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10. Biostratigraphy of Late Miocene–Early Pliocene Radiolarians from ODP Leg 183 Site 1138[1]

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ABSTRACT

Well-preserved radiolarian assemblages of late middle Miocene to early Pliocene age are found in Ocean Drilling Program (ODP) Hole 1138A (Cores 183-1138A-12R to 20R), which was rotary drilled into the Central Kerguelen Plateau. The faunas are typical for Antarctic assemblages of this time interval, and the site appears to have been south of the Polar Front during the time period studied. Despite only moderate drilling recovery of the section, most late middle to early Pliocene radiolarian zones are present, although at the sample resolution used, subzones could not be identified. A significant discontinuity in the section is present at the boundary between lithologic Units I and II (between Cores 183-1138A-12R and 13R), corresponding to an interval from at least 4.6 to 6.1 Ma. Mixed late Miocene–early Pliocene assemblages are seen in the base of Core 183-1138A-12R (Sample 183-1138A-12R-3, 20 cm), and the overlying basal Pliocene Tau Zone appears to be absent. It cannot be determined if the discontinuity is due to incomplete recovery of the section and drilling disturbance or if it reflects a primary sedimentary structure—a hiatus or interval of condensed sedimentation.

INTRODUCTION

Radiolarian faunas have frequently been used in Antarctic Neogene biostratigraphy, beginning with the work of Hays (1965), Chen (1975), and the more recent work of Abelmann (1990, 1992), Caulet (1991),

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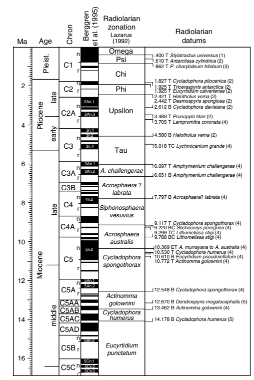
and Lazarus (1990, 1992). Because of the highly endemic nature of Antarctic Neogene radiolarian faunas, calibration of the events by direct comparison to low-latitude zones has not proved feasible. Diatom floras are similarly affected, and, for at least the later Neogene, it is not possible to use standard low-latitude planktonic foraminifers or calcareous nannofossil events for calibration purposes, as the marker taxa are generally absent in Southern Ocean sediments. The calibration of the current zonation (Fig. F1) to the geologic timescale is largely based on the biomagnetostratigraphic syntheses of Ocean Drilling Program (ODP) Legs 113, 119, and 120 (Gersonde et al, 1990; Barron et al., 1991; Harwood et al., 1992). In these previous studies, some uncertainties remain, particularly in the ranges and calibration of taxon events in the latest Miocene and early Pliocene intervals, where hiatuses have made interpretation of the sections difficult. Obtaining a clear picture of the true sequence of events requires piecing together data from a large number of (individually incomplete) sections. During ODP Leg 183 at Site 1138, a section was recovered from the Kerguelen Plateau with well-preserved radiolarian faunas of late Miocene to early Pliocene age. We have studied these faunas with the dual aims of providing age estimates for this site and documenting the ranges of species during this time interval in a section that may eventually assist in resolving the remaining uncertainties in the Antarctic Neogene radiolarian zonation. In this paper, we report the primary stratigraphic results for the site. Comparative analysis with other Antarctic sites will be the subject of a future paper.

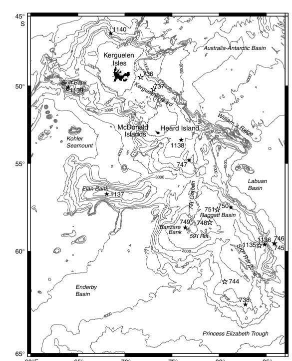
F1. Neogene radiolarian biostratigraphy, p. 9.



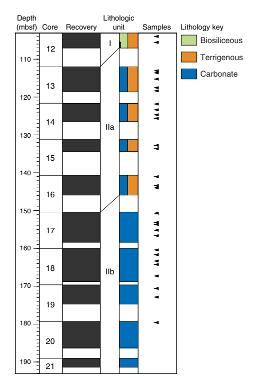
MATERIALS

Site 1138, located north of Site 747 (Leg 120) on the Central Kerguelen Plateau (Fig. F2), reached nearly 900 meters below seafloor (mbsf), retrieving Cretaceous basement rock and ~700 m of sediment, mostly chalk, clay, and ooze. This study is based on 30 sediment samples, taken at a resolution of ~1 per section from Cores 183-1138A-12R to 20R from the single hole drilled at this site (Fig. F3). The samples range in depth from ~105 to 230 mbsf, an interval initially determined to be of late Miocene and younger age (Shipboard Scientific Party, 2000). The sediment, described on board as diatom clay, foraminifer-bearing nannofossil clay, and foraminifer-bearing nannofossil ooze, is also rich in radiolarians and other siliceous microfossils (Shipboard Scientific Party, 2000). The interval chosen for this study includes the lowermost part of lithologic Unit I (diatom clay in Core 183-1138A-12R) and the upper part of lithologic Unit II (nannofossil clay and ooze; Cores 183-1138A-13R to 20R). Recovery of sediments in this interval was only moderate (~50%) because of the use of rotary coring technology, which limits the resolution of any biostratigraphic study of the section.

F2. Location map, p. 10.



F3. Interval, recovery, and lithology, p. 11.



METHODS

Between 1.5 and 6.5 g of dried sediment from each sample was treated with sodium pentaphosphate and H_2O_2 (to disperse the sediment), heated, placed in an ultrasonic bath for ~5 s, and sieved to retain only material >45 µm. Calcareous material was removed with HCl, and heating, ultrasound, and sieving were repeated twice more. Each sample was randomly distributed on gelatin-coated coverslips after the settling method of Moore (1973), using the coverslip holders of Lazarus (1994), and the coverslips were fixed to slides with Canada balsam. For each sample, two slides were prepared and at least half of one slide was examined, depending on radiolarian abundance, mostly with a Zeiss Axioskop at magnifications between 100× and 640×.

Overall abundances of radiolarians as well as those of other material, particularly pennate diatoms, centric diatoms, silicoflagellates, and lithic fragments (including ash) were noted (Table T1). The amount of dry sediment used per square millimeter of slide surface was calculated for each sample and is also listed in Table T1 as an aid to future use of the slides in quantitative analysis.

