LATE CRETACEOUS-EARLY PALEOGENE (TURONIAN? TO EARLY DANIAN) PLANKTIC FORAMINIFERA FROM DSDP SITE 356: A BIOSTRATIGRAPHIC REAPPRAISAL

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ABSTRACT – Biostratigraphic results obtained with a systematic study of the planktic foraminiferal assemblages recovered from Upper Cretaceous-Lower Paleogene strata (Turonian? to early Danian in age) of Deep Sea Drilling Program (DSDP) Site 356, São Paulo Plateau, are presented and discussed herein. Fifty-nine planktic foraminiferal species were identified within the studied interval, enabling the identification of 11 planktic foraminiferal zones (Turonian? to early Danian in age): *Marginotruncana schneegansi*, *Dicarinella concavata*, *Dicarinella asymetrica*, *Globotruncanella elevata*, *Contusotruncana plummerae*, *Radotruncana calcarata*, *Globotruncanella havanensis*, *Pseudoguembelina palpebra*, *Abathomphalus mayaroensis*, *Pseudoguembelina hariaensis* and Pa. An unconformity spanning at least 0.96 Ma could also be suggested within core 31 (Maastrichtian in age), due to the absence of the *Racemiguembelina fructicosa* Interval Zone from the studied section. High sedimentation rates were estimated within the Santonian (*Dicarinella asymetrica* Total-range Zone) and the uppermost Maastrichtian (*Pseudoguembelina hariaensis* Interval Zone) of DSDP site 356, while lower and more constant values were suggested for the Campanian-lower Maastrichtian interval (*Globotruncanella elevata* Partial-range Zone to *Pseudoguembelina palpebra* Interval Zone). The reliability in identifying the *Contusotruncana plummerae* Interval Zone (Campanian in age) in Cretaceous sections of the South Atlantic Ocean is confirmed herein.

Key words: planktic foraminifera, biostratigraphy, Turonian?-early Danian, São Paulo Plateau, DSDP Site 356.

RESUMO – Resultados bioestratigráficos obtidos com o estudo sistemático das assembleias de foraminíferos planctônicos recuperadas de estratos atribuídos ao intervalo Cretáceo Superior-Paleógeno inferior (de idade turoniana?-daniana inicial) do *Deep Sea Drilling Program* (DSDP) Site 356, Platô de São Paulo, são aqui apresentados e discutidos. No intervalo estudado, foram identificadas 59 espécies de foraminíferos planctônicos, permitindo o reconhecimento de 11 zonas (de idade turoniana?-daniana inicial): *Marginotruncana schneegansi*, *Dicarinella concavata*, *Dicarinella asymetrica*, *Globotruncanella elevata*, *Contusotruncana plummerae*, *Radotruncana calcarata*, *Globotruncanella havanensis*, *Pseudoguembelina palpebra*, *Abathomphalus mayaroensis*, *Pseudoguembelina hariaensis* e Pa. A presença de uma discordância abrangendo ao menos 0.96 Ma foi sugerida no interior do testemunho 31 (de idade maastrichtiana), devido à ausência da Zona de Intervalo *Racemiguembelina fructicosa*. Altas taxas de sedimentação foram estimadas para os intervalos Santoniano (Zona de Amplitude *Dicarinella asymetrica*) e Maastrichtiano superior (Zona de Intervalo *Pseudoguembelina hariaensis*) do DSDP Site 356, enquanto valores mais baixos e mais constantes são sugeridos para o intervalo Campaniano-Maastrichtiano inferior (Zona de Amplitude Parcial *Globotruncanella elevata* à Zona de Intervalo *Pseudoguembelina palpebra*). O presente estudo confirma a viabilidade da identificação da Zona de Intervalo *Contusotruncana plummerae* (de idade campaniana) em seções cretáceas do Oceano Atlântico Sul.

Palavras-chave: foraminíferos planctônicos, bioestratigrafia, Turoniano?-Daniano inicial, Platô de São Paulo, DSDP Site 356.

INTRODUCTION

During the Cretaceous period, planktic foraminifera experienced their highest rates of speciation, enabling the identification of a series of high-resolution global bioevents, from the Aptian through the Maastrichtian (*e.g.* Robaszynski & Caron, 1995; Premoli Silva & Sliter, 1999). Planktic foraminiferal assemblages recovered from Upper Cretaceous-Lower Paleogene strata (Turonian? to early Danian in age) of Deep Sea Drilling Program (DSDP) Site 356, São Paulo Plateau (Figure 1), are herein restudied in a biostratigraphic approach. This planktic foraminiferal fauna was previously described by Premoli Silva & Boersma (1977), and is revised herein on the basis of up-to-date planktic foraminiferal taxonomic revisions [Mesozoic Planktonic Foraminiferal Taxonomic Dictionary (http://portal.chronos.org/gridsphere/gridsphere?cid=res_foram)] and biostratigraphic schemes (*e.g.* Caron, 1985; Sliter, 1989; Premoli Silva & Sliter, 1995; Robaszynski & Caron, 1995; Huber *et al.*, 2008; Petrizzo *et al.*, 2011). Since studies on Cretaceous planktic foraminifera from the South Atlantic Ocean are patchy in the literature (*e.g.* Sliter, 1976; Premoli Silva & Boersma, 1977; Caron, 1978; Krasheninnikov & Basov, 1983; Viviers, 1987; Viviers & Beurlen, 1987; Koutsoukos, 1989, 1992; Huber & Leckie, 2011; Kochhann *et al.*, 2013), detailed bio-/chronostratigraphic studies in the few sedimentary successions available are quite relevant.

Geological setting

The DSDP Site 356 is located at the eastern border of the São Paulo Plateau (28°17.22'S/41°05.28'W), at a water depth of 3,175 m (Figure 1), between the São Paulo High and the zone of salt structures (Mascle & Renard, 1976). The plateau extends from 20°S (Vitória-Trindade chain) to 28°S (southern boundary of the Santos Basin, Brazilian continental margin), its basement is composed of continental crust (Macedo, 1990), and Albian to Recent strata were recovered at DSDP Site 356 (Supko *et al.*, 1977). Three lithologic units (Supko *et al.*, 1977) occur in the late Turonian? to early Danian studied stratigraphic interval (units 6, 5 and 4 from bottom to top; Figure 2). Unit 6 was characterized as dark-gray mudstones and clay-pebble conglomerates; unit 5 was defined as marly chinks; and unit 4 was described as nannofossil-foraminifera chinks.

