

Late Jurassic foraminifera from the southern Waschberg-Ždánice Unit (Klentnice beds, Lower Austria)

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KEYWORDS

Late Jurassic, Waschberg-Ždánice Unit, biostratigraphy, foraminifera, Klentnice beds

Abstract

Foraminiferal assemblages from Upper Jurassic Klentnice beds in Lower Austria are described and analysed. The early late Tithonian assemblages comprise 75 foraminiferal taxa and simple diversities reach up to 31 taxa per sample, pointing to comparatively high diversity in general. The assemblages are dominated by lenticulinid forms (Genera *Astacolus*, *Lenticulina*, *Saracenaria*, *Vaginulinopsis*). *Trocholina* is the most common genus and present in all samples. Other frequent genera are *Marssonella* and *Neobulimina*. Co-occurrence of epifaunal (grazing) herbivores and epi- to deep infaunal active deposit feeders points to mixed assemblages from different sources and supports the concept of turbiditic systems as prevailing sedimentary regimes in the basinal setting.

1 Introduction

Outcrops of Jurassic rocks in the southern part of the Waschberg-Ždánice Unit (Fig. 1) are known for many decades and were displayed in several geological maps of the region (e.g., Grill, 1957; 1962; Schnabel et al., 2002; Wessely et al., 2006; Schneider et al., 2013). During systematic field mapping, a number of additional occurrences were found and recorded recently (Fig. 2; Gebhardt, 2018). Facies and microfossil content indicate clearly the classification of these rocks as Upper Jurassic Klentnice beds. Outcrops of the also Upper Jurassic Ernstbrunn-Limestone were found only north of the investigated area. Schneider et al. (2013) published a comprehensive overview on the present knowledge about Ernstbrunn Limestone and Klentnice beds in Lower Austria and Moravia.

The known occurrences of the Late Jurassic rocks of the Waschberg-Ždánice Unit are interpreted to be sheared off from the Mesozoic basement below the Vienna Basin and dragged up in the course of the thrusting of the Waschberg-Ždánice Nappe onto the Alpine-Carpathian Foredeep (or Molasse Basin; Eliáš and Wessely, 1990; Malzer et al., 1993; Haviř and Stráník 2003; Wessely et al. 2006; Poul et al., 2011; Schneider et al., 2013). The Waschberg-Ždánice Unit represents the most distal nappe in the boundary region between the Alpine and the Carpathian orogens. Its Upper Jurassic rocks were recognized as unrooted tectonic klippen. Borehole data confirm that identical rocks cover the eastern crystalline slope of the Bohemian Massif (Eliáš and Wessely, 1990; Malzer et al., 1993; Wessely et al., 2006). In the type-region of the Klentnice beds, the Pavlov Hills

near Mikulov in southern Moravia, the Upper Jurassic sediments form N-S to NNE-SSW oriented klippen that were originally deposited on the Pavlov carbonate platform and incorporated into this imbricated structure during the late Karpatian (late Early Miocene), contemporaneous with the final stage of the overthrust of the Ždánice Nappe (Eliáš, 1992; Haviř and Stráník 2003).

Although the term “dunkelgraue Mergel von Klentnitz” (dark-grey marls of Klentnice) was introduced already in the 19th century (Abel, 1899), Klentnice beds as well as Ernstbrunn Limestone have not yet been formalized and type localities and sections are still to be designated (Schneider et al., 2013). Mikulov Marls and Kurdějov Arenite in Moravia are considered to be equivalents of the Klentnice beds. The published maximum thickness of the Klentnice beds ranges from c. 200 m (Picha et al., 2006) to more than 1000 m if tectonically duplicated (Eliáš and Wessely, 1990). The Ernstbrunn Limestone is partly time equivalent to or interfingering with the Klentnice beds but also tops the Late Jurassic succession (e.g., Wessely et al. 2006; Poul et al., 2011; Schneider et al., 2013).

In this contribution, foraminiferal assemblages will be described and compared with assemblages found in boreholes of the type region and those from elsewhere in Central Europe. Some occurrences of Jurassic foraminiferal assemblages from the Austrian Waschberg-Ždánice Unit were published in Grill (1953) or Papp and Turnowsky (1964). With ongoing geological field mapping, more occurrences of Late Jurassic rocks were found recently at the southern end of the Waschberg-Ždánice Unit (Gebhardt, 2018) and its foraminiferal assemblages require

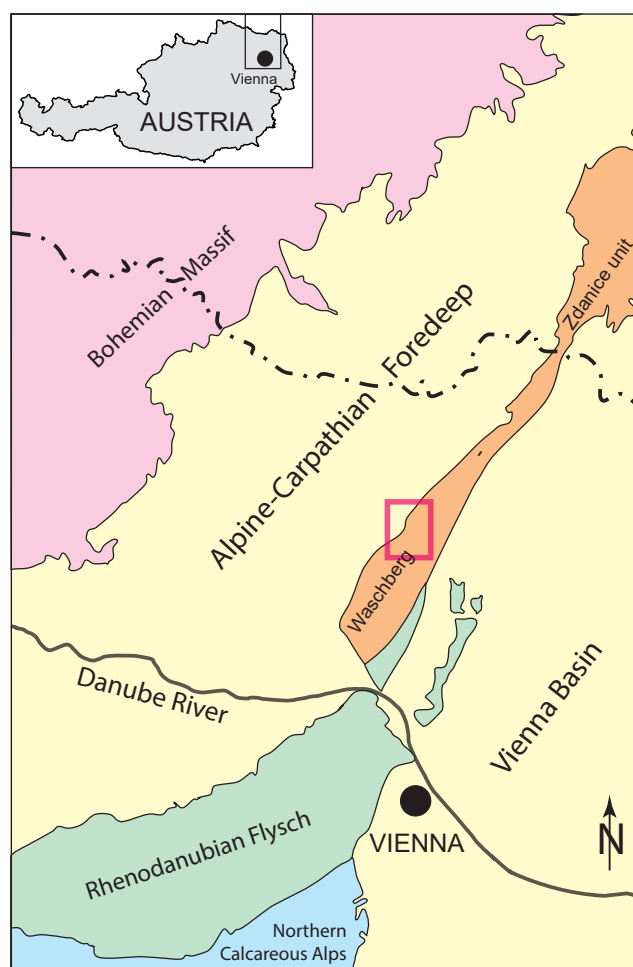


Figure 1: Geological sketch map of NE Austria with mayor tectonic units. Red frame indicates area displayed in Fig. 2.

a comprehensive interpretation. Schneider et al. (2013) counted 82 foraminiferal species in the Klentnice beds from various regions. Foraminifera are the fossil group with the highest number of species, followed by ostracoda with 60 species. All other groups (gastropods, bivalves, echinoids, sponges, brachiopods, crinoids, belemnites, or nannofossils) count with less than 20 species.

