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Globigerina ciperoensis (Foraminiferida) in the Oligocene and Miocene of the Central Paratethys.

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(With 1 textfigure, 4 plates and 2 appendices)

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Abstract

An analysis of five-chambered globigerinas of the *G. ciperoensis*-group and related forms from the Oligocene and Miocene of the Central Paratethys shows that, by applying a strict species concept including morphometric analysis, it is possible to distinguish a series of different morphospecies. During the Oligocene the central type *Globigerina ciperoensis* BOLLI is present, accompanied by *G. angulisuturalis* BOLLI, and *G. angulioffícinalis* BLOW. The microperforate "*Globigerina*" *angustiumbilicata* BOLLI is excluded from the *ciperoensis*-group; it has been selected as the typespecies of the genus *Tenuitellinata* by LI QIANYU.

In the lower Miocene the *ciperoensis*-group becomes relatively variable. In the Central Paratethys *Globigerina ottnangiensis* RÖGL, *Globigerina dubia* EGGER (not very common) and *G. angulioffícinalis* BLOW are present. *Globigerina* cf. *pseudociperoensis* BLOW occurs in the late early Miocene (Karpatian). A distinctly new group appears together with this species, *Globigerina concinna* REUSS, a very large species with a wide and open umbilicus.

Similar large forms are present in the early – middle Oligocene (Kiscellian) of the Alpine – Carpathian foredeep in the Paratethys: *Globigerina wagneri* n. sp. and *Globigerinella megaperta* n. sp. Both species exhibit about 5–6 chambers in the final whorl, and occasionally aberrant, sacklike chambers during ontogeny. This is interpreted to reflect abnormal palecological conditions which existed during the formation of the Paratethys.

Keywords: planctonic foraminifera, taxonomy, *Globigerina ciperoensis* BOLLI, *Globigerina wagneri* n.sp., *Globigerinella megaperta* n.sp., biostratigraphy, Oligocene, Miocene, Central Paratethys, Middle Europe.

Zusammenfassung

Die Entwicklung fünfkammeriger Globigerinen des Formenkreises von *Globigerina ciperoensis* BOLLI und ähnlicher Arten im Oligozän und Miozän der Zentralen Paratethys wurde untersucht. Es zeigt sich, daß eine eng begrenzte Artendefinition notwendig ist, um die zahlreichen Morphotypen zu separieren und ihre stratigraphische Abfolge erkennen zu können. Ausgehend von den Faunen der Typlokalitäten in Trinidad wird *Globigerina*

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ciperoensis genauer definiert. Es handelt sich dabei um eine Art, die eine regelmäßige Kammerzunahme und damit verbunden eine fast kreisförmige Peripherie besitzt; in jeder Windung sind 5 kugelige, gut voneinander getrennte Kammern vorhanden. Die Apertur liegt umbilikal, über einem offenen Umbilikus. Neben der Gehäusemorphologie wurde eine morphometrische Auswertung der größten Gehäusedurchmesser herangezogen, um die anderen fünfkammerigen Arten separieren zu können. *G. ciperoensis* ist in der Zentralen Paratethys durchschnittlich kleiner als in der Karibik.

Eine ähnliche Gehäusemorphologie besitzt *Globigerina angulisuturalis* BOLLI mit einem geringeren Gehäusedurchmesser, eng aneinanderschließenden Kammern und markanten, tief eingeschnittenen, U-förmigen Suturen. Parallel dazu erscheint durchlaufend im ganzen Oligozän, aber auch noch im Untermiozän *Globigerina angulofficinalis* BLOW. Diese Art unterscheidet sich dadurch, daß die Suturen ebenfalls tief eingeschnitten, aber nicht breit U-förmig sind, und außerdem der Umbilikus sehr klein ist. *„Globigerina" angustiumbilicata* BOLLI gehört zu den mikroperforaten planktonischen Foraminiferen und ist die Typusart des Genus *Tenuitellinata* LI QIANYU.

Im Untermiozän der Paratethys setzt sich die *ciperoensis*-Gruppe mit *Globigerina ottnangiensis* RÖGL fort. Sie hat kugelige Kammern, dadurch eine lobate Peripherie, aber im Unterschied zu *G. ciperoensis* eine in Größe und Position sehr variable Endkammer. Die innersten Windungen bestehen aus sehr kleinen, eng anschließenden Kammern und bilden eine flache Spira. Durch eine deutlich hoch-trochospirale Aufrollung und eine meist gegen den Umbilikus geneigte Endkammer unterscheidet sich die im gleichen Zeitbereich auftretende *Globigerina dubia* EGGER. Als jüngste Form des *ciperoensis*-Kreises erscheint im höheren Untermiozän *Globigerina* cf. *pseudociperoensis* BLOW. Sie hat einen weiten, offenen Umbilikus und im Gegensatz zu den anderen Arten eine vierkammerige vorletzte Windung, in einer Anordnung wie bei *Globigerina praebulloides* BLOW.

Einem neuen Formenkreis der fünfkammerigen Globigerinen gehört *Globigerina concinna* REUSS an, die ab dem Karpatien auftritt. Sie besitzt ein wesentlich größeres Gehäuse, 5–6 aufgeblähte, kugelige Kammern in der letzten Windung und einen weiten, offenen Umbilikus. In diesen münden die letzten 2–3 Kammern.

Eine neue, ebenfalls sehr große Art wird aus dem Unter- bis Mitteloligozän der Alpen-Karpatenvortiefe (von den Prealps bis in die Waschbergzone) beschrieben: *Globigerina wagneri* n.sp. Sie besitzt im letzten Umgang 5–6 aufgeblähte, kugelige Kammern in lockerer Aufrollung; die letzte Kammer variiert in Größe und Lage; nicht selten treten aberrante, sackförmige Kammern auf. Im vorletzten Umgang sind nur vier, deutlich abgesetzte Kammern vorhanden. Die letzten 2–3 Kammern münden in einen sehr weiten, offenen Umbilikus; die Apertur bildet einen weiten Bogen ohne Lippe. Die Wandtextur ist spinos, nicht cancellat, entsprechend dem *G. bulloides*-Typus.

Im gleichen stratigraphischen Horizont findet sich noch eine zweite große Form, die häufig aberrante Kammerbildungen aufweist: *Globigerinella megaperta* n. sp. Diese Art besitzt ein pseudo-planspirales Gehäuse mit einer kleinen, etwas unregelmäßigen (streptospiralen) Anfangswindung. Die Kammern des letzten Umganges sind wesentlich größer, aufgebläht kugelig, deutlich voneinander getrennt. Der Umbilikus ist weit und offen, die Apertur der letzten Kammer hoch, asymmetrisch äquatorial, mit einem wulstförmigen Rand. Die Wandtextur ist spinos, die Kammerwand glatt, nicht cancellat.

Das Auftreten der großen Formen *G. wagneri* und *Gl. megaperta*, die meist pyritgefüllt sind, wird mit den extremen palökologischen Bedingungen (Kaltwassereinfluß und dysaerobe Bodenverhältnisse) im Unter- bis Mitteloligozän, am Beginn der Paratethys in Zusammenhang gebracht.

Schlüsselwörter: Planktonische Foraminiferen, Taxonomie, *Globigerina ciperoensis* BOLLI, *Globigerina wagneri* n.sp., *Globigerinella megaperta* n.sp., Biostratigraphie, Oligozän, Miozän, Zentrale Paratethys, Mitteleuropa.

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Introduction

The marine strata of the Paratethys are characterized by *Globigerina* assemblages with globorotalias restricted to distinct horizons. This pattern resulted from palecological and paleogeographical conditions of this Central European epicontinental sea which was situated between the Eurasian platform and the Alpine tectonic realm.

Primarily the Paratethys bioprovince which exhibits strong endemisms corresponds to the Neogene sea between the Rhone valley in the west and the Lake of Aral in the east (LASKAREV 1924). In this study the central part of the Paratethys between eastern Bavaria and the Black Sea is considered. The geological history of the Paratethys begins at the Eocene – Oligocene boundary (BALDI 1980; RÖGL & STEININGER 1983). In the final stage of the Tethys Ocean the Paratethys Sea was separated from the Mediterranean and Indo-Pacific by the rising Alpine-Himalayan mountain range. West-east stretching troughs existed throughout the Oligocene and early Miocene. In the middle Miocene intramontane basins (e.g. Pannonian Basin) opened. The connection to open seas are intermittent to the Mediterranean, Indo-Pacific or northern seas, depending on tectonic activities. The environment in the earlier Oligocene was strongly influenced by restricted circulations, dysaerobic deep-water conditions, and cold water influx from the North Sea. During the late Oligocene and the Miocene short-term connections opened repeatedly to the Indopacific, whereas seaways to the Mediterranean existed most of the time.

In the middle Oligocene a horizon of large globigerinids occurs both in the Paratethys and in the Caribbean. The five-chambered globigerinas in this horizon have led to a more intensive investigation of all species related to *Globigerina ciperoensis* BOLLI. The stock of *G. ciperoensis* continues from the Oligocene to the middle Miocene, varying in morphologic details. The discrimination of morphospecies within the *G. ciperoensis* group may prove useful in stratigraphy.

