16. LATE PALEOCENE DIATOMS IN THE CAPE BASIN[1]

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ABSTRACT

The stratigraphic distribution of 39 diatom species is documented in a 2-m-thick interval in Cores 4 and 5 of Hole 524 in the northern Cape Basin. The interval is dated as late Paleocene (Zone NP9) by the associated calcareous nannofossils. The diatom assemblage in Hole 524 represents the third known occurrence of late Paleocene diatoms in the oceans. Other occurrences have been reported from a piston core in the Indian Ocean and in DSDP Hole 327A on the Falkland Plateau. The calcareous nannofossils indicate that the assemblage in Hole 524 is slightly younger than that in Hole 327A. Together the sections from Holes 327A and 524 provide a composite section ranging in age from early late Paleocene (Calcareous Nannofossil Zone NP5) to late late Paleocene (Calcareous Nannofossil Zone NP9).

SUMMARY OF SILICEOUS MICROFOSSIL OCCURRENCES IN HOLE 524

Hole 524 is located in the northern Cape Basin (29°29.055′S; 3°30.74′E), just south of Walvis Ridge (Fig. 1) and at a water depth of 4805 m. Siliceous microfossils (i.e., diatoms, radiolaria, silicoflagellates) occur in varying abundances and states of preservation in Cores 4, 5, and 6 of Hole 524 (Fig. 2).

Near the top of Core 4, Section 1, a chert layer about 3 cm thick occurs in sharp contact with an 18-cm-thick siliceous limestone (Pl. 9, Fig. 1). Thin-section analysis of the chert reveals the presence of radiolarian and foraminiferal "ghosts" (Pl. 9, Fig. 2).

Below the siliceous limestone, the sediment is barren of siliceous microfossils down to Section 4-3 (87–89 cm). At that level a well preserved and moderately diverse assemblage of late Paleocene diatoms occurs; radiolarians and silicoflagellates are also abundant. Samples taken at Sections 4-4 (4–6 cm) and 4-4 (26–28 cm) are barren of diatoms and silicoflagellates but contain a few radiolarians. Samples from Sections 4-4 (46–48 cm); 4,CC; and 5-1 (70–72 cm) contain diatoms, radiolaria, and silicoflagellates. The first two samples contain a poorly preserved, low diversity diatom assemblage; the last contains well preserved and moderately diverse diatoms. All subsequent samples down to, and including, that from Section 6-3 (78–80 cm) contain radiolarians only. The radiolarians decrease in abundance and preservation with depth until, in the core-catcher sample for Core 6, only recrystallized tests are present. Below Core 6, no siliceous microfossils were observed.

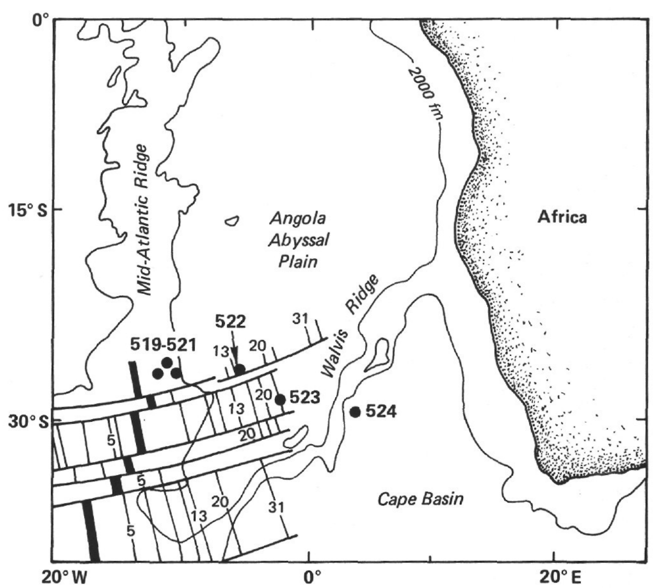

Figure 1. Location of Leg 73 sites.

MATERIAL AND METHODS

The 22 samples examined in this study were collected on board the *Glomar Challenger* by the author. Only core-catcher samples were examined on board ship. The samples were preserved for shore-based analysis as described below.

Approximately 10 cc of dried sediment from each sample were treated with hydrogen peroxide and hydrochloric acid to clear the diatom valves of all organic and calcareous material. Two slides were prepared from the cleaned and washed residue by using 40-mm × 22-mm cover slips with Hyrax (n.d. = 1.71) mounting medium. Next, the remaining residue was passed through stacked 63-μm and 38-μm sieves. Each fraction, including the finer-than-38-μm fraction, was retained. Slides of the 38- to 63-μm and the greater-than-63-μm fraction were prepared in the same way as those for the unsieved fraction. For the purpose of diatom analysis, one slide of the unsieved fraction and one slide of the 38- to 63-μm fraction were examined by making two traverses with a Zeiss Photomicroscope III of the cover slip. A magnification of ×400 was used unless a higher magnification was necessary to identify a specimen. Counts of each species per field of view were recorded during the traverses. After the slides were examined the counts obtained were converted into abundance designations as defined in Table 1.

The artificial concentration of different diatom size fractions by sieving may alter the relative abundance of various species, one to another. At the same time, however, such concentration may enhance otherwise subtle abundance variations within a single lineage by revealing the presence of rare specimens that might be obscured in unsieved slide preparations. Such changes in abundance may serve as useful biostratigraphic datums if they are consistent within given regions. Concentration by sieving also allows for the more precise determination of first and last appearance datums, since a species becomes increasingly rare toward either end of its stratigraphic range in a continuously deposited section.

[1] Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office).

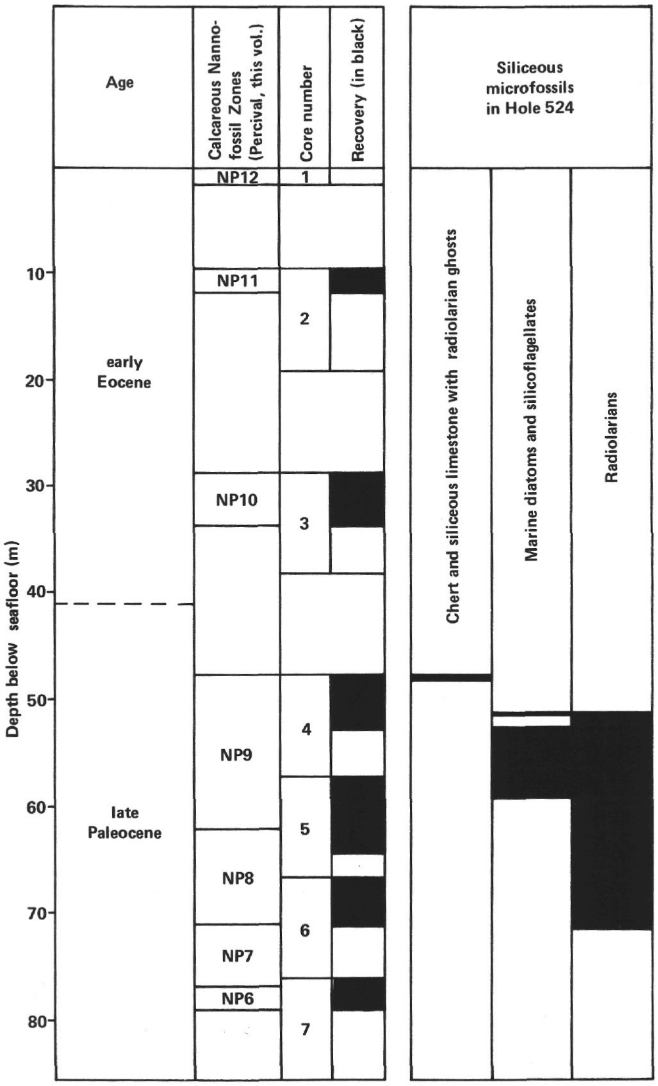

Figure 2. Occurrences of siliceous microfossils in Hole 524.

Table 1. Abundance categories used in this report.

Number of specimens[a]	Category	Symbol
1	Very rare	VR
2–5	Rare	R
6–10	Frequent	F
11–50	Common	C
51–100	Abundant	A
101–50	Very abundant	VA
501–1000	Dominant	D

[a] Based on counts per field of view during two traverses of a 40- × 22-mm cover slip at a magnification of ×400 of one slide of unsieved material and one slide of the 38- to 63-μm fraction. See text for detailed discussion.

AGE DETERMINATION FOR THE DIATOM ASSEMBLAGE IN HOLE 524

Percival (this vol.) has determined that Samples 524-4-1 (87–89 cm) through 524-5-4 (86–88 cm) occur within the late Paleocene Calcareous Nannofossil Zone NP9 (see Fig. 2 and Table 2). Diatoms occur only in the interval from Sample 524-4-3 (87–89 cm) to 524-5-1 (70–72 cm), that is, entirely within Calcareous Nannofossil Zone NP9.

The presence of the diatoms *Hemiaulus incurvus, H. inaequilaterus*, and *Trinacria exsculpta* in Hole 524 also indicates a late Paleocene age. These species have been identified by Mukhina (1974, 1976) and Gombos (1977) in late Paleocene sediments from the Indian and Atlantic oceans.