2 Material and methods

The samples were taken from near sub-surface at 0.3 to 1.0 m depth by hand-drilling (Fig. 2), were relatively soft and probably weathered to some degree or suggest a marly origin. Thin sections were made only from (still) indurated rocks (point P on Fig. 2, Fig. 3). No outcrops of rocks with original layering were found during field-work. The microfossil material is always recrystallized and hollow foraminiferal chambers or ostracod carapaces were not found (Figs 3, 4). The diagenetic aragonite loss (Schneider et al., 2013) gave the fossil assemblages a partly impoverished appearance. Furthermore, the surfaces of nearly all tests and shells appear frosted (Fig. 4). The focus of this paper are the foraminiferal assemblages and due to the state of preservation, only free specimens could be classified at species level (Fig. 4, Table 1).

For microfossil identification, 200 g of dry sediment were disintegrated with 5 % hydrogen peroxide solution and washed over a 0.063-mm sieve. The residue was dried and dry sieved into 0.063 to 0.125 and 0.125 to 1 mm fractions. In order to prevent uncertain species identification of juvenile specimens, classifications were performed with the 0.125 to 1 mm fraction only. All sample material is stored in the collection of the Geological Survey of Austria under the collection number GBA2019/013/0001ff.

3 Results

3.1 Washing residues, microfossil assemblages and carbonate microfacies

The washed residues are characterized by high amounts of bio-detritus such as echinoid and bivalve fragments, brachiopods, sponge spiculae, calcareous rock fragments and, at least in some samples, glauconitic grains. This composition corresponds largely to that reported in earlier publications (e.g., Grill, 1968). Ostracods are relatively rare but foraminifera are frequent in most samples. In thin sections (Fig. 3), the ratios of the components can be estimated. The still indurated rocks found at Hundsberg and Leeberg (point P on Fig. 2) can be best classified as packstones (Fig. 3) according to the scheme of Dunham (1962) although their micrite content can be very low (Fig. 3, lower part), or as densely packed biomicrite according to Folk (1962).

3.2 Occurring foraminiferal taxa

Foraminifera are the most common microfossils found in the washed residues. Ostracods are not as common in the investigated samples and not within the scope of this contribution. The occurrences or frequencies given in this chapter are estimates based on assemblage overviews during picking and presence or absence in the investigated samples (see Appendix, Table 1). In total, 75 foraminiferal taxa are recognized in the 15 samples investigated. This points to rather high diversities for the Klentnice beds of the southern portion of the Waschberg-Ždánice Unit. Depending on the degree of weathering (partial dissolution), simple diversities (number of species found per sample) range from 1 to 31.

The assemblages are dominated by lenticulinid forms (Genera *Astacolus*, *Lenticulina*, *Saracenaria*, *Vaginulinopsis*, 17 species). These are epifaunal to infaunal active deposit grazers, feeding on detritus and bacteria in fine-grained, pelitic sediments. They typically occur in middle-deep neritic to upper bathyal settings (e.g., Koutsoukos and Hart, 1990; Reolid et al., 2008). *Trocholina* is the most common genus (represented by *T. solecensis* only) and present in all samples. *Trocholina* are epifaunal, shallow-water, grazing herbivores (primary weed fauna; Reolid et al., 2008). They are typical for shallow neritic settings and are known to have been transported to deeper neritic or even bathyal settings by gravity flows or turbidites (e.g., Haas et al. 2006). Other frequent genera are *Marssonella* and

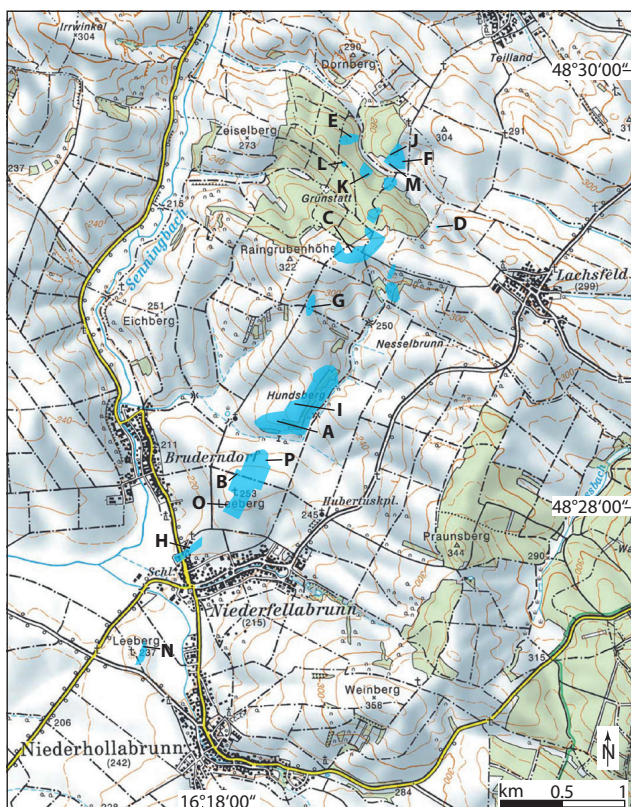


Figure 2: Locations of collection points. Capital letters correspond to sample numbers in Table 1. Pale blue areas indicate rocks of Klentnice beds in place, based on Grill (1962) and recent field mapping (Gebhardt, 2018).

Neobulimina. Both genera lived infaunally, are typical of middle to deep neritic settings and thrived in larger numbers under low-oxygen conditions in fine-grained pelitic sediments (e.g., Koutsoukos and Hart, 1990; West et al., 1998; Gebhardt et al., 2004; Svobodova et al., 2011). This gives the assemblages a typical appearance (Fig. 4, Table 1) and samples from the Klentnice beds can be identified at the first glance in the residues after washing.

3.3 Age assignment

The Jurassic age of the Klentnice beds was first stated by Suess (1852). Since Jurassic stratigraphy is typically based on ammonites which are rare in the Klentnice beds, the age assignment has been extensively discussed in the past (see overview in Schneider et al., 2013). Frequently cited is a *Pseudovirgatites scruposus* from the area around Niederfellabrunn (Grill 1968), which corresponds to the locations B, H, O, or P in Fig. 2. The results of Zeiss (1977) and latest updates of Zeiss and Hofmann (2001) indicate an early late Tithonian age for these strata based on ammonites. Due to generally long stratigraphic ranges and uncertainties in correlations of strata, ostracods in the Klentnice beds do not provide useful age indicators (Pokorný, 1973).

The range of the foraminifera found in this study extends from the Lower Jurassic to basal Cretaceous. As deduced from stratigraphic ranges in Hanzlíková (1965), an Oxfordian to late Kimmeridgian age is most likely assigned for the assemblages from the southern Waschberg-Ždánice

Unit recorded in this study. Based on all fossil groups but mainly on ammonites, Schneider et al. (2013) concluded a Kimmeridgian to early late Tithonian age for the Klentnice beds, while the Ernstbrunn Limestone was probably deposited a little later (middle Tithonian to Berriassian).

