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The Styrian Basin: a key to the Middle Miocene (Badenian/Langhian) Central Paratethys transgressions

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Abstract

In the Styrian Basin, early Miocene marine sedimentation of the Karpatian (upper Burdigalian) ended with basin shallowing, marked regression and tectonic movements. The Karpatian sedimentation cycle corresponds to the global 3rd order cycle TB 2.2, followed by the Bur5/Lan1 sea-level fall. This regression was combined with tectonic movements (the Styrian Tectonic Phase), seen in the Styrian Unconformity by an angular discordance at the Wagna and Katzengraben outcrops and also in deep wells. Sediments of the first middle Miocene (Badenian/Langhian) transgression are commonly eroded or reduced in thickness at the basin borders. In the basin center, the bathyal environment continues from the Karpatian to the Badenian. Sediments of the first Badenian transgression have been dated by calcareous nannoplankton as NN4 and correlated by the occurrence of *Praeorbulina sicana* with the basal Langhian. The 3rd order sequence corresponds to TB 2.3. The erosional phase of the sea-level fall Lan2/Ser1 can only be observed in near-shore facies, followed by transgressive beds within Zone NN5, which represents the second, main Badenian transgression in the Central Paratethys and corresponds to the long global cycle TB 2. The highstand system tract of this cycle is expressed in carbonate build-ups of the Weissenegg Formation. According to the global 3rd order sequences, the youngest sediments of the Retznei section (< 14.39 Ma) overlying the carbonate buildups belong to the falling-stage system tract of TB2, but did not record regression, but instead continuous deepening of the Styrian Basin, indicating strong subsidence during the early middle Miocene.

Die marine Sedimentation während des älteren Miozäns (Karpatium / Oberes Burdigalium) endete im Steirischen Becken mit einer starken, durch tektonische Bewegungen verstärkten Regression. Der Sedimentationszyklus im Karpatium entspricht der globalen Sequenz TB 2.2 und wird durch das Absinken des Meeresspiegels (Bur5/Lan1) begrenzt. Die Kombination der Regression mit den tektonischen Bewegungen („Steirische Tektonische Phase“) ist als Winkeldiskordanz und Sedimentationsunterbrechung („Styrian Unconformity“) sowohl in den Tagesaufschlüssen Wagna und Katzengraben, als auch in Tiefbohrungen ausgebildet. Sedimente der folgenden, ersten Transgression im Badenium/Langhium sind in den Randbereichen des Beckens zumeist erodiert oder nur spärlich erhalten, während im Beckeninneren durchwegs bathyale Sedimente sowohl im Karpatium als auch im Badenium auftreten. Die folgende Transgression im Badenium läßt sich anhand des kalkigen Nannoplanktons in die Nn4 Zone stellen und korreliert wegen des Auftretens der planktonischen Foraminifere *Praeorbulina sicana* mit dem basalen Langhium. Die Sequenz 3. Ordnung entspricht der TB 2.3. Die erosive Phase an der Lan2/Ser1 Grenze ist in den Randbereichen des Beckens als Sedimentationsunterbrechung ausgeprägt, die von der 2. Transgression im Badenium, der Haupttransgression innerhalb der Paratethys, gefolgt wird. Letztere entspricht dem globalem Zyklus TB 2. Karbonate der Weissenegg-Formation kennzeichnen im Steirischen Becken den Höhepunkt dieser Trangression. Die über den Karbonaten folgenden Siliziklastika müssten entsprechend der Sequenzstratigraphie als zum „falling stage system tract“ gehörend eine Regression anzeigen, sie kennzeichnen aber durch das kontinuierliche Absinken des Meeresbodens die tektonisch bedingte Subsidenz des Steirischen Beckens im Laufe des älteren Mittleren Miozäns.

1. Introduction

During the early Miocene, the region of the circum-Mediterranean, including the vast area of the Paratethys, underwent profound changes. The Mediterranean was cut off from the Indian Ocean; the Eastern Paratethys became an isolated basin and the sea regressed from the Alpine Foredeep in the West and from the Transylvanian Basin, reducing the Central Paratethys marine realm to the Pannonian Basin area and the Carpathian Foredeep (e.g. Kovač et al., 2003). Tectonic movements attributed to the Styrian Tectonic Phase (Stille, 1924), as a consequence of plate movements (e.g. Mazzolki and Helman, 1994) opened the former seaways again by the end of the early Miocene, leading to extensive middle Miocene transgressions (Rögl, 1998, 1999). Transgression in the Central Paratethys occurred as far as the area of Karpatian sedimentation (Fig. 1; Kovač et al., 2007), extending towards the Transylvanian and Dacian Basins, to the Carpathian Foredeep, and connected with the Eastern Paratethys, which was also again marine (Fig. 1; Hamor & Halmai, 1988).

The Styrian Tectonic Phase of Stille (1924) characterizes tectonic events at the early/middle Miocene boundary; that is, at the Karpatian/Badenian and Burdigalian/Langhian boundaries in the Central Paratethys and Mediterranean regions, respectively. This phase, as indicated by its name, is defined by the Neogene tectonic history of the Styrian Basin of SE Austria, which forms a segment of the western part of the Intra-Carpathian Pannonian Basin system. Tectonic activity was accompanied by extensive volcanism (Ebner and Sachsenhofer, 1991; Sachsenhofer, 1996).

Figure 1: Central Paratethys: palaeogeographic reconstruction of the Early Badenian main transgression within nannoplankton zone NN5 (Rögl and Repp, Naturhistorisches Museum Wien).

Palaeoecological as well as tectonic changes characterize the Karpatian/Badenian boundary interval, with a general increase in warm-water species (Badenian climatic optimum) and changing water depths in regional settings (Harzhauser et al., 2003; Spezzaferri et al., 2002a, 2004).

One of the problems encountered when correlating the transgression forming the base of the Badenian in the Central Paratethys area is connected with the biostratigraphical identification of the event. Commonly, the main transgression near the base of calcareous nannoplankton Zone NN5 (Martini, 1971), with co-occurring *Praeorbulina circularis* and *Orbulina suturalis*, has been considered to be the basal Badenian transgression. Due to this coincidence, the Badenian in the Carpathian area of Romania and also in the Transylvanian Basin was considered to start with nannoplankton Zone NN5, subzone NN5a, the *Geminithella rotula* subzone (Marunteanu et al., 1999; Chira, 2000). However, in the Mediterranean, the base of the Langhian falls within the calcareous nannofossil Zone NN4 and has historically been identified with the first appearance of *Praeorbulina sicana* (Fornaciari and Rio, 1996; Fornaciari et al., 1997). Consequently, some authors correlated the lowermost Langhian (calcareous nannofossil Zone NN4) with the Karpatian instead with the basal Badenian (e.g. Andrejeva-Grigorovich et al., 2001).

Work in the Styrian Basin from 2000 to 2006 revealed complex Styrian Tectonic Phase deformation and Badenian transgressions. As a result, it was possible to separate different Badenian transgressive horizons for the first time, especially in the upper part of the Wagna section, and to document what were previously extended gaps in the sedimentation.

In an initial attempt, these problems were discussed by comparing the Karpatian/Badenian transition in the Styrian Basin and in the Molasse Basin of Lower Austria (Spezzaferri et al., 2002 a,b; Rögl et al., 2005, 2007). In the Molasse Basin, a distinct clastic Badenian sequence (calcareous nannofossil Zone NN4 to NN5) lies between the Karpatian Laa Formation and the early Badenian Grund Formation, showing at least two transgression events (Ćorić and Rögl, 2004). The new implications of repeated Badenian transgressions in the Central Paratethys have been recently considered by Kovač et al. (2007).

The definition and separation of the Karpatian and Badenian successions in the investigated sections was made possible by an evaluation of calcareous nannoplankton, planktonic and benthic foraminifera and also mollusc associations (Rögl et al., 2003; Ćorić et al., 2004a,b). As in the Langhian type section, an overlap of the calcareous nannoplankton Zone NN4 and

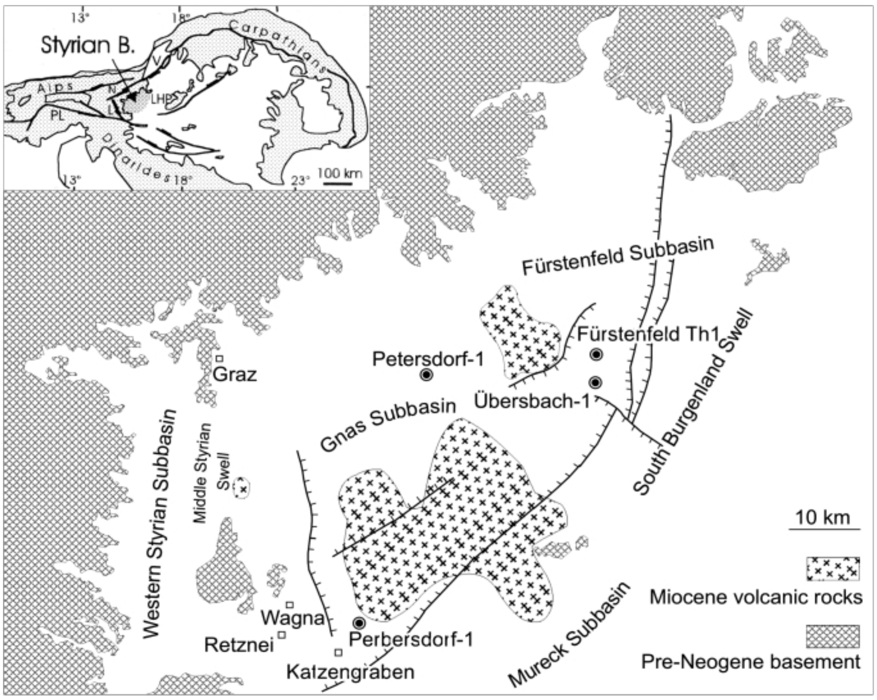

Figure 2: Styrian Basin: tectonic setting with location of Wagna, Retznei, Katzengraben and the investigated deep wells (according to Sachsenhofer, 1996).

Figure 3 A-C: a) Wagna, old brickyard: overview with extended section of the Karpatian "Steirischer Schlier", cut by the “Styrian Unconformity” (1), transgressed by Badenian shallow water sediments with a patch reef (2), and base of sandstone layers demonstrating discontinuity at the Zone NN4/NN5 boundary (3); the top of the section formed by corallinacean limestone of the Weissenegg Formation (4); b) Retznei, Lafarge-Perlmooser cement factory, main quarry: sampled sections (arrows); c) Katzengraben near Spielfeld, outcrop during excavation of the sand pit: the slightly tilted Karpatian “Steirischer Schlier” is cut by the “Styrian Unconformity” (arrow) and topped by Badenian silts and sands of the Kreuzberg Formation (photo J.G. Friebe, Dornbirn).

the first appearance of *Praeorbulina* was taken as diagnostic of the basal Badenian. Spectacular occurrences of molluscs in the Central Paratethys demonstrate the differences between the Karpatian and Badenian stages; for examples, 72 gastropod species made their first appearance in the Karpatian, compared to 439 in the early Badenian, whilst for bivalve taxa the values are 128 species compared to ca. 350, respectively (Harzhauser et al., 2003; Harzhauser and Piller, 2007).

In the present study, the lithological sequences in the Wagna brickyard and neighbouring Retznei cement quarry, as well as the Katzengraben section near Spielfeld, have been biostratigraphically dated with calcareous nannoplankton and planktonic foraminifera. Preliminary results were given by Lirer et al. (2006) and Rögl et al. (2005, 2006 a, c). Palaeomagnetic measurements have been correlated with the polarity time scale of Lourens et al. (2004a) and new radiometric ages from the Styrian Basin (Handler et al., 2006) are discussed. For a better understanding of the development in deeper parts of the basin and in sections with more continuous sedimentation, some deep wells have been studied in detail (Perbersdorf 1, Petersdorf 1; Fig. 2).

Foraminifera have been deposited with the Micropalaeontological Collection of the Natural History Museum, Vienna, while the calcareous nannoplankton and the Perbersdorf 1 microfossils have been placed at the Austrian Geological Survey, Vienna. A number of publications have documented the results produced during the project (Spezzaferri et al., 2001a-c, 2002a-b, 2004; Rögl et al., 2002, 2005, 2006 a-c, 2007; Ćorić et al., 2004a,b; Hohenegger et al., 2005; Lirer et al., 2006). Identical sections and sample splits were used by Latal and Piller (2003) for isotope studies and by Soliman and Piller (2007) for the investigation of dinoflagellates.

2. Geological setting

The Styrian Basin, which is part of the western Pannonian Basin system, has been subdivided by swells into different subbasins. The main structure, the Middle Styrian Swell, separates the Western from the Eastern Styrian Basin (Fig. 2). The basement is formed by the Austroalpine nappe system. Subsidence of the basin, which started during the early Miocene, probably during the Ottnangian, was connected with the lateral extrusions of crustal wedges along strike-slip faults towards the Pannonian Basin (Decker and Peresson, 1996; Frisch et al., 2000). A combination of block rotation, subsidence and uplift formed the different subbasins. Large areas were covered by lava flows during extensive volcanic activity. Extended lignite formation occurred in the Western Styrian Basin during the early and early middle Miocene, on top of coarse-grained fan deposits. During the Karpatian, the Paratethys Sea transgressed across the Eastern Styrian Basin, which was comprised of swamp and floodplain deposits of probably Ottnangian age, resting on a deeply eroded metamorphic substratum. Angular unconformities and sedimentation gaps (Styrian Unconformity) mark the Karpatian/Badenian boundary. A series of marine transgressions of the Badenian Sea followed on top of the Karpatian deep-water sediments (the Steirischer Schlier). In the Styrian Basin, the transgressions reached their greatest extent in the early Badenian. During the Sarmatian and Pannonian, a continuous shrinking of the relict sea and lake has been documented (Kollmann, 1965; Flügel and Neubauer, 1984; Ebner and Sachsenhofer, 1991; Sachsenhofer, 1996; Gross et al., 2007; Schreilechner and Sachsenhofer, 2007).

The sections investigated at Wagna, Retznei and Katzengraben belong to the southern Gnas Subbasin and were strongly influenced by the development of the Middle Styrian or Sausal Swell (Fig. 2). Extensive research in this region, with descriptions of outcrops, lithostratigraphic subdivisions, and cyclostratigraphic interpretations were presented by Friebe (1988, 1990, 1991, 1993), Schell (1994) and Holzer (1994).

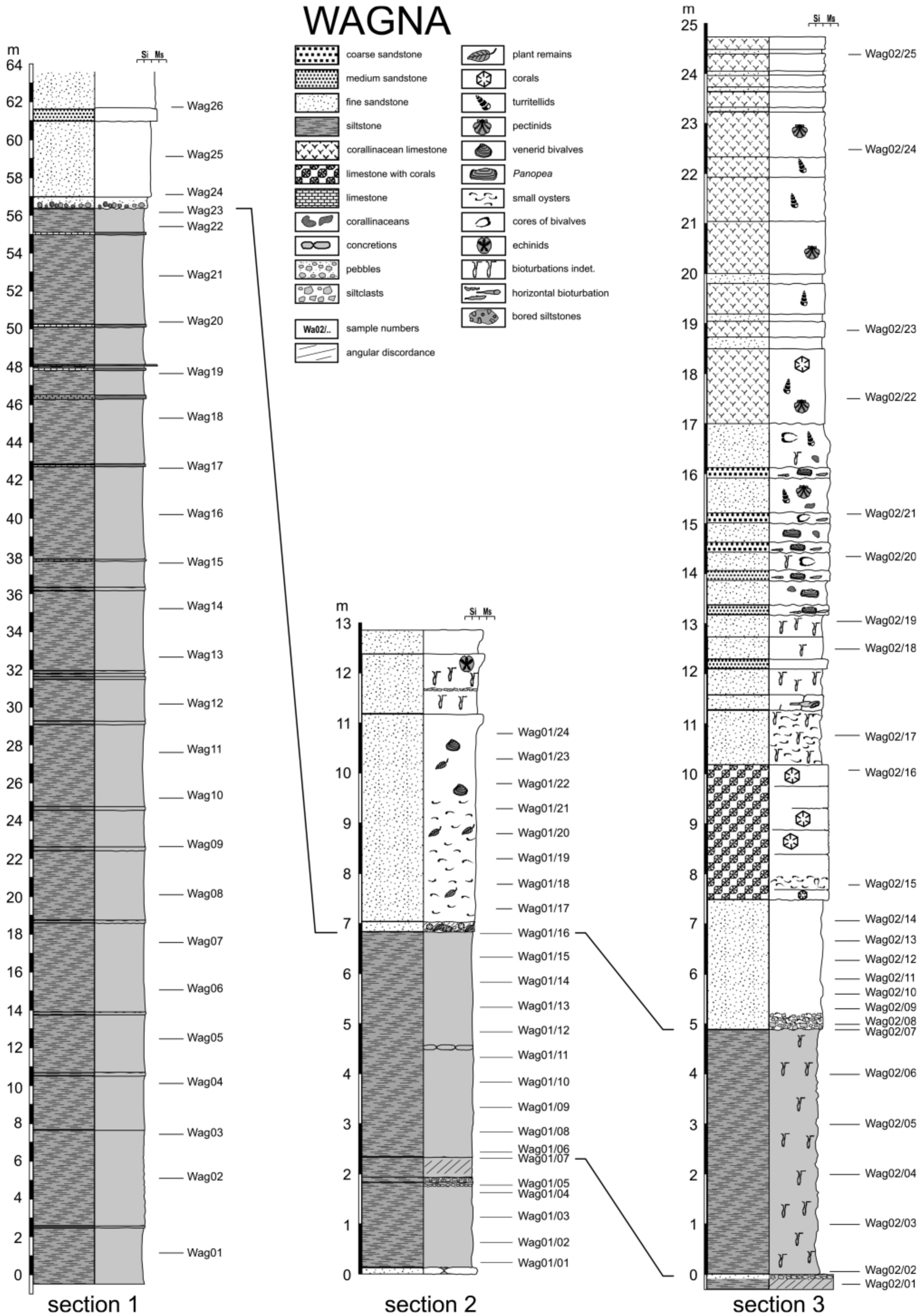

Figure 4: Wagna, old brickyard; section 1 sampled in 2000; sections 2 and 3 sampled 2001- 2002.

3. Lithostratigraphy and Lithofacies

3.1 Wagna, old brickyard

The old brickyard at Wagna is located south of Leibnitz, on the western side of the river Sulm, on the road to Aflenz. The section is divided into two parts (Fig. 3a). The lower extended part belongs to the Karpatian Steirischer Schlier (Kreuzkrumpel Formation; Schell, 1994), whereas the upper part shows the Styrian Unconformity with various Badenian lithologies. The term Steirischer Schlier is used here instead of the Kreuzkrumpl Formation of Schell (1994), which generally refers to Karpatian near-shore deposits. A description of the Wagna section was recently given by Gross et al. (2007). The palaeomagnetic profile of Auer (1996) from this locality was supplemented and updated during the research presented here.

Section 1 (samples Wag01–Wag26; Fig. 4), sampled in the lower part of the former clay pit, comprises mainly Karpatian Steirischer Schlier, with the Styrian Unconformity lying between samples Wag23-24 near the top (Spezzaferri et al., 2002a). Sections 2 and 3, in the upper part of the outcrop, cross the Karpatian/Badenian boundary and expose the Styrian Unconformity between samples Wag01/16-17 and Wag02/07-08 (Fig. 4).

The exposed 75 m of Steirischer Schlier shows a cyclic sedimentation of dark-grey, calcareous, silty shales, interbedded by 15-20 cm thick dolomitic limestones (Fig. 5a). In the upper part of the Steirischer Schlier, a channel filling with basement pebbles cuts the layered succession (Fig. 5b). The beds show a dip of about 20° towards 085° E, becoming less inclined in the upper part. A slight angular disconformity, with a thin pebble layer, separates the shales from overlying sediments. Above this disconformity follow 5 m grey, bioturbated, clayey silts of Karpatian age.

