



## Revised Diagnostic First and Last Occurrences of Mesozoic and Cenozoic Planktonic Foraminifera

MARCELLE K. BOUDAGHER-FADEL

OVPR, UCL, Gower Street, London WC1E 6BT, UK

Email: [m.fadel@ucl.ac.uk](mailto:m.fadel@ucl.ac.uk)

**Abstract:** The diagnostic first and last occurrences of Cretaceous, Paleogene and Neogene planktonic foraminifera species are given, and have been calibrated and revised against the most recent biostratigraphical time scale and radio-isotope data.

The major planktonic foraminiferal bioevents for the Late Mesozoic and the Cenozoic (as defined by BouDagher-Fadel, 2015) have been updated, revised and calibrated against the biostratigraphical time scale and the radio-isotopes (as defined by Gradstein *et al.*, 2012 and revised by Cohen *et al.*, 2017). This calibration builds upon and supersedes that of BouDagher-Fadel (2013).

The Cenozoic calibrations are compared with the earlier zonations of Berggren and Pearson (2005) and Wade *et al.* (2011). The biostratigraphic resolution of the alpha-numeric biozonations is determined by distinct evolutionary lineages of morpho-species and have been deduced through extensive industrial work, calibrated against Sr-isotopes and other biostratigraphic markers, involving global offshore wells by the present author and compared to already published works (for further details see BouDagher-Fadel, 2015).

Three figures are presented. Fig. 1 shows the diagnostic calibration based on species of planktonic foraminifera for the Cretaceous biozonations as defined by BouDagher-Fadel (2015). First occurrences and last appearances of index foraminiferal taxa are plotted against the biostratigraphical time scale of Gradstein *et al.* (2012).

Figs 2 and 3 show respectively the diagnostic calibration of planktonic foraminifera of the Paleogene and Neogene biozonations as defined by BouDagher-Fadel (2015). First occurrences and last appearances of index foraminiferal taxa are plotted against the biostratigraphical time scale of Gradstein *et al.* (2012) and compared against the earlier zonations of Berggren and Pearson (2005) and Wade *et al.* (2011).

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REVISED DIAGNOSTIC FIRST AND LAST OCCURRENCES OF PLANKTONIC FORAMINIFERA

Fig. 1. Diagnostic First and Last Occurrences of Cretaceous Planktonic Foraminifera.

