the Middle Miocene regional stage Badenian for the Central Paratethys. Stratigraphy and correlation are up-dated, and the present state of the art on fossil groups is shown. The stratotype belongs to the Upper Lagenidae Zone in a regional paleoecological zonation. For interregional correlation the section belongs to a part of calcareous nannoplankton Zone NN5 without *Helicosphaera waltrans*, to dinocyst Zone Cte, and in planktonic foraminiferal zonation by the occurrence of *Orbulina suturalis* to Zone M6, and to the middle part of the Langhian stage. The sediments of the so-called "*Badener Tegel*" are part of the Baden Formation, correlated with the Lanžhot Formation in the Czech and Slovak part of the basin. Deposition of the calcareous silty clays occurred at a water depth of around 200 m in a relatively warm, well-stratified water column. Re-deposition of fossiliferous coarser sediments from shallow regions occurs.

Key words: Middle Miocene, Badenian, Paratethys, stratigraphy, stratotype Baden-Sooss.

Introduction

In the middle of last century a new stratigraphic order was introduced for the Central European Paratethys marine realm. It was clear that for the Miocene the old correlations between this area and the Mediterranean and Atlantic stage system of Mayer-Eymar (1858) were incorrect (Seneš 1958). As a driving motor, Ján Seneš (Slovak Academy of Sciences, Bratislava) organized within the Committee on Mediterranean Neogene Stratigraphy (CMNS — Paratethys Working Group) and the International Geological Correlation Program (IGCP) one of the early projects to solve the open problems (IGCP Project No. 25: Stratigraphic Correlation Tethys–Paratethys Neogene). Coming home from the 4th CMNS Congress in Bologna (1967), the members of the working group established a series of new regional stages for the Central Paratethys (Cicha & Seneš 1968; Papp et al. 1968).

At the beginning of the geological research, the terms "mariner Tegel von Baden" and "Leythakalk" were in use for Middle Miocene sediments in the Vienna Basin and adjoining areas. A stratigraphic subdivision of the Neogene was presented by Fuchs (1873) with "I. und II. Mediterranstufe". And later the stages of Mayer-Eymar (1858) were introduced by Schaffer (1927), defining the marine Middle Miocene as *Tortonien.* The new stage *Badenien* replaced this term, and was defined by the stratotype locality Baden-Sooss, Lower Austria, and the formation "*Badener Serie*". A formal definition of the Badenian was given by Cicha et al. (1975) and a description of the holo-stratotype Baden-Sooss by Papp & Steininger (1978). Historical annotations were given in that description, together with fossil lists. Therefore only important groups and new results are updated here.

Geological setting

The type locality Baden-Sooss is positioned near the western border of the Southern Vienna Basin (Fig. 1). The NNE-SSW oriented Vienna Basin is >200 km long and about 50 km wide, situated at the Alpine-Carpathian junction. In the central part of the basin Neogene sediment thickness exceeds 5000 m. The lateral eastward extrusion of the Eastern Alps caused the formation of the Vienna Basin transform system as a pull-apart basin in the Middle Miocene (Royden 1985; Ratschbacher et al. 1991; Decker & Peresson 1996). The Badenian sedimentary history and basin development was recently compiled by Jiříček & Seifert (1990), Kreutzer (1993), Weissenbäck (1996), Wessely (2000, 2006), Kováč et al. (2004). Depending on the position within the basin, Lower Miocene (Eggenburgian to Karpatian) marine, brackish or fresh-water beds were deposited. Sedimentation occurred still in a piggy-back-position. Karpatian sedimentation ended in the southern part of the basin with the meandering river system of the Aderklaa Formation and the Láb Member. In the northern basin marine conditions ended with the Závod Formation.

After an erosion phase at the Karpatian/Badenian boundary, marine conditions returned. In contrast to earlier interpretations, the first Lower Badenian transgression occurred during nannoplankton Zone NN4 (Martini 1971), dated in marine marls on top of the "Gainfarn breccia" and between the "Vös-

