2004 program

RV Southern Surveyor

MARINE NATIONAL FACILITY

voyage summary SS03/2004

(Geoscience Australia Cruise 265)

CSIRO

SS03/2004 (Geoscience Australia Cruise 265)

Geological framework of the Bremer and Denmark Sub-basins, southwest Australia.

Itinerary

Departed Fremantle 1045 hrs, Monday 8 February, 2004
Arrived Albany 1030 hrs, Thursday 12 February to collect replacement compressor parts

Departed Albany 1200 hrs, Thursday 12 February
Arrived Albany 0800 hrs, Tuesday 17 February for compressor overhaul

Departed Albany 2000 hrs, Tuesday 17 February
Arrived Albany 1000 hrs, Tuesday 24 February to exchange scientific crews

Departed Albany 1600 hrs, Tuesday 24 February
Arrived Hobart 1000 hrs, Wednesday 10 March

Principal Investigators

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Voyage Summary authors

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1) Scientific Objectives

To investigate the nature of sedimentary sequences and the history of basin development in the Bremer and Denmark Sub-basins, as part of an assessment of their petroleum potential.

Geophysical investigations indicate that the Bremer and Denmark Sub-basins (western Bight Basin) contain thick sedimentary sequences containing major unconformities, faults and folds. Present-day water depths are largely 500-3000 m. The RV *Southern Surveyor* was used to:

- continue seismic mapping of basin sequences;
- ground-truth seismic data by sampling older outcropping sequences;
- core to help determine the origin and composition of any hydrocarbons, especially in any identified seafloor structures above sediment diapirs or faults;
- and core to establish the composition, character and climate history of shallow sediment of Holocene and Pleistocene age.

This Geoscience Australia research voyage is the first geological and geophysical research voyage to be funded as part of the "Big New Oil" program of assessing the oil prospects of frontier basins around Australia. A major industry-standard contract seismic survey is planned as a follow-up to the results of the present survey.

2) Voyage Objectives

To acquire geoscience data from the outer shelf to abyssal plain:

- 200-4500 m water depth
- 116°30'E to 121°30'E
- Highest priorities were seismic profiling (planned 3060 km at 7 knots) and dredging (planned 40 dredges, 500-4000m water depth)
- Secondary priorities were magnetic profiling (on seismic profiles), swath mapping, echosounder profiling and coring (10 cores, 200-4500m water depth)
- Multibeam sonar was to be run the whole time for swath-mapping, at least until we left our area of interest
- Transits at 11 knots to and from the work area

Twenty-six days were available for work in the study area. The first half of the survey as planned consisted of seismic and magnetic profiling, and swath-mapping of the sea floor at 7 knots. The seismic system was to use two airguns and a 600 m long, 24 channel solid streamer. After a partial crew change in Albany, the second half was to be devoted to geological sampling. About 40 dredge hauls or short gravity cores would be deployed for stratigraphic sampling of older targets. About 12 x 6 m Quaternary gravity cores were to be sampled aboard for later work on hydrocarbon content.

3) Geophysical results

The equipment used on the geophysical leg is listed in Appendix 1, and a summary of data acquired is given in Table 1. Pre-existing and new seismic profiles are shown in Figure 1. The new seismic profiles (Table 2) were acquired at an average speed (while actually profiling) of 15 km/hour or 8 knots, with a 550 m cable (300 m active section). They were processed aboard ship and proved to be largely of good quality. A total of 1027 km of seismic data were acquired, much less than had been hoped for.

The purely swath-mapping profiles of the last 4.5 days were run at a speed of 17 km/hr (9 knots). The swath-mapping program was designed to give full seabed coverage of the upper slope in the area from Albany to 150 km west of Esperance. The pre-existing deepwater swath coverage, from *Marion Dufresne* and *L'Atalante*, was limited to depths generally exceeding 2000 m. The present survey, of about 1650 line km, filled the large upper slope gaps in the existing coverage, giving full seabed coverage up to a water depth of 700-1000 m. The resulting maps will be valuable to scientists, environmental and fisheries managers, and fishers.

The new and pre-existing seismic and swath data were all used in planning the follow-up sampling program, which was aimed at providing a stratigraphic framework (and rocks for a variety of analytical purposes) for an assessment of basin development and petroleum potential. The rocks would be the first recovered from the region.

3.1. Bremer and Denmark Sub-basins seismic profiles

A total of 1027 km of 24 channel seismic data were collected on three east-west lines traversing the Bremer, Denmark and Recherche Sub-basins of the Bight Basin along the southern continental margin of Australia (Figure 1). The survey started in the west (35°47.95'S, 116°43.11'E) with line BREM-1 ending at 34°55.68'S, 121°21.47'E. BREM-2 was acquired from 34°49.55'S, 121°22.17'E in an easterly direction finishing at 35°41.91'S, 116°52.17'E, and BREM-3 was acquired from 35°39.55'S, 117°50.56'E towards the east and terminating at 34°59.94'S, 119°31.72'S. The seismic acquisition was initially restricted and then ultimately terminated by the ongoing breakdowns of the diesel compressor.

Seismic line BREM-1

BREM-1, the southernmost line, crosses 423 km of the study area. Overall, the seismic transect runs west to east, diverting north-east for a middle section of 198 km, after which it returns eastward to follow the 3500 m bathymetry contour. BREM-1 intersects previously acquired seismic lines Shell Petrel lines N400 and N402 and reprocessed Esso lines R74a-15 and R74a-25a.

BREM-1 was broken into two sections by a 43.2 km gap in the data acquisition. The first section measures 25 km with an average water depth of 3750 m, and overlies the outer Denmark and deepwater Recherche Sub-basins. The boundary between the Denmark and Recherche Sub-basins appears to be marked by a major normal fault downthrown to the south. The sedimentary section of the outer Denmark Sub-basin is poorly imaged and shows a thin sequence about 0.4s twt thick. The Recherche Sub-basin shows a possible wedge of Jurassic sediments at the base of the bounding fault. This sequence displays strong internal reflections and is about 0.5s twt thick. Overlying the Jurassic sequence is a Cretaceous succession 0.7s twt thick.

The second section of BREM-1 is 338 km long and varies from 1800 m to 4130 m in water depth. The easternmost portion of this section overlies the Recherche Sub-basin with intersections into the Bremer Sub-basin. Large canyons, including the Bremer Canyon, which here reaches a depth of 3675 m, incise the Bremer Sub-basin and appear to be structurally controlled, as they are located between uplifted blocks. Seismic data show strong reflectors at shallow depths that gradually fade, giving about 2s twt total penetration. Stronger reflectors are observed at the basement in the Bremer Sub-basin on line BREM-1 due to a thinner sediment pile than are seen on lines BREM-2 and -3. Sedimentary packages overlying basement in the Recherche and Bremer sub-basins have similar thicknesses of up to 1.1s twt, and are interpreted to be dominantly Cretaceous. The Bremer and Recherche sub-basins are separated by a series of downthrown en-echelon normal faults.

The uppermost sediments observed across the line are laterally extensive. They have an average thickness of 1.1s twt and are probably Cainozoic in age. This Cainozoic sequence contains a dominant reflector that probably represents the regional Eocene-Oligocene unconformity.

Seismic line BREM-2

BREM-2 extends from east to west for 429 km, in water depths ranging from 3975 m in the Albany Canyon up to a maximum of 1875 m in the Bremer Sub-basin. This line spans the full length of the study area and intersects the Bremer and Denmark Sub-basins with about 2s twt penetration. However, as a result of problems during acquisition, a 105 km section of the line (sp 4200: 35°13.98'S, 119°16.17'S to sp 6300: 35°44.12'S, 118° 17.23'E) in the centre of the study area has limited penetration.