Age (Ma)	Period, Epoch, Stage	Planktonic zonation	Diagnostic First Occurrence of Planktonic Foraminifera		Diagnostic Last Occurrence of Planktonic Foraminifera			
			Age (Ma)	Species	Age (Ma)	Species		
66.0	Cretaceous	Late	Maast.	3	66.2	<i>Ventilabrella multicamerata</i>	66.0	<i>Globotruncana</i> spp./ <i>Rugoglobigerina</i> spp.
					a	67.0	<i>Plummerita reicheli</i>	66.2
			2	70.0	<i>Racemiguembelina powelli</i>	67.0	<i>Rugotruncana subpennyi</i>	
			1	b	71.0	<i>Contusotruncana plicata</i>	70.0	<i>Globotruncana lapparenti</i>
				a	72.1	<i>Plummerita hantkeninoides</i>	72.1	<i>Radotruncana subspinoso</i>
			3	b	74.5	<i>Rugotruncana subpennyi</i>	74.5	<i>Globotruncanita atlantica</i>
				a	77.0	<i>Globotruncanita stuarti</i>	77.0	<i>Radotruncana calcarata</i>
			2	80.3	<i>Radotruncana calcarata</i> , <i>Globotruncanita atlantica</i>	80.3	<i>Rugoglobigerina subrugosa</i>	
			1	83.6	<i>Globotruncana mariei</i>	83.6	<i>Concavototruncana asymetrica</i>	
			2		84.9	<i>Rugoglobigerina subrugosa</i>	86.3	<i>Marginotruncana paraconcavata</i>
					85.6	<i>Globotruncana linneiana</i>		
			1	b	86.3	<i>Concavototruncana asymetrica</i>		
				a	88.0	<i>Globotruncana lapparenti</i>		
			2	89.8	<i>Marginotruncana paraconcavata</i>			
			3		91.3	<i>Dicarinella primitiva</i>	89.8	<i>Sigalitruncana biconvexiformis</i>
					92.8	<i>Helvetoglobotruncana helveticae</i>	91.3	<i>Helvetoglobotruncana helveticae</i>
			1	93.9	<i>Sigalitruncana biconvexiformis</i>	92.8	<i>Concavototruncana elata</i>	
			3	b	95.1	<i>Rotalipora cushmani</i>	93.9	<i>Rotalipora cushmani</i>
				a	97.2	<i>Thalmaninella reicheli</i>	95.1	<i>Favusella washitensis</i>
			2	b	98.8	<i>Thalmaninella greenhornensis</i>	99.6	<i>Alanlordella bentonensis</i>
				a	100.5	<i>Thalmaninella globotruncanoides</i>	100.5	<i>Hedbergella rischi</i>
			1	b	101.5	<i>Thalmaninella gandolfi</i>	102.2	<i>Ticinella praeticinensis</i>
				a	102.2	<i>Ticinella madecassiana</i>	106.7	<i>Blefuscuiana aptiana</i>
			3	b	104.4	<i>Pseudothalmaninella subticinensis</i>	106.7	<i>Blefuscuiana aptiana</i>
				a	106.7	<i>Ticinella praeticinensis</i>	113.0	<i>B. maslakovae/L. globulifera</i>
			2	109.8	<i>Ticinella roberti</i>	119.5	<i>Praehedbergella tatianae</i>	
			1	b	111.4	<i>Ticinella primula</i>	119.5	<i>Praehedbergella ruka</i>
				a	113.0	<i>Hedbergella rischi</i>	122.9	<i>Gorbachikella anteroapertura</i>
4	b	115.0	<i>Blefuscuiana kuznetsovae</i>	125.0	<i>Gorbachikella grandiapertura</i>			
	a	116.5	<i>Lilliputianella kuhryi</i>	129.0	<i>Praehedbergella tuschepsensis</i>			
3		119.5	<i>Praehedbergella tatianae</i>	132.4	<i>Gorbachikella anteroapertura</i>			
		122.9	<i>Blefuscuiana infracretacea</i>	132.9	<i>Praehedbergella handousi</i>			
1		125.0	<i>Blefuscuiana maslakovae</i>	136.6	<i>Gorbachikella grandiapertura</i>			
		127.0	<i>Lilliputianella globulifera</i>	136.65	<i>Conoglobigerina gulekhensis</i>			
3		127.0	<i>Lilliputianella globulifera</i>	139.8	<i>Conoglobigerina</i> sp. A			
		129.0	<i>Blefuscuiana daminia</i>	145.0	<i>Conoglobigerina gulekhensis</i>			
2		129.4	<i>B. aptiana/Pr. tuschepsensis</i>	145.0	<i>Conoglobigerina conica</i>			
		132.4	<i>Gorbachikella anteroapertura</i>					
1		132.9	<i>Praehedbergella handousi</i>					
		136.6	<i>Gorbachikella grandiapertura</i>					
2		136.6	<i>Gorbachikella grandiapertura</i>					
		139.8	<i>Gorbachikella</i> sp.					
1		139.8	<i>Gorbachikella</i> sp.					
		145.0	<i>Conoglobigerina gulekhensis</i>					
Berr.		145.0	<i>Conoglobigerina gulekhensis</i>					
		152.1	<i>Conoglobigerina conica</i>					
145.0	Cretaceous	Early	Alb.	4	115.0	<i>Blefuscuiana kuznetsovae</i>	113.0	<i>B. maslakovae/L. globulifera</i>
				3	116.5	<i>Lilliputianella kuhryi</i>	119.5	<i>Praehedbergella tatianae</i>
2		122.9	<i>Blefuscuiana infracretacea</i>	119.5	<i>Praehedbergella ruka</i>			
		125.0	<i>Blefuscuiana maslakovae</i>	122.9	<i>Gorbachikella anteroapertura</i>			
3		127.0	<i>Lilliputianella globulifera</i>	125.0	<i>Gorbachikella grandiapertura</i>			
