The Campanian-Maastrichtian Boundary
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CHAPTER C5b

Planktic foraminiferal quantitative analysis across the Campanian/Maastrichtian boundary at Tercis (Landes, France)

J. A. Arz & E. Molina

Sommaire

L'analyse quantitative des foraminifères planktoniques de la Grande Carrière de Tercis nous a permis de reconnaître les changements des assemblages, de déterminer certaines caractéristiques du paléoenvironnement et d'établir une biostratigraphie détaillée à travers la limite Campanien/Maastrichtien. Les biozones suivantes ont été reconnues de bas en haut: Biozone à *Globotruncana ventricosa*, Biozone à *Heterohelix glabrans* (limite entre les cotes 39,6 et 64,8), Biozone à *Globotruncanella havanensis* (limite entre les cotes 73,9 et 76,1), Biozone à *Rugoglobigerina hexacamerata* (limite entre les cotes 76,9 et 79,4), Biozone à *Rugoglobigerina rotundata* (Campanien moyen et supérieur, limite entre les cotes 115,7 et 116,8) et Biozone à *Rugoglobigerina scotti* (Maastrichtien inférieur). Le Point Stratotypique Global qui sera placé entre les cotes 115 et 116 coïncide avec l'apparition du foraminifère planktonique *Rugoglobigerina scotti.* Cet événement est marqué par l'apparition locale de *Planogoglobulina carseyae*, *Contusotruncana walfischensis* et *Gublerina acuta*. Les assemblages sont assez constants et ne présentent pas de changement significatif sauf près de la limite Campanien/Maastrichtien telle qu'illustrée dans ce volume.

1. Introduction

In terms of planktic foraminifera the Campanian/Maastrichtian (C/M) boundary has been usually placed at the top of *Globotruncanita* (=*Radotruncana*) *calcarata* Biozone (Bolli, 1966; Pessagno 1967; Postuma 1971; Van Hinte 1976; Sigal, 1977; Wonders, 1980; Robaszynski et al., 1984; Caron, 1985). More than 30 samples from Tercis were studied and we did not find *Rd. calcarata.* Based in the appearance or disappearance of other species in certain sections in Spain (see below), the *Rd. calcarata* Biozone can be correlated to the *H. glabrans* Biozone recognised at the Tercis section.

In order to solve the problem of the position of the C/M boundary, and to define the GSSP at Tercis, the planktic foraminifera assemblages have been quantitatively analysed. Planktic foraminifera are frequent across the potential GSSP around level 116 and allow us to recognise the characteristics of the palaeoenvironment and to quantify the faunal turnover. Furthermore, our research tries to establish the biozonation and to determine which planktic foraminifera events are close to the potential GSSP.

2. Materials and methods

The lithology is composed of grey limestones with few marly levels interbedded. Odin & Odin (1994) divided the section in 8 units based mainly in the content of chert and glauconite. The sampling was accomplished under the guidance of Gilles S. Odin and using his column 31 samples were taken in the less calcareous levels.

Samples of about 0.5 kg were disaggregated in water using calgoon and H_2O_2, then washed in sieves bigger than 63 μm and dried in a drying oven at 50°C. The quantitative planktic foraminiferal analysis was based on representative splits, using a modified Otto microspliter, of 300 or more specimens in the size fraction larger than 106 μm. All the representative specimens were picked, identified and mounted on microslides for a permanent record. Finally, the remaining sample was scanned for rare species.

The planktic foraminifera preservation is good but the shells are very recrystallised in the more indurated samples. The presence of frequent planktic foraminifera in 21 of the samples allowed the quantitative analysis but the scarcity in the samples from the upper part of the section did not allow to have a representative split and only the stratigraphical distribution was established. The percentages are shown in tables 1 and 2.

3. Results and palaeoecology

The planktic foraminifera quantitative analysis provides a rigorous foundation to determine some palaeoecological aspects. It allows to establish the faunal turnover and the palaeoenvironmental reconstruction. Consequently, planktic foraminifera are not only very useful in biostratigraphy but also in palaeoecology. The results of the quantitative analysis from the lower and middle part of the section are shown in figures 1 and 2.

Planktic foraminiferal assemblages are composed by 60 different species, increasing from 31 species at the base of the section to a maximum of 48 species in the middle part of the section (lower part of *Rg. scotti* Biozone). In the upper part of the section (not included in figures 1 and 2) the diversity is very low and only 14 species were found in the topmost sample at level 174.0.

Across the lower and middle parts of the section, that has been quantitatively studied, some cosmopolitan species are abundant. *Heterohelix globulosa* is always present in percentages between 20% and 40%. Other very frequent species are: *Globigerinelloides prairiehillensis*, *Hedbergella holmdelensis* and *Globotruncana arca*. In contrast, some species are very scarce such as *Guembelitria cretacea*, *Pseudoguembelina palpebra*, *Globotruncanita subspinosa*, *Planoglobulina carseyae*, *Contusotruncana walfischensis*, *Gublerina acuta* and *Pseudoguembelina excolata* and their ranges could be locally restricted (figure 1).