Systematics

Order Foraminiferida EICHWALD, 1830

Superfamily Globigerinacea CARPENTER, PARKER & JONES, 1862

Family Globigerinidae CARPENTER, PARKER & JONES, 1862

Subfamily Globigerininae CARPENTER, PARKER & JONES, 1862

Genus *Globigerina* d'ORBIGNY, 1826

Globigerina ciperoensis BOLLI, 1954

(Pl. 1, Figs. 1–3; Pl. 4, Fig. 1)

1945 *Globigerina* cf. *concinna* REUSS – CUSHMAN & STAINFORTH: 67, pl. 13, fig. 1.
1954 *Globigerina ciperoensis* nov. spec. – BOLLI: 1, text-figs. 3–4.
1957 *Globigerina ciperoensis ciperoensis* BOLLI – BOLLI: 109, pl.22, figs. 10 a–b.
1962 *Globigerina ouachitaensis ciperoensis* BOLLI – BLOW & BANNER: 90, pl. IX, figs. E–G.
1985 *Globigerina ciperoensis ciperoensis* BOLLI – BOLLI & SAUNDERS: 182, pl.–fig. 13, figs. 1–3.

Diagnosis: The species is characterized by a relatively small size of about 0.3 mm in diameter, a relatively low trochospiral test, and 5 chambers in the final whorl which gradually increase in size. The chambers of the earlier whorls are distinct and well separated with 5 per whorl. The umbilicus is large, open, pentagonal in shape, with a distinct umbilical aperture. The wall is non-cancellate spinose.

Remarks: BOLLI (1954) demonstrated that the difference between *G. ciperoensis* and *G. concinna* REUSS was related to size. BLOW & BANNER (1962) derive *G. ciperoensis* from *Globigerina ouachitaensis* HOWE & WALLACE, and give it the status of a subspecies. In this study the different small five-chambered forms are treated as distinct species. A morphometric analysis of largest diameters is given in Appendix 1.

The type of *G. ciperoensis* is restricted from the Oligocene to the lowermost Miocene. Several morphotypes of this species appear in the early Miocene and are herein described as different regional species. In the Central Paratethys typical *G. ciperoensis* with a distinct intraumbilical position of the aperture and a circular periphery are not very common.

Stratigraphic range: The holotype is described from the *Globigerina ciperoensis* zone in the Cipero section, Trinidad. The stratigraphic range in the Caribbean is reported from the *Globigerina ampliapertura* to the *G. ciperoensis* zone (BOLLI 1957). BLOW (1969) has reported a range from zone N 3 (= P 22) to N 5. In the Central Paratethys it occurs from the Kiscellian to the late Egerian.

Investigated material: Trinidad, Cipero Coast (Cipero formation, coll H.M. BOLLI nos. 364, 408); drill sites, Upper Austrian Molasse Basin; Ottenthal, Lower Austria, Waschberg unit (Ottenthal no.138, farm yard L. Hauer, coll. F. RÖGL).

Globigerina angulisuturalis BOLLI, 1957

(Pl. 1, Figs. 5–6)

1957 *Globigerina ciperoensis angulisuturalis* BOLLI, new subspecies – BOLLI: 109, pl. 22, figs. 11a–c.
1962 *Globigerina angulisuturalis* BOLLI – BLOW & BANNER: 84, pl. IX, figs. Aa–Cc.
1985 *Globigerina ciperoensis angulisuturalis* BOLLI – BOLLI & SAUNDERS: 182, pl.-fig.13, figs. 4–7.

Diagnosis: *Globigerina angulisuturalis* is a very distinct short-ranging species, similar in outline to *G. ciperoensis* s.str.; five chambers in the final whorl, circular peripheral outline, about 0.25 mm in diameter; rather low trochospire, and deeply incised, U-shaped straight sutures.

Remarks: Determination of this species is often too broad, including also *Globigerina angulioffícinalis* BLOW (see below).

Stratigraphic distribution: In the Caribbean from the *G. opima* to the *G. ciperoensis* zone, Oligocene (BOLLI 1957). According to BLOW (1969) the species ranges from zone N 2 (= P 21) to within N 4. It is rare in the Paratethys, in the upper Kiscellian (middle Oligocene).

Investigated material: Trinidad, Cipero Coast (Cipero formation, coll. H.M. BOLLI no. 364); Trinidad Oropuche area (coll. J.P. BECKMANN no. G.152); Ottenthal, Lower Austria, Waschberg unit (farm yard L. HAUER, Ottenthal no.138, coll. F. RÖGL; type section coll. R. BRAUNSTEIN, sample +8.20 m Rögl).

Globigerina angulioffícinalis BLOW, 1969

(Pl. 1, Figs. 7–10)

1969 *Globigerina angulioffícinalis*, n. sp. – BLOW: 379, pl.11, figs. 1–5.
1985 *Globigerina angulioffícinalis* BLOW – BOLLI & SAUNDERS: 182, pl.-fig. 13, figs. 10–11.
1987 *Globigerina angulioffícinalis* BLOW – REISER: 106, pl.14, figs. 5,9,10.

Diagnosis: Test small, diameter about 0.2 mm, relatively low trochospiral test, with four and half to five chambers in the final whorl. It is similar to *G. ciperoensis* but has distinct deeply incised sutures, less broad then in *G. angulisuturalis*. The umbilicus is small, not as open as in *G. ciperoensis*, and the aperture is a low arch. The wall texture is non-cancellate spinose.

Stratigraphic distribution: The holotype is from the lowest part of the Cipero formation in Trinidad (lower Oligocene); occurring from P 17 (upper Eocene) to N 2 (= P 21), BLOW (1969). At ODP sites it is reported by SPEZZAFERRI (1992) from P 19 to N 4b (early Miocene). This stratigraphic range agrees with the Paratethys distribution, from the Kiscellian to Eggenburgian.

Investigated material: Trinidad, Cipero coast (Cipero formation, coll. H.M. BOLLI no.364); Ottenthal, Lower Austria, Waschberg unit (type section , coll. R. BRAUNSTEIN, sample +8.20 m Rögl); Michelstetten, Lower Austria, Waschberg unit (Michelstetten beds, coll. F. RÖGL); Pucking, Upper Austria, "Älterer Schlier" (Traunkraftwerke, coll. F. RÖGL); Galpiia, Rumania (Chechis clay, coll. N. SURARU).

Globigerina ottnangiensis RÖGL, 1969

(Pl. 1, Figs. 11–16; Pl. 4, Fig. 2)

1969 *Globigerina ciperoensis ottnangiensis* n. ssp. – RÖGL: 221, pl. 2, figs. 7–10; pl. 4, figs. 1–7.
1985 *Globigerina ciperoensis ottnangiensis* RÖGL – RÖGL: 321, pl.-fig. 5, figs. 5 a–d.
1987 *Globigerina ciperoensis ottnangiensis* RÖGL – WENGER: 319, pl. 20, figs. 4, 8–9.

Diagnosis: Small, low trochospiral test, with 13 to 18 chambers in two and half to three whorls; about 0.25 mm in diameter; 5 globular chambers in the final whorl; last chamber variable in size and position, sometimes directed towards the umbilicus. Inner whorls of the spiral side flat; innermost whorl with more then 5 small strongly appressed chambers. Umbilicus open; aperture a low umbilical arch without a distinct lip. Wall texture spinose non-cancellate.

Remarks: *G. ottnangiensis* is distinguished from *G. ciperoensis* by the flat initial whorls with numerous small, appressed chambers; the final chamber which changes in size and position; and the smaller test size. In *G. angulioffícinalis* the periphery is less lobate, the chambers are less globular, and the sutures are distinctly more incised. It is not conspecific with the species from the open oceans described by SPEZZAFERRI (1992:.116) as *"Globigerina" ottnangiensis*, which has a cancellate wall texture and probably belongs to the genus *Globoturborotalita*.

Stratigraphic distribution: In the Paratethys lower Miocene, Eggenburgian to Karpatian.

Investigated material: Eggenburgian: Ernstbrunn, Lower Austria, Waschberg unit, Ernstbrunn beds (old brickyard, coll P. GOTTSCHLING, F. RÖGL). Ottnangian: Plesching,

Upper Austria, Molasse Basin, Phosphorite sands (old sand pit, coll. F. RÖGL); Ottnang, Upper Austria, Molasse Basin, Ottnang Schlier (Schanze, coll. F. RÖGL); Finklham, Upper Austria, Molasse Basin, "Robulus-Schlier" (coll. H. STRADNER HS 78/90b); Maierhof near Ortenburg, Bavaria, Molasse Basin, Neuhofen beds (coll. RAG excursion); Neustift near Vilshofen, Bavaria, Molasse Basin, Neuhofen beds (coll. F. STEININGER); Varpalota, Hungary (drill site V. 219, don. J. KOKAY). Karpatian: Cebovce, Slovakia (clay pit north of the village, coll. F. RÖGL).

