New species of the genus Parkiella (Foraminifera) from the Late Cretaceous Central Pacific Ocean: biostratigraphy, biogeography, and the Cretaceous–Palaeogene boundary

JOEN G. V. WIDMARK & MICHAL KUCERA
Department of Marine Geology, Earth Sciences Centre, Göteborg University 413 81 Göteborg, Sweden.

ABSTRACT – Two new species, Parkiella angulocamerata sp. nov. and P. globocamerata sp. nov., are described from the Late Cretaceous (late Maastrichtian) Central Pacific Ocean, DSDP Sites 465 and 171. Examination under the SEM revealed apertural features that were not documented in the original description of Parkiella. An ‘L’-shaped aperture was originally considered as a diagnostic character of Parkiella; we suggest that this is a preservational artefact and question its diagnostic value. The existence of internal toothplates determine both Parkiella described here as members of the family Turrilinidae Cushman 1927. Both species were found to be endemic to the tropical Pacific Ocean. They occurred in sequence throughout the Maastrichtian section at Site 465 with a minimum (one sample) stratigraphic overlap. Parkiella globocamerata is one of the few deep-sea benthic foraminiferal species that indeed became extinct at the Cretaceous–Palaeogene (K/Pg) boundary. However, we document a decrease in both relative abundance and accumulation rate of the species already prior to the K/Pg transition. We propose that the interval between the LO (Last Occurrence) of P. angulocamerata and the LO of P. globocamerata is indicative of uppermost Cretaceous (Micula prinsii Zone) strata in the tropical Pacific. J. Micropalaeontol. 17(1): 51–60, April 1998.

INTRODUCTION
The benthic foraminiferal fauna from the uppermost Cretaceous and lowermost Palaeogene strata at Site 465 (and from the Late Cretaceous of the Central Pacific Ocean in general) has not yet been described in detail – apart from the documentation of the most common taxa by Widmark & Malmgren (1992a, b) and short communication by Widmark & Henriksson (1995). In this paper we describe two new species typical for this fauna, discuss their taxonomic position, biostratigraphic significance, and biogeographic distribution.

During a study on benthic foraminiferal changes across the Cretaceous/Palaeogene (K/Pg) boundary at three DSDP sites, one from the Pacific Ocean (Site 465) and two from the South Atlantic Ocean (Sites 525 and 527), Widmark & Malmgren (1992a) encountered several taxa that had not been previously described in the literature. Among these was a ‘buliminid’ species from Site 465, tentatively named Buliminella sp. A. This species, here described under the name of Parkiella globocamerata sp. nov. and a probable closely related species, Parkiella angulocamerata sp. nov., are the subjects of the present study.

It has been suggested and later demonstrated that deep-sea benthic foraminifers (as a group) were not severely affected by the biotic crisis at the K/Pg boundary (e.g. Douglas & Woodruff, 1981; Emiliani et al., 1981; Berggren, 1984; Hansen et al., 1987; Thomas, 1990; Nomura, 1991; Kaiho, 1992; Widmark & Malmgren, 1992a) compared to the vast majority of planktonic organism and shallow benthic groups. Some benthic foraminiferal taxa did, however, respond to this event in that they became extinct or declined drastically in abundance across the K/Pg boundary. Buliminella sp. A. (= Parkiella globocamerata sp. nov.) was among the relatively few taxa that significantly decreased in relative abundance across the K/Pg boundary (Widmark & Malmgren, 1992a). Here, we present a detailed account on its response to the K/Pg boundary event in terms of both relative abundances and accumulation rates.

Fig. 1. Known distribution of the genus Parkiella during the Late Cretaceous. Filled circles denote DSDP sites, filled squares denote West African localities (see text).

