JAHRBUCH DER GEOLOGISCHEN BUNDESANSTALT

Jb. Geol. B.-A. | ISSN 0016–7800 | Band 155 | Heft 1–4 | S. 109–120 | Wien, Dezember 2015

Eocene Larger Benthic Foraminifera (Nummulitids, Orthophragminids) from the Waschberg-Ždánice Unit, Lower Austria

ANA I. TORRES-SILVA[1, 2] & HOLGER GEBHARDT[1]

1 Text-Figure, 1 Table, 2 Plates, 1 Appendix

Österreichische Karte 1:50.000
BMN / UTM
40 Stockerau / 5313 Hollabrunn

Eocene
Waschberg-Ždánice Unit
Biostratigraphy
nummulitids
orthophragminids

Contents

Abstract

The Eocene rocks of the Waschberg-Ždánice Unit were deposited at the northern limit of mass-occurrences of larger benthic foraminifera (LBF). The found LBF-assemblages are well suitable for biostratigraphic classifications and therefore for the reconstruction of the sedimentary and tectonic development of the area. We found 1) an Ypresian to basal Lutetian (SBZ, Shallow Benthic Zone 10–11) assemblage dominated by *Nummulites partschi* and *Orbitoclypeus schopeni,* 2) a Bartonian (SBZ 18) assemblage dominated by *Nummulites striatus* and *Orbitoclypeus varians,* and 3) a Priabonian (SBZ 20) assemblage dominated by *Asterocyclina priabonensis, Nummulites stellatus,* and *Discocyclina trabayensis vicenzensis.* Orthophragminids from this area were studied on species level for the first time.

Eozäne Großforaminiferen (Nummuliten, Orthophragminen) aus der Waschberg-Ždánice-Einheit, Niederösterreich

Zusammenfassung

Die eozänen Gesteine der Waschberg-Ždánice-Einheit wurden am nördlichen Rand der Massenvorkommen von Großforaminiferen abgelagert. Die gefundenen Großforaminiferenassoziationen sind für biostratigrafische Einstufungen gut geeignet und damit auch für die Rekonstruktion der sedimentären und tektonischen Entwicklung des Gebietes. Wir fanden 1) eine Assoziation des Ypresium bis basalem Lutetium (SBZ, Shallow Benthic Zone 10–11), dominiert von *Nummulites partschi* und *Orbitoclypeus schopeni,* 2) eine Assoziation des Bartonium (SBZ 18), dominiert von *Nummulites striatus* und *Orbitoclypeus varians*, und 3) eine Assoziation des Priabonium (SBZ 20), dominiert von *Asterocyclina priabonensis, Nummulites stellatus* und *Discocyclina trabayensis vicenzensis*. Orthophragminen aus diesem Gebiet wurden zum ersten Mal auf Artniveau untersucht.

1 ANA I. TORRES-SILVA, HOLGER GEBHARDT: Geologische Bundesanstalt, Neulinggasse 38, 1030 Vienna, Austria. holger.gebhardt@geologie.ac.at,
2 ANA I. TORRES-SILVA: Institut für Paläontologie, Universität Wien, Althanstraße 14, 1090 Vienna, Austria. ana_ivist@hotmail.com

Introduction

The Waschberg-Ždánice Unit has been a product of intense tectonic movements at least since the Paleogene period. Large blocks of Paleogene rocks are embedded into Neogene marls. The source of these rocks remains largely unclear and the tectono-sedimentary development of the unit is still under discussion (e.g., the olistolithic origin of several rock units). Detailed biostratigraphic information is therefore a necessary but powerful tool in order to explain the geological history of this area. In particular for the Eocene rocks, the analysis of larger benthic foraminifera (LBF) provides valuable information for this task.

Overviews on the state of the art of the tectono-sedimentary development were given by KRHOVSKY et al. (2001) and WESSELY et al. (2006). Thrusting as the main tectonic process was the major factor for the distribution of rocks in the region, but it can be assumed that climatic and eustatic sea-level changes were also crucial for the Paleogene local facies development as it has been shown for the subsequent Neogene period (e.g., KOVÁČOVA et al., 2011; GEBHARDT & ROETZEL, 2013).

Beside the lack of knowledge on the tectono-sedimentary development, the available biostratigraphic information on the several occurring rock units is limited. Particularly the original literature on larger benthic foraminifera is restricted to a few papers and partly outdated (GLAESSNER, 1937; SIEBER, 1953; PAPP, 1958, 1962). Therefore, the taxonomy and biostratigraphy of the larger foraminifera from these units need to be revised. This contribution is not a formal taxonomic review and does not claim to be complete or representative. However, it expands our knowledge to a number of new localities and applies modern species concepts to the reported occurrences of larger benthic foraminifera from the southern part of the Waschberg-Ždánice Unit. The above mentioned authors reported at species level only on nummulitids. In addition to this, we included orthophragminids into our assemblage analyses and reported on them at species level for the first time.

Although the Waschberg-Ždánice Unit is located at the northern limit of the distribution of mass-occurrences of nummulitids and orthophragminids (compare RACEY, 2001), the age and environmental information generated from these groups in combination with planktic foraminifera and calcareous nannofossils will contribute considerably to our knowledge of the geological development. Thus, we present here our results of recently collected fossils from ongoing geological field mapping activities. Assignment of the assemblages to standard zonal schemes (here: Shallow Benthic Zones [SBZ] according to SERRA-KIEL et al., 1998) may allow their worldwide correlation.

Material and Methods

We collected a number of individual nummulitids and orthophragminids from four localities south and southeast of Haselbach (Text-Fig. 1, localities 1–4), and several solid rock samples for thin section analysis (Text-Fig. 1, localities 5–12). From these and additional localities (Tab. 1), individual specimens were classified to species level where possible. We largely applied the taxonomic concepts of SCHAUB (1981a, b, c; nummulitids) and LESS (1987, orthophragminids). Stratigraphic ranges of the LBF were determined by using the Shallow Benthic Zonation of SERRA-KIEL et al. (1998). We were able to identify three *Nummulites* species, two *Orbitoclypeus* species, and one *Discocyclina* species (see Appendix 1).