		129.0	<i>Blefuscuiana daminia</i>	129.0	<i>Praehedbergella tuschepsensis</i>			
1		129.4	<i>B. aptiana/Pr. tuschepsensis</i>	132.4	<i>Gorbachikella anteroapertura</i>			
		132.4	<i>Gorbachikella anteroapertura</i>	132.9	<i>Praehedbergella handousi</i>			
2		132.9	<i>Praehedbergella handousi</i>	136.6	<i>Gorbachikella grandiapertura</i>			
		136.6	<i>Gorbachikella grandiapertura</i>	136.65	<i>Conoglobigerina gulekhensis</i>			
1		136.6	<i>Gorbachikella grandiapertura</i>	139.8	<i>Conoglobigerina</i> sp. A			
		139.8	<i>Gorbachikella</i> sp.	145.0	<i>Conoglobigerina gulekhensis</i>			
Berr.		139.8	<i>Gorbachikella</i> sp.	145.0	<i>Conoglobigerina conica</i>			
		145.0	<i>Conoglobigerina gulekhensis</i>					
Jurassic	Cretaceous	Late	Maast.	3	66.2	<i>Ventilabrella multicamerata</i>	66.0	<i>Globotruncana</i> spp./ <i>Rugoglobigerina</i> spp.
					a	67.0	<i>Plummerita reicheli</i>	66.2
2		70.0	<i>Racemiguembelina powelli</i>	67.0	<i>Rugotruncana subpennyi</i>			
		71.0	<i>Contusotruncana plicata</i>	70.0	<i>Globotruncana lapparenti</i>			
1		72.1	<i>Plummerita hantkeninoides</i>	72.1	<i>Radotruncana subspinoso</i>			
		74.5	<i>Rugotruncana subpennyi</i>	74.5	<i>Globotruncanita atlantica</i>			
3		77.0	<i>Globotruncanita stuarti</i>	77.0	<i>Radotruncana calcarata</i>			
		80.3	<i>Radotruncana calcarata</i> , <i>Globotruncanita atlantica</i>	80.3	<i>Rugoglobigerina subrugosa</i>			
2		83.6	<i>Globotruncana mariei</i>	83.6	<i>Concavototruncana asymetrica</i>			
		84.9	<i>Rugoglobigerina subrugosa</i>	86.3	<i>Marginotruncana paraconcavata</i>			
	85.6	<i>Globotruncana linneiana</i>						
1		86.3	<i>Concavototruncana asymetrica</i>					
		88.0	<i>Globotruncana lapparenti</i>					
2		89.8	<i>Marginotruncana paraconcavata</i>					
		91.3	<i>Dicarinella primitiva</i>	89.8	<i>Sigalitruncana biconvexiformis</i>			
3		92.8	<i>Helvetoglobotruncana helveticae</i>	91.3	<i>Helvetoglobotruncana helveticae</i>			
		93.9	<i>Sigalitruncana biconvexiformis</i>	92.8	<i>Concavototruncana elata</i>			
1		95.1	<i>Rotalipora cushmani</i>	93.9	<i>Rotalipora cushmani</i>			
		97.2	<i>Thalmaninella reicheli</i>	95.1	<i>Favusella washitensis</i>			
2		98.8	<i>Thalmaninella greenhornensis</i>	99.6	<i>Alanlordella bentonensis</i>			
		100.5	<i>Thalmaninella globotruncanoides</i>	100.5	<i>Hedbergella rischi</i>			
1		101.5	<i>Thalmaninella gandolfi</i>	102.2	<i>Ticinella praeticinensis</i>			
		102.2	<i>Ticinella madecassiana</i>	106.7	<i>Blefuscuiana aptiana</i>			
3		104.4	<i>Pseudothalmaninella subticinensis</i>	106.7	<i>Blefuscuiana aptiana</i>			
		106.7	<i>Ticinella praeticinensis</i>	113.0	<i>B. maslakovae/L. globulifera</i>			
2		109.8	<i>Ticinella roberti</i>	119.5	<i>Praehedbergella tatianae</i>			
		111.4	<i>Ticinella primula</i>	119.5	<i>Praehedbergella ruka</i>			
1		113.0	<i>Hedbergella rischi</i>	122.9	<i>Gorbachikella anteroapertura</i>			
		115.0	<i>Blefuscuiana kuznetsovae</i>	125.0	<i>Gorbachikella grandiapertura</i>			
4		116.5	<i>Lilliputianella kuhryi</i>	129.0	<i>Praehedbergella tuschepsensis</i>			
		119.5	<i>Praehedbergella tatianae</i>	132.4	<i>Gorbachikella anteroapertura</i>			
3		122.9	<i>Blefuscuiana infracretacea</i>	132.9	<i>Praehedbergella handousi</i>			
		125.0	<i>Blefuscuiana maslakovae</i>	136.6	<i>Gorbachikella grandiapertura</i>			
1		127.0	<i>Lilliputianella globulifera</i>	136.65	<i>Conoglobigerina gulekhensis</i>			
		129.0	<i>Blefuscuiana daminia</i>	139.8	<i>Conoglobigerina</i> sp. A			
2		129.4	<i>B. aptiana/Pr. tuschepsensis</i>	145.0	<i>Conoglobigerina gulekhensis</i>			
		132.4	<i>Gorbachikella anteroapertura</i>	145.0	<i>Conoglobigerina conica</i>			
1		132.9	<i>Praehedbergella handousi</i>					
		136.6	<i>Gorbachikella grandiapertura</i>					
2		136.6	<i>Gorbachikella grandiapertura</i>					
		139.8	<i>Gorbachikella</i> sp.					
1		139.8	<i>Gorbachikella</i> sp.					
		145.0	<i>Conoglobigerina gulekhensis</i>					
Berr.		145.0	<i>Conoglobigerina gulekhensis</i>					
		152.1	<i>Conoglobigerina conica</i>					

