AUSTRALIAN NATIONAL ANTARCTIC RESEARCH EXPEDITIONS

ANARE RESEARCH NOTES 90

Recent diatom and foraminiferal assemblages in surficial sediments of Prydz Bay, Antarctica

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ANTARCTIC DIVISION
DEPARTMENT OF THE ENVIRONMENT, SPORT AND TERRITORIES

ANARE RESEARCH NOTES (ISSN 0729-6533)

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Published September 1993
ISBN: 0 642 196788

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RECENT DIATOM AND FORAMINIFERAL ASSEMBLAGES IN SURFICIAL SEDIMENTS OF PRYDZ BAY, ANTARCTICA

by

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ABSTRACT

Surficial bottom sediments collected from Prydz Bay, Antarctica contain three sedimentary facies, four foraminiferal faunas, and two diatom floras. A sandy diamict (Facies Ds) is deposited by iceberg rafting and reworked by currents of the Prydz Bay Cyclonic Gyre. A massive mud (Facies Mm) represents the sediments being supplied to the Bay and could provide a high resolution record of the Quaternary in Antarctica. A carbonate sand (Facies Cs) is a modern cold water carbonate deposited under special conditions on the outer continental shelf.

The presence of the *Triloculina* fauna indicates areas of sediment reworking and chemical conditions hostile to carbonate. The *Neogloboquadrina pachyderma* (Ehrenberg), *Trifarina angulosa* (Williamson), and *Ehrenbergina glabra* (Heron *et al.*) faunas all indicate areas subject to marine influence. The cosmopolitan and sympagic *Nitzschia curta* (Van Heurck) flora is replaced by the planktonic *Nitzschia kerguelenensis* (O'Meara) flora supporting the presence of marine influence. A relationship between the proportion of biogenic material and reworking of sediments may be useful in elucidation of the palaeoceanography within Prydz Bay.

The presence of planktonic flora and fauna, and variations in sedimentological parameters are consistent with the physical oceanographic evidence for a large cyclonic gyre operating in the Bay.

1. INTRODUCTION

The continental margin of Antarctica has three large embayments, the Ross Sea, the Weddell Sea and Prydz Bay, associated with significant ice shelves. The continental shelf around Antarctica is deeper (up to 500 m) than around other continents as a result of factors such as isostatic adjustment to continental ice loading, sediment starvation, and periodic catastrophic erosion by advancing ice sheets (Quilty 1985, Cooper *et al.* 1991).

Prydz Bay is a triangular embayment situated between 68°S and 70°S, and 69°E and 80°E in East Antarctica (Figure 1). The apex points south and the Bay is bordered by Mac.Robertson Land and the Amery Ice Shelf to the south-west and by Princess Elizabeth Land to the south-east. Its maximum dimensions are approximately 400 km east-west and 300 km north-south.

Onshore, rocks near the study area include Proterozoic metamorphics, metasediments and intrusives as well as some Permian and Triassic strata near Beaver Lake in the Prince Charles Mountains. The lithology underlying Prydz Bay consists of a Mesozoic to Cainozoic molasse and/or riftogenic complex (Fedorov *et al.* 1982, Stagg 1985, Barron *et al.* 1991, Turner 1991). These sediments fill the so-called Lambert Graben (Fedorov *et al.* 1982) which extends 700 km inland and which may have been juxtaposed with the Indian Mahanadi complex in pre-breakup Gondwana (Fedorov *et al.* 1982, Stagg 1985 Figure 14).

Within the Bay (Figure 2) is a large basin, the Amery Depression, which reaches depths of greater than 750 m and which has a north trending extension, the Prydz Channel, with depths in excess of 500 m. The Amery Depression is bordered to the north-east by the Four Ladies Bank, to the south by Princess Elizabeth Land, to the south-west by the Amery Ice Shelf, and to the north-west by the Fram Bank. Proximal to the Amery Ice Shelf are two very deep (>1000 m), features named the Lambert and Nanok Deeps. A crescentic plateau, the Nella Rim, surrounds the Nanok Deep (Quilty 1985). The seabed is generally smooth throughout the Bay except in the south-west where it has been scoured by the Amery Ice Shelf (Stagg 1985).

The sediment supply into the Bay is from three main sources. The Lambert Glacier, which discharges into Prydz Bay by iceberg formation and peripheral melting at the edge of the Amery Ice Shelf (Quilty 1985), is a source of terrigenous sediment. Several smaller glaciers which discharge into the Bay along the Ingrid Christensen Coast contribute terrigenous sediment but the relative contributions between these and the Lambert Glacier are not known. The other main contribution is from biogenic input that is composed of the remains of calcareous and silicic fauna and flora.

Previous studies have used variation in sedimentological parameters to make semi-qualitative assessments of current strengths in sediments from deep sea cores (Blaeser and Ledbetter 1982, Pudsey *et al.* 1988, Pudsey 1990, and Pudsey in press). This study uses these criteria to establish the presence of bottom currents thus providing evidence to support the physical oceanographic evidence that suggests that a large cyclonic gyre operates within Prydz Bay (Smith *et al.* 1984).

2. MATERIALS AND METHODS

2.1 *Sampling*

This study is based on samples collected during the austral summer season in early 1991 as a part of the Australian Antarctic Marine Biological Ecosystem Research (AAMBER) cruise undertaken by the Australian National Antarctic Research Expedition (ANARE) onboard RSV *Aurora Australis*.

Thirty-three sites were sampled on a 50 km sampling grid throughout Prydz Bay and the Mac.Robertson Shelf (Table 1, Figure 2). A Van Veen grab sampler was used at eight sites, of which two were successful. Using a small phleger corer, gravity cores were attempted at twenty-seven sites with fourteen cores recovered. Three mud clast samples were recovered from a bottom trawl being used to collect biological specimens for other projects.

Cores were sampled at four regular intervals along their length. Four random subsamples were removed from grab and mud clast samples. Each of the subsamples was split three ways and prepared in different manners for the extraction of foraminifera, diatoms and for the analysis of sediments. Sample nomenclature used has the site number as the first letter and second and/or third number while the last number is the subsample taken at each site sample. At cored sites the shallowest in the core is '1' and the deepest is '4'.

2.2 *Preparation of faunal samples*

Subsamples for foram analysis were disaggregated with a 3% solution of H_2O_2 for 3 weeks, and agitated periodically. Treated samples were washed through a 60 µm sieve and dried. Concentrates were inspected and foraminifera extracted under a microscope using a fine brush.

2.3 *Preparation of floral samples*

A 5 - 10 g subsample of the sediment was digested in 20 mL of 10% H_2O_2 for diatom analysis. On completion of the reaction, 1 g of $K_2Cr_2O_7$ was added to oxidise and clean the frustules. The solution was diluted to 200 mL with double-distilled water and left overnight for the fine fraction to settle. The solution was decanted to 50 mL and centrifuged at 2000 rpm for 10 min. The supernatant was poured off and the sediment diluted to 50 mL. The sediment was resuspended and centrifuged until the supernatant was clear.

