

Evolutionary classification of the Upper Cretaceous (Turonian–lower Campanian) planktic foraminifera with incipient meridional ornamentation

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ABSTRACT – A new genus, *Fingeria*, is recognized among the globular-chambered trochospiral planktic foraminifera of the Upper Cretaceous (upper Cenomanian–lower Campanian). It consists of two pre-existing species: *F. loetterlei* (Nauss, 1947) and *F. kingi* (Trujillo, 1960). The ornamentation consists of scattered pustules, which can often fuse to form rugosities and, occasionally, costellae, especially over the earlier chambers of the test. Meridional ornamentation pattern is occasionally developed over isolated chambers. *Fingeria* is the only lineage of the whiteinellid stock that exhibits ornamentation coarsening and preferential orientation, which can be meridional or parallel to the periphery. *J. Micropalaeontol.* 29(2): 149–161, December 2010.

KEYWORDS: planktic foraminifera, taxonomy, Upper Cretaceous, evolutionary classification, *Fingeria* – new genus

INTRODUCTION

The process of developing an evolutionary classification framework for the Cretaceous planktic foraminifera requires high resolution observations on the test morphology in stratigraphical context and continuous re-evaluation and improvement of the operating concepts (e.g. taxon definition, etc.). Steineck & Fleisher (1978) demonstrated that convergence and iterative evolution are the dominant patterns in the Cenozoic planktonic foraminiferal evolution. The existence of these patterns in the Cretaceous planktics was demonstrated in a number of studies based on high detail test morphology (Georgescu & Huber, 2006, 2008, 2009; Georgescu, 2007; 2009a, b, c; 2010a, b; Georgescu & Abramovich, 2008a, b, 2009; Georgescu *et al.*, 2009). The effects of recognizing such processes in Cretaceous planktic foraminiferal evolution became apparent in the classification approach used in group taxonomy. Evolutionary classification, which can be developed through the application of classical evolutionary methods, can provide a method to group species into higher units according to inferred ancestor–descendant relationships.

Developing an evolutionary classification framework is a challenging process, partly due to the existence of a single taxonomical method (i.e. typology) for more than 250 years. According to the fundamental principle of this time-honoured method, the units at any rank are grouped into units of higher rank according to morphological resemblances between them. The practice resulted in groups that are based on a relatively small number of features, which were often developed through convergent and/or iterative evolution. Therefore, the vast majority of the typological units are artificial (polyphyletic and paraphyletic). Phylogenetic classification was proposed as an alternative to the typological classification by Hennig (1950; 1966). In contrast to the typological approach, phylogenetic classification takes into account the ancestor–descendant relationships between the various taxonomical units (e.g. species, genera), but the influences of the time factor as reflected in the fossil and stratigraphical records play a rather minor role in taxa grouping at any hierarchical level. As a result, few specialists adopted it as a working method. A possible explanation for the

lack of success in developing an alternative classification to the typological one is that all the phylogenetic classification framework attempts were entirely based on typological, Linnaean taxa, which have little likelihood of representing natural units (Georgescu, 2009c; 2010a, b).

A first step in developing an evolutionary classification for the Cretaceous planktic foraminifera was the critical review of the species concept used in taxonomical studies and current practice. The necessity to re-evaluate the species concept was primarily generated by the inadequacy of the extensively used morphospecies concept in accommodating species variability. The composite palaeontological species was defined by Georgescu & Huber (2007, 2009) in order to recognize species as natural units, whose existence is observed directly in the fossil and stratigraphical record.

A composite paleontological species is the basic unit with taxonomic significance in the fossil record, and has the following characteristics: (1) it is monophyletic; (2) it has a distinct range of morphological variability, showing relative stability over a definable period of time and presenting relatively discrete evolutionary changes; (3) it is a morphologically heterogeneous and discontinuous entity, consisting of one or (mostly) more morphological and/or paleoecological varieties; (4) it has its own and continuous developmental history traceable in space and time, which can be directly derived from the fossil record; and (5) its existence and integrity can be tested not only by comparative morphological distinctiveness, but also by its response to paleoenvironmental and geological factors (e.g., paleoclimatic changes, sea level fluctuations), as inferred from paleontology and related geological disciplines (Georgescu & Huber, 2009, p. 360).

Species grouping into higher-level units strongly depends on the classification approach. In the typological approach species are grouped into genera according to their morphological resemblances; the degree of resemblance is determined by a relatively small number of features, which are considered of taxonomical

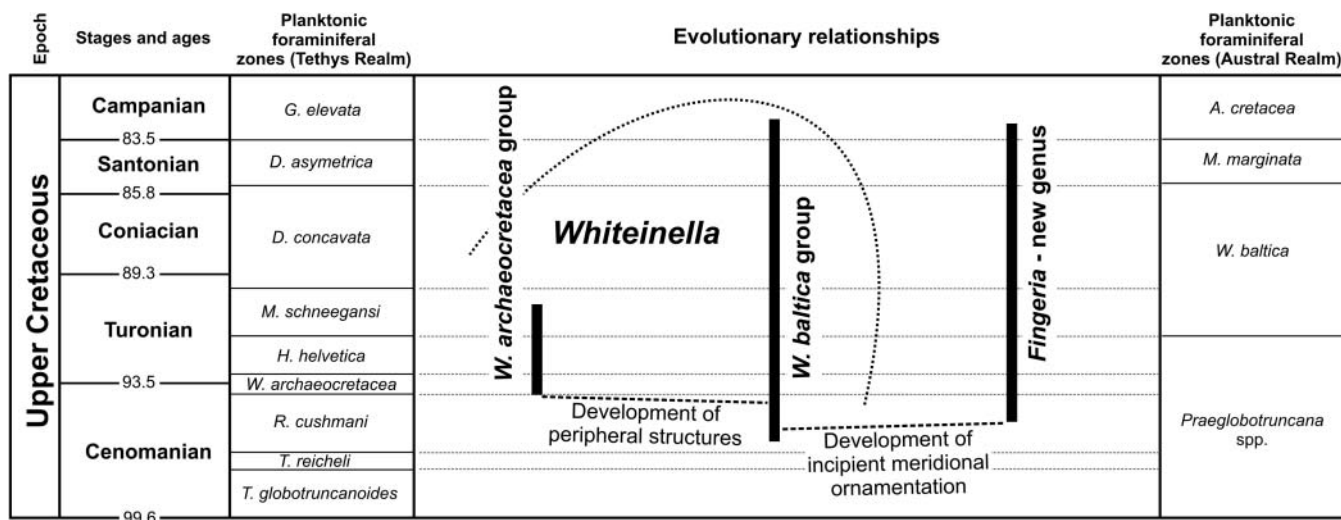


Fig. 1. Diagram presenting the three groups of whiteinellid species, their stratigraphical distribution and inferred evolutionary relationships. Tethyan Realm biozonation is after Robaszynski & Caron (1995), Austral Realm zonation after Huber (1992) and ages after Gradstein *et al.* (2004). Abbreviations: *A.*, *Archaeoglobigerina*; *D.*, *Dicarinella*; *G.*, *Globotruncanites*; *H.*, *Helvetoglobotruncana*; *M.*, *Marginotruncana*; *R.*, *Rotalipora*; *T.*, *Thalmaninella*; *W.*, *Whiteinella*.

significance. Evolutionary classification is fundamentally different and a taxonomist using this approach will group species into higher units (i.e. lineages) based on a mixture of morphological resemblances resulting from common ancestry and differences resulting from evolutionary changes (Georgescu, 2009c; 2010b). Therefore, the higher units have a dynamic sense in evolutionary classification whereas in typology the units are rather static. The lineage as a taxonomical unit in evolutionary classification was defined by Georgescu (2009c, p. 264) as follows:

... a monophyletic taxonomic unit with significance in evolutionary classification, situated immediately above the species level, representing a grouping of species based on the phylogenetical relationships between them, having a distinct evolutionary history in space and time that can be reconstructed from the fossil and stratigraphic record and is separated by morphological gaps from other similar units.