Nannofossil assemblages from the Steirischer Schlier are rich and well preserved, dominated by *Coccolithus pelagicus*, *Reticulofenestra minuta* and *Sphenolithus heteromorphus*. The foraminiferal fauna, which has been recrystallized, is dominated by agglutinated species such as *Gaudryinopsis beregoviensis*, *Textularia laevigata*, *Spirorutilus carinatus* and *Cribrostomoides*. Among calcareous benthic foraminifera, large *Globobulimina pupoides* and *G. pyrula*, together with *Allomorphina trigona*, *Chilostomella ovoidea* and *Valvulineria complanata* indicate dysoxic bottom conditions. The water depth during deposition of the Steirischer Schlier has been estimated at between 225 m and 315 m, with small variations and a shallowing upward tendency (Spezzaferri et al., 2004; Hohenegger et al., 2005; Hohenegger, 2005). Planktonic foraminifera are mainly small-sized, five-chambered globigerinas, e.g. *Globigeri-*

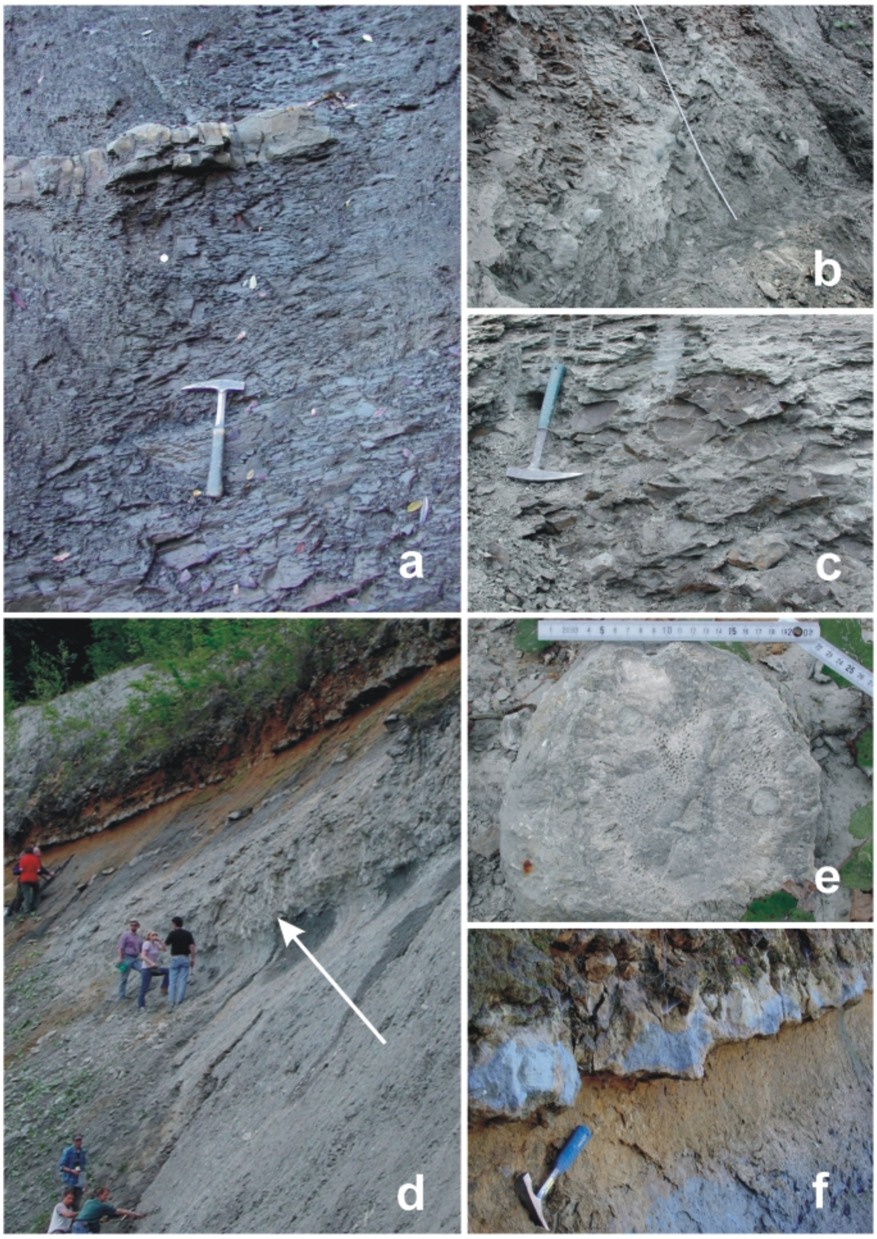

Figure 5: a) Karpatian cyclic sedimentation of "Steirischer Schlier" in the old brickyard Wagna; b) Wagna, upper part of "Steirischer Schlier", channel filling with crystalline pebbles; c) Wagna, “Styrian Unconformity”, a layer of mudstone pebbles, interbedded in grey silt marks the Karpatian/Badenian boundary; d) Wagna, Badenian patch reef, intercalated in bioturbated grey silt and fine sand (arrow); e) Wagna, coral head from the patch reef; f) Wagna, erosive base of stratified sandstone beds with mollusc casts. Sedimentation gap at the NN4/NN5 zonal boundary.

na ottnangiensis, *G. tarchanensis* and *Turborotalita quinqueloba*. The abundance of agglutinated and sparseness of planktonic foraminifera have been interpreted to be a result of volcanic activity in the Styrian Basin (Spezzaferri et al., 2002a).

The top of the Karpatian shales is marked by a distinct erosional and angular unconformity, with reworked silty clasts of Steirischer Schlier in the pebbly mudstone of the Geröllmergel (Fig. 5c) and small oysters, followed by 3-5 m of bluish-grey, sandy silts. The foraminiferal fauna, as well as shallow-water ostracods and bivalves, mark this distinct unconformity. A strong change from deep-water assemblages of about 250 m water depth to inner neritic depths (< 50 m) characterizes this Styrian Unconformity that here encompasses the Karpatian/Badenian boundary and the Bur5/Lan1 sequence boundary (Rögl et al., 2002; Spezzaferri et al., 2002 a). The nannoflora of Zone NN4 in these sandy silts shows a strong increase in *Helicosphaera ampliaperta*. Foraminiferal assemblages are corroded and dominated by *Ammonia* and elphidiids. The first *Praeorbulina sicana* occurs, as well as abundant small globigerinids.

The following ca. 2.5 m of grey, bedded sandy limestone (dip 5° towards 015° E) contains a high amount of skeletal debris. In section 3, these beds interfinger laterally with a small patch reef (Wag02/15 to Wag02/16, Fig. 4), different from the succession in the Weissenegg Formation (Figs 5d, e). The following horizon is characterized by bioturbated, greyish, micaceous sandy silts and silty sands, interrupted by a thin concretion layer, and with fragments of thin-shelled bivalves at the base. The first *Praeorbulina glomerosa* occurs on top of the patch reef.

These beds are overlain by ca. 3 m of rhythmically stratified brownish silty sandstone and siltstone layers with erosive bases and with abundant mollusc casts (Fig. 5f). The erosive base of the lowermost sandstone bed (above Wag02/19, Fig. 4) encompasses the NN4/NN5 boundary, thus indicating a distinct sedimentation gap. Foraminifera are mostly dissolved, but the first record of *Amphistegina mammilla*, typical of the Badenian has been observed. *Praeorbulina circularis* and *Orbulina suturalis* also have their first occurrences here.

A lithostratigraphic definition of the clastic sequence between the Steirischer Schlier and the corallinacean limestones of the Weissenegg Formation (see below) is missing, probably also due to former biostratigraphic misinterpretations of the Karpatian/Badenian boundary (e.g. Latal and Piller, 2003). A correlation with the Kreuzberg Formation (Friebe 1990) has to be checked, as this formation interfingers with the younger Weissenegg Formation. The Geröllmergel of Retznei at least partly corresponds to this clastic sequence.

The top of the section consists of ca. 7 m of layered corallinacean limestone with intercalated silty marls of a carbonate buildup, the Weissenegg Formation (Friebe, 1990). This marks a distinct facies change, with a clear sedimentary discordance

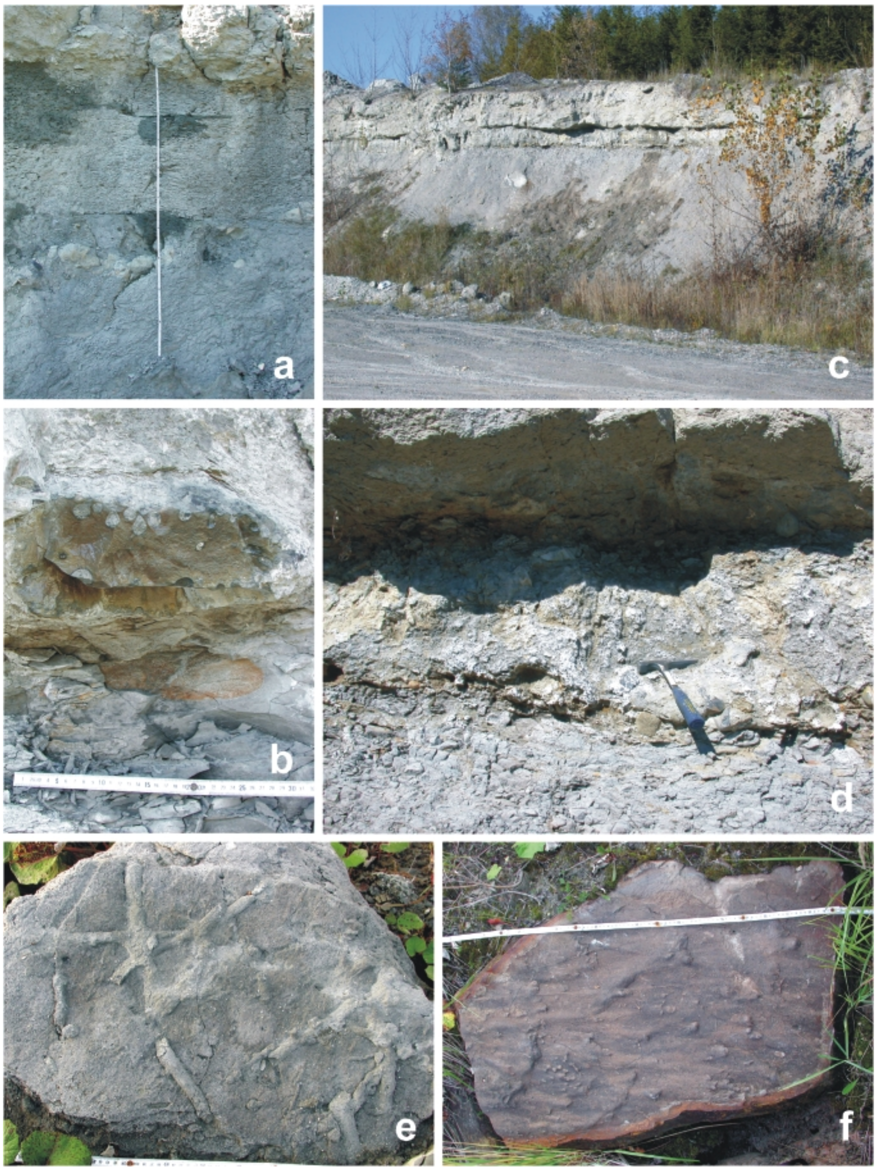

Figure 6: a) Retznei, main quarry; Karpatian section of "Steirischer Schlier" below the carbonate buildup; b) Retznei, main quarry; base of Badenian carbonate buildup with bored boulders; c) Retznei, main quarry; outcrop of so-called "Geröllmergel"; d) Retznei, main quarry; detail of Figure 6c: grey silts and sands with mainly crystalline pebbles, intercalated between Karpatian Schlier and Badenian carbonate buildup; e) *Thalassinoides* from Retznei, main quarry, section 2b; f) Flute casts of the base of the main sandstone layer at section 1, between 22.8 and 24.5 m.

and erosive base to the underlying sandstones. In the marly layers, a rich foraminiferal fauna, with agglutinated tropical/subtropical shallow water species, such as *Pseudogaudryina lapugyiensis*, *P. sturi* and *Paragaudryinella interjuncta* and also common *Amphistegina*, occur together with planktonic species of *Globigerinoides*, *Praeorbulina* and *Orbulina*. The calcareous nannoplankton belong to the nannoplankton Zone NN5.

Dinoflagellate cysts from these sections were studied by Soliman and Piller (2007). The occurrence of *Nematosphaeropsis labyrinthus* as an indicator of deep water in the Karpatian confirms results based on benthic foraminifera whilst a number of thermophilic species point to subtropical conditions throughout the sections. The position of the Karpatian/Badenian boundary proposed by Soliman and Piller (2007) is not in agreement with our observations. The correct position of the boundary in section 1 of Soliman and Piller (2007), which is based on the sections presented here, lies between samples Wag23 and Wag24, in section 2 between Wa01/16 and Wa01/17, and in section 3 between Wa02/07 and Wa02/08 (Fig. 4). The change of dinocyst assemblages was connected to a change in the palaeoenvironment reflected in the lithological change in the upper part of the Steirischer Schlier.

3.2 Retznei, Lafarge-Perlmooser cement quarries

3.2.1 Hauptstock, main quarry

The Wagna section continues to the south and is exposed in the Lafarge-Perlmooser cement quarries in Retznei. Depending on the relief, some Karpatian shales and relics of clastic basal Badenian sediments below the corallinacean limestone are exposed here.

Two outcrops were noted by Friebe (1988, 1993) as Geröllmergel. This small, 4 m high first outcrop lies in the middle of the quarry and exposes Steirischer Schlier (Fig. 6a) and the eroded top of the Karpatian. The Steirischer Schlier consists of dark-grey, silty, calcareous shales with sparse pebbles from the basement. Another pebble layer, containing calcareous clasts bored by bivalves and with trace fossils (*Gastrochaenolites*; Fenninger and Hubmann 1997), forms the base of a huge carbonate buildup (Fig. 6b). The nannoflora and microfauna of this short section are similar to the upper part of the Karpatian in Wagna. The calcareous nannoplankton comprises small reticulofenestrids; the agglutinated foraminiferal species *Spirorutilus carinatus* (Spezzaferri et al., 2002a) is characteristic. Elsewhere, the dark grey shales contain a typical Karpatian microfauna with *Gaudryinopsis beregoviensis* and *Cribrostomoides*, together with small calcareous benthic and planktonic foraminifera.

The second outcrop (Friebe 1988, 1993), which lies further to the north, exposes Karpatian Steirischer Schlier, Geröllmergel and the base of the carbonate buildup (Fig. 6c). The Karpatian is overlain by a pebble layer, followed by 1 to 4.5 m (Fenninger and Hubmann, 1997) of silt and micaceous fine sand with mainly basement pebbles (Geröllmergel; Fig. 6d). The sediment contains some mollusc and echinoid debris, and a rich foraminiferal and ostracod fauna. Shallow water species of *Ammonia* and *Elphidium* have been transported or reworked. *Pseudogaudryina*, *Textularia*, *Uvigerina*, *Heterolepa*, *Cibicidoides* and lagenids indicate an inner shelf environment. This fauna and the planktonic assemblage with *Globigerinoides trilobus*, *G. quadrilobatus*, *Praeorbulina glomerosa* and the nannoplankton of zone NN 5 indicate a correlation with the clastic Badenian part of the Wagna section below the carbonate buildup.

The carbonate buildup of the Weissenegg Formation starts in the main quarry (Fig. 6b) with a small coral reef and extends into corallinacean limestones (Leithakalk; Friebe, 1988, 1990). Towards the southeast, the limestones show a basinward transition into reworked material of the reef slope facies. Marly sands and silts, with tuffitic intercalations, drowned the top of the buildup and carbonate sedimentation ended after the start of intense volcanic activity. A thick tuff layer with black biotite and sanidine is present on top of the limestones. This layer was recently radiometrically dated to 14.21 ± 0.07 Ma or 14.39 ± 0.12 Ma (Handler et al. 2006).

The section above the carbonate buildup investigated (sampled in two overlapping sub-sections, Fig. 7) lies in the southeastern part of the main quarry (Fig. 3b). The lower part commences with 5 m of corallinacean limestones of the Weissenegg Formation, of which the base is not exposed. Approximately 8 m of silty clay and silt-clay that contains several tuffitic intercalations follow above an erosional surface (Fig. 7, sample R 01/07). The following 45 m show mostly bioturbated, homogeneous greenish-grey silty clays with intercalated horizons of silty fine sands and silty sands. The pelitic sediments frequently contain plant remains, molluscs, echinoids, crustaceans and fish teeth. The sandy horizons mostly show an upwards fining and bioturbation (*Thalassinoides*, *Ophiomorpha*; Fig. 6e). Additionally, a 1 m thick sandstone layer, deposited about 18 m above the top of the limestones (R 01/28 and R 01/29), shows flute casts at its base (Fig. 6f).

The rich foraminiferal fauna of the Lower Lagenidae Zone assemblages points to an upwards deepening in the section, from 150 to 300 m water depths, indicating strong subsidence (Hohenegger et al., 2005). *Praeorbulina circularis* and *Orbulina suturalis* occur throughout the section. The nannoplankton assemblages point to the *Helicosphaera waltrans* biohorizon within zone NN5 (Ćorić et al., 2007). This datum conforms to the recently proposed data in the Mediterranean area (Di Stefano et al., 2008). The dinoflagellate cysts of the siliciclastic sequence were studied by Soliman (in Gross et al. 2007). The occurrences of *Cerebrocysta poulsenii*, *C. placacanthum*, *Habibacysta tectata* and *Unipontidinium aquaeductum* indicate a middle Miocene age.

3.2.2 Rosenberg quarry

A detailed description of the Rosenberg quarry (new Retznei quarry) was given by Gross et al. (2007). As before, Badenian sedimentation starts on top of the Styrian Unconformity with a

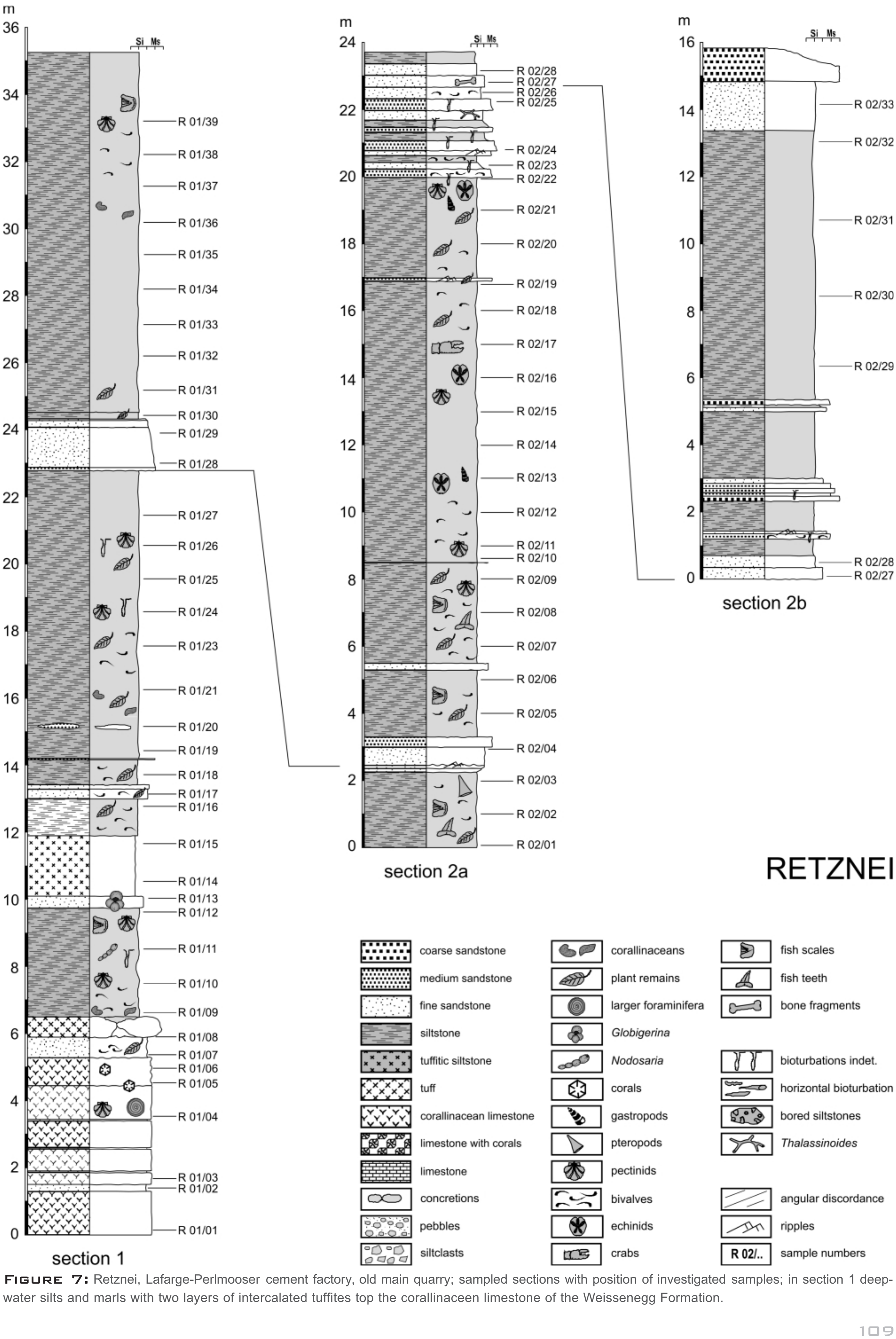

Figure 7: Retznei, Lafarge-Perlmooser cement factory, old main quarry; sampled sections with position of investigated samples; in section 1 deep-water silts and marls with two layers of intercalated tuffites top the corallinaceen limestone of the Weissenegg Formation.