DIATOM STRATIGRAPHY

Gombos (1977) defined three diatom zones for the late Paleocene diatomaceous interval in Hole 327A on the Falkland Plateau. The youngest of the three zones is the *Hemiaulus inaequilaterus* Zone, the base of which is defined as the first occurrence of *H. inaequilaterus;* the top of the zone is not defined. The diatomaceous interval in Hole 524 is within the range of *H. inaequilaterus* and is therefore assigned to the *H. inaequilaterus* Zone.

The data from Hole 524 suggest that the zonation of Gombos (1977) may not be entirely applicable to sediments deposited at deep water sites. The 1977 zonation is based, in part, on the occurrence of *Sceptroneis* sp. A (Gombos, 1977), and that genus appears to be more susceptible to dissolution than some other Paleocene genera such as *Hemiaulus* and *Trinacria.* As a result, *Sceptroneis* may be absent or very rare in sediments deposited at water depths much greater than 4000 m.

The range of *Odontotropic klavsenii* is used by Gombos (1977) to define the oldest of three late Paleocene diatom zones in Hole 327A. A fragment of *O. klavsenii* was observed in Sample 524-4-3 (87–89 cm) and nowhere else in Hole 524. The range of *O. klavsenii* may be restricted to the early late Paleocene or its geographic distribution may have been limited to the western part of the South Atlantic in the late Paleocene. Further corroborative data from areas outside the region of the Falkland Plateau are needed to determine whether *O. klavsenii* is restricted in range to the early late Paleocene. Until the range of this species is firmly determined, the *O. klavsenii* Zone of Gombos (1977) should be considered to be of local significance.

OBSERVATIONS

Thirty-nine species and varieties of diatoms belonging to 16 genera were observed in samples from Cores 4 and 5 of Hole 524. No diagnostic stratigraphic datums were discernible in the ±2-m diatomaceous interval recovered from the hole. The changes in diversity and abundance in the various samples illustrated in Table 2 are attributable to differences in preservation. The late Paleocene assemblage in Hole 524 is characterized by the following common species: *Hemiaulus inaequilaterus, H. incurvus, H. polymorphus, H. subacutus, Triceratium heibergi, Trinacria excavata* f. *tetragona*, and *T. simulacrum.* Other species, which are not as abundant as these but appear to be indicative of late Paleocene sediments, include *Coscinodiscus* sp. A, *Fenestrella barbadensis, Huttonia virgata, Hyalodiscus* sp. A, *Tricera-*

Table 2. Occurrence and relative abundance of diatoms in Hole 524.

Age	Calcareous Nannofossil Zones (Percival, this vol.)	Core-Section (interval in cm)	*Actinoptychus wittii*	*Arachnoidiscus indicus*	*Aulacodiscus hirtus*	*Auliscus* sp.	*Coscinodiscus marginatus*	*C.* sp. A	*C.?* sp. B	*Fenestrella barbadensis*	Genus and species indet. A	*Hemiaulus capitatus*	*H. caracteristicus*	*H. inaequilaterus*	*H. incurvus*	*H. polymorphus*	*H. subacutus*	*Huttonia virgata*	*Hyalodiscus* sp. A	*Odontotropis* sp.	*Pseudopyxilla dubia*	*Pterotheca aculeifera*	*Stephanopyxis grunowii* s.l.	*S. turris* s.l.	*Triceratium crenulatum*	*T. glandarium*	*T. heibergi*	*T. imperator*	*T. inelegans*	*T. pulchrum*	*T.* sp. A	*T.* cf. *T. subcapitatum*	*T. trisulcum*	*Trinacria excavata*	*T. excavata* f. *tetragona*	*T. exsculpta*	*T. exsculpta* (5 angles)	*T. pileolus*	*T. regina*	*T. simulacrum*	*T. wittii*
early Eocene	NP11	2-1, 122–124	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		2-2, 58–60	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	NP10	3-1, 23–24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		3-1, 70–72	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		3-2, 70–72	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		3-3, 70–72	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		3-4, 22–24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
late Paleocene	NP9	4-1, 87–89	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		4-2, 87–89	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		4-3, 87–89	R	F	VR		R	R	R	R		R	R	F	C	C	C	VR	R	VR	R		R	F	R	R	C	R	R	R	R		R	F	C	R	R	R	R	F	
		4-4, 4–6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		4-4, 26–28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		4-4, 46–48		R				R					R												VR		R						R		F			R		C	
		4-4,CC													R	R	R				R						C							R	R			R		R	
		5-1, 70–72	VR	R	R	R		R			R			R	C	A	C		F		R	VR	VR		R		VA					F		R	R			R		F	F
		5-2, 60–62																									R														
		5-3, 110–112	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		5-4, 86–88	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	NP8	5-5, 86–88	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		6-1, 78–80	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		6-2, 78–78	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		6-3, 78–80	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: Dashes denote barren intervals.

tium imperator, T. trisulcum, Trinacria exsculpta, and *T. wittii.*

COMPARISON WITH OTHER LATE PALEOCENE DIATOM ASSEMBLAGES

At present, only two other late Paleocene diatom assemblages have been documented in the literature. One is from a piston core in the Indian Ocean (Mukhina, 1974, 1976); the other is from a DSDP hole in the southwest Atlantic Ocean.

Mukhina (1974, 1976) reported the occurrence of 34 species and varieties of 13 diatom genera in material recovered in Vityaz Piston Core 6744-40 (12°46′S; 88° 54′E) from the southeast Indian Ocean. According to Mukhina (1976), the sediment from Core 6744-40 can be assigned to the late Paleocene *Discoaster multiradiatus* Calcareous Nannofossil Zone of Martini (1971). The diatom assemblage in the core is dominated by species of the genera *Hemiaulus, Stephanopyxis*, and *Trinacria.* Characteristic species include *Hemiaulus polymorphus* and its varieties, *H. incurvus, H. lobatus, Stephanopyxis turris, S. lavrenkoi, Trinacria pileolus*, and *T. exsculpta.* Mukhina (1976) believes that *H. incurvus*, a robust, easily identified diatom, is a good late Paleocene–early Eocene marker. This species is known from the late Paleocene of the Indian Ocean (Mukhina, 1974, 1976) and the southwest Atlantic (Gombos, 1977) and from the early Eocene of the central Urals (Krotov and Shibkova, 1959).

Gombos (1977) reported the occurrence of 26 species belonging to nine genera in sediment dated as late Paleocene by calcareous nannofossils (Wise and Wind, 1977) from Hole 327A (50°52.38′S; 46°47.02′W) on the Falkland Plateau in the southwest Atlantic Ocean. Of the nine genera recorded from Hole 327A, *Hemiaulus, Stephanopyxis, Triceratium, Trinacria*, and *Sceptroneis* are the dominant genera. Characteristic species include *Hemiaulus inaequilaterus, H. incurvus, H. subacutus, H. polymorphus, Trinacria simulacrum, T. pileolus, Sceptroneis* sp. A, *S. caduceus, S. grunowii, Stephanopyxis turris*, and *Odontotropis klavsenii.* Occurrences of *Pyxilla* (*Pyrgupyxis*) *prolongata* and *Syndra jouseana* in the late Paleocene of Hole 327A as reported by Gombos (1977) are now assumed to have resulted from downhole contamination during drilling and are not to be considered representative of late Paleocene sediment.

In Hole 524, the floral assemblage is dominated by species of the genera *Hemiaulus, Triceratium*, and *Trinacria. Stephanopyxis* is not a major constituent of the assemblage in Hole 524 as it is in Vityaz Core 6744-40 and DSDP Hole 327A. *Stephanopyxis turris* s.l. and *S. grunowii* s.l. are most abundant in Sample 524-4-3 (87–89 cm), which is the best preserved sample studied. The absence or low abundance of *Stephanopyxis* species in other samples from Hole 524 reflects poor preservation.

In Vityaz Core 6744-40 and DSDP Hole 327A, pennate diatoms such as *Sceptroneis* and *Grunowiella* make up at least a small percentage of the floral assemblage (Mukhina, 1974, 1976; Gombos, 1977). In samples from Hole 524, no undoubted pennates were observed. A few fragments of what could either be parts of *Sceptroneis* valves or horns from *Hemiaulus* valves were noted in the samples, but they were impossible to diagnose because of their fragmentary condition and often obscured positions on the slides.

A comparison of the three late Paleocene sites suggests that the apparent absence of pennate diatoms from the sediment of Hole 524 is probably explained by the great water depth through which the valves must have passed before being deposited. At Site 327 (water depth 2401 m), *Sceptroneis* is quite common in the assemblage (Gombos, 1977). At Station 6744 (water depth 4780 m), *Grunowiella* makes up less than 1% of the assemblage (Mukhina, 1976). At Site 524 (water depth 4805 m), which is twice as deep as Site 327 and slightly deeper than Station 6744, *Sceptroneis* and *Grunowiella* are apparently absent. This suggests that these genera are less resistant to dissolution than other members of the late Paleocene assemblage and are selectively dissolved with increasing water depth.

