7. CENOZOIC CALCAREOUS NANNOFOSSILS, DEEP SEA DRILLING PROJECT SITES 415 AND 416, MOROCCAN BASIN

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INTRODUCTION

During Leg 50 (central Atlantic) of the Deep Sea Drilling Project, two sites were cored: Site 415 and Site 416 (about 2 km from Site 370), in the Moroccan Basin (Figure 1). The primary goal of Leg 50 was to document the history of early rifting and sedimentation in the Central Atlantic by sampling as deeply as possible in the pre-Upper Jurassic strata. To reach these objectives the Tertiary sections had to be penetrated, and this part of the section was cored only intermittently in order to obtain the necessary biostratigraphic control.

We received 86 samples from DSDP Sites 415 and 416 for stratigraphic evaluation of the calcareous nannofossils (Table 1) of the cored Tertiary sections. Assemblage lists of the major constituents of the nannoflora and age determinations for these samples are given below in text form. No checklist was prepared for these samples because the cores were taken at widely spaced intervals, and consequently it would not be particularly enlightening.

The recognition of the calcareous nannofossils was made mainly by inspection with light microscope of smear slides prepared from samples which were treated with an ultrasonic apparatus. The boundary between the *Gephyrocapsa oceanica* Zone and the *Emiliania huxleyi* Zone was recognized on the basis of scanning-electron-microscope study.

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CALCAREOUS-NANNOFOSSIL BIOSTRATIGRAPHY AND ZONATION

Many studies of Cenozoic coccoliths have been published and several zonations—Hay et al. (1967), Gartner (1969), Martini and Worsley (1970), Bukry and Bramlette (1970), Bukry (1971), Martini (1971), and Gartner (1977)—have been proposed. The zonation used in this report is a combination of the zonations of Martini (1971) and Gartner (1977) Table 2.

SITE 415
(latitude 31°01.72′N, longitude 10°39.11′W water depth 2794 m)

Pleistocene

Pleistocene sediments were recovered only in the uppermost core of Hole 415 (0-7.5 m). Nannofossils are abundant and well preserved. The assemblages in Samples 415-1-1, 0-1 cm to 415-1-3, 97-98 cm belong to the *Emiliania huxleyi* Acme Zone. Samples 415-1-4, 16-17 cm and 415-1-5, 111-112 cm are assigned to the *Emiliania huxleyi* Zone. The base of this zone is placed at the first occurrence of *Emiliania huxleyi* (Lohmann).

The sediments of Samples 415-1-6, 117-118 cm and 415-1, CC, with *Gephyrocapsa oceanica* Kamptner, but without *Emiliania huxleyi* (Lohmann) and *Pseudoemiliania lacunosa* (Kamptner), belong to the *Gephyrocapsa oceanica* Zone.

Core 415A-1 yielded one specimen of *Cretarhabdus crenulatus,* which is a late-Berriasian to Maestrichtian species, Bramlette and Martini. No reworking from the Tertiary was observed.

Pliocene

Liner scrapings of Core 415B-1, and Samples 415B-2-1, 8-9 cm; 415B-2-1, 130-131 cm; 415-2-1, 32-33 cm, 415-2-1, 75-76 cm, and 415-2-1, 85-86 cm comprised Pliocene sediments (37.5 to ~75.0 m). Liner scrapings of 415B-1 fall in the *Discoaster surculus* Zone of the lower upper Pliocene, with *Gephyrocapsa caribbeanica* Boudreaux and Hay, *Pseudoemiliania lacunosa* (Kamptner), *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster challengeri* Bramlette and Riedel, *Discoaster* sp. cf. *D. surculus* Martini and Bramlette, but without *Gephyrocapsa oceanica* Kamptner and *Reticulofenestra pseudoumbilica* (Gartner). It is to be noted, however, that some of this material may represent contamination. Samples 415B-2-1, 8-9 cm and 415B-2-1, 130-131 cm are placed in the interval of the *Discoaster surculus* Zone to the *Reticulofenestra pseudoumbilica* Zone; they contain specimens of *Reticulofenestra pseudoumbilica* (Gartner) and *Pseudoemiliania lacunosa* (Kamptner). *Ceratolithus rugosus* Bukry and Bramlette is not present. The base of the lower Pliocene was identified in the interval from Sample 415-2-1, 32-33 cm to Sample 415-2-1, 62-63 cm. In this interval *Ceratolithus rugosus* Bukry and Bramlette was observed without *Discoaster asymmetricus* Gartner and *Discoaster quinqueramus* Gartner; *Ceratolithus rugosus* Bukry and Bramlette is the marker species for the *Ceratolithus rugosus* Zone.

The nannofossils of the Pliocene sequence are abundant and well preserved.

Pliocene/Miocene Boundary

The Pliocene/Miocene boundary according to Cita and Gartner (1973) is within the interval from the last

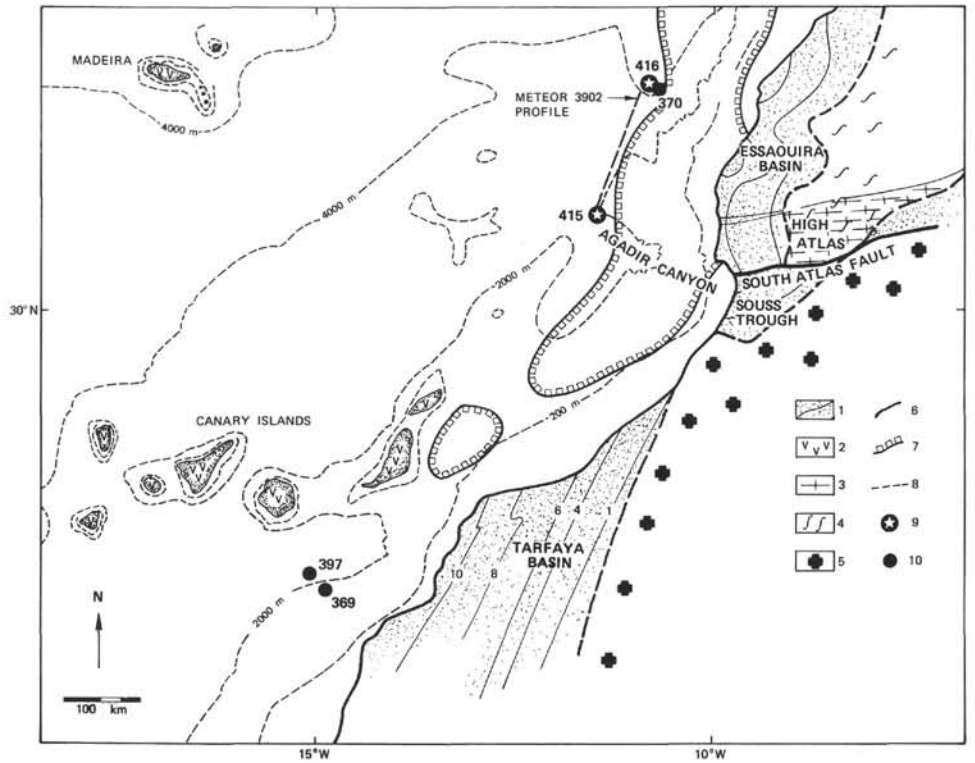

Figure 1. *The continental margin off southern Morocco and the locations of Sites 415 and 416. (1) Mesozoic-Cenozoic sedimentary basins with approximate isopachs in km. (2) Tertiary volcanic rocks. (3) High Atlas fold belt. (4) Hercynian metamorphic basement. (5) Pre-Hercynian basement. (6) Major fault zone. (7) Limit of offshore diapiric provinces. (8) Bathymetric contour. (9) Leg 50 sites. (10) Other DSDP sites.*

occurrence of *Discoaster quinqueramus* Gartner to the first occurrence of *Ceratolithus acutus* Gartner and Bukry. This interval may be represented in Samples 415-2-1, 75-76 cm and 415-2-1, 85-86 cm, although this judgment is founded upon negative evidence, since no *Ceratolithus* or *Amaurolithus* species were recorded, and *Discoaster quinqueramus* Gartner is lacking as well. The stratigraphic determination is made on the basis of the absence of birefringent ceratoliths (genus *Ceratolithus),* which are present at the top of the same section (32-33 cm and 62-63 cm), and the absence of *Discoaster quinqueramus* Gartner, which identifies the *Discoaster quinqueramus* Zone. The lack of *Ceratolithus* and *Amaurolithus* was also noted at Site 397, and we do not know whether environmental restrictions or dissolution effects are responsible for the extremely small number of specimens of these two genera.