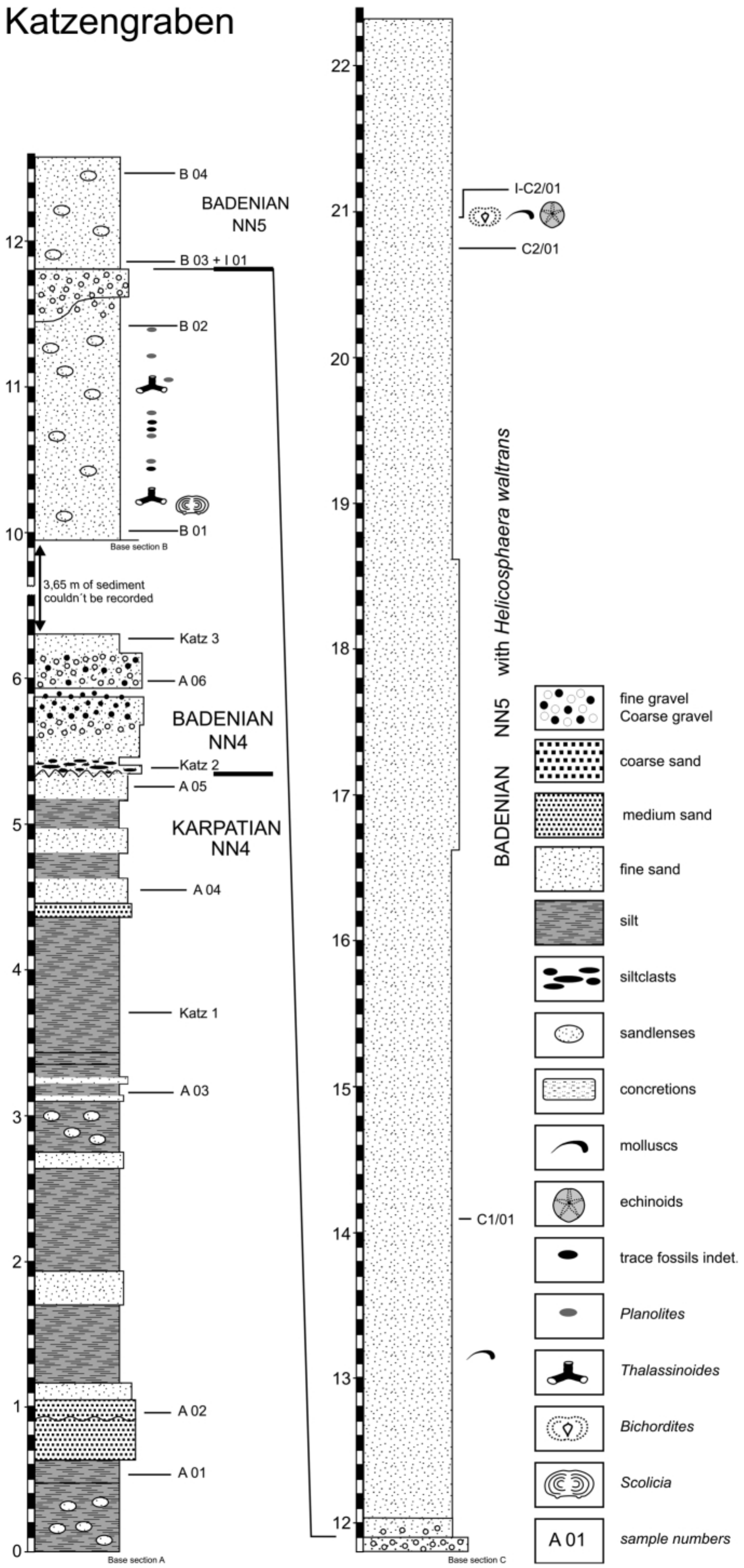

Figure 8: Katzengraben near Spielfeld; sampled section with lithology and stratigraphy.

layer of coarse pebbles (Basalkonglomerat – Geröllmergel). The overlying carbonate complex (Erhart and Piller, 2003) is heterogeneous, but also starts with coral growth. Fine-grained calcareous sandstones with corallinacean debris and *Planostegina*, the Aflenz Stone (a well-known building stone of the region), overlie coral patchreefs. Corallinacean limestones and patches of corals form the upper part of the carbonate build-up. The occurrence of *Planostegina giganteoformis* is characteristic for the Lower Badenian in the Styrian Basin. An erosional surface truncates the limestones, followed by a siliciclastic sequence, reflecting increasing water-depths.

3.3 Katzengraben section near Spielfeld

A stratigraphic succession, comparable to the Wagna and Retznei sections, but with a more clastic character, is exposed in the abandoned sand pit at Katzengraben west of Spielfeld (Figs 2, 3c). The >22 m high section consists of silt with fine sand layers and lenses; layers of medium sand are present in the basal section and clean, sometimes concretionary sandstone is characteristic of the upper part (Fig. 8). Coarse gravels and fine gravel horizons occur within a silt layer exposed from 5.35 to 6.20 m above the present base of the outcrop. At the base of these gravel bearing silts, a layer of reworked Karpatian shale pebbles was also observed. From 11.5 to 11.80 m, a silty fine sand layer with fine gravels contains dispersed lonestones on its top. Besides very rare mollusc shell fragments in the higher fine sandy part, the Katzengraben section is free of macrofossils. Trace fossils such as *Planolites*, *Thalassinoides* and *Scolicia* mainly occur in the upper part of the section.

The Kreuzkrumpel Formation was defined from Karpatian deposits in the southwestern part of the Gamlitz embayment (Schell 1994). This formation, which is unpublished (and thus invalid), encompasses silty calcareous shales (Steirischer Schlier), with interbedded sands, sandstones and gravel layers. Friebe (1990) described the Badenian sands and gravels in this area as the Kreuzberg Formation.

Friebe (1993), who described the Katzengraben outcrop with the Styrian Unconformity (Fig. 3c), regarded the lowermost part of the transgressive sequence with sandy conglomerate and siltstone cobbles as Karpatian. However, based on our observations, this part of the succession should be correlated with the sediments characteristic of the first Badenian transgression in the Wagna section (Fig. 4: Wag02/08 to Wag02/19). In both places, Karpatian shale cobbles mark the base of Badenian, accompanied by a distinct change from deep-water to shallow-water deposits. Friebe (1993) noted fossil debris, with oysters and *Gastrochaenolites*-borings, indicating shallow-water conditions. The occurrence of glauconite in the proposed Badenian sands confirms an environmental change to warmer and shallower conditions, as pyrite is a common component in Karpatian sediments. Holzer (1994) correlated the Karpatian shales with the Kreuzkrumpl Formation and the sediments above the angular unconformity with the Weissenegg Formation. The conglomerate bed in the higher part (ca. 12 m) of the sand succession (Fig. 8) corresponds to another disconformity and a further Badenian transgression, as demonstrated by calcareous nannoplankton and foraminifera. Planktonic species of *Praeorbulina* and *Orbulina* were not recorded. The Karpatian/Badenian boundary is marked by the first occurrence of the stratigraphically important shallow benthic foraminiferal species *Colominella paalzowi* and *Lingulina costata* and the overlying disconformity by the occurrence of *Vaginulina legumen* and *Pseudogaudryina lapugyensis*. The calcareous nannoplankton flora is similar to associations in the Wagna section, showing both an assemblage change within Zone NN4 at the Karpatian/Badenian boundary and the NN4/NN5 boundary at the base of the Badenian conglomerate, with the occurrence of *H. waltrans*. The mass occurrence of the small planktonic foraminiferal genus *Cassigerinella* in both Karpatian and Badenian (reworked?) sediments is interesting, as this was not observed in the Wagna section.

3.4 Perbersdorf 1 deep well

In the southern Styrian Basin (southern Gnas Subbasin), a deep well at Perbersdorf (Fig. 2) was fairly continuously cored for scientific research in 1953, by the R.K. van Sickle Company (material deposited at the Austrian Geological Survey). The succession shown in Table 1 is based on Kapounek (1954). Volcanic layers and tuffites are common, especially below 600 m drilling depth.

The results were reported by Kapounek (1954) and Kollmann (1965), partly revised by Rögl et al. (2002) and Spezzaferri et al. (2004). The well ended in Palaeozoic phyllites. Although Spezzaferri et al. (2004) placed the Karpatian/Badenian boundary at 501 m depth, at the highest occurrence of *Uvigerina graciliformis*, subsequent research, also based on calcareous nannoplankton, showed that the Badenian started much lower. The important Badenian nannoplankton marker horizon of *H. waltrans* was found between 304 m and 370 m, with the nannoplankton zonal boundary NN4/NN5 placed at 501 m, accompanied by a disconformity. Typical Karpatian nannoplankton

Depth	Lithology (acc. Kapounek, 1954)	Stratigraphy (Rögl et al., 2002 - revised here)	C. Paratethys Stages	Mediterranean Stages
0-7m	loam, sand, gravel	Quaternary	Quaternary	Quaternary
7-16	shale		Middle Badenian	Serravallian
16-156m	clayey sand and sandy shale			Langhian
156-376m	156-354m grey hard calcareous shale with corallinacean bed and molluscs 354-376m dark grey shales with sandstone (with volcanic mica)	216-288m upper part of Lagenidae Zone with *O. suturalis* & *Po. circularis*; 247-248m *Orbulina* bloom; 288-376m Lower Lagenidae Zone with *Po.circularis* & *Po.glomerosa*; 299-370m *H. waltrans* horizon; 376m FOD *Praeorbulina glomerosa*	Lower Badenian NN5	
376-501m	376-501m grey micaceous sandy calcareous shale and sandstone with volcaniclastic intercalations	376-444m Lower Lagenidae Zone with rare *Praeorbulina* cf. *sicana*, scarce *Globigerinoides*, *U. macrocarinata*, *Colominella paalzowi*; 444-501m Lower Lagenidae Zone with rare *U. macrocarinata*, *U. uniseriata*, *Psammolingulina papillosa*, LOD *U. graciliformis*; NN5		
501-838m	501-762m sandstones, grey and black shales with lignitic remains, conglomerates and gravels, and volcaniclastic intercalations	501-750m agglutinated assemblages with common *Bathysiphon*, rare Globigerinoides, *U. acuminata*, *U.* cf. *barbatula*, *V. legumen*; 750-838m rich fauna with globigerinas, *U. acuminata*, *U. macrocarinata*, *U.* cf. *barabtula*, *V. legumen*; NN4	Lower Badenian NN4	
	762-769m shale and volcaonoclastic sandstone			
	769-790m dark grey shales, sandstone and volcaniclastic layers			
	790-806m dark grey shales with floating pebbles			
	806-838m dark grey shales with floating pebbles, sandstones, conglomerates, and volcaniclastic layers			
838-935m	838-862m dark grey shales with tuffites and conglomerate layers	838-930m rich fauna with *U. graciliformis*, *U. acuminata*; NN4	Karpatian	Burdigalian
	862-930m dark grey hard shales with sandstone, conglomerate, volcaniclastic layers			
935-1335m	939-944m conglomerate with tuffitic matrix, basal dark grey sandy shale; 944-1335m dark grey micaceous and some reddish shales with sandstone, volcaniclastic layers and dominance of conglomerates, with lignitic remains and seams	939-1335m only silicified small tubes and stems	limno-fluvial Ottnangian	
1335-1470m	1335-1470m reddish, greenish and black shales with layers of conglomerates and phyllitic breccia	barren of microfossils, at 1400m continental gastropods	continental Ottnangian?	
1470-1477m	greenish phyllite		Paleozoic	Paleozoic

Table 1: Perbersdorf 1 deep well; lithology and revised biostratigraphy of the deep well in the southern Gnas Subbasin.

assemblages of NN4 were observed between 862.0 m and 930.8 m. Planktonic foraminiferal assemblages in the lower part of the section are dominated by *Globigerina* s.l., but index species are very rare. The first occurrence of *Praeorbulina* cf. *sicana* was in the upper part of the section at 442 m. Only very rare *Globigerinoides* were found down to 800 m. In the deeper parts of the well, agglutinated assemblages with a dominance of *Bathysiphon* alternate with rich calcareous benthic faunas. Occurrences of *Uvigerina macrocarinata* and *Vaginulina legumen* indicate an early Badenian age. Based on this and the well-log, the base of the Badenian has been placed at 838 m.

The Karpatian sediments show foraminiferal assemblages similar to the Badenian, with abundant agglutinated species. No sedimentary break or distinct faunal change was observed. The lowermost investigated sample, at 927.8 m, has a well-developed foraminiferal fauna with common *Spirorutilus*. This indicates sedimentation at water depths greater than those in the sublittoral facies. Coastal or near-shore Karpatian sediments are missing. Marine Karpatian sediments were only documented from 838 to 935 m.

Dark grey to red brown shales with layers of conglomerates and tuffites form the lower part of section, with some traces of lignite. The microfossil content is reduced to silicified stems and tubes, probably of plant roots. This lower part of the section is subdivided into two parts. The upper part (935 – 1335 m) is dominated by conglomerates and dark shales that might be correlatives of limno-fluviatile Ottnangian deposits (the lower Eibiswald Formation of Kollmann, 1965). The lowermost part (1335 – 1470 m), with reddish, greenish and black shales and red breccias corresponds to the continental ?Ottnangian Limnic Series. Kapounek (1954) reported some fragments of terrestrial gastropods from these shales. The sediments lie unconformably on the metamorphic basement. The core ended at 1477 m, in Palaeozoic phyllites.

Depth	Lithology (acc. cuttings)	Fossil Remains & Stratigraphy	C. Paratethys Stages	Mediterranean Stages
- 265m	50-230m alternating sand, finegrained sandstone and sitly-sandy clay with lignitic remains, and some calcareous concretions	rare mollusc debris	Pannonian	Tortonian
	250m micaceous sandstone and sand	mollusc debris with cardiids and *Melanopsis*		
267-973m	270-310m light grey to brownish silty clays	rare mollusc debris	Late Sarmatian 265-505m	Serravallian
	330-470m light grey biogeneous limestone with some quartz grains and sand	mollusc debris, ostracods, elphidiids, with *Spirolina, Borelis, Elphidium hauerinaum, Porosononion granosum*		
	490m brownish limestone	barren		
	510-610m light grey clay, sand and sandstone with lignitic remais and fecal pellets	mollusc debris, scarce foraminiferal fauna with *Elphidium hauerinum, E.* cf. *josephinum, E.* cf. *koberi*	Middle Sarmatian 505-600m	
	630-690m light grey clay and sand	mollusc debris, ostracoda, rich foraminifera with *Elphidium reginum, E. aculeatum, Bolivina sarmatica: E. reginum* Zone	Early Sarmatian 600-973m	
	710-970m sand with pebbles and light grey silty clay	typical fauna with *Anomalinoides dividens, A. transcarpathicus, Varidentella sarmatica, Fissurina* cf. *mironovi: A. transcarpathicus* Zone		
973-2127m	990m grey silty calcareous shale and sandy marl	rich fauna with *Bulimina insignis*	Late Badenian 973.0-1123.5m	
	1010-1130m grey silty shales, brownish limestone, sand and sandstone	pyritized pteropods, common foraminifera with *Pavonitina styriaca, Pappina neudorfensis, Velapertina indigena*		
	1150-1390m grey silty shale, sandy marl, sand, sandstone, and some dark limestone	some pteropods, foraminifera with *Uvigerina venusta, U.* cf. *pygmea, Orbulina suturalis*	Middle Badenian 1123.5-1374.5m	
	1410-1450m grey silty calcareous shale, micaceous sandstone	lagenid fauna with *Lenticulina ariminensis, L. orbicularis, U. grilli, U. semiornata, Orbulina suturalis,* rare *Praeorbulina:* Upper Lagenidae Zone? 1374.5-1458.8m	Early Badenian 1374.5-2127.0m	Langhian
	1470-1490m grey silty-sandy shales, fine sand and sandstone	rich plankton with *Orbulina* maximum, *Praeorbulina glomerosa, Amphistegina bohdanowiczi:* Lower Lagenidae Zone 1458.8-1490.0m		
	1510-1670m sand, sandstone and grey silty shales	rich plankton with *Praeorbulina glomerosa, Globigerinoides bisphericus, U.* cf. *macrocarinata, Cylindroclavulina rudis:* Lower Lagenidae Zone 1490-1673m		
	1690 whitish tuffite with quartz, feldspar, black mica	scarce fauna with *Po. glomerosa*		
	1710-1830m sand and some grey shales	scarce fauna		
	1850m light grey tuffaceous shales with black mica	scarce fauna -1867m		
	1870-2030m grey calcareous silty-sandy shales, sand and sandstone	agglutinated foraminifera dominant; plankton with *Po. circularis, Po. glomerosa, G. bisphericus* 1867-2035m		
	2050-2150m dark grey and brownish silty shales and sand	scarce fauna with agglutinated species, rare *Globigerinoides* and *Po. circularis* 2035-2127m		
2127-2342m	2170-2330m dark grey and brownish shales and sandstone (core 1: 2308-2318m)	scarce agglutinated fauna, rare small globigerinas with *G. bisphericus, G. trilobus*	Karpatian	Burdigalian
2342-2901m	2370-2890m conglomerates, sandstone, dark shales: basal conglomerate	barren	limno-fluvial Ottnangian	
2901-3084m	2930m grey tectonized micaceous slate		Central Alpine Palaeozoic	

Table 2: Petersdorf 1 deep well; lithology and biostratigraphy of the deep well in the northern Gnas Subbasin.

3.5 Petersdorf 1 deep well

The Petersdorf 1 deep well was drilled in 1995 by the Rohöl-Aufsuchungs AG (Vienna) in the northern Gnas Subbasin (Fig. 2), penetrating mainly coarse clastics of Pannonian und Sarmatian age. A complete Badenian succession was drilled down to 2127 m (Tab. 2). A bloom of *Orbulina* was observed at 1470 – 1490 m; this occurs in the lower Badenian of the Styrian Basin at many drill sites. Only scarce microfossil assemblages were observed between 1673 m and 1867 m, probably due to volcanic activity. Index fossils are rare below 2030 m, while agglutinated foraminifera are more common. The Karpatian part comprises the section from 2127 m to 2342 m. A core was taken from 2308 m to 2318 m, from which thin-sections showed dark grey-brown, bioturbated shales with rare agglutinated tubes. The core samples were barren of micro- and nannofossils. Conglomerates with intercalated shales, sandstones and some tuffites were found from 2342 m to 2901 m. This sequence can be correlated with the limno-fluvial Ottnangian deposits in other wells. The well ended at 3084 m in Palaeozoic micaceous slates.

3.6 Übersbach 1 deep well

The Übersbach deep well 1 was drilled in 1958/1959 by the Rohöl-Aufsuchungs AG (Vienna) in the Fürstenfeld Subbasin (Fig. 2). A profile and detailed description was given by Kollmann (1965: Pl. 3); this is presented here in short form (Fig. 9). From 8 m to 209 m, Pannonian gravel, sand and calcareous clay were drilled, followed by Sarmatian clays, oolites, sand, and gravel down to 1023 m, with a discordance and gap to the Upper Badenian *Bulimina-Bolivina* Zone. Calcareous clays with sandstones, corallinacean limestones and some tuffites form the Badenian succession, which transgressed with a basal conglomerate at 1582 m. Rich microfossil assemblages belonging to the Lagenidae Zone appear in the Lower Badenian, with a first occurrence of *Orbulina*. Marine Karpatian sandstones, calcareous shales and tuffites were recorded between 1582 m and 1980 m. Trace fossils, a few bivalves and a poor microfauna were observed, dominated by agglutinated foraminifera. Index species are missing; only a few *Ammonia* and *Elphidium* occur in the lowermost part. The underlying sequence consists of sandstones, conglomerates and shales with some lignite seams. This part of the sequence is considered to be non-marine, and therefore correlated with the limno-fluvial Ottnangian, in contrast to the interpretations of Ebner and Sachsenhofer (1991) and Polesny (2003). Flood-plain deposits with red loam, coal seams and bituminous marls at the base (Limnic Series) are considered to be Ottnangian (Polesny, 2003) but terrestrial gastropods and plant fossils did not allow a precise biostratigraphic determination. The basement, at 2636 m, is formed by Palaeozoic banded limestones.

3.7 Fürstenfeld Thermal 1 deep well

The deep geothermal well at Fürstenfeld was drilled in 1984/1985 in the Fürstenfeld Subbasin (Fig. 2). Friebe and Poltnig (1991) published a lithological and biostratigraphic subdivision of the well (Fig. 9). Early Pannonian sediments were drilled down to 194.5 m. Sarmatian sediments containing the basal *Anomalinoides* Zone followed, down to 1330 m. The Badenian succession was difficult to subdivide; based on other, nearby wells, it was here assumed that the lower part of upper Badenian correlates with the zone of agglutinated foraminifera and that the boundary of the middle/lower Badenian should be placed at 1690 m. In contrast to Friebe and Poltnig (1991) and Polesny (2003), we have placed the Karpatian/Badenian boundary at 2620 m, based on the occurrence of *Praeorbulina glomerosa*. The Karpatian, rich in conglomerates (2620 – 2748 m), yielded *Globigerinoides bisphericus*. The well ended at 3145 m in Palaeozoic rocks. Limno-fluviatile, coarse-clastic ?Ottnangian sediments were missing in this well.