MATERIAL AND METHODS
The studied material was obtained from an 84 m long section including the Maastrichtian, the K/Pg boundary, and the lowermost Palaeocene at the Pacific DSDP Site 465 (Hole 465A, southern Hess Rise; Fig. 1, Table 1); a lithostratigraphic column of the section investigated is given in Fig. 2. The upper part of the section (Cores 3–8) consists of foraminifer–nannofossil chalk and ooze and nannofossil ooze; the K/Pg boundary occupies a ‘mixed zone of Danian and Maastrichtian sediments’, approximately 30 cm thick (Fig. 2A) (Thiede et al., 1981a). Below Core 3, the section is divided by a thick cherty drilling breccia represented by four short cores (4, 6, 7, 8; Core 5 is missing) between 67.5 and 105.5 mbsf (Thiede et al., 1981a). The lower part of the sequence (Cores 9–12) consists also of foraminifer–nannofossil ooze and nannofossil ooze and chalk with occasionally higher chert contents (Fig. 2B). The history of the calcium–carbonate dissolution during the
Maastrichtian at Site 465 was studied using the fragmentation of planktonic foraminifera following the method described in Malmgren (1987). Usually more than 300 specimens per sample were counted to determine the proportion of fragments and its precision (95% confidence intervals). Two intervals of strong dissolution (>45% of fragments of planktonic foraminifera) were identified (Fig. 3A). The first interval is represented by one pyrite containing sample in the 'mixed zone' above the K/Pg boundary. The second interval (identified in the four lowermost samples from Core 3) coincides with the upper range limit of the cherty drilling breccia. Remaining samples are relatively well preserved and the fragmentation of planktonic foraminifera indicates low to moderate calcium carbonate dissolution during their deposition.

Altogether 31 samples from Hole 465A were analysed with a closer sampling towards the K/Pg boundary in order to obtain a higher resolution at this transition (Table 2). The samples were immersed in de-ionized water and placed on a rotary table for about 24 h. They were washed over a 63 μm sieve; both fractions were dried and (in most cases) weighed. The sand fraction was immersed in de-ionized water and placed on a rotary table for dissolution (set to 1.925 g/cm³ in this study), and number of specimens (84 complete and 17 broken) of 'Globigerina' eugubina, Micula prinsii, and de Klasz et al. (1993). These characteristics together with the 'low trochospiral coil' and 'complex 'L'-shaped aperture' indicate low preservation. K/Pg denotes the Cretaceous–Palaeogene boundary. 'Zone' refers to planktonic foraminifera following the method described in Boersma (1981). Sample 20 was barren of planktonic foraminifera, and sample 23 was not included in the study due to poor preservation. Abm = Abathomphalus mayaroensis; Gco = Globotruncana contusa; Gga = Globotruncanana gansseri; Gsc = Globotruncanana scutilla.

**Table 1.** Data on present-day location and water depth, palaeolatitude, and palaeodepth at the end of the Maastrichtian for those DSDP Sites where the genus *Parkiella* occurred. Figures within parentheses refer to sources of information. References: *Thiede et al. (1981a); Winterer et al. (1973); Thiede et al. (1981b); Vallier et al. (1981).

| Site 465 | Site 171 |
|----------|----------|
| Location | Southern Hess Rise (Central Pacific) | Horizon Guyot † (Central Pacific) |
| Latitude | 34°N* | 19°N* |
| Longitude | 179°E* | 169°W † |
| Water depth | 2161 m* | 2290 † |
| Palaeolatitude | 13°N ‡ | 2°N ‡ |
| Palaeodepth | 1.500 m § | 1.000 m § |

**Table 2.** Data for DSDP samples used in the present study. 'Weight' is total dry sample weight, 'N' is the number of *Parkiella* spp. nov. specimens encountered in each sample, and 'B' is the total number of benthic foraminifera in samples. 'Zone' refers to planktonic foraminifera zones as identified by Boersma (1981). Sample 20 was barren of foraminifera, and sample 23 was not included in the study due to poor preservation. K/Pg denotes the Cretaceous–Palaeogene boundary.