Distribution of genera across the C/M boundary is quite stable and the most abundant are: *Heterohelix*, *Globigerinelloides* and *Hedbergella*, though from the middle part up of the section the genus *Globotruncana* increases its frequency (figure 2). In contrast, a significant feature is the low relative abundances of the genera *Pseudoguembelina* and *Pseudotextularia* in comparison with other low latitude sections in Spain (Arz, 1996), which reflect the relatively high latitude of the palaeoenvironment of the Tercis section. The relative abundance of *Guembelitria* is extremely low, due to the opportunistic strategy of their species, blooming after mass extinction crisis. *Rugoglobigerina* is frequent and its abundances increase due to the appearance of new species. These species show a meridional pattern which is not so strongly ornamented as the specimens from low latitudes.

The planktic/benthic ratio is low, especially at the potential GSSP (Odin, 1996), but it shows the maximum just above the *Rg. scotti* appearance (figure 2). The low values in the planktic/benthic ratio indicate that the sedimentation took place in a middle-outer shelf. This explains the diachronic appearance in relation to other sections (Arz, 1996) of certain planktic foraminifera deep dwellers such as *Globotruncanita subspinosa*, *Globotruncanita conica*, *Globotruncana falsostuarti*, *Globotruncanita angulata* and *Globotruncanita stuarti*. These species seem to appear in coincidence with the transgressive episodes. The minimum in planktic foraminifera coincident with the appearance of *Rg. scotti* has also been observed by us in other sections in the Pyrénées (Zumaya & Músquiz) and Betic Cordilleras (Alamedilla). Immediately above this regressive episode the lower part of the *Rg. scotti* Biozone shows an increase in the deep an low latitude species. Nevertheless, certain species such as *P. palpebra* and *P. excolata* are very rare probably due to the relatively low temperature of the Tercis palaeoenvironment.

Planktic foraminifera abundance decreases significantly in the upper part of the section and it was

Table 1. Relative abundances of planktic foraminiferal species from the lower part of Tercis section.

SPECIES	SAMPLES >106 µ										
	11.5	22.7	39.6	64.8	73.9	76.1	79.4	89.4	95.7	97.1	97.8
Guembelitria cretacea							0.32			0.63	
Heterohelix planata	0.96	6.76	9.63	5.63	2.58	4.09	2.24	0.97	5.45	1.58	3.96
H. globulosa	18.91	30.96	36.54	22.85	30.00	21.07	41.85	28.90	30.45	24.37	21.10
H. pulchra	x	x	0.66	0.33		0.94		0.32	0.64		0.31
H. punctulata	x	0.36	0.33	0.66		0.31	0.32		1.60		
H. glabrans			x	x	0.32	x	0.64		1.92	0.31	0.61
H. labellosa				x			0.64	0.65	0.32		0.31
H. navarroensis	0.32	1.07	0.66	0.99	0.65	0.94	2.88	1.30	0.32	0.31	0.31
Pseudotextularia nuttalli	0.96	1.42	0.66	0.66	0.97	0.63	0.32	2.92	2.56	0.63	0.92
P. elegans				x		x				0.31	
Gublerina acuta											
Pseudoguembelina costulata	x	x	1.00	1.32				0.32	0.96	2.22	
P. excolata											
P. palpebra											
Planoglobulina carseyae											
P. riograndensis								0.32	x		
Globigerinelloides yaucoensis	4.17	2.14	2.99	3.64	3.55	4.09	2.46	2.27	2.89	3.48	3.98
G. rosebudensis			x	1.32		0.31	0.96		0.64	1.27	0.31
G. prairiehillensis	12.18	11.39	10.00	18.87	6.77	14.78	2.56	3.25	12.18	3.16	12.84
G. volutus	6.09	4.98	3.32	4.64	8.71	4.72	3.83	1.62	5.13	17.72	16.51
G. subcarinatus						3.14	1.60	0.97		2.53	x
Hedbergella monmouthensis	4.49	4.27	3.65	4.97	5.48	6.92	8.63	1.62	8.01	5.70	2.14
H. holmdelensis	22.76	14.59	6.31	8.28	7.74	10.06	11.50	3.90	7.69	3.48	3.98
Globotruncanella havanensis				x	0.65	4.40	0.32	1.30	x		
G. petaloidea					0.32	6.60	0.32	0.32	0.64		
Archaeoglobigerina cretacea	1.92	2.85	3.99	2.32	1.29	3.77	2.88	1.95	1.28	0.63	1.22
A. blowi	1.60	1.78	3.32	1.66	0.32	1.89	1.28	0.65	0.96	0.31	
Rugoglobigerina rugosa	x	1.07	0.33	0.66	0.97	3.14	1.28	2.27	1.28	0.31	3.06
R. hexacamerata						x	0.32		0.32	0.63	1.22
R. rotundata							0.32	0.32	0.64		
R. pennyi									x	1.26	
R. scotti											
R. macrocephala							0.32				0.61
Globotruncana arca	6.73	3.91	4.98	6.29	8.07	1.89	3.20	8.12	3.21	9.81	8.87
G. aegyptiaca				x	5.80	x	0.96	4.87	1.60	1.90	4.28
G. bulloides	2.56	2.49	2.66	0.99	0.65	0.63	0.96	2.60	2.56	1.58	2.14
G. orientalis			0.66	1.32	0.32	0.63	0.64	0.32	0.32	0.31	
G. rosetta	x		x	x			0.32	0.65	x	x	0.31
G. linneiana	4.17	0.71	2.66	3.31	4.84	2.52	2.56	10.39	0.96	2.85	3.67
G. ventricosa	x	x	x	x	0.32	0.31		2.93			
G. falsostuarti						x			x		
G. mariei	6.09	4.63	2.99	4.64	6.13	1.57	0.96	7.14	1.92	10.13	4.59
Globotruncanita stuarti									x		0.31
Glta. stuartiformis	0.64	1.07	x	0.33	0.65	x			x		
Glta. angulata						x			x	0.31	
Glta. insignis	0.64		x	0.33	0.32	x		0.97	x		0.31
Glta. fareedi				0.99	0.97	x	0.64	3.57	0.32	0.31	0.31
Glta. subspinosa				x		x			x		
Glta. elevata	1.28										
Glta. atlantica	x	x	x								
Glta. conica											
Contusotruncana contusa											
C. patelliformis	x		0.33	x	0.32	x		0.32			
C. fornicata	0.64	1.78	1.33	2.98	0.65	x	0.64	0.32	x	0.95	1.22
C. plummerae	x	1.42	0.66	x	0.65	0.31	0.96	1.30	0.64	0.95	
C. plicata								0.32			0.31
C. walfischensis											
Marginotruncana undulata	0.32	x									
M. sinuosa	0.64	0.36	x								
M. marginata	1.92	1.07									
COUNTED SPECIMENS	312	284	301	302	310	318	313	308	312	316	327
% PLANKTIC / BENTHIC	10.00	30.95	28.21	21.05	28.38	21.74	25.00	28.21	18.52	21.43	31.58

