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Triassic and Jurassic possible planktonic foraminifera and the assemblages recovered from the Ogrodzieniec Glauconitic Marls Formation (uppermost Callovian and lowermost Oxfordian, Jurassic) of the Polish Basin

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Abstract. In the 1960s and 1970s Werner Fuchs of the Austrian Geological Survey (Vienna) described a significant number of new foraminiferal taxa that he considered ancestral to the planktonic foraminifera. All these taxa are well-curated in the collections of the Austrian Geological Survey and have been studied by one of us (Malcolm B. Hart). Some of these taxa, from the Triassic and lowermost Jurassic strata of Austria and northern Italy, are poorly preserved, possibly the result of having an original aragonitic wall structure. None of these taxa possess characters which give the appearance of a planktonic mode of life, although some of them (e.g. *Oberhauserella*, *Praegubkinella*) may well have been ancestral to the holoplanktonic foraminifera that appeared in the Toarcian and younger strata. Other taxa in the collections of the Austrian Geological Survey (part of GeoSphere Austria), from the Jurassic of Poland, are preserved as glauconitic steinkerns and are either unidentifiable as foraminifera or suspect in terms of their stratigraphical and evolutionary significance.

1 Introduction

In a series of papers in the 1960s and 1970s Werner Fuchs described many new species of foraminifera from the Triassic and lowermost Jurassic strata of Austria and northern Italy (Fuchs, 1967, 1971, 1973). Some of the sediment samples may have been collected by Fuchs himself during the Tenth European Micropalaeontological Colloquium, although much of the material was probably collected by Manfred E. Schmidt, one the Austrian Geological Survey's field geologists. Many of the taxa described in the 1967 paper were identified as either planktonic or ancestral to planktonic foraminifera. Fuchs was so convinced of their planktonic nature that one species was named as *Schmidita hedbergelloides*, a clear link to the Cretaceous genus *Hedbergella*. Fuchs' taxa were discussed by BouDhager-Fadel et al. (1997) and BouDhager-Fadel (2015) in a major study of the early planktonic foraminifera. The Jurassic taxa, described by Simmons et al. (1997), Gradstein (2017) and Gradstein et al. (2017a, b), are clearly Bathonian to Kimmeridgian in age, although Wernli (1988, 1995), Görög (1994), Wernli and Görög (1999, 2000), Görög and Wernli (2013), Kaminski et al. (2018), and de Cabrera et al. (2020) have also described planktonic taxa from the Toarcian, Aalenian, Bajocian and Kimmeridgian. There appears to be convincing evidence that the earliest forms that could be regarded as quasi-planktonic or holoplanktonic date from the late Toarcian, and there are a significant number of other groups of microfossils that also became planktonic or expanded their diversity and

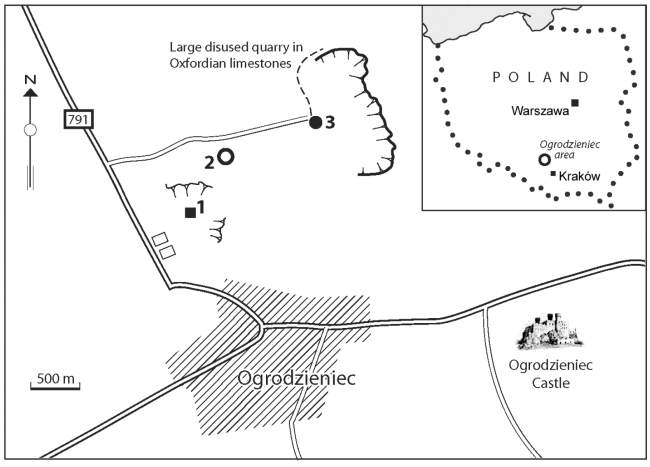

Figure 1. Location of the sections around Ogrodzieniec Quarry including (1) the brick-works quarry in the Bathonian ore-bearing clays, (2) the sections, away from the main quarry which is the type locality for *Globuligerina bathoniana* (Pazdrowa, 1969), and (3) the roadside outcrop exposed in our excavations in July 2011. The main face of the Ogrodzieniec Quarry is indicated, and, during the preparations for the Jurassic Symposium in 2006, a face was excavated (Matyja and Wierzbowski, 2006), approximately 500 m to the south-east of location (3).

Figure 2. The excavation of locality (3 – Fig. 1) in July 2011, with ES inspecting the small exposure of beds 19–22 (Bielecka and Styk, 1967). On the left, behind MBH, is the main quarry face of the Ogrodzieniec Quarry, which is formed of Oxfordian limestones.

abundance at this time (Hylton and Hart, 2000; Danise et al., 2013, 2019; Reolid et al., 2021, and papers therein).

1.1 The Triassic and lowermost Jurassic taxa

The species described by Fuchs in his 1967 paper (together with some described earlier by Oberhauser, 1960) are all curated in the collections of the Geological Survey of Austria (now GeoSphere Austria) in Vienna, and all the holotypes and paratypes have been studied by Malcolm B. Hart (MBH) (see Appendix A). Many of these slides were safely transported to London, where they were imaged – un-coated and under low voltage – in the Natural History Museum (London) under the direction of the late John E. Whittaker.

The majority of these taxa display a low trochospiral test with a distinct umbilicus and a typically benthic-style, interio-marginal aperture with, in some cases, evidence of supplementary apertures on some septa. Some of the species were described by their author as "discorbid-like". Most of these species have features that are completely different to the typical *Conoglobigerina* and *Globuligerina* of the mid-Upper Jurassic planktonic taxa. Some of the more inflated species of *Oberhauserella* and, especially, *Praegubkinella* indicate a possible evolutionary relationship with the earliest holoplanktonic taxa (Wernli, 1988, 1995; BouDagher-Fadel et al., 1997; Hart et al., 2003, fig. 2), but this remains slightly speculative (von Hillebrandt, 2012). The work by Wernli (1995) in the Fribourg Alps demonstrated the appearance of possible planktonic taxa stratigraphically above the black shales of the Toarcian Oceanic Anoxic Event (OAE) in the Lower Jurassic. The appearance of inflated *Oberhauserella* immediately above the Toarcian OAE on the Yorkshire coast (Hart et al., 2003) appears to indicate a potentially synchronous appearance of possible planktonic ancestors immediately following the Toarcian OAE.

In the Bajocian strata of sections north of Lake Balaton (Hungary), Wernli and Görög (1999, 2000) and Hudson (2007) have described planktonic foraminifera in thin sections and in acetic acid reductions. Kaminski et al. (2018) have, more recently, described planktonic foraminifera in the middle Dhruma Formation of Saudi Arabia. These individuals have a variable spire height and thickness of wall, with a characteristic ∼four inflated chambers in the final whorl. In the Bathonian strata of the Ogrodzieniec area of Poland, undoubted planktonic foraminifera are present, including *Conoglobigerina bathoniana* (Pazdrowa, 1969; Hart et al., 2012; Kendall et al., 2020; Gajewska et al., 2021).

