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PARVULARUGOGLOBIGERINA EUGUBINA TYPE-SAMPLE AT CESELLI (ITALY): PLANKTIC FORAMINIFERAL ASSEMBLAGE AND LOWERMOST DANIAN BIOSTRATIGRAPHIC IMPLICATIONS

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Riassunto. La Biozona a *Parvularugoglobigerina eugubina* (Daniano basale) è stata definita a Gubbio (Italia) per caratterizzare in modo preciso il limite Cretaceo/Paleogene (K/P). Questa biozona è definita dalla distribuzione totale del taxon *Pv. eugubina*, ma questa piccola morfospecie presenta alcuni problemi tassonomici. Sono stati riesaminati, per caratterizzare e definire l'esatta posizione stratigrafica di questa biozona, l'olotipo della *Pv. eugubina* e l'associazione a foraminiferi planctonici del campione-tipo della *Pv. eugubina* a Ceselli (Ceselli 3). 21 morfospecie sono state identificate in Ceselli 3, 14 delle quali sono specie del Paleocene inferiore e 7 sono possibili "survivors" cretacei dell'evento di estinzione del K/P. Per definire meglio la biozonazione del Paleogene basale è stata necessaria una revisione tassonomica di *Pv. eugubina* e *Parvularugoglobigerina longiapertura*, forme identificate in questo campione. Sulla base della definizione di *Pv. eugubina* e della definizione originale della biozona a *Pv. eugubina* la base della biozona dovrebbe essere posizionata alla prima comparsa della specie eponima e non al dato di prima comparsa di *Pv. longiapertura*.

Abstract. The *Parvularugoglobigerina eugubina* Biozone (lowermost Danian) was defined at Gubbio (Italy) to precisely characterise the Cretaceous/Paleogene (K/P) boundary. It was defined by the total range of *Pv. eugubina*, but this small morphospecies presents some taxonomic problems. The *Pv. eugubina* holotype and the planktic foraminiferal assemblage of the *Pv. eugubina* type-sample at Ceselli (Ceselli 3) were revised to precise the biostratigraphic position of this biozone. Of the 21 morphospecies identified in Ceselli 3, 14 are early Paleocene species and 7 are possible Cretaceous "survivors" of the K/P boundary extinction event. To clarify the lowermost Danian biozonation, it was necessary to taxonomically revise *Pv. eugubina* and *Pv. longiapertura*, which have both been identified in this sample. Following the definition of *Pv. eugubina* and the original definition of the nominal biozone, the base of *Pv. eugubina* Biozone should be placed at the first appearance datum of the eponymous species and not at the first appearance datum of *Pv. longiapertura*.

Introduction.

In order to bio- and chronostratigraphically place different evolutionary, paleoceanographical and paleoclimatical events, micropaleontologists have tended to establish more and more detailed biozonations, mainly across the Cretaceous-Paleogene (K-P) transition. Luterbacher & Premoli Silva (1964) established a new biozone for the lowermost part of the Danian, called the *Globigerina eugubina* Biozone and characterised by a minute globigerinid assemblage including "*Globigerina*" *eugubina*. This biozone spanned the interval between the Maastrichtian sediments with typical Cretaceous planktic foraminiferal assemblages (*Abathomphalus*, *Globotruncana*, *Rugoglobigerina*, etc.) and the *Globigerina pseudobulloides*/*Globigerina daubjergensis* Biozone (Leonov & Alimarina, 1961) or, its equivalent, the *Globorotalia pseudobulloides* Biozone (Bolli, 1966). Later, the same biozone was defined by the total range of *Parvularugoglobigerina eugubina* (Bolli, 1966; Stainforth et al., 1975). Historically, this last definition has been used in the classical biozonations (Premoli Silva & Bolli, 1973; Premoli Silva, 1977; Toumarkine & Luterbacher, 1985; Berggren & Miller, 1988).

Smit (1982) defined another biozone in the lowermost Danian to prove the existence of an interval between the Cretaceous/Paleogene (K/P) boundary and the appearance of the first Paleocene morphospecies. This biozone was termed P0, or *Gb. cretacea* Biozone, and was accepted in later biozonations (Keller, 1988, 1993; Canudo et al., 1991; Keller et al., 1995; Berggren et al., 1995; Molina et al., 1996; Apellaniz et al., 1997). The boundary between the *Gb. cretacea* Biozone and the *Parvularugoglobigerina eugubina* Biozone is usually placed at the first appearance datum (FAD) of *Pv. eugubina*. However, there is currently a controversy about the possible synonymy of *Pv. eugubina* (Luterbacher & Premoli Silva, 1964) and *Parvularugoglobigerina longiapertura* (Blow, 1979). This synonymy has been consid-

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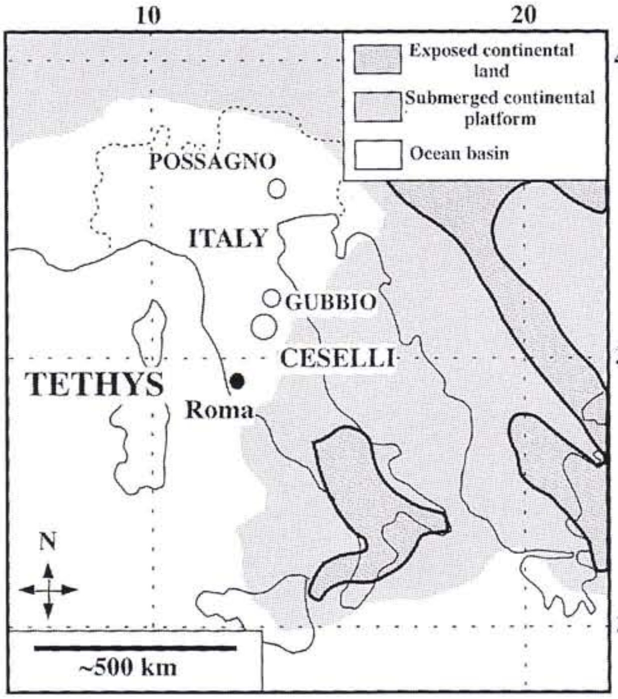


Fig. 1 - Paleolatitudinal and paleogeographic location of the Ceselli section and other Italian sections.

ered valid by many planktic foraminiferal micropaleontologists and, for this reason, the *Pv. longiapertura* FAD is frequently used to identify the base of the *Pv. eugubina* Biozone. This taxonomic problem has important biostratigraphic implications. To solve it, Canudo et al. (1991) defined the *Pv. longiapertura* Biozone whose base coincides with the first appearance of the eponymous morphospecies (Apellaniz et al., 1997). This new biozone is useful because its base coincides with the decline of the survivor Cretaceous morphospecies above the K/P boundary. However, the *Pv. eugubina* Biozone has been traditionally used in nearly all the biostratigraphic studies of the K-P transition and some micropaleontologist's advise to continue using it (Molina et al., 1996).

The *Pv. eugubina* Biozone was defined by Luterbacher & Premoli Silva (1964) at Gubbio (Italy) after a detailed taxonomic and biostratigraphic study of the K/P boundary in Central Apennines (Luterbacher, 1964; Premoli Silva, 1977), including the Ceselli and other Italian sections (Fig. 1). The *Pv. eugubina* holotype was described from Ceselli and the type-sample of the species (Ceselli 3) is now deposited at the Institut und Museum für Geologie und Paläontologie of the Universität Tübingen (Germany). This sample is the key to specify the faunal assemblage of the lowermost part of the *Pv. eugubina* Biozone. Its comparison with Gubbio and other more expanded and continuous sections allow us to approximately specify the biostratigraphic placement of the base of the *Pv. eugubina* Biozone. In order to describe the faunal assemblage of the original *Pv. eugubina* Biozone and to biostratigraphically place the original *Pv. eugubina* Biozone, we have revised the Ceselli 3 type-sample and the holotypes of *Pv. eugubina* and associated species (*Pv. sabina*, *Pv. anconitana*, *Pv. umbrica*). These species were defined by Luterbacher & Premoli Silva (1964) and are in the collections of the Naturhistorisches Museum of Basel (Switzerland).

