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Fast Track Article

Stratigraphic re-evaluation of the stratotype for the regional Ottnangian stage (Central Paratethys, middle Burdigalian)

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With 5 figures and 4 plates

Abstract. The Ottnangian stage represents the middle Burdigalian (c. 18.1–17.2 Ma) within the regional stratigraphic concept for the Central Paratethys. The section Ottnang-Schanze in the North Alpine Foreland Basin of Upper Austria has been defined as its stratotype by Rögl et al. (1973). We present an updated stratigraphic evaluation of the section based on biostratigraphy of foraminifers, dinoflagellate cysts and calcareous nannoplankton as well as magnetostratigraphy.

In agreement with earlier studies, assemblages of benthic foraminifers (co-occurrence of *Amphicoryna ottnangensis* and *Sigmoilopsis ottnangensis*, mass-occurrences of *Lenticulina inornata*) document a late early Ottnangian age. Dinoflagellate cyst *Exochosphaeridium insigne* is recorded for the first time in the early Ottnangian and its occurrence together with *Apteodinium spiridoides*, *Cordosphaeridium cantharellus* and *Glaphyrocysta reticulosa* s.l. extends the regional dinoflagellate zone *Ein* from the middle to the early Ottnangian. On a global scale, the revealed marker species indicate zone D17a (middle-late Burdigalian). Calcareous nannoplankton assemblages with the very rare occurrence of *Sphenolithus* cf. *belemnos* and *S.* aff. *heteromorphus* show remarkable affinities to Mediterranean nannoplankton zone MNN3b. Together with the frequent occurrence of *Helicosphaera ampliaperta* and the absence of *Triquetrorhabdulus carinatus* an assignment to standard nannoplankton zone NN3 (early-middle Burdigalian) is indicated.

Magnetostratigraphy revealed an inverse polarisation for the outcrop. In combination with the biostratigraphic age constraints and the present correlation of the Ottnangian to the Bur3 sea-level cycle the section belongs to polarity chron C5Dr.2r. For the first time, an absolute age between 17.95–18.056 Ma for the stratotype can be inferred.

Key words. Central Paratethys; Ottnangian; stratotype; biostratigraphy; magnetostratigraphy

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1. Introduction

Through Oligocene-Miocene the epicontinental Central Paratethys Sea covered major parts of Europe. Its complex paleogeographic evolution is mainly related to tectonic processes of the Alpine orogeny creating a highly dynamic environment (see e. g., Harzhauser and Piller 2007 for details). Changing land-bridges and seaways had a severe impact on the fauna and flora and resulted in distinct biogeographic patterns, recognised already by Laskarev (1924) who was the first to introduce the concept of the Paratethys. With the progress in understanding the unique and complex history of this epicontinental sea, efforts towards a regional stratigraphic concept were taken culminating in the series "Chronostratigraphie und Neostratotypen" (Cicha et al. 1967; Steininger and Seneš 1971; Baldí and Seneš 1975; Papp et al. 1973, 1974, 1978, 1985; Stevanović et al. 1990). This concept paralleling global Oligocene-Miocene stratigraphy has been applied to the Central Paratethys since then and further attempts have been made to correlate the regional stages more and more precisely to the international chronostratigraphic framework (e. g., Rögl 1998; Kováč et al. 2004; Piller et al. 2007; Lirer et al. 2009). For each of the regional stages a holostratotype and several faciostratotypes have been selected. As the latter represent characteristic facies reflecting regional environmental changes these sections do not follow the GSSP concept of the International Commission for Stratigraphy which was established somewhat later (Hedberg 1976).

In this study we present a detailed stratigraphical re-evaluation of the section Ottnang-Schanze in Upper Austria, representing the holostratotype for the Ottnangian stage (Early Miocene, middle Burdigalian; Figs. 1, 2). As for most of the Paratethyan stratotypes, the outcrop lacks a modern examination with respect to the international Cenozoic time-scale (Lourens et al. 2004). Since the initial description by Rögl et al. (1973) only few stratigraphic studies have been carried out on the section mainly focusing on regional aspects (Martini and Müller 1975; Hochuli 1978; Zorn 1995; Rupp and Haunold-Jenke 2003). Some brief overviews on the section have been published in field-trip guide books and in the course of geological mapping in the area (e. g. Roetzel and Nagel 1991; Rupp and van Husen 2007; Rupp et al. 2008). However, up to now, no detailed log or lithological description of the stratotype has been published.

This paper focusing on stratigraphy is the first outcome of an integrated project on the Ottnangian stratotype. The new data come from an evaluation of microfossil assemblages (foraminifers, dinoflagellate cysts, calcareous nannoplankton) and magnetostratigraphy. A detailed facies-analysis based on lithology, sedimentology and paleontology will be published in an accompanying paper.

2. Regional setting

2.1 The Ottnangian stage: stratigraphic and paleogeographic framework

According to the current stratigraphic correlation of the regional Central Paratethyan stages to the international time-scale the Ottnangian corresponds to the 3rd-order sea-level cycle Bur3 of Haq et al. (1998) thus lasting from 18.12–17.23 Ma (Lourens et al. 2004; Piller et al. 2007). Based on lithostratigraphy a threefold internal subdivision of the Ottnangian has been developed (Seneš 1973; Doppler et al. 2005; Rupp et al. 2008). However, in a geochronological context this concept is poorly constrained. While there is some evidence from sequence stratigraphy (Zweigel 1998; Grunert 2009) and Sr-isotope data (Pippèrr et al. 2007) and for an early/middle Ottnangian boundary between 17.8–17.9 Ma, the boundary between middle and late Ottnangian remains unclear due to an asynchronous retreat of the Central Paratethys from the North Alpine Foreland Basin (NAFB) at the time.

Biostratigraphy of the Ottnangian is primarily based on endemic benthic foraminiferal and mollusc species (Cicha and Rögl 1973; Steininger et al. 1973). Ostracods, silicoflagellates, diatoms, dinoflagellate cysts and pollen have been locally used as additional markers (Hochuli 1978; Zorn 1995; Jiménez-Moreno et al. 2006; Roetzel et al. 2006). Due to the high rate of endemism a correlation to the international biostratigraphic zonation schemes proved to be difficult (Harzhauser and Piller 2007; Piller et al. 2007). Although Cicha and Rögl (1973) and Rögl (1985) suggest a possible correlation to the Burdigalian *Globigerinoides trilobus*-zone of the Mediterranean (sensu Iaccarino 1985), planktic foraminiferal assemblages of the Ottnangian generally do not reveal taxa useful for biostratigraphy (Rögl 1985). Only the FAD of the endemic species *Cassigerinella spinata* is documented for the base of the Ottnangian in Bavaria and Upper Austria (Cicha et al. 1998). Studies on dinoflagellate cysts and calcareous nannoplankton seem more promising in this respect (Martini and Müller

