

UPPER MIOCENE NANNOFOSSIL BIOSTRATIGRAPHY AND TAXONOMY OF EXXON CORE CH30-43-2 FROM THE GULF OF MEXICO

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Abstract: Exxon Core CH30-43-2 from the NE Gulf of Mexico yielded very abundant and well preserved Upper Miocene calcareous nannofossils. The succession of the nannofossil events established for this core provides some useful information toward an improved biostratigraphic scheme in the Gulf of Mexico. Some new taxonomic observations were made, which include the description of three new species (*Discoaster pentabollii* n. sp., *Discoaster styzenii* n. sp. and *Discoaster wisei* n. sp.), two new subspecies (*Discoaster berggrenii berggrenii* n. subsp. and *Discoaster berggrenii extensus* n. subsp.), and amendment of two species (*Discoaster prepentaradiatus* and *Discoaster neohamatus*).

1. Introduction

Nannofossil biostratigraphy has become ever more important in the Gulf of Mexico, as there are more petroleum drilling activities there than in any other comparable ocean basin (http://images.pennnet.com/articles/os/cap/cap_100187.gif). However, only a few Miocene nannofossil studies have been published for the Gulf of Mexico (e.g. Gartner *et al.*, 1983; Aubry, 1993) and it is highly desirable to improve nannofossil taxonomy and biostratigraphy in this important basin. Exxon Core CH30-43-2, recovered from the NE Gulf of Mexico (Figure 1), offers a good opportunity for taxonomic and biostratigraphic study, as Core CH30-43-2 contains very abundant and well-preserved Upper Miocene nannofossils. Weiterman (1989) studied two samples from this core. The current study attempts to contribute more-detailed nannofossil taxonomic and biostratigraphic information.

2. Materials and methods

Exxon Corehole CH30-43 was drilled in the NE Gulf of Mexico in the early 1960s by Exxon and a consortium of oil companies. The corehole was located at 28°01.1'N,

86°24.7'W, in a water-depth of 1351m, and spot-cored to the Middle Eocene. There is a coring gap of about 18m above and below Core CH30-43-2. Above the core lies the Upper Pliocene and below the core lies the Lower Miocene. This study concentrates on the apparently complete Upper Miocene Core CH30-43-2.

Smear-slides were examined with a light-microscope at a magnification of 1000x. The abundance of selected nannofossil taxa on each slide was estimated using the following criteria: V = very abundant, more than 10 specimens per field of view (fov); A = abundant, 1-10 specimens per fov; C = common, 1 specimen per 2-10 fov; F = few, 1 specimen per 11-50 fov; R = rare, 1 specimen per 51-200 fov. For preservation of nannofossil assemblages, G = good, little evidence of etching or overgrowth.

The bibliographic references of the species used in this study can be found in Perch-Nielsen (1985) or Bown (1998). Those not given in Perch-Nielsen (1985), that is, *Discoaster berggrenii* Knuttel *et al.* (1989) and *Reticulofenestra rotaria* Theodoridis (1984) are given in the references of this paper. New species and subspecies are discussed below. Numerical ages discussed in this paper refer to the time-scale of Berggren *et al.* (1995).

3. Biostratigraphy

The distribution of selected nannofossil taxa in Core CH30-43-2 is presented in Table 1. As the samples were originally taken and recorded in feet and inches, they have been converted to metres in the second column, with the original sample notations listed in the third column for easy comparison.

The nannofossil succession found in Core CH30-43-2 is generally consistent with that prescribed in some of the latest zonation schemes, for example, Young (1999). Current data, together with the generalised zonation scheme of Young (1999), suggest that the following nannofossil events may be applicable in the Gulf of Mexico (Figure 2):