**SYSTEMATIC DESCRIPTIONS**

The genus *Parkiella* was recently established by Seiglie et al. (1993) on the type species *Buliminella gabonica* de Klasz and Rérat, 1962. It includes a group of morphologically distinct species described from Upper Cretaceous shelf deposits from West Africa (Cameroon and Gabon) by de Klasz & Rérat (1962) and de Klasz et al. (1963). The diagnosis of *Parkiella* is based on its 'low trochospiral coil' and 'complex 'L'-shaped aperture' (Seiglie et al., 1993). These characteristics together with the generally lower number of chambers/whorl separate *Parkiella* from *Buliminella* Cushman 1927 and *Praebuliminina* Holker 1957 according to Seiglie et al. (1993). Other turritillid genera, such as Sporobulimina Stone 1949 and *Sporobuliminina* Stone 1949 (both possess supplementary apertures) and *Sitella* Voloshina 1974 (with an inverted 'T'-shaped aperture), are separated from
New species of the genus *Parkiella*

Fig. 2. Lithology, depth in Hole (metres below sea floor [mbsf]), and sampling of the section studied at Site 465 (Hole 465A); (A) Cores 3-8; (B) Cores 9-12. Figure modified after Thiede et al. (1981a).
Fig. 3. (A) Calcium carbonate dissolution history at Site 465 in terms of planktonic foraminiferal fragmentation; note that two intervals of strong dissolution were detected, one coinciding with the thick chert (drilling breccia) and the other (represented by one sample only) associated with the pyrite containing layer at the K/Pg boundary. Horizontal bars represent 95% confidence intervals. (B) The relative abundance (%) of Parkiella spp. nov.; note that P. angulocamerata sp. nov. is succeeded by P. globocamerata sp. nov. with a minimum of stratigraphic overlap (one sample only). Cores 4–7 were omitted in both figures; vertical scale changes below Core 3.

| K/Pg boundary | 62.44 mbsf † |
| Top *G*. eugubina Zone* | +1.2 m ‡ |
| Base *M*. prinsii Zone* | −2.3 m ‡ |
| Base *M*. murus Zone* | −9.9 4.8 m § |
| Estimated sedimentation rate above the K/Pg boundary | 0.4 cm/kyr |
| Estimated sedimentation rate below the K/Pg boundary | 1.2 cm/kyr |

Table 3. Biostratigraphic data upon which the age model for Core 3, Hole 465A was established (see also Widmark & Malmgren, 1992a). * meters below/above the K/Pg boundary. †Thiede et al. (1981a); ‡Boersma & Shackleton (1981); §Henriksson (1993); §Cepek (1981).

Parkiella on the basis of apertural characteristics (Seiglie et al., 1993). Seiglie et al. (1993) found it problematic, however, to place Parkiella in a higher systematic category, since the specimens in their well samples were completely replaced by pyrite or completely pyrite infilled, which made it impossible to observe any internal apertural features. Nevertheless, based on the ‘morphological characteristics’ alone, Seiglie et al. (1993) placed Parkiella in the Turritilinidae Cushman 1927. The main argument for this allocation was that a taxon with such morphological characteristics would possess a toothplate and, therefore, should be placed in Turritilinidae (Seiglie et al., 1993).

A close examination under the SEM elucidated some new apertural features in our Parkiella species. Well preserved apertures were found to be equipped with a delicate apertural flap (Fig. 4G), which covers an analogue of the periapertural depression as in Bulimina (see Verhallen, 1986). In addition, an apertural lip (Fig. 4B–C, G–H) is present in most specimens. The apertural flap is, however, often broken off as shown in Fig. 4B–C, H–I. In even worse preserved specimens the aperture is excavated along the basal suture of the last chamber into an ‘L’-shaped opening (Fig. 4C, H-I); sometimes even the apertural lip is destroyed by postmortal processes (Fig. 4I). These ‘L’-shaped openings observed in both species described here is, hence, a preservational artefact. Although we did not have the possibility to examine the type material of Parkiella, the validity of this character as diagnostic of this genus has to be questioned.
New species of the genus *Parkiella*

In order to examine the internal apertural features of our *Parkiella* spp. nov., the last chambers in specimens of each species were removed (Fig. 4A, D). Both species exhibit a short internal toothplate, which connects the 'periapertural depressions' of successive chambers (Fig. 4A, D–E). The presence of a toothplate in our *Parkiella* spp. nov. determines them to be placed in the family Turrilinidae and supports the relationship between such apertural features and 'turrilinid test-morphologies' as suggested by Seiglie *et al.* (1993).

