NEW CALCAREOUS NANNOFOSSIL SPECIES AND STRATIGRAPHIC MARKERS FROM THE UPPER PALEOCENE

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Abstract: A new species, *Discoaster protomultiradiatus*, is described from the Upper Paleocene. The stratigraphic distributions of this and a poorly known species, *Ericsonia robusta*, are documented from seven DSDP/ODP sites from low through high latitudes. *D. protomultiradiatus* generally ranges from slightly below to slightly above the first occurrence of *Discoaster multiradiatus* (NP8/NP9 zonal boundary) and correlates with the middle part of magnetic chron C25n. *E. robusta* ≥11µm has a longer range and generally occurs from near the bottom of magnetic chron C25n to the top of chron C25n. These datums provide four potentially useful stratigraphic markers for low through high latitude correlations in the Upper Paleocene.

Introduction

Since publication of the calcareous nannofossil zonations of Martini (1971) and Bukry (1973a), nannofossils have been used extensively for stratigraphic correlation of Cenozoic marine sediments. However, improvements in the stratigraphic resolution of the Upper Paleocene have been few, partly due to only a limited number of high-resolution studies of this stratigraphic interval (*e.g.* Romein, 1979; Varol, 1989; Bybell & Self-Trail, 1995). In this paper, a new species, *Discoaster protomultiradiatus*, is described. The stratigraphic distributions of this and a poorly known species, *Ericsonia robusta* (Bramlette & Sullivan) Perch-Nielsen, are documented from seven DSDP/ODP sites ranging from low through high latitudes, and their first and last occurrences are shown to be useful stratigraphic markers in the Upper Paleocene.

Material and methods

Samples were taken from DSDP/ODP Sites 524, 528, 577, 605, 690 and 752 (Figure 1). These are basically all the DSDP/ODP sites that have moderate to good magnetostratigraphies that allow detailed magnetobiostratigraphic correlations for the Upper Paleocene. In addition, Site 245, which does not have magnetostratigraphy, was studied in order to further test the stratigraphic distributions of *Discoaster protomultiradiatus* n. sp. and *Ericsonia robusta* within a biostratigraphic framework. References for detailed information about these DSDP/ODP sites are provided in Table 1. Previous nannofossil studies of these sites have been made by MacKenzie & Wise (1983) for Site 245, Percival (1984) for Site 524, Backman (1986) for Site 528, Monechi (1985) and Backman (1986) for Site 577, Lang & Wise (1987) for Site 605, Pospichal & Wise (1990) for Site 690, and Pospichal *et al.* (1991) for Site 752. However, *E. robusta* was either not recorded, or its stratigraphic distribution was generally misrecorded, due to problematic species concepts. There appears to be no correct publication of SEM micrographs of this species to date. Misidentification of the species is common in the literature, as can be seen from the synonymy list in the 'Systematic descriptions' (below).

Besides using standard smear-slides, mobile mounts were made so that the nannofossil specimens could be turned and observed in different orientations using a light microscope. This was very helpful in examining the thicknesses of *D. protomultiradiatus* and *E. robusta*. In addition, the new species was examined using a slightly