The calcareous nannofossils of the Pliocene/Miocene boundary interval are abundant and well preserved.

Miocene

The presence of *Discoaster quinqueramus* Gartner in Samples 415-2-2, 40-41 cm and 415-2-2, CC indicates that this level is the *Discoaster quinqueramus* Zone.

Middle- to lower-Miocene floras were recovered in the lowermost three cores of Hole 415 (415-3 to 415-5; 145.0-283.0 m). The presence of *Discoaster exilis* Martini and Bramlette and *Discoaster pentaradiatus* Tan Sin Hok suggests that Samples 415-3-1, 109-110 cm to 415-3-3, 75-76 cm are not older than middle Miocene.

Discoaster pentaradiatus Tan Sin Hok is missing from Sample 415-3,CC, but *Discoaster,* sp. cf. *D. kugleri* Martini and Bramlette is present, which indicates that the sample is upper middle Miocene, probably the *Discoaster kugleri* Zone to *Catinaster coalitus* Zone.

The sediments of Samples 415-4-2, 36-37 cm to 415-4-4, 97-98 cm contain *Sphenolithus heteromorphus* Deflandre but not *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon); they therefore belong to the *Sphenolithus heteromorphus* Zone of the lower middle Miocene.

Section 415-4-4, bottom and Core 415-5 are placed in the *Helicopontosphaera ampliaperta* Zone—*Sphenolithus belemnos* Zone on the basis of the presence of *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon) (top of this horizon) and *Sphenolithus heteromorphus* Deflandre (base of this horizon).

Nannofossils are abundant in Cores 415-3 and 415-4 and common in 415-5, but their preservation is poor to moderate. No reworking was observed. Some overgrowths were found on specimens from Core 415-3.

TABLE 1
Nannofossil Species Discussed in this Report, Listed Alphabetically by Specific Name

Sphenolithus abies Deflandre
Cyclococcolithus aequiscutum Gartner
Helicopontosphaera ampliaperta (Bramlette and Wilcoxon)
Discolithina anisotrema (Kamptner)
Discoaster aulakos Gartner
Discoaster barbadiensis Tan Sin Hok
Prinsius bisulcus (Stradner)
Discoaster brouweri Tan San Hok
Discoaster calculosus Bukry
Gephyrocapsa caribbeanica Boudreaux and Hay
Helicopontosphaera carteri (Wallich)
Coccolithus cavus Hay and Mohler
Discoaster challengeri Bramlette and Riedel
Rhabdosphaera clavigera Murray and Blackman
Chiasmolithus danicus (Brotzen)
Amaurolithus delicatus Gartner and Bukry
Discoaster decorus Bukry
Discoaster deflandrei Bramlette and Riedel
Distyococcites dictyodus (Deflandre and Fert)
Sphenolithus distentus (Martini)
Discoaster distinctus Martini
Discoaster spp.
Zygolithus dubius Deflandre
Discoaster exilis Martini and Bramlette
Cyclicargolithus floridanus (Roth and Hay)
Cyclococcolithus formosus Kamptner
Scapholithus fossilis Deflandre
Discoaster gemmeus Stradner
Chiasmolithus gigas (Bramlette and Sullivan)
Chiasmolithus grandis (Bramlette and Riedel)
Helicopontosphaera granulata (Bukry and Percival)
Sphenolithus heteromorphus Deflandre
Emiliania huxleyi (Lohmann)
Markalius inversus (Deflandre)
Umbellosphaera irregularis Paasche
Helicopontosphaera kamptneri Hay and Mohler
Discoaster kugleri Martini and Bramlette
Pseudoemiliania lacunosa (Kamptner)
Cyclococcolithus leptoporus (Murray and Blackman)
Discoaster lodoensis Bramlette and Riedel
Cyclococcolithus macintyrei Bukry and Bramlette
Coccolithus miopelagicus Bukry
Umbilicosphaera mirabilis Lohmann
Sphenolithus moriformis (Brönnimann and Stradner)
Discoaster neohamatus Bukry and Bramlette
Discoaster nephados Hay
Cyclolithella nitescens (Kamptner)
Gephyrocapsa oceanica Kamptner
Discolithina pachymorpha (Kamptner)
Discoaster pansus Bukry
Helicopontosphaera parallela (Bramlette and Wilcoxon)
Coccolithus pelagicus (Wallich)
Discoaster pentaradiatus Tan Sin Hok
Helicopontosphaera perch-nielseniae Haq
Reticulofenestra pseudoumbilica (Gartner)
Scyphosphaera pulcherrima Deflandre
Syracosphaera pulchra Lohmann
Discoaster quinqueramus Gartner
Ceratolithus rugosus Bukry and Bramlette
Discoaster saipanensis Bramlette and Riedel
Helicopontosphaera sellii Bukry and Bramlette
Aspidorhabdus stylifer (Lohmann)
Ericsonia subpertusa (Hay and Mohler)
Discoaster surculus Martini and Bramlette
Cruciplacolithus tenuis (Stradner)
Umbellosphaera tenuis (Kamptner)
Marthasterites tribrachiatus (Bramlette and Riedel)
Amaurolithus tricorniculatus (Gartner)
Fasciculithus tympaniformis Hay and Mohler
Discoaster variabilis Martini and Bramlette

Lower Eocene

Lower-Eocene sediments were recovered only in Section 415A-1, CC (349.0 to 357.5 m). The species *Marthasterites tribrachiatus* (Bramlette and Riedel) and *Discoaster lodoensis* Bramlette and Riedel identify the *M. tribrachiatus* Zone at this level. Nannofossils are abundant to common and are poorly to moderately well preserved. We observed no reworking, dissolution, or overgrowths. Some nannofossils are fragmented. No material was recovered in Cores 415A-2 and 415A-3.

Paleocene

Cores 415A-4 and 415A-6 are considered to be lower Paleocene (443.0 to 510.0 m). The core-catcher sample of Core 415A-4 contains very few and very poorly preserved (high fragmentation and dissolution) nannofossils. The presence of *Discoaster gemmeus* Stradner (lower limit) and *Fasciculithus tympaniformis* Hay and Mohler (upper limit) identifies the sediments as middle- to upper-Paleocene *Discoaster gemmeus* Zone to *Heliolithus riedeli* Zone. Core 415A-5 lacks nannofossils.

