Swiss J Palaeontol (2017) 136:161–185
DOI 10.1007/s13358-017-0127-8

New and emended species of Jurassic planktonic foraminifera

Felix M. Gradstein[1,2]

Received: 3 January 2017 / Accepted: 2 February 2017 / Published online: 3 March 2017

Abstract Two Jurassic planktonic genera are emended and two new species and one subspecies of Jurassic planktonic foraminifera are defined. The genera are *Globuligerina* Bignot and Guyader 1971 and *Conoglobigerina* Morozova 1961 and the two new species are *Globuligerina tojeiraensis* Gradstein and *Conoglobigerina grigelisi* Gradstein. Both new species commonly occur in the Tojeira Formation, Montejunto, Portugal. The Tojeira Formation is a deeper marine shale unit of Early Kimmeridgian age. The new subspecies is *Globuligerina oxfordiana calloviensis* Gradstein, from the Callovian in the Crimea and Ukraine. A detailed description is provided for one of the historically oldest Jurassic taxa, *Conoglobigerina helvetojurassica* Haeusler 1881, re-discovered in the Birmenstorfer Schichten of Middle Oxfordian age near Mönthal, Canton Aargau, Switzerland. A neotype is proposed for this taxon. One specimen of *C. helvetojurassica* may have been attached to a substrate during a later part of its life cycle. The same Birmenstorfer Schichten also yielded two small specimens of an unknown planktonic genus with longitudinal ribs along its pyramidal and probably triserial test. The test is microperforate and wall textures reticulate. The types and type locality of '*Globuligerina' stellapolaris* Grigelis, described from Northwestern Russia should be carefully investigated, to determine if it is a Late Jurassic or a Late Cenozoic taxon.

Keywords Portugal · Switzerland · NW Russia · *Globuligerina* · *Conoglobigerina* · Biostratigraphy

Introduction

Planktonic foraminifera are single-celled marine organisms with a calcareous and chambered test. The group first appeared during late Early Jurassic (Toarcian; Wernli 1988) and developed over a time span of about 180Ma. From Toarcian through Hauterivian time species have a simple trochoid (globigeriniform) test with spherical, elongated or oval chamber shapes and no keel. Their shells are microperforate, with an almost smooth, or pustulose to reticulate wall surface. Macroperforate taxa only appear in the mid Cretaceous. The test building material is considered to be high-magnesium carbonate (aragonite) (Gorbachik and Kuznetsova 1986; Simmons et al. 1997). The aperture is a simple opening at the base of the last chamber. A kummerform (bulla-like) last chamber with one or rarely two basal openings is often present. Bullae have a smoother wall surface than the overall test and are in umbilical position, generally covering the primary aperture of the last chamber. Hemleben et al. (1989) reports that a bulla is grown after gametogenesis.

Jurassic planktonic foraminifera have been studied since the second half of the nineteen's century with over 70 scientific publications mainly by East and West European and Canadian micropalaeontologists. These studies are annotated in Gradstein (in prep), and several are discussed in some detail in Gradstein et al. (in prep). Despite this effort, the knowledge on the origin, test morphology, geographic and stratigraphic distribution and speciation of taxa in the first 40 million years of their record is fragmentary, incomplete and taxonomic criteria applied are not consistent and conflicting.

Editorial handling: Daniel Marty.

✉ Felix M. Gradstein
felix.gradstein@gmail.com

[1] Natural History Museum, University of Oslo, Oslo, Norway

[2] SEES, University of Portsmouth, Portsmouth, UK

This study reports on new and emended taxa of Jurassic planktonic foraminifera. Two genera, *Globuligerina* Bignot and Guyader 1971 and *Conoglobigerina* Morozova 1961 are emended and two new species are defined, *Globuligerina tojeiraensis* Gradstein and *Conoglobigerina grigelisi* Gradstein. The new species commonly occur in deeper marine marls of Early Kimmeridgian age in central Portugal. *Globuligerina oxfordiana calloviensis* Gradstein from the Callovian of Crimea, Russia is a new subspecies. A detailed description is provided for *Conoglobigerina helvetojurassica* (Haeusler), (Haeusler 1890). A neotype is proposed for this distinctive taxon that was originally described in 1881 from the Oxfordian of Switzerland. One rare taxon from thin Upper Jurassic deposits in NW Russia, '*Globuligerina' stellapolaris* Grigelis et al. 1978 was studied in some detail with original material, but demands more sampling and more study.

All material and type species are stored in the European Micropaleontological Reference Centre of the Micropress Foundation, AGH University, Krakow, Poland; Dr. A. Waskowska in charge; waskowsk@agh.edu.pl; http://micropresseurope.eu. Specimens of *Conoglobigerina helvetojurassica* (Haeusler) also are stored in the microfossil collection of the Natural History Museum, Basel, Switzerland.

Material

Montejunto, Portugal

An almost complete, but folded and faulted sequence of Bathonian through Kimmeridgian marine sediments is exposed in the Montejunto area, ca. 50 km north of Lisbon. The strata are well visible along the flanks of Montejunto, a 664 m high mountain, ca. 7 km NE of the village of Vila Verde. Tectonically, Montejunto is a diapiric structure. The stratigraphic account below follows Stam (1986).

From Bathonian through Oxfordian time, a carbonate platform existed, locally with lagoonal facies. A Kimmeridgian rifting event, which preceded the influx of over 1 km thick marine siliciclastic of the Abadia Formation, caused breaking-up of the carbonate platform. Reworking of limestones occurred into the deeper part of the basins. The Early Kimmeridgian Tojeira shale unit, target of this investigation, is a local basin floor deposit. Details of the Tojeira Formation outcrops and micropalaeontological sampling strategies between 1978 and 2016 are in Gradstein et al. (in prep).

The exposed sedimentary succession (Fig. 1) from older to younger starts with 50–100 m thick-bedded, micritic, sometimes oolithic/pisolithic limestones with rare crinoids and oysters. The presence of the larger foraminifera

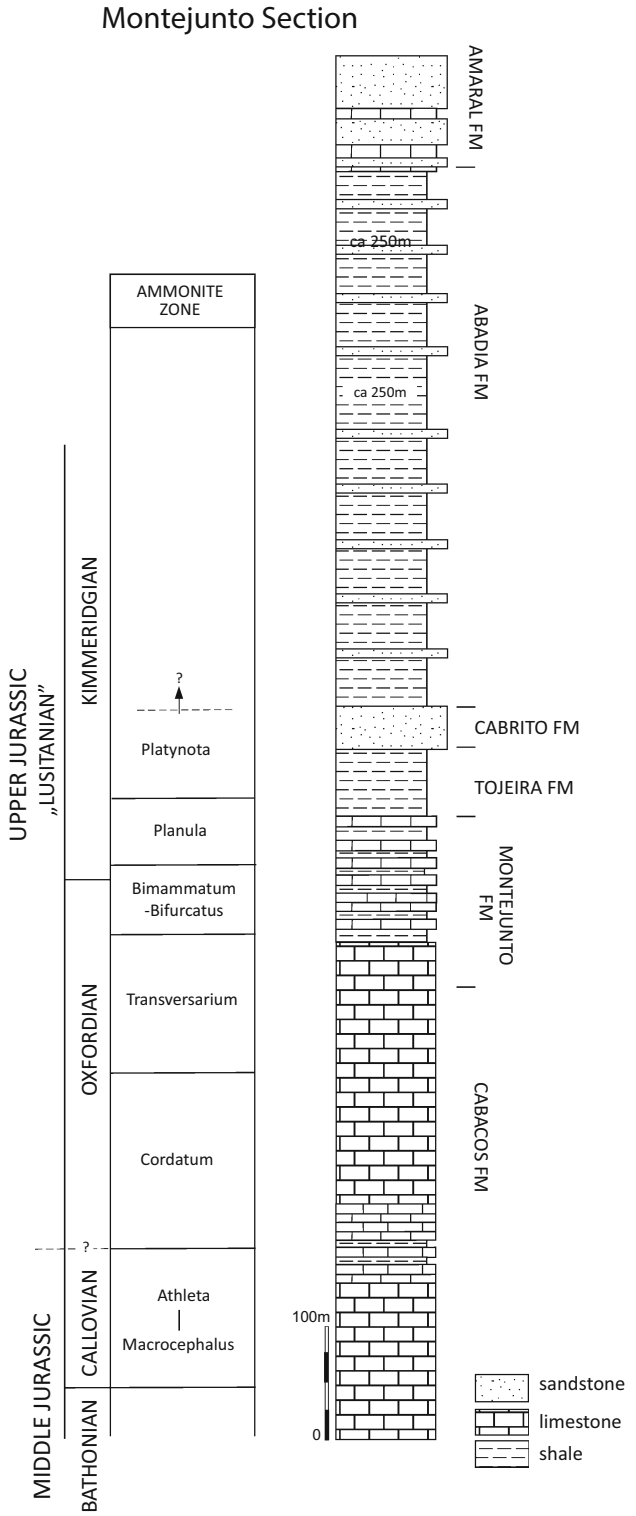


Fig. 1 Middle and Late Jurassic stratigraphy of the Montejunto section, exposed along the flanks of the diapirically uplifted Middle Jurassic limestone massive, about 50 km north of Lisbon, Portugal

Meyendorffina bathonica is considered indicative of the Upper Bathonian. The overlying 100 m of sediments is composed of oolitic, algal and bioclastic limestone with

intercalated shale layers, and ammonites indicative of the Callovian *Macrocephalus* through *Athleta* Zones.

Middle to Upper Oxfordian strata disconformably overly Middle Callovian beds, with *Lamberti* and *Mariae* zones missing.

Upper Jurassic strata include, from older to younger, the Cabacos, Montejunto, Tojeira, Cabrito, Abadia and Amaral Formations, with a total thickness of over 1500 m. Above the Upper Callovian through Lower Oxfordian disconformity, the Cabacos Formation (*Cordatum-Transversarium* zones) contains about 250 m of platy, thin-bedded grey limestones and shaly limestones, all bituminous, micritic and locally oolithic; lumachelles and ammonites occur.

The Montejunto Formation (*Transversarium-Planula* zones) contains thick-bedded, white to grey micritic limestone, changing to alternating bluish-grey limestone and grey, hard shale, with thicker shales near the top. Several meters wide crinoid-brachiopod biostromes occur in the middle part of the unit. The Montejunto Formation is over 200 m thick; ammonites are common to frequent.

The Tojeira Formation (*Planula-Platynota* zones) is over 70 m thick and consists almost entirely of dark grey shales with limonitic concretions; it is brownish-red in the middle part. Pyritized ammonites are common in the lower part of the unit, and silt content increases much near the top; belemnites are rare. TOC is less than 0.7% in all samples measured (pers. comm. 1985 of L. Snowdon, GSC, Calgary to B. Stam).

The Cabrito, Abadia and Amaral units, together are over 1 km thick with marine sands, silts, and conglomerates. Olistolithic limestone blocks and reworked coralline bodies occur, sand channel deposits with abundant ripple marks, and low-angle cross-bedding. Macrofossils have been found, but no foraminifera. Individual beds rapidly change thickness.

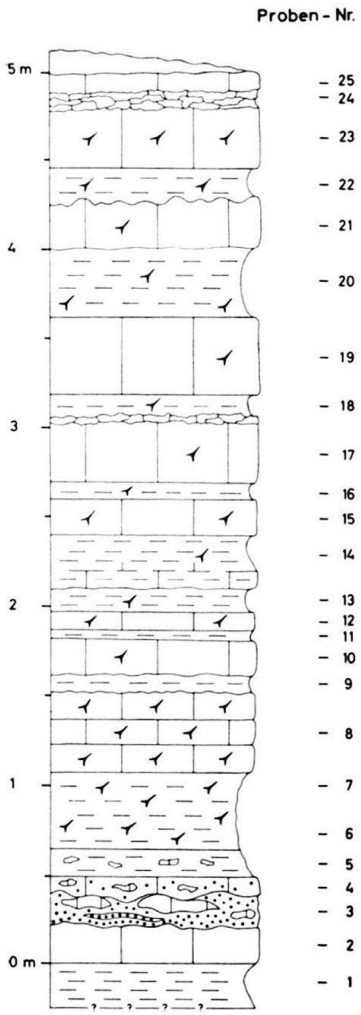
The Tojeira Formation (*Planula-Platynota* zones), with its rich foraminiferal assemblage, was the target of our investigation (Figs. 1, 2). The micropaleontology of the

Fig. 2 Tojeira Formation of Fig. 1, immediately SW of the Montejunto massive, Estremadura, Portugal. The thin couplet of limestones occurs approximately in the middle of the Tojeira unit of Fig. 1. In the foreground a field with small walnut tree plantation, covering 35–50 m of unexposed Tojeira Formation above the Montejunto Formation marls and limestones (photograph Gradstein pers. comm.)

Tojeira Formation, studied by Stam (1986) and Agterberg et al. (1989), revealed Jurassic planktonic foraminifera, easily grouped in several taxa. Many samples, particularly in the lower and middle part of the Tojeira unit, are rich in these taxa, using fractions of 65–125 μm and occasionally also 125–180 μm of washed residues. Hundreds of well-preserved specimens may be picked in relatively short time, with up to six, easily recognized species per sample. These taxa include *Globuligerina oxfordiana* (Grigelis), *G. bathoniana* (Pazdrowa), *G. balakhmatovae* (Morozova), *G. helvetojurassica* (Haeusler), and two new taxa described below. Micro-gastropods also are abundant, together with epistominid foraminifera like *E. mosquensis*; both also did built tests of aragonite.