Hanzlíková (1965) subdivided the sedimentation period of the Klentnice beds into four foraminifera biozones: 1. *Haplophragmium*-Zone, 2. *Epistomina* (*Brozenia*)-Zone, 3. *Nodosariid*-Zone, and 4. an Impoverished-Zone. Holz-knecht and Hamršímid (1988) correlated the more than 400 m thick parautochthonous Mikulov Marls (equivalent to Klentnice beds) in a borehole located close to the Pavlov Hills in Moravia with the Kimmeridgian *Epistomina*-Zone of Hanzlíková (1965). All of the here investigated samples probably fall within the *Nodosariid*-Zone as indicated by the assemblage composition or by the dominating species (high diversity, dominance of lenticulinid taxa). The here investigated samples are therefore probably slightly younger than those of Holz-knecht and Hamršímid (1988). The *Nodosariid*-Zone corresponds to the stratigraphic range of *Pseudovirgatites scruposus* in Hanzlíková (1965) and therefore confirms the early late Tithonian age for the investigated samples. The sole finding of *Trocholina* in one case (location D, Fig. 2) may not indicate the Impoverished Zone but merely points to post-depositional diagenetic alteration or dissolution of all other species of the original assemblages.

4 Discussion

A comparison of the Late Jurassic foraminiferal assemblages of the Waschberg-Ždánice Unit of Lower Austria with Jurassic assemblages of surrounding areas shows some similarities at genus level, e.g., Lower Jurassic of the Northern Calcareous Alps (Fuchs, 1970; Ebli, 1993) or Frankonian Alb (Waltschew, 2000) but rarely at species level. A few more common species are found in Middle Jurassic rocks of the French Jurassic Mountains (Wernli, 1971) and the Rhône Basin (Bastien and Sigal, 1962) as well as in the lowermost Cretaceous rocks of the German North Sea Basin (Bartenstein and Kaever, 1973), Helvetic Units in Vorarlberg (Fuchs, 1971) and the Caribbean (Bartenstein et al., 1957). Upper Jurassic strata from the Kutch Basin (India) have many genera and some species in common with the assemblages studied here (Wasim et al., 2020). Naturally, the highest degree of similarity can be found in the nearby strata of the Klentnice beds north of the area investigated or in neighbouring Moravia. For example, 14 out of 74 species found by Holz-knecht and Hamršímid (1988) occur in both areas. The number of species found in the Waschberg-Ždánice Unit of Lower Austria is not as high as described in Hanzlíková (1965) but the vast majority of species occur in both regions, Moravia and Lower Austria.

The detrital limestones, marls and claystones of the Klentnice beds were probably deposited at moderate depth in a basin with open marine conditions (Wessely et al., 2006; Schneider et al., 2013) in contrast to the platform carbonate facies of the Ernstbrunn Limestone. The

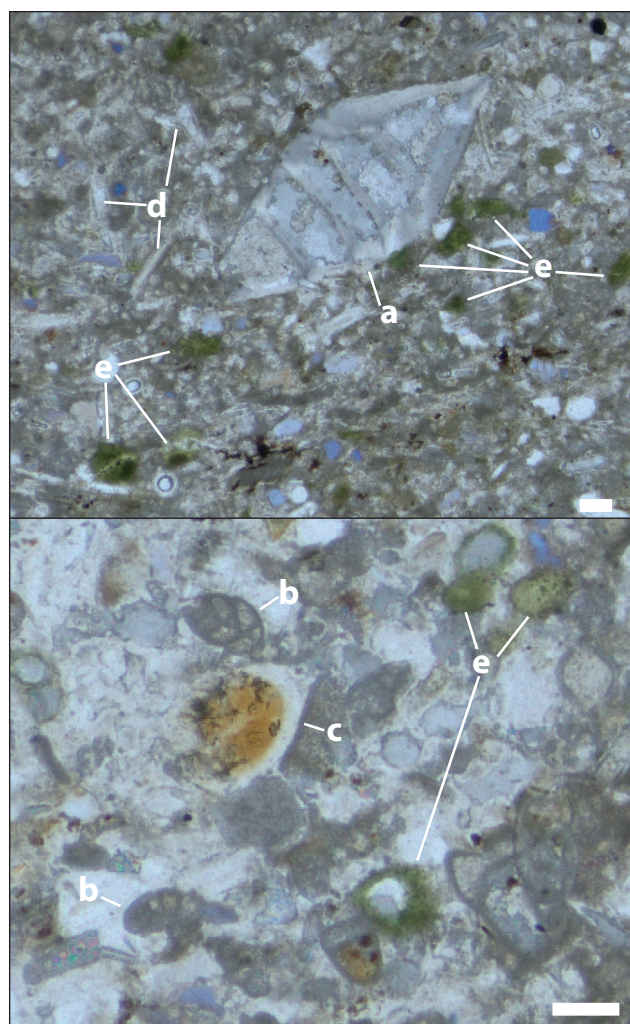


Figure 3: Thin section photographs of sample GEB18/04/11-2. All scale bars 0.1 mm. a. benthic foraminifera (probably *Lenticulina* sp.), b. small benthic foraminifera (probably *Neobulimina* sp.), c. echinoderm fragment, d. sponge spiculae, e. glauconitic grains.

source of the coarse grained portions of the Klentnice bed-sediments might be turbidites and fluxoturbidites transported from the Pavlov carbonate platform in Moravia (Eliáš, 1992), possibly storm induced. A similar depositional system was described from the Middle Jurassic of Hungary (platform derived foraminifera transported by gravity flows; Haas et al., 2006).

The found foraminiferal assemblages (Fig. 4; Tab. 1) with predominance of calcareous-hyaline deposit feeders are typical of an outer shelf/deep neritic to upper bathyal settings. They can be compared with a combination of the (Cretaceous) associations B1 and B2 of Koutsoukos and Hart (1990). This modern interpretation is different from earlier interpretations of the Klentnice beds as very shallow, quiet water deposits ("strandnahe Stillwasserablagerungen", Grill, 1968).

Similar to the concept of Koutsoukos and Hart (1990), Reolid et al. (2008) interpreted the paleoecology of the Late Jurassic foraminiferal assemblages from Scotland and Spain based on shell morphology (morphogroups) and related microhabitats and feeding strategies.

Plano-convex *Trocholina* (epifaunal grazing herbivores) and biconvex planispiral *Lenticulina* and related taxa (epi- to deep infaunal active deposit feeders) co-occur in the investigated Klentnice beds samples. This supports the concept of mixed assemblages from different sediment sources, i.e., as such in turbiditic systems. Both morphogroups are frequent to dominant in their samples and represent contrary paleoenvironments or microhabitats (weed v/s mud). Also Pokorný (1973) raised the suspicion of admixture of redeposited ostracod specimens. Near the Buschberg, located a few kilometers north of the area investigated here, sandy carbonates of the Klentnice beds with various macrofossils and a primarily weed dwelling foraminiferal assemblage (if interpreted according to Reolid et al., 2008; *Spirillina*, *Trocholina*) change into oolites and interfinger with Ernstbrunn-Limestone (Hofmann et al., 1991). This area is closer to the carbonate platform and consequently all southern occurrences may represent the basinal facies if compared with the Pavlov Hills area. The basinal facies interpretation is supported by the partly high numbers of species found in the samples (simple diversity) because foraminiferal diversity generally increases with depth in modern environments (e.g., Murray, 1991).

