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4. NEOGENE FORAMINIFERS AND ACCESSORIES, ODP LEG 188, SITES 1165, 1166, AND 1167, PRYDZ BAY, ANTARCTICA[1]

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ABSTRACT

Foraminifers are reported from Ocean Drilling Program (ODP) Leg 188, Sites 1165, 1166, and 1167 in and near Prydz Bay, off East Antarctica. Assemblages are generally sporadic and do little to provide a chronostratigraphic framework for the aims of Leg 188. Dissolution below the carbonate compensation depth (CCD) has been a major factor controlling preservation of some assemblages. Descriptions of each section include reference to the significance of accessory components such as other non-foraminifer microfossils and some minerals.

The composition of the early Miocene and younger assemblages at Site 1165 suggests that they are in situ or are at the depth where they accumulated. The occurrences, apparently in situ, of *Globigerina bulloides* in Sample 188-1165A-1H-CC and an assemblage (also recorded on southern Kerguelen Plateau) including *Globorotalia puncticulata* and *Globorotalia scitula* in Quaternary sediments of Sample 188-1165B-2H-2, 70–75 cm, support the longer range for *G. puncticulata* and indicate a short interval of warmer-water conditions in the early Pleistocene. Accessory microfossils are important indices in the section. A major change in environment is obvious in Core 188-1165B-25X (middle–late Miocene transition; approximately Chron C5R). Above this level glauconite becomes a regular component of samples, possibly reflecting an influx of reworked material from Paleogene sediments on the nearby Mac. Robertson Shelf. Another change is evident at the base of Core 188-1165B-58X (latest early Miocene; Chron C5Dr) where sponge spi-

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cules and orosphaerid radiolarians become regular components, perhaps marking a significant cooling event. These radiolarians disappear uphole at Section 188-1165B-34X-CC within the middle Miocene (Subchron C5Abr–Acr).

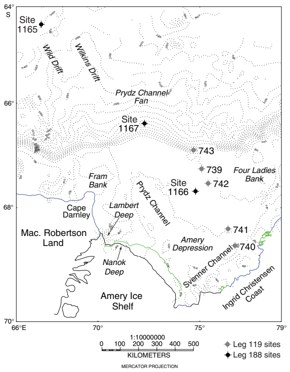
Site 1166, although penetrating rocks as old as Cretaceous, yielded foraminifers only from the Neogene. The total benthic assemblage is diverse, but agglutinated species are rare. Conditions of deposition were fully marine through the Neogene in an open shelf environment. No effects of dissolution are obvious; the planktonic *Neogloboquadrina pachyderma* dominates. Recycled Permian coal is a normal accessory throughout the section, and younger fossil wood and lignite are present at and below Section 188-1166-17R-CC. Foraminifer linings in palynological residues in the Paleogene section are consistent with estuarine conditions at that time.

Foraminifers are recorded throughout the 447.5-m Quaternary section in Hole 1167A on the mid-continental slope north of Prydz Bay. The foraminifer assemblages alone are of little value in establishing the age of the section but yielded enough for Sr dating and $\delta^{18}O$ studies. Presence/absence and features of the benthic component are used to divide the section into six units:

1. 0.6 meters below seafloor (mbsf): modern.
2. 2.1–33.7 mbsf: low foraminifer numbers and little else.
3. 34.3–54.7 mbsf: higher foraminifer numbers and significant other biota.
4. 64.3–98.1 mbsf: low foraminifer numbers.
5. 99.6–208.6 mbsf: highest foraminifer numbers and most diverse other biota.
6. 210.1–447.5 mbsf: very low foraminifer numbers, many barren samples, and little else.

Foraminifer numbers are low, and other biota are represented by fragments. Opaline siliceous fossils are virtually absent. Most Site 1167 assemblages have moved from the continental shelf, where they lived, to the continental slope, where they accumulated. Benthic assemblages are dominated by spherical and tapered infauna that probably lived at ~250–400 m water depth and have been transported to current depths through the mechanism of debris flow. A few thin horizons contain assemblages that are consistent with accumulation in the mid-bathyal realm and thus may not have moved since deposition. The site is near the current CCD, and movement of this surface over time probably accounts for many of the absences.

F1. Location map for Leg 188 sites, p. 32.



INTRODUCTION

During Leg 188 of the Ocean Drilling Program (ODP), employing *JOIDES Resolution,* we drilled holes at three sites in the southern Indian Ocean in and near Prydz Bay, East Antarctica, between 28 January and 29 February 2000. The area is shown on Figure **F1,** and the locations are given in Table **T1.**

The objectives of the voyage were to:

1. Core through sediments deposited when Antarctica underwent the transition from "greenhouse" to the modern "icehouse" state late in the Eocene or early in the Oligocene, at sites obtain-

T1. Locality details for sites drilled, p. 33.

ing their sediment from the currently subglacial Gamburtsev Mountains that probably were the site of nucleation of the ice sheet (principally Site 1166);
2. Obtain a sediment record from times at which major changes in the ice sheet volume and characteristics took place as judged from oxygen isotope records, especially at ~23.7 Ma (Oligocene/Miocene boundary), 12–16 Ma (middle Miocene), and 2.7 Ma (late Pliocene) (mainly Site 1165); and
3. Sample through the upper Pliocene and Quaternary in an attempt to document fluctuations in the extent of the ice sheet over the continental shelf during the Quaternary (especially Site 1167).

Paleogene foraminifer-bearing marine sections were not intersected, and thus discussion of marine sections is restricted to the Neogene. Foraminifers are not major contributors to Leg 188 chronostratigraphy but contribute to paleoenvironmental interpretation, to issues such as carbonate compensation depth (CCD) effects and source and history of sediment, and provide a basis for Sr and $\delta^{18}O$ studies. Chronostratigraphy for the various sections was compiled from diatoms, radiolarians, and paleomagnetism (Shipboard Scientific Party, 2001).

Foraminifers were sporadic rather than continuous except in short intervals; however, the Neogene foraminifers from the region are very poorly known and the new records proved to be of significant value in paleoenvironmental interpretation. Only at Site 1167 did drilling intersect a section that yielded foraminifers virtually throughout. Other than for the very young section at each site, there is virtually no continuity of assemblages between sites and thus each section is treated here as separate and unrelated.

This paper documents the foraminifers encountered and uses them to reconstruct the environment in the vicinity of each hole at the time of deposition. In addition to any chronostratigraphic/paleoenvironmental value, samples were selected for oxygen/carbon isotope studies (**Theissen et al.,** this volume) and for strontium dating. Unfortunately, the hoped-for detailed comparison with nearby onshore sections has not been possible.

PREVIOUS STUDIES

Very few studies have been conducted on the foraminifers of the Prydz Bay region to provide a basis for comparing past with modern distributions. Quilty (1985) and Schröder-Adams (1990) reported foraminifers of Prydz Bay sensu stricto, and further records are included in reports such as Harris et al. (1997b). Milam and Anderson (1981) analyzed material from farther east. Several studies (e.g., Quilty et al., 1990) have recorded foraminifers from Pliocene and younger sections marginal to Prydz Bay. Thus, comparative analysis of the assemblages depends on literature from many other areas on the continental margin of Antarctica. Huber (1991) recorded the planktonic foraminifers of the Cenozoic section at ODP Sites 738 and 744 on the southern Kerguelen Plateau.

MATERIAL AND METHODS

Samples were selected by three methods. As drilling proceeded, core catcher (CC) samples (from the base of each core) were collected and processed immediately. Core catcher samples commonly are the best samples, and their position in the hole is better known than for other sample types. Secondly, a request had been made for samples to be collected on a routine basis from the middle of each section (1.5 m long) from each core (9.5 m long, if complete). Thirdly, immediately after the core was made available for examination, samples were selected on the basis of experience gained during the voyage, on likely productivity or for solving problems that were identified onboard *JOIDES Resolution* on an ad hoc basis.

Once selected, most samples were processed onboard ship. Techniques varied depending on degree of induration of the sediment. Some were simply washed; others needed some physical treatment (pressure between fingers or gentle crushing), but all were treated with only tap water. Samples were routinely washed over 63- and 125-µm sieves, but when coarse sediment or nondisaggregated material was a significant part of the residue coarser sieves were used. A few samples were broken down using kerosene, and some were thin sectioned. Study, mainly of that preserved in the 125-µm fraction, then proceeded under stereobinocular microscopes on board and later at the University of Tasmania. Finer material was examined cursorily and, in some instances, the foraminifer content was high enough and distinct enough to justify later, more detailed, study.

Samples were to be a standard 10-mL volume but commonly were a little larger, usually ~20 g of damp sediment, although this was not always achievable. In particular instances, much larger samples were chosen. Where several successive core catcher samples were barren, processing was restricted to samples that showed promise.

In the deeper section at Site 1165, sediment is well and finely bedded, and bedding surfaces were examined for benthic foraminifers. Agglutinated forms are present on some bedding surfaces. In some instances, it is not clear what group(s) of organisms are responsible for the visible shapes, but where reasonable, they are taken to be foraminifers.

Figured specimens are catalogued in the Commonwealth Palaeontological Collection (CPC) administered by Geoscience Australia (Canberra), and the accession number in that collection is given on the plate.

SITE 1165 RESULTS

Foraminifers are recorded from relatively few samples at this site, and the distribution is shown on Table **T2.** Barren samples examined are listed in **"Appendix A,"** p. 29. Planktonic foraminifers are very rare. This is not surprising in light of the water depth and previous estimates of the level of the CCD, which at this locality is known to be at ~1500 m water depth (Quilty, 1985; Poisson et al., 1987). Even where calcareous benthic species are present, they commonly are not accompanied by planktonic species. Foraminifers have very little contribution to make to the chronostratigraphy at this site except potentially for the Pliocene–Pleistocene section.

T2. Distribution of foraminifers, Site 1165, p. 34.

Below ~665 meters below seafloor (mbsf), preservation changes markedly; the few calcareous foraminifers assume a yellowish color, providing a useful contrast with the gray of the enclosing sediment.

In the lower reaches of Site 1165, assemblages are almost entirely of large characteristic agglutinated species (*Cyclammina, Hyperammina, Reophax,* and *Bathysiphon*) that are common and identifiable in situ with hand lens. In some instances, thin sections were cut; in others, specimens were extracted under the stereobinocular microscope. This ensured that some delicate forms that would be destroyed during routine processing were subject to study.

Biota other than foraminifers, diatoms, or radiolarians recovered during examination for foraminifers are shown on Table T3. Glauconite is included there because of its significance in indicating reworking from older sediments.

T3. Distribution of accessories and glauconite, Site 1165, p. 35.

Planktonic Foraminifers

Hole 1165A

The record from Hole 1165A consists of one mudline core (Core 1H). A sample from the core catcher contains a few specimens of *Neogloboquadrina pachyderma* (Ehrenberg), showing signs of dissolution. Perhaps surprising, because of expected evidence of low seawater temperatures, is the occurrence of a few specimens of *Globigerina bulloides*. The benthic foraminifers are either in situ or consistent with being transported within the bathyal zone.

Hole 1165B

Planktonic foraminifers occur virtually continuously from the surface to Section 188-1165B-4H-5 but only very sporadically below that level (late Pliocene). *N. pachyderma* is very abundant in the >125-µm fraction in Sample 188-1165B-1H-CC and constitutes ~80% of the residue. Specimens in this sample show signs of dissolution and are quite commonly partly infilled with black manganese oxides. *N. pachyderma* is accompanied by a minor benthic fauna and is present through Cores 1H and 2H but is rare below that depth because of dissolution effects. It also occurs very rarely in Sample 188-1165B-6H-CC.