Lower-Paleocene nannofossils are sparse to common and are fragmented, corroded, and poorly preserved in Core 415A-6. Sample 415A-6-1, 67-69 cm is assigned to the *Chiasmolithus danicus* Zone. It contains an assemblage with *Chiasmolithus danicus* (Brotzen) but without *Ellipsolithus macellus* (Bramlette and Sullivan) and *Fasciculithus tympaniformis* Hay and Mohler.

The interval from Sample 415A-6-1, 74-75 cm to 415A-6-1, CC, with *Cruciplacolithus tenuis* (Stradner), *Coccolithus cavus* Hay and Mohler, *Prinsius bisulcus* (Stradner), and *Ericsonia subpertusa* Hay and Mohler, falls in the lower-Paleocene *Cruciplacolithus tenuis* Zone.

Hole 415

Sample 415-1-1, 7-8 cm

Emiliania huxleyi (Lohmann), *Gephyrocapsa oceanica* Kamptner, *Umbilicosphaera mirabilis* Lohmann, *Helicopontosphaera kamptneri* Hay and Mohler, *Rhabdosphaera clavigera* Murray and Blackman.

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Acme Zone.

Sample 1-1, 91-92 cm

Emiliania huxleyi (Lohmann), *Gephyrocapsa oceanica* Kamptner, *Syracosphaera* sp. cf. *S. pulchra* Lohmann, *Rhabdosphaera clavigera* Murray and Blackman, *Umbilicosphaera mirabilis* Lohmann, *Umbellosphaera irregularis* Paasche.

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Acme Zone.

Sample 415-1-2, 35-36 cm

Gephyrocapsa oceanica Kamptner, *Umbilicosphaera mirabilis* Lohmann, *Cyclococcolithus leptoporus* (Murray and Blackman), *Umbellosphaera tenuis* (Kamptner), *Emiliania huxleyi* (Lohmann), *Syracosphaera* sp.

TABLE 2
Zonal and Geological Age Assignments for Tertiary Calcareous Nannofossil Assemblages in Sites 415 and 416

Age		Calcareous-Nannoplankton Zones	Hole 415		Hole 415A		Hole 415B		Hole 416		Hole 416A	
			Top	Base	Top	Base	Top	Base	Top	Base	Top	Base
Quaternary		*Emiliania huxleyi* Acme Zone	1-1, 7–8 cm	1-3, 97–98 cm								
		Emiliania huxleyi Zone	1-4, 16–17 cm	1-5, 111–112 cm					1-1, 2 cm	1-1, 42–43 cm		
		Gephyrocapsa oceanica Zone	1-6, 117–118 cm	1, CC								
		Pseudoemiliania lacunosa Zone										
		Small *Gephyrocapsa* Zone										
		Helicopontosphaera sellii Zone										
		Cyclococcolithina macintyrei Zone										
Pliocene	Late	*Discoaster brouweri* Zone										
		Discoaster pentaradiatus Zone										
		Discoaster surculus Zone					2-1, 8–9 cm		1-1, 45–46 cm	1, CC		
	Early	*Reticulofenestra pseudoumbilica* Zone						2-1, 130–131 cm			1-1, 7–8 cm	1-1, 22–23 cm
		Discoaster asymmetricus Zone										
		Ceratolithus rugosus Zone	2-1, 32–33 cm	2-1, 62–63 cm								
Miocene	Late	*Ceratolithus tricorniculatus* Zone										
		Discoaster guingueramus Zone	2-2, 40–41 cm	1, CC							1-1, 34 cm	1-1, 86–87 cm
		Discoaster calcaris Zone										
	Middle	*Discoaster hamatus* Zone										
		Catinaster coalitus Zone										
		Discoaster kugleri Zone										
		Discoaster exilis Zone										
	Early	*Sphenolithus heteromorphus* Zone	4-2, 36–37 cm	4-3, 69–70 cm							1-1, 93–94 cm	(?) 1-2, 32–33 cm
		Helicopontosphaera ampliaperta Zone	4-4, bottom								1, CC	
		Sphenolithus belemnos Zone		5, CC								2, CC
		Discoaster druggi Zone										
		Triquetrorhabdulus carinatus Zone										
Oligocene	Late	*Sphenolithus ciperoensis* Zone									(?) 3-1, 15–16 cm	
	Mid	*Sphenolithus distentus* Zone										
		Sphenolithus predistentus Zone										3, CC
	Early	*Helicopontosphaera reticulata* Zone										
		Ericsonia subdisticha Zone										
Eocene	Late	*Sphenolithus pseudoradians* Zone										
		Isthmolithus recurvus Zone										
		Chiasmolithus oamaruensis Zone										
		Discoaster saipanensis Zone										
	Middle	*Discoaster tanii nodifer* Zone										
		Chiphragmalithus alatus Zone										
		Discoaster sublodoensis Zone										
		Discoaster lodoensis Zone										
	Early	*Marthasterites tribrachiatus* Zone			1, CC	1, CC						
		Discoaster binodosus Zone										
		Marthasterites contortus Zone										
Paleocene	Late	*Discoaster multiradiatus* Zone										
		Heliolithus riedeli Zone			4, CC							
	Middle	*Discoaster gemmeus* Zone				4, CC						
		Heliolithus kleinpelli Zone										
		Fasciculithus tympaniformis Zone										
	Early	*Ellipsolithus macellus* Zone										
		Chiasmolithus danicus Zone			6-1, 67–68 cm	6-1, 67–69 cm						
		Cruciplacolithus tenuis Zone			6-1, 74–75 cm	6, CC, top						
		Markalius inversus Zone										

cf. *S. pulchra* Lohmann, *Helicopontosphaera carteri* (Wallich).

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Acme Zone.

Sample 415-1-3, 80-81 cm

Emiliania huxleyi (Lohmann), *Gephyrocapsa oceanica* Kamptner, *Helicopontosphaera kamptneri* Hay and Mohler, *Umbilicosphaera mirabilis* Lohmann, *Cyclococcolithus leptoporus* (Murray and Blackman), *Rhabdosphaera clavigera* Murray and Blackman, *Aspidorhabdus stylifer* (Lohmann).

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Acme Zone.

Sample 415-1-3, 97-98 cm

Gephyrocapsa oceanica Kamptner, *Umbilicosphaera mirabilis* Lohmann, *Cyclococcolithus leptoporus* (Murray and Blackman), *Emiliania huxleyi* (Lohmann), *Helicopontosphaera carteri* (Wallich). (Severely corroded specimens.)

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Acme Zone.

Sample 415-1-4, 16-17 cm

Gephyrocapsa oceanica Kamptner, *Gephyrocapsa caribbeanica* Boudreaux and Hay, *Cyclococcolithus leptoporus* (Murray and Blackman), *Umbilicosphaera mirabilis* Lohmann, *Helicopontosphaera carteri* (Wallich), *Emiliania huxleyi* (Lohmann) (rare). (Corroded specimens, residual assemblage.)

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Zone.

Sample 415-1-5, 111-112 cm

Gephyrocapsa oceanica Kamptner, *Helicopontosphaera carteri* (Wallich), *Umbilicosphaera mirabilis* Lohmann, *Cyclococcolithus leptoporus* (Murray and Blackman), *Emiliania huxleyi* (Lohmann), *Gephyrocapsa caribbeanica* Boudreaux and Hay.

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Zone.

Sample 415-1-6, 117-118 cm

Gephyrocapsa oceanica Kamptner, *Gephyrocapsa caribbeanica* Boudreaux and Hay, *Cyclococcolithus leptoporus* (Murray and Blackman), *Rhabdosphaera clavigera* Murray and Blackman, *Umbellosphaera irregularis* Paasche.