5 Conclusions

Foraminiferal assemblages from Klentnice beds in Lower Austria are described and analysed in this presentation. The early late Tithonian assemblages were classified on species level wherever possible and comprise 75 foraminiferal taxa. The simple diversities range from 1 to 31 taxa per sample, depending on the intensity of diagenesis and weathering. The potentially high number of taxa per sample points to comparatively high diversity in general and a deep water (basinal) depositional environment. The assemblages are dominated by lenticulinid forms (genera *Astacolus*, *Lenticulina*, *Saracenaria*, *Vagulinopsis*). *Trocholina* is the most common genus and present in all samples. Other frequent genera are *Marssonella* and *Neobulimina*. The co-occurrence of epifaunal (grazing) herbivores and epi- to deep infaunal deposit feeders point to possibly mixed assemblages from different settings. Redeposited ostracods suggest similar processes in Moravia. As suggested by sedimentary analyses in the type-region of the Klentnice beds in southern Moravia, gravity-flow (turbiditic) systems, possibly storm-induced, were most likely the prevailing sedimentary regime.

Acknowledgements

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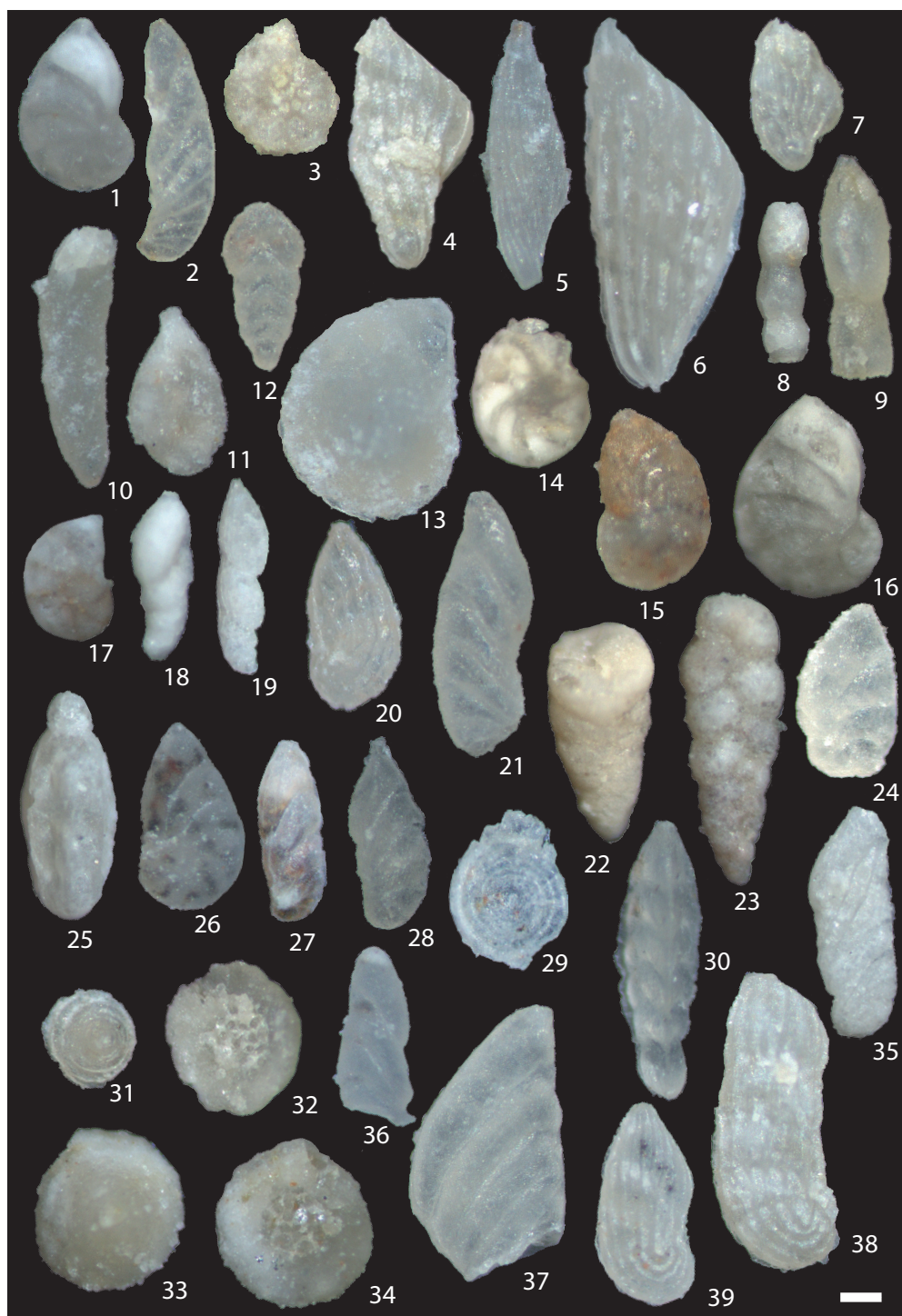


Figure 4: Frequent or prominent foraminiferal species found. All specimens same scale, length of scale bar 0.1 mm. 1. *Astacolus bronni*, lateral view, sample GEB17/03/21-10. 2. *Astacolus irretita*, lateral view, sample GEB17/03/21-10. 3. *Brotenia pastelligera*, umbilical view, sample GEB18/04/06-1. 4. *Citharina implicata*, lateral view, sample GEB18/04/06-1. 5. *Citharina lepida*, lateral view, sample GEB18/04/21-13. 6. *Citharina malicenta*, lateral view, sample GEB18/04/06-1. 7. *Citharina tenuicostata*, lateral view, sample GEB18/04/06-1. 8, 9. *Dentalina* cf. *varians*, lateral view, sample GEB18/04/06-1. 10. *Dentalina* sp., lateral view, sample GEB17/03/21-10. 11. *Eoguttulina* cf. *helvetica*, lateral view, sample GEB17/03/21-10. 12. *Fronicularia lingulaeformis*, lateral view, sample GEB18/04/06-1. 13. *Lenticulina* cf. *crassa*, lateral view, sample GEB18/04/06-1. 14. *Lenticulina cultrata*, lateral view, sample GEB18/04/06-1. 15. *Lenticulina polonica*, lateral view, sample GEB18/04/06-1. 16. *Lenticulina quenstedti*, lateral view, sample GEB17/03/21-10. 17. *Lenticulina vistulae*, lateral view, sample GEB18/04/06-1. 18. *Marginulina declivis*, lateral view, sample GEB17/03/21-10. 19. *Marginulina linearis*, lateral view, sample GEB17/03/21-10. 20. *Marginulinopsis dichotoma*, lateral view, sample GEB18/04/05-3. 21. *Marginulinopsis glabra*, lateral view, sample GEB18/04/06-1. 22. *Marssonella oxycona*, lateral view, sample GEB17/03/21-13. 23. *Neobulimina varsoviensis*, lateral view, sample GEB17/03/21-10. 24. *Planularia cordiformis*, lateral view, sample GEB17/03/21-10. 25. *Rectoglandulina* cf. *quinquecostata*, lateral view, sample GEB17/03/21-10. 26. *Saracenaria alata-angularis*, lateral view, sample GEB17/03/21-10. 27. *Saracenaria cornucopiae*, lateral view, sample GEB18/04/06-1. 28. *Saracenaria praecornucopiae*, lateral view, sample GEB18/04/06-1. 29. *Spirillina tenuissima*, spiral view, sample GEB17/03/21-10. 30. *Tristix acutangulus*, lateral view, sample GEB17/03/21-10. 31-34. *Trocholina solecensis*. 31, 33 spiral view, 32, 34 umbilical view, 31, 32 sample GEB18/04/06-1. 33, 34 sample GEB17/03/21-10. 35. *Vaginulina contracta*, lateral view, sample GEB18/04/06-1. 36. *Vaginulina duckcreekensis*, lateral view, sample GEB17/03/21-10. 37. *Vaginulina kochii*, lateral view, sample GEB18/04/06-1. 38. *Vaginulinopsis radiata*, lateral view, sample GEB18/04/06-1. 39. *Vaginulinopsis tenuicostata*, lateral view, sample GEB17/03/21-10.