Globigerina dubia EGGER, 1857

(Pl. 1, Figs. 17–19)

1857 *Globigerina dubia* nov. spec. – EGGER: 281, pl. 9, figs. 7–9.
1985 *Globigerina dubia* EGGER – RÖGL: 321, pl.- fig. 5, fig. 1.
1987 *Globigerina dubia* EGGER – WENGER: 320, pl. 20, figs. 5–7.

Diagnosis: Small, about 0.25 mm in diameter; high trochospiral test; 5 inflated chambers in the last and prelast whorl; earliest whorl flat with more then 5 small chambers; final chamber commonly directed towards the umbilicus; umbilicus small and deep; aperture umbilical, without a lip; periphery lobate, sutures incised; wall texture as in *G. bulloides*.

Remarks: This species is similar to *G. ottnangiensis*, but is distinguished by the high trochospiral test.

Distribution: Paratethys: lower Miocene, Eggenburgian to Karpatian; rather rare occurrence.

Investigated material: Eggenburgian: Ernstbrunn, Lower Austria, Waschberg unit, Ernstbrunn beds (old brickyard, coll. P. GOTTSCHLING); Ottnangian: Dorf near Frankenburg, Upper Austria, Molasse Basin, Ottnang Schlier (old clay pit, coll. F. RÖGL); Zwickledt near Schärding, Upper Austria, Molasse Basin, "Blättermergel" (coll. O. SCHULTZ); Neustift near Vilshofen, Bavaria, Molasse Basin, Neuhofen beds (coll. F. STEININGER); Cebovce, Slovakia (clay pit north of the village, coll. F. RÖGL).

Globigerina cf. *pseudociperoensis* BLOW, 1969

(Pl. 1, Figs. 20–22; Pl. 4, Fig. 3)

1969 *Globigerina praebulloides pseudociperoensis* n. subsp. – BLOW: 381, pl. 17, figs. 8–9.

Diagnosis: Test small, less then 0.3 mm in diameter, with 5 loosely coiled chambers in the final whorl. Spiral side with a low spire and chambers of the penultimate whorl in a *Globigerina praebulloides*-arrangement, in contrast to *G. ciperoensis* which has 5 chambers in the penultimate whorl. *G.* cf. *pseudociperoensis* has a deep rectangular open umbilicus, with open umbilical apertures in the last two chambers; *Globigerina* wall texture.

Remarks: This species differs from *G. ottnangiensis* in the wider open umbilicus, the umbilical apertures of the last two chambers, a *praebulloides*-arrangement of the penultimate whorl, and the larger test size. It differs from *G. ciperoensis* in the coiling of earlier whorls. The Paratethys species is similar to *G. pseudociperoensis* s. str., specially in the umbilical view; it does not always show the *praebulloides* coiling in the earlier whorls, which is typical according to BLOW (1969). Some individuals have four and half chambers in the penultimate whorl, whereas the innermost coil contains numerous small chambers.

Stratigraphic range: In the Central Paratethys this species occurs from the Karpatian to the middle Badenian, together with the other 5-chambered species, *G. concinna*. The corresponding observed range of BLOW (1969) is similar, the interval of N 7 to N 12.

Investigated material: Karpatian: Laa an der Thaya, Lower Austria, Molasse Basin (brick-yard, coll. F. RÖGL); Cebovce, southern Slovakia (clay pit N of the village, coll. F. RÖGL). Badenian: Wien-Grinzing, Vienna Basin (clays of Grinzing, coll. A.E. REUSS).

Globigerina concinna REUSS, 1850

(Pl. 1, Figs. 23–26; Pl. 2, Figs. 1–6)

1850 *Globigerina concinna* – REUSS: 373, pl. 47, figs. 8a–b.
1969 *Globigerina* cf. *concinna* REUSS – RÖGL: 95, pl. 8, figs. 2–4.
1978 *Globigerina concinna* REUSS – PAPP & al.: 270, pl. 1, figs. 12–14.
1985 *Globigerina concinna* REUSS – RÖGL: 321, pl.-fig. 4, figs. 17–20.

Diagnosis: Large, low trochospiral species with 5 inflated chambers in the final whorl, sometimes up to 6 chambers; test about 0.4–0.5 mm in diameter; chambers increasing gradually in size in the final whorl as well as in the earlier whorls; periphery lobate, chambers loosely arranged; sutures depressed, radial; the last 2–3 chambers open into a very large umbilicus which is elongate pentagonal in shape; aperture a low arch without a lip. Wall texture as in *Globigerina bulloides* d'ORBIGNY.

Remarks: As pointed out by BOLLI (1954) this species is distinctly different from the Oligocene *G. ciperoensis*. The large test size and the large and open umbilicus into which open some chambers of the final whorl are characteristic features. Commonly the position of the last two chambers is directed to a peripheral position, enlarging the umbilicus in an extraumbilical direction. In the Karpatian stage the species is generally somewhat smaller and has a large, elongated quadrangular umbilicus, with wider coiling of the last few chambers. This form is herein determined as *G.* cf. *concinna*. The species appears to have evolved from the *Globigerina bulloides* d'ORBIGNY – stock via *Globigerina diplostoma* REUSS. All these species appear in the Karpatian (*Globigerinoides bisphericus* zone). The appearance of this assemblage of large globigerinas may have been influenced by ecological conditions. A similar assemblage is observed in the Pleistocene of Cariaco Trench (RÖGL & BOLLI 1973) with a fauna of *Globigerina bulloides* d'ORBIGNY, *Globigerina* cf. *quadrilatera* GALLOWAY & WISSLER, and *Globigerina umbilicata* ORR & ZAITZEFF.

Distribution: In the Central Paratethys this species is common in the Karpatian and Badenian.

Investigated material: Karpatian: Laa an der Thaya, Lower Austria, Molasse Basin (brick-yard, coll. F. RÖGL); Cebovce, southern Slovakia (clay pit N of the village, coll. F. RÖGL). Badenian: Wien-Grinzing, Vienna Basin (clays of Grinzing, coll. A.E. REUSS); Wien-Nussdorf, Grünes Kreuz, Vienna Basin (*Amphistegina* marls, coll. K. GOHRBANDT, A.E. REUSS, F. RÖGL, and old samples of the museum collection); Baden – Sooss, Lower Austria, Vienna Basin (coll. F. RÖGL); Walbersdorf, Burgenland, Eisenstadt Basin (old brickyard, coll. F. RÖGL); Staropatica, western Bulgaria, Carpathian foredeep (coll. F. RÖGL); Wieliczka, Komora Poray, Poland, Carpathian foredeep (coll. F. RÖGL); Kynicky near Brno (= "Kinitz"), Moravia, Carpathian foredeep (coll. M. AUINGER, 19th cent.).

Globigerina wagneri n. sp.

(Pl. 2, Figs. 7–12; Pl. 3, Figs. 1–6; Pl. 4, Figs. 4–5)

Derivatio nominis: In honor of Dr. Ludwig WAGNER, Wien, for his subsurface studies of the Upper Austrian Molasse Basin, and his continuous interest in micropaleontology and stratigraphy.

Holotype: Pl. 2, figs. 7–9; pl. 4, figs. 4–5. – NHMWien Inv. no. 1994/26

Locality of holotype: water drill site Schallerbach 2, cuttings 460 m; Upper Austria, Molasse Basin.

Type level: middle Oligocene, lower Egerian, Lower Puchkirchen Formation.

Dimensions of holotype: maximum diameter 0.35 mm.

Description of holotype: Large, low trochospiral test, with 5 inflated chambers in the final whorl; 14 globular chambers in 2– whorls, gradually increasing in size, last chamber smaller then the penultimate one; penultimate whorl with 4 chambers; chambers loosely coiled, periphery lobate; sutures radial, deeply incised. Umbilicus very large, open, quadrangular elongated (not completly visible, filled with sediment); aperture a very low umbilical arch; penultimate chamber opens into the umbilicus. Wall spinose, as in Globigerina s. str. with spine holes, spine bases and inter-pore ridges in earlier chambers.

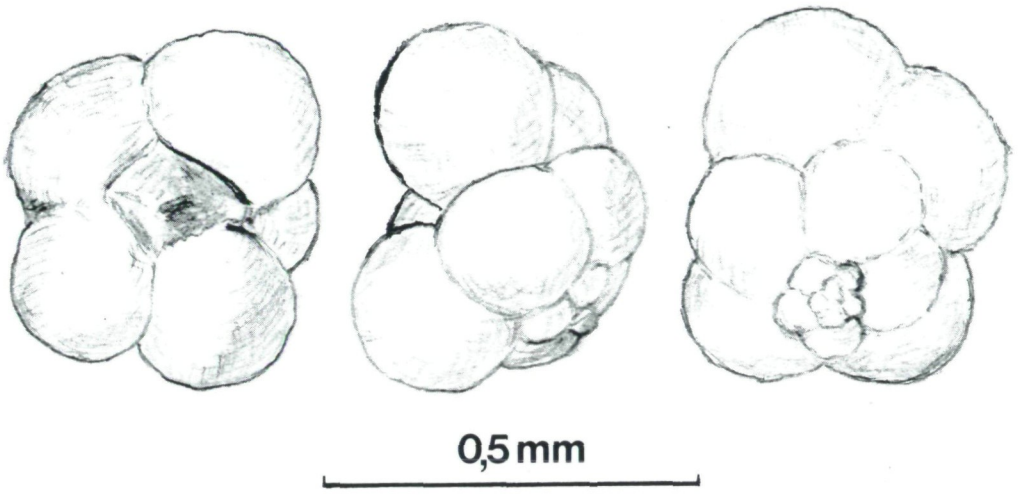
Paratypes: 149 specimens; average diameter 0.384 mm

Inv. nos. NHMWien 1994/27 – 33, 61–85 (141 specimens); additional paratypes are deposited in the Cushman Collection, Smithsonian Institution, Washington, and at The Natural History Museum, London.