the top of *Discoaster quinqueramus* at 5.6Ma. This

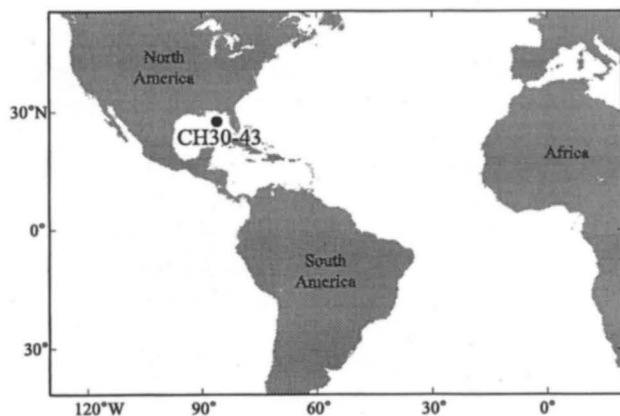


Figure 1: Location map of Exxon Corehole CH30-43

Nannofossil subzone	Sample interval (m)	Sample interval (foot, inch)	Abundance	Preservation	<i>Amaurolithus amplifolius</i>	<i>Amaurolithus delicatus</i>	<i>Catinaster coalitus</i>	<i>Discoaster bergrenii</i>	<i>Discoaster berggrenii berggrenii</i>	<i>Discoaster berggrenii extensus</i>	<i>Discoaster bollii</i>	<i>Discoaster hamatus</i>	<i>Discoaster loeblichii</i>	<i>Discoaster neohamatus</i>	<i>Discoaster pentaradiatus</i>	<i>Discoaster pentabollii</i>	<i>Discoaster prepentaradiatus</i>	<i>Discoaster quinquaramus</i>	<i>Discoaster styzenii</i>	<i>Discoaster surculus</i>	<i>Discoaster wisei</i>	<i>Minylitha convallis</i>	<i>Reticulofenestra rotaria</i>	<i>Reticulofenestra umbilicus</i> (>7µm)
CN9b	0.00-0.33	0'0"-0'1"	V	G	R										C			A	R	C			R	
	0.46-0.48	1'6"-1'7"	V	G	R	R			C						C			A	R	C			R	
	0.91-0.94	3'0"-3'1"	V	G		R			C	F		R			C			C	R	F			R	
CN9a	1.37-1.40	4'6"-4'7"	V	G				F	F	C		F	R	F				F		F				
	1.85-1.88	6'1"-6'2"	V	G				F	C	A		R	R	F				F	R	F				
	2.29-2.31	7'6"-7'7"	V	G					C			R	R	F				C	R			F		
	2.95-2.97	9'8"-9'9"	V	G								R	R	F				R				F		
CN8b	3.35-3.38	11'0"-11'1"	V	G								R	F	F								C	C	
CN8a	3.78-3.81	12'5"-12'6"	V	G									F	R		C		R				C	C	
CN7b	4.27-4.29	14'0"-14'1"	V	G		R				C	R		F		R	F		R		F	F		C	

Table 1: Distribution of selected nannofossils in Exxon Core CH30-43-2. V = very abundant; A = abundant; C = common; F = few; R = rare. For preservation, G = good

age is taken from Young's (1999) compilation, and has been calibrated with magnetostratigraphy in different oceans (see Wei, 1995, p.296, fig.6);

- the top of *Reticulofenestra rotaria* at 6.1Ma (age from Young's (1999) compilation). This study provides probably the first documentation of the species in the Gulf of Mexico (Table 1);
- the top of *Discoaster berggrenii* at 6.2?Ma. The age is a rough estimate based on a slightly lower stratigraphic level than the top of *R. rotaria* (6.1Ma) in Core CH30-43-2 (Table 1). See taxonomic discussion below for the species concept of *D. berggrenii*;
- the top of *Discoaster loeblichii* at 6.6Ma (age from Young's (1999) compilation); the top of *Discoaster berggrenii extensus* at 6.6?Ma. The latter age is a rough estimate based on the co-occurrence of the datum with the top of *D. loeblichii* in Core CH30-43-2 (Table 1), although current sample resolution is insufficient to reveal the precise relationship between the two datums. See taxonomic discussion below for the definition of the new subspecies (*D. berggrenii extensus*);
- the top of *Discoaster bergrenii* at 7.2?Ma; the bottom of the *Amaurolithus primus-A. delicatus* group at 7.2Ma (age from Young, 1999). The age for the top of *D. bergrenii* is a rough estimate based on the co-occurrence of the datum with the bottom of the *A. primus-A. delicatus* group in Core CH30-43-2 (Table 1). Cur-

rent sample resolution is insufficient to reveal the precise relationship between the two datums. See taxonomic discussion below for the species concept of *D. bergrenii*;