Materials and Methods.

The Ceselli section (Fig. 1) is geographically located to the south of Ceselli (Perugia, Italy) and stratigraphically in the Scaglia Rossa from the Central Apennines in South Umbrian facies. For a more precise location see Luterbacher & Premoli Silva (1964). Uppermost Maastrichtian and lowermost Danian sediments consist of pink and white pelagic limestone with interbedded calcareous marly calcareous layers (Luterbacher & Premoli Silva, 1964). This section is near the Gubbio section where Alvarez et al. (1980) found the famous iridium anomaly layer of the K/P boundary and proposed the hypothesis of an extraterrestrial asteroid impact. At Ceselli, the base of the Paleocene is marked by a 3 cm-thick red marly layer (Ceselli 3 layer). The Ceselli 3 layer is in the same stratigraphic position as Iridium layer from Gubbio, but they probably are not coincident. The K/P boundary layer from Gubbio consists of 1 cm-thick clay layer, green at the base and red on top and devoid of planktonic foraminifera and carbonates. Therefore, the K/P boundary clay is probably absent in Ceselli due to a short hiatus.

Luterbacher & Premoli Silva (1964) analysed 14 samples from the Ceselli section: the two lowermost samples (Ceselli 1 and 2) belong to the Maastrichtian sediments and the others (from Ceselli 3 to Ceselli 14) to the Danian sediments. All these samples, except Ceselli 3, were studied in thin-section, due to the hard calcareous facies (Luterbacher & Premoli Silva, 1964; Premoli Silva, 1977). The marly nature of the Ceselli 3 layer allowed to disaggregate and use the washing technique. The Ceselli-3 sample was disaggregated in water with H_2O_2, washed through a 63 microns sieve and oven dried at 50°C. The preservation of the planktic foraminifera in this sample is poor.

Planktic foraminiferal assemblage at Ceselli 3 type-sample.

We identified a total of 21 morphospecies in the Ceselli 3 type-sample. Of these, 7 were Cretaceous and 14 Paleocene. The Cretaceous morphospecies may be survivors of the K/P extinction event but the specimens found were very poorly preserved and could also be reworked. These morphospecies belong to the genera

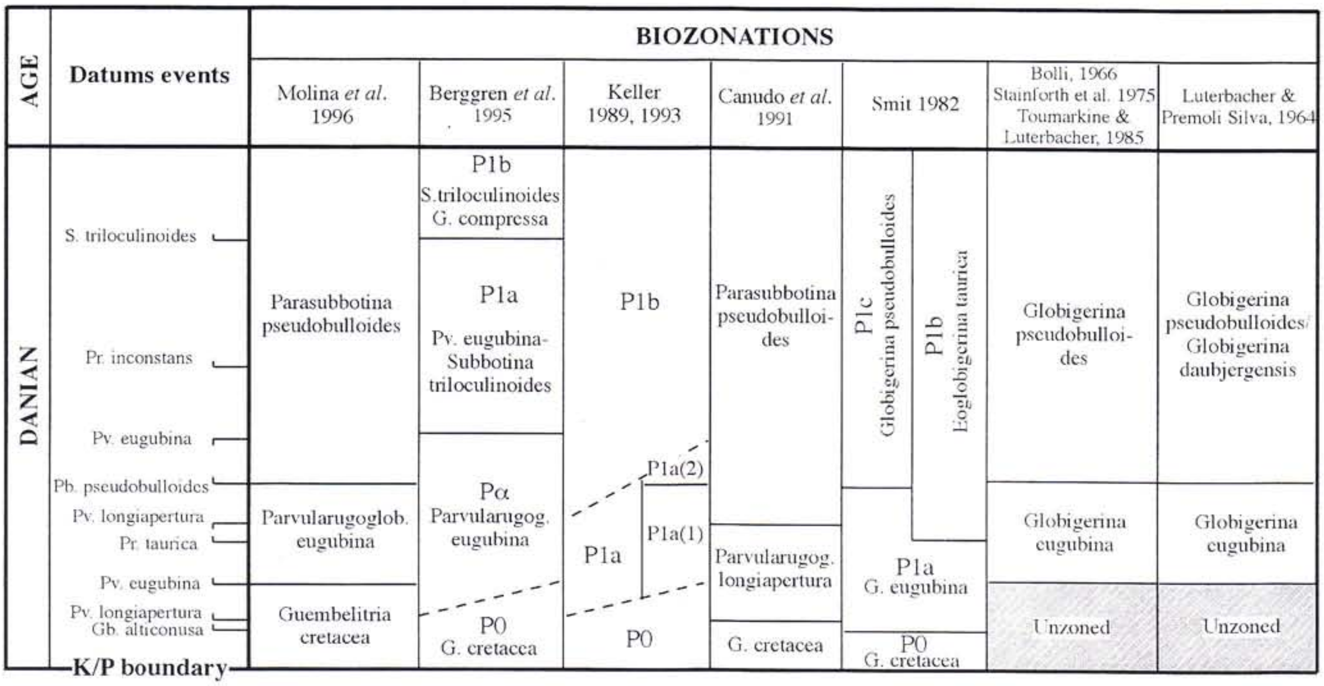


Fig. 2 - Comparison of uppermost Maastrichtian and lowermost Danian planktic foraminiferal biozonations with the biozonations used in this paper.

Hedbergella, *Globigerinelloides*, *Heterohelix* and *Guembelitria*. The Cretaceous morphospecies identified in the Ceselli 3 type-sample were: *Heterohelix globulosa* (Ehrenberg), *Heterohelix navarroensis* (Loeblich), *Globigerinelloides yaucoensis* (Pessagno), *Hedbergella holmdelensis* Olsson, *Hedbergella monmouthensis* (Olsson), *Globigerinelloides prairiehillensis* (Pessagno) and *Guembelitria cretacea* Cushman (Pl. 2, fig. 25).

The Paleocene morphospecies evolved in the lowermost Danian and belong to the genera *Parvularugoglobigerina*, *Globoconusa?*, *Woodringina* and *Chiloguembelina*. The identification and the taxonomy of the different Paleocene morphospecies from the lowermost Danian are based on the original holotype descriptions and the specialised taxonomic work on *Guembelitria*, *Woodringina* and *Chiloguembelina* (D´Hondt, 1991; MacLeod, 1993) and *Globoconusa?* and *Parvularugoglobigerina* (Luterbacher & Premoli Silva, 1964; Stainforth et al., 1975; Hofker, 1978; Blow, 1979; Liu & Olsson, 1992, 1994; Olsson et al., 1992, 1999; Li et al., 1995; Berggren & Norris, 1997). We used the diagnostic criteria compiled by Arenillas & Arz (1996) and Arenillas (1996).