Whiteinella Pessagno, 1967 (type species: *W. archaeocretacea* Pessagno, 1967) was created to accommodate middle Cenomanian–lower Campanian globular-chambered planktic foraminifera with a broadly rounded periphery, umbilical–extraumbilical aperture bordered by a flap and ornamentation consisting of relatively large scattered pustules, resulting in a spinose appearance. The genus was reviewed by Robaszynski & Caron (1979), who included within it the following species: *W. aprica* (Loeblich & Tappan, 1961), *W. archaeocretacea*, *W. baltica* Douglas & Rankin, 1969, *W. brittonensis* (Loeblich & Tappan, 1961) and *W. paradubia* (Sigal, 1952). This revision was widely accepted. The origin of *Whiteinella* was considered to have been among the globular-chambered *Hedbergella* Brönnimann & Brown, 1958 (Caron, 1983; Hart, 1999; Hart *et al.*, 2002).

The polyphyletic nature of *Whiteinella* was demonstrated with the taxonomic revision of *Anaticinella* Eicher, 1973 (Georgescu, 2010a). *Anaticinella* was redefined in an evolution-

ary classification to accommodate a late Albian–early Turonian lineage that gradually develops a faint peripheral keel, complex umbilical system consisting of portici and ornamentation exhibiting fused pustules and, occasionally, vermicular structures in the terminal species. A significant outcome of this study is that it demonstrated that the whiteinellid stage of this lineage is transitional from the hedbergellid stage to the anaticinellid one. Moreover, the study demonstrated the necessity of a higher accuracy in evaluating the taxonomical significance of detailed morphological features (e.g. ornamentation elements and their distribution, pore characteristics, etc.).

Three groups of species can be recognized among the *Whiteinella* representatives, excepting *A. aprica*, based on high resolution morphological features (Fig. 1). *Whiteinella baltica* group of species apparently represents the stem of the whiteinellid group, with the first evolutionary occurrence in the late Cenomanian (*Rotalipora cushmani* Biozone) and having generalized features, such as globular chambers, broad periphery without peripheral structures and ornamentation consisting of scattered pustules. This group includes *W. baltica*, *W. brittonensis* and *W. paradubia*. The *Whiteinella archaeocretacea* group, which includes *W. archaeocretacea* and, probably, *W. inornata*, evolved in the latest Cenomanian with the development of a subangular periphery and incipient peripheral structures comprised of agglomerated pustules. Globular-chambered trochospiral planktic foraminifera with incipient meridional ornamentation are defined herein as a new lineage developed in a new genus, *Fingeria*. It consists of two composite palaeontological species, *F. loetterlei* (Nauss, 1947) and *F. kingi* (Trujillo, 1960), which never received senior species status in the past in any of the taxonomical reviews based on typological principles (Masters, 1977; Robaszynski & Caron, 1979; Caron, 1985).

MATERIAL PROVENANCE

The material studied was collected from Turonian–lower Campanian sediments drilled at two Deep Sea Drilling Project

(DSDP) sites: 95 (Yucatan outer shelf, offshore Mexico, Caribbean region) and 463 (Mid-Pacific Mountains, equatorial Central Pacific Ocean). Most of the samples were made available at request by the DSDP/Ocean Drilling Program (ODP)/Integrated Ocean Drilling Program (IODP) headquarters. Additional samples from the two sites were examined in the Ocean Micropaleontology Collection (OMC) at the National Museum of Natural History (NMNH), Smithsonian Institution, Washington D.C. Samples are labelled according to the DSDP/ODP/IODP standards as follows: leg number–site number–core number–section, sample depth in centimetres.

A collection of four species was studied in the Cushman Collection: *Hedbergella murphyi* Marianos & Zingula, 1966 (USNM 641539), *Archaeoglobigerina bosquensis* Pessagno, 1967 (USNM 689281) and *Hedbergella bornholmensis* Douglas & Rankin, 1969 (USNM 464651) and from the University of California Museum of Paleontology, Berkeley: *Globigerina loetterlei* Nauss, 1947 (UCMP48788); the environmental scanning electron microscope (ESEM) micrographs of the Cushman Collection specimens were illustrated online by the Mesozoic Planktonic Foraminifera Working Group (2006). Newly taken ESEM micrographs of the holotypes of *Rugoglobigerina kingi* Trujillo, 1960 (UCMP 26678) and *Hedbergella hansbollii* Trujillo, 1960 (UCMP 26676) deposited in the University of California Museum of Paleontology were also examined. In addition, topotype material of *Rugoglobigerina plana* Belford, 1960 from the lower Santonian Toolonga Calcilitite of Western Australia was studied in the NMNH collections.

Most of the material of this study was collected from the sediments from DSDP Site 463 (Fig. 2). The preservation at this site is very good in most of the 23 samples studied; although tests are recrystallized, many of them preserve the delicate periapertural structures and test ornamentation. *Fingeria kingi* and *F. loetterlei* occur at this site in the Turonian–lower Campanian sediments and they are often abundant in the planktic foraminiferal assemblages of the lower Turonian. Tests affected by dissolution are mostly recorded in the upper Turonian–lower Santonian interval. The high planktic/benthic foraminiferal ratios (84.8–99.8%) apparently indicate bathyal sedimentation.

The coeval distal shelf carbonate sediments at Site 95 also yielded occurrences of both *Fingeria* species (Fig. 3). Preservation is good to very good but a significant proportion of the specimens are fragmentary tests or exhibit traces of dissolution. The globular-chambered species, including those of *Fingeria*, are rather sporadic in occurrence, probably due to the unstable conditions in the uppermost layer of the oceanic water column. In contrast, the deeper-water species of heterohelics and globotruncanids occur continuously and have stratigraphical ranges that can be correlated easily to those in the adjacent regions (e.g. Gulf of Mexico, southern USA).

EVOLUTIONARY CLASSIFICATION

The higher classification units are after Loeblich & Tappan (1987). The composite palaeontological species concept (Georgescu & Huber, 2007, 2009) is followed throughout.

Order **Foraminiferida** Eichwald, 1830
Suborder **Globigerina** Delage & Hérouard, 1896
Superfamily **Rotaliporacea** Sigal, 1958
Family **Hedbergellidae** Loeblich & Tappan, 1961
Subfamily **Hedbergellinae** Loeblich & Tappan, 1961
Genus *Fingeria* gen. nov.