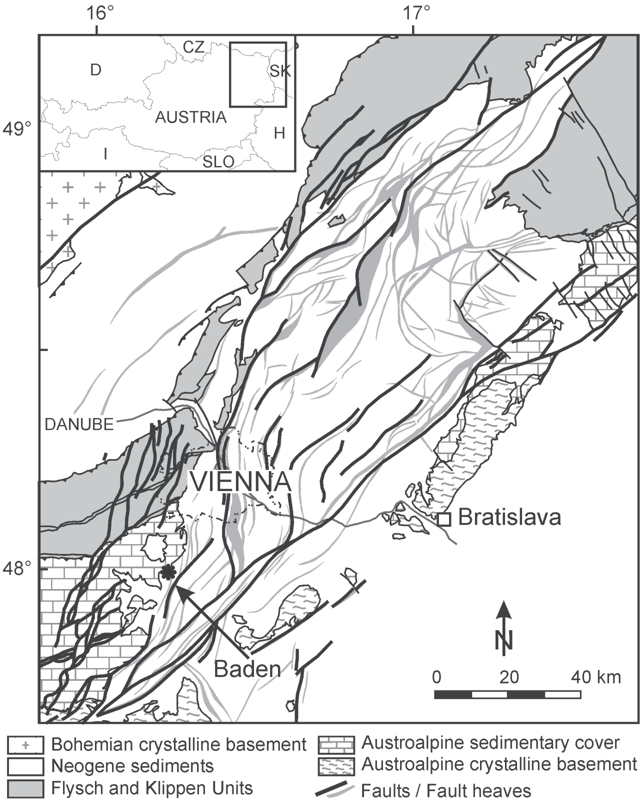

Fig. 1. Geological setting of the Vienna Basin at the Alpine-Carpathian junction (provided by K. Decker, University of Vienna).

lau conglomerate" in the southern Vienna Basin (Wessely et al. 2007). The next transgression followed within the lower part of Zone NN5, in the horizon with *Helicosphaera waltrans* recorded along the borders of the basin (Gajary, Suchohrad and Leváre Depressions in the east, and in the Niederleis and Frättingsdorf embayments in the west). Recent nannoplankton investigations of marine sandy intercalations, allowed dating of the upper part of the Aderklaa Conglomerate in the Aderklaa drill site 40 as NN5 with *H. waltrans* and being time-equivalent to the above cited marine marls. Conglomerates of the Zohor Member along the eastern basin border are correlated with the Aderklaa Conglomerate. This Lower Badenian transgressions covered also the Alpine-Carpathian Foredeep north of the Danube.

Nannoplankton investigations of Lower Lagenidae Zone sediments with the "*Lanzendorf Fauna*" (Grill 1941, 1943) in boreholes south of Vienna (e.g. Oberlaa Thermal 1) did not contain the horizon with *H. waltrans*. These marls of nannoplankton Zone NN5 are therefore younger and correspond to the cycle of deposition of the "*Badener Tegel*" of the Baden and Lanžhot Formation. Shoals, such as the Leitha Mountains corallinacean limestones of the "*Leithakalk*" indicate highstand system tracts (Strauss et al. 2006). Within the basin pelitic sedimentation prevailed in the Middle Badenian, with various intercalations of deltaic sand bodies. Upper Badenian transgressive sedimentation of the *Bulimina-Bolivina* Zone (nannoplankton Zone NN6) is characterized by the Studienka Formation, the Sandberg Member and corallinacean limestones. It ended in parts of the basin with the regressive phase of the "*Rotalienzone*" or "*Verarmungszone*" (impoverished zone). A strong erosion marks the Badenian/Sarmatian boundary. The younger sedimentary history of the basin and the Sarmatian to Pannonian basin filling was interpreted recently by Harzhauser & Piller (2004) and Harzhauser et al. (2004).

Locality and sections

The former brickyard of Wienerberger Company at Baden-Sooss was proposed as the type locality of the Badenian stage by Cicha et al. (1975). The clay pit of the Wienerberger brickyard is positioned at the southern end of the town of Baden, Lower Austria, east of the Vöslauer Strasse and east of the "*Südbahn*" railway. It belongs to the suburb of Sooss. The Baden embayment lies at the south-western border of the Vienna Basin, where Neogene sediments transgress on the nappes of the Calcareous Alps (Fig. 2). Fault systems cross the embayment. The main fault along the Vienna Basin in the area is the Baden Fault reaching a displacement of about 100 m, and a series of lesser faults perpendicular to it, with the Merkenstein Fault-system. The basement is formed by an erosional relief, and the Mesozoic carbonates are a reservoir of thermal water (drilling Josephsplatz 1). At the surface most of the area is covered by Badenian basinal sediments, only along the coastline breccias, conglomerates, sands and bryozoan marls are developed. Upper Sarmatian fine pelitic sediments, the Kottingbrunn Beds are preserved by downthrust along faults. Erosional relics of brownish sandy gravels and conglomerates belong to the Lower Pannonian Hartberg Conglomerate (Brix & Plöchinger 1988).