1.2 Historical material collected from Poland

During the 10th European Micropalaeontological Colloquium in 1967, there was an opportunity for the participants to collect material that was destined to enter their national and other collections. These colloquia, which were by invitation only, primarily involved an extended field excursion, during which time the participants were assisted in collecting a complete suite of samples from the host country. The 1967 Colloquium visited several locations in Poland, including the Jurassic outcrops around Ogrodzieniec, which is located to the north of Kraków (Bielecka and Styk, 1967; Pazdrowa, 1967). The quarry that exposes the Ogrodzieniec Glauconitic Marls Formation was described as the "Wiek" quarry by Bi-

Figure 3. The excavated section of the roadside outcrop (location (3) in Fig. 1). This shows the Callovian succession described as beds 19 to 22 by Bielecka and Styk (1967, fig. 28, p. 134). Bed 20 is a distinctive calcareous "marl" with abundant belemnites, phosphate concretions/nodules, and evidence (in the field) of glauconite grains. All the beds 19 to 22 are described as rich in glauconite molds of fossils, the majority of which are foraminifera.

elecka and Styk (1967, p. 131) and this was reported as the "Kalksteinbruch Wiek bei Ogrodzieniec" by Fuchs (1973). The Jurassic strata of the Polish Basin (Gajewska et al., 2021, fig. 3) are exceptionally rich in foraminifera, and these assemblages have been described in a number of papers that are recorded in the excursion guide. Under the supervision of the field excursion leaders, Manfred E. Schmidt (Austrian Geological Survey) collected a suite of samples, including material from beds 21 and 26 within the "Wiek quarry" (Fig. 1). After shipping to Austria, these samples were studied by Fuchs and the assemblage of foraminifera (including several new species) was described in his 1973 paper. Almost all the specimens from Ogrodzieniec were described by Fuchs (1973, p. 462, 474) as glauconitic steinkerns; internal casts of chambers with no calcareous test present, no external ornamentation or a clear indication of the shape and position of apertures. The great majority of the new species would, therefore, be classed as invalid on the basis of a lack of describable characters. The observations of MBH, and a partial list of the taxa, are given in Appendix B.

The significance of the Ogrodzieniec material was increased in 2006, when the 7th International Symposium on the Jurassic System also visited the area (Wierzbowski et al., 2006). The excursion guide (Matyja and Wierzbowski, 2006) describes a newly excavated succession in the Ogrodzieniec Quarry which exposed the Callovian–Oxfordian boundary interval (Matyja and Wierzbowski, 2006, fig. B1.8). Wendy Hudson (University of Plymouth) – aided by Michael Simmons – collected a small number of samples across the boundary (Fig. 1). When these samples were washed on a

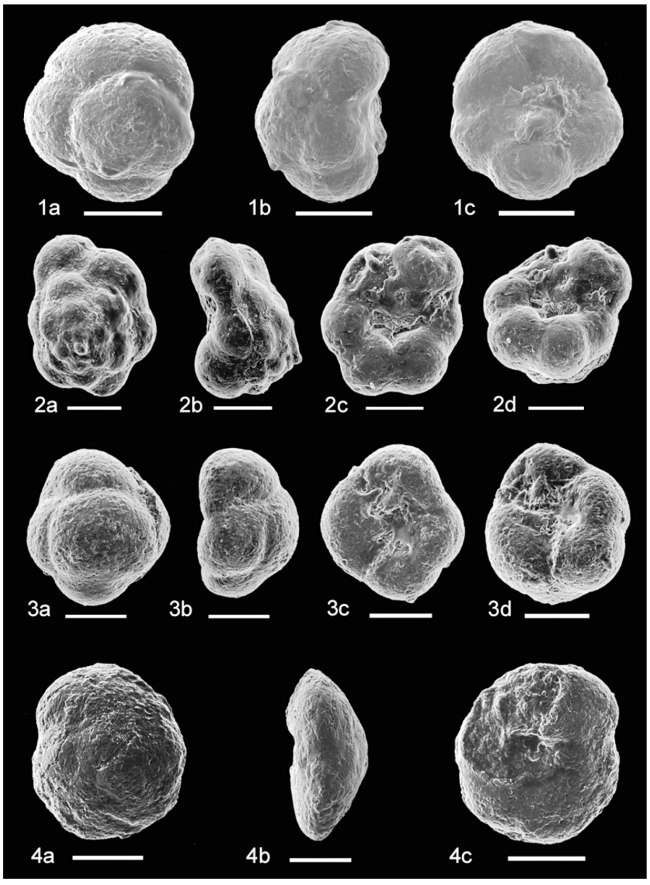

Figure 4. (1) *Oberhauserella mesotriassica* (Oberhauser, 1960), holotype; **(a)** spiral view, scale bar 75 µm [jwh 0890], **(b)** edge view, scale bar 75 µm [jwh 0945], **(c)** umbilical view, scale bar 75 µm [jwh 0926]. Figured by Oberhauser (1960, pl. 5, fig. 18a–c) from a locality in the Settsass Scharte, north of the Richthofen Riff, near St. Kassian, South Tyrol, northern Italy. Upper Cassian beds, Ladinian. Type slide 1960/4/106. (2) *Oberhauserella mesotriassica* (Oberhauser, 1960), paratype; **(a)** spiral view, scale bar 100 µm [P 059762], **(b)** edge view, scale bar 100 µm [P 059814], **(c)** umbilical view, scale bar 100 µm [P 059732], **(d)** oblique–umbilical view, scale bar 100 µm [P 059735]. Figured by Oberhauser (1960, pl. 5, fig. 19a–c) from a locality in the Settsass Scharte, north of Richthofen Riff, near St. Kassian, South Tyrol, northern Italy. Upper Cassian beds, Ladinian. Type slide 1960/4/107. (3) *Oberhauserella alta* Fuchs, 1967, ?paratype; **(a)** spiral view, scale bar 86 µm [P 059763], **(b)** edge view, scale bar 86 µm [P 059815], **(c)** umbilical view, scale bar 86 µm [P 059733], **(d)** oblique–umbilical view, scale bar 86 µm [P 059734]. From Plackles, Lower Austria. Plackles marls, Rhaetian. Type slide 1967/5/25 (4/6). (4) *Oberhauserella crassa* Fuchs 1970, holotype; **(a)** spiral view, scale bar 120 µm [P 074675], **(b)** edge view, scale bar 120 µm [P 074682], **(c)** umbilical view, scale bar 120 µm [P 074667]. Figured by Fuchs (1970, pl. 9, fig. 10) from Hernstein, Lower Austria. Lias α, Lower Jurassic. Type slide 1970/3/130.