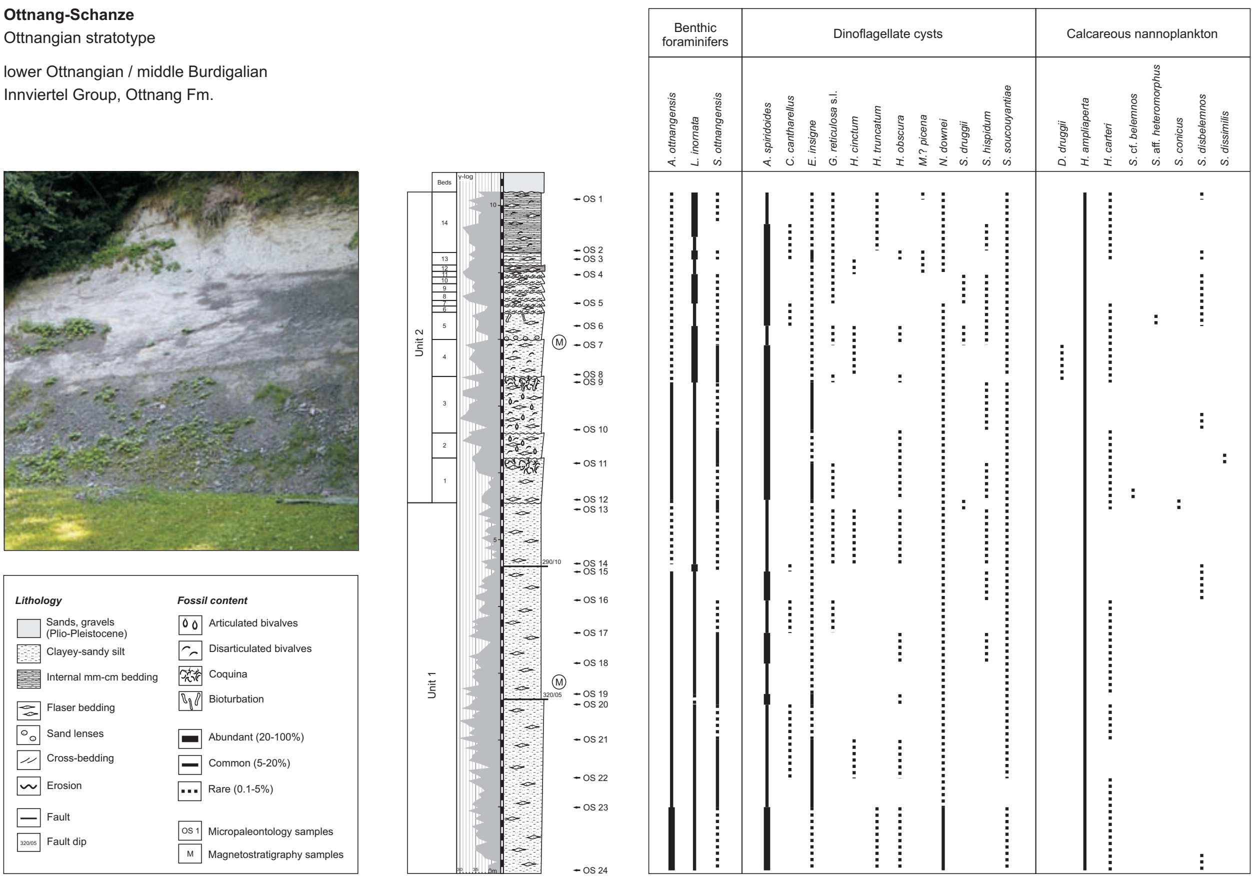


Fig. 1. Log of the stratotype section Ottnang-Schanze and range chart for biostratigraphically relevant species of benthic foraminifers, dinoflagellate cysts and calcareous nannoplankton as revealed in this study. See text for discussion.

1975; Chira 2004; Jiménez-Moreno et al. 2006; Roetzel et al. 2006). However, this work is still in its early stages.

The stratotype section of the Ottnangian is located within the NAFB of Upper Austria (Fig. 2a). Reaching from Switzerland via southern Germany to Austria, the NAFB provided the connection between the Central Paratethys and the Atlantic from Oligocene to Early Miocene (Fig. 3). Its sedimentary infill is characterized by several regressive/transgressive cycles and the final retreat of the Central Paratethys from the basin by the end of the Early Miocene (Rögl 1998; Doppler et al. 2005; Harzhauser and Piller 2007). The Ottnangian is part of the last of these cycles starting in the late Eggenburgian when a transgression re-established the marine pathway towards the Atlantic (Berger 1996). This temporary connection is called the Burdigalian Seaway and persisted throughout the early Ottnangian (Rögl 1998). Early Ottnangian sedimentation was mainly siliciclastic resulting in deposition of characteristic clayey-sandy silts ("Schlier") which are also present at the stratotype section (Harzhauser and Piller 2007). Widespread tidal deposits are reported from the area of the Burdigalian Seaway (Faupl and Roetzel 1987, 1990; Martel et al. 1994; Bieg 2005). Carbonate deposits like the bryozoan-corallinacean limestones of the Zogelsdorf Formation in Lower Austria are scarce (Nebelsick 1989, 1992). A frequent occurrence of diatomites is reported from the NAFB of Lower and Upper Austria and the Carpathians and has been locally related to upwelling conditions (Kotlarczyk and Kaczmarska 1987; Kotlarczyk 1988; Roetzel et al. 2006; Grunert et al. in press). During late Ottnangian this paleogeographic situation changed distinctly when the seaways towards the Atlantic and Mediterranean seas ceased. Brackish lakes developed in parts of the NAFB and in the Carpathian Foredeep (Rögl 1998; Harzhauser and Mandic 2008).

2.2 Study area

The stratotype is located in Upper Austria in the Ried district (Fig. 2). In this area the Ottnangian sediments are represented by the Innviertel Group (Papp and Cicha 1973; Rupp et al. 2008; Fig. 4). While the lower and middle Ottnangian silts and sands originate from fully marine transgressive and high-stand phases, the brackish-fluvial *Oncophora* beds represent the regressive facies of the late Ottnangian. The sediments of the stratotype section belong to the lower Ottnangian Ottnang Fm. summarizing the pelitic basinal deposits in the area (Rupp et al. 2008). The Ottnang Formation lies above the Atzbach Fm., the Kletzenmarkt-Glaukonit Fm. and the Plesching Fm. and partly interfingers with these units. It is overlain by the middle Ottnangian Ried, Reith and Enzenkirchen Fms. (Rupp and van Husen 2007; Rupp et al. 2008). The average thickness of the Ottnang Fm. is reported with 80–100 m (Kaltbeitzer 1988). The regional geological setting can be found on the Austrian geological maps of ÖK 200 "Upper Austria" (Krenmayr and Schnabel 2006) and ÖK 47 "Ried im Innkreis" (Rupp et al. 2008).