4. Biostratigraphy

Biostratigraphic problems of the early/middle Miocene, Kar-

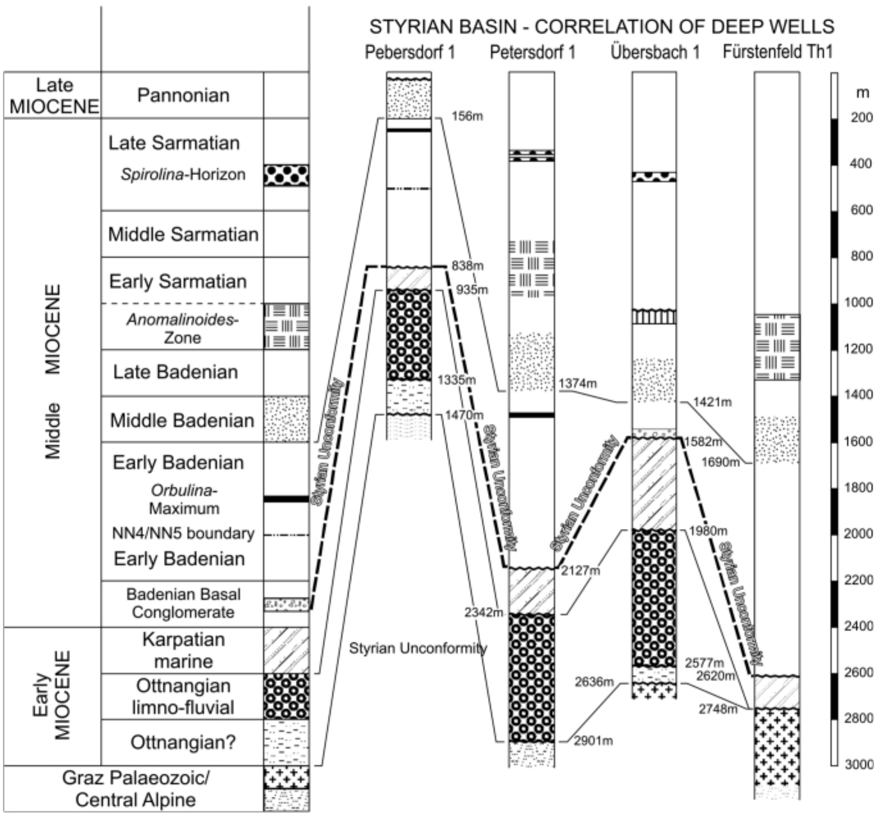

Figure 9: Correlation of deep wells in the Styrian Basin: differences of subsidence in different subbasins..The Karpatian marine sedimentation ended at the Styrian Unconformity, followed by the Badenian transgression. A basal Badenian conglomerate is developed in the Fürstenfeld Subbasin (Übersbach 1).

patian/Badenian boundary in the Central Paratethys and correlations with Mediterranean stages were recently discussed in detail (Rögl et al., 2002, 2007; Ćorić et al., 2004a, b). The Karpatian stage is characterized by the first appearance of the benthic foraminifer *Uvigerina graciliformis* within nannoplankton zone NN4, defined as the interval between the LO of *Sphenolithus belemnos* and the LO of *Helicosphaera ampliaperta*, as well as by the appearance of *Globigerinoides bisphericus* in the upper part (Cicha and Rögl, 2003). The upper surface of the Karpatian was commonly an erosion surface in Austrian Neogene basins. The base of the Badenian is determined by the first appearance of the planktonic foraminiferal genus *Praeorbulina*. This boundary is correlated with the Burdigalian/Langhian boundary in the Mediterranean region. Therefore, the basal early Badenian still belongs to nannoplankton Zone NN4 (Ćorić et al., 2004a).

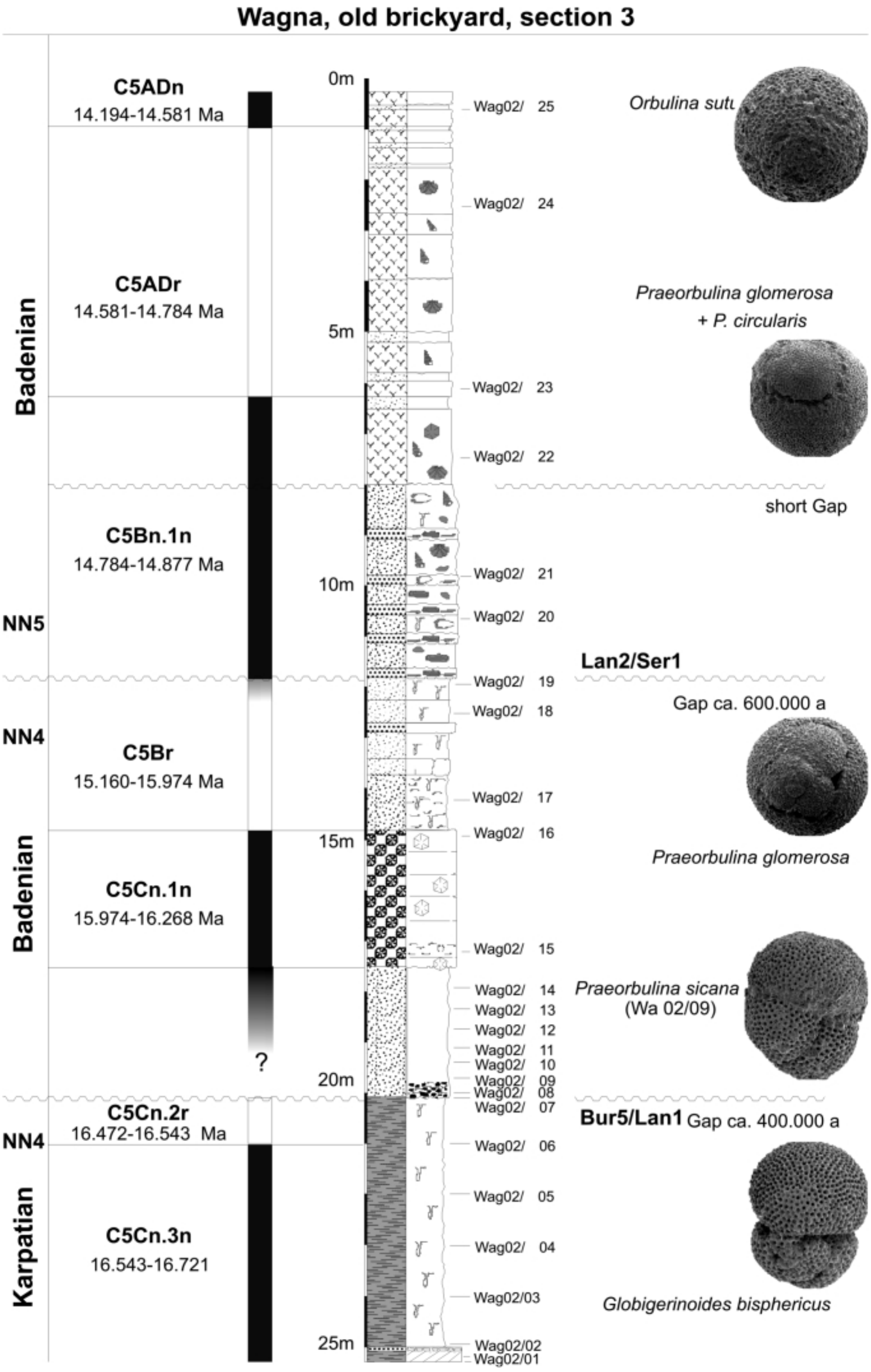

Figure 10: Wagna, old brickyard, section 3. Interpreted stratigraphy, combining lithology, biostratigraphy and palaeomagnetic results. The Styrian Unconformity is interpreted to corresponds to the Bur5/Lan1 sequence boundary. The intra-Badenian discontinuity at the Lan2/Ser1 sequence boundary separates a first Badenian transgression from the Central Paratethys wide Badenian main transgression. At the base of the corallinacean limestone of the Weissenegg Formation an additional sedimentation gap is observed.

The historical method to identify the base of the Langhian is represented by the first evolutionary appearance of *Praeorbulina glomerosa*. Fornaciari et al. (1997) proposed a revision of the Langhian historical stratotype, suggesting that the base of the type Langhian predates the *H. ampliaperta* LO and contains *Sphenolithus heteromorphus*, hence falling within Zone NN4 of Martini (1971), whilst the first evolutionary appearance of *P. glomerosa* occurs about 100 meter below the base of the Cessole Marls, which historically indicate the base of the Langhian (Vervloet 1966). Moreover, Gelati et al. (1992) considered the Langhian stratotype to represent a single depositional sequence, correlated to the 3rd-order cycle 2.3, supercycle TB2, of the Global Cycle Chart of Haq et al. (1988).

Recently, Lourens et al. (2004a) proposed, but without a formal definition, placing the base of the Langhian, and therefore the early/middle Miocene boundary, at the top of chron C5Cn, dated at 15.974 Ma.

At present, the available published data clearly indicate that there is no general agreement for the identification of the base of the Langhian. Moreover, the poorly preserved marine Langhian records prevent a clear identification of the *Globigerinoides-Praeorbulina* lineage, which is always used to identify the base of the Langhian.

In Appendix 2 of Lourens et al. (2004 b), the first appearance of *P. glomerosa* is given at 16.27 Ma, which is in full agreement with the former usage. Therefore, we conti-nue to use this biostratigraphical marker, in combination with the base of the polarity chron C5Cn.1r at 16.303 Ma, as the base of the middle Miocene (Langhian) and, consequently, as the base of the Badenian.

In the Central Paratethys and the Styrian Basin, the Steirischer Schlier belongs to the Karpatian, due to the occurrence of *G. bisphericus* and the marker of the calcareous nannoplankton zone NN4, *H. ampliaperta*. The Karpatian benthic foraminiferal marker *Uvigerina graciliformis* is also common here. In most sections, the topmost part of the Steirischer Schlier has been eroded and thus the marker species, *G. bisphericus*, is not well represented.

For stratigraphical subdivisions based on nannoplankton, the marker species *H. ampliaperta* and *S. heteromorphus* have been used; zone NN5 is defined by the absence of the former and presence of the latter. Karpatian and the lower part of the Badenian sediments in Wagna, Katzengraben und Retznei can be assigned to nannoplankton Zone NN4, whereas the upper part of the lower Badenian belongs to NN5.

Helicosphaera waltrans (Theodoridis, 1984) can be used as an additional marker within the *S. heteromorphus* Zone (NN5), by defining the LO of this species as the upper boundary of the *H. waltrans* subzone. The importance of this short range species was recognized by Fornaciari et al. (1996), but was not used as a marker for the subdivision of the miocene Mediterranean nannofossil zonation. *H. waltrans* was described by Švábenická (2002) and Ćorić and Švábenická (2004) from middle Miocene localities in the Central Paratethys (Vienna Basin and Alpine-Carpathian Foredeep). Recently, the Last Common Occurrence (LCO) of this form was used by Di Stefano et al. (2008) for the subdivision of the *Sphenolithus heteromorphus* Interval Zone (MNN5) and for defining the upper boundary of the *Sphenolithus heteromorphus – Helicosphaera waltrans* Subzone (MNN5a). Abdul Aziz et al. (2008) dated the short range of this form, with the First Common Occurrence (FCO) at 15.476 Ma and the LCO at 14.357 Ma (interpolated to ATNTS 04).

A subdivision of the Badenian in the Styrian Basin similar to the ecostratigraphic zonation of Grill (1941, 1943) for the Vienna Basin, is problematic, especially for the early Badenian. The revision of this zonation by Papp and Turnovsky (1953) was based on *Uvigerina* lineages; this subdivided the early Badenian successions by the range of *U. macrocarinata* into the Lower and Upper Lagenidae Zones. In the Styrian Basin, this species ranges throughout the early Badenian because of a distinctly deeper environment, where heavily costate *Uvigerina* species dominate. Markers of the early Badenian in the deep basin are represented by *Vaginulina legumen*, large lenticulinas (e.g. *Lenticulina ariminensis*, *L. orbicularis*), together with *U. macrocarinata*, and sometimes replace the missing *Praeorbulina*. In shelf areas, agglutinated species such as *Colominella paalzowi*, *Psammolingulina papillosa*, *Pseudogaudryina lapugyensis*, *P. sturi* and *Paragaudryinella interjuncta* mark the climatic change to warmer conditions at the base of the Badenian by their first occurrences. In the deep wells of the Styrian Basin, a bloom of *Orbulina* has been observed in the upper part of the lower Badenian, probably still in the Lower Lagenidae Zone.

In the investigated sections, a biostratigraphic subdivision of Karpatian and Badenian sediments and a correlation between shallow and deep water regions can be demonstrated:

4.1 Wagna, former clay pit

Here, only the upper part of the section, with the Styrian Unconformity and the Badenian part (Fig. 10) is discussed, because Spezzaferri et al. (2002a, 2004) gave detailed analyses of the Karpatian part.

The Karpatian and Badenian sediments from section 1 (Fig. 4, App. 1a) and section 2 (Fig. 4, App. 1b) contain *Helicosphaera ampliaperta*, which defines nannoplankton Zone NN4. Most of section 3 (Wag02/01 to Wag02/19), including the Styrian Unconformity, contains similar nannoplankton assemblages as the samples from sections 1 and 2 (App. 1c). There-

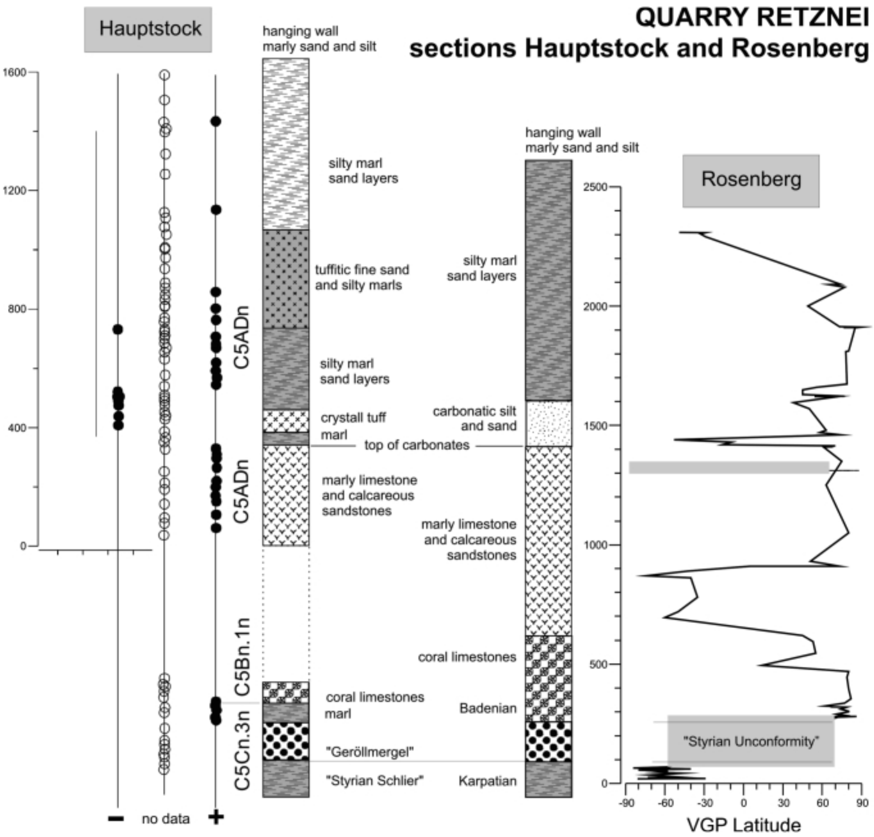

Figure 11: Palaeomagnetic results and interpretation of chrons from the Retznei Lafarge-Perlmooser cement factory, old main quarry and new quarry Rosenberg (Stingl and Scholger 2005).

fore, this part of section 3 can be assigned to the same nannoplankton zone. The last occurence of *H. ampliaperta* was observed in sample Wag02/19 and thus the NN4/NN5 boundary can be placed between samples Wag02/19 and Wag02/20, on the erosive base of the lowermost sandstone bed. Silty marls from the uppermost part of section 3 (Wag02/20 to Wag02/25) contain very rich nannoplankton assemblages, including *Helicosphaera waltrans* and can thus be attributed to Zone NN5. Just above the angular discordance and clay-pebble layer, the planktonic foraminifer *Praeorbulina sicana* marks the base of the middle Miocene (base Badenian) in sample Wag 02/09 (Fig. 4), followed by *Praeorbulina transitoria* and *P. glomerosa*. In one of the weakly cemented samples between the sandstones, *Praeorbulina circularis* is recorded together with *Orbulina suturalis*. Starting with the corallinacean limestones near the top of the Wagna section, a rich planktonic assemblage with co-occurrence of *Praeorbulina* and *Orbulina* is observed. In this upper part of the Wagna section, a typical early Badenian benthic foraminiferal fauna appears also (Apps 1d, e).

4.2 Retznei, main quarry

A small outcrop of the Steirischer Schlier (Fig. 6a) was investigated by Spezzaferri et al. (2002a) in the Retznei quarry. Calcareous nannoplankton constrain the age of these sediments to zone NN4; the appearance of *U. graciliformis* without *Praeorbulina* is indicative for the Karpatian. The uppermost, Badenian part of this section yielded nannoplankton assemblages with *H. waltrans*, indicating nannoplankton zone NN5 (App. 1f). Thus in this section, the Karpatian/Badenian and the NN4/NN5 boundaries coincide, indicating a sedimentation gap that extended for more than 1 Ma. In the second outcrop, the foraminiferal fauna of the Geröllmergel lying above the Steirischer Schlier (Fig. 6c) contains *Praeorbulina glomerosa* and *Amphistegina mammilla*, the latter being a benthic marker not represented in the Karpatian. The nannoflora of these sands and silts belong to zone NN5, with *H. waltrans*. The lower part of this section, in the Steirischer Schlier, contains *H. ampliaperta* and can be assigned to zone NN4.

In the Badenian part of the main quarry at Retznei (Fig. 7), the nannoplankton zone NN5 is recorded throughout the section and belongs to the *Helicosphaera waltrans* horizon (Apps 1g, h). Benthic assemblages correspond to the typical fauna of the Lagenidae Zone, with *Uvigerina macrocarinata*, *Vaginulina legumen* and *Amphistegina mammilla* (App. 1i). *Praeorbulina circularis* and *Orbulina suturalis* occur together in both the basal marls and the corallinacean debris, topping the autochthonous corallinacean limestone. Of stratigraphic importance are the occurrence of the globorotaliids *Paragloborotalia siakensis/acrostoma* and *Globorotalia transsylvanica* (App. 1j).

4.3 Katzengraben

The regular occurrence of *H. ampliaperta* in marly sediments from the lower part of the section at Katzengraben (Fig. 8: A01 to B02) indicates nannoplankton Zone NN4 (App. 1k). The NN4/NN5 boundary has been placed between samples B02 and B03. Note that the rare occurrence of *H. ampliaperta* in sample C1/01 probably results from reworking. The upper part of the section (B03 to C2/1) contains *H. waltrans* and can be placed into the lower part of zone NN5. *Sphenolithus heteromorpus* is rare. High percentages of *Helicosphaera carteri* indicate a shallow-water palaeoenvironment.

A rich foraminiferal fauna was determined in marly samples of the Karpatian section part. Tests were commonly corroded and some transportation from shallower regions was recorded (e.g. *Amphistegina*, *Elphidium*). Particularly remarkable are floods of the small planktonic species *Cassigerinella boudecensis* and *C. globulosa*. Most globigerinas (e.g. *Globigerina falconensis*, *G. ottnangiensis*, *G. pseudociperoensis*, *G. subcretacea*) are small and *Globoturborotalita connecta*, *Globigerinella* cf. *regularis* and *Globoquadrina langhiana* also occur. Small microperforate genera *(Tenuitella*, *Tenuitellinata*, *Turborotalita*) are common. The index fossil *Globigerinoides bisphericus* was observed in sample Katz 1 (Fig. 8). Some agglutinated species, such as *Haplophragmoides laminatus*, *Reticulophragmium karpaticum* and *Cyclammina karpatica* indicate greater water depths (outer shelf). The main fauna consists of calcareous species, where the following uvigerinids and bolivinids are stratigraphically important: *Uvigerina graciliformis*, *U. pygmoides*, *U.* cf. *bulbacea*, *Pappina primiformis*, *P. breviformis*, *Bolivina hebes* and *B. matejkai*.

No distinct faunal change was observed in the Badenian samples above the main unconformity. *Cassigerinella* dominates the planktonic assemblages but the benthic assemblages of the marly samples are highly diverse. The first typical Badenian immigrants, for example the agglutinated shallow water species *Colominella paalzowi*, *Pseudogaudryina mayeriana*, together with *Bolivina scalprata muscosa* and *B. viennensis*, occur in sample Katz 3. In sample B 02, the species *Uvigerina macrocarinata* indicates the Lower Lagenidae Zone. In the upper part of the Badenian section (samples B 03 to C 1/1) *Pseudogaudryina lapugyensis*, *P. sturi*, *Lingulina costata*, *Planularia dentata*, *Planostegina costata* and *Vaginulina legumen* occur first. The planktonic assemblages are still of small size, *Cassigerinella* is common but may have been reworked from the lower part of the section. The stratigraphically important genera *Praeorbulina* and *Orbulina* have not been observed.

4.4 Perbersdorf 1 deep well

Sediments from the lowermost part (947 m – 1311 m) do not contain nannofossils (App. 1l). As *Helicosphaera ampliaperta* is abundant in samples between 520 – 523 m, the NN4/NN5 boundary has been placed at the disconformity at 501 m. Due to the absence of this marker species, the upper part of the section (246 m to 496 m) can be assigned to nannoplankton Zone NN5. Calcareous nannoplankton assemblages with *H. waltrans* were observed from 299 m to 370 m. Abundant small reticulofenestrids within the nannoplankton assemblages above the last occurrence of *H. ampliaperta* confirm this stratigraphic subdivision.