T1. Radiolarian range chart, p. 12.

Although a broad range of species of radiolarians is present in each slide, attention was most closely paid to known stratigraphically significant species. Presence (or absence) of these species was noted in the form of estimates of their relative abundances (described as abundant, common, few, or rare; each rank being approximately four times as numerous as the next rank [Lazarus, 2001]). Most images of specimens for plates were captured digitally with a Sony black-and-white video camera with 400 lines of resolution and a Hauppage WinTV Frame Grabber Card at a 640 pixel × 480 pixel resolution. A few were captured with an Olympus DP/50 digital camera and BX51 microscope at resolutions up to 6 Mpixel. The digital pictures have been adjusted for contrast, brightness, and pixel resolution but have not been otherwise altered.

RESULTS

General Abundance and Preservation of Microfossils and Other Coarse-Fraction Components

The presence of radiolarian taxa, together with general information on coarse-fraction composition, are given in Table T1. Almost all slides contained common to abundant well-preserved or moderately well preserved radiolarians. Both pennate and centric diatoms were common to abundant in many slides but were rarely so abundant as to significantly obscure or dilute the radiolarian faunas. Silicoflagellates, sponge spicules, and lithic fragments (both ash and rock fragments) were more sporadically present, although they were common in some intervals in the section. No obvious relationship between the presence of these latter components and other aspects of the assemblages (abundance and preservation of radiolarians and diatoms) could be detected.

Radiolarian Assemblages and Taxonomy

Radiolarian faunas from Site 1138 are all of a typical Neogene Antarctic biogeographic affinity, with robust, high optical contrast shells and a dominance of prunoids (Pylonidae), Actinommidae, and Plagiacanthidae, particularly members of the genus *Antarctissa* (Lazarus and Caulet, 1994). No subantarctic faunas were observed. The standard stratigraphic marker species (Lazarus, 1992) for this time interval were all seen and in most samples were easily identifiable. In addition to the standard marker species, we noted the distribution of several other common taxa that are typical of late Miocene to early Pliocene Antarctic radiolarian faunas and include as well one species—*Cenosphaera* sp. Keany (1979)—whose presence has until now not been reported in

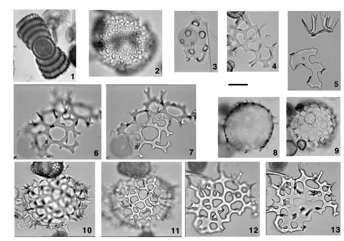
Deep Sea Drilling Project (DSDP) or ODP sections, but whose distribution may be of stratigraphic value. Except as noted below, all taxonomic concepts used are those given in Lazarus (1990, 1992). Some difficulties were noted with certain taxa in determining the morphologic limits to closely related species, which make the precise placement of some of the first appearance datums (FADs) and last appearance datums (LADs) difficult.

Also, in many slides at least some specimens were seen that partly fit a species description but that have characteristics that exclude them from being positively identified. Such specimens are marked on a chart by a question mark (?) or by "sl" (sensu latu). Given these occasional taxonomic and preservational problems, an empty cell in the chart indicates that the nominate taxa was not seen, but not that it was necessarily absent. Specific slides were searched to confirm the absence of marker taxa; such data cells are marked with a dash.

Notes on Taxa

Cenosphaera sp. Keany 1979 (Plate P1, figs. 4–13).

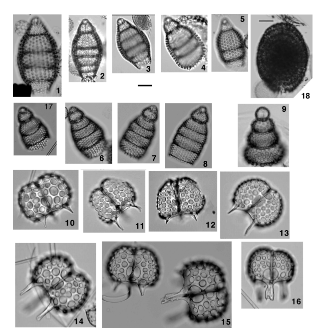
Remarks: although only fragments of this form have been seen in our study, the distinctive short forked radial spines on the outside of the cortical shell and the moderately large, irregular pores strongly resemble a form illustrated by Keany (1979), which he referred to as *Cenosphaera* sp. Chen (Chen, 1975). Chen's (1975) illustration, however, does not appear to have either the forked spines or irregular pores of Keany's form, and we believe the two are not conspecific. *Cenosphaera* sp. Keany 1979 appears to have a restricted stratigraphic range in the Antarctic, although further work is needed to ensure that this species can be reliably distinguished from *Heliosomma watkinsi* Keany 1979, even in fragmentary specimens. The latest Miocene (basal Gilbert magnetochron) absolute age range assigned to this species by Keany is questionable, as it was found by him only in a single piston core (E34-19) without any other positive biostratigraphic or paleomagnetic evidence that would allow an unambiguous absolute assignment of the section to the geochronologic timescale.



P1. Radiolarians, p. 15.

Prunopyle titan (Plate P2, fig. 18).

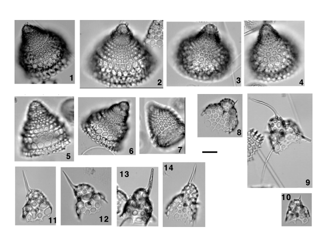
Remarks: specimens rounder than the late Miocene–early Pliocene form of *P. titan* used in Southern Ocean stratigraphy (Lazarus, 1990, 1992) were identified in many slides and are marked in the range chart with a question mark, as it is unclear if they really are conspecific with the marker taxon. It is also unclear if the late Miocene form of *P. titan* is really conspecific with the type specimens of the species, which were described by Campell and Clark (1944) from older North Pacific material.



P2. Radiolarians, p. 16.

Lithomelissa stigi (Plate P3, figs. 8–14).

Remarks: this species' range is discontinous, and it is morphologically very variable. A true *L. stigi* should be small, with large pores and a strong spine to one side. It is likely that more than one species has been included in our study in this category—many specimens identified as *L. stigi* were larger or smaller than usual, had small pores, or had only a very small spine.



P3. Radiolarians, p. 17.

Eucyrtidium cienkowski and *Eucyrtidium calvertense* (Plate P2, figs. 1–8).

Remarks: transitional forms are common in the lower part of the studied section where both the nominate species are present. Farther upsection, specimens that closely resemble *E. cienkowski* but have more ridged walls are found alongside typical *E. calvertense* specimens.