Another difference between the Paleocene diatom assemblage in Hole 524 and Hole 327A is the virtual absence from the former of *O. klavsenii.* In Hole 372A, *O. klavsenii* is rare to common and consistent in occurrence in the lower part of the late Paleocene interval. In Hole 524, only one fragment of *Odontotropis* cf. *O. klavsenii* was observed in Sample 524-4-3 (87–89 cm).

As illustrated in Figure 3, the late Paleocene interval cored at Site 327 is older than that cored at Site 524. Therefore, the occurrence of *O. klavsenii* may serve as a useful stratigraphic indicator of early late Paleocene sediment. On the other hand, this dubious species (see Taxonomic Notes) may reflect paleoceanographic conditions unique to the region around Site 327 during the early late Paleocene.

The late Paleocene section cored in Hole 327A is older than that cored in Hole 524. As shown in Figure 2, the late Paleocene diatomaceous interval in Hole 524 is

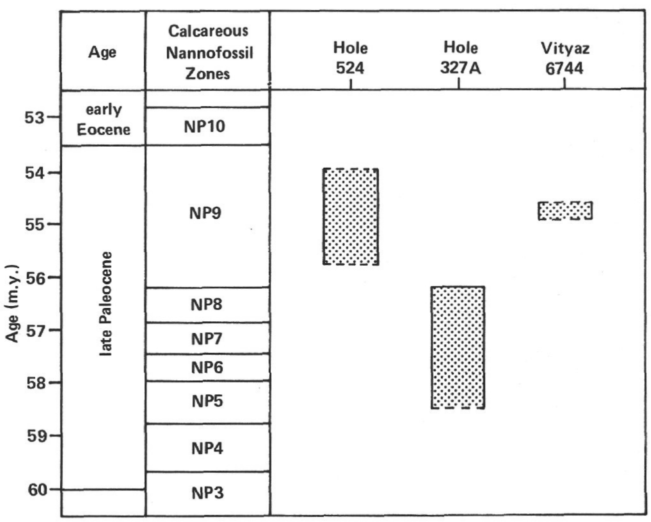

Figure 3. Stratigraphic coverage represented by the three sections known to contain late Paleocene diatoms.

entirely within Calcareous Nannofossil Zone NP9. The base of NP9 is defined by the lowest occurrence of *D. multiradiatus*. The lowest occurrence of *D. multiradiatus* in Hole 327A is at the bottom of Core 4 (Wise and Wind, 1977). The highest occurrence of diatoms in Hole 327A is at the top of Core 5 (Gombos, 1977); the diatoms range down through Core 8. Therefore, the diatoms in Hole 327A are no younger than NP8 and may be older (if the lowest occurrence of *D. multiradiatus* is a true FAD and not a relic of dissolution).

It was not possible to correlate the nannofossils in Cores 5 through 8 of Hole 327A to standard zonations because of the absence of key species as a result of dissolution and the restricted range characteristic of flora of high-latitude depositional sites (Wise and Wind, 1977). The early late Paleocene of Hole 327A has been divided into two calcareous nannofossil zones by Wise and Wind (1977) for purposes of local correlation, but neither the regional significance of those zones nor their correlation to standard calcareous microfossil zones has been demonstrated. No stratigraphically useful planktonic foraminifers occur in the late Paleocene of Hole 327A (Tjalsma, 1977).

Except for late Paleocene palynomorphs (Harris, 1977), no microfossils occur in Core 9 of Hole 327A. Core 10 of that hole contains Late Cretaceous calcareous nannofossils (Wise and Wind, 1977) and foraminifers (Tjalsma, 1977). This hiatus between late Paleocene and Late Cretaceous in Hole 327A indicates that the diatoms are no older than late Paleocene. Because of the correlation problems discussed above, it is not possible to tell how much of the late Paleocene is represented in Hole 327A. Therefore, the amount of coverage illustrated for the diatomaceous interval in Hole 327A in Figure 3 is highly speculative and is intended only to show that the late Paleocene diatoms in that hole are older than those in Hole 524.

SUMMARY

Late Paleocene diatoms are very rare. The documentation of 39 species in a 2-m-thick interval in Cores 4 and 5 of Hole 524 represents only the third reported late Paleocene diatom assemblage in the world. The other two reported occurrences are from Vityaz Piston Core 6744 in the Indian Ocean and from DSDP Hole 327A on the Falkland Plateau in the southwest Atlantic Ocean. The diatomaceous late Paleocene intervals from Holes 327A and 524 together form a composite stratigraphic section that provides data on the occurrence of diatoms through most of the late Paleocene (Fig. 3).

The diatom assemblage in Hole 524 is characterized by species of the genera *Hemiaulus, Trinacria*, and *Triceratium*. Notably absent from the assemblage are species of the order Pennales. It is presumed that the great water depth at Site 524 resulted in the selective dissolution of those species, because they do occur at the other two sites, which are at shallower water depths.

TAXONOMIC REFERENCES AND NOTES

The following section cites the original taxonomic references for the species considered in this report. In some instances additional references are also given if they are believed to be of use in identifying the species or are generally easier to obtain. More comprehensive reference lists, as well as synonomies, may be found in VanLandingham (1967–1979).

Genus *ACTINOPTYCHUS* Ehrenberg, 1841

Actinoptychus wittii Janisch, 1886
(Plate 6, Figs. 5, 6)

References. Janisch *in* Schmidt, 1886, pl. 100, fig. 12; pl. 132, fig. 24.

Remarks. Rare in Sample 524-4-3, 87–89 cm.

Genus *ARACHNOIDISCUS* Deane *in* Pritchard, 1852

Arachnoidiscus indicus Ehrenberg, 1854
(No illustration)

References. Ehrenberg, 1854, p. 165, pl. 36, fig. 34; Schmidt, 1882, pl. 73, fig. 2.

Genus *AULACODISCUS* Ehrenberg, 1844

Aulacodiscus cf. _A. hirtus_ Barker and Meakin, 1949
(Plate 6, Fig. 8)

References. Barker and Meakin, 1949, p. 301, pl. 31, fig. 1; Benda, 1972, p. 254, pl. 1, figs. 6, 7.

Genus *AULISCUS* Ehrenberg, 1843

Auliscus sp. A
(Plate 6, Fig. 7)

Remarks. Only two examples of the form illustrated were observed in Sample 524-4-3, 87–89 cm.

Genus *COSCINODISCUS* Ehrenberg, 1838

Coscinodiscus marginatus Ehrenberg, 1841
(No illustration)

References. Ehrenberg, 1841, p. 142; Hustedt, 1930, pp. 416–418, fig. 223.

Coscinodiscus sp. A
(Plate 5, Figs. 1–3)

Remarks. This species is characterized by the presence of randomly distributed elongate or irregularly shaped areolae. The diameter of valves ranges from 60 to 90 μm. The species is rare in the material from Hole 524. No reference to a species similar to this was found in the literature.

Coscinodiscus sp. B
(Plate 2, Fig. 9)

Remarks. This very rare species is tentatively placed in this genus. It is characterized by parallel radiating rows of areolae which become smaller toward the margin. Rows are more numerous near the margin; toward the valve center, the rows become discontinuous and more widely spaced.

Genus *FENESTRELLA* Greville, 1863

Fenestrella barbadensis Greville, 1863
(Plate 6, Figs. 1–4)

Reference. Greville, 1863, p. 68, pl. 4, fig. 8.

Remarks. The example illustrated herein differs from the illustration of Greville (1863) by the absence of pronounced parallel rows of areolae connecting the two midradial crescent-shaped hyaline fields. Scanning electron microscope photomicrographs taken by T. H. Miller (pers. comm., 1982) have shown that the hyaline fields are the sites of internally projecting labiate processes, the external openings of which appear in the light microscope as six or seven small pores aligned along the inner margin of the hyaline fields. The species is rare in material from Hole 524.

Other occurrences. Late Paleocene of DSDP Hole 327A (author's notes); Cambridge Estate, Barbados (Greville, 1863).

Genus *HEMIAULUS* Ehrenberg, 1844

Species of this genus are common in late Paleocene sediment (Mukhina, 1974, 1976; Gombos, 1977). Ultramicroscopic examination with the scanning electron microscope indicates that the genus is large and in need of revision. The species list presented herein is not complete. Only species that are thought to have biostratigraphic significance or that were too obvious to be ignored are dealt with in this study.

***Hemiaulus capitatus* Greville, 1865**
(No illustration)

References. Greville, 1865, p. 54, pl. 6, fig. 24; Ross, 1971, pp. 333–335, fig. 3.

Remarks. Rare in the material from Hole 524.

***Hemiaulus caracteristicus* Hajós, 1976**
(No illustration)

Reference. Hajós, 1976, pp. 828–829, pl. 15, fig. 10.

Synonyms. *Hemiaulus* "new species" Schmidt, 1888, pl. 142, fig. 12; *Hemiaulus* "artifacts" Gombos 1977, p. 594, pl. 15, figs. 4–6.

Remarks. This curious species is quite unlike any other *Hemiaulus* in that the valve surface is almost entirely hyaline. Scanning electron micrographs have revealed the presence of minute pores along portions of the horns.

