AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Record Number

1993/5

Preliminary Results of AGSO *RV Rig Seismic* survey 112 LegB: Offshore Sydney Basin Continental Shelf and Slope Geochemistry, Sedimentology and Geology

A joint Program of the Australian Geological Survey Organisation, Sydney University, and NSW Department of Mineral Resources

AGSO Project 121.37

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Shipboard Scientists (in alphabetical order)

AGSO
G Bickford [1]
D Heggie [1]

NSW–DMR
P Roy [5]

SYDNEY UNIVERSITY

SCIENTIFIC STAFF
G Birch [2]
M Ferland [3]
C Jenkins [4]
J Keene [2]

TECHNICAL STAFF
D Mitchell [2]

STUDENTS
D. Evenden [2]
A Gordon [2]
A Judge [2]
M Teutsch [2]

[1] Program in Marine Geosciences and Petroleum Geology
[2] Department of Geology and Geophysics
[3] Department of Geography
[4] Ocean Sciences Institute
[5] New South Wales Geological Survey

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: The Hon. Alan Griffiths
Secretary: Geoff. Miller

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION
(formerly BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS)

Executive Director: Roye Rutland

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Inquiries should be directed to the Principal Information Officer, Australian Geological Survey Organisation, GPO Box 378, Canberra City, ACT, 2601.

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Executive Summary

This document presents the preliminary shipboard results from AGSO Survey 112B aboard RV Rig Seismic to an area of the eastern Australian continental margin, between Jervis Bay and Port Stephens. This multidisciplinary and multi-institutional research cruise was conducted from 28/9/92 to 16/10/92.

The objectives were to:

1. collect baseline data on the spatial and temporal (vertical) distribution of metallic and organic contaminants in shelf sediments to establish source, dispersal processes, and fixation mechanisms in support of environmental monitoring;
2. determine the patterns of Quaternary and contemporary shelf sedimentation and sediment transport, with special reference to the accumulation and/or dispersal of contaminants;
3. provide new information on non-renewable resources (hydrocarbons, seafloor minerals and marine aggregate) present in the offshore Sydney Basin;
4. to determine how climatic and sea level oscillations in the Quaternary affected sedimentation and the intensity of the East Australian Current (EAC) on the continental slope; and
5. provide essential scientific data for the management of human activities, resources and wastes in the coastal and maritime zone adjacent to Australia's major population centre.

Boomer data (203 line km) provided information on the spatial and vertical distribution of inner shelf sediment accumulations and of thin patches of sediment on the middle and outer shelf. The boomer data also helped delineate the lateral and vertical extent of potential marine aggregate deposits, as well as the distribution of the mid shelf mud belt - a potential contaminant sink. High quality air-gun seismic profiling (493 line km) produced high resolution, moderately deep information on the complex internal structure of the Tertiary wedge of the outer continental shelf and upper slope.

Fifty-eight vibrocores, collected in water depths of 30 m to 167 m along 9 transects, record late Quaternary shelf sedimentation. These cores, which are up to 5.7 m long, include the first vibrocores to be recovered from the central NSW outer shelf, and contain sediment deposited during the last glacial maximum. The inner shelf is characterised by relatively clean quartzose sand, while the mid shelf is veneered with mud and muddy sand (at least 3 m thick at some sites). In contrast, the outer shelf sediment is composed predominantly of calcareous sand and shell gravel, which is sometimes cemented, either as a pavement at the shelf surface or at depths of 1 m to 5 m in the cores. The generally coarse, carbonate-rich sediment reflects both the lack of terrigenous sand supply to the outer shelf under present high energy conditions, and

high energy winnowing by the EAC. Mineral resource potential is greatest on the inner shelf where large, discrete deposits of clean sand could provide a source of marine aggregate. While concentrated placer deposits were not encountered during the survey, detailed analyses are needed to determine whether the proportion and composition of disseminated heavy minerals in shelf sediment warrants further investigation.

Surficial and subsurface samples were collected from the continental shelf to delineate the concentration and distribution of organic and metallic contaminants. Spatial surficial samples were acquired from grabs (57) and box cores (11), whereas historical (vertical) contaminant information was obtained from vibrocores (12) and gravity cores (4). Pore water and high resolution surficial samples were also acquired to provide information on the fixation of contaminants and the complex exchanges occurring at the sediment-water interface. These samples constitute both present baseline and historical data sets, and provide the data necessary to construct the first contaminant stratigraphy for the central NSW mid shelf sediment.

Five gravity cores (3 to 5.4 m in length) recovered from the continental slope contain evidence for cyclic patterns of sedimentation on a scale of tens of centimetres and, in two cores, on a scale of millimetres. These cycles are the preserved record of changes in climate, oceanography, productivity and sediment supply. The larger cycles probably represent glacial/interglacial conditions whereas the millimetre scale laminations represent a much higher resolution record. Although detailed laboratory work is yet to be done, the cores will reveal the magnitude of oceanographic changes which accompanied past climate changes offshore of Sydney - including water oxygen content, current strength and temperature, and plankton productivity.

Rocks dredged from the continental slope include Palaeozoic basement and Sydney Basin strata, as well as the overlying syn-rift and post-rift sequences. Environments of deposition range from fluvial conglomerates and sandstones, to shallow marine conglomerates and sandstones, to shelf mudstones and greensands. Intermediate volcanics and basalt were also sampled. These samples are the first collected from offshore of Sydney and will provide valuable data on the history and structure of the continental margin. Already, in the early stages of analysis, the findings have overturned established knowledge about the Sydney Basin, indicating a thick but lithologically different sequence to the east, extremely significant volcanic history and tectonic deformations of Mesozoic rocks. There are important implications for Sydney Basin gas and coal exploration, and also for the prospectivity of the Lord Howe Rise.

1. Introduction

The seabed offshore of the Newcastle-Sydney-Wollongong conurbation (ie. Sydney Basin) is a site of competing interests, in terms of resources and recreational facilities:

- Significant discharge of industrial and human wastes occurs via rivers, estuaries, stormwater runoff and ocean outfalls to the coastal zone.
- It is currently being explored by industry for hydrocarbon resources in an effort to provide for the future energy needs of metropolitan Sydney.
- The continental shelf of NSW contains offshore minerals, sands and aggregates that may be used for construction materials.
- There is significant commercial and recreational exploitation of the fisheries.
- The inshore parts of the seabed are in dynamic balance with the famous recreational beaches of the region.

Responsible management of these often competing interests requires scientific data on the physical-chemical-biological processes and the sought-after resources, so that an adequate balance may be found to sustain the various activities.

This AGSO Record documents the data and samples collected during a multi-institutional and inter-disciplinary survey aboard RV Rig Seismic during September/October 1992 (Fig. 1.1, Enclosure 1.1). The survey collected data from the eastern Australian continental margin between Port Stephens and Jervis Bay (32.5^{o} to 35^{o}S). Participants in the survey included staff from the Program in Marine Geoscience and Petroleum Geology of the Australian Geological Survey Organisation (AGSO), the Departments of Geography, Geology and Geophysics (DG&G) and Ocean Sciences Institute (OSI) of Sydney University (SU), and the Geological Survey of the NSW, Department of Mineral Resources (DMR NSW).

The cruise objectives, outlined in the Executive Summary and at the beginning of each section of the report, were varied and reflect the lack of knowledge about many aspects of the central NSW continental margin, in spite of the location adjacent to Australia's most populated urban centre. Investigations over the extensive area encompassed by Cruise 112B provide information about regional variations and processes, as well as a context within which site-specific studies may be better understood.

Rig Seismic Cruise 112B embarked four students from the Department of Geology and Geophysics (University of Sydney) to participate in the survey. RV Rig Seismic is the only Australian geophysical/geological research vessel, so cruise 112B provided a rare opportunity for these students to gain experience of doing science at sea. Providing experience of this nature is vital if we are to continue to encourage students to pursue their interests in marine geology and related sciences. It will also ensure that Australian universities produce well-qualified marine geoscientists.

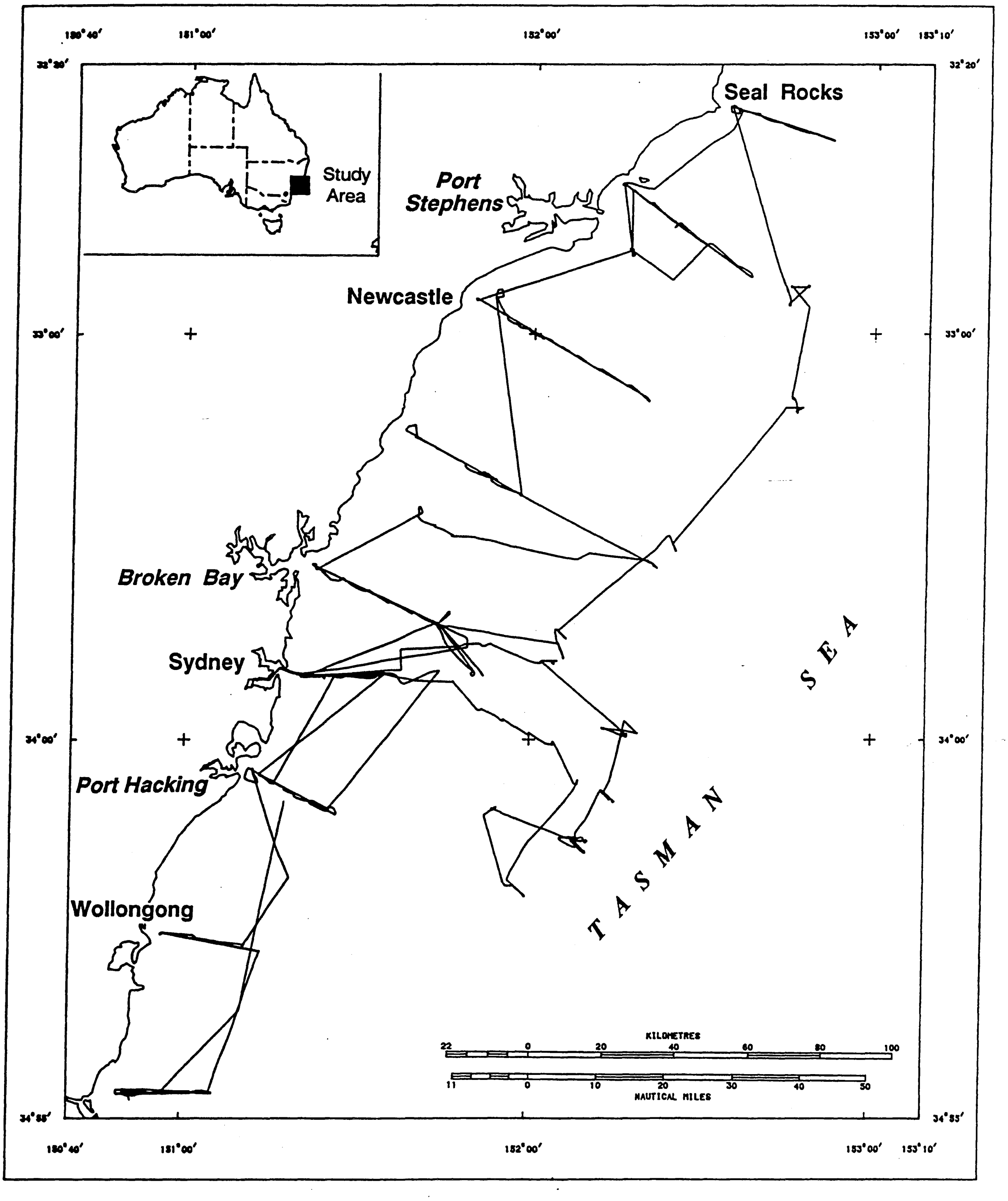


Fig. 1.1 Trackline map of all sample sites and seismic lines occupied during Cruise 112B.

2. Summary of seafloor sampling

Sample sites occupied during Cruise 112B are presented in chronological order in Table 2.1. Latitude and longitude are presented using the WGS84 standard. Specific objectives, methods, sample descriptions and preliminary results are given for each aspect of the cruise in following sections in this report. This section briefly details all the samples collected, using various sampling equipment, during Leg B of Cruise 112.

2.1 Navigation

During Cruise 112B, differential global position system (dGPS) navigation, based on a Racal system, was available at all times except when constrained by equipment and/or satellite problems. Differential corrections were usually provided by the Sydney reference station. During the survey 97.7% of the navigation was dGPS with noise levels of 2-3 metres during sampling and 5-8 metres while underway. This high quality navigation was essential to the success of the program. Prior to the survey, several discussions between AGSO and the Overseas Telecommunications Corporation (OTC) were necessary to determine the sampling sites and ensure that OTC cables offshore Sydney were not jeopardised. The AGSO would like to thank OTC for their co-operation in the development of this sampling program. Navigation presented in this report is using the WGS84 standard. It should be noted that the sampling information provided in the pre-cruise report (Heggie et al, 1992) was using the ANS standard.

2.2 Van Veen grab samples

At each sampling site a Van Veen grab sampler was deployed to determine the presence or absence of sediment, and the sediment type if a sediment was present. Table 2.2 shows the grab samples collected, with a brief description of sediment type, location of the sample, water depth and additional comments. The location of the grab samples is shown in Figure 2.1 and at a larger scale in Enclosure 2.1. Additional information regarding these grab sample sites, and scientific rationale is presented in Sections 4 and 5.

2.3 Vibrocore samples

Following a successful grab, at least one vibrocore was attempted at the site. A summary of all vibrocore samples collected during this Leg of the survey is presented in Table 2.3. The position of the vibrocore sample sites is shown in Figure 2.2 and Enclosure 2.2. Additional information regarding vibrocore samples, including a more detailed inventory, and the scientific rationale is presented in Section 4. Vibrocore samples that were collected for geochemical analyses are discussed in Section 5.

2.4 Gravity core samples

The fined grained sediments usually found on the continental slope and abyssal plain are generally more easily cored using a gravity corer, whereas a vibrocorer is generally more suitable for the coarse grained sediments of the continental shelf. However, due to failures of the vibrocore umbilical cable, it was necessary to sometimes use the gravity corer on the continental shelf. Sediment samples were successfully obtained on the continental shelf in muddy sediments. Additional information regarding gravity core samples, and scientific rationale for the samples collected on the shelf is presented in Sections 4 and 5. Several successful gravity cores were collected on the continental slope and these results are presented in Section 6. Sampling details, latitude and longitude, water depth, and additional comments, for all the gravity cores attempted are presented in Table 2.4. The locations of the gravity core sites are shown in Figure 2.3 and Enclosure 2.3.

2.5 Box core samples

Samples of muddy sediments were obtained using a Souter type box corer. Data including site location, water depth, amount of sample recovery and additional comments for the box cores are presented in Table 2.5. The locations of the box core sites are shown in Figure 2.4 and Enclosure 2.4. Additional information regarding box core samples, and scientific rationale is presented in Sections 4 and 5.

2.6 Dredge Samples

Dredge samples were collected on the continental slope. The locations, and additional comments for the dredge samples are presented in Table 2.6. The locations of the dredge sites are presented in Figure 2.5 and Enclosure 2.5. More detailed information regarding the dredge sites, including time on and off the bottom with corresponding co-ordinates, and a description of the various sample types recovered is presented in Section 7.

2.7 Sample Recovery

Table 2.7 summarises the success rate of the various sampling tools deployed during the survey.

The grab sampler gives a good indication as to the presence or absence of sediment types, as it is the first tool deployed after arriving 'on-station'. If a grab is unsuccessful, this generally infers that there is a lack of sediment, or that a mechanical problem resulted in nil recovery.

However, the success rate of the vibrocorer and boxcorer can be dependent on the skills of the operator. The operator determines, from the sediment type in the grab, whether a vibrocorer or a boxcorer would be successful. Therefore, a skilled operator should have high success rates with a vibrocorer or a boxcorer. During this survey several different operators may have influenced the success rates for the vibrocorer and the boxcorer. The recovery of sediments using the vibrocorer appears to be independent of water depth (Figure 2.6). The number of vibrocores recovered for various sediment lengths is shown in Figure 2.7. A plot of recovery versus penetration for the vibrocores is shown in Figure 2.8. Those data that fall above the line, may be a result of 'suck-up', and those that fall below the line can be caused by sediment compaction. A discussion of the vibrocoring method is presented in Appendix B. The boxcorer works well in muddy sediments, and the high success of the boxcorer (92%) is a reflection of a good choice of sediment types selected for sampling by the operators.

Two of the gravity cores deployed were unsuccessful. These sites were occupied in 600m of water on the continental slope. These sites were probably unsuccessful due to the lack of suitable soft sediment for gravity coring at this position on the slope.

All dredges deployed recovered either sediment or rock. However, only 12 of the dredges deployed successfully recovered rock. It is therefore probable that some of the slopes dredged were covered in sediment (possibly due to a gentle slope), or that there was no rock outcropping.

Track maps are presented in Enclosures 2.6 through 2.9.

2.8 Sample Storage

Following the survey, samples and sub-samples were stored both at the AGSO's storage facilities (in Canberra) and at Sydney University's facilities in Sydney. Samples stored at 4 degrees Celsius (within the secure store located at Barrier Street) in Canberra are listed in Appendix C. The reference to different sample 'type' refers to different lithofacies of the dredge samples. Type A from different dredge sites refers to the first lithofacies recorded. "Type A" (from different dredges) does not therefore necessarily indicate the same lithofacies.

Archive core halves of vibrocores and both halves of the gravity cores are stored in the Barrier Street store. Samples are stored at room temperature in the Maryborough Street store in Canberra. The corresponding halves of all the vibrocores are stored within the Sydney University store. Details of sample storage are presented in Appendix C.

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
Site 1A	GS039	274	931	34 51.30	150 50.04	41.6		15	1 500ml SU geochem;1 30 ml OC;1 250g sieve 2mm shells
									2x1Kg for grain size.2bags AGSO
Site 1A	VC070	274	945	34 51.30	150 50.04	41.6	0	0	gates didn't trigger
Site 1A	VC071	274	1019	34 51.30	150 50.04	42	0	0	core barrel broken
Site 1A	VC072	274	1105	34 51.30	150 50.04	42	216	171	sandy muddy sediment and shells.Penetration 216cms
Site 1A	VC073	274	1522	34 51.40	150 50 .0	42	97	456	used P.Roy's VC head to compare recovery.Penetration 97cms
Site 1B	GS040	274	1636	34 51.30	150 53.168	70.1		10	1bag AGSO,SU 1bag,2s/vials+geo/chem samples
Site 1B	VC074	274	1655	34 51.30	150 53.168	70.1	224	369	Penetration 224cms
Site 1B	BC078	274	1808	34 51.30	150 53.168	68		10	SU 3 geochem samples 1BagAGSO
Site 1C	GS041	274	1921	34 51.40	150 57.000	98			Nav backup Diff GPS
Site 1C	VC075	274	1935	34 51.40	150 57.000	99	168	493	Penetration 168 cms
Site 1C	VC076	274	2013	34 51.40	150 57.000	98	242	151	" " 242 "
Site 1D	GS042	274	2123	34 51.305	151 01.569	131	0	0	Triggered in water
Site 1D	GS043	274	2133	34 51.305	151 01.569	130		10	1Bag AGSO muddy shelly sand+SU/1bag,2s/vials+geo/chem samples
Site 1D	VC077	274	2156	34 51.305	151 01.569	131	353	245	Penetration 353 cms hit shelly base
Site 1D	VC078	274	2235	34 51.305	151 01.569	131	348	232	" " 348 "
Site 1E	GS044	274	2345	34 51.29	151 4.869	146		10	sandy shelly sediments
Site 1E	VC079	274	2354	34 51.29	151 4.869	149	0	0	only 15 cms brown mud to f/ grained sand
Site 1E	VC080	275	33	34 51.29	151 4.869	147	169	61	Penetration 169 cms
Site 1E	VC081	275	115	34 51.305	151 4.869	149	169	63	" " sand /mud at surface
Site3A	GS045	275	846	34 28 .305	150 56.667	30		10	1Bag SU/grain size 1/250ml 1/125ml Geo/Chem 2Bags
									AGSO 1eel/1m in length
Site3A	VC082	275	919	34 28 .305	150 56.667	30	0	0	Bent barrel -cut and lost overboard
Site3A	VC083	275	1012	34 28 .305	150 56.667	30	340	81	Penetration 340cm
Site3A	VC084	275	1059	34 28 .305	150 56.667	30	520	185	" " about520cm
Site3B	GS046	275	1123	34 28.505	151 00.068	70		0	Grab triggered
Site3B	GS047	275	1211	34 28.505	151 00.068	71		5	Small rocks,gravel,sand 1Bag AGSO,1Bag grain sizeSU
									2 s/vials 1/250ml,1/125ml for Geo/Chem
Site3B	BC079	275	1246	34 28.505	151 00.068	69.5		0	Seaweed
Site3C	GS048	275	1345	34 29.10	151 02.78	107		12	1 bag BMR 3 geochem samples SU
Site3C	BC080	275	1408	34 29.12	151 02.77	107		15	1 bag , 1 sub core AGSO; 3 sub cores SU
Site3C	VC085	275	1524	34 29.10	151 02.76	107	148	215	Penetrated 148 cms

Table 2.1 Summary of sampling tools deployed- Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
Site 3D	GS049	275	1646	34 29.70	151 06.28	138		10	Small rocks,gravel,sand 1Bag AGSO,1Bag grain sizeSU
									2 s/vials 1/250ml,1/125ml for Geo/Chem
Site 3D	VC086	275	1715	34 29.69	151 06.27	138	0	0	Tower fell over??
Site 3D	VC087	275	1748	34.29.70	151 06.28	137	333	343	Penetrated 333 cms
Site 3D	VC088	275	1836	34.29.69	151 06.29	138	201	78	Penetrated 201 cms.
Site3E	GS050	275	1942	34 30.28	151 10.76	152	0	0	Triggered in water column
Site3E	GS051	275	1952	34 30.32	151 10.77	151		6	Small rocks,gravel,sand 1Bag AGSO,1Bag grain sizeSU
									2 s/vials 1/250ml,1/125ml for Geo/Chem
Site3E	VC089	275	1900	34 30.31	151 10.77	152	378	230	Penetrated 378cms
Site3E	VC090	275	2048	34 30.29	151 10.82	153	265	97	Penetrated 265 cms
Site 5 E	GS052	276	848	34 10.405	151 25.10	167		15	SU-1Bag,1/250,1/125ml>Geo/chem,2s/vials,1seived
Site 5 E	VC091	276	918	34 10.405	151 25.15	167	0	0	Barrel broken-ship moved 250m-wind
Site 5D	GS053	276	1030	34 09.105	151 22.068	143		20	SU-1seived bag,1bag,3vials,2./250,1/125ml>Geo/chem
									AGSO-2 bags
Site 5D	VC092	276	1050	34 09.105	151 22.068	143	0	0	Electrical fault-retermination no penetration
Site 5C	GS054	276	1259	34 07.905	151 19.369	136		15	SU-1sieved gravel,3s/vials,2/250,1/125ml>Geo/Chem
									AGSO-2Bags
Site 5B	GS055	276	1356	34 06.26	151 15.9	126		12	SU - 1 bag, 1 seived mud, 3 small vials, 2 259ml geochem,
									1/125ml geochem, AGSO - 2 bags
Site 5B	BC081	276	1431	34 06.27	151 15.91	126		15	SU - 1 bag, 1 sub-core,3 geochem cores, AGSO - 1 bag, 1 sub core
Site 5A	GS056	276	1532	34 05.12	151 13.37	87		13	SU - 1 bag, 1 seived mud, 3 small vials, 2/ 250ml geochem,
									1/125ml geochem, AGSO - 1 bags
Site 5A	BC082	276	1542	34 05.11	151 13.36	87		25	SU - 1 bag, 1 sub-core,3 geochem cores, AGSO - 1 bag, 1 sub core
Site 7A	GS057	276	2225	33 50.70	151 21.86	70.3		15	Shelly-sand sediment, 1 AGSO bag, 3 SU geochem and 2 SU bags
SIte 7B	GS058	276	2319	33 50.60	151 24.18	105		0	
Site 7B	GS059	277	1	33 50.60	151 24.18	105		25	SU-1sieved gravel,3s/vials,2/250,1/125ml>Geo/Chem,1sub-core
									AGSO 2 bags
SIte 7B	GC003	277	40	33 50.61	151 24.22	105		127	
SIte 7C	GS060	277	143	33 50.61	151 26.04	120		14	1 AGSO bag, 2 SU vials, 1x500,1x250,1x125, 1 bag seived
									1 SU bulk sample.
Site 7C	GC004	277	215	33 50.61	151 26.07	118		107	
Site 7D	GS061	277	303	33 50.50	151 28.16	126		15	1 AGSO bag, 2 SU vials, 1x500,1x250,1x125, 1 bag seived

Table 2.1 Summary of sampling tools deployed- Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
									1 SU bulk sample.
Site 7D	GC005	277	331	33 50.5	151 28.16	123		< 50	bulk sample by SU
SIte 7D	GC006	277	356	33 50.50	151 28.16	124		25	mudy sand overlying sand, grit in catcher,
Site 7E	GS062	277	447	33 50.36	151 31.27	130		15	mudy olive green sand, 2 s/vials, 1 sieve, 1 bag, 1x500, 2x125
									for geochem, 1 AGSO bag
Site7F	GS063	277	535	33 50.255	151 34.268	141		10	sand less mud ,SU-2s/vials,1bag,1sieved.1/500,2/125ml
									1bag Geochem, AGSO-1bag
Site 7F(b)	GS064	277	700	33 49.905	151 44.068	295		0	No sample repeat
Site 7F(b)	GS065	277	716	33 49.905	151 44.068	295		0	" "
Site 5E	VC093	277	1100	34 10.400	151 25.05	166	265	54	Penetration 265cms
Site 5E	VC094	277	1147	34 10.42	151 25.06	167	575	577	Penetration 575cms
Site 5D	VC095	277	1305	34 09.12	151 22.06	143	250	180	Penetration 250cms(difficult to determine)
Site 5C	VC096	277	1423	34 07.91	151 19.38	136	305	281	Penetration 305cms
Site5F	GS066	277	1555	34 07.09	151 17.60	134		10	sand less mud ,SU-2s/vials,1bag,1sieved.1/500,2/125ml,1bag>Geo/Chem
									AGSO-1bag
Site5G	GS067	277	1650	34 05.71	151 14.67	114		30	sand less mud ,SU-2s/vials,1bag,1sub-core,1sieved
									.1/500,2/125ml,1bag>Geo/Chem
									AGSO-1bag
Site5A	VC097	277	1722	34 05.12	151 13.38	88.3	580	552	Penetraion 580cms
Site5A	VC098	277	1804	34 05.11	151 13.36	88	473	276	Penetraion 473cms
Site5B	VC099	277	1905	34 06.27	151 15.89	127	478	256	Penetraion 478cms
Site5B	VC100	277	1935	34 06.27	151 15.90	126	565	352	Penetraion 565cms
Site7C	VC101	277	2235	33 50.61	151 26.03	119	323	295	Penetraion 323cms
Site7D	VC102	277	2335	33 50.51	151 28.12	125	150	128	Penetraion 150cms
Site7F	VC103	278	109	33 50.29	151 34.24	141	150	328	Penetration possibly only 1.5 m, extra recovery = "suck-up"?
Site 7G	GC007	278	328	33 51.51	151 46.50	486		25	25cm bagged -1/2AGSO
Site 7H	GC008	278	457	33 55.50	151 51.50	977	300	300	Penetration 3m(3m barrel)
Site 7J	GC009	278	615	33 57.02	151 55.40	1467		438	Using 6m barrel
Site 7k	GC010	278	837	33 59.00	152 00.00	2007		536	Using 6m barrel
Site 7L	GC011	278	1026	34 00.48	152 04.00	2445		438	Using 6m barrel
Site 7M	GC012	278	1252	34 06.50	152 08.50	3017		334	Using 6m barrel
Site A	DR001	278	1806	34 22.20	151 58.50	4219/4119			full dredge, approx 0.5 tonne of rocks

Table 2.1 Summary of sampling tools deployed- Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
Site B	DR002	279	230	34 10.14	151 54.20	3115/2776			2 pipe dredges full; one with pink calcareous ooze, the other with
									grey green mud with many tube worms present
SiteE	DR003	279	832	34 14.91	152 10.11	4662/4060			AGSO-1Bag,S.U-2Bags,1bag sieved
Site F	DR004	279	1315	34 14.43	152 08.47	3967/3887			Dredge -350kgs
SiteE	DR005	279	1748	34 16.54	152 10.001	4612/4358			1Rock 1pipe mud AGSO1/2load -Repeat of site "E" again
Site G	DR006	280	157	34 09.21	152 14.81	4818/4187			4s/rocks,1/2pipe mud
Site H	DR007	280	929	34 08.70	152 14.00	4288/3867			est 100kg of mudstones and sandstones
Site K	DR008	280	1959	33 59.09	152 16.54	3533/3306			est 50 kg of greensands and mudstones.
Site L	DR009	281	250	33 48.47	152 04.67	1658/1594			pipe dredge of mud ooze, small corals.
Site M	DR010	281	603	33 48.55	152 03.64	1606/1406			est 5 kg rocks, corals, marine life.
Site 9A	GS068	281	2152	33 34.71	151 23 08	39.4		10	1 bag AGSO, 2 bags + 3 geochem samples SU
Site 9A	VC104	281	2309	33 34.69	151 23.06	40.3	565	463	Penetration 565cms
Site 9A	VC105	281	2338	33 34.70	151 23.08	39.4	459	406	Penetration 459cms
Site 9B	GS069	282	44	33 36.24	151 27.23	59.2		15	1 bag AGSO, 2 bags + 3 geochem samples SU,1sub-core
Site 9B	VC106	282	51	33 36.23	151 27.29	59.1	350	343	Penetration 350cms
Site 9B	VC107	282	113	33 36.22	151 27.25	58.6	360	296	Penetration 360cms
Site 9C	GS070	282	218	33 37.99	152 31.67	99		20	2 subcores,2x125/1x250/1 bag, 2 vials, 2 AGSO bags of muddy sand.
Site 9C	VC108	282	240	33 38.00	151 31.64	100	350	365	Penetration 350cms
Site 9C	VC109	282	322	33 38.00	151 31.67	100	220	216	Penetration 220cms
Site 9D	GS071	282	422	33 39.805	151 35.469	129		15	2 subcores,1x125/1x250/1 bag, 2 vials, 2 AGSO bags of muddy sand.
Site 9D	VC110	282	440	33 39.805	151 35.469	129	570	500	Penetration 570cms
Site 9D	BC083	282	521	33 39.805	151 35.469	129		15	SU-3 subcores,1bulk sample. AGSO -1sub-core
Site 9E	GS072	282	638	33 41.304	151 39.569	138		20	2 subcores,1x125/1x250/1 bag, 2 vials, 2 AGSO bags of muddy sand.
Site 9E	VC111	282	653	33 41.304	151 39.569	138	225	209	Penetration 225cms
Site 9F	GS073	282	816	33 43.105	151 43.969	150		15	2 subcores,1x125/1x250/1 bag, 2 vials, 2 AGSO bags of muddy sand.
Site M	DR011	282	1314	33 47.66	152 05.67	1971/1634			Small quantity of soft fine ooze inclosed dredge pipe
Site M	DR012	282	1836	33 47.03	152 05.34	1638/1539			Pipe dredges 1/2 full of mud-ooze olive-grey
Site N	DR013	282	2352	33 44.95	152 05.91	1745/1314			small quantity of fine soft ooze(10 kgs rocks)
Site P	DR014	283	834	33 32.11	152 25.30	3082/2691			Both pipes with mud and small sandstone
Site R	DR015	283	1646	33 11.53	152 46.13	3714/3470			Four types of rocks
Site 17D	GS074	284	1002	32 30.56	152 49.02	137		15	SU-1/500ml,2/125ml,2s/vials,1bag,1sieved.AGSO-2Bags
Site 17D	VC112	284	1015	32 30.53	152 49.02	137	250	257	Penetration 250cms

Table 2.1 Summary of sampling tools deployed- Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
Site 17C	GS075	284	1137	32 28.87	152 42.93	109		16	SU-1/500ml,2/125ml,2s/vials,1bag,1sieved.AGSO-2Bags
Site 17C	VC113	284	1148	32 28.87	152 42.93	109	340	273	Penetration 340cms
Site 17B	GS076	284	1253	32 27.50	152 38.70	102		14	SU-1/500ml,2/125ml,2s/vials,1bag,1sieved.AGSO-2Bags
Site 17B	VC114	284	1303	32 27.50	152 38.70	102		0	Cable wrapped around tower
Site 17B	VC115	284	1345	32 27.50	152 38.70	102	257	413	Penetration 257cms
Site 17A	GS077	284	1445	32 26.71	152 35.22	79.8		6	SU-1/500ml,2/125ml,2s/vials,1bag,1sieved.AGSO-1Bag
Site 17A	VC116	284	1455	32 26.70	152 35.21	73	213	521	Penetration 213cms
Site 17A	VC117	284	1526	32 26.70	152 35.22	72.2	0	0	Core gate closed
Site 17A	VC118	284	1540	32 26.72	152 35.23	73.2	395	400	Penetration 395cms
Site 15E	GS078	285	54	32 49.90	152 35.03	140		18	SU-1Sub-core,1/500ml,2/125ml,2s/vials,1bag,1sieved.AGSO-1Bag
Site 15E	VC119	285	114	32 49.92	152 35.00	140		0	Strong bottom current
Site 15E	VC120	285	129	32 49.91	152 35.00	140		0	Strong bottom current
Site 15D	GS079	285	237	32 46.80	152 29.77	139		20	SU-1/500ml,2/125ml,2s/vials,1bag,1sieved.AGSO-2Bags
Site 15D	VC121	285	251	32 46.80	152 29.77	139	460	372	Penetration 460cms
Site 15C	GS080	285	402	32 43.81	152 24.77	111		20	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 15C	VC122	285	413	32 43.81	152 24.77	111	70	73	Little penetration retry Penetration 65-70cms. Moved ship 100m up
Site 15C	VC123	285	451	32 43.81	152 24.77	111			line-electrical fault reterminate cable(1 bag Penetration 20cm)
Site 15B	GS081	285	1519	32 40.81	152 19.87	83.4		20	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-1Bags
Site 15B	VC124	285	1531	32 40.79	152 19.91	84.5	230	295	Penetration 230cms
Site 15B	BC089	285	1557	32 40.80	152 19.86	84.1		40	1 sub core, 1 bag AGSO, 1Bag, 3 sub cores SU (NB-BC083 already used)
Site 15A	GS082	285	1705	32 38.91	152 16.56	35.7		10	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 15A	VC125	285	1714	32 38.90	152 16.567	36.6	163	192	Penetration 163cms
Site 15A	VC126	285	1747	32 38.90	152 16.57	36.6	215	103	Penetration 215cms
Site 13G	GS083	286	351	33 07.80	152 16.47	146		10	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,3 Sub-core.AGSO-2Bags
Site 13G	VC127	286	402	33 07.80	152 16.47	146	350	295	Penetration 350cms
Site 13F	GS084	286	518	33 05.40	152 11.47	138		7	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,2 Sub-core.AGSO-2Bags
Site 13F	VC128	286	529	33 05.40	152 11.47	138	200	192	Penetration 200cms
Site 13E	GS085	286	630	33 03.40	152 07.57	130		12	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,2 Sub-core.AGSO-2Bags
Site 13E	VC129	286	646	33 03.40	152 07.57	130	175	131	Penetration 175cms
Site13J	GS086	286	740	33.02.2	152 04.8	127		11	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,2 Sub-core.AGSO-2Bags
Site13J	BC084	286	751	33.02.2	152 04.8	127		10	AGSO-1bag.SU-2sub-cores,1bulk 1/500ml
Site13D	GS087	286	852	33 01.11	152 03.07	123		10	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,2 Sub-core.AGSO-2Bags

Table 2.1 Summary of sampling tools deployed- Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
Site13D	VC130	286	904	33 01.11	152 03.07	123	400	357	Penetration 400cms
Site13I	GS088	286	948	33 00.8	152 01.4	124		15	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site13I	BC085	286	1018	33 00.8	152 01.4	124		25	SU-2sub-cores,1/250ml vial,1bulk AGSO-1sub-core 2bags
Site 13C	GS089	286	1132	32 59.20	151 59.07	117		14	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13C	VC131	286	1143	32 59.20	151 59.07	117	420	400	Penetration 420cms core in SYDNEY settling
Site 13C	BC086	286	1213	32 59.20	151 59.07	117		30	SU-2sub-cores,1/250ml vial,1bulk AGSO-1sub-core 2bags
Site 13H	GS090	286	1308	32 58.8	151 57.2	104		25	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13H	BC087	286	1323	32 58.8	151 57.2	104		45	SU-2sub-cores,1/250ml vial,1bulk AGSO-1sub-core 2bags
Site 13B	GS091	286	1433	32 57.30	151 55.28	80		12	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13B	VC132	286	1445	32 53.0	151 55.27	80	565	369	Penetration 565 cms
Site 13B	BC088	286	1511	32 57.29	151 55.27	81		45	SU-2sub-cores,1/250ml vial,1bulk AGSO-1sub-core 2bags
Site 13A	GS092	286	1626	32 54.61	151 53.08	36		13	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13A	VC133	286	1634	32 54.61	151 53.07	37	198	106	Penetration 198cms
Site11E	GS093	286	2206	33 23.90	151 58.09	150		3	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site11E	VC134	286	2214	33 23.90	151 58.09	150	514	506	Penetration 514cms
Site11D	GS094	286	2348	33 21.50	151 52.67	136		10	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site11D	VC135	286	2400	33 21.52	151 52.67	136	120	203	Penetration 120cms(difficult to determine)
Site11C	GS095	287	107	33 19.41	151 48.17	125		2	No samples taken
Site11C	GS096	287	126	33 19.41	151 48.17	125		0	
Site11C	GS097	287	133	33 19.41	151 48.17	124		11	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site11C	VC136	287	143	33 19.41	151 48.17	123	400	330	Penetration 400cms(penetration difficult to determine)
Site 11B	GS098	287	245	33 17.00	151 43.07	75		1	1small sample toSU only
Site 11B	GS099	287	255	33 17.00	151 43.07	75		9	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 11B	VC137	287	306	33 17.00	151 43.07	75	430	385	Penetration 430cms
Site11A	GS100	287	405	33 15.40	151 39.47	46		12	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-1Bag
Site11A	VC138	287	411	33 15.40	151 39.47	46	200	204	Penetration 200cms
Site O	DR016	287	1428	33 34.27	152 21.27	2875/2531			Pipe with ooze 350 kgs rocks
Site 10C	GS101	287	2113	33 29.92	151 46.17	139		3	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-1Bag
Site 10B	GS102	287	2215	33 28.39	151 43.05	132		3	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-1Bag
Site 10B	BC090	287	2220	33 28.40	151 43.07	134		3	SU use all for geochem
Site 10A	GS103	287	2313	33 26.90	151 40.07	96		4	SU-1/500ml,2/125ml,2s/vials,1bag,1sieve,1 Sub-core.AGSO-1Bag

Table 2.1 Summary of sampling tools deployed- Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
Site 7AA	GC013	288	707	33 50.00	151 50.00	630		0	Re-try
Site 7AA	GC014	288	730	33 50.00	151 50.00	632		0	
Site 9F	VC139	288	911	33 43.2	151 43.9	149	500	422	About 500cms Penetration

Table 2.1 Summary of sampling tools deployed- Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD (m)	Recovery (cm)	Comment
Site 1A	GS039	274	931	34 51.30	150 50.04	41.6	15	1 500ml SU geochemistry ;! 30 ml OC;1 250g sieve 2mm shells
	GS039							2x1Kg for grain size.2bags AGSO
Site 1B	GS040	274	1636	34 51.30	150 53.168	70.1	10	1bag AGSO,SU 1bag,2small vials plus geochemistry samples
Site 1C	GS041	274	1921	34 51.40	150 57.000	98		Navigation is using backup dGPS
Site 1D	GS042	274	2123	34 51.305	151 01.569	131	0	Grab sampler triggered in water column
Site 1D	GS043	274	2133	34 51.305	151 01.569	130	10	1Bag AGSO muddy shelly sand+SU/1bag,2small vials+geochemistry sanples
Site 1E	GS044	274	2345	34 51.29	151 4.869	146	10	sandy shelly sediments
Site3A	GS045	275	846	34 28 .305	150 56.667	30	10	1Bag SU/grain size 1/250ml 1/125ml geochemistry 2Bags
	GS045							AGSO 1eel/1m in length
Site3B	GS046	275	1123	34 28.505	151 00.068	70	0	Grab sampler triggered in water column
Site3B	GS047	275	1211	34 28.505	151 00.068	71	5	Small rocks,gravel,sand 1Bag AGSO,1Bag grain size SU
	GS047							2 small vials 1/250ml,1/125ml for geochemistry
Site3C	GS048	275	1345	34 29.10	151 02.78	107	12	1 bag BMR, 3 geochem samples SU
Site 3D	GS049	275	1646	34 29.70	151 06.28	138	10	Small rocks,gravel,sand 1Bag AGSO,1Bag grain size SU
	GS049							2 small vials 1/250ml,1/125ml for geochemistry
Site3E	GS050	275	1942	34 30.28	151 10.76	152	0	Grab sampler triggered in water column
Site3E	GS051	275	1952	34 30.32	151 10.77	151	6	Small rocks,gravel,sand 1Bag AGSO,1Bag grain size SU
	GS051							2 small vials 1/250ml,1/125ml for geochemistry
Site 5 E	GS052	276	848	34 10.405	151 25.10	167	15	SU-1Bag,1/250,1/125ml for geochemistry,2 small vials,1scived
Site 5D	GS053	276	1030	34 09.105	151 22.068	143	20	SU-1seived bag,1bag,3vials,2./250,1/125ml for geochemistry
	GS053							AGSO-2 bags
Site 5C	GS054	276	1259	34 07.905	151 19.369	136	15	SU-1sieved gravel,3small vials,2/250,1/125ml for geochemistry
	GS054							AGSO-2Bags
Site 5B	GS055	276	1356	34 06.26	151 15.9	126	12	SU - 1 bag, 1 seived mud, 3 small vials, 2 250 ml geochemistry
	GS055							1/125ml geochemistry, AGSO - 2 bags
Site 5A	GS056	276	1532	34 05.12	151 13.37	87	13	SU - 1 bag, 1 seived mud, 3 small vials, 2/ 250ml geochemistry
	GS056							1/125ml geochemistry, AGSO - 1 bags
Site 7A	GS057	276	2225	34 50.70	151 21.86	70.3	15	Shelly-sand sediment, 1 AGSO bag, 3 SU geochemistry and 2 SU bags
SIte 7B	GS058	276	2319	33 50.60	151 24.18	105	0	No sampled recovered
Site 7B	GS059	277	1	33 50.60	151 24.18	105	25	SU-1sieved gravel,3small vials,2/250,1/125ml for geochemistry,1sub-core
	GS059							AGSO 2 bags
SIte 7C	GS060	277	143	33 50.61	151 26.04	120	14	1 AGSO bag, 2 SU vials, 1x500,1x250,1x125, 1 bag seived