Foraminiferal assemblages vary in this section strongly in abundance as well as in composition. All investigated core samples from 216 to 838 m belong to the early Badenian. A rich planktonic assemblage, with *O. suturalis*, *P. circularis*, *P. sicana* and *Paragloborotalia siakensis*, is present only in the uppermost part (down to 376 m; App. 1m). At 247 – 248 m, the marker horizon with the *Orbulina* bloom was observed. In the deeper parts, in which there is an increase of volcaniclastic intercalations, the biostratigraphic subdivision depends mainly on calcareous nannoplankton. Agglutinated foraminifera dominate down to 750 m, followed by rich assemblages of globigerinas and calcareous and agglutinated benthics. Benthic species such as *Vaginulina legumen* and *U. macrocarinata* indicate a Badenian age (App. 1n). In contrast to earlier interpretations (Kollmann, 1965; Spezzaferri et al., 2004), nannoplankton and foraminifera indicate that the Karpatian/Badenian boundary must be placed at 838 m. No distinct assemblage change could be observed at the boundary and thus continuous sedimentation may have occurred in this deeper part of the basin. Rich assemblages of globigerinas and benthic species occur in the Karpatian part of the section (838 – 935 m), with *U. graciliformis* as the only marker species.

4.5 Petersdorf 1 deep well

At Petersdorf, the well-log and foraminiferal assemblages indicate that the early/middle Badenian boundary lies at 1374.5 m. Within the early Badenian, at 1470 – 1490 m, the characteristic *Orbulina* bloom was recorded (App. 1o). A rich foraminiferal fauna with *O. suturalis* (down to 1590 m) and *P. circularis*, *P. glomerosa*, *U. macrocarinata* and *Cylindroclavulina rudis* (down to 1673 m) was observed. As in many drill cores, a less abundant fauna occurs deeper down (1673 – 1867m). This part is followed by a strong increase in agglutinated foraminifera, comparable to the section in Perbersdorf 1. Scarce *P. circularis* and *P. glomerosa* indicate Badenian sedimentation down to 2127 m. In the well-log, the Karpatian/Badenian boundary

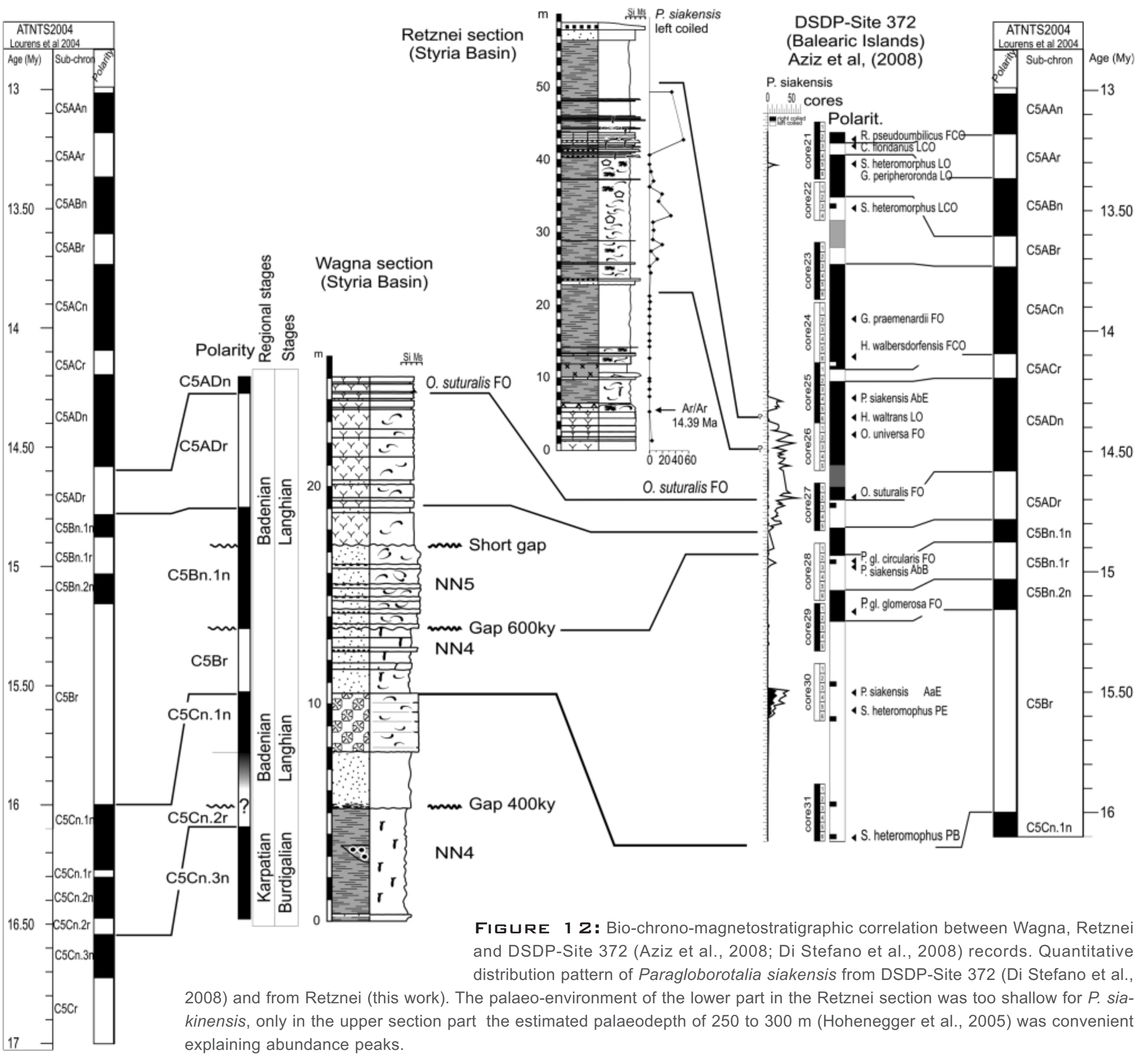

Figure 12: Bio-chrono-magnetostratigraphic correlation between Wagna, Retznei and DSDP-Site 372 (Aziz et al., 2008; Di Stefano et al., 2008) records. Quantitative distribution pattern of *Paragloborotalia siakensis* from DSDP-Site 372 (Di Stefano et al., 2008) and from Retznei (this work). The palaeo-environment of the lower part in the Retznei section was too shallow for *P. siakinensis*, only in the upper section part the estimated palaeodepth of 250 to 300 m (Hohenegger et al., 2005) was convenient explaining abundance peaks.

is shown by dipmeter measurement to be an angular unconformity. The Karpatian sequence (2127 – 2342 m) contains a scarce foraminiferal fauna with *G. bisphericus* and *G. trilobus*. Uvigerinas are missing.

4.6 Correlation between wells

A correlation profile of the investigated wells, including the published sections of Übersbach 1 and Fürstenfeld Th 1 is shown in Fig. 9. Sedimentation started in most regions with a thick cover of continental and limno-fluviatile clastics (Ottnangian). The thickness of the marine Karpatian deposits varies strongly between the wells and subbasins. The distinct Styrian Unconformity separates the Karpatian and Badenian in the Petersdorf 1 and Übersbach 1 wells, whilst continuous sedimentation was recognized at Perbersdorf 1. At Übersbach1, in the Fürstenfeld Subbasin, Badenian sedimentation started with a basal conglomerate, whereas the other wells show similar continuous deep-water conditions from the Karpatian to the Badenian. Schreilechner and Sachsenhofer (2007) presented a sequence-stratigraphic interpretation based on seismic sections of this area.

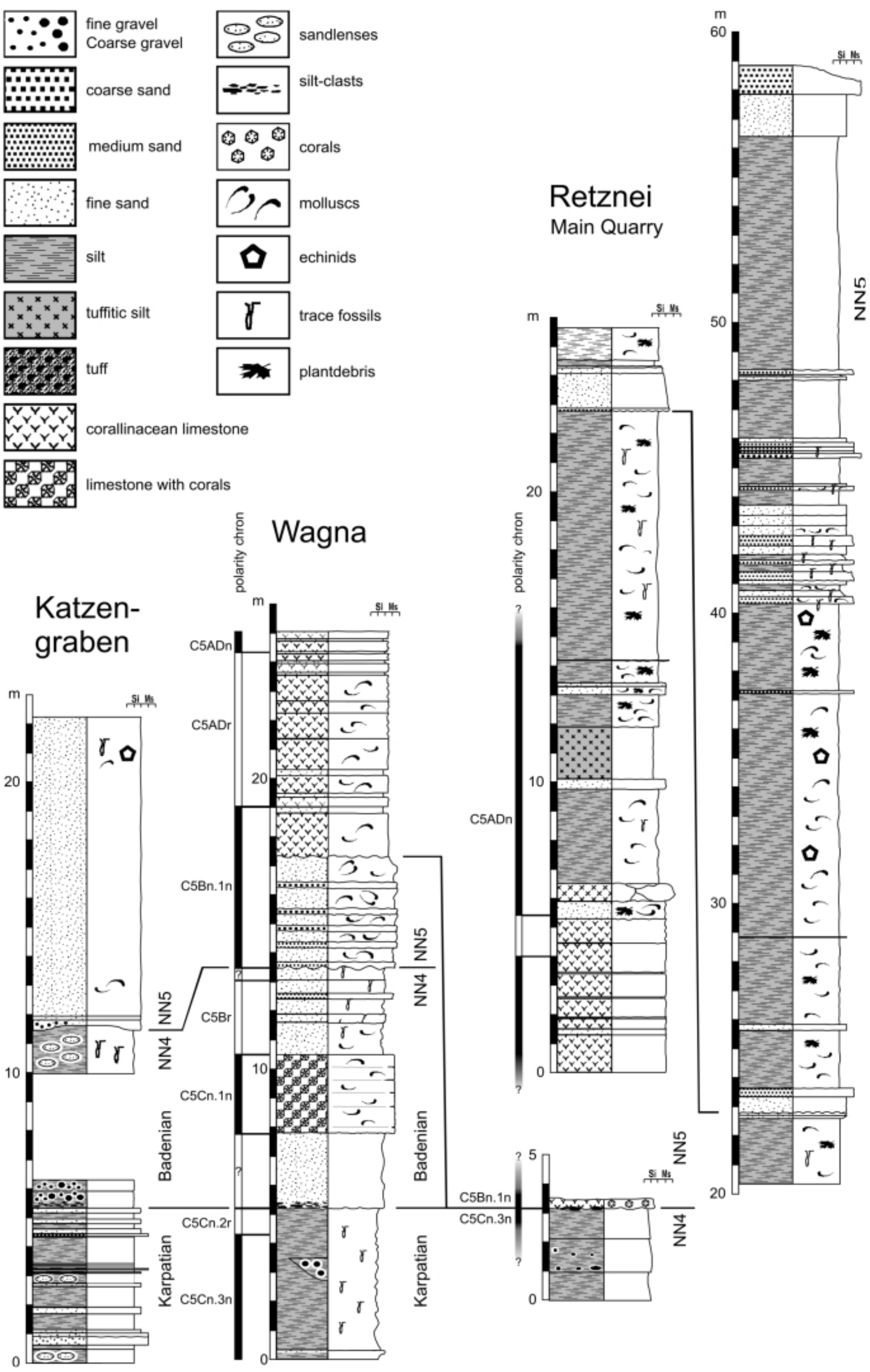

Figure 13: Correlation of the investigated sections Katzengraben near Spielfeld, Wagna/old brickyard and Retznei/main quarry, crossing the Karpatian/Badenian boundary.

5. Magnetostratigraphy

Stingl and Scholger (2005) checked the palaeomagnetic measurements of Auer (1996) in the Wagna quarry, leading to minor corrections, especially in the better-studied section 3 that contains the Karpatian/Badenian boundary. These re-investigations resulted in a sequence of normal and reverse magnetic polarities that could be assigned to distinct chrons using the established biostratigraphic markers (Fig. 10). Based on the Karpatian microfauna, the normal polarity of the basal part of section 3 must be assigned to chron C5Cn.3n and the overlying reversal to chron C5Cn.2r. The marker species *Praeorbulina sicana* in sample Wa 02/09 determines the polarity chron in these beds as C5Cn.1n, followed by the reverse chron C5Br. By assigning the normal–reverse–normal polarity sequence in the corallinacean limestones topping the section with polarity chrons C5Bn.1n, C5ADr and C5ADn, respectively, the overlying beds, characterized by rhythmically stratified brownish silty sandstones and siltstone layers, must belong to polarity chron C5Bn.1n (Fig. 10).

The results of palaeomagnetic measurements in the Hauptstock and Rosenberg sections in the Retznei quarry (Stingl and Scholger 2005) are shown in Fig. 11. In comparison with the lithology and biostratigraphy of the Wagna section (Geröllmergel), both the normal polarity in the Karpatian marls beneath the coral limestone must be placed in chron C5Cn.3n and the single measurement in the following coral limestone must be placed in chron C5Bn.1n (Figs 11, 12). The main section in the Hauptstock, with a silt-clay sequence above corallinacean limestones, shows normal polarity, interrupted by a few reversals (Fig. 11). Since this section in part biostra-tigraphically belongs to nannoplankton zone NN5 (*Helicosphaera waltrans* without *H. ampliaperta*), it must be placed in chron C5ADn. This is additionally shown by the radiometric dating of the tuffite layers.

6. Radiometric Dating and Biostratigraphy

$^{40}Ar/^{39}Ar$ dating of biotite and sanidine from the tuffite layer on top of the corallinacean limestone in the Retznei main quarry gave ages of 14.206 +/- 0.066 Ma and 14.39 +/- 0.12 Ma respectively (Handler et al. 2005, 2006). In the corallinacean limestone below and in the silty marls above the co-occurrence of *P. circularis* and *O. suturalis* is observed. The tuffite was deposited in the normal polarity chron C5ADn (14.194 – 14.581 Ma). The marls above the tuffite encompass all the investigated section at Retznei within the *H. waltrans* horizon of Zone NN5 (Fig. 7). The LCO of *H. waltrans*, dated at 14.357 Ma (Abdul Aziz et al., 2008) would support this. Within the upper part of the marls (samples R 02/07 – R 02/23), a distinct increase in the occurrence of *Paragloborotalia siakensis* left coiled is observed, which correlates with the upper part of the acme abundance of this taxon in the Mediterranean (DSDP – Site 372, Balearic Island) during chron C5ADn (upper part; Fig.12). This correlation indicates, together with the *H. waltrans* horizon, that the sanidine age of 14.39 +/- 0.12 Ma from the Retznei main quarry is reliable.

Another radiometric age was determined on tuffites in a section near Pöls, where shallow marine deposits of the Florian Formation, rich in Lower Badenian mollusc faunas are present (Kopetzky, 1957; Fritz et al., 2003). The foraminiferal fauna consists of miliolids, *Ammonia*, *Buccella*, *Nonion*, *Elphidium*, *Cibicidoides* and *Amphistegina bohdanowiczi*. Planktonic foraminifera are absent. The rare occurrence of *H. ampliaperta* indicates nannoplankton Zone NN4. $^{40}Ar/^{39}Ar$ age dating of sanidine crystals gave a plateau age of 15.75 +/- 0.17 Ma (Handler et al. 2005, 2006). This age correlates the Florian Formation with the earliest Badenian transgression in the Styrian Basin during NN4 (chron C5Br, 15.160 – 15.974 Ma).

7. Discussion

By comparisons with the Mediterranean stratigraphy, the biostratigraphic and palaeomagnetic results have allowed the time ranges of sedimentation gaps to be calculated between the transgressions in the investigated near-shore localities (Figs 10, 12, 13). In the basinwards positioned Wagna clay pit, the time gap between polarity chrones C5Cn.2r and C5Cn.1n, which contains the first Badenian transgression, was ca. 400 ky. The second gap, between C5Br and C5Bn.1n, which includes the second Badenian transgression and the NN4/NN5 boundary, was ca. 600 ky (Figs 10, 12). This gap is much longer at the near-shore Retznei quarry, where polarity chron C5Bn.1n (NN5) directly follows C5Cn.3n (NN4), thus marking a time gap of ca. 1.6 Ma (Figs 11, 13).

The correlation of calcareous nannoplankton and planktonic foraminiferal events between the Styrian Basin and the Mediterranean demonstrates similarities caused by marine connections. In the case of benthic foraminifera, the marker species for regional stratigraphy have been evaluated. Major bio-events, such as some of the observed hiatuses and transgressions, especially in near-shore areas, enables a correlation with the 3rd order sequences of Haq et al. (1988) and Hardenbol et al. (1998). Similar results have been obtained by the interpretation of seismic lines in the eastern part of the basin (Schreilechner and Sachsenhofer 2007).

To compare the global sequences with those of the Styrian Basin, it was necessary to calibrate the curves with the new time-scale and palaeomagnetic geochronology of Lourens et al. (2004 a, b). The palaeomagnetic data of the Haq and Hardenbol tables has been evaluated and correlated accordingly (Tab. 3). The Karpatian transgression has been compared with sequence TB 2.2, where the regression due to the falling-stage system tract was intensified by tectonic movements of the Styrian Tectonic Phase, forming angular unconformities and leading to extreme shallowing and erosion. This was followed by the first Badenian transgression of cycle TB 2.3 (Fig. 14) seen in the Wagna section between samples Wag02/08 and Wag02/19 as shallow water sediments with coral patches (Fig. 10). The global sequence boundary Lan2/Ser1 was found in the Wagna section above sample Wag02/19, followed by the transgressive cycle TB 2.4 of the far-spread Badenian transgression that covered the entire Central Paratethys. Although radiometric and biostratigraphical data indicate that the youngest part of the investigated outcrops in Retznei belongs to the falling-stage system tract, the constantly increasing water depth, seen in the benthic and planktonic foraminifera, demands tectonic subsidence. The sequence boundary Ser2, compared with the Langhian/Serravallian boundary, was only detected in the Petersdorf deep well 1.

Global sequences	Pal.Mag. Chron	Pal.mag. chrons acc. Lourens et al. 2004	sequence age acc. Haq et al.1988	sequence age acc. Hardenbol et al.1998	re-calibrated sequence age (this study)
Tor2	base C4Ar1.1	9.098-9.312	8.2	9.2	9.30
TB 3.1	upper C5n.2n	9.987-11.040	9.2		10.00
Ser4/Tor1	base C5r	11.614-12.014	10.5	12.0	11.60
TB 2.6	in C5r.3r	11.614-12.014	11.6		12.00
Ser3	C5Ar.2r	12.765-12.820	12.5	12.7	12.73
TB 2.5	in C5ABn	13.369-13.605	13.4		13.50
Ser2	mid C5ABr	13.605-13.734	13.8	13.6	13.65
Lan2/Ser1	top C5Bn.1n	14.784-14.877		14.8	14.78
TB 2.4	in C5Bn.1n	14.784-14.877	15.0		14.85
sequ.bound.	mid C5Br	15.160-15.974	15.5		15.50
TB 2.3	in C5Cn.1n	15.974-16.268	16.0		16.10
Bur5/Lan1	in C5Cn.2n	16.303-16.472	16.5	16.4	16.30
TB 2.2	base C5Cn.3n	16.543-16.271	17.0		16.72
Bur4	top C5Dn	17.235-17.533	17.5	17.3	17.23
TB 2.1	base C5Dr	17.740-18.056	18.5		18.00
Bur3	lower C5En	18.056-18.524		18.7	18.45
Bur2	middle C6n	18.748-19.722		19.5	19.20
Aq3/Bur1	top C6An.1n	20.040-20.213	21.0	20.52	20.05

Table 3: Calibration of sequences. Based on the position in palaeomagnetic polarity chrons, global sequences of 3rd order in Haq et al. (1988) and Hardenbol et al. (1998) have been calibrated to the new chron ages of Lourens et al. (2004a).

8. Conclusion

At the early/middle Miocene boundary, that is, the Karpatian/Badenian and Burdigalian/Langhian boundary, a series of transgressive events in the Styrian Basin were combined with tectonic events of the classical Styrian Tectonic Phase. The formation of the Styrian Basin started during the early Miocene, as swamp and floodplain deposits of probable Ottnangian age, lying on top of the deeply eroded Austroalpine nappes, were transgressed during the Karpatian by the Paratethys Sea. A series of marine ingressions of the Badenian Sea followed the deep water sediments of the Karpatian Steirischer Schlier. During the Badenian, tectonic activity was accompanied by extensive volcanism.

Changes in sedimentary facies and sedimentation rates, unconformities, sedimentation gaps, as well as tectonic and volcanic activity demonstrate that the Styrian Phase was an event that occurred around the early/middle Miocene boundary. New stratigraphic results, in combination with palaeomagnetic and micropalaeontological investigations, allow the timing of these events to be constrained. A major event is represented in nearshore sediments between the sedimentation of the Karpatian Steirischer Schlier and the lowermost Badenian silts, with tilting of the Steirischer Schlier, to form the Styrian Unconformity. The first Badenian transgression is represented in the Wagna section after a sedimentation gap between 16.5 and 16.1/16.2 Ma, while in deep wells of the central basin sedimentation was continuous.

The next sedimentation gap in nearshore regions occurred around the nannoplankton zone NN4/NN5 boundary (14.74 Ma), between polarity chrons C5Br and C5Bn.1n, ranging from about 15.4 to <14.8 Ma; this marks the second Badenian transgression.

A third discontinuity, at the base of the corallinacean limestones lying on top of the Wagna section, is too short to be precisely dated. In the Retznei sections, this sedimentation gap extends from top of the Karpatian Steirischer Schlier to the base of the carbonate sedimentation, thus showing a large gap between nannozones NN4 and NN5. At a few places, sandy-silty sediments of the early Badenian are intercalated below the carbonates of the Weissenegg Formation.