From hard and indurated samples, thin sections were made in order to reveal the larger benthic foraminiferal assemblages. Identification at specific level was possible for several well-oriented *Nummulites, Orbitoclypeus,* and *Discocyclina* specimens. Isolated individuals were thin-sectioned in equatorial direction where the diagnostic features are visible. For most of the orthophragminids and nummulitids, internal features such as the size and form of the proloculus and deuteroloculus, number of whorls, presence of pillars and shape of the equatorial and lateral chambers were essential for identification.

The sample material is stored in the paleontological collection of the Geological Survey of Austria (GBA) and can be found under the collection number GBA2015/006/0001 ff.

Results

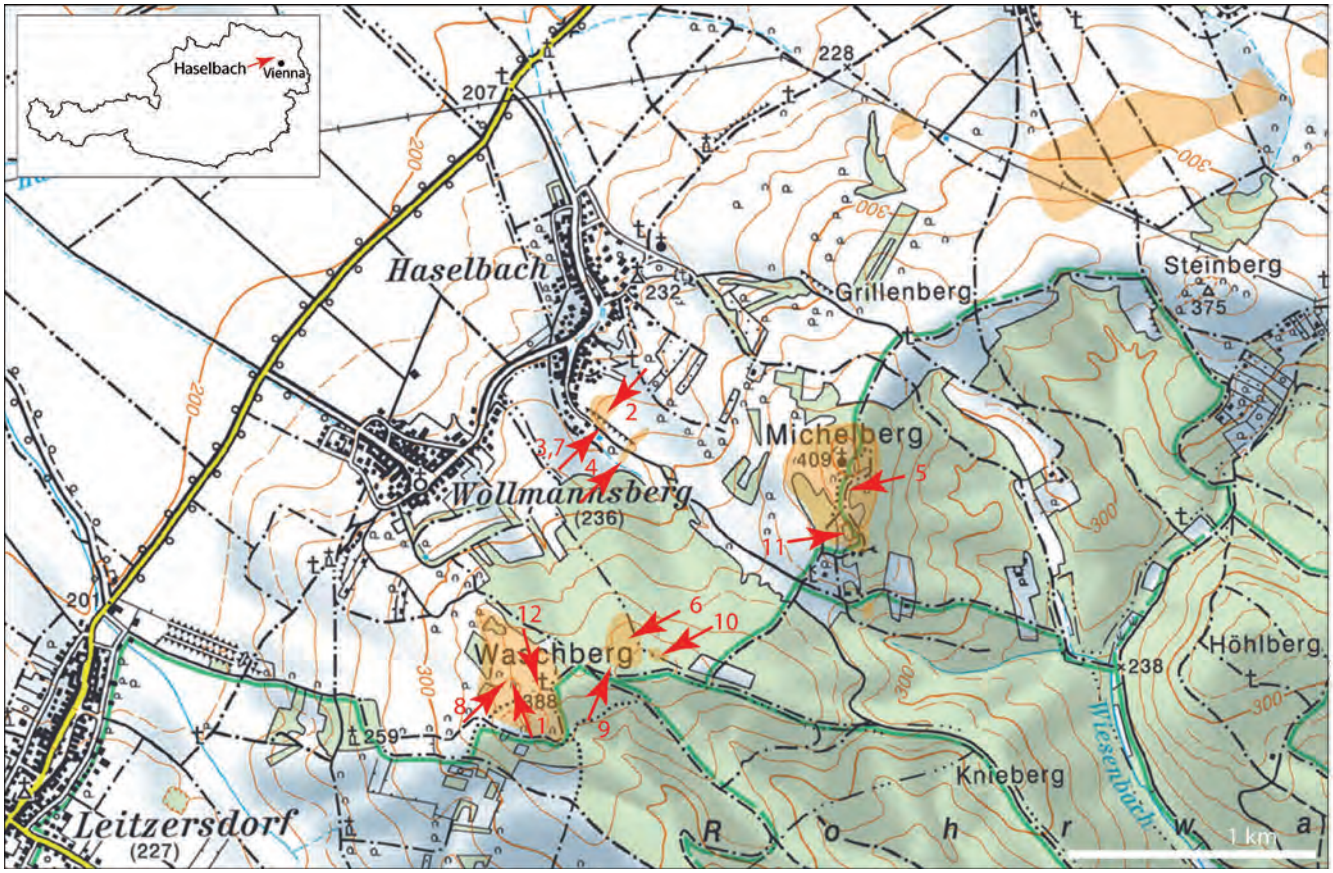
Former studies of nummulitids and orthophragminids of the Waschberg-Ždánice Unit often yielded results that rarely fit into modern distribution charts. E.g. SIEBER (1953) reported *Nummulites incrassatus* from Reingruber Höhe near Bruderndorf, a locality directly north of the area sampled for this study. PAPP (1958) reported a number of nummulite species from the same locality (*N. boullei, N. chavannesi, N.* and *N. ramondiformis,* with *N. incrassatus* = B-form of *N. ramondiformis*) and confirmed the late Eocene (Bartonian) age. These names (or species concepts) are not valid names according to SCHAUB (1981a).

Three groups of localities were samples for this study (Text-Fig. 1): First, the old quarry area west of the Waschberg and occurrences NE of it; second, the outcrops along the road from Haselbach to the Michelberg; and third, old quarries and pits at the Michelberg. The outcrops at Waschberg or at Michelberg are one possible type locality of *Nummulites partschi*, which we found to be the most frequent species in these outcrops. This species was first described by DE LA HARPE (1880) from Gurnigel (Switzerland) or the area investigated here, unfortunately without designation of holotype and type locality. Topotypes of *Nummulites partschi* from the Michelberg were described in detail by BIEDA (1934).