General morphology: The size of the test varies between 0.28 and 0.56 mm, with an average diameter of about 0.4 mm. Generally all specimens exhibit a low trochospiral test with loosely coiled chambers; 4 – to 5 – chambers in the final whorl, and 4 chambers in the penultimate one; the umbilicus is always large and open, with the last 2–3 chambers opening into it; the last chamber may vary in size and in position relative to the umbilicus, resulting in a somewhat umbilical – extraumbilical aperture; the aperture is without a lip, but may contain a small imperforate band. In some specimens commonly the penultimate chamber is inflated, sacklike and transverse to the coiling direction.

Remarks: In a first comparison this species exhibits a relationship to *Globigerina fariasi* BERMUDEZ (1961), described from the middle Oligocene of Cuba. The latter species has a very high trochospiral test which is circular in outline; the holotype has a diameter of 0.4 mm. A sketch of the holotype is given in text-fig. 1. SPEZZAFERRI & PREMOLI SILVA (1992) record *G. fariasi* from zone P 22, late Oligocene in the Gulf of Mexico; but the specimen of Pl. IV, figs. 7a–b, named "*Globigerina*" *ciperoensis* BOLLI compares more closely to *G. fariasi*.

It is very interesting that a geographically wide-spread horizon of large globigerinids occurs in the middle Oligocene in the Central Paratethys and the Caribbean. *Globoquadrina globularis* BERMUDEZ (1961) and *Globoquadrina winkleri* (BERMUDEZ, 1961) also characterize this assemblage of large globigerinids. In the Austrian sites the specimens are commonly filled with pyrite or limonite, often preserved only as casts, as are the other larger faunal



Text-Figure 1. *Globigerina fariasi* BERMUDEZ, 1961. – Holotype. Cuba, Finca Adelina, Colón, Prov. Matanzas (Bermudez sta. 209), Tinguaro formation, middle Oligocene (BERMUDEZ 1961: 1181, pl. 3, figs. 5a–c); Cushman Collection, Washington, no. 638935.

elements. These large globigerinids are also observed in the same time interval in the Prealps, Haute Savoie, France (UJETZ & WERNLI, this volume).

The accompanying planktonic assemblage consists of *Globigerina ciperoensis* BOLLI, *Gg. labiacrassata* JENKINS, *Gg. officinalis* SUBBOTINA, *Gg. ouachitaensis* HOWE & WALLACE, *Gg. praebulloides* BLOW, *Globoquadrina globularis* BERMUDEZ, *Gq. winkleri* (BERMUDEZ), *Paragloborotalia opima opima* (BOLLI) (only in the upper part of distribution), *P. opima nana* (BOLLI), *Beella rohiensis* (POPESCU), *Tenuitella liverovskae* (BYKOVA). In addition, in the Kiscellian *Subbotina angiporoides* (HORNIBROOK), *S. cryptomphala* (GLAESSNER), *S. gortanii* (BORSETTI), and *S. praeturritillina* (BLOW & BANNER), appear. The benthic foraminifera fauna is characterized by the common occurrence of large inflated *Bulimina*, *Chilostomella*, *Allomorphina*, *Loxostomum chalkophilum*, *Cancris*, generally all pyritized, and non-pyritized *Uvigerina* (sometimes in floods). Pyritized casts of pteropods are common. To the East in continuation of the Alpine foredeep these large globigerinas are not observed, but otherwise a similar development is observed in the lower Oligocene of the Polish Carpathians (OLSZEWSKA 1985).

Stratigraphic distribution: Oligocene, Kiscellian to lower Egerian of the Central Paratethys. In the Upper Austrian Molasse Basin this species occurs in the "Bändermergel", "Rupel-Tonmergelstufe" and the Lower Puchkirchen formation; in the imbricated zone from the lower Oligocene upwards.

Investigated material: drill sites in the Upper Austrian Molasse Basin (Schallerbach-2, Hochburg-1, Perwang-1, Zupfing-1); counter-flash drill site CF-N6 in the imbricated zone; Ottenthal, Waschberg unit, Lower Austria (farm yard L. HAUER, Ottenthal no. 138, coll. F. RÖGL).

Genus *Globigerinella* CUSHMAN, 1927

***Globigerinella megaperta* n. sp.**

(Pl. 3, Figs. 7–13; Pl. 4, Fig. 6)

1987 *Globigerina ciperoensis* BOLLI, aberrante Formen – REISER: 109, pl. 15, figs. 12, 15.

Derivatio nominis: named after the large, open aperture; megas = old Greek for big; apertus = Latin for open.

Holotype: pl. 3, figs. 11–13; pl. 4, fig. 6. – NHMWien Inv. no. 1994/34.

Locality of holotype: water drill site Schallerbach-2, cuttings 350 m.

Type level: middle Oligocene, lower Egerian, Lower Puchkirchen formation.

Dimensions of holotype: maximum diameter 0.45 mm.

Description of holotype: Large, low trochospiral pseudo-planispiral test, with a somewhat depressed inner coil; 5 inflated chambers in the final whorl, increasing rapidly in size as added; altogether 11 chambers in two and half whorls. The chambers of the earlier whorls are small, arranged in a streptospiral coil. The last 4 chambers open into a very large, entirely open umbilicus. The aperture of the final chamber is high and open, interiomarginal, an asymmetrical equatorial arch, bordered with a thickened rim. Wall spinose, surface flat between the pores in the last two chambers, with interpore ridges in earlier ones.

Paratypes: 71 specimens; average diameter 0.45 mm, ranging from 0.31 to 0.60 mm. NHMWien Inv. nos. 1994/35–36, 86–102; additional paratypes are deposited in the Cushman Collection, Smithsonian Institution, Washington, and at The Natural History Museum, London.

General morphology: Large test with 5 to 6 chambers in the final whorl; in some specimens aberrant sacklike chambers, broader then long, occur in a last or penultimate position. The earlier whorls are very small compared with the terminal whorl, and somewhat streptospirally coiled. The wall texture is non-cancellate spinose, surface smooth between the pores in the latest formed chambers.

Remarks: This species occurs at the same level as *Globigerina wagneri* n. sp. It is interesting that in both species similar aberrant chambers occur. The preservation is similar, filled with pyrite or limonite, or as casts. The accompanying fauna is the same.

Globigerinella obesa (BOLLI) exhibits tighter regular coiling, globular chambers which increase in size as added, without aberrant chambers; the aperture is restricted to the final chamber.

Stratigraphic distribution: Oligocene (NP 23–24), Kiscellian to lower Egerian of the Central Paratethys; in the Upper Austrian Molasse Basin it occurs in the "Bändermergel", "Rupel-Tonmergelstufe" and the Lower Puchkirchen formation.

Investigated material: Drill sites in the Upper Austrian Molasse Basin (Schallerbach-2, Perwang-1, Eggerding-1, Zupfing-1); Ottenthal, Waschberg unit, Lower Austria (farm yard L. HAUER, Ottenthal no. 138, coll. F. RÖGL).

Family Globigerinitidae BERMUDEZ, 1961

Subfamily Globigerinitinae BERMUDEZ, 1961

Genus *Tenuitellinata* LI QIANYU, 1987

Tenuitellinata angustiumbilicata (BOLLI, 1957)

1957 *Globigerina ciperoensis angustiumbilicata* BOLLI, new subspecies – BOLLI: 109, pl. 22, figs. 12–13.
1969 *Globigerina angustiumbilicata* BOLLI – RÖGL: 219, pl. 1, figs. 14–15; pl. 3, figs. 7–8.
1987 *Tenuitellinata angustiumbilicata* (BOLLI) – LI QIANYU: 311, pl. 2, figs. 15, 17–19.

D i a g n o s i s : Very small, low trochospiral test, 5 chambers in the final whorl; chambers inflated; umbilicus small and shallow; aperture a low interiomarginal arch, often with a thin lip. Wall texture microperforate, surface smooth with small pustules. Probably non-spinose.

R e m a r k s : This wide spread species has been discussed in detail by LI QIANYU (1987). It is distinctly different from the *Globigerina ciperoensis* group by its wall texture. It is recorded from the Oligocene to the Pliocene.