By the courtesy of H. Summesberger (Natural History Museum of Vienna) it was possible to find out in the archives about the old brickyards at Baden. The clay pits of Doblhoff brickyard were situated along the Vöslauer Strasse, NE of the present military camp. Most of the 19th century descriptions of foraminifera, ostracods and molluscs come from there. Samples preserved in the museum's collections showed nannoplankton Zone NN5 (without *H. waltrans*) and foraminifera of the Lower Lagenidae Zone.

A description of the stratotype locality and section (from 1969) is given by Papp & Steininger (1978). The section in the "*Badener Tegel*" consisted of two parts, the lower one 4.5 m and the upper one 6.0 m thick, divided by an exploitation level. A bed with terebratulid brachiopods forms the base of the section.

The southern part of the pit was cut by the N-S running Baden Fault, displacing Upper Sarmatian sediments. The uppermost part of the clay pit (not included in the Papp & Steininger section) was sampled in a combined action of the Paleontological Institute and the Natural History Museum of Vienna in 1990. The clay pit was later transformed into a waste depository. Only a small area was kept free and protected at the north-eastern side of the pit (240 m NN, 47°59′24″ N, 16°13′54″ E). For scientific research a deep well was drilled at the north-western corner of the clay pit (Wagreich et al. 2008) for a drilling depth of 102 m.

The sediments in the type locality consist mainly of blue-grey bioturbated clayey calcareous sandy silts with rare mac-