Eisengraben Section, Canton Aargau, Switzerland

The Eisengraben Section, ca. 35 km NW of Zurich, Switzerland is the type section of the Birmenstorfer Schichten, *Transversarium* Zone, Middle Oxfordian (Figs. 3, 4). The section has coordinates 651.600/264.070 on Schweizerische Landeskarte 1:25,000, Blatt 1069, Frick. It is in this section that Stam (1986), as advised and assisted by H. Bolli and R. Gygi, collected the so-called topotype material of *Globigerina helvetojurassica* Haeusler. The few specimens collected by Stam were borrowed by Simmons et al. (1997) from the Geological Survey of Canada to describe and illustrate their *Haeuslerina helvetojurassica* (Haeusler). Despite extensive effort, these



25 10 cm graubrauner Spongien-Biomikrit, limonitisiert, gegen oben in Humus übergehend
24 10 cm graubrauner Spongien-Biomikrit, stark korrodiert und limonitisiert
23 35 cm graubrauner spärlicher Spongien-Biomikrit, leicht limonitisiert
22 ca. 20 cm graubrauner Mergel mit Schwämmen
21 ca. 30 cm graubrauner, mergeliger Spongien-Biomikrit, limonitisiert, schlierig (Strömungsstruktur?)
20 40 cm graubrauner, verschwammter Mergel
19 50 cm graubrauner Spongien-Biomikrit, leicht limonitisiert
18 15 cm graubrauner Mergel mit vereinzelten Schwämmen
17 35 cm hellgraubrauner Spongien-Biomikrit, leicht limonitisiert, oberster Teil stark korrodiert
16 10 cm graubrauner Mergel
15 30 cm graubrauner Spongien-Biomikrit
14 30 cm graubrauner Spongien-Biointramikrit, limonitisiert, gegen oben in Mergel übergehend
13 15 cm graubrauner Mergel mit Tellerschwämmen
12 10 cm graubrauner Spongien-Biomikrit
11 5 cm bräunliche Mergel mit wenigen Schwämmen
10 20 cm grünlichgrauer, mergeliger Spongien-Biomikrit
9 10 cm graubrauner Mergel mit Spongien
8 45 cm graubrauner Spongien-Dismikrit
7, 6 } 45 cm brauner Mergel mit Schwämmen
5 15 cm blaugrauer Mergel mit Quarz und Aufarbeitungen
4 10 cm grünlicher, glaukonitischer Spongien-Biomikrit mit Eisenooiden und Aufarbeitungen
3 ca. 20 cm rostbrauner Eisen-Oomikrit mit Aufarbeitungen und spärlichem Biodetritus, sehr stark limonitisiert und korrodiert
2 20 cm blaugrauer Echinodermen-Biomikrit, gegen oben zunehmend limonitisiert
1 dunkelgrauer Mergel ohne Fossilien

Fig. 3 Lithostratigraphic log of the Oxfordian Birmenstorfer Schichten, Eisengraben Section, Canton Aargau, Switzerland (taken from figure 4 in Oesterle 1968). Also, shown is the bed-by-bed position of the samples taken by Oesterle (1968). These sample numbers correspond bed by bed to those taken by Knappertsbusch and Gradstein in 2016 for study of '*Globigerina' helvetojurassica* Haeusler. From bed 4 Gradstein took two samples called 4 mid and 4 top

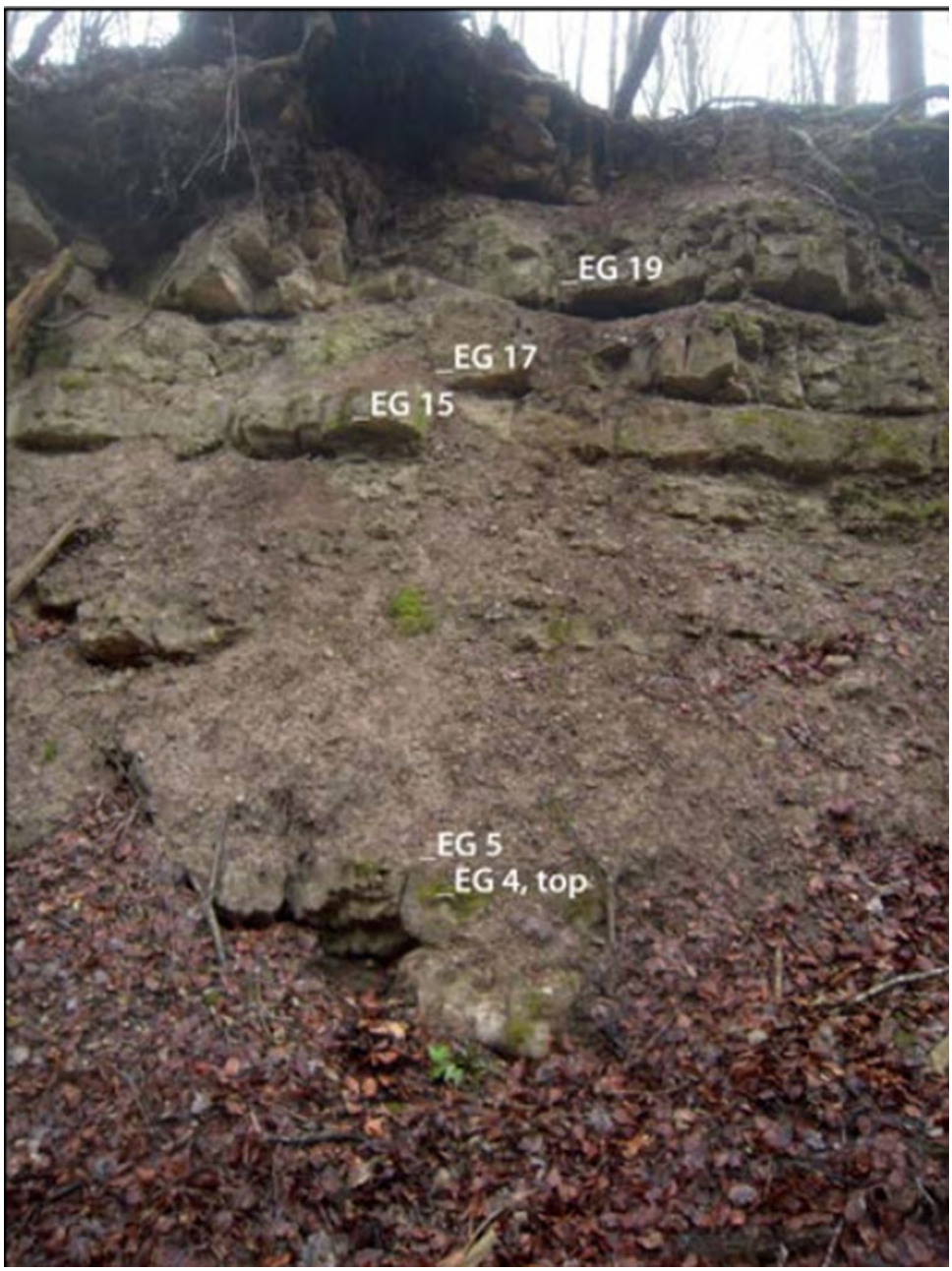


Fig. 4 Birmenstorfer Schichten with some sample levels in the Eisengraben Section, Canton Aargau, Switzerland (photograph Gradstein pers. comm.)

Stam-Simmons types have not been located in the UK and maybe lost.

In April 2016, Gradstein visited the Natural History Museum in Basel to study type slides listed to contain *Globigerina helvetojurassica* Haeusler, and also sample the Eisengraben Section to obtain fresh material. The sampling was accomplished under the expert guidance of W. Etter and M. Knappertsbusch.

Figure 4 shows the Eisengraben outcrop with levels 4 through 20 visible. These levels are listed in the original sample log of Oesterle (1968; see our Fig. 3). A duplicate set of samples were collected by us from each bed in the Eisengraben section, comprising alternating harder limestones and softer marls and clays. The sample levels correspond to the same sample levels investigated by Oesterle (1968). Limestone bed no. 19 can be easily identified due to its thickness. Also, Bed no. 4, just above the level from which Stam (1986) got this *G. helvetojurassica,* is easily recognizable in the outcrop, and both beds serve as reference levels.

The Birmenstorfer samples were treated with peroxide water (H_2O_2) to obtain washed residues. Rock samples were broken into small fragments, placed in a beaker and covered with a solution of H_2O_2 (10%) and water (90%)

until the maximum degree of disaggregation of the rock sample was reached. The samples were then washed under running water, sieved to obtain three size fractions (>38, >125 and >250 μm) and dried using a hot plate. This standard processing, which was performed in the micropalaeontology laboratory of Dr. Maria Rose Petrizzo in Milano, Italy yielded almost a hundred well-preserved specimens of Jurassic planktonic foraminifera. These foraminifera include *Globuligerina oxfordiana* (Grigelis), *G. bathoniana* (Pazdrowa), G. sp. and *Conoglobigerina helvetojurassica* (Haeusler). *C. helvetojurassica* is dealt with in detail below. Brief mention also is made of a triserial and striated planktonic taxon, not previously described.

Timan Pechora, Northwest Russia

Below a brief description is provided of the type locality of *Globuligerina stellapolaris* Grigelis based on the author's (A. Grigelis) notes made during field work in the Timan-Pechora region at River Pizhma of NW Russia in 1974. These notes were kindly provided by Grigelis to Gradstein in 2016. No special analyses of lithology content of sedimentary rocks were made. Microfaunal remnants were picked by the author after standard sediment disintegration and hand-sieving procedure.

The types of *Globuligerina stellapolaris* Grigelis are from very thin Upper Jurassic strata outcropping along the banks of the Pizhma and Ishma Rivers in the Pechora Basin (Fig. 5, # 73). Below we quote from the original description:

1. Black, thin-bedded, silty calcareous shale, 1.7 m thick, exposed along the Izhma River, above the village of Porozhskaya. An Early Kimmeridgian age is assigned based on finds of ammonites *Amoeboceras* sp., *Prorasenia* sp., belemnites *Pachyteuthis panderiana, Cylindroteuthis obeliscoides, C. puzosiana*, and foraminifera *Epistomina praetatariensis*.
2. Greenish-and bluish-grey calcareous silts with nodules of glauconite and phosphite; approximately 0.5 m thick, exposed along the left bank of the Pizhma River, above the village of Zagrivochmaya. Ammonites include *Pectinates pizhmae*, *Subplanites* sp., and *Marginulinopsis embaensis*. An age of Early Volgian is assigned.
3. Dark grey, silty calcareous shale, up to 3 m thick with ammonites *Kachpurites* and *Craspedites* and foraminifer *Bullopora vivejae*. It is assigned an age of early Late Volgian. The outcrop is on the left bank of the Izhma River, between the village of Kedva and the mouth of the Kedva River.

In June 2016, Gradstein and Dr. Ludmila Kopaevich (Moscow) visited Grigelis in Vilnius for the purpose of studying the type specimens of *G. stellapolaris*. The

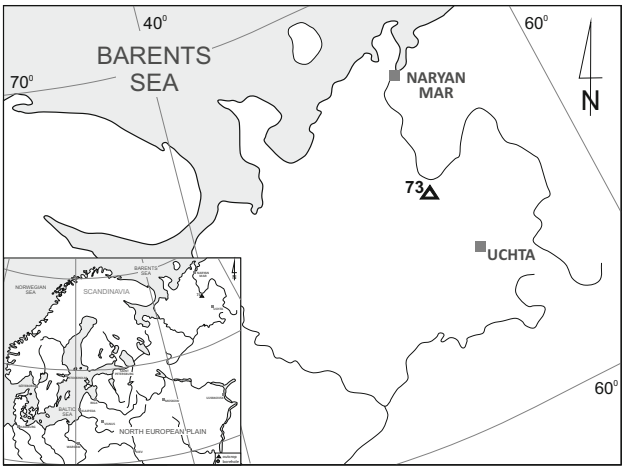


Fig. 5 Location of outcrop 73 where '*Globuligerina' stellapolaris* Grigelis was originally described in the Timan-Pechora region of Northwest Russia. For details see text

holotype of the latter looks very compact, with a coarse reticulate wall, and might readily be confused with Late Cenozoic *Neogloboquadrina pachyderma* (Ehrenberg), if no Jurassic ammonite data were supporting it. Two samples without ammonite control of the same thin Volgian levels were kindly loaned to Gradstein and studied in detail in Oslo, Norway. It turned out that the benthic foraminiferal assemblage in these two samples (15/207 and 15/211) contains common specimens of what appear to be (1) *Reticulophragmium* sp. of a type known from the Late Cenozoic of the central North Sea, (2) *Budashevaella multicamerata* Voloshinova known from the Cenozoic, (3) an abundance of a smooth, rather sharp conical and pointed *Epistomina* (this might be Jurassic or younger ?) and (4) rare foraminiferal genera, not readily known from Jurassic strata. Six specimens of planktonic foraminifera are also present in the slides. One planktonic specimen might be a heavily calcified *Orbulina universa,* and the other planktonics strongly resemble N*eogloboquadrina pachyderma*. See section on Taxonomy for more details.

Morphology of Jurassic planktonic foraminifera

Jurassic planktonic foraminifera are globigeriniform trochospiral, with a high spire, medium high spire, or low spire. Occasionally, a slightly irregular mode of trochospiral coiling is observed, but no streptospiral or triserial modes.

High spire means H/D is bigger than 1; medium high spire means H/D is approximately 1; low spired tests have an H/D ratio smaller than 1. Both Pazdrowa (1969) and Stam (1986) made effective use of this ratio to differentiate higher and lower spired taxa.

Successive chambers in the trochospiral test may increase in size slowly, medium fast or fast.

The shape of the chambers may be:

1. Spherical, with rather circular diameter,
2. Globular, but a bit more irregular in shape,
3. Oval, meaning slightly elongated in a radial sense.
4. Oval and slightly flattened.
5. Reniform (kidney shaped).
6. Petaloid, meaning shaped like the individual petals in a flower.
7. Elongated in a radial sense, rounded or finger-like.