- the tops of *Minylitha convallis* and *Discoaster neohamatus* and the bottom of *Discoaster surculus* at 7.8Ma (age from Young, 1999);
- the bottoms of *D. berggrenii* and *D. bergrenii* at 8.2?Ma. This age is based on their stratigraphic position (Table 1) between the tops of *M. convallis* and *D. neohamatus* (7.8Ma) and the bottom of *Discoaster quinquaramus* (8.5Ma: Young, 1999);
- the bottom of *Discoaster quinquaramus* at 8.5Ma (age from Young, 1999);
- the top of the first *Reticulofenestra pseudoumbilicus* (>7µm) at 9.0Ma (age from Young, 1999). This may also be called the bottom of an upper Miocene interval without *R. pseudoumbilicus* (>7µm);
- the top of *Discoaster prepentaradiatus* and the bottom of *Discoaster loeblichii* at 9.2?Ma. This age is estimated based on their stratigraphic position (Table 1) between the top of the first *R. pseudoumbilicus* (>7µm) at 9.0Ma and the top of *Discoaster hamatus* (9.4Ma: Young, 1999);
- the top of *Discoaster hamatus* at 9.4Ma (Young, 1999); the tops of *Discoaster bollii*, *D. wisei* and *Catinaster coalitus*, and the bottom of *D. pentaradiatus* at 9.4?Ma. The latter age is a rough estimate based on

the co-occurrence of these datums with the top of *D. hamatus* (9.4Ma) in Core CH30-43-2 (Table 1), although sample resolution is insufficient to reveal the precise relationship among these datums.

It is interesting to note that this Upper Miocene interval of over 2my duration is found within about 4m of core, and thus it appears to be an unusually condensed interval. Explanations might include coring artefact, significant hiatuses, and very low sedimentation rates over this interval. Since the interval was captured within one core, and there is a remarkable succession of multiple nannofossil datums through the interval, omission of significant core material or presence of significant hiatuses within the core appears to be unlikely. The more likely explanation is truly low sedimentation rates due to prevailing palaeoceanographic conditions (e.g. strong currents, winnowing, etc.) at the site in the Late Miocene. This may have significant palaeoceanographic implications, but the subject is beyond the scope of the present article.

4. Taxonomy

Discoaster quinquaramus-*D. berggrenii*-*D. bergrenii* group: It has been widely known or assumed that there is morphological gradation among the taxa within this group. However, it has been unclear or there have been large disagreements about the species concepts and the sequence of species events for different taxa within this group. For instance, *D. bergrenii* has been rarely reported in the literature and the species was not included in some of the most comprehensive treatments of the genus or the group (e.g. Perch-Nielsen, 1985; Raffi *et al.*, 1998). There has been considerable confusion in the literature about the difference between *D. berggrenii* and *D. quinquaramus*. Only the top and bottom of the group have been commonly used for biostratigraphy (Martini, 1971; Perch-Nielsen, 1985; Young, 1999).

Here, some of the more distinct, and presumably the more useful, species and subspecies of the group are

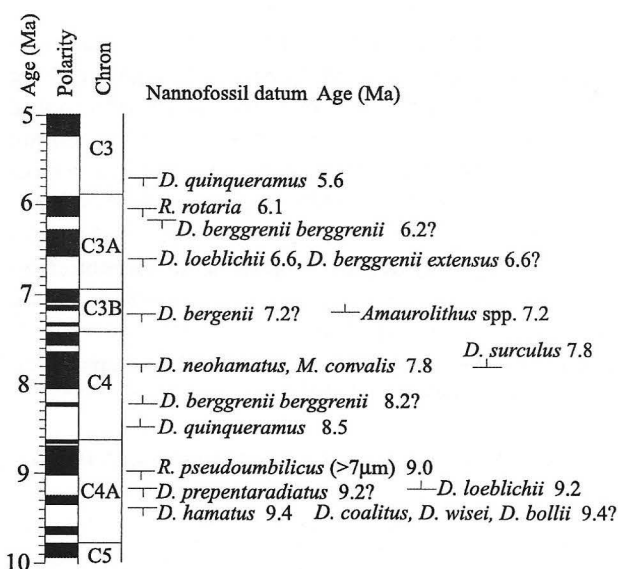


Figure 2: Summary of Upper Miocene nannofossil datums and their ages that may be applicable in the Gulf of Mexico. Ages are given in the time-scale of Berggren *et al.* (1995). See text for discussion of individual datums and ages

documented in both micrographs (Plate 1, Figures 1-8) and the range-chart (Table 1). A total of six species-events within the group can be used to subdivide the Late Miocene in the Gulf of Mexico (Figure 2), when the species concepts described below are adopted.