The finely perforate wall structure of *P. globocamerata* sp. nov. is demonstrated in Fig. 4F; each pore seems to be surrounded by six radially arranged calcite crystals. No distinct dimorphism in terms of micro- and macrospheres could be observed in either of the species described herein.
Explanation of Plate 1

Figs 1–6. Parkiella angulocamerata sp. nov. (sample 465A-11-2, 0–2 cm; all ×200). fig. 1, holotype, apertural view. fig. 2, holotype, side view. fig. 3, holotype, apical view. fig. 4, paratype, apertural view. fig. 5, paratype, side view. fig. 6, paratype, apical view. figs 6–12. Parkiella globocamerata sp. nov. (sample 465A-3-4, 140–142 cm; all ×200, except fig. 10: ×250). fig. 7, holotype, apertural view. fig. 8, holotype, side view. fig. 9, holotype, apical view. fig. 10, paratype, apertural view. fig. 11, paratype, side view. fig. 12, paratype, apical view.
New species of the genus *Parkiella*

Class *Foraminifera* Lee, 1990
Order *Rotaliida* Lankester, 1885
Superfamily *Turrilinacea* Cushman, 1927
Family *Turriliniidae* Cushman, 1927
Genus *Parkiella* Seiglie, Haman & Baker, 1993
*Parkiella angulocamerata* sp. nov. (Pl. 1, figs 1–6)

**Derivation of name.** Refers to the angular shape of chambers.

**Diagnosis.** Test subpyramidal, subquadrate in section, chambers quadriserially arranged and pointed, gradually converting into long spines.

**Type material.** Holotype (Pl. 1, figs 1–3) and one paratype (Pl. 1, figs 1–6). Primary types deposited at the Cushman Collection, National Museum of Natural History, Smithsonian Institution, Washington DC, USA, and filed under the following museum catalogue numbers: USNM 489216 (holotype) and USNM 489217 (paratype).

**Material.** Eighty-four (62 complete and 12 fragmented) specimens from DSDP Site 465 (Hole 465A) and four (two complete and two fragmented) specimens from DSDP Site 171 (Hole 171).

**Locality and type level.** Pacific Ocean, southern Hess Rise, Upper Maastrichtian, *Micula prinsii* Zone, DSDP sample 465A-3-4, 140–142 cm.

**Description.** Test compact, subglobular, and subcircular in section. Chambers arranged in a low trochospiral coil of three whorls, three-to-four subglobular (inflated) chambers/whorl; chambers equipped with a distinct slender short spine (except in chambers of initial whorl); proloculus visible and globular. Sutures distinct and slightly depressed. Wall calcareous (hyaline) and finely perforate. Aperture forming a loop extending from base of last chamber up apertural face; aperture possessing a lip and a internal toothplate; an apertural flap may be observed in well preserved specimens; poorly preserved specimens often exhibit apertures excavated into an ‘L’-shaped opening.

**Dimensions.** Holotype: maximum diameter 0.29 mm without spines (0.35 mm including spines), height 0.19 mm; paratype: maximum diameter 0.24 mm without spines (0.27 mm including spines), height 0.16 mm.

**Remarks.** This form differs from its stratigraphic precursor *P. angulocamerata* sp. nov. in the chamber arrangement, in possessing more inflated chambers (that abruptly end in distinct spines), and in a subcircular rather than quadrate transsection. *Parkiella gabonica* (de Klasz & Rérat) and *P. brevispira* (de Klasz, Magné, & Rérat) do not possess spines; *P. mamelligera* (de Klasz & Rérat) possesses a larger test, much shorter ‘spines’, and a higher number of chambers/whorl (four-to-five instead of three-to-four in *P. globocamerata* sp. nov.).