Triceraspyris coronata and *Triceraspyris antarctica* (Plate P2, figs. 10–16)

Remarks: although *T. coronata* was used as a formal stratigraphic marker by Weaver (1983), we have had great difficulty distinguishing this species reliably both from forms similar to *T. antarctica* and to several other forms that differ from typical *T. coronata* in the size of the pores, robustness of the shell, and several other characteristics. Only a very few of our specimens are as robust as those illustrated by Weaver (1983). A revision of the taxonomy of these forms may be needed in order to improve the reliability of *T. coronata* as a stratigraphic marker. See also discussion in Lazarus (1990, p. 716, 1992, p.797).

Cycladophora bicornis and *Cycladophora pliocenica* (Plate P3, fig. 7).

Remarks: transitional forms between *C. bicornis* and *C. pliocenic*a are fairly common in some slides, although *C. pliocenica* sensu stricto is clearly absent in Sample 183-1138A-13R-2, 20 cm, and below and is present in Sample 183-1138A-12R-3, 20 cm.

Cycladophora spongothorax (Plate P3, fig. 16)

Remarks: specimens near the top and bottom of the range frequently have only traces of external sponge. However, they still possess a steplike external profile and externally developed thoracic rings, and thus are considered to belong to this taxon (Lombari and Lazarus, 1988).

BIOSTRATIGRAPHY

The sequence of radiolarian faunal events observed in Hole 1138A (Table T2) is, with one exception, that expected for the late Miocene to earliest Pliocene, with (in order from the base of the studied section to the top) the presence of the *Actinomma golownini, Cycladophora spongothorax, Acrosphaera australis, Siphonosphaera vesuvius, Acrosphaera*? *labrata,* and *Amphymenium challengerae* Zones. The regularity of the sequence is interrupted by the co-ocurrence of several events within a short interval, near the top of the studied interval between Samples 183-1138A-12R-2, 20 cm, and 183-1138A-13-2, 20 cm, corresponding to the boundary between lithologic Units I and II. Several Miocene species (*Stichocorys peregrina, A. labrata, Eucyrtidium pseudoinflatum,* and *Lychnocanium grande*) disappear in this interval, and several others typical of the Pliocene (*Antarctissa cylindrica, Helotholus vema, Lampromitra coronata* and *Cycladophora pliocenica*) appear for the first time (Table T1). The *A. challengerae* Zone is represented here by a single sample with rare *A. challengerae* in Sample 183-1138A-12R-3, 20 cm. The Tau Zone appears to be totally absent, and the marker for the next younger zone—*H. vema*—in fact, is present in the same sample as *A. challengerae.*

T2. Radiolarian biostratigraphic events, p. 14.

Between Samples 183-1138A-13R-4, 105 cm, and 183-1138A-14R-2, 20 cm, another set of events seems to occur within a fairly short depth interval, with the first appearance of *Cenosphaera* sp. Keany (1979), the first common appearance of *S. peregrina,* the disappearance of *L. stigi* and *S. vesuvius,* as well as the last traces of *A. australis.* The LAD of *C. spongothorax* also occurs in, or just below, this interval. Only the latter is is a formally defined stratigraphic marker, and this is present in the expected sequence within the standard zonation.

The marker events for the subzones within the *C. spongothorax* Zone—the LAD of *A. golownini* and the FAD of *E. pseudoinflatum*—could not be resolved at the sampling resolution of this study from the top of the *C. spongothorax* Zone itself. Nor was the occurrence of *Dendrospyris megalocephalis*—the marker for the upper *A. golownini* Subzone—observed.

DISCUSSION AND CONCLUSIONS

The presence of typical Antarctic faunas and consistently good preservation throughout the studied interval suggests that Site 1138 was always located within the Antarctic radiolarian province and thus south of the Polar Front (sensu Lazarus and Caulet, 1994) during the late Miocene interval studied. This is in accord with results from Site 747, also on the Central Kerguelen Plateau but located to the south (Lazarus, 1992). The sporadic and seemingly uncorrelated distribution of other coarse-fraction components, such as sponge spicules and lithic fragments, suggests that dissolution, winnowing, or other bottom processes have not affected the assemblages to a major degree.

Whereas all standard zones (other than the Tau) are identifiable at Site 1138, taxonomic uncertainties near the end of species' ranges make the precise placement of zonal boundaries somewhat imprecise. Site 1138 thus appears to represent an intermediate condition between more southerly Site 747, where Lazarus (1992) reported a well developed zonal pattern, and Site 737 on the northern edge of Kerguelen Plateau, where both Caulet (1991) and Lazarus (1992) encountered difficulties in identifying taxa and applying the standard zonation.

Faunal changes between Cores 183-1138A-12R and 13R, the apparent absence of the Tau Zone, and the presence in Sample 183-1138A-12R-3, 20 cm, of a mixed assemblage from different time intervals of late Miocene and early Pliocene age, all indicate an interval of missing sediment and sediment mixing at the boundary between lithologic Units I and II. The presence of small amounts of nannofossil clay in the lowermost (base of Core 183-1138A-12R) part of lithologic Unit I, which is otherwise of a biosiliceous nature, supports our interpretation of lithologic mixing across the temporal discontinuity. The duration of the discontinuity according to current age calibrations for the radiolarian events is at a minimum 4.6–6.1 Ma. Drilling disturbance is also possible for the mixed assemblage (Sample 183-1138A-12R-3, 20 cm) interval, as it is near the base of the recovered section in Core 183-1138A-12R. Given that Core 183-1138A-12R recovery was significantly incomplete, it cannot be determined from our data alone if the discontinuity originally was a continuous interval of sedimentation, an interval of no accumulation, or an erosional hiatus.

By contrast, the lithologic shift between nannofossil ooze in Core 183-1138A-17R and nannofossil clay in Core 16R does not seem to correspond to any significant change in the radiolarian assemblages or other coarse-fraction components, nor, within the studied interval, do we note any evidence for additional discontinuities in sedimentation.

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Figure F1. Neogene radiolarian biostratigraphy (from A. Weinheimer in Shipboard Scientific Party, 1999).