The age assignments of the samples investigated are based on modern literature for the found LBF-species (LESS, 1987; SCHAUB, 1981a; SERRA-KIEL et al., 1998). Among the investigated assemblages, we found three distinct levels of Ypresian to basal Lutetian, Bartonian, and Priabonian age.

Ypresian to Basal Lutetian (SBZ 10–11)

The so-called Waschbergkalk is an informal lithostratigraphic unit and is represented by localities at Waschberg and Michelberg. The rocks comprise a high amount of siliclastic components (quartz sand, crystalline pebbles, see Plate 2), that exclude a carbonate platform as a source area for its material. GLAESSNER (1937) reported *N. distans*



Text-Fig. 1.
Locations of collection points. **1.** sample GEB12/03/19-4. **2.** sample GEB12/03/22-1. **3.** sample 5752. **4.** sample 5884. **5.** sample GEB12/03/06-8. **6.** sample GEB12/03/20-3. **7.** sample GEB12/03/06-3. **8.** sample GEB12/03/19-3A. **9.** sample GEB12/03/20-1. **10.** sample GEB12/03/20-2. **11.** samples GEB12/03/06-6 and 06-7. **12.** sample GEB12/03/19-2.
Sample Locations **3** and **4** were adopted from SEIFERT (1980). Pale orange areas indicate Eocene rocks in place, based on GRILL (1962) and ongoing field mapping (GEBHARDT & ĆORIĆ, 2014).

var. *minima* together with *N. bolcensis* var. *densispira* from both localities and inferred a lower Eocene age, confirmed by smaller foraminifera from marly intercalations. PAPP (1962) describes monospecific assemblages of isolated specimens of *N. partschi* from the Michelberg. *N. partschi* is indicative for the Early Eocene (Cuisian of SCHAUB, 1981a, a local stage corresponding to the Ypresian [GRADSTEIN et al., 2012: 864]) which confirms the age interpretation of GLAESSNER (1937). In addition to Waschberg and Michelberg (locations 1, 5, 8, 11, 12), we included further Waschbergkalk occurrences into our analyses (locations 6, 7, 9, 10; Text-Fig. 1). Most frequent are nummulitids and orthophragminids. We identified *Nummulites partschi* A-forms (most frequent; Pl. 1, Fig. 1, Pl. 2, Figs. 2–4), *Orbitoclypeus* (cf. *schopeni,* Pl. 2, Figs. 5–10), and some *N. partschi* B-forms (Pl. 2, Fig. 1). Some samples also yielded unidentified alveolinids. Other frequent biogenes include algal fragments, smaller benthic foraminifera, bivalves, corals, bryozoans, *Gypsina* sp., and encrusting benthic foraminifera (Pl. 2, Tab. 1).

The Waschbergkalk also contains marly intercalations at some places that provided planktic foraminifera (E-zones) and calcareous nannofossils (NP-zones; MARTINI, 1971) that may confine the age determinations by LBF. GEBHARDT & ĆORIĆ (2014) found assemblages with ages ranging from planktic foraminifera zone E5 with *Acarinina* cf. *soldadoensis, Morozovella lensiformis, Parasubbotina varianta,* and *Subbotina roesnaensis* (Michelberg), to E7 with *Acarinina boudreauxi, A. bullbrooki, A.* cf. *coalingensis, A. praetopilensis, A. soldadoensis, Globorotalita bassriveriensis, Igorina* cf. *iodoensis, Planorotalites capdevilensis, Subbotina eocaena,* and *S.* cf. *hagni* (Waschberg). These ages confirm the ages obtained from LBF.

In addition to samples from the Waschbergkalk, we classified isolated LBF collected by Peter Seifert from locality 4 south of the road from Haselbach to the Michelberg (Text-Fig. 1). These include *Nummulites partschi* A-forms (Pl. 1, Fig. 2) and *Orbitoclypeus schopeni* (Pl. 1, Fig. 3). Equivalent marl samples from the surroundings point to zones E6–7 or NP13 (with *Acarinina cuneicamerata, A. cf. soldadoensis, Subbotina eocaena, S. hagni* (GEBHARDT & ĆORIĆ 2014) and *Chiasmolithus grandis, Discoaster barbadiensis, D. distinctus, D. lodensis, D. murus, Neococcolithites dubius* (SEIFERT 1980).

Bartonian (SBZ 18)

All materials are isolated specimens and came from locality 2 (Text-Fig. 1). We identified *Nummulites striatus* A-forms (Pl. 1, Fig. 4), *N. striatus* B-forms (Pl. 1, Fig. 5), and *Orbitoclypeus varians* (Pl. 1, Fig. 6). These species indicate SBZ 18 according to SERRA-KIEL et al. (1998). *N. striatus* is a typical last occurring taxon around the Bartonian–Priabonian larger foraminiferal events of the Western Tethys (LESS & ÖZCAN, 2012). Associated planktic foraminiferal assemblages with *Acarinina* cf. *medizzai, Morozovelloides* cf. *bandyi, Subbotina* cf. *angiporoides*, and *Turborotalia* cf. *cerroazulensis* point to zone E11 (GEBHARDT & ĆORIĆ, 2014) and largely confirm the age assignment of the LBF.