A kummerform last chamber (bulla) is common in most of the taxa. A bulla means a smaller than normal last chamber with one, or rarely two basal openings. Bullae have a smoother wall surface than the overall test, and are in umbilical position, generally covering the primary

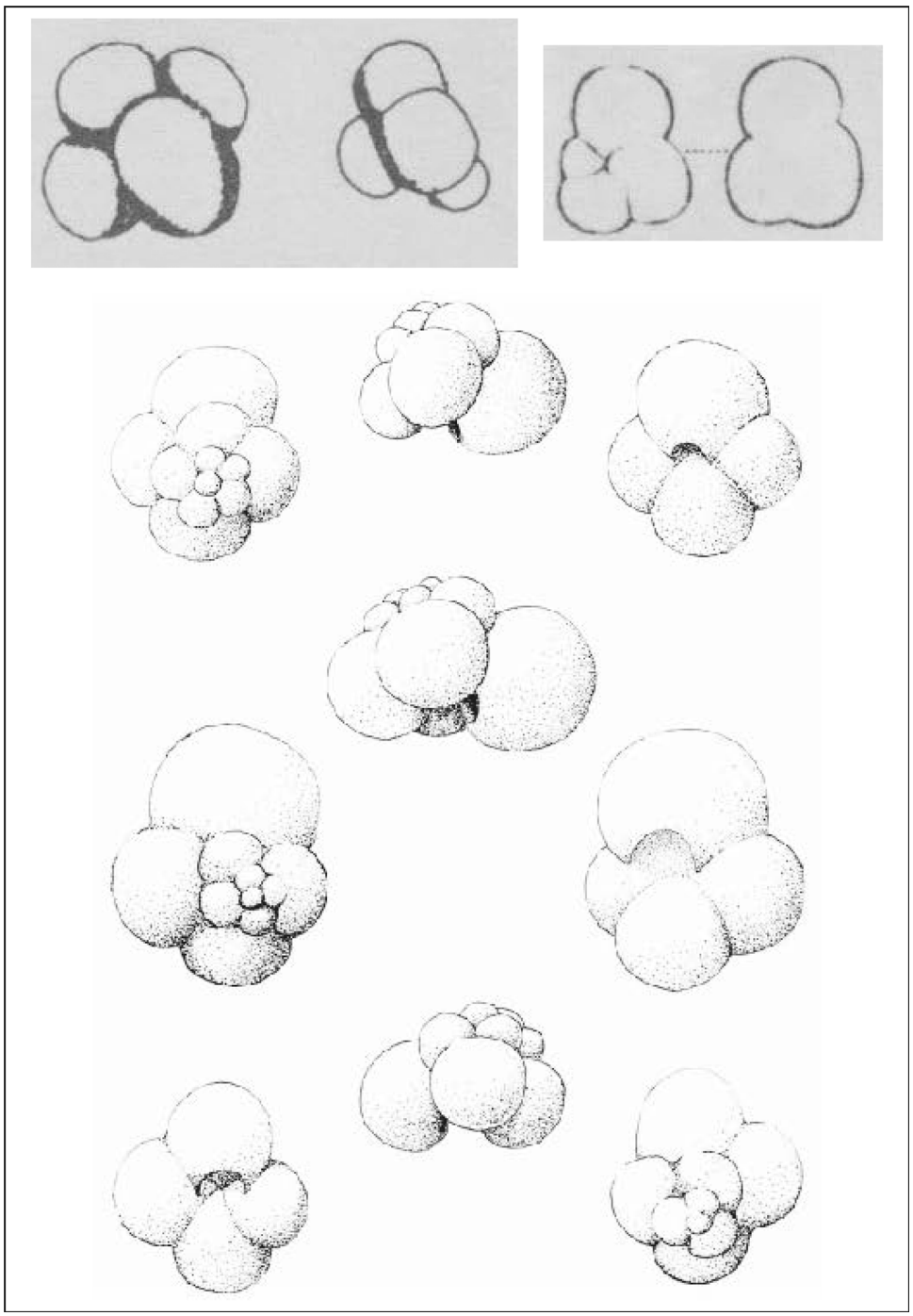


Fig. 6 Upper four specimens are original drawings of *Globigerina helveto-jurassica* by Haeusler (1881); no magnification provided. *Lower nine* specimens are drawings of *Globigerina helvetojurassica* Haeusler by Oesterle (1968); Basel Geological Museum, C 25692-694; magnification ×200. *Cordatus* and *Lamberti* Zones, Oxfordian, Canton Aargau, Switzerland and Birmensdorfer Schichten, *Transversarium* Zone, Oxfordian, Canton Aargau, Switzerland

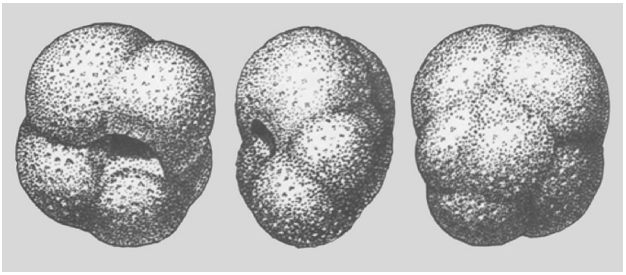


Fig. 7 '*Globuligerina' stellapolaris* Grigelis. Holotype drawing in 1980 by micropaleontology graphic artist Sergei Nikolayev, St. Petersburg. Magnification ×150

aperture of the last chamber. Hemleben et al. (1989) reports that bullae are grown after gametogenesis. This is in line with a lack of megalospheric Jurassic planktonic foraminifera and a lack of clear cut dimorphism.

Sutures on the test may be depressed or little depressed, and radial or (rarely) slightly curved in shape. No raised sutures were observed.

The margin of the test is almost always broadly rounded, but can be subacute, but not keeled. Tests with a weak imperforate peripheral margin have been observed, but are rare and confined to one taxon—*Globuligerina balakhmatovae* (Morozova) 1961, (Gradstein, 1976; Stam, 1986; Gradstein et al., in prep).

The aperture is umbilical or umbilical–extraumbilical in position. Apertural shape may be slit-like (rare), low arch, medium to high arch, or comma-shaped. The comma-shaped aperture is asymmetrical, higher than wide and slightly bend sideways. This comma-shaped aperture is common in some taxa, but is not an exclusive feature at species level. Apertural shape, within one species assemblage is quite a plastic feature. Intra-specific apertural shape variation, with both loops and arches in one assemblage of *Globuligerina bathoniana* (Pazdrowa) was already described by Pazdrowa (1969). The aperture may have a rim surrounding it completely, or in part.

The wall texture (perforation) of planktonic foraminifera may be microperforate (pore diameter < 1–1.5 μm), finely perforate (pore diameter 1–2.5 μm, normally spaced), or macroperforate (pore diameter >2.5 μm, closely spaced).

Jurassic planktonic foraminifera are exclusively described as being microperforate, meaning the outer wall of the test is characterized by having pores with a diameter of less than 1 μm to max 1.5 μm. Our observations, as far as possible, confirm the microperforate wall structure.

Although the wall of Jurassic planktonic foraminifera is almost always calcitic, this is considered to be due to post-mortem change from aragonite to calcite. In this, we follow how Simmons et al. (1997) typify Jurassic planktonic foraminifera, whose authors succinctly write: 'We consider them to belong to the Favusellacea, the aragonitic, microperforate, pseudomuricate superfamily, with an umbilical aperture, and all the adult chambers of all of these species are subglobular in shape'. Although it has to be demonstrated if this superfamily is monophyletic, these features distinguish it from the globigerinids in the Middle and Late Cretaceous and Cenozoic that have tests of calcite and are medium to macroperforate, with or without spines'.

Fig. 8 *1–7 Haeuslerina helvetojurassica* (Haeusler) sensuSimmons ▶ et al. 1997; magnification ×400; specimens diameter ~100 μm; no. 3b, enlargement of surface showing scattered pustules, magnification ×2000. Birmenstorfer Schichten, Canton Aargau, Switzerland. Reproduced with permission of Simmons et al. (1997, plate 2.7, figs. 1–7). *8–10 Globuligerina avariformis* (Kasimova) 1984. Upper Bajocian, Negramkoye Gorge, Aras River, Nakhichevan, Azerbaijan, donated by Dr. G. K. Kasimova to the Natural History Museum, London, metatype. Specimen diameter 320 μm; dorsal, peripheral and ventral views, magnification ×125. Reproduced with permission of Simmons et al. (1997, plate 2.7, figs. 8–10). *11–16 Globuligerina oxfordiana* (Grigelis)subspecies *calloviensis* nov. ssp. Gradstein. Lower to Middle Callovian, Crimea, USSR. Two metatypes deposited in the Geological Institute, Academy of Sciences, Moscow, USSR. 11–13, 110 μm diameter; *14–16*, 180 μm diameter. Reproduced with permission of Simmons et al. (1997; plate 2.5, figs. 5–10)

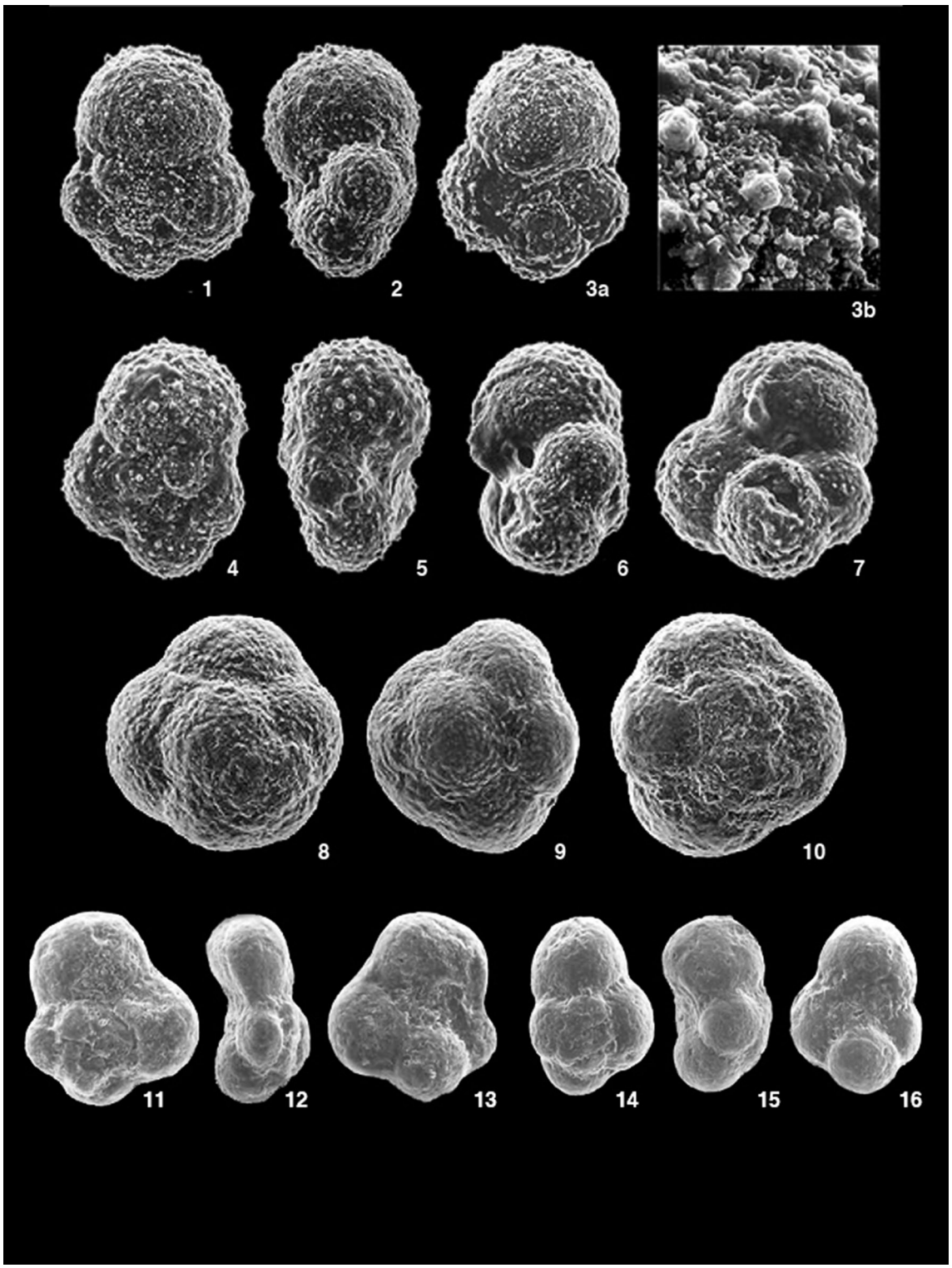
The character of the wall structure has been investigated for the 'popular' and widespread taxa *Globuligerina oxfordiana* and *G. bathoniana* (Pazdrowa, 1969; Gorbachik, 1983; Simmons et al., 1997). During the formation of chambers, the wall extends back over the older chambers; the wall itself is bilamellar, with a radial crystalline prismatic build-up; microcrystals are covered with an organic membrane.

The wall texture and wall surface patterns are not easy to study, since much of our material is not perfectly preserved, and may have secondary calcite overgrowth of tests. Simmons et al. (1997) illustrate well-preserved aragonitic tests, and their wall surface features are taken into account for this study.

Due to this post-mortem test calcification during fossilization, wall surface pattern is a more difficult feature to describe. A smooth pattern, like in some tests of *G. oxfordiana* and *G. balakhmatovae,* was rarely observed. A rather smooth test is more common in smaller (ontogenetically younger) tests.

Wall surface pattern frequently consists of (densely) scattered smaller or larger irregular pustules (calcitic mounds of various shapes). These pustules may be blob-like blunt or pointed, pointed pustules are rare. Pustules may grow in size in older chambers. Pustules may align to form discontinuous ridges (costae). These ridges again may align to form an irregular, reticulate pattern. Real honeycomb reticulation (favulate) appears only with *Favusella hoterivica* (Subbotina) in earliest Cretaceous time.

The term muricate is often used in description of a wall surface that is densely studded with short rough points.



Scanning electron microscope illustrations of well-preserved *Globuligerina oxfordiana* indicate these muricae are folds of the outer wall to form a conical structure (Gradstein et al., in prep). In some other illustrations these ornamentations are more like pustules.

Well-preserved images of *Globuligerina oxfordiana* also show pore mounds (Gradstein et al., in prep). Pore mounds are structure -like 'vulcanos' that surround the pores and are commonly associated with microperforate guembelitriid taxa in Late Cretaceous—Paleogene strata. The feature is

also found in some (but not all) Aptian hedbergellids. The function of the pore mounds is not clear (M. R. Petrizzo pers. comm. to Gradstein) and it is not understood either if there is a relationship between the position or type of primary aperture and the distribution of the pore mounds.

In our free specimens material it was not possible to distinguish thin- or thick-walled tests (Wernli 1987, 1988); its meaning is not understood.

Systematic Palaeontology: Genera

Conoglobigerina Morozova 1961, emended

Test trochospiral, low to medium high spired (H/D ratio 0.5–1, rarely over 1); final whorl may be compact, or more open in shape. Chamber shape: globular, rounded, rarely slightly irregular, with 3.5–4 chambers in last whorl. Chambers of the last whorl may strongly embrace previous whorls. Apertural shape variable, low arch or slit; mostly umbilical, but may be slightly extraumbilical in position. Wall microperforate, with small or larger, blunt pustules; pustules fuse to form ridges that are organized in broken cells that form an (often imperfect) reticulate (favolate) pattern.

Morozova and Moskalenko (1961) defined the subgenus *Globigerina (Conoglobigerina)* with test diameter smaller than test height, and the subgenus *Globigerina (Eoglobigerina*) as small specimens with a very short spire (Morozova and Moskalenko 1961). The latter subgenus has subsequently been abandoned. The genus *Eoglobigerina* Blow itself is a Cenozoic taxon; for taxonomic and phylogenetic reasons the genus name cannot be used in the Jurassic.

Simmons et al. (1997) restricted the genus *Conoglobigerina* to forms having an intraumbilical, interiomarginal and low arch aperture, with species like *C. dagestanica*, *C. balakhmatovae* and *C. gulekhensis*. In the latter, pustules have fused to form short ridges that are organized in broken cells, forming a reticulate, favolate pattern. In this, *C. gulekhensis* is considered an intermediate between non-reticulate Jurassic taxa and the Cretaceous favusellids with a cancellate wall pattern, like *Favusella hoteriva* and *F. washitensis* (Carsey).