Discoaster bergrenii (Plate 1, Figure 1): A discoaster with five tapering, non-bifurcated rays, a prominent inter-ray star, which frequently extends beyond the central area, and with the free rays of the discoaster up to half of the diameter of the central area.

Discoaster berggrenii berggrenii n. subsp. (Plate 1, Figures 4, 5): A discoaster with five tapering, non-bifurcated rays, a prominent inter-ray star (see SEM micrograph of Perch-Nielsen, 1985, fig.33.8) on the distal side, a prominent, 5-element central knob on the proximal side, and with the five elements aligned with the rays of the discoaster; the free rays of the discoaster are longer than half of the diameter of the central-area.

Discoaster berggrenii extensus n. subsp. (Plate 1, Figures 2, 3): A subspecies of *D. berggrenii* with a prominent inter-ray star slightly extending beyond the central area. It differs from *D. bergrenii* in having longer free rays (longer than half of the diameter of the central area) and from *D. berggrenii berggrenii* by possession of a prominent inter-ray star slightly extending beyond the central area, and shorter free rays (50-100% the diameter of the central area).

Discoaster quinquaramus (Plate 1, Figures 7, 8): A discoaster with five tapering, non-bifurcated rays and a prominent, five-element central knob; the five elements of the central knob are aligned with the rays of the discoaster (see SEM micrograph of Perch-Nielsen, 1985, fig.33.9). The species lacks a distal inter-ray star, which is present in *D. berggrenii* and *D. bergrenii*, and this is probably the most fundamental difference between *D. quinquaramus* and *D. berggrenii* or *D. bergrenii*. The free rays of the discoaster in *D. quinquaramus* are longer than the diameter of the central-area. In other words, *D. berggrenii* can be easily distinguished from *D. quinquaramus* by having an inter-ray star, the elements of which are aligned *between* the discoaster rays rather than aligned *with* the discoaster rays, as in the central knob in *D. quinquaramus*. Furthermore, the central-area of *D. quinquaramus* is generally minimal, or practically non-existent, whereas the central-area is relatively wide (up to two times the length of the discoaster rays) in *D. berggrenii*.

Other new taxonomic observations from Core CH30-43-2 are described below (in alphabetical order):

Discoaster pentabollii n. sp. (Plate 1, Figures 13, 14): Similar to *Discoaster bollii* but with only five rays, rather than six rays as in the latter species. The former species probably has been included in the latter one in some previous studies. Here, it has been separated out as a new species because: (1) it can be easily distinguished from the latter species; (2) sufficient specimens (>10) occur in one sample to allow a reasonable understanding of its general characteristics; and (3) its biostratigraphic range and palaeoecological parameters are likely to be different from those of *D. bollii* and thus it may be potentially valuable to record the species separately.

Discoaster prepentaradiatus emended (Plate 2,

Figures 3, 4): The original (Bukry & Percival, 1971) and subsequent descriptions of this species all emphasised the bifurcations of the rays but with no mention of a central knob. However, many specimens of this species do not show bifurcations (just as many specimens of *Discoaster pentaradiatus* do not show bifurcations) and many specimens of *D. prepentaradiatus* have a central knob (see Plate 1, Figure 4).

Discoaster neohamatus: The original description of this species (Bukry & Bramlette, 1969) gave a size-range of 10-15 µm. Here, specimens as large as 30 µm (Plate 1, Figure 15), twice the size of the maximum value originally given, are documented and thereby the size-range of this species is emended.

Discoaster styzenii n. sp. (Plate 2, Figures 5-8): A discoaster with four slender, tapering rays. Typically, the rays are bifurcated at the ends, the discoaster is asymmetrical, and there is a knob in the central area (although not all these features are present in some specimens). These features differ from those of *Discoaster tamalis*. The latter species is limited to the Late Pliocene (e.g. Perch-Nielsen, 1985; Young, 1999), and the two species do not overlap in stratigraphy. This species has also been observed in the *Discoaster hamatus* zone (CN7 or NN9) of the Cipero section, Trinidad.