Location on Text-Fig. 1	Sample	Longitude	Latitude	Sample type	Identified LBF taxa
1	GEB12/03/19-4	594004	5364018	individual	*Nummulites partschi* A-form
2	GEB12/03/22-1	594420	5365074	individual	*Orbitoclypeus varians*
2	GEB12/03/22-1	594420	5365074	individual	*Orbitoclypeus varians*
2	GEB12/03/22-1	594420	5365074	individual	*Orbitoclypeus varians*
2	GEB12/03/22-1	594420	5365074	individual	*Nummulites striatus* A-form
2	GEB12/03/22-1	594420	5365074	individual	*Nummulites striatus* A-form
2	GEB12/03/22-1	594420	5365074	individual	*Nummulites striatus* B-form
3	Seifert5752	594410	5365000	individual	*Discocyclina trabayensis vicenzensis*
3	Seifert5752	594410	5365000	individual	*Asterocyclina priabonensis*
3	Seifert5752	594410	5365000	individual	*Nummulites stellatus*
4	Seifert5884	594490	5364998	individual	*Orbitoclypeus* cf. *schopeni*
4	Seifert5884	594490	5364998	individual	*Nummulites partschi* A-form
4	Seifert5884	594490	5364998	individual	*Orbitoclypeus schopeni*
5	GEB12/03/06-8	595360	5364780	thin section	*Nummulites partschi* B-form, *Orbitoclypeus* sp.
5	GEB12/03/06-8	595360	5364780	thin section	*Nummulites partschi* A-form
5	GEB12/03/06-8	595360	5364780	thin section	*Nummulites partschi* A-form
6	GEB12/03/20-3	594524	5364190	thin section	*Nummulites partschi* A-form
7	GEB12/03/06-3	594390	5365033	thin section	orthophragminids, *Nummulites partschi* A-forms
8	GEB12/03/19-3A	593996	5364004	thin section	*Nummulites partschi* A-forms, orthophragminids
9	GEB12/03/20-1	594393	5364079	thin section	*Orbitoclypeus sp., Nummulites partschi* A-forms
10	GEB12/03/20-2	594644	5364111	thin section	*Orbitoclypeus sp., Nummulites partschi* A-forms
6	GEB12/03/20-3	594524	5364190	thin section	orthophragminids, *Nummulites partschi* A-forms
6	GEB12/03/20-3	594524	5364190	thin section	orthophragminids, *Nummulites partschi* A-forms
7	GEB12/03/06-3	594390	5365033	thin section	*Orbitoclypeus* sp., *Nummulites* sp., alveolinids
7	GEB12/03/06-3	594390	5365033	thin section	*Discocyclina* sp., *Nummulites* sp.
7	GEB12/03/06-3	594390	5365033	thin section	orthophragminids, alveolinids
7	GEB12/03/06-3	594390	5365033	thin section	*Orbitoclypeus* sp., *Nummulites* sp.
3	GEB12/03/06-3A	594410	5365000	thin section	orthophragminid and nummulitid detritus
3	GEB12/03/06-3A	594410	5365000	thin section	orthophragminid and nummulitid detritus
n.a.	GEB12/03/06-5	594653	5364903	thin section	orthophragminids, *Nummulites partschi* A-form
n.a.	GEB12/03/06-5	594653	5364903	thin section	orthophragminids
11	GEB12/03/06-6	595363	5364615	thin section	orthophragminids
11	GEB12/03/06-7	595395	5364675	thin section	*Nummulites partschi* A-form, *Orbitoclypeus* cf. *schopeni*
5	GEB12/03/06-8	595360	5364780	thin section	orthophragminids, *Nummulites partschi* A-form
n.a.	GEB12/03/09-1A	593250	5363640	thin section	orthophragminids
12	GEB12/03/19-2	594128	5363981	thin section	orthophragminids, alveolinids
12	GEB12/03/19-2	594128	5363981	thin section	orthophragminids
12	GEB12/03/19-2	594128	5363981	thin section	*Nummulites* sp., orthophragminids
1	GEB12/03/19-4	594004	5364018	thin section	*Nummulites* sp., orthophragminids
9	GEB12/03/20-1	594393	5364079	thin section	*Nummulites partschi* A form, orthophragminids
10	GEB12/03/20-2	594644	5364111	thin section	*Orbitoclypeus* sp., *Gypsina* sp., *Nummulites* sp.
10	GEB12/03/20-2	594644	5364111	thin section	*Nummulites* cf. *partschi*, orthophragminids
10	GEB12/03/20-2	594644	5364111	thin section	orthophragminids
6	GEB12/03/20-3	594524	5364190	thin section	*Nummulites partschi* A-form, orthophragminids

Tab. 1.
List of studied samples, locations, ages (inferred Shallow Benthic Zones), and identified taxa in this study. Longitude and latitude values refer to the UTM projection (WGS84 33N). Planktic foraminifera and nannoplankton zones are from Gebhardt & Ćorić (2014) and Seifert (1980). n.a. = not applicable.