The supernatant was resuspended and allowed to stand for approximately 40 s for the heavier fractions to sink. One millilitre was then removed from close to the sediment/water interface, dried onto a warm slide (60°C), and mounted in Naphrax (Refractive Index ~1.67). The identification of diatoms was achieved on a Nikon OPTIPHOT POL optical petrographic microscope and a Leitz Wetzlar optical petrographic microscope.

2.4 *Preparation of sediment samples*

Sediment samples were subjected to various treatments to quantify the various proportions of biogenic carbonate, biogenic silica and clay. Before and after each treatment, dry weights were recorded.

Carbonate was removed by an acid leach in HCl. Biogenic silica was removed using the method described by Eggiman *et al.* (1980). This involves the leach of the sediment in 2 M Na_2CO_3 solution for 4 hours followed by three rinses in double-distilled water to remove all the residual Na_2CO_3. Contrary to the experience reported by Demaster (1981), a laboratory test by Franklin (1991) found no evidence for grain size reduction.

Particles less than 6 ϕ were removed by settling as these particles are likely to have been deposited in a flocculated state (Chriss and Frakes 1971) and would have reacted to the sedimentological and hydraulic conditions in a manner different to that expected from disassociated grain size alone. All particles over 1 mm were removed before grain-size analysis as this fraction was probably deposited by ice rafting (Chriss and Frakes 1971).

The remainder was tested for grain size in a Rapid Sediment Analyser (Settling Tube). Cores and half cores were X-rayed at the Royal Canberra Hospital in the manner described by Carver (1971), although it was not found necessary to pack the half-cores in sand.

3. RESULTS

3.1 *Sedimentology*

The lithology of the size fraction larger than sand is not considered in this paper. Sand and silt (–1 to 6 ϕ) are composed of between 95 and 99% quartz while the clay mineralogy is dominated by smectite, illite, and kaolinite and, in some samples, goethite. Quartz grains are angular to subrounded and throughout the area sands are moderately to strongly coarse skewed.

3.2 *Sedimentary facies*

Three sedimentary facies, a sandy diamict, a sandy carbonate and a massive mud, were identified from the area. X-radiographs of cores assisted in these identifications. Sites from which cores were not obtained were placed within a particular facies based on similar grain size and sorting characteristics, dropstone, and biogenic content displayed by samples from known facies.

3.3 *Sandy carbonate (Facies Cs)*

Facies Cs occurs only at site S11. This site was cored but the sediment was unconsolidated and, when recovered, slumped out of the corer so X-ray determination of the sedimentary structures was not obtained. It is identified by its very high biogenic content, with between 32 and 50% biogenic carbonate and between 3.2 and 8.5% biogenic silica. Terrigenous sediment is composed of between 3 and 6% sand, 11 and 20% silt, and 25 to 40% clay. Dropstones of gravel size or larger were rarely seen. Mean grain size of the sand fraction in this facies is between 2.23 and 2.74 ϕ. Quilty (1985) identified this facies as 'coarse sediments with biogenic carbonate'. The faunal composition of the carbonate fraction is described later.

3.4 *Sandy diamict (Facies Ds)*

Facies Ds is the most common in the area and is recognised by a high sand fraction content (between 60 and 70%), a relatively low mud content (21 – 27%) and low biogenic content (<10%). Biogenic carbonate comprises 2.5 – 16%, but rarely higher than 6%, and biogenic silica 2.5 and 16%, but rarely more than 4%. Dropstones are common. The sand/silt fraction is well sorted. The facies is interpreted as a residual IBRD after the Kellogg and Kellogg (1988) classification. Mean grain size of the sand fraction is between 2.23 to 3.21 ϕ.

X-radiographs of this facies show a massive to poorly laminated matrix with small to large rounded clasts of mud and/or aggregated clasts of mud and larger particles. Laminations, where present, are wispy or sinusoidal. Dropstones and bioturbation in this facies have probably destroyed any significant sedimentary structure. This facies is equivalent to the 'terrigenous sands with little biogenic content' identified by Quilty (1985).

3.5 *Massive mud (Facies Mm)*

The massive mud facies is restricted to coretop samples in the south eastern corner of the Bay but can be found in downcore samples in other areas of the Bay. Dropstones are rare. Carbonate content is moderate, between 7 and 10%. Biogenic silica comprises between 8 and 15% of the total while silt and clays account for between 70 and 86% of the sediment.

Very little internal structure was revealed by X-radiography and where found consists of very weak lamination. Quilty (1985) identified this facies as 'sediments dominated by silt and clay size fractions'.

3.6 *Foraminifera*

Microfauna and flora, when collected, were not stained to differentiate live and dead individuals. As with Quilty's (1985) work, this means that foram statistics reflect only gross numbers. Kennett (1966) suggested that *Globigerina bulloides* d'Orbigny and *Globigerinita quinqueloba* (Natland) may only be immature variants of *Neogloboquadrina pachyderma* (Ehrenberg). As planktonic foraminiferids are significant only at three sites, and considering Kennett's comments, the planktonic foraminifera have been grouped together for statistical purposes.

Four foraminiferal assemblages were identified within the study area (Figure 4). These were dominated by *Neogloboquadrina pachyderma*, *Trifarina angulosa* (Williamson), *Triloculina* and *Ehrenbergina glabra* (Heron *et al.*). Samples S154, S322, S324, S434, S501, S502, S503, S504, S622, S623, S624, T72, T73, T82, T83, and T232 contained less than five individual foraminifera.

N. pachyderma Fauna

This assemblage (Table 2), found in core S44 and the coretop of T11, has a low diversity (6, 9 and 4 species) with the lower diversities in downcore samples. Test preservation is good in all samples. This fauna is closely associated with *Triloculina* fauna and differs only in the presence of planktonic forms.

E. glabra Fauna

Although sharing the dominant species of *N. pachyderma* with the fauna taking that name, this fauna is named after another common species and is sufficiently different as to warrant separate consideration. The fauna (Table 3) is characterised by relatively high foram diversity (up to thirty-five species) and is associated with a diverse and disparate calcareous macrofauna (pteropods, gastropods, bivalves, bryozoans, ostracodes, acantharian radiolaria, etc.). All represented groups are abundant and the preservation conditions allow the sediment produced to be approximately 50% biogenic carbonate.

Trifarina angulosa Fauna

This fauna (Table 4) is dominated by an association of *Cassidulinoides porrecta* (Heron *et al.*), *N. pachyderma* (Ehrenberg) and *T. angulosa* that together dominate the rest of the fauna. It occurs seaward and east of Prydz Bay at sites T7 and T8. It has a very low diversity (four species) at site T7 and low diversities (eleven and nine species) downcore at site T8.

Triloculina Fauna

Two species of the genus *Triloculina* dominate this fauna namely, *T. trigonula* (Lamarck) and *T. rotunda* d'Orbigny. This assemblage (Table 5) is characterised by very low diversity (<5 species, usually two or three). Higher diversities (six or seven species) can be found in some coretop samples where the extra species are agglutinated forms making a minor percentage of the total. The absence of complete agglutinated foraminifera in downcore samples suggests that they disassociate soon after death and before burial. This fauna is always associated with a relatively high percentage of biogenic silica and is the most widespread in Prydz Bay. The number of individual *Triloculina* foraminifera vary between 1 and 50 per ~ 10 g.

