Bureau of Mineral Resources, Geology & Geophysics

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A BMR MARINE GEOSCIENCE PROGRAM IN ANTARCTICA

by

H M J Stagg and P J Davies

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Division of Marine Geosciences & Petroleum Geology

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Introduction

The continental margin of the Australian Antarctic Territory (AAT) extends for almost 5000 km, roughly equivalent to the distance from Brisbane to Perth and has a total area within the 200 nautical mile zone of 1 900 000 km^2. With the exception of Prydz Bay and offshore Wilkes Land, this area is almost totally unstudied (Fig. 1). A resume of the current geoscientific database is at Appendix 1. In spite of being so poorly known scientifically, however, Antarctica has great scientific value. The Antarctic margin and the adjacent Southern Ocean are key elements in the present global climate system; a detailed record of the key forcing functions of climate change occurs on the offshore record which will tell when, how and why climate fluctuations run. Furthermore, the Antarctic environment defines a measure of the polution-free world, essential for understanding the extent of anthropogenic change on earth. Finally, the Australian Government wisely believes that the best strategy to achieve environment protection for a unique region is through a fundamentally upgraded scientific database. BMR believes that these needs can be addressed through a program of sedimentological analysis of the Antarctic margin.

Description of Program

A research program consisting of five voyages to the Australian Antarctic margin would have the following aims:

1 to define the sedimentologic and geochemical evolution of the margin; and

2 to decipher the record of past environmental change such as carbon dioxide flux, onset and periodicity of Antarctic glaciations, and Southern Ocean circulation patterns.

The Program should have three elements:

1 Environmental Baseline Studies

Two aspects of baseline studies should be considered within the context of an International Antarctic Heritage Park:

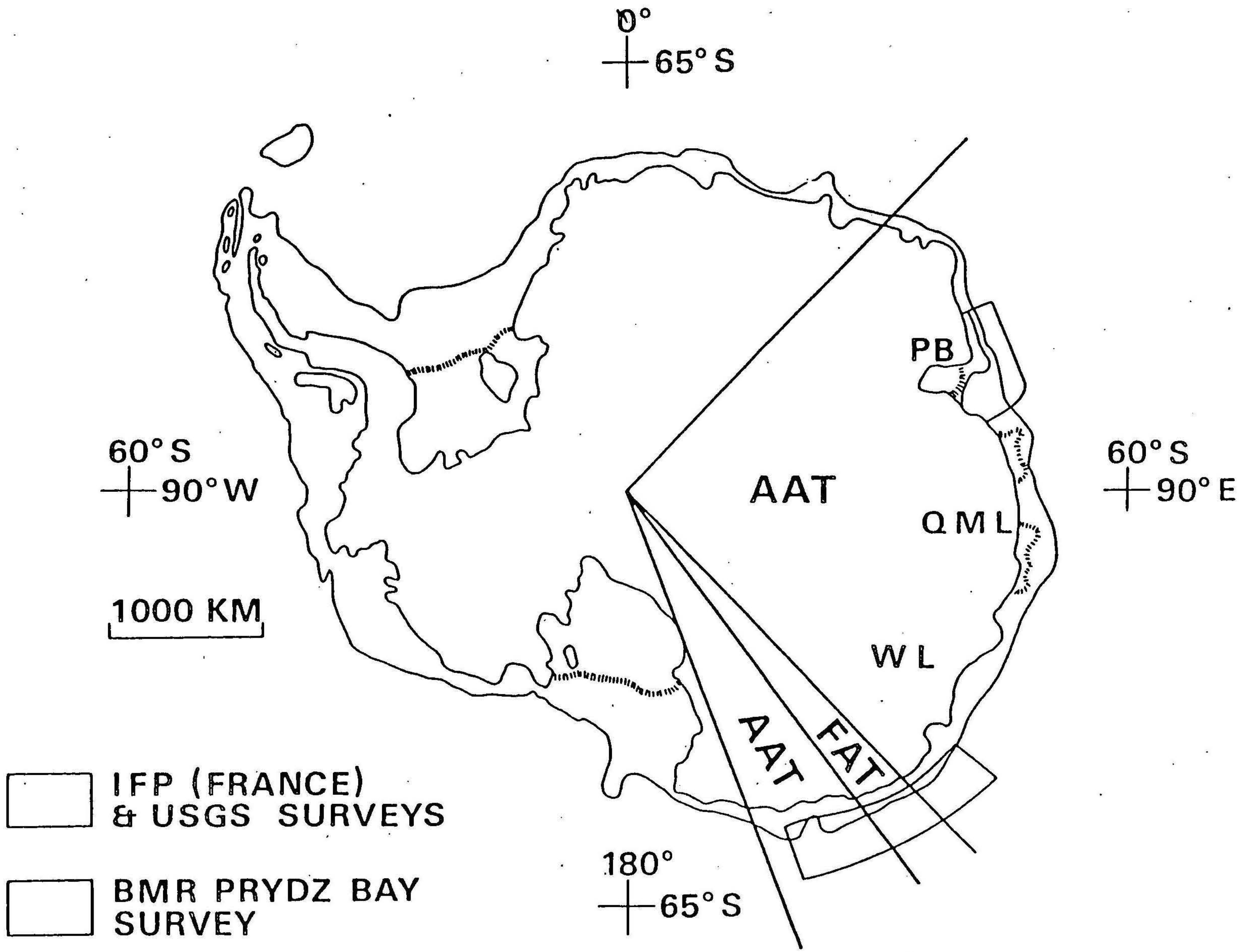


Figure 1: Antarctica - showing those areas of the offshore AAT that have been extensively surveyed by geophysical techniques

a the definition and distribution of seabed bathymetry and substrate types on the Antarctic continental shelf with a view to recognising the principal breeding and feeding grounds for Antarctic marine faunas;

b the definition of the geochemical baseline levels and processes involving metals and nutrients in both sediments and water column in order to estimate the advance of anthropogenically produced pollution and to define future management policy.

2 Studies in Unique Wilderness Laboratory

Certain geological processes and products occur within the Antarctic which currently occur nowhere else on earth. However, such processes and products have occurred elsewhere on earth in the geological past. The Antarctic therefore provides a unique laboratory for studying past events in earth history, eg:

- the effects of ice rafting on shelf sedimentation and morphology;

- the mechanisms, rates and timing of glaciations and their relation to sea level;

- the processes and rates of formation of certain sedimentary minerals, e.g. carbonate and organic carbon production and preservation under conditions of low temperatures;

- conjugate margins. The Wilkes Land margin is considered by some to have been conjugate with the east South Australian margin. The processes controlling the formation of passive continental margins are highly complex. Recent models of these processes indicate an inherent asymmetry in the structure of formerly adjacent (conjugate) margins. Rational analysis of this major geological problem therefore requires the simultaneous study of passive margin <u>pairs</u>. The only fully-developed passive margin pair in the Australian region is the southern margin of Australia and the margin of East Antarctica from 110-150^{o}E. As the structures that control passive margin formation lie at depths from a few kilometres to Moho (12-25 km), it follows that solutions to understanding their formation will be achieved only through the use of deep-penetration seismic.