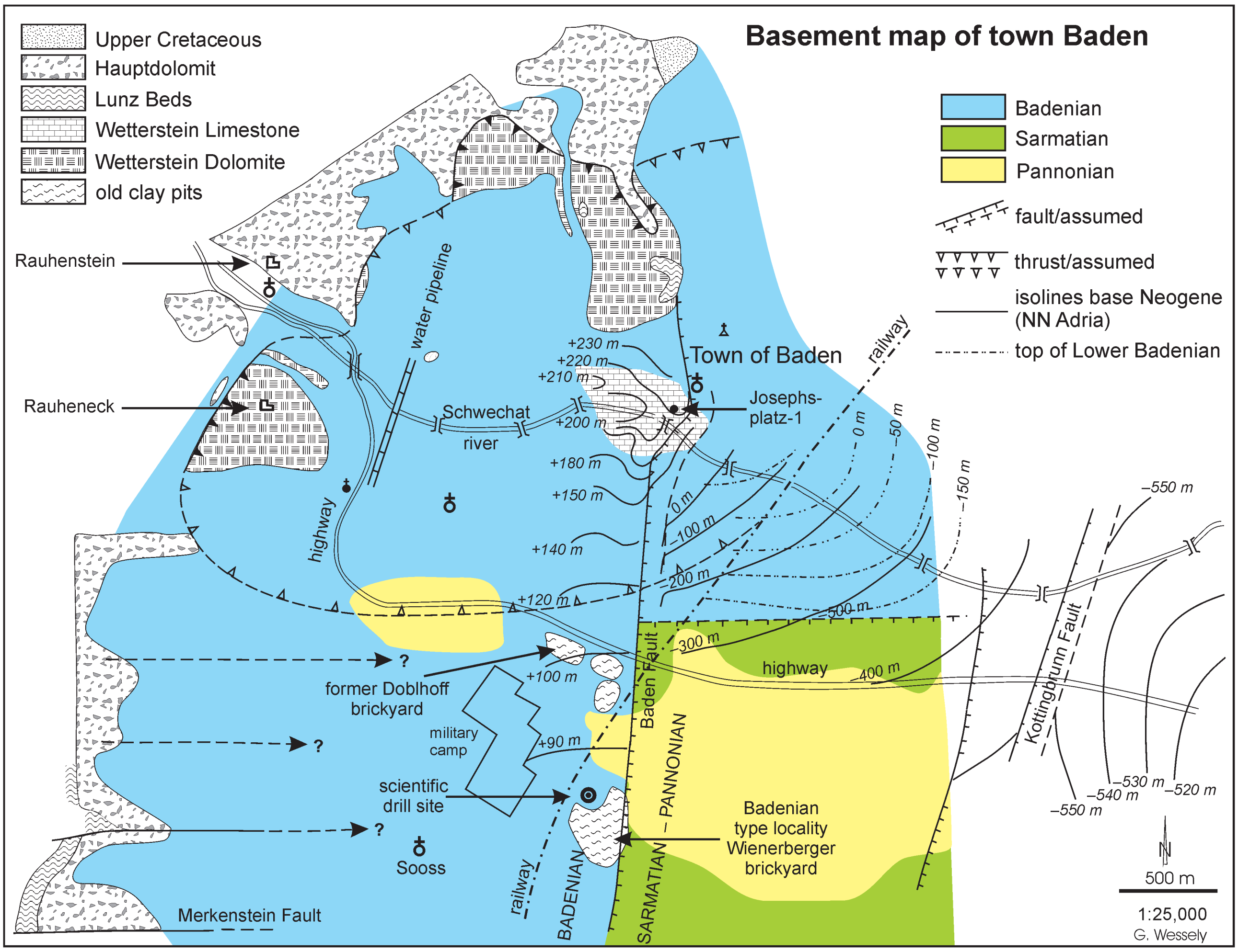

Fig. 2. Geological map of the Baden embayment. Distribution of Miocene sediments on the Mesozoic basement of Northern Calcareous Alps (G. Wessely).

rofossils ("*Tegel*"). Pyrite concretions and pyrite infilling of tests are common. Lenses of sand and gravel with rich biogenic material are intercalated. Beside corallinacean algal debris, the most common fossils are foraminifera and molluscs transported from shallow regions, some bryozoans, echinoid remains, and fish otoliths.

Important fossil groups

Dinoflagellate cysts

Dinoflagellate cysts have been investigated from the Badenian type locality for the first time (Jiménez-Moreno et al. 2006). The accessible section covered only 2.9 m with 4 samples studied. The main components are: *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall, *Operculodinium centrocarpum* (Deflandre & Cookson) Wall, *O. israelianum* (Rossignol) Wall, *Cribroperidinium tenuitabulatum* (Gerlach) Helenes, *Cleistosphaeridium placacanthum* (Deflandre & Cookson) Eaton et al., *Batiacasphaera sphaerica* Stover, and *Spiniferites* spp. The following are of stratigraphical importance: *C. tenuitabulatum*, *Achomosphaera* cf. *andalousiensis* (Jan du Chęne) Jan du Chęne & Londeix, *Cerebrocysta poulsenii* de Verteuil & Norris, *Habibacysta tectata* Head, Norris & Mudie, *Labyrinthodinium truncatum* (Piasecki) de Verteuil & Norris, *Palaeocystodinium miocaenicum* Strauss, and *Trinovantedinium harpagonium* de Verteuil & Norris. The investigated section is correlated with dinocyst Zone Cte.

Calcareous nannoplankton

Kamptner (1948) reported about rich calcareous nannoplankton assemblages from the brickyard Baden-Sooss. Nannoplankton assemblages from the type locality have been described in more detail by Fuchs & Stradner (1977), Stradner & Fuchs (1978) and Fuchs in Papp & Steininger (1978).

Recently, 13 samples were quantitatively studied from the uppermost 9 m of the type locality Baden-Sooss. Besides the stratigraphical marker *Sphenolithus heteromorphus* Deflandre, the nannoplankton assemblages contain numerous and well preserved forms with: *Braarudosphaera bigelowii* (Gran & Braarud) Deflandre, *Coccolithus pelagicus* (Wallich) Schiller, *Coronocyclus nitescens* (Kamptner) Bramlette &

Wilcoxon, *Coronosphaera mediterranea* (Lohmann) Gaarder, *Cyclicargolithus floridanus* (Roth & Hay) Bukry, *Holodiscolithus macroporus* (Deflandre) Roth, *Sphenolithus moriformis* (Brönnimann & Stradner) Bramlette & Wilcoxon, and *Umbilicosphaera jafari* Müller. Helicoliths are represented by *Helicosphaera carteri* (Wallich) Kamptner and *H. walbersdorfensis* Müller. Among reticulofenestrids, the most frequently are small-sized forms *Reticulofenestra minuta* Roth and *R. haqi* Backman. Regular occurrences were observed of *Reticulofenestra pseudoumbilica* (Gartner) Gartner (5–7 µm) and *R. gelida* (Geitzenauer) Backman too. Very low numbers of reworked specimens from the Upper Cretaceous (e.g. *Arkhangelskiella cymbiformis* Vekshina, *Eiffellithus gorkae* Reinhardt, *Microrhabdulus decoratus* Deflandre) and the Lower Eocene (e.g. *Discoaster lodoensis* Bramlette & Riedel, *D. kuepperi* Stradner, *Sphenolithus radians* Deflandre) were determined.