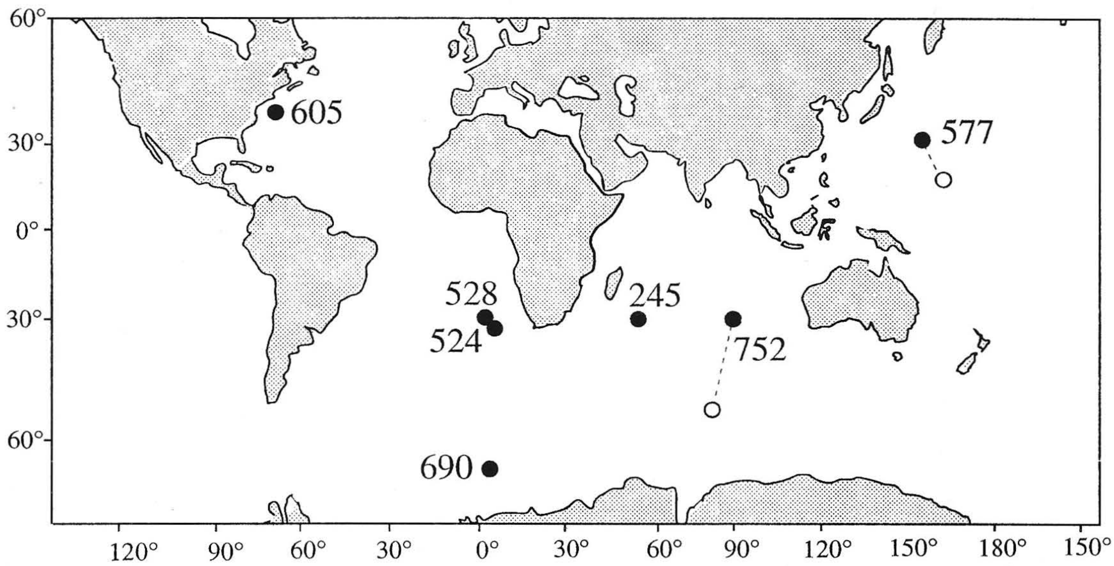


Figure 1: Locations of DSDP/ODP sites investigated in this study. Palaeopositions of Sites 577 and 752 were significantly different from current positions and are shown as open circles.

Hole	Location	Water depth (m)	Reference
245	31°32.02'S; 52°18.11'E	4857	Simpson *et al.* (1974)
524	29°29.055'S; 3°30.74'E	4796	Hsü *et al.* (1984)
528	28°31.49'S; 2°19.44'E	3800	Moore *et al.* (1984)
577	32°26.51'N; 157°43.40'E	2675	Heath *et al.* (1985)
605	38°44.53'N; 72°36.55'E	2194	van Hinte *et al.* (1987)
690B	65°9.692'S; 1°12.296'E	2914	Barker *et al.* (1988, 1990)
752A	30°53.475'S; 93°34.652'E	1086	Peirce *et al.* (1989, 1991)

Table 1: DSDP/ODP hole locations, water depths and references for background information

modified technique of Moshkovitz (1978), which facilitates observation of the same nannofossil specimens under the light microscope and in the SEM. This is particularly important because *D. protomultiradiatus* closely resembles *Discoaster multiradiatus* in the SEM, but the two species are quite distinct in polarised light.

As *E. robusta* has a relatively large size-range, and the larger specimens appeared to have a shorter stratigraphic range, about 40 specimens of this species were measured per sample on a monitor screen connected to a video camera mounted on the microscope. The accuracy of measurement using this system is about 0.3μm, which is sufficient for the problems to be addressed in this study.

Besides the stratigraphic distributions of *D. protomultiradiatus* and *E. robusta*, the first occurrence (FO) of *D. multiradiatus* and the last occurrence (LO) of *Fasciculithus* spp. were documented in order to show the stratigraphic relationships of *D. protomultiradiatus* and *E. robusta* in nannofossil zones NP8-NP9. Abundances of individual species were estimated semiquantitatively at a magnification of x1000, using the following categories (each successive category is five times the preceding category.

- A = abundant: more than one specimen per field of view (FOV)
- C = common: 1 specimen in 1-5 FOV
- F = few: 1 specimen in 6-30 FOV
- R = rare: 1 specimen in 31-150 FOV
- 1, 2: 1 or 2 specimens in over 150 FOV, probably reworked.

The magnetic polarity time-scale and chron terminology of Cande & Kent (1995) are used here. Comparison of the numerical ages given here with those in the polarity time scale of Berggren *et al.* (1985) can be done using the age conversion formula of Wei (1994).

Results and discussion

The stratigraphic distributions of *D. protomultiradiatus* n. sp. and *E. robusta* in Sites 524, 528, 577, 605, 690 and 752 are presented in Figures 2 through 7, respectively. Those in Site 245, which does not have magnetostratigraphies, are presented in Figure 8. Light and SEM micrographs of the two species are shown in Plate 1.

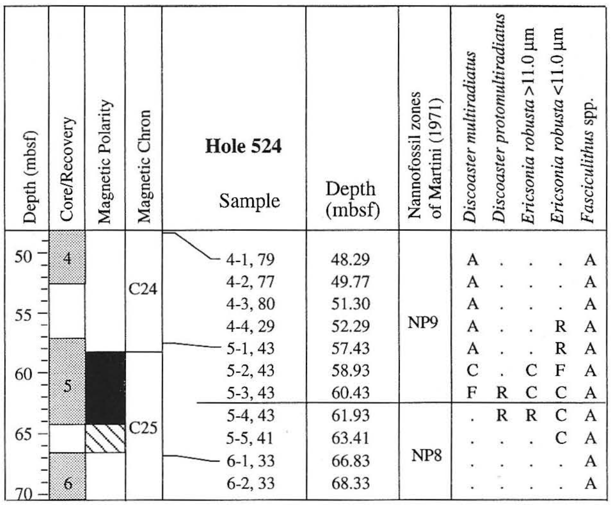


Figure 2: Stratigraphic distribution of selected nannofossil species, DSDP Hole 524. A=abundant, C=common, F=few, R=rare. Magnetostratigraphic data are from Tauxe *et al.* (1983). Black indicates normal polarity, white indicates reversed polarity, and hatched pattern indicates polarity uncertain.