MATERIAL AND METHODS

The studied Turonian? to lower Danian section of DSDP Site 356 comprises the interval from core 44 to core 29 [739.72 mbsf (meters below the seafloor) to 410.70 mbsf]. The studied hole was spot cored, with uncored intervals ranging from 38 to 9.5 m in thickness (Figure 2; Supko *et al.*, 1977). Sixty samples were collected for the micropaleontological survey, consisting of one sample per section, with an average spacing of 1.5 m within cored intervals. The studied samples were sedimentologically characterized mainly as mudstones,

Figure 1. Top, bathymetric map of the studied area with the location of DSDP Site 356 (modified from Supko *et al.*, 1977). Base, section A-A' with the location of the studied site (modified from Mascle & Renard, 1976). **Abbreviation:** SL, sea level.

Figure 2. Stratigraphic range of selected planktic foraminiferal species in DSDP Site 356. Cored intervals are presented in black. Unconformity is represented by a wavy line. **Abbreviations.** *A. may.*, *Abathomphalus mayaroensis*; *P. palp.*, *Pseudoguembelina palpebra*; *G. hav.*, *Globotruncanella havanensis*; *R. calc.*, *Radotruncana calcarata*; *C. plu.*, *Contusotruncana plummerae*; *Gt. ele.*, *Globotruncanita elevata*; *D. con.*, *Dicarinella concavata*; *M. sc.*, *Marginotruncana schneegansi*.

calcareous mudstones, and chalks. Each sample was processed as follows: approximately 20 g of dried rock were crushed and soaked into 200 ml of hydrogen peroxide solution (29% H_2O_2) for 24 hours. Finally, residues were poured through a 38- μ m mesh sieve and around 300 foraminiferal specimens hand-picked and identified from each sample under a stereomicroscope. Selected specimens were imaged under scanning electron microscope (SEM) to assure accurate identifications. First occurrences (FOs) and last occurrences (LOs) of marker species were used in the identification of foraminiferal biozones boundaries in accordance with the studies of Caron (1985), Sliter (1989), Premoli Silva & Sliter (1995) and Robaszynski & Caron (1995), as well as the latest revisions of Huber *et al.* (2008) and Petrizzo *et al.* (2011). Preservation rating followed Petrizzo (2000), where: **G** = good (planktic foraminifera show little diagenetic alteration and minor test fragmentation); **M** = moderate (specimens show minor to moderate test fragmentation and are moderately overgrown by secondary calcite); **P** = poor (most specimens are fragmented and it is difficult to identify them at the species level). Specimens figured herein are housed in the collections of the Museu de História Geológica do Rio Grande do Sul, Universidade do Vale do Rio dos Sinos (UNISINOS), Brazil [curatorial numbers (ULVG) are given after each specimens in Figure 3].

RESULTS

The taxonomic study of the recovered planktic foraminiferal assemblages enabled the identification of 59 species within the studied interval (Figure 4; Appendix 1). The finding of fewer species herein than in Premoli Silva & Boersma (1977) is probably related to the better current understanding of the morphological plasticity of planktic foraminiferal taxa [several taxa reported by Premoli Silva & Boersma (1977) are currently considered junior synonyms of species identified herein]. It is remarkable that both species richness and preservation improve upwards in the studied section; therefore, Turonian? to Santonian assemblages are composed of few species and generally show poor to moderate preservation, while Campanian and Maastrichtian ones are richer and moderately- to well-preserved (Figure 4). The sole studied Danian sample (which is the uppermost sample in the studied section) also yielded well-preserved planktic foraminiferal specimens and displayed low richness (Figure 4). Biostratigraphic data (Figures 2, 4) are described and discussed below, while marker species are shown in Figure 3.

The biostratigraphic scheme applied to the studied section is a compilation of previously published ones (Figure 5), mainly the propositions of Caron (1985), Sliter (1989), Premoli Silva & Sliter (1995) and Robaszynski & Caron (1995). The concepts of the zones *Pseudoguembelina palpebra*, *Racemiguembelina fructicosa* and *Pseudoguembelina hariaensis* are after Huber *et al.* (2008), while the definition of the *Contusotruncana plummerae* Interval Zone is after Petrizzo *et al.* (2011).

Late Cretaceous-Early Paleogene biozonation

The *Marginotruncana schneegansi* Partial-range Zone (Robaszynski & Caron, 1995), Turonian in age, was tentatively identified from 682.77 to 681.27 mbsf. This zone is defined as the interval of occurrence of *Marginotruncana schneegansi*, from the LO of *Helvetoglobotruncana helvetica* to the FO of *Dicarinella concavata* (cf. Caron, 1985). Since the species that defines the basal boundary of this zone and the nominate taxon were not identified in the present study, the zone was tentatively assigned to the interval from the FOs of several late Turonian-Coniacian species (mainly marginotruncanids; see Figure 4) to the FO of *Dicarinella concavata* at Site 356.

The *Dicarinella concavata* Interval Zone (Sigal, 1955), late Turonian to Coniacian in age, was identified from the FO of the nominate taxon (681.27 mbsf) to the FO of *Dicarinella asymetrica* (648.27 mbsf). Besides the nominate taxon, typical species are *Marginotruncana sinuosa*, *Muricohedbergella flandrini*, *Muricohedbergella simplex* and *Heterohelix globulosa*.

The *Dicarinella asymetrica* Total-range Zone (Postuma, 1971; Santonian in age) was identified upward in the section, from the FO of the nominate taxon (648.27 mbsf) to its LO (542.27 mbsf). It is worth mentioning that all marginotruncanids become extinct within this zone.

The *Globotruncanella elevata* Partial-range Zone (Dalbiez, 1955), early Campanian in age, was identified spanning the interval from 542.27 to 518.27 mbsf. This zone is defined as the partial-range of the nominate taxon, from the LO of *Dicarinella asymetrica* to the FO of *Contusotruncana plummerae* (cf. Petrizzo *et al.*, 2011). Typical species of this zone are *Contusotruncana fornicata* and *Archaeoglobigerina blowi*.

On the basis of the proposition of Petrizzo *et al.* (2011), the *Contusotruncana plummerae* Interval Zone (Petrizzo *et al.*, 2011), middle to late Campanian in age, was identified from the FO of the nominate taxon (518.27 mbsf) to the FO of *Radotruncana calcarata* (489.77 mbsf). Typical species of this zone are *Contusotruncana fornicata*, *Globotruncana* sp. aff. *G. bulloides*, “*Globigerinelloides*” sp. aff. “*G.*” *prairiehillensis*, and *Archaeoglobigerina blowi*. In its original proposition, this zone replaces the classic *Globotruncana ventricosa* interval zone (Petrizzo *et al.*, 2011).