S t r a t i g r a p h i c d i s t r i b u t i o n : In the Central Paratethys from Kiscellian to Badenian (Oligocene to middle Miocene). According to BOLLI & SAUNDERS (1985) from late Eocene (*T. cerroazulensis* zone) to early Miocene (*Catapsydrax dissimilis* zone).

Conclusions

A comparison of five-chambered species of *Globigerina* from the Oligocene to Miocene of the Central Paratethys shows that it is possible by using a strict species concept to distinguish a series of different morphotypes (Appendix 1–2) which have different stratigraphic ranges (Tab. 1).

The central species is *Globigerina ciperoensis* BOLLI from the Oligocene. It is characterized by a small test with a regular circular outline, and distinctly separated spherical chambers. The chambers of the earlier whorls are distinct and globular with 5 per whorl. *Globigerina angulisuturalis* BOLLI is very similar, but is characterized by deeply incised broad U-shaped sutures. *Globigerina angulioffícinalis* BLOW with tightly coiled, strongly appressed chambers, deeply incised narrow sutures, and a small umbilicus is a long ranging species covering the *G. ciperoensis* sensu lato pool.

Globigerina ottnangiensis RÖGL which appears in the early Miocene is tightly coiled with globular chambers which give a lobate periphery. The final chamber varies in size and in its position towards the umbilicus which is rather small and open. The flat multichambered initial spire of the test is characteristic. The lower Miocene species *Globigerina dubia* EGGER is distinguished by a high, tightly coiled trochospiral test, with a narrow umbilicus. These species are followed in the early-middle Miocene by *Globigerina* cf. *pseudociperoensis* BLOW which is characterized by a large open umbilicus, low trochospiral coiling, multichambered initial whorl, and a lobate periphery. It is distinguished from *G. concinna* by its small size (see Appendix 1).

The middle Miocene *Globigerina concinna* REUSS is distinctly larger then the *G. ciperoensis*-group and has 5–6 well separated, inflated globular chambers in the final whorl. Two to three chambers open into a wide umbilicus.

Another large form, *Globigerina wagneri* is described as new species from the early/middle Oligocene. It is loosely coiled, the terminal whorl consists of 5–6 globular chambers, the penultimate whorl is characterized by 4 chambers in a *praebulloides* arrangement. Two to three chambers of the final whorl open into a wide umbilicus with the final chamber varying in size and position towards the umbilicus. An aberrant, sacklike chamber is often present in the final whorl.

Another interesting new species from the middle Oligocene is *Globigerinella megaperta*. This species has a pseudo-planispiral test with 5–6 chambers in the final whorl, and a very large and open umbilicus. The aperture of the final chamber is a high asymmetrical equatorial arch; the last 3–4 chambers open into the umbilicus, and aberrant sacklike chambers are common. The coiling of the small earlier whorls is somewhat streptospiral.

The middle Oligocene horizon of large globigerinids which include the new species *Globigerina wagneri* and *Globigerinella megaperta* is interesting in context to the palecological conditions of the Paratethys. Extreme conditions resulted from the separation of the Paratethys from the open oceans during the early – middle Oligocene. Pure nanno-ooze and diatomites within dark clay and marls were deposited under widespread dysaerobic conditions (BALDI 1984, 1986; KOTLARCZYK & KACZMARSKA 1987; KRHOVSKY & al. 1991). These dysaerobic conditions occurred from the western Alps to Crimea. *Globigerina* assemblages with similar aberrant species, *Globigerina bermudezi* SEIGLIE and *G. megastoma cariacoensis* RÖGL & BOLLI, are observed in the modern Caribbean Sea in the Cariaco Basin. In the Cariaco Trough the water masses are influenced by cold water upwelling. Some cold water influx may have existed also in Kiscellian time in the Paratethys due to a connection with the northern seas (BALDI 1984), and marked climatic changes (HOCHULI 1978).

Table 1

Stratigraphic Distribution of the *Globigerina ciperoensis* Group in the Central Paratethys.

The absolute ages and correlation of planktonic foraminifera and nannoplankton zones is based on BERGGREN & al. (in press), and BERGGREN & MILLER (1988). The stratigraphic position of Paratethys stages and Molasse formations follows BALDI (1986), RÖGL & al. (1979), and STEININGER & al. (1990).

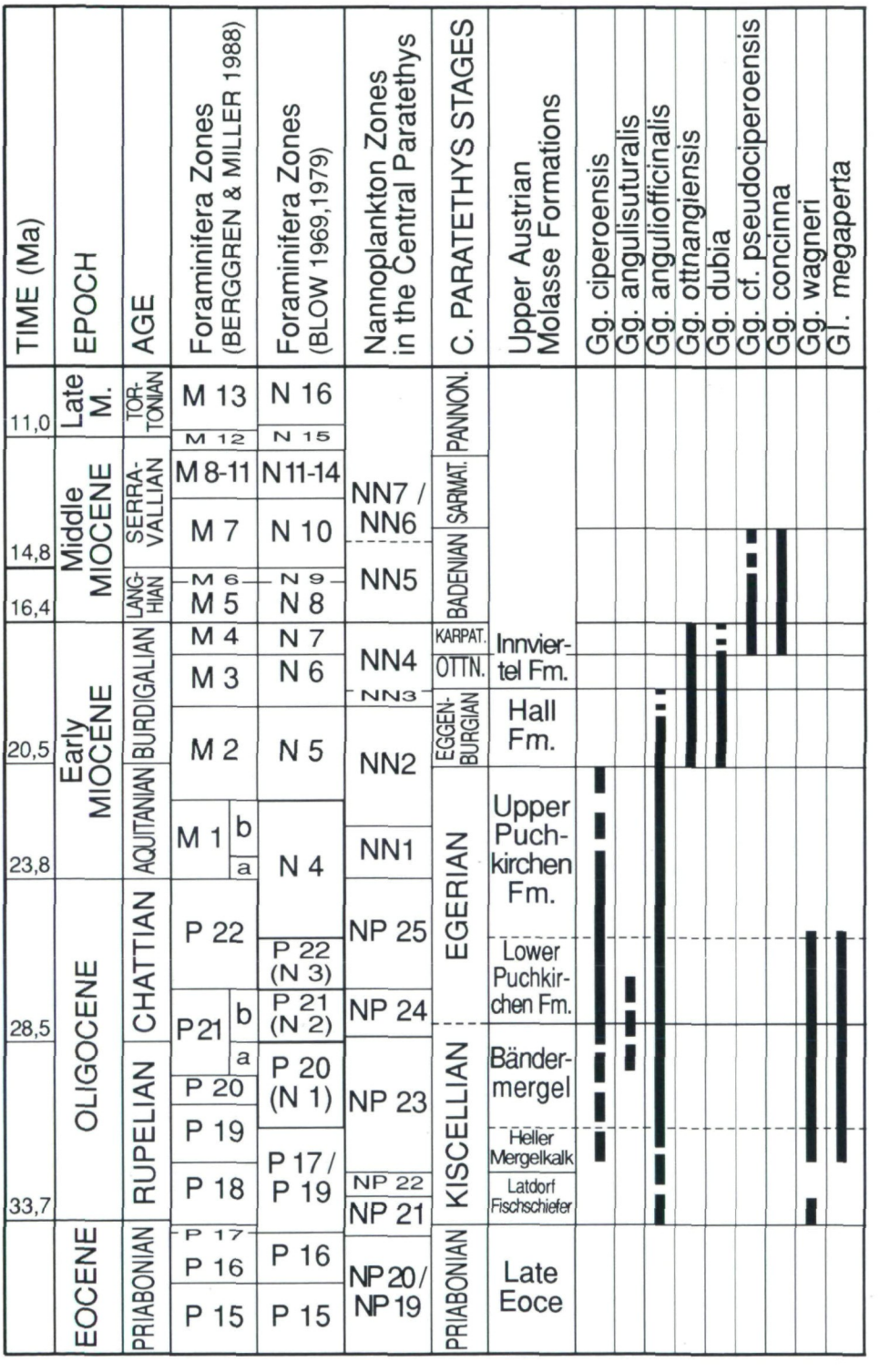


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Plate 1

Figs. 1–2: *Globigerina ciperoensis* BOLLI. Trinidad, Cipero section, Cipero formation. 1. *Globigerina ciperoensis* zone (sample J.P. BECKMANN BO-291A). 2. *Globorotalia opima opima* zone (sample H.M. BOLLI HMB 364); detail of spiral side at pl. 4, fig. 1.

Figs. 3–4: *Globigerina ciperoensis* BOLLI. Lower Austria, Ottenthal, farmyard L. HAUER; Waschberg unit, Kiscellian, nannoplankton zone NP 23 (sample F. RÖGL Rö 11–92).

Figs. 5–6: *Globigerina angulisuturalis* BOLLI, same specimen. Lower Austria, Ottenthal, SE of the village; Waschberg unit, Kiscellian, nannoplankton zone NP 23 (sample R. BRAUNSTEIN: Rögl +8.20 m).