Biostratigraphic interval: Upper Pleistocene—*Gephyrocapsa oceanica* Zone.

Sample 415-1, CC

Gephyrocapsa oceanica Kamptner, *Helicopontosphaera kamptneri* Hay and Mohler, *Coccolithus pelagicus* (Wallich), *Rhabdosphaera clavigera* Murray and Blackman, *Cyclococcolithus leptoporus* (Murray and Blackman), *Gephyrocapsa caribbeanica* Boudreaux and Hay, *Aspidorhabdus stylifer* (Lohmann).

Biostratigraphic interval: Upper Pleistocene—*Gephyrocapsa oceanica* Zone.

Sample 415-2-1, 32-33 cm

Discoaster brouweri Tan Sin Hok, *Discoaster challengeri* Bramlette and Riedel, *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster surculus* Martini and Bramlette, *Ceratolithus rugosus* Bukry and Bramlette, *Cyclococcolith macintyrei* Bukry and Bramlette, *Reticulofenestra pseudoumbilica* (Gartner).

Biostratigraphic interval: Lower Pliocene—*Ceratolithus rugosus* Zone.

Sample 415-2-1, 62-63 cm

Ceratolithus rugosus Bukry and Bramlette.

Biostratigraphic interval: Lower Pliocene—*Ceratolithus rugosus* Zone.

Sample 415-2-1, 75-76 cm

Discoaster brouweri Tan Sin Hok, *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster challengeri* Bramlette and Riedel, *Reticulofenestra pseudoumbilica* (Gartner), but without *Ceratolithus rugosus* Bukry and Bramlette, and *Discoaster quinqueramus* Gartner.

Biostratigraphic interval: Probably lower Pliocene.

Sample 415-2-1, 85-86 cm

Discoaster pentaradiatus Tan Sin Hok, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Sphenolithus abies* Deflandre, *Cyclococcolithus leptoporus* (Murray and Blackman), *Reticulofenestra pseudoumbilica* (Gartner), *Coccolithus pelagicus* (Wallich). (Preservation very poor; nannofossils both corroded and overgrown.)

Biostratigraphic interval: Probably lower Pliocene.

Sample 415-2-2, 40-41 cm

Sphenolithus abies Deflandre, *Coccolithus pelagicus* (Wallich), *Cyclococcolithus leptoporus* (Murray and Blackman), *Discoaster variabilis* Martini and Bramlette, *Reticulofenestra pseudoumbilica* (Gartner), *Discoaster quinqueramus* Gartner, *Discoaster* sp. cf. *D. neohamatus* Bukry and Bramlette.

Biostratigraphic interval: Upper Miocene—*Discoaster quinqueramus* Zone.

Sample 415-2, CC

Discoaster sp. cf. *D. quinqueramus* Gartner, *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster challengeri* Bramlette and Riedel, *Discoaster brouweri* Tan Sin Hok, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Reticulofenestra pseudoumbilica* (Gartner), *Helicopontosphaera kamptneri* Hay and Mohler.

Biostratigraphic interval: Upper Miocene—*Discoaster quinqueramus* Zone.

Sample 415-3-1, 109-110 cm

Discoaster pentaradiatus Tan Sin Hok, *Discoaster challengeri* Bramlette and Riedel, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Discoaster* sp. cf. *D.*

exilis Martini and Bramlette. (Most specimens are fragmented and corroded.)

Biostratigraphic interval: Probably middle Miocene.

Sample 415-3-1, 143-144 cm

Sphenolithus abies Deflandre, *Reticulofenestra pseudoumbilica* (Gartner). (All specimens are severely corroded.)

Biostratigraphic interval: Neogene.

Sample 415-3-3, 13-14 cm

Reticulofenestra pseudoumbilica (Gartner), *Discoaster* sp. cf. *D. exilis* Martini and Bramlette, *Sphenolithus abies* Deflandre (All specimens are severely corroded and fragmented.)

Biostratigraphic interval: Neogene.

Sample 415-3-3, 75-76 cm

Discoaster pentaradiatus Tan Sin Hok, *Discoaster exilis* Martini and Bramlette.

Biostratigraphic interval: Probably middle Miocene.

Sample 415-3, CC

Discoaster exilis Martini and Bramlette, *Discoaster* sp. cf. *D. kugleri* Martini and Bramlette, *Coccolithus pelagicus* (Wallich). (Overgrowth on discoasters.)

Biostratigraphic interval: Middle Miocene.

Sample 415-4-1, 30-31 cm

Reticulofenestra pseudoumbilica (Gartner), *Sphenolithus abies* Deflandre, *Coccolithus pelagicus* (Wallich). (All specimens are severely corroded and fragmented.)

Biostratigraphic interval: Neogene.

Sample 415-4-2, 36-37 cm

Reticulofenestra pseudoumbilica (Gartner), *Sphenolithus heteromorphus* Deflandre, *Coccolithus pelagicus* (Wallich), *Cyclolithella nitescens* (Kamptner), *Discoaster sp. cf. D. variabilis* Martini and Bramlette. (Most specimens are fragmented.)

Biostratigraphic interval: Middle to lower Miocene—*Sphenolithus heteromorphus* Zone.

Sample 415-4-3, 69-70 cm

Sphenolithus heteromorphus Deflandre, *Helicopontosphaera kamptneri* Hay and Mohler, but without *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon).

Biostratigraphic interval: Middle to lower Miocene—*Sphenolithus heteromorphus* Zone.

Sample 415-4-3, 71-72 cm

Reticulofenestra pseudoumbilica (Gartner), *Sphenolithus heteromorphus* Deflandre. (All specimens are fragmented.)

Biostratigraphic interval: Middle to lower Miocene.

Sample 415-4-4, 97-98 cm

Reticulofenestra pseudoumbilica (Gartner), *Discoaster exilis* Martini and Bramlette, *Sphenolithus heteromorphus* Deflandre. (Corroded specimens, residual assemblage.)

Biostratigraphic interval: Middle to lower Miocene.

Sample 415-4-4, bottom

Helicopontosphaera ampliaperta (Bramlette and Wilcoxon), *Sphenolithus heteromorphus* Deflandre, *Helicopontosphaera parallela* (Bramlette and Wilcoxon), *Helicopontosphaera kamptneri* Hay and Mohler, *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 415-5-1, 94-95 cm

Reticulofenestra pseudoumbilica (Gartner), *Cyclicargolithus floridanus,* (Roth and Hay), *Sphenolithus abies* Deflandre, *Sphenolithus heteromorphus* Deflandre, *Helicopontosphaera* sp. aff. *H. ampliaperta* (Bramlette and Wilcoxon). (All specimens are severely corroded.)

Biostratigraphic interval: Probably lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 415-5-2, 62-63 cm

Reticulofenestra pseudoumbilica (Gartner), *Sphenolithus* sp. cf. *S. abies* Deflandre, *Coccolithus pelagicus* (Wallich). (Most specimens are corroded beyond recognition.)

Biostratigraphic interval: Neogene.

Sample 415-5-3, 117-118 cm

Sphenolithus heteromorphus Deflandre, *Sphenolithus* sp. cf. *S. abies* Deflandre, *Reticulofenestra pseudoumbilica* (Gartner), *Cyclicargolithus floridanus* (Roth and Hay), *Helicopontosphaera parallela* (Bramlette and Wilcoxon) *Helicopontosphaera* sp. cf. *H. granulata* (Bukry and Percival), *Discoaster deflandrei* Bramlette and Riedel.