The *Radotruncana calcarata* Total-range Zone (Herm, 1962), late Campanian in age, was identified upwards in the section by the total-range of the nominate taxon (from 489.77 to 485.27 mbsf). Typical species of this interval are *Contusotruncana fornicata*, *Globotruncana* sp. aff. *G. bulloides*, “*Globigerinelloides*” sp. aff. “*G.*” *prairiehillensis*, and *Archaeoglobigerina blowi*.

The *Globotruncanella havanensis* Partial-range Zone (Douglas, 1969), late Campanian-early Maastrichtian in age, was identified from 485.27 to 462.83 mbsf. This zone is defined as the partial interval of occurrence of the nominate taxon, from the LO of *Radotruncana calcarata* to the FO of *Pseudoguembelina palpebra* (cf. Huber *et al.*, 2008). Typical species are *Contusotruncana fornicata* and *Archaeoglobigerina blowi*.

Figure 3. Scanning electron micrographs of selected planktic foraminiferal species from DSDP Site 356. **A-C**, *Dicarinella concavata*, 356-35-1, 77-80 cm (ULVG-10865); **D-F**, *Dicarinella asymetrica*, 356-38-3, 77-80 cm (ULVG-10866); **G-I**, *Globotruncanita elevata*, 356-33-5, 74-78 cm (ULVG-10867); **J-L**, *Contusotruncana plummerae*, 356-31-5, 51-56 cm (ULVG-10868); **M-O**, *Radotruncana calcarata*, 356-33-1, 77-80 cm (ULVG-10869); **P-R**, *Globotruncanella havanensis*, 356-32-6, 82-86 cm (ULVG-10870); **S-T**, *Pseudoguembelina palpebra*, 356-32-5, 83-87 cm (ULVG-10872); **U**, *Racemiguembelina fructicosa*, 356-29-5, 75-75 cm (ULVG-10873); **V-X**, *Abathomphalus mayaroensis*, 356-31-2, 77-80 cm (ULVG-10874); **Y-Z**, *Pseudoguembelina hariaensis*, 356-31-3, 76-79 cm (ULVG-10888). Scale bars = 100 μ m.