3.7 *Diatoms*

Table 6 lists by site diatoms encountered in Prydz Bay sediments. Two main assemblages of diatoms were found (Figure 5). The first and most common is that in which the species *Nitzschia curta* (Van Heurck) is dominant. The other is that in which *Nitzschia kerguelenensis* (O'Meara) is dominant. The latter occurred only in one sample, site T11.

Nitzschia curta Flora

This flora typically consists of between 60 and 80% *Nitzschia* species with a varying component of any, or all, of the other diatom species found in the Bay. Preservation of frustules varies widely, with sample S451 showing extremely good preservation and others showing very poor preservation with most of the frustules being badly broken. The badly preserved state of the frustules is probably due to ingestion by predators. (Baldauf and Barron 1991). Diverse floras were found in samples from sites S11, S14, S15, and S45 (coretop only). This fauna contains mainly species known to inhabit the sympagic environment.

Nitzschia kerguelenensis Flora

This flora is very similar to the *Nitzschia curta* flora except in the lack of an overwhelming dominance by *Nitzschia curta*. It has low to very low abundance and is found only at one sample site, T11. This site has a significant oceanic influence and is probably subject to reworking by incoming bottom currents.

4. DISCUSSION

Faunal and floral assemblages landward of the shelf break in Prydz Bay display little variation. In the Amery Depression, the predominantly infaunal, sparse *Triloculina* foraminiferal fauna and the cosmopolitan *Nitzschia curta* diatom flora are present. The *Triloculina* fauna is closely associated with the terrigenous sand facies but is also found in the massive mud facies in the south of the Bay. At the seaward end of the Bay near the Prydz Channel, the *Triloculina* fauna and the *Nitzschia curta* flora are replaced by the more oceanic *Neogloboquadrina pachyderma* fauna and *Nitzschia kerguelenensis* flora respectively. This reflects the strong oceanic influence of the incoming southward current of the Prydz Bay Cyclonic Gyre. In the north-west of the study area the presence of the unique *Ehrenbergina glabra* fauna defines the boreal marine carbonate facies while in the north-east the incoming west flowing longshore current is evidenced by the presence of planktonic foraminifera in the *T. angulosa* fauna. Conversely, the presence of the *N. curta* flora in the same area suggests that sea ice influences dominate.

These data show that there is no association between sedimentary facies and fauna and flora. As expected, no association between the mainly benthic fauna and mainly planktonic flora is seen. Faunal occurrences are dependant on bottom water characteristics that affect habitability while floral occurrences are mostly dependant on the ability of diatom frustules to be deposited or preserved in sediments. The occurrence of the *E. glabra* fauna is due to very specific, as yet undefined, circumstances that may be related to pH or pCO_2 in upwelling deep waters.

The absolute abundance of foraminifera in Prydz Bay sediments is generally very low. No calcareous organisms other than foraminifera were found in any samples other than S11 and S30 (tube worms and bryozoans), and no lithic carbonate component was seen in the sediments investigated.

4.1 *Sedimentology*

Antarctic sedimentary processes are dominated by ice-rafting, slumping, debris flow and turbidity currents (Pudsey *et al.* 1988). It is possible that dropstones and bioturbation obscure some of the finer structures in those cores likely to contain laminations or debris flows. Prydz Bay sediments are deposited by vertical accretion of larger sands and gravels through ice rafting and by lateral processes acting at the bottom through the action of ocean currents. Clays are also supplied by ice-rafting but the more likely source of the majority of clay particles is from those entrained in the glacial meltwater exiting under the Lambert Glacier and Amery Ice Shelf. Kellogg and Kellogg (1988, Figure 2) presented a model for the deposition of Ice Shelf Rafted Debris (ISRD) and Ice Berg Rafted Debris (IBRD). According to their model the present depositional regime in the area of study is IBRD deposition.

The proportion of biogenic carbonate provides an indication of the abundance of foram tests. Biogenic silica proportion similarly provides an indication of the preservation potential for diatom frustules. Analyses of grain size yielded data on mean grain size and folk sorting. Mean grain size decreases with increasing sorting therefore sorting processes are preferentially increasing the proportion of the smaller sand fractions.

The distribution of facies (Figure 6) and the sand content (Figure 7) show an area of very low sand content area near sites S27 and S28 that indicates an area undisturbed by reworking currents. Large scale bathymetry is not sufficiently detailed to enable this feature to be associated with any topographic bottom feature. The presence of high proportions of fine grained material suggests very little or no reworking due to current action although iceberg gouging is probably widespread throughout the Bay. The composition of the sediments deposited in this area represents the actual composition of the sediments being supplied to the Bay. The site may contain an undisturbed, complete, and probably high-resolution record of palaeoactivity below the influence of iceberg action. This site is of prime importance for further investigation of microbiota and facies variation for the Quaternary in Antarctica.

The production of a modern polar marine carbonate is currently occurring near Site S11. As discussed, this location yielded samples of up to 50% biogenic carbonate with excellent preservation of a very diverse and disparate assemblage of micro and macro calcareous fauna. The site is to the seaward side of the shelf break. Domack (1988, Figure 9) produced a depositional model for the polar glacial marine environment concentrating on shelf deposition. As a part of the drainage system of the Lambert Glacier, Prydz Bay does not wholly conform to this model, however the seaward side of the shelf break does. The faunal composition of the biogenic carbonate fraction is similar to that described by Domack (1988) although the proportion of biogenic carbonate in the S11 sediments is 50% as opposed to the 30% maximum described by Domack.

Figure 8 plots the total biogenic portion as a percentage of whole sediment against the degree of sorting (solid line) and the ratio of biogenic carbonate and biogenic silica against sorting (dashed line). Sorting can be used to infer the action of currents (that is, well sorted infers high energy). Bottom currents are removing silt size particles and preventing the clay size particles from settling. In high energy areas diatoms therefore tend to remain entrained in the current. The data indicate a relationship between the ratio of biogenic carbonate and biogenic silica in Prydz Bay that is predicated by the degree of reworking of bottom sediments. In areas of reworking, the ratio of biogenic carbonate/ biogenic silica increases. This relationship may be useful in the elucidation of the palaeoceanography of the Bay.

4.2 *Foraminifera*

Quilty (1985) identified two faunal associations in Prydz Bay. One association was described as having a very high diversity with abundant planktonic and benthic foraminifera. It was also found associated with a profusion of other calcareous macrofauna. This corresponds to *Ehrenbergina glabra* fauna of this study. The other faunal association described by Quilty (1985) is from within Prydz Bay. It is characterised by very low diversity and low abundance with very low planktonic component and, where present, mainly benthic foraminifera with no dissolution features. According to Quilty (1985) the benthic foraminiferal component is usually dominated by agglutinated species.

The present study found that benthic communities were dominated by agglutinated foraminifera only in the coretop samples. Downcore samples were depauperate in agglutinated foraminifera suggesting that these species were subject to disassociation after death. Therefore water conditions at the sediment water interface are not conducive to the preservation of carbonate remains. At variance to this evidence the individuals of *Triloculina spp*. showed no evidence of significant dissolution of the tests.