Table 2.2 Grab samples Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD (m)	Recovery (cm)	Comment
	GS060							1 SU bulk sample.
Site 7D	GS061	277	303	33 50.50	151 28.16	126	15	1 AGSO bag, 2 SU vials, 1x500,1x250,1x125, 1 bag seived
	GS061							1 SU bulk sample.
Site 7E	GS062	277	447	33 50.36	151 31.27	130	15	mudy olive green sand, 2 small vials, 1 sieve, 1 bag, 1x500, 2x125
	GS062							for geochem, 1 AGSO bag
Site7F	GS063	277	535	33 50.255	151 34.268	141	10	sand less mud ,SU-2small vials,1bag,1sieved.1/500,2/125ml
	GS063							1bag Geochem, AGSO-1bag
Site 7F(b	GS064	277	700	33 49.905	151 44.068	295	0	No sample recovered
Site 7F(b	GS065	277	716	33 49.905	151 44.068	295	0	No sample recovered
Site5F	GS066	277	1555	34 07.09	151 17.60	134	10	sand less mud ,SU-2small vials,1bag,1sieved.1/500,2/125ml,1bag
	GS066							for geochemistry, AGSO-1bag
Site5G	GS067	277	1650	34 05.71	151 14.67	114	30	sand less mud ,SU-2small vials,1bag,1sub-core,1sieved
	GS067							.1/500,2/125ml,1bag for geochemistry,
Site 9A	GS068	281	2152	33 34.71	151 23 08	39.4	10	1 bag AGSO, 2 bags + 3 geochemistry samples SU
Site 9B	GS069	282	44	33 36.24	151 27.23	59.2	15	1 bag AGSO, 2 bags + 3 geochemistry samples SU,1sub-core
Site 9C	GS070	282	218	33 37.99	152 31.67	99	20	2 subcores,2x125/1x250/1 bag, 2 vials, 2 AGSO bags of muddy sand.
Site 9D	GS071	282	422	33 39.805	151 35.469	129	15	2 subcores,1x125/1x250/1 bag, 2 vials, 2 AGSO bags of muddy sand.
Site 9E	GS072	282	638	33 41.304	151 39.569	138	20	2 subcores,1x125/1x250/1 bag, 2 vials, 2 AGSO bags of muddy sand.
Site 9F	GS073	282	816	33 43.105	151 43.969	150	15	2 subcores,1x125/1x250/1 bag, 2 vials, 2 AGSO bags of muddy sand.
Site 17D	GS074	284	1002	32 30.56	152 49.02	137	15	SU-1/500ml,2/125ml,2small vials,1bag,1sieved.AGSO-2Bags
Site 17C	GS075	284	1137	32 28.87	152 42.93	109	16	SU-1/500ml,2/125ml,2small vials,1bag,1sieved.AGSO-2Bags
Site 17B	GS076	284	1253	32 27.50	152 38.70	102	14	SU-1/500ml,2/125ml,2small vials,1bag,1sieved.AGSO-2Bags
Site 17A	GS077	284	1445	32 26.71	152 35.22	79.8	6	SU-1/500ml,2/125ml,2small vials,1bag,1sieved.AGSO-1Bag
Site 15E	GS078	285	54	32 49.90	152 35.03	140	18	SU-1Sub-core,1/500ml,2/125ml,2small vials,1bag,1sieved.AGSO-1Bag
Site 15D	GS079	285	237	32 46.80	152 29.77	139	20	SU-1/500ml,2/125ml,2small vials,1bag,1sieved.AGSO-2Bags
Site 15C	GS080	285	402	32 43.81	152 24.77	111	20	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 15B	GS081	285	1519	32 40.81	152 19.87	83.4	20	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-1Bags
Site 15A	GS082	285	1705	32 38.91	152 16.56	35.7	10	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13G	GS083	286	351	33 07.80	152 16.47	146	10	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,3 Sub-core.AGSO-2Bags
Site 13F	GS084	286	518	33 05.40	152 11.47	138	7	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,2 Sub-core.AGSO-2Bags
Site 13E	GS085	286	630	33 03.40	152 07.57	130	12	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,2 Sub-core.AGSO-2Bags
Site13J	GS086	286	740	33.02.2	152 04.8	127	11	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,2 Sub-core.AGSO-2Bags

Table 2.2 Grab samples Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD (m)	Recovery (cm)	Comment
Site13D	GS087	286	852	33 01.11	152 03.07	123	10	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,2 Sub-core.AGSO-2Bags
Site13I	GS088	286	948	33 00.8	152 01.4	124	15	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13C	GS089	286	1132	32 59.20	151 59.07	117	14	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13H	GS090	286	1308	32 58.8	151 57.2	104	25	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13B	GS091	286	1433	32 57.30	151 55.28	80	12	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 13A	GS092	286	1626	32 54.61	151 53.08	36	13	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site11E	GS093	286	2206	33 23.90	151 58.09	150	3	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site11D	GS094	286	2348	33 21.50	151 52.67	136	10	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site11C	GS095	287	107	33 19.41	151 48.17	125	2	No samples taken
Site11C	GS096	287	126	33 19.41	151 48.17	125	0	No sample recovered
Site11C	GS097	287	133	33 19.41	151 48.17	124	11	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site 11B	GS098	287	245	33 17.00	151 43.07	75	1	1small sample to SU only
Site 11B	GS099	287	255	33 17.00	151 43.07	75	9	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-2Bags
Site11A	GS100	287	405	33 15.40	151 39.47	46	12	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-1Bag
Site 10C	GS101	287	2113	33 29.92	151 46.17	139	3	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-1Bag
Site 10B	GS102	287	2215	33 28.39	151 43.05	132	3	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-1Bag
Site 10A	GS103	287	2313	33 26.90	151 40.07	96	4	SU-1/500ml,2/125ml,2small vials,1bag,1sieve,1 Sub-core.AGSO-1Bag

Table 2.2 Grab samples Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
Site 1A	VC070	274	945	34 51.30	150 50.04	41.6	0	0	gates didn't trigger
Site 1A	VC071	274	1019	34 51.30	150 50.04	42	0	0	core barrel broken
Site 1A	VC072	274	1105	34 51.30	150 50.04	42	216	171	sandy muddy sediment and shells. Penetration 216 cms
Site 1A	VC073	274	1522	34 51.40	150 50 .0	42	97	456	used NSWGS VC head to compare recovery. Penetration 97 cms
Site 1B	VC074	274	1655	34 51.30	150 53.168	70.1	224	369	Penetration 224cms
Site 1C	VC075	274	1935	34 51.40	150 57.000	99	168	493	Penetration 168 cms
Site 1C	VC076	274	2013	34 51.40	150 57.000	98	242	151	" " 242 "
Site 1D	VC077	274	2156	34 51.305	151 01.569	131	353	245	Penetration 353 cms hit shelly base
Site 1D	VC078	274	2235	34 51.305	151 01.569	131	348	232	" " 348 "
Site 1E	VC079	274	2354	34 51.29	151 4.869	149	0	0	only 15 cms brown mud to fine grained sand
Site 1E	VC080	275	33	34 51.29	151 4.869	147	169	61	Penetration 169 cms
Site 1E	VC081	275	115	34 51.305	151 4.869	149	169	63	" " sand /mud at surface
Site3A	VC082	275	919	34 28 .305	150 56.667	30	0	0	Bent barrel -cut and lost overboard
Site3A	VC083	275	1012	34 28 .305	150 56.667	30	340	81	Penetration 340cm
Site3A	VC084	275	1059	34 28 .305	150 56.667	30	520	185	" " about520cm
Site3C	VC085	275	1524	34 29.10	151 02.76	107	148	215	Penetrated 148 cms
Site 3D	VC086	275	1715	34 29.69	151 06.27	138	0	0	Tower may have fallen over
Site 3D	VC087	275	1748	34.29.70	151 06.28	137	333	343	Penetrated 333 cms
Site 3D	VC088	275	1836	34.29.69	151 06.29	138	201	78	Penetrated 201 cms.
Site3E	VC089	275	1900	34 30.31	151 10.77	152	378	230	Penetrated 378cms
Site3E	VC090	275	2048	34 30.29	151 10.82	153	265	97	Penetrated 265 cms
Site 5 E	VC091	276	918	34 10.405	151 25.15	167	0	0	Barrel broken-ship moved due to strong winds
Site 5D	VC092	276	1050	34 09.105	151 22.068	143	0	0	Electrical fault- cable retermination required, no penetration
Site 5E	VC093	277	1100	34 10.400	151 25.05	166	265	54	Penetration 265cms
Site 5E	VC094	277	1147	34 10.42	151 25.06	167	575	577	Penetration 575cms
Site 5D	VC095	277	1305	34 09.12	151 22.06	143	250	180	Penetration 250cms (difficult to determine)
Site 5C	VC096	277	1423	34 07.91	151 19.38	136	305	281	Penetration 305cms
Site5A	VC097	277	1722	34 05.12	151 13.38	88.3	580	552	Penetraion 580cms
Site5A	VC098	277	1804	34 05.11	151 13.36	88	473	276	Penetraion 473cms
Site5B	VC099	277	1905	34 06.27	151 15.89	127	478	256	Penetraion 478cms
Site5B	VC100	277	1935	34 06.27	151 15.90	126	565	352	Penetraion 565cms
Site7C	VC101	277	2235	33 50.61	151 26.03	119	323	295	Penetraion 323cms

Table 2.3 Vibrocore samples Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD (m)	Penetration (cm)	Recovery (cm)	Comment
Site7D	VC102	277	2335	33 50.51	151 28.12	125	150	128	Penetraion 150cms
Site7F	VC103	278	109	33 50.29	151 34.24	141	150	328	Penetration possibly only 150 c m, extra recovery may be due to "suck-up"
Site 9A	VC104	281	2309	33 34.69	151 23.06	40.3	565	463	Penetration 565cms
Site 9A	VC105	281	2338	33 34.70	151 23.08	39.4	459	406	Penetration 459cms
Site 9B	VC106	282	51	33 36.23	151 27.29	59.1	350	343	Penetration 350cms
Site 9B	VC107	282	113	33 36.22	151 27.25	58.6	360	296	Penetration 360cms
Site 9C	VC108	282	240	33 38.00	151 31.64	100	350	365	Penetration 350cms
Site 9C	VC109	282	322	33 38.00	151 31.67	100	220	216	Penetration 220cms
Site 9D	VC110	282	440	33 39.805	151 35.469	129	570	500	Penetration 570cms
Site 9E	VC111	282	653	33 41.304	151 39.569	138	225	209	Penetration 225cms
Site 17D	VC112	284	1015	32 30.53	152 49.02	137	250	257	Penetration 250cms
Site 17C	VC113	284	1148	32 28.87	152 42.93	109	340	273	Penetration 340cms
Site 17B	VC114	284	1303	32 27.50	152 38.70	102	0	0	Cable wrapped around tower
Site 17B	VC115	284	1345	32 27.50	152 38.70	102	257	413	Penetration 257cms
Site 17A	VC116	284	1455	32 26.70	152 35.21	73	213	521	Penetration 213cms
Site 17A	VC117	284	1526	32 26.70	152 35.22	72.2	0	0	Core gate closed
Site 17A	VC118	284	1540	32 26.72	152 35.23	73.2	395	400	Penetration 395cms
Site 15E	VC119	285	114	32 49.92	152 35.00	140	0	0	Strong bottom current
Site 15E	VC120	285	129	32 49.91	152 35.00	140	0	0	Strong bottom current
Site 15D	VC121	285	251	32 46.80	152 29.77	139	460	372	Penetration 460cms
Site 15C	VC122	285	413	32 43.81	152 24.77	111	70	73	Penetration 65-70cms
Site 15C	VC123	285	451	32 43.81	152 24.77	111	20	0	cable-electrical fault, reterminate cable (1 bag, penetration 20cm)
Site 15B	VC124	285	1531	32 40.79	152 19.91	84.5	230	295	Penetration 230cms
Site 15A	VC125	285	1714	32 38.90	152 16.567	36.6	163	192	Penetration 163cms
Site 15A	VC126	285	1747	32 38.90	152 16.57	36.6	215	103	Penetration 215cms
Site 13G	VC127	286	402	33 07.80	152 16.47	146	350	295	Penetration 350cms
Site 13F	VC128	286	529	33 05.40	152 11.47	138	200	192	Penetration 200cms
Site 13E	VC129	286	646	33 03.40	152 07.57	130	175	131	Penetration 175cms
Site13D	VC130	286	904	33 01.11	152 03.07	123	400	357	Penetration 400cms
Site 13C	VC131	286	1143	32 59.20	151 59.07	117	420	400	Penetration 420cms, core left in Sydney
Site 13B	VC132	286	1445	32 53.0	151 55.27	80	565	369	Penetration 565 cms
Site 13A	VC133	286	1634	32 54.61	151 53.07	37	198	106	Penetration 198cms

Table 2.3 Vibrocore samples Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Penetration	Recovery	Comment
						(m)	(cm)	(cm)	
Site11E	VC134	286	2214	33 23.90	151 58.09	150	514	506	Penetration 514cms
Site11D	VC135	286	2400	33 21.52	151 52.67	136	120	203	Penetration 120cms (penetration difficult to determine)
Site11C	VC136	287	143	33 19.41	151 48.17	123	400	330	Penetration 400cms (penetration difficult to determine)
Site 11B	VC137	287	306	33 17.00	151 43.07	75	430	385	Penetration 430cms
Site11A	VC138	287	411	33 15.40	151 39.47	46	200	204	Penetration 200cms
Site 9F	VC139	288	911	33 43.2	151 43.9	149	500	422	About 500cms Penetration

Table 2.3 Vibrocore samples Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD	Recovery	Comment
						(m)	(cm)	
SIte 7B	GC003	277	40	33 50.61	151 24.22	105	127	
Site 7C	GC004	277	215	33 50.61	151 26.07	118	107	
Site 7D	GC005	277	331	33 50.5	151 28.16	123	< 50	bulk sample by SU
SIte 7D	GC006	277	356	33 50.50	151 28.16	124	25	mudy sand overlying sand, grit in catcher,
Site 7G	GC007	278	328	33 51.51	151 46.50	486	25	25cm bagged -half for AGSO
Site 7H	GC008	278	457	33 55.50	151 51.50	977	300	Penetration 3m (sampled with 3m barrel)
Site 7J	GC009	278	615	33 57.02	151 55.40	1467	438	Using 6m barrel
Site 7k	GC010	278	837	33 59.00	152 00.00	2007	536	Using 6m barrel
Site 7L	GC011	278	1026	34 00.48	152 04.00	2445	438	Using 6m barrel
Site 7M	GC012	278	1252	34 06.50	152 08.50	3017	334	Using 6m barrel
Site 7AA	GC013	288	707	33 50.00	151 50.00	630	0	No recovery
Site 7AA	GC014	288	730	33 50.00	151 50.00	632	0	No recovery

Table 2.4 Gravity cores Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD (m)	Recovery (cm)	Comment
Site 1B	BC078	274	1808	34 51.30	150 53.168	68	10	SU 3 geochem samples 1Bag AGSO
Site3B	BC079	275	1246	34 28.505	151 00.068	69.5	0	Seaweed
Site3C	BC080	275	1408	34 29.12	151 02.77	107	15	1 bag , 1 sub core AGSO; 3 sub cores SU
Site 5B	BC081	276	1431	34 06.27	151 15.91	126	15	SU - 1 bag, 1 sub-core,3 geochem cores, AGSO - 1 bag, 1 sub core
Site 5A	BC082	276	1542	34 05.11	151 13.36	87	25	SU - 1 bag, 1 sub-core,3 geochem cores, AGSO - 1 bag, 1 sub core
Site 9D	BC083	282	521	33 39.805	151 35.469	129	15	SU-3 subcores,1bulk sample. AGSO -1sub-core
Site13J	BC084	286	751	33.02.2	152 04.8	127	10	AGSO-1bag, SU-2sub-cores,1bulk 1/500ml
Site13I	BC085	286	1018	33 00.8	152 01.4	124	25	SU-2sub-cores,1/250ml vial,1bulk AGSO-1sub-core 2bags
Site 13C	BC086	286	1213	32 59.20	151 59.07	117	30	SU-2sub-cores,1/250ml vial,1bulk AGSO-1sub-core 2bags
Site 13H	BC087	286	1323	32 58.8	151 57.2	104	45	SU-2sub-cores,1/250ml vial,1bulk AGSO-1sub-core 2bags
Site 13B	BC088	286	1511	32 57.29	151 55.27	81	45	SU-2sub-cores,1/250ml vial,1bulk AGSO-1sub-core 2bags
Site 15B	BC089	285	1557	32 40.80	152 19.86	84.1	40	1 sub core, 1 bag AGSO, 1Bag, 3 sub cores SU
Site 10B	BC090	287	2220	33 28.40	151 43.07	134	3	SU for geochem

Table 2.5 Box cores Cruise 112B

Site #	Sample #	Day	GMT	Lat.	Long.	WD start/end (m)	Comment
Site A	DR001	278	1806	34 22.20	151 58.50	4219/4119	full dredge, approx 0.5 tonne of rocks
Site B	DR002	279	230	34 10.14	151 54.20	3115/2776	2 pipe dredges full; one with pink calcareous ooze, the other with
Site B	DR002						grey green mud with many tube worms present
SiteE	DR003	279	832	34 14.91	152 10.11	4662/4060	AGSO-1Bag,SU-2Bags,1bag sieved
Site F	DR004	279	1315	34 14.43	152 08.47	3967/3887	Dredge -350kgs
SiteE	DR005	279	1748	34 16.54	152 10.001	4612/4358	1Rock 1pipe mud AGSO half load -Repeat of site "E"
Site G	DR006	280	157	34 09.21	152 14.81	4818/4187	4 small rocks,1/2pipe mud
Site H	DR007	280	929	34 08.70	152 14.00	4288/3867	est 100kg of mudstones and sandstones
Site K	DR008	280	1959	33 59.09	152 16.54	3533/3306	est 50 kg of greensands and mudstones.
Site L	DR009	281	250	33 48.47	152 04.67	1658/1594	pipe dredge of mud ooze, small corals.
Site M	DR010	281	603	33 48.55	152 03.64	1606/1406	est 5 kg rocks, corals, marine life.
Site M	DR011	282	1314	33 47.66	152 05.67	1971/1634	Small quantity of soft fine ooze inclosed dredge pipe
Site M	DR012	282	1836	33 47.03	152 05.34	1638/1539	Pipe dredges 1/2 full of mud-ooze olive-grey
Site N	DR013	282	2352	33 44.95	152 05.91	1745/1314	small quantity of fine soft ooze (10 kgs rocks)
Site P	DR014	283	834	33 32.11	152 25.30	3082/2691	Both pipes with mud and small sandstone
Site R	DR015	283	1646	33 11.53	152 46.13	3714/3470	Four types of rocks
Site O	DR016	287	1428	33 34.27	152 21.27	2875/2531	Pipe with ooze 350 kgs rocks

Table 2.6 Dredge samples Cruise 112B

Sampling Tool	Number deployed	Number recovered successfully	Percent success
Grab Sampler	65	58	89
Vibrocorer	70	58	83
Boxcorer	13	12	92
Gravity Corer	12	10	83
Dredge	16	12	75

Table 2.7 Success recovery for sampling tools

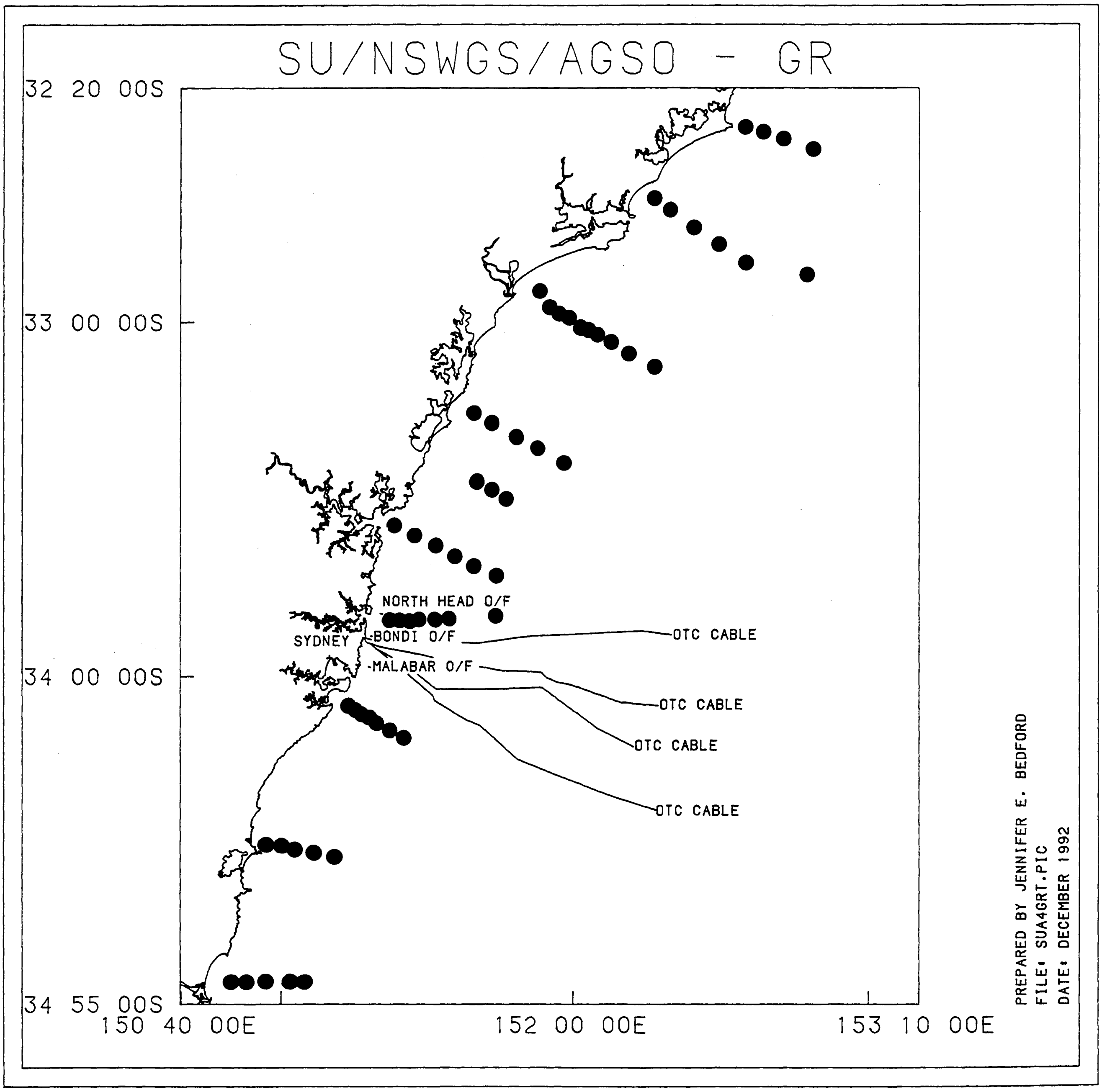


Fig. 2.1 Locations of grab sample sites occupied during Cruise 112B.

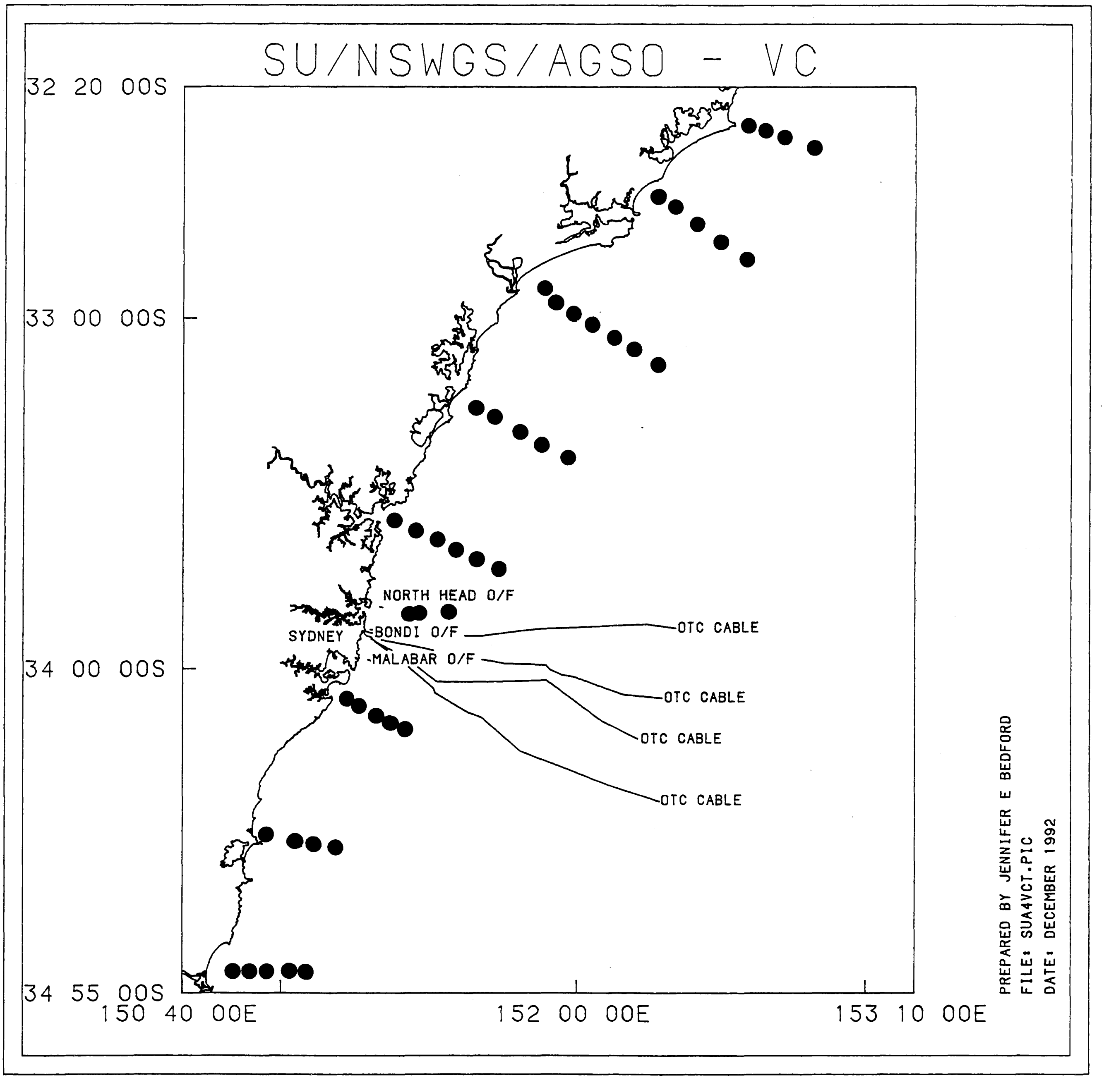


Fig. 2.2 Locations of vibrocore sample sites occupied during Cruise 112B.

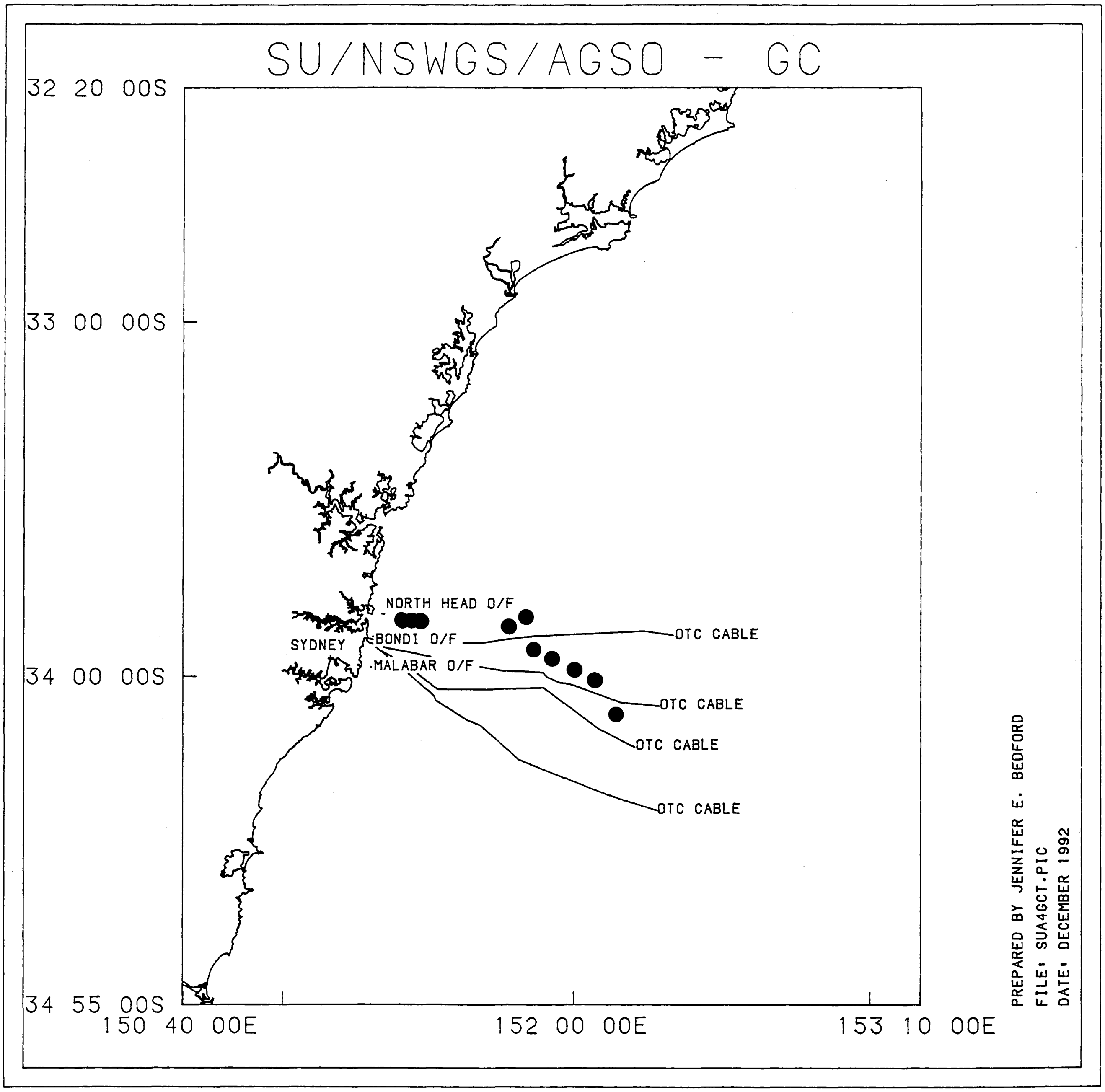


Fig. 2.3 Locations of gravity core sample sites occupied during Cruise 112B.

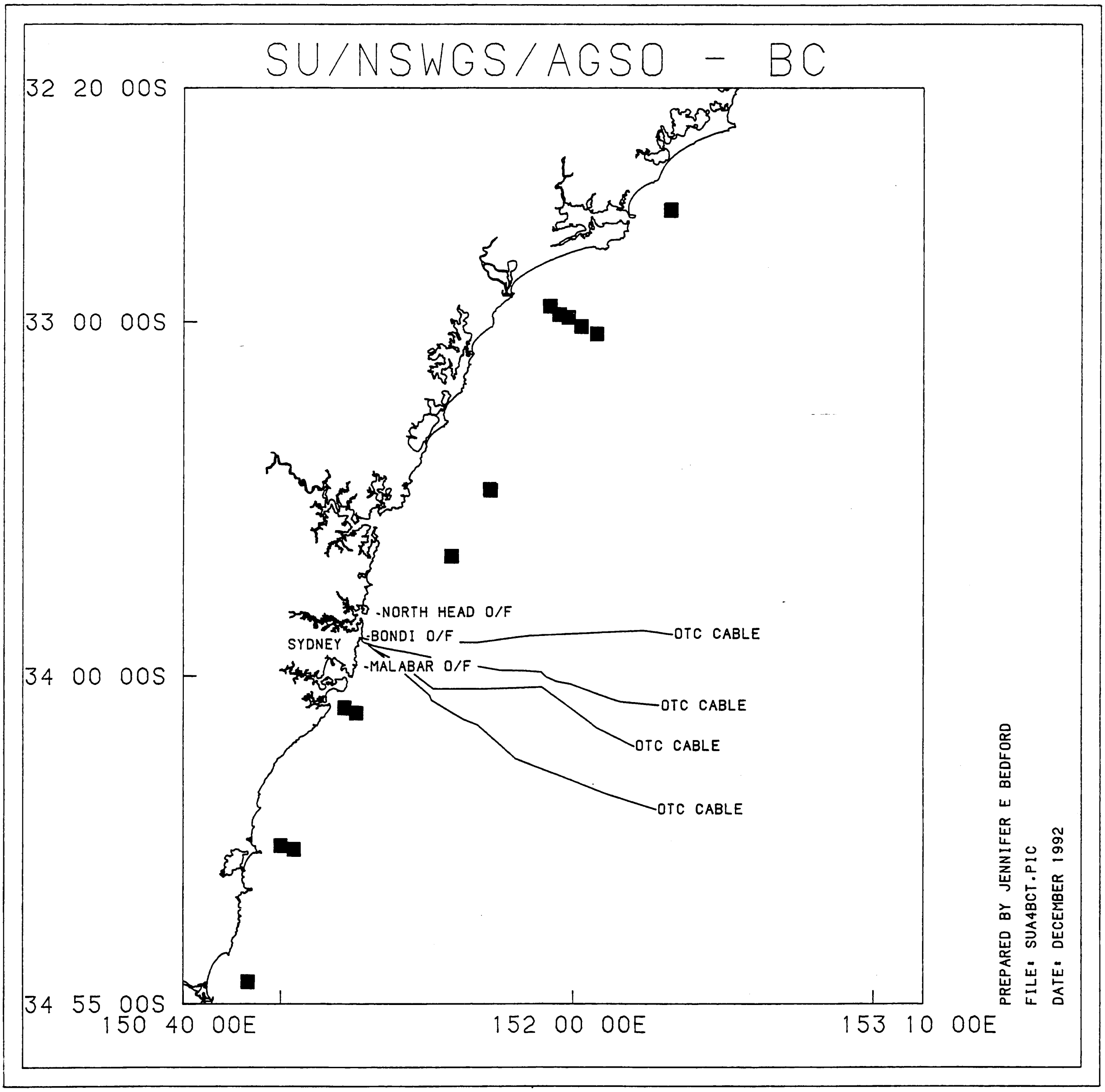


Fig. 2.4 Locations of boxcore sample sites occupied during Cruise 112B.

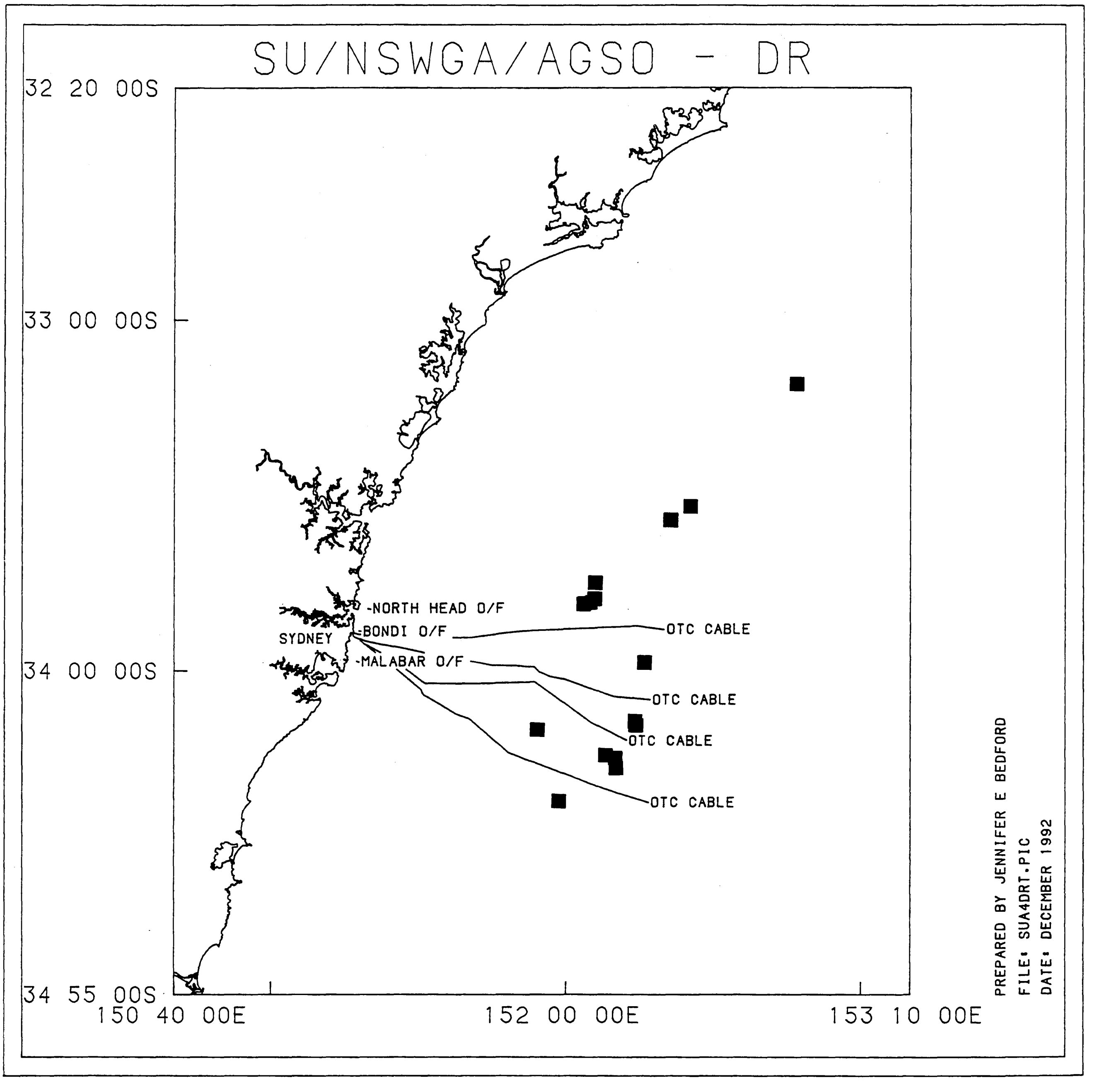


Fig. 2.5 Locations of dredge sites occupied during Cruise 112B.

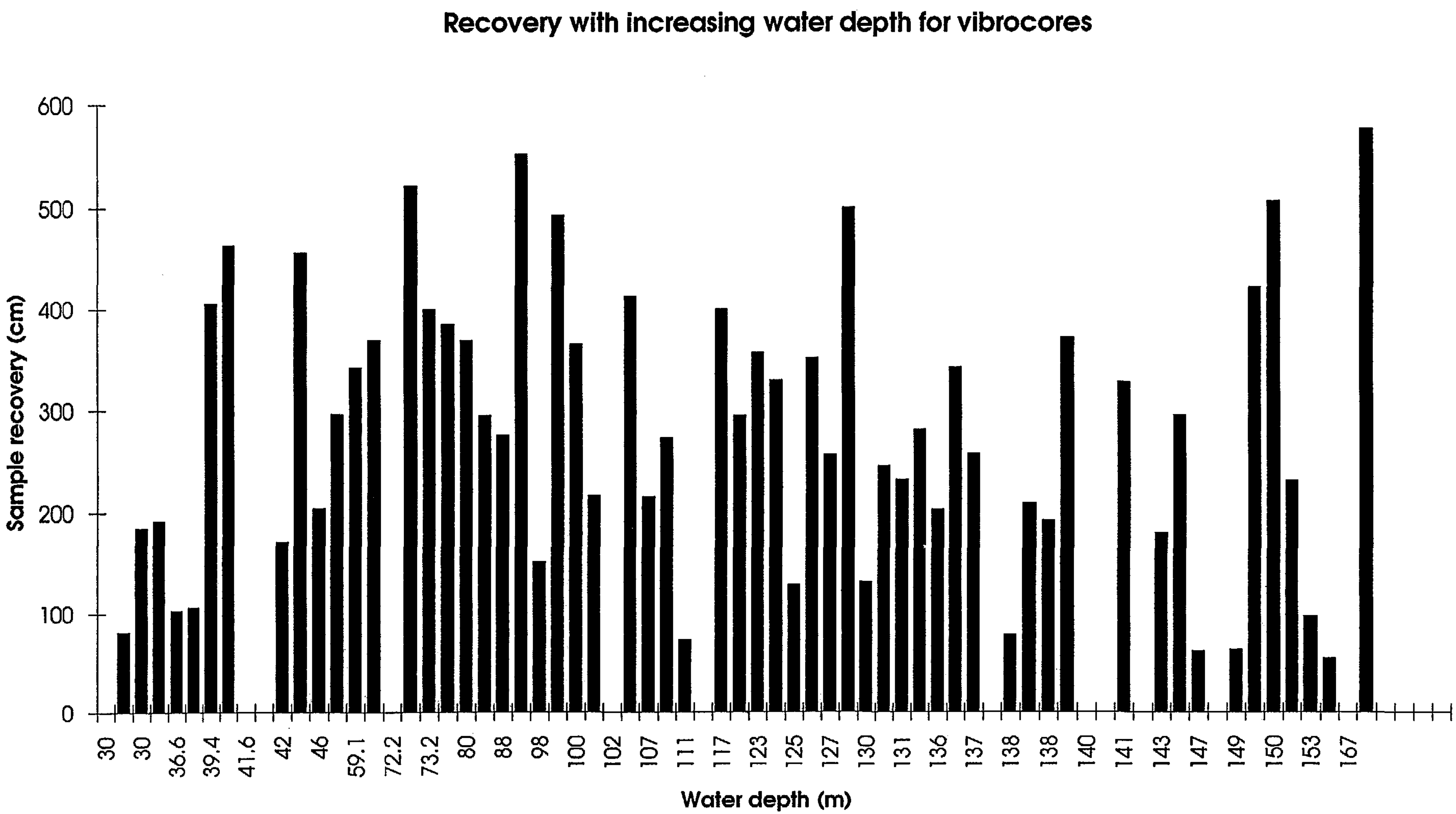


Fig. 2.6 Recovery with increasing water depth for vibrocores.

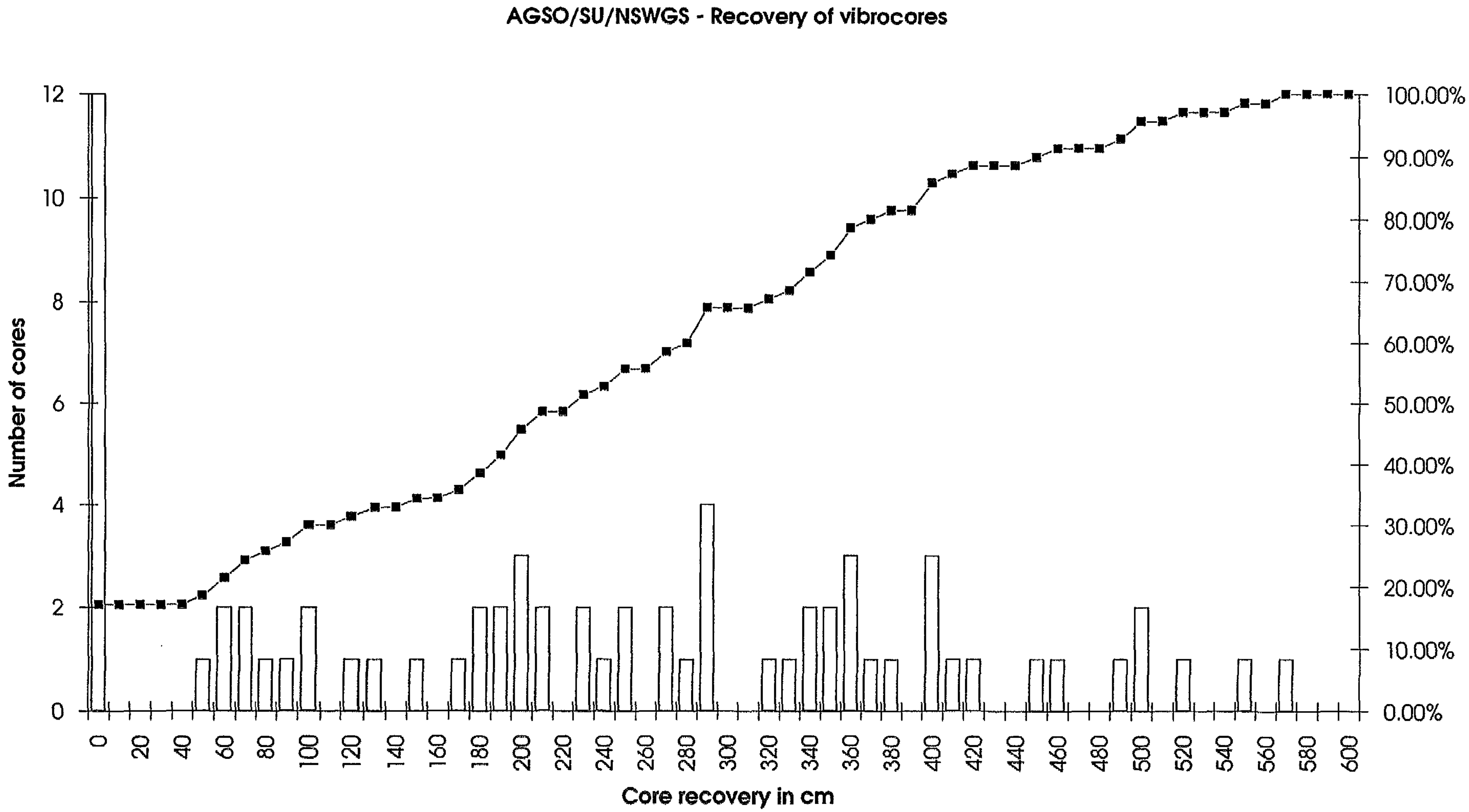


Fig. 2.7 Recovery of vibrocores.