A rich assemblage of planktonic foraminifers from Sample 188-1165B-2H-1, 70–75 cm (probably early Pleistocene, but debated) contains the most diverse late Neogene assemblage recovered. It suffers the dissolution effects of the CCD, but planktonic foraminifers are still the dominant part of the residue. The sample contains *N. pachyderma* accompanied by *Globorotalia puncticulata* (Deshayes) and *Globorotalia scitula* Brady, an association that is not known elsewhere in the hole. This assemblage seems anomalous, as it appeared to be at Site 747 on southern Kerguelen Plateau (Berggren, 1992). Huber (1991) recorded both *G. puncticulata* and *G. scitula* from Site 744, also on southern Kerguelen Plateau, but did not draw any conclusions from their presence. The range of *G. puncticulata* is debated, but it commonly is taken to be a Pliocene (Kennett and Srinivasan, 1983; Stainforth et al., 1975) or Pliocene–Holocene (Blow, 1969) species; some even regard it as more restricted to the early and mid-Pliocene (Hornibrook et al., 1989). *G. scitula* is present to the Holocene, but not at Site 747 or in the Prydz Bay region. Berggren (1992) referred to the Site 747 range as anomalous for *G. puncticulata*. This occurrence supports Blow's suggested longer range

(1969). Kennett and Srinivasan (1983) further regard *G. puncticulata* as a temperate- to warm-water subtropical species. At Site 747 the three species occurred together at the bottom of Core 120-747A-2H, and Sample 188-1165B-2H-1, 70–75 cm, seems to be the equivalent. In Hole 747A, this is believed to be ~2 Ma, applying the time/depth curve in Harwood et al. (1992), an age that would put the expected foraminifer-based age in Hole 1165B in conflict with the paleomagnetic/diatom data. The Pliocene–Pleistocene sections at Sites 747 and 1165 need to be reexamined to resolve the anomaly. Material for Sr dating of the sample has been prepared.

Another consequence of this sample is that it implies some warmer-water influence to explain the presence of two species of *Globorotalia* but only for a very short interval of time. The duration of this "warm" interval is unknown, but assuming the average sedimentation rate between *puncticulata*-free samples above and below, it must have been <200,000 yr, probably considerably less. No other instance of this assemblage was observed from Leg 188 sections.

Planktonic species also are absent from a moderate assemblage in Sample 188-1165B-20X-5, 120 cm, where several benthic species are poorly preserved and identifications a little tentative. No further planktonic species are known until Sample 188-1165B-24X-CC, where planktonic forms constitute 65% of a small assemblage including *Globoturborotalita woodi* (Jenkins), *Globorotaloides variabilis* Bolli, *G. bulloides* d'Orbigny, and *Globigerina praebulloides* Blow. This sample is tentatively placed in Zone AN5 of Berggren (1992), even though the nominate zone marker (*Neogloboquadrina nympha*) is absent. The reason for the absence is not clear, but this location is several degrees farther south than Berggren's (1992) study area and the species may not have lived this far south.

Well-preserved *Catapsydrax unicavus* Bolli, Loeblich, and Tappan is present in Sample 188-1165B-74X-1, 26 cm, and indicates that this sample is no younger than 17.3 Ma and is Zone AN3 or older in the scheme of Berggren (1992).

A single poorly preserved specimen of *C. dissimilis* (Cushman and Bermúdez) was recovered from Sample 188-1165B-74X-CC and is consistent with the early Miocene age identified from study of other fossils from the sample.

Hole 1165C

The richest but most poorly preserved pre-Pliocene planktonic foraminifer assemblage for Leg 188 was recovered from Sample 188-1165C-2R-CC. It contains two genera (*Globoturborotalita* of the *woodi* group, and *Catapsydrax* sp.), but no specimen is well enough preserved for identification to species level. This depth (682 mbsf) marks a dramatic change for the worse in the preservation of planktonic foraminifers. *C. unicavus* in Sample 188-1165B-74X-1, 26 cm, was excellently preserved, and *C. dissimilis* in the same core was uncrushed and identifiable with difficulty. Below this depth, the few planktonic species are severely crushed and unidentifiable. In contrast, benthic species often are very well preserved, even if the test seems delicate (e.g., those identified as *Eponides tenera* [Brady] and *Gyroidina subplanulatus* Echols).

Despite crushing, a few specimens *C. dissimilis* are identified from Sample 188-1165C-11R-CC.

Benthic Foraminifers

Benthic foraminifers are present in many samples, but there is little obvious pattern to their occurrence. Dissolution of tests would be expected at these water depths, and the continuing sporadic presence of *Cyclammina incisa* throughout the sequence (and increasingly important in the lower part) is consistent with this generalization. Even when assemblages are present, they have little commonality in structure or species composition. Thus, it is difficult to comment about significance. Below Core 188-1165B-20X, assemblages are dominantly of agglutinated species. Evidence of dissolution is not prominent, and assemblages from below that depth seem complete.

The few assemblages that yielded calcareous benthic tests contain very little evidence of infaunal species (buliminid species are virtually absent), and thus the waters where these assemblages accumulated probably were fully oxygenated. *Cyclammina* is taken by some (e.g., Gooday, 1990) to be an epifaunal genus, and thus its presence is consistent with the existence of oxygenated conditions to depths below which calcareous species are known. This pattern is in contrast to that recorded in many other ODP studies.

Samples 188-1165A-1H-CC and 188-1165B-1H-CC and 2H-CC contain a few calcareous benthic species which are outnumbered by the planktonic content. They are well preserved and probably in situ.

In the upper reaches (to Sample 188-1165B-2H-5, 70–75 cm; 13.5 mbsf), the planktonic percentage is high and the benthic foraminiferal content is consistent with being in situ or having been transported within the bathyal zone. The presence of a moderately diverse calcareous assemblage some 2000 m below the local CCD is unexpected. Deeper parts of the section are generally barren of foraminifers, but where present, they are consistent with being in situ or transported within the bathyal zone.

A few benthic species (normally less than three specimens per sample) are present in Samples 188-1165C-3R-CC, 4R-CC, 17R-CC, 18R-2, 56–58 cm, and 18R-CC.

Between Samples 188-1165C-12R-CC and 22R-CC, there is an association of agglutinated species having many characteristics in common. Samples almost routinely yield fragments of more than one species, but the remains are poorly preserved because the tests are poorly cemented and do not survive processing well. They are clear in hand specimen examination and consist of flattened white tubes or fragments parallel to bedding. Some may not be foraminifers, but they are included here. If foraminifers, they are astrorhizid/allogromiid or simple ammodiscid species lacking chamber partitions and are thus referable to *Bathysiphon* in most instances. Two species can be recognized. One (*Bathysiphon* sp. 1, present throughout the section) is large and robust, up to 7–8 mm long, straight, or slightly meandrine. The other (*Bathysiphon* sp. 2) is soft, small (to about 1 mm), thin walled, and usually in fragments.

Sample 188-1165B-14H-CC yielded well-preserved diverse benthic foraminifers containing both simple agglutinated and calcareous forms showing only minor evidence of dissolution. Planktonic species are absent. The foraminifers are accompanied by echinoid spines as evidence of a considerable coexisting calcareous benthos. The dominant foraminifer is *Oridorsalis umbonatus* (Reuss) (~50%), which van Morkhoven et al. (1986) regard as indicating a mid–lower neritic depth when living. This suggests that the assemblage, which shows no evidence of dissolution effects, probably originated on the nearby continental shelf and made its way to the present site by mass movement. The absence of any planktonic species is puzzling.

Epistominella vitrea is present in Samples 188-1165B-24X-CC and 26X-CC (204.3–223.3 mbsf) and appears to be approximately equally divided between dextrally and sinistrally coiled.

Both benthic and planktonic species are present in Sample 188-1165B-24H-CC, and again there is no evidence of dissolution. The benthic component of this assemblage is dominated by *Epistominella exigua* (Brady) accompanied by *Cibicides mundulus* (Brady, Parker, and Jones), *Cibicides subhaidingeri* (Parr), and *Hanzawaia mantaensis* (Galloway and Wissler), which suggests that the assemblage is from a bathyal environment and thus is essentially in situ. Also present are several species each of *Lagena, Fissurina,* and miliolid foraminifers.

Sample 188-1165C-30R-3, 142–144 cm, contains *Repmanina charoides* (Jones and Parker), known commonly from bathyal and abyssal assemblages but, in contrast with so many other assemblages, indicates the existence of an infaunal mode of life (Gooday, 1990).

Sample 188-1165B-58X-1, 134–136 cm, contains a diverse, agglutinated/calcareous, benthic-only assemblage, dominated by *C. subhaidingeri* (Parr). Again, the absence of planktonic foraminifers is puzzling. This assemblage has a few specimens (*Stilostomella* and *Virgulina*) that may represent some infauna and is accompanied by echinoid spines.

The labyrinthine agglutinated *C. incisa* (Stache) is present in many samples in Holes 1165B and 1165C and is the most commonly occurring species at this site. Deeper in the section, *C. incisa,* in company with *Bathysiphon* sp. 1, is taken to constitute an assemblage that is found sporadically even higher, for example, in Samples 188-1165C-2R-CC and 3R-CC. In Samples 188-1165C-2R-1, 37 cm; 3R-4, 67–101 cm; 15R-2, 41 cm; and many levels in Cores 188-1165C-29R and 30R, there are intervals in which these two species are clearly visible with the hand lens and sometimes are quite abundant (up to approximately eight specimens of *Cyclammina* on one side of a "biscuit" of core). They probably are more likely to be found through hand specimen examination than after vigorous processing. In some of these co-occurrences, they are accompanied by plentiful coarse sand detritus, in marked contrast with the dark gray mudstone above and below. *C. incisa* is also present deeper in Hole 1165C in association with a variety of other foraminifers. In some depths (e.g., Sample 188-1165C-29R-4, 130–150 cm), their abundance suggests a bottom environment favorable for a diverse fauna.

No other benthic species are known until Sample 188-1165B-74X-CC, which contains a crushed and unidentifiable specimen of *Trochammina.*

Microfossil Assemblages

Because of the erratic nature of assemblages downhole, it is difficult to identify meaningful assemblages within the foraminifers, but two agglutinated assemblages seem to be recognizable—*Cyclammina/Bathysiphon* sp. 1 dominated, and a less well constrained *Bathysiphon* assemblage. Both assemblages seem to imply that the sediment containing them has not moved far since deposition.

The *Cyclammina/Bathysiphon* sp. 1 assemblage seems well defined and recurrent. It is sporadic throughout the section (see above) but is best established toward the lower cores of Hole 1165C. The large (to ~3 mm diameter) tests of *C. incisa* stand out because they are lenticular in vertical section and because the labyrinthine wall is clearly visible. *Bathysiphon* sp. 1 normally occurs with *C. incisa*. It is a robust, thick-walled form ~1 mm in diameter, up to 7–8 mm long, and normally occurs as flattened ovoids with a dark center. Usually, there is no calcareous component in this assemblage, although *Cyclammina* does occur sporadically in association with other assemblages in shallower parts of the section. This assemblage is best developed in a distinctive lithofacies consisting of units up to 20 cm thick that are coarser grained than the dark gray to black siltstone/shale so prevalent in the sequence.

The *Bathysiphon* assemblage is particularly present in Cores 188-1165C-12R through 22R. It is not as well characterized as the *Cyclammina/Bathysiphon* sp.1 assemblage and consists of forms that will not survive rigorous processing. This contrasts with the *Cyclammina/Bathysiphon* sp. 1 assemblage. Two species of *Bathysiphon* are present and may be accompanied by others (e.g., *Psammosphaera* sp. 1 and, rarely, by a calcareous species). These are common in the sandstone beds in the lower part of the dark gray shale so prevalent in the hole. The larger, more robust species has roughly the same size characteristics as *Bathysiphon* sp. 1 but it is much less robust and is visible mainly in the unprocessed rock. The second species (very tentatively placed in *Bathysiphon*) is much smaller, to ~1–2 mm long and 0.3–0.5 mm in diameter. It is present in processed residues as fragments, and complete specimens are found only in the unprocessed rock. Because these specimens are so delicate, they probably can be found only where sediment is not redeposited. They are accompanied by horizontal burrows, some of which could be placed in genera of foraminifers. This assemblage occurs where the prevailing dark gray to black shale/siltstone contains abundant coarser, thin, white siltstone lenses and interbeds.

Sources of Assemblages

It is clear that some of the assemblages have arrived at their resting place by transport rather than being in situ (i.e., they are thanatocoenoses [death assemblages] rather than biocoenoses [life assemblages]. If so, where did they originate and how did they reach their current site? For most assemblages, no answer can be given because of the small, unrepresentative microfossil content; however, an attempt is possible for assemblages from Samples 188-1165B-14H-CC, 24X-CC, and 58X-1, 134–136 cm, but in two cases there is an inconsistency between planktonic percentage and benthic content.