The Bremer Sub-basin was traversed in the eastern section of the line. This area has been block faulted and displays horst and graben style topography. Bradshaw et al. (2003) interpreted Esso reprocessed seismic data over the Bremer Sub-basin as indicating two rift-sag successions, each ending with a period of inversion. Due to the lack of penetration of the present survey's data (about 2s twt) only the upper rift-sag succession can be identified. The syn-rift package on line BREM-2 is interpreted as Cretaceous in age and reflectivity banding indicates sedimentary bedding. These sediments are about 0.8s twt thick and show some folding probably related to a later compressional event. The underlying package is not clearly imaged, but probably consists of the older sag-rift sequences and is approximately 1s twt thick. Basement is interpreted as the deepest strong reflection. However, this horizon cannot be clearly identified across the entire line. The boundaries of the Bremer Sub-basin appear to be normal faults with the sub-basin perched on the footwall.

The Denmark Sub-basin was traversed by the western section of BREM-2. The sedimentary sequence identified in this region averages 0.7 s twt in thickness, and appears massive with no internal reflections like those in the corresponding unit in the Bremer Sub-basin. This sequence is interpreted as Cretaceous in age. Unconformably overlying the Cretaceous sequence is the Cainozoic succession. The Cainozoic unit is laterally extensive and appears to be marginally thicker (0.6s twt thick) over the Denmark Sub-basin sediments than in the Bremer Sub-basin (0.3 to 0.5s twt thick) in the east of the line.

Seismic line BREM-3

BREM-3 extends for 175 km across the study area from west to east and is shorter than the expected 400 km because of equipment problems. The line runs east for 35 km then turns east-northeast for 135 km, at which point it returns to its easterly direction for a further 46 km. Water depths ranged from 1200 to 3700 m with the deepest areas recorded in the basal portions of the canyons. The line commences in the southwest in the Recherche Sub-basin and then enters the Bremer Sub-basin (sp 1700: 35°25.99'S, 118°40.66'E). BREM-3 is intersected by one previous seismic line (Esso R74a-15) in the western part of the Bremer Sub-basin.

The Vancouver Canyon (3150 m deep) and the Albany Canyon (3750 m deep) are notable features of BREM-3, and also appear to be structurally controlled because they are located between uplifted blocks. Block faulting is most prominent on the western end of the line in the Bremer Sub-basin, where horst and graben topography is observed.

A syn-rift sequence about 1s twt thick was observed on the eastern end of line BREM-3 and has been interpreted as Cretaceous in age. This Cretaceous sequence shows strong internal reflectors indicating interbedding of hard and soft sediments. There is also some evidence of a later inversion event. The sedimentary succession underlying this sequence is not imaged on this seismic data, although a deeper reflector interpreted as basement shows that the unit is about 1.5s twt thick.

The boundary between the Recherche and Bremer Sub-basins appears to be a normal fault, with the Recherche Sub-basin located on the downthrown hanging wall (east). The seismic reflections observed in the Recherche Sub-basin (eastern end of the line) are more pronounced than those observed to the west. Basement is interpreted as the last visible reflector and has a strong reflectance indicating its hard nature (igneous or metamorphic composition). Unconformably overlying basement is a 0.2 to 0.9s twt thick sequence containing very few internal reflections, and this has been interpreted as Cretaceous in age.

The uppermost sequence, which unconformably overlies older sediments and is laterally extensive over the whole line, is interpreted as Cainozoic in age. The Cainozoic sediments appear to be thickest (up to 1.4s twt) in the western end of the line, but generally range from 0.3 to 0.9s twt in thickness.

4) Geological results

The consolidated sampling results are given in Table 1. All dredging locations, and the locations two core that recovered older sediment, are shown in Figure 1.

4.1. Dredging

The dredge material was studied aboard ship in hand specimen, including sawn surfaces. It was then sorted into various groups (lithotypes) for each dredge haul before specialist sampling began. For each dredge, each group was assigned a letter, and individual samples were given a numerical suffix; further subsamples were designated by another numerical suffix. Thus a typical designation for Cruise 265 for the first subsample from the second sampled rock in group A, from dredge 2, might be 265/2/DR02/A2.1. The ‘2’ before DR indicates that this was the second station (dredge, core or grab) occupied on the voyage.

Of the 45 dredges attempted, all but one returned sediments or rocks (see Table 3). The dredging program had a wide spread, both geographically (Figure 1) and in terms of geological provinces (three sub-basins plus basement). The basement rocks were all of continental affinities, consisting of granite, gneiss, schist and syenite, (possibly) plus silicified quartz sandstone. Some of the dredged red beds are probably older than the main basin fill. Minor occurrences of basalt indicate volcanism during basinal sedimentation. The basin fill appears to be of Late Jurassic, Cretaceous and younger age on the basis of the limited foraminiferal work done aboard, regional geological considerations, and comparisons with the Southern Carnarvon and Perth Basins to the northwest, and Jerboa No. 1 well to the east. Post-voyage palynological, foraminiferal, and nannofossil studies will help fill out the geological picture sketched below in the *Summary*.

The basement rocks dredged in Albany Canyon, further west on a ridge south of Denmark, and in the far east in Stokes Canyon (dredges 1-5 and 45) are all continental basement (granite, gneiss, schist, syenite). Dredges 6-9, in the Wilson Canyon of the Denmark Basin, yielded small quantities of a variety of rocks including carbonaceous mudstone and silty greensand. Dredges 10-12, largely in the deeper water Denmark Sub-basin southwest of Albany, contained only spiculitic calcareous ooze. Dredge 13, in the deepwater Recherche Sub-basin, contained arkose, sandstone, claystone, and pebbles of granite and quartz.

Dredges 15-24 were largely in the incised shallower parts of the canyons of the western Bremer Sub-basin, west of Bremer Bay. They contained abundant rocks of a great variety of rock types, including sandstones, siltstones, black mudstones and minor coal of a delta plain sequence; and greensands and related sediments with *Inoceramus*, of probable Coniacian-Campanian age. Mudstone was markedly the most abundant rock type, and some of it is highly carbonaceous. The deepwater dredge 25 was dominated by hard blocky-fracturing silicified siltstone. Dredges 27-45, in the central Bremer Sub-basin east of Bremer Bay and extending as far east as Stokes Canyon, contained similar rock-types, but the volume of arkosic sandstone, quartz sandstone and micaceous quartz sandstone predominated over that of mudstones, with highly carbonaceous mudstones generally not abundant. Dredges 34 and 44 also contained older red sandstone of unknown age. Dredge 35 contained a bioclastic grainstone boulder, and Dredge 45 in Stokes Canyon contained orthoclase granite.

Dredge samples of reasonably well-consolidated (older) rocks include lithofacies from continental, coastal, and nearshore marine depositional settings. Those interpreted as continental include poorly sorted feldspathic sandstone, laminated siltstone (commonly with shaly to coaly partings or imprints), and red beds. The recognition of a coastal to marine setting is based on the presence of bioturbation, and on textural (sorting, rounding to a lesser extent) and mineralogical (quartzose, as opposed to feldspathic or lithic) maturity.