Type species. *Fingeria kingi* (Trujillo, 1960).

Derivation of name. Genus named after Dr Kenneth Finger (University of California, Berkeley) for his contributions to the study of foraminifera; suffix ‘-ia’ is added to his name.

Diagnosis. Late Cenomanian–early Campanian globular-chambered trochospiral planktic foraminifera with incipient meridional ornamentation.

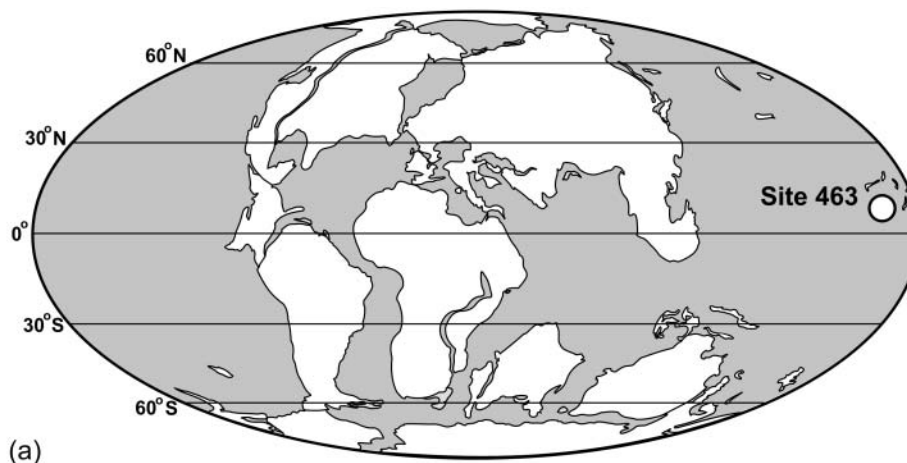
Species included. *Fingeria loetterlei* (Nauss, 1947) and *F. kingi* (Trujillo, 1960).

Description. Test is low to medium high trochospiral, consisting of globular chambers that increase in size at low to moderate, rarely high rates. Sutures are distinct and depressed, perpendicular to oblique on the previous whorl on the spiral side and straight and radial on the umbilical one. Periphery is broadly rounded, without peripheral structures. Umbilicus is small to medium sized, its diameter representing one-fifth to one-third of the maximum test diameter; the widest umbilici occur in evolved species. Aperture is a low to medium high arch, umbilical–extraumbilical in position and bordered by flaps. Ornamentation consists of scattered, often randomly distributed and occasionally aligned pustules and rugosities in the primitive species and aligned or not pustules, rugosities and occasional costellae in the evolved species; an ornamentation pattern that is loosely meridional or parallel to the periphery can be developed over isolated chambers. Test wall is calcitic, hyaline and perforate; pore diameter ranges from 1.7 to 4.9 µm.

Stratigraphical range. Turonian–lower Campanian (from the *Helvetoglobotruncana helvetica* Biozone to the *Globotruncana elevata* Biozone).

Geographical distribution. Cosmopolitan.

Remarks. *Fingeria* is a directional lineage consisting of two composite palaeontological species, which present significant ornamentation variability; pustules are the dominant ornamentation elements but rugosities and faint costellae may occur over some chambers in some specimens. An incipient meridional pattern can sporadically occur in both species. These features separate it from *Whiteinella*, which has tests ornamented with scattered and isolated pustules. *Fingeria* differs from the *Archaeoglobigerina blowi* Pessagno, 1967–*A. cretacea* (d’Orbigny, 1840) group of species by having a broadly rounded and simple periphery rather than with an imperforate peripheral band bordered by two rows of pustules or weak keels and ornamentation with occasionally developed rugosities and incipient meridional pattern. It differs from *Paracostellagerina* Georgescu



SAMPLES	STAGES	Revised planktic foraminiferal zonation (Georgescu & Huber, 2009)	Selected planktic foraminiferal species																					
			<i>Schackoina cenomana</i>	<i>Hillisella hillisi</i>	<i>Fingerina loetterlei</i>	<i>F. kingi</i>	<i>Helvetoglobotruncana prae-helvetica</i>	<i>H. helvetica</i>	<i>Dicarinella algeriana</i>	<i>D. hagni</i>	<i>D. concavata</i>	<i>D. asymetrica</i>	<i>Marginotruncana marianosi</i>	<i>M. coronata</i>	<i>M. sigali</i>	<i>M. schneegansi</i>	<i>Globotruncana bulloides</i>	<i>G. ventricosa</i>	<i>Globotruncanites elevata</i>	<i>Globotruncanites stuartiformis</i>	<i>Contusotruncana plummerae</i>	<i>C. fornicata</i>	<i>Archaeoglobigerina blowi</i>	
24-1, 50-52 cm	Middle Campanian	<i>G. ventricosa</i>																			R			
24-2, 50-52 cm																				R				
24-3, 50-52 cm																		A	R		C	F	F	C
25-1, 51-53 cm	Lower Campanian	<i>G. elevata</i> equivalent				R											C			C	F	A	R	
25-2, 51-53 cm						R											R		R	F	A	R		
26-1, 50-52 cm						C												F		R	C	F	R	R
26-2, 52-54 cm																	A	C			F	A		
26-3, 52-54 cm			R	R		R										C	C				C	F	F	C
26-4, 52-54 cm	Upper Santonian	<i>D. asymetrica</i>	R	C		R					C	F				F		R			F	C	R	
26-5, 53-58 cm	Coniacian-lower Santonian	<i>D. concavata</i>	R	C		R					F										A	R	R	
26-6, 53-55 cm				R							R					R	C				F	C		
27-1, 50-52 cm				R							F					F	A				A	F		
27-2, 20-22 cm	Turonian	<i>M. schneegansi</i>									F					F	A				R	R		
29-1, 50-52 cm				R										A	R	R								
30-1, 50-53 cm			R	R	R	R								A	F	A								
30-2, 50-52 cm				R	R									R	C	R								
31-1, 11-13 cm					R	R								R	A	A								
33-1, 50-52 cm		<i>H. helvetica</i>			A	R		F	F						C	F								
33-2, 52-54 cm					F	R		F	R				R		R									
34-1, 50-52 cm					A	A	F	R	C				R											
34-2, 53-55 cm			R		A	R	R	A		A														
34-3, 50-53 cm					A	R	F	R	R	F			F											
35-1, 10-12 cm					A	R	A	A	R	F			C											

(b)

Fig. 2. (a) Geographical position and (b) stratigraphical distribution and frequencies of selected planktic foraminiferal species in the Turonian–middle Campanian sediments at DSDP Site 463 (Mid-Pacific Mountains, equatorial Central Pacific). Frequency letter scale: R, rare (1–5 specimens/sample); C, common (6–10 specimens/sample); F, frequent (11–25 specimens/sample); and A, abundant (≥ 26 specimens). The two *Fingeria* species are shaded in grey. Base map is after Hay *et al.* (1999).