Biostratigraphic interval: Neogene.

Sample 415-5-4, 43-44 cm

Helicopontosphaera ampliaperta (Bramlette and Wilcoxon), *Cyclicargolithus floridanus* (Roth and Hay), *Cyclolithella nitescens* (Kamptner), *Reticulofenestra* sp. cf. *R. pseudoumbilica* (Gartner), *Sphenolithus heteromorphus* Deflandre.

Biostratigraphic interval: Lower Miocene.

Sample 415-5-5, 90-91 cm

Sphenolithus heteromorphus Deflandre, *Discoaster deflandrei* Bramlette and Riedel, *Reticulofenestra* sp. cf. *R. pseudoumbilica* (Gartner), *Cyclolithella nitescens* (Kamptner), *Helicopontosphaera* sp. aff. *H. ampliaperta* (Bramlette and Wilcoxon). (All specimens are corroded and fragmented.)

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 415-5-6, 79-80 cm

Reticulofenestra sp. cf. *R. pseudoumbilica* (Gartner), *Cyclicargolithus floridanus* (Roth and Hay). (All specimens fragmented beyond recognition.)

Biostratigraphic interval: Neogene.

Sample 415-5, CC

Helicopontosphaera ampliaperta (Bramlette and Wilcoxon), *Helicopontosphaera kamptneri* Hay and Mohler, *Sphenolithus heteromorphus* Deflandre. *Helicopontosphaera parallela* (Bramlette and Wilcoxon), *Discoaster nephados* Hay, *Coccolithus pelagicus* (Wallich), *Discoaster aulakos* Gartner.

Sample 415-5-1, 94-95 cm

Reticulofenestra pseudoumbilica (Gartner), *Cyclicargolithus floridanus,* (Roth and Hay), *Sphenolithus abies* Deflandre, *Sphenolithus heteromorphus* Deflandre, *Heli copontosphaera* sp. aff. *H. ampliaperta* (Bramlette and Wilcoxon). (All specimens are severely corroded.)

Biostratigraphic interval: Probably lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 415-5-2, 62-63 cm

Reticulofenestra pseudoumbilica (Gartner), *Sphenolithus* sp. cf. *S. abies* Deflandre, *Coccolithus pelagicus* (Wallich). (Most specimens are corroded beyond recognition.)

Biostratigraphic interval: Neogene.

Sample 415-5-3, 117-118 cm

Sphenolithus heteromorphus Deflandre, *Sphenolithus* sp. cf. *S. abies* Deflandre, *Reticulofenestra pseudoumbilica* (Gartner), *Cyclicargolithus floridanus* (Roth and Hay), *Helicopontosphaera parallela* (Bramlette and Wilcoxon) *Helicopontosphaera* sp. cf. *H. granulata* (Bukry and Percival), *Discoaster deflandrei* Bramlette and Riedel.

Biostratigraphic interval: Neogene.

Sample 415-5-4, 43-44 cm

Helicopontosphaera ampliaperta (Bramlette and Wilcoxon), *Cyclicargolithus floridanus* (Roth and Hay), *Cyclolithella nitescens* (Kamptner), *Reticulofenestra* sp. cf. *R. pseudoumbilica* (Gartner), *Sphenolithus heteromorphus* Deflandre.

Biostratigraphic interval: Lower Miocene.

Sample 415-5-5, 90-91 cm

Sphenolithus heteromorphus Deflandre, *Discoaster deflandrei* Bramlette and Riedel, *Reticulofenestra* sp. cf. *R. pseudoumbilica* (Gartner), *Cyclolithella nitescens* (Kamptner), *Helicopontosphaera* sp. aff. *H. ampliaperta* (Bramlette and Wilcoxon). (All specimens are corroded and fragmented.)

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 415-5-6, 79-80 cm

Reticulofenestra sp. cf. *R. pseudoumbilica* (Gartner), *Cyclicargolithus floridanus* (Roth and Hay). (All specimens fragmented beyond recognition.)

Biostratigraphic interval: Neogene.

Sample 415-5, CC

Helicopontosphaera ampliaperta (Bramlette and Wilcoxon), *Helicopontosphaera kamptneri* Hay and Mohler, *Sphenolithus heteromorphus* Deflandre, *Helicopontosphaera parallela* (Bramlette and Wilcoxon), *Discoaster nephados* Hay, *Coccolithus pelagicus* (Wallich), *Discoaster aulakos* Gartner.

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Drill cuttings

Barren.

Hole 415A

Sample 415-1, CC

Marthasterites tribrachiatus (Bramlette and Riedel), *Discoaster lodoensis* Bramlette and Riedel, *Discoaster distinctus* Martini, *Zygolithus dubius* Deflandre, *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Lower Eocene—*Marthasterites tribrachiatus* Zone.

Sample 415-4, CC

Discoaster gemmeus Stradner, *Fasciculithus tympaniformis* Hay and Mohler, but without *Discoaster multiradiatus* Bramlette and Riedel. (The nannofossils are very poorly preserved: highly fragmented, and corroded.)

Biostratigraphic interval: Upper to middle Paleocene —*Discoaster gemmeus* Zone to *Heliolithus riedeli* Zone.

Sample 415A-5-1, 20-21 cm

Barren.

Sample 415A-5, CC

Barren.

Sample 415A-6-1, 67-69 cm

Chiasmolithus danicus (Brotzen), *Cruciplacolithus tenuis* (Stradner), *Markalius inversus* (Deflandre), *Coccolithus cavus* Hay and Mohler, but without *Ellipsolithus macellus* (Bramlette and Sullivan), *Fasciculithus tympaniformis* Hay and Mohler.

Biostratigraphic interval: Lower Paleocene—*Chiasmolithus danicus* Zone.

Sample 415A-6-1, 74-75 cm

Cruciplacolithus tenuis (Stradner), *Markalius inversus* (Deflandre), *Coccolithus cavus* Hay and Mohler, *Ericsonia subpertusa* Hay and Mohler, *Prinsius bisulcus* (Stradner), but without *Chiasmolithus danicus* (Brot-

zen), *Ellipsolithus macellus* (Bramlette and Sullivan), *Fasciculithus tympaniformis* Hay and Mohler.

Biostratigraphic interval: Lower Paleocene—*Cruciplacolithus tenuis* Zone.

Sample 415A-6, CC (top)

Cruciplacolithus tenuis (Stradner), *Ericsonia subpertusa* Hay and Mohler, *Prinsius bisulcus* (Stradner), *Coccolithus cavus* Hay and Mohler.

Biostratigraphic interval: Lower Paleocene—*Cruciplacolithus tenuis* Zone.

Sample 415A-6, CC (bottom)

Barren.

Sample 415A-7-1, 12 cm

Barren.

Sample 415A-7-1, 23-24 cm

Barren.

Sample 415A-7, CC (4-6 cm)

Barren.

Sample 415A-8-1, 20-21 cm

Barren.

Hole 415B

Sample 415B-1, Liner Scrapings

Pseudoemiliania lacunosa (Kamptner), *Discoaster challengeri* Bramlette and Riedel, *Geophyrocapsa caribbeanica* Boudreaux and Hay, *Helicopontosphaera kamptneri* Hay and Mohler, *Coccolithus pelagicus* (Wallich), *Discoaster brouweri* Tan Sin Hok, *Discoaster pentaradiatus* Tan Sin Hok, *Cyclococcolithus leptoporus* (Murray and Blackman), *Cyclococcolithus macintyrei* Bukry and Bramlette, *Rhabdosphaera clavigera* Murray and Blackman, *Scapholithus fossilis* Deflandre, *Discoaster* sp. cf. *D. surculus* Martini and Bramlette.