Other occurrences. Gombos (1977) reports this species from the Eocene and Oligocene of Hole 328 in the Tasman Sea; Schmidt (1888) reports it from Mors, Denmark (late Paleocene/early Eocene); and Gombos and Ciesielski (in press) have observed it in the Eocene and Oligocene of Hole 513A in the South Atlantic. It has also been observed in early Paleocene sediment from Hole 208 on the Lord Howe Rise. It is rare in the present material.

***Hemiaulus inaequilaterus* Gombos, 1977**
(Plate 7, Figs. 6, 7)

Reference. Gombos 1977, p. 594, pl. 20, figs. 5–7.

Synonym. *Hemiaulus lobatus* Greville *in* Mukhina 1974 (1975), p. 694, pl. 2, fig. 4.

Remarks. Gombos (1977) found this species to be characteristic of the late Paleocene sediment at Site 327 on the Falkland Plateau. It is common in the late Paleocene of Hole 524.

***Hemiaulus incurvus* Schibkova, 1959**
(Plate 7, Figs. 1–5)

References. Schibkova *in* Krotov and Schibkova, 1959, p. 124, pl. 4, fig. 8; Mukhina, 1976, p. 156, pl. 1, figs. 1–3; Gombos, 1977, p. 594, pl. 16, figs. 6, 7; pl. 17, figs. 1–3.

Remarks. This species exhibits a considerable degree of individual variation in the length of the horns and width of the valves.

Other occurrences. Early Eocene of the central Urals (Krotov and Schibkova, 1959); late Paleocene of the Indian Ocean (Mukhina, 1974, 1976); late Paleocene of the southwest Atlantic Ocean (Gombos, 1977).

***Hemiaulus polymorphus* Grunow, 1884**
(No illustration)

References. Grunow, 1884, p. 66; Schmidt, 1888, pl. 143, figs. 11–13; Fenner, 1978, p. 522, pl. 21, fig. 11; pl. 23, figs. 10, 11; pl. 12, fig. 13.

***Hemiaulus subacutus* Grunow, 1884**
(Plate 7, Figs. 8, 9)

References. Grunow, 1884, p. 61, pl. 5(E), fig. 55; Gombos, 1977, p. 594, pl. 17, figs. 5–8.

Remarks. For this study I have followed the concept of this species presented by Gombos (1977).

Genus *HUTTONIA* Grove and Sturt, 1887

***Huttonia virgata* Grove and Sturt, 1887**
(Plate 8, Fig. 5)

Reference. Grove and Sturt, 1887, p. 142, pl. 14, fig. 55.

Remarks. This species is very rare in the present material. It is represented by a single occurrence in Core 4-3, 87–89 cm. This is the first reported occurrence of this species in the South Atlantic.

Genus *HYALODISCUS* Ehrenberg, 1845

***Hyalodiscus* sp. A**
(Plate 5, Figs. 4–6)

Synonym. *Hyalodiscus* sp. Mukhina, 1974 (1975), pl. 2, fig. 10.

Remarks. In Hole 524 this species is most abundant in Section 5-2 (70–72 cm).

Genus *ODONTOTROPIS* Grunow, 1884

***Odontotropis* cf. *O. klavsenii* Debes *ex* Hustedt, 1930**
(Plate 2, Fig. 3)

References. Debes *ex* Hustedt, 1930, p. 858, fig. 510a; Benda, 1972, p. 255, pl. 4, fig. 26; Gombos, 1977, p. 595, pl. 39, figs. 1–4.

Remarks. Only one fragment of this species was observed (in Sample 524-4-3, 87–89 cm). In Hole 327A, on the Falkland Plateau, this species is rare to common and consistent in occurrence in the early late Paleocene. The absence of *Odontotropis klavsenii* from the late Paleocene of Hole 524 is the result either of the restricted range of the species in the early late Paleocene or limiting paleoceanographic conditions that prevented its deposition at Site 524.

Genus *PSEUDOPYXILLA* Forti, 1909

***Pseudopyxilla dubia* (Grunow) Forti, 1909**
(Plate 2, Figs. 10–12)

References. Forti, 1909, p. 12, pl. 1, figs. 1–3; Kanaya, 1957, p. 114, pl. 8, fig. 10; Fenner, 1978, p. 526, pl. 14, fig. 9, pl. 17, figs. 1–6.

Genus *PTEROTHECA* (Grunow) Forti, 1909

***Pterotheca aculeifera* Grunow, 1880**
(No illustration)

Synonyms. *Pterotheca* sp. 2 McCollum, 1975, p. 535, pl. 10, fig. 10; *Pterotheca crucifera* in Hajós and Stradner, 1975, pl. 12, figs. 8, 22; *Pterotheca* sp. A Gombos, 1977, p. 596, pl. 23, figs. 3, 4; *Pterotheca* sp. in Schrader and Fenner, 1976, p. 994, pl. 43, figs. 5–7.

References. Van Heurck, 1896, p. 430, fig. 151; Fenner, 1978, p. 527, pl. 17, figs. 8–21.

Remarks. Very rare in the present material.

Genus *STEPHANOPYXIS* Ehrenberg, 1844

The two species referenced herein do not represent the complete tally of species of *Stephanopyxis* in Hole 524. The genus is in need of review both as to taxonomy and biostratigraphic usefulness, if any.

***Stephanopyxis grunowii* Grove and Sturt, 1888**
(No illustration)

Reference. Grove and Sturt *in* Schmidt, 1888, pl. 130, figs. 1–5.

***Stephanopyxis turris* (Greville and Arnott) Ralfs *in* Pritchard, 1861**
(No illustration)

Reference. Hustedt, 1930, p. 304, fig. 140.

Genus *TRICERATIUM* Ehrenberg, 1841

***Triceratium crenulatum* Grove and Sturt, 1887**
(Plate 4, Figs. 1–7)

References. Grove and Sturt, 1887, p. 7, pl. 2, fig. 3; Schmidt, 1888, pl. 173, fig. 9; Gombos, 1977, p. 598, pl. 38, fig. 2.

***Triceratium glandarium* Schmidt, 1888**
(Plate 3, Fig. 4)

References. Schmidt, 1888, pl. 128, fig. 19; 1959, pl. 467, figs. 12–17.

***Triceratium heibergii* Grunow, 1883**
(Plate 1, Figs. 1–12)

References. Grunow *in* Van Heurck, 1883, pl. 112, figs. 9–11; Hustedt *in* Schmidt, 1959, pl. 467, figs. 20–22.

Remarks. This species is characterized by what appears to be a bifurcate or trifurcate ridge near the center of the valve. Two or three small openings, which may be labiate processes, are closely associated with the ridges. This species is one of the most common forms of *Triceratium* in the late Paleocene of Hole 524. The illustration of Hustedt in Schmidt (1959) was used to identify this species in the present study.

***Triceratium imperator* Truan and Witt, 1888**
(Plate 3, Figs. 2, 3)

References. Truan and Witt, 1888, p. 23, pl. 7, fig. 15; Schmidt, 1890, pl. 150, fig. 12.
Remarks. This large (≈150 μm from tip to tip of each angle) species is very rare in the material from Hole 524. It was observed most frequently in the greater-than-63-μm fraction slides prepared for radiolarian study.

***Triceratium inelegans* Greville, 1866**
(Plate 2, Fig. 7)

References. Greville, 1866, p. 8, pl. 2, fig. 2; variety *yucatensis* in Schmidt, 1959, pl. 468, figs. 6–8.
The form illustrated herein is very rare in the present material and resembles specimens illustrated by Hustedt in Schmidt (1959) as *T. inelegans* var. *yucatensis* Grunow *in* Van Heurck, 1883.

***Triceratium pulchrum* Hustedt, 1959**
(No illustration)

Reference. Hustedt *in* Schmidt, 1959, pl. 471, fig. 2.
Remarks. Very rare in the present material.

***Triceratium subcapitatum* Greville, 1863**
(No illustration)

Reference. Greville, 1863, p. 234, pl. 10, fig. 20.

***Triceratium trisulcum* sensu Schmidt, 1886**
(Plate 3, Fig. 5)

Reference. Schmidt, 1886, pl. 112, fig. 17.
Remarks. Very rare in the present material.

Genus *TRINACRIA* Heiberg, 1863

***Trinacria excavata* Heiberg, 1863**
(Plate 2, Figs. 1, 2)

References. Heiberg, 1863, p. 51, pl. 4, fig. 9; Schmidt, 1886, pl. 96, figs. 6–8; pl. 97, figs. 6–10.

***Trinacria excavata* f. *tetragona* Schmidt, 1890**
(Plate 5, Figs. 7–9)

Reference. Schmidt, 1890, pl. 152, figs. 26–28.

***Trinacria exsculpta* (Heiberg) Hustedt, 1930**
(Plate 8, Figs. 9–11)

References. Hustedt, 1930, p. 889, fig. 533; Benda, 1972, p. 256, pl. 3, fig. 18; Mukhina, 1976, p. 153, pl. 2, fig. 7.
Remarks. This species is considered to be characteristic of the late Paleocene by Mukhina (1976). The species is rare to frequent in the present material. A form with five angles was observed in the present material and is illustrated in Plate 8, Fig. 11.