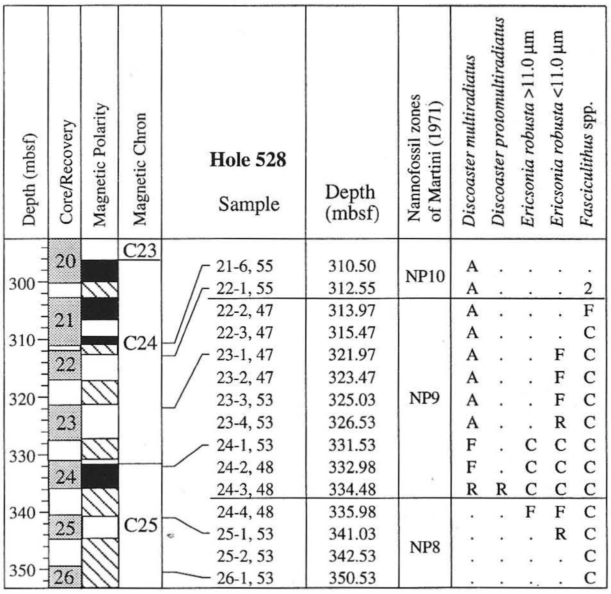
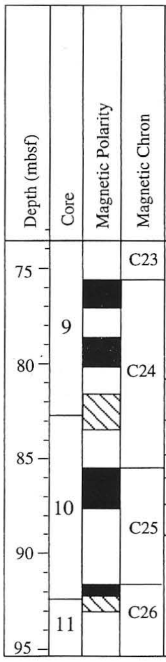


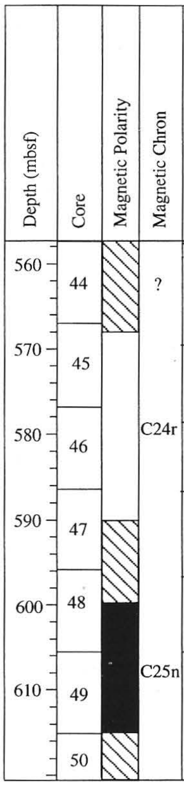
Figure 3: Stratigraphic distribution of selected nannofossil species, DSDP Hole 528. Magnetostratigraphic data are from Shackleton *et al.* (1984). See Figure 2 caption for additional information.

D. protomultiradiatus n. sp. closely resembles *D. multiradiatus* Bramlette & Riedel in SEM micrographs. The difference is that *D. protomultiradiatus* contains two cycles of elements in the centre, whereas *D. multiradiatus* shows only one central cycle (Plate 1, Figures 1-3; compare with Plate of Romein, 1979; Plate 1 of Wei, 1992; and Plate 34 of Bybell & Self-Trail, 1995). The innermost cycle of *D. protomultiradiatus* is birefringent in polarised light (Plate 1, Figures 5, 7 and 13), which differentiates it from *D. multiradiatus*. The ray number of *D. protomultiradiatus* commonly ranges from 33 to 38, similar to early specimens of *D. multiradiatus*, but significantly more than later specimens of *D. multiradiatus* (Romein, 1979; Wei, 1992). More importantly, the stratigraphic range of *D. protomultiradiatus* is very short and significantly different



Hole 577 Sample	Depth (mbsf)	Nannofossil zones of Martini (1971)	*Discoaster multiradiatus*	*Discoaster protomultiradiatus*	*Ericsonia robusta* >11.0 µm	*Ericsonia robusta* <11.0 µm	*Fasciculithus* spp.
9-6, 3	80.83	NP10	A	.	.	.	.
9-6, 93	81.73		A	.	.	.	.
9-6, 113	81.93		A	.	.	.	.
9-6, 123	82.03	NP9	A	.	.	.	R
10-1, 13	82.93		A	.	.	F	F
10-1, 53	83.33		A	.	.	C	C
10-1, 123	84.03		A	.	.	C	C
10-2, 33	84.63		A	.	.	C	A
10-2, 93	85.23		A	.	.	C	A
10-2, 123	85.53		A	.	.	F	A
10-3, 3	85.83		A	.	C	C	A
10-3, 33	86.13		A	.	C	A	A
10-3, 93	86.73		C	R	C	A	A
10-3, 123	87.03	NP8	.	.	R	A	A
10-4, 3	87.33		.	.	R	A	A
10-4, 33	87.63		.	.	.	A	A
10-4, 93	88.23		.	.	.	C	A
10-5, 33	89.13		.	.	.	F	A

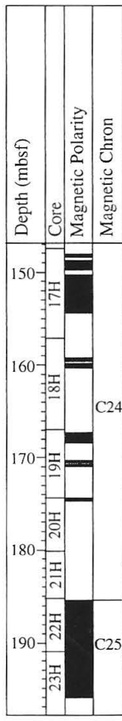
Figure 4: Stratigraphic distribution of selected nannofossil species, DSDP Hole 577. Magnetostratigraphic data are from Bleil (1985). See Figure 2 caption for additional information.