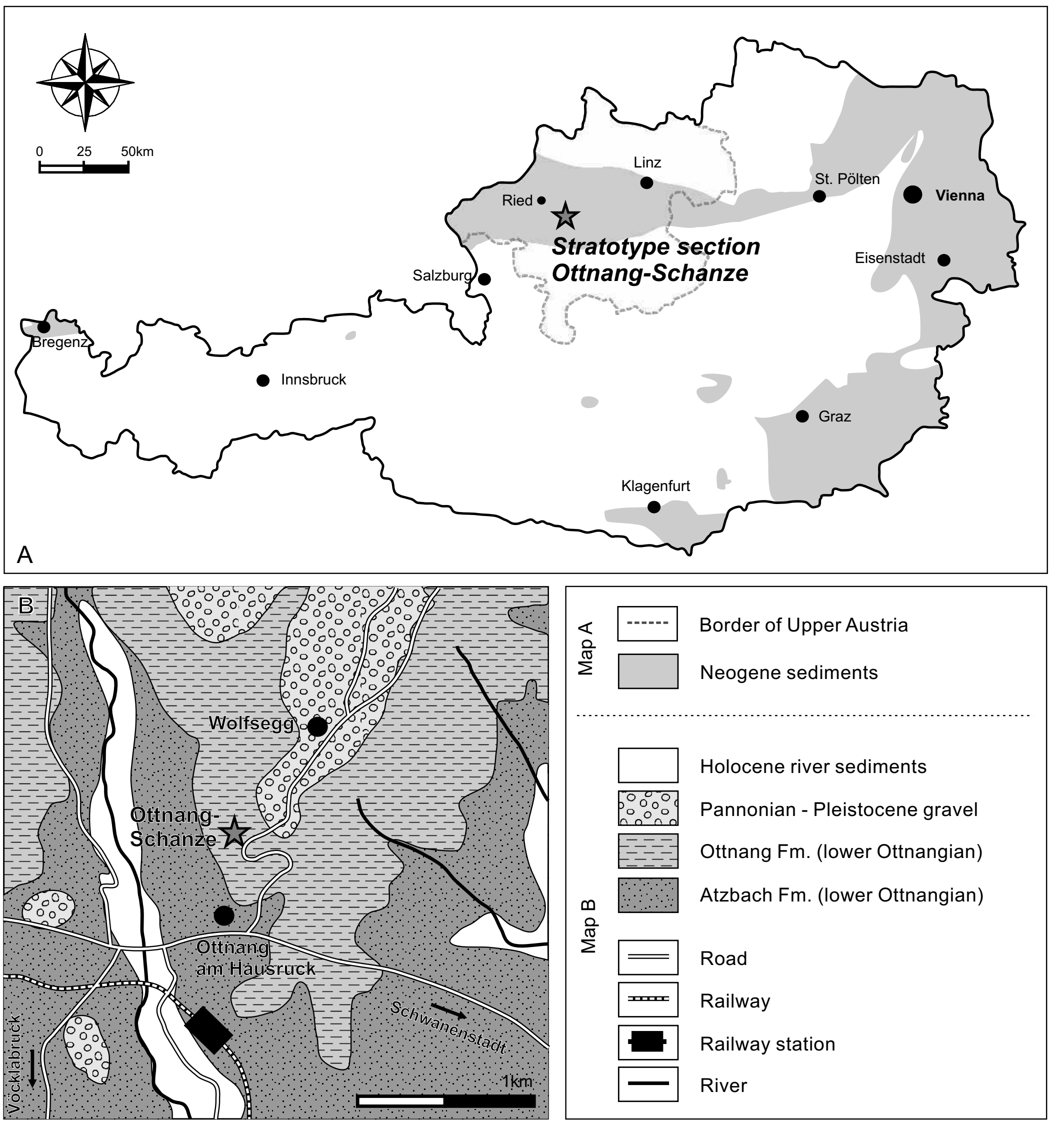


Fig. 2. **(A)** Location of the stratotype section within the Austrian NAFB. **(B)** Geography and geology of the study area based on Krenmayr and Schnabel (2006) and Rupp et al. (2008).

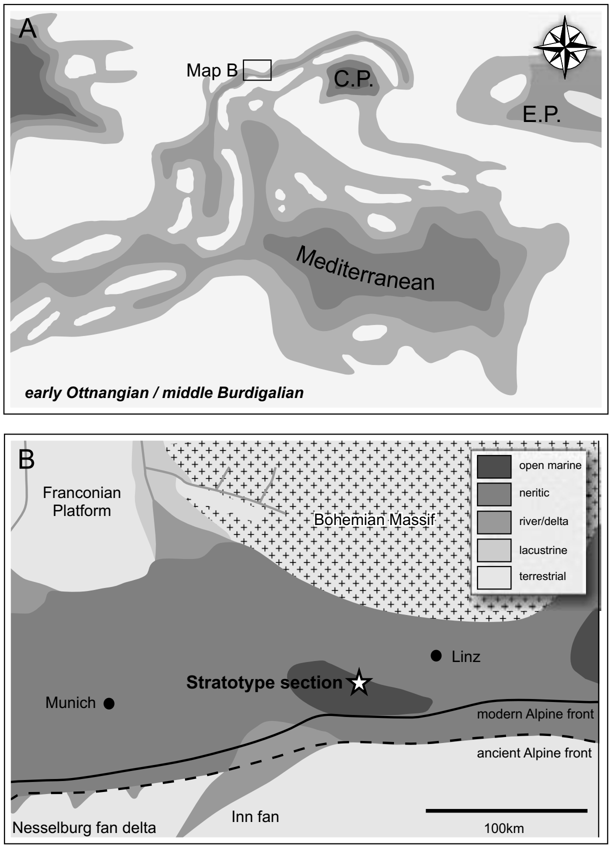


Fig. 3. **(A)** Paleogeography of the early Ottnangian Paratethys and Mediterranean seas based on Rögl (1998) and Harzhauser and Piller (2007). C.P. = Central Paratethys, E.P. = Eastern Paratethys. **(B)** Paleogeography of the study area based on the reconstruction of Kuhlemann and Kempf (2002).

2.3 Present outcrop situation

The Ottnangian stratotype Ottnang-Schanze is located 700 m SSW Wolfsegg and 500 m N of the village Ottnang in Upper Austria (48°06′07″N, 13°40′04″E; Fig. 2b). It is part of an abandoned pit near a memorial to the Peasant Wars (called "Schanze") and has been declared a natural heritage and geotop (Reiter 1989).

The exposed section comprises 10.2 m of sediments with two faults in the lower part (2.6 m, 4.6 m; Fig. 1). It shows a clear change in sedimentation dividing the section into two lithological units: Unit 1 (0–5.5 m) shows rather homogeneous grey-brown sediments of clayey-sandy silts with sand-lenses and flaser bedding. The sand lenses reach a lateral extension up to 30 cm and often contain plant remains. Sediments show no internal bedding but intense bioturbation.

Unit 2 (5.5–10 m) is characterized by 14 beds separated by erosional surfaces and a distinct overall coarsening upward trend. The succession starts with a bed of clayey-sandy silts with flaser bedding similar to Unit 1 which pass into mollusc-rich sediments. Beds 1–11 show internal gradation comprising five coarsening-upward cycles (beds 1–5) and six fining-upward cycles (beds 6–11). Beds with coarsening-upward cycles (thickness: 40–85cm) show indistinct dm-layering often associated with articulated bivalves at the base, passing into bioturbated sediments with bivalve coquinas. Fining-upward cycles (max. thickness: 10 cm) start with cross-bedded sands passing into sandy silts. Finally, the three topmost beds (beds 12–14; thickness: 10–90cm) show a distinct laminated flaser-bedding and disarticulated bivalve shells enriched in sand-lenses.

Only a short part of the Ottnang Fm. crops out at the stratotype section. Based on an evaluation of geological maps and information from drill-sites in the vicinity of the stratotype, most of the Innviertel Group in the study area is made up by the Vöckla and Atzbach Fms. with a thickness up to 520 m (Krenmayr and Schnabel 2006; Rupp et al. 2008; personal communication R. Hinsch, RAG). The overlying Ottnang Fm. is only represented by its lowermost part with a thickness of 15–20 m. Its top is eroded and covered by Pliocene-Pleistocene deposits (Rögl et al. 1973).