***Trinacria pileolus* (Ehrenberg) Grunow, 1884**
(Plate 2, Figs. 4–6, 8)

References. Grunow, 1884, p. 68, pl. 2(B), figs. 59, 60; Hustedt, 1930, pp. 885–886, fig. 529; Gombos, 1977, p. 599, pl. 37, figs. 3, 4; Fenner, 1979, p. 536, pl. 24, figs. 16, 17.

***Trinacria regina* Heiberg, 1863**
(Plate 3, Fig. 1)

References. Heiberg, 1863, p. 50, pl. 3, fig. 7; Benda, 1972, p. 256, pl. 1, figs. 8, 9.
Remarks. Rare to frequent in the present material. Only fragments were observed in slides prepared from the unsieved residue; a few complete specimens were observed in the greater-than-63-μm fraction.

***Trinacria simulacrum* Grove and Sturt, 1887**
(Plate 4, Fig. 8)

References. Grove and Sturt, 1887, ser. 2, vol. 3, p. 144, pl. 13, fig. 46; Schmidt, 1888, pl. 127, fig. 14; Mukhina, 1976, p. 152, pl. 2, fig. 8 (as *Triceratium kinkeri*); Gombos, 1977, p. 599, pl. 35, figs. 1, 2, 4; pl. 36, figs. 1–4.
Remarks. Rare to common in the present material.

***Trinacria wittii* Janisch, 1886**
(No illustration)

References. Janisch *in* Schmidt, 1886, pl. 96, fig. 1; pl. 97, fig. 2; Benda, 1972, p. 256, pl. 4, fig. 38.

***Trinacria* sp. A**
(Plate 8, Figs. 6–8)

Remarks. Valves square with slightly concave sides; length of sides 45 to 65 μm in observed specimens. Central area of valve slightly depressed, areolated with areolae radially arranged; larger toward margin. Margin loculate. Ocelli located at each corner.

INCERTAE SEDIS

Genus and species indeterminate (A) Gombos, 1977
(No illustration)

References. Gombos, 1977, p. 599, pl. 40, figs. 4, 8; Fenner, 1979, p. 519, pl. 25, figs. 1, 4, 10.
Remarks. Gombos (1977) reports this species from the late Paleocene of Hole 327A on the Falkland Plateau. Fenner (1979) reports it from the middle Eocene of Hole 356 on the São Paulo Plateau. In the present material, it is rare in Sample 524-5-1, 70–72 cm.

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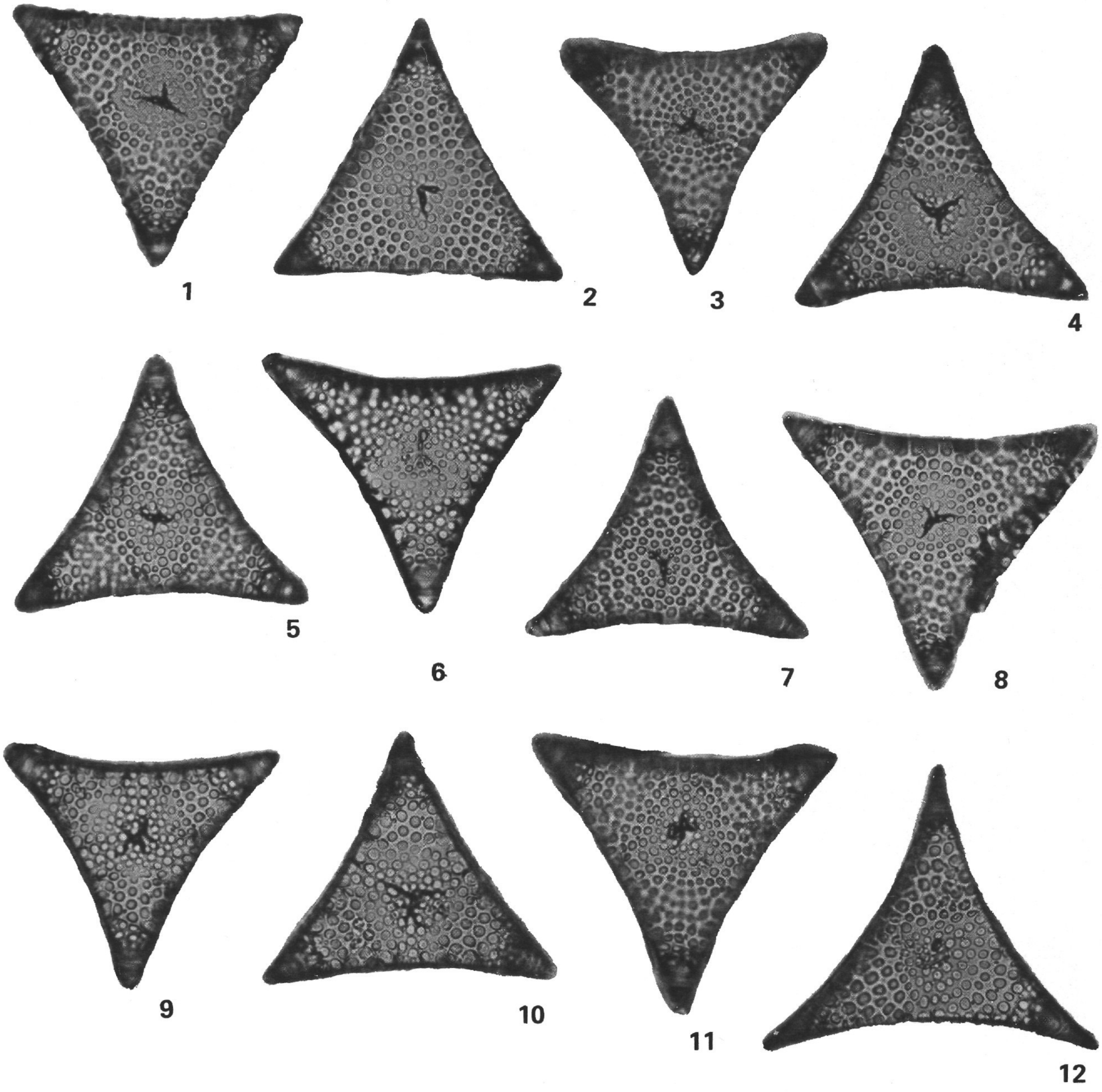


Plate 1. *Triceratium heibergii* Grunow (all magnifications ×500). **1, 3–9, 11.** Sample 524-5-1 (70–72 cm). **2, 10, 12.** Sample 524-4-3 (87–89 cm).