Volcanic ash layers and tuffites were deposited at the base of marls and silts belonging to zone NN5 that overlie the corallinacean limestones of the Weissenegg Formation. The overlapping range of Praeorbulina and Orbulina, both present in this upper section part, allows the assignment to chron C5ADn (14.19 – 14.58 Ma), which is confirmed by radiometric dating. Although the global 3rd order sequence marks a regression for this period, the observed deepening tendency must have been caused by continuing tectonic processes.

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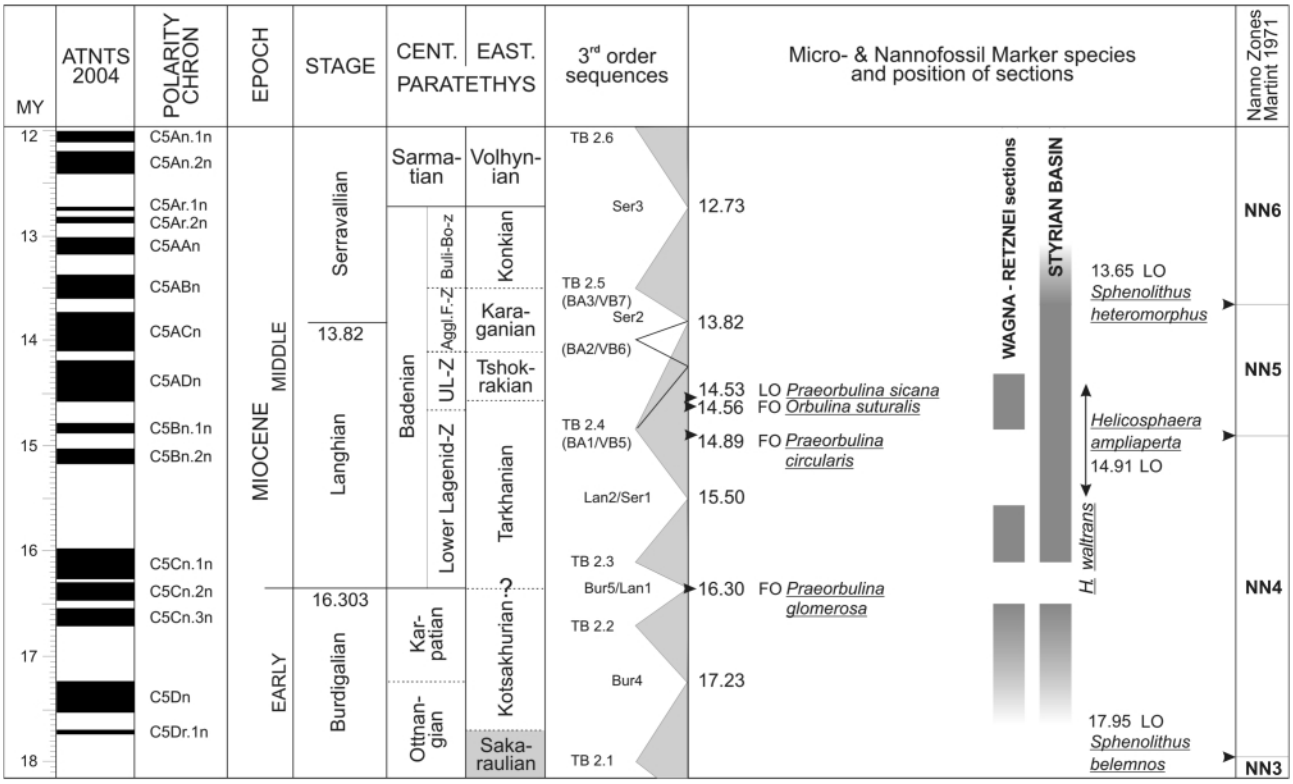

Figure 14: Integrated stratigraphy of the Early/Middle Miocene with a revised cyclostratigraphic model for the Austrian Neogene basins. The discontinuous sections of the Wagna and Retznei outcrops, and the transition in the deeper parts of the Styrian Basin are shown. The additional sequence boundary at 14.20 Ma and cycle BA2/VB6 are given according to Kovač et al. (2004) and Strauss et al. (2006) based on seismic profiles in the Vienna Basin.

the Wagna section was investigated and in 2001 and 2002, when the upper part of the Wagna section and the complete Retznei section were investigated in detail, with support from participants on a field course run by the Department of Palaeontology, University of Vienna. The Katzengraben section was investigated during a field course in 2007. We especially thank Silvia Spezzaferri (University of Fribourg, Switzerland) for her work within project P13743-BIO. For support the sampling work, we thank the owners of the old Wagna quarry and of the Lafarge-Perlmooser Zement AG Retznei. We thank the Rohöl-Aufsuchungs AG (Vienna) and the Austrian Geological Survey for permission to study samples from deep wells. For additional information on the region, we are grateful to our colleagues F. Ebner (Leoben), G. Friebe (Dornbirn), R. Handler (Salzburg) and H. Hiden (Graz).

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Appendix:

Wagna Section 1 Samples	Stage/Nannoplankton Zone	*Calcidiscus leptoporus*	*Coccolithus miopelagicus*	*C. pelagicus*	*Cyclicargolithus floridanus*	*Discoaster deflandrei*	*D. musicus*	*Helicosphaera ampliaperta*	*H. carteri*	*H. scissura*	*H. walbersdorfensis*	*Reticulofenestra haqii*	*R. minuta*	*R. pseudoumbilica*	*R. gelida*	*Sph. heteromorphus*	*Sph. moriformis*	*Syracosphaera pulchra*	*Triquetrorhabdulus millowii*	*Umbilicosphaera jafarii*
Wag26	NN 4 (Martini, 1971) / BADENIAN		r	c	r	r	r	r	f	r	r	r	f	r	r	r	r	r		r
Wag25		r	r	c	r				f				r	r	r	r	r	r		
Wag24		r	r	c	r	r		r	f			r	r	r	r	r	r	r		
Wag23			r	c	r			r	f	r		r	r	r	r	f	r	r		
Wag22		r	r	c	r			r	f			r	r	r	r	f	r	r		
Wag21			r	c	r				f			r	r		r	r	r	r		r
Wag20		r	r	c	r			r	f	r		r	r	r	r	f	r	r		
Wag19		r	r	c	r	r		r	f			r	f	r	r	f	r	r	r	
Wag18		r	r	c	r			r	f			r	r	r	r	f	r	r		
Wag17		r		c	r			r	f			r	r	r	r	f	r	r		
Wag16		r		c	r			r	f	r		r	f	r	r	f	r	r		
Wag15		r	r	c	r			r	f	r		r	r	r	r	f	r	r		
Wag14			r	c	r			r	f	r		r	f	r	r	f	r	r		
Wag13		r	r	c	r				f			r	r	r		f	r	r		
Wag12		r	r	c	r			r	f	r	r	r	r	r	r	r	r	r		
Wag11		r	r	c	r			r	f			r	r		r	f	r	r	r	
Wag10		r	r	c	r			r	f	r		r	r	r	r	f	r	r	r	
Wag09			r	c	r			r	f				r	r	r	r	r	r		
Wag08		r	r	c	r	r		r	f	r		r	f	r	r	f	r	r		
Wag07		r	r	c	r			r	r	r		r	r	r		f	r	r	r	
Wag06			r	c	r			r	f		r	r	r	r	r	r	r	r		
Wag05		r	r	c	r	r		r	f	r		r	r	r	r	r	r	r	r	r
Wag04		r	r	c				r	f	r		r	r	r	r	r	r	r	r	
Wag03		r	r	c	r	r			f		r	r	f	r	r	r	r	r		r
Wag02		r	r	c	r			r	f	r		r	f	r		r	r	r		r
Wag01		r	r	c	r			r	f		r	r	f	r	r	r	r	r		

Appendix 1A: Wagna brickyard; distribution of stratigraphically important calcareous nannoplankton and biostratigraphic zonation in section 1. a = abundant, > 90% ; c = common, 50% – 90%; f = few, 10% – 50%; r = rare, < 10% of total abundance.

Wagna Section 2 Samples	Stage	Nannoplankton Zones (Martini, 1971)	*Calcidiscus leptoporus*	*Calcidiscus tropicus*	*C. miopelagicus*	*C. pelagicus*	*Cyclicargolithus floridanus*	*D. adamanteus*	*D. deflandrei*	*D. exilis*	*D. variabilis*	*H. ampliaperta*	*H. carteri*	*H. scissura*	*H. walbersdorfensis*	*Pontosphaera multipora*	*R. haqii*	*R. minuta*	*R. pseudoumbilica*	*R. gelida*	*S. heteromorphus*	*S. moriformis*	*Triquetrorhabdulus millowii*	*U. jafarii*
Wag01/24		NN4	r	r	r	c	r					r	f	r		r	r	f	r	r	r	r	r	r
Wag01/23	BADENIAN		r		r	c	r					r	f	r		r	r	f	r	r	r	r	r	
Wag01/22				r	r	c	r					r	f	r		r	r	r	r	r	r	r		
Wag01/21					r	c	r					r	f	r			r	f	r	r	r	r		r
Wag01/20			r	r	r	c	r		r			r	f	r	r	r	r	r	r	r	r	r		r
Wag01/19			r	r	r	c	r			r		r	f	r		r	r	f	r	r	r	r		r
Wag01/18			r	r	r	c	r					r	f	r		r	r	f	r	r	r	r		r
Wag01/17					r	c	r		r			r	f	r		r	r	f	r	r	r	r		r
Wag01/16	KARPTIAN		r	r	r	c	r						r				r	r	r	r	r	r	r	
Wag01/15			r	r	r	c	r				r		f				r	r	r	r	r	r	r	
Wag01/14					r	c	r	r	r				r				r	r	r	r	r	r	r	
Wag01/13			r	r		c	r						r	r			r	r	r	r	r	r		
Wag01/12			r	r	r	c	r					r	r				r	r	r	r	r	r	r	
Wag01/11			r	r	r	c	r						r	r			r	r		r	r	r	r	
Wag01/10			r		r	c							r	r			r	r	r	r	r	r	r	
Wag01/09			r	r	r	c	r		r				r				r	r	r	r	r	r		
Wag01/08			r		r	c	r						f				r	r	r	r	r	r	r	
Wag01/07			r	r	r	c	r						f	r				r	r	r	r	r		
Wag01/06			r		r	c	r	r					f			1	r	r	r	r	r	r	r	
Wag01/05			r	r	r	c	r						f			1	r	r	r	r	r	r		
Wag01/04			r		r	c	r						f				r	r		r	f	r	r	r
Wag01/03			r	r	r	c	r						f	r			r	r	r	r	f	r		
Wag01/02			r	r	r	c	r						f	r			r	f	r	r	f	r		
Wag01/01			r		r	c	r						r					r	r	r	f	r		

Appendix 1B: Wagna brickyard; distribution of stratigraphically important calcareous nannoplankton and biostratigraphic zonation in section 2. a = abundant, > 90% ; c = common, 50% – 90%; f = few, 10% – 50%; r = rare, < 10% of total abundance.

Wagna Section 3 Samples	Stage	Nannoplankton Zones (Martini, 1971)	Meters	*Calcidiscus leptoporus*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus floridanus*	*Discoaster adamanteus*	*Discoaster deflandrei*	*Discoaster exilis*	*Discoaster variabilis*	*Helicosphaera ampliaperta*	*Helicosphaera carteri*	*Helicosphaera scissura*	*Helicosphaera walbersdorfensis*	*Helicosphaera waltrans*	*Reticulofenestra haqii*	*Reticulofenestra minuta*	*Reticulofenestra pseudoumbilica*	*Reticulofenestra gelida*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Syracosphaera pulchra*	*Triquetrorhabdulus millowii*	*Umbilicosphaera jafarii*
Wag02/25	BADENIAN	NN5	0.3	r	r	f	r						f		r	r	f	c	r	r	f	r			r
Wag02/24			2.3		r	f				r	r		f			r	r	c	r	r	f	r	r		r
Wag02/23			5.9		r	f	r						f			r	r	c	r	r	r	r			r
Wag02/22			7.3		r	f							f			r	f	c	r		r	r			
Wag02/21			9.7			r	r		r				r		r	r	r	a							r
Wag02/20			10			r							r				r	a	r		r	r			r
Wag02/19		NN4	11	r	r	c						r	f				r	f	r	r	r	r	r	r	r
Wag02/18			12		r	c	r		r			r	f	r			r	f	r	r	r	r	r		r
Wag02/17			14		r	c	r					r	f	r	r		r	f	r	r	r	r	r		r
Wag02/16			15	r	r	c			r				f		r		r	f	r	r	r	r	r		r
Wag02/15			17	r	r	c	r					r	f	r	r		r	f	r	r	r	r	r		r
Wag02/14			18		f	c	r					r	f	r	r		r	f	r	r	r	r	r		
Wag02/13			18	r	r	c						r	f	r			r	f	r	r	r	r	r	r	r
Wag02/12			18		r	c	r		r			r	f	r			r	f	r	r	r	r	r	r	r
Wag02/11			19		r	c	r					r	f	r	r		r	f	r	r	r	r	r		r
Wag02/10			19	r	r	c			r			r	f	r	r		r	f	r	r	r	r	r		r
Wag02/9			19		r	c	r					r	f	r	r		r	f	r	r	r	r	r	r	
Wag02/8			20		r	c	r					r	f	r	r		r	f	r	r	f	r	r	r	r
Wag02/7	KARPATIAN		20	1	r	c	r						f				r	f	r	r	f	r	r		
Wag02/6			21	r	r	c	r					r	f				r	f	r	r	r	r	r	r	
Wag02/5			22		r	c	r		r				r				r	r	r	r	r	r			
Wag02/4			23	r	r	c	r					r	r				r	r	r	r	r	r	r	r	r
Wag02/3			24	r	r	c	r		r				r				r	r	r	r	r	r	r		
Wag02/2			25		r	c	r						f				r	r	r	r	f	r	r		
Wag02/1			25	r	r	c	r						f	r			r	r	r	r	f	r	r	r	r

APPENDIX 1C: Wagna brickyard; distribution of stratigraphically important calcareous nannoplankton and biostratigraphic zonation in section 3. a = abundant, > 90% ; c = common, 50% – 90%; f = few, 10% – 50%; r = rare, < 10% of total abundance.

WAGNA OLD BRICKYARD section 2	small globigerinas	*Globoturborotalita woodi*	*Globigerinoides bisphericus*	*Globigerinoides trilobus*	*Globigerinoides quadrilobatus*	*Praeorbulina circularis*	*Uvigerina graciliformis*	*Uvigerina laviculata*	*Pappina primiformis*	*Pappina parkeri*	STAGES
WA 01/24	x					x	x				BADENIAN
WA 01/23	x			x	x						
WA 01/22	x	x								x	
WA 01/21	x										
WA 01/20	x			x							
WA 01/19	x						x				
WA 01/18	x			x							
WA 01/17	x	x					x				
WA 01/16	x						x		x		KARPATIAN
WA 01/15	x						x		x		
WA 01/14	x						x		x		
WA 01/13	x						x		x		
WA 01/12	x						x				
WA 01/11	x						x				
WA 01/10	x						x				
WA 01/9	x						x				
WA 01/8	x						x	x			
WA 01/7	x						x		x		
WA 01/6	x						x				
WA 01/5	x						x	x	x		
WA 01/4	x		cf				x	x	x		
WA 01/3	x						x	x			
WA 01/2	x	x					x				
WA 01/1	x						x	x	x		

APPENDIX 1D: Wagna brickyard, section 2 in the southern part of the outcrop; stratigraphically important planktonic and benthic foraminiferal species in the upper part of the Karpatian and in the lower Badenian.

WAGNA OLD BRICKYARD section 3	small globigerinas	*Globigerinoides bisphericus*	*Globigerinoides trilobus*	*Globigerinoides quadrilobatus*	*Praeorbulina sicana*	*Praeorbulina transitoria*	*Praeorbulina glomerosa*	*Praeorbulina circularis*	*Orbulina suturalis*	*Uvigerina graciliformis*	*Pappina primiformis*	*Pseudogaudryina lapugyensis*	*Paragaudryinella interjuncta*	*Amphistegina mammilla*	Remarks	STAGES
WA 02/25	x	x	x	x	x		x	x	x			x	x	x		BADENIAN
WA 02/24	x	x	x		x		x	x				x		x	corallinacean limestone with volcanic mica	
WA 02/23	x	x	x			x	x						x	x		
WA 2002/3		x	x		x							x	x	x		
WA 02/22	x	x	x		x		x	x	x			x	x	x		
WA 2002/2		x	x	x				x	x			x	x	x	sandstone and sand	
WA 2002/1																
WA 02/21	x			x												
WA 02/20	x		x													
WA 02/19	x									x						
WA 02/18	x		x			x										
WA 02/17	x	x	x													
WA 02/16	x		x				x									
															patch reef	
WA 02/15		x	x		x	x										
WA 02/14	x		x													
WA 02/13	x															
WA 02/12	x		x													
WA 02/11	x	x														
WA 02/10	x		x													
WA 02/9	x		x		x											
WA 02/8	x			x												
WA 02/7	x		x							x						KARPATIAN
WA 02/6	x		x							x						
WA 02/5	x									x	x					
WA 02/4	x									x	x					
WA 02/3	x									x	x					
WA 02/2	x									x	x					
WA 02/1	x	cf								x	x					

APPENDIX 1E: Wagna brickyard, section 3 in the northern part of the outcrop; important planktonic and benthic foraminiferal species in the upper part of the Karpatian and lower Badenian. The Styrian Unconformity and subdivision of Badenian sediments is demonstrated.

Retznei Section 00 Samples	Stage	Nannoplankton Zones (Martini, 1971)	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Coronocyclus nitescens*	*Cyclicargolithus floridanus*	*Helicosphaera ampliaperta*	*Helicosphaera carteri*	*H. waltrans*	*H. scissura*	*Reticulofenestra gelida*	*R. haqii*	*R. minuta*	*R. pseudoumbilica*	*Sphenolithus heteromorphus*	*Sph. moriformis*	*Syracosphaera pulchra*	*Triquetrorhabdulus milowii*	*Umbilicosphaera jafarii*
Re 00/8	Badenian	NN5		f				r	r			r	a		r				r
Re 00/7	Karpatian	NN4	r	c		r	r	f		r		r	r	r	r	r	r	r	
Re 00/6				c		r	r	f		r	r	r	r	r	r	r	r		
Re 00/5				c		r	r	f		r	r	r	f	r	r		r		
Re 00/4			r	c		r	r	f		r	r	f	f	r	r	r	r		
Re 00/3A			r	c		r	r	r			r	r	f	r	r	r	r		r
Re 00/3			r	c		r	r	f		r	r	r	f	r	r	r	r		
Re 00/2			r	c	r	r	r	f			r	r	f	r	r	r	r		r
Re 00/1			r	c	r	r	r	f		r	r	r	r	r	r	r	r		

APPENDIX 1F: Retznei, Lafarge-Perlmooser Cement Factory, main quarry, section in the center of the quarry (Friebe 1988, 1993). Stratigraphically important calcareous nannoplankton and biostratigraphic zonation. a = abundant, > 90% ; c = common, 50% – 90%; f = few, 10% – 50%; r = rare, < 10% of total abundance.

Retznei Section 01 Samples	Stage/Nannoplankton Zone	m	*Coccolithus miopelagicus*	*C. pelagicus*	*Coronocyclus nitescens*	*Cyclicargolithus floridanus*	*Discoaster adamanteus*	*D. exilis*	*D. formosus*	*D. musicus*	*D. variabilis*	*Geminilithella rotula*	*Helicosphaera carteri*	*H. walbersdorfensis*	*H. waltrans*	*Reticulofenestra haqii*	*R. minuta*	*R. pseudoumbilica*	*R. gelida*	*Rh. sicca*	*S. heteromorphus*	*S. moriformis*	*Syracosphaera pulchra*	*Umbilicosphaera jafarii*
R 01/39		2	r	r				r			r	r	r	r		r	a	r		r	r	r	r	r
R 01/38		3	r	r			r	r			r	r	r	r	r	r	a	r	r	r	r		r	r
R 01/37		4		r			r	r	r		r	r	r	r	r	r	a	r			r	r	r	r
R 01/36		5		r				r			r	r	r	r	r	r	a	r		r	r	r		r
R 01/35		6		r	r						r	r	r		r	r	a	r	r	r	r	r	r	r
R 01/34		7	r	r				r			r	r	r	r		r	a	r	r	r	r	r		r
R 01/33		8		r			r				r	r	r	r		r	a	r		r	r	r	r	r
R 01/32		9		r								r	r	r	r	r	c	r	r	r	r	r		r
R 01/31		10		f								r	r	r	r	r	c	r		r	r	r		r
R 01/30		10.8	r	f								r	r	r	r	r	c	r	r	r	r	r	r	r
R 01/29		11.3		f		r						r	r	r	r	r	c	r		r	r	r	r	r
R 01/28		12.2		r									r	r		r	a	r	r	r	r	r	r	r
R 01/27	N N 5 (Martini, 1971)	13.7		f	r							r	r		r	r	c	r	r	r	r	r		
R 01/26		14.7		f				r				r	r	r		r	c	r			r	r	r	
R 01/25		15.7	r	f								r	r		r	r	c	r		r	r	r		r
R 01/24		16.7		f								r	f	r	r	r	c		r	r	r	r		r
R 01/23		17.7		f								r	r			r	c	r	r	r	r	r		r
R 01/21		19		f								r	r		r	r	c	r	r		r	r	r	r
R 01/20		20.1		f									r		r	f	c	r	r		r	r		r
R 01/19		20.8		f								r	r		r	r	c	r	r	r	r	r	r	r
R 01/18		21.5	r	f								r	r		r	f	c	r	r		r	r		r
R 01/17		22.1		f							r	r	r		r	f	c	r	r		r	r	r	r
R 01/16		22.5		f		r					r	r	r		r	r	c	r	r	r	r	r		r
R 01/15		23.6		c									r				r				r			
R 01/14	B A D E N I A N	24.7		f	r					r	r	r	r	r	r	r	a	r		r	r		r	r
R 01/13		25.2		f/c	r						r	r	r	r	r	r	c	r	r		r	r		r
R 01/12		25.6		f			r				r	r	r	r	r	r	c	r	r		r	r	r	r
R 01/11		26.7		f	r							r	r	r		r	c	r		r	r	r		r
R 01/10		27.7		f	r			r					r		r	r	c	r		r	r	r		r
R 01/9		28.5		f								r	r		r	r	c	r		r	r	r		r
R 01/8		29.2		f									r		r									
R 01/7		29.8		f									r		r	r	c	r		r	r	r	r	
R 01/6		30.2		f	r								r		r	r	c			r	f	r	r	r
R 01/5		30.6		f									r		r	r	c		r	r	r			r
R 01/4		31.6	r	f				r	r			r	r		r	r	c	r	r	r	r			r
R 01/3		33.4		f							r	r	r		r	r	c		r	r	r	r	r	r
R 01/2		33.7		f									r		r	r	c	r	r	r	r	r	r	
R 01/1		35	r	69								r	r	r	r	r	c	r	r		r	r	r	r

Appendix 1G: Retznei, Lafarge-Perlmooser Cement Factory, main quarry, section R 01. Stratigraphically important calcareous nannoplankton and biostratigraphic zonation. a = abundant, > 90% ; c = common, 50% – 90%; f = few, 10% – 50%; r = rare, < 10% of total abundance.