3 Studies of Global Climatic Change

The Southern Ocean, and particularly the seas surrounding the Antarctic margin are key elements in the present global climate system. A detailed record of the forcing functions of climatic change occurs in the Antarctic sedimentary record. Data collected will define when and how climate fluctuations occur. The record will also provide an estimate of the variability of oceanic CO_2 and heat flux over time and their effects on oceanic and atmospheric circulation. These studies, together with studies of the mechanisms and timing of major glaciations will define the natural variability of climate and sea level change. In particular, such studies will provide a better basis for predicting the onset of the next glacially induced sea level fall, against which predicted greenhouse effects must be judged.

This Antarctic Program would be an extension of the Bureau of Mineral Resources' (BMR) Continental Margins Program (CMP) using the RV Rig Seismic, suitably modified for Antarctic waters. The best strategy to achieve wise environmental protection in the Antarctic is through a strong knowledge base. A sedimentologic analysis of the Antarctic margin, aimed at defining the flux of key environmental parameters, would ensure that the Australian Government has relevant and recent information.

<u>Logistics and Methods</u>

The area of the offshore morphologic regions around Antarctica are as follows:

1 Continental Shelf

Total area - 700 000 km^2

Area covered by ice shelves - 66 000 km^2

Area theoretically accessible - 634 000

2 Continental Slope (including marginal plateaux)

Water depths from shelf break to ~3000 m

Average width 75 km

Total area - 365 000 km^2

3 Continental Rise (as far as COB)

Average width 170 km

Total area - 820 000 km^2

To achieve the Program aims, sedimentological analysis of all these areas will require a geological sampling, geochemical sampling, mapping and multichannel seismic analysis. The following five study areas are proposed (Plate 1):

1 Mirny-Shackleton-Casey (offshore Queen Maryland)
2 Sabrina-Banzare-Clairie coasts
3 Adelie-George V-Oates Coast
4 Prydz Bay-West Ice Shelf
5 Enderby Land.

Each of these areas would take up an entire Antarctic summer (prime access) season of 2 months from mid January to mid March to survey. Naturally, if any area was inaccessible because of ice, the vessel would re-deploy to adjacent areas or to the southern Kerguelen Plateau, if feasible. If it is assumed further that one season is a total write-off because of inclement ice conditions, and that one program is mounted every two years, then a time scale of twelve years for the 'first-look' program appears reasonable.

An approximate breakdown of each summer's program is as follows:

Transit to and from Antarctica	-	18 days
Geological and Geochemical Studies	-	52 days
Bad weather standby in Antarctic waters	-	10 days
TOTAL	-	80 days

Margin Accessibility

It is emphasised most strongly that any estimates of ice extent and accessibility to the margin of the AAT during the summer are only estimates and no more. Furthermore, there is little chance of prediction in any given summer whether ice conditions will be good or bad. Two separate cases illustrate this point very well.

1 Ice limit maps compiled from 1973-82 suggest that substantial part of the continental shelf in the vicinity of the Shackleton Ice Shelf may be accessible for geophysical work during the summer. However, in the 1986/87 season a major iceberg (34 x 60 km as measured by Advanced Very High Resolution Radiometer, or AVHRR) grounded on the shelf and caused a

major buildup of pack ice that would normally have cleared during the summer. This ice buildup was entirely unpredicted and caused the cancellation of the second season of the Bunger Hills operations. Glaciologists at Antarctic Division say that, on the basis of past experience, the iceberg could take up to 15 years to melt and break up; however, it is not certain that it will cause an excessive buildup of pack ice every summer.

2 When BMR conducted its geophysical survey of Prydz Bay in early 1982, ice was so sparse that most lines were run to within sight of the coast. The following summer, Prydz Bay was heavily choked with ice, and very little work would have been possible.

Five maps are attached. Plate 1 shows a crude division of the margin of the AAT (except for the segments from 45-60 E and 153-160 E) in the morphological units listed above; the continental shelf is further divided into logical 'compartments'. Plates 2, 3, and 4 show the ice limits at every 10 degrees of longitude for the months of January, February, and March. ('Ice limit' is defined here as the limit of 15% ice density.) The lines shown are the minimum, mean, and maximum ice limits based on data from 1973-82, compiled by Antarctic Division. The map for February, the most ice-free month, also includes two lines, each one standard deviation each side of the mean ice limit.

We also have access to the Sea Ice Climatic Atlas for the Antarctic, produced by the US Naval Oceanography Command. While the Atlas generally agrees with the Antarctic Division data, it also provides several other sets of maps, of which two are particularly useful:

1 Mean concentration of ice when ice is present - these maps show that when ice is present, it is almost always present in high concentrations - typically 50-80%. It is reasonable to assume that when ice is present, no systematic geophysical work can be done.

2 Probability of any ice being present (Plate 5) - if it is assumed that the presence of sea ice precludes marine geophysical surveys, then this map gives a percentage probability that such operations can be conducted in a given area.

Antarctic Division have advised that the resolution of the satellite imagery is about 30 km; consequently, the maps in the Atlas, at a scale of 1:25 m are rather coarse. Although digital data are available from the US, Antarctic Division say that the digital information will probably not be any more enlightening than the Atlas maps. However, it is possible that higher resolution imagery may be available in almost real time in the next few years either on board ship or at Casey ANARE station.

From the maps, we believe the following conclusions may be drawn. In these conclusions, Ship A will refer to an equivalent of the Rig Seismic (DNV Ice Class C, with single-skinned hull), Ship B refers to an upgraded Ice Class C vessel with improved ice protection as outlined in Appendix A, and Ship C refers to a ship with Ice Class A strengthening.

1 All of the continental rise would be accessible to ship A.

2 Over several seasons, the entire continental slope would be accessible to ship A, with minimal risk of entrapment. Ship B would further reduce what would be a small risk.