Biostratigraphic interval: Upper Pliocene—*Discoaster surculus* Zone.

Sample 415B-2-1, 8-9 cm

Pseudoemiliania lacunosa (Kamptner), *Discoaster surculus* Martini and Bramlette, *Helicopontosphaera sellii* Bukry and Bramlette, *Reticulofenestra pseudoumbilica* (Gartner), *Discoaster pentaradiatus* Tan Sin Hok, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Rhabdosphaera clavigera* Murray and Blackman, *Scyphosphaera pulcherrima* Deflandre.

Biostratigraphic interval: "Mid" Pliocene—*Reticulofenestra pseudoumbilica* Zone to *Discoaster surculus* Zone.

Sample 415B-2-1, 130-131 cm

Reticulofenestra pseudoumbilica (Gartner), *Coccolithus pelagicus* (Wallich), *Sphenolithus abies* Deflandre, *Discoaster pentaradiatus* Tan Sin Hok, *Cyclococcolithus leptoporus* (Murray and Blackman), *Cyclococcolithus macintyrei* Bukry and Bramlette, *Helicopontosphaera carteri* (Wallich), *Discolithina anisotrema* (Kamptner), *Rhabdosphaera clavigera* Murray and Blackman, *Discoaster pansus* Bukry, *Discoaster surculus* Martini and Bramlette, *Cyclococcolithus aequiscutum* Gartner, *Discolithina pachymorpha* (Kamptner), *Discoaster decorus* Bukry, *Pseudoemiliania lacunosa* (Kamptner) (small, primitive).

Biostratigraphic interval: "Mid" Pliocene—*Reticulofenestra pseudoumbilica* Zone to *Discoaster surculus* Zone.

Sample 415B-2-2, 130-131 cm

Reticulofenestra pseudoumbilica (Gartner), *Coccolithus pelagicus* (Wallich), *Sphenolithus abies* Deflandre, *Discoaster pentaradiatus* Tan Sin Hok, *Cyclococcolithus leptoporus* (Murray and Blackman), *Helicopontosphaera carteri* (Wallich), *Discolithina anisotrema* (Kamptner), *Discoaster pansus* Bukry, *Discoaster surculus* Martini and Bramlette, *Discoaster decorus* Bukry, *Cyclococcolithus aequiscutum* Gartner, *Amaurolithus* sp. aff. *A. tricorniculatus* (Gartner), *Discoaster quinqueramus* Gartner, *Discoaster brouweri* Tan Sin Hok, *Discolithina pachymorpha* (Kamptner), *Scyphosphaera pulcherrima* Deflandre, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Amaurolithus delicatus* Gartner and Bukry.

Biostratigraphic interval: Uppermost Miocene to lowermost Pliocene.

Sample 415B-2, CC, (6-7 cm)

Reticulofenestra pseudoumbilica (Gartner), *Coccolithus pelagicus* (Wallich), *Sphenolithus abies* Deflandre, *Discoaster pentaradiatus* Tan Sin Hok, *Cyclococcolithus leptoporus* (Murray and Blackman), *Helicopontosphaera carteri* (Wallich), *Discolithina anisotrema* (Kamptner), *Discoaster pansus* bukry, *Discoaster surculus* Martini and Bramlette, *Discoaster decorus* Bukry, *Cyclococcolithus aequiscutum* Gartner, *Amaurolithus* sp. aff. *A. tricorniculatus* (Gartner), *Discoaster quinqueramus* Gartner, *Discoaster brouweri* Tan Sin Hok, *Discolithina pachymorpha* (Kamptner), *Scyphosphaera pulcherrima* Deflandre, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Amaurolithus delicatus* Gartner and Bukry.

Biostratigraphic interval: Uppermost Miocene to lowermost Pliocene.

SITE 416
(latitude 32°50.18′N, longitude 10°48.06′W, water depth 4191 m)

Pleistocene

Pleistocene sediments were recovered only in the top 43 cm of Core 416-1. Nannofossils are abundant and well preserved. These Pleistocene assemblages belong to the *Emiliania huxleyi* Zone, with *Emiliania huxleyi* (Lohmann). Neither *Discoaster brouweri* Tan Sin Hok nor *Pseudoemiliania lacunosa* (Kamptner) were recognized. Reworked Cretaceous coccoliths and Tertiary discoasters were present in both samples.

Pliocene

The two youngest nannofossil zones of the Pliocene are missing in the sediments directly below the Pleistocene sediments in Core 416-1. *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster brouweri* Tan Sin Hok, and *Discoaster surculus* Martini and Bramlette were recognized in Samples 416-1-1, 45-46 cm and 416-1, CC, which indicates they are lower upper Pliocene, equivalent to the *Discoaster surculus* Zone. *Pseudoemiliania lacunosa* (Kamptner) was not found. Also, *Reticulofenestra pseudoumbilica* (Gartner) is lacking, but this species is present in three samples from 416A-1-1, 7-8 cm to 416A-1-1, 22-23 cm and indicates upper lower Pliocene equivalent to the *Reticulofenestra pseudoumbilica* Zone.

The Pliocene nannofossils are abundant and relatively well preserved. Some fragmentation and restricted reworking of Cretaceous and Eocene nannofossils was noted.

Lower to Upper Miocene

Lower- to upper-Miocene floras were recovered in Core 416A-1 below 34 cm to the core-catcher sample of Core 416A-2. *Discoaster quinqueramus* Gartner and *Amaurolithus tricorniculatus* (Gartner) were identified in a sample from the top (416A-1-1, 34 cm to 416A-1-1, 86-87 cm) of this stratigraphic level, and these indicate upper Miocene equivalent to the *Discoaster quinqueramus* Zone.

Discoaster brouweri Tan Sin Hok and *Discoaster exilis* Martini and Bramlette (first occurrence, lower limit) and *Sphenolithus heteromorphus* Deflandre (last occurrence, upper limit) identify the middle-Miocene *Sphenolithus heteromorphus* Zone in Samples 416A-1-1, 93-94 cm to 416A-1, CC.

Sediments with *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon), *Helicopontosphaera parallela* (Bramlette and Wilcoxon), and *Sphenolithus heteromorphus* Deflandre were recovered in the core-catcher sample of Cores 416A-1 and 416A-2, which indicates the lower-Miocene *Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

The middle- to upper-Miocene calcareous nannofossils are abundant and are moderately well to well preserved, but they are only common and poorly to moderately well preserved in the lower-Miocene sediments. Discoasters have overgrowths and are partly fragmented; the coccoliths are partly recrystallized.

Middle to Upper Oligocene

Middle- to upper-Oligocene sediments were recovered in Core 416A-3. The poor preservation and the relatively low abundance of coccoliths in this core made age assignment difficult. The middle to upper Oligocene, *Sphenolithus predistentus* Zone to *Sphenolithus ciperoensis* Zone, was identified by the presence of *Dictyococcites dictyodus* (Deflandre and Fert) (upper limit) and *Sphenolithus distentus* (Martini) (lower limit); other marker species were not found.