In this study, weight on a genus level is given to wall surface pattern and whorl embracement. *Conoglobigerina* is being low to medium trochospiral, with a subreticulate to reticulate wall surface pattern. The genus includes three species: *C. helvetojurassica*, *C. grigelisi* sp. nov. and *C. gulekhensis*, with the former two appearing in Late Jurassic and the latter (as far as known) in earliest Cretaceous time. *C. helvetojurassica* has a rather expanded last whorl with globular-spherical chambers and *C. grigelisi* a strongly embracing last whorl with also heavier reticulation.

Fig. 9 Specimens from the Oesterle (1968) microfossil slide collection, Natural History Museum Basel. Section Eisengraben, Canton Aargau, Switzerland—Birmenstorfer Schichten, *Transversarium* Zone, Middle Oxfordian. The samples probably were subjected to diluted acid preparation to account for the preservation of the tests. Lack of test wall features makes taxonomic determination tentative (hence the affinis insert). *1a*, *b Globuligerina* sp. with slit aperture (aff. *Haeuslerina helvetojurassica* (Haeusler) sensuSimmons et al. 1997)—slide 26094, sample 18. *2* and *3* Aff. *Globuligerina tojeiraensis* Gradstein—slide 26094, sample 18. *4* and *5* Aff. *Globuligerina oxfordiana* (Grigelis), arch aperture—slide 26092, samples 6–12. *6a*, *b* Aff. *Globuligerina bathoniana* (Pazdrowa) (6 b has some glue on test)—slide 26094, sample 18. *7* Aff. *Globuligerina bathoniana* (Pazdrowa) nr. 3 showing remnant of a lip—slide 26095, samples 19–22. *8*, *9* Aff. *Conoglobigerina grigelisi* Gradstein—slide 26095, samples 19–22. *10* Aff. *Globuligerina bathoniana* (Pazdrowa)—slide 26092, sample 9–12 ▶

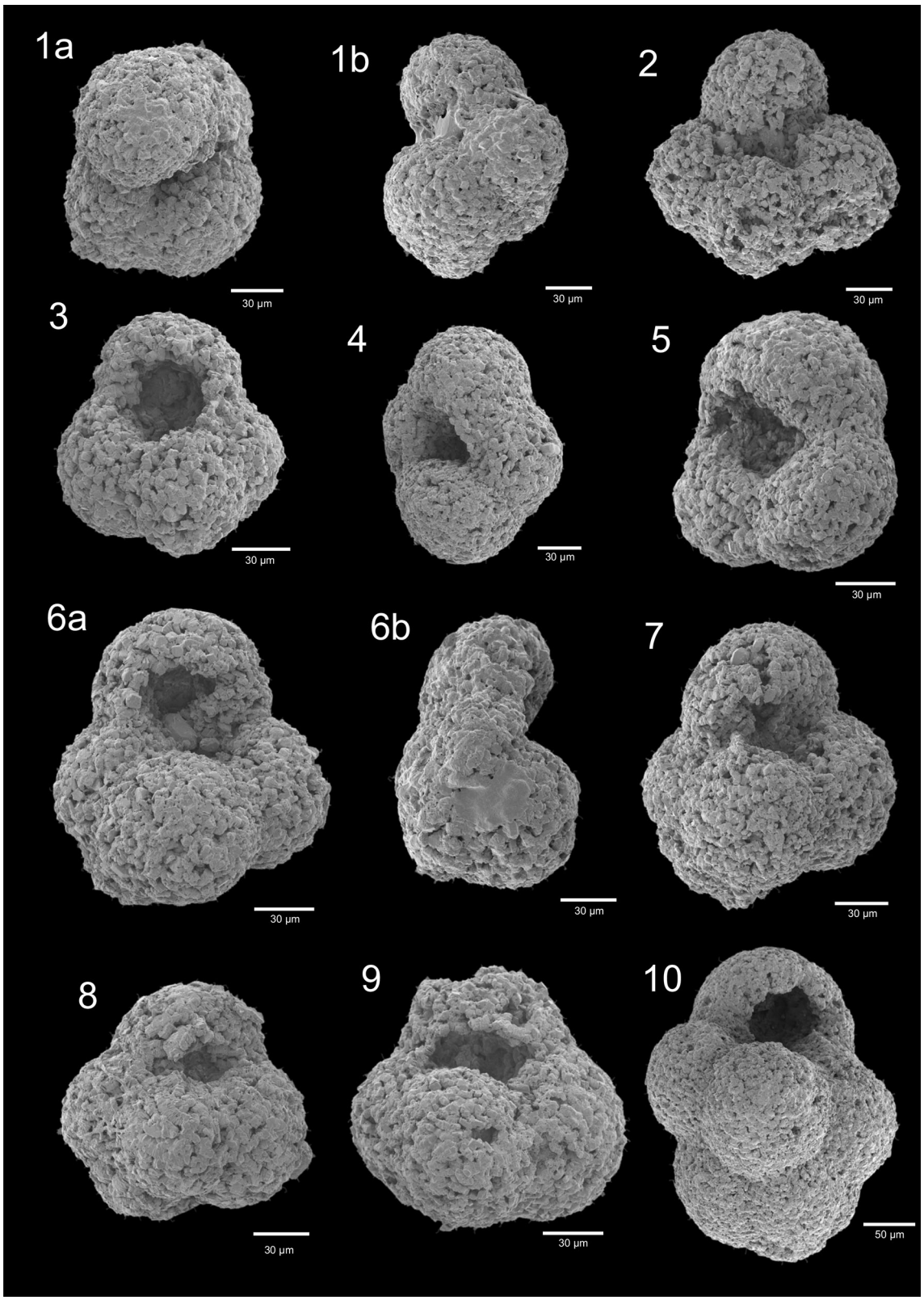
Globuligerina Bignot and Guyader 1971, emended

Test trochospiral, low- to medium- to high-spired (H/D ratio varies between 0.5 and 1.5). Mostly four and rarely 3–4 or only three chambers are in the last whorl. Chamber shape: globular or even spherical, or somewhat flattened, or slightly oblong and elongated in a radial sense. Oblong chambers rarely show an equatorial imperforate band. Apertural shape variable, often a medium to high arch; the arch may be an asymmetrical arch or is comma-shaped; aperture rarely a slit; aperture position mostly umbilical, but may be slightly extraumbilical. The aperture has a thickened and imperforate rim (lip) that may circle the aperture (as observed in well-preserved *G. oxfordiana*). Wall microperforate, smooth to pustulose; pustules may be pointed (pseudomuricae), or blunt; pustules may fuse to form ridges. Pustules may show perforation, called pore mounds.

Taxa include *G. dagestanica* (Morozova), *G. avariformis* (Kasimova), *G. balakhmatovae* (Morozova), *G. bathoniana* (Pazdrowa) *and G. jurassica* (Hofman), *G. oxfordiana* subspecies *calloviensis* Gradstein subsp. Nov., *G. oxfordiana* (Grigelis)and *G. tojeiraensis* sp. nov.

A special case is the species *Globuligerina calloviensis* Kuznetsova, (placed here as subspecies under *G. oxfordiana*) with an almost smooth wall. It is tentatively included in this genus pending more study of its wall structure and (absence of) wall sculpture. The smooth tests suggest that the outer shell is almost not preserved. At present it is only known from the Callovian of Crimea and Ukraine, Russia.

The genus name *Globuligerina* has a slightly confusing historical background. In 1971, G. Bignot and J. Guyader (reprinted in the Proceedings of the II Planktonic


1a
1b
2
30 µm
30 µm
30 µm
3
4
5
30 µm
30 µm
30 µm
6a
6b
7
30 µm
30 µm
30 µm
8
9
10
30 µm
30 µm
50 µm

Conference in Rome, 1970), using their French specimens, erected the subgenus *Globuligerina* under the genus *Globigerina* with a slightly comma-shaped (also named looped or bulimine) aperture with a little lip. Type species is *Globigerina oxfordiana* Grigelis 1958 (not 1956 as Bignot and Guyader wrote).

This was the beginning of the use of apertural shape for generic definition in Jurassic planktonic foraminifera (Grigelis and Gorbachik 1980; Banner and Desai 1988). This, despite the fact that already Pazdrowa (1969) reported that in *G. bathoniana* the apertural shape varies from symmetrical low arch to symmetrical high arch to comma-shaped (bulimine).

Huddleston (1982) pointed out that Bignot and Guyader (1971) established the new genus *Globuligerina* with specimens from the Oxfordian of France, and designated their specimens as type species of *Globigerina oxfordiana* Grigelis. Hence, Huddleston concluded that the specimens of *G. oxfordiana* Grigelis from Lithuania are not anymore the type species.

However, I would like to argue that Bignot and Guyader established the subgenus *Globuligerina* under the genus *Globigerin*a, not a new genus. Also, these authors only refer to their original 1966 publication, where *Globigerina oxfordiana* Grigelis 1958 is specifically referred to as the holotype taxon, and their French material as closely resembling the type material. In the single 1971 sentence on this (sub) genus emendation, no reference is made to any (new) type material. Reference is only made to the 1966 publication of these French authors.

Besides, Grigelis himself was the first (see Grigelis and Gorbachik 1980) to assign *oxfordiana* to the genus (not subgenus) *Globuligerina* of these French authors. Paratypes from *G. oxfordiana* clearly show comma-shaped aperture, clarifying the lack of apertural shape in the holotype drawing.

Hence, I conclude that *Globuligerina oxfordiana* was formally first described by Grigelis (1958) from Lithuania, and that the type species of the genus is from that local occurrence.

Systematic palaeontology: species

Genus *Conoglobigerina* Morozova 1961

Conoglobigerina helvetojurassica (Haeusler) 1881 neotype

Figure 6; Fig.10.1 (neotype) and Fig. 10.2–9; Fig. 11.1a–e.

1881 *Globigerina helvetojurassica* Haeusler. p. 36, plate 2, figs. 44, 44a.

Fig. 10 *Conoglobigerina helvetojurassica* (Haeusler). *Scale bars* for all specimens represent 50 μm; *scale bars* for wall texture scans 1a and 3a are 20 μm long and for wall texture scan 2a is 10 μm long. *1–4 Conoglobigerina helvetojurassica* (Haeusler). Sample 4 mid, Eisengraben Section, Birmenstorfer Schichten, *Transversarius* Zone, Oxfordian, Canton Aargau, Switzerland. The specimen in sem scan 1 is the proposed neotype, with typical specimens of the taxon in sem scans 2, 3 and 4 from the same sample. Aperture likely was arch shaped in sem scans 1, 2 and 3 and is clearly loop shaped in sem scan 4. SEM scans 1a, 2a and 3a show the reticulate wall texture of specimens 1, 2 and 3. *5–9 Conoglobigerina helvetojurassica* (Haeusler), Tojeira Formation, Lower Kimmeridgian, Montejunto area, Portugal. Specimen 7 is from sample 24/2P; specimens 5, 6 and 9 are from sample T2/1 and specimen 8 is from sample T2/2. The Tojeira specimens have a reticulate wall (imperfectly so on some chambers in specimens 6 and 8) and arched to looped aperture with lip

1890 *Globigerina bulloides* d'Orbigny var. *helveto-jurassica* Haeusler, 17, p. 118, plate 15, fig. 46.

1968 '*Globigerina' helvetojurassica* Haeusler, Oesterle, p. 774–777, fig. 50 (3 specimens with 9 illustrations).

2013 *Favusella hoterivi*ca (Subbotina). Görög and Wernli, p. 286–287, fig. 5, nrs. 1–8.

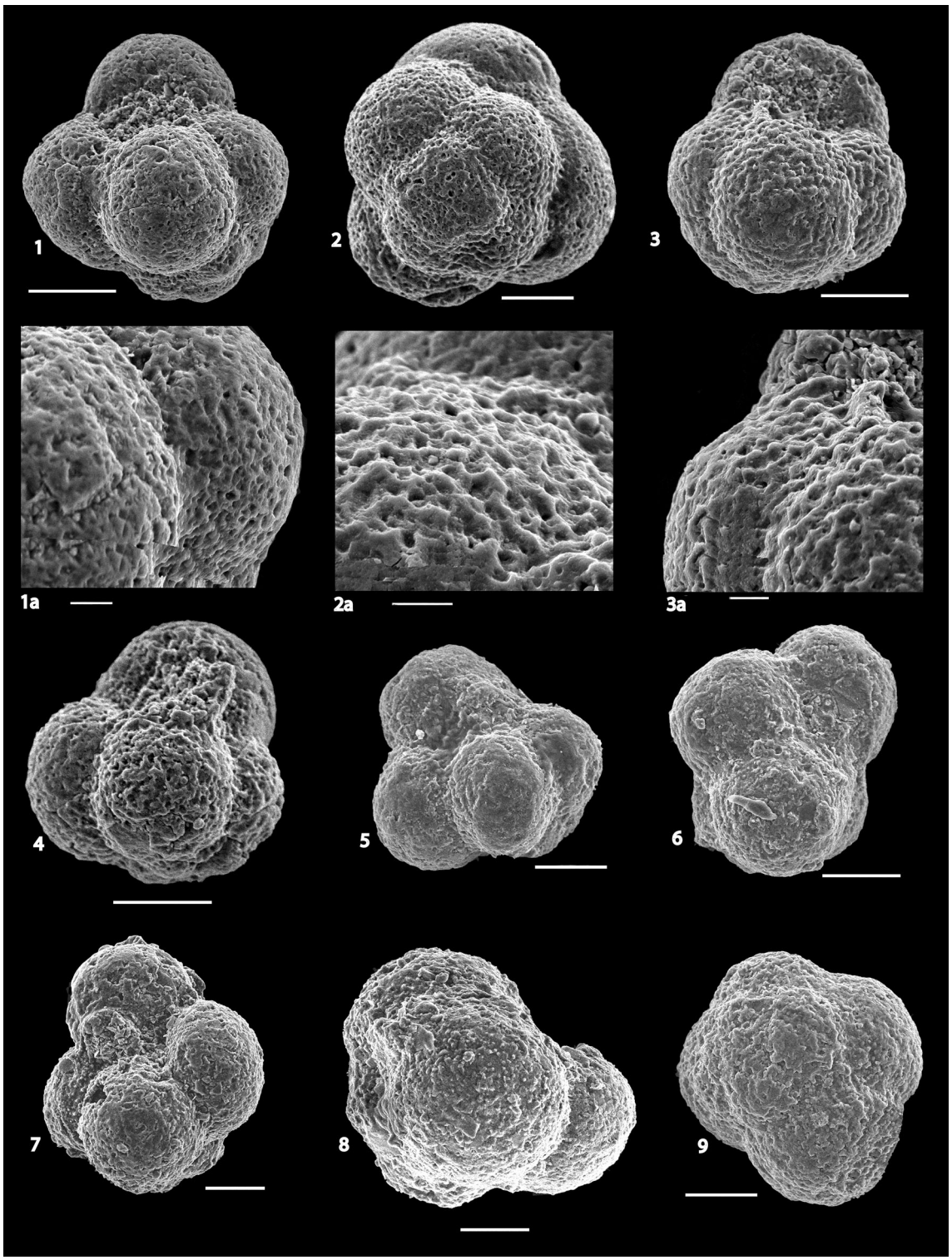
Non 1986 *Globuligerina oxfordiana* (Grigelis), Stam, p. 110–112, plate 7, figs. 6–12, plate 8, figs. 1–3. (Note: Stam 1986 lumped his *G. helvetojurassica* in *G. oxfordiana*).