Figs. 7–10: *Globigerina angulioffícinalis* BLOW. 7–8, same specimen. Lower Austria, Michelstetten, road to Pyhra, Michelstetten beds, late Egerian (sample E. KRESTA). 9–10. Upper Austria, Linz, Ebelsberg. building site Weikerlsee, "Fischschiefer", late Egerian (sample F. RÖGL Rö 1–78)

Figs. 11–16: *Globigerina ottnangiensis* RÖGL. 11–12, same specimen. Upper Austria, Kletzenmarkt, "Robulusschlier", Ottnangian, early Miocene (sample R. ROETZEL 49/10–1/90); detail of spiral side at pl. 4, fig. 2. 13. Upper Austria, Zwickledt near Schärding, "Blättermergel", Ottnangian, early Miocene (sample O. SCHULTZ). 14–16. Lower Austria, Parisdorf, diatomite quarry, late Ottnangian, early Miocene (sample R. ROETZEL no. 3); 14, 16 same specimen.

Figs. 17–19: *Globigerina dubia* EGGER. 17. Lower Austria, Ernstbrunn, old brickyard, Ernstbrunn beds, Eggenburgian, early Miocene (sample P. GOTTSCHLING). 18–19, same specimen. Upper Austria, Kletzenmarkt, "Robulusschlier", Ottnangian, early Miocene (sample R. ROETZEL 49/10–1/90).

Figs. 20–22: *Globigerina* cf. *pseudociperoensis* BLOW. 20–21, same specimen. Southern Slovakia, Cebovce, claypit N of the village, Karpatian, upper early Miocene (sample F. RÖGL 1966). 22. Austria, Wien, Grinzing, Tegel von Grinzing, Badenian, middle Miocene (sample A.E. REUSS); detail of spiral side at pl. 4, fig. 3.

Figs. 23–26: *Globigerina* cf. *concinna* REUSS. Lower Austria, Laa an der Thaya, brickyard, Laa beds, Karpatian, upper early Miocene; 23–24, same specimen; 25–26, same specimen (sample F. RÖGL).

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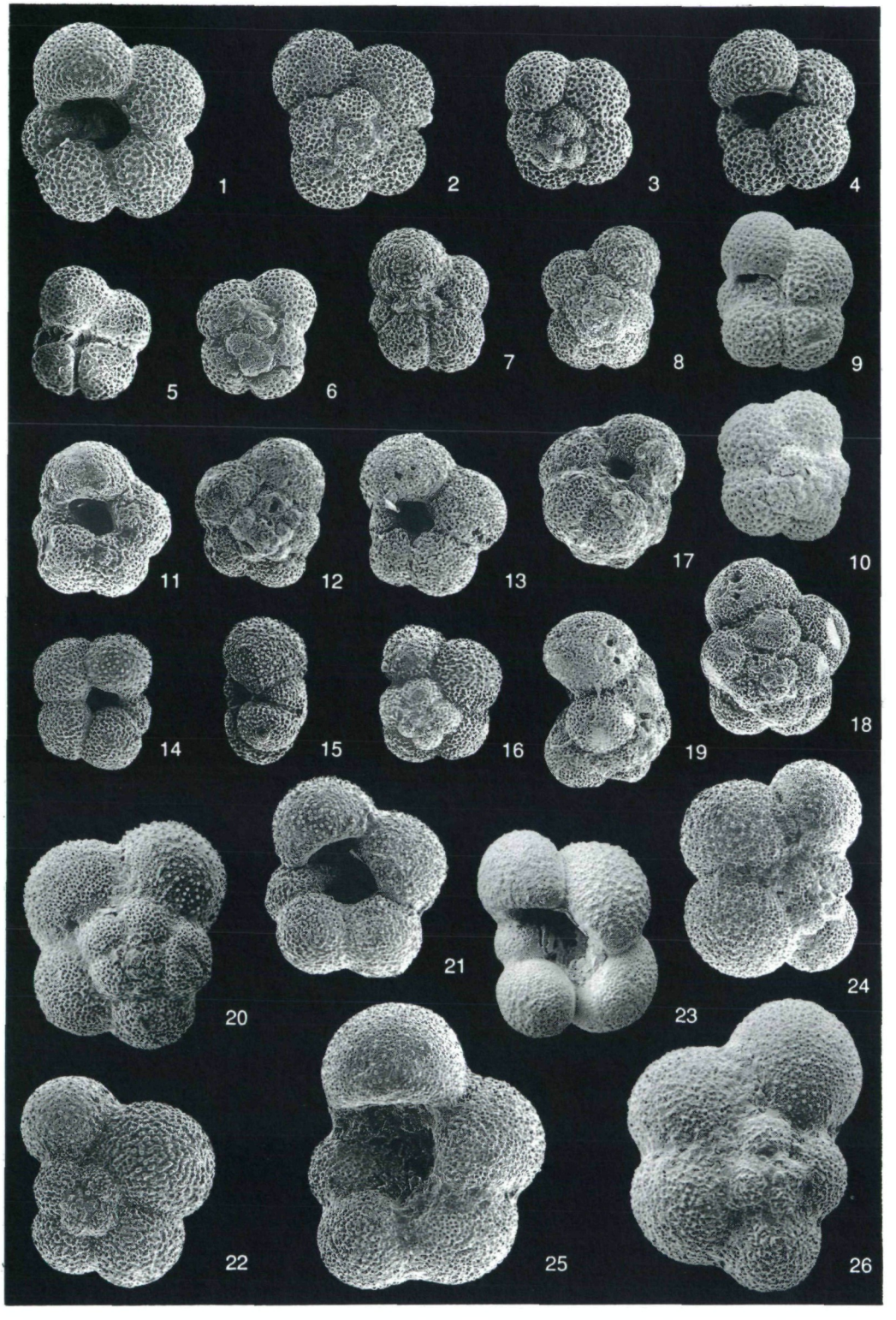


Plate 2

Figs. 1–6: *Globigerina concinna* REUSS. 1–3, same specimen. Austria, Wien, Nussdorf, Grünes Kreuz, *Amphistegina* marls, middle Badenian, middle Miocene (sample A.E. REUSS). 4–6. Lower Austria, Baden, Sooss, brickyard, Baden clays, early Badenian, middle Miocene (sample F. RÖGL, 1968, Terebratelbank).

Figs. 7–12: *Globigerina wagneri* RÖGL n. sp. 7–9. Holotype, Upper Austria, drill site Schallerbach-2 (460 m), Lower Puchkirchen Formation, Egerian, Oligocene. 10–12. Paratypes, Schallerbach-2 (320 m), as above; 10–11, same specimen.