Regular occurrences of *S. heteromorphus* and the absence of *H. ampliaperta* together with blooms of small reticulofenestrids are characteristic for the NN5 Zone in the Badenian. The absence of *H. waltrans* Theodoridis marks a position in the younger part of NN5. The abundances of small reticulofenestrids point to a relatively warm, well-stratified water column. In contrast to assemblages from the drill site of Baden-Sooss discoasterids are absent in the investigated profile. This indicates slight cooling in the uppermost part of the sections.

Bolboforma, *phytoplankton incertae sedis*

In the fine fraction of some samples from Baden-Sooss abundant tests of *Bolboforma moravica* Redinger and *B. reticulata* Daniels & Spiegler are present. These species are indicative for the *Bolboforma reticulata* Biozone (Spiegler & Rögl 1992).

Foraminifera

The clay pits of Baden have been sources for many important publications. The first monograph, based on the collections of Joseph von Hauer was published by d'Orbigny (1846). Additions to this work were given by Czjzek (1847), Reuss (1850a), and Karrer (1861, 1877). A first revision based on new samples was published by Marks (1951), followed by an updated list of Verhoeve (1970). Only Papp & Schmid (1985) studied the orginal material of d'Orbigny for their revision. A list of species from the investigated sections in the Baden-Sooss brickyard was presented by Papp & Steininger (1978). These authors observed in the middle part of the lower section (3.0–4.5 m) a reduction in planktonic foraminiferal numbers, in a horizon of sand lenses ("*Molluskenbank*"). In these lenses rolled *Amphistegina*, *Planostegina*, *Borelis* and mollusc remains are common.

Some biostratigraphically important species, indicating the Upper Lagenidae Zone are listed:

Planktonic foraminifera: *Globigerina concinna* Reuss, *G. diplostoma* Reuss, *Globoturborotalita woodi* (Jenkins), *Globigerinella regularis* (d'Orbigny), *Globigerinoides trilobus* (Reuss), *Orbulina suturalis* (Brönnimann).

Benthic foraminifera: *Amphistegina mammilla* (Fichtel & Moll), *Bolivina dilatata* Reuss, *B. viennensis* Marks, *Borelis melo melo* (Fichtel & Moll), *B. melo curdica* Reichel, *Planostegina costata* (d'Orbigny), *Uvigerina grilli* Schmid, *U. semiornata* (d'Orbigny).

For paleoecological interpretations, the common occurrences of miliolids (*Cycloforina, Quinqueloculina, Triloculina*), textulariids from the shelf region (*Gaudryina*, *Textularia*, *Spirorutilus*), lenticulinas, siphonodosarias, bolivinids, uvigerinds, and cibicidids are important. The environment is interpreted as a muddy bottom of about 200 m water depth with partly dysoxic conditions at the sediment-water interface, as also indicated by pyrite. Transported material from the nearshore is present in sand lenses.

Ostracods

Reuss (1850b) described the first ostracod species from the "*unterer Tegel*" of Baden, namely *Cypridina asperrima* and a few species from Möllersdorf and Vöslau. Subsequently ostracods have been mentioned by several authors from the clay pits of Baden and Baden-Sooss, but rarely selected species have been described or figured (e.g. Triebel 1949; Kempf & Nink 1993). Altogether around 10 species were known in literature. For the description making the Baden-Sooss clay pit the holo-stratotype of the Badenian, ostracods were not investigated. A current study of 10 samples from the 9 m high section of the uppermost part of the clay pit (see above) determined around 50 species. The main elements of the ostracod fauna are *Cytherella* with several species, including *Cytherella compressa* (Münster) sensu Reuss (1850b) and *C. dilatata* (Reuss), *Parakrithe crystallina* (Reuss), *Krithe oertlii* Dieci & Russo, *Pterygocythereis jonesii* (Baird), *Henryhowella asperrima* (Reuss), *Bosquetina carinella* (Reuss), *Cytheropteron vespertilio* (Reuss), *Buntonia subulata* (Ruggieri), and *Argilloecia acuminata* G.W. Müller. This assemblage indicates an environment on the outer shelf with water depths of more than 200 m, which is also confirmed by the rare occurrence of *Pseudocythere armata* Bonaduce et al. and *P. mediterranea* Bonaduce et al. Many of the other species are supposed to represent an allochthonous fauna which was transported from shallower water. In the Central Paratethys the occurrence of several species is stratigraphically restricted to the Badenian, for example, *Aurila angulata* (Reuss), *Bosquetina carinella* (Reuss), *Cnestocythere lamellicosta* Triebel and *Cytheridea acuminata* Bosquet.