Table 2. Relative abundances of planktic foraminiferal species from the middle part of Tercis section.

SPECIES	SAMPLES >106 µ									
	109.5	112.0	113.9	115.7	116.8	117.7	119.9	122.8	131.5	135.6
Guembelitria cretacea										
Heterohelix planata	2.24	4.64	0.97	4.55	2.54	3.13	2.90	3.59	2.29	3.16
H. globulosa	33.87	30.80	36.69	42.31	34.60	34.69	14.52	37.58	31.38	18.67
H. pulchra	0.32	0.33	0.65	0.35	0.32	0.94	x	0.33		0.63
H. punctulata		0.33		0.35	2.22	0.94	2.26	1.31		1.90
H. glabrans	1.60	0.66			3.81	1.88	0.65	1.96	0.65	1.58
H. labellosa	1.28		0.33	0.70	1.27	1.25	x	0.33	0.32	0.32
H. navarroensis	0.96	0.99	1.62	0.70	0.32	0.31	0.32	0.33	2.61	0.63
Pseudotextularia nuttalli	0.64	2.32	2.60	2.10	1.59	2.19	1.94	2.29	2.94	1.27
P. elegans			0.33		x	x	0.32	0.65	x	0.32
Gublerina acuta					0.32		0.32	x	0.32	0.32
Pseudoguembelina costulata	0.64	0.66			0.95	0.63	0.32	1.31		0.63
P. excolata							0.32			
P. palpebra	0.64									
Planoglobulina carseyae					x		x	x		0.32
P. riograndensis			0.65		0.32	0.31	0.97	0.33		0.32
Globigerinelloides yaucoensis	5.43	12.58	0.97	5.94	1.59	1.56	0.32	0.98	2.61	1.27
G. rosebudensis	0.64		0.65		0.32	0.31	x	x	0.98	0.32
G. prairiehillensis	7.67	13.25	1.95	11.19	6.67	7.81	4.19	5.88	3.27	1.27
G. volutus	4.15	5.30	3.25	8.04	2.86	1.25	2.26	3.59	3.27	2.85
G. subcarinatus	0.96	0.66	0.97	1.05	1.90	1.25	1.62	0.65	0.65	1.58
Hedbergella monmouthensis	2.56	5.96	6.82	3.85	2.22	3.75	1.94	1.63	2.69	4.43
H. holmdelensis	4.79	5.96	6.49	6.99	1.59	2.81	2.58	5.23	3.27	2.85
Globotruncanella havanensis			1.30		x	0.31	x	0.65		x
G. petaloidea	x	0.33	1.62	0.70	0.95	0.63	0.65	0.33	0.32	x
Archaeoglobigerina cretacea	1.92	1.33	1.95	1.40	0.63	0.31	0.65	2.61	1.35	1.27
A. blowi	0.32	1.33	0.65	0.70	1.59	0.31		0.98		0.32
Rugoglobigerina rugosa	2.56	2.65	5.20	2.10	4.76	1.88	4.52	3.59	2.94	7.28
R. hexacamerata	0.64	0.99	1.62	0.35	1.27	0.31	0.65	0.33	0.65	2.22
R. rotundata		0.33	0.65		0.63	0.63	2.90	x		0.63
R. pennyi		0.33	0.97		x	x	0.32	x	0.32	0.32
R. scotti					x		x			0.32
R. macrocephala			0.33							
Globotruncana arca	11.50	1.33	5.84	2.80	9.84	10.94	21.29	7.19	13.07	11.71
G. aegyptiaca	2.24	1.99	2.72	1.40	1.27	4.06	7.10	3.92	1.96	8.86
G. bulloides	0.96		1.30	0.35	0.32	1.88	1.29	0.65	1.63	0.32
G. orientalis	0.32	0.99	0.65		0.63	0.31	1.29	0.65	0.32	0.95
G. rosetta	0.64		0.33		x	0.31	1.29	0.65	0.65	1.58
G. linneiana	3.51	1.66	1.30		1.90	1.88	4.84	1.63	3.27	2.53
G. ventricosa	0.64	0.33	0.33		0.32	x	x			
G. falsostuarti			0.33		0.63	0.94	1.29	0.98	0.65	0.63
G. mariei	5.11	1.33	2.60	1.75	6.98	5.94	9.03	2.61	6.86	8.86
Globotruncanita stuarti				0.35	0.32	x	x	0.33	0.32	0.32
Glta. stuartiformis	0.32		0.33		x	x	x		0.32	x
Glta. angulata			0.97		x	0.31	0.32	x		x
Glta. insignis	0.32				0.32		0.32	0.33	0.32	x
Glta. fareedi	x	0.33	0.65	1.75	x	1.88	0.65	0.65	2.29	2.22
Glta. subspinosa										
Glta. elevata										
Glta. atlantica										
Glta. conica								x		x
Contusotruncana contusa	0.32				0.32	0.31	0.32	0.65	0.32	0.32
C. patelliformis	0.96				0.63	x	1.61	0.33	0.98	0.63
C. fornicata		0.33	1.95		0.95	1.56	1.61	0.98	1.96	0.63
C. plummerae			1.95			x	0.65		2.61	
C. plicata						0.31		x		x
C. walfischensis					0.32		x	x		0.32
Marginotruncana undulata										
M. sinuosa										
M. marginata										
COUNTED SPECIMENS	313	302	308	286	315	320	310	306	306	316
% PLANKTIC / BENTHIC	25.37	15.79	27.08	4.17	14.62	34.78	41.18	46.15	15.87	8.33