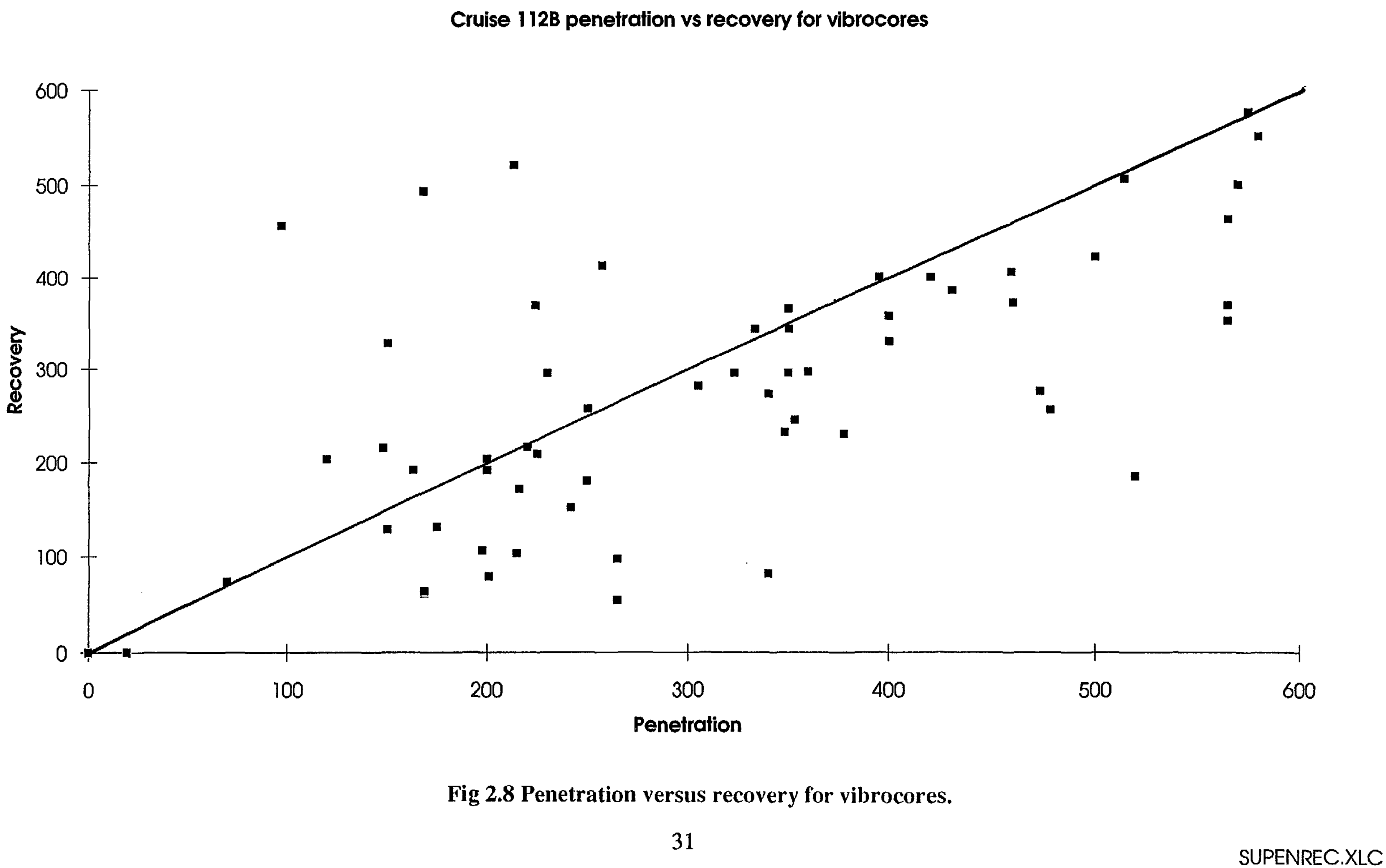


Fig 2.8 Penetration versus recovery for vibrocores.

3. Seismic Profiling

3.1 Background

Previous high-resolution marine seismic surveys in central NSW are restricted primarily to discrete regions of the inner shelf and adjacent estuaries (eg., Lean and Peat, 1972; Caldwell Connell Engineers, 1976; Albani et al., 1973; Albani and Johnson, 1974; Lean, 1978; Albani, 1981; Roy and Ferland, 1987; Albani et al., 1988). An early sparker seismic survey investigated the central to northern NSW inner shelf between the entrance to Port Stephens and the NSW border (Jones and Davies, 1979) for the purpose of heavy mineral resource assessment. A detailed, high resolution study of the Newcastle Bight to Cape Hawke region, including the inner shelf and part of the mid shelf, was undertaken during the SONNE cruise (Jones et al., 1982; von Stackelberg, 1982). Additional seismic data, collected in relation to marine aggregate and heavy mineral exploration, have not been released publicly due to their proprietary nature (regions covered include Sydney, Swansea-Norah Head, Cape Hawke-Forster).

The inner continental shelf of NSW changes from bedrock-dominated in the south to predominantly sediment-covered in the north. In places, thick sequences of marine sand, hypothesised to be relict barriers (Schluter, 1982; Roy et al., 1991), have been identified on the inner to mid shelf. There are regional differences in the character and thickness of the outer shelf sediment wedge (Davies, 1975, 1979; Marshall, 1979; Roy and Thom, 1981, 1991) Seismic profiles extending across the shelf throughout the Cruise 112B study area delineate the morphology and structure of the continental margin (Davies, 1975; 1979), but their low resolution in the uppermost part of the record does not permit interpretation of the Quaternary sedimentary sequence. Moderate to high resolution, cross-shelf seismic profiles would provide the information necessary to develop models of shelf sedimentation and to evaluate mineral resource potential.

3.2 Objectives

The objectives included:

1. Describing and delineating the distribution of Quaternary sediment using high resolution boomer data, and
2. Defining the Quaternary stratigraphy, in combination with the vibrocore data, in order to construct a shelf sedimentation model.

3.3 Methods

Four devices were deployed:

a. ORE Ferranti Boomer and 2 boomer streamers (OSI, SU);

b. Towed Raytheon 3.5 kHz sub-bottom profiler;

c. Hull-mounted Raytheon 3.5 kHz sub-bottom profiler;

d. 110 cubic inch airgun in combination with the boomer streamer.

The data were printed to an EPC 3200s (a,d), EPC 4600 (c), or to a Raytheon LSR recorder (b).

The boomer results were of poor quality, apparently due to a combination of rough sea states, noise from the vessel, seafloor character and water depth. The optimum recordings were obtained with the boomer and streamer towed the maximum distance behind the ship (approximately 55 m) at a ship speed of 4-5 kt. Filter settings were 500-10,000 Hz and boomer energy was 175 J for water depths to 100 m, but 350 J for deeper water depths. A buoy was attached to the electric tow-cable 2-3 m forward of the towbody, to prevent the towbody being pulled nose down by the tow-cable. Typically resolution was only about 6 m and maximum penetration was about 50 m.

A different recording technique was used on boomer Line 9. The signal, after amplification, was fed to a T.S.S. Swell Filter (Model 305) then to an analogue input to the print amplifier of the EPC printer. (Prior attempts to use the swell filter were abandoned when a "bar code" type trace was printed. Both the swell filter and EPC printer have digital processing and the "bar coding" could be an interference involving double digitisation.). This setup bypassed the conditioning amplifiers in the EPC resulting in compromised print quality. The record for water depths greater than 100 m contained little detail, but the stronger returns from "shallow water" had an adequate signal/noise ratio for the swell filter to track, and produced a better record. The best results were obtained using 350 J output and the 20 segment array.

Both of the 3.5 kHz sub-bottom profilers failed to depict subbottom reflections. This was not surprising given the generally sandy/gravelly nature of the seafloor over much of the shelf.

The airgun results gave good penetration (150 m) with moderate resolution (6-8 m). The configuration was:

(i) 110 cubic inch airgun, towed 10m behind the ship at 2 m water depth and operated at 2000 psi, cycling at 4 secs;

(ii) an ORE Ferranti boomer streamer (20 element). The streamer appeared to tow at about 3 m depth and was deployed at full cable payout (55 m).

(iii) without TVG amplification or swell filtering, but filtered at: (a) 100-700 Hz or (b) 300-1000 Hz. The former suffered from a long bubble pulse record and strong ringing but produced a record with good signal/noise ratio.
(iv) an EPC 3200 recorder, recording at either 1, 2 or 4 sec depending on the water depth.

Typically the seismic sections show good record to 500 ms subbottom, with bubble pulse of 16 msec duration and resolution on the recording of approximately 10 msec.

3.4 Seismic Profiling Results

The objectives stated in Section 3.2 focused on delineating the Quaternary sedimentary sequence to assist in the development of a model of Quaternary shelf sedimentation. While boomer data were collected along 8 lines (Fig. 3.1), technical problems reduced the penetration and resolution of the data (discussed in Section 3.4.1). As problems with the boomer system became apparent, shipboard scientists decided to attempt to collect air gun seismic data across the shelf. A total of 13 air gun profiles were successfully collected (Fig. 3.2), but it was not possible to resolve the Quaternary sediment except where the deposits exceeded approximately 15 m in thickness.

A total of 696 line kilometres (376 nm) of seismic data were collected on 12 transects of the continental margin, 9 of which were coincident with sample transects (Figs. 3.1, 3.2 and Table 3.1); 493 kilometres (71%) of airgun data and the remainder boomer. All but one of the 13 airgun lines (Line 4, Port Hacking; Fig 3.2) is located north of Port Jackson, whereas the 8 boomer lines (Fig. 3.1) are well spread across the survey area. The numbering of seismic lines begins in the south with Line 1 and proceeds toward Line 17 in the north (Figs. 3.1, 3.2). The seismic survey initially included an additional line which connected all the odd-numbered shelf perpendicular seismic lines with even-numbered diagonal lines, however data were not collected along most of the diagonal lines. Table 3.1 contains a complete inventory of seismic lines, including both boomer and air gun data.

3.4.1 Boomer Data

The poor penetration and resolution of the boomer data makes meaningful interpretation difficult. The six boomer transects of the central NSW continental margin are located south of Broken Bay and north of Port Stephens (Fig. 3.1).

The lines (Line 1, 3) adjacent to Shoalhaven and Wollongong indicate a minor veneer of surficial sediment located mainly in bedrock depressions. Bedrock (? Tertiary) reflectors extend close to the seabed, and vibrocore data support a thin distribution of unconsolidated sediment in this region (see Section 4.4).

A marked increase in sediment thickness is evident between Port Jackson and Broken Bay (Lines 4A, 5, 7, 9). South of Port Jackson (Line 4A) a well-developed shelf sand body forms a strong bathymetric feature close to the coast (Roy, 1984; Ferland, 1990). This sand body thins rapidly seaward, and surficial sediment occupies bedrock depressions on the inner shelf and also commonly at the slope change where Tertiary strata onlap Sydney Basin rocks. A thin veneer of unconsolidated (mainly calcareous, from vibrocore data) sediment is located on the outer shelf near the shelf break. The mid shelf mud belt (discussed further in Section 4.5) is also clearly observable on the record in water depths of 100-120 m. The mud appears to accumulate in depressions and also to onlap a prominent bedrock high, especially adjacent to North Head (Port Jackson). The mud is not apparent on seismic Line 9, adjacent to Broken Bay and this is supported by results of sampling along this line.

Both boomer lines (Line 15, 17) north of Port Stephens exhibit thick sedimentary deposits on the inner shelf. North of Port Stephens, on Line 15, the accumulation is located behind a bedrock high and may be part of the Port Stephens tidal delta, whereas adjacent to Seal Rocks (Line 17) a well-developed shelf sand body with a steep slope is apparent (Jones and Davies, 1979; Jones et al., 1982; Ferland, 1990). The mid and outer shelf in this area exhibits several step-like terraces probably indicating shallow bedrock.. Minor penetration on the boomer records show that thin sediment may mantle the shelf immediately seaward of these irregularities.

3.4.2 Airgun Data

The air gun data provided high quality profiles of the Tertiary sediment wedge across the shelf and upper slope (Fig. 3.2). The result is a record of the Tertiary sediment wedge in detail not previously seen (Fig. 3.3). Resolution is sufficient to differentiate discrete sedimentary packages, and the penetration allows a complete Tertiary section to be seen. Variable, but typically minor penetration of the underlying Sydney Basin strata was achieved. Resolution, although probably close to optimal for the Tertiary section, was insufficient to give detailed information on the Quaternary sediment distribution of the mid and outer shelves. In isolated regions of the inner shelf the sediment was sufficiently thick (>15 m) to allow resolution of the Quaternary sedimentary sequence. Unfortunately, only five full transects of the shelf were completed using the airgun. While this low seismic coverage provides limited opportunity for detailed interpretation and mapping, the high quality of these data allows general interpretations that will provide the foundation for planning future seismic surveys.

Basement (Permo-Triassic) structure, coincident with the S_2 reflector of Davies (1975, 1979), is well depicted on all transects. It dips gently seawards on the inner part of the shelf in most areas, but on the mid and outer shelf it is highly irregular due to large rotated fault blocks dissecting this surface. On the inner shelf internal strata dip irregularly landward coincident with the known onland structure of the Sydney Basin. In the northern part of the survey area the central shelf section is acoustically transparent. This transparent zone may be related to intrusives postulated from onland and offshore magnetic data for this area (BMR aeromagnetic data). No age has been established for the S_1 reflector, but it is assumed to represent the onset of the rift/drift tectonic phase on the east coast, ie. approximately 83 Ma.

A second, very prominent reflector, coincident with the S_1 reflector of Davies (1975, 1979) is also evident on all transects. This horizon truncates numerous underlying reflectors, and overlying strata very commonly downlap on to it. On some lines this reflector onlaps strata within the S_1-S_2 package, whereas in other areas the S_1 reflector either crops out on the sea floor, or is truncated by a veneer of presumably Quaternary sediment on the middle to inner shelf. The position of the shelf break on the S_1 horizon varies from landward to seaward of the present shelf break, depending on the seismic line. This lateral variation indicates a variable supply of sediment along the margin with respect to time. In all transects the surface is smooth and dips gently and uniformly seaward. The age of this reflector has been tentatively correlated with the early to middle Pliocene of the Gippsland Basin by Davies (1979), but it may be older and may relate to the late Miocene/early Pliocene unconformity of the Gippsland Basin (Rahmanian et al., In press).

A third prominent reflector is observed on all lines in the inner shelf area above the moderately dipping Tertiary strata. Identifying this reflector is sometimes difficult, due to it being lost in the bubble pulse. Only on one line (Line 16, Fig. 3.3) is this reflector evident across the entire shelf width.

The basement-S_2 sedimentary package comprises at least four sequences. The early units exhibit shallow-dipping conformable strata, whereas the middle and late units show either contorted reflectors, or markedly more steeply dipping strata. The thickness of the total package varies markedly due to the irregular basement and the very steep palaeoshelf break.

The S_1-Quaternary sedimentary package exhibits marked variability in internal stratal geometry. Some seismic transects show the interval to comprise two or more sequences (Lines 11, 16), whereas in other areas sequences are difficult to separate and a discrete uniformly prograding package is evident (Line 13). The thickness and lateral extent of this interval also varies geographically with maximum sediment volume occurring adjacent to the Hunter River mouth on Line 13.

A thin veneer of ?Quaternary sediment is evident on the mid and outer shelf on some transects (Line 16). However, on the majority of lines this boundary is located within the bubble pulse and is not resolvable. Where this presumably ?Pleistocene unit is thick enough to be observable, it is seen to be strongly progradational, especially toward the outer shelf. Complex stratal patterns are evident on the shelf break, indicating that the package probably comprises several discrete units (Line 16, Fig. 3.3). A nearshore ?Holocene sediment wedge is evident on the majority of transects. This unit exhibits either strongly positive bathymetry with sharp, steep seaward profiles characteristic of shelf sand bodies (Field and Roy, 1984; Roy, 1984; Ferland, 1990), or form a concave inner shelf wedge.

Table 3.1 Summary information for boomer and air gun seismic tracklines.

Area	Data Type	Line Number	Location........ SOL Latitude	SOL Longitude	EOL Latitude	EOL Longitude	JD GMT SOL	JD GMT EOL	Line length (km)	(nm)	Water depth SOL (m)	EOL (m)
North Wollongong	AG	4	34 18.19	151 17.65	34 04.30	151 12.20	276 0005	276 0300	27.05	14.60	152.5	44.1
Broken Bay	AG	9A	33 34.72	151 23.05	33 49.99	151 49.99	288 0224	288 0610	50.22	27.12	40.0	630.1
Broken Bay	AG	10	32 26.91	151 40.11	33 34.69	151 23.11	287 2323	288 0212	29.95	16.17	97.2	41.1
Norah Head	AG	11	33 14.24	151 37.70	33 34.24	152 21.29	287 0515	287 1255	76.90	41.52	38.1	2969.3
Norah Head-Newcastle	AG	12	32 54.17	151 53.05	33 23.96	151 58.09	286 1745	286 2139	55.72	30.09	34.0	149.5
Newcastle	AG	13	32 54.75	151 49.71	33 09.52	152 19.81	285 2250	286 0256	54.15	29.24	27.5	194.0
Newcastle Bight	AG	13A	32 48.06	152 15.00	32 54.98	151 49.56	285 1945	285 2245	40.50	21.87	108.4	28.0
South Seal Rocks	AG	16	33 03.65	152 46.59	32 26.29	152 33.96	283 2205	284 0445	87.50	47.25	38.0	2264.9
Port Stephens	AG	14A	32 37.74	152 15.07	32 47.73	152 16.67	285 0840	285 1011	18.67	10.08	27.0	110.4
Port Stephens	AG	14B	32 47.47	152 16.89	32 51.68	152 24.31	285 1039	285 1158	13.93	7.52	105.1	141.0
Port Stephens	AG	14C	32 51.68	152 24.31	32 46.71	152 29.71	285 1158	285 1252	12.46	6.73	141	140.2
Port Stephens	AG	15A	32 42.55	152 22.84	32 37.74	152 15.07	285 0718	285 0840	15.04	8.12	101.5	27.0
Port Stephens	AG	15B	32 46.71	152 29.71	32 43.18	152 23.7	285 1252	285 1342	11.42	6.17	140.2	103.3
Total									493.51	266.47		
Shoalhaven	B	1	34 51.41	150 49.10	34 51.22	151 05.15	274 0315	274 0645	24.40	13.17	37.0	161.4
Wollongong	B	3	34 30.54	151 11.34	34 28.33	150 56.51	275 0500	275 0820	23.00	12.42	158.5	30.0
Port Hacking	B	5	34 04.37	151 11.28	34 10.98	151 26.21	276 0445	276 0805	25.96	14.02	28.0	209.8
North Head	B	7	34 50.28	151 33.73	33 50.77	151 20.69	276 1920	276 2145	20.00	10.80	137.4	66.0
Broken Bay	B	9	33 44.15	151 46.44	33 34.06	151 22.04	281 1737	281 2215	42.00	22.68	195.0	33.8
Port Stephens	B	15	32 38.35	152 18.58	32 51.34	152 37.37	284 1833	285 0000	37.89	20.46	41.0	197.0
Seal Rocks	B	17	32 26.83	152 34.99	32 31.19	152 51.41	284 0515	284 0902	26.89	14.52	69.3	163.3
South Port Hacking	B	4A	34 05.28	151 12.54	34 04.66	151 11.09	276 0330	276 0440	2.50	1.35	74.8	26.9
Total									202.64	109.42		

Abbreviations: AG = Air Gun; B = Boomer; SOL = Start of line; EDL = End of line; JD = Julian day; GMT = Greenwich Mean Time

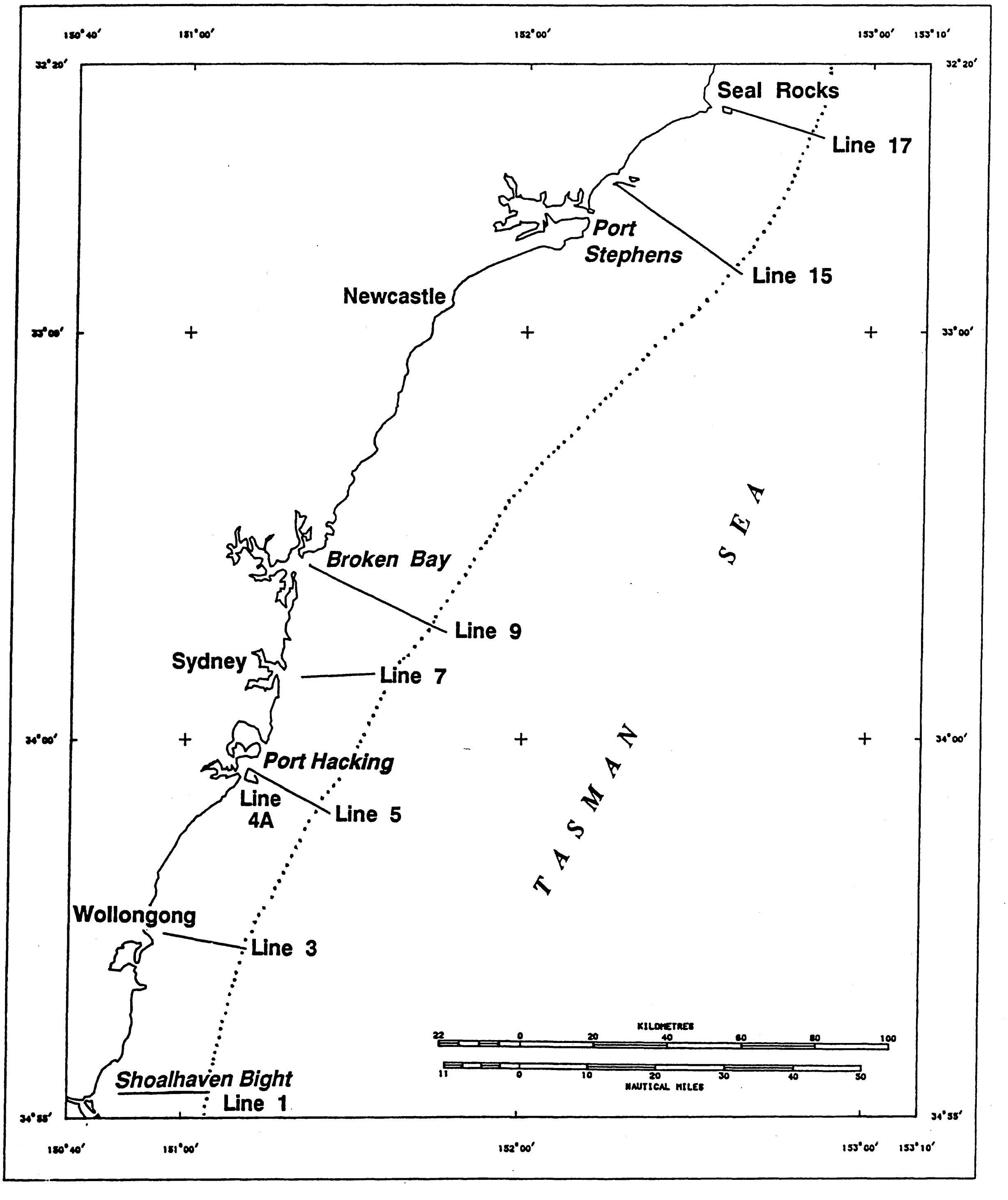


Fig. 3.1 Boomer trackline map.

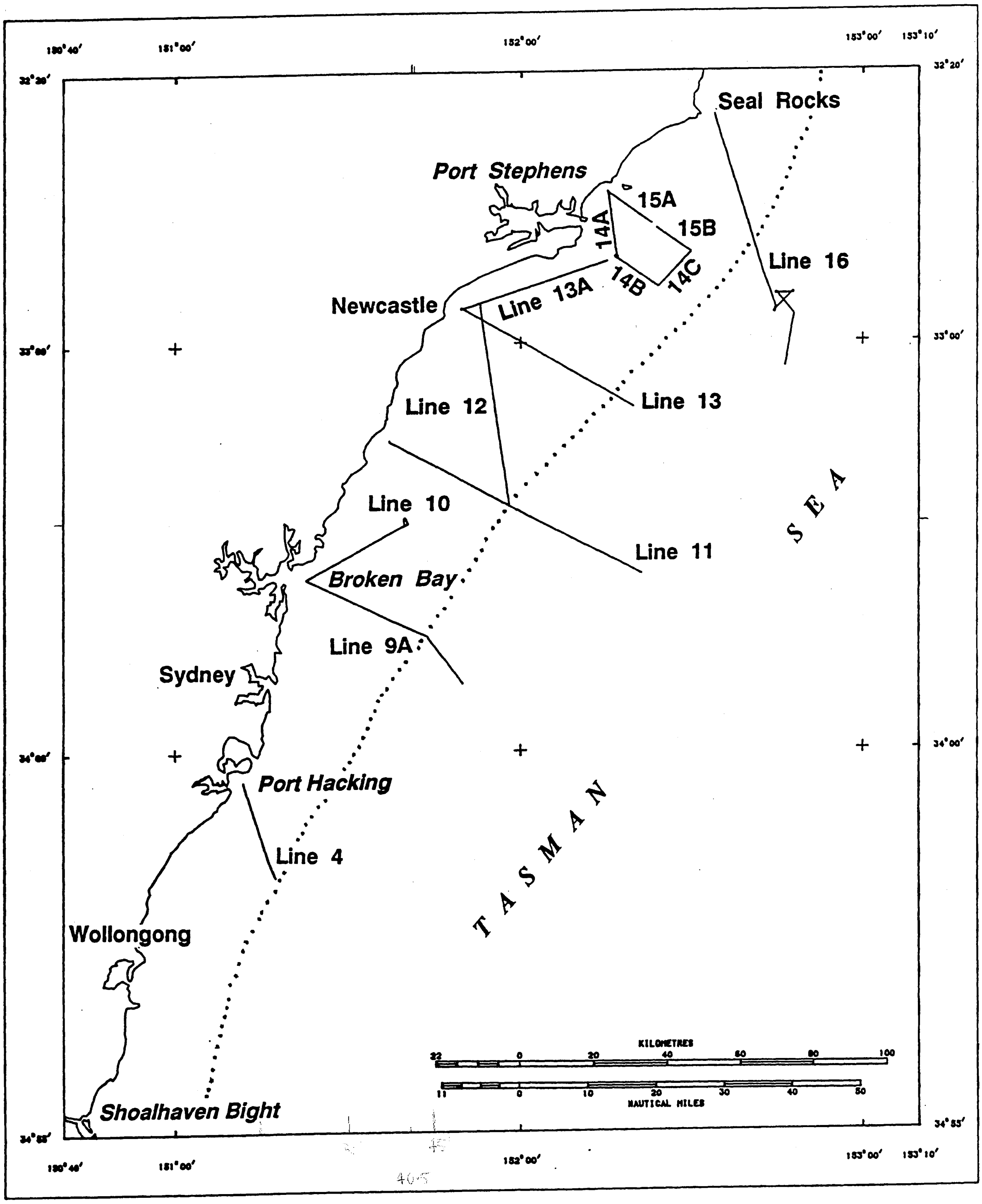


Fig. 3.2 Air gun trackline map.

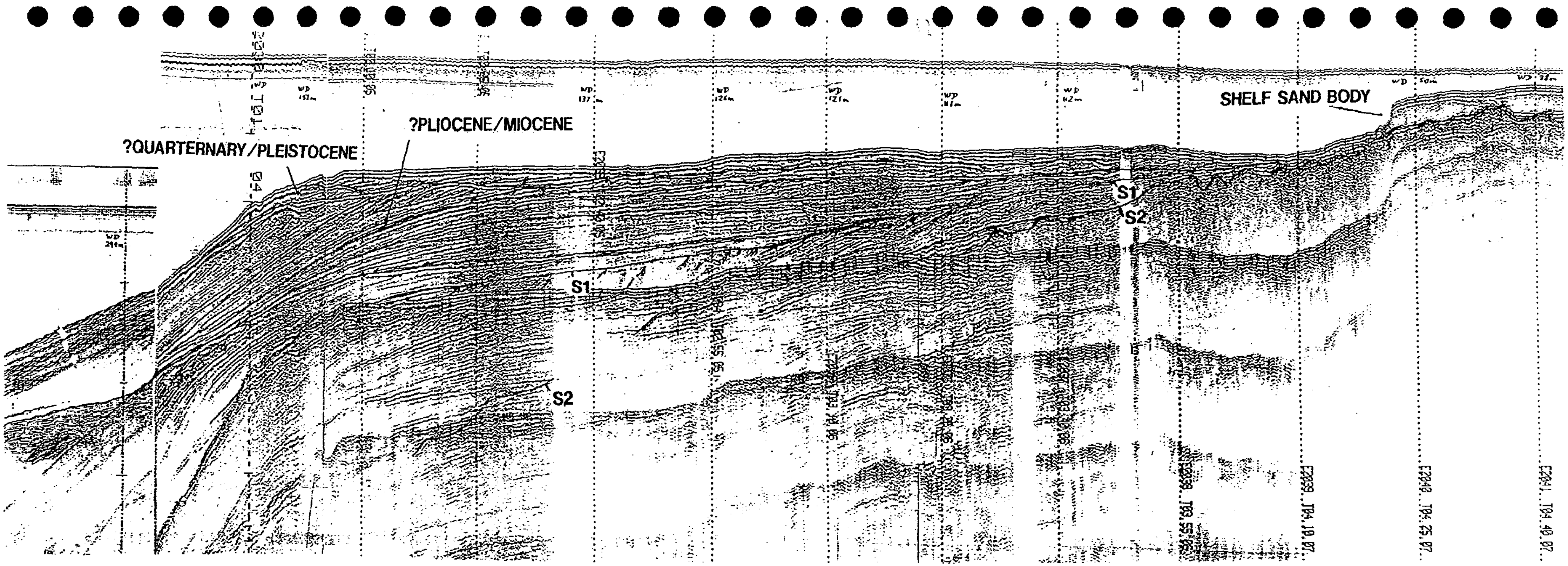


Fig. 3.3 Record of air gun Line 16 showing the Tertiary sediment wedge.

4. Quaternary and Contemporary Shelf Sedimentation

4.1 Background

Prior to this survey, no vibrocores had been collected on the outer shelf of the Sydney Basin and the Quaternary stratigraphy of the area was completely unknown. Consequently, mechanisms of shallow marine sedimentation, especially at lower sea levels, are poorly understood. Early BMR surveys (Davies, 1979; Marshall, 1980) delineated the broad-scale distribution of surface sediments, but subsequent geological investigations have been restricted to the more accessible inner shelf. Previous coring has been confined to parts of the inner shelf adjacent to Sydney (Roy, 1984; Hudson and Roy, 1989; Hudson, pers. comm. 1991) and north of Newcastle (Kudrass, 1982; Colwell and Roy, 1983).

In broad terms, the inner part of the shelf dips seaward (average = 0.6^{0}) and is erosional with continental bedrock (basement) cropping out at the surface, or thinly veneered with sediment. In contrast, the outer shelf is a low gradient planar surface (average = 0.2^{0}) and overlies a seaward thickening wedge of evenly layered Tertiary sediment (Fig. 3.3). The Tertiary sediment wedge is up to 500 m thick and little is known about its composition or exact age.

The southeastern Australian continental shelf is narrow by world standards (<50 km) and is exposed to a moderately high-energy wave climate dominated by southerly storms and swell waves (Short and Trenaman, 1992). In central NSW, the shelf is relatively deep (70% > 100 m) and the shelf break is at about 140-150 m water depth. Ocean currents in this area flow principally to the south under the influence of the East Australian Current, which is most active over the outer shelf and upper slope. The inner shelf is more strongly influenced by storm waves and currents, internal waves and coastal trapped waves (Freeland et al., 1986; Griffin and Middleton, 1991, 1992). The confluence of these processes produces a complex hydrodynamic environment characterised by both northerly and southerly alongshelf currents, and across-shelf currents (although the latter are less well documented or understood).

Deep-water wave regimes during the Quaternary were probably essentially similar to the present, although the zones of nearshore wave and current influence would have been displaced laterally as glacio-eustatic sea levels oscillated. In areas where the outer shelf surface is particularly wide, energy levels near the coast were reduced during sea level lowstands by frictional effects in shallow water and probably also by the greater influence of offshore winds during glacial periods.

The present study area occupies an important transition zone where shelf geometry and along-shelf sediment budgets change. Rates of littoral sediment transport have varied regionally along the shelf over time and also across the shelf during sea level oscillations (Roy and Thom, 1981, 1991; Thom and Roy, 1985). As a result, the northern NSW shelf is more sediment - and mineral-rich than the southern shelf (Jones and Davies 1979; Hudson and Ferland 1987; Roy and Hudson, 1987; Roy 1990; Roy and others 1991). Temporal and spatial changes in sediment budgets and barrier development throughout the Quaternary are thought to be key factors in the formation of heavy mineral beach placers. The results obtained from the present study will provide an opportunity to test existing models of sedimentation and mineralisation on the inner shelf, against new data for the mid and outer shelf, as well as providing a geological framework for the geochemical investigation discussed in Section 5 of this report.

4.2 Objectives

The objectives of the shelf survey were:

1. to map the Quaternary sediments of the continental shelf so as to develop an evolutionary stratigraphic model characterising transgressive and regressive sedimentation on a high energy, sediment-starved shelf;
2. to document the resource potential (heavy minerals and marine aggregate) of the mid and outer shelf sediments;
3. to test hypotheses that shelf sediment dispersal and deposition is significantly controlled by the East Australian Current (EAC); and
4. to verify a computer model describing responses of coastal sediments to changing sea levels in mid and outer shelf environments (Roy, Cowell and Jones, 1989).

The results of this research have direct significance to the following government and industrial programs:

a. commercial mineral exploration (Cable Sands Pty Ltd);
b. sand and gravel (marine aggregate) exploration (Metromix Pty Ltd);
c. laying of submarine telecommunications cables (AOTC Ltd); and
d. coastal engineering and erosion studies, especially in the vicinity of harbours and port facilities (Public Works Department).

4.3 Shelf Sampling Methods

To achieve the objectives, grab samples, vibrocores, box cores and gravity cores were collected along 9 major across-shelf transects (Fig. 4.1). Sample sites were spaced approximately 5 nautical miles (nm) apart along transects, which resulted in a high proportion of samples being collected on the relatively wide outer shelf. This was done in order to take full advantage of RV Rig Seismic's long-range operating capabilities, and to maximise core recovery under conditions that would be unworkable on most other research vessels (eg. rough seas and strong currents). Additional samples were collected for the geochemical aspect of the program (see Section 5).

Once the ship reached a sample site, the surface sediment was sampled using a 20 litre teflon-coated grab sampler which weighed 107 kg (dimensions: 390 x 770 x 460 mm). The grab samples were used immediately to determine whether the sediment was sufficiently muddy to allow deployment of a box corer or gravity corer. The grabs were then sampled for both sedimentological and geochemical analyses, as well as an archive sample for AGSO. In many grab samples (and in all box cores), the surface sediment seemed to be virtually intact, as evidenced by protruding worm tubes and ascidians; occasionally trace fossils were evident on the sediment surface. The preservation of essentially undisturbed surficial sedimentary structures was due, in part, to the large size of both the grab sampler and box corer.

Box cores and/or gravity cores were collected when the sediment was particularly muddy, in order to obtain a vertical sequence of undisturbed sediment for geochemical analyses, especially the determination of baseline levels of contamination. The box corer is a Soutar style, produced by Ocean Instruments of San Diego (USA). It weighs 500 kg, stands 1.1 m high, and the internal dimensions of the box are 250 x 400 x 540 mm. The spring-loaded pin triggered with the release of weight as the corer encountered the seabed. The box corer recovered between 15 and 40 cm of sediment. The gravity corer was fitted with either a 3 or 6 m barrel and inner liner, depending on expected depth of penetration. A one tonne weight was attached to the gravity corer, which was lowered through the water at a rate of 100-120 m/min. The method of subsampling the box and gravity corers is described in Section 5.3.

Vibrocores were collected at nearly all shelf sample sites, as vibrocoring is the most effective and widely used method of obtaining subsurface sediment samples in shallow marine environments, especially in sandy sediment. However, experience elsewhere in NSW shows that, because the sediment cores can become disturbed in unpredictable ways, their interpretation is not always straightforward. Appendix B contains a detailed description and discussion of the general characteristics of the vibrocorer, its deployment, and the measures taken to interpret the results.

Analysis of vibrocores consists of a number of phases, some of which were completed on board. Immediately after collection, the cores were cut into metre lengths, measured from the core bit to the top of the sediment. The core sections were capped and labelled immediately, and then split lengthwise. The total length of sediment in the core was taken as the core "recovery". Half of the core was stored in plastic sheathing, sealed, labelled and archived in the cooler for the AGSO. Labelling follows the standard AGSO procedure: Cruise number/VC (for vibrocore)/core number, followed by 1, 2, 3 etc. designating the cut sections from the top downwards; an arrow points to the top of each core section. The other half was logged and then stored in the same manner as that described for the AGSO archive sample; except that cores collected for Quaternary geology were wrapped in plastic cling wrap, and cores collected for geochemistry were wrapped in aluminium foil prior to being placed in the plastic sheathing.

Preliminary logging of the vibrocores on board enabled estimation of the quality of the core recovered, as well as giving a preliminary description and interpretation of the sedimentary sequence. Vibrocore logs for each site are summarised in Section 4.4. Sampling of the vibrocores was delayed until return to Sydney, so as to allow resin peels to be made from the cores prior to sampling. Subsequent analyses of the vibrocores will include:

a. resin peels (sandy cores) and X-ray analysis (muddy cores);
b. detailed logging and sub-sampling;
c. sedimentological analyses (microscopy, grain size, organic carbon and carbonate, macro- and micro-faunal identification, mineralogy, XRD) to characterise environments of deposition;
d. geochemical analyses for environmental baseline studies (organochlorines, metals and organic carbon); and
e. dating (^{14}C, Thermoluminescence (TL), ^{210}Pb) of selected core intervals to establish chronologies and rates of sedimentation.

4.4 Description of seafloor samples

The following descriptions includes all grab samples (GS), vibrocores (VC), box cores (BC) and gravity cores (GC) collected on the continental shelf. The tables in Section 2 contain sample information, including sample location (latitude and longitude in WGS84 coordinates) and the date and time at which each sample was collected. The term "pectenid" refers to shells and shell fragments of the *Pectenidae* family (to be identified during subsequent detailed core logging).

LINE 1 SHOALHAVEN BIGHT
SITE 1A (42 m w.d.)

112/GS/039: Surface sediment is clean quartzose sand with minor shell.
112/VC/070: No penetration as gate didn't trigger.
112/VC/071: No recovery due to broken core barrel.
112/VC/072: Penetration: 216 cm; Recovery: 171 cm.
112/VC/073: Penetration: 97 cm; Recovery: 456 cm (core expanded due to "suck up").
Top of core 072 contains medium to coarse grained, fawn grey, quartz sand with rounded pebbles at 100-135 cm; sand contains shell fragments above gravel layer, but no obvious shell below. Both cores probably bottomed on gravel layer at depth of 100-200 cm.

SITE 1B (70 m w.d.)

112/GS/040: Surface sediment is fine grained, silty sand.
112/BC/078: Penetration: 8 cm; into same fine, slightly muddy (silty) sand
112/VC/074: Penetration: 224 cm; Recovery: 369 cm (core expanded by approximately 70%)
Slightly muddy, grey to fawn grey quartzose sand with gravel layer at the base (220 cm); bottom 40 cm is graded bed of some shells in gravel. Pebbles at base coated with serpulid worm tubes, therefore they were exposed on seabed in past. Core bottomed on gravel layer at approximately 220 cm, possibly overlying bedrock.

SITE 1C (98 m w.d.)

112/GS/041: Surface sediment is shelly muddy sand with worm tubes.
112/VC/075: Penetration: 168 cm; Recovered: 493 cm.
112/VC/076: Penetration: 242 cm; Recovered: 151 cm.
Olive grey medium grained sand with thin shells and pebble layer at top, and coarse gravel and shell layer at base. Core 076 encountered muddy sand (estuarine?) at 110 cm to base.

SITE 1D (131 m w.d.)

112/GS/042: No recovery; grab triggered in the water.
112/GS/043: Surface sediment is muddy shelly sand.
112/VC/077: Penetration: 353 cm; Recovery: 245 cm.
112/VC/078: Penetration: 348 cm; Recovery: 232 cm.
Upper part of the cores contain shelly quartz sand and shell gravel, with trace mud. Very shelly in top 50 cm and bottom 105 cm; abundant whole bivalves and some pectenids; many species, some intact. Cores penetrated to 350 cm and bottomed in a coarse shell layer; some compaction is possible, due to loose packing of shell gravel.

SITE 1E (149 m w.d.)

112/GS/044: Surface sediment is composed of slightly muddy calcareous sand.
112/VC/079: No recovery.
112/VC/080: Penetration: 169 cm; Recovered 61 cm.
112/VC/081: Penetration: 169 cm; Recovered 63 cm.
Core composed of olive grey sand and shell gravel forming a fining-up sequence. Sand is mainly fine grained and shell fragments increase in size down the core; negligible mud throughout. Core penetrated 170 cm and bottomed in shell gravel or possibly "bit" top of Tertiary substrate.

LINE 3 WOLLONGONG

SITE 3A (30 m w.d.)

112/GS/045: Surface sediment is medium to very coarse grained sand, some pebbles and shell fragments up to gravel size.
112/VC/082: No recovery.
112/VC/083: Penetration: 340 cm; Recovery: 81 cm; core acted as "pile-driver" in the mud.
112/VC/084: Penetration: 520 cm; Recovery: 185 cm.
Core penetrated up to 5 m into estuarine (?) mud sequence beneath a surficial sand layer approximately 180 cm thick. Sand composed of fine to medium quartz sand, scattered pebbles and some mud layers. Mud sequence was not sampled, except on outside of barrel, possibly due to barrel being blocked with large angular pebble from overlying sand layer (resulted in the "pile-driver" effect described in Appendix B).

SITE 3B (70 m w.d.)

112/GS/046: No recovery.
112/GS/047: Limited recovery of calcareous sand containing large fragments of bryozoa and calcareous algae.
112/BC/079: No recovery.
Hard ground, possibly bedrock outcropping at sea bed, but boomer seismic resolution not able to delineate (poor record due to rough weather).

SITE 3C (107 m w.d.)

112/GS/048: Surface sediment is very muddy sand.
112/BC/080: Recovery: 15 cm; same sediment as grab sample.
112/VC/085: Penetration: 148 cm; Recovery: 215 cm.
Surface mud layer of unknown thickness (probably less than 50 cm) overlying coarsening downward sequence of sand (about 100 cm thick). The sediment becomes gravelly at the base of the core, where pebbles are well rounded and some are encrusted indicating past exposure at surface. Core bottomed on gravel (? overlying bedrock); core bit hammered.

SITE 3D (135 m w.d.)

112/GS/049: Surface sediment is muddy shelly sand with large pectens.
112/VC/086: No Recovery.
112/VC/087: Penetration: 333 cm; Recovery: 343 cm.
112/VC/088: Penetration: 201 cm; Recovery: 78 cm.

Top 25 cm of core is fine to coarse sand and shell gravel, overlying dark olive grey very fine sand with minor mud (<10%?) and occasional large shell fragments; interval from 60-90 cm contains more and larger shell fragments. At 125 cm, the sand becomes medium to coarse grained and more calcareous with abundant shells and fragments (especially in lower 150 cm); shells include small bivalves and thin-walled gastropods.

SITE 3E (152 m w.d.)

112/GS/050: No Recovery.
112/GS/051: Surface sediment is slightly muddy calcareous sand.
112/VC/089: Penetration: 378 cm; Recovery: 230 cm.
112/VC/090: Penetration: 265 cm; Recovery: 97 cm.
Top of core to 80 cm contains fine to coarse (fining up) calcareous sand with fine and coarse layering. Underlying sand is olive grey, fine to very fine sand becoming coarser and very poorly sorted with increasing shell gravel down the core to about 200 cm. Abundant pectens and angular shell fragments in medium to coarse calcareous sand, with less large shell fragments below 200 cm.

LINE 5 PORT HACKING
SITE 5A (87 m w.d.)

112/GS/056: Surface sediment is olive grey sandy mud with abundant worm tubes and thin-walled shells.
112/BC/082: Penetration: 25 cm.
112/VC/097: Penetration: 580 cm; Recovery: 552 cm.
112/VC/098: Penetration: 473 cm; Recovery: 276 cm.
Top of core contains olive grey sandy mud with abundant worm tubes and thin walled shells; sand is clastic and very fine grained. With depth, sand content increases toward 1.9 m, to a very muddy sand; gas vughs in upper part of unit. Coarse sand and shell gravel layer at 1.9 to 2.0 m, overlying homogeneous fine to medium sand with occasional large bivalves and variable amounts of shell hash. Unit extends to 5.5 m.

SITE 5G (114 m w.d.) - Additional site for geochemistry sampling.

112/GS/067: Surface sediment is dark grey, soft ("gooey") mud with surprisingly little benthic life. Trace very fine clastic sand.

SITE 5B (126 m w.d.)

112/GS/055: Surface sediment is very muddy olive grey sand.
112/BC/081: Recovery: 15 cm.
112/VC/099: Penetration: 478 cm; Recovery: 256 cm.
112/VC/100: Penetration: 565 cm; Recovery: 352 cm.
Top of core 99, down to 190 cm, contains dark olive grey, slightly sandy mud with a fine to very fine clastic sand fraction; worm tubes and thin walled shells are common. Thin shell layer at 190 cm down to 256 cm overlying dark grey, fine-grained quartz-calcareous sand with variable amounts of fine shell hash, which extends to 350 cm.

SITE 5F (134 m w.d.) - Additional site for geochemistry sampling.