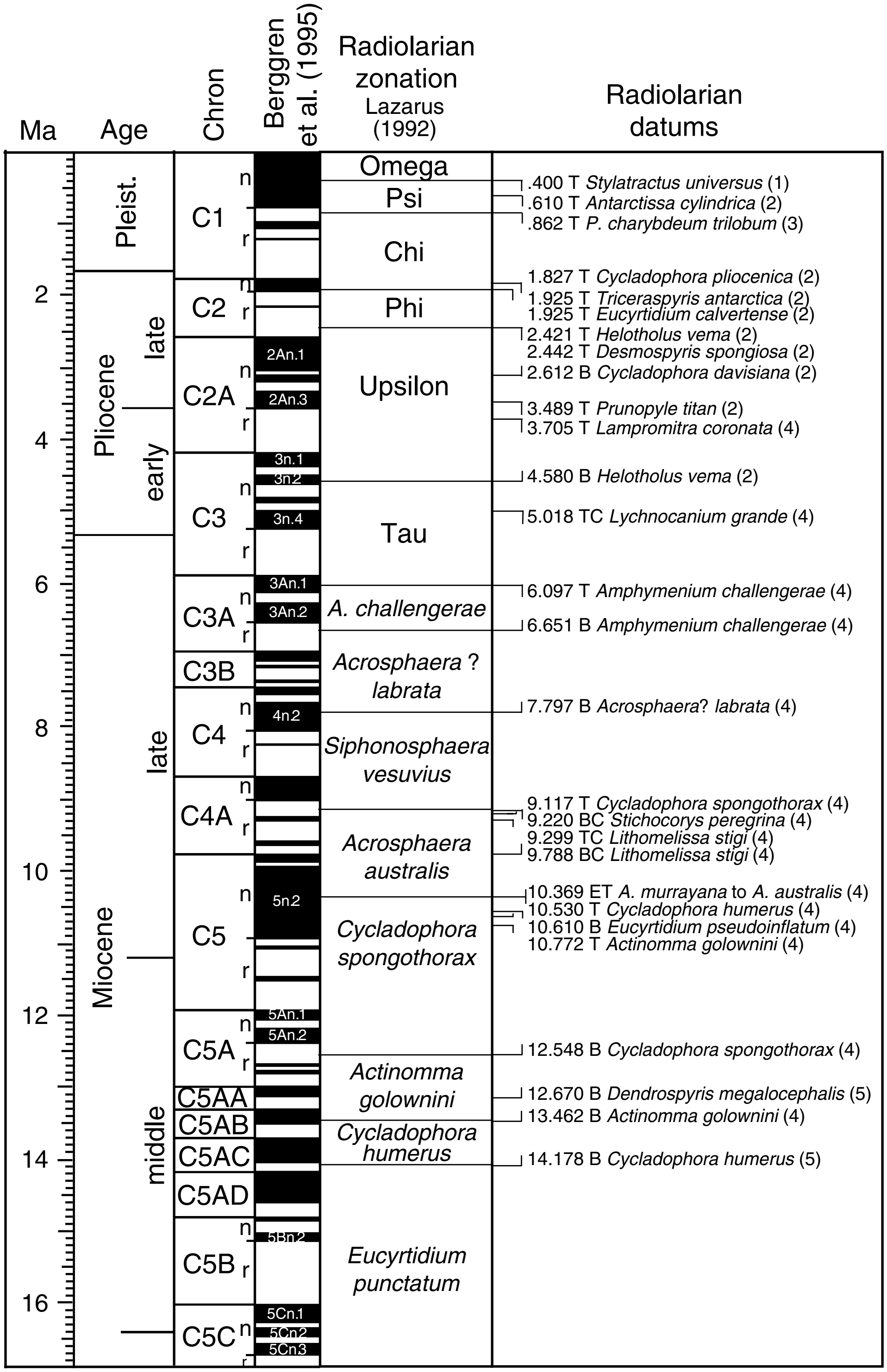

Figure F2. Location map for Site 1138 (from Shipboard Scientific Party, 2000).