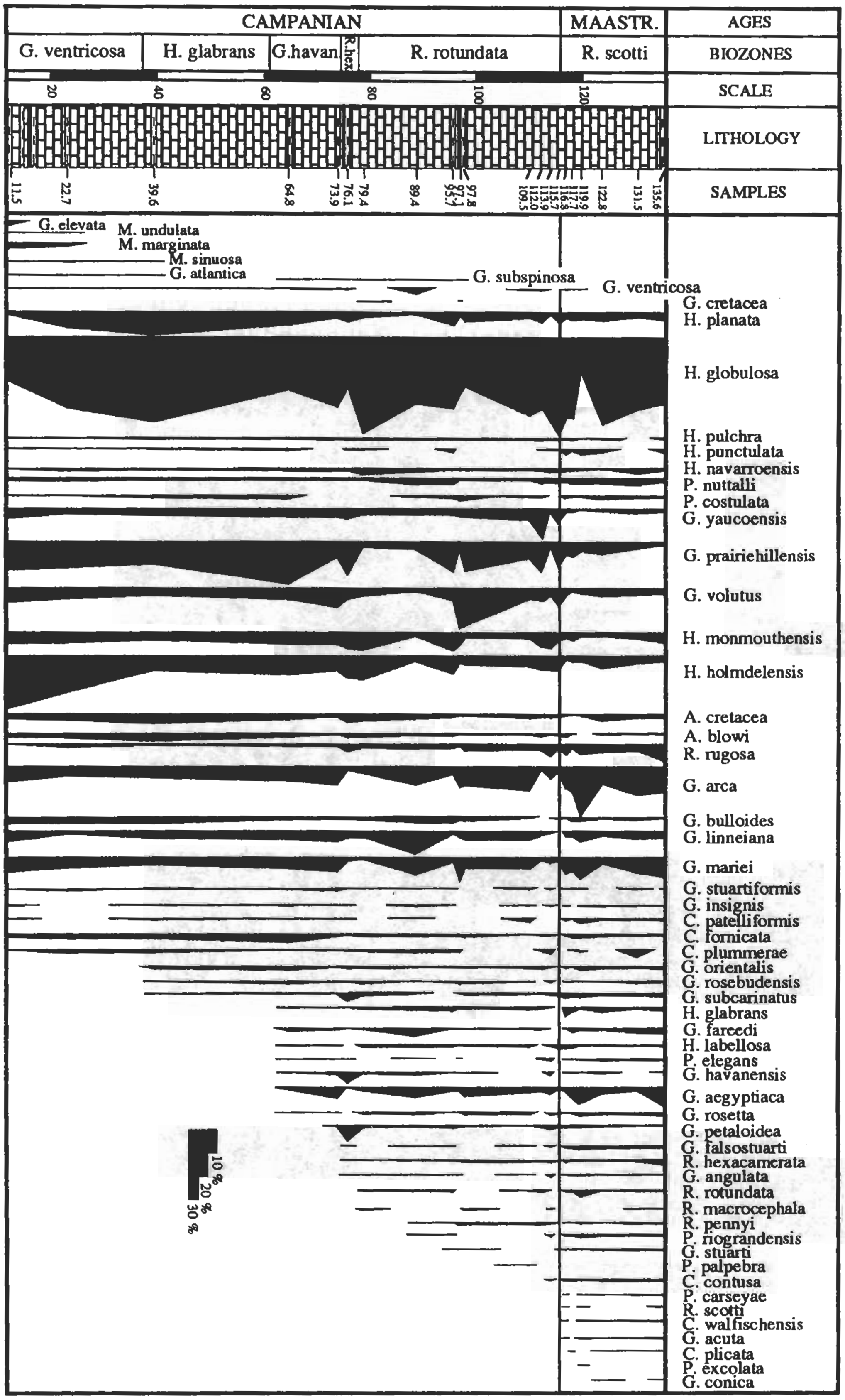

Fig. 1. Relative abundances and stratigraphical distribution of planktic foraminifera species at Tercis.

not possible to have representative splits of 300 specimens for quantitative analysis. This decrease indicates a probable regressive tendency in the basin. This regressive event affected all the genera except *Hedbergella* and in the uppermost sample surface dwellers are the only remaining fauna, with the only possible exception of *Globotruncana linneiana*, which could live in intermediate waters.