3 The continental shelf can be divided into three areas as follows -

   a areas where there is a relatively high probability (>60%) of the continental shelf being clear of ice as far south as the coast (e.g. Prydz Bay and the sector from 135-150E).

   b areas where the probability of ice being found increases steadily as one approaches the coast - i.e. the probability contours are sub-parallel to the coast (e.g. 100-130E).

   c areas where there is low ice probability close to the coast, but a high probability farther offshore (e.g. 91-95E).

We believe that either Ship A or Ship B would be suitable in shelf area (b). Ship B would have an improved margin of safety in case of heavy ice and would obviously be preferred from the point of view of ice protection and risk of total loss. In area (b), no attempt would normally be made to steam south of the ice edge with a seismic streamer deployed - i.e. the chance of being beset should be small. As there is some danger in area (a) of being cut off from the open sea by ice drifting off the pack in adjacent areas, Ship B is the preferred option here. We do not believe that area (c) should be tackled with less ice.

APPENDIX 1

GEOLOGY OF THE AAT MARGIN

This section details the AAT margin, segment by segment, from west to east, summarising the available information and drawing inferences on the geology, where possible (segment locations in Plate 1).

Area 1: Enderby Land (45E - 70E)
Reference Relevant to Offshore: Fedorov and others (1982); Kurinin and Grikurov (1982).

Onshore Geology/Geophysics: Kamenev (1982); Sheraton (1982); Wellman and Tingey (1982); Black and James (1983); Ellis (1983); Harley (1983); James and Tingey (1983); Sandiford and Wilson (1983); Sheraton and others (1980); Wellman (1983).

The metamorphic rocks of Enderby Land consist of the ancient Archaean Napier Complex (granulite facies) bound to the south by the Proterozoic Rayner Complex, a lower grade reworking of the Napier Complex. No unmetamorphosed sedimentary rocks have been found from the area.

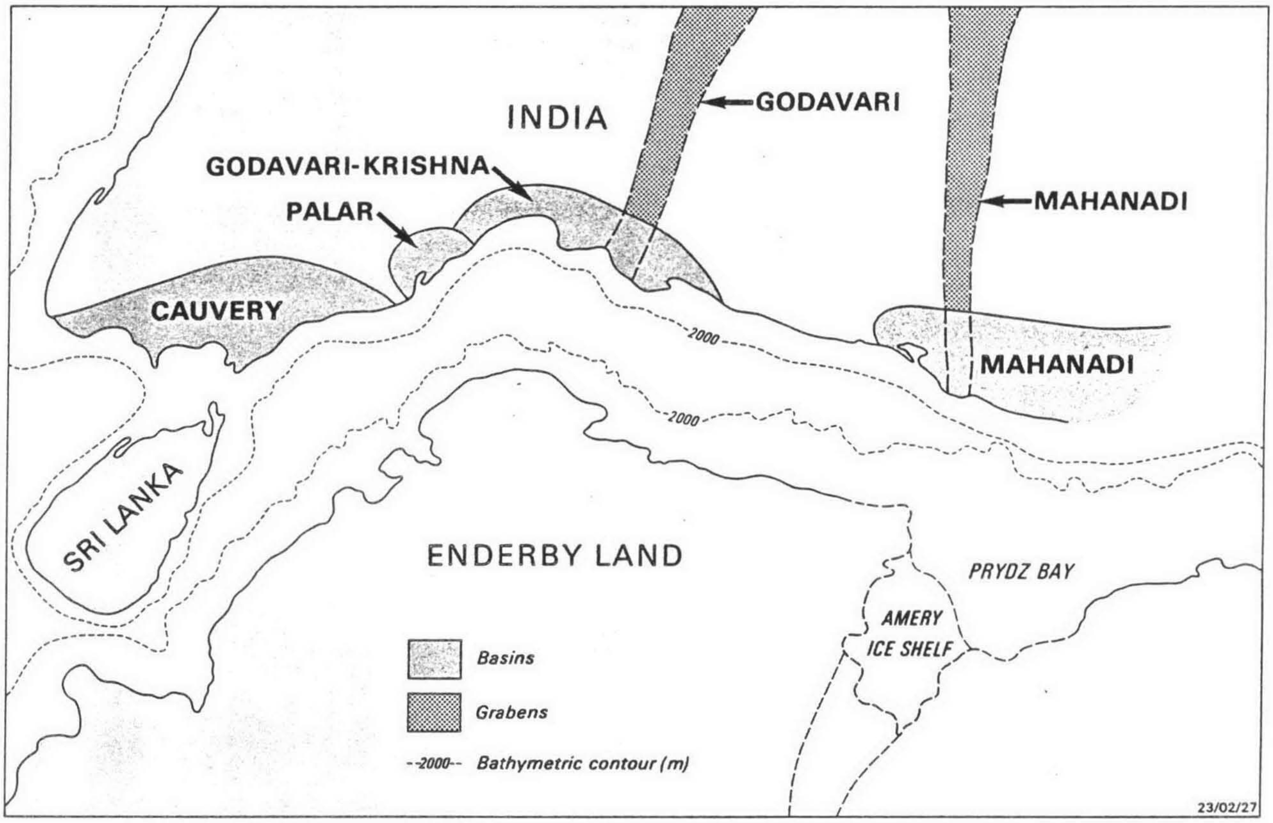
Conjugate Margin: Assumed to be the east coast of India.

Surveys: 1982 BMR survey in the extreme east.

Offshore Geology: Little can be concluded about the offshore geology of Enderby Land based on direct evidence. Fedorov and others (1982b) follow earlier authors in showing a reconstruction of India against Antarctica (their fig. 7.2; Fig. 2) and attempted to match major structures between the two margins. The principal sedimentary basins of the eastern Indian margin (Sastri and others, 1974, 1981) that would lie opposite Enderby Land are -

Cauvery Basin - occupying the southeast part of Peninsular India, is a block-faulted pericratonic basin comprising horst and graben structures. The maximum thickness is about 5500 m and the sediments range in age from Early Cretaceous to Recent.

Figure 2: Reconstruction of India against Enderby Land, showing the relationship of the Indian east coast basins to the Antarctic margin.



Godavari-Krishna Basin/Godavari Graben - a composite basin with comparable areas on land and under the continental shelf, and trending parallel to the coast. The maximum depth to basement is about 4000 m and sediments range in age from Permian to Recent. The underlying Godavari Graben trends at right angles to the coast and contains up to 5000 m of sediments ranging from Early Palaeozoic to Eocene in age. Fedorov and others (1982) have reported that aeromagnetic anomalies over eastern Enderby Land indicate the existence of a sub-longitudinal fault zone with horst and graben-like structures which range from 130-150 km in width and extend for at least 300 km inland between 57 30'E and 60E. They implied that this may be a pre-breakup continuation of the Godavari Graben.