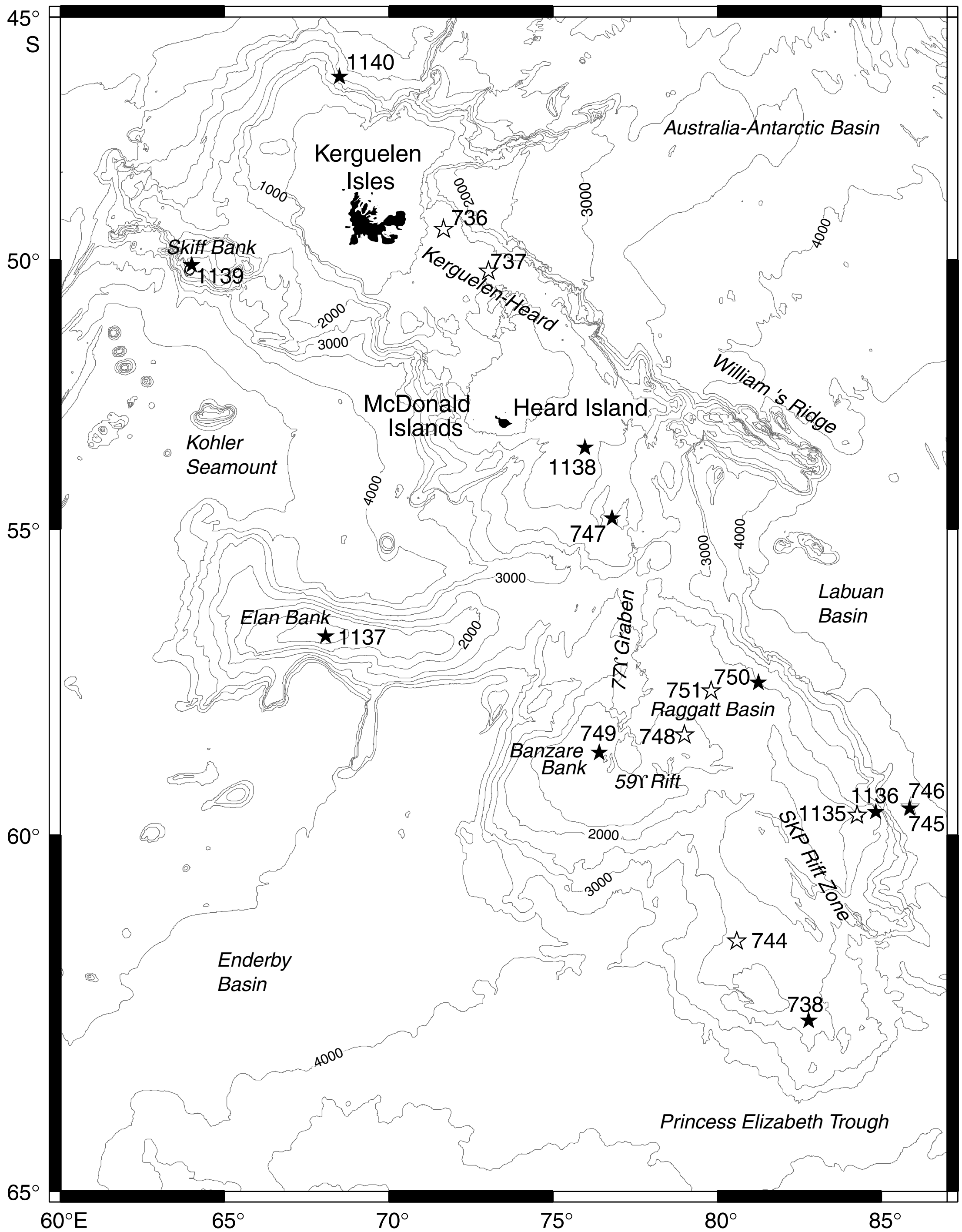

Figure F3. Interval studied, recovery, and lithology, Hole 1138A. Lithologic units are those defined by the shipboard scientists (Shipboard Scientific Party, 2000) and recovery and lithologic column are from core description sheets (Coffin, Frey, Wallace, et al., 2000).

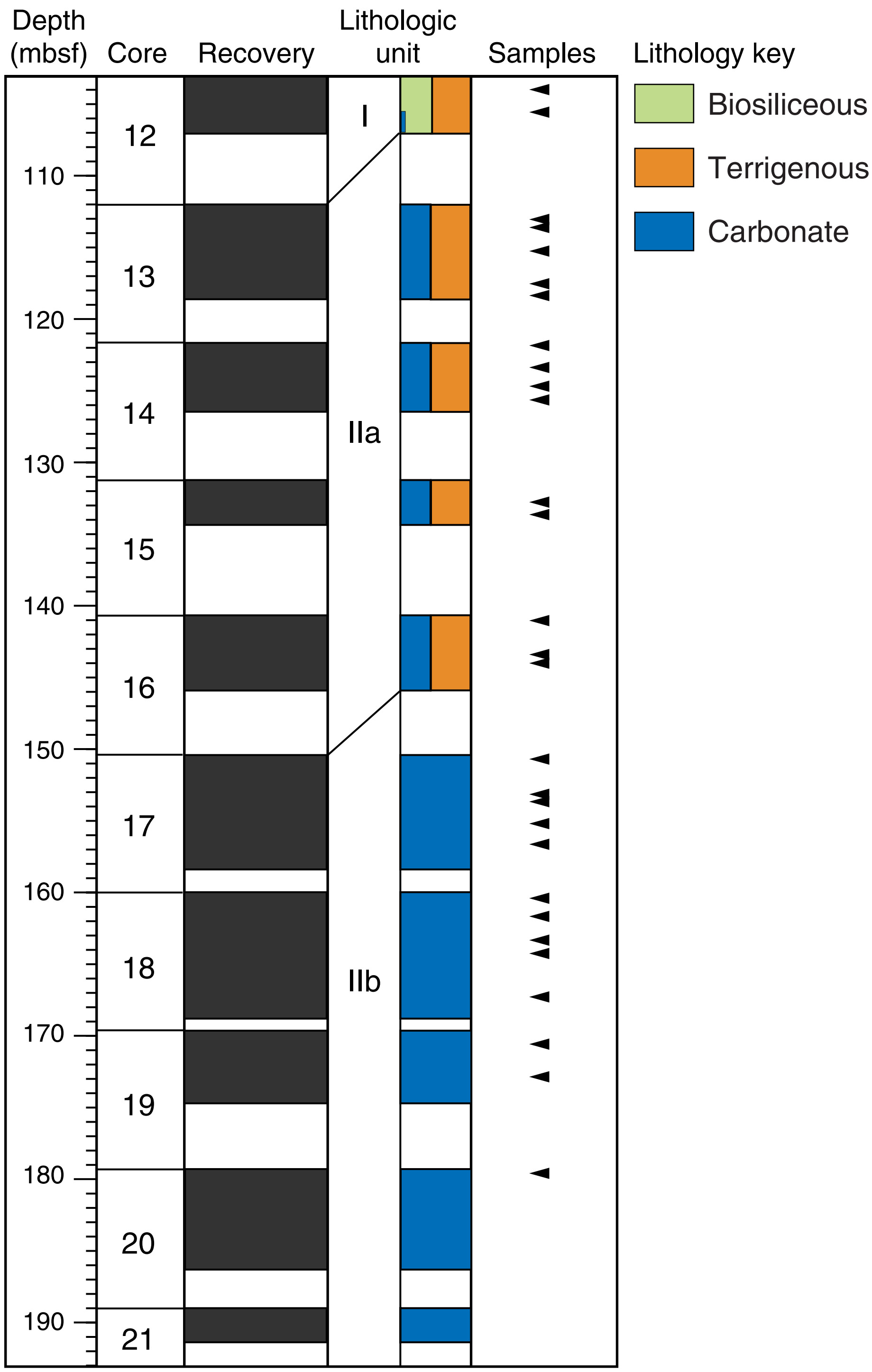

Table T1. Range chart of selected radiolarian taxa, Site 1138. (Continued on next page.)