**BIOSTRATIGRAPHIC DISTRIBUTION AND THE K/Pg BOUNDARY**

*Parkiella angulocamerata* sp. nov. and *P. globocamerata* sp. nov. occurred in sequence throughout the studied section at Site 465 (Table 2) with almost no overlap in their respective vertical ranges. *Parkiella angulocamerata* was found in the lower part, whereas *P. globocamerata* was encountered in the upper part of the sequence.

The lower range limit of *P. angulocamerata* sp. nov. could not be satisfactorily determined due to insufficient sampling and recovery below Core 12. Sample no. 30 represents the lowermost level, at which the species was found; no specimens of the species were encountered below that level, either in the lowermost part of Core 12 (sample no. 31), or in the chert drililng breccia from Core 14 during a preliminary survey of sample 465A-14cc, 0–2 cm. The uppermost sample containing *P. angulocamerata* sp. nov. (sample no. 21) also contains the lowermost specimens of *P. globocamerata* sp. nov., which indicates that both species may have lived at the same time. *Parkiella globocamerata* sp. nov. was found in samples from the interval between the upper limit (sample no. 21) of the 38.6 m thick chert and the ‘mixed zone’ at the K/Pg boundary (sample no. 3). The lower range limit of *P. globocamerata* sp. nov. lies between the bottom of Core 3 and the top of Core 10. No specimens of *Parkiella* were found in this 60 m thick interval; Cores 4–7 are characterized by high chert content resulting in
Site 465

![Diagram of Site 465 showing accumulation rates and depth in Hole (mbsf)]

Figure 5. Accumulation rates (in number of specimens/kyr/cm²) of Parkiella globocamerata n.sp. across the K/Pg boundary within Core 3 at Hole 465A. Note the decrease in accumulation rates about 1 m below the K/Pg boundary and the lag in the decline across the boundary due to the interval of mixed Maastrichtian and Danian sediments.

The deep-sea benthic foraminiferal taxa that became extinct at the K/Pg boundary were mainly endobenthic and they are assumed to have been generally more dependent on relatively high food-fluxes from the euphotic zone than epibenthic taxa (e.g. Thomas, 1990; Widmark & Malmgren, 1992a). The extinction of Parkiella globocamerata sp. nov. suggests that the species could have had an endobenthic mode of life and needed the relatively high food-fluxes that were provided by the primary producers in the eutrophic zone. When a large portion of these primary producers became extinct at the end of the Cretaceous, there was a devastating decline in food availability at deep sea-floor and some eutrophic taxa, such as Parkiella globocamerata sp. nov., could obviously not sustain the new, rougher conditions that emerged at the beginning of the Cenozoic. The decrease in both relative abundance and accumulation rate of the species observed about 1 m below the K/Pg boundary at Site 465 may represent a prelude to the environmental disturbances that caused the biotic crisis at this transition.

The upper range limits of both species are well defined and documented at Site 465. Both limits lie within Core 3, where sediment recovery and stratigraphic control are excellent. The restricted vertical distribution of both species makes them biostratigraphically useful and we propose that the interval between the LO (Last Occurrence) of Bulimina angulocamerata sp. nov. and LO of Parkiella globocamerata sp. nov. may indicate uppermost Cretaceous (upper Maastrichtian) in the tropical Pacific. This interval is roughly comparable to the calcareous nanofossil Micula prinsii Zone at Site 465 (see Fig. 6).