Non 1997 *Haeuslerina helvetojurassica* (Haeusler), Simmons et al., p. 28, 29, plate 2.6, figs. 1–8.

Description: Low to medium high trochospiral, with an H/D ratio of 0.5–1; the trochospire axis may be slightly curved, such that the chambers of the final whorl sit oblique of the chambers of the previous whorl. No preferred coiling direction observed. Last whorl flaring out and much larger than previous (2) whorls. Spherical-circular chambers (ball shaped), four in the last whorl; chambers in the last whorl not much increasing in size. Umbilicus generally open and wide, rarely narrow. Sutures depressed, mostly straight. Aperture variable in shape, low to medium high arch, umbilical to slightly extraumbilical; a looped aperture was rarely observed also. The aperture often has a thickened rim around it. A bulla is observed in some specimens. Wall pustulose and reticulate to strongly reticulate.

Type locality and stratigraphic level: Birmenstorfer Schichten, Eisengraben Section, *Transversarium* Zone, Middle Oxfordian, Canton Aargau, Switzerland.

Occurrence: Middle Oxfordian of Switzerland (Sample EG4 mid, Birmenstorfer Schichten) and Lower Kimmeridgian of Central Portugal (Samples 24/2P and T2/12, respectively, in the middle and upper part of the Tojeira Formation).


1
2
3
1a
2a
3a
4
5
6
7
8
9

Discussion: Lower spired and smaller specimens of *C. helvetojurassica* can be mistaken for *Globuligerina oxfordiana*. *C. helvetojurassica* has a large last whorl, flaring out, ball-shaped chambers that increase little in size and a semi-reticulate to strongly reticulate wall texture. Such is not known from G. oxfordiana, *G. bathoniana* or from *G. dagestanica.*

The specimens from the lower Kimmeridgian of Les Bouchoux, France described by Görög and Wernli (2013) as *Favusella hoterivica* fit in the morphological variation of *C. helvetojurassica* and confirm the taxon ranging upwards from Oxfordian into Kimmeridgian. The Kimmeridgian occurrence of *C. helvetojurassica* is now also known from Portugal (Tojeira Formation).

I postulate *Globuligerina oxfordiana* to be ancestral to *Conoglobigerina helvetojurassica*. The two taxa may be morphologically confused if no detail of the wall texture is available. For the latter a good binocular or low magnitude (200x) petrographic microscope will do, but SEM visualization is a must for detail. *C. grigelisi* is more compact than *C. helvetojurassica*, with less globular and more oblong chambers in the last whorl. The last whorl strongly embraces previous whorls (almost) down to the apex, a feature not seen in *C. helvetojurassica.* The umbilicus in *C. grigelisi* is narrow and the sculpture of the wall surface texture is often (but not always) less perfectly reticulate.

Haeusler (1881) described *Globigerina helvetojurassica* in free specimens with calcareous test from the Birmenstorfer Schichten, *Transversarium* Zone, Middle Oxfordian, Canton Aargau, Switzerland. The description (translated from Latin) runs:

Test rounded, whitish, smooth, rarely a little rough, with 5–6 chambers, the last five ones but little increasing. With larger magnification finely perforate. Many specimens are broken. On good specimens the half moon shaped openings are easily visible; (our note: this clearly refers to an arch-like aperture).

Despite above text, description was inadequate, and no type locality and no type specimens were selected.

Gygi (1969) designated the Eisengraben section (ca 30 km NW of Zurich, Canton Aargau) as type section of the Birmenstorfer Schichten. In the year before, Oesterle (1968) had already selected the same section (see Figs. 3, 4 of the lithostratigraphic column) as type locality for all foraminiferal species described in 1881 by R. Haeusler from the Birmenstorfer Schichten.

Oesterle (1968) also re-described the foraminiferal assemblage in the type locality of the Birmensdorfer Schichten. In this outcrop section, he found about 250 recrystallized and badly preserved specimens of presumably '*Globigerina' helvetojurassica* Haeusler.

Unfortunately, and probably because he did not find suitable material in the type section, Oesterle's (1968) description of this species is based on recrystallized, silicified (? pyritized) moulds from another locality, the so-called Renggeri Tone from Liesberg, 75 km west of the Eisengraben section, SE of Basel.

'Tests consist of 10–14 globular chambers in 2.5–3? whorls; last whorl strongly expanded; sutures straight, deeply incised; half circle like, arched aperture in umbilical to weakly extraumbilical position. Tests are 170–220 μm in diameter and 90–120 μm high'.

The excellent drawings provided by Oesterle (1968) in Fig. 6 leave no doubt as to the identity of the taxon, except for the wall structure (but see below).

Oesterle reported that his *G. helvetojurassica* differs from *G. oxfordiana* by a higher trochospiral test. These steinkern finds from Oesterle (1968), not coming from the designated type locality of *G. helvetojurassica* (i.e. Birmensdorfer Schichten in Eisengraben), and being higher spired, were included by Stam (1986) in *Globuligerina bathoniana*.

With assistance of H. Bolli and R. Gygi, Bert Stam obtained, what he thought were topotypes of Oesterle's *Globigerina helvetojurassica.* The few specimens (see Fig. 8.1–7) were obtained from the same layer as Oesterle's sample number 4 in layer 3 from 'ca 20 cm rostbrauner Eisen-Oomikrit mit Aufarbeitungen und spärlichem Biodetritues, sehr stark limonitisiert und korrodiert' (Figs. 3, 4). Stam (1986) described the specimens as low trochospiral, aperture semicircular to low and elongated slit, bordered with a lip and umbilical to extraumbilical in position. The author grouped the specimens together with *G. oxfordiana,* and applied for Nomen Oblitum status of the original *Globigerina helvetojurassica* Haeusler with the International Commission on Zoological Nomenclature (dd. 3 November 1985). This request was denied.

Simmons et al. (1997) used the three specimens illustrated originally by Stam (1986) of '*G. helvetojurassica'* from layer 3 of the type Birmenstorfer Schichten to erect the new genus *Haeuslerina helvetojurassica* (Haeusler). The authors also re-illustrated Stam's figured specimens (see Fig. 8.1–7). All specimens are covered in pseudomuricae, not aligned into ridges, and possess a small umbilicus and an intra-extraumbilical, low slit aperture.

It should be noted here that Haeusler specifically listed his *Globigerina helvetojurassica* to have a half moon shape (arched) aperture, and not a low slit. Oesterle's specimens all have an umbilical placed arched aperture. Also, the original specimens are higher coiled and more expanding in width than reported by Stam (1986) and Simmons et al. (1997). Hence, both Stam (1986) and Simmons et al.'s

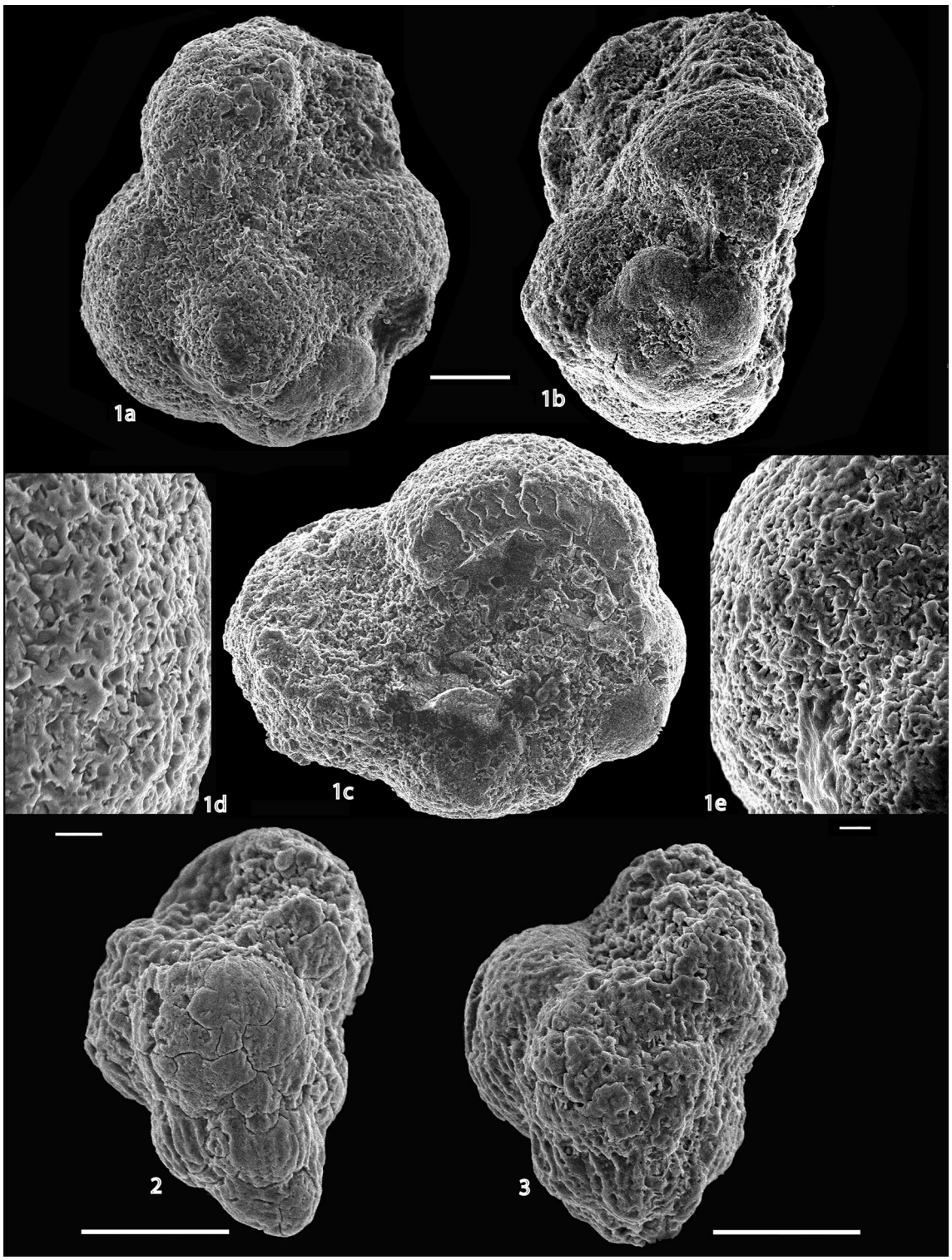


Fig. 11 *1. Conoglobigerina helvetojurassica* (Haeusler), Sample 4 mid, Eisengraben Section, Birmenstorfer Schichten, *Transversarius* Zone, Oxfordian, Canton Aargau, Switzerland. *1a* shows umbilical view; *1b* shows side view; *1c* shows spiral view; *1d* and *1e* show reticulate wall texture. *Scale bar* for the specimen represents 50 μm; *scale bars* for wall texture scans are 10 μm long. This specimen likely was sessile for part of its life cycle; for details see text. *2* and *3* Unknown planktonic genus, sample 4 mid, Eisengraben Section, Birmenstorfer Schichten, *Transversarius* Zone, mid Oxfordian, Canton Aargau, Switzerland. *Scale bars* represent 50 μm. For details see text

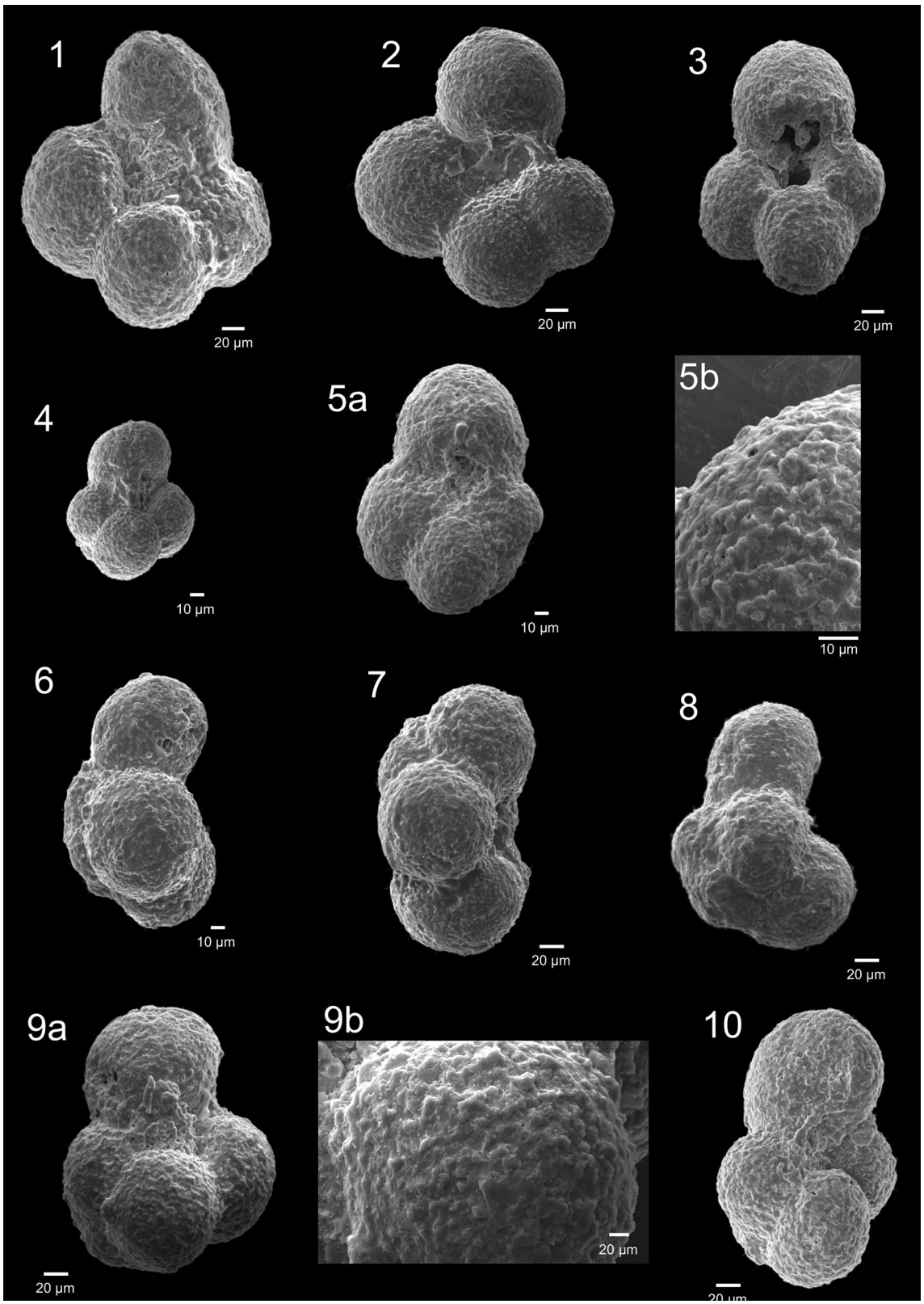


Fig. 12 *1 Globuligerina tojeiraensis* Gradstein nov.sp. holotype. *2–10 Globuligerina tojeiraensis* Gradstein sp. nov. paratypes. Types are from sample 24/2P taken in 1978 from the middle Tojeira Formation, Montejunto, Portugal; *Platyna* through *Platynota* Zones, Early Kimmeridgian. This sample was taken a few meters above the limestone couplet in Fig. 2