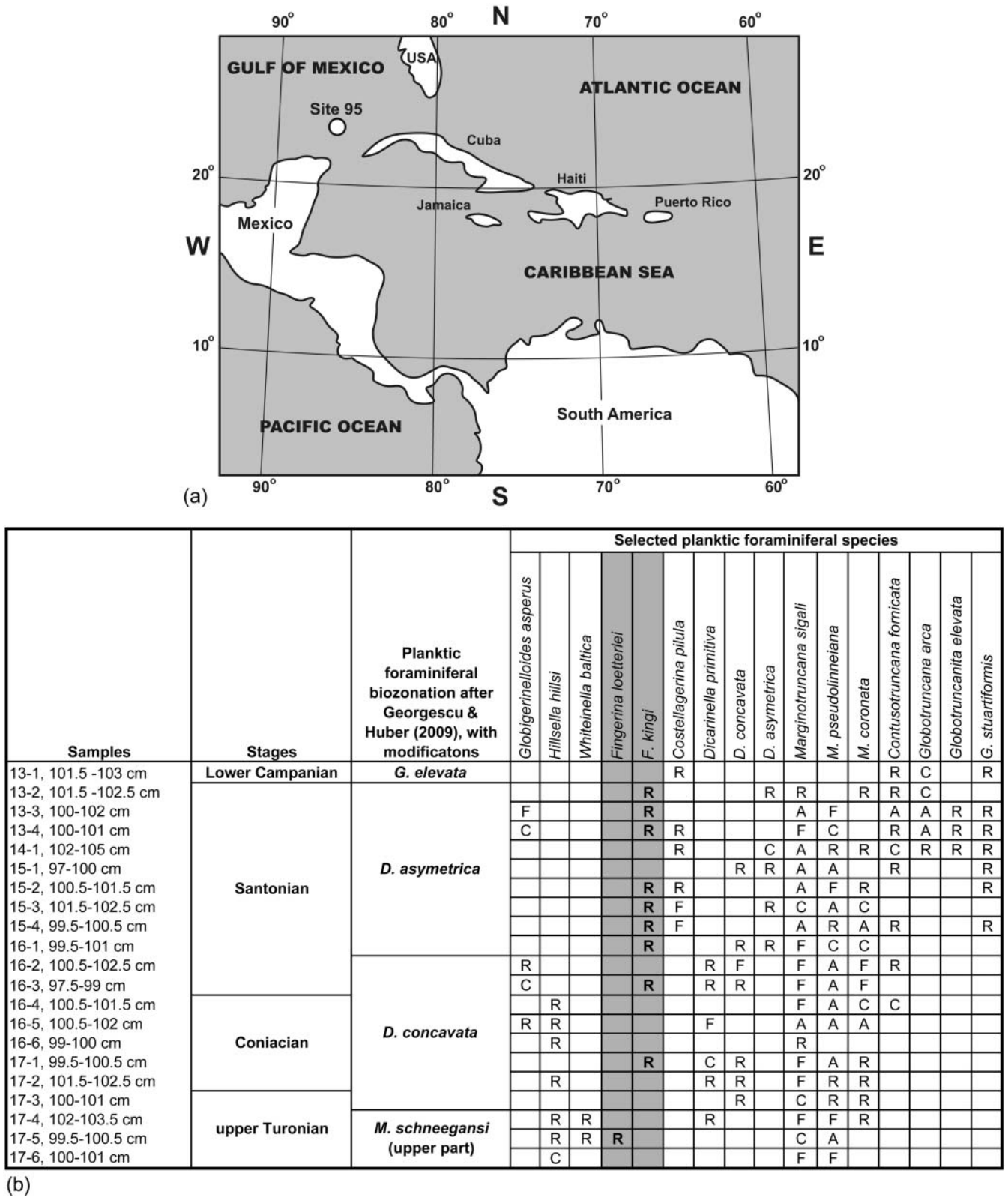


Fig. 3. (a) Geographical position and (b) stratigraphical distribution and frequencies of selected planktic foraminiferal species in the upper Turonian–lower Campanian sediments at DSDP Site 95 (Yucatan outer shelf, Caribbean region). See Figure 2 for frequency letter scale.

& Huber, 2006 (late Albian–early Cenomanian), *Costellagerina* Petters, El-Nakhal & Cifelli, 1983 (Santonian–early Campanian) and *Rugoglobigerina* Brönnimann, 1952 (late Campanian–Maastrichtian) mainly by lacking a consistently ornamented chamber surface with costellae that show well-developed meridional pattern or one that is parallel to the periphery. *Meridionella* El-Nakhal, 1982 (type species: *Hedbergella murphyi* Marianos & Zingula, 1966) is a trans-lineage genus based on nonexistent features (i.e. costellae) in the type species and can be considered valid only if the presence of consistent costellate ornamentation can be documented in the designated type species (El-Nakhal, 1982).

Fingeria loetterlei (Nauss, 1947) – emended
(Pl. 1, figs 1–6)

- 1937 *Globigerina cretacea* d'Orbigny; Loetterle: 44, pl. 7, fig. 1 (only).
 1947 *Globigerina loetterlei* Nauss: 336, pl. 49, fig. 11.
 1951 *Globigerina loetterlei* Nauss; Tappan: 4, pl. 1, fig. 19.
 1953 *Rotundina ordinaria* Subbotina: 186, pl. 3, figs 7–9 (only).
 1956 *Globigerina cretacea* d'Orbigny; Bolin: 292, pl. 39, figs 4–7, 13, 17 (only).
 1962 *Hedbergella loetterlei* (Nauss); Tappan: 196, pl. 55, figs 3–5.
 1965 *Hedbergella loetterlei* (Nauss); Takayanagi: 205, pl. 21, fig. 5.
 1966 *Hedbergella murphyi* Marianos & Zingula: 336, pl. 38, fig. 5.
 1966 *Hedbergella quadrata* Marianos & Zingula: 336, pl. 38, fig. 7.
 1966 *Hedbergella* sp. 2; Douglas & Sliter: 105, pl. 1, fig. 1.
 1967 *Hedbergella loetterlei* (Nauss); Kent: 1448, pl. 183, figs 14–15.
 1967 *Hedbergella loetterlei* (Nauss); Wall: 107, pl. 3, figs 13–21.
 1969 *Hedbergella murphyi* Marianos & Zingula; Douglas: 168, pl. 5, fig. 8.
 1969 *Hedbergella bornholmensis* Douglas & Rankin: 193, fig. 6.
 1974 *Globigerina cretacea* d'Orbigny; Cañon & Ernst: 82, pl. 4, fig. 3.
 1974 *Globigerina wenzeli* Cañon & Ernst: 83, pl. 4, fig. 5.
 1975 *Hedbergella loetterlei* (Nauss); North & Caldwell: pl. 4, fig. 17.
 1976 *Whiteinella archaeocretacea* Pessagno; Lamolda: 18, pl. 1, figs 1–9.
 1977 *Globigerina loetterlei* Nauss; Masters: 464.
 1981 *Hedbergella loetterlei* (Nauss); McNeil & Caldwell: 254, pl. 21, fig. 1.
 1987 *Whiteinella* sp. A; Frerichs & Deiss: figs 4:7, 6:3.
 1987 *Whiteinella loetterlei* (Nauss); Frerichs & Deiss: fig. 6:2.
 2000 *Hedbergella murphyi* Marianos & Zingula; Petrizzo & Premoli Silva: pl. 1, figs 1–4.