This anomaly can be resolved by postulating an infaunal habit for *Triloculina sp*. that would provide them with a much more benign habitat in contact with less corrosive interstitial waters. Arrhenius (1988) discusses the possibility of increased preservation 'depending on the rate at which the components of the sediment are accumulated and buried, and thus protected from corrosive bottom water' however Cranston (1991) estimates sedimentation rates much less than required to justify this explanation. An infaunal habit would provide a foram test the same protection after death as would a high sedimentation rate. Rosoff and Corliss (1992) establish criteria for the identification of infaunal foraminifera in the high northern latitudes to which the gross morphology of the tests of *T. rotunda* and *T. trigonula,* with their tapered shapes and smooth outer walls, agree. Staining of samples would have established an infaunal habit for *Triloculina*. spp. beyond doubt and should be incorporated in any further study.

4.3 *Diatoms*

Diatoms inhabit the photic zone which, in most areas, restricts them to an inshore shallow benthic or a planktonic existence. Benthic forms are known to be epifaunal and/or epiphytic. Some epiphytic forms such as *Acnanthes vincentii* (Manguin) are found on larger planktonic diatoms and algae. (Everitt and Thomas 1986).

Baldauf and Barron (1991) suggest that diatoms reaching the sediment via faecal pellets often display a very poor preservation, being mostly fragmentary. Such a preservation state is evidenced in all the samples from the present study where conservatively >80% of the frustules are badly broken. As such, these frustules are removed from the water column very quickly and are not subject to significant dissolution.

In the high latitudes where sea ice forms in the winter, a number of benthic diatoms inhabit the underside of the sea ice causing an 'inverted benthos' (Thomas and Jiang 1986) or 'sympagic flora' (Whittaker 1987). Seasonal changes in Antarctic diatom abundances have been discussed by Everitt and Thomas (1986). The implications of seasonal variations in diatom abundance for this study are minimal as the sedimentation rate in Prydz Bay is either insufficient to preserve evidence of seasonal changes in diatom abundance (Cranston 1991) or those changes are disturbed by bioturbation. Thus, preserved diatoms reflect an averaged annual or longer term flora. The sympagic diatom species, *N. curta* is overwhelmingly dominant at all but one site. At site T11 the two core-top samples, T111 and T112, are dominated by the planktonic *N. kerguelenensis*.

Even though *N.curta* is a relatively lightly silicified diatom, dissolution is no more evident than in other samples from elsewhere in the Bay. While more data are necessary to reach firm conclusions, the author suggests that the most likely explanation for the lack of *N.curta* at site T11 is that the relatively small size and weight of *N.curta* allows it to be removed from the sediment preferentially by reworking currents.

Conductivity, temperature, and depth (CTD) data from the top 100–200 m show fairly constant temperature and salinity conditions throughout the surface water of the Bay. Salinities at the surface are lower than marine salinities due to dilution through ice and snow melt. During winter months salinity conditions near the surface, under the sea ice, are not well known, although Foldvick and Gammelsrød (1988) suggest that brines are fractionated during sea ice formation resulting in ice less saline, and winter surface water more saline than the original summer water. The data from this study show a cosmopolitan flora. Therefore, either the flora is euryhaline or, more probably, fairly constant salinity conditions exist in the surface waters beneath the sea ice. Because the sympagic flora is so widespread its value as palaeoindicators in Prydz Bay sediments is lessened.

4.4 *Calcite compensation depth (CCD)*

Although the CCD near Antarctica is documented as being much closer to the surface (Kennett 1966, Anderson 1975, Quilty 1985), it is generally considered to be in the vicinity of 1500 m in depth adjacent to the continent. Prydz Bay is not as freely connected to the Southern Ocean as the areas where Antarctic CCD studies have been conducted, so there has been some interest in the role of the CCD in the Bay. Quilty (1985) concluded that the CCD is not a controlling factor in the distribution of foraminifera in areas shallower than 1500 m.

The CCD was not encountered by this study's sampling grid. Salinity profiles suggest that denser waters of open marine salinity overlie the sediment/water interface in all areas sampled during the study. Conversely, the distribution of the depauperate infaunal *Triloculina* fauna suggests that conditions on the Bay floor are hostile to calcareous organisms.

The method for determining relative abundance of individual foraminifera by measuring the proportion of biogenic carbonate in the sediments did not account for the possibility that infaunal foraminifera would not be affected by sediment reworking (that is, that preferential removal of sediment would effectively concentrate infaunal foraminifera). Nonetheless, the presence of infaunal and agglutinated foraminifera suggests conditions hostile to calcite. The carbonate rich sample from Site S11 is found seaward of the shelf break and lies well within the influence of the open ocean where the high carbonate content and preservation of even very fragile foraminifera suggests supersaturation of the waters with respect to $CaCO_3$. It is probable that a lysocline operates at a depth less than 200 m in Prydz Bay and much deeper to seaward of site S11. As carbonate was always present in the sediments investigated, a CCD does not operate in the area sampled.

5. CONCLUSIONS

The distribution of foraminifera, and other calcareous taxa, in the sediments of Prydz Bay relates directly to environmental habitability. Foram abundance within the *Triloculina* faunal association is related to the action of bottom currents that decrease the total proportion of the lithic component of the sediment by winnowing smaller size fractions, consequently increasing the total biogenic carbonate (infaunal *Triloculina spp.*) component of the sediment.

The distribution of diatoms in the sediments of Prydz Bay is related to the ability of frustules to settle out of bottom currents. In high energy areas, the biogenic silica component of the sediment is less in respect of both the whole sediment and the total biogenic content. As a result, the ratio of total biogenic carbonate/total biogenic silica may be useful in the reconstruction of palaeoceanographic conditions of Prydz Bay. The cosmopolitan nature of the diatom floral distributions lessens their usefulness as palaeoceanographic indicators in the taxonomic sense.

Cryogenic sediments in Prydz Bay fall into three main categories. Massive mud with little sand content deposited in the southeast corner of the Bay away from the action of reworking currents, a sandy diamict throughout the rest of the Amery Depression, and boreal marine carbonate in the northwest. Grain size characteristics and sorting indicate reworking of sediments by the removal of the smaller fractions and deposition of the fraction downcurrent. This, along with the indications of incursive marine influence evidenced by planktonic biota distribution, supports oceanographic evidence for the Prydz Bay Cyclonic Gyre.

ACKNOWLEDGMENTS

My thanks go to my supervisor Dr Patrick De Deckker, Dr Patrick Quilty and the Australian Antarctic Division, and the scientific and professional crew of the RSV *Aurora Australis*. Wolfgang Zeidler, Karen Gowlett Holmes, Professor John Penrose, Dr Dave Gilleson, Mr Peter Palmer, Mr Jim Percival from the Royal Canberra Hospital (X-radiography of sediment cores), Dr Andrew McMinn, Dr Phil O'Brien, Dr Lis Sikes, and Meredith Orr provided valuable assistance.