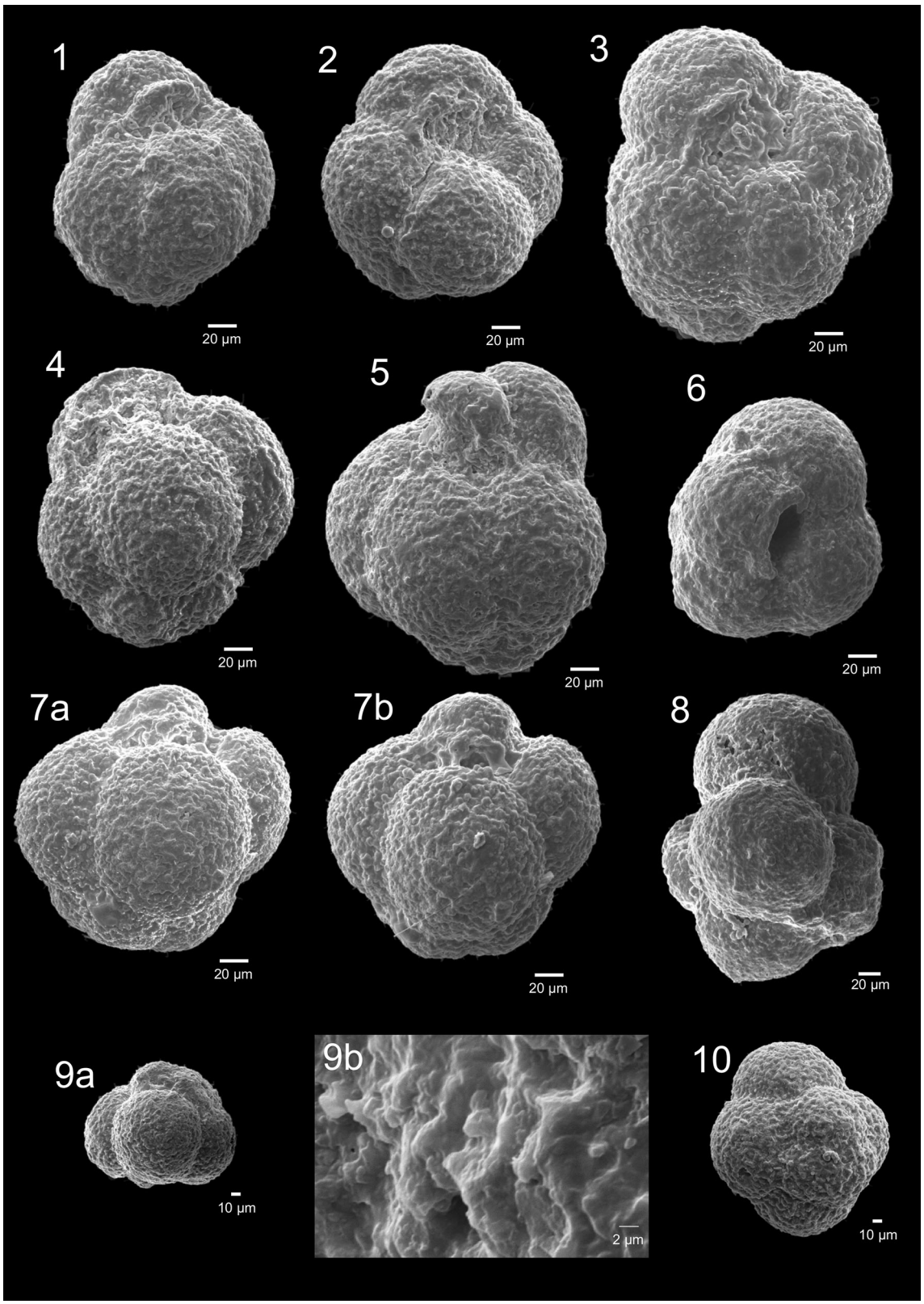


Fig. 13 *1 Conoglobigerina grigelisi* Gradstein sp. nov. holotype. *2–10 Conoglobigerina grigelisi* Gradstein sp. nov. paratypes. Types are from Sample 24/2P taken in 1978 from the middle Tojeira Formation, Montejunto, Portugal; *Platyna* through *Platynota* Zones, Early Kimmeridgian. This sample was taken a few meters above the limestone couplet in Fig. 2

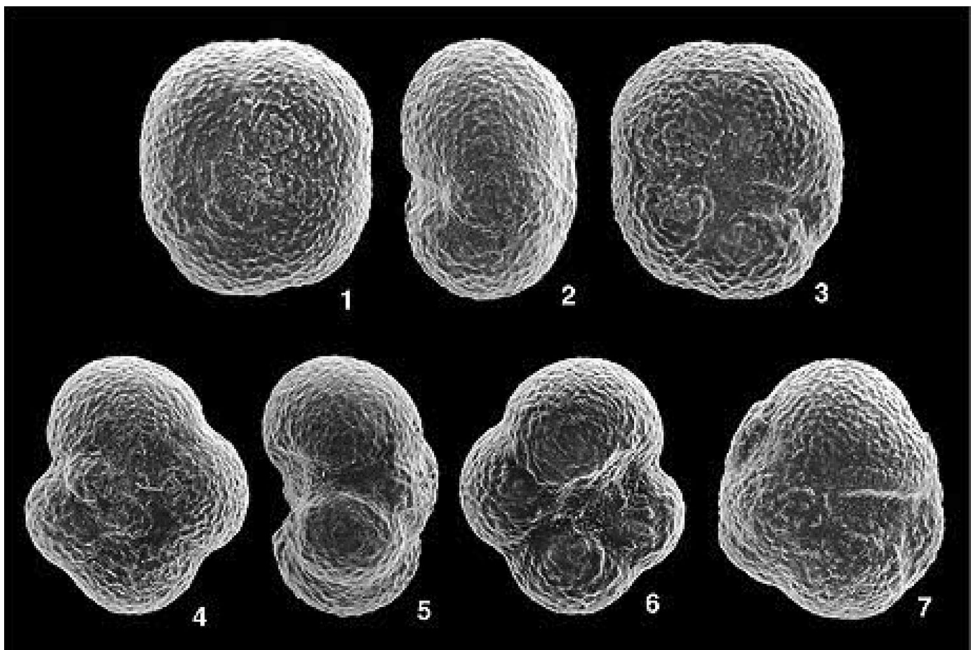


Fig. 14 *1–7 'Globuligerina' stellapolaris* (Grigelis et al. 1978). Early Volgian, Ishma River, Pechora Basin, NW Russia. Three metatypes deposited in the Geological Faculty, Moscow State University, Russia. Metatype (specimen diameter 235 μm) 1–3, dorsal, peripheral and ventral views (magnification ×170); metatype (specimen diameter 265 μm) 4–6, dorsal, peripheral and ventral views (magnification ×150); metatype (specimen diameter 260 μm) 7, ventral view (magnification ×155). Reproduced with permission of Simmons et al. (1997, plate 2.7, figs. 1–7)

(1997) concept of *helvetojurassica* (with an umbilical to extraumbilical slit aperture, and lower coil) diverges from the original species descriptions and illustrations.

In 2016, Gradstein re-studied the original three specimens of *G. helvetojurassica* from the Birmenstorfer Schichten, deposited by Oesterle (1968) in the Natural History Museum of Basel under collection nrs. C-25692, C-25693 and C-25695. Note that slide nr. C-25694 is barren. These specimens are from Oesterle's samples 8 and 11 in the type section (Fig. 3). The specimens consist of moulds of crystallized carbonate fragments (no nannofossils observed) without the original wall. Test is a low to medium high spire; chambers spherical, globular, regularly increasing in size; last whorl with four chambers in the last whorl; aperture a low to medium high arch, umbilical to slightly a-central in position; in one specimen the aperture tends to become loop shaped.

In my view, these few specimens are different from the flat specimens with a slit aperture, illustrated by Stam (1986), and re-imagined by Simmons et al. (1997).

I am of the opinion that the original specimens of *G. helvetojurassica* from Oesterle–Haeusler as described and re-studied by me, do not resemble the three specimens described by Stam-Simmons.

When in Basel, Gradstein also studied many Birmenstorfer type section specimens in another set of Oesterle (1968) slides, numbered 26,092 (sample levels 6–12 in Fig. 3), 26,095 (sample numbers 19–22 of Fig. 3), 26,094 (sample number 18 of Fig. 3) and slide nr. 26,093 (sample numbers 13–17 in Fig. 3). Note that there are no specimens in the Oesterle's collection in Basel of the sample 4, level 3 collected by Stam (1986). All of the 50+ of many more (often broken) specimens which we studied show the same test moulds of crystallized carbonate fragments. The peculiar preservation is the result of a rigorous processing technique (likely a form of acetolysis). Curiously, in the material of the Natural History Museum of Basel at least five morphotypes may be distinguished, which, despite poor preservation, can easily be assigned to the species *G. aff. oxfordiana, G. aff. bathoniana, G. aff. jurassica* (with an elongated, high spired and irregularly trochospiral test), *G. aff. balakhmatovae, G.* aff. *tojeiraensis*(with slightly elongated last chamber) and *Conoglobigerina aff. grigelisi.* The affinis assignment is meant as a precaution when dealing with specimens without original wall structure. Scanning electron microscope illustrations are in Fig. 9.

From this direct study of original, but badly processed material, it is clearly not possible to understand the test morphology of *Globigerina helvetojurassica* Haeusler, sensu Oesterle (1968). This, plus the apertural morphological divergence mentioned above, place doubt on the assignment of the three Stam (1986) specimens of *G. helvetojurassica* to the new genus *Haeuslerina helvetojurassica* by Simmons et al. (1979). An unfortunate incident is that at this time of writing (October 2016) it is not known where Stam's original specimens are. The specimens were loaned in 1996 from the Geological Survey of Canada to Simmons et al. (1997).

It is now clear that the species *G. helvetojurassica* sensu Haeusler and Oesterle cannot be defined from the studies by Stam (1986) and Simmons et al. (1997). And designing a new monotypic genus (*Haeuslerina helvetojurassica*) on three (?) lost specimens of a misunderstood species, does not appear to be viable.

At this stage of investigation, it was useful for taxonomy to discover if level 3 of the Birmenstorfer Schichten type section indeed would yield specimens as described by Stam (1986). Note, that such specimens are not known in the type collections of the Birmenstorfer Schichten in the Natural History Museum of Basel.

With the regional expertise and excellent assistance of the staff of the Natural History Museum in Basel (W. Etter, M. Knappertsbusch and C. Meyer) and students, two sections of the Birmenstorfer Schichten were re-sampled, including the Eisengraben type section (Figs. 3, 4). Our samples 4 mid, 4 top and 12, corresponding to Oesterle's sample notation of the latter section yielded specimens of planktonic foraminifera. Sample 4 top has many agglutinated taxa, but hardly any planktonic specimens. Sample 4 mid, at the level of Stam's sample with '*helvetojurassica*' has best preserved specimens, and also includes well-preserved bentics belonging in *Bigenerina, Textularia, Ophthalmidium, Ammodiscus, Glomospira, Trochammina, Haplophragmoides, Dentalina, Nodosaria, Lenticulina* plus someindeterminate taxa. Micro-gastropods also occur. Small limonitic concretions are common; small glauconite lumps also occur, testifying to a likely neritic mode of deposition. There are no epistominid taxa.

The many and well-preserved planktonic specimens from sample 4 mid can be assigned to several taxa. A small number of 125–150 μm sized specimens have a low to medium high spired test with four globular chambers in the last whorl, a low to medium arched or looped aperture, with rim. The second chamber of the last whorl sticks up, as observed often in *G. oxfordiana*. Wall surface structure is pustulose. The specimens do not resemble in any way *G. helvetojurassica* sensu Stam (1986), and belong in *G. oxfordiana.* Other taxa observed include *Globuligerina bathoniana* and isolated, small (65 μm fraction) and poorly preserved specimens indeed resembling *Haeuslerina helvetojurassica* sensu Simmons et al. (1997). Low numbers of these tiny specimens, and poor preservation prevent proper description.

The importance of this find is in the other, more common and much better preserved specimens. Specimen vary in size from ~100 to ~180 μm, are well preserved with a medium high spire, globular chambers, deeply incised sutures and medium high arched aperture with rim. The last whorl is large relatively to the previous whorls, with the four chambers in this whorl little increasing in size. The last whorl does not overlap the previous whorls as much as in *Conoglobigerina grigelisi*. The wall surface structure is reticulate to strongly reticulate. The test morphology of the specimens bears a remarkable similarity to the drawings by Oesterle (1968) of *G. helvetojurassica* (compare specimens in Fig. 6 with specimens in Fig. 10) and concur with the original description by Haeusler (1881).

With this new find, a neotype is proposed for *Globigerina helvetojurassica* Haeusler under the name *Conoglobigerina helvetojurassica* (Haeusler). The neotype is the specimen on Fig. 10.1 with typical specimens from the same locality on Fig. 10.2, 3 and 4. From Montejunto, Portugal specimens of this taxon are illustrated on Fig. 10. 5 through 9. The new findings confirm that this species can again be properly defined and included as a valid taxon among the Jurassic planktonic foraminifera.

Benthic life cycle stage?

Figure 11.1a–e shows SEM digital images of an unusual Swiss specimen assigned to *Conoglobigerina helvetojurassica* (Haeusler). Only one specimen was obtained (sofar) after picking five trays with washed residue, but its features are clear enough. The overall chamber shape, wall structure and wall texture indicate it most likely belongs in this taxon.