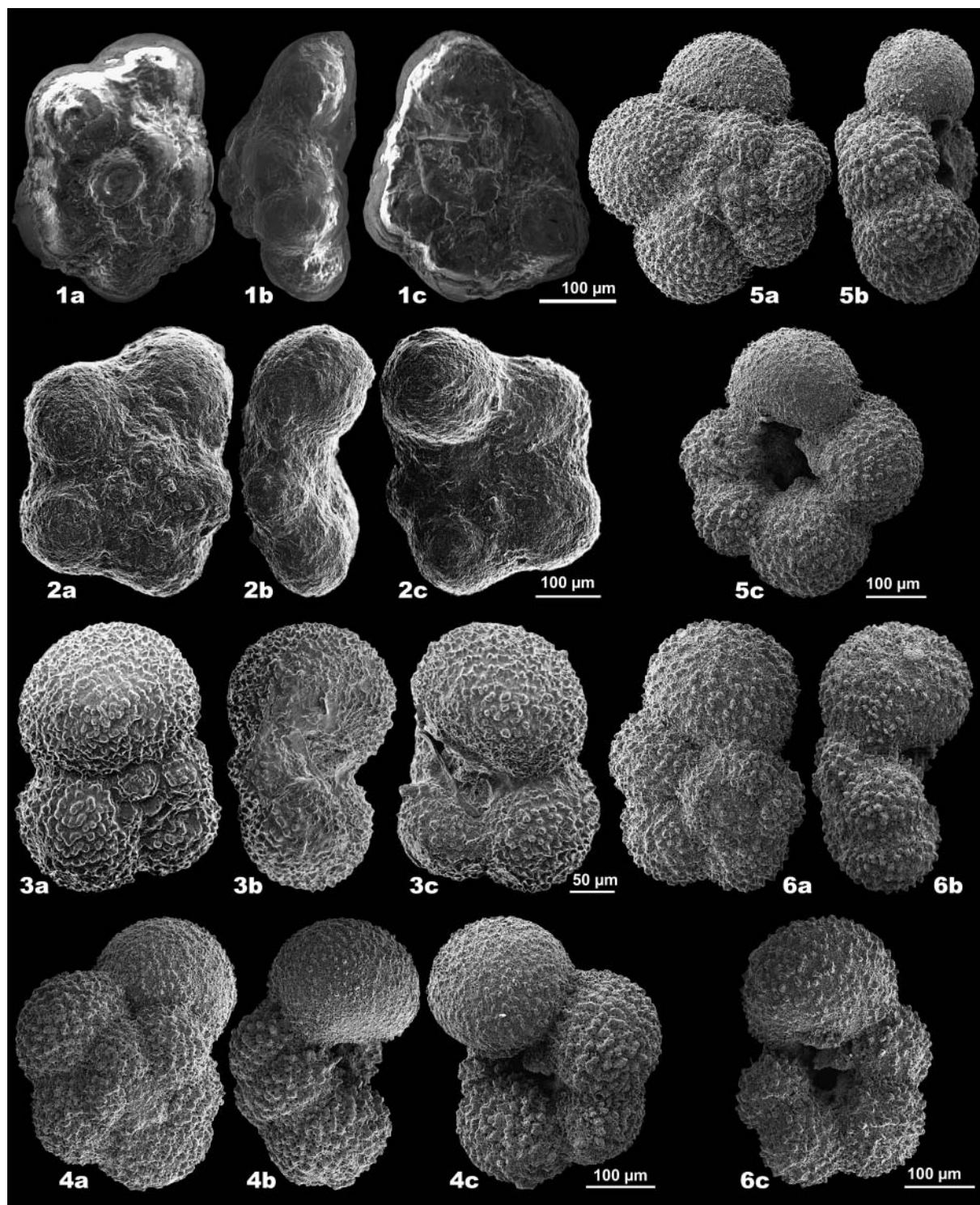
Emended description. Test low to medium high trochospiral consisting of 12–14 globular chambers arranged in $2\frac{1}{2}$ –3 whorls; there are 4–6, commonly 5–5½ chambers in the final whorl; chambers increase in size at low to high rate. Sutures are distinct, depressed, straight to slightly curved and perpendicular to oblique to the previous whorl on the spiral side and straight

and radial on the umbilical side. Test convex–concave, slightly asymmetrical in edge view; periphery is broadly rounded, without peripheral structures. Umbilicus is small to medium sized, its diameter representing approximately one-fifth to one-third of the maximum test diameter. Aperture is a low arch, umbilical–extraumbilical in position and bordered by a thin, rarely preserved imperforate flap. Chamber surface is ornamented with dense pustules (maximum dimension 8.3–15.4 µm) and rarely rugosities; ornamentation elements can be occasionally aligned but without presenting well-developed meridional arrangement. Test wall is calcitic, hyaline and perforate (pore diameter 2.3–4.1 µm).

Stratigraphical range. Turonian (from the *H. helvetica* Biozone to the lower part of *Margino truncana schneegansi* Biozone).