Retznei Section 02 Samples	Stage/Nannoplankton Zone	*Coccolithus miopelagicus*	*C. pelagicus*	*Coronocyclus nitescens*	*Cyclicargolithus floridanus*	*Discoaster adamanteus*	*D. exilis*	*D. formosus*	*D. musicus*	*D. variabilis*	*Discoaster* sp.	*Geminilithella rotula*	*Helicosphaera carteri*	*H. walbersdorfensis*	*H. waltrans*	*Pontosphaera multipora*	*Reticulofenestra haqii*	*R. minuta*	*R. pseudoumbilica*	*R. gelida*	*Rhabdosphaera sicca*	*Sphenolithus heteromorphus*	*S. moriformis*	*Syracosphaera pulchra*	*Thoracosphaera* spp.	*Umbilicosphaera jafarii*
R 02/33		barren																								
R 02/32		barren																								
R 02/31			r									r	r	r			f	c		r						r
R 02/30		r	c	r								r	r		r	r	f	f				r	r	r	r	r
R 02/29			f	r									r	r		r	f	c				r	r	r		r
R 02/28			f		r								r				f	c		r		r				r
R 02/27			f										r				f	c	r	r		r				
R 02/26		r	f	r									r				f	c						r		r
R 02/25	N N 5 (Martini, 1971)	r	f/c	r	r								r		r	r	r	f/c		r		r		r		
R 02/24		r	f		r								r		r		r	f		r		r	r	r		r
R 02/23			f									r	r	r			r	c			r					r
R 02/22			f										r				r	c	r	r		r				r
R 02/21			r										r	r			f	c		r		r				r
R 02/20			r									r	r			r	f	c		r		r		r		r
R 02/19		r	r										r				r	c			r	r	r	r		r
R 02/18			f	r	r		r		r		r	r	r			r	r	c	r	r	r	r	r	r	r	r
R 02/17			r										r				r	c			r					r
R 02/16			r	r								r	r	r			f	c								r
R 02/15			f										r		r		f	c				r	r			r
R 02/14			f										r				r	c	r			r	r	r		r
R 02/13			r			r		r		r	r		r	r			f	c			r	r	r		r	r
R 02/12			f										r	r		r	r	c	r	r		r	r		r	r
R 02/11			r									r	r		r	r	r	c	r							
R 02/10			f	r									r		r		r	c								r
R 02/9	B A D E N I A N		r										r	r	r	r	f	c				r		r		r
R 02/8			r										r		r	r	r	c	r	r		r	r	r		r
R 02/7			f	r						r		r	r	r	r		r	c	r	r		r		r		r
R 02/6			r											r			r	c				r	r			
R 02/5			r									r	r	r			r	c	r		r	r	r			r
R 02/4			f									r	r		r	r	f	c			r	r	r			r
R 02/3			r			r	r			r	r	r	r	r	r	r	r	c	r			r	r			r
R 02/2			f	r								r	r	r	r		r	c				r				r
R 02/1		r	f	r	r			r		r		r	r	r			r	c				r				r

Appendix 1H: Retznei, Lafarge-Perlmooser Cement Factory, main quarry, section R 02. Stratigraphically important calcareous nannoplankton and biostratigraphic zonation. a = abundant, > 90% ; c = common, 50% – 90%; f = few, 10% – 50%; r = rare, < 10% of total abundance.

RETZNEI - MAIN QUARRY sample number	Alveolophragmium crassum	Ammodiscus miocenicus/spp.	Ammomarginulina? matchigarica	Bathysiphon filiformis	Bigenerina agglutinans	Bigenerina directa	Budashevaella laevigata/wilsoni	Cribrostomoides spp.	Cribrostomoides subglobosus	Cyclammina karpatica	Cylindroclavulina rudis	Gaudryinopsis beregoviensis	Gaudryinopsis megagranosus	Glomospira charoides	Haplophragmoides spp.	Hyperammina elongata	Hyperammina granulosa	Karreriella badenensis	Karrerulina apicularis	Karrerulina horrida/conversa	Martinotiella communis	Martinotiella karreri/perparva	Paravulvulina serrata	Popovia sp.	Psammolingulina papillosa	Psammosphaera fusca	Pseudogaudryina lapugyensis	Pseudogaudryina mayeriana	Pseudogaudryina sturi	Reophax brevior/scorpiurus	Reticulophragmium karpaticum	Reticulophragmium obliquicameratum	Reticulophragmium venezuelanum	Rhabdammina sp.	Rhizammina sp.	Semivulvulina deperdita/pectinata	Siphotextularia flexua/concava	Spirorutilus carinatus	Textularia gramen	Textularia laevigata	Textularia lanceolata	Textularia mariae	Tritaxis rara	Vulvulina cf. pennatula	Ammonia spp.	Amphicoryna spp.	Amphimorphina haueriana	Amphistegina bohdan./mammilla	Angulogerina angulosa	Anomalinoides badenensis	Asterigerinata mamilla/planorbis	Baggina arenaria
R 02/32	x	x		x			x	x	x	x			x			x	x				x			x						x	x				x																	
R 02/31	x		x	x		x		x	x	x			x			x	x	x		x		x		x					x	x		x			x				x			x				x			x			
R 02/30																		x				x																							x	x		x				
R 02/29	x	x		x			x	x	x	x						x	x	x			x	x		x							x														x	x	x					
R 02/28				x	x						x		x	x		x	x	x	x	x		x			x											x		x			x				x	x	x	x				
R 02/26		x		x				x	x	x			x			x	x		x		x	x		x							x							x							x	x		x				
R 02/22	x	x		x		x	x		x	x			x		x	x	x		x			x		x							x	x				x	x	x	x		x				x	x	x	x	x			
R 02/20			x	x	x		x		x	x			x			x		x	x	x		x	x						x		x			x		x					x		x			x						
R 02/15			x	x	x			x	x		x		x		x	x	x		x	x		x		x	x				x		x	x		x	x				x			x	x			x			x	x	x	
R 02/10				x																		x									x	x														x	x					
R 02/05			x	x	x						x				x	x					x							x				x				x	x	x	x			x	x						x	x		
R 02/04				x	x	x					x		x		x				x		x		x		x			x		x	x	x						x	x	x		x				x			x			
R 01/25	x	x		x		x		x			x				x		x				x	x			x			x	x		x		x		x	x		x	x			x	x			x			x			x
R 01/24	x			x	x			x	x		x				x	x	x		x		x	x			x			x		x	x	x	x			c		x	x			x	x			x			x		x	
R 01/21	x			x	x				x		x		x		x				x	x	x				x			x	x		x	x	x		x		x	x	x			x	x	x		x	x		x			
R 01/20	x				x				x	x	x		x		x				x		x				x			x			x	x			x			x	x	x	x	x	x	x		x	x		x		x	
R 01/15																																						x														
R 01/10		x			x								x		x	x					x							x			x	x						x		x				x					x			
R 01/07				x	x																x							x	x							x		x	x		x			x				x	x	x		
R 01/02	x	x		x	x						x		x		x				x		x	x			x			x	x		x	x	x			x		x	x	x	x			x		x		x	x	x		
"Geröll-mergel"																																																				
RE2002-2																											x	x										x	x		x				x	x		x			x	
Karpatian																																																			
RE2002-1		x						x	x											x										x	x				x	x										x	x		x			x

Appendix 11: Retznei, Lafarge-Perlmooser Cement Factory, main quarry, sections R 01 – R 02. Distribution of benthic foraminiferal species in the Badenian sediments. The isolated outcrop with Karpatian Steirischer Schlier (RE 2002-1) and Geröllmergel (RE 2002-2) is shown at the base of the table.

RETZNEI - MAIN QUARRY sample number	Bolivina antiqua	Bolivina cf. lowmani	Bolivina dilatata	Bolivina fastigia	Bolivina hebes	Bolivina plicatella	Bolivina pseudoplicata	Bolivina scalprata retiformis	Bulimina buchiana/striata	Cancris auriculus	Caucasina subulata/schischkinskayae	Charltonina tangentialis	Chilostomella ovoidea	Chrysalogonium longicostatum	Cibicidinella ? sp. (wuellerstorfi)	Cibicidoides austriacus/variolatus	Cibicidoides pachyderma/spp.	Cibicidoides ungerianus	Conorbella paradoxica	Coryphostoma digitalis	Dentalina spp.	Dyocibicides biserialis	Ehrenbergina serrata	Elphidiella subnodosa/minuta	Elphidium spp.	Eponides repandus	Fursenkoina acuta	Gavelinopsis praegeri	Glandulina laevigata	Glandulopleurost. pleurostomelloides	Globobulimina pupoides/pyrula	Globocassidulina cruysi	Globocassidulina oblonga	Globocassidulina subglobosa	Globulina gibba/punctata	Grigelis pyrula	Guttulina communis/austriaca	Guttulina irregularis	Gyroidinoides soldanii/umbonatus	Hanzawaia boueana	Hemirobulina spp.	Heterolepa dutemplei/praecincta	Laevidentalina spp.	Lamellodiscorbis cf. dimidiatus	Lapugyina schmidi	Lenticulina spp.	Lingulina costata	Lobatula lobatula	Marginulina hirsuta	Melonis pompilioides	Myllostomella advena	Myllostomella recta
R 02/32													x																		x				x											x						
R 02/31			x		x	x		x	x		x	x	x			x		x			x		x						x			x	x	x	x		x		x	x	x	x	x			x		x	x	x		x
R 02/30									x	x														x															x			x				x				x		
R 02/29					x				x		x				x	x					x			x	x		x		x								x	x	x			x	x			x				x		x
R 02/28	x		x		x				x							x	x	x			x								x	x					x	x	x		x	x		x	x			x			x	x	x	x
R 02/26			x		x		x	x	x		x				x	x	x	x			x				x							x				x	x		x	x		x	x			x			x	x	x	
R 02/22	x		x		x	x		x	x		x				x	x		x			x			x					x		x		x	x	x	x	x	x	x	x	x	x	x		x	x			x	x	x	x
R 02/20	x				x			x	x		x		x		x	x	x	x			x								x	x					x	x	x		x	x	x	x	x		x	x			x	x	x	x
R 02/15	x				x	x	x	x	x				x		x	x	x	x			x						x		x		x	x		x		x	x		x	x	x	x	x		x	x		x	x	x		x
R 02/10					x			x	x		x					x	x	x			x								x		x	x	x	x	x		x		x		x	x	x		x	x		x	x	x	x	
R 02/05		x	x		x	x			x	x		x	x			x	x	x									x	x	x			x			x		x		x	x		x	x			x				x		x
R 02/04		x	x		x	x			x	x		x	x			x		x			x				x		x	x	x	x	x			x	x	x	x	x	x	x		x	x		x	x		x	x	x		x
R 01/25		x	x		x	x		x	x	x		x		x		x		x			x						x		x		x		x	x	x		x	x	x	x		x	x		x	x			x	x		x
R 01/24		x	x		x	x		x	x	x	x	x	x	x		x		x			x							x			x	x		x	x		x	x	x	x		x	x		x	x			x	x		x
R 01/21		x	x	x	x	x			x	x	x	x	x					x									x	x	x		x			x	x		x	x	x	x		x	x		x	x			x	x		x
R 01/20			x	x	x	x			x	x		x	x					x			x		x						x	x	x				x	x	x	x	x	x		x	x		x	x		x		x		x
R 01/15																																							x			x										
R 01/10		x	x	x	x	x			x	x	x		x	x		x	x	x		x	x								x	x					x		x	x	x			x	x		x	x	x	x	x	x		
R 01/07	x		x	x	x				x	x		x		x			x	x			x		x		x				x	x	x	x		x	x		x	x	x			x	x		x	x		x	x	x		
R 01/02		x			x	x	x	x	x	x	x	x	x	x		x	x	x		x	x		x		x			x	x	x	x	x		x	x		x	x	x	x		x	x		x	x		x	x	x	x	x
"Geröll-mergel"																																																			
RE2002-2																x		x	x					x	x	x					x				x		x	x	x	x		x	x	x		x		x	x	x		
Karpatian																																																			
RE2002-1			x					x			x	x					x					x			x			x														x			x	x		x		x	x	

Appendix 11 continue

RETZNEI - MAIN QUARRY sample number	*Neoeponides schreibersi*	*Neolenticulina peregrina*	*Neugeborina longiscata/irregularis*	*Nodosarella rotundata/sp.*	*Nodosaria guttifera*	*Nonion commune*	*Nonionella turgida*	*Nonionoides ventragranosus*	*Oridorsalis umbonatus*	*Orthomorphina spp.*	*Pandaglandulina elliptica/sp.*	*Pappina parkeri*	*Pappina primiformis/breviformis*	*Pararotalia aculeata*	*Planularia dentata/cassis*	*Planularia lanceolata*	*Plectofrondicularia spp.*	*Pleurostomella alternans/spp.*	*Porosononion granosum*	*Pseudonodosaria brevis/sp.*	*Pseudoparrella exigua*	*Pullenia bulloides/quinqueloba*	*Pyramidulina raphanistrum*	*Pyramidulina spp.*	*Pyrgo simplex/lunula*	*Quinqueloculina/Cycloforina spp.*
R 02/32						x																x				
R 02/31			x						x	x	x											x	x		x	x
R 02/30																	x									
R 02/29			x		x	x		x	x	x												x				
R 02/28	x		x					x	x	x	x	x					x			x						
R 02/26			x			x		x	x	x		x										x		x		
R 02/22			x			x		x	x	x	x						x					x	x			
R 02/20			x	x				x	x	x					x		x					x	x			
R 02/15		x	x	x	x		x		x	x	x				x		x	x		x		x	x		x	x
R 02/10			x					x		x	x						x					x				
R 02/05			x		x	x			x	x								x				x			x	
R 02/04			x	x	x	x	x	x		x							x					x		x		
R 01/25	x		x	x												x	x					x	x	x		x
R 01/24	x			x						x	x					x	x					x	x	x		x
R 01/21			x	x	x	x	x		x	x							x					x	x	x		
R 01/20	x		x	x		x		x		x	x						x					x				x
R 01/15																										
R 01/10	x		x	x	x	x		x									x			x			x	x		
R 01/07	x		x					x	x								x					x	x		x	x
R 01/02	x		x	x		x	x		x	x	x						x					x	x			x
"Geröll-mergel"																										
RE2002-2			x		x	x		x						x			x		x	x		x		x		
Karpatian																										
RE2002-1						x		x					x					x			x	x				

RETZNEI - MAIN QUARRY sample number	*Riminopsis boueanus*	*Rosalina globularis*	*Sigmoilinita tenuis*	*Sigmoilinita tschokrakensis*	*Sigmoilopsis foeda/celata*	*Siphogenerinoides vasarhelyi*	*Siphonina reticulata*	*Siphonodosaria adolphina*	*Siphonodosaria consobrina/verneuli*	*Siphonodosaria scabra/scripta/sp.*	*Sphaerogypsina globulus*	*Sphaeroidina bulloides*	*Spiroloculina excavata/canaliculata*	unilocular (*Lagena, Fissurina* etc.)	*Uvigerina* aff. *barbatula*	*Uvigerina* cf. *bulbacea*	*Uvigerina graciliformis*	*Uvigerina grilli*	*Uvigerina laviculata*	*Uvigerina macrocarinata*	*Uvigerina pygmoides*	*Uvigerina semiornata*	*Uvigerina uniseriata*	*Vaginulina legumen*	*Vaginulinopsis spp.*	*Valvulineria complanata*
R 02/32												x														
R 02/31			x		x			x	x	x		x	x	x				x		x	x					x
R 02/30												x						x								
R 02/29			x					x				x		x				x		x		x				x
R 02/28			x					x	x	x									x	x		x	x			x
R 02/26			x					x	x	x		x		x					x	x		x				x
R 02/22			x		x			x	x	x		x		x					x	x		x	x	x		
R 02/20			x						x	x		x	x	x				x	x	x	x	x	x	x		x
R 02/15	x		x	x	x		x	x	x	x		x	x	x		x				x	x	x		x	x	x
R 02/10			x					x	x			x		x				x		x					x	
R 02/05	x	x	x						x			x	x	x						x			x			x
R 02/04		x	x	x	x		x	x	x	x		x		x		x		x		x	x		x		x	
R 01/25	x	x	x		x		x	x	x	x		x	x	x							x					x
R 01/24	x		x				x	x	x	x		x	x	x				x			x	x		x	x	
R 01/21	x	x	x		x		x	x	x	x		x	x	x					x		x		x	x		
R 01/20	x		x	x	x		x	x	x			x		x		x		x		x	x		x		x	x
R 01/15									x												x					
R 01/10	x		x	x	x	x	x	x	x	x		x		x		x					x			x	x	
R 01/07	x		x		x	x	x		x	x	x			x		x					x			x		
R 01/02	x	x	x	x	x		x	x	x	x			x	x		x				x	x			x	x	
"Geröll-mergel"																										
RE2002-2			x						x	x	x				x		x		x							x
Karpatian																										
RE2002-1			x											x												x

Appendix 1I continue

RETZNEI - MAIN QUARRY sample number	*Cassigerinella globulosa*	*Globigerina bollii*	*Globigerina bulloides*	*Globigerina concinna*	*Globigerina diplostoma*	*Globigerina falconensis*	*Globigerina ottnangiensis*	*Globigerina praebullodies*	*Globigerina subcretacea*	*Globigerina tarchanensis*	*Globigerinella regularis/opinata*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinoides apertasuturalis*	*Globigerinoides bisphericus*	*Globigerinoides quadrilobatus*	*Globigerinoides trilobus*	*Globoquadrina* cf. *altispira*	*Globorotalia bykovae*	*Globorotalia peripheroronda*	*Globorotalia praescitula*
R 02/32		x	x	x	x						x				x	x	x		x	x	
R 02/31		x		x	x	x		x	x		x	x	x		x	x	x	x	x		
R 02/30		x	x					x	x		x					x	x		x		
R 02/29		x	x		x			x	x		x	x	x		x	x	x	x	x		
R 02/28		x	x	x	x				x		x	x	x		x	x	x	x	x	x	
R 02/26		x	x	x	x		x		x		x	x	x		x	x	x	x	x	x	x
R 02/22		x	x	x	x			x	x	x	x	x	x		x	x	x		x	x	
R 02/20		x		x	x	x		x	x	x	x	x	x		x	x	x	x	x		
R 02/15		x	x			x		x	x		x		x	x	x	x	x	x	x		
R 02/10		x	x	x		x	x	x	x	x	x	x	x		x	x	x				x
R 02/05		x	x						x	x	x	x	x		x	x	x				x
R 02/04	x	x		x		x		x	x	x	x	x	x		x	x	x				
R 01/25	x		x					x	x	x	x	x	x		x	x	x	x	x		x
R 01/24		x	x		x				x		x	x	x		x	x	x	x	x	x	
R 01/21		x	x					x	x	x	x		x		x	x	x				
R 01/20			x					x	x	x	x	x	x		x	x	x	x			
R 01/15			x	x				x	x	x	x				x	x	x		x		
R 01/10			x					x	x	x	x	x	x		x	x	x				
R 01/07			x						x							x	x				
R 01/02			x					x	x	x	x	x	x		x	x	x				
"Geröllmergel"																					
RE2002-2		x		x			x									x	x				
Karpat																					
RE2002-1		x					x	x		x							x				

RETZNEI - MAIN QUARRY sample number	*Globorotalia transsylvanica*	*Globoturborotalita druryi*	*Globoturborotalita woodi*	*Orbulina suturalis*	*Paragloborotalia inaequiconica*	*Paragloborotalia siakensis/acrostoma*	*Praeorbulina* cf. *sicana*	*Praeorbulina circularis*	*Praeorbulina glomerosa/curva*	*Tenuitella clemenciae*	*Tenuitella minutissima*	*Tenuitellinata angustiumbilicata*	*Tenuitellinata selleyi*	*Turborotalita neominutissima*	*Turborotalita quinqueloba*	*Bachmayerella tenuis*	*Bachmayerella* sp.	*Bolboforma moravica*	*Bolboforma reticulata*	**black volcanic mica**	**sanidine**	Remarks
R 02/32				x																**x**		strongly corroded/pyrityzed
R 02/31	x	x		x		x		x							x				x			Orbulina horizon
R 02/30	x	x		x		x						x	x									gypsum
R 02/29	x	x	x	x	x	x		x			x		x	x								Globigerina horizon
R 02/28				x		x					x		x					x	x			
R 02/26		x	x	x		x					x	x			x							Globigerina horizon
R 02/22				x		x		x							x		x					G. bykovae horizon
R 02/20				x		x		x							x							Orbulina horizon
R 02/15		x		x		x							x		x	x	x		x			
R 02/10				x																**x**	**x**	
R 02/05				x									x	x			x		x			
R 02/04				x				x									x	x		**x**		
R 01/25	x			x	x	x	x	x	x	x			x			x	x	x	x			
R 01/24						x											x	x				Globigerinoides horizon
R 01/21		x	x			x										x		x				
R 01/20													x						x			
R 01/15					x	x									x							smektite? with pumice
R 01/10																						Globigerinoides horizon
R 01/07																	x			**x**		amount of glauconite
R 01/02							x		x				x		x		x	x		**x**	**x**	corallinacean marl
"Geröllmergel"																						
RE2002-2			x						x													silt with pebbles
Karpat																						
RE2002-1										cf	cf	x	cf		x							dark calcareous shale

Appendix 1J: Retznei, Lafarge-Perlmooser Cement Factory, main quarry, sections R 01 – R 02. Distribution of planktonic foraminiferal species in the Badenian sediments. The isolated outcrop with Karpatian Steirischer Schlier (RE 2002-1) and Geröllmergel (RE 2002-2) is shown at the base of the table.