	Upsilon		?	*A. labrata* Zone				*S. vesuvius* Zone		*A. australis* Zone					
Depth (mbsf)	102.50	104.00	105.50	113.05	113.70	115.20	117.55	118.30	121.80	123.30	124.80	125.65	132.90	133.75	141.00
Core, section, interval (cm)	12R-1, 20	12R-2, 22	12R-3, 20	13R-1, 105	13R-2, 20	13R-3, 20	13R-4, 105	13R-5, 30	14R-1, 20	14R-2, 20	14R-3, 20	14R-3, 105	15R-2, 20	15R-2, 105	16R-1, 20
(mg dry sed)/mm^2	0.096	0.0504	0.168	0.17	0.206	0.1693	0.1379	0.1796	0.1303	0.2169	0.1313	0.1359	0.186	0.0875	0.2155
Radiolarian abundance	A	A	A	F	C	A	C-A	A	C	F	F	F	C	C	F-C
Radiolarian preservation	G	G	M	M	G	M	G	G	G	M	G	G	G	G	M-G
Pennate diatoms	A	C-A	C	F	F	F	C	F	R	F	C	C	C	A	C
Centric diatoms	C	C	A	F-C	C	A	C		F-C	F	C-A	C	A	A	C
Sponge spicules	R	R	C	F		R	F-C	C	F-C	F		C	R	R	F-C
Silicoflagellates	C	R-F	C	R							R	F			
Lithics; volcanic ash	R-F	F-C	C	F	C	C	A	C	C-A	C	F	F	F	F	C
Antarctissa cylindrica	X	C-A	C-A												
Cycladophora pliocenica	—	?	C	?									?		
Helotholus vema	?	R	R		?										
Desmospyris spongiosa	C	F-C	?R		?	?C									
Lampromitra coronata	F	F	F-C		R-F		?	?R-F	o	o?		o			
Stichocorys peregrina			R	F-C	F	C	A	A	C	o					
Amphymenium challengerae			R												
Acrosphaera labrata		?sl	F	?	R	R-F	F	—	—						
Prunopyle titan		C	?R					?R	?F				o, sl		F
Eucyrtidium calvertense		F	C	?R	F	R	F-C	F	F	C-A	F	?	F-C	F-C	F
Triceraspyris antarctica			F-C									C			
Triceraspyris coronata	C	R	C	F-C	C	C	C	R			F-C	F			X
Lychnocanium grande			A	F-C	X	R	F-C	F-Csl	R	C	F-C	R	Csl	F-C	Csl
Cenosphaera sp. *Keany*			-	X	F-C	X	X		o, sl						
Eucyrtidium pseudoinflatum			C	R-F	F			F-R	F		R-F	F-C	F	F-C	Css
Cycladophora spongothorax						?		—	—	R	F	F-C	C	C	F
Lithomelissa stigi								C	?C			R			
Acrosphaera australis									o		X				F-C
Siphonosphaera vesuvius									C		F-C	C	F	C	R
Prunopyle hayesi										F			?F	R	C
Actinomma golowhiwi															
Eucyrtidium cienkowski						?C						F			

Notes: Abundance: A = abundant, C = common, F = few, R = rare. Preservation: G = good, M = moderate. Empty cell = the species was not observed in the sample. X = species exists on the slide but abundance was not noted. o = exactly one specimen found. sl = sensu latu, ss = sensu strictu, ? = uncertainty or difficulty in recognition of specimens (poor preservation, unusual morphology, or not clearly defined species). A color **PDF version** of this table is available.

Table T1 (continued).

Depth (mbsf)	*A. australis* Zone							*C. spongothorax* Zone				*A. golownini* Zone			
	143.35	144.00	150.70	153.05	153.70	155.20	156.70	160.30	161.80	163.30	164.15	167.15	170.75	172.90	179.50
Core, section, interval (cm)	16R-2, 105	16R-3, 20	17R-1, 20	17R-2, 105	17R-3, 20	17R-4, 20	17R-5, 20	18R-1, 20	18R-2, 20	18R-3, 20	18R-3, 105	18R-5, 105	19R-1, 105	19R-3, 20	20R-1, 20
(mg dry sed)/mm^2	0.1833	0.164	0.1644	0.1848	0.1176	0.1782	0.1545	0.2789	0.3254	0.2297	0.1922	0.1976	0.1766	0.2664	0.1662
Radiolarian abundance	F	C	F-C	A	F-C	C	C	C-A	F-C	R	F	C	F	F-C	C
Radiolarian preservation	M	G	G	G	G	G	G	G	G	M	G	G	C	G	G
Pennate diatoms	C-A	C-A	A	A	C-A	C	C-A	C	F-C	F	R-F	F	F	F	F
Centric diatoms	A	VA	A	C	C	C	C	C	F	F	R-F	F-C	F	F	F
Sponge spicules	F	F-C	R	F	F	F	F	F	.	F			F	F	C
Silicoflagellates			C	C-A	F-C	F		R-F						C-A	X
Lithics; volcanic ash	C	C		C	R-F	F	F	F		F		F-C	A	R	F
Antarctissa cylindrica															
Cycladophora pliocenica															
Helotholus vema															
Desmospyris spongiosa															
Lampromitra coronata			Xsl?			Xsl?									
Stichocorys peregrina										o	o				
Amphymenium challengerae															
Acrosphaera labrata															
Prunopyle titan			Rss	R-F		R	?F	Rsl	R						
Eucyrtidium calvertense	?	R	?	C	R-F	F-R	F-C	F		F-C	C	R-F			
Triceraspyris antarctica			C-Asl			Csl	Css	Csl	C	C	C	C	F		o
Triceraspyris coronata			F-C	C-A	C	X?	C-A	R	R	R-F	?F	R	R	X	
Lychnocanium grande			F-C		C	R-Fsl	R	C-A	F	—	C	C	o	C	R
Cenosphaera sp. Keany															
Eucyrtidium pseudoinflatum	R	R-F	F	F	R	?	F		—	—	—				
Cycladophora spongothorax	Rsl	C	C	C	C	F	C	R	R	F	R				
Lithomelissa stigi	F	F	C-A	F-C	R	F	F	C	C-A	F-C	F	R	R	C	F
Acrosphaera australis	R	F-C	F	C	R-F	C	C	Rcf	—	—	—			?C	
Siphonosphaera vesuvius	—	—	R	F-C	R	R		Fsl							
Prunopyle hayesi	?R	F-C	R	C	C	F	C-A	F-C	C	C	C	F	C	C-A	C
Actinomma golowhiwi								C	F		C	C	F-C	X	F
Eucyrtidium cienkowski									C		?	F-C	C	C	C

Table T2. Radiolarian biostratigraphic events, Site 1138.