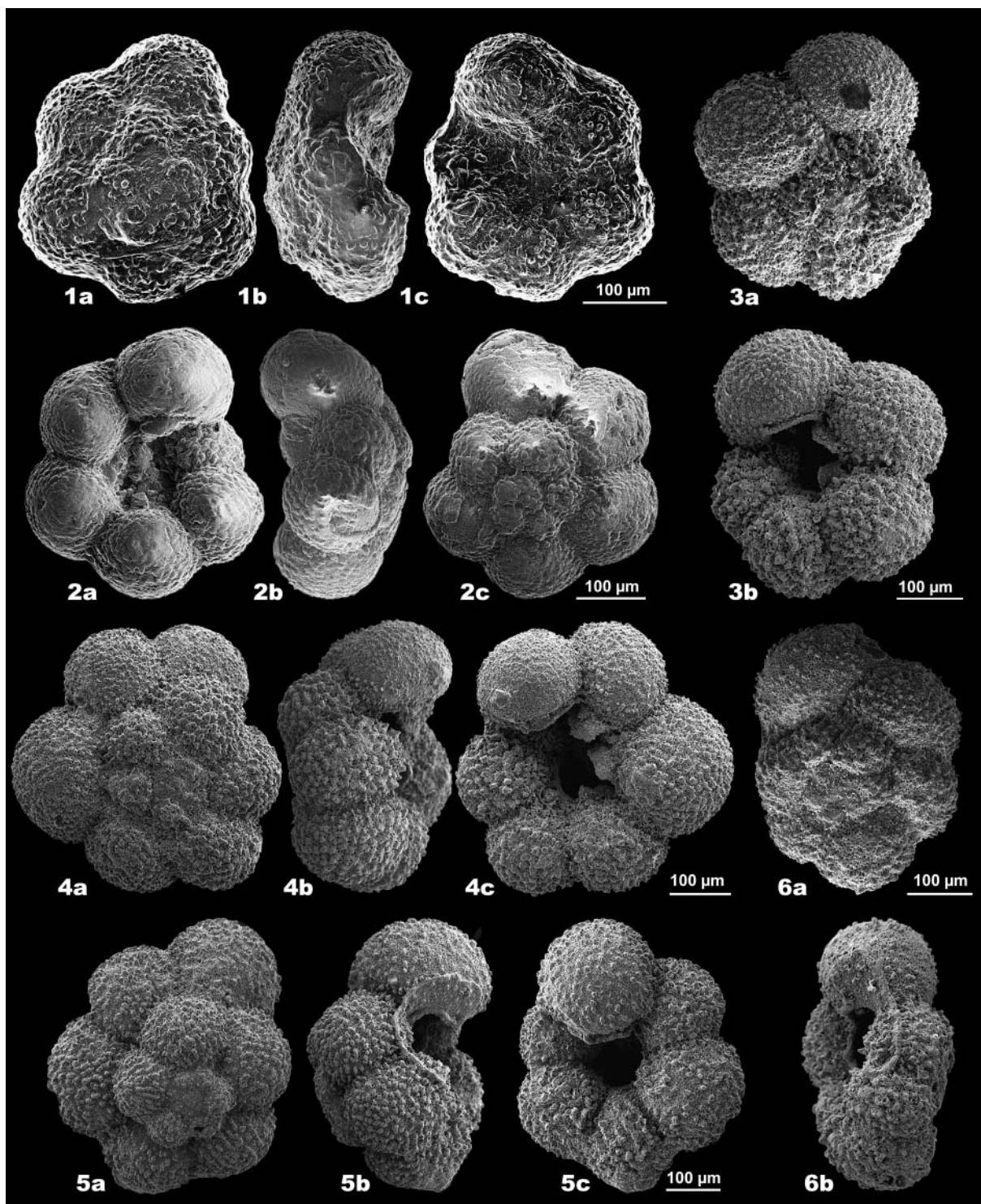
Geographical distribution. Canada (Alberta, Manitoba, Saskatchewan), USA (Alaska, California, Colorado, Kansas, Minnesota, Nebraska, South Dakota), South America (Chile), Europe (Denmark, France, Spain), Russia, western North Atlantic Ocean (Blake Plateau) and equatorial Central Pacific Ocean (Mid-Pacific Mountains).

Remarks. The holotype of *F. loetterlei* is poorly preserved and is covered with thick glue on certain portions, mainly at the periphery; the ornamentation is almost completely removed by erosion and/or dissolution (Pl. 1, Fig. 1). *Fingeria loetterlei* differs from *Whiteinella baltica*, *W. brittonensis* and *W. paradoxia* by having ornamentation with occasionally aligned elements, which can be pustules and rarely rugosities. It differs from *Costellagerina pilula* (Belford, 1960) mainly by lacking costellae and a meridional ornamentation pattern and having the test wall with larger pores (2.3–4.1 µm rather than 1.0–1.9 µm). *Rotundina ordinaria* was described by Subbotina (1953) from the Turonian and Maastrichtian sediments of the middle Volga and Emba regions, respectively. The holotype of this species was selected from the Maastrichtian material and belongs to *Rugoglobigerina hexacamerata* Brönnimann, 1952; three of the four Turonian specimens are assigned herein to *F. loetterlei*. The ornamentation of *F. loetterlei* has been reinterpreted by El-Nakhal (1982, p. 34), who described it as consisting of ‘... meridionally arranged rugosities similar to those of *Rugoglobigerina*’ based on the type illustrations; it appears obvious that this author confused the costellae for rugosities and subsequent articles by the same author (El-Nakhal, 1999, 2002) confirm this, ornamentation being described as ‘costellate’. The holotype of *F. murphyi* was re-examined by Petrizzo & Premoli Silva (2000, p. 306), who showed that it lacks costellate ornamentation and aligned pustules. They suggested that the species has closer affinities to *Whiteinella* rather than *Hedbergella* based on the wide umbilical area and pustulose surface. However, the poor state of preservation of the holotype (Pl. 1, fig. 2) represents an insurmountable impediment in drawing final conclusions on the validity of this species based only on the study of the holotype. Tests with high chamber size growth rate that were included within *H. bornholmensis* Douglas & Rankin, 1969 occur sporadically in the *F. loetterlei* assemblages; they are assigned to the latter species due to the similar ornamentation



Explanation of Plate 1.

fig. 1. Holotype of *Fingeria loetterlei* (Nauss, 1947) originally figured as *Globigerina loetterlei* (Nauss, 1947, pl. 49, fig. 11) from the Lloydminster shale of the Clonmel Well No. 1 (Vermilion Area, Alberta, Canada). **fig. 2.** Holotype of *Hedbergella murphyi* (Marianos & Zingula, 1966, pl. 38, fig. 5) from the Turonian of the Dry Creek, Tehama County, California (USA). **fig. 3.** Holotype of *H. bornholmensis* (Douglas & Rankin, 1969, fig. 6 A–C) from the Bavnodde Greensand (Denmark). **fig. 4.** Hypotype of *F. loetterlei* from the lower Turonian sediments (*H. helvetica* Biozone) of the equatorial Central Pacific, Shatsky Rise, DSDP Site 463, Sample 35-1, 17–19 cm. **fig. 5.** Hypotype of *F. loetterlei* (Marianos & Zingula, 1966) from the lower Turonian sediments (*H. helvetica* Biozone) of the equatorial Central Pacific, Shatsky Rise, DSDP Site 463, Sample 35-1, 17–19 cm. **fig. 6.** Hypotype of *F. loetterlei* from the lower Turonian sediments (*H. helvetica* Biozone) of the equatorial Central Pacific, Shatsky Rise, DSDP Site 463, Sample 35-1, 17–19 cm.



Explanation of Plate 2.

fig. 1. Holotype of *Fingeria kingi* (Trujillo, 1966) originally figured as *Rugoglobigerina kingi* (Trujillo, 1966, pl. 49, fig. 5) from the Coniacian sediments of Clover Creek, east of Reading, Shasta County, California (USA). **fig. 2.** Holotype of *Archaeoglobigerina bosquensis* (Pessagno, 1967, pl. 60, figs 10–12 fig. 3) from the Santonian sediments of Lover's Leap, McLennan County, Texas (USA). **fig. 3.** Hypotype of *F. kingi* from the lower Turonian sediments (*M. schneegansi* Biozone) of the equatorial Central Pacific, Shatsky Rise, DSDP Site 463, Sample 33-1, 50–52 cm. **fig. 4.** Hypotype of *F. kingi* from the lower Turonian sediments (*H. helvetica* Biozone) of the equatorial Central Pacific, Shatsky Rise, DSDP Site 463, Sample 35-1, 17–19 cm. **fig. 5.** Hypotype of *F. kingi* from the lower Turonian sediments (*H. helvetica* Biozone) of the equatorial Central Pacific, Shatsky Rise, DSDP Site 463, Sample 35-1, 17–19 cm. **fig. 6.** Hypotype of *F. kingi* from the lower Turonian sediments (*H. helvetica* Biozone) of the equatorial Central Pacific, Shatsky Rise, DSDP Site 463, Sample 34-2, 53–55 cm.