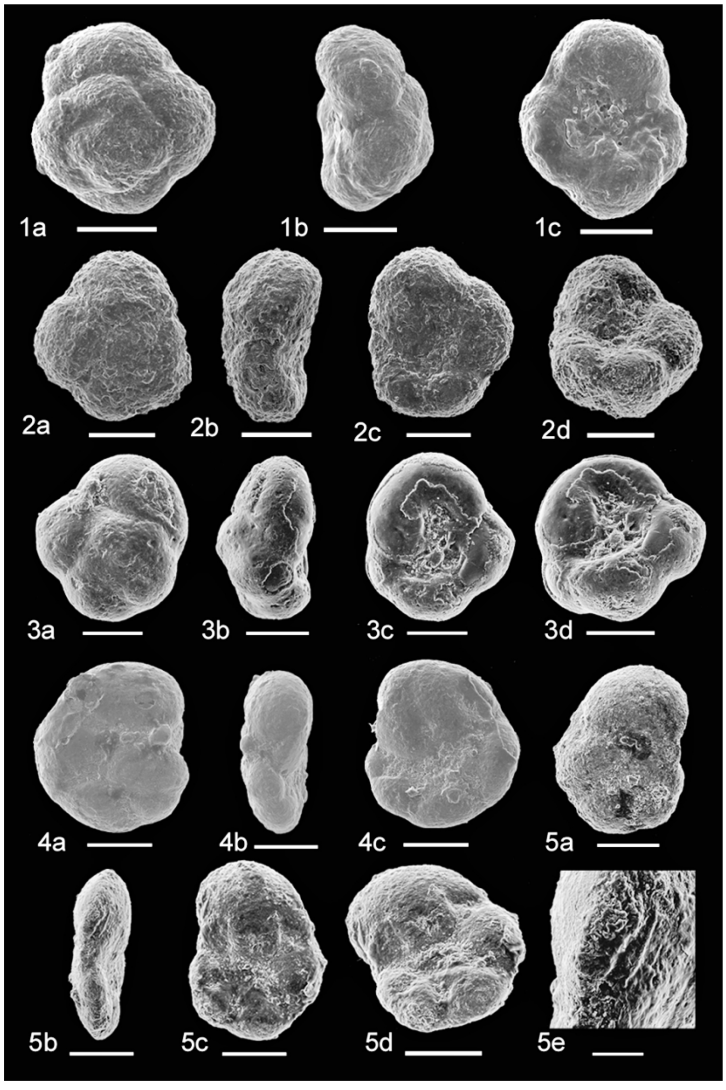

Figure 5. (1) *Oberhauserella karinthiaca* Fuchs 1967, holotype; **(a)** spiral view, scale bar 75 µm [jwh 0927], **(b)** edge view, scale bar 75 µm [jwh 0946], **(c)** umbilical view, scale bar 75 µm [jwh 0891]. Figured by Fuchs (1967, pl. 3, fig. 3) from Eisenkappel, Carinthia, southern Austria. Lower Carnian. Type slide 1967/5/17. (2) *Oberhauserella norica* Fuchs 1967, paratype; **(a)** spiral view, scale bar 86 µm [P 059765], **(b)** edge view, scale bar 86 µm [P 059817], **(c)** umbilical view, scale bar 86 µm [P 059741], **(d)** oblique–umbilical view, scale bar 86 µm [P 059739]. Figured by Fuchs (1967, pl. 6, fig. 2). From Hinterer Gosausee, Upper Austria. Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/28. (3) *Oberhauserella quadrilobata* Fuchs, 1967, ?paratype; **(a)** spiral view, scale bar 60 µm [P 059764], **(b)** edge view, scale bar 60 µm [P 059816], **(c)** umbilical view, scale bar 60 µm [P 059740], **(d)** oblique–umbilical view, scale bar 60 µm [P 059738]. Figured by Fuchs (1967, pl. 3, fig. 6). From Rossmoos, Upper Austria. Upper Norian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/20. (4) *Kollmannita ladinica* (Oberhauser, 1960), holotype; **(a)** spiral view, scale bar 100 µm [jwh 0925], **(b)** edge view, scale bar 100 µm [jwh 0944], **(c)** umbilical view, scale bar 100 µm [jwh 0889]. Figured by Oberhauser (1960, pl. 5, figs 14a–c). From a locality in the Settsass Scharte, north of Richthofen Riff, near St. Kassian, South Tyrol, northern Italy. Upper Cassian beds, Ladinian. Geologische Bundesanstalt, Vienna, inv. no. 1960/4/108. (5) *Kollmannita ladinica* (Oberhauser, 1960), paratype; **(a)** spiral view, scale bar 100 µm [P 059761], **(b)** edge view, scale bar 100 µm [P 059812], **(c)** umbilical view, scale bar 100 µm [P 059731], **(d)** oblique–umbilical view, scale bar 100 µm [P 059736], **(e)** detail of apertural face(?), scale bar 27 µm [P 059813]. Figured by Oberhauser (1960, pl. 5, fig. 12a–c). From a locality in the Settsass Scharte, north of Richthofen Riff, near St. Kassian, South Tyrol, northern Italy. Upper Cassian beds, Ladinian. Geologische Bundesanstalt, Vienna, inv. no. 1960/4/109.

63 µm sieve, the residue was almost 95 % grains of glauconite (Fe-rich clay mineral), the majority of which were the internal casts of planktonic foraminifera, although there is also a significant benthic foraminiferal component. Many of the planktonic taxa have been illustrated (Gajewska et al., 2021, figs. 1, 2), and these scanning electron micrographs show the absence of a calcareous test and, therefore, a complete lack of apertural details. There is a great variation in the spire height of these taxa, the majority of which have ∼ four chambers in the final whorl. Also present are forms that can be referred to as *Conoglobigerina helvetojurassica* (Haeusler), and this species was also noted by Bielecka and Styk (1967) as being "frequent" in many of the beds described in their field guide. In the same assemblage lists they also mention a wide range of benthic species including *Epistomina* spp. and *Reinholdella* spp. Many of the steinkerns of benthic foraminifera may well be these taxa, some of which were described as *Mariannenina* by Fuchs (1973).

In July 2011, MBH, Eiichi Setoyama (ES) and Jarosław Tyszka (JT) visited the Ogrodzieniec Quarry as well as the Bathonian Ore-Bearing Clays in the nearby brick-works quarry (Matyja et al., 2006). The 2006 temporary exposure, excavated for the Jurassic Symposium, could not be located and appeared to have been infilled. At the road junction, marked as (3) in Fig. 1, a thin succession was excavated within beds 19–22 of the Bielecka and Styk (1967) succession. The whole area was littered with abundant ammonites and belemnites, and a face was exposed that could be sampled (Figs. 2, 3). The phosphate-rich bed (Bed 20) was clearly identified and the complete succession was rich in glauconite. These samples, when processed at the University of Plymouth, yielded the typical steinkerns that had been seen in the collections of the Austrian Geological Survey and in the samples collected by Wendy Hudson and Michael Simmons. The planktonic foraminifera are illustrated in the paper by Gajewska et al. (2021), and some of the benthic foraminifera are illustrated here (see Appendix B). Benthic foraminifera are quite difficult to determine as glauconitic steinkerns as one can normally only identify the trochospiral chamber arrangement, height of spire and numbers of chambers. The apertural details and any external ornamentation are completely absent.