Katzengraben section	Stage	Nannoplankton Zones (Martini, 1971)	*Braarudosphaera bigelowii*	*Calcidiscus leptoporus*	*Cd. premacintyrei*	*Cd. tropicus*	*Coccolithus miopelagicus*	*C. pelagicus*	*Coronosphaera mediterranea*	*Cyclicargolithus floridanus*	*Discoaster deflandrei*	*D. variabilis*	*Helicosphaera ampliaperta*	*H. carteri*	*H. euphratis*	*H. granulata*	*H. scissura*	*H. walbersdorfensis*	*H. waltrans*	*Pontosphaera multipora*	*Reticulofenestra gelida*	*R. haqii*	*R. minuta*	*R. pseudoumbilica*	*Sphenolithus heteromorphus*	*S. milanetti*	*S. moriformis*	*Umbilicosphaera jafarii*
C2/1	BADENIAN	N N 5	r					f	r	r				f			r		r	r	r		c		r			r
C2/01						r	r	f		r				r			r	r	r	r	r		c				r	r
C1/01			r					c	r				r	f		r					r		r				r	
B04								f	r	r	r			f		r			r	r		f	c		r			
B03			r			r	r	f	r	r		r		r		r			r	r		f	c				r	
B02		N N 4					r	c	r	r			r	f				r		r		r	f	r	r		r	
B01							r	c	r	r	r		r	f	r		r	r			r	r	f	r	r		r	
A06					r		r	f	r	f			r	c				r		r	r	r	f			r	r	
A05	KARPATIAN							c	r				r	f									r	r			r	
A04							r	c	r	r		r	r	f	r					r	r	r	r	r	r		r	
A03							r	c	r	r		r	r	f	r		r	r		r	r	r	f		r			r
A02								c	r				r	f			r						r					
A01				r				c	r	f				f			r	r		r		r	f		r			

APPENDIX 1K: Katzengraben. Stratigraphically important calcareous nannoplankton and biostratigraphic zonation. a = abundant, > 90% ; c = common, 50% – 90%; f = few, 10% – 50%; r = rare, < 10% of total abundance.

PERBERSDORF 1	Stage	Nannoplankton Zones (Martini, 1971)	*Calcidiscus leptoporus*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus floridanus*	*Helicosphaera ampliaperta*	*Helicosphaera carteri*	*Helicosphaera scissura*	*Helicosphaera walbersdorfensis*	*Helicosphaera waltrans*	*Pontosphaera multipora*	*Reticulofenetra bisecta*	*Reticulofenestra gelida*	*Reticulofenestra haqii*	*Reticulofenestra minuta*	*Reticulofenestra pseudoumbilica*	*Rhabdosphaera sicca*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Triquetrorhabdulus milowii*	*Umbilicosphaera jafarii*
246.00-247.00 m	B A D E N I A N	N N 5		r	f	f		f				f			f	a		r	f	f		
299.00-304.00 m					f			f			r	f			f	c	f	r	f	f		
346.00-352.00 m					f	r		f			r	r			r	a			r	r		
364.00-370.00 m			r	r	f	r		f	r		r			f	f	c		r	f	r		r
382.00-388.00 m				r	f	r		f				r			f	c			r	f	r	r
388.00-394.00 m					f	f		f							f	c			f	f		
461.00-467.00 m			r	r	f	f		f		r		r		f		c				r	r	
492.00-490.00 m				r	f	r		f	r			r	r	f	f	c	f		f	f	r	r
496 m				r	c	r		r		r		r	r		r		r			r		
520.00-523.00 m		N N 4	r	r	c	f	f	f		r		r	r	r	r	r	r		f	r		r
527.40-534.00 m			Volcanic level												No nannofossils							
557.00-563.00 m																						
628.20-632.20 m																						
661.1 m																						
689 m																						
689.00-694.00 m																						
729.00-732.50 m																						
746 m					c			r					r									
785.80-794.00 m			r		c	r		f			r	r		r						r		
809.00-811.00 m				r	c	r		f	r			r				r			r	r		
850.00-856.00 m			r	r	c	f		f	r					r	f	r	r		r	r		
868.00-874.00 m				r	c	r		f	r			r					r		f	r		
933.00-939.00 m	KARPATIAN		r		c		r	f								r			f	r		
947.5-1311m		barren																				

APPENDIX 1L: Perbersdorf deep well 1; distribution of stratigraphically important calcareous nannoplankton. a = abundant, > 90% ; c = common, 50% – 90%; f = few, 10% – 50%; r = rare, < 10% of total abundance.

PERBERSDORF 1 Planktonic Foraminifera Core Sample	box number	Sample Depth in Metres	*Orbulina suturalis*	*Praeorbulina glomerosa circularis*	*Globigerinoides trilobus*	*Globigerinoides quadrilobatus*	*Globigerinoides bisphericus*	*Globoquadrina cf. altispira*	*Globoquadrina cf. globosa*	*Globorotalia transsylvanica*	*Globorotalia peripheronda*	*Praeorbulina transitoria*	*Paragloborotalia mayeri*	*Globorotalia bykovae*	*Praeorbulina sicana*	*Praeorbulina glomerosa glomerosa*	ZONATION
216-223	3	220	x	x	x												Lagenidae Zone - NN5
246-247		246	x	x	x	x	x	x	x	x	x						
247-248		247	x	x	x	x	x			x		x					
252-258		255	x	x						x		x	x			cf.	
270-276	1	275	x	x	x	x	x		x	x	x	x	x	x			
276-282	3	279	x	x	x	x	x	x	x	x	x		x	x			
276-282	2	280	x	x	x	x	x	x	x				x	x			
282-288		285	x		x	x	x					x			x		
288-293		291			x	x	x	x				x			x		
299-304		302			x	x	x								x		
304-310		307			x	x	x					x			x		
310-316	2	314		x	x	x	x								x		
310-316	1	315		x	x	x	x										
316-322	2	320			x	x	x										
316-322	1	321		x	x	x	x										
328-334	3	331		x	x	x	x					x			x		
328-334	2	332		x	x	x	x								x		
328-334	1	333		x			x								x		

APPENDIX 1M: Perbersdorf deep well 1; distribution of important planktonic foraminifera.

PERBERSDORF 1 Planktonic Foraminifera Core Sample	box number	Sample Depth in Metres	*Orbulina suturalis*	*Praeorbulina glomerosa circularis*	*Globigerinoides trilobus*	*Globigerinoides quadrilobatus*	*Globigerinoides bisphericus*	*Globoquadrina cf. altispira*	*Globoquadrina cf. globosa*	*Globorotalia transsylvanica*	*Globorotalia peripheroronda*	*Praeorbulina transitoria*	*Paragloborotalia mayeri*	*Globorotalia bykovae*	*Praeorbulina sicana*	*Praeorbulina glomerosa glomerosa*	ZONATION
334-340	3	337		x	x	x	x					x			x	x	Lagenidae Zone - NN5
334-340	2	338		x	x	x	x		x			x			x	x	
334-340	1	339		x	x	x	x					x			x	x	
346-352		349		x	x	x	x					x			x	x	
352-358	2	356			x		x										
352-358	1	357		x	x	x	x					x				x	
358-364		361					x										
364-370		367		x	x	x	x					x			x	x	
370-376		373			x		x								x	x	
376-382	2	380															
376-382	1	381															
382-388	2	386															
382-388	1	387															
388-394	2	392			x												
388-394	1	393				x											
394-400		397															
400-405.5	2	403.5															
400-405.5	1	404.5															
405.5-411.5	2	409.5															
405.5-411.5	1	410.5															
411.5-417		414															
417-422		419															
422-427.4		425			x	x	x								cf.		
427.4-432.8	2	430.8															
427.4-432.8	1	431.8															
432.8-438.5		435.5															
438.5-444	2	442													cf.		
438.5-444	1	443															
444-450.5	2	448.5					x										
444-450.5	1	449.5															
450.5-456	2	454															
450.5-456	1	455			x		x										
456-461		458.5			x												
461-467		464															
467-473		470															
473-479		476															
479-485		482					x										
485-491	2	489															
485-491	1	490															
491-496.5		493.5															
496.5-502.5	4	498.5															
496.5-502.5	3	499.5															
496.5-502.5	2	500.5															
496.5-501.5	1	501.5															
508.5-514					x	x	x										
514-520	2	518															
514-520	1	519															
520-523		521.5															
523-527.7		525.5															Lagenidae Tone - NN4
527.7-534.2		530.5															
534.2-540		537															
545-551		548															
557-565		561															
568-574		571															
587-591		589			x		x										
606.5-612.7		609.5				x	?										
620.2-626.2		623.2															
666.1-669.3		667.6															
675.4-676.8		675															
689-694.8		692															
718-721		719.5															
721-727		724															
746-749		747.5															
749-752.4	2	750.4															
749-752.4	1	751.4															
752.4-758.8		755.6															
764-769		766.5															
780.1-783.4		781.6															
783.4-786.7		785															
786.7-794		790															
796-800.9		798.5															
800.9-805.2	2	803.2				x											
800.9-805.2	1	804.2															
805.2-809		807				x											
809-811		810.5															
838-844		841															Karpatian - NN4
844-850		847															
850-856		853															
856-862		859															
862-868		865															
868-874		871															
874-880		877															
880-886		883															
886-896		891															
902-908		905															
914-920		917															
924.7-930.8		927.8															
933-939																	
959.5-965.5	1	965															Ottnangian - Karpatian
976-982																	
982-988																	
988-994																	
994-1000																	
1000-1006			?	?						?							
1009-1015																	
1025.8-1032.0																	
1043.4-1049.2																	
1963-1068																	
1114.3-1120.3																	
1191-1193																	
1290.0-1295.7																	
1352-1354																	
1397.5-1403,5																	

Appendix 1M continue

PERBERSDORF 1 Benthic Foraminifera Core Sample	box number	Sample Depth in Metres	*Uvigerina pygmoides*	*Uvigerina macrocarinata*	*Uvigerina uniseriata*	*Uvigerina cf. pudica*	*Uvigerina aculeata*	*Uvigerina cf. costai*	*Uvigerina semiornata*	*Uvigerina grilli*	*Uvigerina cf. bulbacea*	*Uvigerina acuminata*	*Uvigerina graciliformis*	*Uvigerina parviformis*	*Uvigerina cf. laviculata*	*Pappina primiformis*	*Uvigerina cf. barbatula*	*Uvigerina sp. (striate)*	*Vaginulina legumen*	*Colominella paalzowi*	*Cylindroclavulina rudis*	*Psammolingulina papillosa*	*Pseudogaudryina sturi*	Remarks
216-223	3	220	x																x				x	
246-247		246		x	x	x	x	x													x		x	
247-248		247		x	x	x	x	x															x	Orbulina bloom
252-258		255		x				x	x														x	
270-276	1	275	x	x	x				x										x		x			
276-282	3	279		x	x			x													x		x	
276-282	2	280		x	x					x	x										x		x	
282-288		285		x	x				cf.		x										x			
288-293		291	x	x	x			x	x		x										x			
299-304		302	x						cf.	x	x										x		x	
304-310		307	x								x										x			
310-316	2	314	x						cf.		x								x					
310-316	1	315	x								x								x			x	x	
316-322	2	320																				x		
316-322	1	321	x	x							x											x	x	
328-334	3	331	x	x				x	cf.										x				x	
328-334	2	332	x						cf.										x			x	x	
328-334	1	333																						
334-340	3	337	x		x				cf.		x								x		x	x	x	
334-340	2	338							cf.										x			x	x	
334-340	1	339	x	x					cf.		x												x	
346-352		349	x						cf.		x											x		
352-358	2	356																						poor assemblage
352-358	1	357	x	x	x				cf.		x										x	x		
358-364		361										x												poor assemblage
364-370		367	x								x	x												
370-376		373	x	x							x	x								x				
376-382	2	380	x	x					cf.		x	x											x	
376-382	1	381	x	x					cf.		x									x		x	x	
382-388	2	386	x	x				x	cf.		x													
382-388	1	387	x	x				x	x											x			x	
388-394	2	392	x	x				x	x	x	x	x												
388-394	1	393	x	x								x												
394-400		397	x	x							x	x				x								
400-405.5	2	403.5		x	cf.						x	x								x				
400-405.5	1	404.5		x						x	x	x								?				
405.5-411.5	2	409.5		x								x												poor assemblage
405.5-411.5	1	410.5	x	x					cf.			x												
411.5-417		414																						
417-422		419																						
422-427.4		425		cf.	cf.			cf.																
427.4-432.8	2	430.8	x	x																				
427.4-432.8	1	431.8		x						cf.		x												poor assemblage
432.8-438.5		435.5										x												
438.5-444	2	442		cf.				x				x												
438.5-444	1	443								cf.		x												poor assemblage
444-450.5	2	448.5	x		x					cf.		x	x	x										
444-450.5	1	449.5	x					x		x		x	x		x				x				x	
450.5-456	2	454	x										x											
450.5-456	1	455		x				x	x				x									x		
456-461		458.5	x							cf.			x											
461-467		464								cf.			x									x		
467-473		470	x				x			cf.	x		x		x		x						x	
473-479		476											x											
479-485		482											x											
485-491	2	489															x							
485-491	1	490											x				x						x	
491-496.5		493.5																						
496.5-502.5	4	498.5															x							
496.5-502.5	3	499.5											x				x							
496.5-502.5	2	500.5															x							poor assemblage
496.5-501.5	1	501.5															x							
508.5-514		511							x			x					x							
514-520	2	518										x												
514-520	1	519										x												
520-523		521.5										x											x	
523-527.7		525.5																						poor assemblage
527.7-534.2		530.5							cf.			x	x		x		x		x					
534.2-540		537										x												Bathysiphon assemblage
545-551		548										x												
557-565		561																						
568-574		571																						
587-591		589																						
606.5-612.7		609.5																						
620.2-626.2		623.2																						Bathysiphon assemblage
666.1-669.3		667.6																						barren
675.4-676.8		675										x			x		x	x	x					
689-694.8		692										x						x						Bathysiphon assemblage
718-721		719.5																						
721-727		724																						
746-749		747.5										x						x						
749-752.4	2	750.4		cf.								x												
749-752.4	1	751.4							x			x						x						
752.4-758.8		755.6		x								x						x	x					
764-769		766.5		x								x												
780.1-783.4		781.6		cf.								x						x						
783.4-786.7		785		x								x	x					x	x					
786.7-794		790		x														x						
796-800.9		798.5		x														x						
800.9-805.2	2	803.2		cf.									x				x		x					
800.9-805.2	1	804.2		cf.								x					x	x	x					
805.2-809		807		cf.									x				x							
809-811		810.5											x						x					
838-844		841		x	x												x		x					
844-850		847									x		x						x					
850-856		853																						
856-862		859																x						
862-868		865											x		x									
868-874		871											x											
874-880		877										x	x											
880-886		883									x		x					x						
886-896		891											x					x						
902-908		905											x											

Appendix 1N: Perbersdorf deep well 1; distribution of important benthic foraminifera and remarks on faunal events.

PERBERSDORF 1 Benthic Foraminifera Core Sample	box number	Sample Depth in Metres	*Uvigerina pygmoides*	*Uvigerina macrocarinata*	*Uvigerina uniseriata*	*Uvigerina cf. pudica*	*Uvigerina aculeata*	*Uvigerina cf. costai*	*Uvigerina semiornata*	*Uvigerina grilli*	*Uvigerina cf. bulbacea*	*Uvigerina acuminata*	*Uvigerina graciliformis*	*Uvigerina parviformis*	*Uvigerina cf. laviculata*	*Pappina primiformis*	*Uvigerina cf. barbatula*	*Uvigerina sp. (striate)*	*Vaginulina legumen*	*Colominella paalzowi*	*Cylindroclavulina rudis*	*Psammolingulina papillosa*	*Pseudogaudryina sturi*	Remarks
914-920		917									x		x											
924.7-930.8		927.8									x				x									
933-939																								
959.5-965.5	1	965																						silicified stems
976-982																								
982-988																								
988-994																								
994-1000																								
1000-1006																								contamination
1009-1015																								barren
1025.8-1032.0																								
1043.4-1049.2																								
1063-1068																								silicified stems
1114.3-1120.3																								
1191-1193																								
1290.0-1295.7																								
1352-1354																								barren
1397.5-1403,5																								contamination

Appendix 1N continue

PETERSDORF 1 cuttings/meter	*Globigerinoides bisphericus*	*Globigerinoides trilobus*	*Praeorbulina glomerosa circularis*	*Orbulina suturalis*	*Globoquadrina cf. altispira*	*Globigerinoides quadrilobatus*	*Globorotalia bykovae*	*Globorotalia transsylvanica*	*Praeorbulina glomerosa glomerosa*	*Praeorbulina transitoria*	*Uvigerina semiornata*	*Uvigerina grilli*	*Uvigerina aculeata*	*Pappina parkeri*	*Uvigerina cf. bulbacea*	*Uvigerina pygmoides*	*Uvigerina acuminata*	*Uvigerina macrocarinata*	*Pappina primiformis*	*Lenticulina ariminensis*	*Lenticulina orbicularis*	*Lenticulina echinata*	*Pyramidulina raphanistrum*	*Paragaudryina interjuncta*	*Cylindroclavulina rudis*	*Pseudogaudryina lapugyensis*	STRATIGRAPHY
1410		x		x	x	x					x		x							x							Badenian
1430		x	x	x	x	x	x	x			x	x	x								x						
1450		x	x	x	x	x	x				x	x	x	x										x			
1470		x	x	x		x						x															
1490	x	x	x	x	x	x																					
1510	x	x		x	x	x	x	x	x	x	x	x	x					cf.									
1530	x	x		x		x	x	x	x	x					x			cf.							x		
1550	x	x			x	x	x	x	x	x					x	x									x		
1570	x	x			x	x		x	x																		
1590	x	x		x	x	x			x	x	x	x						cf.									
1610	x	x				x			x	x	x				x	x		cf.					x		x		
1630	x	x				x	x		x		x		x	x			x								x		
1650	x	x				x	x		x																x		
1670	x	x				x			x		x							x									
1690	x	x			x				x																		
1710		x																									
1730		x							x																		
1750		x							x																		
1770		x																									
1790																											
1810	x	x	x																		x						
1830	x	x	x	d	x																x						
1850	x	x																				x					
1870	x																				x						
1890	x	x	x		x	x												x	x		x					x	
1910	x	x	x	d		x															x					x	
1930	x	x	x																		x						
1950	x	x	x																		x						
1970	x	x			x								x														
1990	x	x	x	d		x			x												x		x				
2010						x																					
2030	x	x	x	d		x			x																		
2050		x																									
2070																											
2090																											
2110																											
2130		x																									
2150			x																								
2170																											Karpatian
2190	x	x																									
2210		x																								x	
2230		x																									
2250		x																									
2270																											
2310	d	d																								d	
core 2308-2318m																											
2330		d																									
2370	barren																										Ottnangian
2410																											
2450																											
2490		d															d										
2530	barren																										
2570																											
2610																											
2650																											
2690																											
2730																											
2770																											
2810																											
2850																											
2890																											
2930	tectonized metamorphic shales																										

Appendix 1O: Petersdorf deep well 1; distribution of important planktonic and benthic foraminifera in the lower part of the well.