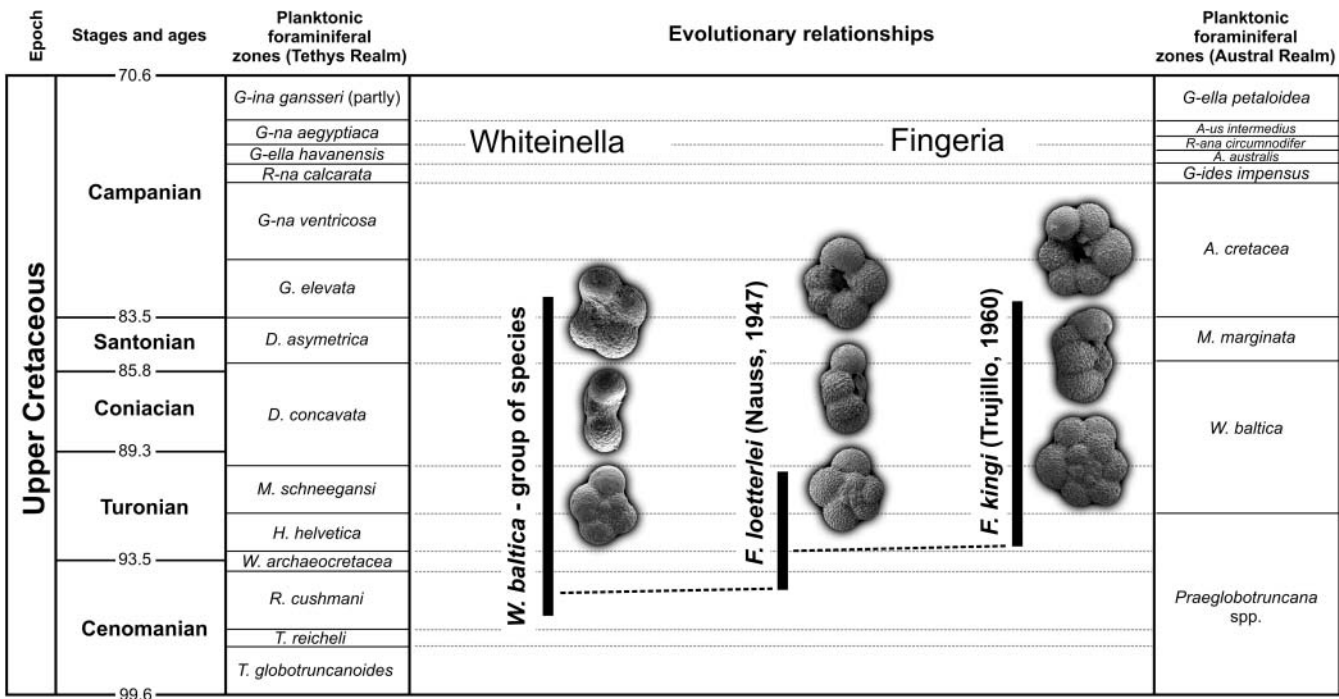


Fig. 4. Diagram presenting the evolutionary relationships between the species of *Fingeria*. Abbreviations: A., *Archaeoglobigerina*; A-us, *Abathomphalus*; D., *Dicarinella*; G., *Globotruncanina*; G-na, *Globotruncana*; G-ella, *Globotruncanella*; G-ina, *Gansserina*; G-ides, *Globigerinelloides*; H., *Helvetoglobotruncana*; M., *Marginotruncana*; R., *Rotalipora*; R-na, *Radotruncana*; R-ana, *Rugotruncana*; T., *Thalmanninella*; W., *Whiteinella*.

features and stratigraphical ranges. It is noteworthy that a similar taxonomic solution was taken by Huber (1994) when he considered *Rugoglobigerina macrocephala* Brönnimann, 1952 – a species with high chamber size growth rate in the last whorl and sporadic occurrences – the junior synonym of *R. rugosa* (Plummer, 1927), which is a frequent species with moderate chamber size growth increase rate.

Fingeria kingi (Trujillo, 1960)
(Pl. 2, figs 1–6)

1937 *Globigerina cretacea* d'Orbigny; Loetterle: 44, pl. 7, fig. 2 (only).
1953 *Rotundina ordinaria* Subbotina: 186, pl. 3, fig. 6 (only).
1956 *Globigerina cretacea* d'Orbigny; Bolin: 292, pl. 39, fig. 8 (only).
1960 *Rugoglobigerina kingi* Trujillo: 339, pl. 49, fig. 5.
1960 *Rugoglobigerina* (*Rugoglobigerina*) *plana* Belford: 95, pl. 27, figs 1–5, text-fig. 8.
1965 *Rugoglobigerina kingi* Trujillo; Takayanagi: 228, pl. 29, fig. 4.
1966 *Rugoglobigerina kingi* Trujillo; Marianos & Zingula: 339, pl. 38, fig. 6.
1967 *Rugoglobigerina* sp.; Burckle *et al.*: fig. 2:4.
1967 *Archaeoglobigerina bosquensis* Pessagno: 316, pl. 60, figs 7–12.
1968 *Globigerina kingi* Trujillo; Scheibnerová: 80, pl. 19, fig. 5.
1969 *Hedbergella kingi* (Trujillo); Douglas: 166, pl. 4, figs 6–7.
1969 *Archaeoglobigerina bosquensis* Pessagno; Douglas & Rankin: 199, figs 10–11.

1971 *Hedbergella kingi* (Trujillo); Belford & Scheibnerová: 334, pl. 4, figs 10–15.
1972 *Archaeoglobigerina bosquensis* Pessagno; Hanzlíková: 100, pl. 25, figs 11–13.
1973 *Archaeoglobigerina bosquensis* Pessagno; Frerichs & Adams: 192, pl. 2, figs 8–9.
1976 *Whiteinella kingi* (Trujillo); Lamolda: 19, pl. 1, figs 10–23.
1977 *Archaeoglobigerina? bosquensis* Pessagno; Petters: pl. 3, figs 14–15.
1977 *Archaeoglobigerina bosquensis* Pessagno; Sliter: 542: pl. 9, figs 3–5.
1981 *Archaeoglobigerina bosquensis* Pessagno; Frerichs & Dring: 68, pl. 3, figs 16–18.
1983 *Archaeoglobigerina bosquensis* Pessagno; Krashenninnikov & Basov: 805, pl. 8, figs 1–8.
1983 *Hedbergella plana* Belford; Belford: pl. 3, figs 6–11.
1985 *Archaeoglobigerina bosquensis* Pessagno; Caron: 43, fig. 16:5–6.
1987 *Archaeoglobigerina bosquensis* Pessagno; Frerichs & Deiss: fig. 10.2.
1992 *Archaeoglobigerina bosquensis* Pessagno; Olsson & Usmani: 313, fig. 7:1.
1994 *Archaeoglobigerina bosquensis* Pessagno; Huber: 41, pl. 7, figs 1–11.
2000 *Archaeoglobigerina bosquensis* Pessagno; Petrizzo: fig. 14:1.
2001 *Archaeoglobigerina bosquensis* Pessagno; Petrizzo: fig. 8:8.
2006 *Archaeoglobigerina bosquensis* Pessagno; Georgescu: fig. 8: 11–13.