Sample	Depth (mbsf)	Lithologic units	Zone	Age
356-29.2-70.72 cm	410.72			
356-29.3-74.76 cm	413.74			
356-29.5-75.75 cm	415.25			
356-29.6-77.79 cm	416.77			
356-30.1-77.79 cm	418.77			
356-30.2-78.80 cm	420.28			
356-30.3-77.80 cm	421.77			
356-30.4-77.80 cm	423.27			
356-30.5-77.80 cm	424.27			
356-30.6-77.80 cm	426.27			
356-31.1-66.70 cm	437.66			
356-31.2-77.80 cm	439.27			
356-31.3-76.79 cm	440.76			
356-31.4-78.81 cm	442.27			
356-31.5-51.56 cm	443.51			
356-31.6-66.70 cm	445.16			
356-32.1-131.134 cm	457.31			
356-32.2-79.82 cm	458.29			
356-32.3-78.82 cm	459.78			
356-32.4-114.117 cm	461.64			
356-32.5-83.87 cm	462.83			
356-32.6-82.86 cm	464.32			
356-33.1-77.80 cm	483.27			
356-33.2-77.80 cm	486.77			
356-33.3-77.80 cm	488.27			
356-33.4-77.80 cm	489.77			
356-33.5-74.78 cm	491.24			
356-34.1-79.81 cm	513.77			
356-34.2-79.81 cm	515.29			
356-34.3-77.80 cm	516.77			
356-34.4-77.80 cm	518.27			
356-34.5-77.80 cm	519.77			
356-34.6-77.80 cm	521.27			
356-34.7-77.80 cm	542.27			
356-35.1-77.80 cm	543.77			
356-35.2-77.80 cm	545.27			
356-35.3-77.80 cm	547.54			
356-35.4-77.80 cm	548.27			
356-35.5-78.81 cm	549.78			
356-36.1-78.81 cm	570.38			
356-36.2-78.81 cm	571.38			
356-36.3-77.80 cm	572.38			
356-36.4-77.80 cm	573.27			
356-36.5-77.80 cm	574.27			
356-36.6-77.80 cm	575.27			
356-36.7-77.80 cm	576.27			
356-36.8-77.80 cm	577.27			
356-36.9-77.80 cm	578.27			
356-37.1-77.80 cm	580.27			
356-37.2-77.80 cm	581.27			
356-37.3-77.80 cm	582.27			
356-37.4-77.80 cm	583.27			
356-37.5-77.80 cm	584.27			
356-37.6-77.80 cm	585.27			
356-37.7-77.80 cm	586.27			
356-37.8-77.80 cm	587.27			
356-37.9-77.80 cm	588.27			
356-38.1-77.80 cm	589.27			
356-38.2-77.80 cm	590.27			
356-38.3-77.80 cm	591.27			
356-38.4-77.80 cm	592.27			
356-38.5-77.80 cm	593.27			
356-38.6-77.80 cm	594.27			
356-38.7-77.80 cm	595.27			
356-38.8-77.80 cm	596.27			
356-38.9-77.80 cm	597.27			
356-39.1-107.110 cm	617.27			
356-39.2-77.80 cm	618.27			
356-39.3-77.80 cm	619.27			
356-39.4-77.80 cm	620.27			
356-39.5-77.80 cm	621.27			
356-39.6-77.80 cm	622.27			
356-39.7-77.80 cm	623.27			
356-39.8-77.80 cm	624.27			
356-39.9-77.80 cm	625.27			
356-40.1-77.80 cm	626.27			
356-40.2-77.80 cm	627.27			
356-40.3-77.80 cm	628.27			
356-40.4-77.80 cm	629.27			
356-40.5-77.80 cm	630.27			
356-40.6-77.80 cm	631.27			
356-40.7-77.80 cm	632.27			
356-40.8-77.80 cm	633.27			
356-40.9-77.80 cm	634.27			
356-41.1-77.80 cm	636.27			
356-41.2-77.80 cm	637.27			
356-41.3-77.80 cm	638.27			
356-41.4-77.80 cm	639.27			
356-41.5-77.80 cm	640.27			
356-41.6-77.80 cm	641.27			
356-41.7-77.80 cm	642.27			
356-41.8-77.80 cm	643.27			
356-41.9-77.80 cm	644.27			
356-42.1-77.80 cm	646.27			
356-42.2-77.80 cm	647.27			
356-42.3-77.80 cm	648.27			
356-42.4-77.80 cm	649.27			
356-42.5-77.80 cm	650.27			
356-42.6-77.80 cm	651.27			
356-42.7-77.80 cm	652.27			
356-42.8-77.80 cm	653.27			
356-42.9-77.80 cm	654.27			
356-43.1-77.80 cm	656.27			
356-43.2-77.80 cm	657.27			
356-43.3-77.80 cm	658.27			
356-43.4-77.80 cm	659.27			
356-43.5-77.80 cm	660.27			
356-43.6-77.80 cm	661.27			
356-43.7-77.80 cm	662.27			
356-43.8-77.80 cm	663.27			
356-43.9-77.80 cm	664.27			
356-44.1-77.80 cm	666.27			
356-44.2-77.80 cm	667.27			
356-44.3-77.80 cm	668.27			
356-44.4-77.80 cm	669.27			
356-44.5-77.80 cm	670.27			
356-44.6-77.80 cm	671.27			
356-44.7-77.80 cm	672.27			
356-44.8-77.80 cm	673.27			
356-44.9-77.80 cm	674.27			
356-45.1-77.80 cm	676.27			
356-45.2-77.80 cm	677.27			
356-45.3-77.80 cm	678.27			
356-45.4-77.80 cm	679.27			
356-45.5-77.80 cm	680.27			
356-45.6-77.80 cm	681.27			
356-45.7-77.80 cm	682.27			
356-45.8-77.80 cm	683.27			
356-45.9-77.80 cm	684.27			
356-46.1-77.80 cm	686.27			
356-46.2-77.80 cm	687.27			
356-46.3-77.80 cm	688.27			
356-46.4-77.80 cm	689.27			
356-46.5-77.80 cm	690.27			
356-46.6-77.80 cm	691.27			
356-46.7-77.80 cm	692.27			
356-46.8-77.80 cm	693.27			
356-46.9-77.80 cm	694.27			
356-47.1-77.80 cm	696.27			
356-47.2-77.80 cm	697.27			
356-47.3-77.80 cm	698.27			
356-47.4-77.80 cm	699.27			
356-47.5-77.80 cm	700.27			
356-47.6-77.80 cm	701.27			
356-47.7-77.80 cm	702.27			
356-47.8-77.80 cm	703.27			
356-47.9-77.80 cm	704.27			
356-48.1-77.80 cm	706.27			
356-48.2-77.80 cm	707.27			
356-48.3-77.80 cm	708.27			
356-48.4-77.80 cm	709.27			
356-48.5-77.80 cm	710.27			
356-48.6-77.80 cm	711.27			
356-48.7-77.80 cm	712.27			
356-48.8-77.80 cm	713.27			
356-48.9-77.80 cm	714.27			
356-49.1-77.80 cm	716.27			
356-49.2-77.80 cm	717.27			
356-49.3-77.80 cm	718.27			
356-49.4-77.80 cm	719.27			
356-49.5-77.80 cm	720.27			
356-49.6-77.80 cm	721.27			
356-49.7-77.80 cm	722.27			
356-49.8-77.80 cm	723.27			
356-49.9-77.80 cm	724.27			
356-50.1-77.80 cm	726.27			
356-50.2-77.80 cm	727.27			
356-50.3-77.80 cm	728.27			
356-50.4-77.80 cm	729.27			
356-50.5-77.80 cm	730.27			
356-50.6-77.80 cm	731.27			
356-50.7-77.80 cm	732.27			
356-50.8-77.80 cm	733.27			
356-50.9-77.80 cm	734.27			
356-51.1-77.80 cm	736.27			
356-51.2-77.80 cm	737.27			
356-51.3-77.80 cm	738.27			
356-51.4-77.80 cm	739.27			
356-51.5-77.80 cm	740.27			
356-51.6-77.80 cm	741.27			
356-51.7-77.80 cm	742.27			
356-51.8-77.80 cm	743.27			
356-51.9-77.80 cm	744.27			
356-52.1-77.80 cm	746.27			
356-52.2-77.80 cm	747.27			
356-52.3-77.80 cm	748.27			
356-52.4-77.80 cm	749.27			
356-52.5-77.80 cm	750.27			
356-52.6-77.80 cm	751.27			
356-52.7-77.80 cm	752.27			
356-52.8-77.80 cm	753.27			
356-52.9-77.80 cm	754.27			
356-53.1-77.80 cm	756.27			
356-53.2-77.80 cm	757.27			
356-53.3-77.80 cm	758.27			
356-53.4-77.80 cm	759.27			
356-53.5-77.80 cm	760.27			
356-53.6-77.80 cm	761.27			
356-53.7-77.80 cm	762.27			
356-53.8-77.80 cm	763.27			
356-53.9-77.80 cm	764.27			
356-54.1-77.80 cm	766.27			
356-54.2-77.80 cm	767.27			
356-54.3-77.80 cm	768.27			
356-54.4-77.80 cm	769.27			
356-54.5-77.80 cm	770.27			
356-54.6-77.80 cm	771.27			
356-54.7-77.80 cm	772.27			
356-54.8-77.80 cm	773.27			
356-54.9-77.80 cm	774.27			
356-55.1-77.80 cm	776.27			
356-55.2-77.80 cm	777.27			
356-55.3-77.80 cm	778.27			
356-55.4-77.80 cm	779.27			
356-55.5-77.80 cm	780.27			
356-55.6-77.80 cm	781.27			
356-55.7-77.80 cm	782.27			
356-55.8-77.80 cm	783.27			
356-55.9-77.80 cm	784.27			
356-56.1-77.80 cm	786.27			
356-56.2-77.80 cm	787.27			
356-56.3-77.80 cm	788.27			
356-56.4-77.80 cm	789.27			
356-56.5-77.80 cm	790.27			
356-56.6-77.80 cm	791.27			
356-56.7-77.80 cm	792.27			
356-56.8-77.80 cm	793.27			
356-56.9-77.80 cm	794.27			
356-57.1-77.80 cm	796.27			
356-57.2-77.80 cm	797.27			
356-57.3-77.80 cm	798.27			
356-57.4-77.80 cm	799.27			
356-57.5-77.80 cm	800.27			
356-57.6-77.80 cm	801.27			
356-57.7-77.80 cm	802.27			
356-57.8-77.80 cm	803.27			
356-57.9-77.80 cm	804.27			
356-58.1-77.80 cm	806.27			
356-58.2-77.80 cm	807.27			
356-58.3-77.80 cm	808.27			
356-58.4-77.80 cm	809.27			
356-58.5-77.80 cm	810.27			
356-58.6-77.80 cm	811.27			
356-58.7-77.80 cm	812.27			
356-58.8-77.80 cm	813.27			
356-58.9-77.80 cm	814.27			
356-59.1-77.80 cm	816.27			
356-59.2-77.80 cm	817.27			
356-59.3-77.80 cm	818.27			
356-59.4-77.80 cm	819.27			
356-59.5-77.80 cm	820.27			
356-59.6-77.80 cm	821.27			
356-59.7-77.80 cm	822.27			
356-59.8-77.80 cm	823.27			
356-59.9-77.80 cm	824.27			
356-60.1-77.80 cm	826.27			
356-60.2-77.80 cm	827.27			
356-60.3-77.80 cm	828.27			
356-60.4-77.80 cm	829.27			
356-60.5-77.80 cm	830.27			
356-60.6-77.80 cm	831.27			
356-60.7-77.80 cm	832.27			
356-60.8-77.80 cm				