	GEB 16/11/21-5	GEB 16/12/05-4	GEB 17/03/15-8	GEB 17/03/16-8	GEB 17/03/21-10	GEB 17/03/21-13	GEB 17/03/22-7	GEB 17/03/22-15	GEB 18/03/27-2	GEB 18/04/03-4	GEB 18/04/05-3	GEB 18/04/05-4	GEB 18/04/06-1	GEB 18/04/12-1	GEB 18/04/12-2
Location in Fig. 1	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
<i>Ammobaculites</i> sp.														?	
<i>Ammopalmula infrajurensis</i>															cf.
<i>Astacolus bronni</i>					x	x	x							x	x
<i>Astacolus comptula</i>	cf.						cf.								
<i>Astacolus irretita</i>					x		x		x			x	x		
<i>Astacolus</i> sp.					x	x					x			x	
<i>Brotzenia parastelligera</i>													x		
<i>Brotzenia</i> sp.		?			?	?			x	?			?	x	
<i>Cassidella</i> sp.						x									
<i>Citharina implicata</i>													x	x	
<i>Citharina lepida</i>						x						cf.			
<i>Citharina macilenta</i>					x										
<i>Citharina tenuicostata</i>													x	x	
<i>Citharina</i> sp.							x								
<i>Cyclammina</i> sp.									?		x				
<i>Dentalina tenuicaudata</i>										cf.					
<i>Dentalina varians</i>												cf.	cf.	cf.	cf.
<i>Dentalina</i> spp.		?			x	x				?		x			
<i>Dorothia tochus</i>							cf.								
<i>Eoguttulina helvetica</i>					cf.	cf.									
<i>Eoguttulina</i> sp.												x	x	x	
<i>Fronicularia lingulaeformis</i>					x	x	x						x		
<i>Fronicularia nikitini</i>		x								x					
<i>Fronicularia</i> sp.												x			
<i>Gaudryina</i> sp.							?								
<i>Globulina</i> sp.					?										
<i>Glomospirella</i> sp.												cf.			
<i>Guttulina</i> sp.													x		
<i>Haplophragmoides</i> spp.							?		?	?				?	
<i>Hippocrepina</i> sp.		x			x	x	?								
<i>Lagena</i> sp.		?	?		x	?									
<i>Lenticulina crassa</i>					cf.										
<i>Lenticulina cultrata</i>		x			x										
<i>Lenticulina hyalina</i>		cf.													
<i>Lenticulina polonica</i>		x	x		x	x	x	x	x	x	x	x	x	x	x
<i>Lenticulina quenstedti</i>		x					x	cf.	x		x		x	x	x
<i>Lenticulina vistulae</i>					x								x		x
<i>Lituotuba nothi</i>														cf.	
<i>Marginulina declivis</i>					x	x	x								
<i>Marginulina linearis</i>					x	x									
<i>Marginulina</i> sp.									?						
<i>Marginulinopsis dichotoma</i>											x	cf.			
<i>Marginulinopsis glabra</i>						x							x	x	x
<i>Marginulinopsis jonesi</i>							cf.								
<i>Marsonella oxycona</i>						x	cf.	cf.	x					x	
<i>Miliammina</i> sp.								?							
<i>Nodosaria</i> sp.							x								
<i>Neobulimina varsoviensis</i>		x			x	x	x		x	x	x			x	x
<i>Paalzowella feifeli</i>						cf.									
<i>Planularia cordiformis</i>	x				x								x		
<i>Planularia filosa</i>									cf.						
<i>Rectoglandulina quinquecostata</i>					cf.										
<i>Reophax</i> sp.												x			
<i>Saccammina</i> sp.		?						?							
<i>Saracenaria alata-angularis</i>					x								x		
<i>Saracenaria cornucopiae</i>					x	x	x		x		x	x	x	x	
<i>Saracenaria praecornucopiae</i>					x	x							x		
<i>Saracenaria</i> sp.		x						x							
<i>Spirillina tenuissima</i>		x	x		x	x	x	x	x	x	x	x	x	x	x
<i>Textularia</i> sp.															?
<i>Triplasia elegans</i>								cf.							
<i>Tristix acutangulus</i>					x	x	x						x		
<i>Trochammina</i> sp.		x			x	x									
<i>Trocholina solecensis</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
<i>Vaginulina cetra</i>					cf.										
<i>Vaginulina contracta</i>		x			x	cf.	x			x			x	x	x
<i>Vaginulina duckcreekensis</i>					x										
<i>Vaginulina jurassica</i>							cf.			cf.				x	
<i>Vaginulina kochii</i>													x		
<i>Vaginulina listi</i>							cf.			cf.					
<i>Vaginulina recta</i>							cf.								
<i>Vaginulina truncata</i>			x										cf.		
<i>Vaginulinopsis pasquetiae</i>		x			cf.	cf.					x			x	x
<i>Vaginulinopsis radiata</i>			x				x	x	x			x	x	x	
<i>Vaginulinopsis tenuicostata</i>					x	x	x		x	x	x	x	x	x	x

Table 1: Occurrences of foraminiferal species identified in the samples. Capital letters beneath sample numbers correspond to those in Fig. 2.

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Appendix: occurring species and frequencies

Key to frequencies: very rare - occurs in one sample, rare - two or three samples, moderate - 4 to 6 samples, frequent - 7 to 10 samples, very frequent - 11 or more samples.