The only marine data available is from the western extremity of the 1982 BMR survey. Only one of the lines extended across the shelf, and it showed that little sediment was present.

Area 2: Prydz Bay (70E - 78E)
References Relevant to Offshore: Fedorov and others (1982a, b); Kurinin and Grikurov (1982); Mizukoshi and others (1986); Stagg and others (1983); Stagg (1985).

Onshore Geology/Geophysics: Mond (1972); Ravich and Fedorov (1982); Tingey (1982); Wellman and Tingey (1976).

Most of the onshore rock exposures occur along the coast and inland in the Prince Charles Mountains chain which extends south of Prydz Bay for at least 600 km. Most exposures consist of Precambrian metamorphics, metasediments, and intrusives. The only known onshore outcrops of Phanerozoic sedimentary rocks are coal-bearing Permian continental strata in the Beaver Lake area, more than 200 km south-southwest of Prydz Bay (Mond, 1972).

The Prince Charles Mountains are exposed along the flanks of and in a regional ice-surface depression caused by ice drainage through the Lambert Glacier. Gravity surveys (Wellman and Tingey, 1976) and deep seismic soundings (Kurinin and Grikurov, 1982; Fedorov and others, 1982b) showed that a major graben structure underlies the Lambert Glacier and Amery Ice Shelf and extends inland for almost 700 km. Soviet aeromagnetic data offshore suggests that the Lambert Graben continues into Prydz Bay.

Conjugate Margin: East coast of India.

Surveys: BMR (1982) - 5000 km of 6-channel, 3 and 6-fold airgun seismic data; Japan (1985) - 2350 km of 24-channel, 6-fold watergun seismic data (only a small portion in Prydz Bay); Soviet Antarctic Expedition (1986) - details unknown.

Offshore Geology: The principal results of the BMR Prydz Bay study can be summarised as follows (Stagg, 1985) -

1 The Prydz Bay basin occupies an area of at least 40 000 km^2 in water depths of 400-900 m and contains at least 5 km of sedimentary rocks.

2 The NE-NNE basin trend suggests that, with the Lambert Graben, the basin forms a failed rift at a triple or four-armed junction.

3 The sedimentary pile in the Prydz Bay basin is little disturbed by folding and faulting other than in the southwest of the bay.

4 Two major groups of seismic sequences can be identified. The lower group possibly consists of Permian to Late Jurassic or Early Cretaceous strata of predominantly continental origin, while the upper group possibly comprises Cretaceous and Cainozoic strata of predominantly shallow marine origin.

5 Three major unconformities can be identified within the Prydz Bay basin. In order of decreasing age, these are interpreted as being due to rift onset (?Triassic-Early Jurassic), margin breakup (?Early Cretaceous), and glacial advances (mid-Miocene-Early Pliocene).

The interpretation uncertainties defined above have, to some extent, been resolved through the efforts of the Ocean Drilling Program. Results from this study are summarised below:

Five holes were drilled aiming to document the initiation of East Antarctic glaciation. The Prydz Bay sequences record major changes in the depositional environment. The oldest succession above acoustic basement, the "red bed" type sediments, suggests deposition within the proximal reaches of a river system. Climatic conditions at the time probably were warm and characterised by seasonal rainfall. Although the paucity of microfossils inhibits age determinations, these sediments may be equivalent to the Amery Group sequence in the Lambert Graben, suggesting a possible Permian age, but a later age is also possible. The overlying thin units of laminated silty claystone, poorly sorted sandstone, and carbonaceous siltstone at Site 741 lie below the Prydz Bay glacial sequence and are of Eocene age, on the basis of spore and pollen detritus present in the sediment.

The sequence recovered at Sites 739 and 742 consists of unsorted mixtures of clay, silt, sand, gravel, and occasional stones (diamictites). They represent various facies of glaciogenic deposition, from lodgment till, deposited beneath grounded ice, through waterlaid till, deposited off but near the grounding line, to glacial marine sediments of a more distal facies. The waterlaid till may have been deposited beneath floating ice shelves and down the upper part of the continental slope during periods when the grounding line was at or near the shelf break. The more distal glacial marine facies are rather poorly represented in the cored sequence, an observation that may be explained by erosion of this facies by subsequent advances of grounded ice. The latter is indicated by various degrees of apparent compaction through the sequence, pointing toward several major glacial oscillations across the shelf. Overcompaction of the sequence seems clear in the upper half of the cored sequence, whereas the loading history in the lower part may be obscured by diagenetic effects. Distinct overcompaction is observed below a thin cover of normally consolidated diamictites, indicating that the last major glacial expansion in East Antarctic reached the shelf edge. This may explain the interbedding of soft waterlaid till and sand of Pliocene-Quaternary age present just a few meters below the seafloor on the continental slope.

Thus, the sediments recovered from Prydz Bay demonstrate that the glaciation proceeded in phases. The deepest glacial levels sampled (Site 742) are nonmarine (early Eocene-earliest Oligocene time), and marine conditions are evident only sometime later (earliest Oligocene time). Glacial sediment fabrics and overconsolidation features indicate that grounded ice occupied Prydz Bay during Eocene-Oligocene and younger time, though these features probably represent a complex series of ice advances and retreats. During the Miocene-Quaternary glacial maximum the ice front extended 170 km beyond the present location.

Area 3: West Ice Shelf (78E - 88E)
Reference Relevant to Offshore: none known.

Onshore Geology/Geophysics: The only known coastal outcrops are of Precambrian granulite facies metamorphic rocks and Cainozoic volcanics.

Conjugate Margin: probably northern India (no longer in existence as a margin; Fig. 3).

Surveys: none.

Offshore Geology: With no useful background information available, it is difficult to draw any conclusions. Dredging by HMS Challenger in the 1870's recovered a variety of rocks that included red sandstone, but no substantial details are available.