The assemblages of basinal sediments, in order of decreasing assumed age, are:

- Coal-bearing sequence of arkose, laminated siltstone, carbonaceous mudstone/shale and coal: poorly sorted sandy lithofacies (continental, fluvial channel); laminated silty lithofacies (continental, overbank and swamp).
- Marginal marine sequence of winnowed quartz arenite, interbedded fine sandstone and siltstone, and bioturbated mudstone: well-sorted sandy siliciclastic lithofacies (marine, nearshore to foreshore).
- Shallow marine sequence of greensand and cherty radiolarian-bearing mudstone: bioturbated silty siliciclastic lithofacies (marine, low energy and ?tidal).
- Shallow marine sequence of calcarenite.
- Deep marine Oligocene to Miocene lithified and semi-lithified spiculitic chalk and calcareous mudstone.
- Almost ubiquitous deep marine Pleistocene and Holocene foram nanno ooze, which becomes less spiculitic and more clayey eastward

4.2. Coring

Fourteen cores were attempted but only eight could be regarded as successful (details in Table 4). The greatest core recovery was 335 cm. Cores 1 to 9 were taken near Esso seismic line 74/25 [note the shortened form for Esso line designations here and below: actual line number is R74a-25a] just west of Whale Canyon and south of Hopetown. Quaternary cores, from water depths of 482-1981 m contain varied calcareous oozes. These were olive brown above 1200 m depth and light grey in deeper water. Cores GC11 and 12 were taken further east in Powell and Stokes Canyons, on Esso seismic line 74/14, the first at 1950 m and the second at 2611 m. They too recovered pale grey calcareous ooze.

Two cores were taken to sample older sequences. Core 4 recovered 25 cm of dark grey carbonaceous and micaceous mudstone of possible Cretaceous age, from 1570 m of water. Core 10 recovered a small ball of dark grey carbonaceous mudstone of possible Cretaceous age from 3530 m of water.

5) Summary

The RV *Southern Surveyor's* acquisition program can be summarised as:

- Limited seismic surveying because of equipment failure, giving 1027 km of data instead of the planned 3000 km. Seismic data quality was largely moderate, but one section was poor. The three new profiles and pre-existing seismic profiles were used to plan sampling targets.

- Successful swath-mapping using the new mid-range SIMRAD EM 300 multibeam sonar system. About 5000 km_ of upper slope was mapped east of Albany. This and pre-existing swath mapping were used to plan sampling targets.

- Successful sampling of older outcropping sequences, largely in canyons, with 45 dredge hauls and two cores.

- Coring at seven sites to establish the composition, character and climate history of shallow sediment of Pleistocene and Holocene age.

The swath mapping results will allow the production of excellent bathymetric maps of the continental slope, in particular of the submarine canyons, of value to petroleum explorers, fishing groups, scientists, and environmental managers. The sampling results will allow us to build up a reliable geological history of this region, and a greatly improved assessment of its petroleum potential. This survey recovered the first ancient rocks from this large frontier offshore region. The presence of coals, and widespread black carbonaceous shales and mudstones, of Cretaceous and possibly Jurassic age, indicates that potential petroleum source rocks exist. Post-voyage geochemistry will establish their quality and maturity. The presence of widespread, possibly coeval, clean quartz sandstones and arenites suggests that potential reservoir rocks exist.

With our present shipboard understanding of the region we suggest the following scenario:

- Gondwana rifted from Late Jurassic times, and Australia drifted northward from the mid-Cretaceous.
- The rift filled first with Early Cretaceous and possibly Late Jurassic non-marine siliciclastic sediments including coals
- During a marine transgression in the Aptian-Albian, shallow-marine muds and sands were deposited
- In the Late Cretaceous the water deepened and glauconitic sands and silts were deposited
- Fast spreading in the Middle Eocene led to rapid subsidence. Terrigenous input declined, probably because a combination of reduced relief and declining rainfall on land caused reduced runoff and erosion. These changes favoured carbonate sedimentation in increasing water depths from the Late Eocene to the present day.

Post-voyage palynological, foraminiferal, and nannofossil studies will help fill out this geological picture. These studies, plus geochemical studies of potential petroleum source rocks, will underpin an assessment of the petroleum potential of this frontier basin.

The performance of the vessel and equipment was generally very good. Feedback in relation to the vessel and its performance has been provided to the vessel's management team.

The entire ship's crew performed very well, being professional, helpful and courteous. The CSIRO support technicians did everything that could be expected of them. Steve Thomas was an excellent voyage manager, always looking for and finding ways to help the Geoscience Australia science contingent in their work. During the geophysical leg, with its many equipment problems, he was a tower of strength, not least because he understood many of the quirks of our equipment from his previous career at Geoscience Australia.

6) Voyage Narrative

The re-mobilization of the *Southern Surveyor* from a fisheries configuration to a geoscience configuration took place in Fremantle from 4-8 February. Geoscience Australia's technical team for the preparations included Ray De Graaf, David Holdway, Craig Wintle, Andrew Hislop and Jon Stratton. This major effort included the installation of the large seismic winch, the hydraulic core cradle and the compressor. The bulk of the voyage contingent arrived from 6 February for loading and setting up of equipment. The late arrival of various parts of the seismic system delayed the preparations, and the vessel sailed a day late. The Geoscience Australia team worked hard and effectively in setting up new and old equipment on a vessel new to most of them, with excellent support from the ship's crew and CSIRO technical people.

A Press Conference was held aboard on Saturday 7 February, to mark the start of the Bremer Sub-basin petroleum-related voyage in the context of the Big New Oil program, and led to good local coverage on the ABC TV News, and in the Sunday Times. Senator Ellison, Clinton Foster, Neville Exon and Captain Ian Taylor spoke to the press, and Sam Lucia did an admirable organisational job.

6.1. Geophysical Leg

The vessel sailed at 1045 local time on Monday 9 February in good conditions, and headed south down the West Australian coast. Julian time was 8 hours behind local time. Trials of the new airgun deployment system and the recently acquired seismic cable were carried out on the transit southward, and whale watches commenced. At 1100 on 10 February the vessel was southwest of Cape D'Entrecasteaux on the transit southeastward to the first seismic way point at about 35º50'S and 116º45'E, 80 km south of Denmark.

Deployment of seismic gear and magnetometer (for the first time on *Southern Surveyor*) commenced at the start of Line 1 (~35 deg 48'S, 116 deg 43'E) in excellent weather conditions late on the afternoon of 10 February. The guns towed well at 4 m depth and 8 knots. Seismic cable and magnetometer were deployed satisfactorily. This first period of deployment took 5 hours, but future deployments should be quicker. Initially, data quality was not good and crashes meant that only patchy data were acquired. Fortunately, Line 1 is the least important of the east-west lines, and was deliberately selected as the first because of the fear of teething problems.

Early on the morning of 11 February, compressor problems stopped seismic acquisition and we attempted two dredges. Dredge 1 recovered 100 kg of massive olive grey, fine quartz-rich sandstone in Albany Canyon at 35º38.35'S, 118º07.0'E. No fossils were visible. The other dredge failed to reach the bottom, so we will add more weight ahead of the dredge in future. Dredging from the vessel is straightforward and efficient. Then 6 hours worth of swath data was recorded in the shallower water canyoned area off Albany, until compressor parts (belts and high-pressure lines) could be picked up in Albany around 1100 on 12 February.

Then we headed south to the start point for line 1B, and started to shoot seismic around 2050 on 12 February. Data quality appeared good. Seismic profiling was suspended between 2330 on 11 February and 0330 on 12 February, and also between 0440 on 12 February and 1800 on 13 February, due to compressor problems. Swath-mapping was undertaken nearby until we were ready to continue seismic profiling on Line 1B (~35 deg 36'S, 118 deg 45'E). Processing of some parts of Line 1A has shown reasonable seismic data quality.

At 1800 on 13 February shooting recommenced on Line 1B, and that segment ended at 0336 on 14 February. Shooting commenced on Leg 1C at 0542, and the 440 km long easterly Line 1 was completed at 1342 (~34 deg 56'S, 121 deg 21'E). Shooting started on the parallel westerly Line 2, about 10 km to the north, at 1542. A gun failed at 2300, but we continued shooting with one gun until 2345, when shooting stopped for maintenance. We were back on line at 0310 on 15 February and completed Line 2A and started Line 2B at 0435. The streamer birds surfaced at 0500 and we circled until 0600 when we were back on line. At 1105 a compressor leak in a plug took us off line until 1625 and Line 2B was finished 2355. Data quality on Line 2B was poor for obscure reasons, so time was put into re-establishing the correct recording parameters before continuing Line 2.