Hole 605 Sample	Depth (mbsf)	Nannofossil zones of Martini (1971)	*Discoaster multiradiatus*	*Discoaster protomultiradiatus*	*Ericsonia robusta* >11.0 µm	*Ericsonia robusta* <11.0 µm	*Fasciculithus* spp.
44-1, 20	557.80	NP10	C	.	.	.	.
44-2, 110	559.50		C	.	.	.	.
44-3, 20	560.80		C	.	.	.	.
44-4, 20	562.30		C	.	.	.	.
44-5, 28	563.88	NP9	C	.	.	.	C
45-2, 110	569.70		C	.	.	.	A
46-2, 50	578.70		C	.	.	.	A
46-5, 50	583.00		C	.	.	.	A
46-6, 50	584.50		C	.	.	.	A
47-1, 50	586.80		C	.	.	.	A
47-2, 50	588.30		C	.	.	R	A
47-6, 50	594.30		C	.	.	R	A
48-1, 110	597.00		C	.	.	R	A
48-2, 50	597.90		C	.	R	R	A
48-3, 50	599.40		C	.	F	R	A
48-4, 50	600.90		C	R	F	F	A
48-5, 20	602.10	NP8	.	R	F	F	A
49-1, 20	605.70		.	.	F	F	A
49-1, 110	606.60			.	.	F	A
49-2, 20	607.20		.	.	.	F	A
49-3, 50	609.00		.	.	.	R	A
49-4, 110	610.60		.	.	.	.	A
49-5, 20	611.20		.	.	.	.	A

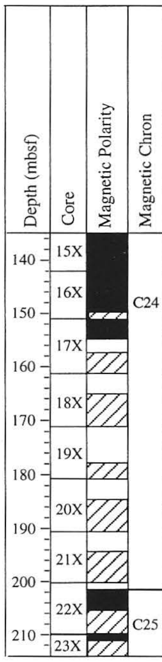
Figure 5: Stratigraphic distribution of selected nannofossil species, DSDP Hole 605. Magnetostratigraphic data are from van Hinte *et al.* (1987). See Figure 2 caption for additional information.

from that of *D. multiradiatus* (Figures 2-8). Previous studies most likely included *D. protomultiradiatus* in *D. multiradiatus*, as the FO of *D. multiradiatus* reported here for Site 524 is younger than that reported by Percival (1984), who placed it at the level of the FO of *D. protomultiradiatus* as recorded herein. Romein (1979)



Hole 690B Sample	Depth (mbsf)	Nannofossil zones of Martini (1971)	*Discoaster multiradiatus*	*Discoaster protomultiradiatus*	*Ericsonia robusta* >11.0 µm	*Ericsonia robusta* <11.0 µm	*Fasciculithus* spp.
18-3, 28	160.48	NP10	C	.	.	.	2
18-3, 130	161.50		C	.	.	.	1
18-4, 28	161.98		C	.	.	.	1
18-5, 28	163.48	NP9	C	.	.	.	R
18-6, 28	164.98		C	.	.	.	C
18-CC	166.90		C	.	.	.	C
19-1, 30	167.20		C	.	.	.	C
19-3 29	170.19		C	.	.	.	C
19-5, 28	173.20		C	.	.	.	C
20-3, 130	177.10		C	.	.	.	C
21-1, 130	181.60		C	.	.	.	C
21-2, 30	182.10		C	.	.	.	C
21-CC	185.20		C	.	.	.	C
22-1, 28	185.48		F	.	R	R	C
22-1, 130	186.50	NP8	.	.	R	R	C
22-2, 28	186.98		.	.	C	C	C
22-3, 28	188.48		.	.	F	C	C
22-4, 28	189.98		.	.	.	.	C
23-1, 28	191.48		.	.	.	.	C

Figure 6: Stratigraphic distribution of selected nannofossil species, ODP Hole 690B. Magnetostratigraphic data are from Spieß (1990). See Figure 2 caption for additional information.