2.4 Historical remarks

By the time the outcrop Ottnang-Schanze was formally defined as the stratotype section for the Ottnangian, stratigraphy of the pelitic deposits near Ottnang ("Schlier of Ottnang") has already been discussed for a long time (Papp and Rögl 1973; Rögl et al. 1973; Rupp and van Husen 2007). Based on mollusc and foraminiferal assemblages collected by Simony (1850) and Ehrlich (1852), Hoernes (1853) and Reuss (1864) correlated the "Schlier of Ottnang" to similar sediments in the Middle Miocene (Langhian/Badenian) of the Vienna Basin. This assessment was supported by Gümbel (1887) who compared deposits from different basins and correlated them to the Middle Miocene ("2. Mediterranstufe"). This interpretation was opposed by Suess (1866), Karrer (1867), Reuss (1867), Hoernes (1875a, b), Suess (1891), Tausch (1896) and Commenda (1900) who favoured an older, Early Miocene age for the deposits.

Hydrocarbon exploration during the first half of the 20th century documented confirmed the Early Miocene age of the "Schlier of Ottnang" and a correlation to the Helvetian stage was established (Götzinger 1926; Hof-

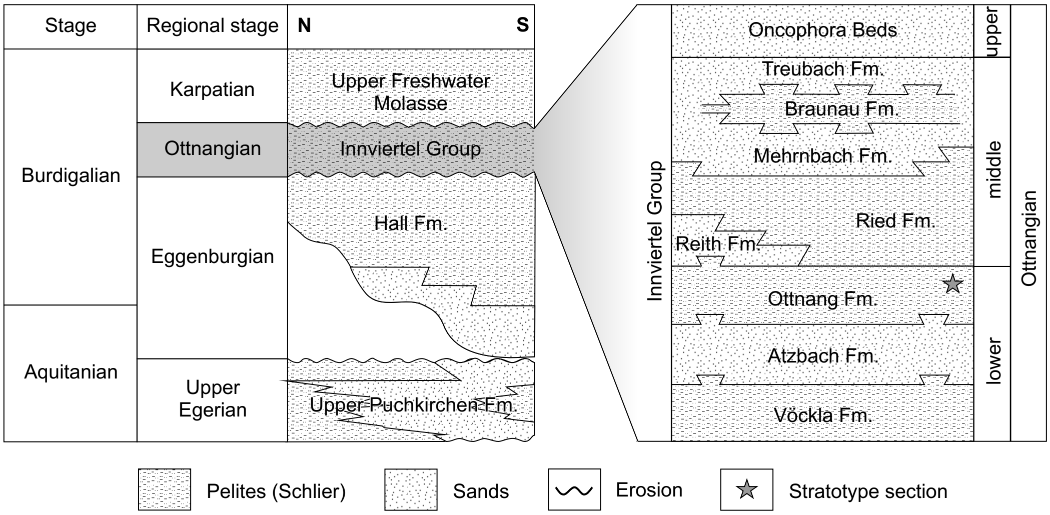


Fig. 4. Lithostratigraphy of the Ottnangian Innviertel Group in the Upper Austrian study area based on Rupp and van Husen (2007) and Rupp et al. (2008).

mann 1932; Petters 1936; Bürgl 1949; Aberer 1958). Recently, the informal lithological units of the Ottnangian Innviertel Group were formalized including the "Schlier of Ottnang" as Ottnang Fm. (Rupp et al. 2008).

3. Material and methods

Biostratigraphy: 24 samples (OS 1–24) taken from the outcrop during 2007 were used for micropaleontological analyses (Fig. 1). For foraminiferal analysis, 100 g of each sample were treated with diluted H_2O_2 for several hours and wet sieved under running tap water. Dried samples were split using a splitting device described in Rupp (1986) and at least 200 specimens were counted from size fractions $> 150\,\mu m$. Foraminifers were identified after Wenger (1987), Cicha et al. (1998) and Rupp and Haunold-Jenke (2003).

A standard palynological technique for the extraction of organic-wall microplankton from sediments has been applied with slight modifications for dinoflagellate cyst analysis (Green 2001; Grunert et al., in press). 20–30 g of sediments were treated with 100 ml of HCl (35 %) and then macerated in 30–50 ml of cold concentrated HF (48 %) for 48–72 hours to remove any carbonates and silicates. Before sieving (meshsizes: 125 µm, 20 µm), residues were treated for 30 seconds in an ultrasonic bath and stained with red Safranin "O". Two slides of each sample were prepared by using glycerine jelly as a mounting media and sealed with nail varnish. 250 dinoflagellate cysts were counted in every sample using a light microscope; the remainder of the slide(s) was then scanned for rare or exceptionally well-preserved specimens. SEM investigation was additionally used for documentation. Taxonomy follows Fensome et al. (1993, 2008).

Smear slides for nannoplankton investigations were prepared using standard methods and examined under light microscope (cross and parallel nicols) with 1000 × magnification. At least 300 specimens were counted from each sample. A further 100 view squares were checked for additional biostratigraphically important nannoplankton taxa.

Magnetostratigraphy: Samples for paleomagnetic investigations were taken from the stratotype section in 2001 and analysis was carried out within the scope of an earlier research project funded by the Austrian Research Fund (FWF-project P13,738-TEC; Fig. 1). 16 standard paleomagnetic samples from two different positions in the section were subjected to detailed stepwise demagnetisation procedure (alternating field and/or thermal treatment). During thermal demagnetisation, the bulk susceptibility of the samples was routinely measured to observe possible mineral transformations. Paleomagnetic data analyses included principal component analysis based on visual inspection of orthogonal projections. Stepwise saturation, measurements of the coercivity, demagnetisation of the saturation magnetization and Curie-point determinations helped to identify the magnetic minerals in the sediments. All measurements were carried out in the

Paleomagnetic Laboratory Gams of the University of Leoben. Natural remanent magnetization was measured on a three-axis cryogenic dc-squid magnetometer with in-line degausser (2G Enterprises). Geofyzika KLY – 2 instruments were used for measuring low-field magnetic susceptibility and its anisotropy.

4. Results

Biostratigraphy: Micropaleontological analysis revealed useful biostratigraphic marker species from all investigated groups. Their abundance in the samples is summarized in Fig. 1, representative images are given in Plates 1–4.

Foraminiferal assemblages are moderately to well-preserved and revealed over 110 benthic species. The frequently occurring benthic foraminifers *Amphicoryna ottnangensis*, *Sigmoilopsis ottnangensis* and *Lenticulina inornata* represent three marker species important in the context of regional Ottnangian stratigraphy. Planktic assemblages revealed no marker species except for the Early Miocene of the Central Paratethys in general (*Globigerina lentiana, G. ottnangiensis*).

All samples revealed well-preserved dinoflagellate cysts with over 60 species. The Early Miocene marker species *Apteodinium spiridoides*, *Exochosphaeridium insigne*, *Glaphyrocysta reticulosa* s.l., *Nematosphaeropsis downiei* and *Sumatradinium soucouyantiae* are present throughout the studied samples. *Cordosphaeridium cantharellus*, *Deflandrea phosphoritica*, *"Distatodinium cavatum"*, *Hystrichokolpoma cinctum*, *H. truncatum*, *Hystrichosphaeropsis obscura*, *Membranilarnacia? picena*, *Sumatradinium druggii* and *S. hispidum* are recorded sporadically.