Ammopalmula cf. *infracurensis* (Terquem)

cf. 1870 - *Haplophragmium infracurensis* - Terquem, figs 27a, b, 28

cf. 1965 - *Ammobaculites infracurensis* - Hanzlíková, pl. 3, figs 2, 3

cf. 1971 - *Ammopalmula infracurensis* - Wernli, pl. 1, fig. 17, pl. 2, fig. 10

Occurrence: very rare.

?*Ammobaculites* sp.

Occurrence: very rare.

Astacolus bronni (Roemer)

Fig. 4.1

1841 - *Planularia bronni* - Roemer, p. 97

1957 - *Lenticulina (Saracenaria)* cf. *bronni* - Bartenstein et al., pl. 3, figs 61a, b

1965 - *Lenticulina* ex gr. (*Astacolus*) *bronni* - Hanzlíková, pl. 4, fig. 14, pl. 5, fig. 2a, b

1971 - *Lenticulina (Vagulinopsis)* *bronni* - Fuchs, pl. 5, fig. 6

1973 - *Lenticulina (Saracenaria)* *bronni* - Bartenstein and Kaefer, pl. 3, fig. 37-38

1988 - *Astacolus bronni* - Holzknecht and Hamršíd, pl. 13, fig. 1.

Occurrence: moderate.

Astacolus cf. *comptula* (Schwager)

cf. 1865 - *Cristellaria comptula* - Schwager, p. 6, fig. 19

cf. 1965 - *Lenticulina* ex gr. (*Astacolus*) *comptula* - Hanzlíková, pl. 4, fig. 10

cf. 1988 - *Astacolus comptula* - Holzknecht and Hamršíd, pl. 13, figs 4-6.

Occurrence: rare.

Astacolus irretita (Schwager)

Fig. 4.2

1865 - *Cristellaria irretita* - Schwager, p. 5, fig. 11

1965 - *Lenticulina (Astacolus)* *irretita* - Hanzlíková, pl. 6, fig. 1a, b, 12a, b

Occurrence: moderate.

Astacolus sp.

Occurrence: moderate.

Brotzenia parastelligera Hofker

Fig. 4.3

1954 - *Brotzenia parastelligera* - Hofker, figs 4-6

1965 - *Brotzenia parastelligera* - Hanzlíková, pl. 8, fig. 5a, b, 6a, b, 7a, b, 8a, b

Occurrence: very rare.

Brotzenia sp.

Occurrence: frequent.

Cassidella sp.

Occurrence: very rare.

Citharina implicata (Schwager)

Fig. 4.4

1865 - *Cristellaria implicata* - Schwager, pl. 6, 5a, b

1965 - *Citharina implicata* - Hanzlíková, pl. 6, fig. 17a, b

Occurrence: rare.

Citharina lepida (Schwager)

Fig. 4.5

1867 - *Cristellaria lepida* - Schwager, pl. 34, fig. 9

1965 - *Citharina* ex gr. *lepida* - Hanzlíková, pl. 6, fig. 8, pl. 7, fig. 23a, b

Occurrence: rare.

Citharina macilenta (Terquem)

Fig. 4.6

1868 - *Marginulina macilenta* (pars) - Terquem, pl. 4, figs 1-6, 10-12, non figs 7, 8a

1965 - *Citharina macilenta* - Hanzlíková, pl. 6, figs 18a, b, 20, pl. 8, fig. 1

1988 - *Citharina macilenta* - Holz knecht and Hamršmíd, pl. 20, fig. 1-3.

Occurrence: very rare.

Citharina tenuicostata Lutze

Fig. 4.7

1960 - *Citharina tenuicostata* - Lutze, pl. 30, figs 5, 6

1965 - *Citharina* cf. *tenuicostata* - Hanzlíková, pl. 7, fig. 17

Occurrence: rare.

Citharina sp.

Occurrence: very rare.

Cyclammina sp.

Occurrence: rare.

Dentalina tenuicaudata Reuss

1860 - *Dentalina tenuicaudata* - Reuss, pl. 2, fig. 3

1971 - *Dentalina tenuicaudata* - Fuchs, pl. 4, fig. 9

Occurrence: very rare.

Dentalina cf. *varians* Terquem

Figs 4.8, 9

cf. 1866a - *Dentalina varians* - Terquem, pl. 5 figs 19a-d

cf. 1970 - *Dentalina varians* - Fuchs, pl. 4, fig. 15

Occurrence: moderate.

Dentalina spp.

Fig. 4.10

Occurrence: moderate.

Dorothia cf. *trochus* (d'Orbigny)

cf. 1840 - *Textularia trochus* - d'Orbigny, pl. 4, figs 25-26

cf. 1957 - *Marssonella* cf. *trochus* - Bartenstein et al., pl. 3, figs 44, 45a, b

cf. 1971 - *Dorothia trochus* - Fuchs, pl. 3, fig. 3

Occurrence: very rare.

Eoguttulina cf. *helvetica* (Kübler and Zwingli)

Fig. 4.11

cf. 1870 - *Eoguttulina helvetica* - Kübler and Zwingli, pl. 3, figs 40-40a

1965 - *Eoguttulina* cf. *helvetica* - Hanzlíková, pl. 7, fig. 15a, b

Occurrence: rare.

Eoguttulina sp.

Occurrence: rare.

Fron dicularia lingulaeformis Schwager

Figs 4.12

1865 - *Fron dicularia lingulaeformis* - Schwager, fig. 95, pl. 4, fig. 11

1965 - *Fron dicularia lingulaeformis* - Hanzlíková, pl. 7, fig. 20

1988 - *Fron dicularia lingulaeformis* - Holz knecht and Hamršmíd, pl. 21, fig. 5-8.

Occurrence: moderate.

Fron dicularia nikitini Uhlig

1883 - *Fron dicularia nikitini* - Uhlig, pl. 9, figs 10, 11

1965 - *Fron dicularia nikitini* - Hanzlíková, pl. 8, fig. 2, pl. 7, figs 18, 21a-c

1988 - *Fron dicularia nikitini* - Holz knecht and Hamršmíd, pl. 20, fig. 4

Occurrence: rare.

Fron dicularia sp.

Occurrence: very rare.

?*Gaudryina* sp.

Occurrence: very rare.

?*Globulina* sp.

Occurrence: very rare.

Glomospirella sp.

Occurrence: very rare.

Guttulina sp.

Occurrence: very rare.

?*Haplophragmoides* spp.

Occurrence: moderate.

Hippocrepina sp.

Occurrence: moderate.

Lagena sp.

Occurrence: moderate.

Lenticulina cf. *crassa* (Roemer)

Fig. 4.13

cf. 1841 - *Robulina crassa* - Roemer, p. 98

cf. 1965 - *Lenticulina* (*Lenticulina*) *crassa* - Hanzlíková, pl. 4, fig. 6a, b

Occurrence: very rare.