Figure 4. Relative abundances for planktic foraminiferal species from Turonian(?) to Danian strata of DSDP Site 356. Grey-shaded intervals represent barren samples. **Abbreviations.** Abundances are represented as follows: **A**, abundant (>25%); **C**, common (10–25%); **F**, few (1–10%); **R**, rare (<1%). Preservation index is in accordance to Petrizzo's (2000) proposition, where: **G**, good; **M**, moderate; **P**, poor. The notation /r refers to occurrences that are considered reworked.

Age (Ma)	Stage	Caron (1985)	Sliter (1989)	Premoli Silva & Sliter (1995)	Robaszynski & Caron (1995)	
					Globotruncanids	Heterohellicids
66	Maastrichtian	<i>Abathomphalus mayaroensis</i>	<i>Abathomphalus mayaroensis</i>	<i>Abathomphalus mayaroensis</i>	<i>Abathomphalus mayaroensis</i>	<i>Pseudoguembelina hariaensis</i>
		<i>Gansserina gansseri</i>	<i>Gansserina gansseri</i>			<i>Racemiguembelina fruticosa</i>
72.1	Campanian	<i>Globotruncana aegyptiaca</i>	<i>Globotruncana aegyptiaca</i>	<i>Racemiguembelina fruticosa</i>	<i>Gansserina gansseri</i>	
		<i>Globotruncanella havanensis</i>	<i>Globotruncanella havanensis</i>			<i>Planoglobulina acervulinoides</i>
		<i>Globotruncanella calcarata</i>	<i>Globotruncanella calcarata</i>	<i>Gansserina gansseri</i>		
				<i>Globotruncana aegyptiaca</i>	<i>Globotruncana aegyptiaca</i>	<i>Pseudoguembelina excolata</i>
		<i>Globotruncana ventricosa</i>	<i>Globotruncana ventricosa</i>	<i>Globotruncanella havanensis</i>	<i>Globotruncanella havanensis</i>	<i>Pseudotextularia elegans</i>
				<i>Globotruncanella calcarata</i>	<i>Globotruncanella calcarata</i>	
83.6	San.			<i>Globotruncana ventricosa</i>	<i>Globotruncana ventricosa</i>	<i>Pseudoguembelina costulata</i>
				<i>Globotruncanella elevata</i>	<i>Globotruncanella elevata</i>	<i>Pseudoguembelina costellifera</i>
						<i>Ventriabrella eggeri</i>
						<i>Sigalia deflaensis</i>
86.3	Con.	<i>Dicarinella asymetrica</i>	<i>Dicarinella asymetrica</i>	<i>Dicarinella asymetrica</i>	<i>Dicarinella asymetrica</i>	<i>Sigalia decoratissima</i>
		<i>Dicarinella concavata</i>	<i>Dicarinella concavata</i>	<i>Dicarinella concavata</i>	<i>Dicarinella concavata</i>	<i>Sigalia carphatica</i>
89.8	Tur.	<i>Marginotruncana sigali</i>	<i>Marginotruncana sigali</i>	<i>Marginotruncana sigali</i>	<i>Marginotruncana schneegansi</i>	<i>Heterohelix moremani</i>

Age (Ma)	Stage	Huber et al. (2008)	Petrizzo et al. (2011)	This study	Bioevents (this study)
66	Maastrichtian	<i>Pseudoguembelina hariaensis</i>		<i>Pseudoguembelina hariaensis</i>	<i>P. hariaensis</i>
		<i>Abathomphalus mayaroensis</i>		<i>Abathomphalus mayaroensis</i>	<i>A. mayaroensis</i>
72.1	Campanian	<i>Racemiguembelina fruticosa</i>		<i>Racemiguembelina fruticosa</i>	<i>R. fruticosa</i>
		<i>Pseudoguembelina palpebra</i>		<i>Pseudoguembelina palpebra</i>	<i>P. palpebra</i>
		<i>Globotruncanella havanensis</i>		<i>Globotruncanella havanensis</i>	
		<i>Radotruncana calcarata</i>		<i>Radotruncana calcarata</i>	<i>R. calcarata</i>
83.6	San.			<i>Radotruncana calcarata</i>	<i>R. calcarata</i>
				<i>Contusotruncana plummerae</i>	<i>C. plummerae</i>
86.3	Con.			<i>Globotruncanella elevata</i>	
				<i>Dicarinella asymetrica</i>	<i>D. asymetrica</i>
89.8	Tur.			<i>Dicarinella concavata</i>	<i>D. concavata</i>
				<i>Marginotruncana schneegansi</i>	

Figure 5. Biostratigraphic framework for Late Cretaceous planktic foraminifera, presenting the studies discussed in the text and the composition applied to Site 356. Ages assigned to stages boundaries are given after Gradstein *et al.* (2012). **Abbreviations:** Tur., Turonian; Con., Coniacian; San., Santonian.

The *Pseudoguembelina palpebra* Interval Zone (Huber *et al.*, 2008), early Maastrichtian in age, was identified from the FO of the nominate taxon (462.83 mbsf) to the FOs of *Racemiguembelina fruticosa* and *Abathomphalus mayaroensis*, identified in the same sample (Figure 4). Typical species are *Archaeoglobigerina blowi*, *Pseudoguembelina palpebra*, and *Contusotruncana fornicata*.

Upward in the section, the *Abathomphalus mayaroensis* Interval Zone (Brönnimann, 1952), late Maastrichtian in age, was identified from the FO of the nominate taxon (443.51 mbsf) to the FO of *Pseudoguembelina hariaensis* (440.76 mbsf; *cf.* Huber *et al.*, 2008). Typical species are *Archaeoglobigerina blowi*, *Pseudotextularia nuttalli*, *Pseudoguembelina palpebra*, and *Racemiguembelina fruticosa*. Since the FOs of *Racemiguembelina fruticosa* and *Abathomphalus mayaroensis* occur in the same sample, an unconformity can be suggested due to the absence of the *Racemiguembelina fruticosa* Interval Zone (Huber *et al.*,

2008) between the *Pseudoguembelina palpebra* Interval Zone and the *Abathomphalus mayaroensis* Interval Zone (*cf.* Huber *et al.*, 2008).