Nannoplankton assemblages are moderately to well preserved and frequently contain a variety of autochthonous and reworked taxa. Over 40 autochthonous species have been identified in total. *Helicosphaera ampliaperta* with its first occurrence at the base of the Burdigalian is recorded frequently in all samples. Additionally, the Early Miocene species *Discoaster drugii*, *H. carteri*, *Sphenolithus conicus*, *S. disbelemnos* and *S. dissimilis* are rarely encountered. Single specimens assigned to *Sphenolithus* cf. *belemnos* (OS 12) and *Sphenolithus aff.* heteromorphus (OS 6) are present.

Magnetostratigraphy: Mineral magnetic characterisation experiments indicate magnetite as main carrier mineral of the magnetisation: magnetic saturation could be reached at low dc-fields during isothermal remanence acquisition, and the remanence coercivity derived from back-field analyses was ranging between 30 mT and 35 mT. Natural remanent magnetization (NRM) was typically fully demagnetised at alternating field strengths of 20mT and temperatures below 400°C, respectively. 8 out of 16 studied samples yielded interpretable demagnetization paths containing two magnetic components. A randomly distributed viscose component could be removed with alternating fields of less than 5 mT. The second magnetic component which was regarded as the characteristic remanent magnetization in both sample groups was characterised by considerably scattering directions, but all vectors yielded inverse polarity. The mean primary magnetization direction from the section Ottnang-Schanze represented a declination of 154° and an inclination of -51°, indicating remanence acquisition during an inverse chron of the Earth's magnetic field.

5. Discussion

5.1 Foraminiferal biostratigraphy of the Ottnangian

As a correlation with the global planktic zonation fails, regional foraminiferal biostratigraphy relies on the evolution of endemic benthic species. *Amphicoryna ottnangensis* is the only well-established marker for the early Ottnangian in Bavaria and Upper Austria (Cicha and Rögl 1973; Wenger 1987; Cicha et al. 1998; Rupp and Haunold-Jenke 2003). It has its FAD at the Eggenburgian/Ottnangian boundary and lasts until the earliest middle Ottnangian. Another species often used in Ottnangian biostratigraphy is *Sigmoilopsis ottnangensis*. While its FAD in Bavaria has been recorded during late Eggenburgian and LAD at end of early Ottnangian, its records from the Austrian NAFB and Vienna Basin seem to be restricted to the early Ottnangian (Cicha and Rögl 1973; Wenger 1987; Cicha et al. 1998). The FAD of *Pappina breviformis* has been suggested as a marker for the base of the middle Ottnangian (Wenger 1987; Cicha et al. 1998).

Problems occur with other species that seem to have regional value but no superregional significance. *Pappina primiformis* and *Bolivina matejka* have their FAD at the base of the Ottnangian in Bavaria, *B. scitula* is restricted to the early Ottnangian (Wenger 1987). In Croatia, *Elphidium fichtelianum* has its FAD at the base of the Ottnangian (Cicha et al. 1998).

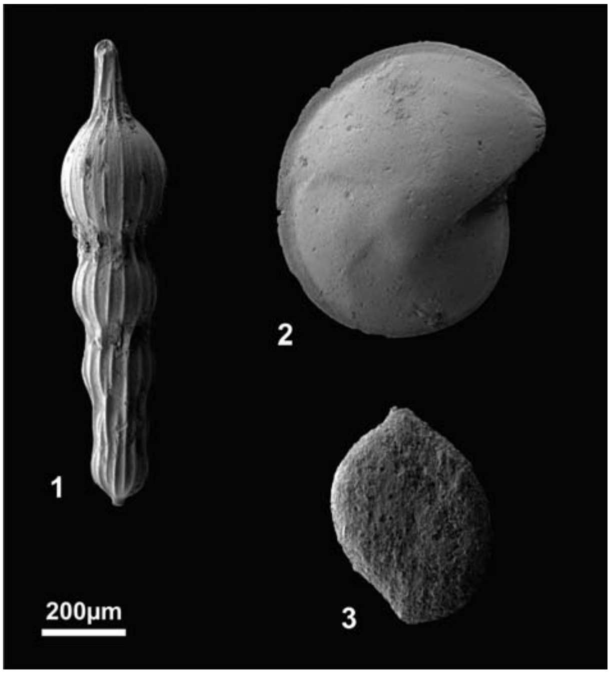


Plate 1. Biostratigraphic marker species of benthic foraminifers. **1:** *Amphicoryna ottnangensis* (Toula); Sample OS 11. **2:** *Lenticulina inornata* (D'Orbigny); Sample OS 11. **3**: *Sigmoilopsis ottnangensis* Cicha, Ctyroka & Zapletalova; Sample OS 24.

The results from this study with the frequent occurrence of both marker species *A. ottnangensis* and *S. ottnangensis* agree well with results from previous reports (Rögl et al. 1973; Rupp and Haunold-Jenke 2003; Rupp and van Husen 2007; Rupp et al. 2008). Other Ottnangian marker species were not encountered. Accordingly, the outcrop belongs to the late early Ottnangian.

The regional biostratigraphic concept is hampered by the obvious dependency of benthic species on facies distribution (a problem that concerns most of the Paratethys stages). Consequently, *A. ottnangensis* and *S. ottnangensis* have only been described from the NAFB of Bavaria and Austria, the Vienna Basin, Croatia and Slovenia (Cicha et al. 1998). As a result workers locally tend to rely on characteristic composition of foraminiferal assemblages as a whole to identify the Eggenburgian/Ottnangian boundary and to differentiate the internal subdivision of the Ottnangian. In Upper Austria, there is a characteristic development during early Ottnangian from an assemblages dominated by *Ammonia parkinsonia*, *Lobatula lobatula* and *Cibicidoides* spp. to a fauna with mass-occurrences of *Lenticulina inornata*. These assemblages become replaced by an *Ammonia parkinsonia* dominated fauna at the beginning of the middle Ottnangian (Bürgl 1949; Aberer 1958; Rupp and Haunold-Jenke 2003; Rupp et al. 2008). Similar faunal successions have been observed in Bavaria (Wenger 1987; Pippèrr et al. 2007). Data of the studied stratotype section correspond to the typical late early Ottnangian *Lenticulina*-pelites.