Molluscs

The earliest geological studies in Austria already referred to the diverse mollusc faunas of the Baden area (e.g. Prevost 1820; Boué 1833). During the 19th century a large part of the fauna became known to science by the key-papers of Hörnes (1852–1856, 1870) and Hoernes & Auinger (1879–1891). Numerous smaller systematic papers followed (see Schultz 2001–2005 for references). Up to now a total of 402 mollusc species became known from the Badenian of Baden, consisting of 272 gastropods, 121 bivalves, 7 scaphopods, 1 polyplacophoran, and 1 cephalopod. The enormous diversity reflects the late phase of the Middle Miocene Climatic Optimum, which allowed numerous thermophilic proto-Mediterranean species to migrate into the Paratethys (Harzhauser et al. 2003). Moreover, the diversity is a result of mixing of faunas from different habitats. The moderately deep soft bottom environment was settled mainly by thin-shelled infaunal borrowing bivalves such as *Nuculana fragilis* (Chemnitz), *N. nucleus* (Linné) and *Solemya doderleini* Mayer along with the thin-shelled epifaunal pectinids *Costellamussiopecten cristatum badense* (Fontannes) and *C. spinulosus* (Münster). The deep water oyster *Neopycnodonte navicularis* (Brocchi) and the chemosymbiont-bearing lucinids *Megaxinus incrassata* (Dubois) and *Saxolucina suessi* Kautsky are further typical autochthonous elements. Scaphopods such as *Antalis bouei* (Deshayes), *Fissidentalium badense* (Partsch) and *Gadilina jani* (Hörnes) and carnivorous and scavenging naticids, nassariid and turrid gastropods are abundant. Due to the high diversity of the turrids (formerly called *Pleurotoma*) the Baden Tegel was also known as the "*Pleurotomen-Tegel*" in the older literature. Most of the molluscs, however, derive from shallow water and near-shore settings and were transported by storms together with coarse sediments. The bivalves *Glycymeris pilosa* (Linné) and *Megacardita jouanneti* (Basterot) and the gastropod *Strombus bonellii* (Brongniart) are typical.

The huge mollusc fauna is clearly distinguished from Early Miocene faunas by the occurrence and arrival of new taxa. Especially the pectinid fauna displays a typical Middle Miocene character with taxa such as *Propeamussium felsineum* (Foresti), *Pseudamussium septemradiatum* (Müller), *Aequipecten malvinae (Dubois)*, *Costellamussiopecten spinulosus* (Münster), and *Flabellipecten besseri* (Andrzejowski) which are restricted to the Badenian stage. Nevertheless, several species, which are typical for the Lower Lagenidae Zone of the Styrian Basin and the North Alpine Foredeep are already missing in the fauna (cf. Harzhauser et al. 2003).

Echinoderms

At the holo-stratotype Baden-Sooss, the silty clays of the "*Badener Tegel*" yielded only sparse echinoderm remains. Most records consist of fragmented cidaroids: *Stylocidaris*? *polyacantha* (Reuss) and spatangoid spines (Spatangoida indet.). Additionally, tiny dwarf urchins (*Echinocyamus transylvanicus* Laube) and deformed coronas or moulds of the burrowing heart urchin *Schizaster karreri* Laube are documented in the collections (Kroh 2005). Lenticular sand intercalations interpreted as distal storm deposits contain an allochthonous death assemblage derived from nearby shallow-water habitats: *Eucidaris zeamays* (Sismonda), Diadematidae indet., *Genocidaris* sp., *Schizechinus* sp., *Tripneustes* sp., Clypeasteroid indet., and Cassiduloida indet. (mostly fragmented spines and plates). From the "*Badener Tegel*" exposures of Bad Vöslau (south of Baden) two additional species are known: *Brissopsis ottnangensis* Hoernes and *Schizaster laubei* Hoernes.

Asteroid and ophiuroid remains are rare and documented by disarticulated ossicles only: "*Astropecten*" *verrucosus* Heller, *Amphiura*? *badensis* Küpper, and *Ephipipiellum symmetricum* Łomnicki (Heller 1858; Łomnicki 1902; Küpper 1954). No holothurian sclerites have been recorded so far, despite intense sampling.

The echinoderm paleo-community of the "*Badener Tegel*" as outlined above is characteristic for low-energy mud-bottoms below the photic zone. Omnivores/predators (cidaroids and asteroids) and burrowing deposit-feeder (spatangoids) make up the bulk of the echinoderm fauna. The occurrence of true shallow-water taxa is restricted to sand intercalations and represents transported debris.