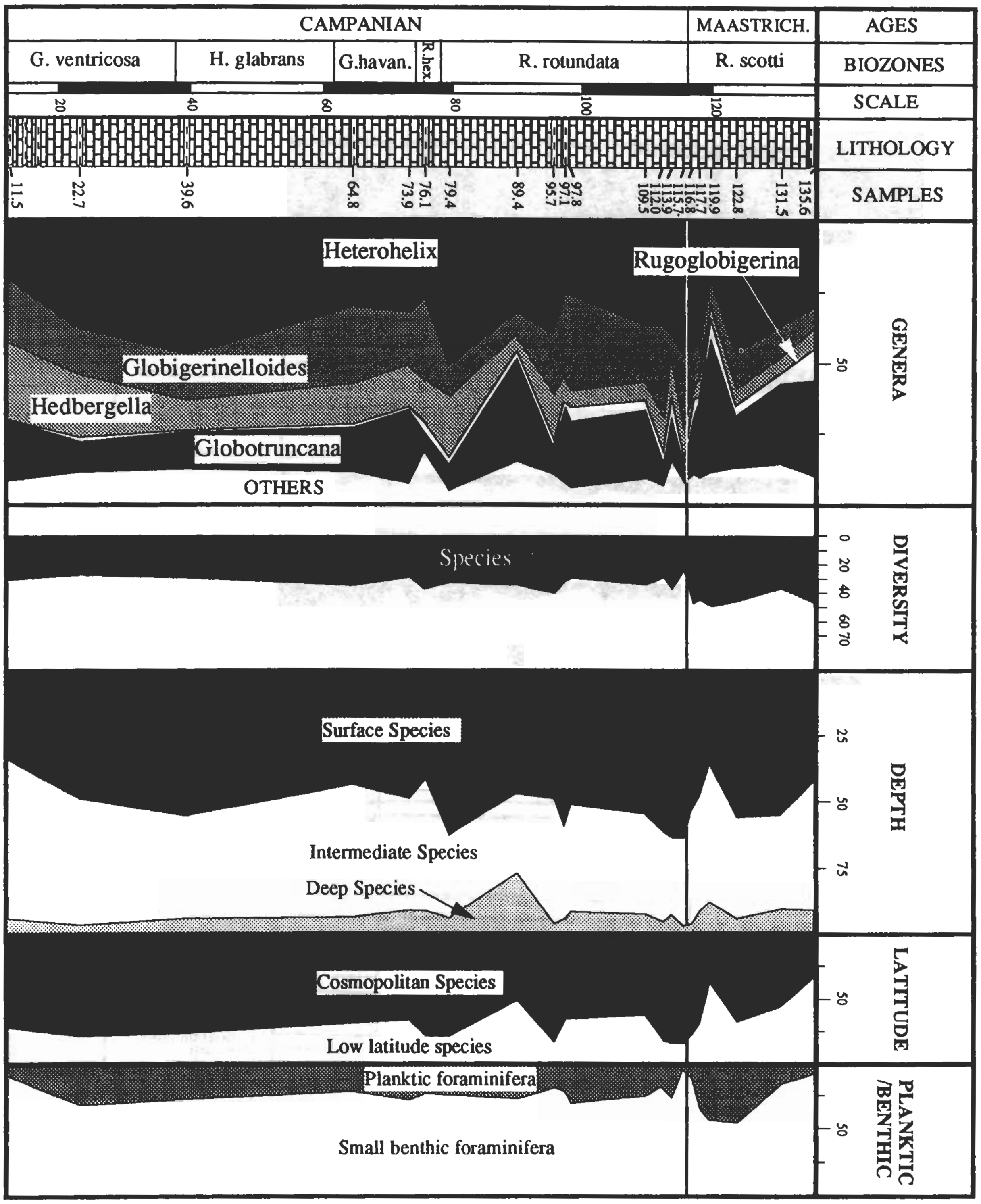

Fig. 2. Quantitative analysis across the Campanian/Maastrichtian boundary at Tercis.

The decrease is quite gradual except in the genus *Globotruncanita*, which probably lived in intermediate or deep waters, and four species (*G. stuartiformis*, *G. angulata*, *G. stuarti* and *G. conica*) that disappeared early in sample 135.6 (figure 3).

4. Biozonation

The biozonation by Robaszynski & Caron (1995) defined for the Mediterranean sector of the Tethys could be applied to the Tercis section. Nevertheless, the use of this biozonation for a shelf environment is not very appropriate because most of the index fossils are deep and low latitudes dwellers. The presence of *Rd. calcarata* and *Gansserina gansseri* in the Tercis shelf environment has been questioned (Simmons et al. 1996; Ward & Orr, 1997). The presence of *Gs. gansseri* in the pyrenean sections was also questioned (Lamolda, 1982; Gómez-Garrido, 1989). In fact, according to Arz (1996) the one keel and flat dorsal side globotruncanid identified in the Pyrénées is *Globotruncanita angulata*.

At the Tercis section the following biozones have been recognised: *Globotruncana ventricosa* Biozone, *Heterohelix glabrans* Biozone, *Globotruncanella havanensis* Biozone, *Rugoglobigerina hexacamerata* Biozone, *Rugoglobigerina rotundata* Biozone (Middle and Late Campanian) and *Rugoglobigerina scotti* Biozone (Early Maastrichtian). The index species that mark their bases are the same than the zonal names. The range of the different species found are indicated in figures 1 and 3.