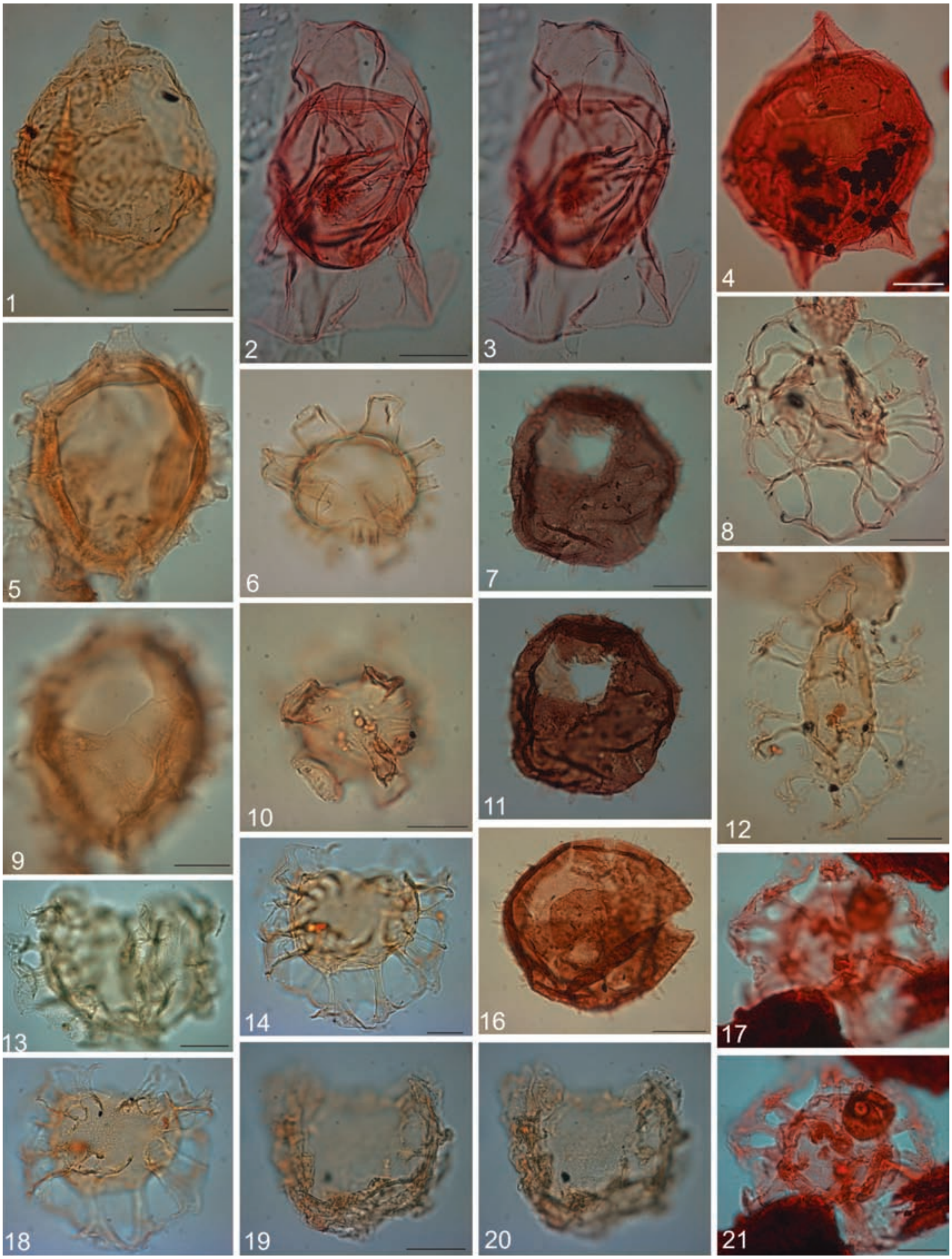
5.2 Dinoflagellate cyst stratigraphy: Central Paratethys and beyond

The composition of the revealed dinoflagellate cyst assemblages is characteristic for an Early Miocene age and allows a biostratigraphic evaluation on the global as well as regional level. While the co-occurrence of *Apteodinium spiridoides*, *Cordosphaeridium cantharellus*, *Exochosphaeridium insigne*, *Hystrichokolpoma truncatum*, *Hystrichosphaeropsis obscura*, *Membranilarnacia? picena*, *Nematosphaeropsis downiei*, *Suma-*

Plate 2. Biostratigraphic marker species of dinoflagellate cysts. Scale bar = 20µm.
1: *Apteodinium spiridoides* Benedek, 1972; Sample OS 1, Slide B, England Finder F67; later view, mid-focus. **2, 3:** *Hystrichosphaeropsis obscura* Habib, 1972; Sample OS 2; Slide B, England Finder, S40/1; successive foci. **4:** *Deflandrea phosphoritica* Eisenack, 1938; Sample OS 22, Slide B, England Finder F69/2; dorsal view. **5, 9:** *Exochosphaeridium insigne* de Verteuil and Norris, 1996; Sample OS 1, slide B, England Finder G47; ventral and dorsal views respectively. **6, 10:** *Hystrichokolpoma truncatum* Biffi and Manum, 1988; Sample OS 1; slide B, England Finder, M37; apical and antapical views respectively. **7, 11:** *Sumatradinium soucouyantiae* de Verteuil and Norris, 1992; Sample OS 1, Slide B, England Finder B38; dorsal view, mid and high-focus. **8:** *Nematosphaeropsis downiei* Brown, 1986; Sample OS 24; Slide A, England Finder C57/2; dorsal view. **12:** *"Distatodinium cavatum"* Zevenboom and Santarelli in Zevenboom, 1995; Sample OS 1; Slide B, England Finder X57; mid-focus. **13:** *Membranilarnacia? picena* Biffi and Manum, 1988; Sample OS 4, Slide B, England Finder W23; mid-focus. **14, 18:** *Glaphyrocysta reticulosa* (Gerlach, 1961) Stover and Evitt, 1978 sensu lato; Sample OS 3; Slide B, England Finder J60/2; ventral view, mid and high-focus. **16:** *Sumatradinium druggii* Lentin, Fensome and Williams, 1994; Sample OS 2, slide B, England Finder O46; dorsal view. **17, 21:** *Cordosphaeridium cantharellus* (Brosius) Gocht, 1969;Sample OS 21, slide A; England Finder O43/1; low and high-focus. **19, 20:** *Membranophoridium* sp.; Samples OS 1, slide B, England Finder M43/3; ? ventral view, low and high-focus.

tradinium hispidum and *S. soucouyantiae* indicates a late Aquitanian to Burdigalian age, the presence of *H. cinctum* and *S. drugii* allows a correlation to D17a dinoflagellate cyst zone (middle-late Burdigalian, 19.03–15.97 Ma; Zevenboom 1995; de Verteuil and Norris 1996; Williams et al. 2004; Lourens et al. 2004; Jiménez-Moreno et al. 2006; Dybkjær and Piasecki 2008). In general, the assemblages are similar to those of the Burdigalian stratotype (Londeix and Jan du Chêne 1998).

Regionally, the species *E. insigne* allows a more precise dating. It has been described as a marker for