Discoaster wisei (Plate 2, Figures 9-12, 19): A six-rayed discoaster with prominent central ridges extending to the ends of the rays. The central-area is relatively large, with no prominent central star or knob (only an indistinct star or knob in some specimens). This species has also been observed in the *D. hamatus* zone (CN7 or NN9) of the Cipero section, Trinidad.

5. Systematic palaeontology

Genus *Discoaster* Tan, 1927

Discoaster berggrenii ssp. *berggrenii* n. subsp.

Plate 1, Figures 4, 5

Description: A subspecies of *D. berggrenii* with free ray length which is longer than the diameter of the central area.

Remarks: This subspecies has a longer stratigraphic range than the subspecies *Discoaster berggrenii extensus* n. subsp. (see below).

Holotype: Pl.2, fig.6 of Bukry (1971).

Type locality: DSDP 3-9-3, 75 cm, Gulf of Mexico.

Discoaster berggrenii ssp. *extensus* n. subsp.

Plate 1, Figures 2, 3

Derivation of name: Latin, *extensus*, extend, referring to the inter-ray star extending beyond the central area.

Description: A subspecies of *D. berggrenii* with a prominent inter-ray star extending beyond the central area. Its free rays are between 50 and 100% of the diameter of the central area.

Remarks: This subspecies differs from *D. berggrenii* by possessing longer free rays (longer than half of the diameter of the central area) and from *D. berggrenii* ssp. *berggrenii* by having a prominent inter-ray star, extending

slightly beyond the central area, and shorter free rays (50-100% of the diameter of the central area).

Occurrence: This subspecies has a shorter stratigraphic range than *D. berggrenii* ssp. *berggrenii*, with its top near that of *Discoaster loeblichii* at about 6.6Ma.

Holotype: Plate 1, Figure 2 (FSU-CH30-43-2-1-2).

Type locality: Exxon Corehole CH30-43 in the Gulf of Mexico (28°01.1'N, 86°24.7'W), Sample CH30-43-2, 1.85-1.88m.

Discoaster pentabollii n. sp.

Plate 2, Figures 13, 14

Derivation of name: *Penta*, refers to the five rays of the discoaster.

Description: Five-rayed discoaster with a large, stellate stem and a relatively large central-area. The rays are bifurcated.

Remarks: This species is most similar to *Discoaster bollii* (most likely recorded as such in previous studies) but is quite distinct in having five rays, rather than six rays as in the latter species. It differs from other five-rayed discoasters by possessing a large, stellate stem, relatively large central-area, and bifurcated rays.

Occurrence: This species has been found in CN7 or NN9.

Holotype: Plate 1, Figure 14 (FSU-CH30-43-2-1-14).

Type locality: Exxon Corehole CH30-43 in the Gulf of Mexico (28°01.1'N, 86°24.7'W), Sample CH30-43-2, 4.27-4.29m.

Discoaster prepentaradiatus Bukry & Percival, 1971, emended

Plate 2, Figures 3, 4

Discoaster prepentaradiatus Bukry & Percival, 1971: p.129, pl.3, figs 6, 7.

Description: Medium-sized, long-rayed, with virtually no developed central area and five rays in one plane. Rays commonly show widely-splayed, short bifurcations. Unlike *Discoaster pentaradiatus*, it shows uniform low birefringence in cross-polarised light.

Remarks: The original (Bukry & Percival, 1971) and subsequent descriptions of this species all emphasised the bifurcation of the rays but with no mention of a central knob. However, many specimens of this species do not show bifurcations (just as many specimens of *Discoaster pentaradiatus* do not show bifurcations), and many specimens of *D. prepentaradiatus* have a central knob. It differs from *D. pentaradiatus* by showing uniform birefringence, whereas *D. pentaradiatus* discoasters show slightly different birefringence of each ray.

Occurrence: This species has a relatively short stratigraphic range, within CN7-CN8.

Discoaster neohamatus Bukry & Bramlette, 1969, emended

Plate 1, Figures 15, 16

Discoaster neohamatus Bukry & Bramlette, 1969: p.133, pl.1, figs 4, 5.

Description: Medium- to large-sized, six slender rays all

bending consistently in one direction and terminating in points. Central area small with no knob.

Remarks: The original description of this species (Bukry & Bramlette, 1969) gave a size-range of 10-15µm. The size of this species is emended here to range up to 30µm (large size) (see Plate 1, Figure 15).