One of the main diagnostic criteria used to identify the parvularugoglobigerinids morphospecies was the apertural shape. Two groups can be distinguished, one with a higher-arched aperture (*Pv. longiapertura*, *Pv. perexigua*, *Pv. umbrica*) and the other with a lower-arched aperture (*Pv. eugubina*, *Pv. sabina*, *Pv. hemisphaerica?*). The observation of this morphological characteristic is difficult in Ceselli 3 specimens since the planktic foraminifera are poorly preserved. This fact hampered a more detailed diagnostic description of the different morphospecies by Luterbacher & Premoli Silva (1964) at Ceselli 3 and, for this reason, the apertural shape was not specified in the original description. However, Stainforth et al. (1975) indicated that the low-arched aperture was a diagnostic character of *Pv. eugubina*. The revision of the *Pv. eugubina* holotype has allowed us to confirm this point.

The existence of different apertural shapes in *Parvularugoglobigerina* has been verified in better preserved specimens from other sections (Canudo et al., 1991; Keller, 1993; Keller & MacLeod, 1994; Arenillas, 1996; Molina et al., 1996, 1998; Arz & Arenillas, 1998; Arenillas et al., 2000) and suggests that the low-arched aperture is a diagnostic characteristic of *Pv. eugubina* and a high-arched aperture of *Pv. longiapertura*. The biostratigraphic studies of the most expanded and continuous sections (El Kef, Elles, Aïn Settara, Agost, Caravaca, Zumaya) demonstrate that the *Pv. longiapertura* appears earlier than *Pv. eugubina*.

Arenillas (1996) and Arenillas & Arz (1996) suggested that "cf. *fringa*" and "*minutula*" (Luterbacher & Premoli Silva, 1964), "*fodina*" (Blow, 1979) and "*alticonusa*" (Li et al., 1995) are possible *Globoconusa*. These morphospecies have smooth-walled texture and tetraserial-trocospiral coiling and are clearly linked with *Guembelitria*. This genus was frequently used in basal part of the Danian to be referred to all these small morphospecies phylogenetically linked with *Guembelitria*

(Keller, 1988, 1993; Brinkhuis & Zachariasse, 1988; Canudo et al., 1991; D´Hondt & Keller, 1991; Keller et al., 1993; Keller & MacLeod, 1994; Arenillas, 1996; Molina et al., 1996, 1998; Apellaniz et al., 1997). However, *Globoconusa* was considered a senior synonym of *Globastica* Blow (Loeblich & Tappan, 1988), grouping morphospecies larger, more modern and with pustulose-walled texture such as *Globoconusa daubjergensis* (Brönnimann). For this reason, the use of *Globoconusa* in the basal part of the Danian may be a mistake and perhaps should be replaced by *Postrugoglobigerina* Salaj. In this work, we used *Globoconusa*? until this taxonomic problem is clarified.

Arenillas & Arz (1996) considered that *Globoconusa*? and *Parvularugoglobigerina* are two distinctive morphological groups, and suggested that *Parvularugoglobigerina* is more related to hedbergellids than guembelitrids. The first globoconusids that appear belong to *Gc.*? *alticonusa*, which is a direct descendent of *Guembelitria* and has a strongly convex spiral side. On the contrary, the first parvularugoglobigerinids to appear belong to *Pv. longiapertura*, which is initially shaped like the specimen in figs. 8-9, Pl. 2. Both *Pv. longiapertura* and *Gc.*? *alticonusa* appear almost at the same time according to Arenillas (1996), Arenillas & Arz (1996), Molina et al. (1996, 1998), Arz et al. (1999) and Arenillas et al. (2000), and there are not intermediate forms between them. For these reasons, the taxonomic differentiation between both genera may be useful. However, other micropaleontologists consider that all these species are *Parvularugoglobigerina* (Olsson et al., 1992, 1999; Li et al., 1995). Olsson et al. (1999) include to all small globoconusids in *Pv. extensa* and grouped to all parvularugoglobigerinds in *Pv. eugubina*.

The Paleocene morphospecies identified in Ceselli 3 type-sample were as follows:

Globoconusa? alticonusa (Li et al.). Pl. 2, figs. 6-7.
Globoconusa? fodina (Blow). Pl. 2, figs. 16-17.
  =? *Postrugoglobigerina hariana* Salaj
  =? *Postrugoglobigerina maamouri* (Salaj)
  =? *Postrugoglobigerina praedaubjergensis* Salaj
Globoconusa? cf. *fringa* (in Luterbacher & Premoli Silva, 1964). Pl. 2, figs. 18-23.
Globoconusa? *minutula* (Luterbacher & Premoli Silva). Pl. 2, figs. 11-15.
Parvularugoglobigerina eugubina (Luterbacher & Premoli Silva). Pl. 1, figs. 1-5, 9-16 (6-8).
  = *Parvularugoglobigerina anconitana* (Luterbacher & Premoli Silva). Pl. 1, figs. 6-8.
Parvularugoglobigerina longiapertura (Blow). Pl. 2, figs. 1-5, 8-10.
Parvularugoglobigerina perexigua (Li, McGowran & Boersma). Pl. 1, figs. 17-18, 24-26 (22-23?).
  = *Parvularugoglobigerina sabina* (in Arenillas & Arz, 1996)
Parvularugoglobigerina sabina (Luterbacher & Premoli Silva). Pl. 1, figs. 29-30 (22-23?).
  = *Parvularugoglobigerina edita edita* (in Brinkhuis & Zachariasse, 1988)
  = *Parvularugoglobigerina* cf. *theodosica* (in Arenillas & Arz, 1996)
Parvularugoglobigerina umbrica (Luterbacher & Premoli Silva). Pl. 1, figs. 19-21, 27-28.
Woodringina claytonensis Loeblich & Tappan. Pl. 2, figs. 26-28.
Woodringina hornerstownensis Olsson. Pl. 2, figs. 29-30.
Chiloguembelina morsei Kline. Pl. 2, figs. 31-32.
Chiloguembelina taurica Morozova. Pl. 2, fig. 24.
Chiloguembelina midwayensis (Cushman). Pl. 2, fig. 33.