The *Pseudoguembelina hariaensis* Interval Zone (Robaszynski & Caron, 1995), latest Maastrichtian in age, was identified from the FO of the nominate taxon (440.76 mbsf) to the level of extinction of virtually all Cretaceous taxa (412.25 mbsf; *cf.* Huber *et al.*, 2008). Typical species are *Archaeoglobigerina blowi*, *Pseudoguembelina palpebra*, and *Globotruncana* sp. aff. *G. bulloides*.

Above 412.25 mbsf (to the top of the studied interval), a Danian planktic foraminiferal assemblage assigned to the Pa Zone [*Parvularugoglobigerina eugubina* Total-range Zone (Luterbacher & Premoli Silva, 1964); Olsson *et al.*, 1999] was recovered. Since a single Danian sample was studied herein, it should not be assumed as representative of the entire Pa Zone, but defines the top of the studied section.

Age/depth model

An age/depth plot was generated by plotting depths (mbsf) at which several planktic foraminiferal bioevents were identified at DSDP Site 356 against their suggested ages [in accordance with Gradstein *et al.* (2012)] (Table 1; Figure 6). A continuous line in Figure 6 joins the bioevents that define the foraminiferal zones identified herein. Sedimentation rates (m/Ma; meters per million years) within the Cretaceous planktic foraminiferal zones were estimated as follows (Figure 6): 7.1 m/Ma within the *Dicarinella concavata* Interval Zone; 35.6 m/Ma within the *Dicarinella asymetrica* Total-range Zone; 5.4 m/Ma within the *Globotruncanita elevata* Partial-range Zone; 9.4 m/Ma within the *Contusotruncana plummerae* Interval Zone; 9.6 m/Ma within the *Radotruncana calcarata* Total-range Zone; 5.6 m/Ma within the *Globotruncanella havanensis* Partial-range Zone; 7.5 m/Ma within the *Pseudoguembelina palpebra* Interval Zone; 1.5 m/Ma within the *Abathomphalus mayaroensis* Interval Zone; and 22.5 m/Ma within the *Pseudoguembelina hariaensis* Interval Zone. In addition, a time span of at least 0.96 Ma is suggested for the unconformity between the *Pseudoguembelina palpebra* Interval Zone and the *Abathomphalus mayaroensis* Interval Zone (Figure 6), as discussed below.

DISCUSSION

From 682.77 mbsf (core 39) to 410.7 mbsf (core 29), age assignments made herein and those reported by Premoli Silva & Boersma (1977) show quite good agreement. The interval attributed herein to the *Marginotruncana schneegansi*, *Dicarinella concavata*, and *Dicarinella asymetrica* zones (Figures 2, 4) was assigned to the *Globotruncana concavata*

concavata (= *Dicarinella concavata* herein) and *Globotruncana concavata carinata* (= *Dicarinella asymetrica* herein) zones by Premoli Silva & Boersma (1977), differing only in a possible Turonian age for one sample (356-39-6, 77-80 cm), attributed herein to the *Marginotruncana schneegansi* Partial-range Zone. Improved biostratigraphic resolution in the present study, mainly in the Campanian-Maastrichtian interval, is likely a result of the application of the latest biostratigraphic revisions (e.g. Huber *et al.*, 2008; Petrizzo *et al.*, 2011). The Campanian interval of DSDP Site 356 was herein attributed to the *Globotruncanita elevata*, *Contusotruncana plummerae*, *Radotruncana calcarata*, and *Globotruncanella havanensis* zones (Figures 2, 4), while Premoli Silva & Boersma (1977) identified the *Globotruncana elevata* (= *Globotruncanita elevata* herein), *Globotruncana calcarata* (= *Radotruncana calcarata* herein) and *Globotruncana tricarinata* zones in the same stratigraphic interval. Maastrichtian strata were herein attributed to the *Pseudoguembelina palpebra*, *Abathomphalus mayaroensis*, and *Pseudoguembelina hariaensis* zones (Figures 2, 4), whereas Premoli Silva & Boersma (1977) identified the *Globotruncana gansseri* and *Abathomphalus mayaroensis* zones for the same interval.

In the same way as reported by Huber *et al.* (2008), rare and sporadic occurrences of the zonal markers *Globotruncana aegyptiaca* and *Gansserina gansseri* hampered the accurate identification of the nominate planktic foraminiferal zones for those species. Therefore, the biozonation proposed by Huber *et al.* (2008) was applied herein to the upper Campanian-Maastrichtian interval of DSDP Site 356. It is also worth mentioning that the FOs of *Globotruncana aegyptiaca*, *Gansserina gansseri*, and *Globotruncanella havanensis* fall quite distant from the line that joins the bioevents used in the planktic foraminiferal zonation presented in the age/depth plot (Figure 6). This pattern may be explained by their sporadic and rare occurrences, leading to the inaccurate identification of these bioevents (e.g. Huber *et al.*, 2008), and/or by the presence of an uncored interval of about 20 m below core 32, within which these species could have their real FOs (Figure 2). On the other hand, the FO of *Globotruncanita elevata* and the LOs of *Gansserina gansseri* and *Abathomphalus mayaroensis* showed good alignment with the continuous line in the age/depth plot (Figure 6). The reliability in identifying the *Contusotruncana plummerae* Interval Zone in Campanian strata of the South Atlantic Ocean, likewise, was confirmed herein, as previously suggested by Petrizzo *et al.* (2011), on the basis of sedimentary successions from the Tethyan region, Pacific and Indian oceans.

Robaszynski & Caron (1995) noticed that *Racemiguembelina fruticosa* and *Contusotruncana contusa* are supposed to have their FOs below the FO of *Abathomphalus mayaroensis*, defining the *Racemiguembelina fruticosa* Interval Zone, from the FO of the nominate taxon to the FO of *Abathomphalus mayaroensis* (Huber *et al.*, 2008). Since *Racemiguembelina fruticosa* and *Abathomphalus mayaroensis* have their FOs in the same sample in the studied site, and since *Contusotruncana* sp. cf. *C. contusa* first appears within the *Abathomphalus mayaroensis* interval zone (Figure 4), an unconformity can

Table 1. Age (according to Gradstein *et al.*, 2012) and depth (at DSDP Site 356) of the bioevents used in the age/depth plot.