Hole 752A Sample	Depth (mbsf)	Nannofossil zones of Martini (1971)	*Discoaster multiradiatus*	*Discoaster protomultiradiatus*	*Ericsonia robusta* >11.0 µm	*Ericsonia robusta* <11.0 µm	*Fasciculithus* spp.
18-1, 35	161.55	NP10	C	.	.	.	.
18-2, 45	163.15		C	.	.	.	.
19-1, 45	171.15		C	.	.	.	2
19-2, 42	172.62	NP9	C	.	.	.	A
19-3, 44	174.14		C	.	.	.	A
19-4, 40	175.60		C	.	.	.	A
20-1, 45	180.65		C	.	.	.	A
20-2, 45	182.15		C	.	.	.	A
21-1, 45	190.85		C	.	.	.	A
21-2, 45	192.35		C	.	.	.	A
22-1, 45	200.55		C	R	R	R	A
22-2, 45	202.05		R	R	C	C	A
22-3, 45	203.55	NP8	.	F	C	C	A
22-4, 45	205.55		.	.	.	.	A
23-1, 45	210.25		.	.	.	.	A
23-2, 15	211.45		.	.	.	.	A

Figure 7: Stratigraphic distribution of selected nannofossil species, ODP Hole 752A. Magnetostratigraphic data are from Gee *et al.* (1991). See Figure 2 caption for additional information.

included in *D. multiradiatus* specimens that have a birefringent central column. He considered the two central cycles as remnants of the (extended) column and the distal cycle in *Heliolithus*, although the outer central cycle is now more clearly related to the middle cycle rather than the distal cycle in *Heliolithus*. Perch-Nielsen (1985) considered the birefringent central column as the remnant of another genus, *Heliolithus*. In other studies, such as

Hole 245 Sample	Depth (mbsf)	Nannofossil zones of Martini (1971)	*Discoaster multiradiatus*	*Discoaster protomultiradiatus*	*Ericsonia robusta* >11.0 µm	*Ericsonia robusta* <11.0 µm	*Fasciculithus* spp.
8-1, 55	283.55	NP10	A	.	.	.	.
8-2, 42	284.92		C	.	.	.	.
9-1, 90	311.90	NP9	A	.	.	R	A
9-2, 27	312.27		A	.	.	R	A
9-2, 72	313.77		A	.	.	R	A
9-3, 52	314.52		A	.	C	C	A
9-3, 120	315.20		A	R	C	C	A
10-1, 70	320.70	NP8	.	.	.	.	A
10-1, 122	321.22		.	.	.	.	A
10-2, 38	321.88		.	.	.	.	A
10-3, 55	323.55		.	.	.	.	A

Figure 8: Stratigraphic distribution of selected nannofossil species, DSDP Hole 245. See Figure 2 caption for additional information.

Pospichal *et al.* (1991), *D. protomultiradiatus* was apparently not included in *D. multiradiatus* because they reported the FO of *D. multiradiatus* between Sample 752A-22-2, 45cm and -22-3, 45cm (Pospichal *et al.*, 1991, p.725), the same stratigraphic level that the datum was recorded herein (Figure 6). *D. protomultiradiatus* occurs further downhole (Figure 6).

Available data suggest that *D. protomultiradiatus* is most likely related to, and evolved from, *Bomolithus* rather than *Heliolithus*. The reason is that *Bomolithus* has three cycles of elements and only the central part (the column) is birefringent in polarised light, whereas in *Heliolithus*, which has three cycles of elements in *H. kleinpellii* but only two cycles in its generotype, *H. riedelii*, all cycles are birefringent in polarised light (see Perch-Nielsen (1985) for justification of the division of *Bomolithus* from *Heliolithus*).

No gradational form between *D. protomultiradiatus* and *D. multiradiatus* was found in this study or illustrated in previous studies. Based on the above discussions, it is considered to be practical and useful to separate *D. protomultiradiatus* from *D. multiradiatus* for biostratigraphic and evolutionary studies.

Size distributions of *E. robusta* in selected sites are presented in Figure 9. Although *E. robusta* has a relatively large size-range (6.5 to 15.5µm), there is no clear pattern of bimodal size distribution (Figure 9), and thus the species is not subdivided based on size. However, specimens ≥11µm appear to have a more restricted stratigraphical range than specimens <11µm (Figures 2-8). Specimens <11µm have a less consistent stratigraphical range, which appears to be longest in the low latitudes (Site 577), shorter in the middle latitudes (Sites 524, 528, 245 and 605), and shortest in the high latitudes (Sites 690 and 752). Furthermore, the FO of *E. robusta* (<11µm) can be difficult to identify at low latitudes because the species overlaps with *Ericsonia subpertusa* Hay & Mohler, and there are transitional forms between these two species.