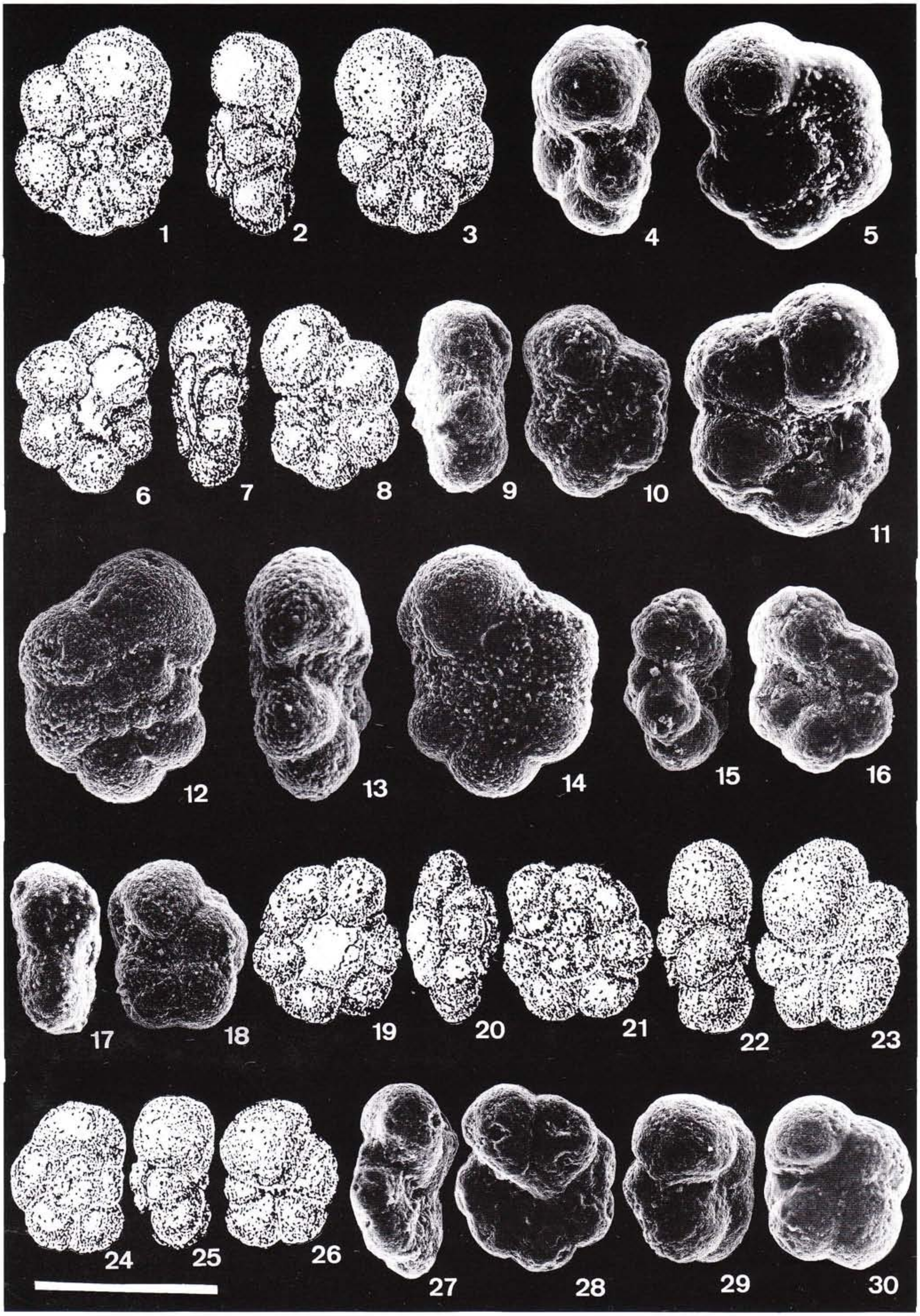
Biozonation and Biostratigraphy.

In this paper we used the biozonation in Molina et al. (1996) (Fig. 2), which is a slight modification of previous biozonations (Bolli, 1966; Stainforth et al., 1975; Toumarkine & Luterbacher, 1985; Berggren et al., 1995). Molina et al. (1996) recognised three biozones in the lowermost Danian: the *Guembelitria cretacea* Biozone, the *Parvularugoglobigerina eugubina* Biozone and the *Parasubbotina pseudobulloides* Biozone. The comparison

PLATE 1

(scale bar: 100 µm)

Fig. 1, 2, 3 - *Parvularugoglobigerina eugubina* (Luterbacher & Premoli Silva). Holotype. Ventral, lateral and dorsal view. In Luterbacher & Premoli Silva (1964).
Fig. 4, 5 - *Parvularugoglobigerina eugubina* (Luterbacher & Premoli Silva). Lateral and dorsal view.
Fig. 6, 7, 8 - *Parvularugoglobigerina anconitana* (Luterbacher & Premoli Silva). Holotype. Ventral, lateral and dorsal view. A possible synonym of *Pv. eugubina*.
Fig. 9, 10 - *Parvularugoglobigerina eugubina* (Luterbacher & Premoli Silva). Lateral and ventral view.
Fig. 11 - *Parvularugoglobigerina eugubina* (Luterbacher & Premoli Silva). Ventral view.
Fig. 12, 13, 14- *Parvularugoglobigerina eugubina* (Luterbacher & Premoli Silva). Dorsal, lateral and ventral view.
Fig. 15, 16 - *Parvularugoglobigerina eugubina* (Luterbacher & Premoli Silva). Lateral and ventral view.
Fig. 17, 18 - *Parvularugoglobigerina perexigua* (Li Q., McGowran B. & Boersma A.). Lateral and ventral view.
Fig. 19, 20, 21- *Parvularugoglobigerina umbrica* (Luterbacher & Premoli Silva). Holotype. Ventral, lateral and dorsal view. In Luterbacher & Premoli Silva (1964).
Fig. 22, 23 - *Parvularugoglobigerina sabina* (Luterbacher & Premoli Silva). Paratype. Dorsal, lateral and ventral view.
Fig. 24, 25, 26- *Parvularugoglobigerina sabina* (Luterbacher & Premoli Silva). Holotype. Dorsal, lateral and ventral view. In Luterbacher & Premoli Silva (1964).
Fig. 27,28 - *Parvularugoglobigerina umbrica* (Luterbacher & Premoli Silva). Lateral and ventral view.
Fig. 29, 30 - *Parvularugoglobigerina sabina*. Ventral and lateral view.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of this biozonation with other lowermost Danian planktic foraminiferal biozonations is shown in Fig. 2.

The *Gb. cretacea* Biozone spans the interval between the last appearance datum (LAD) of *Plummerita hantkeninoides* and *Abathomphalus mayaroensis* coinciding with the K/P boundary and the *Pv. eugubina* FAD. It approximately corresponds to P0 of Smit (1982), Keller (1988, 1993) and Berggren et al. (1995), but is not equivalent. The K/P boundary is recognised by an Ir anomaly and other geochemical anomalies at the El Kef (Tunisia) stratotype section. These anomalies were first recognised in the Gubbio section (Italy) by Alvarez et al. (1980) in the green-red clay layer approximately equivalent to Ceselli 3 layer (Luterbacher & Premoli Silva, 1964).

The original "*Globigerina*" *eugubina* Biozone was defined by Luterbacher & Premoli Silva (1964) at Gubbio (Italy) and characterised by the presence of *Pv. eugubina*. The base of this biozone was later defined by the *Pv. eugubina* FAD (Bolli, 1966; Stainforth et al., 1975). Most micropaleontologists adopted this definition (Blow, 1979; Toumarkine & Luterbacher, 1985; Berggren & Miller, 1988; Keller, 1988, 1993; Berggren et al., 1995; Berggren & Norris, 1997). In this paper, the *Pv. eugubina* Biozone defines the interval between the *Pv. eugubina* FAD and the *P. pseudobulloides* FAD and approximately corresponds with the P1a of Smit (1982) and Keller (1988, 1993), the *Pv. longiapertura* Biozone of Canudo et al. (1991) and Pα of Berggren et al. (1995). These last biozones are not exactly synonyms to the *Pv. eugubina* Biozone of Molina et al. (1996), because their bases are usually placed at the *Pv. longiapertura* FAD. Finally, the *P. pseudobulloides* Biozone, whose base is defined by the *P. pseudobulloides* FAD, is approximately equivalent to P1c of Smit (1982), P1b of Keller (1988, 1993) and P1a-P1b of Berggren et al. (1995).

The stratigraphical ranges of the morphospecies identified in Ceselli 3 are shown in Fig. 3. These ranges of lowermost Danian morphospecies are based on a biostratigraphic correlation among several sections such as Agost, Caravaca and Zumaya (Spain), Aïn Settara, El Kef and Elles (Tunisia) and Ben Gurion (Israel) (Arenillas, 1996, 1998; Molina et al., 1996, 1998; Arz & Arenillas, 1998; Arz et al., 1999; Arenillas et al., 2000). The taxonomy is primarily based on Luterbacher & Premoli Silva (1964) and a later taxonomic revision by Arenillas (1996). The morphospecies ranges allow us to biostratigraphically place the faunal assemblage identified in the *Pv. eugubina* type-sample (Fig. 4).