At 0120 on Monday 16 February, we commenced shooting Line 2C. Compressor problems took us off line at 0200; back on line at 0725; off line at 0805; on line at 0855; and finally off line at 1043 at 35°44.349'S, 117°50.663'E. In all, only about 20 km had been shot on Line 2C. At 1130 we started to pull in the seismic gear and magnetometer, and at 1230 headed north toward dredge station 3 in the Albany canyon. By 1912 we had recovered syenite, schist and gneiss from 35°28.7'S, 118°03.6'E, in water 1160 m deep. We then headed further east to a side canyon of Albany canyon where dredge station 4 recovered orthoclase granite from 35°29.35'S, 118° 05.70'E at 2255, in water 1850 m deep. The dredge hung up at both sites and the overlying sedimentary rocks were not recovered. The vessel moved off at 2320 toward two upper shelf swath-lines west of Albany which were completed at 0630 on 17 February.

We arrived off Albany at 0800, and the compressor mechanic was aboard and working at 1030. At 2000 we departed Albany, transiting to continue Line 2C at ~35°44'S, 117°50'E. Shooting recommenced at 0254 on 18 February; stopped at 0750 because of compressor problems; restarted at 0753; and stopped at 0800 with compressor and firing line problems. It was terminated at 1000 at 35º41.92S, 116º54.38'E, about 35 km before the planned end of the line. We proceeded northwest to dredge a major west-facing ridge. Dredge 5, south of Walpole at 35°36.2'S, 116°40.0'E, in 2650 m of water, recovered a small amount of quartz-rich metasediments, syenite, shelf limestone, foram-rich chalk and foram sand at 2040. At 2055 we headed east toward the higher priority Bremer Basin, swath-mapping en route. Processing of Line 1 has shown it to be of reasonable quality.

By 0430 on 19 February the seismic gear was returned to the water. The magnetometer was not deployed because of problems with it tangling with the seismic bird on the previous deployment. At 0500 recording commenced on Line 3A at 35º39.612'S, 117º51.555'E. At 0714 we ended Line 3A and started Line 3B at 35°40.693'S, 118°11.718'E. At 0819 shot firing failed because the navigation reverted to the previous line, so we turned. At 0909, we were back on line. At 1756 the compressor stopped permanently and all seismic acquisition ceased for the survey. Line 3B ended at 34º59.94'S, 119º31.72'E. By 2000 the airguns and seismic cable had been pulled in, the magnetometer deployed and we were underway from about 35º01'S, 119º23.5'E to carry out a swath survey of the upper slope between 118º20'E and 120º40'E in the remaining time available.

Total seismic coverage was about 1027 km: Line 1 = 423 km; Line 2 = 429 km; Line 3 = 175 km. Associated magnetometer coverage excluded Line 3.

At 2000 on 19 February, we commenced a swath-mapping program designed to give full seabed coverage of the upper slope in the area from Albany to 100 km west of Esperance. The magnetometer was deployed again. The pre-existing deepwater swath coverage, from *Marion Dufresne* and *L'Atalante*, ends at about 2000 m. In order to maximise the number of swath-surveyed dredge sites on the sampling leg, the survey will be in the priority area between 118º20'E and 120º40'E. There are 4.5 days of ship time between the end of the seismic program arrival in Albany around 1000 on 24 February. This survey, of about 1800 km, will fill the large upper slope gaps in the existing coverage, giving full coverage up to a water depth of 300-700 m. It will be valuable to environmental and fisheries managers, petroleum explorers, and fishermen. The irregular bottom has meant that gaps and major overlaps tend to appear if the ship follows a perfectly straight course. As an experiment, we asked the bridge officers (who can see the coverage) to improve the coverage by modifying the course themselves within limits. This delegation of responsibility improved the result.

During the swath-mapping program, processing and interpretation of seismic data was completed. Maps have been produced showing all seismic tracks overlain on swath bathymetry. Unfortunately no way could be found to merge the two sets of swath data (French and *Southern Surveyor*) aboard, so we are now working with two maps rather than one. A multi-authored technical report was prepared on the performance of the geophysical equipment, with recommendations for the future and 'cookbooks' on equipment use. The swath-mapping grid was completed at 0400 on 24 February at 35º25.75'S, 118º31.39'E in water 2600 m deep. Course was the set for Albany. The magnetometer was pulled in at 0545, and was found to have lost fins because of a shark bite. It seems Ok otherwise and the fins can be replaced. Geophysical gear was cleaned, serviced and packed away, and much of it was offloaded in Albany and despatched to Perth, Canberra and Darwin after our arrival at 1000. There was a general sigh of relief when the recalcitrant compressor went onto the wharf.

In Albany, Neville Exon and Jane Blevin were interviewed on the voyage results and plans by GWN TV and the two local newspapers.

6.2. Geological Leg

The geological leg was designed to sample the different offshore sequences, concentrating largely on dredging, using the heavy trawl winch with its 5300 m of 24 mm wire, including a 400 m sacrificial length near the dredge. Coring would be done from the 18 mm coring winch. After refuelling, victualling and changing scientific crews, we departed Albany at 1600 on 24 February and headed west to the next dredge site (6) at which we are arrived at 2200.

The first few dredges were designed to sample the thicker part of the Denmark Sub-Basin sedimentary succession in the westerly trending Wilson Canyon, up the south slope of the canyon. Dredge 6 was located from 2200 to 1850 m water depth, starting at 35°28.3'S, 117°09.2'E. It recovered young spiculitic calcareous ooze. Dredge 7 was located nearby to sample a slightly younger part of the succession and dredged from 1850 to1800 m, starting at 35°28.9'S, 117°10.1'E. It sampled ?Cretaceous silty greensand, Oligocene-Miocene bioclastic limestone and pale grey chalk, and calcareous ooze. Dredge 8 was designed to sample a slightly older sequence further west from 2250 to 2050 metres, starting at 35°33.1'S, 117°00.2'E. Again it sampled a younger sequence, of Miocene or younger white chalk and calcareous ooze. Dredge 9 was designed to sample an older sequence further west from 2800 to 2600 m, starting at 35°33.2'S, 116°56.5'E. It recovered ?Late Cretaceous black carbonaceous calcareous siltstone, sticky black calcareous mudstone, grey calcareous mud and calcareous ooze. The carbonaceous sediments contained planktic forams but deposition must have been in restricted conditions. All four dredges were recovered on 25 February.

We then headed south to dredge three deepwater sites in the outer Denmark Sub-Basin. All three recovered Neogene spiculitic calcareous ooze, so did not help us unravel the older geology. Dredge 10 and 11 were fairly close together on the southeast flank of a canyon that heads in 2000 m of water. Dredge 10 was in water 3300 to 3000 m deep at 35°43.0'S, 117°00.5'E, and sampled up a slope to the southeast. Dredge 11 was 2900-2700 m deep and sampled eastward up a slope to the east, starting at 35°42.0'S, 117°02.3'E. Dredge 12 was on a southerly slope below a major bathymetric high in water 2300-2100 m deep, and sampled northward up a slope starting at 35°42.1'S, 117°19.3'E. Dredge 12 was on deck at 0800 on 26 February, and we headed east for a deepwater station on seismic line 265/01.