The assemblage in Sample 188-1165B-14X-CC probably slumped to its present site or was carried to it through the intervention of some form of mass transport. It seems out of place. The assemblage is dominated by species that have their upper depth limits considerably shallower than their present position (van Morkhoven et al., 1986). Further, that assemblage lacks species known to have upper depth limits deeper than ~1000 m (lower bathyal). The dominant *O. umbonatus* occurs as shallow as ~100 m. These features conspire to suggest the assemblage may have originated in shallower water (upper to mid-bathyal or even shallower). This suggestion should be treated with caution but is consistent with the presence of glauconite and the glaciomarine environment of deposition during the late Miocene, coinciding with the time of increasing influence of lodestones and dispersed clasts (fig. F23 in Shipboard Scientific Party, 2001). As noted above, the absence of planktonic species is a puzzle and could be used to indicate a much shallower source again, but that would be in conflict with the species composition and may be due to dissolution of the porous tests.

The assemblage in Sample 188-1165B-24X-CC has a planktonic percentage of ~65%, which would normally indicate an outer shelf/upper slope depth, but this figure has been potentially affected by current sorting, carbonate dissolution, and also variation in productivity in the ocean above. Other features include the presence of *Eggerella bradyi, C. subhaidingeri,* and dominant (30%) *E. vitrea.* These suggest an upper depth limit of ~600 m, although the recorded upper depth limit of *E. vitrea* is considerably shallower. A mid- to lower-bathyal depth seems reasonable. As it is a single sample and not part of a set of samples with the same characteristics, this approach must be used with caution.

C. subhaidingeri is dominant (45%), *Laticarinina halophora* is present, and there are no planktonic foraminifers in Sample 188-1165B-58X-1, 134–136 cm. Although in conflict with the absence of planktonic species, the benthic fauna would indicate a mid–lower bathyal source.

Accessory Components

During examination of residues for foraminifers, observations on other fossil groups and on various lithologic characteristics of sediments were maintained and are summarized on Table T3. More detail is available in Shipboard Scientific Party (2001).

As the site was drilled on a drift location, reworking of material from older sections was expected, and this expectation is supported through the presence of glauconite and well-rounded grains of terrigenous detritus in most parts of the section. This is particularly true for samples above approximately Core 188-1165B-26X.

Bone and Teeth

Several samples yielded small amounts of fine, unidentifiable bone fragments; however, each of those from Samples 188-1165B-38X-CC and 55X-CC and especially 188-1165C-33R-CC also yielded several teeth, which may be from notothenioid fish, the only fish family now occurring around Antarctica and that has no fossil record (Eastman, 1995).

Sponge Spicules

Sponge spicules are virtually continuous from the surface to Core 188-1165B-58X. There are a few occurrences below this depth, but the change at Core 188-1165B-58X suggests some important change at the time of deposition of this material. This coincides with the diatom zone *T. praefraga* (Subchron C5Dr) at approximately latest early Miocene (18 Ma) and may coincide with a time of cooling.

Orosphaerid Radiolarians

These are members of the Family Orosphaeridae (Eocene–Holocene) (Anderson, 1983). Members of this family can attain a diameter of ~2–3 mm and are not the normal subject of radiolarian studies, partly because they are large and highly fragmented. In the well-defined interval Sections 188-1165B-34X-CC to 58X-CC (diatom zones upper *D. simonsenii/N. grossepunctata* Zone [Subchron C5ABr–Acr] to *T. praefraga* Zone [Subchron C5Dr]), fragments of the genus *Oroscena* are recognizable in the form of small club-shaped remnants of the outer spines of the skeleton accompanied by meshlike fragments of the spherical portion of the skeleton. Occurrence in this interval is consistent and may prove to be of local biostratigraphic value as the area becomes better known.

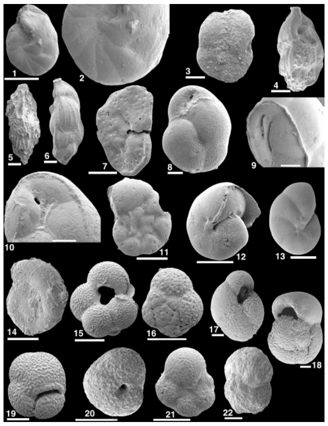
Glauconite

Glauconite is a common component of Paleogene sediments on Mac. Robertson Shelf (Quilty et al., 2000b) and is unlikely to be forming in the current environment around Antarctica. It is present here in several forms—individual rounded grains or in clusters, in elongate, curved, "concertina" form, and, in one instance, pseudomorphic after a foraminifer. It appears to occur almost continuously above Core 188-1165B-26X but only very rarely below that depth, suggesting that this level marks the time of access to a new sediment source.

Dolomite

Sample 188-1165B-6H-5, 70–75 cm, and a few others close by contain abundant small dolomite concretions that appear to consist of two crystals intergrown. One is illustrated (Pl. P1, fig. 21).

P1. Foraminifers, p. 40.



Pyrite

Crystalline pyrite in small irregular clusters or pseudomorphic after organic remains occurs in the interval between Sections 188-1165B-32X-CC and 45X-CC. It appears to be diagenetic and not detrital. In some samples (e.g., Sample 188-1165B-37X-CC) it is in the form of simple rods (length:diameter = 5:1), but in others it is in the form of semicylinders, suggesting growth in the lower half of a horizontal cylindrical fossil on (or slightly under) the seafloor. This has been observed in modern samples in the vicinity of Prydz Bay (e.g., in core sample 186 23GC24) (Harris et al., 1997a).

Pyrite in larger cylindrical bodies to 2.5 mm × 1.0 mm is in the form of framboidal aggregates in Sample 188-1165B-45X-CC, and these are pseudomorphic after fossils, perhaps echinoid spines, suggesting that calcite-secreting organisms lived on the seafloor but are not represented by fossils.

In Samples 188-1165B-37X-CC, 40X-CC, and 45X-CC, in an interval where pyrite occurs almost continuously, there are small rods of pyrite, some framboidal, that are pseudomorphic after other organisms. Some clearly are after echinoid spines and others are probably after simple tubular benthic foraminifers.

Chert

Chert is present in several samples at and below Sample 188-1165B-40X-CC. It is in the form of genuine chert chips (probably from small nodules formed in situ) (e.g., Sample 188-1165B-67X-CC) and commonly in samples below that depth. In most shallower occurrences it is in the form of partly chertified sediment with high organic silica content. This material seems to be in the early diagenetic stages of formation. It appears to be restricted to a discrete depth range because it is absent from cores from Hole 1165C except for Sample 188-1165C-10R-CC, where it is in the form of partly chertified sediment, not solid chert.

Volcanic Glass

Sample 188-1165B-2H-CC contains in the 63- to 125-µm fraction a notable amount of volcanic glass shards. There is no obvious local source, and we did not attempt to "type" the lava represented by the glass. Possible sources include a South Sandwich Islands eruption (and then transport to this site in currents south of the Antarctic Divergence), a local source in an unknown eruption (Gaussberg is only 800 km to the east of this site and has been active in the last 50,000 yr), or some other source such as the recent McDonald Islands eruption west of Heard Island. Each source has its own distinguishing features.

Volcanic glass is present in smaller amounts in several other samples, and three types seem to be present. No information is available on their relationships. One is clear, as noted above, and consists of thin-walled glass that surrounded bubbles. A second widespread but rare form is dark brown with a smaller content of bubbles. Occasionally it appears to be solid. A third form is white grains, usually somewhat elongate, with highly parallel structure, probably resulting from flow of a viscous lava and elongation of bubbles.

Paleoenvironmental Changes

Using the data tabulated on Tables T2 and T3, it is possible to identify a series of levels at which the paleoenvironment changed. Horizons and events are discussed uphole (i.e., in time).

Sample 188-1165B-56X-CC

A fundamental change occurred at this level (Subchron C5Dr; 18 Ma; 491.8 mbsf). Below this depth, residues contain little evidence of terrigenous component coarser than silt or of siliceous microfossils (although diatoms in particular are clear in thin section). The uniformity of the sequence is broken only by occasional chert in the form of chips (in the residue) of genuine dark gray chert, probably fragments of small diagenetic nodules, essentially in situ. The interval from Sections 188-1165B-56X-CC through 53X-CC marks a transition zone from uniform gray, finely bedded mudstone below to a different unit above. Samples in this interval may or may not contain some residue of coarse terrigenous or biogenic origin and may also be marked by other characteristics, such as presence of sponge spicules or minor bone content.

Sample 188-1165B-45X-CC

At this depth, a change in reducing conditions occurred on the seafloor and to Sample 188-1165B-33X-CC. Pyrite, either crystalline or rarely framboidal, becomes a notable component of residues and in some instances clearly is pseudomorphic after organisms.

Sample 188-1165B-33X-CC

This depth marks the normal upper limit of orosphaerid or oroscenid radiolarians and, in one case, significant bone. The lower limit of almost continuous occurrence of the large fragmentary radiolarians is Sample 188-1165B-39X-CC, but there is one shallower record (Sample 22X-CC) and a few as deep as Sample 58X-1, 70–75 cm. The presence of the large radiolarians in this discrete interval suggests changes either in the planktonic realm or in conditions for preservation on the seafloor. The failure to obtain Core 188-1165B-31X may be related to the same change. Pyrite throughout this interval (and deeper to Sample 188-1165B-45X-CC) indicates that reducing conditions applied near the sediment surface (a seafloor feature). The interval of continuous orosphaerid occurrence covers 15–13.5 Ma.

Sample 188-1165B-26X-CC

This is an important marker. Above this depth residues generally are larger, but the most notable feature is the presence of glauconite in most samples, usually only in trace quantities, but in two samples (Samples 188-1165B-11H-CC and 12H-CC) of higher amounts. This change suggests the influx of sediment from a new Paleogene source or a change in transporting mechanism. It is expected that this change of source would be reflected in palynology at this level.

Sample 188-1165B-3H-CC

This level approximates the horizon above which carbonate is present and below which it has suffered the effects of the CCD. Quilty (1985) and Poisson et al. (1987) showed that the CCD near the continental shelf edge of Prydz Bay is at ~1500 m, and thus dissolution is to be expected. Echinoid spines and ostracodes are present above this depth but are very rare below it.

Other Noteworthy Horizons

At the base of Core 188-1165B-2H, volcanic glass is notable. Its presence coincides roughly with the base of abundant carbonate and, with the carbonate above, provides scope for using both radiometric and biochemical dating techniques from the surface to some level in Core 188-1165B-3H.

SITE 1166 RESULTS

A single hole (1166A) was drilled at Site 1166 (Table T1). Recovery in the Neogene part of the hole was poor, and no pre-Neogene foraminifers were recovered. The Neogene section yielded moderate assemblages of both planktonic and benthic foraminifers from Core 188-1166A-1R to interval 12R-1, 18–20 cm, and from most section samples within that interval. Samples 188-1166A-1R-CC and 2R-CC are barren of foraminifers, as are samples including and deeper than 12R-CC. Table T4 is a range chart of species occurrence, and "Appendix B," p. 30, lists barren samples.

T4. Distribution of foraminifers, Site 1166, p. 36.

Planktonic assemblages are dominated by *N. pachyderma* (Ehrenberg), indicating only that the entire section to Sample 188-1166A-12R-1, 18–20 cm, is late Miocene or younger (*N. pachyderma* Zone; AN7 of Berggren, 1992, and Berggren et al., 1995). Benthic assemblages, while yielding small specimen numbers, are, in total, diverse, and assemblages can be related to those identified by Quilty (1985) from the modern continental shelf in Prydz Bay. Agglutinated forms are very rare, and the assemblages are almost entirely calcareous.

Assemblages are those to be expected on an open shelf with no evidence of salinity less than fully marine. There is no evidence of dissolution, but some specimens of *N. pachyderma* from the shallower parts of the section show evidence of some physical abrasion. Other than the abrasion, there is no evidence of reworking or mixing of faunas.

Accessory marine biogenic components are limited to a few sponge spicules, echinoid spines, and shell fragments, but there is ample evidence of detrital black coal (probably from the Permian farther south) throughout the section and brown coal or lignite at and below Section 188-1166A-17R-CC. The presence of marine invertebrates from Section 188-1166A-13R-1 and above supports the conclusion of fully marine conditions.