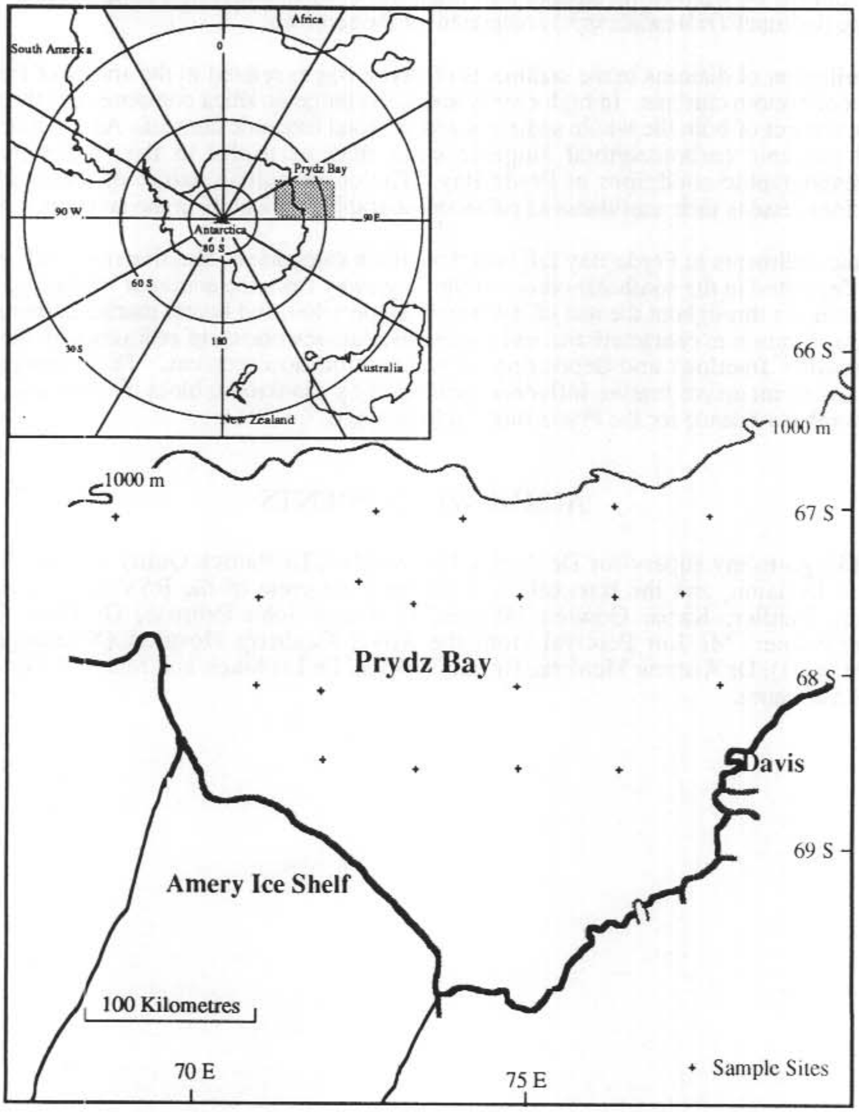

Figure 1. The study area in relation to Australia, New Zealand, and South America.

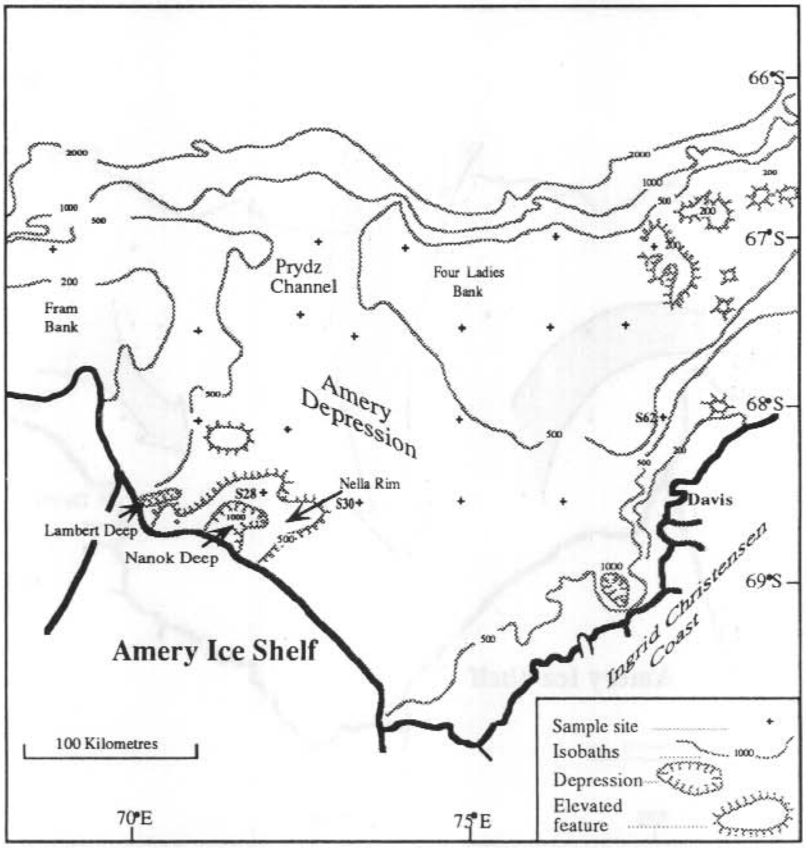

Figure 2. Bathymetry, major features, and geographic distribution of sampling sites in Prydz Bay. (Adapted from Quilty 1985)

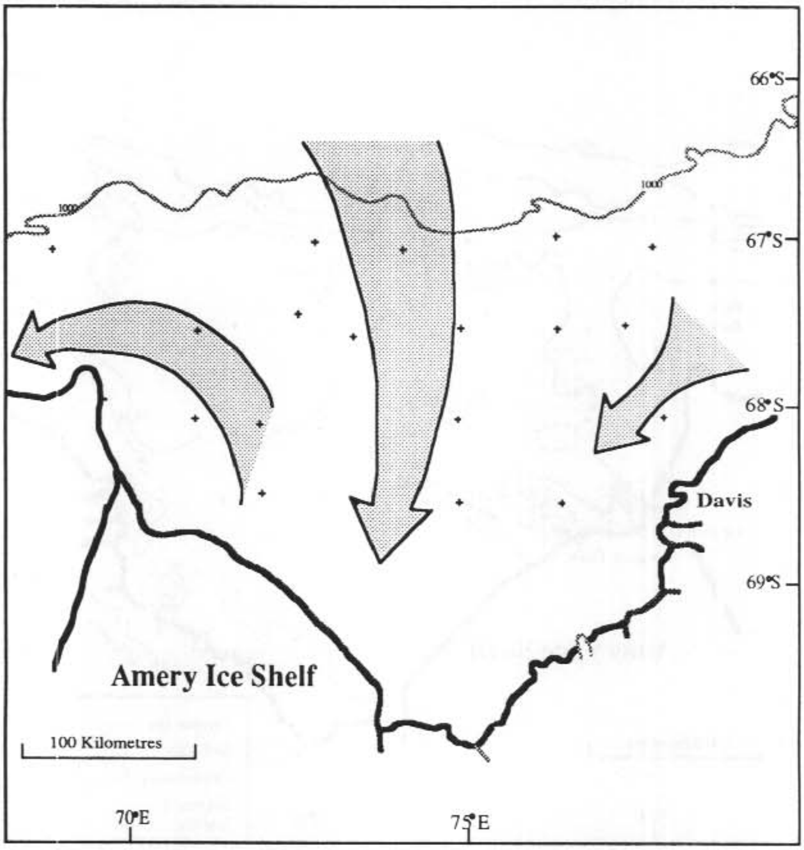

Figure 3. Major currents acting in Prydz Bay.