Dredge 13 sampled northeast up an up-thrown block in the Recherche Sub-Basin from 3900 to 3700 m, starting at 35°43.9'S, 118°30.2'E. It recovered granite and vein quartz pebbles, arkose, very fine quartz sandstone, orange to pale olive silty claystone, foram-rich chalk, and calcareous ooze. This indicates that granitic basement is present in the sub-basin, and that a normal range of terrestrial sediments are overlain by chalk and ooze. Dredge 14 sampled the Vancouver Canyon in the Recherche Sub-basin in water 3150-2850 m deep on seismic line 265/3. It recovered only chalk and calcareous ooze.

We started a series of highly successful full dredges in the shallower, sharply incised canyons of the Bremer Sub-basin on 27 February. Dredge 15 and 16 were in Two Peoples Canyon southeast of Albany. Dredge 15 was in a water depth of 1400-1000 m at ~35°17.8'S,118°36.6'E on seismic line ESSO 74/10. It contained black shale, black claystone, chalk and calcareous ooze. Dredge 16 was in a water depth of 1400-1000 m at ~35°18.9'S, 118°38.9'E. It recovered arkosic sandstone, fine grained quartz sandstone, black shale, chalk and calcareous ooze.

Dredge 17 and 18 were fairly close together in branches of an unnamed canyon south of Cape Riche. Dredge 17 was in a water depth of 2050-1700 m at ~35°20.2'S, 118°52.9'E. It recovered black shale, grey mudstone, glauconitic sandstone, and calcareous ooze. Dredge 18 was in a water depth of 1850-1500 m at ~35°17.8'S, 118°53.9'E. It recovered fresh basalt, dark grey siltstone, dark grey claystone, calcareous lithic sandstone, calcareous ooze, and a ferruginous ?coprolite.

Dredge 19 and 20 were close together in a western branch of Wilyanup Canyon south of Torbay Bay. Dredge 19 was in a water depth of 1800-1350 m at ~35°09.1'S, 119°03.2'E. It yielded a probable coal measure sequence of interbedded lithic quartz sandstone, quartz sandstone and carbonaceous micaceous siltstone, and calcareous ooze. Some of the sandstone was gritty and contained coal fragments. Some sandstones contained thin layers of rose quartz. Dredge 20 was recovered early on 28 February from water 2120-1650 m deep on seismic line 265/3 at ~35°11.4'S, 119°05.9'E. It contained quartz sandstone, black claystone, minor granite pebbles and calcareous ooze.

Dredges 21-24 were in the upper parts of a series of canyons south of Bremer Bay. Dredge 21 was in Wilyanup Canyon, at a depth of 2000-1600 m at ~35°05.9'S, 119°12.7'E on seismic line 265/3. It contained carbonaceous mudstone and shale, siltstone, pebbles of basic igneous rock and breccia, and calcareous ooze. Dredges 22-24 were in unnamed canyons further east. Dredge 22 was at a depth of 1900-1600 m at ~35°03.9'S,119°16.8'E, also on seismic line 265/3. It recovered quartz sandstone, carbonaceous mudstone, phyllite pebbles, limestone, chalk, and calcareous ooze. Dredge 23 was at1600-1200 m depth at ~34°57.8'S, 119°19.2'E, near ESSO seismic lines 74/17 and 74/19. It recovered quartz sandstone, carbonaceous siltstone and mudstone, and pale siltstone and mudstone, minor coal, and calcareous ooze. Dredge 24 was from 1800-1250 m depth at ~34°57.8'S, 119°22.7'E. It contained a highly varied assemblage of carbonaceous siltstone, glauconite-bearing siltstone, quartz arenite, fine calcarenite with the bivalve *Inoceramus*, bryozoal calcarenite, spiculitic chalk and calcareous ooze.

Dredges 25 and 26 came from an upthrown fault block in the deepwater Bremer Sub-basin on seismic line 265/1. Dredge 25, the last of 28 February, came from 3400-3050 m at ~35°10.3'S, 119°41.5'E. It contained grey, silicified, blocky-fracturing siltstone, quite different to anything seen thus far; grey mudstone; grey siltstone; soft green mudstone; yellow puggy claystone; and calcareous ooze. Dredge 26 came from 2800-2600 m depth at ~35°07.8'S, 119°41.3'E. It recovered only chalk and calcareous ooze.

Dredges 27 and 28 were in Henry Canyon south of Bremer Bay. Dredge 27 was in water 1900-1700 m deep at ~34°52.2'S, 119°41.3'E on seismic line ESSO 74/19. It contained arkosic sandstone, quartz sandstone, v.f. carbonaceous sandstone, f-m. micaceous sandstone, minor coal, carbonaceous mudstone, greensand and calcareous ooze. Dredge 28 was 2100-1500 m deep at ~34°50.4'S, 119°36.8'E near seismic lines ESSO 74/10 and 74/19. It recovered quartz arenite, grey siltstone and sandy mudstone, green fine sandstone, cherty nodules with *Inoceramus*, and foram ooze.

Dredges 29 to 32 were in Hood Canyon southeast of Bremer Bay. Sandstone was relatively much more abundant than mudstone in this canyon. Dredge 29 was taken 2500-2300 m deep at ~34°48.7'S, 119°46.1'E. It recovered fine to very fine, well sorted, cross-bedded micaceous quartz sandstone, possibly from a nearshore or foreshore environment. Dredge 30 was in water 2600-2200 m deep at ~34°47.3'S, 119°52.3'. It contained very micaceous grey bioturbated mudstone, brown fine to medium quartz arenite, grey medium to coarse quartz arenite, and calcareous ooze. Dredge 31 was in water 2450-2000 m deep at ~34°45.4'S, 119°47.3'S. It contained fine to medium quartz sandstone, arkosic sandstone and calcareous ooze. Dredge 32 was 2050-1650 m deep at ~34°43.37'S, 119°52.18'E. It recovered fine to medium quartz sandstone, arkosic sandstone, micaceous sandstone, carbonaceous mudstone, chalk, and calcareous ooze.

Dredge 33 and 34 were in Bremer Canyon southeast of Bremer Bay. Dredge 33 was taken in water 2300-1950 m deep at ~34°43.3'S, 120°00.8'E. It contained fine to medium micaceous quartz sandstone, muddy micaceous sandstone, carbonaceous mudstone, and calcareous ooze. Dredge 34 was 2000-1750 m deep at ~34°41.3'S, 119°56.8E' It contained gritty quartz sandstone, fine quartz arenite, fine micaceous quartz arenite, grey silty mudstone, red quartz arenite (the first red beds recovered), and calcareous ooze.

On the afternoon of 1 March, we commenced a gravity coring and grab sampling program along Esso seismic line 74/25, southward from east of Bremer Bay, and generally west of Whale Canyon. This had three aims: to sample older sequences (successful), to obtain samples above faults for hydrocarbon analysis (3 taken), and to recover thick Quaternary cores for seabed mapping purposes (no thick Quaternary sections). This ended on the evening of 2 March and was only moderately successful. Grabs 1 and 2, from the outermost shelf at 34°29.66'S 120°10.67'E and 34°32.86'S, 120°10.68'E, recovered coarse bryozoal sand from hard (limestone) bottom at 78 m and 99 m depth. Grab 3 and Core 1 gave essentially the same result at the same spot. Core 1 at ~34°34.51'S, 120°10.63'E, recovered 38 cm of light olive brown clayey foram nanno ooze at a depth of 482 m. Core 2 at 34°36.43'S 120°10.72'S, in the upper reach of Whale Canyon and designed to penetrate an older sequence near a fault, recovered 59 cm of light olive brown, clayey calcareous ooze over quartz grit at a depth of 1140 m. It apparently sampled canyon fill. Core 3 failed, but Core 3A recovered 194 cm of light olive brown clayey calcareous ooze from 34°39.65'S, 120°06.85'E.