At the base of Section188-1166A-2R-2, the sediment appears to have been overlain at some time by a significant overburden (e.g., by thick ice or sediment) and thus would appear to predate the Last Glacial Maximum. The sediment is not lithified through diagenetic cementation but by decreased porosity and is very compact, giving the impression of having a high clay content. An alternative explanation is that a significant unconformity exists immediately above the base of Section 188-1166A-2R-CC.

Residues generated in the search for foraminifers in the upper part of the hole (to Section 188-1166A-11R-CC) constitute a considerable volume of the sample and are very highly dominated by terrigenous debris, commonly, but not uniformly, poorly sorted. Rounded grains are present but rare in the fine to medium sand fraction but may be abundant in coarser fractions. Traces of black coal are present in most samples.

No sample was studied from Section 188-1166A-3R-CC because of very small sample recovery or from several cores deeper in the hole where the evidence is overwhelmingly of nonmarine deposition.

The presence of wood below Section 188-1166A-17R-CC and a barnacle plate in interval 188-1166A-11R-1, 47–50 cm, are significant macropaleontological records. The wood and lignite in the Paleogene part of the section are accompanied in samples by the tectin lining of a few agglutinated foraminifers, akin to *Haplophragmoides* and *Trochammina*. These are of little chronostratigraphic value but suggest that conditions were estuarine or shallow nearshore.

Planktonic Foraminifers

Planktonic foraminifers are present and relatively common (several tens of specimens) in several samples from Sections 188-1166A-1R-1 and 1R-2, but not from Section 1R-CC. They are much less abundant at the base of Section 188-1166A-3R-2, where few specimens of *N. pachyderma* are present, and in Section 4R-CC. They are gray and slightly abraded with the effect of removing details of surface texture, but do not show any evidence of dissolution. In each case they are accompanied by a single benthic species. Planktonic foraminifers are generally more abundant, by a factor of 1.5–4 over the benthic component, consistent with an outer continental shelf environment of deposition.

Sample 188-1166A-5R-CC contains both four- and five-chambered forms of *N. pachyderma* (dominant). This association is common in modern shelf assemblages in the region. Samples 188-1166A-6R-CC, 7R-CC, and 9R-CC contain *N. pachyderma,* with or without *Globigerina falconensis,* but numbers are very low. Sample 188-1166A-8R-CC is barren of any fauna. Several samples from the interval 188-1166A-5R-CC through 10R-CC contain small planktonic species in the 63- to 125-µm fraction.

Samples 188-1166A-10R-1, 11–13 cm, 10R-CC, and 11R-CC contain a relatively diverse planktonic foraminiferal assemblage, the best available in the Neogene at this site. They are dominated by the normal four-chambered form of *N. pachyderma,* and there are few of the five-chambered form. There is a single specimen of *Globigerinita parkerae* (Bermudez) in Sample 188-1166A-10R-CC. This sample also yielded a small benthic fauna significantly different from others at this site.

The deepest occurrence of planktonic species is in Sample 188-1166A-12R-1, 18–20 cm, which contains a few *N. pachyderma.*

Benthic Foraminifers

It is highly likely that the records presented here understate (but only to a limited degree) the foraminifer fauna because more delicate agglutinated forms (e.g., what appears to be *Haplophragmoides* sp.) were observed during examination of sediment samples under hand lens and stereobinocular microscope. These would not survive vigorous processing. Only the more robust forms are therefore recorded.

Benthic assemblages are dominated by members of the Cassidulinacea—*Globocassidulina, Cassidulina,* and *Ehrenbergina.* Lagenid/nodosariid forms are lacking, and other types are rare and apparently not systematic in occurrence. Four forms of *Globocassidulina* are recognized here—*G. crassa crassa* (d'Orbigny), *G. crassa biora* (Crespin), *G. crassa rossensis,* and *G. subglobosa* (Brady).

Scattered specimens of *Globocassidulina* are present throughout Core 188-1166A-1R and can be identified at generic level with the hand lens because of their white porcellanous appearance. Selected samples from this core, such as Samples 188-1166A-1R-1, 16–21 cm; 1R-1, 117–122 cm; and 1R-2, 9–11 cm, all contained useful benthic assemblages including sporadic specimens of *Trifarina angulosa.* The source cannot have been far distant but must have been to the south or southeast. It is evidence of some infauna, but numbers are too low to draw meaningful conclusions about environmental significance.

Small assemblages are present in Section 188-1166A-3R-2, base of section, and in Samples 188-1166A-4R-CC, 5R-1, 26–31 cm, 5R-CC, 6R-CC, 7R-CC, 8R-1, 42–45 cm, and 9R-CC. Samples 188-1166A-10R-1, 11–13 cm, and 10R-CC contain larger, more diverse benthic faunas. Sample 188-1166A-10R-CC yielded, in addition to species discussed above, two species of *Astrononion.*

Paleoenvironment in the Neogene

Enough samples contain significant assemblages to give credence to planktonic percentage as a depth indicator. Planktonic percentage is normally ~50%–80%, suggesting water depths corresponding to outer continental shelf or deeper. Assemblages with high globocassidulinid content (especially *Globocassidulina*) are widespread in modern Prydz Bay in shallower, better oxygenated environments such as the Four Ladies Bank (Quilty, 1985) but not in deeper parts of the region where siliceous mud and ooze (SMO of Harris et al., 1997b) dominates. SMO conditions are not indicated in any of the assemblages studied from Site 1166. The outer continental shelf association also is consistent with the Deep Shelf Calcareous Assemblage of Milam and Anderson (1981).

Two distinct lithologic associations are recorded for cores at this site. Some are massive diamicts (coarser) and silty clays (finer). An attempt was made to relate foraminifers to these different lithologies, but assemblages seem to bear little relationship to the lithologic description. Best assemblages come from dark silty clay, whether or not the overall lithology is described as fine or coarse. This may indicate that similar marine conditions held throughout this time and that the difference in lithology reflects very little change in salinity, depth, or temperature between intervals of deposition of different sediments.

Accessory Components

The distribution of accessory components is summarized on Table T5.

T5. Distribution of accessories, Site 1166, p. 37.

Sponge Spicules

Sponge spicules were consistent components of samples at Site 1165 and are conspicuous in modern sediments of Prydz Bay. With the exceptions of the 63- to 125-µm fraction in Sample 188-1166A-1R-CC, which is a sponge spicule–rich horizon with simple diactinellid monaxon spicules to ~10 mm long, and Samples 188-1166A-1R-1, 16–21 and 117–122 cm, 2R-CC, 1R-2, 9–12 cm, and 12R-CC, they are either absent or very minor constituents at this site.

Barnacle

Sample 188-1166A-11R-1, 47–50 cm, contains a highly fragmented barnacle plate.

Pre-Neogene Terrestrial Vegetation

Black coal fragments are present throughout the sequence, but most are genuine coal and probably originated in the Permian sequence of the Prince Charles Mountains region, 250–500 km to the south. A few trilete and bisaccate pollen or spores were recovered from diatom preparations from Sample 188-1166A-16R-2, 140–141 cm. The bisaccate forms are likely to be from the Permian, but the source of the trilete is not as clear and could be related to the presence of wood fragments in the next core.

Wood fragments, <0.5 mm long, make their appearance downhole in Sample 188-1166A-17R-CC and are present in several samples below that. Under the microscope, the small fragments are still flexible when wet and retain their orange-brown color. Details of wood and cuticle are clearly visible in mounted slides of the material. They are not to be confused with woody structure that is visible in some of the black coal fragments that accompany most samples.

In Sample 188-1166A-25R-2, 0–5 cm, there are fragments up to 8–9 mm in diameter of dark brown lignified wood, contrasting strongly with the black coal. Woody structures are essentially pristine. It also contrasts with descriptions of the Cretaceous coals recovered during Leg 119, indicating strongly that this is Tertiary material close to its origin. The wood tissue is very well preserved in many samples.

Sample 188-1166A-27R-CC consists of highly coaly sediment, almost lignite. The major constituent is wood in fragments up to 20 mm long. The rest is quartz sand and mica, consistent with deposition in a coal swamp environment. There is ample wood and diversity, and preservation seems adequate to allow reconstruction of the vegetation at the time.

The wood fragments are clear evidence of coeval terrestrial vegetation in the samples, which are dated on other bases as latest Eocene–earliest Oligocene. Results of palynological analysis of this material is the subject of **Macphail and Truswell** (this volume).

SITE 1167 RESULTS

A single hole (1167A) was drilled at this site (Table **T1**), and cores from the surface to total depth (0.6–447.5 mbsf; Cores 188-1167A-1H through 49X), with few notable exceptions, produced large residues very dominantly of coarse, poorly sorted, angular sandstone dominated by terrigenous debris, different in appearance from that of coeval material at other Leg 188 sites. The volumes of residues captured on sieves during processing are remarkably uniform throughout the section. Most sediments are gray and obviously clayey during washing, but with high content of sand and coarser fragments. Sample 188-1167A-2H-CC was notably different in being reddish and yielded sand with a high content of iron oxide–coated grains. It is barren of foraminifers. Preservation of assemblages generally is very good and provides material of quality adequate for oxygen/carbon isotope analysis and, where common enough, Sr dating. The water depth, at 1640 m, is close to the CCD in the area (Quilty, 1985; Poisson et al., 1987).

Most samples yield few foraminifers, but over many samples a quite diverse assemblage (Table **T6**) emerges. The samples are remarkable in lacking siliceous microfossils—diatoms, radiolarians, sponge spicules—that are normal in Antarctic sediments.

T6. Distribution of foraminifers, Site 1167, p. 38.

Most samples produced foraminifer assemblages with *N. pachyderma* dominant over other planktonic species, and planktonic content very dominant over benthic. *N. pachyderma* is consistent with an age of late Miocene or younger (*N. pachyderma* Zone; AN7 of Berggren 1992, and Berggren et al., 1995). It is, as expected, almost 100% sinistrally coiled, but a few dextral specimens were seen (e.g., Sample 188-1167A-19X-CC). The benthic component of the assemblage usually is dominated by species of *Globocassidulina,* but with species of *Trifarina* and *Uvigerina* an appreciable component, the first section from Leg 188 to contain evidence of a significant infauna. Assemblages with benthic species dominated by globocassidulinids probably represent mid–outer shelf faunas that have moved downslope.

Following identification by the diatomists as containing many "microforaminifera," Samples 188-1167A-5H-3, 34–36 cm, and 25X-CC, 22–23 cm, were sampled separately. They are very different from other samples by virtue of (1) the high abundance of foraminifers (very dominantly planktonic to ~6000 per sample) in a section where they consistently are rare, (2) abundant thin-walled planktonic forms in the fine fraction, and (3) a different benthic assemblage of small species that may represent mid-bathyal conditions consistent with a short interval lacking debris flow activity. The same samples have higher (but still minor) glauconite content. Some *N. pachyderma* specimens are black through Mn oxide staining and infilling, again consistent with a short hiatus in debris flow activity.

Higher in the hole, benthic species comprise a few percent of each sample and are mainly of calcareous species, especially of globocassidulinds, but with a few uvigerinid species, indicating the existence of an infauna. Variation between samples in foraminiferal content probably reflects variation in the following factors:

1. The amount of continental shelf and slope floor and water column available for colonization by foraminifers—sediments barren of foraminifers may represent times of low habitat availability (glacial maxima), and sections with higher foraminifer content should indicate higher habitat availability during times of low ice cover (glacial minima);
2. Effectiveness of carbonate dissolution under the influence of oscillation in the position of the CCD (and the effects of simple sea level variation on this level); and
3. Sedimentation rate.

It is likely that sedimentation of foraminifers at the site is controlled by (1) periodic, but volumetrically dominant, influx of shelf sediment and (2) short intervals of pelagic conditions when the shelf sediment influx is dramatically reduced. In the former association, benthic species represent outer continental shelf conditions (their source, but redeposited over the shelf edge), and the latter, the in situ mid–upper bathyal fauna in which the calcareous biogenic component of the sediment is correspondingly higher. It is possible, but speculative, that the variation in numbers of planktonic species is a proxy for the difference in rate of influx of sediment. This assumes that the rate of production of planktonic species is approximately constant.