Bioevent	Age (Ma)	Depth (mbsf)
LO <i>Racemiguembelina fruticosa</i>	66.04	412.25
LO <i>Abathomphalus mayaroensis</i>	66.35	415.25
LO <i>Gansserina gansseri</i>	66.49	415.25
FO <i>Pseudoguembelina hariaensis</i>	67.3	440.67
LO <i>Globotruncana linneiana</i>	68.37	445.16
FO <i>Abathomphalus mayaroensis</i>	69.18	443.51
FO <i>Racemiguembelina fruticosa</i>	70.14	443.51
FO <i>Pseudoguembelina palpebra</i>	71.75	462.83
FO <i>Gansserina gansseri</i>	72.97	459.78
FO <i>Globotruncana aegyptiaca</i>	74.00	462.83
LO <i>Radotruncana calcarata</i>	75.71	485.27
FO <i>Globotruncanella havanensis</i>	75.94	464.32
FO <i>Radotruncana calcarata</i>	76.18	489.77
FO <i>Contusotruncana plummerae</i>	79.20	518.27
FO <i>Globotruncanita elevata</i>	83.64	545.27
LO <i>Dicarinella asymetrica</i>	83.64	542.27
LO <i>Dicarinella concavata</i>	83.64	542.27
FO <i>Dicarinella asymetrica</i>	86.66	649.77
FO <i>Dicarinella concavata</i>	91.08	681.27

Figure 6. Age/depth plot for DSDP Site 356. Age (according to Gradstein *et al.*, 2012) and depth (at Site 356) of the bioevents (FOs and LOs) are given in Table 1. Inferences of sedimentation rates for each planktic foraminiferal zone identified herein are also given. **Abbreviations.** Species names: **Ph**, *Pseudoguembelina hariaensis*; **Am**, *Abathomphalus mayaroensis*; **Rf**, *Racemiguembelina fructuosa*; **Pp**, *Pseudoguembelina palpebra*; **Gl**, *Globotruncana linneiana*; **Gg**, *Gansserina gansseri*; **Ga**, *Globotruncana aegyptiaca*; **Gh**, *Globotruncanella havanensis*; **Rc**, *Radotruncana calcarata*; **Cp**, *Contusotruncana plummerae*; **Ge**, *Globotruncanella elevata*; **Dc**, *Dicarinella concavata*; **Da**, *Dicarinella asymetrica*. Zones follow those of Figure 2, except for: **P. har.**, *Pseudoguembelina hariaensis*; **A. m.**, *Abathomphalus mayaroensis*; **R. f.**, *Racemiguembelina fructuosa*; **R. c.**, *Radotruncana calcarata*; **D. asym.**, *Dicarinella asymetrica*.

be suggested within core 31 (Figure 2) due to the direct superposition of the *Pseudoguembelina palpebra* Interval Zone by the *Abathomphalus mayaroensis* Interval Zone. An abrupt change of color observed in core photographs between 445.51 and 443.51 mbsf (Supko *et al.*, 1977), from dark marly chalk to light colored chalk, could well represent this unconformity, spanning at least 0.96 Ma (Figure 6).

Sedimentation rates showed high variability within the studied section (Figure 6). High sedimentation rates were observed in the Santonian (*Dicarinella asymetrica* Total-range Zone) and in the uppermost Maastrichtian (*Pseudoguembelina hariaensis* Interval Zone) intervals of Site 356, while lower and more constant values were observed in the Campanian-lower Maastrichtian interval (*Globotruncanella elevata* Partial-range Zone to *Pseudoguembelina palpebra* Interval Zone). The identification of high sedimentation rates within the *Dicarinella asymetrica* Total-range Zone is in accordance with previous studies that have suggested the same pattern for Santonian strata in some Brazilian continental margin basins, including the closely related Santos Basin (Moreira *et al.*, 2007). This pattern may be a consequence of the increased clastic input and shelf progradation driven by the uplift of the Serra do Mar and Serra da Mantiqueira mountain ranges, which peaked at this time interval (Almeida

& Carneiro, 1998; Cobbold *et al.*, 2001; Modica & Brush, 2004; Contreras *et al.*, 2010). The lowest sedimentation rate identified in the studied section was within the *Abathomphalus mayaroensis* Interval Zone. It may represent a real trend as well as be a result of the absence of part of this zone due to the unconformity between the *Pseudoguembelina palpebra* and *Abathomphalus mayaroensis* zones (Figures 2, 6). The sampling resolution applied herein, however, did not enable to support any of these hypotheses.

It is worth mentioning that *Plummerita hantkeninoides*, a taxon of reported biostratigraphic usefulness (*cf.* Koutsoukos, 2006) that evolved within the last 0.3 Ma of the Maastrichtian, is absent from the studied section (Figure 4). Despite the fact that open-ocean pelagic carbonate sediments of this age were probably recovered at DSDP Site 356, the absence of this species from the studied site could be interpreted as a consequence of its probable preference for inhabiting eutrophic shelf to upper slope environments (Abramovich & Keller, 2002; MacLeod *et al.*, 2007; Huber *et al.*, 2008), or due to its low potential of preservation. In addition, this species could have presented a paleobiogeographic distribution restricted to low-latitude areas (*e.g.* Koutsoukos, 2006; Gallala, 2013), being absent from higher-latitude sites. Therefore, it is more convenient to apply the concept

of the *Pseudoguembelina hariaensis* Interval Zone to upper Maastrichtian strata of DSDP Site 356, since the nominate species had a wider paleobiogeographic distribution (e.g. Huber *et al.*, 2008).

CONCLUDING REMARKS

Fifty-nine planktic foraminiferal species were identified within the studied interval of DSDP Site 356. The following planktic foraminiferal zones (Turonian? to early Danian in age) were identified: *Marginotruncana schneegansi*, *Dicarinella concavata*, *Dicarinella asymetrica*, *Globotruncanita elevata*, *Contusotruncana plummerae*, *Radotruncana calcarata*, *Globotruncanella havanensis*, *Pseudoguembelina palpebra*, *Abathomphalus mayaroensis*, *Pseudoguembelina hariaensis*, and Pa.

The reliability in identifying the *Contusotruncana plummerae* Interval Zone (Campanian in age) in Cretaceous sections of the South Atlantic Ocean is confirmed herein. The direct superposition of the *Pseudoguembelina palpebra* Interval Zone by the *Abathomphalus mayaroensis* Interval Zone (both Maastrichtian in age) suggests an unconformity spanning at least 0.96 Ma within core 31 of DSDP Site 356. High sedimentation rates were inferred for the Santonian (*Dicarinella asymetrica* Total-range Zone) and in the uppermost Maastrichtian (*Pseudoguembelina hariaensis* Interval Zone) intervals of the studied site. Lower and more constant values in sedimentation rates, however, are suggested for the Campanian-lower Maastrichtian interval (*Globotruncanita elevata* Partial-range Zone to *Pseudoguembelina palpebra* Interval Zone).