**BIOGEOGRAPHIC DISTRIBUTION AND ITS EVOLUTIONARY IMPLICATIONS**

Widmark (1995) conducted a biogeographic survey encompassing terminal Cretaceous (Abathomphalus mayaroensis Zone) DSDP/ODP material from all over the world (Table 4). During this survey he encountered Parkiella globocamerata sp. nov. and Bulimina angulocamerata sp. nov. (merged into his Bulimina? sp. A), only at one site, namely the Central Pacific Site 171 (Horizon Guyot), in addition to Site 465 (Tables 2, 4). Similarly, Douglas (1973) documented a form from Site 171 that he considered undescribed and called Bulimina? sp. (his pl. 7, fig. 5), which also is identical to Parkiella globocamerata sp. nov. The only information provided on the vertical distribution of Bulimina? sp. (= Parkiella globocamerata sp. nov.) was its occurrence in Maastrichtian–early Palaeocene strata at Site 171 (Douglas, 1973).

In the two samples available from Site 171 we encountered Parkiella globocamerata sp. nov. in the upper sample only, whereas Bulimina angulocamerata sp. nov. was found in both samples; this corresponds to the stratigraphic succession we observed at Site 465. The relative abundances of Parkiella in the samples from
New species of the genus Parkiella

Site 171 are, however, significantly higher (6.6 and 8.9%; see Table 2) than at Site 465. This may indicate that the palaeoenvironmental conditions at Site 171 were closer to the ecological optimum of the two species.

Both Sites 171 and 465 were located within the tropical Pacific sector of the Tethyan realm at the end of the Cretaceous (Fig. 1). Consequently, we can assume that during at least the Late Maastrichtian both *P. globocamerata* sp. nov. and *P. angulocamerata* sp. nov. were endemic to the Pacific realm. Other representatives of the genus *Parkiella*, including *Parkiella gabonica*, *P. brevispira* and *P. mameligera*, have only been reported from shelf deposits from a restricted area in Gabon and Cameroon, West Africa (de Klasz & Rerat, 1962; de Klasz et al., 1963; Seiglie et al., 1993).

Figure 7 illustrates the stratigraphic ranges of species referable to the genus *Parkiella*. Two scenarios of the phylogenetic relationship between the geographically separated West African and Central Pacific stocks are possible: (1) a common ancestor of both stocks occurred (at the latest) in the Turonian; (2) the Central Pacific stock descended from *P. mameligera*, the only representative of the ‘older’ West African stock that possessed spines (Fig. 7). A third alternative might be that our new species were not at all related to the West African stock, and represented an independent lineage within the turritilins (Fig. 7). In the latter case, *P. globocamerata* sp. nov. and *P. angulocamerata* sp. nov. should not be included in the genus *Parkiella*, but be considered as a separate deep-water genus morphologically parallel to shallow-water *Parkiella*.

ACKNOWLEDGEMENTS
We wish to thank Stefan Majoran, Björn Malmgren, and Robert Speijer, Göteborg University, for valuable suggestions on an early version of the article and to two anonymous reviewers for comments on the final manuscript. Smithsonian Institution, Washington, DC, USA, is acknowledged for disposal facilities of the primary types through the courtesy of Brian Huber. Samples were Provided by the ODP/DSDP. This study was supported by the Swedish Natural Science Research Council (NFR).

Manuscript received January 1996
Manuscript accepted March 1996

REFERENCES
Berggren, W. A. 1984. Cenozoic deep water benthic Foraminifera: A review of major developments since Bentholics’ 75. In Oertli, H. J. (Ed.) Bentholics ‘83; Second International Symposium on Benthic Foraminifera (Pau, April 1983), Elf Aquitaine, Esso REP and Total CFP, Pau and Bordeaux, 1984, 41–43.
Berggren, W. A., Kent, D. V. & Van Couvering, J. A. 1985. Jurassic to Paleogene: Part 2, Paleogene geochronology and chronostratigraphy. In Stirling, N. J. (Ed.) The Chronology of the Geological Record, Geological Society of London, Memoir, 10: 141–195.
Boersma, A. 1981. Cretaceous and Early Tertiary foraminifers from Deep Sea Drilling Project Leg 62 sites in the Central Pacific. Initial