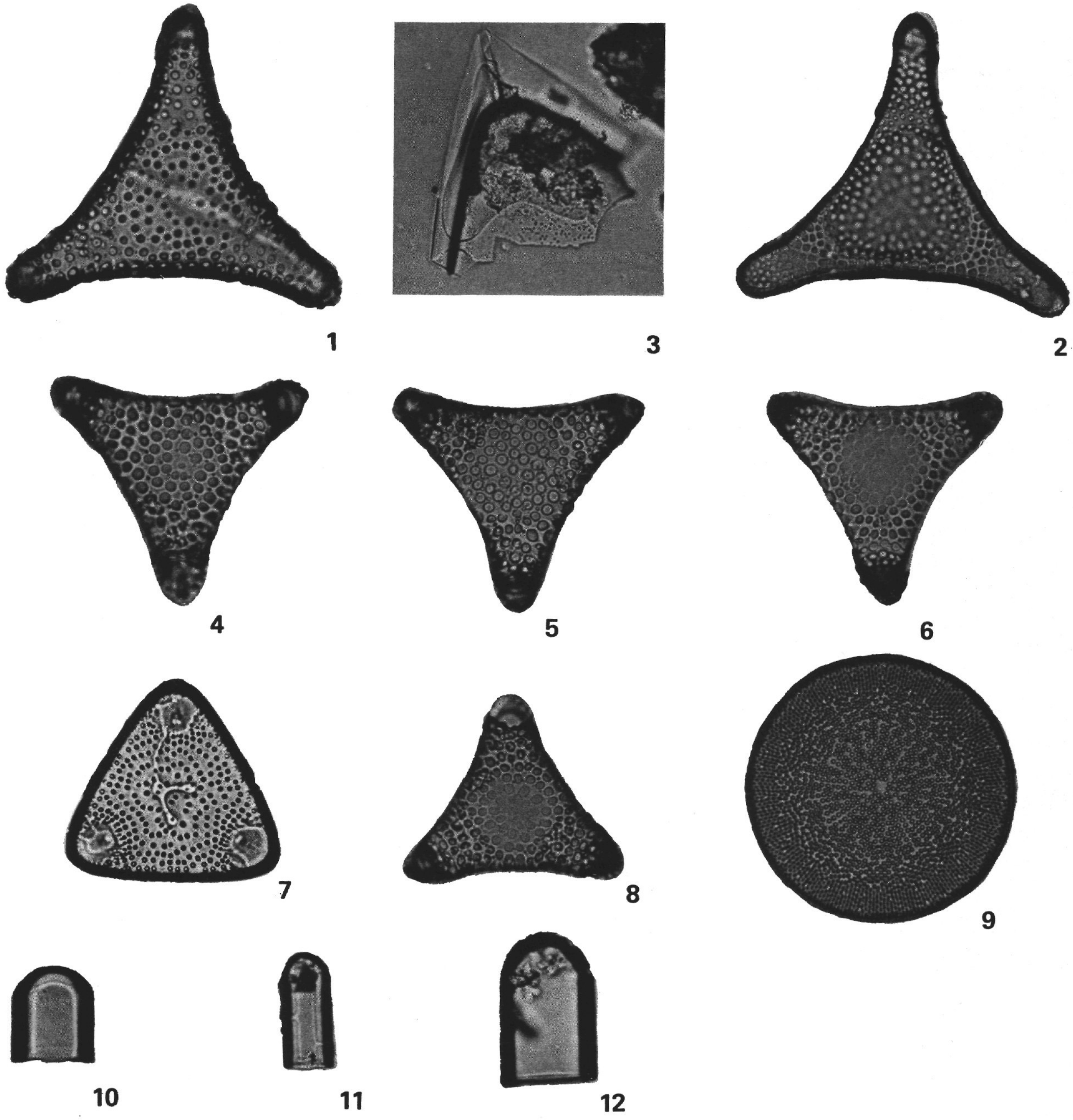


Plate 2 (all magnifications ×500). **1, 2.** *Trinacria excavata* Heiberg. Sample 524-4-3 (87–89 cm). **3.** *Odontotropis* sp. (fragment). Sample 524-4-3 (87–89 cm). **4–6, 8.** *Trinacria pileolus* (Ehrenberg) Grunow. Sample 524-4-3 (87–89 cm). **7.** *Trinacria* cf. *inelegans* Greville. Sample 524-4-3 (87–89 cm). **9.** *Coscinodiscus* sp. B. Sample 524-4,CC. **10–12.** *Pseudopyxilla dubia* (Grunow) Forti. Sample 524-4-3 (87–89 cm).

Plate 3 (all magnifications ×500). **1.** *Trinacria regina* Heiberg. Sample 524-5-1 (70–72 cm). **2, 3.** *Triceratium imperator* Truan and Witt. Sample 524-5-1 (70–72 cm). **4.** *Triceratium glandarium* Schmidt. Sample 524-4-3 (87–89 cm). **5.** *Triceratium trisulcum* sensu Schmidt. Sample 524-4-3 (87–89 cm).

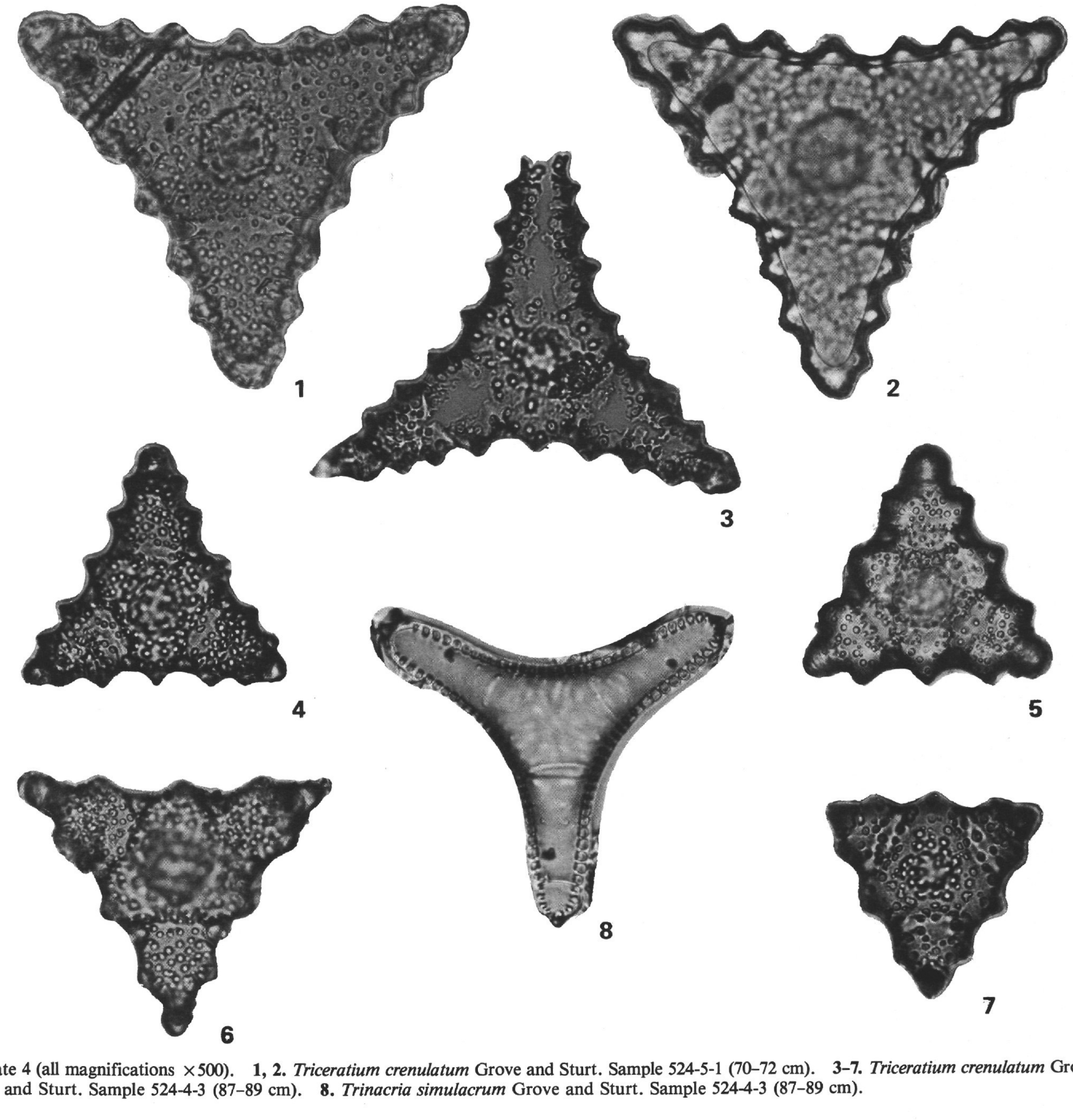


Plate 4 (all magnifications ×500). **1, 2.** *Triceratium crenulatum* Grove and Sturt. Sample 524-5-1 (70–72 cm). **3–7.** *Triceratium crenulatum* Grove and Sturt. Sample 524-4-3 (87–89 cm). **8.** *Trinacria simulacrum* Grove and Sturt. Sample 524-4-3 (87–89 cm).