Core 4 was designed to penetrate an older seismic sequence near a fault. It recovered 2 cm of calcareous ooze overlying 25 cm dark grey carbonaceous and micaceous mudstone (?? Cretaceous), from 34°40.14'S, 120°10.78'E, in 1570 m of water. Core 5 recovered only 14 cm of nanno foram ooze, more consolidated at the base, from 34°42.76'S, 120°09.70'E in 1374 m of water. The follow-up Core 5A bent a barrel and was empty. Core 6 recovered 65 cm of very light grey nanno foram ooze from 34°45.67'S, 120°10.66'E at a depth of 1805 m. Core 7 and Grab 4 failed. Both were at ~34°47.05'S, 120°06.31'E, in 1635 m of water. Core 8 recovered 20 cm of yellowish grey foram ooze from 1981 m deep at 34°50.59'S, 120°10.66'E.

Core 9 was designed to sample an older seismic sequence. It recovered 335 cm of light grey consolidated foram-bearing nanno ooze of probable pre-Quaternary age from 34°53.59'S, 120°10.64'E in 2550 m of water. Core 10 recovered a little ball of dark grey carbonaceous mudstone (ground away in the swinging core barrel) of probable Cretaceous age from 3530 m of water at 34°56.79' 120°16.94'. At that stage we terminated the coring program and returned to dredging.

Dredging continued on 3 March with a series of sites (Dredges 35-39) moving up the western side of Whale Canyon in the hope of building up a stratigraphic column near Esso seismic line 74/25. Dredge 35, in water 2400-2000 m deep, recovered a bioclastic grainstone boulder (perhaps beach rock), chalk, and calcareous ooze from ~34°48.9'S, 120°12.8'E. Dredge 36 from 2600-2500 m deep contained fine micaceous quartz sandstone, micaceous siltstone, carbonaceous mudstone of the non-marine older sequence, fine glauconitic quartz sandstone from the transgressive sequence, and calcareous ooze from ~34°42.4'S, 120°14.1'E. Dredge 37, from 1900-1700 m deep, obtained micaceous quartzose siltstone, carbonaceous mudstone, and calcareous ooze from ~34°40.4'S, 120°12.7'E. Dredge 38 (very near Dredge 37 and again in water 1900-1700 m deep) recovered quartzose siltstone, bioturbated possibly marine muddy micaceous quartzose siltstone, and calcareous ooze from ~34°40.4'S, 120°12.7'E. Dredge 39 from 1500-1200 m deep, recovered brown puggy mudstone, weathered brown siltstone and mudstone, hard white calcarenite, and calcareous ooze from ~34°38.4'S, 120°11.8'E. Whether we recovered an interpretable stratigraphic column from this canyon awaits palynology.

Dredges 40-42 were taken on 4 March sampled dredged a very steep slope at 2000-1700 m depth at ~34°42.6'S, 120°11.7'E that appeared to be layered pre-Mesozoic basement in the seismic profile. We recovered moderately silicified coarse quartz sandstone (probably basement), fine quartz sandstone, muddy siltstone, carbonaceous mudstone, and green calcareous ooze. Dredge 41 contained slightly calcareous very fine sandstone to siltstone showing some bioturbation, and green calcareous ooze, from 2500-2200 m depth at ~34°46.9'S, 120°28.6'E. Dredge 42 recovered muddy siltstone, carbonaceous mudstone, a trace of coaly mudstone, and grey calcareous ooze from 2800-2550 m deep at ~34°45.9'S, 120°32.3'E.

Dredge 43 was in Powell Canyon, southwest of Esperance, 2700-2500 m deep at ~34°47.0'S, 120°48.3'E. It contained bioturbated marine carbonaceous mudstone and siltstone (?? Aptian-Albian), non-bioturbated siltstone mudstone, and grey calcareous ooze.

Dredges 44 and 45 were in Stokes Canyon. Dredge 44 was at 2700-2200 m depth at ~34°44.8'S, 120°54.7'E, near Esso seismic line 74/31. It contained coarse red quartz sandstone of redbed facies like that in Dredge 33, medium quartz sandstone, muddy siltstone, carbonaceous mudstone, a trace of rippled shallow marine siltstone, and cream calcareous ooze. Dredge 45, the last dredge, was on a steep basement slope near seismic line 265/2. It was taken at 3300-2900 m depth at ~34°47.3'S, 120°57.7'E, and contained two cobbles of orthoclase granite.

Two cores (GC11 and 12) were taken late on 4 March and early on 5 March to conclude the program, on the upper slope south of Powell Point on Esso seismic profile 74/14. Core 11 was on the western side of a tributary of Whale Canyon at 1950 m at ~34°39.55'S, 120°49.63'E. It recovered 334 cm of light grey foram nanno ooze.
Core 12 was taken in a closed basin at the bottom of the next canyon east, at a depth of 2611 m at ~4°39.44'S, 120°57.29'E. It recovered 165 cm of pale grey calcareous ooze with molluscs.

The vessel headed ESE on transit to Hobart at 0130 on 5 March at 11 knots, with the multibeam sonar still recording. It lost bottom around 2100 in water more than 5000 m deep and was turned off.

7) Scientific personnel lists

7.1. Geophysical Leg

Neville Exon – Chief Scientist
Ed Chudyk – Deputy leader/geophysicist
Mike Sexton – Geophysicist/seismic processor
Georgina Burch – Geologist/seismic processor
Cameron Mitchell – Geologist
Robin O'Leary – Geologist
Cameron Buchanan – Swath expert
Andrea Cortese – Swath expert
Andrew Hislo – Mechanical technician
Jim Whatman – Electronics technician
Stephen Thomas – National Facility electronics (voyage manager)
Lindsay Pender – National Facility computing

7.2. Geological Leg

Neville Exon – Chief Scientist
Andrew Heap – Watch leader/geologist
Jane Blevin – Geologist
Georgina Burch – Geologist/swath operator
Cameron Mitchell – Geologist/swath operator
Roger Hocking – GSWA geologist
Barry Taylor – UWA paleontologist
Andrew Hislop – Mechanical/science technician
Alex McLachlan – Science technician
Colin Tindall – Science technician
Stephen Thomas – National Facility electronics (voyage manager)
Bernadette Heaney – National Facility computing

8) Crew list

Ian Taylor – Master
John Boyes – Chief Officer
Robert Barwick – 2nd Officer
John Morton – Chief Engineer
David Jonker – 1st Engineer
John Hinchliffe – Electrical Engineer
Malcolm McDougall – Senior Integrated Rating (Bosun)
Tony Hearne – Integrated Rating (seaman)
Graham McDougall – Integrated Rating
Simon Beale – Integrated Rating
Philip French – Integrated Rating (engineering)
Andrew Goss – Chief Cook
Marianne Lund – 2nd Cook
Peter Williams – Chief Steward

9) Acknowledgements

We are very grateful to the Master, Ian Taylor, the Mates, John Boyes and Robert Barwick, and all the maritime crew for their wholehearted support and professional seamanship throughout the voyage, and to the engineers for their support during our struggles with the compressor. The deck crew, led by bosun Malcolm McDougall, were efficient and helpful at all times. The excellent food helped keep spirits up. We thank the CSIRO Marine Research staff of Steve Thomas, Lindsay Pender and Bernadette Heaney for ensuring that all the necessary scientific support was provided. The Geoscience Australia technical group did an excellent job in very difficult conditions; the performance of everybody on the first extremely difficult geophysical leg went above and beyond the normal call of duty. Especial mention must be made of mechanical technician Andrew Hislop. Ed Chudyk and Jim Whatman laboured to get the seismic recording system under control. The performance of everyone on the very busy geological leg was also of a very high standard, especially as many of them lacked marine experience. Roger Hocking from the Western Australian Geological Survey, and Barry Taylor from the University of Western Australia, provided invaluable expertise and local knowledge.