Brachiopods

At the base of the stratotype section, a bed with numerous large, fragmented terebratulid brachiopods was exposed (Papp & Steininger 1978). The formation of this accumulation is unclear. The lack of anchoring possibilities on the clay substrate and apparent absence of secondary hardgrounds seem to suggest an allochthonous origin.

Bryozoa

In the "*Badener Tegel*" bryozoa are scarce and low in diversity. Free-living bryozoa-like *Cupuladria* and *Batopora* are the taxa most commonly found. In the sand lenses a rich, transported and abraded shallow-water bryozoan fauna consisting of incrusting colonies on coralline red algae debris and erect forms is preserved.

Fish remains

The fish fauna consists of around 30 taxa. Sharks are observed by isolated teeth: *Notorynchus primigenius* (Agassiz), *Carcharias acutissimus* (Agassiz), *C. cuspidatus* (Agassiz), *Anotodus retroflexus* (Agassiz), *Megaselachus megalodon* (Agassiz), *Galeocerdo aduncus* Agassiz, *Carcharhinus priscus* (Agassiz).

Otoliths are common. They were described by Brzobohatý (1978), and Brzobohatý in Papp & Steininger (1978) and updated now. The most common species is *Trisopterus sculptus* (Koken), followed by *Palaeogadus emarginatus* (Koken), *Merluccius merlucius* Linné, *Phycis blenioides* (Brünnich), *Coelorinchus coelorhinchus* (Risso), and *Gadiculus labiatus* (Schubert). The dominant species are neritic, but meso- to bathypelagic species of the Myctophidae and *Coelorinchus* are immigrants from the deeper sea.

Stratigraphy and correlation

A paleoecological subdivision by means of foraminifera was developed for the local Vienna Basin Miocene stratigraphy by Grill (1941, 1943). The Badenian (former *Tortonian*) was subdivided into the following eco-zones:

a) uppermost impoverished Tortonian with *Rotalia beccarii* in drilling Schossberg 1;

b) fauna with *Bolivina dilatata* from the Tortonian in drilling Aderklaa 1;

c) rich marine fauna with *Spiroplectammina carinata* in drilling Aderklaa 1;