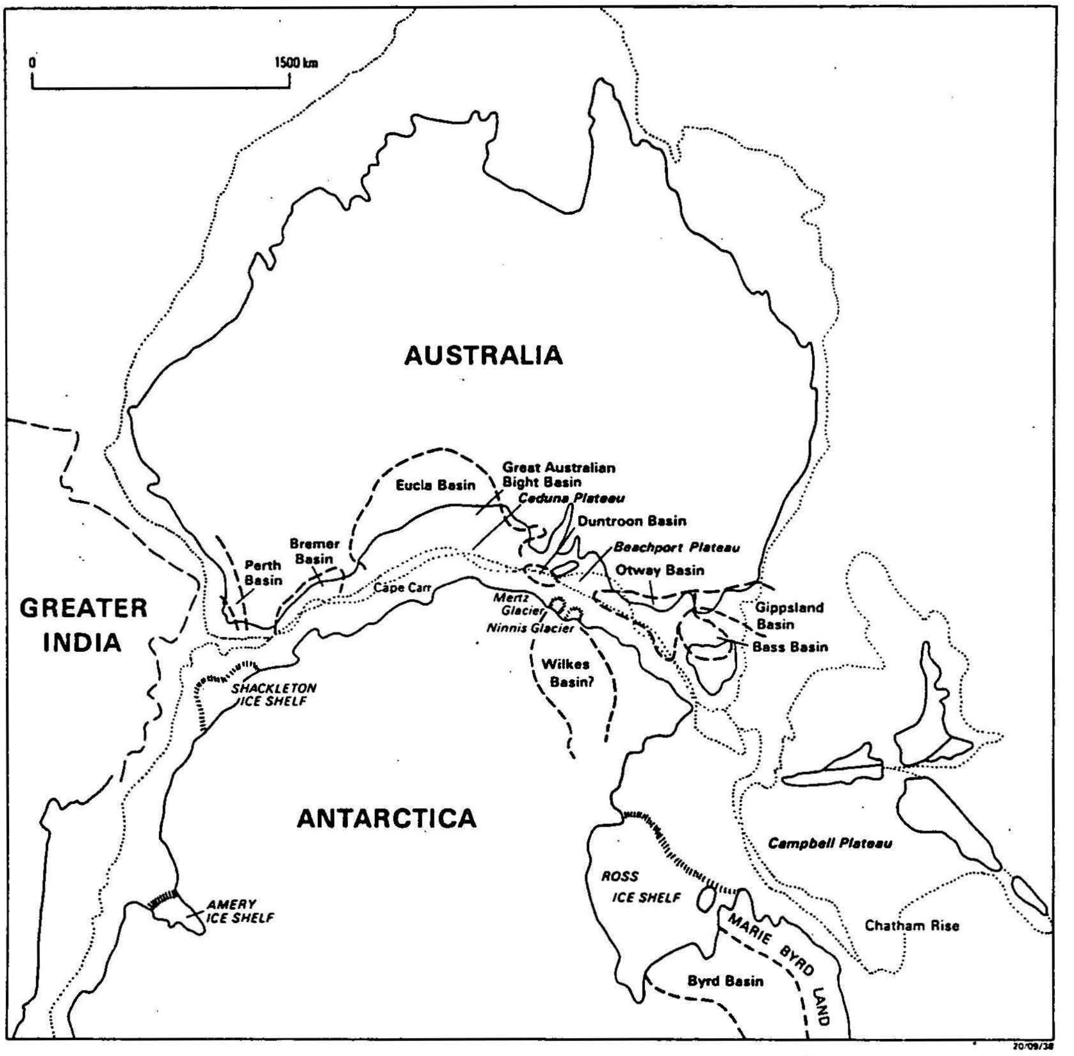
Area 4: Mirny-Shackleton Ice Shelf-Casey (88E - 112E)
References Relevant to Offshore: Truswell (1982, 1983); Tsumuraya and others (1985).

Onshore Geology/Geophysics: The coastal outcrops again consist of Precambrian granulite facies and charnockite bodies. The Bunger Hills area, behind the central part of the Shackleton Ice Shelf, has been the target of recent Australian work, but few results have been published so far. No sedimentary rocks have been reported from the coastal strip, but Cambrian sandstones are abundant in moraines and crop out inland.

Conjugate Margin: northern India (margin no longer in existence) and southwest Australia (Fig. 3).

Surveys: Japan (1984) - 3 lines (~800 km) of 24-channel, 6-fold airgun seismic data.

Figure 3: Continental reconstruction of Australia, Antarctica, and Greater India (after Truswell, 1983).



Offshore Geology: The three Japanese lines (Tsumuraya and others, 1985) provide little information on the margin. The line drawings presented show the typical Antarctic continentward-dipping shelf, a sharp shelf break, and a steep slope. Little detail is visible beneath the shelf (due to multiples) and the deep-water sequences appear similar to those observed off Prydz Bay.

Truswell (1982, 1983) examined dredge samples collected by Douglas Mawson's 1911-14 Australasian Antarctic Expedition from several areas for traces of recycled palynomorphs in an attempt to predict the presence or otherwise of sedimentary basins, either onshore or beneath the continental shelf. Samples from the western side of the Shackleton Ice Shelf yielded abundant palynomorphs which fell into three age groups - Permian, Late Jurassic to Early Cretaceous, and Late Cretaceous to Early Tertiary. There was little evidence for marine influence in the Late Jurassic-Early Cretaceous element, whereas the Late Cretaceous-Early Tertiary samples appeared to indicate marine source rocks. Truswell speculated that the Mesozoic and Tertiary palynomorphs may have been derived from sediments being eroded near the shelf edge. In contrast, the Permian samples appear to originate from onshore, possibly from beneath the Denman Rift, which may be a similar feature to the Lambert Graben.

The Perth Basin usually reconstructs against the eastern end of the Shackleton Ice Shelf-Casey area (Fig. 3), and probably forms a triple junction (or perhaps a four-armed junction, if the Vanderford Glacier marks a major rift structure in Antarctica. It is worth pointing out that the only substantial marginal plateau in the offshore AAT (Bruce Rise) lies north of the Shackleton Ice Shelf. Nothing is known of this feature's origins (?continental or oceanic) or how it fits into pre-rift reconstructions. It would not be unreasonable to suggest the presence of sedimentary basins on this part of the Antarctic margin, and we regard the general area as having a high priority for marine geoscience.

Area 5: Sabrine-Banzare-Clarie Coasts (112E - 135E)
References Relevant to Offshore: Truswell (1982, 1983); Tsumuraya and others (1985).

Onshore Geology/Geophysics: ?references. Rare onshore outcrops consist of Precambrian granulite facies and charnockite bodies.

Conjugate Margin: Southern margin of Australia (western half of the Great Australian Bight (GAB) and southwest Australia; Fig. 3).

Surveys: Japan (1984) - ~2300 km of 24-channel, 6-fold airgun seismic data.

Offshore Geology: The Japanese seismic data consist essentially of a long east-west tie line on the slope and rise, and north-south transects at about 120E and 128E. One of the N-S transects (120E) crosses the shelf, and again Tsumuraya and others (1985), fig. 8) show a continentward-dipping shelf, sharp shelf break, and a steep slope, with no geological detail visible beneath the shelf, presumably because of multiples. The deep-water sequences appear similar to those off Casey and Prydz Bay.