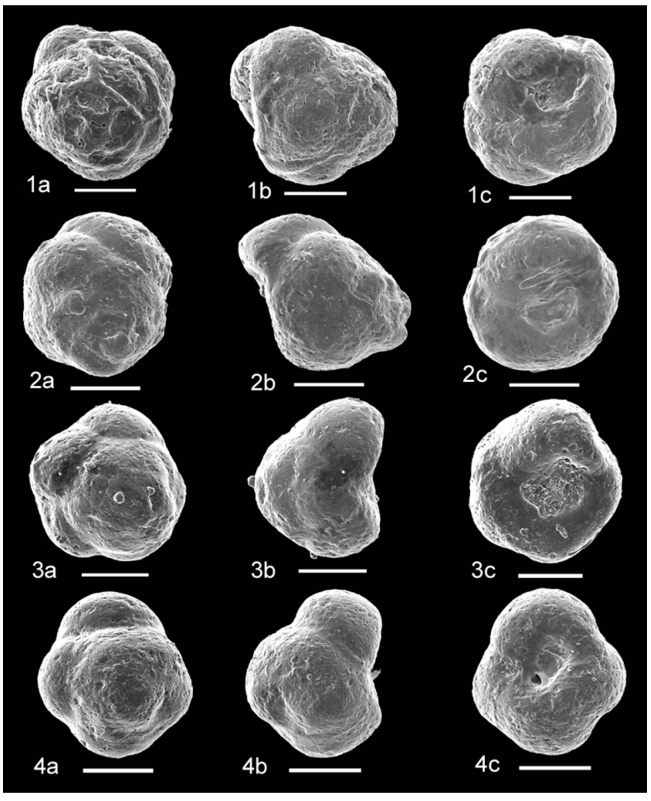

Figure 6. (1) *Praegubkinella kryptumbilicata* Fuchs, 1967, holotype; **(a)** spiral view, scale bar 75 µm [jwh 0892], **(b)** edge view, scale bar 75 µm [jwh 0928], **(c)** umbilical view, scale bar 75 µm [jwh 0947]. Figured by Fuchs (1967, pl. 7, fig. 3). From Xanten, Salzburg, Austria. Upper Rhaetian. Geologische Bundesanstalt, Vienna, no. 1967/5/48. (2) *Praegubkinella turgescens* Fuchs, 1967, holotype; **(a)** spiral view, scale bar 75 µm [jwh 0893], **(b)** edge view, scale bar 75 µm [jwh 0929], **(c)** umbilical view, scale bar 75 µm [jwh 0948]. Figured by Fuchs (1967, pl. 7, fig. 2). From Xanten, Salzburg, Austria. Upper Rhaetian. Geologische Bundesanstalt, Vienna, no. 1967/5/43. (3) *Praegubkinella turgescens* Fuchs, 1967, ?paratype; **(a)** spiral view, scale bar 75 µm [jwh 0930], **(b)** edge view, scale bar 75 µm [jwh 0949], **(c)** umbilical view, scale bar 75 µm [jwh 0894]. Figured by Fuchs (1967, pl. 6, fig. 4). From Xanten, Salzburg, Austria. Upper Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/44. (4) *Praegubkinella turgescens* Fuchs, 1967, ?paratype; **(a)** spiral view, scale bar 75 µm [jwh 0931], **(b)** edge view, scale bar 75 µm [jwh 0950], **(c)** umbilical view, scale bar 75 µm [jwh 0895]. Figured by Fuchs (1967, pl. 7, fig. 1). From Xanten, Salzburg, Austria. Upper Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/56.

2 Conclusions

Almost all the species of foraminifera described by Oberhauser (1960) and Fuchs (1967, 1970, 1973) appear to be benthic in terms of their palaeoecology. Some of the more inflated forms of *Oberhauserella* and, especially, *Praegubkinella* may have been ancestral to the holoplanktonic foraminifera that appeared in the Toarcian (Lower Jurassic), associated with the aftermath of the Oceanic Anoxic Event that is typical of many successions in Europe and elsewhere. The subsequent Jurassic planktonic foraminifera all appear to have an aragonitic wall structure, originating in the Mesozoic "Aragonitic Ocean" (van Dijk et al., 2016). The favusellids, which appeared in the Late Jurassic, continued into the Early Cretaceous and eventually became extinct in the mid-Cenomanian (Carter and Hart, 1977; Hart and Harris, 2012). The favusellids do not appear to evolve into the calcitic planktonic foraminifera of the early to mid-Cretaceous, being unable to change their wall structure

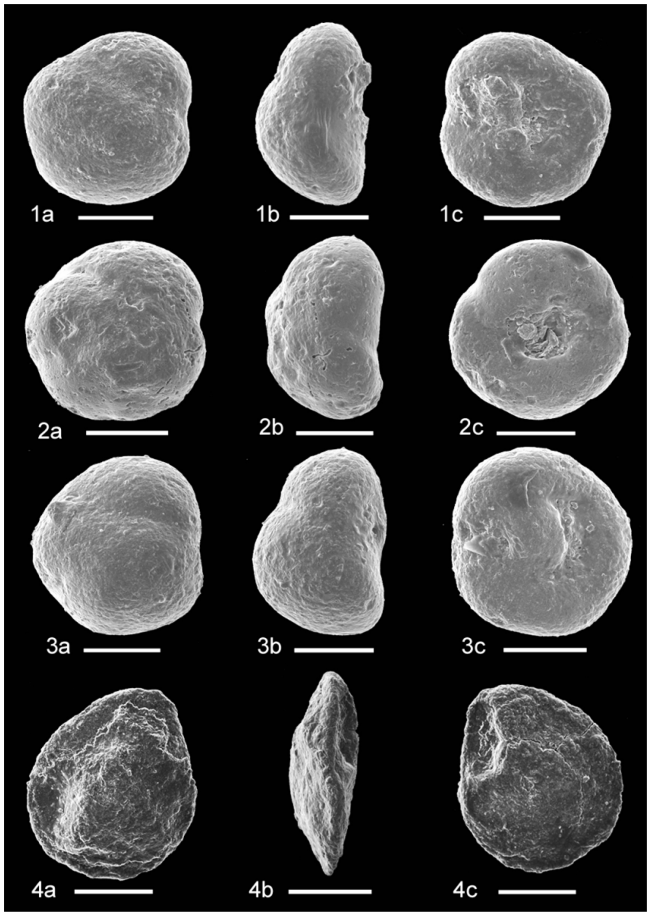

Figure 7. (1) *Schlagerina angustiumbilicata* Fuchs, 1967, ?paratype; **(a)** spiral view, scale bar 75 µm [jwh 0932], **(b)** edge view, scale bar 75 µm [jwh 0951], **(c)** umbilical view, scale bar 75 µm [jwh 0896]. Figured by Fuchs (1967, pl. 3, fig. 10). From Plackles, Lower Austria. Plackles Marls, Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/37. (2) *Schlagerina angustiumbilicata* Fuchs, 1967, ?paratype; **(a)** spiral view, scale bar 75 µm [jwh 0897], **(b)** edge view, scale bar 75 µm [jwh 0952], **(c)** umbilical view, scale bar 75 µm [jwh 0933]. Figured by Fuchs (1967, pl. 6, fig. 3). From Xanten, Salzburg, Austria. Upper Rhaetian. Geologische Bundesanstalt, Vienna, no. 1967/5/38. (3) *Schlagerina altispira* Fuchs, 1967, holotype; **(a)** spiral view, scale bar 75 µm [jwh 0934], **(b)** edge view, scale bar 75 µm [jwh 0953], **(c)** umbilical view, scale bar 75 µm [jwh 0898]. Figured by Fuchs (1967, pl. 4, fig. 1). From Plackles, Lower Austria. Plackles Marls, Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/39. (4) *Schlagerina orbis* Fuchs, 1967, holotype; **(a)** spiral view, scale bar 120 µm [P 074676], **(b)** edge view, scale bar 120 µm [P 074683], **(c)** umbilical view, scale bar 120 µm [P 074668]. Figured by Fuchs (1970, pl. 9, fig. 9). From Hernstein, Lower Austria. Lias α, Lower Jurassic. Geologische Bundesanstalt, Vienna, inv. no. 1970/3/132.

(Segev and Erez, 2006; van Dijk et al., 2016). This suggests that the modern planktonic foraminifera developed from a completely separate rotaliid benthic lineage (Darling et al., 1997, 2009; de Vargas et al., 1997; Bowser et al., 2006; Aurahs et al., 2009; van Dijk et al., 2016).

The new species described by Fuchs from the material collected in Poland are almost certainly invalid as they consist of glauconitic steinkerns and lack almost all the diagnostic features required for their identification. A significant number of these steinkerns from the strata adjacent to the Callovian–Oxfordian boundary represent planktonic taxa that have a simple morphology, ~ four chambers in the final whorl and a quite variable spire height. Examples of these taxa from the Polish Basin are presented by Pazdrowa (1969), Hart et al. (2012) and Gajewska et al. (2021). The assemblages of planktonic foraminifera from the Polish Basin are, therefore, significant in the discussion of the evolution of Jurassic plankton, even if their lineages petered out in the mid-Cretaceous and were replaced by the calcitic taxa.

Appendix A: Triassic and Lower Jurassic benthic foraminifera from Austria and northern Italy

Oberhauser (1960) and Fuchs (1967, 1970) described a significant number of new species from the Triassic and Lower Jurassic of Austria and northern Italy. All the species that were discussed in terms of their relationship with early planktonic foraminifera have been studied by MBH in the Offices of the Austrian Geological Survey (now part of GeoSphere Austria) in Vienna, and observations on each taxon were noted. Additional comments were added following the scanning electron microscopy, although some of the images are quite poor as a result of using un-coated specimens under low voltage. Preservation was generally moderate to poor, or even very poor, and this is probably related to the presence of an aragonitic wall structure. Many of the *Oberhauserella* recorded by Clémence and Hart (2013) from the Lower Jurassic (Lias) of Somerset show a similar state of preservation. In all cases the reference number in the collections of the Austrian Geological Survey are given and, in many cases, the negative number of the images generated in the Natural History Museum (London) are also given (with the prefix of jwh or P). It is suggested here that none of these species had a holoplanktonic mode of life, although some of the more inflated *Oberhauserella* and *Praegubkinella* species may have been ancestral to the planktonic taxa that appeared in the late Toarcian.