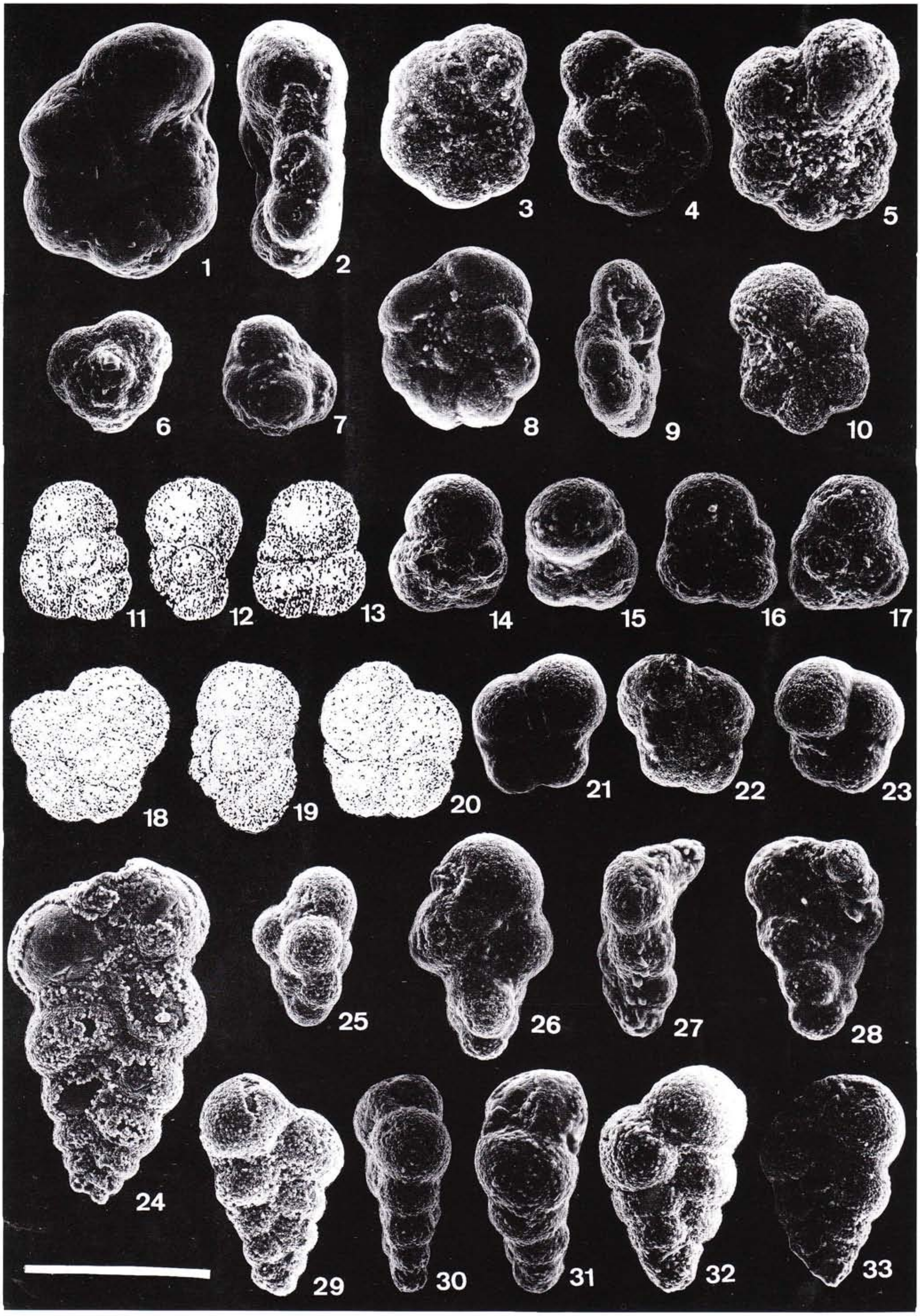
Discussion.

According to the planktic foraminiferal assemblage recorded in Ceselli 3 (Figs. 3 and 4), the *Pv. eugubina* type-sample is approximately situated in the lower part of the *Pv. eugubina* Biozone of Molina et al. (1996) or middle part of the P1a of Smit (1982) and Keller (1988, 1993), *Pv. longiapertura* Biozone of Canudo et al. (1991) and Pα of Berggren et al. (1995). Both *Pv. longiapertura* and *Pv. eugubina* have been identified together in the Ceselli 3 assemblage confirming the proposed hypothesis (Fig. 4). The *Gb. cretacea* Biozone at Ceselli has not been recognised, which could be due to the presence of a hiatus or because the section is stratigraphically condensed.

PLATE 2

(scale bar: 100 µm)

Fig. 1, 2. - *Parvularugoglobigerina longiapertura* (Blow). Ventral and lateral view.
Fig. 3, 4 - *Parvularugoglobigerina longiapertura* (Blow). Ventral and dorsal view.
Fig. 5 - *Parvularugoglobigerina longiapertura* (Blow). Ventral view.
Fig. 6, 7 - *Globoconusa ? alticonusa* (Li et al.). Dorsal and ventral view.
Fig. 8, 9 - *Parvularugoglobigerina longiapertura* (Blow). Dorsal and ventral view.
Fig. 10 - *Parvularugoglobigerina longiapertura* (Blow). Ventral view.
Fig. 11, 12, 13- *Globoconusa? minutula* (Luterbacher & Premoli Silva). Holotype. Dorsal, lateral and ventral view. In Luterbacher & Premoli Silva (1964).
Fig. 14, 15 - *Globoconusa ? minutula* (Luterbacher & Premoli Silva). Dorsal and ventral view.
Fig. 16, 17 - *Globoconusa ? fodina* (Blow). Ventral and dorsal view.
Fig. 18, 19, 20- *Globoconusa* ? cf. *fringa* (in Luterbacher & Premoli Silva, 1964). Dorsal, lateral and ventral view.
Fig. 21, 22 - *Globoconusa* ? cf. *fringa* (in Luterbacher & Premoli Silva, 1964). Ventral and dorsal view.
Fig. 23 - *Globoconusa* ? cf. *fringa* (in Luterbacher & Premoli Silva, 1964). Ventral view.
Fig. 24 - *Chiloguembelina taurica* Morozova. Side view.
Fig. 25 - *Guembelitria cretacea* Cushman. Side view.
Fig. 26 - *Woodringina claytonensis* Loeblich & Tappan. Side view.
Fig. 27, 28 - *Woodringina claytonensis* Loeblich & Tappan. Edge and side view.
Fig. 29, 30 - *Woodringina hornerstownensis* Olsson. Side and edge view.
Fig. 31, 32 - *Chiloguembelina morsei* Kline. Side and edge view.
Fig. 33 - *Chiloguembelina midwayensis* (Cushman). Side view.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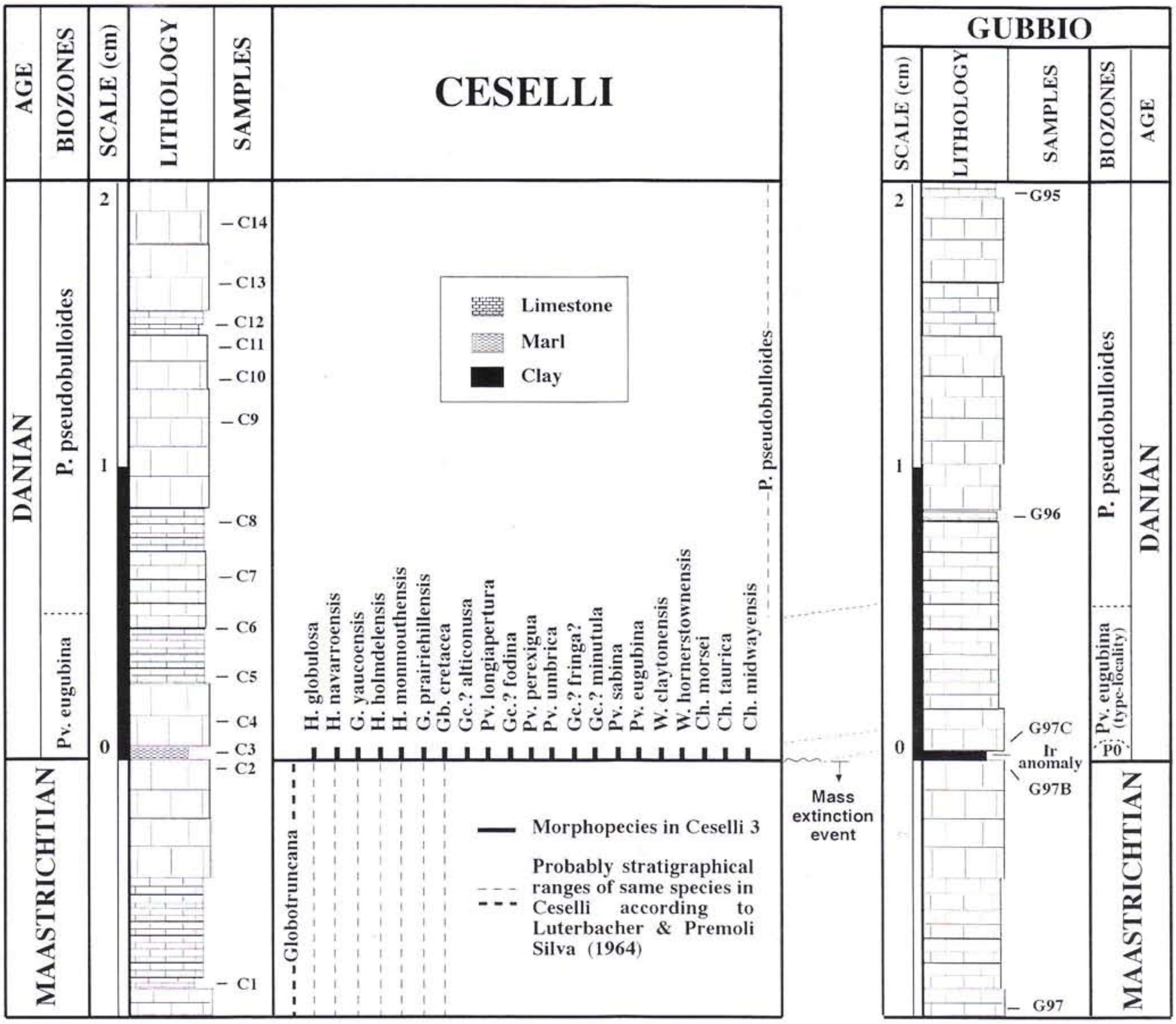