112/GS/066: Surface sediment is dark grey sandy mud with abundant worm burrows and common shell fragments.

SITE 5C (136 m w.d.)

112/GS/054: Surface sediment is somewhat muddy, calcareous-rich sand and gravel; gravel is composed of pectens and large carbonate fragments.
112/VC/096: Penetration: 305 cm; Recovery: 281 cm.
Muddy coarse calcareous sand and shell gravel (some pectens) at surface extending down the core to a basal shell gravel layer at 270 cm. Gravel layer contains carbonate concretion nodules and possibly overlies bedrock/Tertiary (based on seismic and core recovery).

SITE 5D (143 m w.d.)

112/GS/053: Surface sediment is slightly muddy, calcareous-rich (outer shelf) sand containing bryozoa, calcareous algae, etc.
112/VC/092: Electrical problem prevented motors from vibrating once vibrocorer on the seabed. Retrieved without penetration.
112/VC/095: Penetration: 250 ? cm; Recovery: 180 cm.
Top of core contains olive grey, medium to coarse calcareous sand; slightly muddy at surface and becoming cleaner with depth. Shelly layer with pebble at 75 cm; scattered shell hash throughout.

SITE 5E (167 m w.d.)

112/GS/052: Surface sediment is muddy, calcareous-rich (50-70%) sand with many thin-walled bivalves, bryozoa fragments, and sponges.
112/VC/091: No recovery.
112/VC/093: Penetration: 265 cm; Recovery: 54 cm.
112/VC/094: Penetration: 575 cm; Recovery: 577 cm.
Top of core contains slightly muddy, olive grey, fine to coarse sand that is poorly sorted and calcareous-rich, especially in bryozoa, algae and thin-walled bivalves (throughout length of core). Numerous fining upward sequences marked by basal shelly layers. Some incipient cementation at about 460 cm.

LINE 7 PORT JACKSON
SITE 7A (70 m w.d.)

112/GS/057: Surface sediment is grey-brown, medium-grained quartzose sand with trace mud; minor shell and worm tubes.
NB: No other samples collected here due to position adjacent to Port Jackson.

SITE 7B (104 m w.d.)

112/GS/058: No recovery.
112/GS/059: Surface sediment is olive-grey, soft mud.
112/GC/003: Recovery: 125 cm.
Top of core contains olive grey soft "gooey" mud, extending to 125 cm; abundant worm tubes at surface; no sedimentary structures.

SITE 7C (119 m w.d.)

112/GS/060: Surface sediment is soft "gooey" mud.
112/GC/004: Recovery: 107 cm.
112/VC/101: Penetration: 323 cm; Recovery: 295 cm.
The top of the core contains dark, olive grey soft "gooey" mud at the surface extending down to 150 cm; a sharply defined layer of clean sand occurs at 60-80 cm within the mud. The sand content increases between 150-200 cm to muddy sand, which changes to clean fine, well-sorted quartzose sand below 200 cm. The base of the core contains fine grained, slightly muddy sand (quartz-calcareous) and shell gravel.

SITE 7D (125 m w.d.)

112/GS/061: Surface sediment is very muddy, olive sand with both relict and modern carbonate fragments.
112/GC/005: Recovery: 40-45 cm (bulked).
112/GC/006: Recovery: 20-25 cm; lost sand out of the bottom of corer.
112/VC/102 : Penetration: 150 cm; Recovery: 128 cm.
Top of the core contains very muddy, olive grey sand composed of relict and modern carbonate and minor iron-stained quartz. Mud content decreases down the core. A calcareous sand forms a graded unit coarsening downward to a shell gravel at 80 cm. This unit forms a sharp contact with a dark grey, semi-cohesive muddy sand unit containing *in situ* shells. Mud unit is 25 cm thick and overlies a non-muddy, coarse basal gravel composed primarily of bivalves and less common quartz pebbles. The core bottomed on a large cemented calcareous pebble at 128 cm.

SITE 7E (130 m w.d.)

112/GS/062: Surface sediment is very muddy, olive grey, fine to coarse-grained calcareous sand.
NB: No other samples collected at this site due to time and delays with vibrocorer.

SITE 7F (141 m w.d.)

112/GS/063: Surface sediment is olive grey, slightly muddy sand.
Surface sediment is olive grey, slightly muddy sand.
112/VC/103: Penetration: 150 ? cm; Recovery: 328 cm. (possible "suck-up" explains greater recovery than penetration).
Top of the core contains olive grey, slightly muddy sand which is calcareous and medium-grained to approximately 70 cm. The sediment coarsens progressively downward to a basal calcareous gravel at 300 cm (the "graded" unit is probably an artefact, produced during coring). Gravel-sized clasts are composed of bryozoa, bivalves, algae and cemented sand nodules; most grains are iron-stained and brown.

SITE 7F(b) (295 m w.d.)

112/GS/064: Essentially no recovery.
112/GS/065: Very little sediment recovered (c. 10 gm). Appears to be very fine grained quartzose sand with about 30% carbonate as fine fragments.

LINE 9 BROKEN BAY
SITE 9A (40 m w.d.)

112/GS/068: Surface sediment is clean (no mud) coarse, iron-stained sand.
112/VC/104: Penetration: 565 cm; Recovery: 463 cm.
112/VC/105: Penetration: 459 cm; Recovery: 400 cm.
Top of core (104) contains 4 upward fining sequences in fine-coarse iron-stained quartzose sand; each sequence contains coarse sand, pebbles or pectenid at base. Sharp contact at 82 cm separates inner shelf sand from mottled, black-grey clay with yellow shell fragments. Mud becomes stiff at about 100 cm and peat-like, with possible high organic content, at 200 cm. At 305 cm, the sediment changes to muddy sand, which is increasingly shelly and sandy with depth. The lowermost meter of the core contains cohesive, hard (semi-consolidated) mud with minor shell fragments, and 15 cm of muddy sand.

SITE 9B (59 m w.d.)

112/GS/069: Surface sediment is medium-grained sand, with a trace of mud.
112/VC/106: Penetration: 350 cm; Recovery: 343 cm.
112/VC/107: Penetration: 360 cm; Recovery: 296 cm.
Top of core contains 75 cm of iron-stained, fine-medium sand with somewhat coarser shell fragments (also whole valves). Sharp contact with underlying unit of clean, well-sorted and non-iron-stained fine to medium grained sand which grades into a slightly muddy fine sand with occasional mud-filled burrow casts. The lowermost 115 cm contains fine to coarse, poorly sorted quartzose sand with abundant shell fragments and whole valves (scattered and in laminae). Shells appear to be modern/fresh and typical of shallow marine environments.

SITE 9C (99 m w.d.)

112/GS/070: Surface sediment is grey muddy sand with abundant worm tubes and shells.
112/VC/108: Penetration: 350 cm; Recovery: approximately 365 cm (core catcher slightly hammered).
112/VC/109: Penetration: 220 cm; Recovery: 216 cm (core catcher hammered).
Core 108 contains muddy sand at the surface grading into homogeneous slightly muddy sand. Shell content increases toward the base of the core, both as fragments and valves. Lowermost 50 cm of core contains well-sorted muddy sand and then well-rounded pebbles, cobbles and large shell fragments. Core 109 contains a 2 m graded sequence from fine sand with scattered shell at the top of the core to gravel with coarse shell and whole valves at the base. Grading may have occurred during coring process, even though penetration and recovery lengths are similar, due to the long penetration time.

SITE 9D (129 m w.d.)

112/GS/071: Surface sediment is olive grey, muddy sand with 30-40% shell fragments and worm tubes.
112/BC/083: Recovery: 15 cm. Sediment is same as grab.
112/VC/110: Penetration: 570 cm; Recovery: 500 cm. Some loss out bottom of barrel as fingers of core catcher bent downward.
Entire core contains very to fine-grained olive grey sand with varying amounts of mud. Scattered whole shells (bivalves) and shell fragments; some thin-walled shells are intact. Slight increase in mud with depth down the core and distinct shelly layers. At 380-390 cm there is an increase in carbonate and also angular, cemented aggregate fragments. Wood fragment at 430 cm to be radiocarbon dated.

SITE 9E (138 m w.d.)

112/GS/072: Surface sediment is slightly muddy, carbonate-rich iron-stained sand.
112/VC/111: Penetration: 225 cm; Recovery: 209 cm. (core catcher in good condition, though cemented sand nodule of 2-3 cm diameter was jammed in fingers). Core appears to be disturbed/"graded" during coring.
Slightly muddy, carbonate sand at surface becoming coarser downward, with cemented calcareous sand nodules and large pectenid shells at base of core. Between 100-130 cm, there is a fine-grained, olive grey slightly muddy sand unit (like mid shelf).

SITE 9F (150 m w.d.)

112/GS/073: Surface sediment is very slightly muddy, carbonate-rich sand (both shell and quartz are iron-stained).
112/VC/139: Penetration: 500 cm; Recovery: 422 cm; some compaction.
Top of core contains foraminiferal sand overlying slightly muddy fine sand to a sharp contact at 48 cm. Below the contact, the sand is coarse, iron-stained and poorly sorted, and contains a thick sequence of interlocking pectenid valves oriented horizontally across the core barrel. At 123 cm there is a rapid transition to fine sand with somewhat coarser shell fragments; the sand is calcareous and contains thin-walled bivalves and virtually no pectenid valves. At 230 cm, this unit grades into a slightly muddy sand which is the uppermost part of a fining up sequence (and may be the partial source of the foraminiferal sand at the top of the core). A sharp contact a 272 cm occurs above another sequence of iron-stained, poorly sorted coarse sand and pectenid valves. The base of the core contains grey-brown, finer sand with fewer valves.

LINE 10 TERRIGAL
SITE 10A (96 m w.d.) - Additional site for geochemistry sampling.

112/GS/103: Surface sediment is muddy sand.

SITE 10B (132 m w.d.) - Additional site for geochemistry sampling.

112/GS/102: Surface sediment is olive mud with minor very fine sand.
112/BC/090: Recovery: 10 cm. Mud at the surface with a shell layer at base of core; surface is undisturbed.

SITE 10C (139 m w.d.) - Additional site for geochemistry sampling.

112/GS/101: Surface sediment is olive, slightly muddy sand.

LINE 11 TUGGERAH LAKE
SITE 11A (46 m w.d.)

112/GS/100: Surface sediment is fine-coarse, quartzose sand with iron-stained quartz granules.
112/VC/138: Penetration: 200 cm; Recovery: 204 cm; may have hammered on hard subsurface layer.
Top of core contains thin mud layer overlying 35 cm of iron-stained, moderately-poorly sorted clean quartzose sand with relatively little shell. Beneath a disturbed gradational contact, the sand coarsens and becomes extremely poorly sorted with large shell fragments down to 120 cm. The lowermost unit is poorly sorted, fine to coarse sand with some heavily iron-stained quartz granules.

SITE 11B (75 m w.d.)

112/GS/098: Limited recovery; re-sampled.
112/GS/099: Surface sediment is very slightly muddy, fine to coarse quartz sand.
112/VC/137: Penetration: 430 cm; Recovery: 385 cm.
Top of core contains muddy, moderately well sorted, fine to medium-grained sand with fine shell fragments down to approximately 100 cm; there is also evidence of some transport of sediment along the sides of the core barrel from unit below. A gradational, disturbed contact at 100 cm separates the fine sand from primarily coarse, poorly sorted sand which continues down to a sharp contact at 184 cm. This is underlain by very slightly muddy, dark grey fine sand with multiple layers (5-10 cm thick) of mottled, shelly poorly sorted, coarse sand. The

basal 10 cm of the core is fine to coarse, slightly muddy sand with coraline algae and a large piece of cemented calcarenite (similar to base of core 136).

SITE 11C (125 m w.d.)

112/GS/095: No recovery.
112/GS/096: No recovery. Moved site slightly to recover sediment.
112/GS/097: Surface sediment is sandy mud with abundant worm tubes; also contains small pea-sized gravel in base of grab.
112/VC/136: Penetration: approximately 400 cm, but difficult to determine; Recovery: 330 cm. Top of core contained liquefied mud, some of which was lost during cutting, and much of the sequence in the upper 134 cm of core appears to have been artificially produced as a result of vibration.
The recovered core contained muddy silt and sand, which becomes coarser and less well sorted down to 134 cm (possibly artificially-see above). The grain size and proportion of carbonate fragments increases down the unit; composition includes bivalve fragments, cephlapods, and thick echinoderm spines. Below 134 cm, the sediment is intact, olive-grey very muddy fine sand containing articulated bivalves, cephlapods, gastropods (typical mid-shelf fauna) down to a 15 cm thick layer of poorly sorted, muddy sand and shell gravel (with sharp upper and lower contacts). This is underlain by a grey-black muddy very fine sand (estuarine?) with fine-coarse shell fragments throughout and organic patches at 278-290 cm. The basal unit of the core is 35 cm of cemented calcarenite, and a black volcanic rock fragment (the latter may have moved up along the side of the barrel during vibration).

SITE 11D (137 m w.d.)

112/GS/094: Surface sediment is very muddy, fine-grained calcareous sand.
112/VC/135: Penetration: 120 cm; Recovery: 203 cm; core is artificially graded.
Top of core contains buff-coloured, fine silty foraminiferal sand (probable artefact of vibration) overlying fine to coarse, poorly sorted, iron-stained quartzose sand with 50% carbonate fragments; sequence coarsens and becomes more poorly sorted with depth. Base of core contains pectenid valves, small pebbles (1 cm) and miscellaneous shell fragments.

SITE 11E (150 m w.d.)

112/GS/093: Surface sediment is slightly muddy, fine-medium grained calcareous sand.
112/VC/134: Penetration: 514 cm; Recovery: 506 cm.
Top of core contains a 5 cm thick layer of foraminiferal sand, overlying very poorly sorted, calcareous, iron-stained fine-coarse grained sand with shell gravel. Some of shells are horizontally packed in core barrel. Below a gradational contact at 115 cm, the sand is

extremely poorly sorted, non-iron st: ed calcareous sand and shell gravel with large pectenid valves in a layers at 190 cm, 360-40(1, and in basal section of core.

LINE 13 NEWCASTLE
SITE 13A (36 m w.d.)

112/GS/092: Surface sediment is clean, medium-grained quartzose sand.
112/VC/133: Penetration: 198 cm; Recovery: 106 cm (poor performance by vibrocorer as no basal gravel to prevent penetration).
Top of core is composed of clean, medium to coarse, moderately sorted quartz sand with scattered shell fragments. Coarse granular layer at approximately 50 cm probably represents base of zone of contemporary reworking. Underlying sand unit is light fawn and less oxidised than the upper unit.

SITE 13B (80 m w.d.)

112/GS/091: Surface sediment is soft ('gooey") slightly sandy mud.
112/BC/088: Recovery: 30 cm; same as surface sample.
112/VC/132: Penetration: 565 cm; Recovery: 369 cm.
Top of core contains soft grey mud with trace sand. Proportion of sand increases downward, becoming predominantly sand below 50 cm. The sand is uniformly fine grained, well sorted and quartzose with minor shell fragments. Muddy sand containing occasional shell layers of mid shelf species continues down to 330 cm where it grades into black-grey sandy mud with fine charcoal fragments.

SITE 13H (104 m w.d.) - Additional site for geochemistry sampling.

112/GS/090: Surface sediment is dark olive grey, slightly sandy mud with worm tubes.
112/BC/087: Recovery: 45 cm; sediment same as grab sample.

SITE 13C (117 m w.d.)

112/GS/089: Surface sediment is slightly sandy, dark olive grey mud.
112/BC/086: Recovery: 30 cm; sediment is same as grab sample.
112/VC/131: Penetration: 420 cm; Recovery: approximately 400 cm; core full of liquid mud and will be opened in Sydney.

SITE 13D (123 m w.d.)

112/GS/087: Surface sediment is olive grey, muddy sand and abundant carbonate fragments.
112/VC/130: Penetration: 400 cm; Recovery: 357 cm.
Top of core contains dark olive grey, muddy fine sand grading down into less muddy sand. The sand is fine-grained and moderately uniform throughout. Shell layers define a number of coarsening downward sequences, each of which is 40-60 cm thick. Pectenid valves dominate in most layers, but some shell layers are composed of other shelf species, such as Placamen, and appear to contain no pectenid shells.

SITE 13I (124 m w.d.) - Additional site for geochemistry sampling.

112/GS/088: Surface sediment is olive grey fine sand with abundant worm tubes.
112/BC/085: Recovery: 25 cm; sediment is same as grab sample.

SITE 13J (127 m w.d.) - Additional site for geochemistry sampling.

112/GS/086: Surface sediment is muddy, carbonate-rich sand with abundant worm tubes.
112/BC/084: Recovery: 10 cm; sediment is same as grab sample.

SITE 13E (130 m w.d.)

112/GS/085: Surface sediment is carbonate-rich fine sand.
112/VC/129: Penetration: 175 cm; Recovery: 131 cm.
Top of core contains a foraminiferal sand layer (probably artefact of vibrocoring technique) overlying olive grey mixed quartz-carbonate sand with minor mud and layers of shell gravel. Shell layers define bases of a number of coarsening down sequences to the base of the core at 131 cm.

SITE 13F (138 m w.d.)

112/GS/084: Surface sediment is fine carbonate sand with trace mud.
112/VC/128: Penetration: 200 cm; Recovery: 192 cm.
Top of core contains grey-brown fine carbonate sand that shows a number of very subtle coarsening downward sequences. Iron-stained grains are carbonate primarily and less commonly rounded quartz granules. The core bottomed at 190 cm in a coarse shell gravel and nodules of cemented sand.

SITE 13G (146 m w.d.)

112/GS/083: Surface sediment is moderately fine-grained, well-sorted calcareous sand with large shells.
112/VC/127: Penetration: 350 cm; Recovery: 295 cm.
Top of core contains light brown, fine to medium grained calcareous sand and scattered shells that coarsens downward; shell fragments are iron-stained. Coarse sand with large shells (mainly pectenid) and shell gravel occurs from 70-215 cm, and overlays a basal unit of finer grained, more uniform sand with scattered shells.

LINE 15 PORT STEPHENS
SITE 15A (36 m w.d.)

112/GS/082: Surface sediment is clean quartz sand.
112/VC/125: Penetration: 163 cm; Recovery: 192 cm.
112/VC/126: Penetration: 215 cm; Recovery: 103 cm.
Top core contains clean, fawn-coloured oxidised (iron-stained) quartz sand that is uniformly medium grained and moderately sorted, with scattered shell fragments and rare small pebbles. The sand becomes less iron-stained below a thin shelly layer at 25 cm (? base of zone of contemporary reworking).

SITE 15B (84 m w.d.)

112/GS/081: Surface sediment is olive grey, slightly sand mud with worm tubes.
112/BC/089: Recovery: 40 cm; sediment is same as grab sample.
112/VC/124: Penetration: 230 cm; Recovery: 295 cm.
Top of core contains slightly sandy mud at least 40 cm thick grading down into fine to coarse quartz calcareous sand to about 130 cm. 80 cm of dark olive grey mud occurs below 130 cm and overlies a downward coarsening clastic gravel layer, composed of well-rounded siliceous pebbles and less common shell fragments. Core bottomed at 230 cm.

SITE 15C (111 m w.d.)

112/GS/080: Surface sediment is muddy, calcareous-rich sand; abundant worm tubes.
112/VC/122: Penetration: 65-70 cm; Recovery: 73 cm.
112/VC/123: Penetration: 20 cm; Recovery: 20 cm (as disturbed/core catcher sample).
Top of core 122 contained slightly muddy quartzose sand with abundant shell fragments and valves down to a gradational contact at 22 cm. Below contact, the proportion of whole shells and fragments increase, as does the proportion of coarse sand. Basal 35 cm of core contains

gravel composed of cemented pebbles, pectenid valves, echinoderm spines, coral, bryozoa, etc. Core 123 recovered only 20 cm of muddy sand, like the surface grab sample.

SITE 15D (139 m w.d.)

112/GS/079: Surface sediment is fine to coarse, poorly sorted carbonate-rich sand.
112/VC/121: Penetration: 460 cm; Recovery: 372 cm.
Top of core contained 36 cm of fine to coarse muddy, iron-stained quartz sand and sand-sized shell fragments overlying 130 cm of very poorly sorted, iron-stained sand and abundant quartzose pebbles and pectenid valves; the latter are horizontally oriented. Below 164 cm, the matrix fines and becomes muddy, and numerous pectenid valves occur especially between 175-185 cm and 250-290 cm; iron-stained quartz pebbles and shell fragments are common throughout. The basal unit is similar, though generally less muddy, except for the last 15 cm which is muddy sand.

SITE 15E (141 m w.d.)

112/GS/078: Surface sediment is clean, brown calcareous sand with large "pebble" of cemented sand and encrusting algae.
112/VC/119: No recovery; hammered on hard substrate (carbonate cemented?) for 4 min.
112/VC/120: No recovery; hammered on hard substrate (carbonate cemented?) for 4 min.
Presumably the seabed is current scoured.

LINE 17 SEAL ROCKS
SITE 17A (80 m w.d.)

112/GS/077: Surface sediment is very slightly muddy, olive grey sand.
112/VC/116: Penetration: 213 cm; Recovery: 521 cm (severe expansion of core).
112/VC/117: No recovery.
112/VC/118: Penetration: 395 cm; Recovery: 400 cm.
Top of core contains very slightly muddy light olive grey sand that becomes non-muddy just below the surface. The sand is uniformly fine-grained and well-sorted, quartzose sand with approximately 10% fine angular shell fragments. A sharp contact at 3.2 m separates the quartzose sand from a basal unit of grey, coarse calcareous sand that coarsens downward to fine shell gravel and coarse abraded shell; less common rounded siliceous pebbles are found at the base. A minor matrix of fine sand in shell gravel decreases down the core.

SITE 17B (103 m w.d.)

112/GS/076: Surface sediment is very slightly muddy calcareous sand.
112/VC/114: No recovery.
112/VC/115: Penetration: 257 cm; Recovery: 413 cm (bottom of core hammered; core expanded).
Top of core to 25 cm contains very slightly muddy, fine-grained dark olive grey sand. Below 25 cm, the sand is grey, very calcareous, medium to coarse-grained and moderately well-sorted (very little quartz); there is a subtle overall coarsening downward trend. The core bottomed in coarse shell gravel and some cemented pebbles at 4.0 m.

SITE 17C (109 m w.d.)

112/GS/075: Surface sediment is clean, poorly sorted, fine to coarse, calcareous sand.
112/VC/113: Penetration: 340 cm; Recovery: 273 cm.
Top of core contains brown, medium to coarse calcareous sand with a trace of mud that decreases with depth. Calcareous detritus is iron-stained, moderately sorted and non-graded. It is composed of fragments of shell, minor calcareous algae and bryozoa (all abraded to varying degrees).

SITE 17D (137 m w.d.)

112/GS/074: Surface sediment is fine-coarse, carbonate rich sand with bryozoa and calcareous algae.
112/VC/112: Penetration: 250 cm; Recovery: 257 cm.
Top of core contains greyish brown, fine to coarse shelly sand with trace mud; grades downward into brown, iron-stained calcareous sand that becomes progressively more coarse with depth. Cemented sand pebbles and shell gravel, including large pectenid valves, occur at base (approximately 250 cm).

4.5 Shelf Sedimentation Results

Samples collected on the central NSW shelf, along 9 across-shelf transects, included 57 grab samples, 11 box cores, 4 gravity cores and 58 vibrocores (Fig. 4.1; Section 4.4). The vibrocores span a depth range of 30-168 m and constitute the first subsurface data set from the outer continental shelf of central NSW. Preliminary descriptions of the grab samples and logging of the vibrocores, enable generalisations to be made about the patterns of shelf sedimentation between Port Stephens and Shoalhaven Bight. Future detailed analyses, including sedimentology, mineralogy, microfauna, and dating will provide the necessary information to develop an evolutionary stratigraphic model characterising shelf sedimentation.

During the 9.5 days the vessel operated on the shelf, 57 sites were sampled, but vibrocores were collected only at 43 sites. At these, 70 cores were attempted and 58 recovered; dual cores were collected at 15 sites. Overall, the average penetration was 3.1 m and the recovery was 2.8 m. Sixteen cores penetrated 4.0 m or more, but only 8 recovered this much sediment (excluding those cores artificially expanded or disturbed). Of the 58 cores recovered, 24 (41%) hit hard layers of gravel or cemented sand that stopped penetration prematurely. Most core recoveries were similar to penetration (+/- 30%), but 7 cores expanded by more than 50%, thus severely disturbing the natural stratigraphy. All the expanded cores except one hit hard layers a metre or so into the sea bed, based on the depth of penetration marks on the side of the core barrel. The reasons for the expansion or disturbance of the vibrocores are discussed in Appendix B.

Strong southward-flowing currents, believed to be associated with the East Australian Current, persisted on the shelf during most of Cruise 112B. While current velocity and direction were not measured directly, qualitative estimates of 0.5 to 1.5 m/sec (at the surface) are based on the response of both the ship and sampling equipment that was lowered overboard. Currents were particularly strong on the outer shelf, and at several sites the energetic conditions hindered vibrocoring and gravity coring.

Many vibrocores encountered a thin sediment sequence (<2 m) and bottomed in a gravel layer composed primarily of shells, cemented nodules or clastic pebbles, which probably represents an erosional unconformity. In places the coarse gravel layer appears to coincide with bedrock, or the inferred top of the Tertiary sequence (identified on the boomer records), but it is unlikely that the gravel everywhere forms the base of the Quaternary sediment. Thicker Quaternary sequences (> 4 m) were encountered on the inner shelf, as discussed in detail below, and on the outermost shelf in a carbonate sand sequence that contains cyclic (graded) bedding (Site 5E) and numerous shell layers (site 9F, 11E, 15D). Core 5E shows evidence of incipient cementation at depth, and may be quite old.

Preliminary interpretation of the surface samples and vibrocores indicates that Quaternary shelf sediment belongs to one of three general lithofacies (see Figs. 4.2, 4.3):

* an inner shelf clastic (quartzose) sand facies
* a mid shelf mud to muddy sand facies (mixed clastic and carbonate)
* an outer shelf calcareous sand facies

While these three facies have been identified previously on the basis of surface sediment samples from the entire NSW shelf (eg., Shirley, 1964; Davies, 1979; Marshall, 1980; Roy and Thom, 1981; Colwell, 1982; Clark, 1985), the new vibrocore data provide the first indication of the subsurface extent of the middle and outer shelf sedimentary facies.

Results from this cruise and previous studies indicate that the inner shelf clastic sand lithofacies varies considerably in thickness, due in part to the irregular nature of the basement surface. Inner shelf sand reaches a maximum thickness of 20-30 m in (1) shelf sand bodies (SSB) along steep sections of the south Sydney and Seal Rocks coast (Roy, 1984; Hudson, 1985; Ferland, 1990), (2) flood tide deltas in drowned river valleys (Roy, 1983; Albani et al., 1988), and (3) barrier complexes in shallow embayments. There is also a marked difference in the texture of inner shelf sediment, although the composition is usually dominated by quartz. The fine sands in cores at site 5A may belong to the transgressive (lower shoreface) facies of the Sydney SSB. Fluvial-estuarine sequences probably occur extensively in the deeper parts of drowned valleys transecting the inner shelf, however these sequences were encountered during Cruise 112 only in cores collected at Sites 3A and 9A.

The mid shelf muddy sand facies is a surficial deposit, at least 3 m thick (Site 7C, Fig. 4.3) in water depths of 70-125 m which is located immediately inshore of the decrease in shelf gradient. This muddy zone probably represents a low-energy window between the wave/storm-dominated inner shelf and the current-dominated outer shelf (Roy and Thom, 1981). In Figure 4.2, two areas of very muddy sediment occur within the zone of muddy sand in water depths of 100-120 m, and are here referred to as the 'mud belt' (approximately >70 % mud); The mud belt adjacent to Newcastle may be due, in part, to lower-energy shelf currents that characterise this region, which is located within the East Australian Current shadow zone identified by Godfrey et al. (1980). The explanation for the mud belt on the mid shelf between Sydney and Wollongong is less clear, especially since the shelf is much narrower than off Newcastle. Surprisingly, the shelf adjacent to Broken Bay does not seem to be as muddy as elsewhere, despite the proximity of a major river.

The clastic sand facies thins seaward and may be underlain by basal gravels in the mid shelf region. To the south of Sydney the contact, between the inner shelf quartzose sand and the outer shelf carbonate sand, coincides approximately with the inner margin of the outer shelf plain in water depths of 130 m. To the north of Sydney, the clastic sand facies appears to widen, and its contact with the carbonate sand facies is located mid way across the outer shelf plain (Fig. 4.2). Here it becomes increasingly calcareous and grades into outer shelf calcareous sands. Typically, these are slightly muddy and poorly sorted, and range in size from fine sand to shell gravel. They are made up mainly of angular fragments of shell (large pectenid valves are common); bryozoa, calcareous algae and foraminifer; detrital quartz is fine to very fine and decreases in proportion in a seaward direction. There is some evidence of diagenesis, including both incipient cementation and oxidation, and the basal gravels underlying the sands commonly contain *in situ* cemented nodules. Previous analysis of a limited number of outer shelf samples show that sediments southeast of Newcastle are more quartzitic than elsewhere in the Cruise

112B study area (Davies, 1979). However, detailed comparisons await the results of quantitative analyses on vibrocore and grab samples from the present study.

The mid shelf mud facies is thought to be the product of post-glacial sedimentation, primarily during the Holocene stillstand (Roy and Thom, 1981), although Davies (1979) suggests that deposition occurred during a period of lower sea level. The quartzose inner shelf and calcareous outer shelf sand lithofacies, on the other hand, are probably the product of a number of glacial-eustatic cycles (Marshall and Davies, 1978; Roy and Thom, 1981). The moderately well-rounded quartz grains and relatively mature mineralogy of the inner shelf sand support the idea, as does the existence of dated marine coastal deposits elsewhere on the inner shelf (Kudrass, 1982; Roy et al., 1992; Roy et al., in prep.).

The tripartite subdivision of the Quaternary shelf lithofacies agrees with earlier work based on grab sampling alone (Davies, 1979; Marshall, 1980). Apparently throughout the late Quaternary, the deposition of terrigenous sand has been confined mainly to the inner shelf. This is probably due to the combination of waves and littoral currents which reworked and transported sand alongshore, and the low continental denudation rates and hence relatively low supply of sand to the shelf by rivers (Bishop, 1985; Young, 1983). Wave action at the coast was apparently sufficient to inhibit the seaward dispersal of all except the finest clastic sediment. The powerful effect of littoral drift, operating at virtually all positions of sea level has ensured that clastic sand is transported alongshore, mainly to the north, at rates that are generally faster than it is supplied. Sediment sampled in the vibrocores indicates that even during periods of low sea level (approximately 120 to 140 m below PSL), the outer shelf plain has probably remained a marine-dominated carbonate production zone (Fig. 4.3), with minimal deposition of clastic sand supplied from the continent. Thus, the partitioning of lithofacies observed on the central NSW shelf may have operated throughout the Quaternary, under the influence of rapid sea level oscillations.

4.6 Mineral Resources Potential

The partitioning of the shelf lithofacies into quartzose sand and carbonate sediment, as described above, has the effect of limiting the mineral resource potential of the shelf to its inner part, specifically to the zone inshore of about 70 m water depth that is not blanketed by mid shelf mud. At our present stage of knowledge, the mineral resources of the shelf are heavy minerals, in placer-like deposits, and marine aggregate, primarily of use to the construction industry. Both types of mineral deposits are associated with the clastic sandy sediment, shed originally from the continent and now found on the inner shelf.

The occurrence of economic heavy minerals, such as rutile, zircon, ilmenite and monazite, is known to be related to the distribution of drowned barriers and shelf sand bodies (Roy et al, 1991, 1992, In prep.). These features are site specific and occur at a number of sites within the area encompassed by Cruise 112. Shelf sand bodies occur off the southern Sydney coast, off Morna Point just south of Port Stephens, and off Seal Rocks. Drowned barriers are thought to occur in Newcastle Bight and off Belmont (15 km south of Newcastle). Delineation of these features, and assessment of their mineral potential, require detailed investigation of the type carried out by industry and the Geological Survey of NSW over the past few years in the Forster-Tuncurry area (eg., Roy et al., 1991).

The heavy mineral content of the inner shelf sand sampled on Cruise 112 will be determined during post-cruise analyses. While the wide spacing of the cores will not allow full assessment of heavy minerals and aggregate resources, the results provide a framework within which to evaluate the resource potential of various shelf regions and depositional environments.

Marine aggregate sand and gravel-sized sediment composed of quartz, resistant rock fragments and minor shell fragments, were encountered in most inner shelf samples and are widespread along this coast. Gravel layers were encountered frequently in the shelf cores, but these are thought to be quite thin and not of economic importance. In contrast, the areas with greatest aggregate potential are in Shoalhaven and Newcastle Bights, where large rivers existing in the past have deposited coarse sand and gravel in water depths of less than 60 m. However, suitable sand is quite widespread on the inner shelf, and constraints on the future development of marine aggregate will have more to do with accessibility and proximity to markets than to geology.

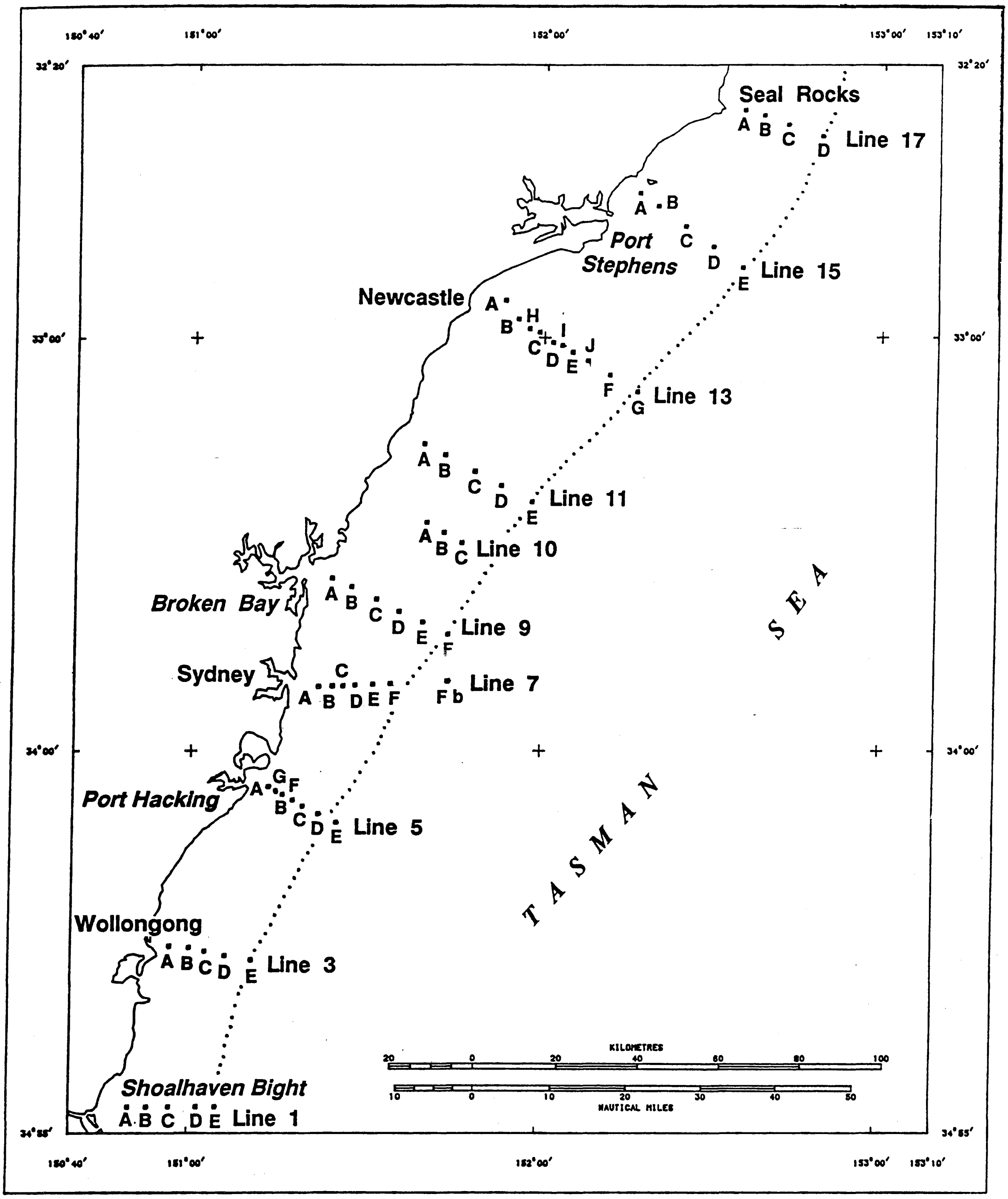


Fig. 4.1 Sample site map for shelf samples.

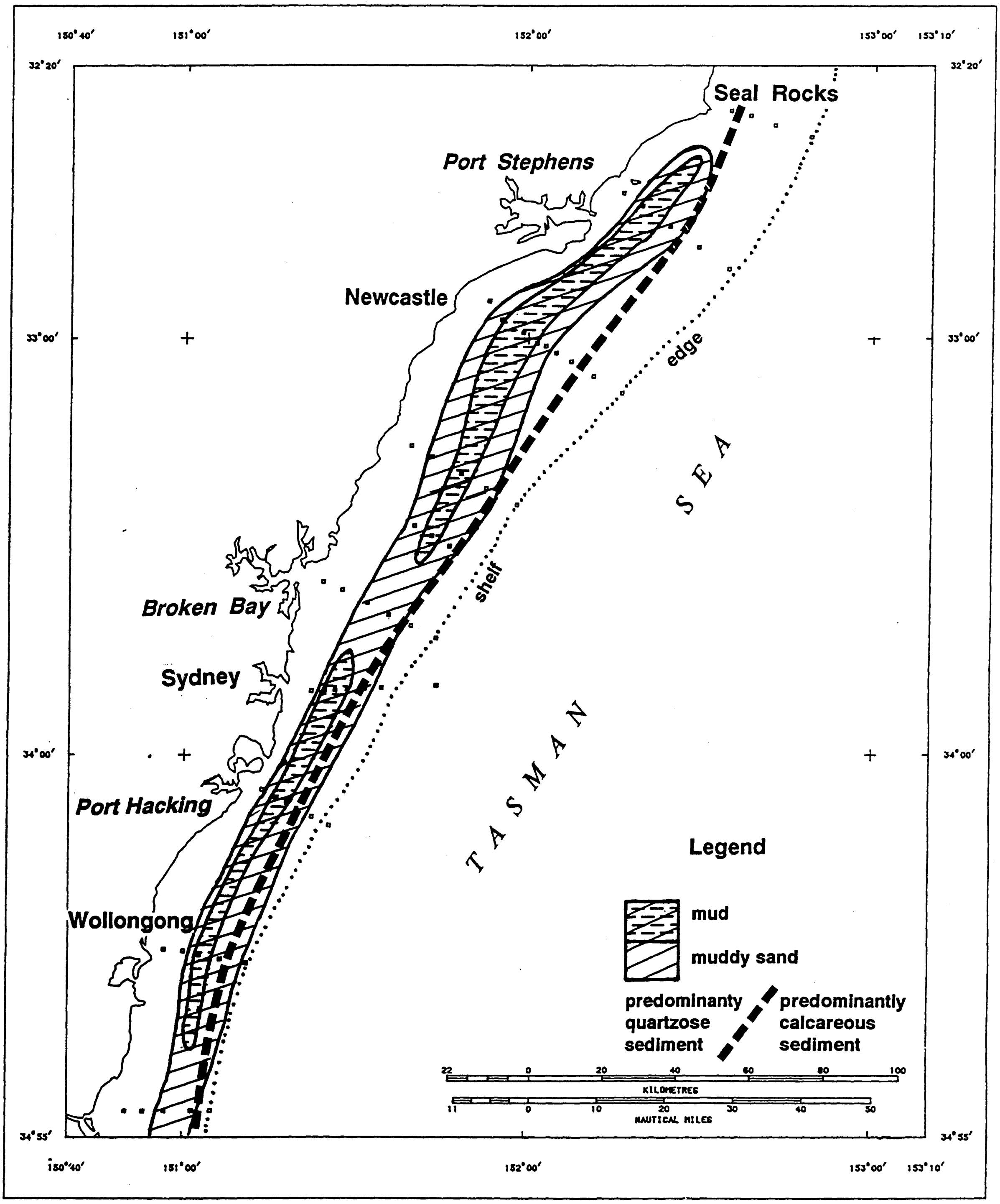


Fig. 4.2 Map delineating the mid shelf mud belt and the boundary between quartzose and carbonate sediments.

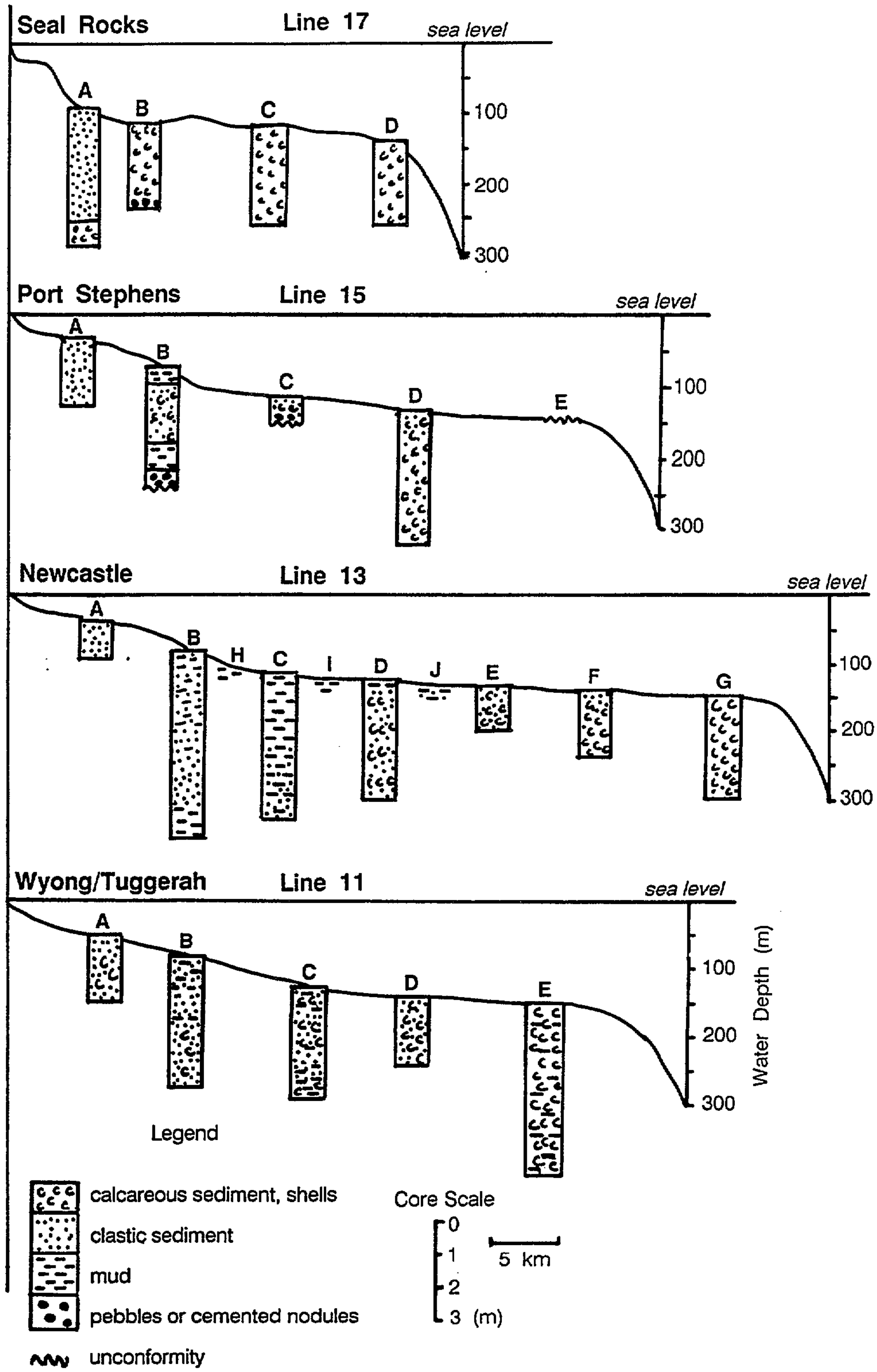
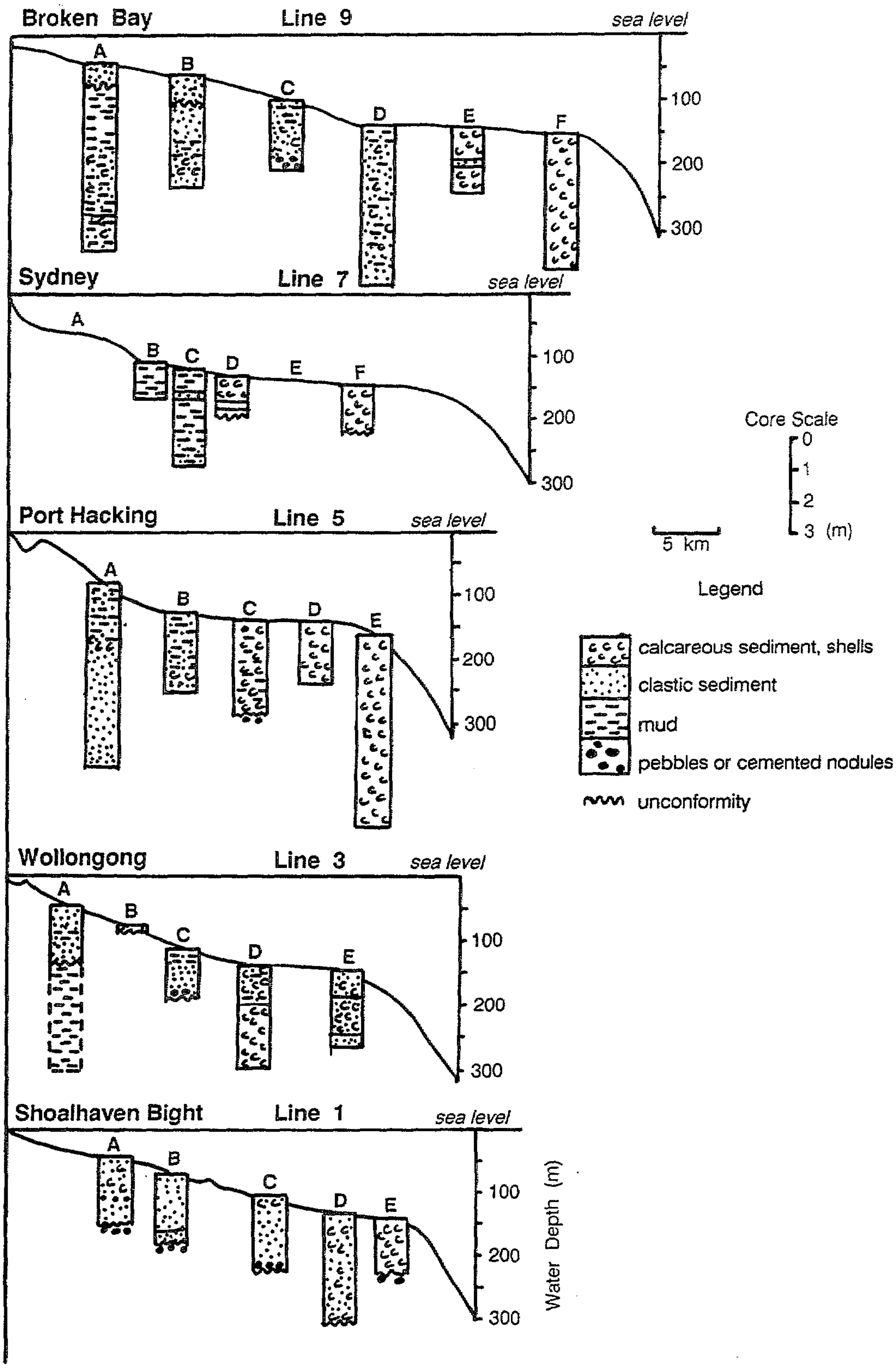


Fig. 4.3 Shelf cross-sections showing the character of late Quaternary sediment based on preliminary interpretation of the vibrocores.