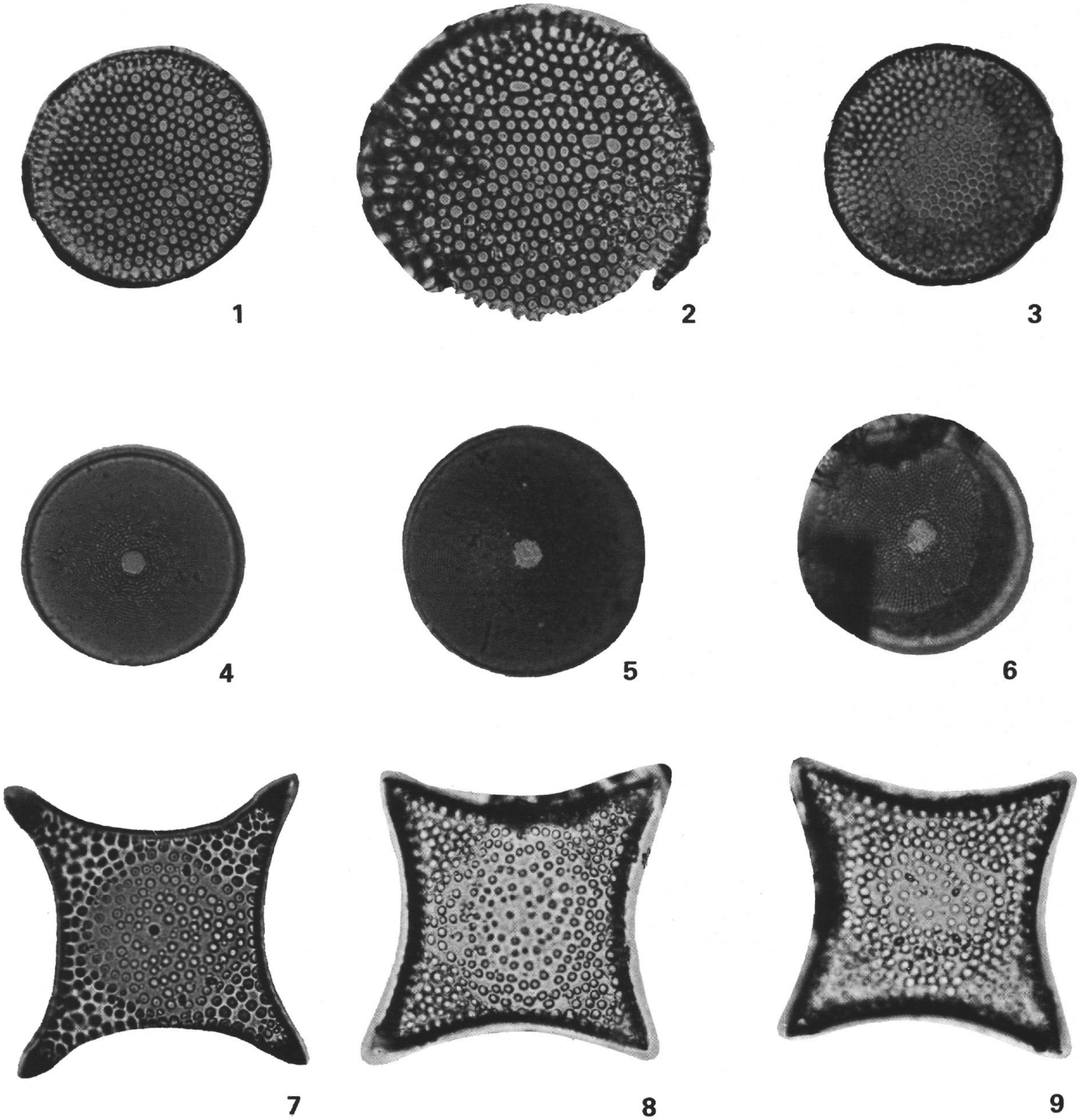


Plate 5 (all magnifications ×500). **1, 3.** *Coscinodiscus* sp. A. Sample 524-4-3 (87–89 cm). **2.** *Coscinodiscus* sp. A. Sample 524-5-1 (70–72 cm). **4, 5.** *Hyalodiscus* sp. A. Sample *Islas Orcadas* 775-46 (125–126 cm). **6.** *Hyalodiscus* sp. A. Sample 524-4-3 (87–89 cm). **7.** *Trinacria excavata* Heiberg f. *tetragona* Schmidt. Sample 524-4-3 (87–89 cm). **8–9.** *Trinacria excavata* Heiberg f. *tetragona* Schmidt. Sample 524-4,CC.

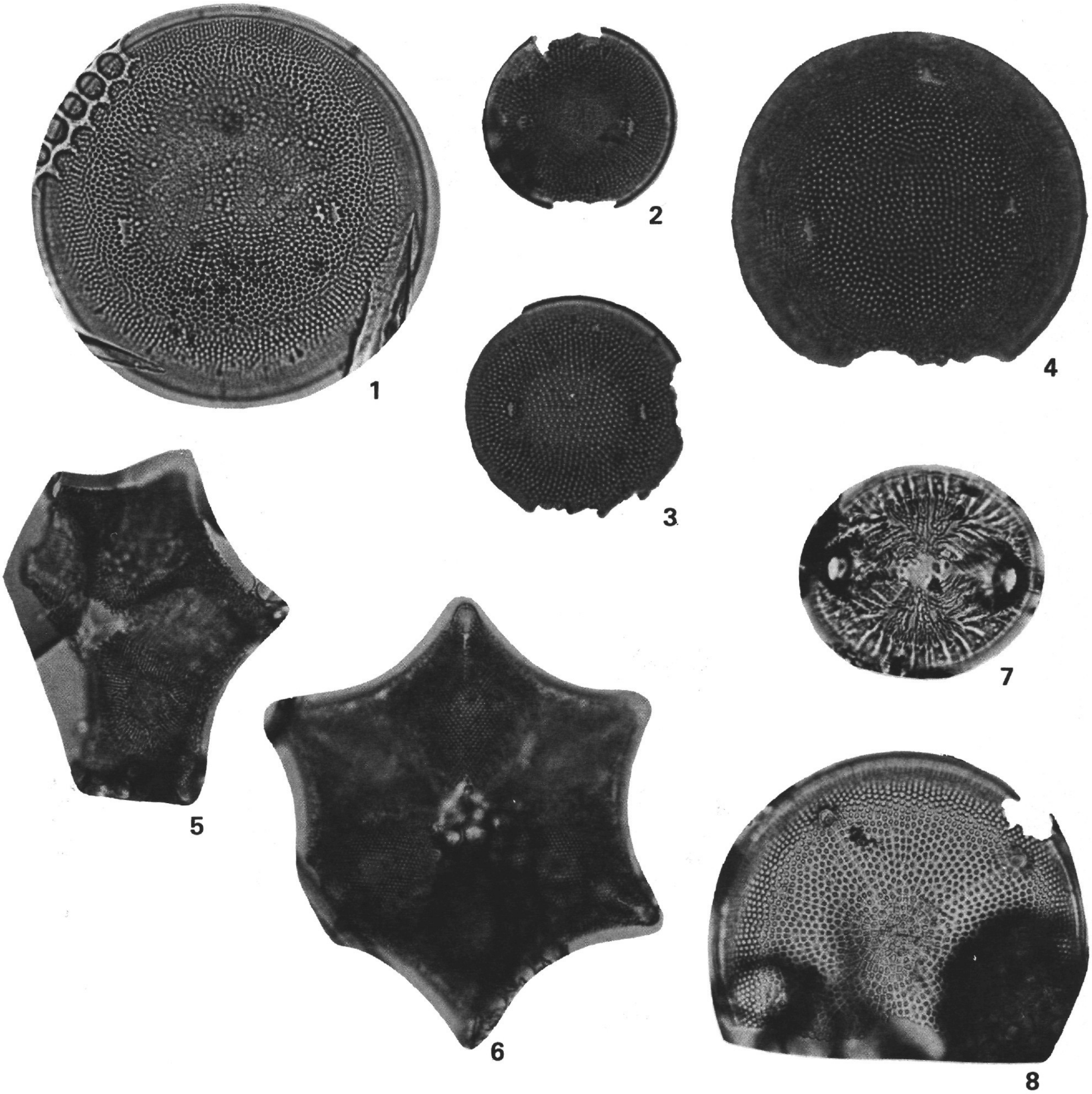


Plate 6 (all magnifications ×500). **1.** *Fenestrella barbadensis* Greville. Sample 524-4-3 (87–89 cm). **2–4.** *Fenestrella barbadensis* Greville. Sample *Islas Orcadas* 775-46 (125–126 cm). **5, 6.** *Actinoptychus wittii* Janisch. Sample 524-4-3 (87–89 cm). **7.** *Auliscus* sp. A. Sample 524-5-1 (70–72 cm). **8.** *Aulacodiscus* cf. *A. hirtus* Barker and Meakin. Sample 524-5-1 (70–72 cm).