According to the ranges observed in other sections of the Pyrenees and Betic Cordilleras the following events can be considered local and hence diachronic: last appearances of *Guembelitria cretacea*, *Pseudoguembelina palpebra* and *Globotruncanita subspinosa*, and first appearances of *Planoglobulina carseyae*, *Contusotruncana walfischensis* and *Gublerina acuta* and in general most of the disappearances in the uppermost part of the section with the exception of *C. fornicata* and *C. plummerae*.

The use of certain species of the *Rugoglobigerina* genus as index species is not frequent but it was previously done by Masters (1977), using *Rg. hexacamerata* and *Rg. scotti*. The first appearance datum of *Rg. rotundata* is very useful since it characterises an alternative biozone to the *Gs. gansseri* Biozone which is absent in these domains. Furthermore, the first appearance datum of *Rg. scotti* can be used to divide the *Gs. gansseri* Biozone with an added advantage, since it approximately coincides with the potential GSSP that will be placed between levels 115 and 116. The coincidence of the *Rg. scotti* and *P. neubergicus* appearances has been double checked at the Zumaya section (Arz, 1996), where Ward et al. (1991) found the first appearance of *P. neubergicus* at the base of the calcareous strata placed over the flysch of the Aguinaga Formation.

Rg. scotti is an excellent index fossil since it is easy to be identified, quite cosmopolitan across latitudes and a surface dweller; furthermore, it exists a certain consensus about its quite isochronic appearance (Robaszynski et al. 1984; Butt, 1981). The top of the new *Rg. scotti* biozone is marked by the first appearance of *Abathomphalus mayaroensis*, although it has not been found in our samples. Consequently, the base of the *Rg. scotti* Biozone can be a good marker for the C/M boundary as it will be defined at Tercis, but apparently this potential C/M boundary is placed in a higher level than the one that was placed at the top of *Rd. calcarata* Biozone, since the first appearance of *Rg. scotti* can be correlated to the middle part of *Gs. gansseri* Biozone of Robaszynski and Caron (1995) and to the lower part of *P. acervulinoides* of Nederbragt (1991), whereas the *Rd. calcarata* Biozone restricted by Robaszynski and Caron (1995) can be correlated to the *H. glabrans* Biozone of this paper, since at Alamedilla and Campo sections in Spain these two species appears at the same level (Arz, 1996).

5. Conclusions

The planktic foraminifera fossil record across the C/M boundary at Tercis is quite diversified and the assemblages are dominated by surface dwellers and cosmopolitan species of temperate affinities. The assemblages are quite stable, being more diversified from the level 115.7 in the upper part of *Rg.*