Lenticulina cultrata (Montfort)

Fig. 4.14

1808 - *Robulus cultratus* - Montfort, fig. 541957 - *Lenticulina* (*Lenticulina*) *cultrata* - Bartenstein et al., pl. 5, fig. 911965 - *Lenticulina* (*Lenticulina*) *cultrata* - Hanzlíková, pl. 4, fig. 15a, b

Occurrence: rare.

Lenticulina hyalina (Mjatljuk)1939 - *Cristellaria hyalina* - Mjatljuk, pl. 3, fig. 37a, b1965 - *Lenticulina* (*Lenticulina*) aff. *hyalina* - Hanzlíková, pl. 4, fig. 9a, b

Occurrence: very rare.

Lenticulina polonica (Wisniewski)

Figs 4.15

1890 - *Cristellaria polonica* - Wisniewski, pl. 10, fig. 3a-c1965 - *Lenticulina* (*Lenticulina*) *polonica* - Hanzlíková, pl. 4, fig. 2, 3a, b, 4, 13a, b1988 - *Lenticulina polonica* - Holzknecht and Hamršmíd, pl. 10, figs 3, 4, pl. 11, figs 1, 2.

Occurrence: very frequent.

Lenticulina quenstedti (Gümbel)

Fig. 4.16

1862 - *Cristellaria quenstedti* - Gümbel, pl. 4, fig. 2a, b1962 - *Cristellaria plexus-quenstedti* - Bastien and Sigal, pl. 6, fig. 15-19, pl. 7, fig. 1-31965 - *Lenticulina* (*Lenticulina*) *quenstedti* - Hanzlíková, pl. 4, fig. 8a, b, 11, 13, pl. 5, 2a, b1971 - *Lenticulina quenstedti* - Wernli, pl. 4, figs 14, 21, 23, 25, 27, 28, pl. 10, fig. 11988 - *Lenticulina quenstedti* - Holzknecht and Hamršmíd, pl. 11, figs 4, 5, pl. 12, figs 1-4.

Occurrence: frequent.

Lenticulina vistulae Bielecka and Pozaryski

Figs 4.17

1954 - *Lenticulina vistulae* - Bielecka and Pozaryski, fig. 151965 - *Lenticulina* (*Lenticulina*) *vistulae* - Hanzlíková, pl. 4, 1a-c

Occurrence: rare.

Lituotuba cf. *nothi* (Majzon)cf. 1943 - *Thalmanina nothi* - Majzon, pl. 2, fig. 14cf. 1971 - *Lituotuba nothi* - Fuchs, pl. 1, fig. 16, pl. 2, fig. 2

Occurrence: very rare.

Marginulina declivis (Schwager)

Fig. 4.18

1865 - *Dentalina declivis* - Schwager, pl. 3, fig. 11965 - *Marginulina declivis* - Hanzlíková, pl. 7, figs 7, 11a, b

Occurrence: rare.

Marginulina linearis (Reuss)

Fig. 4.19

1863 - *Cristellaria* (*Marginulina*) *linearis* - Reuss, pl. 5, fig. 151971 - *Marginulina linearis* - Fuchs, pl. 7, fig. 11

Occurrence: rare.

?Marginulina sp.

Occurrence: very rare.

Marginulinopsis dichotoma (Terquem)

Fig. 4.20

1862 - *Marginulina dichotoma* - Terquem, pl. 6, fig. 1a, b1965 - *Lenticulina* (*Marginulinopsis*) *dichotoma* - Hanzlíková, pl. 7, fig. 12a, b

Occurrence: rare.

Marginulinopsis glabra (d'Orbigny)

Fig. 4.21

1826 - *Marginulina glabra* - d'Orbigny, p. 2591965 - *Lenticulina* (*Marginulinopsis*) *glabra* - Hanzlíková, pl. 6, fig. 13a, b

Occurrence: moderate.

Marginulinopsis cf. *jonesi* (Reuss)cf. 1863 - *Marginulina jonesi* - Reuss, pl. 5, fig. 19cf. 1971 - *Lenticulina* (*Marginulinopsis*) *jonesi* - Fuchs, pl. 5, fig. 12

Occurrence: very rare.

Marsonella oxycona (Reuss)

Fig. 4.22

1860 - *Gaudryina oxycona* - Reuss, pl. 12, fig. 31957 - *Marssonella* cf. *oxycona* - Bartenstein et al., pl. 2, figs 42a, b, 431965 - *Marsonella* ex gr. *oxycona* - Hanzlíková, pl. 9, fig. 5a, b1988 - *Marsonella oxycona* - Holzknecht and Hamršmíd, pl. 4, figs 1-7

Occurrence: moderate.

?Miliammia sp.

Occurrence: very rare.

Nodosaria sp.

Occurrence: very rare.

Neobulimina varsoviensis Bielecka and Pozaryski

Figs 4.23

1954 - *Neobulimina varsoviensis* - Bielecka and Pozaryski, pl. 10, fig. 501965 - *Neobulimina varsoviensis* - Hanzlíková, pl. 9, figs 9a, b, 10

Occurrence: frequent.

Paalzowella cf. *feifeli* (Paalzow)cf. 1932 - *Trocholina feifeli* - Paalzow, pl. 11, fig. 4cf. 1962 - *Paalzowella* aff. *feifeli* - Bastien and Sigal, pl. 5, fig. 4a-ccf. 1965 - *Paalzowella* ex gr. *feifeli feifeli* - Hanzlíková, pl. 9, figs 20a-c, 21

Occurrence: very rare.

Planularia cordiformis (Terquem)

Fig. 4.24

1864 - *Cristelleria cordiformis* - Terquem, p 413

1965 - *Lenticulina (Planularia) cordiformis* - Hanzlíková, pl. 7, fig. 6a, b

non 1970 - *Lenticulina (Planularia) cordiformis* - Fuchs, pl. 5, fig. 14

1988 - *Planularia cordiformis* - Holzknicht and Hamršíd, pl. 15, figs 1-3.

Occurrence: rare.

Planularia cf. filosa (Terquem)

cf. 1866b - *Cristelleria filosa* - Terquem, pl. 22, fig. 8a, b

cf. 1965 - *Lenticulina (Planularia) filosa* - Hanzlíková, pl. 7, fig. 8a, b

Occurrence: very rare.

Rectoglandulina cf. quinquecostata (Bornemann)

Fig. 4.25

1854 - *Glandulina quinquecostata* - Bornemann, pl. 2, fig. 6a, b

1965 - *Rectoglandulina cf. quinquecostata* - Hanzlíková, pl. 9, fig. 5a, b

2000 - *Pseudonodosaria quinquecostata* - Waltschew, pl. 1, figs 12-14

Occurrence: very rare.

Reophax sp.

Occurrence: very rare.

?*Saccamina* sp.

Occurrence: rare.

Saracenaria alata-angularis (Franke)

Fig. 4.26

1936 - *Cristellaria (Saracenaria) alata-angularis* - Franke, pl. 9, fig. 32

1965 - *Lenticulina (Saracenaria) alata-angularis* - Hanzlíková, pl. 9, fig. 5a, b

Occurrence: rare.