Truswell (1982, 1983) examined recycled palynomorphs from this area (Cape Carr), reporting the existence of Early to mid-Cretaceous and Late Cretaceous to Early Tertiary components. The only marine influence found was in the late Palaeocene to Eocene assemblages. While sparse sampling made it difficult to pinpoint the source rocks, Truswell speculated that the recycled material may be eroding from strata outcropping at the steep slopes of the shelf break.

The assumed conjugate margin of southwest Australia and the western half of the GAB, does not give much assistance. The Bremer Basin in the west appears to be limited to the continental slope and is poorly known, while the Eyre Sub-basin, although much better known and containing as much as 6 km of sediment (Bein and Taylor, 1981), may be part of a system of grabens on the southern margin of Australia (Willcox and others, in prep.) with no obvious counterpart in Antarctica.

<u>Area 6: Adelie Coast</u> (135E - 147E)

References Relevant to Offshore: Davey (1985); Domack (1982); Domack and Anderson (1983); Domack and others (1980); Eittreim and Hampton (1987); Eittreim and others (1985); Stagg and others (in press); Truswell (1982, 1983); Tsumuraya and others (1985); Vanney and Johnson (1979a, b); Wannesson and others (1985).

Onshore Geology/Geophysics: Mawson (1942); Steed (1980, 1983); Steed and Drewry (1982).

Coastal outcrops here contain more unmetamorphosed sedimentary rocks than are usually found in East Antarctica. In addition to the Precambrian granulite facies and charnockite bodies, common to much of the East Antarctic Shield, Beacon Group sediments (blue and purple shale, sandstone, and argillaceous sandstone; Mawson, 1942) overlain by ?Jurassic dolerite have been found in the cliffs of Horn Bluff (approximately 150E). Davey (1985) suggests that sediments of Beacon age may also be present deep under the margin.

Steed (1980, 1983) and Steed and Drewry (1982) have interpreted a major sub-ice basin, the Wilkes Basin, from radio echo-sounding data. Steed (1983) concluded that the basin is sedimentary in origin and developed by tensional growth and subsidence similar to the development of the North Sea Basin.

Conjugate Margin: southern margin of Australia (?eastern half of the GAB) - Ceduna Terrace (GAB Basin) and Beachport Terrace (Otway Basin; Fig. 3).

Surveys: France (1982) - ~3000 km of 24-channel, 24-fold airgun array seismic data; Japan (1984) - ~600 km (total) of 24-channel, 6-fold airgun seismic data; USA (1984) - 1800 km of 24-channel, 24-fold airgun array seismic data.

Offshore Geology: Offshore Wilkes and Adelie Lands now constitute probably the best studied part of the offshore AAT, with French, Japanese, and US multichannel seismic (MCS) programs being completed. It is unfortunate that only a single transect from oceanic crust to inner shelf has been published (Wannesson and others, 1985); the US study was principally restricted to the continental slope and rise by adverse ice conditions. The single French line defines three major seismic sequences overlying acoustic basement beneath the shelf and slope. The ages of the intra-sequence unconformities were considered to be Upper Eocene (42 Ma) and late Oligocene (25 Ma). The total thickness of sediments under the continental shelf and above acoustic basement exceeds 4s two-way time (twt).

The only available geological sample that gives an indication of the age of the older part of the section is a non-marine Aptian core obtained from the flank of the George V (morphologic) Basin between the Ninnis and Mertz Glaciers (Domack and others, 1980; Domack, 1982; Domack and Anderson, 1983). Truswell (1982, 1983) also examined palynomorphs from the Mawson dredge collection in this area and found Early Cretaceous spores and pollen that resembled an assemblage recovered from the George V Basin core, and less common Late Cretaceous to Early Tertiary taxa.

As previously noted, the US MCS data, whilst of high quality and displaying Moho reflections in a number of places, were restricted to the slope and rise (Eittreim and Hampton, 1987). Four major sedimentary sequences were identified (Fig. 4) and interpreted as being terrestrial or early synrift basin, synrift basin, continental shelf, and continental slope and rise sequences. The total sedimentary thickness is again at least 4s twt.

In summary, a considerable thickness of sediment appears to be present beneath the shelf and the slope/rise. While we have access to the US MCS data, we are unlikely to see any more of the French data than has already been published in the scientific press. Although this area is an attractive area for further exploration, we suggest that the poorer-known parts of the AAT margin warrant first priority.

<u>Area 7: George V - Oates Coasts</u> (147E - 160E)
References Relevant to Offshore: none known.

Onshore Geology/Geophysics: McLeod and Gregory (1967); Ravich and others (1968). Beacon Group (Permian - Jurassic) sediments are found in the west (Horn Bluff); Upper Precambrian metasediments and older Precambrian medium to high grade metasediments and metavolcanics are found in the east. The Horn Bluff dolerites are an important potential geological tie to Australia.

Conjugate Margin: southeast Australia (?Otway Basin; basins of the Tasmanian west coast; Fig. 3).

Surveys: none.

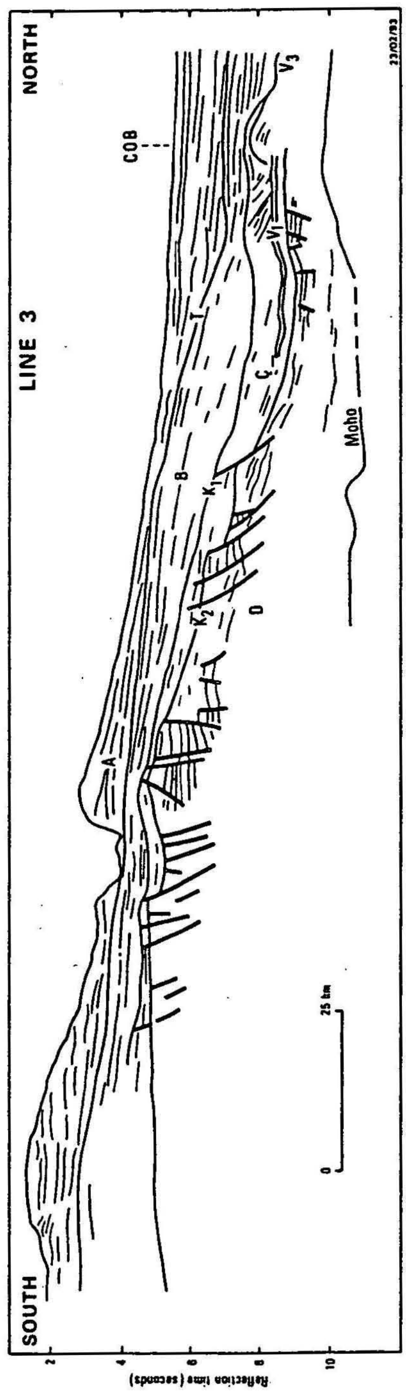


Figure 4: Line drawing of reflection seismic profile recorded by US Geological Survey approximately along longitude 131°E (after Stagg and others, 1986).