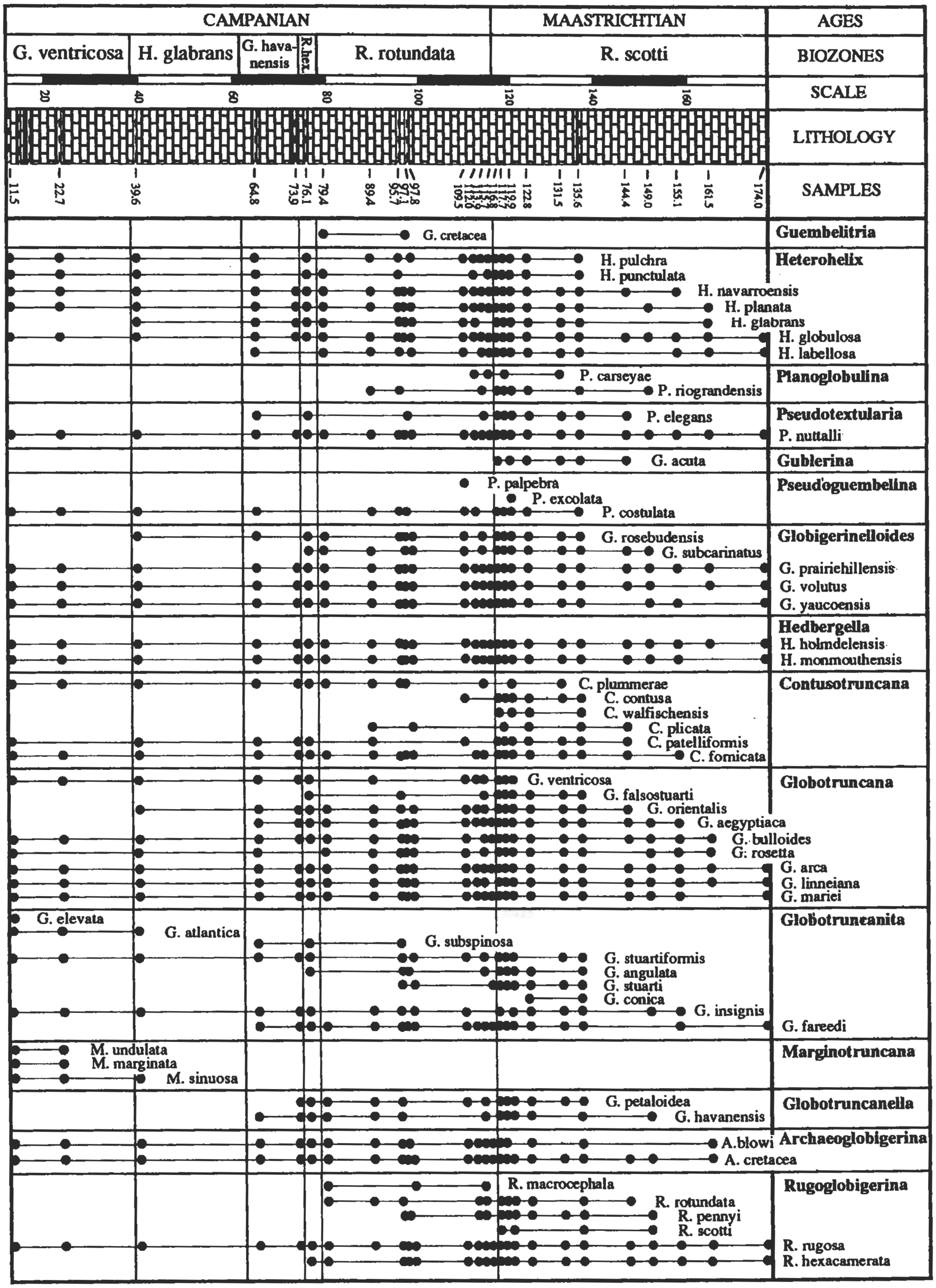

Fig. 3. Stratigraphical distribution of planktic foraminifera species at Tercis.

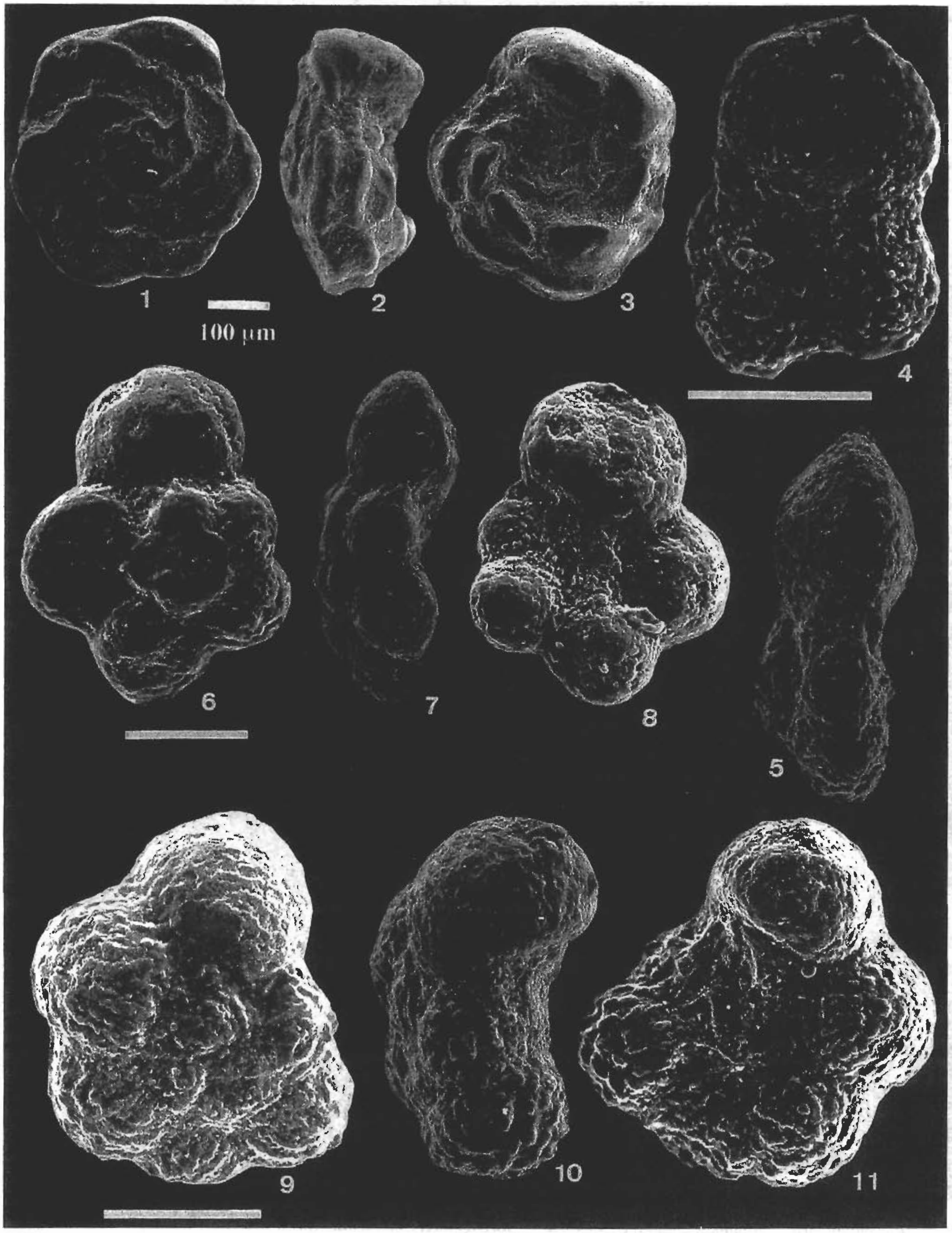

Plate I. 1–3. *Globotruncana ventricosa*, sample 11.5; 4–5. *Globigerinelloides subcarinatus*, sample 64.8; 6–8. *Globotruncanella havanensis*, sample 76.1; 9–11. *Rugoglobigerina hexacamerata*, sample 76.1.