Occurrence: CN7-CN9.

***Discoaster styzenii* n. sp.**

Plate 2, Figures 5-8

Derivation of name: In honour of Michael Styzen for his significant contribution to Gulf of Mexico Neogene nannofossil biostratigraphy.

Description: A discoaster with four slender, tapering rays. Typically, the rays are bifurcated at the ends, the discoaster is asymmetrical, and there is a knob in the central-area.

Remarks: This species is similar to *Discoaster tamalis*, but differs from the latter by its asymmetric and bifurcated rays, and the presence of a central knob (although not all of these features are present in some specimens of *D. styzenii*). *D. tamalis* is limited to the Upper Pliocene (e.g. Perch-Nielsen, 1985; Young, 1999) and the two species do not overlap in stratigraphy. It differs from another four-rayed Neogene discoaster, *Discoaster quadramus* (Bukry, 1973), in having asymmetric rays rather than the regular angles of 60° and 120° in *D. quadramus*. The latter species was described from the Pliocene (Bukry, 1973), and is probably limited to the Pliocene, whereas *D. styzenii* appears to be limited to the Miocene.

Occurrence: *Discoaster styzenii* has been observed in CN7-CN9 in Core CH30-43-2 in the Gulf of Mexico and in CN7 of the Cipero section, Trinidad.

Holotype: Plate 2, Figure 8 (FSU-CH30-43-2-2-8).

Type locality: Exxon Corehole CH30-43 in the Gulf of Mexico (28°01.1'N, 86°24.7'W), Sample CH30-43-2, 3.78-3.81m.

***Discoaster wisei* n. sp.**

Plate 2, Figures 9-12, 19

Derivation of name: In honour of Sherwood W. Wise, Jr. for his significant contribution to nannofossil palaeontology, especially in nannofossil education.

Description: Six tapering rays with prominent central ridges extending to the end of the rays. The central-area is relatively large, with no prominent central star or knob.

Remarks: This species is quite distinctive, with its prominent central ridges and relatively large central-area, and differs from other large-bodied, six-rayed discoasters by the lack of a prominent central star or knob, as in *Discoaster musicus*/*Discoaster sanmiguelensis*, and *Discoaster intercalaris*. It differs from *Discoaster exilis* in possessing a relatively large central-area and prominent central ridges; *D. exilis* has a very small central-area, and faint ridges extending radially to one side of the median line.

Occurrence: *Discoaster wisei* has been observed in CN7 in Core CH30-43-2 in the Gulf of Mexico, as well as in the Cipero section, Trinidad.

Holotype: Plate 2, Figures 10, 11 (FSU-CH30-43-2-2-10, FSU-CH30-43-2-2-11).

Type locality: Exxon Corehole CH30-43 in the Gulf of Mexico (28°01.1'N, 86°24.7'W), Sample CH30-43-2, 4.27-4.29m.