Magnification 100x

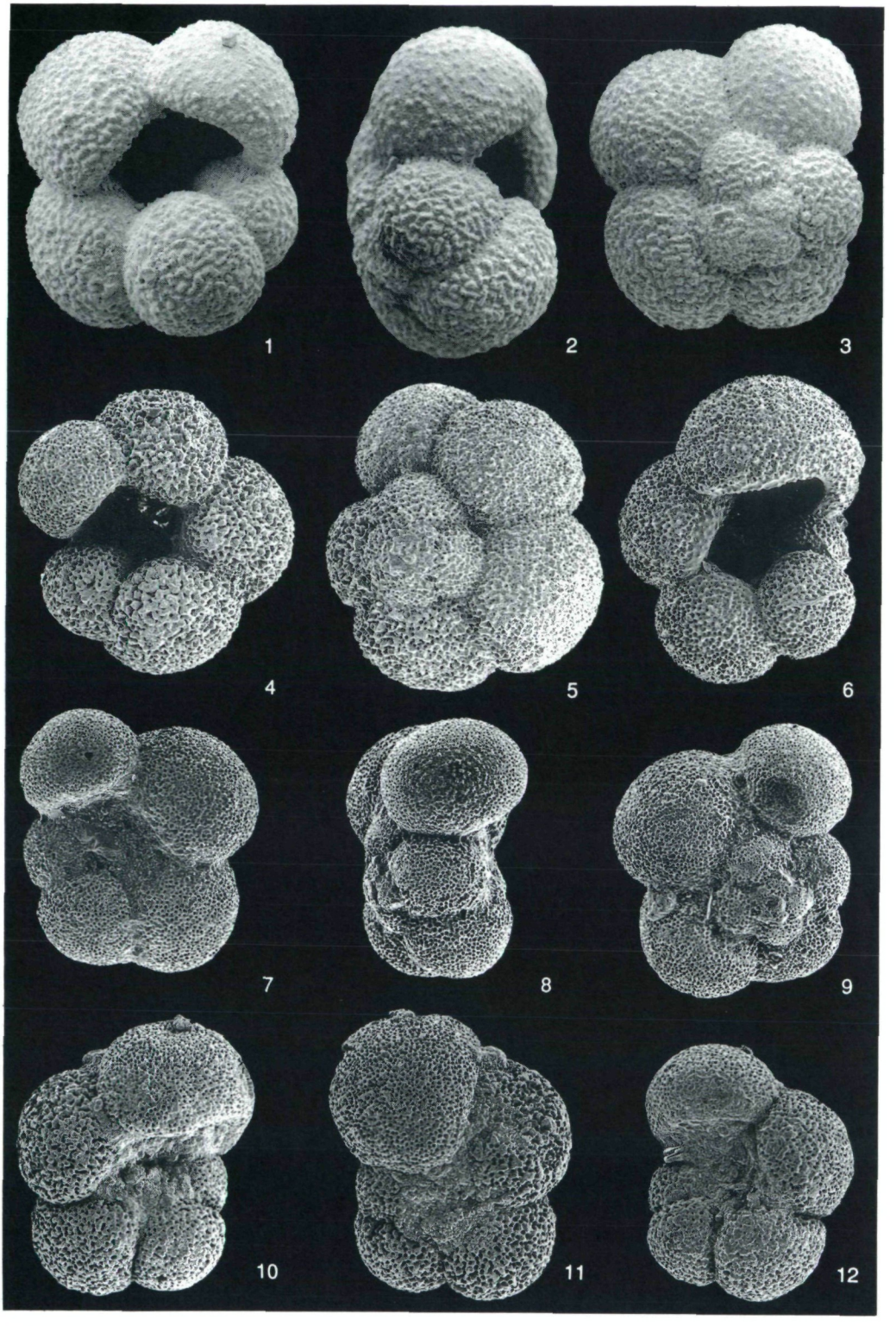


Plate 3

Figs. 1–6: *Globigerina wagneri* RÖGL n. sp., paratypes. 1–3. Lower Austria, Ottenthal, no.138, farmyard L. HAUER, Waschberg unit, Kiscellian, nannoplankton zone NP 23, (sample F. RÖGL, Rö 4-91); 4–5. Upper Austria, drill site Schallerbach-2 (370 m), Lower Puchkirchen Formation, Egerien. 6. Upper Austria, drill site Hocheck-1 (180 m), lowermost Upper Puchkirchen Formation, Egerian; figs. 1–2 same specimen. 4–5, same specimen.

Figs. 7–13: *Globigerinella megaperta* RÖGL n. sp. 7, paratype, Lower Austria, Ottenthal, no. 138 framyard L. HAUER, Waschberg unit, Kiscellian, nannoplankton zone NP 23 (sample RÖGL, Rö 12-92). 8–10, paratype, same specimen, Upper Austria, drill site Schallerbach-2 (320 m), Lower Puchkirchen Formation, Egerian. 11–13. Holotype, Upper Austria, drill site Schallerbach-2 (350 m), Lower Puchkirchen Formation, Egerian.

Magnification 100x

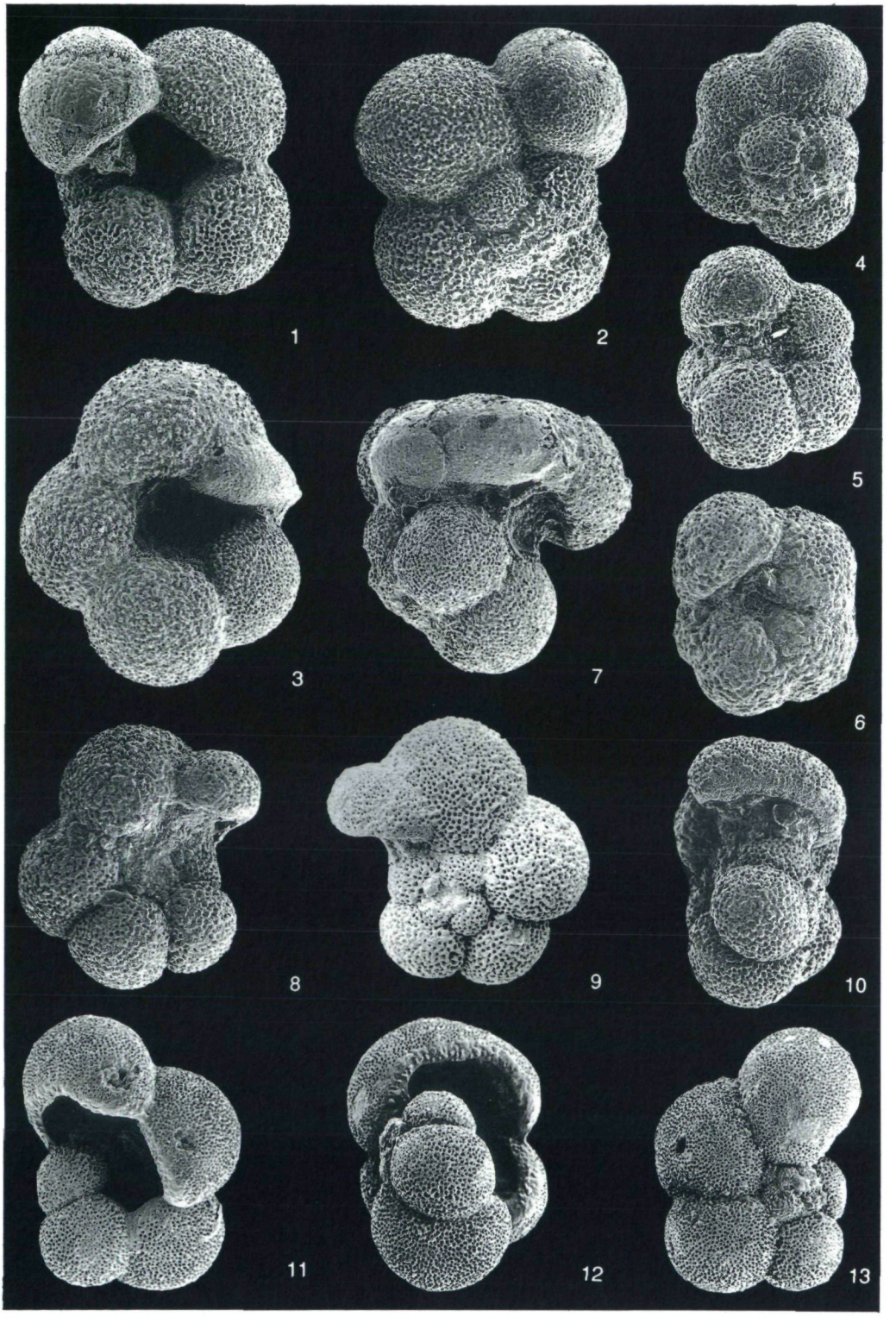


Plate 4

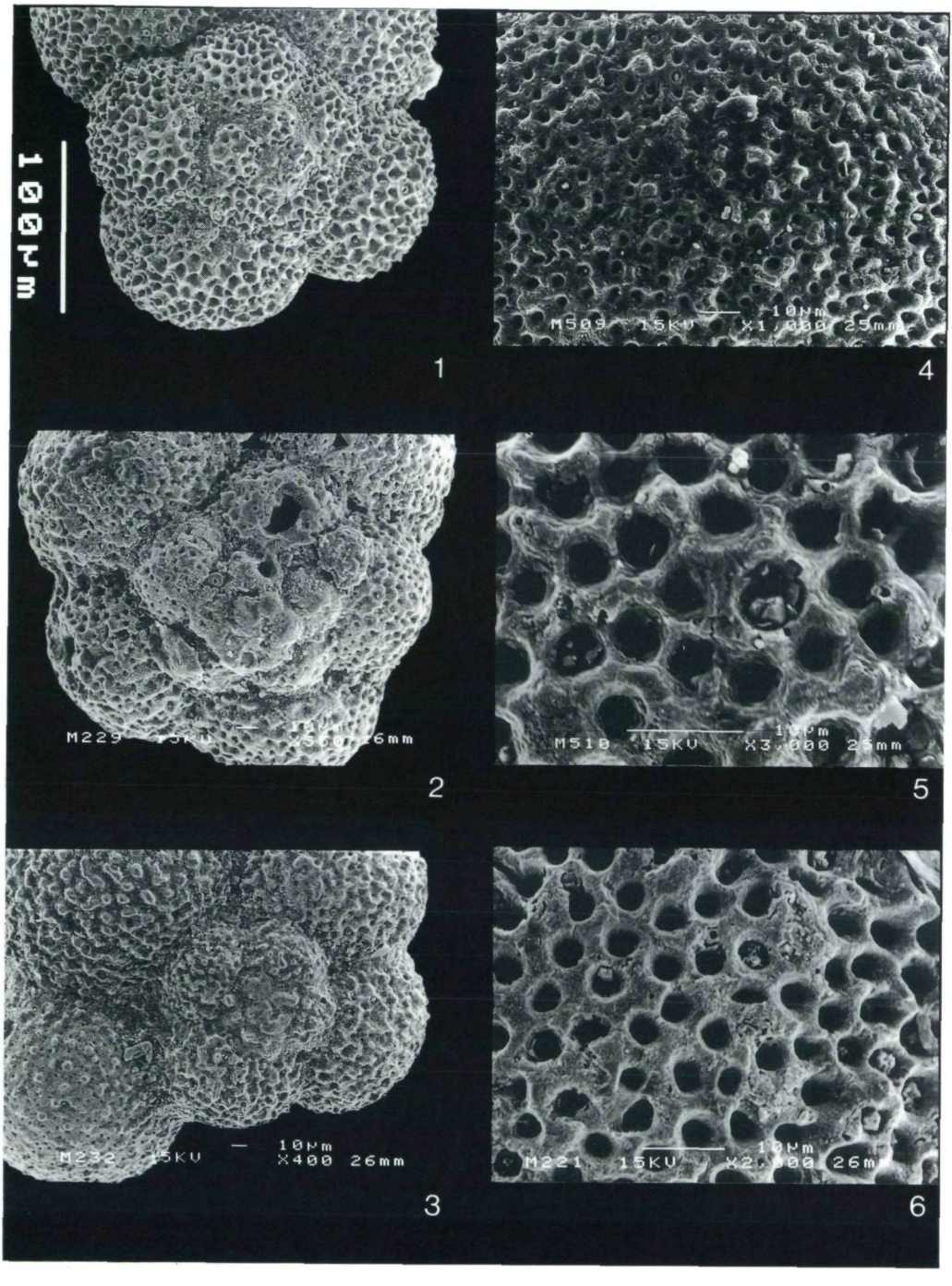
Fig. 1: *Globigerina ciperoensis* BOLLI, see pl. 1, fig. 2. The earlier coils have 5 chambers in each whorl; the chambers are globular, loosely arranged, well separated.