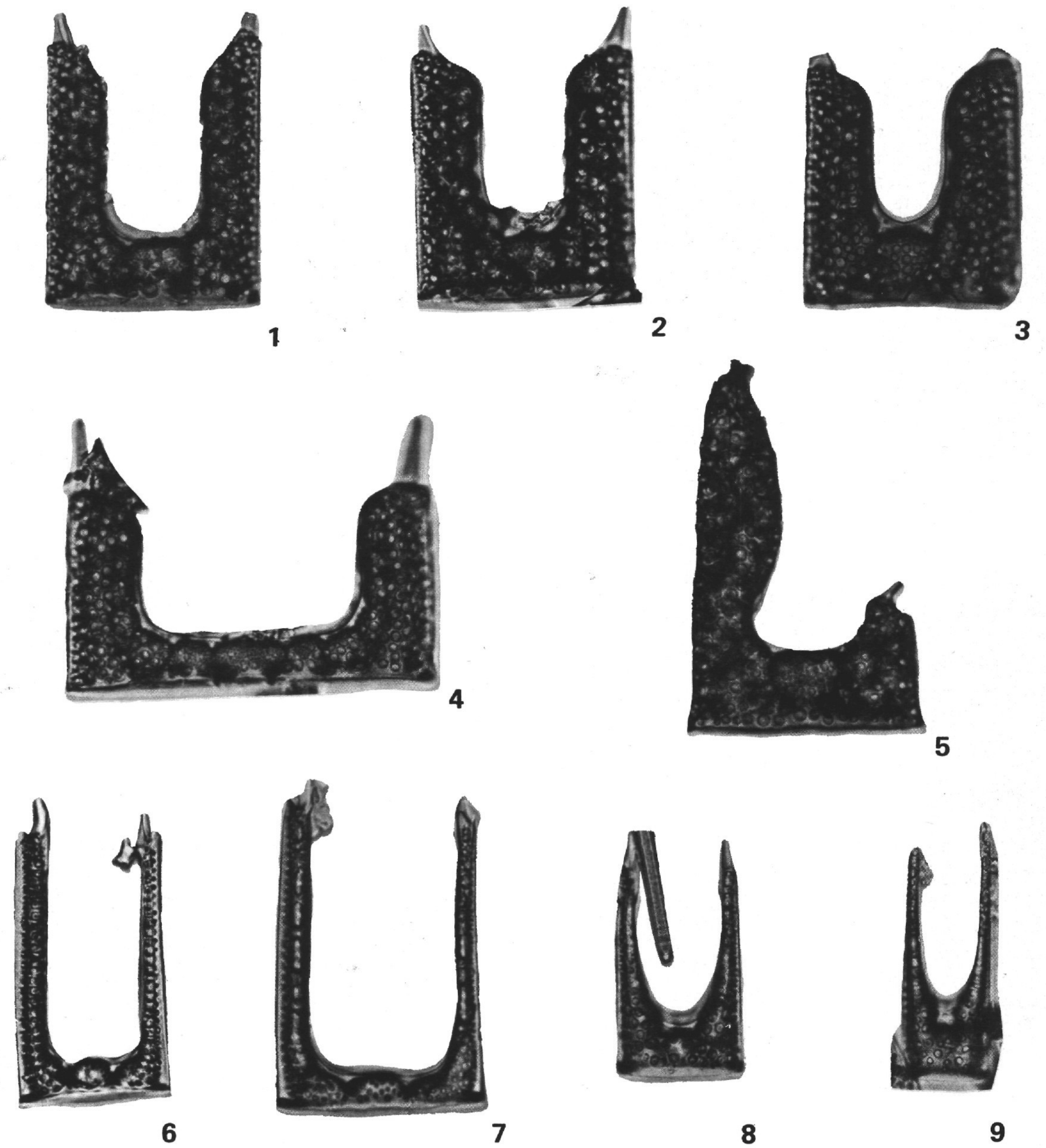


Plate 7 (all magnifications ×500). **1, 2.** *Hemiaulus incurvus* Schibkova. Sample 524-4-3 (87–89 cm). **3, 4.** *Hemiaulus incurvus* Schibkova. Sample 524-4,CC. **5.** *Hemiaulus incurvus* Schibkova (freak). Sample 524-4-3 (87–89 cm). **6, 7.** *Hemiaulus inaequilaterus* Gombos. Sample 524-4-3 (87–89 cm). **8, 9.** *Hemiaulus subacutus* sensu Gombos, 1977. Sample 524-4-3 (87–89 cm).

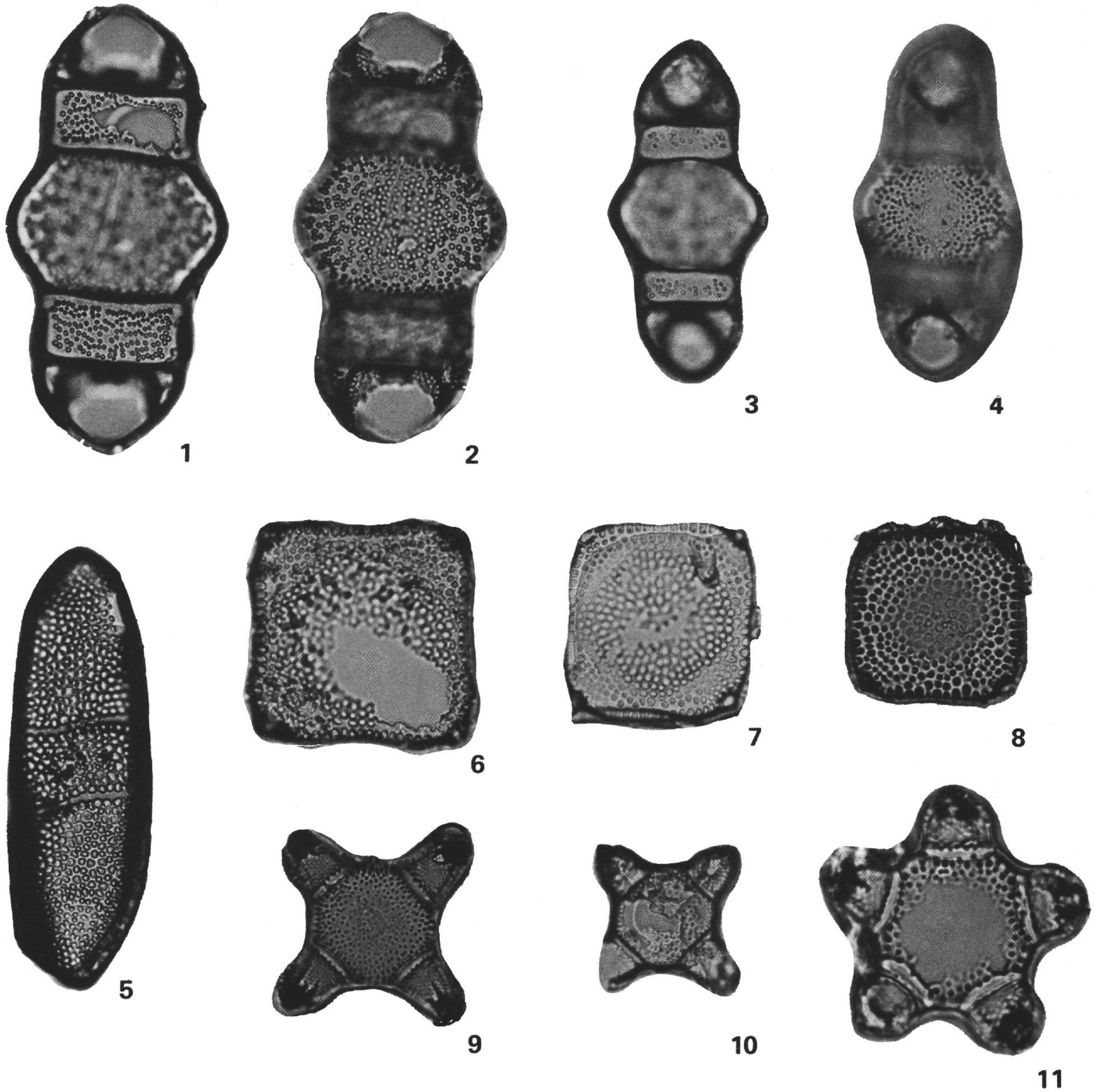
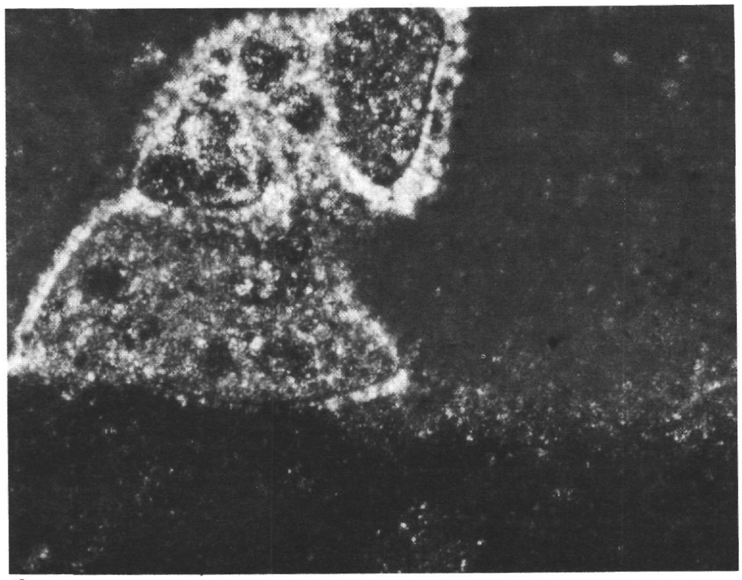


Plate 8 (all magnifications ×500). **1–4.** *Biddulphia*? sp. Sample 524-4-3 (87–89 cm). (Not listed in Table 2.) **5.** *Huttonia virgata* Grove and Sturt. Sample 524-4-3 (87–89 cm). **6–8.** *Trinacria* sp. A. Sample 524-4-3 (87–89 cm). **9–11.** *Trinacria exsculpta* (Heiberg) Hustedt. Sample 524-4-3 (87–89 cm).



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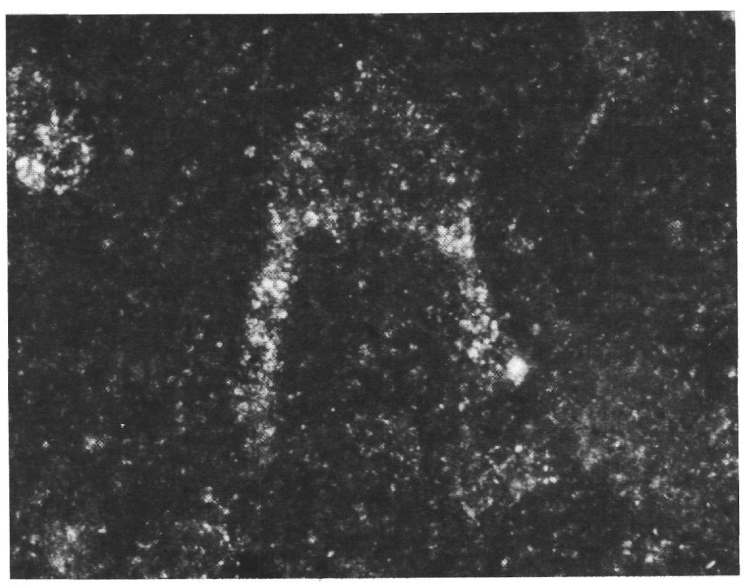

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Plate 9 (all magnifications ×200). **1.** Photomicrograph of thin section cut at the limestone/chert (light gray/black) contact in the early Eocene part of Sample 524-4-1 (10–16 cm). **2.** Photomicrograph of a "radiolarian ghost" in the early Eocene chert of Sample 524-4-1 (10–16 cm).