Offshore Geology: nothing is known directly. Given the presence on the conjugate margin of complex rift/wrench basins, we speculate that there is good potential for the development of similar basins on the Antarctic margin.

APPENDIX 2: PROPOSED MODIFICATIONS TO *RIG SEISMIC* to provide a safety factor when operating off Antarctica.

(After M.J. Doherty & Co. Pty. Ltd)

The following alterations describe additional watertight subdivision to provide some degree of protection to the dangers of operating off the ice. One compartment subdivision cannot be achieved because of the size of the engine room, but the alterations will provide a reasonable level of protection against flooding. There is no increase to the Ice Classification by DNV.

(<u>Note:</u> numbers in brackets in the following text refer to the numbers on the lower part of Figure 5.)

The compartment between frame 87 (1) and frame 40 (2) shall be divided into three watertight compartments by the addition of two watertight steel bulkheads, one on frame 70 (3) across the full width of the vessel (thereby separating the instrument room and the workshop area), and one on frame 50 (4) at the starboard side between the instrument room and the office. Each of these steel bulkheads shall be fitted with a hinged W/T steel door.

The shell plating shall be increased in thickness by the addition of 8mm doubler plates plug welded to the outside of the existing shell between frames 78 and 14 (5), and extending from the tank top to the shelter deck approximately, thereby covering the instrument room and the engine room.

All steel used in the modifications shall be approved to DNV standard.

All electrical and pipework services passing through the main deck shall be made watertight with glands and/or packing, as shall the services passing through bulkheads 50, 54, 70, and 75.

The sonar trunk at frame 54 approximately shall be made watertight up to the shelterdeck level by the addition of bulkheads and watertight doors above the main deck.

All access doors down through the main deck shall be fitted with W/T doors, and steel bulkheads around as necessary (frame 82, 51, 30P, 30S, 10).

The ship side insulation shall be removed as necessary to allow welding of the side shell doubler plate, and replaced on completion.

Ventilation trunking, watertight as required, shall be provided to the workshop and office as necessary.

Figure 5: *Rig Seismic* general arrangement, showing modifications proposed.

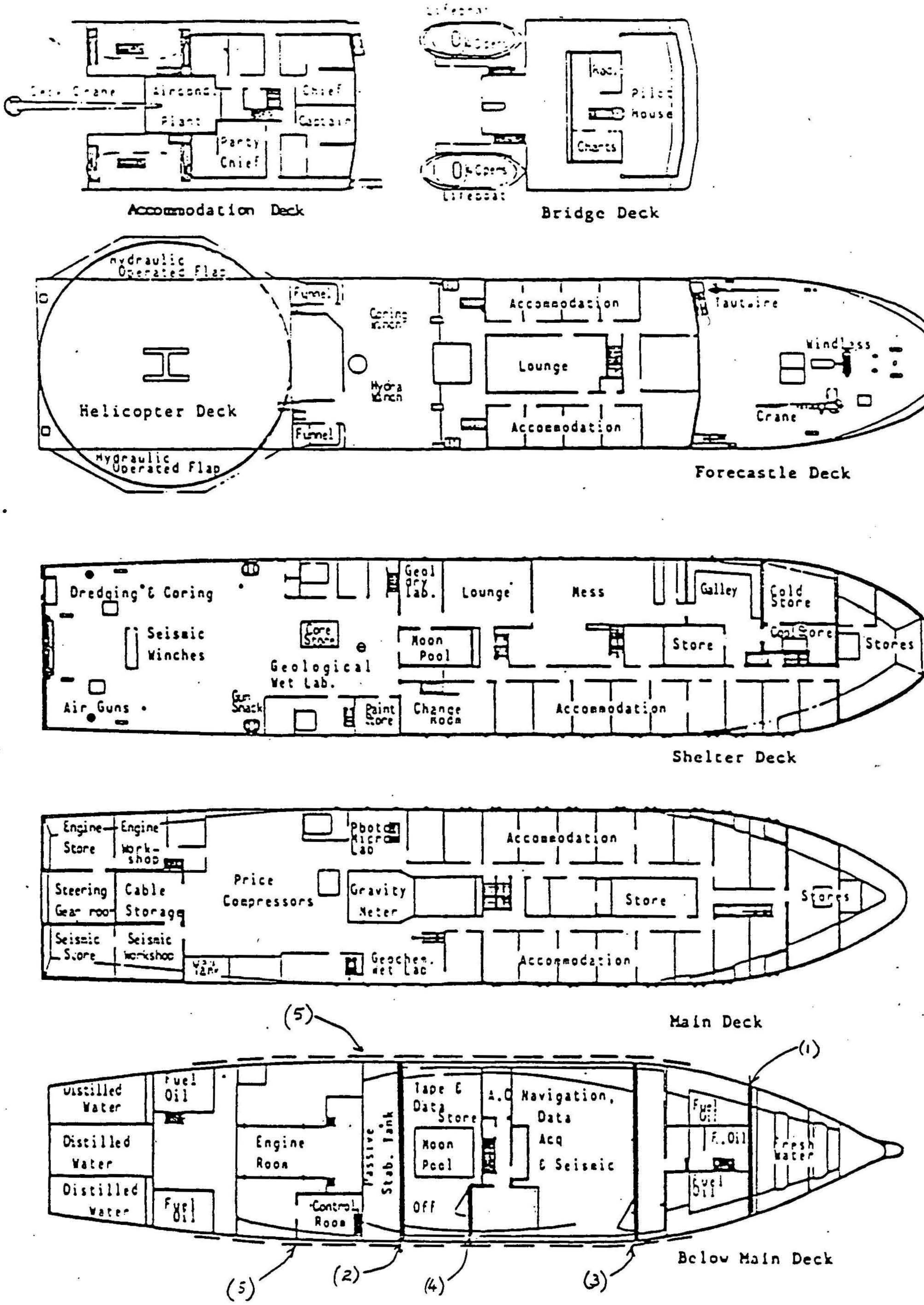


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PLATE1


60°E
70°
80°
90°E
100°E
110°
120°
130°
140°
150°
60°
65°
69°S
70°S
CONTINENTAL RISE
CONTINENTAL SLOPE
SHACKLETON ICE SHELF
26000
WEST ICE SHELF
48000
MIRNY
43000
ENDERBY
10000
PRYDZ BAY
100000
Mac-Robertson Coast
PRINCESS ELIZABETH LAND
WILHELM LAND
Queen Mary Coast
EASTERN SHACKELTON ICE SHELF
KNOX COAST
CASEY
35000
SABRINA
48000
BUDD COAST
SABRINA COAST
BANZARE CLARIE
48000
BANZORE COAST
CLARIE COAST
ADELIE
64000
ADELIE COAST
GEORGE V
112000
GEORGE V COAST