Broken Bay
Line 9
sea level
A
B
C
D
E
F
100
200
300
Sydney
Line 7
sea level
A
B
C
D
E
F
100
200
300
Port Hacking
Line 5
sea level
A
B
C
D
E
100
200
300
Wollongong
Line 3
sea level
A
B
C
D
E
100
200
300
Shoalhaven Bight
Line 1
sea level
A
B
C
D
E
100
200
300
Water Depth (m)
Core Scale
0
1
2
3 (m)
5 km
Legend
calcareous sediment, shells
clastic sediment
mud
pebbles or cemented nodules
unconformity

5. Geochemistry of Contemporary Shelf Sediments

5.1 Background

The central NSW coast is the most densely urbanised and industrialised area in Australia. Waste from Newcastle, Sydney, Wollongong and Port Kembla have been discharged into the ocean for 100 years and, as a result, adjacent continental shelf sediments have become contaminated with heavy metals and organic residues. Davies (1974, 1979) found arsenic concentrations up to 0.18 mg/g off Wollongong. Birch and Davey (subm.) and Batley (CSIRO, pers. comm., 1990) have also identified high levels of Ni, Cu, Zn, Pb and Hg in surficial sediments off Sydney. Because contaminants originate from three metropolitan centres and shelf water movements are energetic, along-shelf mixing of the contaminated sediments is expected and the contaminants may act as a tracer indicating modern sediment dispersal pathways.

5.2 Objectives

The objectives were:

1. to delineate the nature, concentration and provenance of organic and metallic contaminants in surficial shelf sediments located adjacent to the urban and industrial centres;
2. to establish present baseline and historical background data sets, and construct a contaminant stratigraphy for the mid shelf sediments;
3. to study the nature and mechanisms of fixation and release of contaminants from marine sediments; and
4. to use assemblages of contaminants to identify sources and dispersal pathways for suspended sediments on the open shelf.

The results of this research have direct significance to the following government and industrial programs:

a. monitoring of the new Sydney deepwater sewage outfalls (Environmental Protection Authority, Fisheries Research Institute);
b. dumping of dredge spoils off Newcastle and Sydney;
c. evaluation of sewage ocean outfalls (Sydney Water Board); and
d. geochemical investigation of pollutants in sediments off Wollongong (Jones and Ohmsen, University of. Wollongong).

5.3 Methods

5.3.1 Sample Acquisition

There is no universally accepted methodology for collecting an uncontaminated, perfectly representative sample of the seabed for all sediment types for geochemical analyses. The optimum sampling strategy is determined by the nature of the sediment and whether a surficial or vertical sample distribution is required. In order to fulfil all requirements, a variety of sampling devices was used, ie. grab, vibrocorer, box core and gravity core.

Acquiring an uncontaminated, representative sample of seabed comprising predominantly (>90%) sand-size material (>63 micron) is difficult. Experience gained on Cruise 112B indicates that vibrocoring may produce a graded interval toward the top of the core (see discussion, Appendix B). Fines (silt and clay) are vibrated up the core barrel through the coarser sediment and, either concentrate as a 'mud cap' at the uppermost surface, or are completely lost to the water column. For this reason, vibrocoring was not considered to be representative for surficial samples of sandy sediment. Fines may also be winnowed from grab samplers and box cores are unable to penetrate sandy substrates.

Obtaining a representative sandy sample is therefore difficult regardless of what device is used. However, because our approach to contaminant research is to use only size-normalised (<63 micron) material for geochemical analysis, the proportion of fines in the sample is irrelevant and the problem of winnowing is alleviated. Size-normalisation is used to allow inter-sample comparability and to assist in determination of source and dispersal of contaminants. The large quantities of material required for sufficient fines in sandy sediment was obtained by taking bulk samples from the centre of a teflon-coated grab. Potential contamination by metals used in the construction of the grab will be ascertained by comparing box core and grab samples taken at the same sites. For vertical (chronological) contamination studies, vibrocoring is the only option in sandy sediment. Vibration-induced grading has been noted, and thus vertical analyses of vibrocore material are probably only valid after thorough examination of the core for disturbance.

Muddy sands (10-50% mud) are cohesive enough to remain essentially undisturbed during sampling, except for the uppermost microlayer (top few mm). As the box core cannot penetrate this material, the centre of the teflon-coated grab was used for surficial contaminant analyses. Push cores were also pushed into the grab for surficial sediment subsamples. Vibrocores were used for vertical distribution analysis after examination for disturbance. Gravity cores generally do not penetrate this substrate type.

Obtaining an undisturbed sample of muddy sediment is generally not problematical because of the cohesive nature of the material. Both the grab and the box core were used for surficial sediment acquisition, and push cores taken from these devices gave limited vertical (up to 40 cm) information. For data from greater depths, either a gravity core or vibrocore is appropriate. The former gave 3 m undisturbed cores, whereas the vibrocore regularly produced 3-5 m penetration. Both the vibrocorer and the gravity core can "pile-drive" if the mud is highly cohesive. The vibration mechanism consistently hydrated the upper part of vibrocores and surficial mud was lost to the water column whereas the top of gravity cores are generally undisturbed.

Multiple samples were collected at each sample station according to the procedure outlined below.

5.3.2 Pore water Geochemistry

This is a pilot study of the geochemistry of the pore waters of a select number of sample sites located in the mid shelf mud belt. The pore water data will be related to the same heavy metal parameters of the sediment in an attempt to understand some of the fundamental processes whereby the trace elements are being fixed in the substrate, and more importantly whether these metals are being recycled back into the water column.

The distribution of samples for pore water analysis was designed to test several aspects of variability. The samples are spread over the entire north-south extent of the mid shelf mud belt to determine any regional differences in geochemistry, possibly relating to the proximity of the Newcastle, Sydney, and Wollongong/Port Kembla urban/industrial centres. Box core samples were taken at 2 to 5 nm apart at 5 sites on the same line (Line 13) to test mesoscale spatial variability. At a smaller spatial scale two push cores from the same box core (BC/083) are being examined for small scale variability. A push core from an undisturbed grab (GS/071) sample at the same site (9D) is being analysed to determine the magnitude of chemical and textural variation between box cores and grab samples.

Push cores (90 mm, 70 mm and 50 mm diameter polycarbonate tubing) were inserted into the box core and carefully capped top and bottom before retrieval of the core. This allowed the uppermost microlayer (topmost 1-3 mm) of sediment and the overlying seawater to be collected intact, and it also prevented oxidation of the sediment and pore water. The water-sediment interface was collected in such a pristine state that micro-organisms could be observed still actively burrowing and crawling about on the surface. Worm tubes were still extended and pumping water. Push cores were immediately stored at $4^{o}C$.

Within 24-36 hours, push cores were vertically subsampled for pore water extraction. Push cores were placed in a glove bag, air extracted, and sealed under N_2. Push core caps were removed and 15 mm slices (sufficient to neatly fit a centrifuge tube) were taken down the core, using acid-washed and seawater-rinsed polycarbonate utensils. The vials were tightly capped under N_2 and centrifuged at a constant temperature of $4^{o}C$ for 8 minutes at 15000 RPM. Supernatant fluid was withdrawn using a plastic syringe, filtered through a 0.45 micron millipore filter and acidified (2 pH). Associated sediment was kept and stored at $4^{o}C$ for trace metal geochemical analysis.

5.3.3 Surficial Sediment Geochemistry

In addition to the pore water geochemical samples, additional push cores were collected to investigate geochemical changes in the uppermost 20-40 cm of sediment. Because the upper sections of vibrocores are susceptible to disturbance, push cores were taken in undisturbed grabs and in box cores to examine in detail small-scale vertical variance in metal distribution. Fifteen millimetre down-core sections were subsampled and stored at 4°C. These high resolution data will assist in determining the effect of bioturbation, physical turn-over in sediment and/or changes in contaminant supply. If satisfactory results are obtained, ^{137}Se and ^{238}Pb dating may be undertaken to ascertain chronological analysis. Push cores, of box cores and grabs from the same sites, were taken to assess the chemical and textural variation in the sediment collected by these two devices.

5.4 Inventory of samples

An inventory of samples, by site number, taken for heavy metal and organochlorine analyses is shown in Table 5.1. The numeral represents the line number and the alphameric is the station location on the line. Intervals for vibrocore and gravity core subsamples are in millimetres, and "pc" is used as an abbreviation for push core. Subsamples identified as "500 ml" or "125 ml" were collected in containers of that size; the containers were composed of polycarbonate, unless glass is specified.

The following subsampling procedure was employed:

Grab Samples: For disturbed samples, a 500 ml polycarbonate jar was filled with a scoop of sediment; a 125 ml glass jar was scoop-filled for organochlorine analysis; another 125 ml polycarbonate jar was scoop-filled for pathogen analysis by the Sydney Water Board, Scientific Services Branch; and a large bulk sample (+/- 4 litre) was taken. For undisturbed grab samples, an additional 500 ml polycarbonate push core was collected which was later logged and subsampled.

Box Cores: 90 mm, 70 mm, 50 mm polycarbonate push cores (pc) were collected for sediment and pore water geochemical analysis. The 90 mm core was split, logged, and subsampled. A 125 ml glass container was filled for organochlorine analysis and a bulk (+/- 4 litre) sample was taken.

Vibrocores and Gravity cores: Cores were split, described, and subsampled. Generally, the top of the core was subsampled every 100 mm down to 500 mm and thereafter at 200 mm or 300 mm intervals.

5.5 Results

5.5.1 Spatial and Temporal Data Sets

The total numbers of samples and subsamples collected for geochemical analyses, during the exceptionally successful program, are shown in Table 5.2. The large data set is sufficient to provide preliminary information on large scale spatial and temporal distribution of metallo- and organo-contaminants on the continental shelf adjacent to the biggest conurbation on the east coast of Australia. However, it is envisaged that more detailed sampling will have to be undertaken to improve the resolution.

5.5.2 Pore Water Geochemistry

Ten push core samples from 7 sites were subsampled in preparation for pore water geochemical analysis (see Table 5.3). The sites are located in the mid shelf mud belt on three lines from the south (Line 1), central (Line 9) and northern (Line 13) parts of the surveyed area. The 79 pore water samples and their associated sediments will be analysed for select trace metals, nutrients phosphates and nitrates and other pore water metabolites. These data will provide information on the relationship between the reduction-oxidation potential, the oxidation state of metals and their vertical distribution, and hence will provide essential information on the natural geochemical cycles of metals, particularly the early diagenetic reactions. An understanding of these internal recycling processes is essential in separating potential anthropogenic effects from natural concentration mechanisms.

5.5.3 Surficial Sediment Geochemistry

Fifteen push core samples from 12 sites on 6 lines were recovered for high resolution vertical distribution studies (see Table 5.4). Eight of these samples were from grabs, and the rest were collected from box cores. Push cores from grabs and box cores were taken at the same site to test for variance between the two devices. At least one sample was taken on each line that transected the mid shelf mud belt, to determine any large scale spatial variance in the uppermost sediment layer.

Table 5.1 Inventory of subsamples collected for geochemical analyses.

LINE 1		
Site 1A	GS/039	500 ml; 125 ml glass.
Site 1B	GS/040	500 ml pc; 125 ml glass.
	BC/078	90 mm pc; 70 mm pc; 50 mm pc; 125 ml glass.
Site 1C	GS/041	500 ml; 125 ml glass.
	VC/076	A:0-25; B:300-325; C:1140-1165.
Site 1D	GS/043	500 ml; 125 ml glass.
	VC/078	A:344-365; B:800-825; C:1650-1675.
Site 1E	GS/044	500 ml; 125 ml glass.
	VC/079	A:0-10; B:75-100; C:0-100 (combined).
	VC/080	A:0-25; B:250-275.
	VC/081	A:0-15.
LINE 3		
Site 3A	GS/045	500 ml; 125 ml glass; 1 bulk.
	VC/084	A:75-100; B:200-225; C:390-415; D:550-575; E:700-725; F:clast at 580; G:900-915.
Site 3B	GS/047	500 ml; 125 ml glass; 1 bulk.
	BC/079	90 mm pc; 70 mm pc; 50 mm pc; 125 ml glass; 1 bulk.
Site 3C	GS/048	500 ml pc; 125 ml; 125 ml glass; 1 bulk.
	BC/080	90 mm pc; 70 mm pc; 50 mm pc; 125 ml; 125 ml glass.
Site 3D	GS/049	500 ml pc; 125 ml; 125 ml glass; 1 bulk.
Site 3E	GS/050	500 ml pc; 125 ml; 125 ml glass; 1 bulk.
LINE 5		
Site 5A	GS/056	500 ml; 125 ml; 125 ml glass; 1 bulk.
	BC/082	90 mm pc; 70 mm pc; 50 mm pc; 125 ml glass; 1 bulk.
	VC/098	A:10-50; B:100-150; C:200-250; D:300-350; E:400-450; F:500-550; G:800-850; H:1000-1050; I:1500-1550; For organochlorines: A:50-75; B:150-175; C: 350-375; D:550-575.
Site 5B	GS/055	500 ml pc; 125 ml; 125 ml glass; 1 bulk.
	BC/081	90 mm pc; 70 mm pc; 50 mm pc; 125 ml; 125 ml glass; 1 bulk.

	VC/100	A:0-25; B:50-80; C:100-125; D:150-175; E:200-225; F:300-325; G:400-425; H:500-525; I:750-775; J:1000-1025; K:1500-1525.
Site 5C	GS/054	500 ml pc; 125 ml; 125 ml glass; 1 bulk.
Site 5D	GS/053	500 ml pc; 125 ml; 125 ml glass; 1 bulk.
Site 5E	GS/052	500 ml pc; 125 ml; 125 ml pc; 1 bulk.
Site 5F	GS/066	500 ml pc; 125 ml; 125 ml glass; 1 bulk
Site 5G	GS/067	500 ml pc; 125 ml; 125 ml glass; 1 bulk.

LINE 7

Site 7A	GS/057	500 ml pc; 125 ml; 125 ml glass; 1 bulk.
Site 7B	GS/059	500 ml; 500 ml pc; 125 ml; 125 ml glass; 1 bulk.
	GC/003	A:0-50; B:50-75; C:150-175; D:200-225; E:300-325; F:400-425; G:500-525; G1:700-725; H:900-925; I:1200-1225.
Site 7C	GS/060	500 ml; 500 ml pc; 125 mml; 125 ml glass; 1 bulk.
	GC/004	A:10-35; B:100-125; C:200-225; D:300-325; E:400-425; F:500-525; G:700-725; H:900-925 (metals).
	GC/004	A:50-75; B:150-175; C:250-275; D:350-375; E450-475; F:550-575; G:750-775; H:950-975 (organochlorines).
	VC/101	A:0-50; B:100-125; C:200-225;D:300-325; E:500-525; F:700-725; G:900-925; H:1300-1325; I:1800-1825.
Site 7D	GS/061	500 ml; 125 ml; 125 ml glass; 1 bulk.
	GC/006	A:0-100; B:150-175; C:0-250 (combined).
	VC/102	B:30-35; C:90-95.
Site 7E	GS/062	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 7F	GS/063	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 7G	GC/007	A:0-10.
Site 7H	GC/008	A:0-10.
Site 7I	GC/009	A:0-10.

LINE 9

Site 9A	GS/068	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 9B	GS/069	500 ml; 125 ml; 125 ml glass; 1 bulk.
	VC/106	A: 0-100.
Site 9C	GS/070	500 ml; 125 ml; 125 ml glass; 1 bulk.
	VC/109	A: 0-10 (mud cap possibly artefact of coring)

Site 9D	GS/071	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 9E	GS/072	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 9F	GS/073	500 ml; 125 ml; 125 ml glass; 1 bulk.

LINE 10

Site 10A	GS/103	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 10B	GS/102	500 ml; 125 ml; 125 ml glass; 1 bulk.
	BC/090	500 ml; 125 ml; 125 ml glass; 1 bulk; 500 ml pc (shell layer at base)
Site 10C	GS/101	500 ml; 125 ml; 125 ml glass; 1 bulk.

LINE 11

Site 11A	GS/100	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 11B	GS/099	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 11C	GS/097	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 11D	GS/094	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 11E	GS/093	500 ml; 125 ml; 125 ml glass; 1 bulk.

LINE 13

Site 13A	GS/092	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 13B	GS/091	500 ml; 125 ml; 125 ml glass; 1 bulk.
	BC/088	500 ml; 125 ml; 125 ml glass; 1 bulk; 70 mm pc (31 cm).
Site 13C	GS/089	500 ml; 125 ml; 125 ml glass; 1 bulk.
	BC/086	2 x 70 mm pc; 500 ml pc; 125 ml glass; 1 bulk.
Site 13D	GS/087	500 ml; 125 ml; 125 ml glass; 1 bulk; 2 x 70 mm pc.
	VC/130	A: 50-75; B: 150-175; C: 350-375; D: 1100-1115 .
Site 13E	GS/085	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 13F	GS/084	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 13G	GS/083	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 13H	GS/090	500 ml; 125 ml; 125 ml glass; 1 bulk.
	BC/087	two 70 mm pc; 125 ml glass; 1 bulk.
Site 13I	GS/088	500 ml; 125 ml; 125 ml glass; 1 bulk.
	BC/085	two 70 mm pc; 125 ml glass; 1 bulk.
Site 13J	GS/086	500 ml; 125 ml; 125 ml glass; 1 bulk.
	BC/084	2 x 70 mm pc; 125 ml; 125 ml glass; 1 bulk.

LINE 15

Site 15A	GS/082	500 ml; 125 ml; 125 ml glass; 1 bulk; 70 mm pc; 50 mm pc.
Site 15B	GS/081	500 ml; 125 ml; 125 ml glass; 1 bulk; 500 ml pc.
	BC/089	500 ml; 125 ml; 125 ml glass; 70 mm pc (400 mm).
Site 15C	GS/080	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 15D	GS/079	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 15E	GS/078	500 ml; 125 ml; 125 ml glass; 1 bulk.

LINE 17

Site 17A	GS/077	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 17B	GS/076	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 17C	GS/075	500 ml; 125 ml; 125 ml glass; 1 bulk.
Site 17D	GS/074	500 ml; 125 ml; 125 ml glass; 1 bulk.

Table 5.2 Total numbers of samples and subsamples collected for geochemical analyses.

Samples by type:	
Sites occupied:	59
Grab Samples:	57
Box cores:	11
Vibrocores:	12
Gravity cores:	4
Subsamples by type:	
Push cores:	28
Bulk samples (4 litre):	62
500 ml: subsamples	66
125 ml: organochlorine subsamples	70
125 ml: metals subsamples	67

Table 5.3 Samples collected for pore water geochemical analysis.

Samples sites	Samples	Subsamples
Site 1B:	BC/078	4
Site 9D: (in duplicate)	BC/083	5,4
Site 9D:	GS/071	5
Site 13B:	BC/088	10
Site 13C:	BC/086	12
Site 13H:	BC/087	14
Site 13I: (in duplicate)	BC/085	10, 10
Site 13J:	BC/084	5
TOTAL		79

Table 5.4 Push cores from grab samples and box cores collected for high resolution vertical distribution studies.

Site Number:	Sample Number
Site 3C:	BC/080
Site 5A:	BC/082
Site 5B:	BC/081
Site 5G:	GS/067
Site 7B:	GS/059
Site 9B: (duplicate samples)	GS/069
Site 9C: (duplicate samples)	GS/070
Site 13B:	BC/088
Site 13C:	GS/089
Site 13C:	BC/086
Site 13J:	GS/086
Site 13J:	BC/084
Site 13H:	BC/087
Site 15C:	GS/080

6. Record of Quaternary Climate Change in continental slope sediments

6.1 Background

Marine sediments of the continental slope contain a record of surface water productivity and sea level oscillations for the late Cenozoic. The fluctuations in magnetic susceptibility in the sediments can be correlated with oxygen isotope values to measure ice volume, and indirectly sea levels. A core collected offshore from Sydney in May 1991 from 2400 m water depth contains cyclical layering which may be related to an intensification of the oxygen minimum zone (OMZ) during sea level lowstands. Both productivity and the OMZ are related to upwelling and the intensity of the EAC. The switching on and off of this current is a function of climate and, on a longer time span, the northward motion of the Australian plate. During periods of high productivity the O_2 minimum is intensified and benthic organisms are excluded, allowing organic-rich sediment to be preserved on the slope. Past changes in the intensity of the OMZ most likely correlate to sea level and ocean current circulation. These cycles can be studied for high frequency climatic fluctuations.

The deposition in the sediments of varying amounts of organic matter results in a variety of diagenetic reactions which drive the dissolution and precipitation of minerals. Reduction-oxidation sensitive trace elements are particularly influenced by variations in organic matter preservation rates, and the relative abundances of some trace elements (down-core) has been shown to be indicative of varying rates of organic matter preservation. Also, the mass accumulation rates of trace elements, organic carbon and calcium carbonate, may be used to document periods of varying oceanic productivity. While a variety of geochemical indicators have been used to document these cycles, they provide no clues as to causal mechanisms. One such mechanism may be variations in the vertical nutrient structure in the water column - an oceanographic phenomena that can be examined by the use of carbon isotopic studies of benthic and planktonic foraminifers preserved in the sediments. This approach has provided some promising results on glacial/interglacial variations in oceanic productivity and nutrient profiles in the northeastern Indian Ocean, where they are related to variations in the Leeuwin Current off Western Australia.

Data from the Sydney slope will extend, to the south, the climatic record obtained from samples collected off the Queensland coast (Ocean Drilling Program (ODP) Leg 133). Also, major and trace element data from these cores will provide terrigenous and biogenic mass accumulation rates (at key climatic periods), further our knowledge of geochemical tracers and proxy indicators for oceanographic processes, and extend our observations from the northern NSW coastline phosphorite sediments.

6.2 Objectives

The objectives included:

1. to document climatic oscillations in the Quaternary (and possibly Neogene) by sampling sediment cores from the slope, and
2. to examine Quaternary variations in (organic and carbonate) carbon fluxes (for oceanic productivity), sediment accumulation rates and terrigenous inputs (for continental weathering), related to glacial/interglacial cycles and variations in the East Australian Current.

6.3 Methods

A coring transect was occupied on the upper- and mid-slope (500 - 3500 m) offshore of Sydney, where extensive Sea Beam bathymetry is available at 50 m isobaths (Hughes Clarke et al., 1990). The sampling was targeted on a uniform slope with the lowest gradients, and with a possibility of a continuous record of Quaternary sedimentation. Submarine canyons were avoided because of the increased possibility of redeposition and loss of section due to erosion.

A one tonne gravity corer was used with either a 3 m or 6 m length barrel. The corer was lowered into the sediment at 120 m/min by the main coring winch. Cores were retrieved in 90 mm H.D. stormwater UPVC with an internal diameter of 87 mm.

Cores were split on board, described and then stored at 4^{o}C.

6.4. Inventory of gravity cores

The locations of gravity cores collected on the continental slope are summarised below and in Figure 6.1. All sampling will be done post-cruise as this enables photography, X-radiography and magnetic susceptibility to be carried out on complete cores.

SITE 7G (486 m w.d.)

112/GC/ 007: Recovery: 25 cm.
Much of this core washed out as it was brought to the surface in rough weather. The core catcher was bent/peeled back by hitting lithified sediments. Sediment left in the barrel was bulked. Sediment is slightly muddy - gravelly sand, with lithified (calcareous) rock gravel and small gastropods.

SITE 7AA (630 m w.d.)

112/GC/013: Recovery: nil.
112/GC/014: Recovery: nil.
Both attempts to gravity core at this site failed. The small amount of sediment sampled was lost through the core catcher as the corer was lifted out of the water. A combination of sandy sediment and bad wire angle (due to strong current) prevented successful gravity coring at this site.

SITE 7H (977 m w.d.)

112/GC/008: Recovery: 300 cm.
Top of core contains 8 cm of oxidised brown sediment, followed by alternating sequences of olive-grey muddy sand and sandy mud, where sand is composed of foraminiferal tests and mud is largely carbonate; most contacts are gradational. Both textural types are mottled/ bioturbated and mud units often contain organic material and rare carbonate granules (shell, echinoderm spines, etc.). Base of core appears to be disturbed and may represent "second bite" during pullout.

SITE 7J (1467 m w.d.)

112/GC/009: Recovery: 438 cm.
Top 2 cm of core is oxidised muddy, foramineral-rich sand which is underlain by 240 cm of olive-grey sandy mud and muddy sand sequences, separated by gradational contacts. These units contain black specks of organic material/pyrite and scattered shell fragments. Sharp boundary at 243 cm overlies sandy mud unit with obvious burrows filled with foraminifer sand, and faint laminations preserved. Mud underlies another sharp contact at 292 cm; mud unit is mottled with darker patches throughout, and possibly mica (higher terrigenous input?). Intensely bioturbated carbonate-rich mud at 415 cm. and small bivalves and fragments at base of core.

SITE 7K (2007 m w.d.)

112/GC/010: Recovery: 536 cm.
Oxidised olive-brown muddy sand in upper 2-3 cm of core, grading into 250 cm of mostly olive-grey muddy sand with thin (approximately 1 cm) laminae of sandy mud; each laminae has sharp upper and lower contacts. Below 250 cm, sediment is mostly sandy mud with varying amounts of mottling/burrows and scattered shell fragments and bits of black organics. From 495 cm to base of core, sediment is intensely mottled/bioturbated slightly sandy mud.

SITE 7L (2445 m w.d.)

112/GC/011: Recovery: 438 cm.
Oxidised olive-brown muddy sand in upper 2-3 cm of core, grading into slightly mottled olive-grey sandy mud which becomes light grey (higher in carbonate?) at 260 cm. Sharp boundary at 285 cm marks the change to mud with patches of black flecks (organics, pyrite) and occasional laminae of lighter coloured mud or foraminifer sand. At 344 cm, the mud becomes intensely mottled and contains rare lithified sand clasts up to 1 cm in size. This bed may represent a slump. Below a sharp boundary at 401 cm, the mud contains some mottled zones and some laminations (0.5 cm laminae).

SITE 7M (3017 m w.d.)

112/GC/012: Recovery: 334 cm.
Top of core contains a relatively thick (17 cm) oxidised layer of grey-brown muddy foraminiferal-rich sand and then a sharp contact at 23 cm, separating muddy sand from mottled and bioturbated olive-grey sandy mud with black (reduced) organic flecks. From 80 cm downward, the core is composed primarily of mud with slump features, overturned folds and a well laminated zone (OMZ) at about 160 cm (illustrated in Figure 6.2). At 269 cm, the sediment changes to mottled/bioturbated muddy sand with some black flecks and distinct patches. The lowermost several cm of the core (in the core cutter) contain a distinct boundary (though bioturbated) overlying mud. Note: The core has penetrated a slump or slide that was displaced downslope.

6.5. Continental Slope Gravity Coring Results

The location of four of the sites in the cruise proposal had to be moved to avoid being within 2 nm of the three submarine cables which traverse the slope in this area. This restriction, together with incomplete Sea Beam data and the presence of canyons, limited the choice of sites available. Coring attempts were made at seven sites: five were successful and two unsuccessful. The unsuccessful sites were the shallowest (486 m and 630 m), and the failure was due to the presence of sandy sediment (muddy sand) with some calcareous cementation. Piston-coring may be more successful in this type of sediment.

The five successful cores form the first transect sampled down the continental slope offshore of Sydney. The slope here extends for 60 km (200-4800 m w.d.) with an average gradient of 4.5°. Along the cored transect the continental slope can be divided into three segments based on bottom topography and gradient: a smooth upper slope (500 to 2000 m w.d., 25 km) with a 4.5° gradient; hummocky mid-slope (2000 to 3000 m w.d., 13 to 16 km) with a 3.5° to 4.5° gradient; steep and rough lower slope (3000 to 4800 m w.d., 6 km) with average gradient of 15°.

Cycles on the scale of tens of centimetres are visible in all five cores collected. These cycles are readily identified on the basis of texture (sand/mud ratio) and colour (carbonate content). More detailed analysis will establish the intensity of these cycles, and their significance as indicators of climatic/oceanographic change along this margin.

Bioturbation is present in all cores and laminations are present in the four deeper water cores (1467 to 3017 m). Some of the laminations which are better sorted may be the result of bottom currents (contourites) winnowing the sediments, but most are the result of lack of bioturbation enabling the preservation of variations in the supply of sediment settling out of suspension. The lack of bioturbation in these layers is due to the exclusion of benthonic organisms as the oxygen-poor bottom waters impinge on the sea floor.

The slump sampled in core GC/012 emphasises the importance of gravity driven processes on this relatively thinly sedimented continental slope (see also Jenkins and Keene, 1992). This mid-slope slump has probably moved less than 6 km and may have helped form the slight step in bathymetry at 2500 to 2700 m. Layers in the core have reacted differently to slumping: the more muddy laminated horizons have remained coherent and have become tightly folded and even overturned (see Fig. 6.2), while other horizons (more sandy?) have been totally disturbed (fluidised?). Sharp contacts in this core may represent slip surfaces.

Of some interest to the physical sedimentology of the upper slope is the possibility of internal wave activity. Acoustic scattering layers were observed on a number of occasions in the top 100m of the water column, which could be interpreted as water mass boundaries subject to internal waves of 20m amplitude. The undulating boundaries were recorded with the 3.5 kHz sub-bottom profiler east of Broken Bay. The morphology of the boundaries suggests that the internal waves (if present) may be breaking over the shelf edge. The record is illustrated in Figure 6.3.

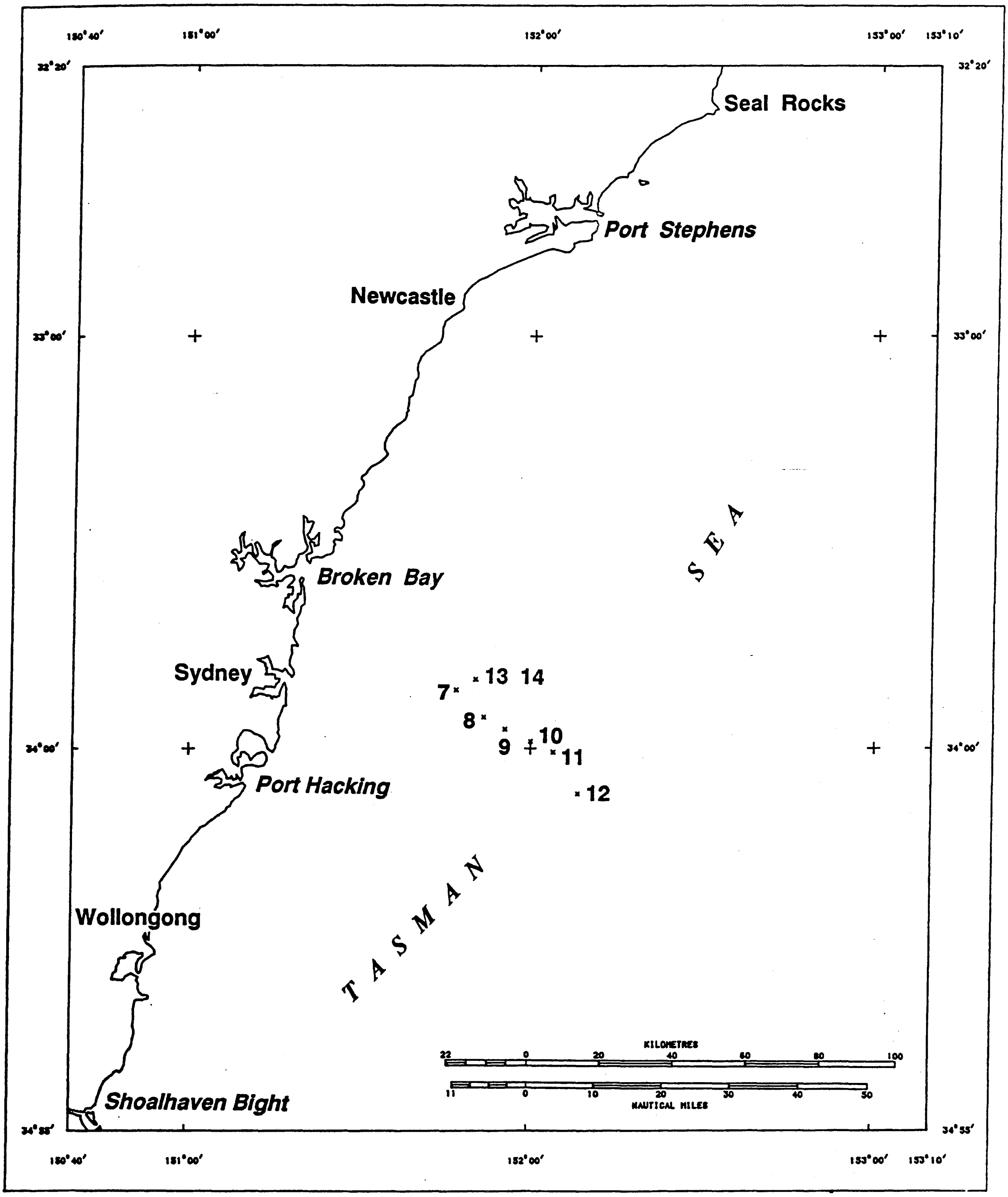


Fig. 6.1 Gravity core locations on the central NSW continental slope.

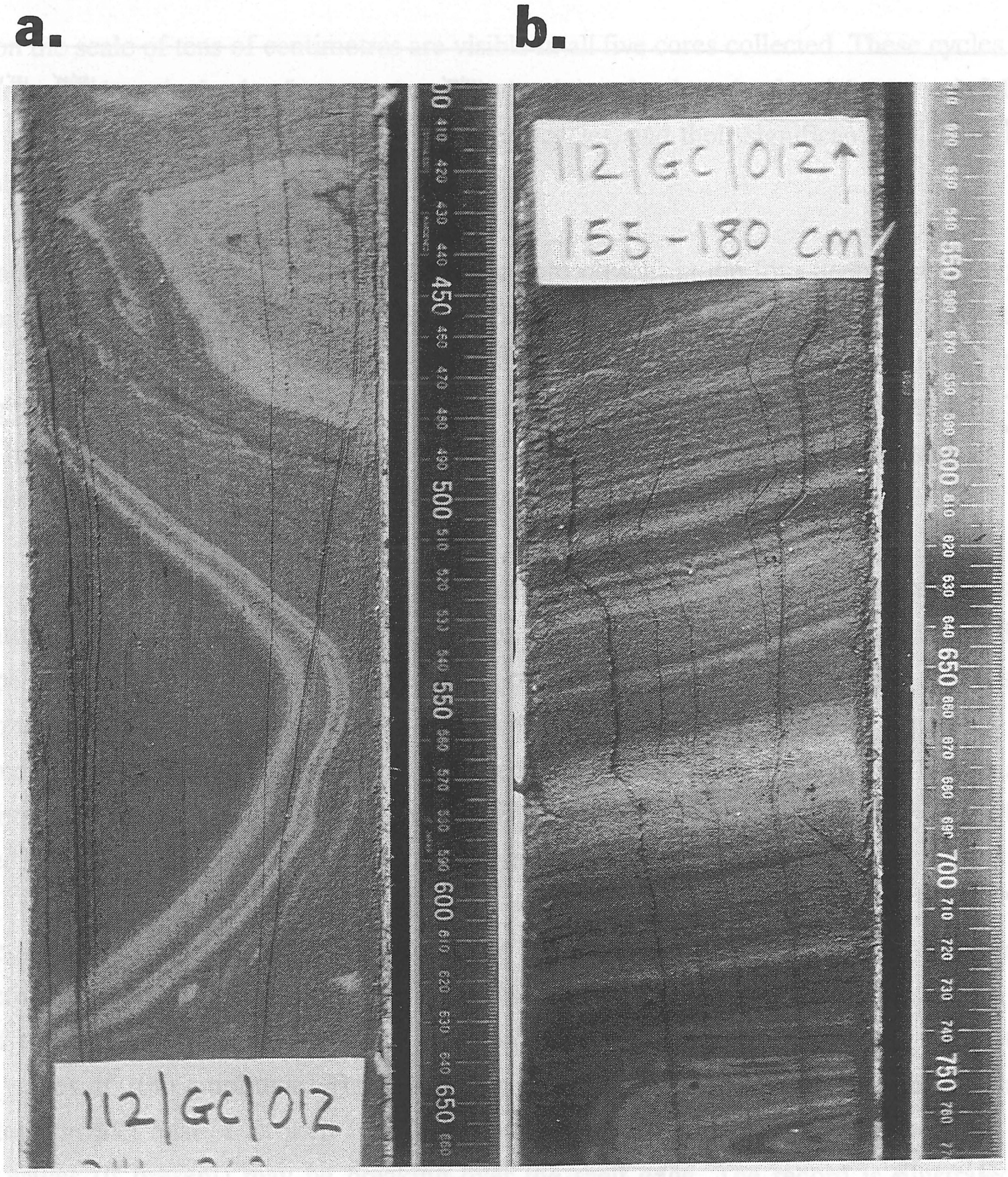


Fig. 6.2 Photographs of Gravity Core 012 showing (a) slump features and overturned folds, and (b) well-laminated sediments of the oxygen minimum zone.

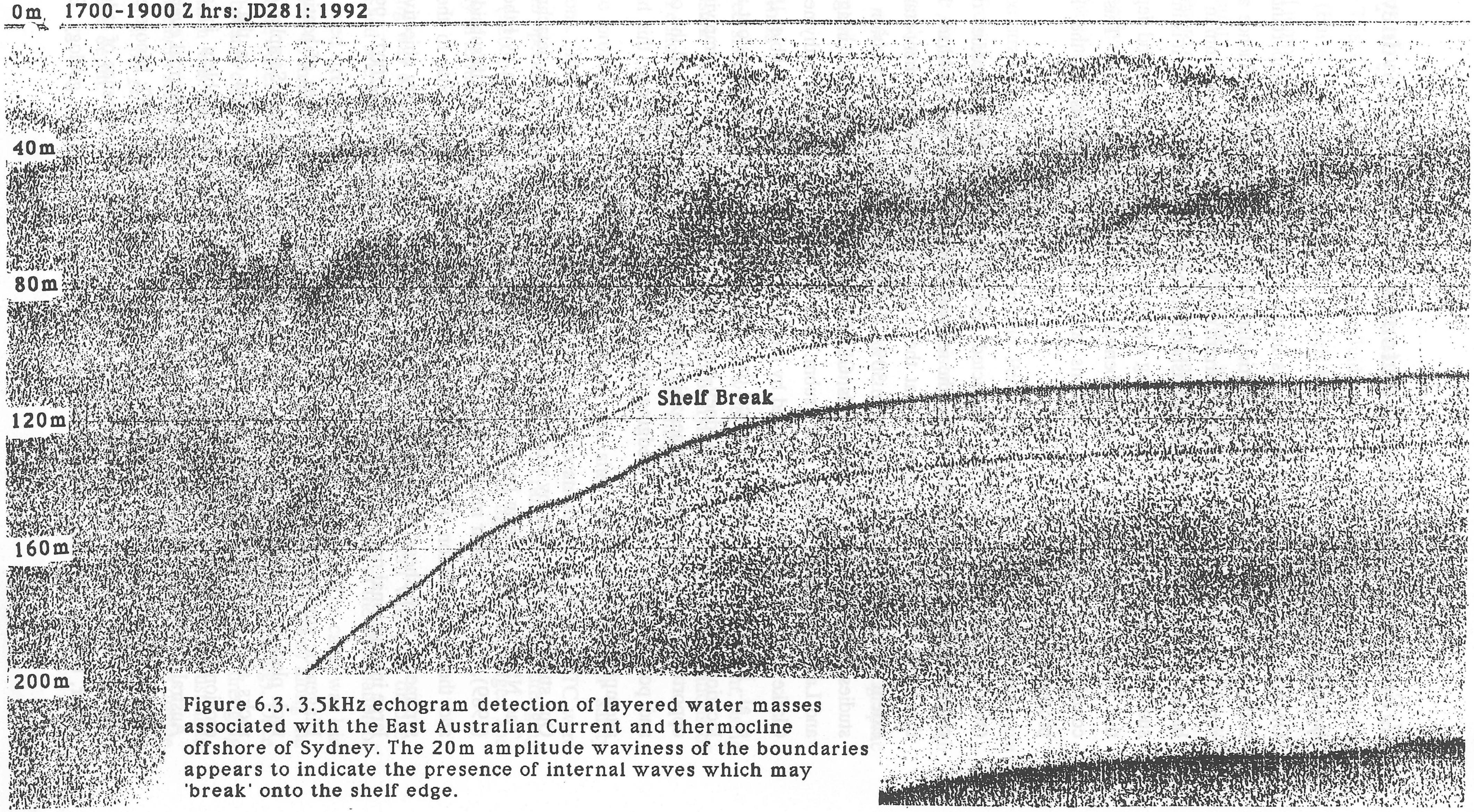


Figure 6.3. 3.5kHz echogram detection of layered water masses associated with the East Australian Current and thermocline offshore of Sydney. The 20m amplitude waviness of the boundaries appears to indicate the presence of internal waves which may 'break' onto the shelf edge.

7. Sedimentary facies and tectonics of the offshore Sydney Basin

7.1 Background

Onshore exposures and borehole records in the Sydney Basin indicate important changes of facies towards the east of the basin, particularly in thicknesses, marine influence and volcanic supply (Herbert, 1980). In view of the current exploration activity for petroleum in the offshore basin extension, and there being no published data on the sequence offshore, it is important that such changes be investigated. One glaring unknown at present is the extent and depth to which the Sydney Basin sequence extends beneath the continental shelf/slope. This study will contribute answers to these questions and help in assessments of the hydrocarbon prospectivity.