10) Key equipment

Kongsberg-Simrad EM 300 multibeam sonar swath-mapper
Scientific echosounder (12 kHz)
Charge-Air DC330/2000 diesel compressor of 2000 psi capacity for airguns
2 x GI airguns, each of capacity 45/105 cubic inches
Seismic winch
Stealtharray solid seismic cable 550 m long, with 300 m active section and 24 channels
Stratavisor seismic acquisition system
Seismic processing work station
Plotter for seismic profiles and sampling locations
MMC *Seaspy Overhauser* magnetometer and towing winch
Gravity corer, 1 tonne, for 4-6m cores
Dredges, chain bag and pipe
Ship's winches and deck machinery
Coring cradle
DGPS navigation

Table 1. Data and samples gathered

Data type	Results
Seismic profiles	1027 km of 24 channel (3 fold) data
Magnetic profiles	852 km on seismic profiles 1 and 2; total ~1500 km of data
Multibeam sonar lines	6200 km in study area (116ºE-121ºE); ~8500 km altogether
Bathymetric profiles	6200 km in study area; ~9300 km altogether
Dredges	45 total: 44 successful
Gravity cores	14 total: 9 successful; many very short; maximum 335 cm; total 1190 cm; average successful 170 cm
Grabs	4 total; 3 successful

Table 2. Seismic line statistics

Line	Start WP (lat S/long E)	End WP (lat/long)	Intermediate WP(s)	Length (km)
1 (pt 1)	35°47.95' 116º51.42'	35°50.4' 117°48.1'		85
1 (pt 2)	35°50.7' 117°56.8'	35°55.6' 121°22.5'	35°51.58' 118°16.22' 34°57.06' 120°01.23'	338
2	34°49.53' 121°22.82'	35°41.92' 116°54.38'	34°51.62' 119°59.67' 35°45.40' 118°14.74'	429
3	35°39.61 117°51.55'	34°59.94' 119°31.72'	35°40.73' 118°11.68'	175

Total kilometres = 1027 km

Table 3. Dredges

Station/ Dredge	Latitude (S) Longitude (E)		Depth (m)	Recov. (kg)*	Description	Line
1/1	35°38.5'	118°07'	3225	100	? Cretaceous olive grey fine quartz sandstone; pale cream calcareous ooze [sst 100 %]	Esso 74/11**
2/2	35°30'	118°05'	2100	0		Esso 74/11
3/3	35°28.7'	118°03.6'	1160	4	Gneiss, schist, syenite; olive green calcareous ooze	Esso 74/11
4/4	35°29.3'	118°05.7'	1850	80	Orthoclase granite; olive grey calcareous ooze	Esso 74/10
5/5	35°36.2'	116°40.0'	2650	1	Metasediments; ?syenite; ?Miocene shallow water limestone; Oligocene chalk; foram sand	
6/6	35°28.3' 117°09.2'	35°29.1' 117°09.2'	2200-1850	0	Calcareous ooze	Shell N400
7/7	35°28.9' 117°10.1'	35°29.1' 117°10.1'	1850-1800	13	Late Cretaceous (Turonian- Coniacian) silty greensand, Oligocene and Miocene chalk, calcareous ooze	Shell N400
8/8	35°33.1' 117°00.2'	35°33.4' 117°00.4'	2250-2050	10	Miocene white chalk, calcareous ooze	
9/9	35°33.2' 116°56.5'	35°33.6' 116°56.7'	2800-2600	2	Late Cretaceous (Turonian- Coniacian) black carbonaceous calcareous siltstone, ?Miocene sticky black calcareous mudstone, ?Miocene grey calcareous mud, calcareous ooze [sst 50%; carb mudst 50%]	
10/10	35°43.0'	117°00.5”	3300-3000	10	Miocene spiculitic calcareous ooze	265/02
11/11	35°42.0' 117°02.3'	35°42.2' 117°02.3'	2900-2700	0	Spiculitic calcareous ooze	265/02
12/12	35°42.1' 117°19.3'	35°41.5' 117°19.5'	2300-2100	0	Spiculitic calcareous ooze	265/02, Esso 74/09
13/13	35°43.9' 118°30.2'	35°43.5' 118°31.0'	3900-3700	30	Granite and vein quartz pebbles, arkose, v.f. quartz sandstone, orange to pale olive silty claystone, Miocene foram-rich chalk, calcareous ooze [sst 50%; carb mudst 50%]	265/1
14/14	35°32.5' 118°27.7'	35°33.0' 118°26.9'	3150-2850	40	Chalk, calcareous ooze	265/3
15/15	35°17.8' 118°36.6'	35°17.6' 118°36.9'	1400-1000	50	Black shale, ?Early Cretaceous black claystone, chalk, calcareous ooze [carb mudst 100%]	Esso 74/10
16/16	35°18.9' 118°38.9'	35°18.6' 118°38.8'	1400-1100	50	Arkosic sandstone, f. quartz sandstone, black shale, chalk, calcareous ooze [sst 50%; carb mudst 50%]	
17/17	35°20.2' 118°52.9'	35°20.7' 118°52.1'	2050-1700	200	Black shale, grey mudstone, glauconitic sandstone, calcareous ooze	266/3
18/18	35°17.8' 118°53.9'	35°18.0' 118°53.6'	1850-1500	200	? Early Cretaceous dark grey siltstone, dark grey claystone, calcareous lithic sandstone, basalt, calcareous ooze [sst 5%; carb mudst 25%]	265/3

Station/ Dredge	Latitude (S) Longitude (E)		Depth (m)	Recov. (kg)*	Description	Line
19/19	35°09.1' 119°03.2'	35°08.6' 119°03.6'	1800-1350	120	Coal measure sequence: interbedded lithic quartz sandstone, quartz sandstone, and carbonaceous micaceous siltstone; calcareous ooze [sst 70%; carb mudst 10%]	
20/20	35°11.4' 119°05.9'	35°11.4' 119°05.3'	2120-1650	70	Quartz sandstone, black claystone, granite pebbles, calcareous ooze [sst 45%; carb mudst 55%]	265/3
21/21	35°05.9' 119°12.7'	35°05.5' 119°12.2'	2000-1600	100	Carbonaceous mudstone and shale, siltstone, basic igneous rock, breccia, calcareous ooze [carb mudst 95%]	265/3, Esso 74/17
22/22	35°03.9' 119°16.8'	35°04.0 119°17.4'	1900-1600	100	Quartz sandstone, carbonaceous mudstone, phyllite, limestone, chalk, calcareous ooze [sst 45%; carb mudst 55%]	265/3
23/23	34°57.8' 119°19.2'	34°57.6' 119°19.7'	1600-1200	200	Quartz sandstone, carbonaceous siltstone and mudstone, pale siltstone and mudstone, coal, calcareous ooze [sst 40%; carb mudst 1%]	Near Esso 74/17 and 74/19
24/24	34°57.8' 119°22.7'	34°58.0' 119°22.5'	1800-1250	200	Carbonaceous siltstone, glauconite-bearing siltstone, quartz arenite, Late Cretaceous (Turonian-Coniacian) fine calcarenite with *Inoceramus*, bryozoal calcarenite, spiculitic chalk and calcareous ooze [sst 2%; carb mudst 90%]	
25/25	35°10.3' 119°41.5'	35°10.0' 119°42.1'	3400-3050	150	Grey, silicified, blocky fracturing siltstone; grey mudstone; grey siltsone; soft green mudstone; yellow puggy claystone; calcareous ooze [carb mudst 60%]	265/1
26/26	35°07.8' 119°41.3'	35°07.4' 119°41.7'	2800-2600	20	Chalk and calcareous ooze	265/1
27/27	34°52.2' 119°41.3'	34°52.5' 119°41.7'	1900-1700	200	Arkosic sandstone, quartz sandstone, v.f. carbonaceous sandstone, f-m. micaceous sandstone, minor coal, carbonaceous mudstone, greensand; calcareous ooze [sst 60%; carb mudst 40%]	Esso 74/19
28/28	34°50.4' 119°36.8'	34°50.7' 119°36.1'	2100-1500	100	Quartz arenite, grey siltstone and sandy mudstone, green f. sandstone, cherty nodules with *Inoceramus*, foram ooze [sst 45%]	Near Esso 74/10 and 74/19
29/29	34°48.7' 119°46.1'	34°49.0' 119°45.7'	2500-2300	60	Fine to v.f. well sorted micaceous quartz sandstone. ?nearshore [sst 100%]	
30/30	34°47.3' 119°52.3'	34°47.2' 119°52.5'	2600-2200	100	Very micaceous grey bioturbated mudstone, brown f-m. quartz arenite, grey m-c. quartz arenite, calcareous ooze [sst 70%]	Esso 74/21
31/31	34°45.4' 119°47.3'	34°45.1' 119°47.7'	2450-2000	100	Fine to medium quartz sandstone, arkosic sandstone [sst 100%]	Esso 74/21
32/32	34°43.37' 119°52.18'	34°43.40' 119°52.10'	2050-1650	100	Fine to medium quartz sandstone, arkosic sandstone, micaceous sandstone, carbonaceous mudstone, chalk, calcareous ooze [sst 95%; carb mudst 7%]	Esso 74/21