PLATE 2

60°E
70°
80°
90°E
100°E
110°
120°
130°
140°
150°
70°S
65°S
Mac-Robertson Coast
PRINCESS ELIZABETH LAND
WEST ICE SHELF
WILHELM LAND
Queen Mary Coast
EASTERN SHACKELTON ICE SHELF
KNOX COAST
BUDD COAST
SABRINA COAST
BANZORE COAST
CLARIE COAST
ADELIE COAST
GEORGE V COAST
INDEX
MAXIMUM
MEAN
MINIMUM
ICE LIMIT - JANUARY

PLATE 3

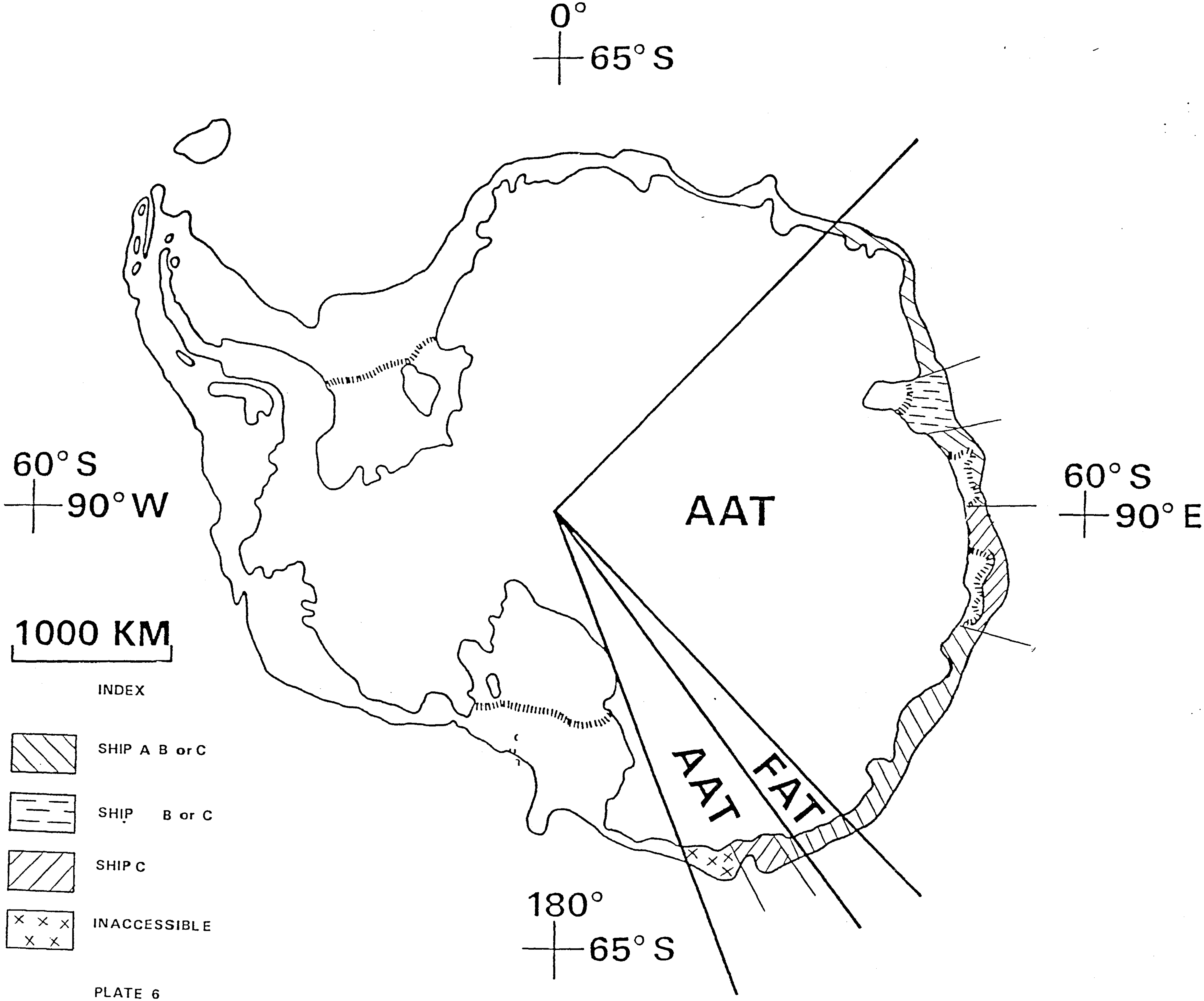

60°E
70°
80°
90°E
100°E
Mac-Robertson Coast
PRINCESS ELIZABETH
LAND
WEST
ICE
SHELF
WILHELM LAND
Queen Mary Coast
70°S
EASTERN SHACKELTON
ICE SHELF
KNOX COAST
BUDD COAST
SABRINA COAST
BANZORE COAST
CLARIE COAST
ADELIE COAST
GEORGE V COAST
INDEX
MAXIMUM
MEAN
MINIMUM
STANDARD DEVIATION
110°
120°
130°
140°
150°
ICE LIMIT - FEBRUARY

PLATE 4

60°E
70°
80°
90°E
100°E
110°
120°
130°
140°
150°
60°S
65°
69°S
70°S
Mac-Robertson Coast
PRINCESS ELIZABETH LAND
WILHELM LAND
Queen Mary Coast
WEST ICE SHELF
Fram Bank
EASTERN SHACKELTON ICE SHELF
KNOX COAST
BUDD COAST
SABRINA COAST
BANZORE COAST
CLARIE COAST
ADELIE COAST
GEORGE V COAST
INDEX
MAXIMUM
MEAN
MINIMUM
ICE LIMITS - MARCH

PLATE 5

PERCENT PROBABILITY OF OCCURRENCE OF ANY ICE ON FEBRUARY



0°
65° S
60° S
90° W
60° S
90° E
AAT
AAT
FAT
1000 KM
INDEX
SHIP A B or C
SHIP B or C
SHIP C
INACCESSIBLE
180°
65° S

PLATE 6