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Plate 1

All images have the same magnification, which is indicated by the scale-bar

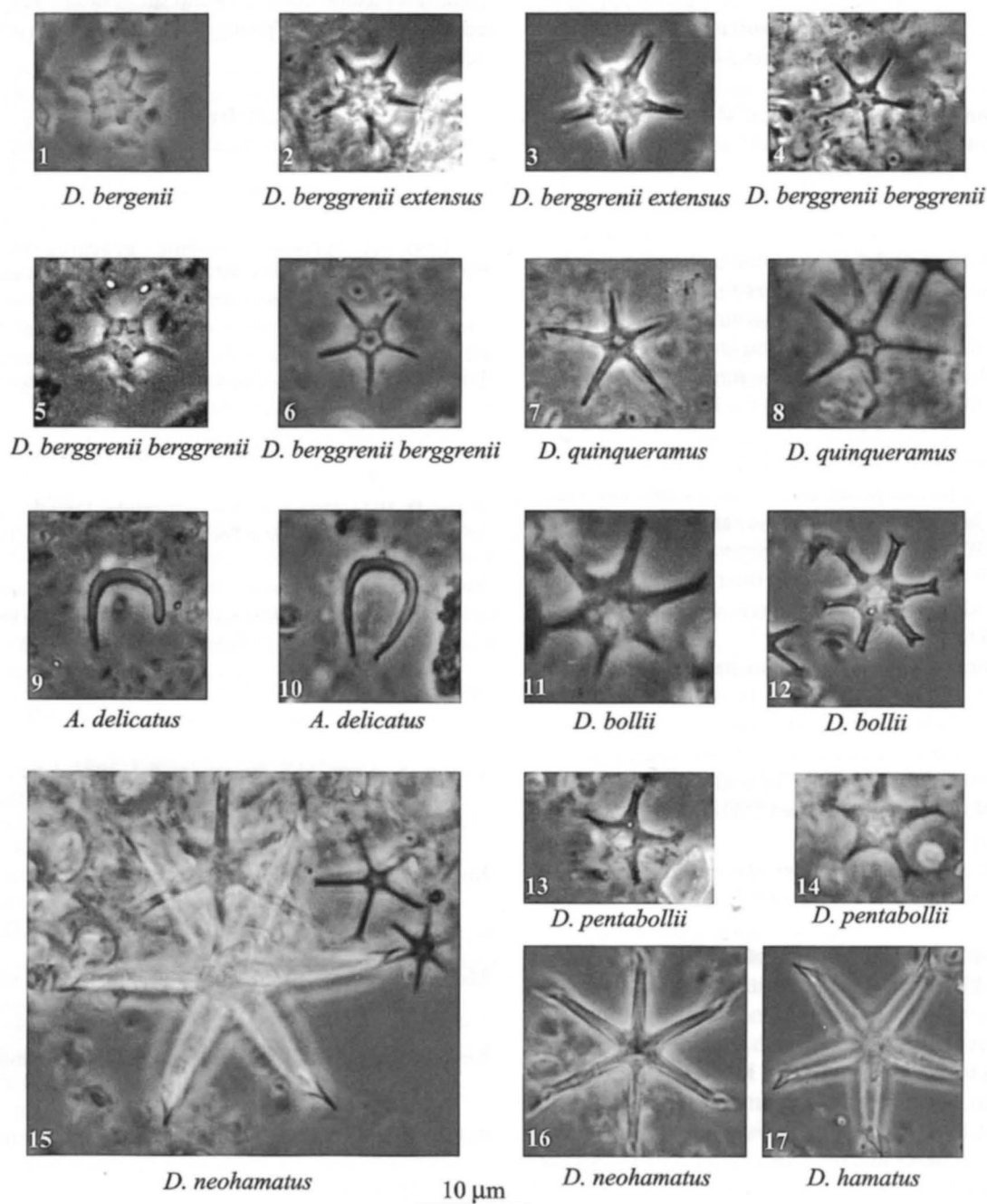


Fig.1: *Discoaster bergonii*. Sample CH30-43-2, 1.85-1.88m. **Figs 2,3:** *Discoaster berggrenii extensus* n. subsp. Sample CH30-43-2, 1.85-1.88m; 2, holotype. **Figs 4-6:** *Discoaster berggrenii berggrenii* n. subsp. Sample CH30-43-2, 0.91-0.94m; 5, 6, same specimen, 5, focus on the inter-ray star on the distal side, 6, focus on the knob on the proximal side. **Figs 7, 8:** *Discoaster quinquaramus*. Sample CH30-43-2, 0.91-0.94m. **Figs 9, 10:** *Amaurolithus delicatus*. Sample CH30-43-2, 0.91-0.94m. **Figs 11, 12:** *Discoaster bollii*. Sample CH30-43-2, 4.27-4.29m. **Figs 13, 14:** *Discoaster pentabollii* n. sp. Sample CH30-43-2, 4.27-4.29m; 14, holotype. **Figs 15, 16:** *Discoaster neohamatus*. Sample CH30-43-2, 3.35-3.38m. **Fig.17:** *Discoaster hamatus*. Sample CH30-43-2, 4.27-4.29m.