The stratigraphic relationships between *D. protomultiradiatus*, *E. robusta* ≥11µm, and *D. multiradiatus*, as well as their correlations to the magnetic polarity time-scale of Cande & Kent (1995), are summarised in Figure 10, based on data presented in Figures 2-8. As the stratigraphic range of *D. protomultiradiatus*, and its overlap with that of *D. multiradiatus*, is very short, the FO of *D. protomultiradiatus* before that of *D. multiradiatus* may not always be seen (as at Site 245, 528 and 577 in this study) due to large sample-spacing or condensation of the section. The absence of *D. protomultiradiatus* in Site 690 (Figure 5), however, is probably due to environmental exclusion from this extremely high latitude. The southern limit of this species thus lies between ~50°S (palaeolatitude of Site 752) and 65°S (Site 690). Nevertheless, whenever *D. protomultiradiatus* is found, that stratigraphical interval generally can be placed within the vicinity of the FO of *D. multiradiatus*, *i.e.* the NP8/NP9 zonal boundary around the middle of magnetic chron C25n.

The stratigraphic range of *E. robusta* ≥11µm also overlaps with that of *D. multiradiatus*, and is longer than that of *D. protomultiradiatus* (Figure 10). The FO of *E. robusta* ≥11µm precedes the FO of *D. multiradiatus*, which is followed by the LO of *E. robusta* ≥11µm, at all the sites investigated here except Site 245. The apparent concurrence of the FOs of *D. multiradiatus* and *E. robusta* ≥11µm at Site 245 is attributed to poor core recovery in core 9, where about 5m of sediment was not recovered (Figure 7). The FO of *E. robusta* ≥11µm is located near the bottom of chron C25n and the LO of *E. robusta* ≥11µm is associated with the top of chron C25n (Figure 10).

Conclusions

D. protomultiradiatus n. sp. is a distinct species that generally ranges from slightly below to slightly above the FO of *D. multiradiatus* and correlates with the middle part of magnetic chron C25n. *E. robusta* ≥11µm generally ranges from below the FO of *D. protomultiradiatus* to above the LO of *D. protomultiradiatus*, that is, from near the bottom of magnetic chron C25n to the top of chron C25n. These datums provide four potentially useful stratigraphic markers within a 0.5m.y. interval for low through high latitude stratigraphic correlation in the Upper Paleocene. These markers appear to be particularly useful in stratigraphic correlations because they are relatively cosmopolitan and they appear to be nearly synchronous (within 0.1-0.2m.y. resolution) from low through high latitudes, as revealed by magnetobiostratigraphic calibrations.

Systematic descriptions

Family Discoasteraceae Tan, 1927

Genus *Discoaster* Tan, 1927

***Discoaster protomultiradiatus* n. sp.**
Plate 1, Figures 1-7, 13, 14

Derivation of name: Latin, *proto* = first, primitive; *multiradiatus* = many-rayed.