REVISED DIAGNOSTIC FIRST AND LAST OCCURRENCES OF PLANKTONIC FORAMINIFERA

Fig. 2. Diagnostic First and Last Occurrences of Paleogene Planktonic Foraminifera.

Age (Ma)	Period, Epoch, Stage	Berggren and Pearson 2005	Wade et al., 2011	Planktonic Zonation (this study)	Diagnostic First Occurrence of Planktonic Foraminifera	Diagnostic Last Occurrence of Planktonic Foraminifera
56.0	Early Danian	P1c, P1b, P1a	P1c, P1b, P1a	P1	Subbotina fringa, S. triloculoides, Parasubbotina varianta Turbeogoborotalia polycamera, Praerenuca inconstans Subbotina simplicissima, Parasubbotina pseudobulboides Parvularugoglobigerina eugubina, Globanomalina planocompressa	Hedbergella holmdelensis, H. nonmouthensis Parvularugoglobigerina eugubina Guembeltrina cretacea
51.6	Late Danian	P2	P2	P2	Subbotina triangularis, Praerenuca uncinata	Eoglobigerina ebulboides (Globococconeus daubjergensis)
59.2	Late Selandian	P3	P3	P3	Morozovella acuta, Morozovella velascoensis Morozovella conotrunca, M. aequa, Igorina albeana, Acarinina praesphaerica Igorina pusilla, Morozovella angulata	Zaauvigerina reuina
56.0	Early Ypresian	P4	P4	P4	Acarinina esnaensis, A. primitiva Acarinina mckennai, Pseudomenardella pseudomargaritae	Acarinina wilcoxensis
47.8	Middle Lutetian	E6	E6	P10	Truncorotaloides haynesi	Acarinina wilcoxensis
41.2	Middle Bartonian	E11	E11	P12	Igorina anapetes, Aragonella nuttalli Globigerina hagni, Morozovella caucasica Dentoglobigerina galavisi, Acarinina collactea Guembeltrina higginsii Acarinina decepta	Morozovella spinulosa/Truncorotaloides topliensis
37.8	Late Praborian	E14	E14	P15	Globorotaloides eovariabilis Praetenuitella mpariapertura	Hantkenina alabamensis/Truncorotaloides topliensis
33.9	Late Rupelian	E15	E15	P16	Subbotina angiporoides Carnoborotalia coccaensis Orbulinoides beckmanni	Hantkenina alabamensis/Truncorotaloides topliensis
27.8	Late Chattian	O5	O5	P21	Globooborotalia woodi, Paraglobooborotalia pseudokugleri	Tenuitella gemma/Paraglobooborotalia opima
23.0	Early Chattian	O6	O6	P22	Paraglobooborotalia mayeri, Globigerina brazieri	Globooborotalia woodi, Paraglobooborotalia pseudokugleri



REVISED DIAGNOSTIC FIRST AND LAST OCCURRENCES OF PLANKTONIC FORAMINIFERA

Fig. 3. Diagnostic First and Last Occurrences of Neogene Planktonic Foraminifera.