Plate 2

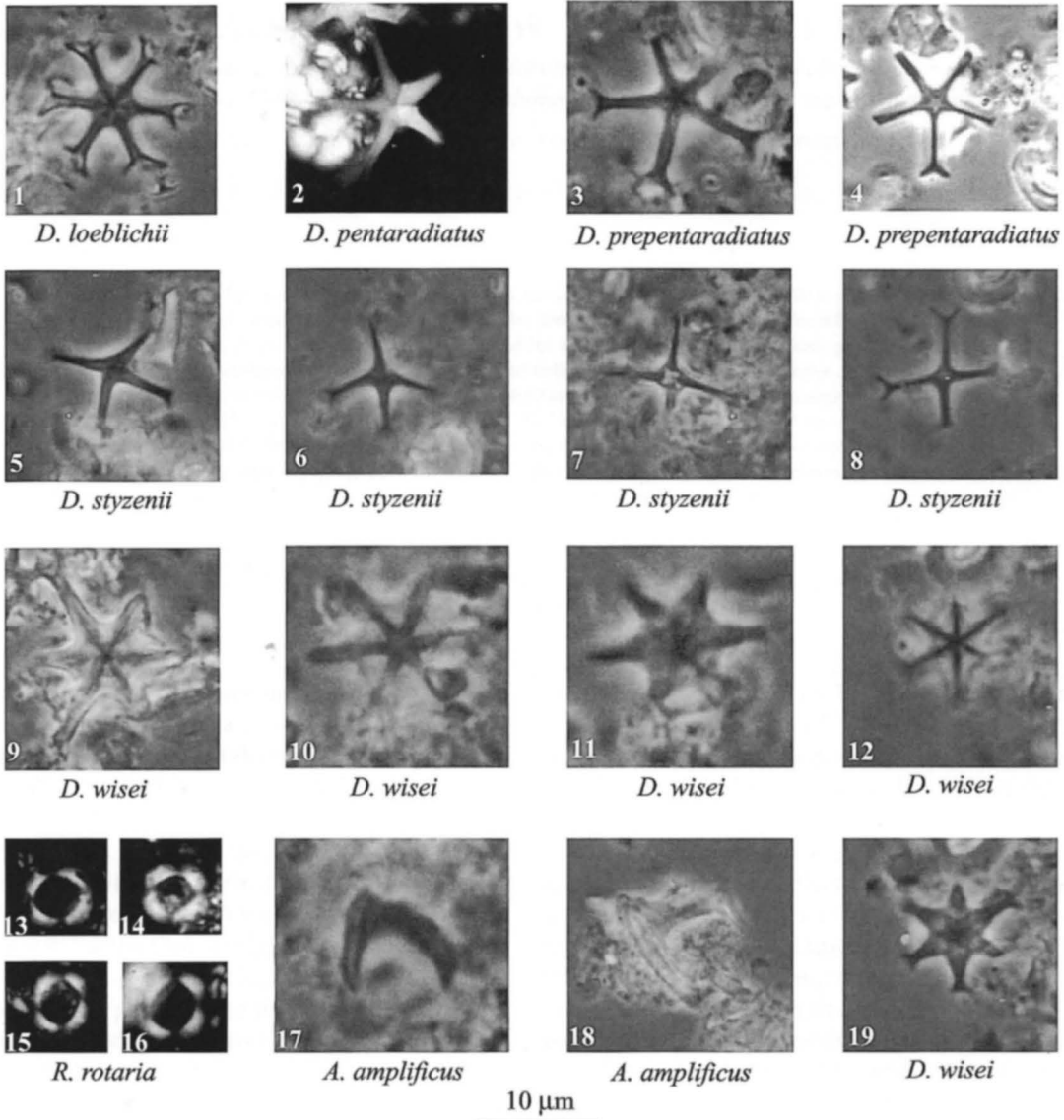


Fig.1: *Discoaster loeblichii*. Sample CH30-43-2, 3.35-3.38m. **Fig.2:** *Discoaster pentaradiatus*. Sample CH30-43-2, 3.35-3.38m. **Figs 3, 4:** *Discoaster prepentaradiatus*. Sample CH30-43-2, 3.78-3.81m. **Figs 5-8:** *Discoaster styzenii* n. sp. Sample CH30-43-2, 3.78-3.81m; 8, holotype. **Figs 9-12, 19:** *Discoaster wisei* n. sp. Sample CH30-43-2, 4.27-4.29m; 10, 11 (holotype), same specimen with different focus levels; 12, 19, same specimen with different focus levels. **Figs 13-16:** *Reticulofenestra rotaria*. Sample CH30-43-2, 0.46-0.48m (13, 14); sample CH30-43-2, 0.91-0.94m (15, 16). **Figs 17, 18:** *Amaurolithus amplificus*. Sample CH30-43-2, 0.46-0.48m.