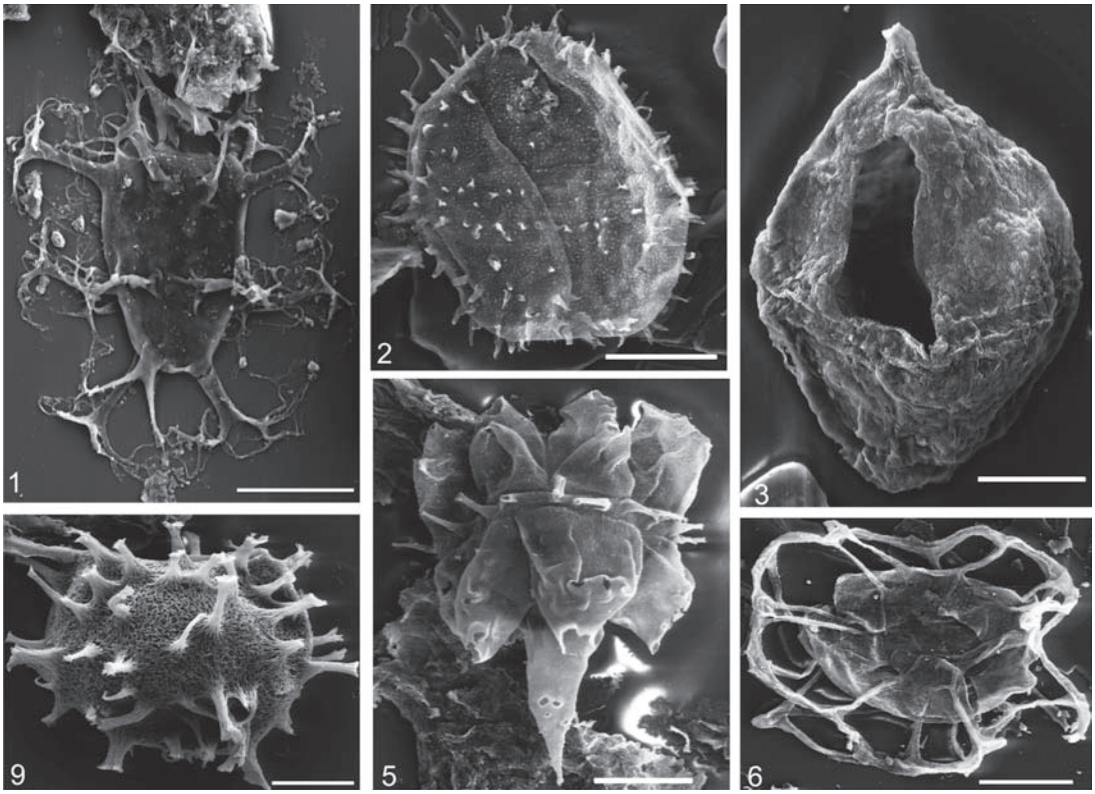


Plate 3. Biostratigraphic marker species of dinoflagellate cysts. Scale bar = 20μm
1: *Distatodinium paradoxum* (Brosius) Eaton 1976: Sample OS 1. **2:** *Sumatradinium hispidum* (Drugg) Lentin and Williams emend. Lentin *et al.,* 1994; Sample OS 7; dorsal view. **3:** *Apteodinium spiridoides* Benedek, 1972; Sample OS 7; dorsal view. **4:** *Exochosphaeridium insigne* de Verteuil and Norris, 1996; Sample OS 4. **5:** *Hystrichokolpoma cinctum* Klumpp, 1953; sample OS 4; dorsal view. **6:** *Nematosphaeropsis downiei* Brown, 1986; Sample OS 24.

early-middle Burdigalian from the western North Atlantic, the North Sea and the Gulf of Suez (de Verteuil and Norris 1996; Köthe 2003; Dybkjær 2004; Soliman 2006; Dybkjær and Piasecki 2008). Earlier occurrences reported for the North Sea are most likely related to caving (Schiøler 2005; Jiménez-Moreno et al. 2006). Notably, *E. insigne* is missing at the Burdigalian stratotype (Londeix and Jan du Chêne 1998). It defines the top of DN2 zone of de Verteuil and Norris (1996) and its last occurrence defines the boundary between D16c and D17a zones in the North Atlantic (Lourens et al. 2004). Dybkjær and Piasecki (2008), however, recently suggested to extend the stratigraphic range of *E. insigne* boundary into zone D17a with a last occurrence at the NN3/NN4 boundary.

In good agreement with Dybkjær and Piasecki (2008), *E. insigne* has been described from an early middle Ottnangian outcrop at Straß-Eberschwang the Upper Austrian NAFB (Jiménez-Moreno et al. 2006). Based on its occurrence together with *A. spiridoides*, *C. cantharellus*, *Glaphyrocysta reticulosa* s. l. and *Membranophoridium* sp. the authors defined the regional dinoflagellate cyst zone *Ein*. Our results together with similar assemblages revealed from Ottnang-Schanze (Hochuli 1978) and ongoing studies on Burdigalian drill-sites (Soliman and Piller 2009) suggest to extend this zone to the entire early Ottnangian.

5.3 Calcareous nannoplankton: the link to global stratigraphy

As the Ottnangian spans parts of two standard nannoplankton zones (upper NN3-lower NN4) an exact dating is problematic. In general, the assemblages resemble the results of previous studies on early Ottnangian sediments from the NAFB of Lower Austria (Roetzel et al. 2006) and the Transylvanian Basin (Chira 2004). Martini and Müller (1975) described similar, though less diverse assemblages with *Helicosphaera ampliaperta* and *H. carteri* from the stratotype.

Our new data allow a more precise dating. The frequent occurrences of *Helicosphaera ampliaperta* and

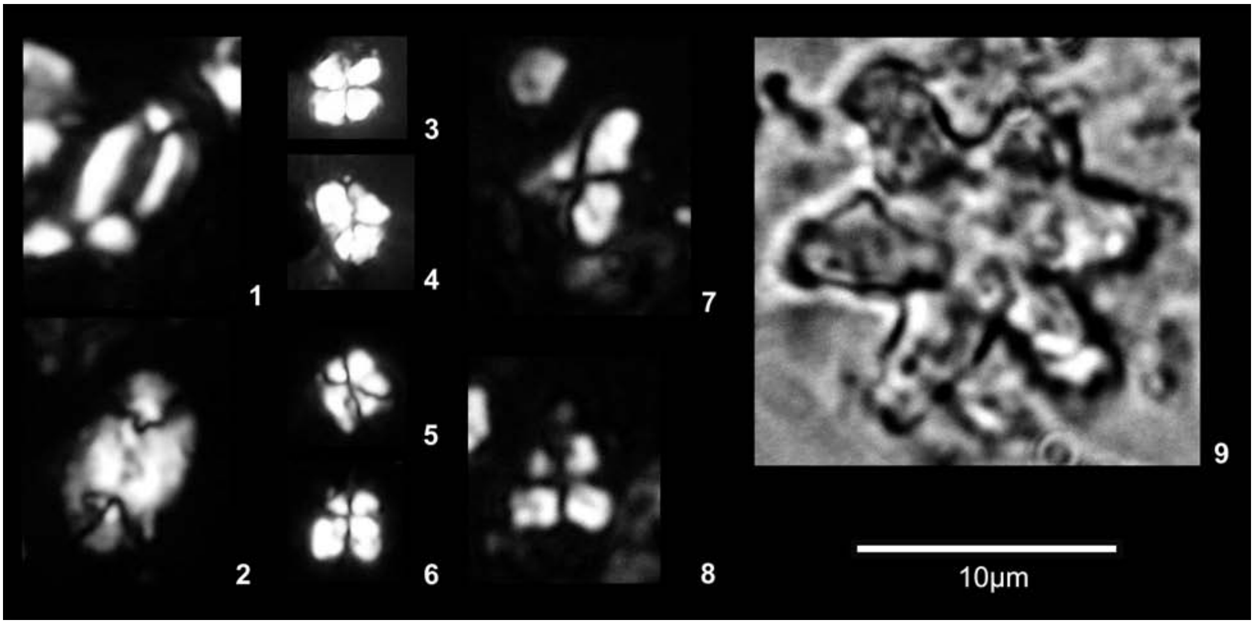


Plate 4. Biostratigraphic marker species of calcareous nannoplankton.
1: *Helicosphaera ampliaperta* Bramlette and Wilcoxon, 1967; Sample OS 6. **2:** *Helicosphaera carteri* (Wallich, 1877) Kamptner, 1954; Sample OS 6. **3-4:** *Sphenolithus* aff. *heteromorphus* Deflandre, 1953; Sample OS 6. **5–6:** *Sphenolithus disbelemnos* Fornaciari and Rio, 1996; Sample OS 3. **7–8:** *Sphenolithus conicus* Bukry, 1971; Sample OS 13. **9:** *Discoaster druggii* Bramlette and Wilcoxon, 1967; Sample OS 9.

the presence of *Discoaster drugii*, *H. carteri* and *Sphenolithus disbelemnos* prove the Early Miocene age of the section. The absence of *Triquetrorhabdulus carinatus* (LAD at NN2/NN3 boundary) indicates a correlation of Ottnang-Schanze with nannoplankton zone NN3 (early-middle Burdigalian; 20.43–17.95 Ma) (Martini 1971; Lourens et al. 2004).