Age (Ma)	Period, Epoch, Stage	Berggren and Pearson, 2005	Wade et al., 2011	Planktonic Zonation (this study)	Diagnostic First Occurrence of Planktonic Foraminifera	Diagnostic Last Occurrence of Planktonic Foraminifera			
23.03	Early Miocene	M1	M1	N4	Paragloboborotalia kugleri, Globoborotalia brazieri, Globigerinoides parawadi	Globoborotalia flexuosa Truncorotalia hessi/Truncorotalia tosaensis Globoborotalia pertenuis			
							22.0		
15.97	Middle Miocene	M4	M4	N7	Paragloboborotalia birnageae, Globigerina diplostoma Globoborotalia miozea, Catapsydrax parvulus	Globoborotalia conomiozea			
							17.0		
		M5	M5	N8	.....	a	Globoborotalia praemenardii, Praeorbulina sicana Globigerinoides bisphericus	Globoborotalia merotumida	
									15.9
		M6	M6	N9	M6	a	Orbulina universa Orbulina suturalis	Globoborotalia merotumida	
									14.5
		M7	M7	N10	M7	a	Globoborotalia praefohsi, Globigerina druryi Paragloboborotalia perpheroacuta, Globoborotalia rifensis	Globoborotalia merotumida	
									13.7
		11.63	Late Miocene	M8-M9	M8-M9	N12	M7-M9	Globoborotalia lobata, Globigerinoides bollii Globoborotalia praemenardii, Globoborotalia fohsi	Paragloboborotalia paralenguensis
M10	M10			N13	M10	b	Globoborotalia tenguensis, Sphaeroidinellopsis subdehiscens Globoborotalia lobata, Globigerinoides bollii	Paragloboborotalia paralenguensis	
									11.8
M11	M11			N14	M11	b	Globigerinoides ruber, Globoborotalia paralenguensis Globoborotalia repentes	Paragloboborotalia paralenguensis	
									11.6
M12	M12			N15	M12	b	Globoborotalia plesiolumida Truncorotalia oceanica	Paragloboborotalia paralenguensis	
									9.0
5.33	Pliocene	PL1	PL1	N18	Globoborotalia margaritae Globoborotalia tumida	Paragloboborotalia paralenguensis			
							5.3		
1.81	Pleistocene	PT1	PT1	N23	Globoborotalia neoflexuosa Sphaeroidinella excavata Hastigerinella digitata Beella digitata	Paragloboborotalia paralenguensis			
							1.0		
		PL3-PL6	PL3-PL6	N20	PL3-PL6	a	Truncorotalia tenuitheca Tenuitella anfracta Globoborotalia rubescens Neogloboquadrina eggeni, Pulleniatina obliquiloculata	Neogloboquadrina acostaensis Globoborotalia cibaoensis Globoborotalia juanai	
									3.6
		PL2	PL2	N19	PL2	b	Globoborotalia unguolata	Neogloboquadrina acostaensis Globoborotalia cibaoensis Globoborotalia juanai	
									4.2
		M13-M14	M13-M14	N17	M13-M14	a	Globoborotalia miocenica	Neogloboquadrina acostaensis Globoborotalia cibaoensis Globoborotalia juanai	
									7.2
		20.4	Early Miocene	M2	M2	N5	Globoborotalia praescitula, Paragloboborotalia zealandica Tenuitella minutissima, Globigerinita incrusta	Globigerinita praestainforthi	
									21.0
21.0	Early Miocene	M1	M1	N4	Turborotalia quinqueloba, Paragloboborotalia continuosa Paragloboborotalia kugleri, Globoborotalia brazieri, Globigerinoides parawadi	Globigerina ciproensis Globigerina angulituralis			
							22.0		

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