Other than the transport of continental shelf assemblages to the slope, there is little evidence of reworking. A little glauconite is present in a few samples such as Samples 188-1167A-5H-CC, 12X-CC, 25X-1, 128–130 cm, and 27X-CC.

Biostratigraphic Subdivision of the Column

Nowhere at Site 1167 was the horizon with *G. puncticulata* (Deshayes) identified as it was at Site 1165 in Sample 188-1165-2H-1, 70–75 cm. This may suggest that drilling at Site 1167 has not yet reached this stratigraphic level. Although not recorded by Berggren (1992) as a zonal fauna, it is present at Sites 744, 747, and 1165 and would be expected at Site 1167, which is relatively close to Site 1165.

Because of dissolution effects, there is little value in subdividing the section on the basis of foraminifers alone, and thus a more subjective approach is used to recognize the following intervals:

1. Sample 188-1167A-1H-1, 60–64 cm (0.60–0.64 mbsf): a single sample with abundant foraminifers and a diverse biota of other groups such as echinoderms, ostracodes, etc.).
2. Samples 188-1167A-1H-2, 60–64 cm, through 4H-CC (2.1–33.7 mbsf): characterized by very low foraminifer numbers, occasional barren samples, and very little other biota.
3. Samples 188-1167A-5H-1, 60–64 cm, through 8X-CC (343.3–54.7 mbsf): a richer foraminifer assemblage, with continuous planktonic species and spherical and tapered benthic species (sensu Thomas, 1990) and significant other biota, although this always consists of a few indications only.
4. Samples 188-1167A-9XCC through 13X-4, 60–64 cm (64.3–98.1 mbsf): similar to the above, but with lower foraminifer numbers. The impression is of lower productivity, slightly higher effects of dissolution, or higher sedimentation rate leading to swamping of the biota;

5. Samples 188-1167A-13X-5, 60–64 cm, through 25X-1, 60–64 cm (99.6–208.6 mbsf): consistently higher foraminifer numbers, rather akin to the interval above it, but with higher numbers (though still low) of other biota. There are no barren samples in this interval. Spherical and tapered benthic species are present consistently. The impression is of reduced effects of dissolution, lower sedimentation rates, or higher productivity.
6. Samples 188-1167A-25X-2, 60–64 cm, through 49X-CC (210.1–447.5 mbsf): characterized by very low foraminifer numbers, almost half the samples are barren, and other biota are almost nonexistent. It appears to have been a high-dissolution regime.

An alternative approach is to differentiate only two intervals, that above Core 188-1167A-25X and that below. Core 188-1167A-25X seems to mark a very clear boundary with CCD effects almost total below and much reduced above.

Accessory Components

The characteristics of the sand in the sandstone changed downhole. The higher samples contain very immature sands with a high content of garnet and other diverse heavy minerals. By Core 188-1167A-25X, the content of heavy minerals has decreased markedly and residues are very clean, white sand. This change with time may reflect an early source of mature, well-washed, well-sorted material carried initially by water, followed by the modern interval of glacially transported, less mature detritus with less opportunity for weathering and sorting to remove the heavy minerals. The change could be from a clean sandstone source (large fragments of clean sandstone are present in the coarse fraction) to one more dependent on the Precambrian shield of East Antarctica, or a change in dominance of the source.

Detrital Pyrite

Detrital pyrite (identified as such because it is present in coarse crystals that also occur in fragments of sandstone) is a consistent accessory throughout this section. In Sample 188-1167A-26X-CC, diagenetic pyrite appears differentiated because it is very fine (sometimes framboidal) and occurs as what appear to be pseudomorphs after tubular and globular organic remains. In Sample 188-1167A-40X-CC, pyrite is pseudomorphic after a planktonic foraminifer.

Black Coal

Probably from the Permian Amery Group in the Prince Charles Mountains, traces of black coal are present in virtually all samples.

Other Accessories

The absence of opaline siliceous microfossils such as radiolarians, diatoms, and sponge spicules (apart from in the upper section) seems anomalous in the light of their abundance in modern sediments of Prydz Bay. Shell material and echinoderm debris is very seldom encountered and is very rare where present. Bivalve shell fragments occur sporadically, but they are small and not adequate for identification, even to generic level. No bone or teeth were seen. Ostracodes are so rare that no pattern can be detected in their occurrence. In Sample 188-1167A-25X-CC, 22–23 cm, they are represented by rinds of the more insoluble parts of the valves and indicate that their absence may in part be due to dissolution.

Glauconite

Glauconite is present sporadically but is very rare. Its source is unknown, but glauconite is a common component of Paleogene sediments on Mac. Robertson Shelf (Quilty et al., 2000b) and its presence may be associated with downslope (or across shelf) movement from this source.

Assemblage Structure and Its Paleoenvironmental Significance

Thomas (1990), following Corliss and Chen (1988), provided a basis for analyzing the benthic content of assemblages and differentiating epi- and infaunal elements. Unfortunately, recovery was not enough or the effects of dissolution so marked that the approach cannot be employed except on samples near the surface (e.g., Sample 188-1167A-1H-1, 60–64 cm) where the infauna is dominant. The dominance is even more marked in the few deeper samples where the specimen numbers are high enough to consider applying the technique. The principal result of trying to use the approach is to show that dissolution has been active.

Table T7 is a plot of planktonic percentage (percent of the foraminiferal assemblage composed of planktonic species). Whereas generally the figures are consistent with expectations in water this deep, the numbers must be used cautiously because of dissolution effects and the probability of significant downslope movement. The high proportion of barren samples also suggests caution in interpretation.

T7. Planktonic percentages, Hole 1167A, p. 39.

CCD Effects

The modern CCD at the continental shelf edge of Prydz Bay is at ~1500 m (Quilty, 1985; Poisson et al., 1987), and thus dissolution was expected to have a significant negative influence on recovery of calcareous organisms. CCD effects are not visually obvious until Sample 188-1167A-25X-CC, 22–23 cm, when ostracodes and foraminifers both show evidence of dissolution even though abundance still is relatively very high. In ostracodes dissolution is indicated by the presence only of a few rinds of valves and in foraminifers by partial dissolution of layers of the thick tests of *N. pachyderma*. The CCD may be responsible for some absences where dissolution has been complete, but few samples show much evidence of the effects of the CCD. In Sample 188-1167A-40X-CC, foraminifers are absent but there is a single pyrite pseudomorph after a globigerinid species to indicate that some planktonic specimens were present but have been dissolved. Sample 188-1167A-25R-CC yielded no foraminifers but contains a few pyrite pseudomorphs that may represent infilling of benthic tests. This supports the suggestion that some other absences may be CCD related.

Although visible effects are only rarely obvious, there are other indications that dissolution has been active. Analysis of data from the distribution shown on Table T6 shows clearly that epifaunal species are very rare and that benthics are very dominantly infaunal. Many samples are barren of any foraminifers, but there are intervals in which identical lithology contains useful assemblages, all indicating that any foraminifers exposed on the seafloor were subject to dissolution at some times.

Downslope Movement of Sediments and Assemblages

A major consideration in this study has been to determine whether the sediments at this site are in situ or have been brought downslope from the continental shelf by debris flow activity. Throughout the section, assemblages are dominantly of planktonic species and the planktonic percentages are consistent with their being in situ. Above Core 188-1167A-26X, benthic faunas are dominated by *Globocassidulina,* subdominant tapered infaunal species such as *T. angulosa* and *Uvigerina hispidocostata,* and subsidiary *Ehrenbergina glabra*. Agglutinated species are essentially absent. Assemblages with this composition are found in the Shallow Shelf Calcareous Assemblage of Milam and Anderson (1981) in water depths of 230–400 m. They also occur over an almost identical depth range in the Ross Sea, documented by Fillon (1974), who differentiated those faunas from within the Ross Sea from those of the northwestern or ocean open environment. The Milam and Anderson study indicates that the difference means little. Other species occurring sporadically are consistent with assemblages from this depth interval. This suggests that downslope movement is highly likely and that the assemblages (and sediments) have moved some 1000–1100 m vertically and several tens of kilometers horizontally. Planktonic species probably represent the local supply and are likely to be essentially in situ.

Samples 188-1167A-5H-3, 34–36 cm, and 25X-CC, 22–23 cm, contain faunas that, while constituting <1% of the total foraminifers, yield forms not seen elsewhere during studies of Leg 188 material. It is not a shelf assemblage and includes *Planulina wuellerstorfi* (Schwager). The contrast between this assemblage and the globocassidulinid-dominated shelf assemblages is very marked and suggests strongly that this assemblage is in situ, accumulated in bathyal depths, and is not a product of transport from shallower depths.

Sample 188-1167A-8H-CC provided a diverse, well-preserved assemblage with evidence (in the form of an ostracode and echinoid spines) of a diverse assemblage on the seafloor.

COMPARISON WITH NEARBY ONSHORE SECTIONS

Pliocene marine foraminifer assemblages are known from Larsemann Hills (Quilty et al., 1990), Marine Plain (Quilty et al., 2000a), and Heidemann Valley (Hirvas et al., 1993), and Paleogene foraminifer assemblages occur on Mac. Robertson Shelf (Quilty, 2001). It was hoped that the Leg 188 sections would provide continuous offshore sections with assemblages in common so that the onshore sections, each representing a short time interval, could be correlated with a longer-term reference section. The offshore assemblages have very little in common with those onshore, the differences being due to differences in environment of deposition (very shallow marine embayments onshore, deeper, open-ocean waters with CCD effects offshore). Knowledge of the Paleogene faunas of the Mac. Robertson Shelf has helped interpret other aspects (presence of recycled glauconite) in the section at Site 1165.

CONCLUSIONS

Neogene foraminifers and accessory components are documented from each of the sites drilled during Leg 188 of the ODP in Prydz Bay, Antarctica. Although contributing little to the chronostratigraphy at any site, they are important in consideration of the paleoenvironment, especially as that relates to short-term warm-water episodes and source and downslope movement of sediment. The assemblages are very different between sites, and little integration of results can be made of assemblages between sites. Foraminifers at all sites occasionally provide enough calcite for oxygen isotope studies and strontium dating. Only in a few cases were assemblages preserved adequately for epifaunal/infaunal analysis.

At Site 1165, planktonic foraminifers are rare because of expected CCD effects, but the poorly dated Sample 188-1165B-2H-1-CC contains *G. puncticulata* and suggests that the longer estimates of the range (Pliocene–Holocene) of this species are correct and that there was a short interval of quite warm marine conditions at this site. Sporadic samples (e.g., Sample 188-1165B-14X-CC) indicate that sediment arrived at the site by mass movement. The uphole influx of glauconite in Core 188-1165B-26X indicates a new source of sediment at that time.

The assemblages from the lower reaches of the section at this site are dominated by large agglutinated species such as *C. incisa* (Stache) and species of *Bathysiphon, Reophax,* and *Hyperammina.*

Sediments at Site 1166 yielded foraminifers only from the Neogene. These are similar to modern assemblages of Prydz Bay and appear essentially to be in situ. Assemblages are dominated by globocassidulinid species and subspecies.

The Quaternary section at Site 1167 is close to the modern CCD and is composed dominantly of sediment coarser than that at other sites. This provided foraminifers from most samples, but the yield varied markedly. Although dominated by planktonic assemblages of monospecific, sinistral *N. pachyderma,* enough benthos is available to indicate that, with a few noted exceptions, the assemblages accumulated in shallower water and moved to their present site by debris flow activity. There is clear evidence in assemblages and residues of a marked change of sediment source in Core 188-1167A-25X.

In addition to foraminifers, accessory components, such as other microfossils and some minerals, are recorded. These, while of little paleontological value, often indicate changes of environment.

TAXONOMIC COMMENTS

Planktonic Species

***Neogloboquadrina pachyderma* (Ehrenberg), 1861 (Pl. P1, figs. 19–21).**
Aristospira pachyderma Ehrenberg, 1861, pp. 276, 277, 303.
Neogloboquadrina pachyderma (Ehrenberg), Collen and Vella, 1973, p. 19, pl. 1, figs. 11, 12.