SBZ	Stage	pl. foram. and Nannopl. zones	Figure, remark
10–11	Ypresian to basal Lutetian	E7, NP14-15	Plate 1, Fig. 1
18	Bartonian	E7-E13 or E11	Plate 1, Fig. 6
18	Bartonian	E7-E13 or E11	specimen no. GEB12_03_22_1_1_15_2
18	Bartonian	E7-E13 or E11	specimen no. GEB12_03_22_1_1_15_3
18	Bartonian	E7-E13 or E11	specimen no. GEB12_03_22_1_1_15_4
18	Bartonian	E7-E13 or E11	Plate 1, Fig. 4
18	Bartonian	E7-E13 or E11	Plate 1, Fig. 5
20	Priabonian	NP19-20	Plate 1, Fig. 7
20	Priabonian	NP19-20	Plate 1, Fig. 8
20	Priabonian	NP19-20	Plate 1, Fig. 9
10–11	Ypresian to basal Lutetian	E6-7, NP13	specimen no. Seifert5884_1
10–11	Ypresian to basal Lutetian	E6-7, NP13	Plate 1, Fig. 2
10–11	Ypresian to basal Lutetian	E6-7, NP13	Plate 1, Fig. 3
10–11	Ypresian to basal Lutetian	E5, NP14-16	Plate 2, Fig. 1
10–11	Ypresian to basal Lutetian	E5, NP14-16	Plate 2, Fig. 2
10–11	Ypresian to basal Lutetian	E5, NP14-16	Plate 2, Fig. 3
10–11	Ypresian to basal Lutetian	no data available	Plate 2, Fig. 4
10–11	Ypresian to basal Lutetian	no data available	Plate 2, Fig. 5
10–11	Ypresian to basal Lutetian	E7, NP14-15	Plate 2, Fig. 6
10–11	Ypresian to basal Lutetian	no data available	Plate 2, Fig. 7
10–11	Ypresian to basal Lutetian	no data available	Plate 2, Fig. 8
10–11	Ypresian to basal Lutetian	no data available	Plate 2, Fig. 9
10–11	Ypresian to basal Lutetian	no data available	Plate 2, Fig. 10
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/06-3a
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/06-3Ba
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/06-3c
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/06-3d
20	Priabonian	no data available	photo 12/03/06-3Aa
20	Priabonian	no data available	photo 12/03/06-3Ab
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/06-5a, rocks not in place
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/06-5b, rocks not in place
10–11	Ypresian to basal Lutetian	E5, NP14-16	photo 12/03/06-6a
10–11	Ypresian to basal Lutetian	E5, NP14-16	photo 12/03/06-7a
10–11	Ypresian to basal Lutetian	E5, NP14-16	photo 12/03/06-8d
n.a.	(Ypresian to basal Lutetian)	no data available	photo 12/03/09-1A, rocks not in place
10–11	Ypresian to basal Lutetian	E7, NP14-15	photo 12/03/19-2a
10–11	Ypresian to basal Lutetian	E7, NP14-15	photo 12/03/19-2b
10–11	Ypresian to basal Lutetian	E7, NP14-15	photo 12/03/19-2c
10–11	Ypresian to basal Lutetian	E7, NP14-15	photo 12/03/19-4Bb
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/20-1b
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/20-2b
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/20-2c
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/20-2d
10–11	Ypresian to basal Lutetian	no data available	photo 12/03/20-3a

Priabonian (SBZ 20)

The youngest LBF assemblage was found at location 3 (Text-Fig. 1). The following species were found: *Discocyclina trabayensis vicenzensis* (Pl. 1, Fig. 7), *Asterocyclina priabonensis* (Pl. 1, Fig. 8), and *Nummulites stellatus* (Pl. 1, Fig. 9) with *A. priabonensis* as the most abundant LBF component. *Nummulites stellatus* is distinguishable from *N. chavanensis* and *N. cunialensis* by its strongly inclined and arcuate septa. The species composition of the LBF assemblage points to the late Priabonian SBZ 20, an age confirmed by the associated nannoplankton assemblage of NP19–20 (with *Discoaster barbadiensis* and *Isthmolithus recurvus*, SEIFERT 1980). The fine grained limonitic glauconite sandstones of the Reingrub Formation contain orthophragminid and nummulitid detritus with a relatively high amount of smaller benthic and unclassifiable planktic foraminifera. The nearby location 7 is a few meters upslope and contains an Ypresian LBF assemblage (see above).

Discussion

Larger benthic foraminiferal assemblages from the localities investigated here are characterized by high abundances but low diversity. Only one or two species of *Nummulites*, *Discocyclina,* and *Orbitoclypeus* were observed in the several assemblages. We assume that more detailed analyses of larger amounts of sample material of isolated specimens may gain additional, however less frequent species.

The occurrences of nummulitids in the Waschberg-Ždánice Unit of Lower Austria do not represent so called "nummulite banks" as neither massive occurrences have been reported nor particular abundances of B-forms (AIGNER, 1982, 1983) were found. The lack of very large *Nummulites* specimens point to non-optimal conditions for symbiont flourishing and very fast test growth (compare FERRÀNDEZ-CAÑADELL, 2012). Furthermore, the co-occurrence of *Nummulites* with *Asterocyclina* and *Discocyclina* point to life habitats in deeper or more turbid waters. GEBHARDT et al. (2013) deduced paleo-water depths of 70 to 200 m for similar assemblages from Helvetic units of Bavaria (Adelholzen) based on existing schemes along depth gradients and planktic to benthic foraminifera ratios.

The relatively northern position, combined with the high siliclastic input into the depositional environment may explain the relative scarcity and dominance of only a few LBF species in the area of investigation. The found LBF assemblages are restricted to the Tethyan realm and nummulitids with secondary chambers such as *Heterostegina* or *Spiroclypeus*, which are widespread during the Priabonian in this bioprovince, do not occur. Despite these limitations, we have shown the high value of nummulitids and orthophragminids for biostratigraphic purposes.

Conclusions

Larger benthic foraminifera (LBF) assemblages from Eocene sediments of the southern part of the Waschberg-Ždánice Unit of Lower Austria were studied. These include for the first time, in addition to nummulitids, also orthophragminids. Three different LBF assemblages occur in the study area:

- An Ypresian to basal Lutetian (SBZ 10–11) assemblage dominated by *Nummulites partschi* and *Orbitoclypeus schopeni.*
- A Bartonian (SBZ 18) assemblage dominated by *Nummulites striatus* and *Orbitoclypeus varians.*
- A Priabonian (SBZ 20) assemblage dominated by *Asterocyclina priabonensis, Nummulites stellatus,* and *Discocyclina trabayensis vicenzensis.*

Despite the unfavorable environmental conditions, the found LBF assemblages are well suitable for biostratigraphic classifications of rocks, particularly for limestones.

Acknowledgements

FRANZ ALLRAM (GBA) produced thin sections of great quality for facies and species analyses. PETER SEIFERT (GBA) kindly made available isolated specimens from material related to his doctoral thesis. We thank CHRISTOPH JANDA (GBA) and CHRISTIAN CERMAK (GBA) for their careful editorial handling. We thank GYÖRGY LESS (University of Miskolc, Hungary) for his kind assistance in species recognition.

References

AIGNER, T. (1982): Event-stratification in nummulite accumulations and in shell beds from the Eocene of Egypt. – In: EINSELE, G. & SEILACHER, A. (Eds.): Cyclic and Event Stratification, 248–262, Berlin (Springer).