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Appendix 1. List of the species identified in the present study. Suprageneric classification follows Loeblich & Tappan (1987, 1992) modified by Lee (1989). Species concepts are mainly based on the Mesozoic Planktonic Foraminiferal Taxonomic Dictionary (http://portal.chronos.org/gridsphere/gridsphere?cid=res_foram).

- Supergroup RHIZARIA Cavalier-Smith, 2002
 Class FORAMINIFERA d'Orbigny, 1826
 Order GLOBIGERININA Delage & Hérouard, 1896
 Family GUEMBELITRIDA Longoria, 1974
 Genus *Guembelitra* Cushman, 1933
 Guembelitra cretacea Cushman, 1933
 Genus *Woodringina* Loeblich & Tappan, 1957
 Woodringina claytonensis Loeblich & Tappan, 1957
 Woodringina hornerstownensis Olsson, 1960
 Family HETEROHELICIDAE Cushman, 1927
 Genus *Heterohelix* Ehrenberg, 1843
 Heterohelix punctulata (Cushman, 1938)
 Heterohelix globulosa (Ehrenberg, 1840)
 Genus *Planoglobulina* Cushman, 1927
 Planoglobulina brazoensis Martin, 1972
 Genus *Pseudotextularia* Rzehak, 1891
 Pseudotextularia nuttalli (Voorvijk, 1937)
 Genus *Racemiguembelina* Montanaro Gallitelli, 1957
 Racemiguembelina fruticosa (Egger, 1899)
 Genus *Praegublerina* Georgescu et al., 2009
 Praegublerina acuta (de Klasz, 1953)
 Genus *Gublerina* Kikoin, 1948
 Gublerina spp.
 Genus *Pseudoguembelina* Brönnimann & Brown, 1953
 Pseudoguembelina hariaensis Nederbragt, 1990
 Pseudoguembelina palpebra Brönnimann & Brown, 1953
 Genus *Guembelina* Egger, 1900
 Guembelina globocarinata Cushman, 1938
 Family GLOBIGERINELLOIDAE Longoria, 1974
 Genus *Globigerinelloides* Cushman & ten Dam, 1948
 "*Globigerinelloides*" *subcarinatus* (Brönnimann, 1952)
 "*Globigerinelloides*" sp. aff. "*G.*" *subcarinatus* (Brönnimann, 1952)
 "*Globigerinelloides*" sp. aff. "*G.*" *prairiehillensis* Pessagno, 1967
 "*Globigerinelloides*" sp. cf. "*G.*" *asper* (Ehrenberg, 1854)
 Family SCHACKOINIDAE Pokorny, 1958
 Genus *Schackoina* Thalmann, 1932
 Schackoina cenomana (Schacko, 1897)
 Family HEDBERGELLIDAE Loeblich & Tappan, 1961
 Genus *Muricohedbergella* Huber & Leckie, 2011
 Muricohedbergella flandrini (Porthault, 1970)
 Muricohedbergella sp. aff. *M. sliteri* (Huber, 1990)
 Muricohedbergella simplex (Morrow, 1934)
 Family Rotaliporidae Sigal, 1958
 Genus *Ticinella* Reichel, 1950
 Ticinella? sp. cf. *T. primula* Lutherbacher, 1963
 Family GLOBOTRUNCANIDAE Brotzen, 1942
 Genus *Contusotruncana* Korchagin, 1982
 Contusotruncana fornicata (Plummer, 1931)
 Contusotruncana plummerae (Gandolfi, 1955)
 Contusotruncana sp. cf. *C. contusa* (Cushman, 1926)
 Genus *Gasserina* Caron et al., 1984
 Gasserina gansseri (Bolli, 1951)
 Genus *Globotruncana* Cushman, 1927
 Globotruncana hilli Pessagno (1967)
 Globotruncana aegyptiaca Nakkady, 1950
 Globotruncana falsostuati Sigal, 1952
 Globotruncana arca (Cushman, 1926)
 Globotruncana sp. aff. *G. bulloides* Vogler, 1941
 Globotruncana linneiana (d'Orbigny, 1839)
 Genus *Globotruncanita* Reiss, 1957
 Globotruncanita stuarti (de Lapparent, 1918)
 Globotruncanita stuartiormis (Dalbiez, 1955)
 Globotruncanita pettersi (Gandolfi, 1955)
 Globotruncanita angulata (Tilev, 1951)
 Globotruncanita elevata (Brotzen, 1934)
 Genus *Marginotruncana* Hofker, 1956
 Marginotruncana sinuosa Porthault, 1970
 Marginotruncana sigali (Reichel, 1950)
 Marginotruncana tafayaensis (Lehmann, 1963)
 Marginotruncana paraconcovata Porthault, 1970
 Marginotruncana marginata (Reuss, 1845)
 Genus *Radotruncana* El-Naggar, 1971
 Radotruncana calcarata (Cushman, 1927)
 Radotruncana subspinoso (Pessagno, 1967)
 Genus *Globotruncanella* Reiss, 1957
 Globotruncanella havanensis (Voorvijk, 1937)
 Genus *Abathomphalus* Bolli et al., 1957
 Abathomphalus mayaroensis (Bolli, 1951)
 Genus *Dicarinella* Porthault, 1970
 Dicarinella concavata (Brotzen, 1934)
 Dicarinella primitiva (Dalbiez, 1955)
 Dicarinella asymetrica (Sigal, 1952)
 Family RUGOGLOBIGERINIDAE Subbotina, 1959
 Genus *Archaeoglobigerina* Pessagno, 1967
 Archaeoglobigerina blowi Pessagno, 1967
 Archaeoglobigerina bosquensis Pessagno, 1967
 Archaeoglobigerina cretacea (d'Orbigny, 1840)
 Genus *Rugotruncana* Brönnimann, 1952
 Rugotruncana sp.
 Rugotruncana circumnodifer (Finlay, 1940)
 Rugotruncana subcircumnodifer (Gandolfi, 1955)
 Family EOGLOBIGERINIDAE Blow, 1979
 Genus *Eoglobigerina* Morozova, 1959
 Eoglobigerina edita (Subbotina, 1953)
 Genus *Globoconusa* Khalilov, 1956
 Globoconusa daubjergensis (Brönnimann, 1953)
 Genus *Parvularugoglobigerina* Hofker, 1978
 Parvularugoglobigerina eugubina (Luterbacher & Premoli Silva, 1964)
 Parvularugoglobigerina sp.