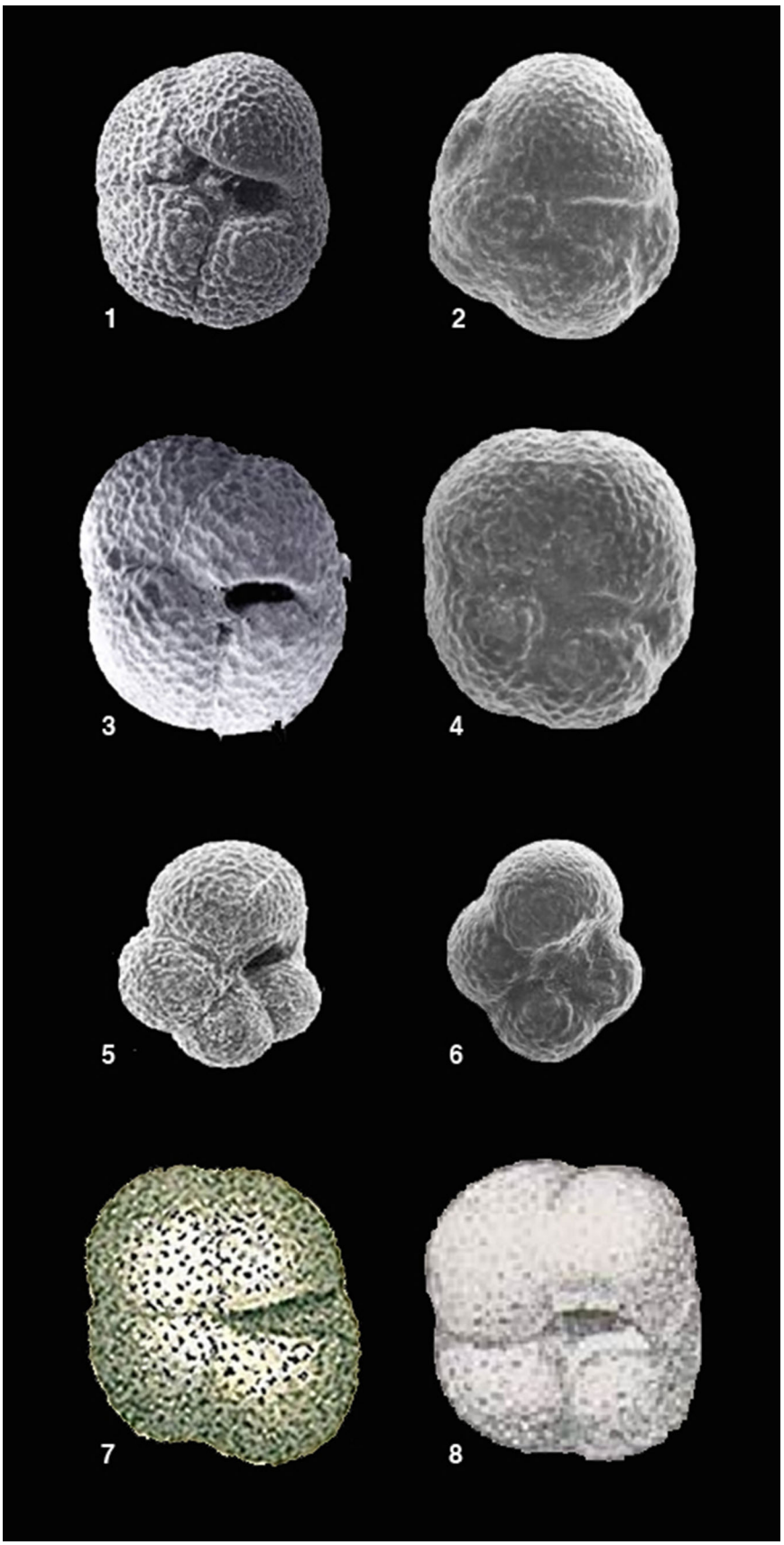
The planoconvex and involute test is relatively large (150–200 μm in diameter) and has four chambers in the last whorl, with chambers slightly increasing in size. Aperture is not preserved. The wall is microperforate and wall textures reticulate.

Normally, *C. helvetojurassica* has a medium high trochospiral test, but as seen on Fig. 11.1c the spiral side is concave and involute and not trochoid and evolute. Concave spiral sides maybe observed with sessile foraminifera that are attached to a hard surface. Such attachment surfaces maybe somewhat irregular in shape and the foraminiferal test may accommodate such a surface; hence a concave test shape might occur if the attachment surface is convex. The actual surface attachment spots on the specimen of *C. helvetojurassica* are clearly shown on Fig. 11.1c as darker coloured, rather smooth surfaces on chambers 1 and 3 of the last whorl.

A peculiarity is the small test with five (?) globular chambers in a flat coil that under higher magnification appears to be microperforate and pustulose or semi-reticulate. It is attached to the larger specimen, but appears to be a separate individual. More specimens are required to assemble a thorough description and interpretation. At this stage the large specimen is considered a possible benthic, attached life cycle individual of the nominate taxon.

Jurassic planktonic foraminifer sp.
Figure 11.2 and 3

At the sample level 4 mid with *Conoglobigerina helvetojurassica* in the Eisengraben Section of the Birmenstorfer Schichten, four small (less than 125 μm) specimens were found, two of which may be assigned to *Globuligerina bathoniana*. Two other ones appear to be a new taxon, not described earlier.


1
2
3
4
5
6
7
8

◀**Fig. 15** *2*, *4* and *6* '*Globuligerina' stellapolaris* Grigelis et al. 1978 (re-illustrated from Fig. 14. *7*, *3* and *6*). Drawing 8 on this figure shows the holotype (see also single Fig. 7). *1*, *3*, *5* and *7* *Neogloboquadrina pachyderma (Ehrenberg), Recent Oceans from* https://www.google.no/search?q=Neogloboquadrina+pachyderma. No scale available, but specimens likely between 100 and 200 μm in size

The test is triserial or slightly trochoid coiled, with three whorls; test chambers regularly increase in size. Last chamber markedly sticking up. Aperture not preserved. Test wall is microperforate and reticulate and shows many low and longitudinal ribs, crossing chamber sutures.

Until more and better preserved specimens are located, it is refrained from formally describing this taxon. *Conoglobigerina pupa*Wernli and Görög 2007 (their plate 4, figs. 1 and 2) bears resemblance, including what looks like striation on these specimens from the Middle Jurassic of France.

Genus *Globuligerina* Bignot and Guyader 1971.

Globuligerina tojeiraensis sp. nov. Gradstein

Figure 12.1–10.

Holotype in Fig.12.1. Paratypes in Fig.12.2–10. Types are from Sample 24/2P taken in 1978 from the middle Tojeira Formation, Montejunto, Portugal, Platyna through Platynota Zones, Early Kimmeridgian. Sample 24/2P was positioned slightly above the thin limestone beds in Fig. 2.

Description: Relatively low to medium high trochospiral, with an H/D ratio of 0.3–05, rarely larger. Test consists of 2–3 whorls with a tiny initial chamber (where visible). No preferred coiling direction observed. Last whorl with four chambers, which strongly increase in width, flaring out. Chambers are rounded with deeply incised sutures; chambers in the last whorl often radially elongate and higher than broad; last chamber often pointing slightly left or right in the equatorial plane. The test has a sunk-in umbilical region; umbilicus small to large (wide open). *G. tojeiraensis* has this peculiar knack (depressed umbilicus) with surrounding chambers often sticking up two by two. The chambers 2 and 4 of the last whorl stick more up than chambers 1 and 3.

Aperture a low to rarely high arch; it may be slightly asymmetrical in shape, as shown on Fig. 12.5a; aperture generally umbilical in position, rarely umbilical—extraumbilical. A small bulla occurs rarely; it obscures the aperture of the final chamber. Wall pustulose; pustules may fuse to form broken ridges.

Differential diagnosis: G. tojeiraensis differs from *G. oxfordiana* in its elongated (stretched) chambers in the last whorl, often oblique last chamber (pointing left or right), and often wide open umbilicus. The wall sculpture is densely pustulose, with pustules forming broken ridges; a trend not normally seen in *G. oxfordiana*. *G. tojeiraensis* is generally higher spired than *G. balakhmatovae* and *G. oxfordiana* and lower spired than *G. bathoniana,* none of which have elongated chambers, or a wide umbilicus.

Range and occurrence: The type level is the Tojeira Formation, Montejunto Formation, central Portugal of Early Kimmeridgian age (Planula-Platynota zones). The species is common in the Portugese outcrops.

A number of small, compact specimens with limited umbilical opening, but typical oblique last chamber occur in swc 5000′, Bittern M-62 well, Grand Banks. The sample is of Late Callovian to Early Oxfordian age (Gradstein et al., in prep.).

The taxon probably also occurs in the Birmenstorfer Schichten (Oxfordian), Canton Aargau, Switzerland.

Non-reticulate specimens of *Conoglobigerina caucasica* Gorbachik and Poroshina (1997) from the early Berriasian of Azerbijan, shown by Simmons et al. (1997) on their plate 2.6 may belong in *Globuligerina tojeiraensis*. Possibly, this species extends from Kimmeridgian into Berriasian. More discussion on this is in Gradstein et al. (in prep).

Phylogeny: In Bittern M-62 well, compact specimens with a 'sideways leaning' last chamber assigned to *G. tojeiraensis* have the second chamber of the last whorl typically 'sticking up', as in *G. oxfordiana.* In the Portugese material, where the taxon is common, morphological transitions occur to *G. oxfordiana.* Hence, this indicates that the latter is a possible ancestor.

Genus Conoglobigerina Morozova 1961

Conoglobigerina grigelisi sp. nov.

Figure 13.1–10.

Conoglobigerina ?avariformis Kasimova, Görög & Wernli 2013, p.285, fig. 4, nrs. 8–13.

Holotype in Fig. 13.1. Paratypes in Fig.13.2–10. Types are from sample 24/2P taken in 1978 from the middle Tojeira Formation, Montejunto, Portugal; Platyna through Platynota Zones, Early Kimmeridgian. Sample 24/2P was positioned slightly above the thin limestone bed in Fig. 2.

Description: Low to medium high conical test with a compact spire and 3.5–4 chambers in the last whorl. H/D ratio 0.5–1, rarely over 1. No preferred coiling direction observed. The chambers of the last whorl are large and have deeply incised sutures. Last whorl strongly embraces previous (? 2) whorls such that the earlier part of the test maybe hardly visible. Apex generally blunt, rarely pointed. Umbilical area depressed. Aperture generally a more or less symmetrical arch with lip, rarely comma-shaped.

Specimens may have a small bulla over the umbilicus with one or two, low-arch apertures; it may resemble the bulla structure of Cenozoic *Catapsydrax* taxa. Wall microperforate, strongly pustulose; pustules form low and broken ridges that create an imperfectly reticulate pattern over the surface of the chambers.

Conoglobigerina grigelisi Gradstein sp. nov. is named after Algimantas Grigelis for his early study of Jurassic planktonic foraminifera.

Differential diagnosis: *Conoglobigerina grigelisi* sp. nov. differs from *G. bathoniana* in its more compact test, strongly embracing chambers in the last whorl, often wider last whorl and wider umbilicus, and by its densely pustulose, reticulate wall sculpture. The pustules form broken ridges that arrange in an imperfect, low reticulate pattern over the whole test. *C. helvetojurassica* has more spherical, globular chambers which do not so strongly overlap previous whorls as in *C. grigelisi.*

The specimens of *C. grigelisi* in shape somewhat resemble *Globuligerina avariformis* (Kasimova, 1984) from the Bajocian of Azerbaijan. This taxon is poorly documented, but the original description under the genus name *Conoglobigerina* by Kasimova and Aliyeva (1984) mentions a smooth test and low arch aperture. The original drawings of the holotype show that the last whorl much less embraces the test than in *C. grigelisi* sp. nov. Gorog and Wernli (2002) report common *C. aff. avariformis* from the middle and late Bathonian of Hungary.

The SEM illustration on Fig. 8.8–10 of a specimen of *G. avariformis* (Kasimova) from Simmons et al. (1997), donated by G. K. Kasimova to the Museum of Natural History, London, UK shows the rather smooth wall and compact test. The sutures are less incised than in our specimens of *C. grigelisi* sp. nov. Another key difference is that the Bajocian age specimens from Azerbaijan have a wall with low pustules and ridges, instead of a dense muricate and rather reticulate wall sculpture. In *C. grigelisi* the last whorl also is more embracing the older part of the test.

Görög and Wernli (2013) described a morphotype from the Kimmeridgian of SE France under the name *C.? avariformis*, using acetolysis, that strongly resembles *C. grigelisi* sp. nov.

Range: Common in the Tojeira Formation, Lower Kimmeridgian of Central Portugal, and observed with few, small specimens in slightly older strata on the Grand Banks. Likely occurs also in the Kimmeridgian of SE France.

Phylogeny: The more embracing test and more advanced wall texture of *C. grigelisi* sp. nov. compared to *G. avariformis* (Kasimova) may indicate an evolutionary trend from the latter to the former taxon in Late Jurassic time. A problem is the lack of record of the latter in Callovian through Oxfordian strata.

Globuligerina oxfordiana (Grigelis) subspecies *calloviensis* ssp. nov. Gradstein

Figure 8.11–16.

1980 *Globuligerina calloviensis* Kuznetsova. In Kuznetsova and Uspenskaya 1980, p. 750, plate 2, figs. 1–4.
1986 *Globuligerina calloviensis* Kuznetsova. In Gorbachik 1986, plate 5, fig. 3; plate 6, fig. 1–2.

Description: Based on more than 200 specimens in Lower Callovian strata from the Meganom Peninsula, Eastern Crimea, K. Kuznetsova in 1980 described *Globuligerina calloviensis*. The low trochospiral test of two whorls has a low convex spiral side and a slightly concave umbilical side, with a fairly wide umbilicus. The second whorl is much wider than the first one. On the relatively poor illustrations the aperture is not well visible, but maybe a low arch; the wall appears smooth. The illustrations are in contrast to the description that describes a tuberous and cellular wall structure. Variability is in the flattening of the test, with more convex specimens being rare.

Stam (1986) included *G. calloviensis* in *G. oxfordiana*. Simmons et al. (1997) also argued that *G. calloviensis* is morphologically very close to *G. oxfordiana* and might be considered a subspecies of the latter. Despite limited data on definition and restricted distribution, this species of Jurassic planktonic foraminifera was retained by Simmons et al. (1997), who illustrated metatypes (see Fig. 8.1–6). These specimens clearly show the comma-shaped aperture and overall test shape like *G. oxfordiana*. The remarkable feature is the lack of ridges (pseudomuricae) on the test surface, which appears almost smooth. This is in contrast to the original description by Kuznetsova. The tests are not internal moulds. We conclude that there is wide variation in sculpturing and preservation of the type specimens, which should be investigated.