AIGNER, T. (1983): Facies and origin of nummulitic buildups: an example from the Giza Pyramids Plateau (Middle Eocene, Egypt). – Neues Jahrbuch für Geologie und Palaeontologie, Abhandlungen, **166**, 347–368, Stuttgart.

BIEDA, F. (1934): Remarques sur la nomenclature et classification de certaines espèces de Nummulines. – Bulletin de l'Académie Polonaise des Sciences et des Lettres, Classe des Sciences Mathématiques et Naturelles, Séries B: Sciences Naturelles (II), **1933**/3, 291–303, Krakau.

DE LA HARPE, P. (1880): Note sur les Nummulites Partschi et Oosteri de la Harpe du calcaire du Michelberg près Stockerau (Autriche) et du Gurnigelsandstein de Suisse. – Bulletin de la Societé Vaudoise des Sciences Naturelles, **17**/84, 33–40, Lausanne.

FERRÀNDEZ-CAÑADELL, C. (2012): Multispiral growth in *Nummulites*: paleobiological implications. – Marine Micropaleontology, **96–97**, 105–122, Amsterdam.

GEBHARDT, H. & ĆORIĆ, S. (2014): Bericht 2012–2013 über geologische Aufnahmen im Paläogen/Neogen auf Blatt 5313 Hollabrunn Südost. – Jahrbuch der Geologischen Bundesanstalt, **154**, 365–370, Wien.

GEBHARDT, H. & ROETZEL, R. (2013): The Antarctic viewpoint of the Central Paratethys: cause, timing, and duration of a deep valley incision in the Middle Miocene Alpine-Carpathian Foredeep of Lower Austria. – International Journal of Earth Sciences (Geologische Rundschau), **102**/4, 977–987, Heidelberg.

GEBHARDT, H., ĆORIĆ, S., DARGA, R., BRIGUGLIO, A., SCHENK, B., WERNER, W. & ANDERSEN, N. (2013): Middle to Late Eocene paleoenvironmental changes in a marine transgressive sequence from the northern Tethyan margin (Adelholzen, Germany). – Austrian Journal of Earth Sciences, **160**/2, 45–72, Wien.

GLAESSNER, M.F. (1937): Die alpine Randzone nördlich der Donau und ihre erdölgeologische Bedeutung. – Petroleum, **33**/43, 1–8, Berlin.

GRADSTEIN, F.M., OGG, J.G., SCHMITZ, M.D. & OGG, G.M. (2012): The Geological Time Scale 2012. – 1144 pp., Amsterdam (Elsevier).

GRILL, R. (1962): Erläuterungen zur geologischen Karte der Umgebung von Korneuburg und Stockerau. – 52 pp., Geol. B.-A., Wien.

KOVÁČOVA, M., DOLÁKOVA, N. & KOVÁC, M. (2011): Miocene vegetation pattern and climate change in the northwestern Central Paratethys domain (Czech and Slovak Republic). – Geologica Carpathica, **62**/3, 251–266, Bratislava.

KRHOVSKY, J., RÖGL, F. & HAMRSMID, B. (2001): Stratigraphic correlation of the Late Eocene to Early Miocene of the Waschberg Unit (Lower Austria) with the Zdanice and Pouzdrany Units (South Moravia). – In: PILLER, W.E. & RASSER, M.W. (Eds.): Paleogene of the Eastern Alps. – Schriftenreihe der Erdwissenschaftlichen Kommission der Österreichischen Akademie der Wissenschaften, **14**, 225–254, Wien.

LESS, G. (1987): Paleontology and stratigraphy of the European orthophragminae. – Geologica Hungarica, **51**, 1–373, Budapest.

LESS, G. & ÖZCAN, E. (2012): Bartonian–Priabonian larger benthic foraminiferal events in the Western Tethys. – Austrian Journal of Earth Sciences, **105**/1, 129–140, Wien.

MARTINI, E. (1971): Standard Tertiary and Quaternary calcareous nannoplankton zonation. – In: FARINACCI, A. (Ed.): Proceedings II Planktonic Conference, Roma 1970, 739–785, (2), Rome.

PAPP, A. (1958): Vorkommen und Verbreitung des Obereozäns in Österreich. – Mitteilungen der Geologischen Gesellschaft in Wien, **50**, 251–270, Wien.

PAPP, A. (1962): Die Nummulitenfaunen vom Michelberg (Waschbergzone) und aus dem Greifensteiner Sandstein (Flyschzone). – Verhandlungen der Geologischen Bundesanstalt, **1962**, 281–290, Wien.

RACEY, A. (2001): A review of Eocene nummulite accumulations: structure, formation and reservoir potential. – Journal of Petroleum Geology, **24**, 79–100, Chichester.

SCHAUB H. (1981a): Nummulites et Assilines de la Téthys paléogène. Taxinomie, phylogenèse et biostratigraphie. – Schweizerische Palaeontologische Abhandlungen, **104**, 1–236, Basel.

SCHAUB, H. (1981b): Nummulites et Assilines de la Téthys paléogène. Taxinomie, phylogenèse et biostratigraphie. Atlas 1. – Schweizerische Palaeontologische Abhandlungen, **105**, Plates 1–48, Basel.

SCHAUB, H. (1981c): Nummulites et Assilines de la Téthys paléogène. Taxinomie, phylogenèse et biostratigraphie. Atlas 2. – Schweizerische Palaeontologische Abhandlungen, **106**, Plates 49–97, Basel.

SEIFERT, P. (1980): Das Eozän der Waschbergzone (NÖ) (und die angrenzenden Teile des Oberpaläozän und Unteroligozän): Stratigraphie, Mikrofazies, Paläogeographie und Tektonik. – Dissertation Universität Wien, 419 pp., Wien.