Over the last 9 years, OSI has conducted geological and geophysical studies of the NSW continental margin, mainly addressing the regions south of Sydney (eg. Packham, 1983). From that work it has become apparent that the slope is extraordinarily sediment-starved, to the extent that basement is exposed over 30% of the lower slope. This conclusion is based on studies of seismic and 3.5 kHz records, GLORIA super-sidescan backscatter imagery (Jenkins and Lawrence, 1990; Jenkins et al., subm.) and on Sea Beam multibeam bathymetry (Hughes Clarke et al., 1990). It is also verified by the results of direct dredging (Hubble, 1989; Hubble et al., In press). The same geophysical data sets indicate that basement crops out at numerous locations in the Wollongong-Sydney-Newcastle offshore slope sector, implying that the opportunity exists to sample Palaeozoic basement, Sydney Basin strata, and the overlying rift and post-rift sequences, by dredging those outcrops. To our knowledge, this has not been attempted previously.

Our study provides data by which to test tectonic models of upper plate detachment rifting. The NSW passive margin has been interpreted as an upper plate margin by Etheridge et al. (1989), who claim their model can predict the morphology, structure, uplift/subsidence history and thermal evolution of such margins. Thus, our work will contribute to the debate on symmetric 'pure shear' versus asymmetric 'simple shear' rifting: a primary objective of several large international programs including the ODP ('Long Range Plan 1989-2002', 1990, p. 72).

Diagenetic studies of dredged samples will determine if lateral changes of heating or burial took place in the east of the basin (>100 km from present boreholes). Samples of basement rocks and sediments from the slope will provide significant new data on the burial/uplift, erosional and thermal history, which has been a long-standing problem in southeastern Australian geology (Branagan, 1983; Middleton and Hunt, 1989). A thermal event leading to uplift is thought to have occurred between 80 and 100 Ma (Ollier, 1982; Moore et al., 1986). High vitrinite reflectance values for onshore sequences suggest the presence of at least 1 km of cover, but no remnants of that cover have been found in the surface geology. Evidence for continuing Triassic/Jurassic sedimentation in the basin, and its subsequent removal, comes from the Lower Triassic Narrabeen Group by using fluid inclusions, stable isotopes and authigenic illite ages (Bai et al., 1991), which suggest high heat flow at 91-146 Ma (coincident with rifting) and removal of >1 km of section.

Cenozoic strata, also outcropping on the slope, were sampled during dredging. They will contain a record of the post-rift history of the margin, particularly its subsidence.

7.2 Objectives

The objectives included:

1. to define stratigraphic facies changes in the Permian-Mesozoic Sydney Basin sequence eastwards from the present coastline;
2. to define diagenetic, thermal and subsidence history of the offshore Sydney Basin through laboratory analyses of rock samples; and
3. to seek evidence regarding the geological structure, and the tectonic and stratigraphic development of this part of the SE Australian continental margin.

7.3 Methods

Twenty three sites for dredging were identified, in water depths from 900 to 4800 m, using existing seismic data (AGSO, industry), multibeam bathymetry (Sea Beam), compilations of broad-beam echosounding (GEBCO) and super-sidescan imagery (GLORIA).

Due to the proximity of telecommunication cables, the sites were reviewed for safety considerations. Sites closer than 3 nautical miles from cable locations supplied by AOTC were deleted from operations. Further culling took place during the cruise on the basis of dredging slope angle (>20° preferred), structural/stratigraphic position in the light of earlier dredges, and achievability in terms of sea conditions/transit times.

The dredging was done with the AGSO box/chain-bag dredge in tandem with pipe dredges (one closed and one open). Weak link shear pins (8 tonnes) were installed at the termination of cable, with rated strengths appropriate to the water depth and winch rating. The cable was laid out (usually at 45 m/min) to 110% of the water depth, and the vessel made headway along the dredging track. After tension 'bites' the cable was slowly drawn in (vessel still drifting). Once the dredge became clear of bottom again, it was retrieved at 80 m/min. The length of dredging runs on bottom was typically <1 nm. When strong current prevailed (in the East Australian Current at northern sites particularly), an extra slug weight was put on the cable and the dredge was lowered at 80 m/min to minimise the cable angle deviations. Also, wire out was up to 125% of water depth.

In the winch room, scientists and technical staff monitored the line-out/line speed and tension readings, and conducted the dredging. The tension reading aboard RV Rig Seismic comes from the winch hydraulics. Whether the dredge was on/off bottom could sometimes be judged from the sensitivity of tension readings to sea swell. Tension bites due to dredging the bottom were slight (<8 k Newton) and were generally no guide to success of the dredging. However they were invaluable in the rare cases of 'hang-up'.

The protocol for sampling and analysis of the dredge materials followed usual AGSO practice, with the dredging coded as 'cruise number/DR/sample number' (eg. 112/DR/007). Different lithological types were then coded as 'TYPE A' etc or sub-type 'TYPE A1'. Specimens were partitioned between AGSO and Sydney University collections (40%:60%).

Petrographic and textural studies will be performed on the dredge samples from the slope. The post-cruise laboratory program for the rock samples is:

a. petrographic descriptions of sedimentology, provenance and diagenesis;
b. SEM and stable isotope analysis of quartz overgrowths and clay-carbonate cements to determine diagenetic sequence;
c. XRD to identify mineral species;
d. study of fluid inclusions trapped in quartz overgrowths for burial P/T conditions;
e. palynology and foraminifer biostratigraphy;
f. vitrinite reflectance;
g. apatite fission-track; and
h. K-Ar dating of illite cements, glauconites and igneous phases.

7.4 Inventory of dredges

Of 16 dredgings, 12 yielded samples of rock. Dredge locations are shown in Figures 7.1, 7.2a, 7.2b in relation to the SeaBeam bathymetry. For each dredge, the information following the Julian day (JD) is the time in GMT, latitude, longitude (both in WGS84), and the water depth for the start of dredging, and the position at which the dredge was on and off the bottom.

112/DR/001 Site: A

Lower continental slope south of Sydney Canyon (near seismic line BMR 15/034)

JD 278

Start:	1806	34° 22.77'S	151° 59.36'E	4579 m
On bottom:	2000	34° 22.07'S	151° 58.35'E	4219 m
Off bottom:	2203	34° 21.45'S	151° 57.28'E	4119 m

Dredge Haul: 500 kg of rocks

Type A: hard metasediments (argillites/sandstones), metavolcanics; fractured into angular blocks; some laminated (? tuffs); brown-black Mn-Fe stains on many surfaces; contain scattered pyrite; ?Palaeozoic basement; 90%

Type B: brecciated grey-green argillite with brownish-white calcitic veins up to 5 mm wide throughout; one sample of coarse crystalline quartz vein; ?Palaeozoic basement; 5%

Type C: grey calcareous sandstone; contains scattered pyrite; ?Permian; 2%

Pipe haul: Type D: brown impure (terrigenous) foraminifer-nannofossil ooze; 3%

112/DR/002 Site: B

Middle reaches of Sydney Canyon

JD 279

Start:	0120	34° 10.02'S	151° 54.29'E	3057 m
On bottom:	0230	34° 10.14'S	151° 54.20'E	3115 m
Off bottom:	0337	34° 10.41'S	151° 53.70'E	2776 m

Dredge Haul: Empty

Pipe haul: Mud with 0.5 kg of rock

Type A: small pieces of friable brown siltstone; slightly calcareous; also non-calcareous mudstone; both bored by recent organisms and Fe-Mn stained; ?Palaeogene; 0.1%

Type B: foram-terrigenous clay sandy mud; brown oxic surface layer and anoxic olive colour generally; numerous long, black worm tubes; 99.9%

112/DR/003 Site: E

Lower continental slope just north of Sydney Canyon

JD 279

Start:	0830	34° 14.91'S	152° 10.11'E	4880 m
On bottom:	0930	34° 14.94'S	152° 09.34'E	4662 m
Off bottom:	1056	34° 15.11'S	152° 08.15'E	4060 m

Dredge Haul: Empty

Pipe haul: Mud with rock granules

Type A: hemipelagic brownish-olive sandy mud; foraminifer, nannofossils, terrigenous clay; 99.9%

Type B: granules of quartz; 0.1%

112/DR/004 Site: F

Lower continental slope just north of Sydney Canyon

JD 279

Start:	1316	34° 14.43'S	152° 08.47'E	4062 m
On bottom:	1404	34° 14.46'S	152° 08.15'E	3967 m
Off bottom:	1548	34° 14.48'S	152° 07.43'E	3887 m

Dredge Haul: 350 kg of rocks

Type A: mudstone; dark grey, non-calcareous; bioturbation common; moderately well lithified; contains black flecks of plant material; coated with 1 mm thickness or more of Fe-Mn crust; ?Late Mesozoic; 70%

Type B: lithofeldspathic quartz sandstone; moderately well sorted; Cretaceous: Mid to Late Campanian*; 25%

Type C: conglomerate; poorly sorted; lithic (volcanic and sedimentary) clasts, angular and sub-rounded, up to 3 cm in size; sandy matrix; matrix-supported; ? Mesozoic; <2%

Pipe haul: Mud

Type D: Brown foraminifer-nannofossil sandy mud; 3%

112/DR/005 Site: E (repeat)

Lower continental slope just north of Sydney Canyon

JD 279

Start:	1748	34° 16.54'S	152° 10.00'E	4880 m
On bottom:	2116	34° 15.73'S	152° 08.99'E	4612 m
Off bottom:	2234	34° 15.43'S	152° 08.64'E	4358 m

Dredge Haul: 1 kg of rocks

Type A: sandstone; non-calcareous, brown, lithic-feldspathic; medium grainsize, moderate sorting, contains some wood organic matter; no sedimentary structures visible; Triassic*; 5%

Type B1: mudstone; grey friable, with black plant material; non-calcareous; recent borings on surfaces; ?Late Mesozoic; 3%

Type B2: lesser amount of chocolate grey mudstone; with plant material; 2%

Type C: buff coloured calcareous claystone; ?pelagic nannofossil chalk; possible Zoophycus structures; firm, friable; ?Late Mesozoic; <1%

Pipe haul: mud

Type D: olive calcareous mud; 90%

112/DR/006 Site: G

Lower continental slope 15 nm north of Sydney Canyon

JD 280

Start:	0200	34° 09.22'S	152° 14.81'E	4786 m
On bottom:	0339	34° 09.13'S	152° 14.88'E	4818 m
Off bottom:	0645	34° 08.39'S	152° 14.00'E	4187 m

Dredge Haul: 2 kg of rocks

Type A: altered basaltic andesite, relatively fresh centre; phenocrysts of white euhedral plagioclase up to 3 mm size; pinkish brown aphanitic groundmass; groundmass contains microlaths of feldspar; 60%

Type B: brecciated siliceous mudstone; angular clasts of metasediments/metavolcanics cemented by a fine yellowish-brown non-calcareous zeolitic clay; sample is coated by dark staining and 2 mm thick Fe-Mn crust; ?Late Mesozoic; 20%

Pipe haul: mud

Type C: olive green hemipelagic calcareous mud; 20%

112/DR/007 Site: H

Lower continental slope 15 nm north of Sydney Canyon

JD 280

Start:	0926	34° 08.76'S	152° 14.10'E	4329 m
On bottom:	1055	34° 08.70'S	152° 14.01'E	4290 m
Off bottom:	1324	34° 08.03'S	152° 13.17'E	3867 m
	?1206	34° 08.27'S	152° 13.50'E	3994 m

Dredge Haul: 200 kg of rocks:

Type A: green-brown volcanic sandstones; hard, angular, fractured blocks; some with bivalves (A1); some with grit (A2); some with sandstone clasts (A3); ?Permian or ?Early Cretaceous; 40%

Type B: same with calcite veining (A2); 5%

Type C: pebbly and clast-bearing sandy mudstones; Late Cretaceous*; 5%

Type D: very soft (semi-consolidated) dark brown mud; ?Palaeogene; 5%

Type E: well lithified (indurated), blocky, fine volcanic sandstone/siltstone; bioturbated; ?Mesozoic; 10%

Type G: brecciated black siliceous mudstone; ?Permian or ?Early Cretaceous; 5%

Type F: lithified, dark grey bioturbated mudstones with carbonaceous particles; 5%

Type H: ferruginous nodules and crusts, some brecciated; ?Permian or ?Early Cretaceous; 5%

Type I: fractured tan siltstones; ?Permian or ?Early Cretaceous; 5%

Type J: manganese crusts on fine brown sandstone (type I); 5%

Pipe haul: mud

Type K: hemipelagic calcareous mud; 10%

112/DR/008 Site: K

West wall of canyon upslope from transform block, lower slope east of Botany Bay

JD 280

Start:	1959	33° 59.09'S	152° 16.54'E	3536 m
On bottom:	2035	33° 58.83'S	152° 16.21'E	3533 m
Off bottom:	2235	33° 57.88'S	152° 15.00'E	3306 m

Dredge Haul: 100 kg of rocks

Type A: sandstone-mudstone; purply-greenish-grey-tan; soft, consolidated; 40%

Type B: chocolate mudstone; very soft, semi-consolidated; 5%

Type C: soft mudstone; purply-greenish-grey-tan; 5%

Type D: coarse greensand; glauconite, quartz, feldspar, carbonate grains; 5%

Type E: mottled chocolate mudstone; lithified; 10%

Type F: very dark chocolate mudstone; 5%

Type G: greensand; medium-fine grainsize; 5%

Type H: yellowish greensand; medium-fine grainsize; 5%

Type I: greensand; burrowed and with slickensides; 5%

Entire suite: Early Eocene*

Pipe haul: Type J: hemipelagic calcareous mud; 10%

Note: 2126 33° 58.6'S 152° 15.9'E 3447 m

was a temporary 'off bottom' before a big hit at 2235 (?main sampling); this implies greensands are from approximately 3300 m water depth.

112/DR/009 Site: L

Upper slope east of Manly (seismic line BMR 12/029)

JD 281

Start:	0250	33° 48.48'S	152° 04.67'E	1650 m
On bottom:	0325	33° 48.47'S	152° 04.47'E	1605 m
Off bottom:	0435	33° 48.58'S	152° 03.76'E	1594 m

Dredge Haul: Empty

Pipe haul: Small rocks and mud

Type A: 0.1 kg fine sandstone; < 1%

Type B: hemipelagic calcareous mud; 99%

112/DR/010 Site: 'L-1'

Upper slope east of Manly (seismic line BMR 12/029)

JD 281

Start:	0603	33° 48.55'S	152° 03.64'E	1603 m
On bottom:	0632	33° 48.50'S	152° 03.69'E	1606 m

Off bottom:	0740	33° 48.51'S	152° 02.68'E	1406 m

Dredge Haul: 5 kg of corals, 5 kg of rocks

Type A: mudstone; brown calcareous; contains quartz, feldspar and clay minerals; well-lithified; ?Mesozoic; 30%

Type B: hard, light brown, quartzose lithic sandstone; fine-grained; moderately well sorted; ?Mesozoic 30%

Type C: olive-grey bioturbated fine sandstone; containing quartz and feldspar; well lithified; ?Late Mesozoic; 10%

Type D: Recent corals, dead and living; with sponges (silica and soft), annellids, echinoderms (brittle stars, sea urchins), brachiopods, bivalves, gastropods; 15%

Pipe haul: mud

Type E: calcareous brown mud; 15%

112/DR/011 Site: M

Upper slope east of Dee Why (near seismic line BMR 12/029)

JD 282

Start:	1215	33° 47.81'S	152° 05.65'E	2021 m
On bottom:	1314	33° 47.66'S	152° 05.67'E	1971 m
Off bottom:	1630	33° 46.63'S	152° 05.14'E	1634 m

Dredge Haul: Empty

Pipe haul: mud

Type A: olive-grey calcareous mud; 100%

112/DR/012 Site: M (repeat)

Upper slope east of Dee Why (near seismic line BMR 12/029)

JD 282

Start	1836	33° 47.03'S	152° 05.34'E	1800 m
On bottom:	1921	33° 46.66'S	152° 05.14'E	1638 m
Off bottom:	2052	33° 46.21'S	152° 04.90'E	1539 m

Dredge Haul: Empty

Pipe haul: mud

Type A: Olive-grey calcareous mud; 100%

112/DR/013 Site: N

Upper slope east of Dee Why (near seismic line BMR 12/029)

JD 282-283

Start:	2326	33° 45.00'S	152° 05.91'E	1749 m

On bottom:	2352	33° 44.95'S	152° 05.91'E	1745 m
Off bottom:	0217	33° 44.04'S	152° 04.76'E	1314 m

Dredge Haul: 10 kg of rocks

Type A: brown mudstone; with minor bioturbation of sand; Early Eocene*; 40%

Type B: greensand; friable; some laminated; ?Palaeocene; 40%

Pipe haul: mud

Type C: grey calcareous mud; 20%

112/DR/014 Site: P

Mid slope north of Broken Bay

JD 283

Start:	0728	33° 32.16'S	152° 25.33'E	3121 m
On bottom:	0834	33° 32.11'S	152° 25.30'E	3082 m
Off bottom:	1007	33° 31.41'S	152° 24.98'E	2696 m

Dredge Haul: 0.5 kg of rocks

Type A: well sorted grey quartzose sandstone/siltstone; with granules (up to 5 mm, lithic); visible black organic materials; moderate porosity; Cretaceous: Mid to Late Campanian*; 10%

Type B: yellowish brown-grey friable, coarse sandstone, lithic (feldspar, minor quartz); 5%

Pipe haul: mud

Type C: Yellowish-brown and grey calcareous mud; 85%

112/DR/015 Site: R

Mid slope offshore of Gosford (seismic line BMR 12/033)

JD 283

Start:	1555	33° 11.78'S	152° 46.19'E	3556 m
On bottom:	1646	33° 11.53'S	152° 46.13'E	3470 m
Off bottom:	1931	33° 09.56'S	152° 45.57'E	3714 m

Dredge Haul: 10 kg of rocks

Type A: zeolitic, vesicular altered basalt with hyaloclastite fissure-fill (yellow-cream, calcitic, with clay, possibly nontronite or celadonite, and palagonite); two 'fresh' kernels at least; ?Late Mesozoic; 15%

Type B: dark olive-grey fine sandstone; recently burrowed and ferrug-stained; ?Palaeogene; 5%

Pipe haul: muds and semi-consolidated materials

Type C: very soft (semi-consolidated) olive grey and pale brown sand-silt-clay (?Neogene); 5%

Type D: pale tan foraminiferal mud; 70%

Note: in the pipe dredge the rotted hyaloclastite was sampled earlier than the Type C consolidated mud; note that pipe sampling of hyaloclastite (5% of total) implies that the volcanics are *in situ.*

112/DR/016 Site: O
Mid slope canyon offshore of The Entrance
JD 287

Start:	1338	33° 34.31'S	152° 21.23'E	2895 m
On bottom:	1428	33° 34.27'S	152° 21.27'E	2876 m
Off bottom:	1706	33° 33.73'S	152° 20.28'E	2551 m

Dredge Haul: 350 kg of rocks
Type A: agglomerate volcanic breccia (lapilli tuff); lithic vitric tuff; angular rhyolitic volcanic fragments, light coloured, ranging in size up to 4 cm set in a dark grey groundmass (ash); poorly sorted; no bedding visible; fresh central dark grey kernel in 20-30 cm block; outer rim pale brown stained by weathering; sometimes thin (<1 mm coating of Fe-Mn crust on surface; bright green and purple variants; ?Early Cretaceous; 5%;
Type B: coarse lithic-quartz sandstone; grains of chlorite (?altered volcanic); silicic volcanics, fossil debris; poorly sorted; (finer phase of Type D); poorly sorted angular lithic sand matrix 25%; friable, weakly lithified; ?chloritized cements; fossil clasts are (? reworked Permian) bivalves /brachiopods up to 3 cm; bed thickness 3-10 cm; some contains rip-up clast of Type C; Cretaceous: Mid to Late Campanian*; 30%
Type Bp: pebbles, miscellaneous; including indurated black silty mudstone, ? silicified mudstone, volcanics, tuff (type A)
Type C: sandy mudstone; poorly sorted; uniform, forms flagstones; grey when fresh, brown when weathered; Cretaceous: Mid to Late Campanian*; 20%
Type D: conglomerate; calcareous fossiliferous, indurated mudstone, and chloritic altered volcanic clasts; clasts both angular and well-rounded; vaguely bedded; sandy matrix like Type B; pebbles up to 10 cm; ? Permian; 20%
Type E: bedded coal-bearing sandy mudstone; ? phosphoratized, ?dolomitized; with wood/plant fragments, many uncompacted and pyritized (cellular structure still clearly visible); colour grey when fresh, tan-creamy; possible septarian/syneresis veining and fractures; coaly material in bands with lithic/volcanic granules; matrix sandy mud; all poorly sorted; Cretaceous: Mid to Late Campanian*; 10%
Type F: ferruginous fine quartz sandstone; lithified; thin (1 cm) flags; Cretaceous: Mid to Late Campanian*; <1%
Pipe haul: mud
Type G: grey foraminiferal mud; 10%
Type H: brown mud; semi-consolidated; 5%

7.5 Dredging Results

Palaeozoic basement underlying the Sydney Basin was sampled at the southernmost site (DR/001), offshore from Port Hacking, in 4,200 m of water. Argillites and metavolcanics dominate the suite, representing thin-bedded turbidite and volcanogenic facies. Minor limestone and calcareous sandstone were also sampled. These rocks are similar to those outcropping around the southern and western margins of the Sydney Basin. Calcite and quartz veining indicate low temperature hydrothermal alteration.

Sandstone, conglomerates and mudstones were sampled from DR/004, 007, 010, 014, 016 and probably represent Sydney Basin rocks. The presence of quartz clasts and a wide range of lithic clasts make these rocks similar to the Permian and the Triassic Narrabeen Group on land. Some samples may be of Jurassic age. Environments of deposition range from fluvial sands through shallow marine conglomerates and sands to bioturbated shallow marine mudstones. Plant fossils and carbonaceous particles are common in most samples. The volcanogenic sandstones in DR/007 may have been deposited as syn-rift Cretaceous sediments. These may be the equivalent of the Strzelecki Group in the Gippsland Basin; however, dating by palynology is required for confirmation.

Post-rift rocks are dominated by non-calcareous mudstones (probably Late Cretaceous) and calcareous greensands (probably Paleocene). The mudstones are bioturbated and probably shallow marine and represent a period of high terrigenous sediment supply (DR/004, 005, 007). The Paleocene glauconitic sands contain macrofossils, and represent a marine transgression and relative sediment starvation or sediment bypassing (DR/002, 008, 013, 015).

Volcanic rocks were dredged from sites DR/006 (basaltic andesite), DR/015 (basalt and hyaloclastite), and DR/016 (agglomerate/lapilli tuff). The samples are extensively altered and may be difficult to date. Chemical analysis and dating should determine their magma type and relationship to the evolution of the margin. The possibilities include: Carboniferous basement similar to that north of the Sydney Basin (DR/006, 016); Permian volcanics within the Sydney Basin (DR/006, 016) similar to those outcropping at Kiama; rift-related volcanism during the early-mid Cretaceous (DR/006, 015, 016); post-rift basaltic volcanism (DR/015).

Site DR/010 sampled a rich benthic community living on the sea floor at water depths of 1400 to 1600 m. Several live corals, large worms, brachiopods, bivalves, starfish, shrimp, sea urchins, sponges and unidentified specimens were found. The possibility exists that this biological community may be associated with the venting of fluids from the seafloor.

7.6 Investigation of the 'FRI Pinnacles' area

A brief transect of this area at 31°00'S to 31°12'S and 152°50'E, offshore of Newcastle in 1000m WD, was conducted using the 12.5 kHz echosounder and airgun seismic. Previously, the Fisheries Research Institute of NSW (FRI) had acquired 23 kHz echosounder data showing a series of puzzling bottom contacts of high reflectivity which at first were thought to be schools of fish. However the features were constant and no fish were trawled.

The 12.5 kHz echosounder record (Figure 7.3), verified the existence of seafloor structures up to 30 m in height, composed of acoustically 'hard' materials. The seismic data which were acquired at 8 kts, show the pinnacles only as faint diffractions above the general seafloor (Figures 7.4, 7.5; representing a selection of the data only). A map, combining the (backcorrected) FRI cruise 8810 and 8812 and RV Rig Seismic Cruise 112 locational data, was compiled (Figure 7.6).

Our preferred interpretation of the seismic and echosounder data - in the context of the dredging results - is that the pinnacles represent igneous dykes protruding from the seafloor. In the seismic profiles, the underlying geologic structure appears to consist of 2 igneous bodies. They are conceivably Late Mesozoic intrusive/extrusive bodies, such as those found onshore and offshore in southern NSW (Hubble & others, in press; Jenkins & others, Subm.) or the rhyodacite dredged earlier in this cruise. It may be possible in the future, to sample one such body at the scarp east of the FRI Pinnacles. The chaotic stratigraphy which lies between and above the two igneous bodies is interpreted as associated volcanics, in which case the presence of dykes left upstanding after erosion would not be unusual. If the pinnacles are indeed dykes, then later (Cenozoic) sediments have partly filled in around them.

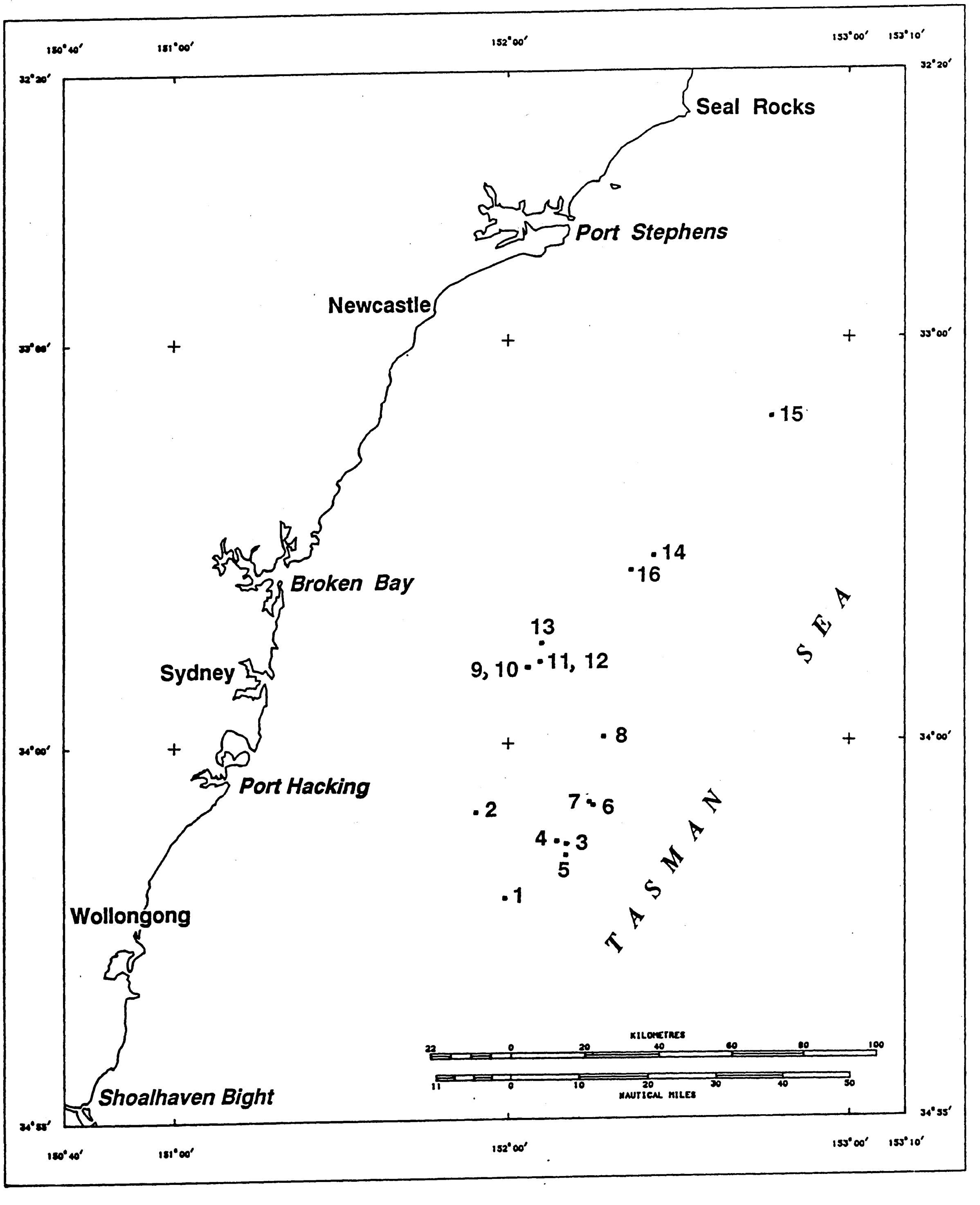


Fig. 7.1 Location of dredge sites.

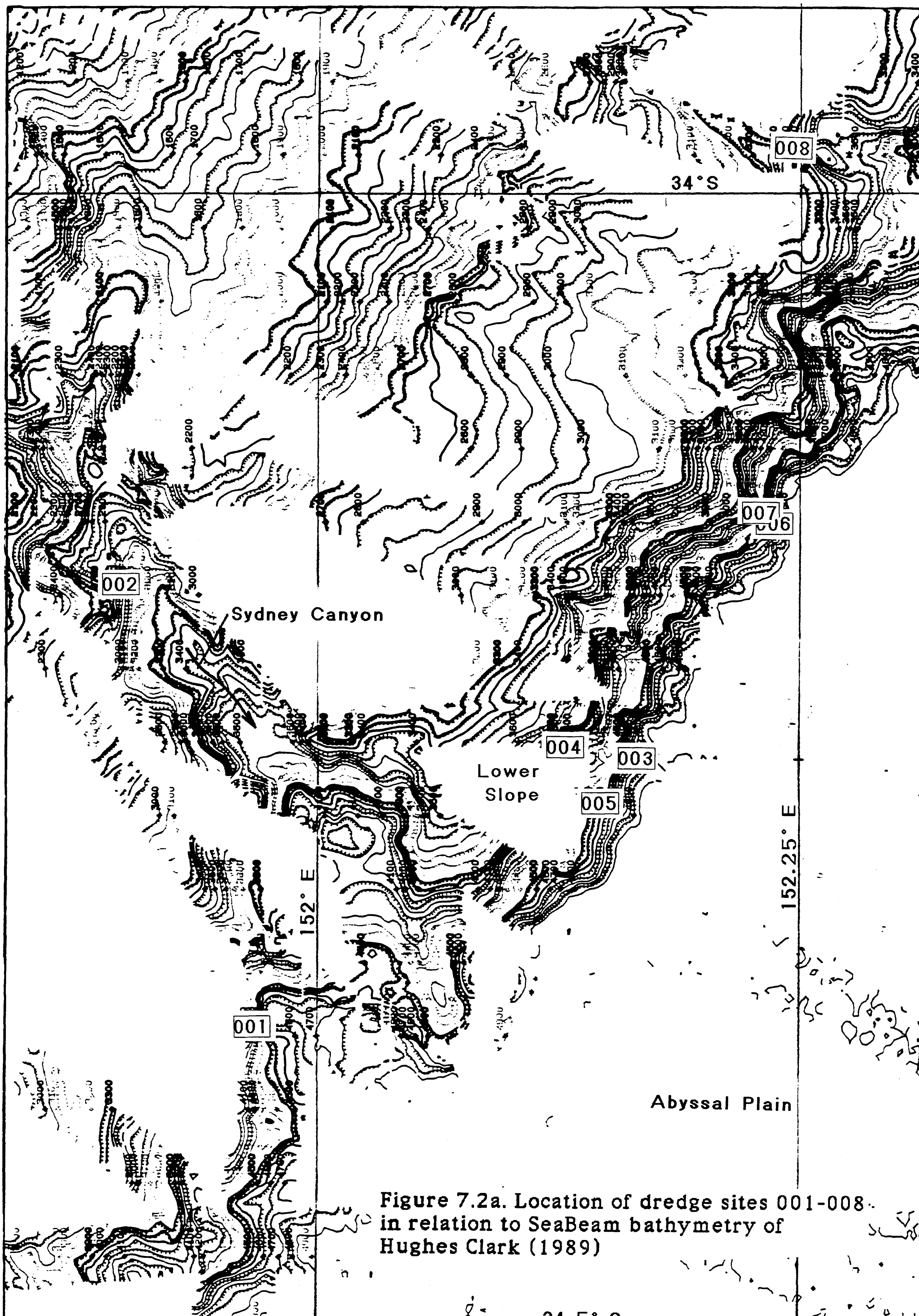


Figure 7.2a. Location of dredge sites 001-008 in relation to SeaBeam bathymetry of Hughes Clark (1989)

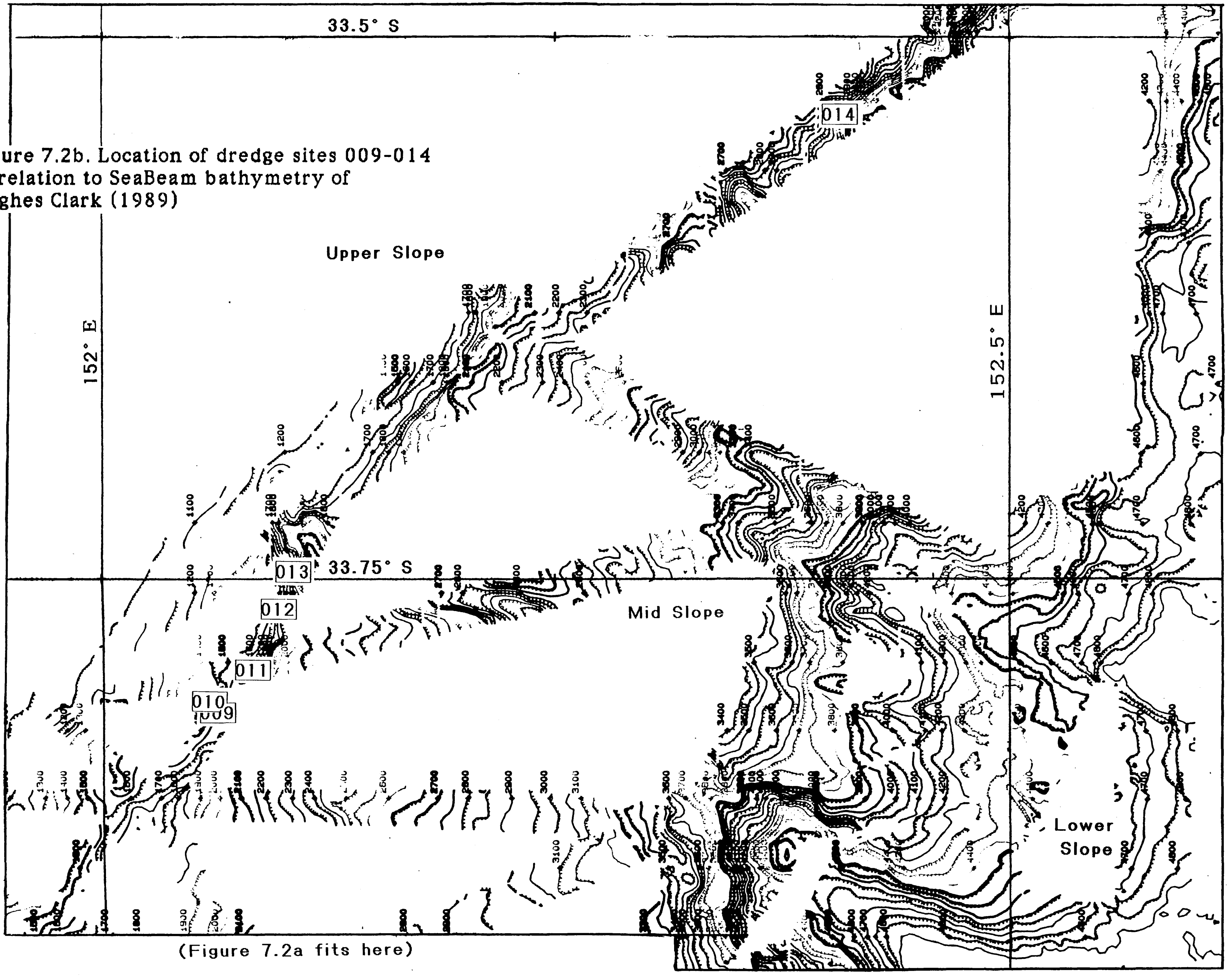


Figure 7.2b. Location of dredge sites 009-014 in relation to SeaBeam bathymetry of Hughes Clark (1989)

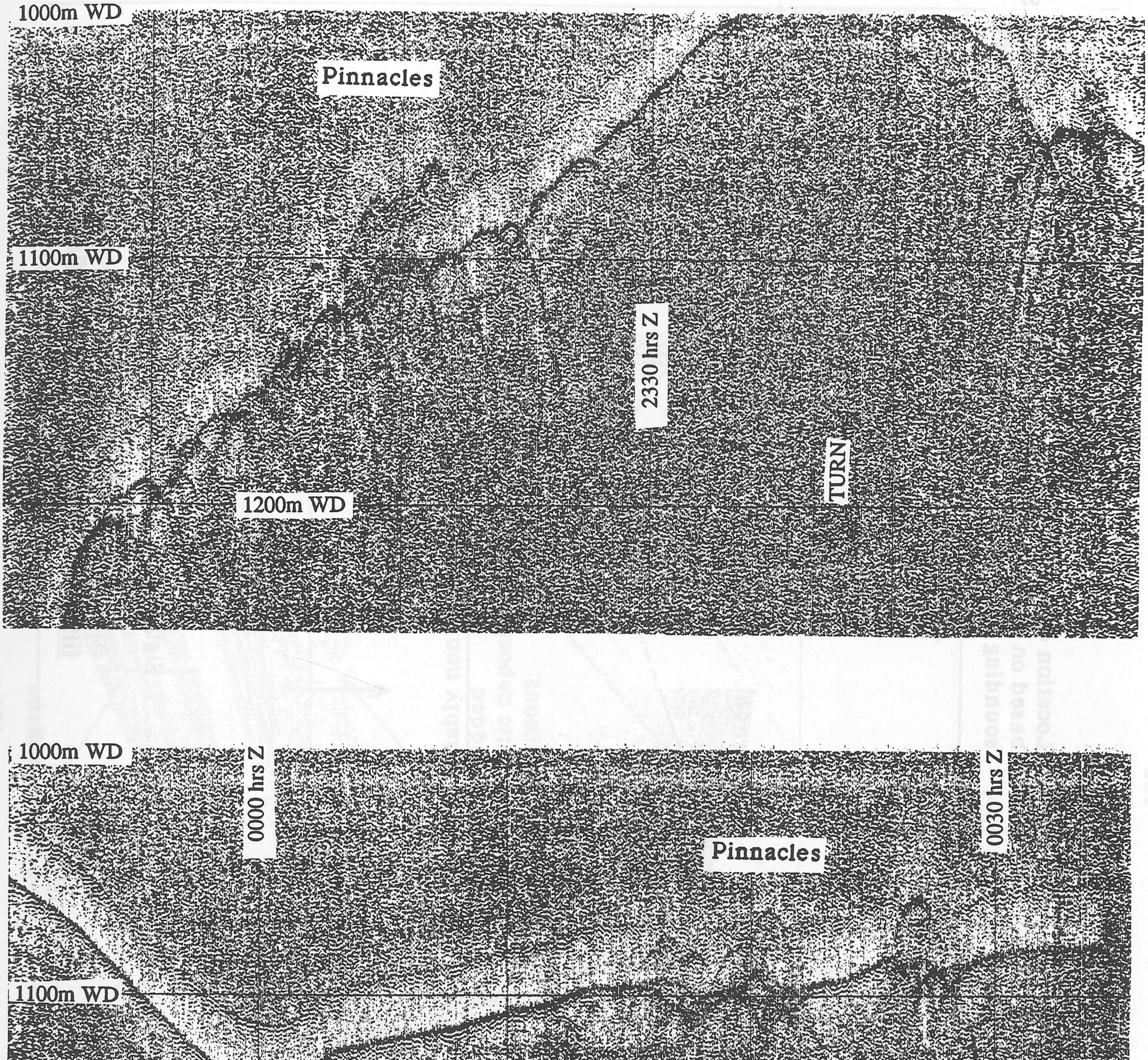


Figure 7.3

FRI Pinnacles offshore of Newcastle, imaged using the *Rig Seismic* 12.5kHz echosounder at 7.5kt speed

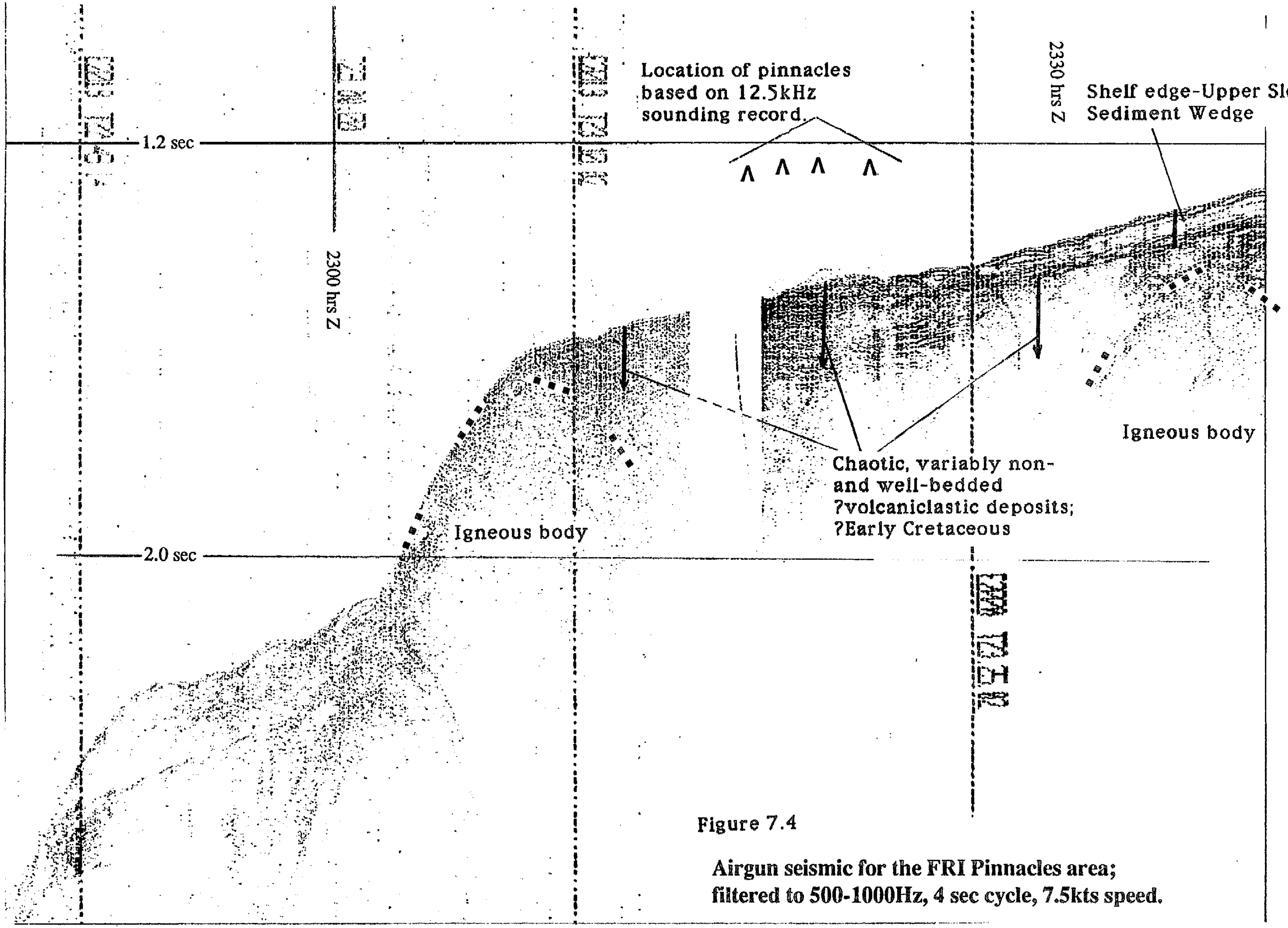


Figure 7.4

Airgun seismic for the FRI Pinnacles area; filtered to 500-1000Hz, 4 sec cycle, 7.5kts speed.