This interpretation is supported by a comparison with the Mediterranean nannoplankton zonation based on quantitative composition of assemblages (Fornaciari and Rio 1996). Nannoplankton assemblages from Ottnang-Schanze with the very rare *S.* cf. *belemnos, S.* aff. *heteromorphus, S. conicus*, *S. dissimilis* and the absence of *Helicosphaera mediterranea* show remarkable similarities in their composition with MNN3b zone (*Sphenolithus belemnos-Sphenolithus heteromorphus* Interval Zone). MNN3b is defined as interval between the last common and continuous occurrence (LCO) of *S. belemnos* and the first common and continuous occurrence (FCO) of *S. heteromorphus* and can be correlated with the upper part of NN3 and lowermost NN4 of Martini (1971) (Fornaciari and Rio 1996).

The suggested correlation to upper NN3 of the standard zonation and to MNN3b of the Mediterranean zonal scheme is in accordance with silicoflagellate *Dictyocha triacantha*-zone earlier recorded from the outcrop (Martini and Müller 1975). The results also confirm the previously assumed correlation of the Ottnangian with the *Globigerinoides trilobus*-Zone (Cicha and Rögl 1973; Rögl 1985).

5.4 Absolute age

Based on the revealed biostratigraphic data, the assessement of an absolute age for the section is possible. Biostratigraphy constrains the time-frame for deposition to an age between 19.03 and 17.95 Ma (lower boundary of D17a – upper boundary of NN3; Lourens et al. 2004). According to the current Central Paratethyan age model based on 3rd-order sequences presented by Kovác et al. (2004) and Piller et al. (2007) the Ottnangian corresponds to cycle Bur3 of Haq et al. (1998) with a lower boundary at 18.12 Ma (Fig. 5). Within this temporal limits only chron C5Dr.2r (18.056–17.740 Ma; Lourens et al. 2004) shows reverse polarity. Consequently, Ottnang-Schanze corresponds to a maximum age of 18.056 Ma and a minimum age of 17.95 Ma.

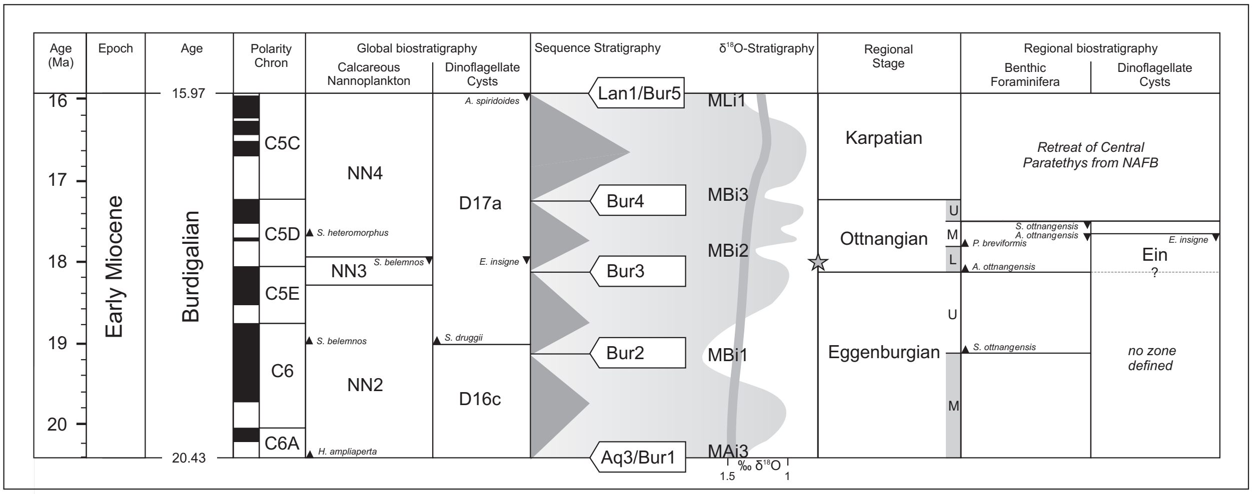


Fig. 5. Summary of regional Eggenburgian-Karpatian and international Burdigalian stratigraphy. Asterisk indicates the position of the Ottnangian stratotype. Stratigraphic data are based on Wenger (1987), Cicha et al. (1998), Lourens et al. (2004), Jiménez-Moreno et al. (2006) and Piller et al. (2007). See text for a discussion of the stratigraphic range of *E. insigne*.

6. Conclusions

The section Ottnang-Schanze in the North Alpine Foreland Basin of Upper Austria represents the stratotype for the regional Ottnangian stage (Central Paratethys; middle Burdigalian, c. 18.1–17.2 Ma). In the present study it has been re-evaluated with respect to regional and global stratigraphy based on biostratigraphy (foraminifers, dinoflagellate cysts, calcareous nannoplankton) and magnetostratigraphy.

In agreement with earlier studies, benthic foraminifers (co-occurrence of *Amphicoryna ottnangensis* and *Sigmoilopsis ottnangensis*, mass-occurrences of *Lenticulina inornata*) document a late early Ottnangian age. For the first time, dinoflagellate cyst *Exochosphaeridium insigne* is documented from the early Ottnangian and its occurrence together with *Apteodinium spiridoides*, *Cordosphaeridium cantharellus* and *Glaphyrocysta reticulosa* s.l. extends the regional dinoflagellate zone *Ein* (Jimenéz-Moreno et al. 2006) from the middle to the early Ottnangian. With respect to the international stratigraphic frame-work, the revealed marker species indicate zone D17a (middle-late Burdigalian). Calcareous nannoplankton assemblages with the very rare occurrence of *Sphenolithus* cf. *belemnos* and *S.* aff. *heteromorphus* show remarkable affinities to Mediterranean nannoplankton zone MNN3b. The frequent occurrence of *Helicosphaera ampliaperta* and the absence of *Triquetrorhabdulus carinatus* allow an assignment to standard nannoplankton zone NN3 (early-middle Burdigalian) is possible.

Magnetostratigraphy revealed an inverse polarisation for the section. In combination with the biostratigraphic age constraints and the present correlation of the Ottnangian to the Bur3 sea-level cycle the section belongs to polarity chron C5Dr.2r. Thus, for the first time, it is possible to propose an absolute age between 18.056–17.95 Ma for the stratotype.

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