Fig. 3 - Location of the Ceselli 3 (*Pv. eugubina* Biozone type-sample) in the stratigraphical column of the Ceselli section and planktic foraminiferal assemblages identified. Biostratigraphic correlation between Ceselli section and Gubbio section (according to Luterbacher and Premoli Silva, 1964).

Alvarez et al. (1980) used the green-red clay layer with Ir anomaly from the Gubbio section to characterise the base of the Paleocene and the base of the *Gb. cretacea* Biozone. The green-red clay at Gubbio is devoid of planktic foraminifera and carbonates, but the assemblage just above it is equivalent to the Ceselli 3 assemblage (Luterbacher & Premoli Silva, 1964). Both Ceselli and Gubbio sections are very similar (Fig. 3) but the boundary clay layer is absent in Ceselli, marking a probable short hiatus in this section. The stratigraphic condensation of both sections impedes a more detailed sampling of the K-P transition.

The present controversy over the possible synonymy of *Pv. eugubina* and *Pv. longiapertura* affects the established biostratigraphy and biozonations in the lowermost Danian. Ever since Smit (1982), both morphospecies have historically been considered synonyms. He placed the base of P1a (*Pv. eugubina*) at the first appearance of *Globigerina minutula* (= *Gc.? alticonusa*), which is a biohorizon close to *Pv. longiapertura* FAD. Nevertheless, the *Pv. eugubina* FAD is the biohorizon that was normally used to identify the base of this biozone. This datum has been used in theory but in practice *Pv. eugubina* has generally been misinterpreted for *Pv. longiapertura*. Usually the term "*eugubina*" has been erroneously used to refer to the typical forms with high-arched aperture (Keller, 1988; Berggren et al., 1995; Berggren & Norris, 1997). This misinterpretation was first noted by Canudo et al. (1991) and later documented in several papers (MacLeod & Keller, 1994; Keller et al., 1995; MacLeod, 1995; Arenillas, 1996; Molina et al., 1996, 1998) and has partly caused the recent taxonomic con-