Remarks: *N. pachyderma* in Sample 188-1167A-37X-CC (Pl. P1, fig. 19) is unusual in being very small and compact, in contrast with younger collections, which are large, less compact, and, generally, more abundant.

Within *N. pachyderma,* I have included a variant that may be juvenile but may warrant separation as a subspecies. It is readily separable in a population of *N. pachyderma*. It has a test with a very low trochospire, with 4.5 chambers in the final whorl, and an almost flat dorsal surface. The wall is thin and finely hispid until the adult, when some thickening may occur and the *Neogloboquadrina* stage is reached. At this stage, ~30% develop a bulla. The umbilicus is small and narrow. Dorsal intercameral sutures are straight and the ventral (umbilical) sutures are straight, all meeting at the umbilicus. The periphery is lobulate, and all sutures are broadly and gently depressed. The aperture is a low arch from the umbilicus to three-fourths of the distance to the periphery and is umbilical-extraumbilical and bordered by a distinct thin, regular rim.

I have been puzzled for many years, studying Antarctic foraminiferal assemblages, with a thin-walled form (Pl. P1, fig. 20), commonly associated with *N. pachyderma* and referred by various authors to a variety of names. It is very like *Globigerina angustiumbilicata* Bolli but has a lower spire (Stainforth et al., 1975, fig. 105, figure it well) and thinner, more finely structured wall, even in the normal early adult stages. This may incorporate the younger part of the range of *G. angustiumbilicata* suggested by Stainforth, which is in conflict with the shorter range attributed by several authors (e.g., Kennett and Srinivasan, 1983). Wall structure differences even suggest different lineages. Blow (1969) figured the holotype of *G. angustiumbilicata,* which has a smaller, globigerine aperture with less marked rim or lip.

In Sample 188-1166A-10R-1, 11–13 cm, there are forms that seem transitional to the five-chambered form of *N. pachyderma. N. pachyderma* always is bullate in its compact, thick-walled adult form. This form generally has a thinner wall, 4.5 chambers in the final whorl, and only 30% or less of any population are bullate. The equatorial profile is very different because of the thickening so characteristic of *N. pachyderma. N. pachyderma* has a little over four chambers in the final whorl, but the small difference in number of chambers makes a great deal of difference in appearance.

***Globigerina* sp. (Pl. P1, figs. 15, 16).**

Remarks: In Sample 188-1167A-19X-CC there are five specimens of a high-spired, thin-walled form with up to 4.5 chambers in the final whorl. Specimens have apertures that vary from open (and very similar to that of *G. bulloides*) to closed with a small bulla.

Benthic Species

***Haplophragmoides canariensis* (d'Orbigny), 1839 (Pl. P1, fig. 3).**

Nonionina canariensis d'Orbigny, 1839, p. 128, pl. 2, figs. 33, 34.

Haplophragmoides canariensis (d'Orbigny), Brady, 1884, p. 310, pl. 35, figs. 1–5.

Remarks: The species recorded from Sample 188-1165B-58X-1, 70–75 cm, is not that recorded by Barker (1961) under this name but that noted by McKnight (1962) and Milam and Anderson (1981) and is characterized by four to five chambers per whorl.

***Uvigerina hispidocostata* Cushman and Todd, 1945 (Pl. P1, figs. 4, 5).**

Uvigerina hispidocostata Cushman and Todd, 1945, p. 51, pl. 7, figs. 27, 31.

Remarks: This species is interpreted liberally to include species identical with those of Mackensen (1992) to approximately Core 188-1167A-18X (form A). Below that depth, specimens are decidedly more hispid (form B) than those shallower and perhaps warrant separation as a distinct species. The final chamber or two are totally hispid in the deeper samples.

***Trifarina angulosa* (Williamson), 1858 (Pl. P1, fig. 6).**

Uvigerina angulosa Williamson, 1858, p. 67, fig. 140.

Remarks: This species name is used broadly to include several names that have been applied in different studies of Neogene Antarctic foraminifers. It is used to include those non-hispid, ribbed forms with carinate chambers, the carinae parallel to the test length. Forms included are *Uvigerina bassensis* (of Milam and Anderson, 1981), *Trifarina pauperata* (of Leckie and Webb, 1985), and *Trifa-*

rina earlandi of Ishman and Webb (1988) and McKnight (1962). In this it follows the practice of Mackensen (1992).

Cibicides lobatulus **(Walker and Jacob), 1798 (Pl. P1, fig. 7).**
Nautilus lobatulus Walker and Jacob, 1798, p. 642, pl. 14, fig. 36.
Cibicides lobatulus (Walker and Jacob), Cushman, 1931, p. 118, pl. 21, fig. 3.

Remarks: Sample 188-1167A-1H-1, 60–64 cm, contains three specimens that are an extremely flattened variant of this species and are similar to a specimen figured by Echols (1971) as this species. It may also be the form recorded by Ishman and Webb (1988, pl. 5, fig. 2) as *Cibicides* sp.

Genus *Globocassidulina* Voloshinova, 1960

Remarks: *Globocassidulina* is the dominant benthic genus, and several distinct morphotypes can be differentiated. It is clear that *Globocassidulina crassa crassa, Globocassidulina crassa rossensis,* and *Globocassidulina crassa biora* intergrade, that some identification is subjective, and that the differentiation probably has very little biological significance. If different times of origin can be proven, the differentiation will have biostratigraphic significance. These forms seem to be of Antarctic occurrence only. Occasional specimens of *G. crassa rossensis* and *G. crassa biora* have a pustulose surface in their early stages and may thus be *Cassidulina subglobosa* var. *tuberculata* of Heron-Allen and Earland (1922). The tuberculate character then would seem to be of little taxonomic significance. It is likely that some specimens identified as *Globocassidulina subglobosa* are merely less mature variants of *G. crassa*.

Globocassidulina subglobosa **(Brady), 1881.**
Cassidulina subglobosa Brady, 1881, p. 60, pl. 54, figs. 17a–c.

Remarks: A generally small, compact globular species with single comma-shaped aperture perpendicular to the basal suture of the final chamber.

Globocassidulina crassa crassa **(d'Orbigny), 1839 (Pl. P1, fig. 8).**
Cassidulina crassa d'Orbigny, 1839, p. 56, pl. 7, figs. 18–20.

Remarks: A large species, often slightly laterally compressed, with a single aperture that is part of the basal suture of the ultimate chamber, or parallel to it.

Globocassidulina crassa rossensis **Kennett, 1967 (Pl. P1, fig. 10).**
Globocassidulina crassa rossensis Kennett, 1967, p. 133, pl. 11, figs. 4, 6.

Remarks: Normally a large form with a bifurcate aperture, generally with the base of the aperture perpendicular to the basal suture of the ultimate chamber; however, there is considerable variation in this feature.

Globocassidulina crassa biora **(Crespin), 1960 (Pl. P1, fig. 9).**
Cassidulina biora Crespin, 1960, p. 28, pl. 3, figs. 1–10.
Globocassidulina biora (Crespin), Fillon, 1974, p. 139, pl. 1, figs. 9–12.

Remarks: This form is very similar to *G. crassa rossensis* but has two parallel slitlike apertures parallel to the basal suture of the ultimate chamber. There is some variation in this feature and some specimens may have the apertures, while roughly parallel, join at one end.

Astrononion antarcticum **Parr, 1950 (Pl. P1, fig. 11).**
Astrononion antarcticus Parr, 1950, p. 371, pl. 15, figs. 13, 14.

Remarks: The single specimen in Sample 188-1167A-3H-3, 60–64 cm, is a regular planispiral test, in contrast with the distinctly asymmetrical form of the holotype figured by Parr (1950) and that of Milam and Anderson (1981). The apertural flaps are not so stellate as those of earlier figured specimens, but other features of the test are consistent with this identification.

Anomalinoides **sp. (Pl. P1, fig. 13).**

Remarks: This record refers to a small species that is present throughout the sequence but is always a very minor constituent. It may the form recorded by Echols (1971, pl. 13, fig. 7a, b) as *Melonis* cf. *M. affinis* (Reuss). From examination of lateral aspects it appears planispiral, but the aperture has a slight asymmetry consistent with placement in this genus. Under scanning electron microscope examination, specimens commonly have what appears to be incipient, but not developed, lateral apertures that would characterize *Astrononion.* It seems likely, because of its persistent occurrence, that it is a widely occurring species, and thus some records of planispiral forms in the Antarctic may refer to this species.

Gyroidinoides neosoldanii **(Brotzen), 1936 (Pl. P1, fig. 14).**
Gyroidina soldanii d'Orbigny, 1826, p. 276, modeles 36.
Gyroidina neosoldanii Brotzen, 1936, p. 158.

Remarks: This species occurs only rarely through the sections studied. That in Sample 188-1165B-58X-1, 70–75 cm, is unusual in that it has a raised but not angular *Globorotalites*-type ridge around the margin of the dorsal surface.

Cancris nuttalli **(Palmer and Bermúdez), 1936.**
Valvulineria nuttalli Palmer and Bermúdez, 1936, p. 300, pl. 19, figs. 3–5.
Cancris nuttalli (Palmer and Bermúdez), van Morkhoven et al., 1986, p. 120, pl. 38, figs. 1–3.

Remarks: The specimen from Sample 188-1165B-20X-5, 120 cm, is poorly preserved and is identified because of the projection on the distal anterior of the ultimate chamber. It also has some of the characteristics of species of *Nonionella* recorded by Leckie and Webb (1985), but the features of the ultimate chamber seem persuasive. It is a mid- to upper-bathyal species according to van Morkhoven et al. (1986).

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APPENDIX A

Samples Barren of Foraminifers, Site 1165

Core, section, interval (cm)
188-1165B-
3H-1, 70–75
3H-2, 70–75
3H-3, 70–75
3H-4, 70–75
3H-5, 70–75
3H-6, 70–75
3H-CC
4H, 3, 70–75
4H-4, 70–75
4H-CC
5H-3, 70–75
6H-1, 70–75
6H-2, 70–75
6H-5, 70–75
6H-6, 70–75
8H-1, 70–75
8H-3, 70–75
8H-4, 70–75
8H-6, 70–75
8H-7, 30–35
8H-CC
9H-1, 70–75
9H-3, 70–75
9H-5, 70–75
9H-CC
10H-1, 70–75
10H-3, 70–75
10H-5, 70–75
10H-CC
11H-1, 70–75
11H-3, 70–75
11H-5, 70–75
11H-CC
12H-CC
13H-1, 70–75
13H-3, 70–75
13H-5, 70–75
14H-1, 70–75
14H-3, 70–75
14H-5, 70–75
15H-1, 70–75
15H-CC
16H-1, 70–75
16H-4, 70–75
16H-CC
17H-1, 70–75
17H-3, 70–75
17H-5, 70–75
19X-1, 70–75
19X-CC
20X-1, 70–75
20X-3, 70–75
20X-CC
21X-1, 70–75
21X-CC
22X-1, 70–75
22X-CC
23X-1, 70–75
23X-3, 50–54
23X-3, 70–75
23X-5, 70–75
23X-CC
27X-CC
28X-CC
30X-CC
32X-CC
33X-CC
34X-CC
35X-CC
36X-CC
37X-CC
38X-CC
39X-CC
40X-CC
41X-CC
42X-CC
43X-CC
44X-CC
45X-CC
46X-CC
48X-CC
49X-CC
50X-CC
51X-CC
52X-CC
53X-3, 53–54
53X-CC
54X-3, 114–115
54X-CC
55X-CC
56X-CC
57X-1, 86–88
57X-CC
58X-3, 50
58X-CC
59X-3, 50–54
59X-CC
60X-CC
61X-CC
62X-3, 50–54
63X, 24–29
63X-CC
64X-CC
65X-CC
66X-3, 50–54
66X-CC
67X-3, 50–54
67X-CC
68X-CC
69X-CC
70X-CC
71X-CC
72X-CC
73X-1, 44–45
73X-CC
74X-2, 62–63
75X-1, 7–8
75X-CC
76X-CC
188-1165C-
1R-1, 70–75
2R-3, 50–54
1R-3, 70–75
1R-5, 70–75
1R-CC
2R-1, 37
4R-3, 50–54
5R-3, 50–54
5R-CC
6R-3, 50–54
6R-CC
7R-CC
8R-CC
9R-CC
10R-CC
11R-3, 50–54
13R-3, 50–54
14R-3, 90–92
14R-6, 2–3
15R-3, 50–54
16R-3, 50–54
17R-3, 50–54
18R-2, 141–143
18R-3, 50–54
18R-CC
19R-3, 50–54
19R-CC
20R-3, 50–54
21R-1, 35–37
21R-3, 50–54
21R-CC
22R-3, 50–54
22R-5, 3–9
22R-CC
23R-3, 50–54
23R-CC
24R-3, 50–54
24R-CC
25R-3, 50–54
26R-3, 50–54
26R-CC
27R-CC
28R-5, 131–133
28R-CC
29R-3, 50–54
29R-CC
30R-3, 50–54
30R-CC
31R-3, 50–52
31R-CC
32R-CC
34R-CC
35R-3, 50–52
35R-CC