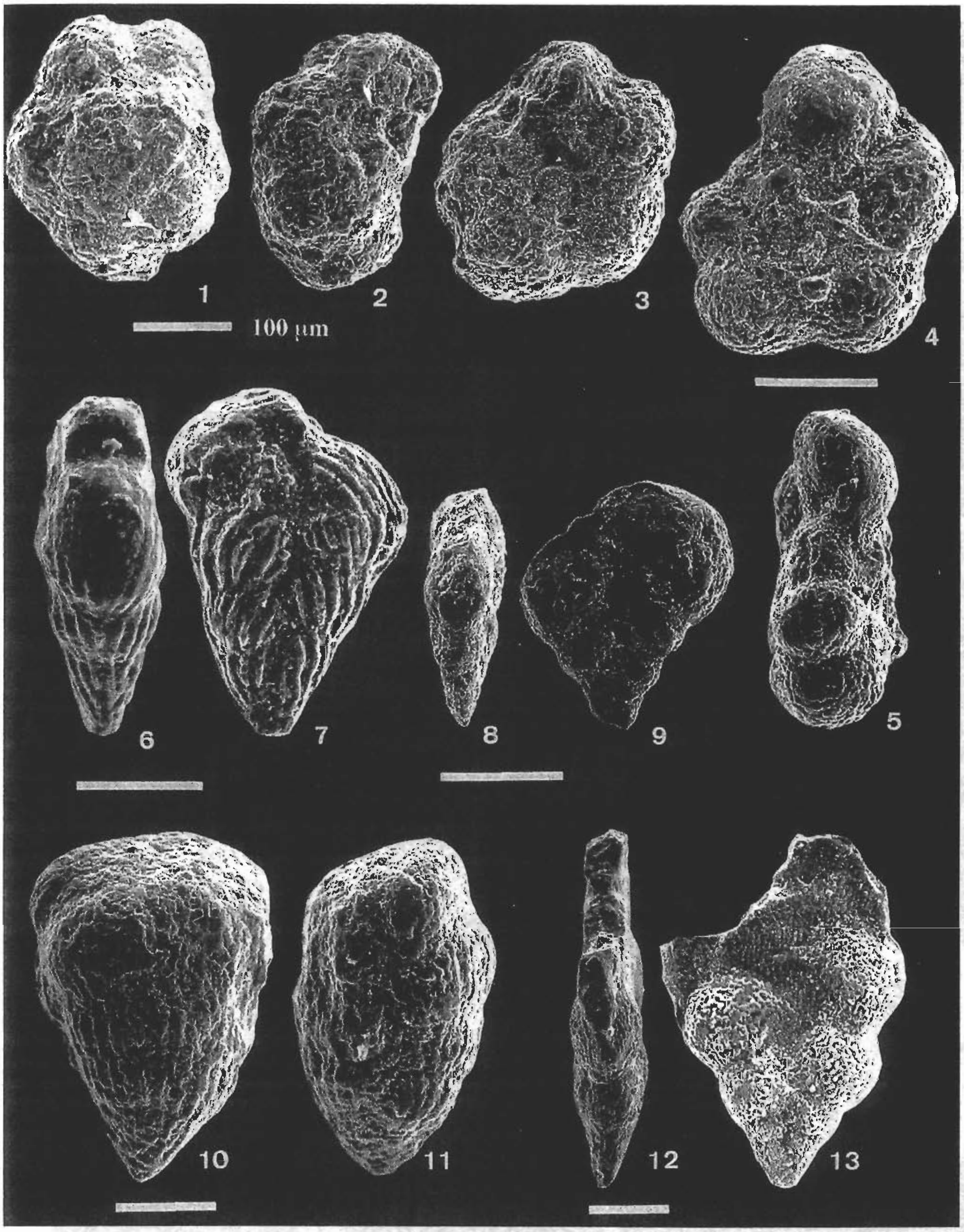

Plate II. 1–3. *Rugoglobigerina rotundata*, sample 95.7; 4–5. *Rugoglobigerina scotti* (primitive form) sample 116.8; 6–7. *Pseudoguembelina costulata*, sample 39.6; 8–9. *Heterohelix glabrans*, sample 64.8; 10–11. *Pseudotextularia elegans*, sample 64.8; 12–13. *Gublerina acuta*, sample 117.7.

rotundata Biozone to the level 135.6 in the lower part of *Rg. scotti* Biozone, with the exception of a short regressive event between levels 115.7 and 116.8 at the boundary between *Rg. rotundata* and *Rg. scotti* Biozone. The following biozones have been recognised: *Globotruncana ventricosa* Biozone, *Heterohelix glabrans* Biozone, *Globotruncanella havanensis* Biozone, *Rugoglobigerina hexacamerata* Biozone, *Rugoglobigerina rotundata* Biozone (Middle and Late Campanian) and *Rugoglobigerina scotti* Biozone (Early Maastrichtian). In terms of planktic foraminifera the potential GSSP coincides with the first appearance of *Rg. scotti* and, apparently, this new C/M boundary is placed in a higher level than the one that was considered to be placed at the top of *Rd. calcarata* Biozone, since the new boundary can be correlated to the middle part of the classical *Gs. gansseri* Biozone, whereas the *Rd. calcarata* Biozone can be correlated to the *H. glabrans* Biozone of this paper.

6. Acknowledgements

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