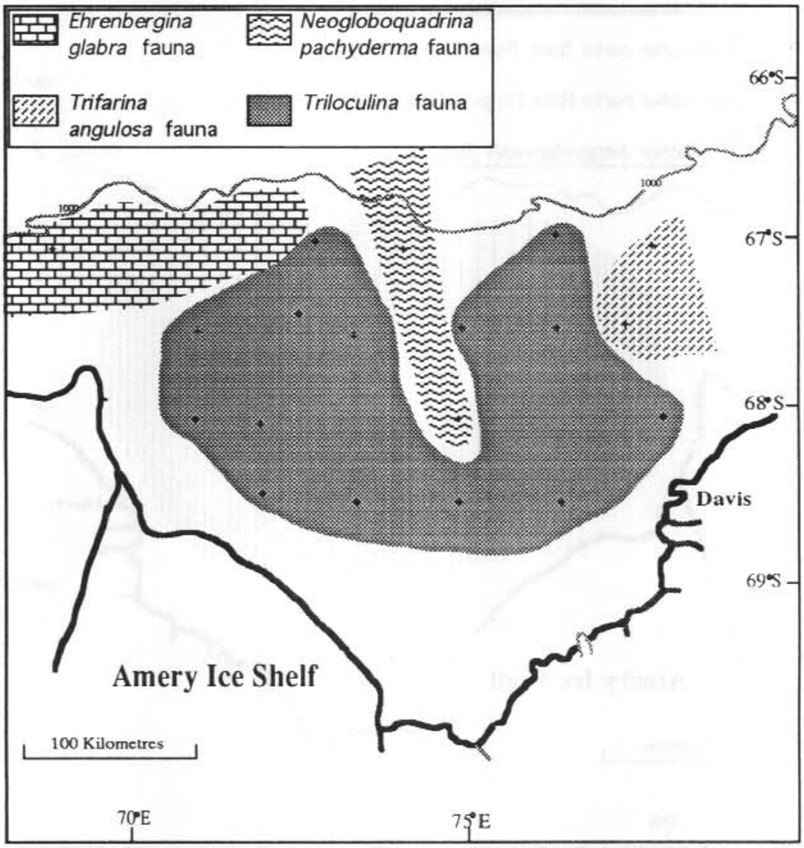

Figure 4. Distribution of foraminiferal faunas in Prydz Bay.

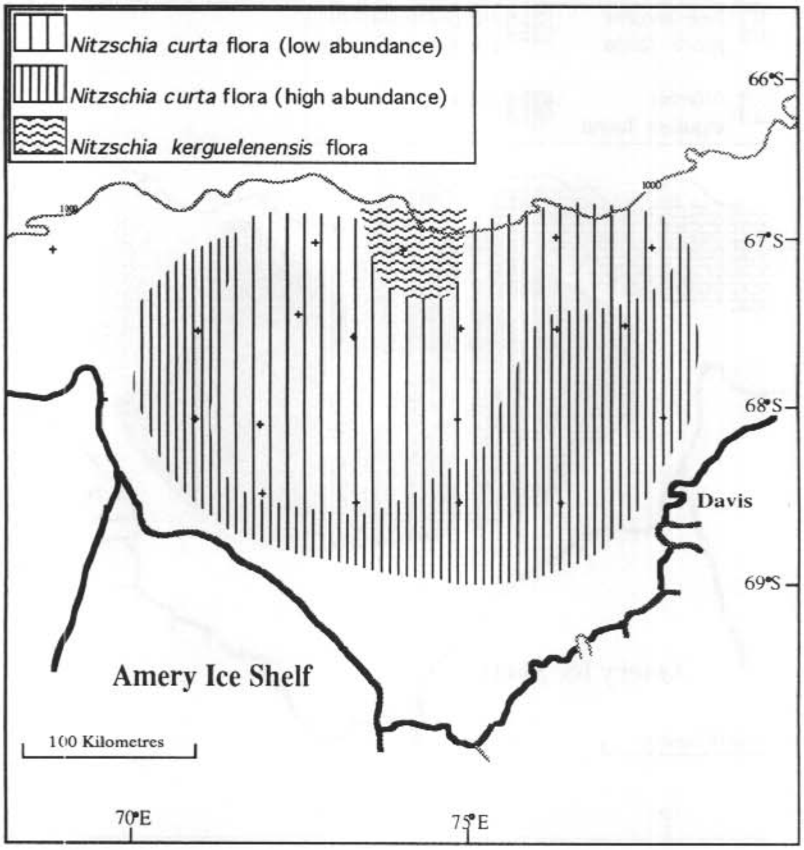

Figure 5. Distribution of diatom floras in Prydz Bay.

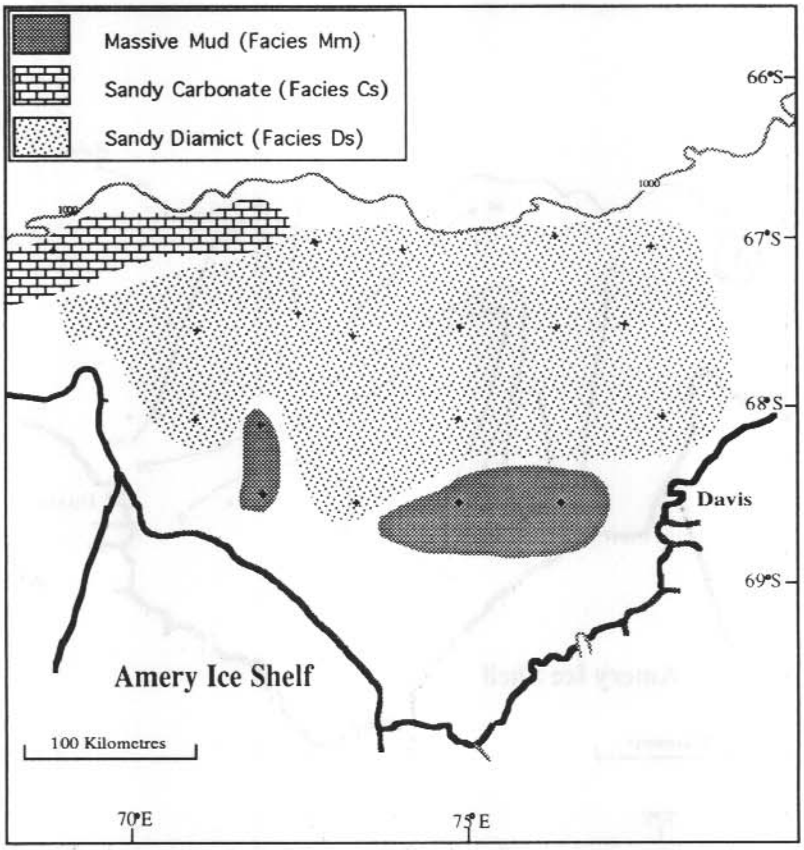

Figure 6. Distribution of sedimentary facies in Prydz Bay.