Phylum Foraminifera d'Orbigny, 1826

Class Globothalamea Pawlowski et al., 2013

Order Robertinida Loeblich and Tappan, 1984

Suborder Robertinina Loeblich and Tappan, 1984

Superfamily Duostominacea Brotzen 1963

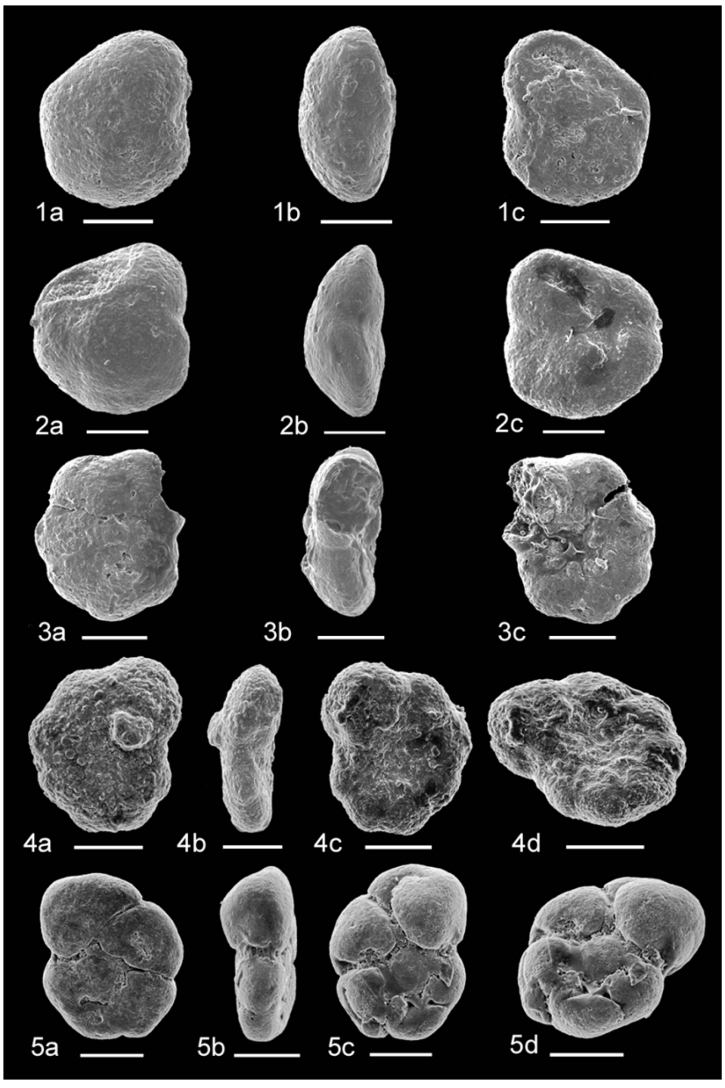

Figure 8. (1) *Schlagerina scissumbilicata* Fuchs, 1967, holotype; **(a)** spiral view, scale bar 75 µm [jwh 0935], **(b)** edge view, scale bar 75 µm [jwh 0954], **(c)** umbilical view, scale bar 75 µm [jwh 0899]. Figured by Fuchs (1967, pl. 4, fig. 2). From Plackles, Lower Austria. Plackles Marls, Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/42. (2) *Schlagerina subcircularis* Fuchs, 1967, holotype; **(a)** spiral view, scale bar 86 µm [jwh 0936], **(b)** edge view, scale bar 86 µm [jwh 0955], **(c)** umbilical view, scale bar 86 µm [jwh 0900]. Figured by Fuchs (1967, pl. 4, fig. 4). From Plackles, Lower Austria. Plackles Marls, Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/40. (3) *Schmidita hedbergelloides* Fuchs, 1967, holotype; **(a)** spiral view, scale bar 75 µm [jwh 0937], **(b)** edge view, scale bar 75 µm [jwh 0956], **(c)** umbilical view, scale bar 75 µm [jwh 0901]. Figured by Fuchs (1967, pl. 4, fig. 3). From Plackles, Lower Austria. Plackles Marls, Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/14. (4) *Schmidita inflata* Fuchs, 1967, holotype; **(a)** spiral view, scale bar 75 µm [P 059810], **(b)** edge view, scale bar 75 µm [P 059958], **(c)** umbilical view, scale bar 75 µm [P 059759], **(d)** oblique, umbilical view, scale bar 75 µm [P 059766]. Figured by Fuchs (1967, pl. 3, fig. 1). From Eisenkappel, Carinthia, southern Austria. Lower Carnian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/13. (5) *Mariannenina nitida* Fuchs 1973, ?paratype; **(a)** spiral view, scale bar 75 µm [P 059760], **(b)** edge view, scale bar 75 µm [P 059811], **(c)** umbilical view, scale bar 75 µm [P 059730], **(d)** oblique–umbilical view, scale bar 75 µm [P 059737]. Figured by Fuchs (1973, pl. 4, fig. 1). From Kalksteinbruch Wiek bei Ogrodzieniec, Bed 26, lowermost Oxfordian. Geologische Bundesanstalt, Vienna, inv. no. 1973/3/28.

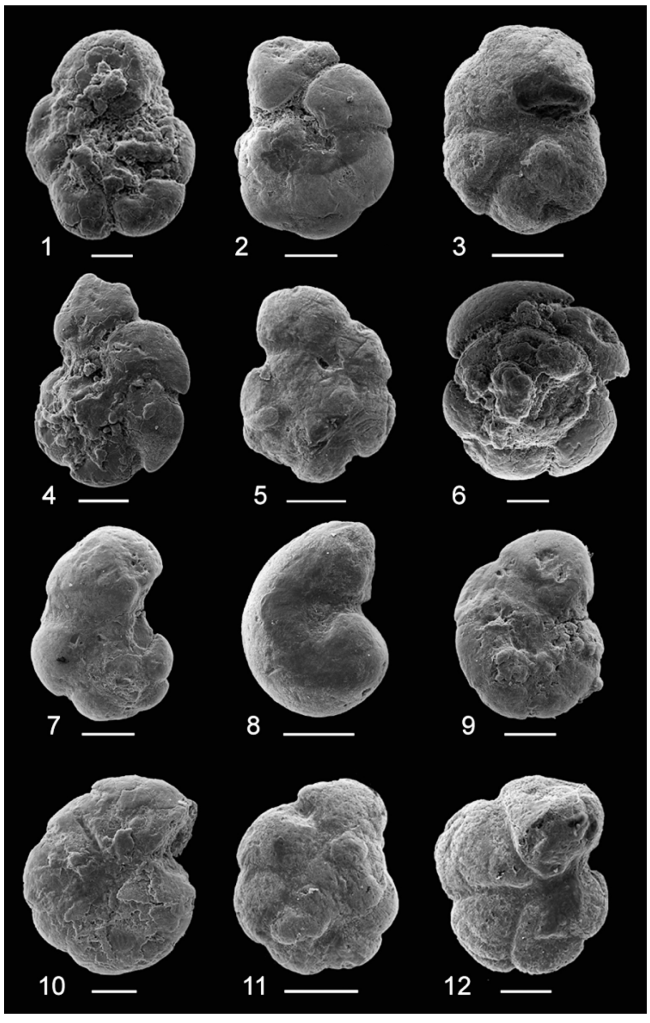

Figure 9. Benthic taxa from the beds 19–22 of the succession exposed at locality (3) or the 2006 temporary exposure near the Ogrodzieniec Quarry. (1) Sensu *Mariannenina multiloculata* Fuchs 1973, scale bar 50 µm. (2–5) Sensu *Mariannenina* sp. cf. *M. nitida* Fuchs 1973, scale bars 100 µm. (6) Sensu *Woletzina gaurdakensis* Fuchs 1973, scale bar 50 µm. (7) Sensu *Jurassorotalia curva* Fuchs 1973, scale bar 100 µm. (8) Unknown benthic cf. *Lenticulina* sp., scale bar 100 µm. (9) Unknown benthic species, scale bar 100 µm. (10) Trochospiral benthic species, scale bar 50 µm. (11) Unknown benthic species, scale bar 100 µm. (12) Unknown benthic species, scale bar 50 µm.