APPENDIX B

Samples Barren of Foraminifers, Site 1166

Core, section, interval (cm)
188-1166A-
1R-CC
2R-CC
8R-CC
9R-1, 41–45
12R-CC
13R-1, 71–73
13R-CC
14R-4, 56–59
14R-CC
15R-3, 127–130
15R-4, 25–28
15R-4, 67–70
15R-CC
16R-1, 40–43
16R-CC
17R-1, 33–36
17R-CC
18R-1, 33–36
18R-CC
19R-CC
20R-CC
21R-CC
22R-CC
23R-CC
24R-CC
25R-CC
26R-CC
27R-CC
28R-CC

APPENDIX C

Samples Barren of Foraminifers, Site 1167

Core, section, interval (cm)
188-1167A-
1H-CC
2H-1, 60–64
3H-2, 60–64
13X-2, 60–64
25X-2, 60–64
25X-4, 60–64
25X-CC
26X-1, 60–64
26X-2, 60–64
26X-4, 60–64
26X-6, 60–64
26X-7, 30–34
26X-CC
27X-1, 60–64
28X-1, 60–64
28X-2, 60–64
28X-CC
29X-CC
30X-1, 60–64
30X-2, 60–64
31X-CC
34X-1, 60–64
34X-CC
38X-2, 60–64
40X-CC
41X-1, 60–64
41X-3, 60–64
42X-1, 60–64
44X-CC
45X-1, 60–64
45X-CC
47X-1, 60–64
47X-CC
48X-2, 60–64
48X-3, 60–64
48X-4, 46–50
48X-4, 60–64
49X-CC

Figure F1. Locality map for Sites 1165, 1166, and 1167. Earlier sites in Prydz Bay also are shown.

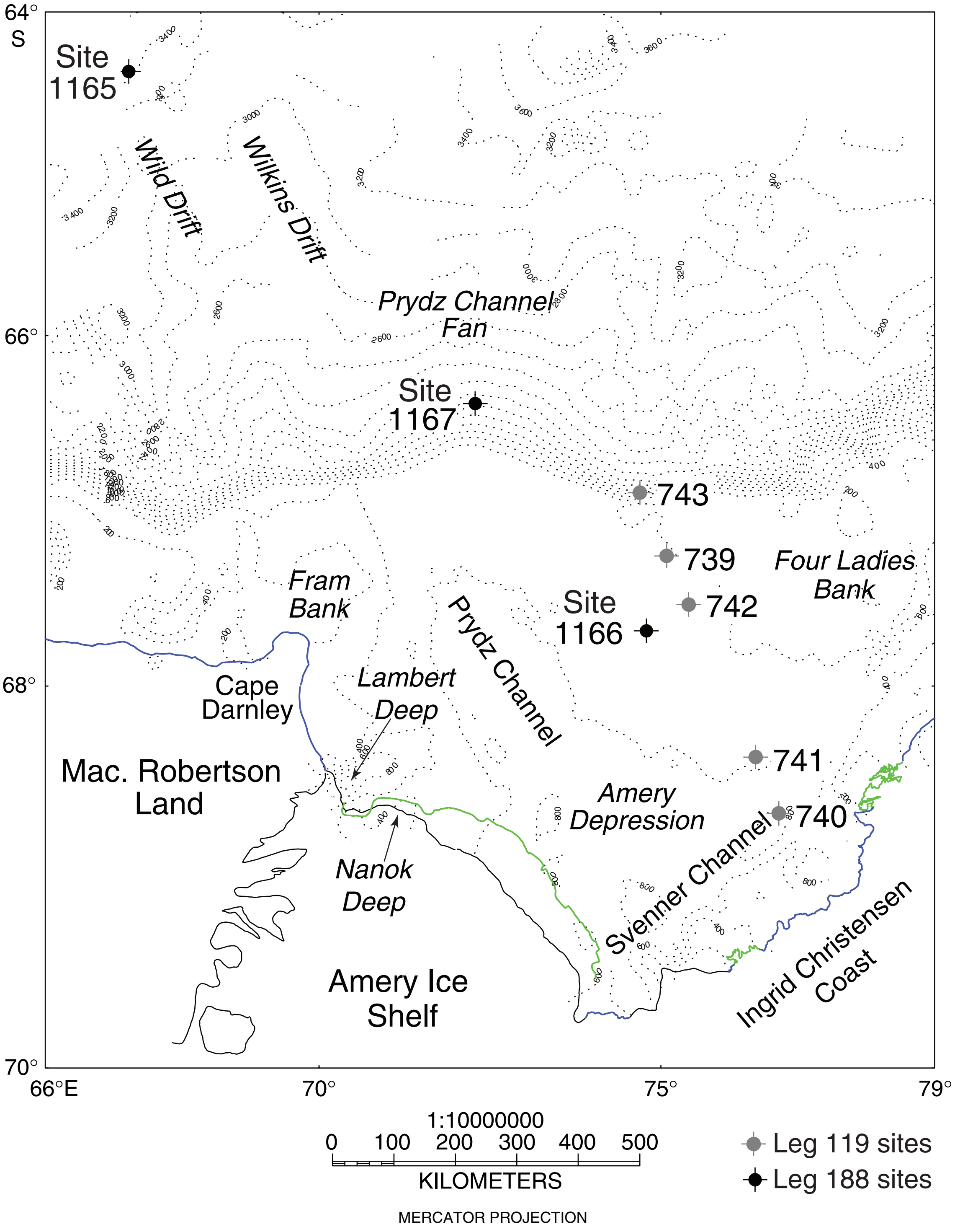

Table T1. Locations and water depths of sites drilled during ODP Leg 188.

Hole	Latitude	Longitude	Water depth (m)
188-			
1165A	64°22.22′S	67°13.14′E	3537
1165B	64°22.77′S	67°13.14′E	3538
1165C	64°22.76′S	67°13.08′E	3538
1166A	67°41.77′S	74°47.22′E	475
1166B	67°41.79′S	74°47.22′E	469
1167A	66°24.10′S	72°17.05′E	1640
1167B	66°23.98′S	72°17.10′E	1640

Table T2. Distribution of foraminifers, Site 1165. (This table is available in an **oversized format.**)

Table T3. Distribution of accessory assemblages and glauconite, Site 1165.

Core, section, interval (cm)	Sponge spicules	Oroscenid radiolarians	Echinoid spines	Teeth/bone	Pyrite pseudomorphs	Glauconite	Ostracodes
188-1165A-							
1H-CC	x					x	
(1*)							
188-1165B-							
1H-2, 70–75	x					x	
1H-3, 70–75	x					x	
1H-4, 70–75						x	
1H-CC			x				x
2H-1, 70–75			x				x
2H-2, 70–75	x					x	x
2H-3, 70–75						x	
2H-4, 70–75	x		x			x	
2H-5, 70–75	x						
2H-6, 70–75						x	
2H-7, 33–35				x		x	
2H-CC	x			?		x	
3H-1, 70–75	x					x	
(1*)							
3H-2, 70–75	X					X	
3H-4, 70–75	X					X	
3H-5, 70–75						X	
3H-6, 70–75	X					X	
3H-CC	X					X	
4H-1, 70–75	X					X	
(1*)							
4H-3, 70–75	X					X	
4H-4, 70–75						X	
4H-5, 70–75	X					X	
4H-6, 70–75	X					X	
4H-7, 30–35	X					X	
(1*)							
5H-1, 70–75	X					X	
(1*)							
5H-3, 70–75	X						
5H-4, 70–75						X	
5H-5, 70–75						X	
5H-6, 70–75	X						
5H-CC						x	
6H-1, 70–75	x					x	
(1*)							
6H-3, 70–75				x			
6H-4, 70–75	x						
6H-5, 70–75						x	
6H-6, 70–75	x					x	
6H-7, 30–35	x					x	
6H-CC	x					x	
188-1165C-							
1R-1, 70–75	x						
1R-3, 70–75	x						
1R-5, 70–75	x						
1R-CC	x					x	
188-1165B-							
8H-1, 70–75	x					x	
8H-2, 70–75	x					x	
8H-3, 70–75	x					x	
8H-4, 70–75	x					x	
8H-5, 70–75	x					x	
(1*)							
8H-7, 30–35	x						
8H-CC	x					x	
9H-1, 70–75	x						
9H-3, 70–75	x						
9H-5, 70–75	x						
9H-CC	x					x	
10H-1, 70–75	x						
(2*)							
10H-CC	x					x	
11H-1, 70–75						x	
11H-3, 70–75						x	
11H-5, 70–75	x						
11H-CC	x					x	
12H-CC	x					x	
13H-3, 70–75	x					x	
13H-CC	x					x	
14H-1, 70–75				x		x	
14H-3, 70–75				x		x	
(1*)							
14H-CC			x	x			
15H-1, 70–75	x					x	
15H-CC						x	
(1*)							
16H-4, 70–75						x	
16H-CC				x		x	
17H-1, 70–75						x	
(1*)							
17H-5, 70–75						x	
17H-CC	x					x	
18H-CC	x						
(1*)							
19X-CC	x						
20X-1, 70–75						x	
20X-3, 70–75	x						
20X-5, 70–75	x						
(1*)							
20X-CC				x		x	
21X-1, 70–75						x	
(1*)							
21X-CC	x						
(1*)							
22X-3, 70–75	x						
22X-4, 52–58	x						
22X-4, 70–75				x			
22X-5, 70–75				x			
22X-7, 30-35		x					
(1*)							
23X-1, 70–75						x	
(1*)							
23X-3, 70–75	x						
(4*)							
26X-CC						x	
27X-CC	x						
(3*)							
33X-CC		x					
34X-5, 25–27	x	x					
34X-CC		x					
35X-CC		x					
36X-CC		x					
37X-CC					x		
38X-CC	x	x		x			
39X-CC	x	x		x			
40X-CC					x		
(5*)							
45X-CC					x		
(9*)							
55X-CC	x	x					
(3*)							
58X-1, 70–75	x	x	x	x			
(9*)							
62X-CC				x			
(19*)							
74X-CC				x			
(3*)							
188-1165C-							
(42*)							
22R-4, 52–58	x			x			
(16*)							
29R-4, 130–150	x						
(2*)							
30R-3, 142–144				x			
(5*)							
33R-CC				x			
(3*)							

Notes: * = number of barren samples between listed intervals. X = extended core barrel coring. x = present.

Table T4. Distribution of foraminifers, Site 1166.