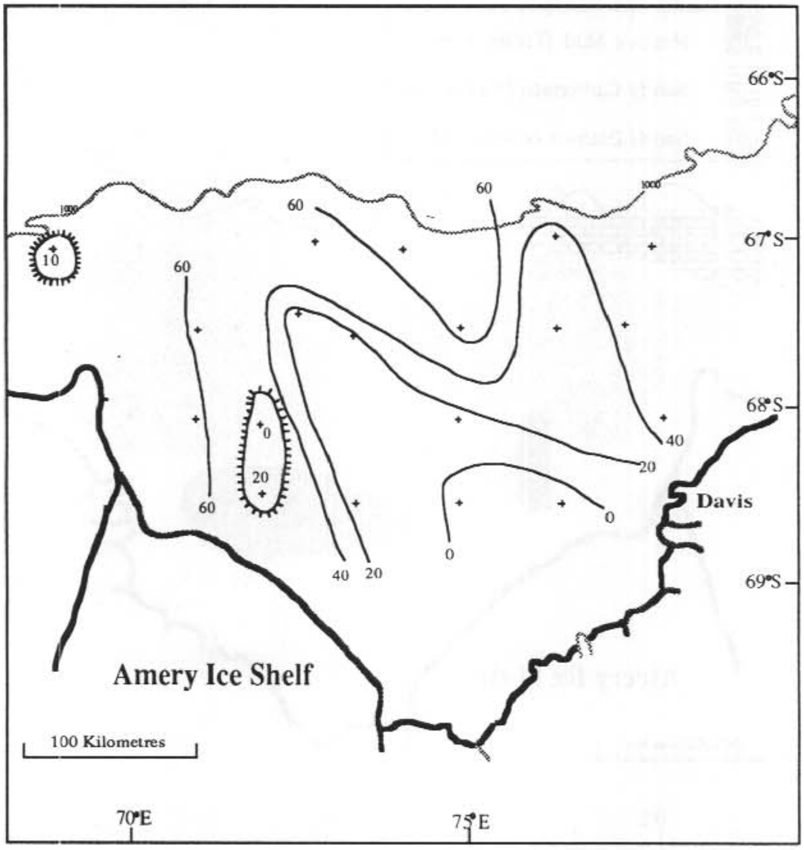

Figure 7. Contour plot of sand proportion in Prydz Bay. Sand percentages are highest in the north of the Bay where the finer fractions are removed or are prevented from settling out. Very low values in the vicinity of the Amery Ice Shelf indicate an area not being reworked. The low value in the northwest is the result of the very high proportion of biogenic material in that sample.

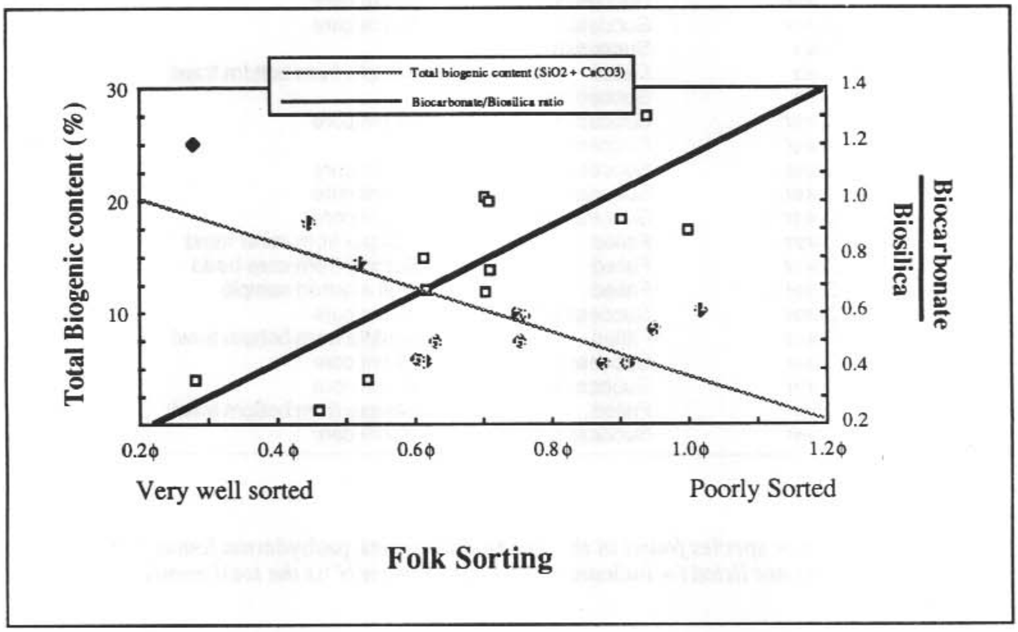

Figure 8. Plot of total biogenic content as a percentage of whole sediment and biogenic carbonate/biogenic silica ratio against folk sorting for samples to landwards of the shelf break. This plot demonstrates that the total biogenic component is highest in areas that are subject to the most reworking. Further, a loose association between sorting and the biogenic carbonate/ biogenic silica ratio indicates that higher energy areas prevent the deposition of diatom frustules.

Table 1. Site details for Prydz Bay sampling grid.

Site	Device	Comments		Depth (m)
S11	Corer	Successful	Core collapsed	396
S14	Corer	Successful	50 cm core	487
S15	Corer	Successful	15 cm core	429
S27	Grab	Successful		769
S28	Grab	Failed	Sample from bottom trawl	504
S29	Grab	Successful		766
S30	Corer	Successful	50 cm core	760
S32	Corer	Successful		566
S43	Corer	Successful	47 cm core	456
S44	Corer	Successful	20 cm core	540
S45	Corer	Successful	20 cm core	646
S48	Corer	Failed	Sample from corer head	620
S50	Corer	Failed	Sample from core head	356
S51	Corer	Failed	Well washed sample	335
S62	Corer	Successful	45 cm core	544
T7	Corer	Failed	Sample from bottom trawl	249
T8	Corer	Successful	20 cm core	330
T11	Corer	Successful	15 cm core	434
T22	Corer	Failed	Sample from bottom trawl	612
T23	Corer	Successful	10 cm core	550

Table 2. List of foram species found in the Neogloboquadrina pachyderma *fauna. Percentages of individual species are listed (+ indicates <1%) and 'Foram N' is the total number of individuals counted.*