We assign the type, which has not been reliably recorded outside the Callovian of the Crimea and Ukraine, subspecies status, as suggested by Simmons et al. (1997). Stam (1986) on his plate 14, figs. 8–14, shows specimens of *G. oxfordiana* from the Tojeira Formation, Montejunto in Portugal that well resemble the type illustration by Kuznetsova and the metatypes of *G. calloviensis* illustrated by Simmons et al. (1997).

The only difference is the more rugulose wall of the Portugese specimens that are also younger in age than the types.

I take the opportunity to mention the possible similar preservation of some Callovian specimens of *G. bathoniana* figured in Stam (1986) from Algarve, Southern Portugal. Although some of these Algarve specimens appear to be internal moulds, some others appear to be thin-shelled,

as if Callovian Jurassic planktonic foraminifera underwent an unusual change in wall structure.

Genus Globuligerina Bignot and Guyader 1971

'Globuligerina' stellapolaris Grigelis et al. 1978

Figure 7; Fig.14.1–7; Fig. 15.2, 4, 6 and 8.

Globuligerina stellapolaris Grigelis et al. 1978 (in 1977 in same journal in Russian). p. 926–927.

Compactogenerina stellapolaris (Grigelis).Simmons et al. 1997, p. 29, plate 2.7, figs. 1–7.

Original description: The test is small, trochoid and round. Dorsal side is low trochospiral, and the ventral side involute. The spire consists of two whorls, with three chambers in the first whorl and four in the second and last whorl. The chambers are round and adjoin each other closely. Sutures are linear and slightly incised. The aperture is arch (arcuate) shaped. The test wall is calcareous, thin and with large pores. The H/D ratio of the holotype is 0.72 and over 200 μm large.

The taxon differs from *Globuligerina oxfordiana* in the round (not oval) shape of the test, greater size, and its more closely packed chambers.

Twenty or more specimens were found in the type area, some fairly well-preserved. The types are stored in the Lithuanian Institute of Geological Exploration, Vilnius, Lithuania.

The types of '*Globuligerina' stellapolaris* are from very thin Upper Jurassic strata outcropping along the banks of the Pizma and Ishma Rivers in the Pechora Basin. A description of the outcrops is in the section on Material. Note that this occurrence is unusual in that other latest Jurassic planktonic foraminifera occur much further south (Hungary).

The well-placed taxonomic remarks by Simmons et al. (1997) are: 'The holotype figure by Grigelis et al. (1978) is a specimen with a very compact test, in which the sutures are only slightly depressed and the equatorial periphery is not lobulate. This morphology agrees with that of two metatypes illustrated here (plate 2.7, figs. 1–3, 7). The sutures of another topotypic specimen also illustrated on plate 2.7, figs. 4–6, however, are much more depressed and the equatorial periphery is more lobulated. If the specimens figured here are indeed all conspecific, then they give a view of the range of variation which occurred in the species, but not enough specimens are available to us to be sure. The aperture possesses a narrow lip which partly covers the umbilicus (this lip appears to be broken away on plate 2.7, fig. 6)'.

Sofar the wording in the original descriptions by Grigelis et al. (1978) and twenty years later by Simmons et al. (1997). The metatypes are re-illustrated here in Fig. 14.1–7.

My first comment is that if peripheral test shape is a generic feature than *G. bathoniana* surely should be a different genus from *G. jurassica* and from *G. oxfordiana*. Both metatypes grouped by Grigelis under '*Globuligerina'stellapolaris* and illustrated here also might be split in two different genera. Hence, the genus name *Compactogenerina* assigned by Simmons et al. (1997) to the '*G'. stellapolaris* specimens of Grigelis et al. (1978) is not followed here. Generic splitting obscures detailed taxonomy, paleobiogeography and evolutionary trends.

A second comment is that the original description specifically refers to large pores. A photograph of a strongly encrusted specimen of '*G'. stellapolaris,* kindly shown by Grigelis to the author in 2016 in Vilnius, shows long vertical pores over 9 μm in diameter. Planktonic species with large pores are only known from Middle Cretaceous and younger strata, hence this give hint of an unusual situation (see below).

A third comment is that it is curious that (after 40 years) no reliable record exists of the species outside the type locality, which also is unusually far north ($\sim 67^{\circ}$ N), well outside the common distribution realm of Jurassic planktonic foraminifera. It is possible to pick morphotypes somewhat resembling *'G'. stellapolaris* in the Kimmeridgian Tojeira Formation at Montejunto, Portugal. But these specimens do not have large pores or the type of reticulate wall surface, as '*G'. stellapolaris* is described with. Such Montejunto specimens somewhat resembling '*G'. stellapolaris* are aberrant, dwarfed and stunted specimens of *C. helvetojurassica* or of *C. grigelisi*. These specimens mostly have a bulla, with one or two apertures that obscures the primary aperture. We consider that such specimens belong in the natural, albeit gerontic variation of the two *Conoglobigerina* taxa.

Similarly, Görög and Wernli (2013, fig. 4.14) found a single specimen of *Compactogenerina stellapolaris* in Lower Kimmeridgian strata of the Jura Mountains, France. Unfortunately, Kimmeridgian sample processing was with acid, destroying wall texture. The specimen has a bulla hiding the aperture and what looks like resorbed wall distorting the shape of the last two chambers. The wall structure appears different from that shown by the metatypes of *C. stellapolaris* in Simmons et al. (1997). It may be an aberrant specimen of another taxon.

This brings me to the important issue that the types of '*G'. stellapolaris* show a partly recrystallized and strongly reticulate wall surface pattern. In June 2016, the author and L. Kopaevich (Moscow) visited A. Grigelis in Vilnius for the purpose of studying both *G. oxfordiana* and the types of '*G'. stellapolaris*. The holotype of the latter looks very compact, with a coarse reticulate wall, and might readily be confused with Late Cenozoic *Neogloboquadrina*

pachyderma (Ehrenberg), if no Jurassic ammonite data were supporting its sampling.

Two samples without ammonite control of the same (and very thin) Volgian levels in the type area of Pizhma were kindly loaned by Grigelis to the author and studied in detail in Oslo, Norway. It turned out that the benthic foraminifera assemblage in these two samples (15/207 and 15/211) contains common specimens of what appear to be *Reticulophragmium* sp. (of a type well known from the Late Cenozoic of the central North Sea). Other specimens may be referred to *Budashevaella multicamerata* Voloshinova, well known from Cenozoic strata. There also is an abundance of a smooth, rather sharp conical and pointed *Epistomina* and rare foraminiferal genera not readily known from Jurassic strata. The *Epistomina* genus could be Jurassic, but could also be (much) younger; it does not resemble Jurassic E. *praetatariensis* or *E. ulighi* reported from the Volgian of Russia. Six specimens of planktonic foraminifera are also present in the slides. One specimen might be a heavily calcified *Orbulina universa* and the others look mostly like *Neogloboquadrina pachyderma*.

As a final comment, Fig.15.2, 4, 6 and 8 feature the types of '*Globuligerina' stellapolaris* (Grigelis) in juxtaposition with *Neogloboquadrina pachyder*ma (Ehrenberg) on Fig. 15.1, 3, 5 and 7. The latter is from the Recent in oceanic environments. The morphological resemblance is remarkable and cannot be mistaken. Although this type of comparison is not a thorough scientific exercise, it further highlights that '*G'. stellapolaris* and its original deposits and fossil content need detailed study. A. Grigelis communicated to Gradstein in December 2016 that he is looking into the geology of the original location of the taxon. Nannofossil study of relevant samples might also be useful.

Acknowledgements Many earth science colleagues and students have been helpful with creating and executing this taxonomic study: Andrew Gale (Portsmouth, UK), Anna Waskowska and Slawomir Bebenek (Krakow, Poland), Ludmila Kopaevich (Moscow, Russia), Larisa Glinskikh (Novosibirsk, Russia), Algimantas Grigelis (Vilnius, Lithuania), Mike Simmons (Oxford, UK), John and Gregory Whittaker (London, UK), Gabi Ogg (West Lafayette, USA), Walter Etter, Christian Meyer, Michael Knappertsbusch and Evi Bieler (Basel, Switzerland), Maria Rose Petrizzo (Milano, Italy), Brian Huber (Washington, USA), Agnes Görög, (Budapest, Hungary), Giovanni and Vakaré Borgo (Sao Leopoldo, Brazil), Martin Gibling and Darlene van Rijt (Halifax, NS, Canada) and Kate Jarrett (Dartmouth, NS, Canada). I thank them all very much. Chief editor Marty Daniel of the Swiss Journal of Palaeontology and two anonymous reviewers provided much appreciated advice to get the manuscript in final shape for publication.

References

Agterberg, F.P., Gradstein, F.M.,& Nazli, K. 1989. Correlation of Jurassic microfossil abundance data from the Tojeira sections. Portugal. Geol. Survey Canada, Paper 89-9, 467–482

Banner, F. T., & Desai, D. (1988). A review and revision of the Jurassic-Early Creteaceous Globigerinina, with special reference to the Aptian assemblages of Speeton (North Yorkshire, England). *Journal of Micropalaeontology, 7*(2), 143–185.

Bignot, G. & Guyader, J. 1971. Farenacci, A., (ed). Proc. II Planktonic Conference, Roma, 1970, pp. 79–83.

Gorbachik, T.N. 1983. *Globuligerina oxfordiana* (Grigelis)—a typical species of the genus *Globuligerina* in electron microscope. *Akad. Nauk. SSSR, 26*, 48–51+6 plates.

Gorbachik, T.N., 1986. Jurassic and Early Cretaceous Planktonic Foraminifera of the southern USSR. *Akademia Nauk SSSR*, 'Nauka', Moscow, pp. 239. **(in Russian)**.

Gorbachik, T. N., & Kuznetsova, K. I. (1986). Study of shell mineral composition of planktonic foraminifera. *Voprosy Mikropaleontologii, 28,* 42–44.

Görög, A., & Wernli, R. (2013). Protoglobigerinids of the Early Kimmeridgian of the Jura Mountains (France). *Journal of Foraminiferal Research, 43*(3), 280–290.

Gradstein, F.M. 1976. Biostratigraphy and biogeography of Jurassic Grand Banks Foraminifera. First Int. Symp. Benthic Foraminifera, Pt. B. Maritime Sediments Spec. Publ. vol. 1, pp. 557–583.

Gradstein, F. M., in prep. The planktonic foraminifera of the Jurassic, Part III: Annotated Historical Review.

Gradstein, F., Gale, A., Kopaevich, L., Waskowska, A., Grigelis, A., & Glinskikh, L., in prep. The planktonic foraminifera of the Jurassic, Part I: Material and Taxonomy.

Grigelis, A. A. (1958). *Globigerina oxfordiana* sp.nov.–an occurrence of *Globigerina* in the Upper Jurassic strata of Lithuania. *Nauschny Doklady Vysschei Shkoly, Geologo-Geographicheskie Nauki, 3,* 109–111. **(in Russian)**.

Grigelis, A., & Gorbachik, T. (1980). Morphology and taxonomy of Jurassic and Early Cretaceous representatives of the superfamily Globigerinacea (Favusellidae). *Journal of Foraminiferal Research, 10*(3), 180–190.

Grigelis, A. A., Mesezhnikov, M. S., Yakovleva, S. P., & Kozlova, G. E. (1978). First find of planktonic Foraminifera in the Upper Jurassic deposits of the Pechora River Basin. *Translated from Doklady Akademii Nauk SSSR, 1977, 233*(5), 926–927.

Gygi, R. A., 1969. Zur Stratigraphie der Oxford-Stufe (oberes Jura–System) der Nordschweiz und des süddeutschen Grenzgebietes. Beiträge zur geologische Karte der Schweiz N. F., 136, 123pp.

Haeusler, R., 1881. Untersuchungen ueber die microscopischen Structurverhaeltnisse der Aargauer Jurakalke, mit besonderes Berueckschtigung ihrer Foraminiferenfauna. Diss. Univ. Zurich, pp. 47.

Haeusler, R. 1890. Monographie der Foraminiferen-Fauna der schweizerischen Transversarius-zone. *Abh. Schweiz. Palaeont. Ges. 17*, 134.

Hemleben, C., Spindler, M. & Anderson, O.R. 1989. Modern Planktonic Foraminifera (363pp., 107 figures). New York: Springer.

Huddleston, R. W. (1982). Comments on the nomenclatural status of the families Caucasellidae and Favusellidae (Foraminiferida). *Proceedings of the Biological Society of Washington, 95*(3), 637–638.

Kasimova, G. K., & Aliyeva, D. G. (1984). Planktonic foraminifera of the Middle Jurassic beds of Azerbaijan. *Voprosy Paleontologii I Stratigrafii Azerbaijana, 479,* 8–19. **(in Russian)**.

Kuznetsova, K.I. & Uspenskaya, Ye.A., 1980. New finds of planktonic Foraminifera in the Upper Jurassic deposits of the Crimea. *Translated from Doklady Akad. Nauk.SSSR, 1980, 254(3)*, 748–752.

Morozova, V. G., & Moskalenko, T. A. (1961). Foraminifères planktoniques des depots limitrophes du Bajocien et du Bathonien du Daghestan central (Nord-East du Caucase). Translated from Voprosy Mikropaleontol. *SSSR, 5,* 3–30.

Oesterle, H. (1968). Foraminiferen der Typlokalitat der Birmenstorfer-Schichten, unterer Malm. *Eclogae Geologicae Helvetiae, 61*(2), 695–792.

Pazdrowa, O., 1969. Bathonian *Globigerina* of Poland. Rocznik Polskiego Towarz. *Geology39 (1–3)*, 41–56+plates.

Simmons, M.D., Boudagher-Fadel, M.K., Banner, F.T. & Whittaker, J.E. 1997.The Jurassic Favusellacea, the earliest Globigerina.In:Boudagher-Fadel, M.K., Banner, F.T. & Whittaker, J. E. The early evolutionary history of planktonic Foraminifera. Publ. British Micropal. Soc. Publ. Series (pp. 17–53). London: Chapman & Hall.

Stam, B. (1986). Quantitative analysis of Middle and Late Jurassic Foraminifera from Portugal and its implications for the Grand Banks of Newfoundland. *Utrecht Micropaleontology Bulletin, 34,* 167.

Wernli, R. (1987). Les protoglobigerines (Foraminifers) du Bajocien inferieur des sofs (Rif, Maroc). *Eclogae Geologicae Helvetiae, 80*(3), 817–829.

Wernli, R. (1988). Les protoglobigerines (foraminifers) du Toarcien et de L'Aalenien du Domuz Dag (Taurus Occidental, Turquuie). *Eclogae Geologicae Helvetiae, 81*(3), 661–668.

Wernli, R., & Görög, A. (2007). Protoglobigérines et Oberhauserellidae (Foraminifères) du Bajocien-Bathonien du Jura méridional, France. *Révue de Micropaléontologie, 50,* 185–205.