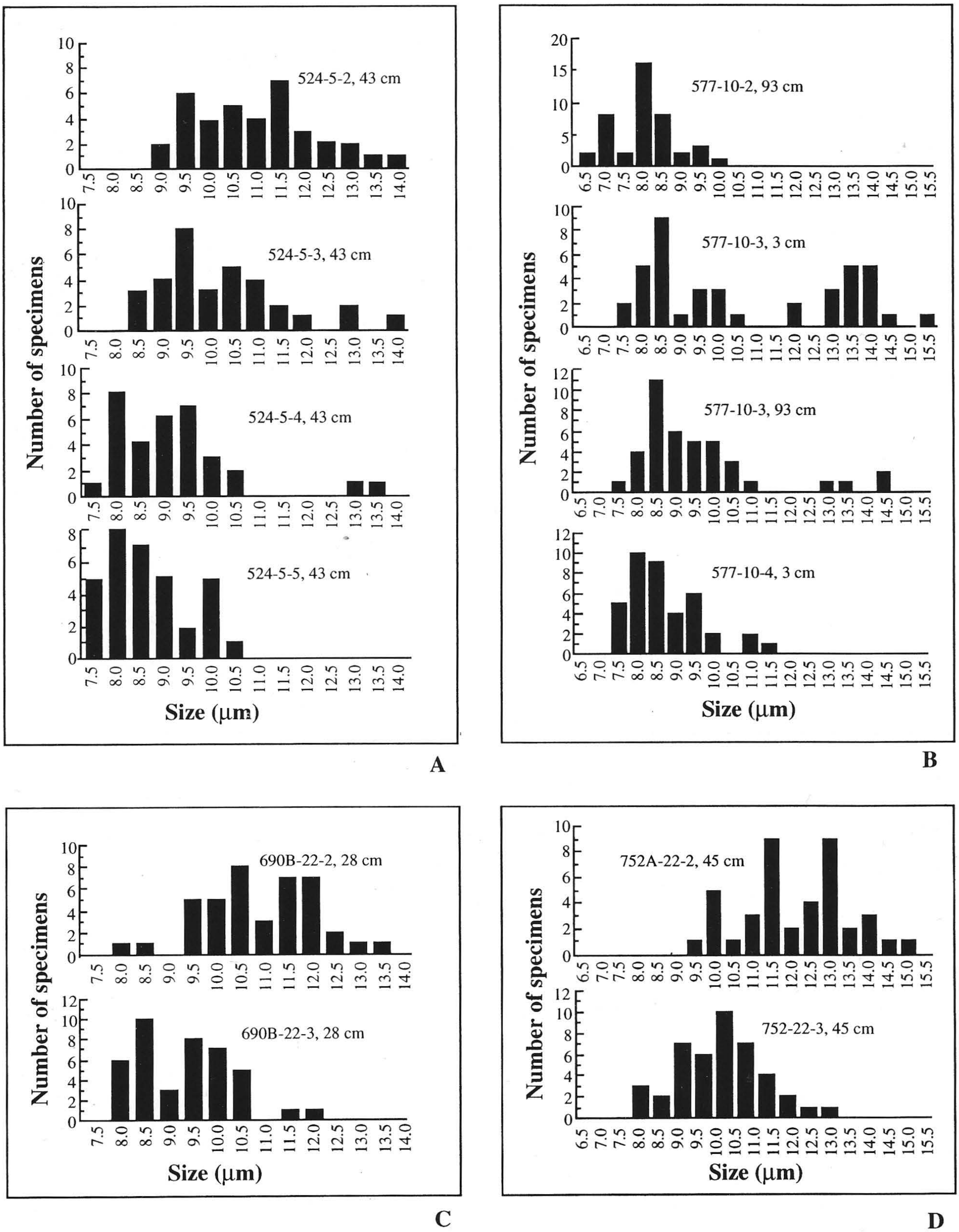


Figure 9: Size distribution of *Ericsonia robusta* (Bramlette & Sullivan) Perch-Nielsen. (A) Hole 524; (B) Hole 577; (C) Hole 690B; (D) Hole 752A.

Holotype: Plate 1, Figures 1, 4 and 5 (deposited at the Nannofossil Laboratory, Scripps Institution of Oceanography, University of California, San Diego).

Diagnosis: A species of *Discoaster* with over 30 rays and a birefringent centre.

Description: Medium- to large-sized discoaster with rays joined throughout their length. Ray numbers commonly range from 33 to 38.

Remarks: *D. protomultiradiatus* closely resembles *Discoaster multiradiatus* Bramlette & Riedel but differs

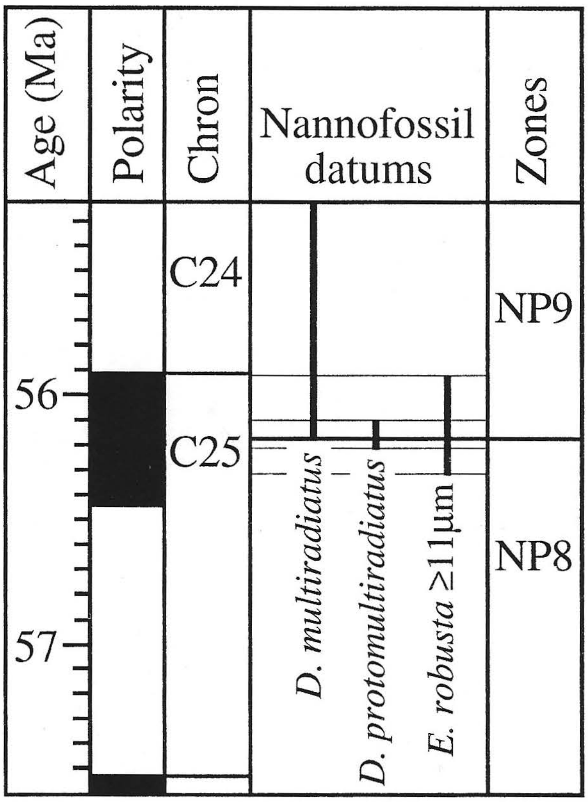


Figure 10: Summary of stratigraphic relationships between *D. multiradiatus* Bramlette & Riedel, *D. protomultiradiatus* n. sp., and *E. robusta* (Bramlette & Sullivan) Perch-Nielsen based on data from Figures 2-8. The magnetic polarity time-scale of Cande & Kent (1995) is shown on the left, and the nannofossil zones of Martini (1971) are shown on the right.

from the latter in that it has a central cycle of elements that are birefringent. The species differs from *Discoaster bramlettei* (Bukry & Percival) Romein by having a larger size, more rays, and a smaller birefringent centre. *D. protomultiradiatus* is considered the predecessor of *D. multiradiatus* and it shows a clear link between two genera: *Bomolithus* and *Discoaster*.