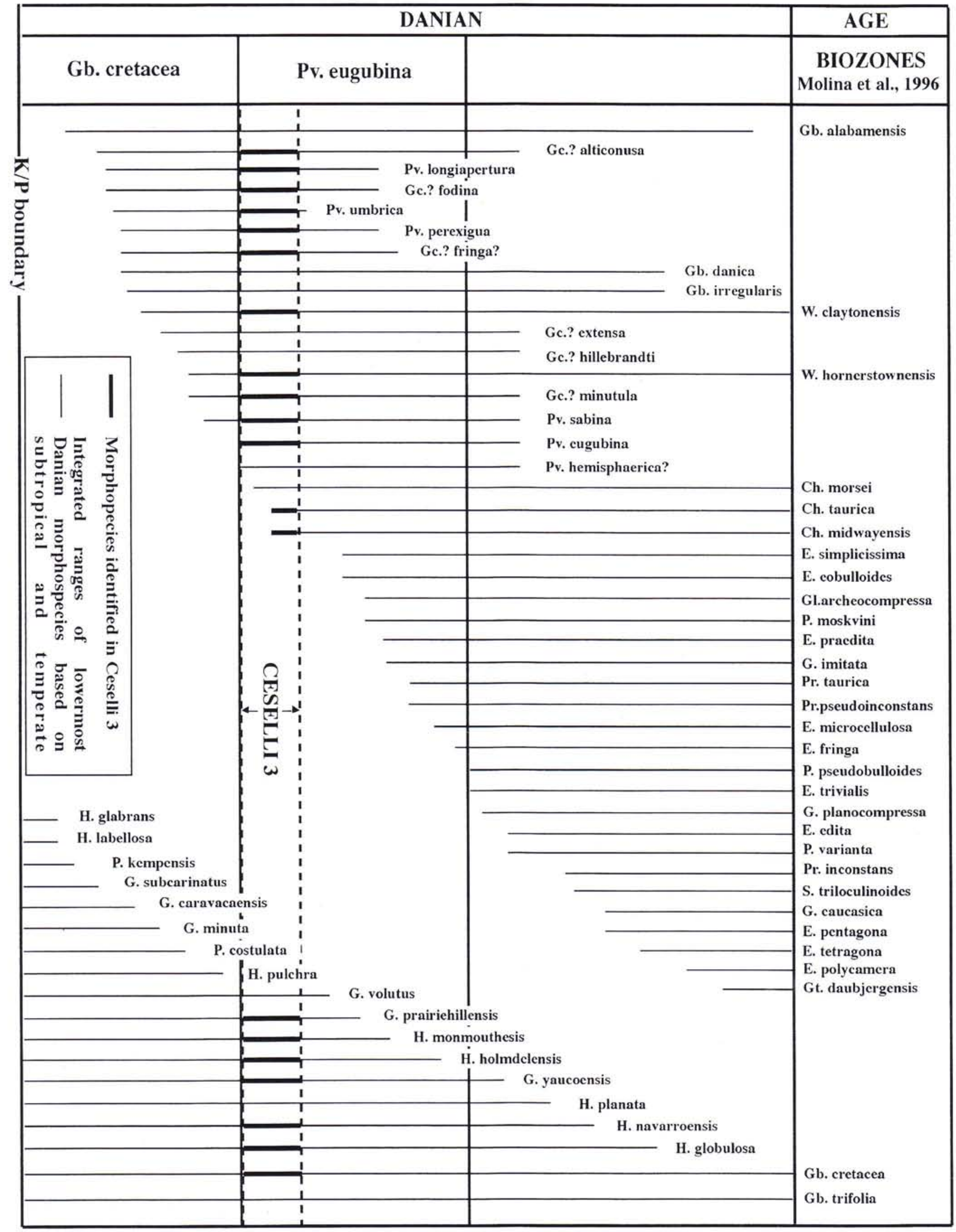

Fig. 4 - The most probable placement of sample Ceselli 3 with respect to the *Pv. eugubina* biozone. Based on planktic foraminiferal ranges from subtropical-temperate sections (Arenillas, 1996; Molina et al., 1998), the Ceselli 3 assemblage is representative of the lower part of the *Pv. eugubina* biozone.

troversy (Keller & MacLeod, 1994, vs. Huber et al., 1994).

As this synonymy has been historically accepted, the *Pv. longiapertura* FAD may have been used erroneously to identify the base of the *Pv. eugubina* Biozone and, therefore, the biozones of most of the lowermost Danian biozonations (Keller, 1988, 1993; Keller et al., 1995; Berggren et al., 1995) could be misplaced (Fig. 2). The problem now is to decide what datum must be used to identify the boundary between the *Gb. cretacea* Biozone or P0 of Smit (1982) and the *G. eugubina* Biozone of Luterbacher & Premoli Silva (1964). There are three possibilities:

1. - To continue using the *Pv. eugubina* FAD as characterised by Luterbacher & Premoli Silva (1964) and defined by Bolli (1966), but re-establishing the original taxonomic concept of the homonym morphospecies and using its true first appearance (Molina et al., 1996).

2. - To use the *Pv. longiapertura* FAD and define and describe a new biozone with a different name as the *Pv. longiapertura* Biozone was defined by Canudo et al. (1991) and used by Apellaniz et al. (1997) in a different way. This datum is approximately placed in the middle part of the *Gb. cretacea* Biozone of Molina et al. (1996).

3. - To use the "*Globigerina*" *minutula* (= *Gc.*? *alticonusa*) FAD following Smit (1982) to place the boundary between the *Gb. cretacea* and *Pv. eugubina* Biozones. This datum approximately coincides with the *Pv. longiapertura* FAD.

The Ceselli 3 planktic foraminiferal assemblage we identified would suggest that, following its original definition, the most suitable biozonal concept to place the base of the *Pv. eugubina* Biozone is the possibility 1. Since most of the biozonations have used the term "*eugubina*", we suggest the continued use of the classical *Pv. eugubina* Biozone in order to avoid further problems.

Conclusions.

The *Pv. eugubina* Biozone was defined by Luterbacher & Premoli Silva (1964) from the Gubbio section (Italy) and is characterised by the presence of *Pv. eugubina*. This species was described from Ceselli and, therefore, the revision of the planktic foraminiferal assemblage of the *Pv. eugubina* type-sample was fundamental to specify the biostratigraphic position of the *Pv. eugubina* Biozone. Of the 21 morphospecies identified in *Pv. eugubina* type-sample, seven were Cretaceous and 14 Paleocene. Both *Parvularugoglobigerina longiapertura* and *Pv. eugubina* were identified in this assemblage, demonstrating that the *Pv. eugubina* type-sample falls in the lower part of the Molina et al. (1996) *Pv. eugubina* Biozone.

The taxonomic differentiation between *Pv. eugubina* and *Pv. longiapertura* is very important to clarify the lowermost Danian biozonations. Both morphospecies are distinguished by the apertural shape, being high-arched in *Pv. longiapertura* and low-arched in *Pv. eugubina*. We suggest the continued use of the *Pv. eugubina* Biozone since it was the first biozonal concept used. Consequently, the base of the *Pv. eugubina* Biozone should be placed at the true FAD of *Pv. eugubina*, as this biozone was originally defined, and not at the FAD of *Pv. longiapertura* FAD.

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REFERENCES

Alvarez W., Alvarez L.W., Asaro F. & Michel H.V. (1980) - Extraterrestrial cause for the Cretaceous-Tertiary extinction. *Science*, v. 208, pp. 1095-1108, Washington.

Apellaniz E., Baceta J.I., Bernaola-Bilbao G., Núñez-Betelu K., Orue-etxebarria X., Payros A., Pujalte V., Robin E. & Rocchia R. (1997) - Analysis of uppermost Cretaceous-lowermost Tertiary hemipelagic successions in the Basque Country (Western Pyrenees): evidence for a sudden extinction of more than half planktic foraminifer species at the K/T boundary. *Bull. Soc. géol. Fr.*, v. 168, n. 6, pp. 783-793, Paris.

Arenillas I. (1996) - *Los foraminíferos planctónicos del Paleoceno-Eoceno Inferior: Sistemática, Bioestratigrafía, Cronoestratigrafía y Paleoceanografía*. Tesis Doctoral, Univ. Zaragoza, V. of 513 pp., Zaragoza. Unpublished

Arenillas I. (1998) - Biostratigrafía con foraminíferos planctónicos del Paleoceno y Eoceno Inferior de Gubbio (Italia): calibración biomagnetoestratigráfica. *Neu. Jahrb. Geol. Paläont., Monats.*, v. 5, pp. 299-320, Stuttgart.

Arenillas I. & Arz J.A. (1996) - Origen y filogenia de las primeras especies de foraminíferos planctónicos del Paleoceno basal, tras el límite Cretácico/Terciario. *Act. XII Bienal Real Soc. de Esp. Hist. Nat.*, pp. 267-271, Madrid.

Arenillas I., Arz J.A., Molina E. & Dupuis C. (2000) - Planktic foraminiferal independent test across the Cretaceous/Paleogene (K/P) boundary at El Kef (Tunisia): catastrophic mass extinction and possible survivorship. *Micropaleontology*, v. 46, no. 1, in press. New York.

Arz J.A. & Arenillas I. (1998) - Extinción en masa catastrófica de foraminíferos planctónicos en el límite Cretácico/Terciario del Pirineo occidental (España). *Rev. Soc. Mexicana de Paleontología*, v. 8, n. 2, pp. 146-162. Mexico.

Arz J.A., Arenillas I., Molina E. & Dupuis C. (1999) - La extinción en masa de foraminíferos planctónicos en el límite Cretácico/Terciario (K/T) de Elles (Túnez): Los efectos tafonómico y "Signor-Lipps". *Rev. Soc. Geol. España*, v. 12, n. 2, Madrid.

Berggren W.A., Kent D.V., Swisher III C.C. & Aubry M.P. (1995) - A revised Paleogene Geochronology and Chronostratigraphy. In Berggren, W.A. et al. (eds.) - *Geochronology, Time and Global Stratigraphic Correlation*, Society of Economic Geologist and Paleontologist, Special Publication, pp. 1-392, Tulsa.

Berggren W.A. & Miller, K. G. (1988) - Paleogene tropical planktonic foraminiferal biostratigraphy and magnetobiochronology. *Micropaleontology*, v. 34, n. 4, pp. 362-380, New York.