Saracenaria cornucopiae (Schwager)

Fig. 4.27

1865 - *Cristelleria cornucopiae* - Schwager, pl. 5, fig. 7

1962 - *Lenticulina (Saracenaria) cornucopiae* - Bastien and Sigal, pl. 6, fig. 5a, b

1965 - *Lenticulina (Saracenaria) cornucopiae* - Hanzlíková, pl. 5, fig. 8a, b

1971 - *Saracenaria cornucopiae* - Wernli, pl. 8, figs 1-2

1988 - *Saracenaria cornucopiae* - Holzknicht and Hamršíd, pl. 14, figs 2, 3.

Occurrence: frequent.

Saracenaria praecornucopiae (Hanzlíková)

Fig. 4.28

1965 - *Lenticulina (Saracenaria) praecornucopiae* - Hanzlíková, pl. 5, fig. 9a, b, c

Occurrence: rare.

Saracenaria sp.

Occurrence: rare.

Spirillina tenuissima Gümbel

Figs 4.29

1862 - *Spirillina tenuissima* - Gümbel, pl. 4, fig. 12a, b

1965 - *Spirillina tenuissima* - Hanzlíková, pl. 9, figs 19, 23a, b

1970 - *Spirillina tenuissima* - Fuchs, pl. 9, fig. 2

1971 - *Spirillina tenuissima* - Fuchs, pl. 9, fig. 4

1988 - *Spirillina tenuissima* - Holzknicht and Hamršíd, pl. 37, figs 1-6.

Occurrence: very frequent, occurs in almost all samples with high numbers.

?*Textularia* sp.

Occurrence: very rare.

Triplasia cf. elegans (Mjatljuk)

cf. 1939 - *Frankeina elegans* - Mjatljuk, pl. 2, fig. 26

cf. 1965 - *Triplasia elegans* - Hanzlíková, pl. 2, figs 3a, b, 5a, b

Occurrence: very rare.

Tristix acutangulus (Reuss)

Fig. 4.30

1863 - *Rhabdogonium acutangulum* - Reuss, pl. 4, fig. 14

1957 - *Tristix acutangula* - Bartenstein et al., pl. 5, fig. 111. pl. 6, fig. 139

1965 - *Tristix acutangulus* - Hanzlíková, pl. 9, figs 7a, b

1971 - *Tristix acutangula* - Fuchs, pl. 7, fig. 7

1988 - *Tristix acutangulus* - Holzknicht and Hamršíd, pl. 6, fig. 1.

Occurrence: moderate.

Trochammina sp.

Occurrence: rare.

Trocholina solecensis Bielecka and Pozarski

Figs 4.31-34

1954 - *Trocholina solecensis* - Bielecka and Pozarski, pl. 11, fig. 57

1965 - *Trocholina ex gr. solecensis* - Hanzlíková, pl. 9, figs 11-18

1988 - *Trocholina solecensis* - Holzknicht and Hamršíd, pl. 24, figs 4-8, pl. 15, figs 1-6.

Occurrence: very frequent, occurs in all samples.

Vaginulina cf. cetra Lalicker

cf. 1950 - *Vaginulina cetra* - Lalicker, pl. 3, fig. 5

cf. 1965 - *Vaginulina cetra* - Hanzlíková, pl. 6, fig. 15

Occurrence: very rare.

Vaginulina contracta (Terquem)

Fig. 4.35

1868 - *Marginulina contracta* - Terquem, pl. 8, figs 13-24

1965 - *Vaginulina contracta* - Hanzlíková, pl. 7, figs 3a, b, 5a, b

1971 - *Vaginulina contracta* Fuchs, pl. 7, fig. 12
Occurrence: frequent.

Vaginulina duckcreekensis Tappan

Fig. 4.36

1943 - *Vaginulina duckcreekensis* - Tappan, pl. 80, figs 27-29

1971 - *Vaginulina duckcreekensis* - Fuchs, pl. 7, fig. 16, pl. 8, fig. 4

Occurrence: very rare.

Vaginulina jurassica (Gümbel)

1862 - *Marginulina jurassica* - Gümbel, pl. 3, fig. 21a, b

1965 - *Vaginulina jurassica* - Hanzlíková, pl. 7, fig. 4a, b, 9

Occurrence: rare.

Vaginulina kochii Roemer

Fig. 4.37

1841 - *Vaginulina kochii* - Roemer, pl. 15, fig. 10

1957 - *Vaginulina kochii* - Bartenstein et al, pl. 5, fig. 105, pl. 6, fig. 124

1965 - *Vaginulina kochii* - Hanzlíková, pl. 6, fig. 19a, b

1971 - *Vaginulina kochii* - Fuchs, pl. 7, fig. 18, 22

1973 - *Vaginulina kochii* - Bartenstein and Kaever, pl. 3, fig. 50, pl. 7, fig. 18, 22

Occurrence: very rare.

Vaginulina cf. *listi* (Bornemann)

cf. 1854 - *Cristelleria listi* - Bornemann, pl. 4, fig. 28a-c

cf. 1965 - *Vaginulina listi* - Hanzlíková, pl. 8, fig. 12a, b

Occurrence: rare.

Vaginulina recta Reuss

1863 - *Vaginulina recta* - Reuss, pl. 3, figs 14-15

1971 - *Vaginulina recta* - Fuchs, pl. 7, fig. 6

Occurrence: very rare.

Vaginulina truncata Reuss

1863 - *Vaginulina truncata* - Reuss, pl. 3, fig. 9

1965 - *Vaginulina* ex gr. *truncata* - Hanzlíková, pl. 6, fig. 16a, b

1971 - *Vaginulina truncata* - Fuchs, pl. 8, figs 1, 7

Occurrence: rare.

Vaginulinopsis pasquetae (Bizon)

1958 - *Vaginulina pasquetae* - Bizon, pl. 2, fig. 9, pl. 4, fig. 9

1965 - *Lenticulina (Vaginulinopsis) pasquetae* - Hanzlíková, pl. 9, fig. 5a, b

cf. 2000 - *Planularia ornata* - Waltschew, pl. 1, fig. 28

Occurrence: moderate.

Vaginulinopsis radiata (Terquem)

Fig. 4.38

1864 - *Marginulina radiata* - Terquem, pl. 9, fig. 10a, b

1965 - *Lenticulina (Vaginulinopsis) radiata* - Hanzlíková, pl. 6, figs 5a, b, 6a, b, 7

1988 - *Vaginulinopsis radiata* - Holzknecht and Hamršmíd, pl. 16, figs 3-6, pl. 17, figs 1-4, pl. 18, figs 1-5.

Occurrence: frequent.

Vaginulinopsis tenuicosta (Wisniowski)

Figs 4.39

1890 - *Marginulina costata* (Bartsch) var. *tenuicosta* - Wisniowski, pl. 8, fig. 55

1965 - *Lenticulina (Vaginulinopsis) tenuicostata* - Hanzlíková, pl. 6, figs 1, 2a, b, 3, 4

Occurrence: frequent.

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