Size: Commonly 12-18µm in diameter.

Occurrence: *D. protomultiradiatus* generally occurs from low through high latitudes and has a very short (~0.2m.y) stratigraphic range. It generally occurs from slightly below to slightly above the FO of *D. multiradiatus* (NP8/NP9 zonal boundary) and correlates with the middle part of magnetic chron C25n, with an age-range of about 56.1 to 56.3Ma in the magnetic polarity time scale of Cande & Kent (1995).

Family Coccolithaceae Poche, 1913

Genus *Ericsonia* Black, 1964

Ericsonia robusta (Bramlette & Sullivan, 1961) Perch-Nielsen, 1977

Plate 1, Figures 8-12

1961 *Cyclolithus? robustus* Bramlette & Sullivan: Pl.2, fig.7.
1977 *Ericsonia* cf. *E. robusta* (Bramlette & Sullivan) Perch-Nielsen: Pl.16, figs 1, 4, 5, 6; Pl.50, figs 34, 35.
1977 *Non Ericsonia robusta* (Bramlette & Sullivan) Perch-Nielsen: Pl.16, figs 2, 7; Pl.50, fig.23.
1977 *Heliolithus* sp.A Wind & Wise *in* Wise & Wind: Pl.13, figs 3, 4; Pl.14, figs 7-10; *non* Pl.13, figs 5, 6.
1977 *Heliolithus* sp. Wise & Wind: Pl.14, figs 4-6.
1977 *Heliolithus universus* Wind & Wise *in* Wise & Wind: *partim.*, Pl.14, figs 2, 3; *non* Pl.12, figs 1-6; *non* Pl.13, figs 1, 2; *non* Pl.14, fig.1.
1990 *Heliolithus* sp. cf. *H. universus* Wind & Wise; Pospichal & Wise: Pl.3, fig.12.

Remarks: It has been traditional to use the genus *Ericsonia* rather than *Coccolithus* for a group of Paleocene and Eocene coccoliths (Romein, 1979; Perch-Nielsen, 1985), although *Ericsonia* may be a junior synonym of *Coccolithus,* as pointed out by a number of authors (*e.g.* Bukry, 1973b; Wise, 1983). However, the optical characteristics of *E. robusta* are substantially different from those of *Coccolithus pelagicus*, *i.e.* the former appears to be entirely birefringent whereas in the latter, only the central area is birefringent under polarised light. Under phase-contrast light, the shield elements in *C. pelagicus* are dark and quite visible, whereas they are not in *E. robusta.* Based on these, *E. robusta* is not placed in the genus *Coccolithus.* This species differs from *Ericsonia subpertusa* in that virtually the entire placolith is birefringent in *E. robusta*, which also has a larger central opening than *E. subpertusa.* There is a transition between the two species, and *E. robusta* is believed to have evolved from *E. subpertusa*, as suggested by Romein (1979).

The synonymy list of *E. robusta* in this study is similar to that of Romein (1979). The significant difference between the two studies stems from different concepts of *Heliolithus universus* Wind & Wise. Romein (1979) placed *H. universus* in the genus *Ericsonia.* However, *H. universus* is significantly different from *Ericsonia* and truly belongs to the genus *Heliolithus*, because it consists of two thick, partial cones flaring outwards. This also differs significantly from *E. robusta*, which does not have two cones. *H. universus* resembles *Heliolithus riedelii*, but differs in having a greater number of elements (ranging upto about 60) (Wise & Wind, 1977).

Size: 6.5 to 15.5µm in diameter.

Occurrence: Generally common from low to high latitudes. Specimens ≥11µm generally occur from below the FO of *D. protomultiradiatus* to above the LO of *D. protomultiradiatus*, that is, from near the bottom of magnetic chron C25n to the top of chron C25n. Specimens <11µm have longer and less consistent age ranges.

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PLATE 1

All SEM micrographs have the same magnification, which is given as a scale bar in Fig. 1. All light micrographs have the same magnification, which is given as a scale bar in Fig.4. All specimens are from ODP Sample 752A-22-3, 45 cm.

Figs 1-7, 13, 14: ***Discoaster protomultiradiatus*** **n. sp. 1, 4, 5**: same specimen, holotype; **2, 6, 7**: same specimen, isotype; **13, 14**: same specimen, isotype.

Figs 8-12: ***Ericsonia robusta*** **(Bramlette & Sullivan) Perch-Nielsen. 11, 12:** same specimen.

PLATE 1