Sample	S441	S442	S444	T111	T112	T113	T114
Astrorhiza sp.		+			1		
Reophax nodulosis	+			6			
Globigerina bulloides		3					
Neogloboquadrina pachyderma	58	84	52	32	45	34	45
Globorotalia sp.					1		
Pullenia simplex	3		+				
Pullenia subcarinata		+		10	5		
Triloculina trigonula	26	6	27	+	1	2	
Triloculina rotunda	8	2	18				
Cassidulinoides porrecta		+		13	7	20	18
Eponides sp.	+				1		
Astrononion echolsi		1	+				
Fissurina sp.		1		3			
Favulina hexagona						2	
Trifarina earlandi	3	+	2		2	2	
Trifarina angulosa				15	28	36	27
Cibicides refulgens				16	6	4	9
Oolina sp.		1			+		
Fissurina cf. wrightiana				3	1		
Foram N	43	208	56	31	93	50	27

Table 3: List of foram species found in the Ehrenbergina glabra *fauna. Percentages of individual species are listed (+ indicates <1%) and 'Foram N' is the total number of individuals counted.*

Sample	S111	S112	S113	S114
Bathysiphon crassitinium	+	+		
Recurvoides contortus	1	+		
Reophax guttifer	1			
Reophax nodulosis	1			
Trochammina grisea	+			
Neogloboquadrina pachyderma	50	45	39	20
Globorotalia sp.	1	2	2	3
Oolina sp.		1	1	
Pullenia simplex	+		2	5
Pullenia subcarinata	+	1	2	
Triloculina rotunda		1		
Cassidulina subglobosa		2		
Cassidulina cf. subglobosa		1		
Globocassidulina cf. boira	1	1		
Cassidulinoides porrecta	2	1	5	
Eponides sp.	6	15	6	22
Astrononion echolsi	2		1	
Ehrenbergina glabra	13	11	16	15
Trifarina angulosa	+	2	2	2
Cibicides refulgens	3	4	2	14
Nonion sloanii	+			
Fissurina subcircularis		2	1	
Quinqueloculina tasmanica		3		
Rosalina globularis	+	2	6	
Spirillina sp.	3	1		3
Heronallenia wilsoni	1	+	4	2
Astrononion dicus	1	+	1	
Prygo spp.	2	1	2	
Lagena weisneri	+	1	2	3
Triloculina sp.	8	3	7	8
Nonionella sp.		+		
Buliminella sp.		+		2
Eponides punctulatus	1			
Foram N	206	241	197	187

Table 4: List of foram species found in the Trifarina angulosa *fauna. Percentages of individual species are listed (+ indicates <1%) and 'Foram N' is the total number of individuals counted.*

Sample	S152	S153	T81
Neogloboquadrina pachyderma	25	17	30
Triloculina trigonula	2		
Cassidulina subglobosa	+	+	55
Cassidulina cf. subglobosa			3
Cassidulinoides porrecta	46	62	
Eponides sp.	2		3
Astrononion echolsi	1		
Ehrenbergina glabra	8	1	3
Trifarina earlandi	+		5
Trifarina angulosa	9	17	+
Cibicides refulgens	2		+
Eponides timidulus	1	1	
Bulimina gibba	2		
Foram N	127	72	37

Table 5. List of foram species found in the Triloculina *fauna. Percentages of individual species are listed (+ indicates <1%) and 'Foram N' is the total number of individuals counted.*

Sample	S141	S142	S143	S151	S154	S271	S272	S273	S301	S302	S303	S304	S321	S323	S431	S432	S433	S434	S443	S451	S452
Bathysiphon crassitinium																				2	
Hyperammina cylindricus	37	20							4						8						
Recurvoides contortus	6												9		8						
Reophax guttifer									2												
Reophax nodulosis															33						
Textularina sp.													4								
Trochammina sp.						4															
Globigerina bulloides						4															
Triloculina trigonula	57	70	100	100	100	65	80	83	52	52	54	58	57	47	42	63	57	67	63	76	69
Triloculina rotunda		10				27	20	17	41	48	46	42	26	53	8	37	43	33	38	22	31
Astrononion echolsi													4								
Foram N	32	28	25	15	4	30	15	22	53	24	59	69	27	17	15	20	7	3	16	52	37

Sample	S453	S454	S481	S482	S501	S502	S511	S512	S513	S514	S621	S622	S623	T71	T221	T222	T223	T224	T231	T232
Bathysiphon crassitinium															3				6	
Hyperammina cylindricus				6		25									15				9	
Recurvoides contortus															3				23	
Reophax guttifer															21					
Rhabdammina linearis																			6	
Saccammina socialis																			3	
Neogloboquadrina pachyderma														10						
Triloculina trigonula	73	89	84	36	100	75	67	76	72	85	18	50	50	70	36	84	74	75	37	
Triloculina rotunda	27	11	16	58			33	20	24	8		50		10	18	16	26	25	17	100
Lenticulina sp.								4	4											
Bulimina sp.														10						
Elphidium sp.											9				3					
Oolina sp.										8										
Elphidium cf. *jenseni*											73		50							
Foram N	37	81	21	42	1	4	27	25	25	13	12	2	2	10	37	56	23	28	28	1

Table 6. List of species of diatoms found by sample. Percentages of individual species are listed (+ indicates <1%) and 'N' is the total number of individuals counted.

Diatom	S111	S112	S113	S114	S142	S144	S151	S153	S272	S273	S282	S283	S301	S431	S434	S451	S454	S482	S501
Nitzschia kerguelenensis	13	3	25	4	+	4	9	22	5	5	17		11	11	6	11	7	10	8
Actinocyclis actinochilus	3	3	2	5	6	4	7	11	+							5		4	
A. cholnokyi					1	1	2									3	+		
A. curvulatis	5	10	5		12		9									4			4
Asteromphalus heptarchis					3	3	2									2			
A. hookerii																7			
Aspeitia tabularis		+	+			+								22	11	3			
Cocconeis fasciolata	2		3	15	6	4	2		5	10		11	11				7		17
Coscinodiscus oculoides	7	14	5	19	6	8	1		5	5	17	22	5		11	1	7	8	8
Eucampia antarctica	13	21	5	4	4		11								11	6		4	
Nitzschia curta	58	48	54	51	58	77	57	67	84	80	67	67	63	67	56	56	79	75	65
Thallassiosira spp.			1	2	3		1						11		6	3			
N	124	116	118	105	98	77	89	9	19	20	6	9	19	9	18	102	14	52	26

Diatom	S502	S503	S504	S511	S512	S513	S514	S621	S622	S623	T83	T111	T112	T113	T114	T222	T223	T231	T232
Nitzschia kerguelenensis	25	13	10	14	28	11	6		5	18	33	50	38	50	63	+			9
Actinocyclis actinochilus	13	6	2	14				33		13	11			7		7		9	9
A. cholnokyi										5								+	
A. curvulatis			6							3				3					
Asteromphalus heptarchis																			
A. hookerii																			
Azpeitia tabularis										8	11			3					5
Cocconeis fasciolata			2		6														
Coscinodiscus oculoides		22	15		6				5	13	+								5
Eucampia antarctica				29	6		6			8				20				4	23
Nitzschia curta	63	56	65	43	56	89	88	67	90	31	44	50	63	13	38	93	100	87	45
Thallassiosira spp.		3								3				3					5
N	8	32	48	7	18	18	16	3	20	39	9	2	8	30	8	15	10	23	22

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