Emended description. Test low to medium high trochospiral consisting of 15–19 globular chambers arranged in 2½–3 whorls;



Genus: <i>Fingeria</i> – new	
<i>F. loetterlei</i> (Nauss, 1947)	<i>F. kingi</i> (Trujillo, 1960)
	
Total number of chambers 12 – 14	15 – 19
Number of chambers in the last whorl 4 – 6	5 ½ – 6
Umbilicus diameter $\frac{1}{4} - \frac{1}{2} D_{\max}$	$\frac{1}{4} - \frac{1}{2} D_{\max}$
Periapertural structures Flaps	Flaps
Ornamentation elements Pustules, rarely rugosities	Pustules, rarely rugosities and costellae
Pustule maximum dimension (µm) 8.3 – 15.4	10.9 – 16.7
Pore diameter (µm) 2.3 – 4.1	1.7 – 4.9

Fig. 5. Diagram showing the resemblances and differences of selected key features between the two species of the *Fingeria* lineage.

there are 5½–6 chambers in the final whorl; chambers increase in size at a low to moderate rate. Sutures are distinct and depressed, straight or slightly curved and perpendicular to oblique to the previous whorl on the spiral side and straight and radial on the umbilical one. Test is asymmetrical, convex–concave in edge view; periphery is broadly rounded, without peripheral structures. Umbilicus is deep with diameter representing one-quarter to one-third of the test maximum diameter. Aperture is a low to medium high arch, situated in umbilical–extraumbilical position; it is bordered by a thin imperforate flap, which is rarely preserved. Chamber surface is ornamented with pustules (maximum dimension 10.9–16.7 µm) and rarely rugosities and faint costellae, which can exhibit an arrangement that is incipiently meridional or parallel to the periphery, especially over the earlier chambers on the dorsal side. Test wall is calcitic, hyaline and perforate (pore diameter 1.7–4.9 µm).

Stratigraphical range. Turonian–lower Campanian (from the lower part of *H. helvetica* Biozone to the lower part of *G. elevata* Biozone).

Geographical distribution. USA (Alaska, California, Colorado, Kansas, Minnesota, Nebraska, New Jersey, South Dakota, Texas, Wyoming), Mexico, Australia, Europe (Denmark, Slovakia, Spain), Russia, Africa (Morocco), Caribbean region (Yucatan outer shelf), South Atlantic Ocean (Falkland Plateau), Indian Ocean (Exmouth Plateau, Kerguelen Plateau, Naturaliste Plateau) and equatorial Central Pacific Ocean (Mid-Pacific Mountains).

Remarks. Two species were published simultaneously for this taxon, namely *Rugoglobigerina kingi* Trujillo, 1960 and *Rugoglobigerina* (*Rugoglobigerina*) *plana* (Belford, 1960). The former

was published in the *Journal of Paleontology*, 34(2), for which the publication date is March 1960; in the absence of a specified day, the publication date should be considered to be 31 March 1960 (International Code of Zoological Nomenclature (ICZN), Article 21.3.1). Publication date for the latter, as mentioned in the *Bureau of Mineral Resources, Geology and Geophysics Bulletin*, 57, is 31 March 1960. As First Reviser (ICZN, Article 24.2.1), the present author's decision is to validate *Rugoglobigerina kingi* Trujillo, 1960 as *Fingeria kingi* (Trujillo, 1960) because it was published in a journal with wider distribution and the type material is more accessible. *Fingeria kingi* differs from *F. loetterlei* by having more chambers in the final whorl (5½–6 rather than 4 to 6), slower chamber increase in size and larger tests. It differs from *W. baltica*, *W. brittonensis* and *W. paradoxia* mainly in the development of ornamentation that is incipiently meridional or parallel to the periphery, consisting of pustules and rarely rugosities and faint costellae. Large-sized specimens ($D_{\max} = 0.459\text{--}0.471\text{ mm}$) of *F. kingi* are frequent throughout the stratigraphical range of the species.

CONCLUSIONS

Taxonomic re-evaluation of some coarsely ornamented planktic foraminifera of Late Cretaceous (late Cenomanian–early Campanian) age reveals the existence of a new genus, *Fingeria*, which includes *F. loetterlei* (Nauss, 1947) and *F. kingi* (Trujillo, 1960) (Fig. 4). The two species are characterized by coarse ornamentation consisting of pustules, which can fuse occasionally to form rugosities and, more rarely, costellae. Most of the specimens of *F. loetterlei* and *F. kingi* have randomly orientated ornamentation elements; an incipient meridional pattern is occasionally developed. From a purely morphological point of view, the ornamentation characteristics of *Fingeria* appear intermediate between those of *Whiteinella* (randomly oriented scattered pustules) and *Costellagerina* and *Rugoglobigerina* (well-developed costellae with an ornamentation pattern that is meridional or parallel to the periphery).

There are discrete evolutionary changes in the *Fingeria* lineage: increase in the total number of chambers, number of chambers of the last whorl, umbilical diameter, pustule maximum dimension and pore size (Fig. 5). This demonstrates that at least in some lineages of globular-chambered species the Cretaceous evolution process happened mostly at the test ultrastructural level (Georgescu, 2010a). The general resemblances in the chamber shape, test ornamentation and periapertural structures (i.e. flaps) between *F. loetterlei* and *W. baltica* indicate that the ancestor of the *Fingeria* lineage is among the whiteinellid group, which first occurred in the upper Cenomanian. The transition between the two taxa happened with the ornamentation coarsening, generated by formation of rugosities and development of a loose meridional ornamentation pattern.

There is no compelling evidence to support the existence of any descendant from this lineage. *Costellagerina* of the Santonian–early Campanian is ornamented with well-developed meridionally arranged costellae. However, its pores are much smaller than those of the contemporaneous *F. kingi* (1.0–1.9 µm rather than 1.7–4.9 µm). Therefore, it appears more reasonable to consider a whiteinellid ancestry for *Costellagerina*, as suggested by Huber (1994) based on detailed test wall morphology and growth patterns. *Archaeoglobigerina australis* Huber, 1990

was considered by Huber (1994) to be the descendant of *A. bosquensis*, the latter being considered herein a junior synonym of *F. kingi*. Although specimens of *A. australis* with an incipient meridional ornamentation pattern were observed during this study in the late Campanian–Maastrichtian age material from ODP Hole 689B, the pore size of the two species shows significant differences. Pore diameter is larger in *F. kingi* (1.7–4.9 µm) and smaller in its presumed descendant, *A. australis* (1.5–3.1 µm). Additional data are necessary to clarify the phylogenetic relationships between the two species in the absence of a mechanism to explain such a decrease in pore diameter and similar examples in the Cretaceous planktic foraminiferal evolution.

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