Berggren W.A. & Norris R.D. (1997) - Biostratigraphy, phylogeny and systematics of Paleocene trochospiral planktic foraminifera. *Micropaleontology*, v. 43, n. 1, pp. 1-116, New York.

Blow W.H. (1979) - The Cainozoic Globigerinidae. A study of the morphology, taxonomy, evolutionary relationship and the stratigraphical distribution of some Globigerinidae (mainly Globigerinacea). E. J. Brill (ed.) 3 V. of 1413 pp., Leiden.

Bolli H.M. (1966) - Zonation of Cretaceous to Pliocene marine sediments based on Planktonic foraminifera. *Boletín inform. Asoc. Venezolana Geol. Min. Petrol.*, v. 9, n. 1, pp. 1-34, Caracas.

Brinkhuis H. & Zachariasse W.J. (1988) - Dinoflagellate cyst, sea level changes and planktonic foraminifers across the Cretaceous-Tertiary boundary at El Haria, Northwest Tunisia. *Mar. Micropal.*, v. 13, pp. 153-191, Amsterdam.

Canudo J. I., Keller G. & Molina E. (1991) - Cretaceous/Tertiary boundary extinction pattern and faunal turnover at Agost and Caravaca, SE Spain. *Mar. Micropal.*, v. 17, pp. 319-341, Amsterdam.

D´Hondt S. L. (1991) - Phylogenetic and stratigraphic analysis of earliest Paleocene biserial and triserial planktonic foraminifera. *Journ. Foramin. Res.*, v. 21, n. 2, pp. 168-181, Washington.

D´Hondt, S.L. & Keller, G. (1991) - Some patterns of planktic foraminiferal assemblage turnover at the Cretaceous-Tertiary boundary. *Mar. Micropal.*, v. 17, pp. 77-118, Amsterdam.

Hofker J. (1978) - Analysis of a large succession of samples through the Upper Maastrichtian and the Lower Tertiary of Drill Hole 47.2, Shatsky Rise, Pacific, Deep Sea Drilling Projet. *Journ. Foram. Res.*, v. 8 n. 1, pp. 46-75, Washington.

Huber B.T., Liu Ch., Olsson R.K. & Berggren W.A. (1994) - Comment on "The Cretaceous-Tertiary boundary transition in the Antarctic Ocean and its global implications", by G. Keller. *Mar. Micropal.*, v. 24, pp. 92-99, Amsterdam.

Keller G. (1988) - Extinction, survivorship and evolution of Planktic Foraminifera across the Cretaceous/Tertiary boundary at El Kef, Tunisia. *Mar. Micropal.*, v. 13, pp. 239-263, Amsterdam.

Keller G. (1993) - The Cretaceous-Tertiary boundary transition in the Antarctic Ocean and its global implications. *Mar. Micropal.*, v. 21, pp. 1-45, Amsterdam.

Keller G. & MacLeod N. (1994) - Reply to coment on "The Cretaceous-Tertiary boundary transition in the Antarctic Ocean and its global implications". *Mar. Micropal.*, v. 24, pp. 101-118, Amsterdam.

Keller G., Li L. & MacLeod N. (1995) - The Cretaceous/Tertiary boundary stratotype sections at El Kef, Tunisia: How catastrophic was the mass extinction?. *Palaeogeog., Palaeoclim., Palaeoecol.*, v. 119, pp. 221-254, Amsterdam.

Leonov G.P. & Alimarina V.P. (1961) - Stratigraphy and foraminifera of Cretaceous-Paleogene "transition" beds of the central part of the North Caucasus. *Moscow Univ. Geol. Fac., sbornik Trudov*, pp. 29-60, Moscow.

Li Q., McGowran B. & Boersma A. (1995) - Early Paleocene *Parvularugoglobigerina* and late Eocene *Praetenuitella*: does evolutionary convergence imply similar habitat?. *Journ. Micropal.*, v. 14, pp. 119-134, London.

Liu Ch. & Olsson R.K. (1992) - Evolutionary radiation of microperforate planktonic foraminifera the K/T mass extinction event. *Journ. Foramin. Res.*, v. 22, n. 4, pp. 328-346, Washington.

Liu Ch. & Olsson R.K. (1994) - On the origin of Danian normal perforate planktonic foraminifera from *Hedbergella*. *Journ. Foramin. Res.*, v. 24, n. 2, pp. 61-74, Washington.

Loeblich, A.R., Jr. y Tappan, H. (1988). Foraminiferal general and their clasification. Van Nostrand Reinhold Company (ed.), 2 V. of 970 pp., New York.

Luterbacher H.P. (1964) - Studies in some *Globorotalia* from the Paleocene and lower Eocene of the central Apennines. *Ecl. geol. Helv.*, v. 57, n. 2, pp. 631-730, Basel.

Luterbacher H.P. & Premoli Silva I. (1964) - Biostratigrafia del limite Cretaceo-Terziario nell´Apennino Centrale. *Riv. It. Paleont. Strat.*, v. 70, n. 1, pp. 67-128, Milano.

MacLeod N. (1993) - The Maastrichtian-Danian radiation of triserial and biserial planktic foraminifera: Testing phylogenetic and adaptational hypotheses in the (micro) fossil record. *Mar. Micropal.*, v. 21, pp. 47-100, Amsterdam.

Molina E., Arenillas I. & Arz J.A. (1996) - The Cretaceous/Tertiary boundary mass extinction in planktic foraminifera at Agost (Spain). *Rev. Micropal.*, v. 39, n. 3, pp. 225-243, Paris.

Molina E., Arenillas I. & Arz J.A. (1998) - Mass extinction in planktic foraminifera at the Cretaceous/Tertiary boundary in subtropical and temperate latitudes. *Bull. Soc. géol. Fr.*, v. 169, n. 3, pp. 351-363, Paris.

Olsson R.K., Hemleben C., Berggren W. & Liu Ch. (1992) - Wall texture classification of planktonic foraminifera genera in the Lower Danian. *Jour. Foramin. Res.*, v. 22, n. 3, pp. 195-213, Washington.

Olsson R.K., Hemleben C., Berggren W. & Huber B.T. (1992) - Atlas of Paleocene Planktonic Foraminifera. Smithsonian Contributions to Paleobiology, n. 85, 252 pp., *Smith. Inst. Press*, Washington D.C.

Premoli Silva I. (1977) - The earliest Tertiary *Globigerina eugubina* zone: Paleontological significance and geographical distribution. *Mem. Segundo Congreso Latinomericano de Geología*, v. 3, n. 7, pp. 1541-1555, Caracas.

Premoli Silva I. & Bolli H.M. (1973) - Late Cretaceous to Eocene planktonic foraminifera and stratigraphy of Leg 15 sites in the Caribbean Sea. *Initial Reports of the Deep Sea Drilling Project*, v. 15, pp. 449-547, Washington.

Smit J. (1982) - Extinction and evolution of planktonic foraminifera after a major impact at the Cretaceous/Tertiary boundary. *Geol. Soc. Am. Spec. Pap.*, v. 190, pp. 329-352, New York.

Stainforth R.M., Lamb J.L., Luterbacher H., Beard J.H. and Jeffords R.M. (1975) - Cenozoic planktonic foraminiferal zonation and characteristics of index forms. *The University of Kansas Paleontological Contributions*, v. 62, pp. 1-425, Lawrence.

Toumarkine M. & Luterbacher H.P. (1985) - Paleocene and Eocene planktic foraminifera. In Bolli, H.M., Saunders J.B., Perch-Nielsen K. (eds.) - *Plankton Stratigraphy*, Cambridge University Press, pp. 88-153, Cambridge