Table 4. DSDP/ODP sites used in a biogeographic survey of late Maastrichtian benthic foraminifera by Widmark (1995). Localities (sites) where *Parkiella* was encountered are highlighted in bold. *Data on palaeoaltitudes for the sites investigated were obtained (or estimated) from various DSDP and ODP reports.

| Site | Ocean   | Palaeolatitude* |
|------|---------|-----------------|
| 47   | Shatsky Plateau | Pacific | 20°N |
| 171  | Horizon Guyot    | Pacific | 2°N |
| 208  | Lord Howe Rise   | Pacific | 50°S |
| 305  | Shatsky Rise     | Pacific | 20°N |
| 465  | Hess Rise        | Pacific | 13°N |
| 10   | N. American Basin | N. Atlantic | 29°N |
| 111  | Orphan Knoll     | N. Atlantic | 41°N |
| 384  | J-Anomaly Ridge  | N. Atlantic | 31°N |
| 390  | Blake Nose       | N. Atlantic | 29°N |
| 548  | Goban Spur       | N. Atlantic | 38°N |
| 605  | Off New Jersey   | N. Atlantic | 36°N |
| 20   | Brazil Basin     | S. Atlantic | 33°S |
| 356  | Sao Paulo plateau | S. Atlantic | 32°S |
| 363  | Walvis Ridge     | S. Atlantic | 29°S |
| 516  | Rio Grande Rise  | S. Atlantic | 30°S |
| 525  | Walvis Ridge     | S. Atlantic | 36°S |
| 527  | Angola Basin     | S. Atlantic | 36°S |
| 216  | Ninetyeast Ridge | Indian     | 37°S |
| 217  | Ninetyeast Ridge | Indian     | 33°S |
| 758  | Ninetyeast Ridge | Indian     | 35°S |
| 689  | Maud Rise        | Southern   | 70°S |
| 698  | Georgia Rise     | Southern   | 55°S |
| 700  | Georgia Basin    | Southern   | 55°S |
| 738  | Kerguelen plateau | Southern   | 62°S |
| 750  | Kerguelen plateau | Southern   | 44°S |

Fig. 6. Biostratigraphic summary of the vertical ranges of *Parkiella* spp. nov. and the Maastrichtian planktonic foraminifer (Boersma, 1981), and nannofossil (Cepek, 1981; Henriksson, 1993) zones recognized at Hole 465A. Last Occurrences (LOs) of both *Parkiella* species are well defined within Core 3, which enables us to propose that the interval between the LO of *P. globocamerata* sp. nov. and LO of *P. angulocamerata* sp. nov. is indicative of upper Maastrichtian strata in the Central Pacific. This interval is slightly longer than the Maastrichtian interval within Core 3, which enables us to propose that the interval between the LO of both stocks occurred (at the latest) in the Maastrichtian. Consequently, we can assume that during at least the Late Maastrichtian both *P. globocamerata* sp. nov. and *P. angulocamerata* sp. nov. is indicative of upper Maastrichtian strata in the Central Pacific. This interval is slightly longer than the Maastrichtian interval within Core 3, which enables us to propose that the interval between the LO of both stocks occurred (at the latest) in the Maastrichtian. Consequently, we can assume that during at least the Late Maastrichtian both *P. globocamerata* sp. nov. and *P. angulocamerata* sp. nov. is indicative of upper Maastrichtian strata in the Central Pacific. This interval is slightly longer than the Maastrichtian interval within Core 3, which enables us to propose that the interval between the LO of both stocks occurred (at the latest) in the Maastrichtian.
Fig. 7. Stratigraphic ranges of species assigned to the genus *Parkiella* (de Klasz & Rérat, 1962; de Klasz et al., 1963; Seiglie et al., 1993; and this study). Possible evolutionary relationships between West African and Central Pacific representatives of *Parkiella* are illustrated by dashed lines. The Central Pacific stock may have evolved directly from one of the species of the West African stock, most probably from *P. mamelligera* (1); both Central Pacific and West African stocks could have descended from a common pre-‘Senonian’ ancestor (2); or, alternatively, the Central Pacific