Family Oberhauserellidae Fuchs 1970

Oberhauserella Fuchs, 1967

Type species. Globigerina mesotriassica Oberhauser, 1960

Oberhauserella mesotriassica Oberhauser (Fig. 4, nos. 1a–c, 2a–d)

Globigerina mesotriassica Oberhauser, 1960, pl. 5, figs. 18a–c, 19a–c.

Holotype. Oberhauser, 1960, pl. 5, fig. 18a–c. Deposited at the Geologische Bundesanstalt in Vienna, inv. no. 1960/4/104 (single form).

Paratype. Oberhauser, 1960, pl. 5, fig. 19a–c, inv. no. 1960/4/105 (single form).

Comments. Paratype. Figured by Oberhauser (1960, pl. 5, fig. 19a–c). From a locality in the Settsass Scharte, north of the Richthofen Riff, near St. Kassian, South Tyrol, northern Italy. Upper Cassian beds, Ladinian. Geologische Bundesanstalt, Vienna, inv. no. 1960/4/107. Spiral view (P 059762), edge view (P 059814), umbilical view (P 059732), oblique–umbilical view (P 059735).

Oberhauserella alta Fuchs (Fig. 4, no. 3a–d)

Oberhauserella alta Fuchs, 1967, pl. 4, figs. 5–6; pl. 5, figs. 3 and 7.

Holotype. Fuchs, 1967, pl. 5, fig. 7.

Comments. Paratype(?). From Plackles, Lower Austria, Carinthia. Plackles Marls, Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/25 (4/6). Spiral view (P 0590763), edge view (P 059815), umbilical view (P 059733), oblique–umbilical view (P 059734).

Oberhauserella crassa (Fig. 4, no. 4a–c)

Oberhauserella crassa Fuchs, 1970, pl. 9, fig. 10.

Holotype. Fuchs, 1970, pl. 9, fig. 10.

Comments. Holotype from the Lias α (Lower Jurassic) of Hernstein, Lower Austria. Geologische Bundesanstalt, Vienna, inv. no. 1970/3/130, holotype; a. spiral view, scale bar 120 µm [P 074675], b. edge view, scale bar 120 µm [P 074682], c. umbilical view, scale bar 120 µm [P 074667]. This was described by Fuchs (1970) as discorbid-like in appearance.

Oberhauserella karinthiaca (Fig. 5, no. 1a–c)

Oberhauserella karinthiaca Fuchs, 1967, pl. 3, fig. 3.

Holotype. Fuchs, 1967, pl. 3, fig. 3.

Comments. The holotype was figured by Fuchs (1967, pl. 3, fig. 3). From Eisenkappel, Carinthia, southern Austria. Lower Carnian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/17. Spiral view (jwh 0927), edge view (jwh 0946) and umbilical view (jwh 0891).

Oberhauserella norica Fuchs (Fig. 5, no. 2a–d)

Oberhauserella norica Fuchs, 1967, pl. 3, fig. 7, pl. 6, figs. 2, 6.

Holotype. Fuchs, 1967, pl. 3, fig. 7.

Comments. Paratype(?). Figured by Fuchs (1967, pl. 6, fig. 2). From Hinterer Gosausee, Upper Austria. Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/28. Spiral view (P 059765), edge view (P 059817), umbilical view (P 059741), oblique–umbilical view (P 059739).

Oberhauserella praerhaetica Fuchs

Oberhauserella praerhaetica Fuchs, 1967, pl. 3, fig. 8; pl. 5, figs. 5–6.
Holotype. Fuchs, 1967, pl. 5, fig. 6.
Comments. Paratype(?). Figured by Fuchs (1967, pl. 3, fig. 8). From Rossmoos, Upper Austria. Upper Norian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/32 was borrowed but the specimen was found to be badly broken, most of the test being missing. It was impossible to comment on the specimen or image using SEM.

Oberhauserella quadrilobata Fuchs (Fig. 5, no. 3a–d)

Oberhauserella quadrilobata Fuchs, 1967, pl. 3, figs. 5–6, pl. 4, fig. 8, pl. 6, figs. 1, 7.
Holotype. Fuchs, 1967, pl. 4, fig. 8.
Comments. Paratype(?). Figured by Fuchs (1967, pl. 3, fig. 6). From Rossmoos, Upper Austria. Upper Norian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/20. Spiral view (P 059764), edge view (P 059816), umbilical view (P 059740), oblique–umbilical view (P 059738).

Schmidita Fuchs, 1967

Type species. Schmidita hedbergelloides Fuchs, 1967.
Schmidita inflata Fuchs (Fig. 8, no. 4a–d)
Schmidita inflata Fuchs, 1967, pl. 3, fig. 1.
Holotype. Fuchs, 1967, pl. 3, fig. 1.
Comments. Holotype. Figured by Fuchs (1967, pl. 3, fig. 1). From Eisenkappel, Carinthia, southern Austria. Lower Carnian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/13. Spiral view (p 059810), edge view (p 059958), umbilical view (P 059759), oblique–umbilical view (P 059766).

Schmidita hedbergelloides (Fig. 8, no. 3a–c)

Schmidita hedbergelloides Fuchs, 1967, pl. 3, fig. 4, pl. 4, fig. 3.
Holotype. Fuchs, 1967, pl. 4, fig. 3.
Comments. This is the type species of *Schmidita*. The holotype was figured by Fuchs (1967, pl. 4, fig. 3). From Plackles, Lower Austria. Plackles Marls, Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/14. Spiral view (jwh 0937), edge view (jwh 0956) and umbilical view (jwh 0901).

Schlagerina Fuchs 1967

Type species. Schlagerina angustiumbilicata Fuchs, 1967
Schlagerina angustiumbilicata Fuchs (Fig. 7, nos. 1a–c, 2a–c)
Schlagerina angustiumbilicata Fuchs, 1967, pl. 3, figs 9–10, pl. 6, fig. 3.
Holotype. Fuchs, 1967, pl. 3, fig. 9.
Comments. The paratype (Fuchs, 1967, pl. 6, fig. 3) was from Xanten, Salzburg, Austria. Upper Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/38. Spiral view (jwh 0897), edge view (jwh 0952) and umbilical view (jwh 0933). The other specimen illustrated by Fuchs (1967, pl. 3, fig. 10) is assumed to be a paratype, though this is not stated.

Schlagerina altispira Fuchs (Fig. 7, no. 3a–c)

Schlagerina altispira Fuchs, 1967, pl. 4, fig. 1.
Holotype. Fuchs, 1967, pl. 4, fig. 1.
Comments. The holotype of *Schlagerina altispira* is from Plackles, Lower Austria. Plackles Marls, Rhaetian. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/39. Spiral view (jwh 0934), edge view (jwh 0953) and umbilical view (jwh 0898).
Schlagerina orbis Fuchs (Fig. 7, no. 4a–c)
Schlagerina orbis Fuchs, 1970, pl. 9, fig. 10.
Holotype. Fuchs, 1970, pl. 9, fig. 10.
Comments. The holotype is from the Lias α (Lower Jurassic) of Hernstein, Lower Austria. Geologische Bundesanstalt, Vienna, inv. no. 1970/3/130. Spiral view (P 074675), edge view (P 074682) and umbilical view (P 074668).