The sediments of Core 416A-4 are poorly preserved and recrystallized and contain few nannofossils. The flora includes *Chiasmolithus grandis* (Bramlette and Riedel) (upper limit) and *Reticulofenestra umbilica* (Levin) (lower limit), which suggest middle- to upper-Eocene sediments. The base of the Tertiary section in Sample 416A-5-1, 34-35 cm contains a middle-Eocene nannoflora with common but poorly to moderately well preserved *Discoaster lodoensis* Bramlette and Riedel (upper limit).

Hole 416

Sample 416-1, 2 cm

Emiliania huxleyi (Lohmann), *Gephyrocapsa oceanica* Kamptner, *Gephyrocapsa caribbeanica* Boudreaux and Hay, *Coccolithus pelagicus* (Wallich), *Helicopontosphaera kamptneri* Hay and Mohler, *Syracosphaera pulchra* Lohmann, *Rhabdosphaera clavigera* Murray and Blackman, *Scapholithus fossilis* Deflandre.

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Zone.

Sample 416-1-1, 42-43 cm

Emiliania huxleyi (Lohmann), *Gephyrocapsa oceanica* Kamptner, *Gephyrocapsa caribbeanica* Boudreaux and Hay, *Aspidorhabdus stylifer* (Lohmann), *Helicopontosphaera kamptneri* Hay and Mohler, *Scapholithus fossilis* Deflandre, *Cyclococcolithus leptoporus* (Murray and Blackman), *Coccolithus pelagicus* (Wallich), *Cyclococcolithus macintyrei* Bukry and Bramlette, *Umbilicosphaera mirabilis* Lohmann, *Rhabdosphaera clavigera* Murray and Blackman, *Syracosphaera pulchra* Lohmann.

Biostratigraphic interval: Upper Pleistocene—*Emiliania huxleyi* Zone.

Sample 416-1-1, 45-46 cm

Pseudoemiliania lacunosa (Kamptner), *Discoaster surculus* Martini and Bramlette, *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster brouweri* Tan Sin Hok, *Helicopontosphaera kamptneri* Hay and Mohler, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Syracosphaera pulchara* Lohmann.

Biostratigraphic interval: Upper Pliocene—*Discoaster surculus* Zone.

Sample 416-1, CC

Discoaster surculus Martini and Bramlette, *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster brouweri* Tan Sin Hok, *Helicopontosphaera kamptneri* Hay and Mohler, *Coccolithus pelagicus* (Wallich), *Rhabdosphaera clavigera* Murray and Blackman, *Syracosphaera pulchra* Lohmann, *Scapholithus fossilis* Deflandre.

Biostratigraphic interval: Upper Pliocene—*Discoaster surculus* Zone.

Hole 416A

Sample 416A-1-1, 7-8 cm

Reticulofenestra pseudoumbilica (Gartner), *Discoaster surculus* Martini and Bramlette, *Discoaster pentaradiatus* Tan Sin Hok, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Lower Pliocene—*Reticulofenestra pseudoumbilica* Zone.

Sample 416A-1-1, 21-22 cm

Reticulofenestra pseudoumbilica (Gartner), *Discoaster surculus* Martini and Bramlette, *Cyclococcolithus macintyrei* Bukry and Bramlette, *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster brouweri* Tan Sin Hok, *Discoaster challengeri* Bramlette and Riedel, *Helicopontosphaera kamptneri* Hay and Mohler, *Coccolithus pelagicus* (Wallich), *Aspidorhabdus stylifer* (Lohmann), *Cyclococcolithus leptoporus* (Murray and Blackman).

Biostratigraphic interval: Lower Pliocene—*Reticulofenestra pseudoumbilica* Zone.

Sample 416A-1-1, 22-23 cm

Reticulofenestra pseudoumbilica (Gartner), *Discoaster surculus* Martini and Bramlette, *Discoaster brouweri* Tan Sin Hok, *Discoaster challengeri* Bramlette and Riedel, *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster* sp. cf. *D. variabilis* Martini and Bramlette, *Coccolithus pelagicus* (Wallich), *Cyclococcolithus macintyrei* Bukry and Bramlette, *Helicopontosphaera kamptneri* Hay and Mohler, *Ceratolithus rugosus* Bukry and Bramlette.

Biostratigraphic interval: Lower Pliocene—*Reticulofenestra pseudoumbilica* Zone.

Sample 416A-1-1, 34 cm

Discoaster quinqueramus Gartner, *Discoaster variabilis* Martini and Bramlette, *Discoaster challengeri* Bramlette and Riedel, *Discoaster pentaradiatus* Tan Sin Hok, *Amaurolithus tricorniculatus* (Gartner), *Coccolithus pelagicus* (Wallich), *Cyclococcolithus leptoporus* (Murray and Blackman), *Cyclococcolithus macintyrei* Bukry and Bramlette.

Biostratigraphic interval: Upper Miocene—*Discoaster quinqueramus* Zone.

Sample 416A-1-1, 47-48 cm

Discoaster quinqueramus Gartner, *Amaurolithus tricorniculatus* (Gartner), *Discoaster surculus* Martini and Bramlette, *Reticulofenestra pseudoumbilica* (Gartner), *Discoaster pentaradiatus* Tan Sin Hok, *Discoaster challengeri* Bramlette and Riedel, *Discoaster brouweri* Tan Sin Hok, *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Upper Miocene—*Discoaster quinqueramus* Zone.

Sample 416A-1-1, 86-87 cm

Discoaster quinqueramus Gartner, *Amaurolithus tricorniculatus* (Gartner), *Reticulofenestra pseudoumbilica* (Gartner), *Discoaster pentaradiatus* Tan Sin Hok, *Coccolithus pelagicus* (Wallich).

Sample 416A-1-2, 32-33 cm

Coccolithus miopelagicus Bukry, *Cyclicargolithus floridanus* (Roth and Hay), *Cyclococcolithus leptoporus* (Murray and Blackman), *Sphenolithus abies* Deflandre, *Coccolithus pelagicus* (Wallich), *Sphenolithus heteromorphus* Deflandre, *Discoaster exilis* Martini and Bramlette, *Discoaster aulakos* Gartner, *Helicopontosphaera carteri* (Wallich).

Biostratigraphic interval: Lower middle Miocene—probably *Sphenolithus heteromorphus* Zone.

Sample 416A-1, CC

Sphenolithus heteromorphus Deflandre, *Discoaster exilis* Martini and Bramlette, *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon), *Helicopontosphaera kamptneri* Hay and Mohler, *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 416A-2-1, 62-63 cm

Helicopontosphaera parallela (Bramlette and Wilcoxon), *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon), *Helicopontosphaera kamptneri* Hay and Mohler, *Sphenolithus heteromorphus* Deflandre, *Cyclicargolithus floridanus* (Roth and Hay).

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 416A-2-1, 70-71 cm

Sphenolithus heteromorphus Deflandre, *Coccolithus miopelagicus* Bukry, *Discoaster exilis* Martini and Bramlette, *Cyclicargolithus floridanus* (Roth and Hay), *Reticulofenestra* sp. cf. *R. pseudoumbilica* (Gartner), *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon), *Discoaster calculosus* Bukry.

Biostratigraphic interval: Lower Miocene—Sphenolithus belemnos Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 416A-2-2, 38-39 cm

Cyclicargolithus floridanus (Roth and Hay), *Sphenolithus heteromorphus* Deflandre, *Coccolithus miopelagicus* Bukry, *Sphenolithus moriformis* (Brönniman and Stradner), *Discoaster exilis* Martini and Bramlette, *Helicopontosphaera ampliaperta* Bramlette and Wilcoxon).

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Biostratigraphic interval: Upper Miocene—*Discoaster quinqueramus* Zone.