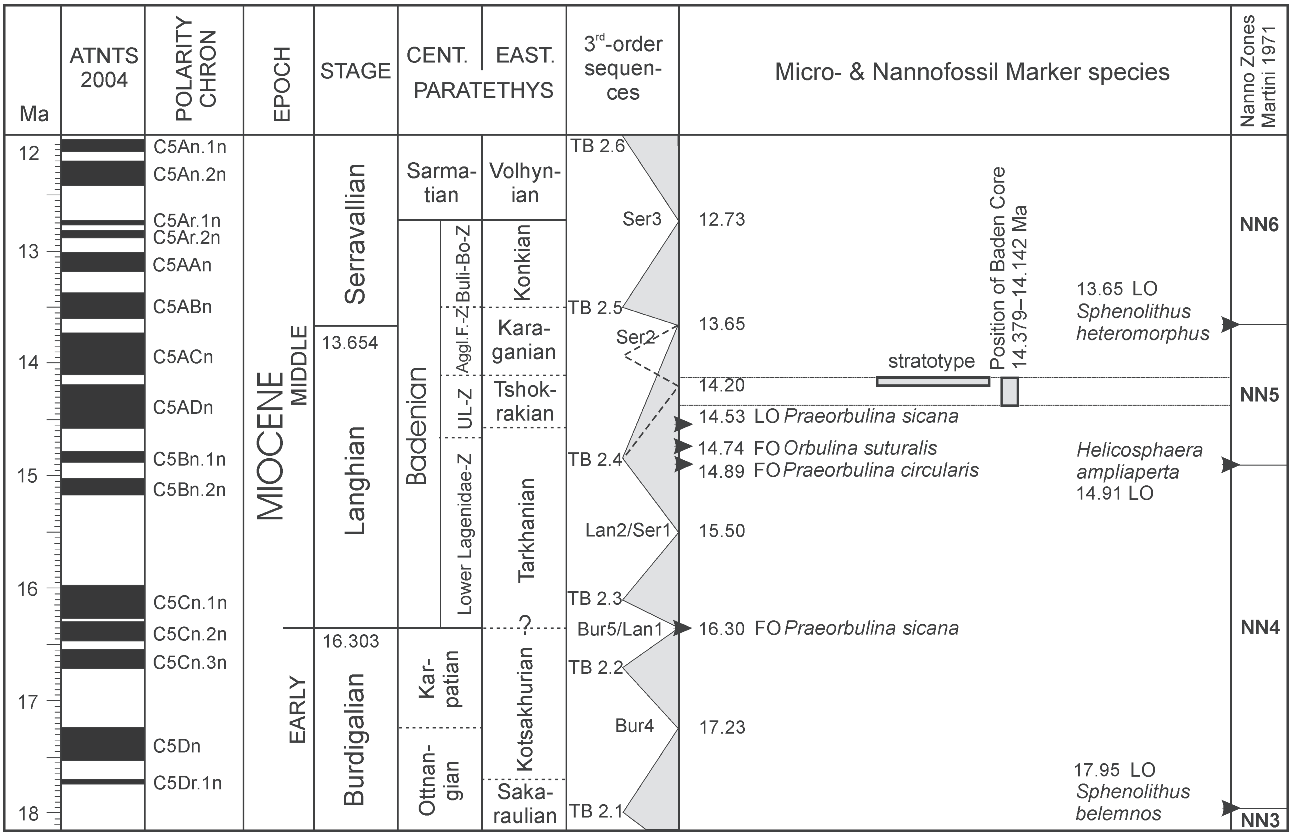

Fig. 3. Middle Miocene stratigraphy and correlation with the position of the Badenian type-locality and Baden-Sooss borehole. The base of the Langhian based on the FO of *Praeorbulina sicana*, according to EEDEN project at the base of Chron C5Cn.1r. Paleomagnetic chronology (ATNTS2004) and ages of biostratigraphic markers according to Lourens et al. (2004a,b), global 3rd-order sequences re-calibrated (Haq et al. 1998; Rögl et al. 2007), position of Baden core according to Hohenegger et al. (2008).

d) rich marine fauna with common lagenids and *Robulus cultratus* in drilling Aderklaa 1;

e) "Lanzendorf fauna" from the Tortonian of the Maustrenk 1 borehole and from the Hörersdorf-Frättingsdorf outcrops.

This subdivision was simplified and based on evolutionary lineages of *Uvigerina* by Papp & Turnovsky (1953) (Fig. 3):

— For the uppermost part of the Badenian, in the oil industry the terms "*Rotalia*" (correctly *Ammonia*) Zone or Impoverished Zone are in use, followed down-hole by: *Bulimina-Bolivina* Zone;

— Zone of agglutinated foraminifera ("*Spiroplectammina*" = *Spirorutilus* Zone);

— Upper Lagenidae Zone;

— Lower Lagenidae Zone.

The Badenian stratotype locality Baden-Sooss belongs to the Upper Lagenidae Zone (Fig. 3), which is characterized by the presence of *Orbulina suturalis* Brönnimann, *Uvigerina grilli* Schmid, and *Bolivina viennensis* Marks. Calcareous nannoplankton of Zone NN5 is represented by *Sphenolithus heteromorphus* Deflandre, *Helicosphaera carteri* (Wallich) Kamptner, *Discoaster exilis* Martini & Bramlette, *D. formosus* Martini & Worsley. In the scientific borehole at Baden-Sooss similar assemblages, without *H. waltrans* are present. In the deepest part of the core the last occurrence of *Praeorbulina circularis* Blow is observed. In a lithostratigraphic subdivision the "*Badener Tegel*" belongs to the Baden Formation, correlated with the Lanžhot Formation in the Czech and Slovak part of the basin.

The occurrence of *O. suturalis* and the absence of *H. waltrans* allow a correlation with the upper part of the NN5 nannoplankton Zone and with planktonic foraminiferal Zone M6, within the middle part of the Langhian stage, Middle Miocene (Lourens et al. 2004a; Ćorić et al. 2007).

In a cyclostratigraphic interpretation for the Vienna Basin Middle Miocene sedimentation (Strauss et al. 2006; Kováč et al. 2007; Rögl et al. 2007), the Badenian stratotype and section falls in cycle TB2.4 of third order sequences (Haq et al. 1988). It lies near the sequence boundary SB2 of Strauss et al. (2006), correlated to an important sea-level drop in the Vienna Basin. In an astronomical tuning the scientific Baden core has been dated as 14.379–14.142 Ma (Hohenegger et al. 2008).

The base of the Badenian stage used in this study, corresponds to the first appearance of the planktonic foraminiferal genus *Praeorbulina* at 16.303 Ma, as described by Lourens et al. (2004a,b). The base of the Langhian in the time table of the same publication contrasts this bio-event and is positioned on top of the paleomagnetic Chron C5Cn at 15.97 Ma without presenting new results or a new stratotype section. The same datum was used as the base of the Badenian by Piller et al. (2007), who do not correspond to the first appearance of *Praeorbulina sicana* (Blow).

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