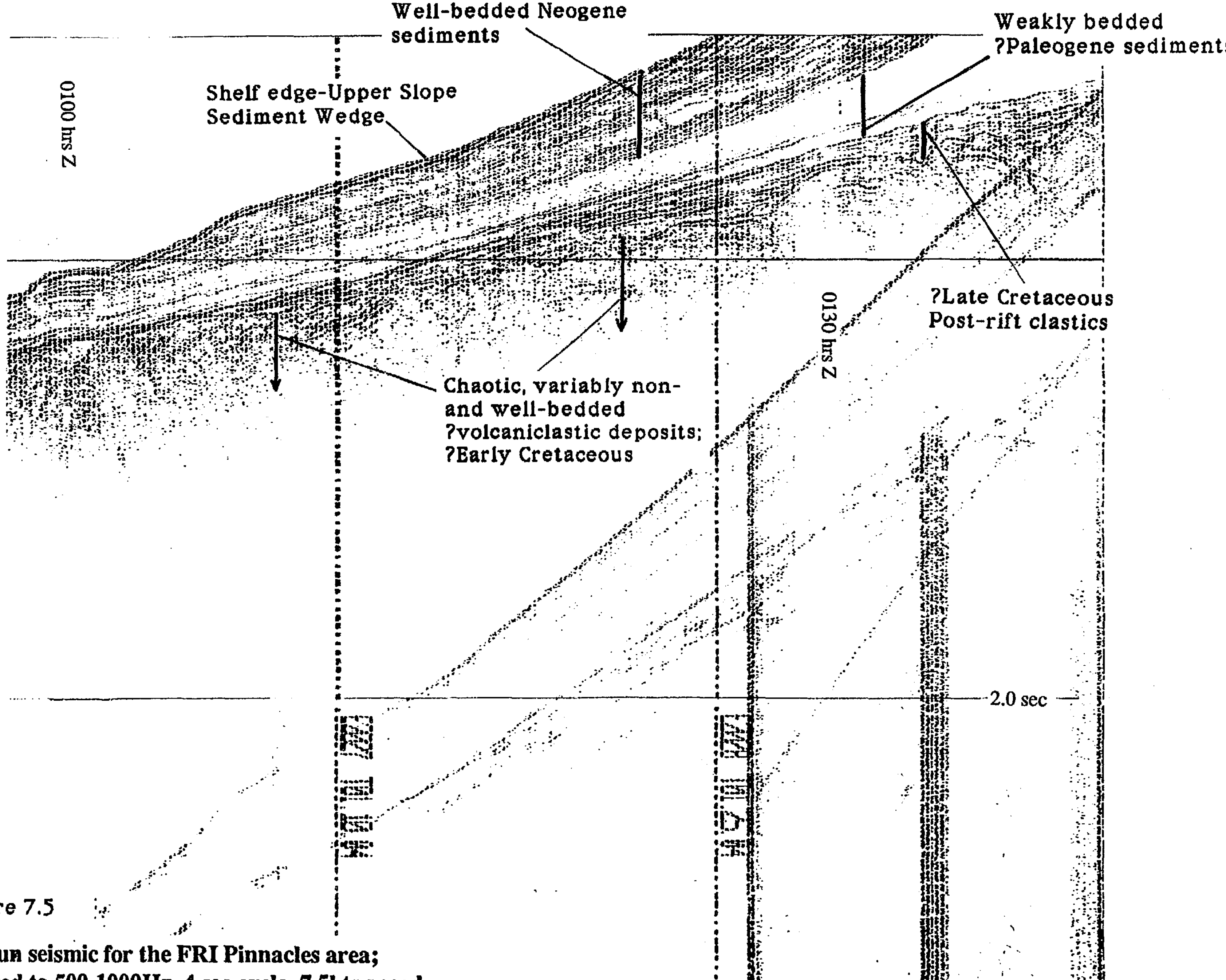


Figure 7.5

Airgun seismic for the FRI Pinnacles area; filtered to 500-1000Hz, 4 sec cycle, 7.5kts speed.

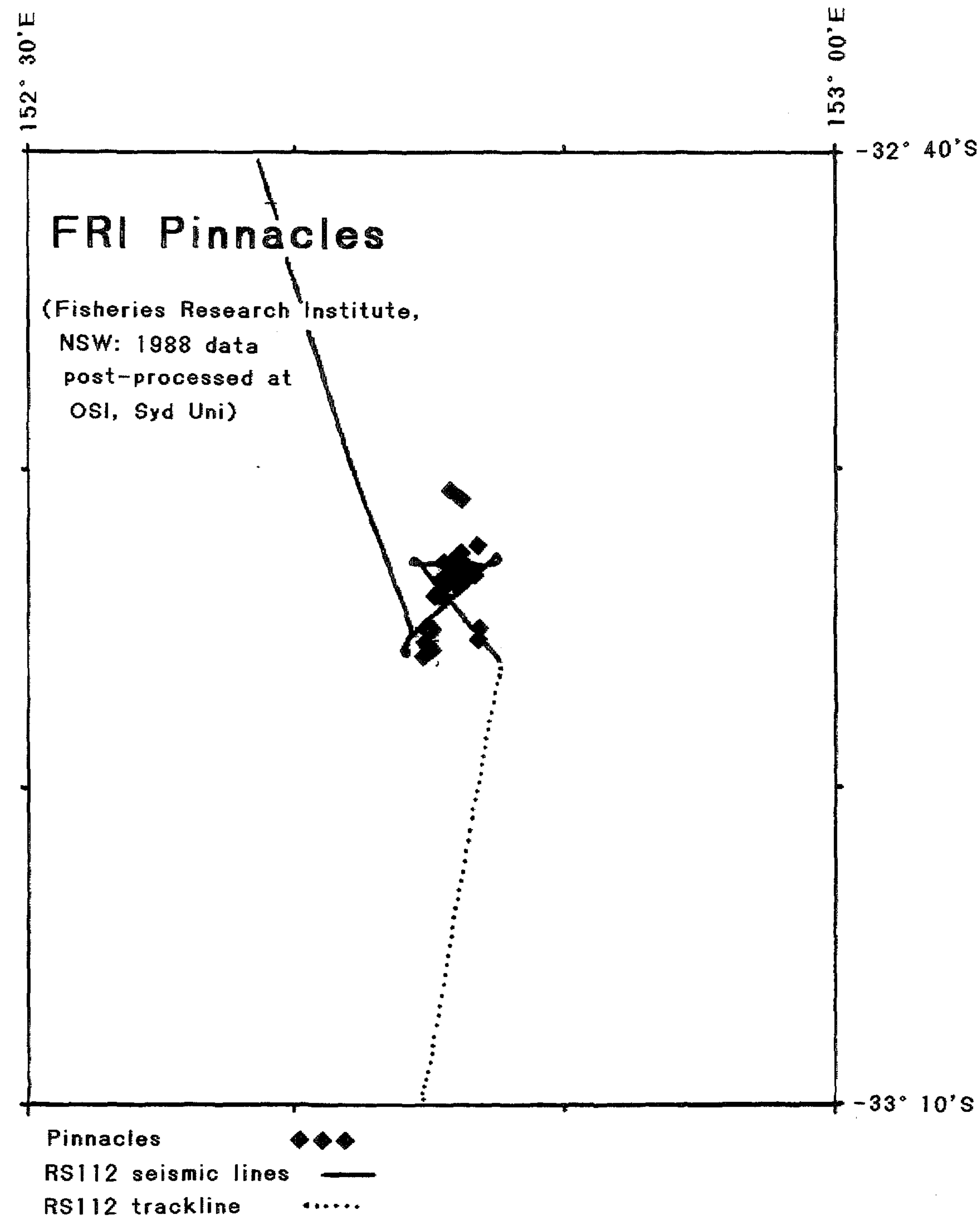


Fig 7.6 A map combining the (backcorrected) FRI cruise 8810 and 8812 and RV Rig Seismic Cruise 112 locational data.

8. Summary

This report summarises the preliminary shipboard results from AGSO Survey 112B aboard RV Rig Seismic, which covered the central NSW region of the eastern Australian continental margin. Data were collected during the cruise, conducted from 28/9/92 to 16/10/92, from the continental shelf and slope of the Sydney Basin (32.5 to 35°S). Although the study area is proximal to Australia's most densely urbanised and industrialised region, very little was known about the level of contaminants in the sediments, mineral resources of the shelf, Quaternary shelf stratigraphy, long term sea level and climate change record, the offshore extent of the Sydney Basin rocks, or the potential for offshore hydrocarbon reserves. Each of these topics formed a major objective of Cruise 112B, and the preliminary results are summarised below.

Twelve transects of the continental margin were made between Seal Rocks and Shoalhaven Bight using boomer and air gun seismic profiling. Nine of these were coincident with sampling transects. Boomer data provided information on the distribution and thickness of Quaternary sediment, whereas exceptionally high quality air gun records gave detailed information on the deeper Tertiary sediment wedge overlying basement rocks.

Thick deposits (>15 m) of Quaternary sediment on the shelf are confined to localised regions of the inner shelf, where shelf sand bodies (eg. south of Port Hacking and off Seal Rocks) and valley-fill sequences (eg., entrance to Port Kembla/Wollongong and Broken Bay) have been identified. Isolated, thin sedimentary deposits occur in mid shelf depressions and as a veneer on the outer shelf. The Holocene mid shelf mud belt is also observable on the boomer record.

The Tertiary wedge comprises two major sedimentary packages, each exhibiting a number of unconformities. The lower unit overlies a basement surface which is either smooth and undulating, or highly irregular, probably reflecting underlying rotated fault blocks. The unit comprises strongly prograding clinoforms and some contorted bedding in the central paleoshelf location. The upper unit is also strongly prograding and exhibits some evidence of instability on the slope.

Surface and subsurface samples collected across the central NSW shelf show that the Quaternary sediment is distributed in three shore-parallel lithofacies. These are the inner shelf clastic (quartzose) sand facies, the mid shelf muddy sand facies, and the outer shelf calcareous sand facies. These facies have been identified previously on the basis of surface sediment samples (Shirley, 1964; Davies, 1979; Marshall, 1980; Roy and Stephens, 1980; Colwell, 1982; Clark, 1985; Ferland, 1990); however, vibrocores collected during Cruise 112B represent the first subsurface data from the outer shelf of central NSW. In addition, several cores contain sediment deposited in a shallow shelf environment during the last glacial maximum, which has not been sampled before in Australia.

Seismic data (boomer and air gun) and vibrocores confirm that the Quaternary sedimentary sequence on most of the central NSW shelf is relatively thin, except in isolated inner shelf locations where sediment thickness exceeds 15 m (shelf sand bodies, flood tidal deltas, valley-fill sequences, and drowned barrier complexes). Vibrocores penetrating a thin inner shelf sequence (<2 m) frequently encountered gravel layers above a (presumed) erosional unconformity, which may coincide with bedrock or the top of the Tertiary sediment wedge. The inner shelf is dominated by quartzose sediment, with generally small but variable amounts of lithics, shells and shell fragments. This sediment comprises a source of marine aggregate and heavy minerals on the shelf; however, further detailed studies are required to assess resource potential at specific sites.

The mid shelf muddy sand facies is a surficial deposit, in water depths of approximately 70 to 120 m, that varies in thickness from 1 to at least 3 m thick. The sediment is composed of both clastic and calcareous components. Two areas of very muddy sediment (>70% mud) occur within the zone of muddy sand; these are adjacent to Newcastle and between Sydney and Wollongong (Fig. 4.2). The mid shelf muddy sand facies is of primary interest in the study of contaminant concentration and dispersal, as discussed below.

Calcareous sand and shell gravel, often in stacked fining-upward sequences, dominate the outer shelf sedimentary sequence encountered in the vibrocores. Grain size ranges from slightly muddy, poorly sorted fine sand to extremely coarse gravel-sized material composed primarily of pectenid valves and fragments oriented horizontally across the core barrel. The high proportion of calcareous sediment on the outer shelf indicates that substantial amounts of quartzose sediment have not been deposited through at least the late Quaternary, and that deposition of terrigenous sand has been confined mainly to the inner shelf. The tripartite division of the Quaternary shelf lithofacies is due to the complex interaction of a number of factors, including low sediment supply by rivers, high energy waves and littoral currents at the coast, a low energy mid shelf region, and high energy outer shelf processes. Changes in sea level resulted in the lateral displacement of the shoreface across the present shelf, but the lack of quartzose sediment on the outer shelf indicates that any clastic sand transported to the coast at lower sea levels did not accumulate there.

Waste from the Newcastle/Sydney/Wollongong urban and industrial conurbation has been discharged into the adjacent ocean for over 100 years. As a result, the sediment mantling the continental shelf in this area has become contaminated in organic and metallic residues. A sampling program was devised to delineate the nature, concentration and provenance of these contaminants and to establish baseline and historical background data sets.

Obtaining uncontaminated and representative samples from the seabed for geochemical analyses is difficult, especially in sandy substrates. Samples of shelf sand and muddy sand were acquired by grab, whereas vertical (temporal) sampling was done by vibrocoring. Surficial mud was sampled by box core, and vertical data were gathered by gravity core and vibrocore. Grab samples were retrieved from each sampling site and a good geographic distribution of box core and vertical sampling was recovered from the survey area.

High resolution vertical sampling was also completed in the mid shelf mud belt for pore water geochemical analysis and for studying complex processes taking place in the uppermost microlayer of surficial sediments. A total of 293 samples and subsamples are now available for processing and analysis.

Sedimentation on the continental shelf and slope of central NSW has been affected by glacial-eustatic sea level fluctuations and high energy processes throughout at least the late Quaternary. These processes include waves, wind- and wave-induced currents, coastal trapped waves, tidally-induced internal waves at the shelf break, and the East Australian Current; the latter two were active during Cruise 112B. Shelf processes influence sediment transport and dispersal on the continental shelf, and this is particularly important in those areas which contain sediment contaminated by urban and industrial wastes.

Our knowledge of the geological structure of the continental margin has been greatly extended by the activities of Cruise 112. Aside from sampling Palaeozoic basement from the lowermost slope, it was shown that Late Mesozoic sediments also compose significant sections of the lower slope. The fact that some were strongly deformed, suggests that strike-slip or active faulting occurred there at late stages of rifting. The lithological diversity of sandstones in the Late Mesozoic facies suggests complex patterns of clastic input- quartzose, quartz-felspatho-lithic and (particularly) volcanic- to the basin. The dredging of significant quantities of volcanic rock types indicates evidence that the rifting was not non-volcanic, but that the volcanic record is preserved mainly offshore. The recovery of large quantities of Early Cenozoic greensand points to a significant period of low sedimentation rates in the post-rift period.

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11. List of survey personnel

AGSO complement.

David Heggie	Gary Bickford	Andrew Hislop
Stephen Dutton	David Sewter	John Roberts
Chris Lawson	Claude Saroch	Colin Tindall
Leo Kalinisan	Simon Milnes	Richard Schuler
Heather Miller	Jeremy Bishop	Peter Davis
Jon Stratton	Tony Hunter	Vojciech Wierzbicki

Sydney University and NSW Geological Survey complement.

G. Birch	J. Keene	Student Participants
C. Jenkins	P.Roy(NSWGS)	D. Evenden
M. Ferland	D. Mitchell	A. Gordon
		A. Judge
		M. Teutsch

AMSA complement.

Bob Hardinge	Cedric Hellier	Roger Thomas
Ian McCarthy	Bob Dickman	Phil Hutchinson
Tony Dale	Mike Pitcher	Graham Pretsel
Bill Fowler	Geoff Conley	Pat Hutchins
Mark Cummer	Trevor Walters (16 - 24 September 1992)	

Bill Orgill (24 - 29 September 1992)

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Appendix B Vibrocoring methodology.

Appendix C Locations of samples within storage areas.

Appendix A: Bibliography

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Appendix B: Vibrocoring Method

The equipment used in Cruise 112 comprised an electrically powered vibrating head connected to an aluminium core barrel, fitted with a 'bit' and a newly designed core catcher by AGSO. A 7 m high steel tower and supporting legs holds the corer in a vertical position. The vibrating head comprises a robust water tight housing which contains twin opposing electric motors with eccentrics to produce the vibration. The 6 m aluminium core barrels have an ID of 75 mm and a 2 mm wall thickness; they are treated as disposable and only used once. The stainless steel core catchers have overlapping leaves/fingers that usually close on withdrawal from the seabed and greatly reduce the loss of bottom sediment. A simple flap valve, mounted in the base of the head, pumps water out of the core barrel as the head vibrates and the barrel penetrates the sea bed. The flap valve also provides suction during its withdrawal.

The tower is of steel construction, with an opening that extends the full height of the tower to permit core barrels to be installed and removed while the tower is in an upright position. A spring-loaded gate is fitted to the base plate of the tower; this closes when the core barrel is retracted from the seabed. Three-phase (415 volt) power is supplied to the vibrocorer head via a drum-mounted coaxial cable which also lifts the tower.

Two vibrating heads were used during Cruise 112: (1) a heavy head (approximately 150 kg) supplied by the AGSO, and (2) a lighter head (approximately 65 kg) supplied by the GSNSW. In theory, the lighter head should allow more vibration energy to be transferred to the core bit, however in practice, both heads performed satisfactorily. The degree of variability in penetration versus recovery for both heads make it difficult to compare their performance. Penetration seemed to be influenced primarily by local geology, but other factors such as ship handling, sea conditions and the tension on the lifting cable while the vibrocorer was on the bottom undoubtedly influenced core recovery on some occasions.

During the first half of the cruise (Cruise 112A) the vibrocorer was fitted with a shortened tower and 3 m aluminium barrels deployed from the helicopter deck. While this was an efficient operation in reasonable sea conditions, it was dangerous in rough weather and not considered feasible when deploying the 7m tower. Consequently, for the second half of the cruise, the vibrocorer was successfully deployed from the "A-frame" deck on the port side of the ship; the upper deck was used to clamp and release the top of the barrel to the head, and to operate the winch. The vibrocorer was successfully deployed under a range of sea conditions, including winds up to 40 knots and short rough seas of up to 2 m. Initially barrels were fitted with a weighted sponge plug tied inside the core catcher with string and tape that would release into the core barrel when the bit penetrated the sea bed. The sponge plug was designed to rest on the sediment surface as the corer penetrated through the sediment, and prevent sediment from becoming disturbed by washing when the barrel was removed and laid horizontally to be cut. In some cases the sponge malfunctioned (ie., was found embedded in the sediment sequence), possibly because the chain used to weight the sponge became jammed in the core catcher. In order to avoid contamination, the sponge plug was omitted entirely from cores collected for geochemical analyses, but in some of these cores the uppermost sediment was washed and disturbed. Subsequently the sponge was replaced by a teflon plug that could be inserted in the top of the core after it was removed from the vibrocorer head, but before it was laid horizontally. The teflon plug sank through the water in the top of the core, to rest on the sediment surface, thus immobilising the sediment during cutting. This system failed to work in very muddy sediment where the coring disturbed the surface mud to produce a slurry in the top of the core barrel, that prevented the plug from sinking.

At each core site, the ship was maintained as close as possible to stationary while the vibrocorer was lifted outboard on the "A" frame and lowered to the seabed. Vibration time was normally 3-4 minutes. Previous experience with the GSNSW vibrocorer head showed that longer vibration time was likely to crack the aluminium barrel just beneath the clamp. However, this probably doesn't apply to the heavier AGSO head, which has a lower frequency vibration. On average it took about one hour to collect a grab sample and one vibrocore at a site; a second vibrocore or a box core added an extra half hour to the sampling program.

The vibrocorer was not fitted with a penetrometer for indicating the precise rate at which the core barrel was entering the sea bed. This presented problems of interpretation in those cores where penetration stopped before the vibration time elapsed. Apparently the vibration of the head causes the flap valve to operate as a suction pump. Under ideal conditions, water is excavated from the core barrel at about the same rate as it is displaced by the entering sediment; the suction effect also assists the sediment to enter the barrel. However, if penetration ceases, due for instance to the corer hitting an impenetrable gravel layer, continued action of the flap valve sucks sediment and water into the barrel creating a situation where the measured recovery exceeds the penetration (cores VC/073, 074, 075, 103, 108, 115, 116, 131 and 135). Much of the sediment in these cores is completely disturbed and, in the case of VC/103, the "suck-up" effect seems to have produced a graded (upward fining) unit over a core length of 2 m, presumably water has been pumped through the sediment in the barrel. Since some natural sedimentary sequences do, in fact, coarsen downward to terminate in a basal gravel layer, it is difficult to distinguish true sediment patterns from an artefact of coring. Clearly, it is desirable to know (in real time) how the corer is operating on the seabed so as to stop vibration as soon as penetration ceases. A mechanical/electric meter recording the downward movement of the vibrocorer head would provide the necessary information; alternatively, a video camera could achieve the same results and also provide a view of the sea bed.

Once the vibrocorer was retrieved, the core barrel was removed and inspected for chatter/scrape marks caused as it moves past the gate at the base of the tower. This gave the penetration depth, although in some cases it was difficult to determine absolutely. This problem can be resolved by drawing a single thick line down the length of each core barrel with a "Sakura Solid Marker"; this leaves a waxy line that is removed as the barrel penetrates through sediment and the line remains in tact above the point of penetration. It is best to mark the barrel just prior to fitting it into the vibrocorer tower, so that the mark is not scraped off during transport, etc. The condition of the core bit - whether it is hammered or unmarked - provides information about why penetration may have ceased, especially in the case of gravel or cemented layers.

The opposite effect to "suck-up" occurs when a significantly smaller amount of sediment is recovered than is penetrated. This can arise in a number of ways: (1) through the loss of sediment out of the bottom of the core barrel; unlikely in most cases because of the effectiveness of the new AGSO core catcher; (2) by compaction during coring; a common occurrence in muds and possibly in coarse, poorly sorted shell gravels (20-30%) but unlikely to be significant in clean sand; or (3) as a result of a "pile-driver" effect; produced when the core catcher becomes blocked (with a large pebble, etc) and the underlying sediment is sufficiently soft (ie., mud) to allow the core barrel to penetrate the subsurface as a solid plug. In practice, it was sometimes difficult to identify the specific cause of under-recovery. Cores that recovered much less than they penetrated are: VC/076, 080, 081, 083, 084, 088, 090, 093, 098, 099, 126, 132, and 133.

Appendix C: Locations of samples within storage areas

The working sample half of all gravity cores and vibrocores, and 60% of all dredge material is stored at Sydney University, Department of Geology and Geophysics.

A inventory of all samples stored at Sydney University for geochemical analysis is presented in Table 5.1.

Sample Identification	Sample Description		Storage Location			
	Archive Length	Sampled Length	Bay	Tray	Row	
111/GC/001	0-60		32	H	1	
	60-160		32	H	2	
			32	H	3	
			32	H	4	
112/GC/001	UNCUT CORES		32	I	1	
	/LHC/ANALYSIS		32	I	2	
			32	I	3	
			32	I	4	
112/GC/002	" " "		32	J	1	
			32	J	2	
			32	J	3	
112/GC/003	0-27		32	J	4	
	27-127		32	K	1	
112/GC/004	0-38		32	K	2	
	38-100		32	K	2	
112/GC/008	0-100		32	K	3	
	100-200		32	K	4	
	200-300		32	L	1	
112/GC/009	0-36		32	L	2	
	36-136		32	L	3	
	136-236		32	L	4	
	236-336		32	M	1	
	336-436		32	M	2	
112/GC/010	0-36		32	M	3	
	36-136		32	M	4	
	136-236		32	N	1	
	236-336		32	N	2	
	336-436		32	N	3	
	436-536		32	N	4	
112/GC/011	0-39		32	O	1	
	39-139		32	O	2	
	139-239		32	O	3	
	239-339		32	O	4	
	339-439		32	P	1	
112/GC/012	KK 3321-334		32	P	2	
	CC 310-321		32	P	2	
	0-21		32	P	2	
	21-121		32	P	3	
	121-221		32	P	4	
	221-3221		32	Q	1	
			32	Q	2	
			32	Q	3	
			32	Q	4	
112/VC/072	0-71		33	C	1	
	71-171		33	C	2	
112/VC/073	0-56		33	C	3	

Appendix C. Location of cores stored at Barrier Street

	56-156		33	C	4	
	156-256		33	D	1	
	256-356		33	D	2	
	356-456		33	D	3	
112/VC/074	0-69		33	D	4	
	69-169		33	E	1	
	169-269		33	E	2	
	269-369		33	E	3	
112/VC/075	0-66		33	E	4	
	66-92		33	E	4	
	92-192		33	F	1	
	193-293		33	F	2	
	293-393		33	F	3	
	394-490		33	F	4	
112/VC/076	0-51		33	G	1	
112/VC/077	0-50		33	G	1	
112/VC/076	51-148		33	G	2	
112/VC/077	50-150		33	G	3	
	150-245		33	G	4	
112/VC/078	33-133	0-33missing	33	H	1	
	133-233		33	H	2	
112/VC/080	0-61		33	H	3	
112/VC/081	0-63		33	H	4	
112/VC/083	0-81		33	I	1	
112/VC/084	0-80		33	I	2	
112/VC/085	0-19		33	I	2	
112/VC/084	80-180		33	I	3	
112/VC/085	19-119		33	I	4	
	119-219		33	J	1	
112/VC/087	0-46		33	J	2	
	46-146		33	J	3	
	146-246		33	J	4	
	246-346		33	K	1	
112/VC/088	0-78		33	K	2	
112/VC/089	0-30		33	K	2	
	30-130		33	K	3	
	130-230		33	K	4	
112/VC/090	0-97		33	L	1	
112/VC/093	0-54		33	L	2	
112/VC/094	0-77		33	L	3	
	77-177		33	L	4	
	177-277		33	M	1	
	277-377		33	M	2	
	377-477		33	M	3	
	477-577		33	M	4	
112/VC/095			33	N	1	
			33	N	2	
112/VC/096	0-85		33	N	3	
	85-185		33	N	4	

Appendix C. Location of cores stored at Barrier Street

	185-281		33	O	1	
112/VC/097	0-51		33	O	2	
	51-151		33	O	3	
	151-251		33	O	4	
	251-352		33	P	1	
	352-452		33	P	2	
	452-552		33	P	3	
112/VC/098	0-76		33	P	4	
	76-176		33	Q	1	
	176-277		33	Q	2	
112/VC/099	0-56		33	Q	3	
	56-156		33	Q	4	
			33	R	1	
112/VC/100	0-55		33	R	2	
	55-155		33	R	3	
	155-255		33	R	4	
	255-355		33	S	1	
112/VC/101	0-96		33	S	2	
	96-150		33	S	3	
	150-195		33	S	3	
	195-295		33	S	4	
112/VC/102	0-21		33	T	1	
112/VC/103	0-28		33	T	1	
112/VC/102	21-121		33	T	2	
112/VC/103	28-128		33	T	3	
	128-228		33	T	4	
	228-328		33	U	1	
112/VC/104	0-65		33	U	2	
	65-165		33	U	3	
	165-265		33	U	4	
	265-365		33	V	1	
	365-465		33	V	2	
112/VC/105	0-100		33	V	3	
	100-200		33	V	4	
	200-300		33	W	1	
	300-400		33	W	2	
1112/VC/106	0-34		33	W	3	
	34-134		33	W	4	
	134-244		33	X	1	
	245-345		33	X	2	
112/VC/107	0-96		33	X	3	
	96-196		33	X	4	
	196-296		33	Y	1	
112/VC/108	0-65		33	Y	2	
	65-165		33	Y	3	
	165-265		33	Y	4	
	265-365		34	A	1	
112/VC/109	0-17		34	A	2	
	17-117		34	A	3	

	117-217		34	A	4	
112/VC/110	0-46		34	B	1	
	46-100		34	B	1	
	100-200		34	B	2	
	200-300		34	B	3	
	400-500		34	B	4	
	390-500		34	C	1	
112/VC/111	9-109		34	C	2	
	109-209		34	C	3	
112/VC/112	0-57		34	C	4	
	57-157		34	D	1	
	157-257		34	D	2	
112/VC/113	0-73		34	D	3	
	73-173		34	D	4	
	173-273		34	E	1	
112/VC/115	113-215	0-13/SU all of sample	34	E	2	
	113-213		34	E	3	
	213-313		34	E	4	
	313-413		34	F	1	
112/VC/116	0-25		34	F	2	
	25-125		34	F	3	
	125-225		34	F	4	
	225-325		34	G	1	
	325-425		34	G	2	
	425-525		34	G	3	
112/VC/118	0-100		34	G	4	
	100-200		34	H	1	
	200-300		34	H	2	
	300-400		34	H	3	
112/VC/121	0-72		34	H	4	
	72-172		34	I	1	
	172-272		34	I	2	
	272-372		34	I	3	
112/VC/122	0-73		34	I	4	
112/VC/124	0-93		34	J	1	
	93-193		34	J	2	
	193-295		34	J	3	
112/VC/125	0-98		34	J	4	
	98-192		34	K	1	
112/VC/126	0-100		34	K	2	
112/VC/127	0-96		34	K	3	
	96-196		34	K	4	
	196-296		34	L	1	
112/VC/128	0-50		34	L	2	
	50-90		34	L	2	
	90-190		34	L	3	
112/VC/129	0-31		34	L	4	
112/VC/130	0-57		34	L	4	
112/VC/129	31-131		34	M	1	

Appendix C. Location of cores stored at Barrier Street -

112/VC/130	57-157		34	M	2	
	157-257		34	M	3	
	257-357		34	M	4	
112/VC/132	0-69		34	N	1	
	69-169		34	N	2	
	169-269		34	N	3	
	269-369		34	N	4	
112/VC/133	0-106		34	O	1	
112/VC/134	0-100		34	O	2	
	100-206		34	O	3	
	206-306		34	O	4	
	306-406		34	P	1	
	406-506		34	P	2	
112/VC/135	0-106		34	P	3	
	106-203		34	P	4	
112/VC/136	0-30		34	Q	1	
	30-130		34	Q	2	
	130-230		34	Q	3	
	230-330		34	Q	4	
112/VC/137	0-85		34	R	1	
	85-185		34	R	2	
	185-285		34	R	3	
	285-385		34	R	4	
112/VC/138	0-22		34	S	1	
	22-104		34	S	1	
	104-204		34	S	2	
112/VC/139	0-22		34	S	3	
	22-122		34	S	4	
	122-222		34	T	1	
	222-322		34	T	2	
	322-422		34	T	3	
			34	T	4	
112/VC/001	0-62		34	U	1	
112/VC/002	0-44		34	U	1	
		0-44	34	U	2	
	44-90		34	U	2	
		44-90	34	U	3	
	90-132		34	U	3	
		90-132	34	U	4	
112/VC/003	0-56		34	U	4	
112/VC/002	132-232		34	V	1	
		132-232	34	V	2	
	0-28		34	V	2	
		0-28	34	V	3	
112/VC/004	0-21	0-21	34	V	3	
112/VC/005	0-75		34	V	4	
	75-175		34	W	1	

Appendix C. Location of cores stored at Barrier Street

112/VC/007	0-92		34	W	2	
	92-210		34	W	3	
112/VC/008	0-39		34	W	4	
112/VC/010	0-16		34	W	4	
112/VC/011	0-68		34	X	1	
112/VC/014	0-33		34	X	1	
112/VC/011	68-168		34	X	2	
112/VC/012	0-110		34	X	3	
112/VC/016	0-57		34	X	4	
112/VC/018	0-28		34	X	4	
112/VC/015	0-100		34	Y	1	
	100-137		34	Y	2	
112/VC/017	0-80		34	Y	2	
	80-180		34	Y	3	
112/VC/019	0-90		34	Y	4	
	90-190		35	A	1	
	190-290		35	A	2	
112/VC/021	0-100		35	A	3	
	100-200		35	A	4	
	200-262		35	B	1	
112/VC/023	0-42		35	B	1	
112/VC/022	0-100		35	B	2	
	100-140		35	B	3	
112/VC/024	100-148		35	B	3	
	0-100		35	B	4	
112/VC/025	0-100		35	C	1	
	100-200		35	C	2	
	200-268		35	C	3	
112/VC/026	0-76		35	C	4	
		0-76	35	D	1	
	76-176		35	D	2	
		76-176	35	D	3	
112/VC/027	0-116		35	D	4	
112/VC029	0-81		35	E	1	
		0-81	35	E	2	
	81-181		35	E	3	
		81-181	35	E	4	
	181-281		35	F	1	
		181-281	35	F	2	
112/VC/030	0-100		35	F	3	
	100-142		35	F	4	
112/VC/032	100-156		35	F	4	
	0-100		35	G	1	
112/VC/034	0-63		35	G	2	

Appendix C. Location of cores stored at Barrier Street -

112/VC/035	0-15		35	G	2	
112/VC/037	0-96		35	G	3	
112/VC/038	100-160		35	G	4	
	0-100		35	H	1	
112/VC/039	0-107		35	H	2	
112/VC/040	0-100		35	H	3	
	100-136		35	H	4	
112/VC/042	0-68		35	H	4	
112/VC043	0-37		35	I	1	
112/VC/044	31-131		35	I	2	
		31-131	35	I	3	
112/VC/045	0-100		35	I	4	
	100-200		35	J	1	
112/VC/046	0-100		35	J	2	
	100-174		35	J	3	
112/VC/047	0-100		35	J	4	
112/VC/048	0-100		35	K	1	
112/VC/049	0-38		35	K	2	
112/VC/050	0-45		35	K	2	
112/VC/051	0-27		35	K	3	
112/VC/052	100-125		35	K	3	
112/VC/053	0-15		35	K	3	
		0-15	35	K	3	
112/VC/052	0-100		35	K	4	
112/VC/054	0-100		35	L	1	
112/VC/055	0-100		35	L	2	
	100-147		35	L	3	
112/VC/056	100-128		35	L	3	
	0-100		35	L	4	
112/VC/057	0-114		35	M	1	
	114-209		35	M	2	
112/VC/058	0-45		35	M	3	
		0-45	35	M	3	
	45-145		35	M	4	
		45-145	35	N	1	
	145-245		35	N	2	
		145-245	35	N	3	
112/VC/059	0-100		35	N	4	
	100-128		35	O	1	
112/VC/060	0-78		35	O	1	
112/VC/061	0-100		35	O	2	
	100-123		35	O	3	
	123-218		35	O	3	
112/VC/062	0-81		35	O	4	
112/VC/063	0-100		35	P	1	
	100-198		35	P	2	

Appendix C. Location of cores stored at Barrier Street -

112/VC/064	0-100		35	P	3	
	100-201		35	P	4	
112/VC/065	0-90		35	Q	1	
		0-90	35	Q	2	
	90-190		35	Q	3	
		90-190	35	Q	4	
112/VC/066	0-92		35	R	1	
UNCUT		0-92	35	R	2	
112/VC/067	0-27	0-27	35	R	3	
			35	R	4	
112/VC/069	0-100		35	S	1	
		0-100	35	S	2	
	100-150		35	S	3	
		100-150	35	S	3	
			35	S	4	
F0177	112GS002	1BAG				
	112BC005	1s/BAG				
	112BC006	3BAGS				
	112BC007	3BAGS	PLUS 1BAG FROM SWB(0-25cms)			
F0178	112BC009	2BAGS				
	112BC010	3BAGS	PLUS 1BAG FROM SWB(5-25cms)			
	112BC012	3BAGS				
F0179	112BC015	2BAGS	PLUS 1BAG FROM SWB			
	112BC018	1BAG				
	112BC020	1BAG				
	112BC021	1BAG				
	112BC022	1BAG				
	112VC013	1BAG				
F0180	112GS006	1BAG				
	112GS009	1BAG				
	112GS008	1S/BAG				
	112GS010	2BAG				
	112BC025	1BAG				
	112BC026	1BAG				
	112BC027	1BAG				
	112GS014	2BAG				
F0181	112BC029	2BAG				
	112BC030	2BAG				
	112BC031	2BAG				
	112BC032	2BAG				
	112BC033	2BAG				
	112GS015	2BAG				
F0182	112GS016	2BAG				
	112GS017	2BAG				
	112GS018	2BAG				
	112GS019	2BAG				
F0183	112BC034	1BAG				
	112BC035	1BAG(SEAWEED)				

Appendix C. Location of cores stored at Barrier Street -

	112BC036	1BAG				
	112BC038	1BAG				
	112GS020	2BAG				
	112GS021	2BAG				
	112BC039	1BAG				
	112BC042	1BAG				
F0184	112GS022	1BAG				
	112BC043	1BAG				
	112BC044	1BAG				
	112BC047	1BAG				
	112GS024	2BAG				
	112GS023	1BAG				
	112GS025	2BAG				
	112BC049	2BAG				
F0185	112GS026	2BAG				
	112GS027	2BAG				
	112GS028	2BAG				
	112BC051	1BAG				
	112BC052	1BAG				
	112GS029	2BAG				
	112BC053	2BAG				
F0186	112BC054	2BAG				
	112BC055	1BAG				
	112BC056	2BAG				
	112GS030	2BAG				
	112BC057	2BAG				
	112BC058	1BAG				
F0187	112GS031	2BAG				
	112BC059	2BAG				
	112BC060	2BAG				
	112GS032	2BAG				
F0188	112BC061	2BAG				
	112BC062	2BAG				
	112GS033	2BAG				
	112GS034	1BAG				
F0189	112GS035	1BAG				
	112BC063	1BAG				
	112BC064	1BAG				
	112BC065	1BAG				
	112BC066	1BAG				
	112BC067	1BAG				
	112GS036	2BAG				
	112GS037	1BAG				
F0190	112BC068	1BAG				
	112BC069	1BAG				
	112GS038	1BAG				
	112BC070	2BAG				
	112BC071	2BAG				
	112BC072	2BAG				

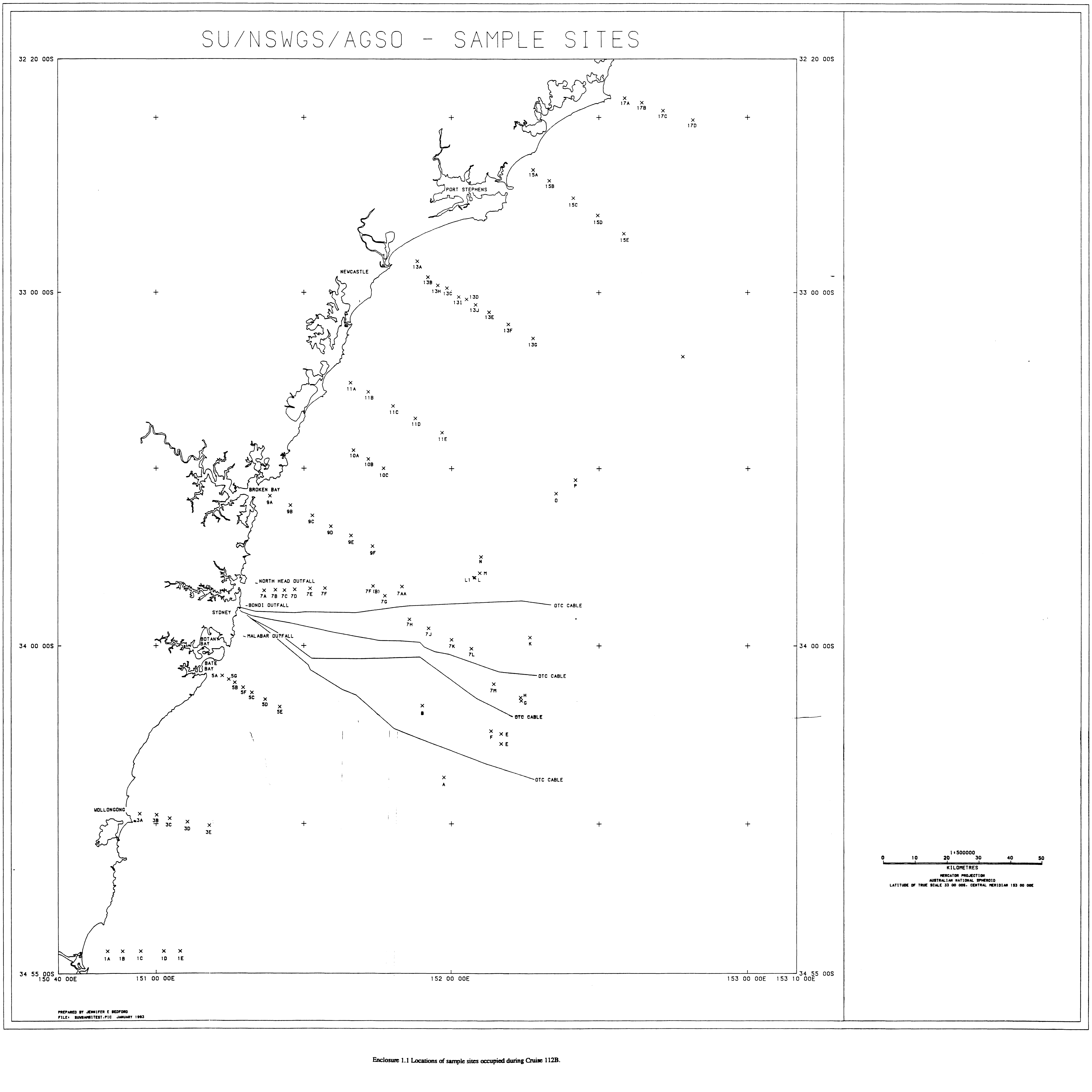
F0191	112BC073	2BAG				
	112BC071	1s/BAG				
	112GS036	1s/BAG				
	112BC074	2BAG				
	112BC075	1BAG				
	112BC076	1BAG				
	112BC077	2BAG				
F0192	112GS039	2BAG				
	112BC078	1BAG				
	112GS041	1BAG				
	112GS043	1BAG				
	112GS044	1BAG				
	112GS049	1BAG				
	112BC080	1BAG				
F0193	112GS040	1BAG				
	112GS041	1BAG				
	112GS045	2BAG				
	112GS047	1BAG				
	112GS048	3BAG				
F0194	112GS052	2BAG				
	112GS053	2BAG				
	112GS054	2BAG				
	112GS055	2BAG				
F0195	112GS056	1BAG				
	112GS057	1BAG				
	112GS059	1BAG				
	112GS060	2BAG				
	112GS061	1BAG				
	112BC081	1BAG				
	112BC082	1BAG				
F0196	112GS063	1BAG				
	112GS066	1BAG				
	112GS067	1BAG				
	112GC007	1BAG				
	112DR001	1BAG				
	112DR002	1BAG(TYPE A)				
	112DR002	2BAG(PIPE)				
	112DR003	1BAG(PIPE)				
F0197	112DR006	1BAG				
	112DR005	1BAG				
	112DR007	1BAG				
	112DR008	1BAG				
	112DR009	1BAG				
	112DR010	1BAG				
	112GS069	1BAG				
	112GS068	1BAG				
F0198	112GS070	2BAG				
	112GS071	2BAG				
	112GS072	2BAG				

Appendix C. Location of cores stored at Barrier Street -

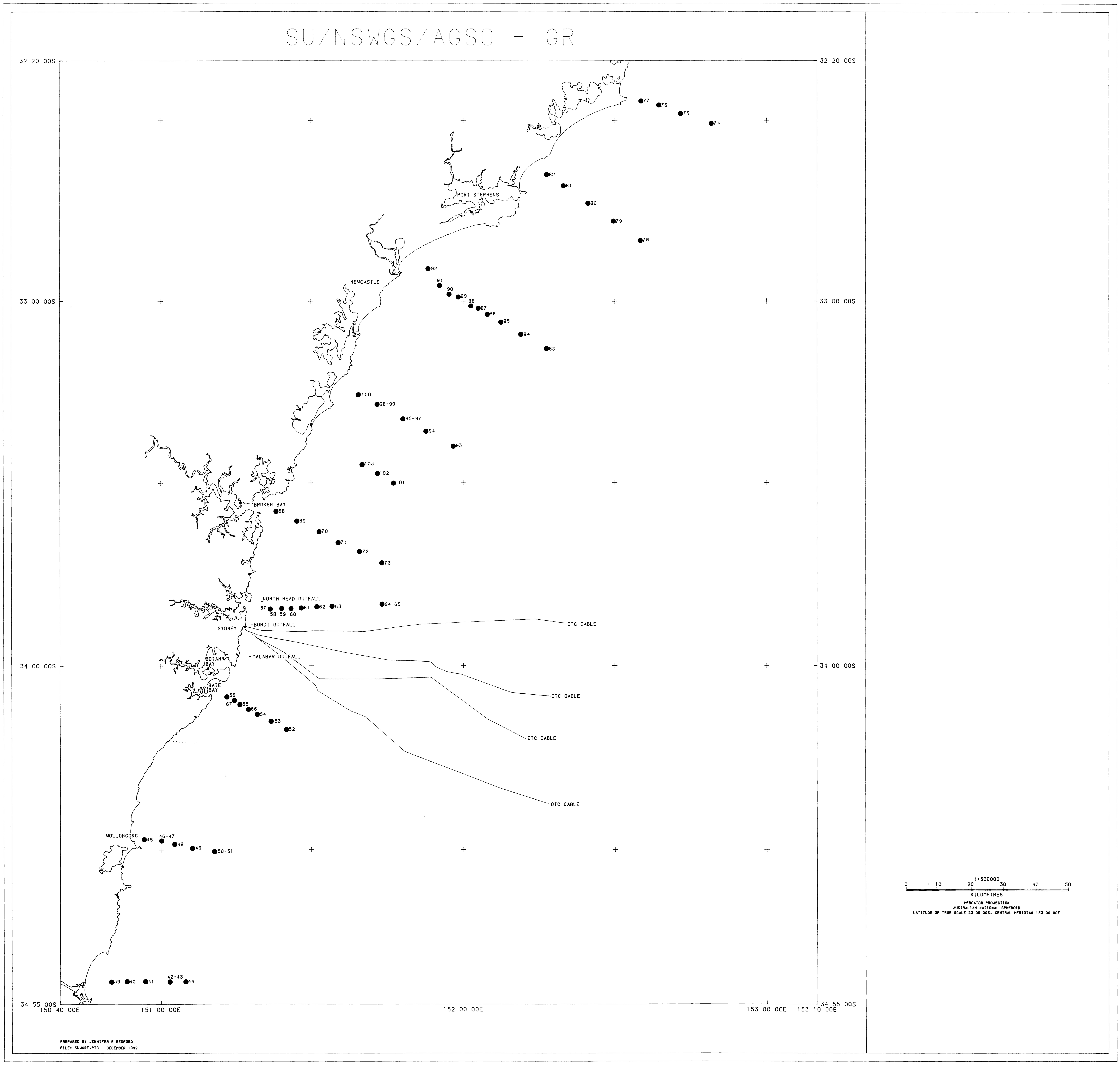
	112GS073	2BAG				
F0199	112GS088	1BAG				
	112GS078	1BAG				
	112GS079	2BAG				
	112GS077	1BAG				
	112GS076	2BAG				
	112GS075	2BAG				
F0200	112BC088	1BAG				
	112GS091	1BAG				
	112BC087	1BAG				
	112GS090	2BAG				
	112BC987	1BAG				
F0201	112GS089	2BAG				
	112BC084	1BAG				
	112BC085	1BAG				
	112GS087	2BAG				
	112GS085	2BAG				
	112GS086	1BAG				
F0202	112BC086	1BAG				
	112GS084	2BAG				
	112GS083	2BAG				
	112GS081	1BAG				
	112GS082	1BAG				
	112BC089	1BAG				
	112GS080	2BAG				
F0203	112GS092	1BAG				
	112GS093	1BAG				
	112GS094	1BAG				
	112GS097	1BAG				
	112GS099	2BAG				
	112GS101	2BAG				
F0204	112GS100	2BAG				
	112GS103	1BAG				
	112DR015	2BAG(TYPE A)				
	112DR015	1BAG(TYPE B)				
	112DR015	1BAG(TYPE C)				
	112DR015	1BAG(TYPE D)				
	112GS074	2BAG				
F0205	112DR011	1BAG				
	112DR012	1BAG				
	112DR013	1BAG(TYPE A)				
	112DR013	2BAG(TYPE B)				
	112DR013	2BAG(TYPE C)				
	112DR014	1BAG(PIPE)				
	112DR016	1BAG(PIPE)				