SERRA-KIEL, J., HOTTINGER, L., CAUS, E., DROBNE, K., FERRÀNDEZ, C., JAHURI, A.K., LESS, G., PAVLOVEC, R., PIGNATTI, J., SAMSÓ, J.M., SCHAUB, H., SIREL, E., STROUGO, A., TAMBAREAU, Y., TOSQUELLA, J. & ZAKREVSKAYA, E. (1998): Larger foraminiferal biostratigraphy of the Tethyan Paleocene and Eocene. – Bulletin de la Societé géologique de France, **169**/2, 281–299, Paris.

SIEBER, R. (1953): Eozäne und oligozäne Makrofaunen Österreichs. – Sitzungsberichte der Österreichischen Akademie der Wissenschaften, Mathematisch-naturwissenschaftliche Klasse, **162**, 359–376, Wien.

WESSELY, G., GANGL, G., GOTTSCHLING, P., HEINRICH, M., HOFMANN, T., LENHARDT, W., MATURA, A., PAVUZA, R., PERESSON, H. & SAUER, R. (2006): Niederösterreich. – 416 pp., Geol. B.-A., Wien.

Received: 13. November 2015, accepted: 2. December 2015

Plate 1

Selected isolated specimens of large benthic foraminifera:

Figs. 1–3: Ypresian.

Fig. 1: *Nummulites partschi* A-Form, sample GEB12/03/19-4, location 1.
Fig. 2: *N. partschi* A-form, sample 5884, location 4.
Fig. 3: *Orbitoclypeus* cf. *schopeni*, sample 5884, location 4.

Figs. 4–6: Bartonian, sample GEB12/03/22-1, location 2.

Fig. 4: *Nummulites striatus* A-Form.
Fig. 5: *N. striatus* B-Form.
Fig. 6: *Orbitoclypeus varians*.

Figs. 7–9: Priabonian, sample 5752, location 3.

Fig. 7: *Discocyclina trabayensis vicenzensis*.
Fig. 8: *Asterocyclina priabonensis*.
Fig. 9: *Nummulites stellatus*.

Length of all scale bars: 0.5 mm.

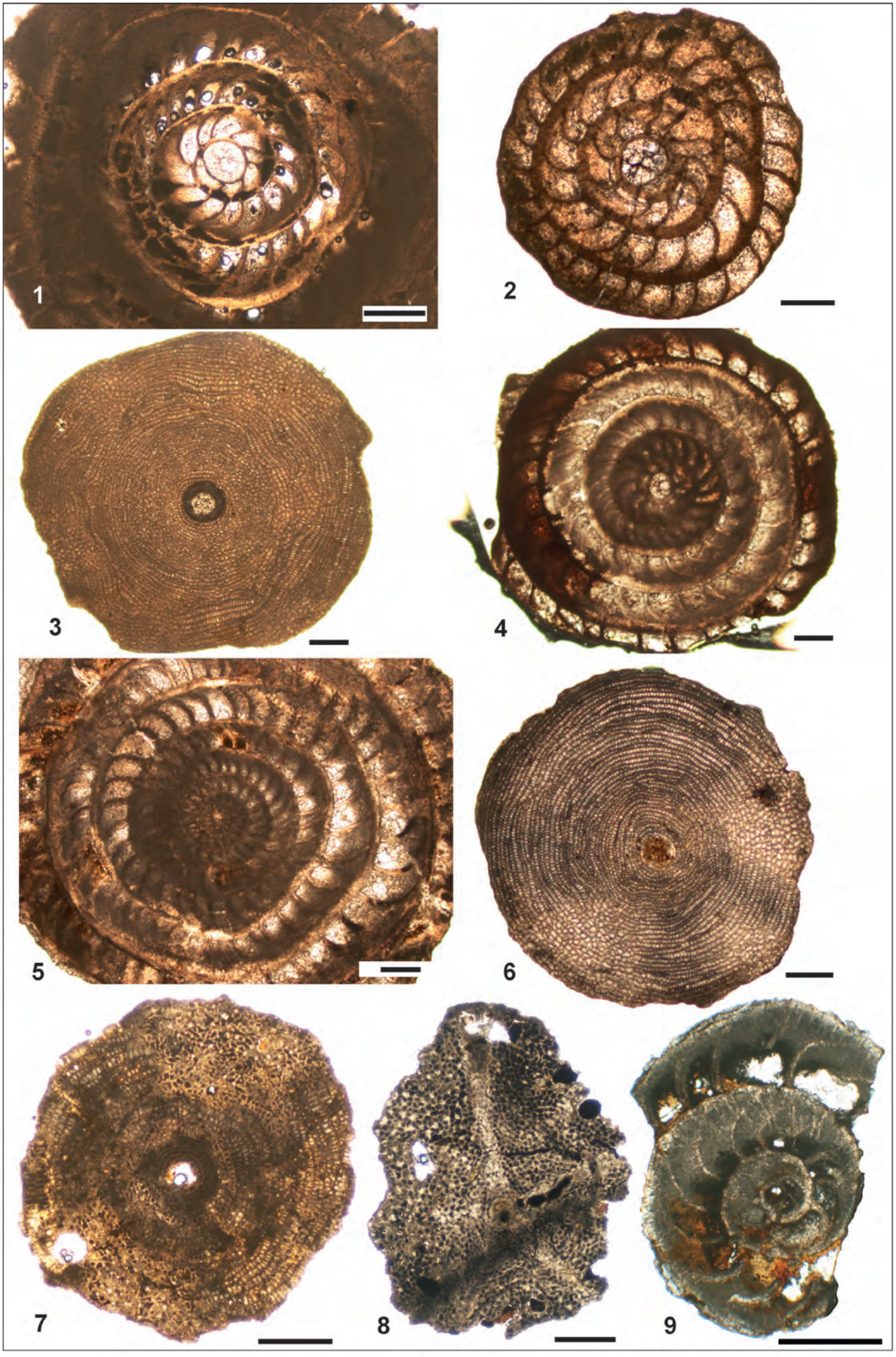

1
2
3
4
5
6
7
8
9

Plate 2

Selected Ypresian thin sections with larger benthic foraminifera:

Fig. 1: *Nummulites partschi* B-form and orthophragminids, algal fragments, quartz grains, *Gypsina* sp., and encrusting benthic foraminifera, sample GEB12/03/06-8 (location 5).