Fig. 2: *Globigerina ottnangiensis* RÖGL, see pl. 1, fig.12. The prelast whorl has 5 chambers as the last one; the chambers of the innermost whorl are small, strongly appressed, more then 5 per whorl (recognizable in transmitted light); the spire is flat.

Fig. 3: *Globigerina* cf. *pseudociperoensis* BLOW, see pl. 1, fig. 22. The prelast whorl has an arrangement as *Globigerina praebulloides* BLOW, with 4 chambers; the innermost coils are not very distinct, about 5 chambers in a whorl, and flat.

Fig. 4–5: *Globigerina wagneri* RÖGL n.sp., holotype, see pl. 2, fig. 8. Wall texture spinose non-cancellate; with spine bases at the final chamber (fig. 4), and spine holes in the interpore ridges of the first chamber in the final whorl (fig. 5, see arrows).

Fig. 6: *Globigerinella megaperta* RÖGL n.sp., holotype, see pl. 3, fig. 13. Wall texture of the penultimate chamber; flat surface between the pores (the formation of interpore ridges by secondary calcification occurs only along the sutures and in the earliest chambers).



APPENDIX 1

GENUS	SPECIES	LOCALITY	n	Diameter	minimum	maximum
Globigerina	ciperoensis	Trinidad HMB 364	14	0.284	0.176	0.360
Globigerina	ciperoensis	Trinidad HMB 408	9	0.253	0.262	0.300
Globigerina	ciperoensis	Zupfing-1, 550 m	14	0.293	0.214	0.334
Globigerina	ciperoensis	Ottenthal no.138	9	0.267	0.209	0.332
Globigerina	angulisuturalis	Trinidad HMB 364	15	0.239	0.181	0.322
Gllobigerina	angulisuturalis	Trinidad G.152	13	0.239	0.201	0.284
Globigerina	angulisuturalis	Ottenthal, +8,20 m, NÖ.	10	0.222	0.189	0.279
Globigerina	angulіofficinalis	Trinidad HMB 364	12	0.225	0.183	0.261
Globigerina	angulіofficinalis	Ottenthal, +8,20 m, NÖ.	10	0.208	0.156	0.279
Globigerina	angulіofficinalis	Michelstetten, NÖ.	22	0.212	0.151	0.259
Globigerina	angulіofficinalis	Pucking, OÖ.	8	0.218	0.176	0.209
Globigerina	ottnangiensis	Ernstbrunn, NÖ.	46	0.208	0.150	0.269
Globigerina	ottnangiensis	Plesching, OÖ.	19	0.245	0.214	0.307
Globigerina	ottnangiensis	Finklham, OÖ.	10	0.271	0.256	0.304
Globigerina	ottnangiensis	Maierhof, Bavaria	64	0.208	0.133	0.282
Globigerina	ottnangiensis	Cebovce, Slovakia	22	0.255	0.229	0.272
Globigerina	ottnangiensis	Varpalota, Hungary	28	0.213	0.178	0.251
Globigerina	pseudociperoensis	Laa a.d.Thaya, NÖ.	5	0.275	0.252	0.304
Globigerina	pseudociperoensis	Cebovce, Slovakia	41	0.297	0.226	0.357
Globigerina	pseudociperoensis	Wien-Grinzing	14	0.291	0.246	0.372
Globigerina	concinna	Laa a.d.Thaya, NÖ.	38	0.369	0.302	0.448
Globigerina	concinna	Cebovce, Slovakia	17	0.382	0.325	0.456
Globigerina	concinna	Wien-Nussdorf	12	0.472	0.390	0.586
Globigerina	concinna	Baden-Sooss, NÖ.	8	0.490	0.427	0.546
Globigerina	concinna	Walberdorf, Burgenland	20	0.463	0.332	0.586
Globigerina	concinna	Staropatica, Bulgaria	7	0.505	0.390	0.654
Globigerina	concinna	Wieliczka, Poland	11	0.454	0.407	0.528
Globigerina	concinna	Kynicky - Brno, Moravia	11	0.434	0.407	0.480
Globigerina	wagneri	Schallerbach-2, OÖ.	86	0.380	0.327	0.558
Globigerina	wagneri	Zupfing-1, OÖ.	29	0.368	0.309	0.478
Globigeina	wagneri	Ottenthal no. 138, NÖ.	25	0.457	0.329	0.556
Globigerina	wagneri	Perwang-1, OÖ.	7	0.327	0.276	0.352
Globigerinella	megaperta	Schallerbach-2, OÖ.	27	0.422	0.334	0.560
Globigerinella	megaperta	Zupfing-1, OÖ.	16	0.420	0.314	0.415
Globigerinella	megaperta	Eggerding-1, OÖ.	3	0.504	0.380	0.604
Globigerinella	megaperta	Ottenthal, no.138, NÖ.	11	0.439	0.332	0.508

KEY TO SPECIES

FEATURES	Globigerina ciperoensis	Globigerina angulisuturalis	Globigerina anguli-officinalis	Globigerina ottnangiensis	Globigerina dubia
coiling	trochospiral	trochospiral	trochospiral	trochospiral	trochospiral
size, average diameter	small 0.30 mm	small 0,25 mm	small 0.20 mm	small 0.25 mm	small 0.25 mm
trochospire	medium high to low	low	low	medium high to flat	high
periphery	circular, lobate	circular, slightly lobate	circular, slightly lobate	pentagonal, slightly lobate	circular, slightly lobate
sutures	distinct, sharp	deep, broad, U-shaped	deep, narrow, U-shaped	distinct, narrow	distinct, narrow
final whorl	5 chambers	5 chambers	5 chambers	5 chambers	5 chambers
penultimate whorl	5 chambers	5 chambers	5 chambers	5 chambers	5 chambers
primary whorl	5 chambers	5 chambers	5 chambers	flat coil, more than 5	flat coil, more than 5
umbilicus	large, open, pentagonal	medium, open	small	medium, open	small, deep
aperture	umbilical	umbilical	umbilical	umbilical to extra-umbilical	umbilical
wall texture	spinose, non-cancellate	spinose, non-cancellate	spinose, non-cancellate	spinose, non-cancellate	spinose, non-cancellate

APPENDIX 2

FEATURES	Globigerina cf. pseudo-ciperoensis	Globigerina concinna	Globigerina wagneri	Globigerinella megaperta	Tenuitellinata angusti - umbilicata
coiling	trochospiral	trochospiral	trochospiral	pseudo-planispiral	trochospiral
size, average diameter	small 0.30 mm	large 0.40-0.50 mm	large, 0.40 mm (0.28-0.56 mm)	large, 0.45 mm (0.31-0.60 mm)	small 0.15 mm
trochospire	low	low	low	low	low
periphery	pentagonal, lobate	pentagonal, lobate	circular to pentagonal	lobate	lobate
sutures	distinct, narrow	distinct, narrow	distinct, narrow	distinct, narrow	distinct, narrow
final whorl	5 chambers	5-6 chambers	4½ -5½ chambers (p.p. aberrant)	5-6 chambers, (p.p.aberrant)	5 chambers
penultimate whorl	4 to 4 ½ chambers	5 chambers	4 chambers	4 chambers, streptospiral	5 chambers
primary whorl	flat coil, 5 to more than 5	5 chambers	very small, 4 chambers	indistinct	5 chambers
umbilicus	open, rectangular	large, open, elongate	large, open, quadrangular	large, entirely open	small, closed
aperture	umbilical, with open 2 last chambers	umbilical, with open 2-3 last chambers	umbilical to extraumbilical, 2-3 chambers open	asymmetrical equatorial	low arch, umbilical to extra-umbilical
wall texture	spinose, non-cancellate	spinose, non-cancellate	spinose, non-cancellate	spinose, smooth surface	microperforate, spinose ?