Schlagerina subcircularis Fuchs (Fig. 8, no. 2a–c)

Schlagerina subcircularis Fuchs, 1967, pl. 4, fig. 4, pl. 5, fig. 4.
Holotype. Fuchs, 1967, pl. 4, fig. 4.
Comments. The holotype is from the Plackles Marls (Rhaetian), Plackles, Lower Austria. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/40. Spiral view (jwh 0936), edge view (jwh 0955) and umbilical view (jwh 0900).

Schlagerina scissumbilicata Fuchs (Fig. 8, no. 1a–c)

Schlagerina scissumbilicata Fuchs, 1967, pl. 4, fig. 2.
Holotype. Fuchs, 1967, pl. 4, fig. 2.
Comments. The holotype is from the Plackles Marls (Rhaetian), Plackles, Lower Austria. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/42. Spiral view (jwh 0935), edge view (jwh 0954) and umbilical view (jwh 0899).

Praegubkinella Fuchs, 1967

Type species. Praegubkinella kryptumbilicata Fuchs, 1967
Praegubkinella kryptumbilicata Fuchs (Fig. 6, no. 1a–c)
Praegubkinella kryptumbilicata Fuchs, 1967, pl. 7, fig. 3.
Holotype. Fuchs, 1967, pl. 7, fig. 3.
Comments. The holotype figured by Fuchs (1967, pl. 7, fig. 3) is from the Upper Rhaetian of Xanten, Salzburg, Austria. Geologische Bundesanstalt, Vienna, inv. no.

1967/5/43. Spiral view (jwh 0893), edge view (jwh 0928) and umbilical view (jwh 0947). The holotype is a very conical form with four rounded chambers in the final whorl. The proloculus and early chambers are hidden by ornamentation.

Praegubkinella turgescens Fuchs (Fig. 6, nos. 2a–c, 3a–c, 4a–c)

Praegubkinella turgescens Fuchs, 1967, pl. 6, figs. 4, 5, 8, pl. 7, figs. 1–2.

Holotype. Fuchs, 1967, pl. 7, fig. 2.

Paratype. Fuchs, 1967, pl. 7, fig. 1.

Comments. The holotype is from the Upper Rhaetian of Xanten, Salzburg, Austria. Geologische Bundesanstalt, Vienna, inv. no. 1967/5/43. Spiral view (jwh 0893), edge view (jwh 0929) and umbilical view (jwh 0948). The ?paratype is from the same locality and horizon and listed as no. 1967/5/46. Spiral view (jwh 0931), edge view (jwh 0950) and umbilical view (jwh 0895). The four chambers in the final whorl are all inflated. The holotype had, unfortunately, been gold-coated and the depressed apertural face had no sign of an aperture. A slide in the collection marked 1967/5/47 contains a very high-spired specimen with rounded chambers. The specimen in slide 1967/5/44 is also gold-coated but has a slightly lower spire, giving an appearance close to *Oberhauserella*. The specimen in slide 1967/5/46 is very rounded in appearance and looks like that figured by Fuchs (1967, pl. 6, fig. 5) and has three whorls visible.

Kollmannita Fuchs, 1967

Type species. Kollmannita ladinica (Oberhauser, 1960)

Kollmannita ladinica (Oberhauser, 1960) (Fig. 5, nos. 4a–c, 5a–c)

Globigerina ladinica Oberhauser, 1960, pl. 5, fig. 12, 14, 16.

Kollmannita ladinica (Oberhauser), Fuchs, 1967, pl. 2, figs. 4–6, pl. 3, fig. 2.

Holotype. Figured by Oberhauser, 1960, pl. 5, fig. 14a–c.

Comments. The holotype is from the upper Cassian Bed (Ladinian, Triassic) from a locality in the Settsass Scharte, north of the Richthofen Riff near St. Kassian, South Tyrol, northern Italy. Geologische Bundesanstalt, Vienna, inv. no. 1960/4/108. Spiral view (jwh 0925), edge view (jwh 0944) and umbilical view (jwh 0889).

Mariannenina Fuchs, 1973

Type species. Mariannenina pulchra Fuchs, 1973.

Mariannenina nitida Fuchs (Fig. 8, no. 5a–d)

Mariannenina nitida Fuchs, 1973, pl. 3, fig. 3; pl. 4, fig. 1.

Holotype. Fuchs, 1973, pl. 3, fig. 3.

Comments. Paratype(?). Figured by Fuchs (1973, pl. 4, fig. 1). From Wiek, near Ogrodzieniec, Poland. Bed 26, lowermost Oxfordian. Geologische Bundesanstalt, Vienna, inv. no. 1973/3/28. Spiral view (P 059760), edge view (P 059811), umbilical view (P 059730), oblique–umbilical view (P 059737).

Globigerina ladinica Oberhauser

Globigerina ladinica Oberhauser, 1960, pl. 5, figs. 12a, 12b, 12c, 14a, 14b, 14c, 16a, 16b, 16c.

Holotype. Oberhauser, 1960, pl. 5, fig. 14a, 14b, 14c. Deposited at the Geologische Bundesanstalt in Vienna (inv. no. 0106).

Paratype. Oberhauser, 1960, pl. 5, figs. 12a, 12b, 12c, 16a, 16b, 16c (inv no. 0107,0108).

Comments. Paratype. Figured by Oberhauser (1960, pl. 5, fig. 12a–c). From a locality in the Settsass Scharte, north of the Richthofen Riff, near St. Kassian, South Tyrol, northern Italy. Upper Cassian beds, Ladinian. Geologische Bundesanstalt, Vienna, inv. no. 1960/4/109. Spiral view (P 059761), edge view (P 059812), detail of apertural face (P 059813), umbilical view (P 059731), oblique–umbilical view (P 059736).

Appendix B: Mid-Upper Jurassic benthic foraminifera from Ogrodzieniec

The species identified by Fuchs (1973), or described as new species, are based on glauconitic steinkerns and are normally green in colour. The septa are pale green (or almost white) in colour, and the majority of specimens display irregular shapes that are probably the result of mineral growth. In none of the specimens is a calcareous wall present and the surface ornament is not visible. Apertures are also indistinct, or impossible to recognize. A number of genera (*Eoceratobulimina*, *Eoheterohelix*, *Jurassorotalia* and *Tectoglobigerina*) include some forms that are probably not foraminiferids and represent a variety of mineral growths. Some of these taxa are illustrated in Fig. 9.

Globuligerina frequens Fuchs, 1973

Globuligerina frequens Fuchs, 1973, pp. 465, 466, pl. 2, fig. 6, pl. 5, fig. 2.

Holotype. Fuchs, 1973, pl. 5, fig. 2.

Depository. Geologische Bundesanstalt, inv. no. 1973/3/18.

Type location. Kalksteinbruch Wiek bei Ogrodzieniec (i.e. Ogrodzieniec Quarry).

Type stratum. Bed 26, lowermost Oxfordian, Upper Jurassic.

Comments. Slide 19 (inv. no. 1973/3/18) is a moderately spired form but does not appear to be that illustrated (as the holotype) by Fuchs (1973, pl. 5, fig. 2). There is no aperture visible and certainly not the clear, loop-shaped aperture shown in the drawing. Slide 18 (inv. no. 1973/3/19) contains a specimen from Bed 21 of the upper Callovian and, while not indicated as the type slide,

it contains a specimen that is more like that figured as the holotype by Fuchs. The "groove" up the face of the last chamber is, however, not an aperture (as illustrated) but simply a "join" in the mineral infilling.