Sample Identification	Sample Number	Sample Description
702	112/DR/001	Type A loose
703	112/DR/001	Type B loose
		1bag Type C
704	112/DR/004	Type A loose
705	112/DR/004	Type B loose
706	112/DR/007	1 Rock
707		loose
708		loose
709		loose
710		loose
711	112/DR/008	Type A&F
712		Type C
713		Pipe Dredge
714	112/DR/006 &	
	DR/007	
715	112/DR/016	loose
716		loose
717		loose
718		loose

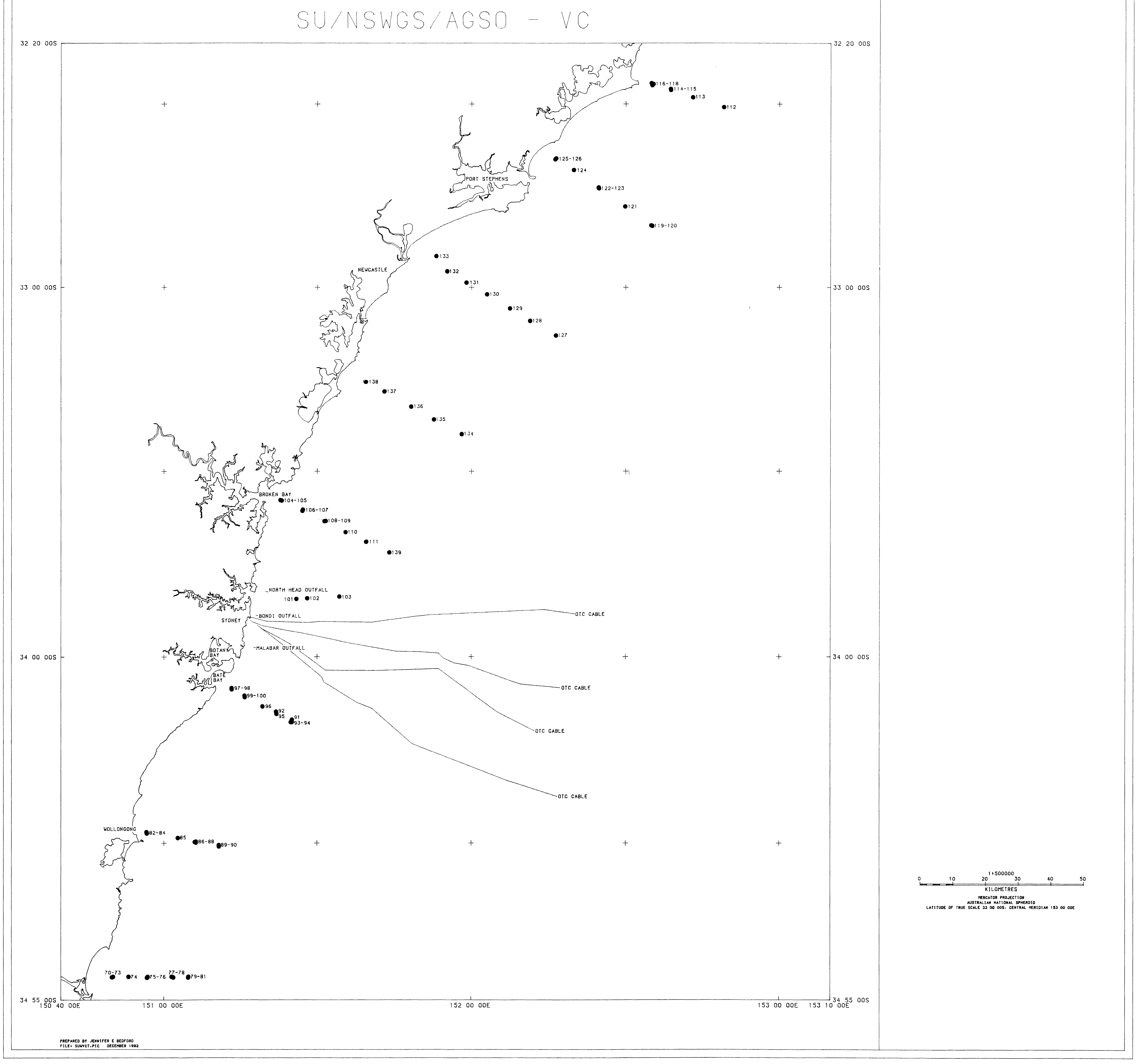
Appendix C. Location of samples stored at Maryborough Street



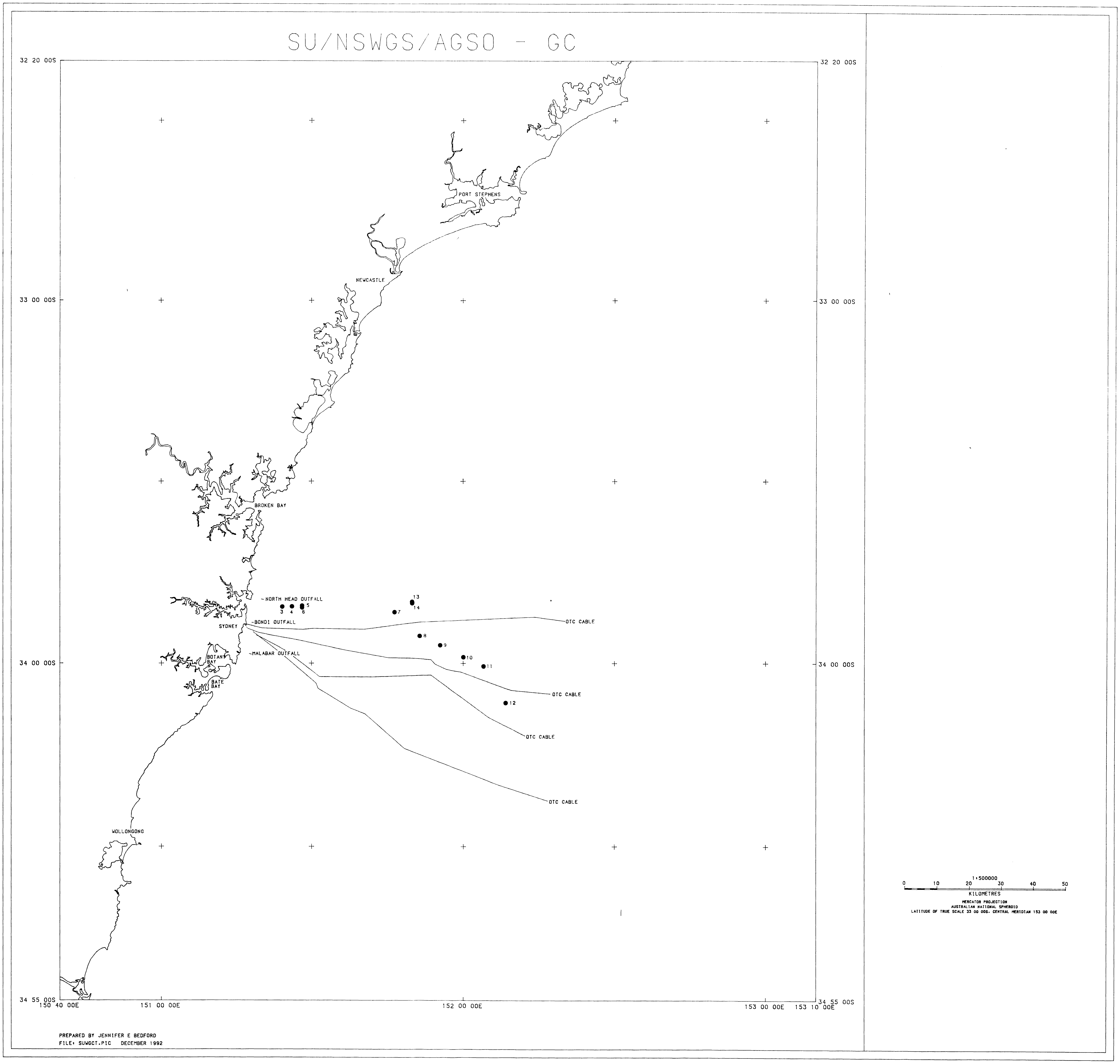
Enclosure 1.1 Locations of sample sites occupied during Cruise 112B.



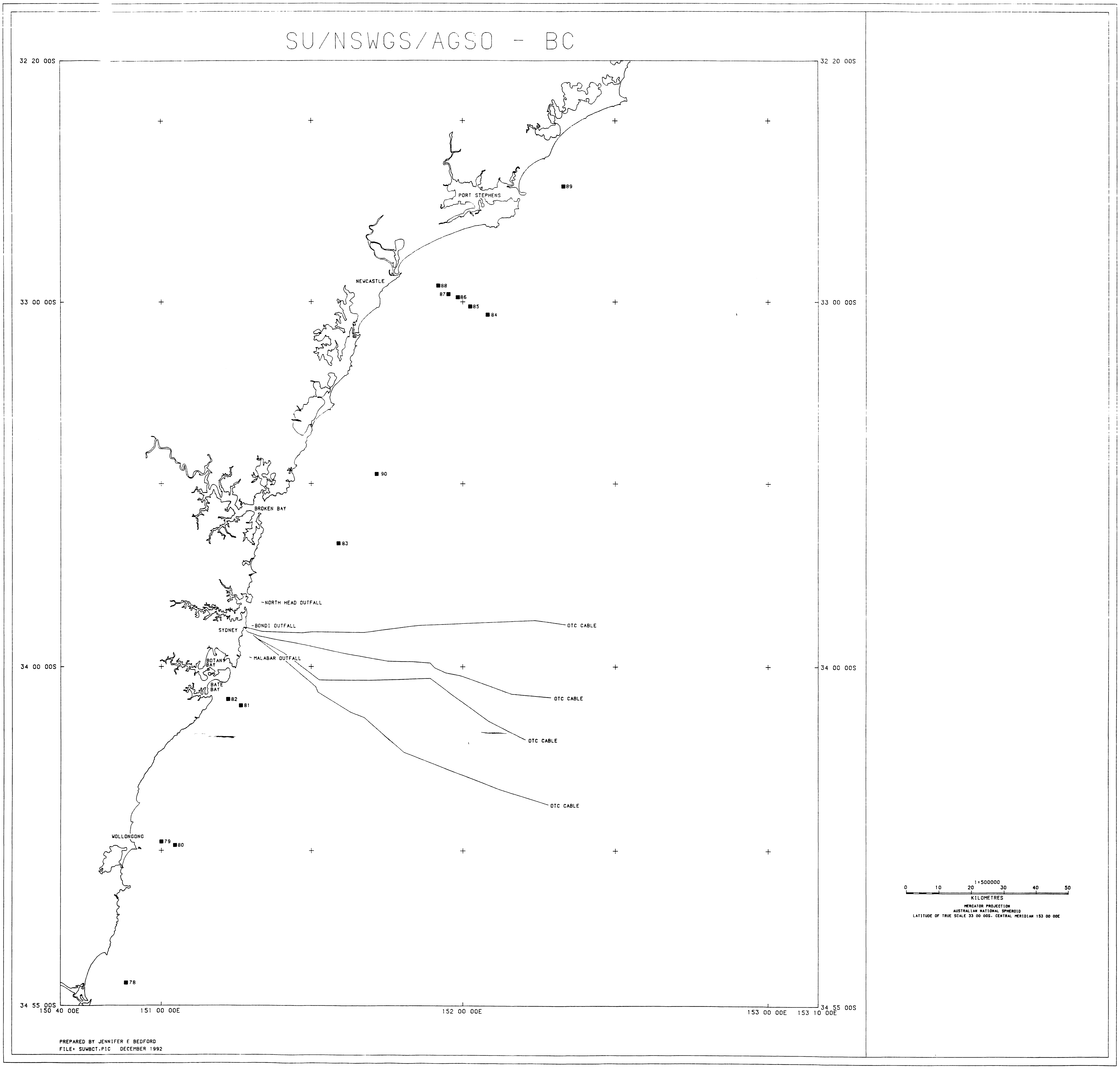
Enclosure 2.1 Locations of grab sample sites occupied during Cruise 112B.



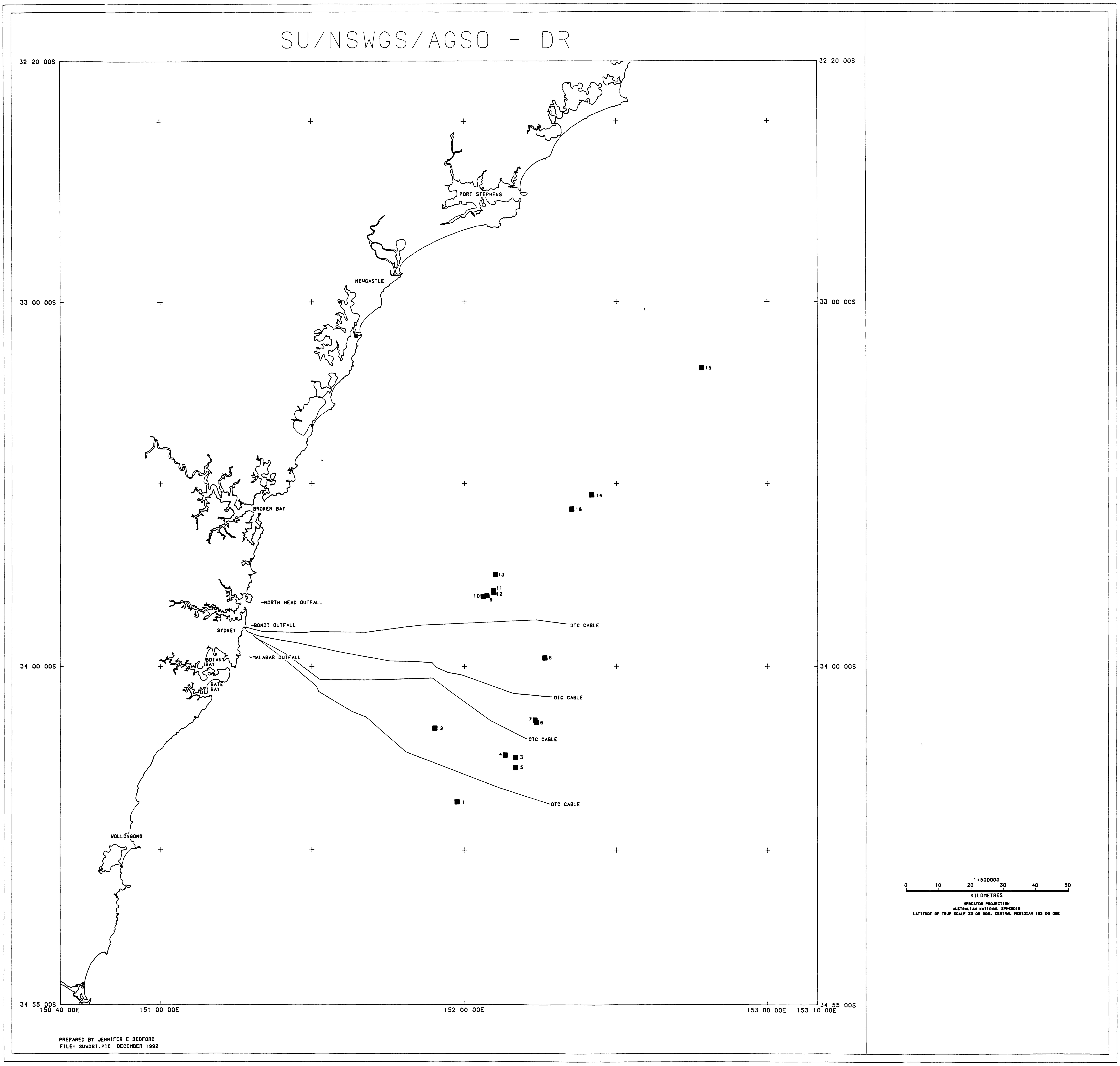
Enclosure 2.2 Locations of vibrocore sample sites occupied during Cruise 112B.



Enclosure 2.3 Locations of gravity core sample sites occupied during Cruise 112B.



Enclosure 2.4 Locations of boxcore sample sites occupied during Cruise 112B.



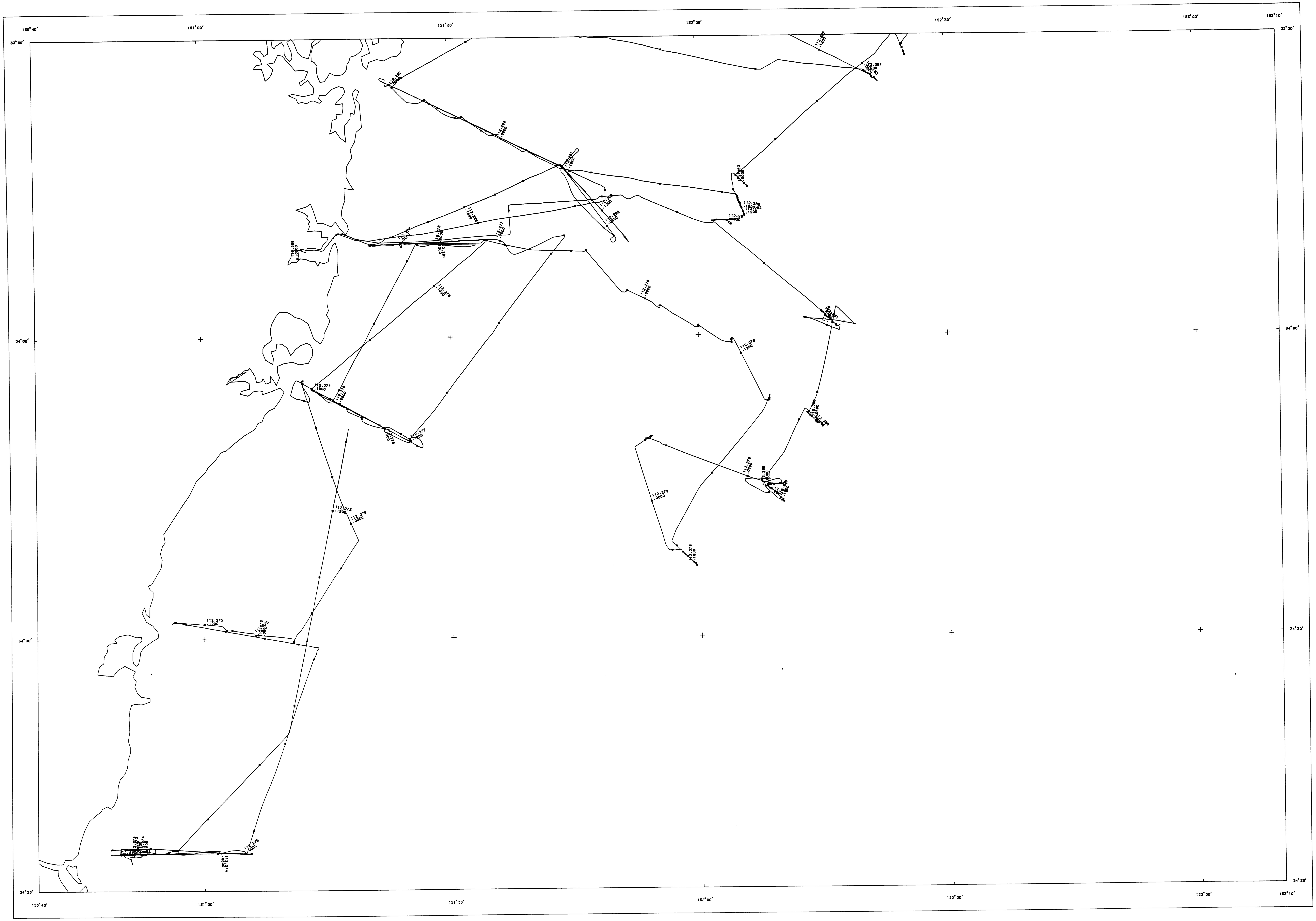
Enclosure 2.5 Locations of dredge sites occupied during Cruise 112B.

SCALE 1:250000

AGSO & SU MARINE SURVEY 112

PRELIMINARY TRACKS

EDITION OF 1992/11/11



AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

COMPUTER DRAWN AT THE DIVISION OF
MARINE GEOSCIENCES & PETROLEUM GEOLOGY

Enclosure 2.6a Survey 112B preliminary ship track map.

AGSO & SU MARINE SURVEY 112
PRELIMINARY TRACKS
1

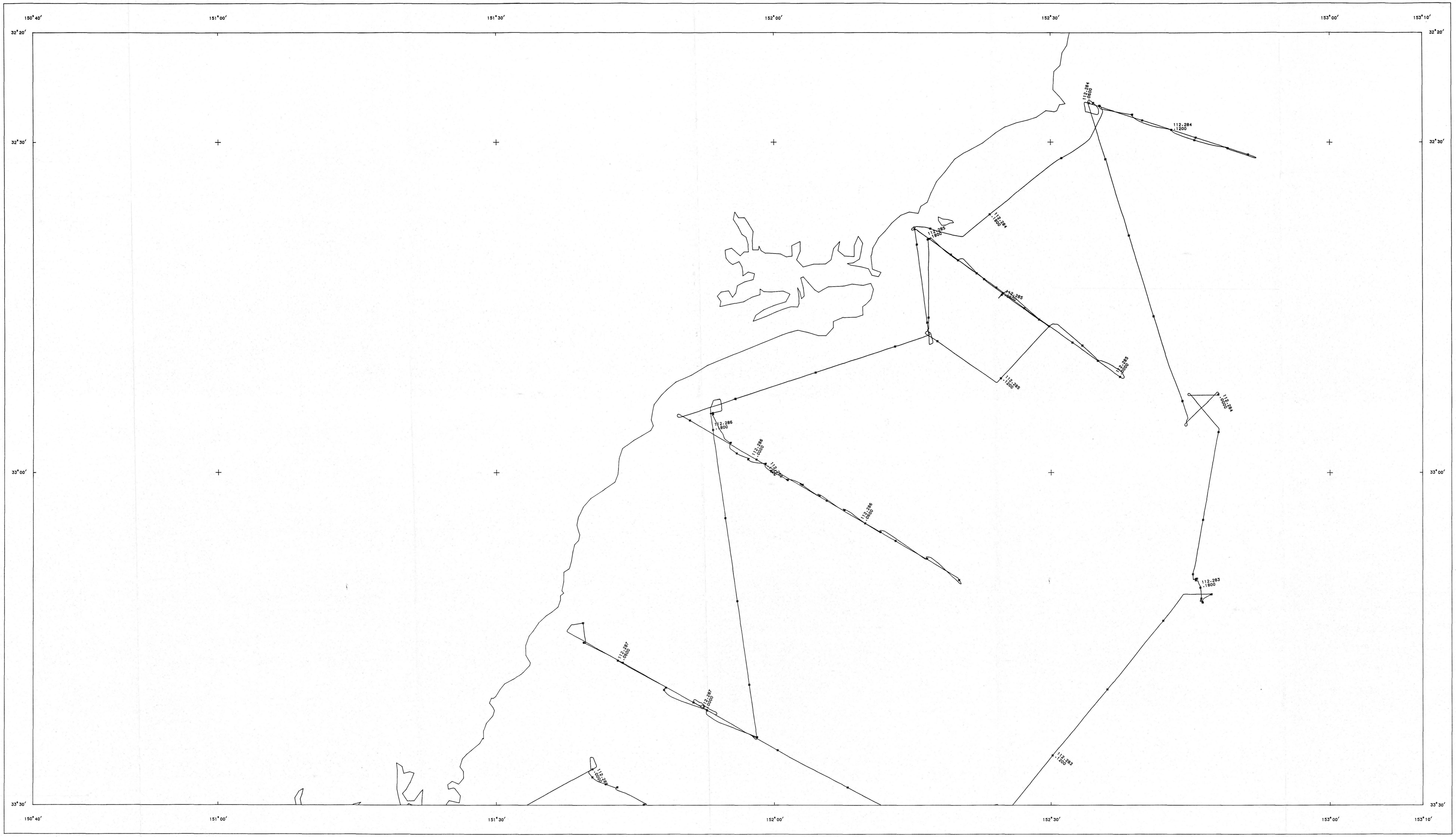
R9300509

AGSO & SU MARINE SURVEY 112

SCALE 1:250000

PRELIMINARY TRACKS

EDITION OF 1992/11/11



AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

COMPUTER DRAWN AT THE DIVISION OF
MARINE GEOSCIENCES & PETROLEUM GEOLOGY

Enclosure 2.6b Survey 112B preliminary ship track map.

KILOMETRES
4 0 4 8 12 16 20

2 0 2 4 6 8 10
NAUTICAL MILES

AGSO & SU MARINE SURVEY 112

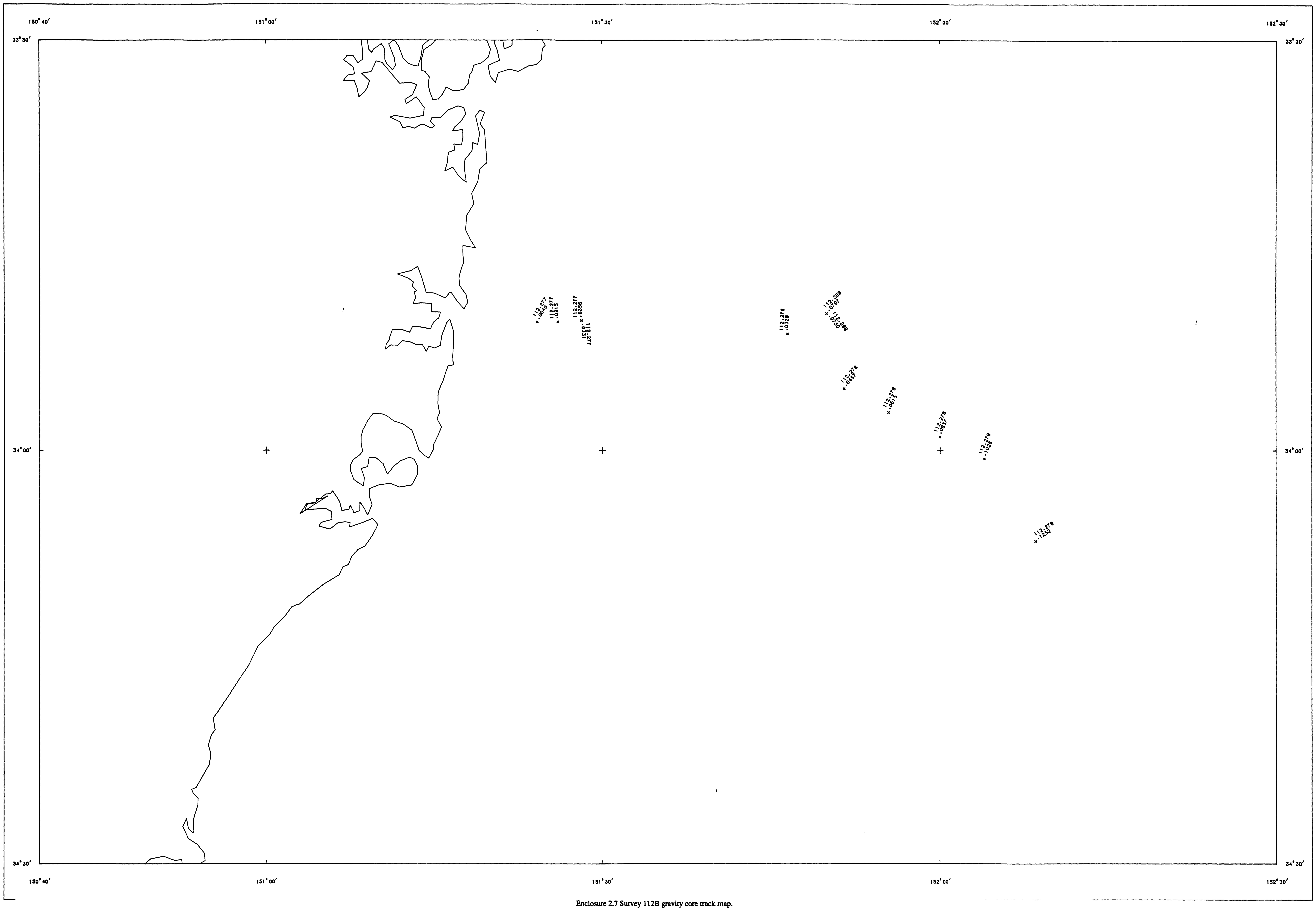
PRELIMINARY TRACKS
2

AGSO & S.U MARINE SURVEY 112

GRAVITY CORE SITES

SCALE 1:250000

EDITION OF 1992/11/12



Enclosure 2.7 Survey 112B gravity core track map.

AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

COMPUTER DRAWN AT THE DIVISION OF
MARINE GEOSCIENCES & PETROLEUM GEOLOGY

PRELIMINARY TRACKS

KILOMETRES
4 0 4 8 12 16 20

2 0 2 4 6 8 10
NAUTICAL MILES

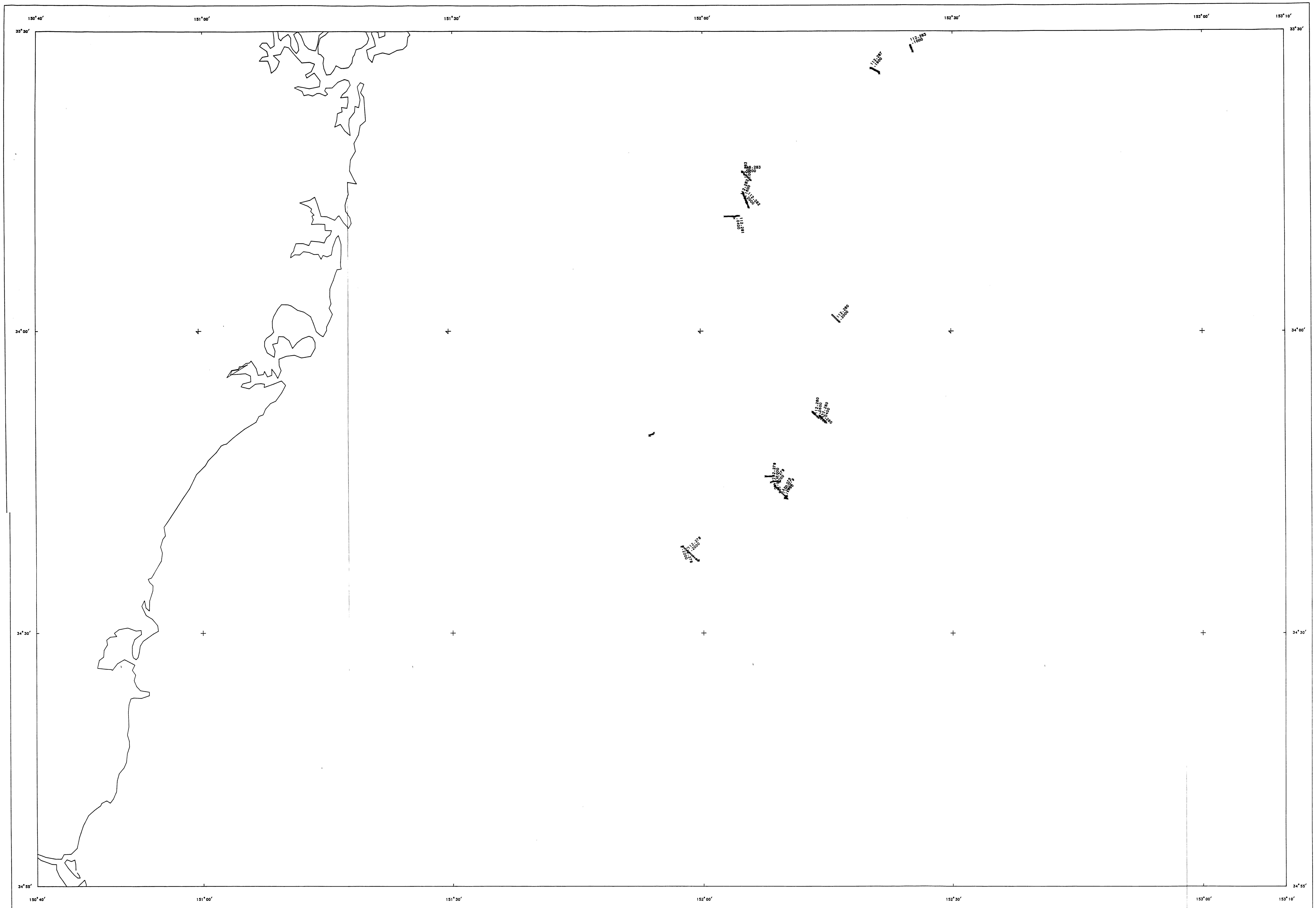
AGSO & S.U MARINE SURVEY 112
GRAVITY CORE SITES

AGSO & S.U MARINE SURVEY 112

SCALE 1:250000

DREDGE SITES

EDITION OF 1992/11/11



Enclosure 2.8a Survey 112B dredge sites track map.

PRELIMINARY TRACKS

KILOMETRES

4 0 4 8 12 16 20

2 0 2 4 6 8 10

NAUTICAL MILES

UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

COMPUTER DRAWN AT THE DIVISION OF
MARINE GEOSCIENCES & PETROLEUM GEOLOGY

AGSO & S.U MARINE SURVEY 112

DREDGE SITES

1

R9300507

AGSO & S.U MARINE SURVEY 112

DREDGE SITES

SCALE 1:250000

EDITION OF 1992/11/12

Enclosure 2.8b Survey 112B dredge sites track map.

PRELIMINARY TRACKS

AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

COMPUTER DRAWN AT THE DIVISION OF
MARINE GEOSCIENCES & PETROLEUM GEOLOGY

KILOMETRES
4 0 4 8 12 16 20

2 0 2 4 6 8 10
NAUTICAL MILES

AGSO & S.U MARINE SURVEY 112
DREDGE SITES
2

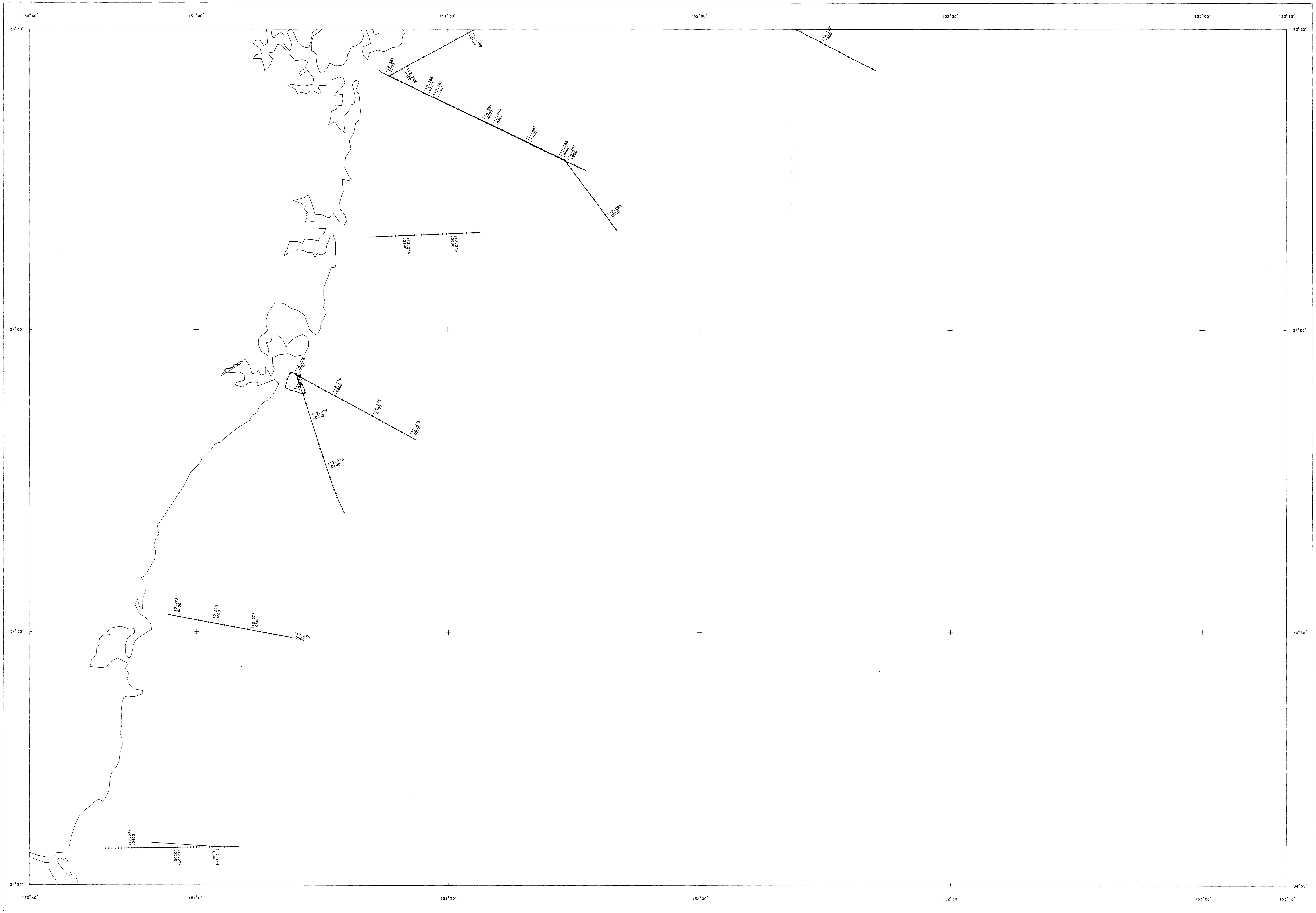
R9300506

AGSO & S.U MARINE SURVEY 112

SCALE 1:250000

BOOMER & AIRGUN LINES

EDITION OF 1992/11/11



Enclosure 2.9a Survey 112B boomer and airgun track map.

AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

COMPUTER DRAWN AT THE DIVISION OF
MARINE GEOSCIENCES & PETROLEUM GEOLOGY

PRELIMINARY TRACKS

KILOMETRES
4 0 4 8 12 16 20

2 0 2 4 6 8 10
NAUTICAL MILES

AGSO & S.U MARINE SURVEY 112

BOOMER & AIRGUN LINES

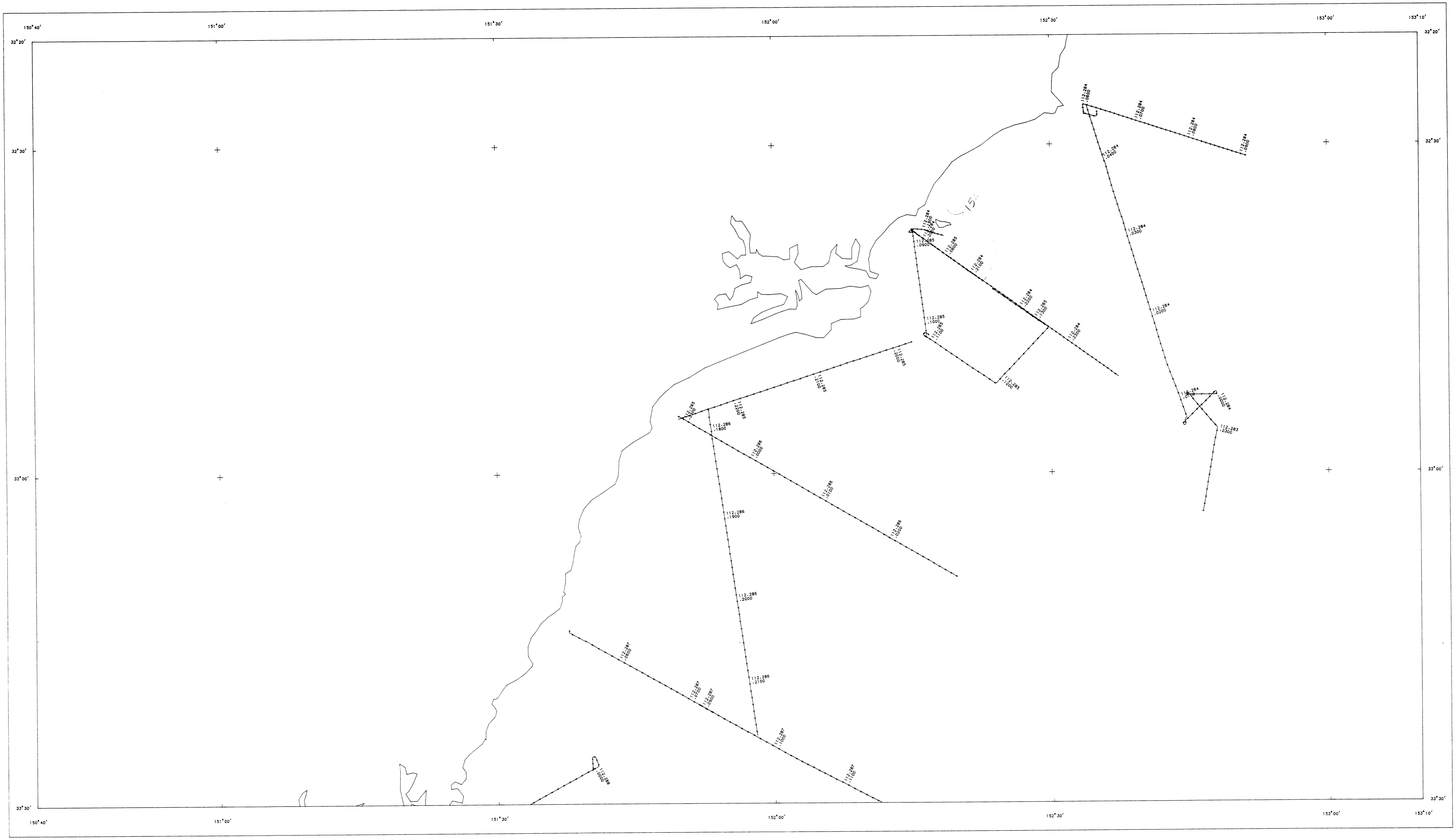
1

AGSO & S.U MARINE SURVEY 112

AIR GUN & BOOMER LINES

SCALE 1:250000

EDITION OF 1992/11/11



Enclosure 2.9b Survey 112B boomer and airgun track map.

PRELIMINARY TRACKS

AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHERE)
WITH NATURAL SCALE CORRECT
AT LATITUDE 33 00

COMPUTER DRAWN AT THE DIVISION OF
MARINE GEOSCIENCES & PETROLEUM GEOLOGY

KILOMETRES
4 0 4 8 12 16 20
2 0 2 4 6 8 10
NAUTICAL MILES

AGSO & S.U MARINE SURVEY 112

AIR GUN & BOOMER LINES

2

R9300504