Sample 416A-1-1, 93-94 cm

Sphenolithus heteromorphus Deflandre, *Discoaster exilis* Martini and Bramlette, *Discoaster brouweri* Tan Sin Hok, *Coccolithus pelagicus* (Wallich), *Cyclococcolithus macintyrei* Bukry and Bramlette, *Helicopontosphaera kamptneri* Hay and Mohler.

Biostratigraphic interval: Middle Miocene—*Sphenolithus heteromorphus* Zone.

Sample 416A-1-1, 138-139 cm

Discoaster exilis Martini and Bramlette, *Discoaster brouweri* Tan Sin Hok, *Helicopontosphaera granulata* (Bukry and Percival), *Cyclococcolithus leptoporus* (Murray and Blackman), *Coccolithus pelagicus* (Wallich), *Helicopontosphaera kamptneri* Hay and Mohler, *Discoaster* sp. cf. *D. challengeri* Bramlette and Riedel.

Biostratigraphic interval: Middle Miocene—probably *Sphenolithus heteromorphus* Zone.

Sample 416A-1-2, 9-10 cm

Discoaster exilis Martini and Bramlette, *Discoaster brouweri* Tan Sin Hok, *Helicopontosphaera kamptneri* Hay and Mohler, *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Middle Miocene—probably *Sphenolithus heteromorphus* Zone.

Sample 416A-2-3, 0-1 cm

Helicopontosphaera sp. cf. *H. perch-nielseniae* Haq, *Helicopontosphaera* sp. cf. *H. granulata* (Bukry and Percival), *Sphenolithus heteromorphus* Deflandre, *Coccolithus miopelagicus* Bukry, *Cyclicargolithus floridanus* (Roth and Hay), *Sphenolithus moriformis* (Brönnimann and Stradner), *Discoaster* sp. cf. *D. calculosus* Bukry, *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon).

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 416A-2-4, 11-12 cm

Helicopontosphaera ampliaperta (Bramlette and Wilcoxon), *Helicopontosphaera parallela* (Bramlette and Wilcoxon), *Sphenolithus heteromorphus* Deflandre, *Helicopontosphaera kamptneri* Hay and Mohler, *Coccolithus pelagicus* (Wallich), *Cyclicargolithus floridanus* (Roth and Hay). *Sphenolithus moriformis* (Brönnimann and Stradner).

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 416A-2-4, 12-13 cm

Sphenolithus heteromorphus Deflandre, *Coccolithus miopelagicus* Bukry, *Discoaster exilis* Martini and Bramlette, *Cyclicargolithus floridanus* (Roth and Hay), *Sphenolithus moriformis* Brönnimann and Stradner, *Discoaster* sp. cf. *D. calculosus* Bukry, *Helicopontosphaera ampliaperta* (Bramlette and Wilcoxon)

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 416A-2, CC

Sphenolithus heteromorphus Deflandre, *Helicopontosphaera* sp. cf. *H. ampliaperta* (Bramlette and Wilcoxon), *Helicopontosphaera kamptneri* Hay and Mohler, *Cyclicargolithus floridanus* (Roth and Hay), *Sphenolithus moriformis* (Brönnimann and Stradner), *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Lower Miocene—*Sphenolithus belemnos* Zone to *Helicopontosphaera ampliaperta* Zone.

Sample 416A-3-1, 15-16 cm

Dictyococcites dictyodus (Deflandre and Fert), *Cyclicargolithus floridanus* (Roth and Hay), *Sphenolithus moriformis* (Brönnimann and Stradner), *Coccolithus pelagicus* (Wallich), but without *Reticulofenestra umbilica* (Levin), and Genus *Helicopontosphaera.*

Biostratigraphic interval: Middle to upper Oligocene —probably *Sphenolithus predistentus* Zone to *Sphenolithus ciperoensis* Zone.

Sample 416A-3-1, 16-17 cm

Cyclicargolithus floridanus (Roth and Hay), *Discoaster deflandrei* Bramlette and Riedel, *Discoaster* sp. cf. *D. calculosus* Bukry, *Sphenolithus moriformis* (Brönniman and Stradner), *Coccolithus miopelagicus* Bukry.

Biostratigraphic interval: Upper Oligocene to lower Miocene.

Sample 416A-3-1, 108 cm

Helicopontosphaera perch-nielseniae Haq, *Cyclicargolithus floridanus* (Roth and High), *Sphenolithus moriformis* (Brönnimann and Stradner), *Helicopontosphaera parallela* (Bramlette and Wilcoxon), *Discoaster deflandrei* Bramlette and Riedel.

Biostratigraphic interval: Middle to upper Oligocene —probably *Sphenolithus predistentus* Zone to *Sphenolithus distentus* Zone.

Sample 416A-3-2, 28-29 cm

Discoaster deflandrei Bramlette and Riedel, cf. *Discoaster calculosus* Bukry, *Cyclicargolithus floridanus* (Roth and Hay), *Sphenolithus moriformis* (Brönnimann and Stradner), *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Upper Oligocene to upper Miocene.

Sample 416A-3-3, 6-7 cm

Barren.

Sample 416A-3-3, 9-10 cm

Dictyococcites dictyodus (Deflandre and Fert), *Reticulofenestra umbilica* (Levin), *Coccolithus pelagicus*

(Wallich), *Sphenolithus moriformis* (Brönnimann and Stradner), *Discoaster* sp. cf. *D. deflandrei* Bramlette and Riedel, *Discoaster* spp.

Biostratigraphic interval: Middle Eocene(?), lower Oligocene(?).

Sample 416A-3, CC

Dictyococcites dictyodus (Deflandre and Fert), *Sphenolithus distensus* (Martini), *Sphenolithus moriformis* (Brönnimann and Stradner), *Coccolithus pelagicus* (Wallich), *Cyclicargolithus floridanus* (Roth and Hay), *Discoaster* sp.

Biostratigraphic interval: Middle to upper Oligocene—*Sphenolithus predistentus* Zone to *Sphenolithus distentus* Zone.

Sample 416A-4-1, 68 cm

Chiasmolithus grandis (Bramlette and Riedel), *Coccolithus pelagicus* (Wallich), *Discoaster* sp.

Biostratigraphic interval: Middle to upper Eocene.

Sample 416A- 4-1, Bottom

Reticulofenestra umbilica (Levin), *Cyclococcolithus formosus* Kamptner, *Chiasmolithus* sp. cf. *C. grandis* (Bramlette and Riedel), *Coccolithus pelagicus* (Wallich), *Zygolithus dubius* Deflandre, *Discoaster* sp.

Biostratigraphic interval: Middle to upper Eocene.

Sample 416A-5-1; 4 cm

Barren.

Sample 416A-5-1; 27 cm

Barren.

Sample 416A-5-1, 34-35 cm

Discoaster lodoensis Bramlette and Riedel, *Chiasmolithus gigas* (Bramlette and Sullivan), *Discoaster barbadiensis* Tan Sin Hok, *Coccolithus pelagicus* (Wallich), *Sphenolithus moriformis* (Brönnimann and Stradner), *Markalius inversus* (Deflandre).

Biostratigraphic interval: Middle to upper Eocene.

Sample 416A-5-1, 38 cm

Helicopontosphaera parallela (Bramlette and Wilcoxon), *Discoaster* sp. cf. *D. saipanensis* Bramlette and Riedel, *Coccolithus pelagicus* (Wallich).

Biostratigraphic interval: Probably Eocene.

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