Globuligerina parva Fuchs, 1973

Globuligerina parva Fuchs, 1973, p. 466, pl. 4, fig. 6.

Holotype. Fuchs, 1973, pl. 4, fig. 6.

Depository. Geologische Bundesanstalt, inv. no. 1973/3/20.

Type location. Kalksteinbruch Wiek bei Ogrodzieniec (i.e. Ogrodzieniec Quarry).

Type stratum. Bed 26, lowermost Oxfordian, Upper Jurassic.

Comments. The specimen in Slide 20 (inv. no. 1973/3/20) is a mineral infilling but is unfortunately broken in half. From what was visible, this is probably the specimen figured by Fuchs (1973).

Globuligerina umbilicata Fuchs, 1973

Globuligerina umbilicata Fuchs, 1973, pp. 466, 467, pl. 2, fig. 4.

Holotype. Fuchs, 1973, pl. 2, fig. 4.

Depository. Geologische Bundesanstalt, inv. no. 1973/3/21.

Type location. Kalksteinbruch Wiek bei Ogrodzieniec (i.e. Ogrodzieniec Quarry).

Type stratum. Bed 21, upper Callovian, Middle Jurassic.

Comments. Slide 21 (inv. no. 1973/3/21) contains a specimen that is clearly that figured by Fuchs. The final chamber is much extended, but this could just be a variant in a limited number of specimens. There is a moderate spire, with two whorls visible on the spiral side. The nature of the mineral infilling makes it impossible to comment on the form of the aperture.

Polskanella altispira Fuchs, 1973

Polskanella altispira Fuchs, 1973, p. 457, pl. 2, fig. 5.

Holotype. Fuchs, 1973, pl. 2, fig. 5.

Depository. Geologische Bundesanstalt, inv. no. 1973/3/4.

Type location. Kalksteinbruch Wiek bei Ogrodzieniec (i.e. Ogrodzieniec Quarry).

Type stratum. Bed 21, upper Callovian, Middle Jurassic.

Comments. Slide 4 (inv. no. 1973/3/4) is a mineral infilling with an extremely irregular growth form. It is difficult to be certain that the high spire is real and not a function of mineral growth.

Polskanella bisphaerica Fuchs, 1973

Polskanella bisphaerica Fuchs, 1973, p. 458, pl. 3, fig. 5.

Holotype. Fuchs, 1973, pl. 3, fig. 5.

Depository. Geologische Bundesanstalt, inv. no. 1973/3/5.

Type location. Kalksteinbruch Wiek bei Ogrodzieniec (i.e. Ogrodzieniec Quarry).

Type stratum. Bed 26, lowermost Oxfordian, Upper Jurassic.

Comments. Slide 5 (inv. no. 1973/3/5) contains the figured specimen and is a glauconitic internal cast of two "chambers" which may not be a foraminiferid.

Polskanella megastoma Fuchs, 1973

Polskanella megastoma Fuchs, 1973, pp. 458, 459, pl. 5, fig. 5.

Holotype. Fuchs, 1973, pl. 5, fig. 5.

Depository. Geologische Bundesanstalt, inv. no. 1973/3/6.

Type location. Kalksteinbruch Wiek bei Ogrodzieniec (i.e. Ogrodzieniec Quarry).

Type stratum. Bed 26, lowermost Oxfordian, Upper Jurassic.

Comments. This mineral infilling is an irregularly conical form that looks like the middle figure of Fuchs (1973, pl. 5, fig. 5).

Polskanella oxfordiana (Grigelis, 1958)

Globigerina oxfordiana Grigelis, 1958, p. 109, pl. 1.

Polskanella oxfordiana (Grigelis) Fuchs, 1973, p. 459, pl. 1, fig. 7, pl. 5, fig. 1.

Comments. The specimen in Slide 7 (inv. no. 1973/3/7), from Bed 21 of the upper Callovian in Ogrodzieniec Quarry, is a pale green glauconite cast with the septa showing up white. It has a higher spire than shown in the figure in Fuchs (1973, pl. 5, fig. 1). However, the coiling direction is the reverse of that shown and the apertural area is damaged. The apertural view shows four clearly inflated chambers, and the specimen is, therefore, typical of many specimens from this stratigraphical level. The specimen in Slide 8 (inv. no. 1973/3/8), from Bed 26 of the lowermost Oxfordian, shows the same preservation, has the same pattern of four chambers and, again, has no aperture visible (as it is an internal cast).

Woletzina cylindrica Fuchs, 1973

Woletzina cylindrica Fuchs, 1973, pp. 461–462, pl. 3, fig. 2, pl. 4, fig. 4.

Holotype. Fuchs, 1973, p. 461, pl.3, fig. 2.

Depository. Geologische Bundesanstalt, inv. no. 1973/3/10.

Type location. Kalksteinbruch Wiek bei Ogrodzieniec (i.e. Ogrodzieniec Quarry).

Type stratum. Bed 21, upper Callovian, Middle Jurassic.

Comments. The holotype in slide no. 1973/3/10 looks like the illustration in Fuchs (1973, pl. 3, fig. 2). While the initial spire looks foraminiferid (?*Mariannenina*), the remainder of the specimen has the appearance of mineral overgrowth. The specimen of *W. cylindrica* in Slide 11 (inv. no. 1973/3/11), from Bed 26 of the lowermost Oxfordian, could not be examined properly as the individual was stuck to the edge of the cover slip by static and removal could have damaged the specimen. The specimen has a "crazed" mineral surface in a series of globular shapes rather than being a discernible foraminiferid.

Woletzina gaurdakensis (Balakhmatova and Morozova, 1961)

Globigerina (Conoglobigerina) gaurdakensis Balakhmatova and Morozova, 1961, p. 25, pl. 6, figs. 1–3.

Woletzina gaurdakensis (Balakhmatova and Morozova): Fuchs, 1973, p. 462, pl. 1, fig. 6.

Comments. The specimen in Slide 12 (inv. no. 1973/3/12) is a large mineral infilling, and it is impossible to identify the chamber arrangement shown in Fuchs (1973, pl. 3, fig. 1). This is more likely to be an overgrowth on a benthic foraminiferid rather than the Bajocian–Bathonian planktonic species of Balakhmatova and Morozova (1961).

Woletzina irregularis Fuchs, 1973

Woletzina irregularis Fuchs, 1973

Holotype. Fuchs, 1973, pl. 1, fig. 6.

Depository. Geologische Bundesanstalt, inv. no. 1973/3/13.

Type location. Kalksteinbruch Wiek bei Ogrodzieniec (i.e. Ogrodzieniec Quarry).

Type stratum. Bed 21, upper Callovian, Middle Jurassic.

Comments. The specimen in Slide 13 (inv. no. 1973/3/13) is a hook-shaped cluster of infilled chambers, and while it may have been based on a foraminiferid, the final appearance cannot be regarded as diagnostic of a new taxon.

Woletzina jurassica (Hofman, 1958)

Globigerina jurassica Hofman, 1958, p. 125, pl. 1.

Woletzina jurassica (Hofman) Fuchs, 1973, p. 463, pl. 2, fig. 7, pl. 5, fig. 4.

Comments. The mineralized specimen in Slide 124 (inv. no. 1973/3/14) looks like Fuchs' figure but is probably not a foraminiferid. The specimen in Slide 15 (inv. no. 1973/3/15) may be a planktonic form but is more likely an irregular cluster of infilled chambers. This is almost certainly the specimen illustrated by Fuchs (1973, pl. 5, fig. 4) but is less convincing in terms of foraminiferid shape.

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Competing interests. The contact author has declared that none of the authors has any competing interests.

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