Core, section, interval (cm)	Depth (mbsf)	*Globigerina falconensis*	*Globigerinita parkerae*	*Globigerinita* sp. 1	*Globorotaloides* sp.	*Neogloboquadrina pachyderma*	*Anomalinoides* sp.	*Astrononion antarcticus*	*Astrononion echolsi*	*Cassidulina laevigata*	*Cibicides lobatulus*	*Cibicides refulgens*	*Ehrenbergina glabra*	*Epistominella vitrea*	*Globocassidulina crassa crassa*	*Globocassidulina crassa rossensis*	*Globocassidulina crassa biora*	*Globocassidulina subglobosa*	*Miliammina lata*	*Miliolinella subrotunda*	*Neoconorbina tuberocarinata*	*Nonionella bradyi*	*Trifarina angulosa*	*Uvigerina hispidocostata*	Sponge spicules	Echinoid spines	Shell fragments
188-1166A-																											
1R-1, 16–21	0.16–0.21					23				2	1		1		5	1	1	9					1		x	x	x
1R-1, 117–122	1.17–1.22					28		1	1		3							12	1				2		x	x	
1R-2, 9–12	1.59–1.62					43				1		1	1		5		6	9			1		1				
1R-CC	10.4																								x		
2R-CC	19.8																								x		
3R-1, 79–83	20.59–20.63	2				7										1		1									
3R-2, base	21.3					6																	1				
4R-CC	38.2					2									1												
5R-1, 26–31	38.46–38.51					1																					
5R-CC	47.3					19										1	1	4					1		x		
6R-CC	56.4	1				1									2					1							
7R-CC	65.4					7									1												
8R-1, 25–27	65.65–65.67	1				8									2					1							
8R-1, 42–45	65.82–65.85					1																					
9R-CC	84.4					2												1									x
10R-1, 11–13	84.51–84.53			1		71					1		1	1		6	4	10		1		1					
10R-CC	94		1			66		1										12					1				
11R-1, 55–59	94.55–94.59			1		164	7		2								1	19					4	1			
11R-CC	103.7				1	38	1										6	2						1			x
12R-1, 18–20	103.88–103.90					5							1					2								x	
12R-CC	113.3																								x		
13R-1, 71–73	114.0–114.03																								x		

Note: x = present.

Table T5. Distribution of accessories, Site 1166.

Core, section, interval (cm)	Residue	Content	Sorting	Planktonic foraminifers	Benthic foraminifers	Sponge spicules	Echinoid spines	Bone	Black coal	Wood	Pyrite	Micrometeorite
188-1166A-												
1R-1, 16–21	L	T		C	C	X	X		Tr			
1R-1, 117–122	L	T	P	C	C	X	X		C			
1R-2, 9–12	L	T		C	C	X	X					
1R-CC	L	T	P	B	B	Tr			Tr			
2R-CC	L	T		B	B	Tr			Tr			
3R-2, base	L	T		F	R				Tr			X
4R-CC	L	T		R	R				Tr			
5R-1, 26–31	L	T		R	B				Tr		Tr	
5R-CC	L	T	P	F	R						Tr	
6R-CC	S	T		R	R				Tr			
7R-CC	L	T		F	R				Tr			
8R-1, 42–45	L	T		R	B							
8R-CC	L	T		B	B				Tr		Tr	
9R-CC	L	T		R	R				Tr		Tr	
10R-1, 11–13	L	T		C	C				Tr			
10R-CC	L	T	P	C	F							
11R-1, 47–50								N				
11R-CC	L	T	P	C	R						Tr	
12R-1, 18–20	L	T	P	R	R		X		Tr			
12R-CC	S	T	P	B	B	Tr			Tr			
14R-CC	L	T	P	B	B				C		Tr	
17R-CC	L	T	P	B	B					N		

Notes: Residue: L = large, S = small. Content: T = terrigenous. Sorting: P = poor. Abundance: C = common, F = few, R = rare, B = barren. Tr = trace, X = present above trace quantities, N = noteworthy.

Table T6. Distribution of foraminifers, Site 1167. (This table is available in an **oversized format.**)

Table T7. Planktonic percentages, Hole 1167A.

Core, section, interval (cm)	Depth (mbsf)	Planktonic (%)
188-1167A-		
1H-1, 60–64	0.60–0.64	91.5
1H-2, 60–64	2.10–2.14	93
1H-3, 60–64	3.60–3.64	100
(2*)		
2H-2, 60–64	7.30–7.34	97
(1*)		
2H-4, 60–64	10.30–10.34	94.5
2H-5, 60–64	11.80–11.84	93.3
2H-CC	14.7	93.9
3H-1, 60–64	16.20–16.24	65
(1*)		
3H-3, 60–64	19.20–19.24	89
3H-4, 60–64	20.70–20.74	75
3H-5, 60–64	22.20–22.24	50
3H-6, 60–64	23.70–23.74	100
3H-CC	24.2	100
4H-1, 60–64	24.80–24.84	89
4H-2, 60–64	26.30–26.34	75
4H-3, 60–64	27.80–27.84	96
4H-4, 60–64	29.30–29.34	76
4H-5, 60–64	30.80–30.84	40
4H-CC	33.7	50
5H-1, 60–64	34.30–34.34	87
5H-2, 60-64	35.80–35.84	81
5H-3, 34–36	37.04–37.06	99
5H-3, 60-64	37.30–37.34	99
5H-4, 60–64	38.80–38.84	83
5H-CC	39.7	61
7X-1, 60–64	40.30–40.34	82.8
7X-2, 60–64	41.80–41.84	65.2
7X-CC	45	72.4
8X-1, 60–64	45.60–45.64	66.9
8X-2, 60–64	47.10–47.14	75
8X-3, 60–64	48.60–48.64	74.1
8X-CC	54.7	73.5
9X-CC	64.3	66.7
10X-1, 60–64	64.90–64.94	100
10X-2, 60–64	66.40–66.44	87
10X-3, 60–64	67.90–67.94	87.5
10X-CC	73.7	57.1
11X-2, 60–64	75.80–75.84	83.3
11X-3, 60–64	77.30–77.34	88.5
11X-4, 60–64	78.80–78.84	70.3
11X-5, 60–64	80.30–80.34	81.6
11X-6, 60–64	81.80–81.84	50
11X-CC	83.3	62.5
12X-1, 60–64	83.90–83.94	100
12X-2, 60–64	84.40–84.44	75
12X-CC	93	81.2
13X-1, 60–64	93.60–93.64	94.1
(1*)		
13X-3, 60–64	96.60–96.64	89.6
13X-4, 60–64	98.10–98.14	81.8
13X-5, 60–64	99.60–99.64	97.9
13X-CC	102.6	85.9
14X-1, 60–64	103.20–103.24	96.1
14X-2, 60–64	104.70–104.72	86.9
14X-3, 60–64	106.20–106.24	83.7
14X-4, 60–64	107.70–107.74	82.1
14X-5, 60–64	109.20–109.24	93.3
14X-6, 60–64	110.70–107.74	80.8
14X-CC	112.3	82.1
17X-CC	140.7	83.2
19X-1, 60–64	150.90–150.94	96.1
19X-2, 32–34	152.12–152.14	97.3
19X-2, 60–64	152.40–152.44	89.6
19X-3, 60–64	153.90–153.94	94.9
19X-4, 60–64	154.40–154.44	80.9
19X-CC	159.9	88.5
20X-, 23–27	160.13–160.17	81.4
20X-1, 60–64	161.40–161.14	82.7
20X-2, 60–64	161.90–161.94	82.5
20X-3, 60–64	163.40–163.44	73.8
20X-CC	169.6	77.8
21X-, 60–64	170.l0–170.14	90.5
21X-CC	179.2	81.8
22X-1, 60–64	179.80–179.84	91.4
22X-CC	188.8	73.7
23X-CC	198.4	66.7
24X-CC	208	83.3
25X-1, 60–64	208.60–208.64	94.8
(1*)		
25X-3, 60–64	211.60–211.64	66.7
(1*)		
25X-5, 60–64	214.60–216.64	85.7
25X-7, 60–64	217.60–217.64	100
(3*)		
26X-3, 60–64	221.20–221.24	50
(1*)		
26X-5, 60–64	224.20–224.24	50
(5*)		
27X-CC	236.9	100
28X-3, 60–64	240.50–240.54	91.7
28X-4, 60–64	242.00–242.04	100
(1*)		
29X-1, 60–62	247.10–247.12	86.2
29X-2, 60–64	248.60–248.64	100
(4*)		
30X-5, 60–64	262.70–262.74	100
30X-CC	265.7	100
(1*)		
32X-1, 60–64	275.90–275.94	0
32X-2, 60–64	277.40–277.44	62.5
32X-3, 60–64	278.90–278.94	85.7
32X-4, 60–64	280.40–280.44	75
32X-5, 60–64	281.90–281.94	66.7
32X-CC	284.6	72.6
33X-1, 60–64	285.20–285.24	91.8
33X-2, 60–64	286.70–286.74	100
33X-CC	293.9	0
(1*)		
34X-2, 60–64	296.00–296.04	88.2
(2*)		
35X-1, 68–73	303.88–303-93	100
36X-CC	322.5	98.5
37X-CC	332.1	100
38X-1, 60–64	332.70–332.74	100
(1*)		
38X-3, 60–64	335.70–335.74	100
38X-CC	341.7	66.7
39X-CC	351.3	95
40X-1, 60–64	351.90–351.94	100
40X-2, 60–64	353.40–353.44	91.7
40X-3, 60–64	354.90–354.94	100
(2*)		
41X-2, 60–64	363.00–363.04	84.2
(1*)		
41X-4, 60–64	366.00–366.04	82.3
41X-5, 60–64	367.50–367.54	93.2
41X-CC	370.6	87.5
(1*)		
42X-2, 60–64	372.70–372.74	77.8
42X-CC	380.2	98.8
43X-1, 60–64	380.60–380.64	92.9
43X-2, 60–64	382.07–382.11	100
43X-3, 60–64	383.60–383.64	89.3
43X-CC	389.8	92.4
44X-1, 60–64	390.40–390.44	100
44X-2, 60–64	391.90–391.94	100
(3*)		
46X-CC	418.7	75
(7*)		
48X-CC	437.9	89
49X-1, 60–64	438.50–438.54	91.2
49X-2, 60–64	440.00–440.04	66.7
49X-3, 60–64	441.50–441.54	100
49X-4, 60–64	443.00–443.04	88.5
(1*)		

Note: * = number of barren samples between listed intervals.

Plate P1. Scale bar (fig. 1) = 1 mm; (figs. 3–22) = 100 µm. **1, 2.** *Cyclammina incisa* (Stache) (Sample 188-1165C-30R-5, 34–36 cm) (CPC37137); (2) enlargement of part of 1. **3.** *Haplophragmoides canariensis* (d'Orbigny) (Sample 188-1165B-59X-1, 70–75 cm) (CPC37138). **4, 5.** *Uvigerina hispidocosta* Cushman and Todd (4) form A (Sample 188-1167A-8X-1, 60–64 cm) (CPC37139); (5) form B (Sample 188-1167A-11X-4, 60–64 cm) (CPC37140). **6.** *Trifarina angulosa* (Williamson) (Sample 188-1167A-8X-1, 60–64 cm) (CPC37141). **7.** *Cibicides lobatulus* (Walker and Jacob) (Sample 188-1167A-1H-1, 60–64 cm) (CPC37142). **8.** *Globocassidulina crassa crassa* (d'Orbigny) (Sample 188-1166A-1R-1, 16 cm) (CPC37143). **9.** *Globocassidulina crassa biora* (Crespin) (Sample 188-1167A-8X-1, 60–64 cm) (CPC37144). **10.** *Globocassidulina crassa rossensis* (Kennett) (Sample 188-1167A-8X-1, 60–64 cm) (CPC37145). **11.** *Astrononion stelligerum* (d'Orbigny) (Sample 188-1167A-3H-3, 60–64 cm) (CPC37146). **12.** *Astrononion echolsi* Kennett (Sample 188-1166A-11R-1, 58–59 cm) (CPC37147). **13.** *Anomalinoides* sp. (Sample 188-1167A-14X-CC) (CPC37148). **14.** *Gyroidinoides neosoldanii* (Brotzen) (Sample 188-1165B-58X-1, 70–75 cm) (CPC37149). **15, 16.** *Globigerina* sp. (Sample 188-1167A-19X-CC) (CPC37150). **17, 18.** *Globorotalia puncticulata* (Deshayes) (Sample 188-1165B-2H-1, 70–75 cm) (CPC37151). **19, 20, 21.** *Neogloboquadrina pachyderma* (Ehrenberg); (19) "normal" (Sample 188-1167A-1H-1, 60–64 cm) (CPC37152); (20) "small, compact" (Sample 188-1167A-37X-CC) (CPC37153); (21) *"Globigerina"* type (Sample 188-1166A-10R-1, 11–13 cm) (CPC37154). **22.** Dolomite concretion (Sample 188-1165B-6H-5, 70–75 cm) (CPC37155). (**Plate shown on next page.**)

Plate P1 (continued). (Caption shown on previous page.)