Event	Minimum depth	Maximum depth	Age (Ma)
	183-1138A-	183-1138A-	
FAD *H. vema*	12R-3, 20	13R-1, 105	4.58
LAAD *L. grande*	12R-2, 22	12R-3, 20	5.02
LAD *A. challengerae*	12R-2, 22	12R-3, 20	6.10
FAD *A. challengerae*	12R-3, 20	13R-1, 105	6.65
FAD *A. labrata*	13-4R, 105	13R-5, 30	7.80
LCO *L. stigi*	13-4R, 105	13R-5, 30	9.30
LAD *C. spongothorax*	14R-1, 20	14R-2, 20	9.12
FCO *S. peregrina*	14R-1, 20	14R-2, 20	9.22
ET *A. murrayana* > *australis*	17R-5, 20	18R-1, 20	10.37
FAD *E. pseudoinflatum*	17R-5, 20	18R-1, 20	10.61
LAD *A. golownini*	17R-5, 20	18R-1, 20	10.77
FAD *C. spongothorax*	18R-3, 20	18R-5, 105	12.55

Notes: Information after Lazarus (1992, 2001). FAD = first appearance datum, LAAD = last abundance appearance datum, LAD = last appearance datum, LCO = last common occurrence, FCO = first common occurrence, ET = evolutionary transition. Events in bold are formal zonal markers.

Plate P1. 1. *Amphymenium challengerae* (Sample 183-1138A-12R-3, 20 cm) (scale bar = 80 µm). **2.** *Acrosphaera labrata* (Sample 183-1138A-17R-1, 20 cm) (scale bar = 64 µm). **3.** *Acrosphaera australis* (Sample 183-1138A-14R-3, 20 cm) (scale bar = 64 µm). **4–13.** *Cenosphaera* sp. Keany. (4, 5) Sample 183-1138A-13R-3, 20 cm: (4) scale bar = 25 µm, (5) scale bar = 20 µm. **6–13.** *Cenosphaera* sp. Keany (Sample 183-1138A-13R-1, 105 cm). (6, 7, 10–13) scale bar = 25 µm, (8, 9) scale bar = 80 µm.