Figs. 2, 3: *Nummulites partschi* A-form, sample GEB12/03/06-8 (location 5).

Fig. 4: *Nummulites partschi* A-form, sample GEB12/03/20-3 (location 6).

Fig. 5: Orthophragminid (*Orbitoclypeus*) rudstone with algal fragments, smaller benthic foraminifera, *Nummulites partschi* A-forms, and *Gypsina* sp., sample GEB12/03/06-3 (location 7).

Fig. 6: Foraminiferal rudstone with *Nummulites partschi* A-forms, orthophragminids, rock fragments, quartz grains, bivalves, and algal fragments, sample GEB12/03/19-3A (location 8).

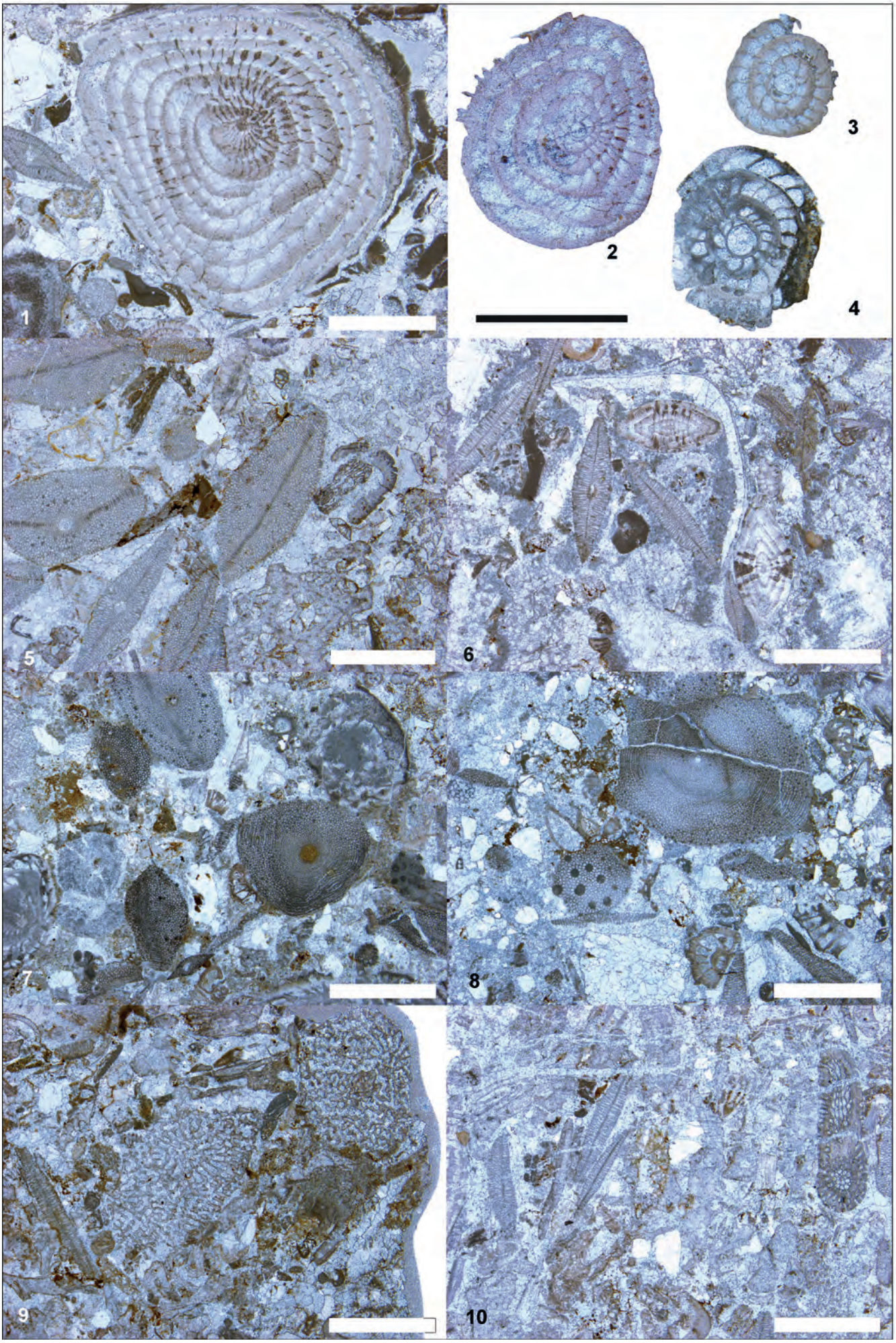
Fig. 7: Orthophragminid (*Orbitoclypeus*) wackestone with *Nummulites partschi* A-forms, algal fragments, and quartz grains, sample GEB12/03/20-1 (location 9).

Fig. 8: Orthophragminid (*Orbitoclypeus*) rudstone with quartz grains, rockfragments, algal fragments, and encrusting benthic foraminifera, sample GEB12/03/20-2 (location 10).

Fig. 9: Coralline rudstone with orthophragminids, quartz grains, algal and foraminiferal fragments, sample GEB12/03/20-3 (location 6).

Fig. 10: Orthophragminid wackestone with quartz grains, bryozoans, and algal fragments, sample GEB12/03/20-3 (location 6).

Length of all scale bars: 1.0 mm. 2–4: same scale.


1
2
3
4
5
6
7
8
9
10

Appendix 1: List of identified species

Discocyclina trabayensis vicenzensis Less, 1987

Nummulites partschi De la Harpe, 1880

Nummulites stellatus Roveda, 1961

Nummulites striatus (Brugière, 1792)

Orbitoclypeus schopeni (Checchia-Rispoli, 1908)

Orbitoclypeus varians (Kaufmann, 1867)

Orbitoclypeus sp.