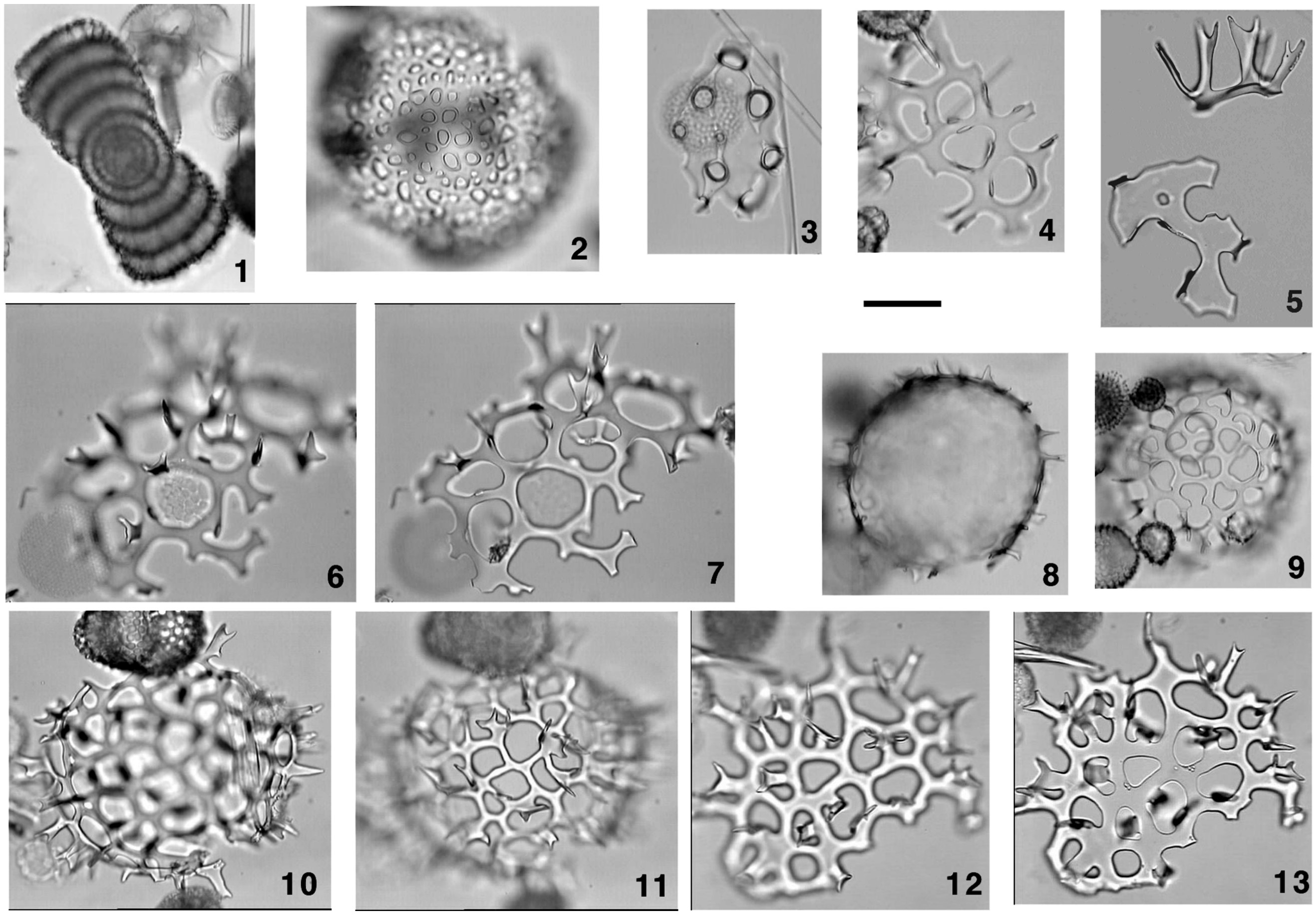

Plate P2. 1–4. *Eucyrtidium calvertense*. (1, 2) Sample 183-1138A-12R-3, 20 cm: (1) scale bar = 32 µm, (2) scale bar = 40 µm. (3) Sample 183-1138A-17R-3, 20 cm (scale bar = 40 µm). (4) Sample 183-1138A-12R-2, 22 cm (scale bar = 40 µm). **5.** *Eucyrtidium pseudoinflatum* (Sample 183-1138A-14R-3, 20 cm) (scale bar = 40 µm). **6.** *Eucyrtidium cienkowski*? (Sample 183-1138A-18R-3, 20 cm) (scale bar = 40 µm). **7–8.** *Eucyrtidium cienkowski* (Sample 183-1138A-18R-2, 20 cm) (scale bar = 40 µm). **9.** *Stichocorys peregrina* (Sample 183-1138A-13R-5, 30 cm) (scale bar = 32 µm). **10.** *Triceraspyris antarctica* (Sample 183-1138A-17R-5, 20 cm) (scale bar = 40 µm). **11–14.** *Triceraspyris antarctica*? (scale bar = 40 µm). (11–13) Sample 183-1138A-18R-5, 105 cm, (14) Sample 183-1138A-17R-3, 20 cm. **15.** *Triceraspyris antarctica*? and *Triceraspyris coronata* (Sample 183-1138A-17R-3, 20 cm) (scale bar = 40 µm). **16.** *Triceraspyris coronata* (Sample 183-1138A-14R-3, 20 cm) (scale bar = 40 µm). **17.** *Eucyrtidium cienkowski*? (Sample 183-1138A-14R-3, 105 cm) (scale bar = 40 µm). **18.** *Prunopyle titan* (scale bar = 40 µm).

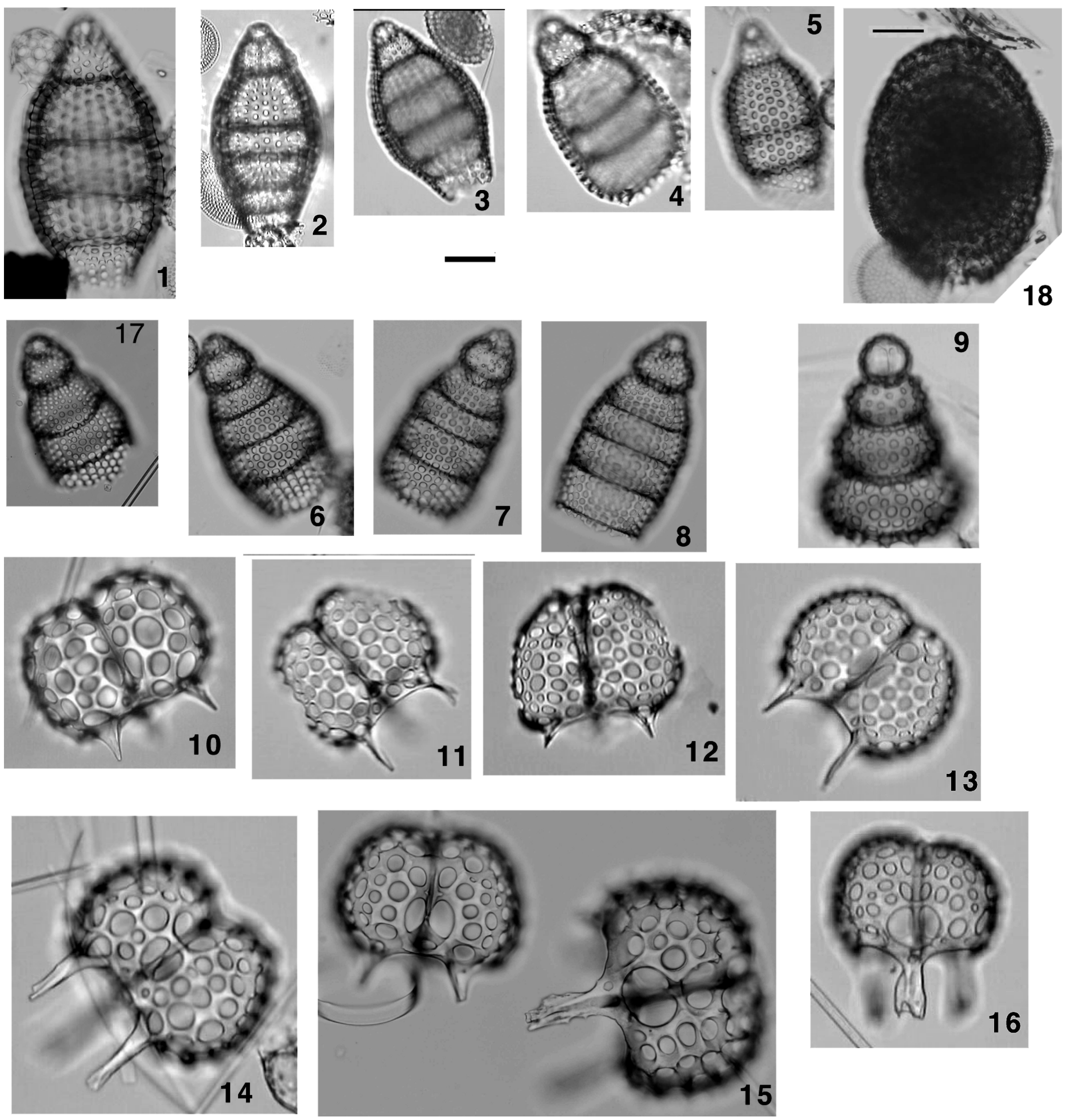

Plate P3. 1–5. *Cycladophora spongothorax* (scale bar = 40 µm) (1, 2) Sample 183-1138A-17R-5, 20 cm. (3) Sample 183-1138A-17R-3, 20 cm, (4) Sample 183-1138A-16R-2, 105 cm, (5) Sample 183-1138A-16R-3, 20 cm. **6.** cf. *Cycladophora spongothorax* (Sample 183-1138A-16R-2, 105 cm) (scale bar = 40 µm). **7.** *Cycladophora pliocenica* (Sample 183-1138A-17R-4, 20 cm) (scale bar = 50 µm). **8–13.** cf. *Lithomelissa stigi* (scale bar = 25 µm). (8) Sample 183-1138A-18R-5, 105 cm. (9, 12) Sample 183-1138A-17R-5, 20 cm. (10) Sample 183-1138A-19R-3, 20 cm. (11) 183-1138A-17R-3, 20 cm. (13) Sample 183-1138A-13R-5, 30 cm. **14.** *Lithomelissa stigi*? (Sample 183-1138A-18R-3, 20 cm) (scale bar = 25 µm).