Station/ Dredge	Latitude (S) Longitude (E)		Depth (m)	Recov. (kg)*	Description	Line
33/33	34°43.3' 120°00.8'	34°43.1' 120°01.2'	2300-1950	150	Fine to medium micaceous quartz sandstone, muddy micaceous sandstone, carbonaceous mudstone, calcareous ooze [sst 80%; carb mudst 20%]	Esso 74/23
34/34	34°41.3' 119°56.8'	34°41.1' 119°56.6'	2000-1750	50	Gritty quartz sandstone, fine quartz arenite, fine micaceous quartz arenite, grey silty mudstone, red bed quartz arenite, calcareous ooze [sst 65%]	Esso 74/23
47/35	34°48.9' 120°12.8'	34°48.9' 120°11.7'	2400-2000	10	Bioclastic grainstone boulder (perhaps beach rock), chalk, calcareous ooze	265/3, Esso 74/25
48/36	34°42.4' 120°14.1'	34°42.4' 120°13.4'	2600-2500	100	Fine micaceous quartz sandstone, micaceous siltstone, carbonaceous mudstone, fine glauconitic quartz sandstone, calcareous ooze	Esso 74/25
49/37	34°40.4' 120°12.7'	34°40.4' 120°12.3'	1900-1700	150	Micaceous quartzose siltstone, carbonaceous mudstone, calcareous ooze [carb mudstone 90%]	Esso 74/25
50/38	34°40.4' 120°12.7'	34°40.4' 120°12.4'	1900-1700	50	Quartzose siltsone, possibly marine bioturbated, muddy micaceous quartzose siltstone, calcareous ooze	Esso 74/25
51/39	34°38.4' 120°11.8'	34°38.4' 120°11.7'	1500-1200	50	Brown puggy mudstone, weathered brown siltstone and mudstone, hard white calcarenite, calcareous ooze [?carb mudstone 15%]	Esso 74/14 and 74/25
52/40	34°42.6' 120°32.6'	34°42.4' 120°32.7'	2000-1700	50	Moderately silicified coarse quartz sandstone (possible basement), fine quartz sandstone, muddy siltstone, carbonaceous mudstone, green calcareous ooze [sst 30%; carb mudst 30%]	265/3
53/41	34°46.9' 120°28.6'	34°47.1' 120°27.8'	2500-2200	150	Slightly calcareous v.f. sandstone to siltstone showing some bioturbation; green calcareous ooze	Esso 74/29 and Shell N401
54/42	34°45.9' 120°32.3'	34°45.7' 120°32.1'	2800-2550	125	Muddy siltstone, carbonaceous mudstone, trace coal, grey calcareous ooze [carb mudst 25%]	Esso 74/29
55/43	34°47.0' 120°48.3'	34°46.6' 120°48.9'	2700-2500	70	Bioturbated (marine) carbonaceous mudstone and siltstone (?? mid Cretaceous), non-bioturbated siltstone mudstone, grey calcareous ooze [carb mudst 60%]	265/2
56/44	34°44.8' 120°54.7'	34°44.7' 120°54.3'	2700-2200	50	Coarse red quartz sandstone (redbed), medium quartz sandstone, muddy siltstone, carbonaceous mudstone, trace rippled siltstone (?shallow marine), cream calcareous ooze. [sst 35%; carb mudst 25%]	Esso 74/31
57/45	34°47.3' 120°57.7'	34°47.1' 120°58.0'	3300-2900	2	2 angular cobbles of orthoclase granite containing biotite	265/2

*Excluding ooze

**Short form of Esso designation [R74a-xxa] used throughout

[Percentages of two major components dredged in non-marine Cretaceous coal-bearing sequence; remainder siltstone]

Table 4. Grabs and Cores

Station/ Grab Core	Latitude (S) Longitude (E)	Depth (m)	Recovery	Description/comments	On Esso* seismic line 74/25?
35/GR1	34°29.66' 120°10.67'	78	_ grab	Coarse bryozoal sand	yes
36/GR2	34°32.86' 120°10.68'	99	1/8 grab	Coarse bryozoal sand; living corals	yes
37/GR3	34°34.75' 120°10.65'	467	_ grab	Light olive brown clayey foram nanno ooze	yes
37/GC1	34°34.51' 120°10.63'	482	38 cm	Light olive brown clayey foram nanno ooze	yes
38/GC2	34°36.43' 120°10.72'	1140	59 cm	Light olive brown clayey calcareous ooze over quartz grit	yes
39/GC3	34°39.63' 120°06.83'	1107	0		no
39/GC3A	34°39.65' 120°06.85'	1110	194 cm	Light olive brown clayey calcareous ooze. Hydrocarbon sample	no
40/GC4	34°40.14' 120°10.78'	1570	25 cm	2 cm calcareous ooze over dark grey carbonaceous and micaceous mudstone (?? Cretaceous). Aimed at deep seismic reflector	yes
41/GC5	34°42.76' 120°09.70'	1374	14 cm	Nanno foram ooze; more consolidated at base	yes
41/GC5A	34°42.77' 120°09.76'	1372	0	Bent barrel	yes
42/GC6	34°45.67' 120°10.66'	1805	65 cm	Very light grey nanno foram ooze. Hydrocarbon sample	yes
43GC7	34°47.05' 120°06.31'	1635	0	Hard bottom?	no
43GR4	34°47.04' 120°06.27'	1641	0	Did not trigger	no
44GC8	34°50.59' 120°10.66'	1981	20	Yellowish grey foram ooze	yes
45GC9	34°53.59' 120°10.64'	2550	335	Light grey consolidated foram-bearing nanno ooze. Hydrocarbon sample	yes
46GC10	34°56.79' 120°16.94'	3530	10 cc	Dark grey carbonaceous mudstone (?? Cretaceous)	no
59/GC11	34°39.55' 120°49.63'	1950	334	Light grey foram nanno ooze. Hydrocarbon sample	74/14
59/GC12	34°39.44' 120°57.29'	2611	165	Pale grey calcareous ooze with molluscs. Hydrocarbon sample	74/14

*Short form of Esso designation [R74a-xxa] used throughout

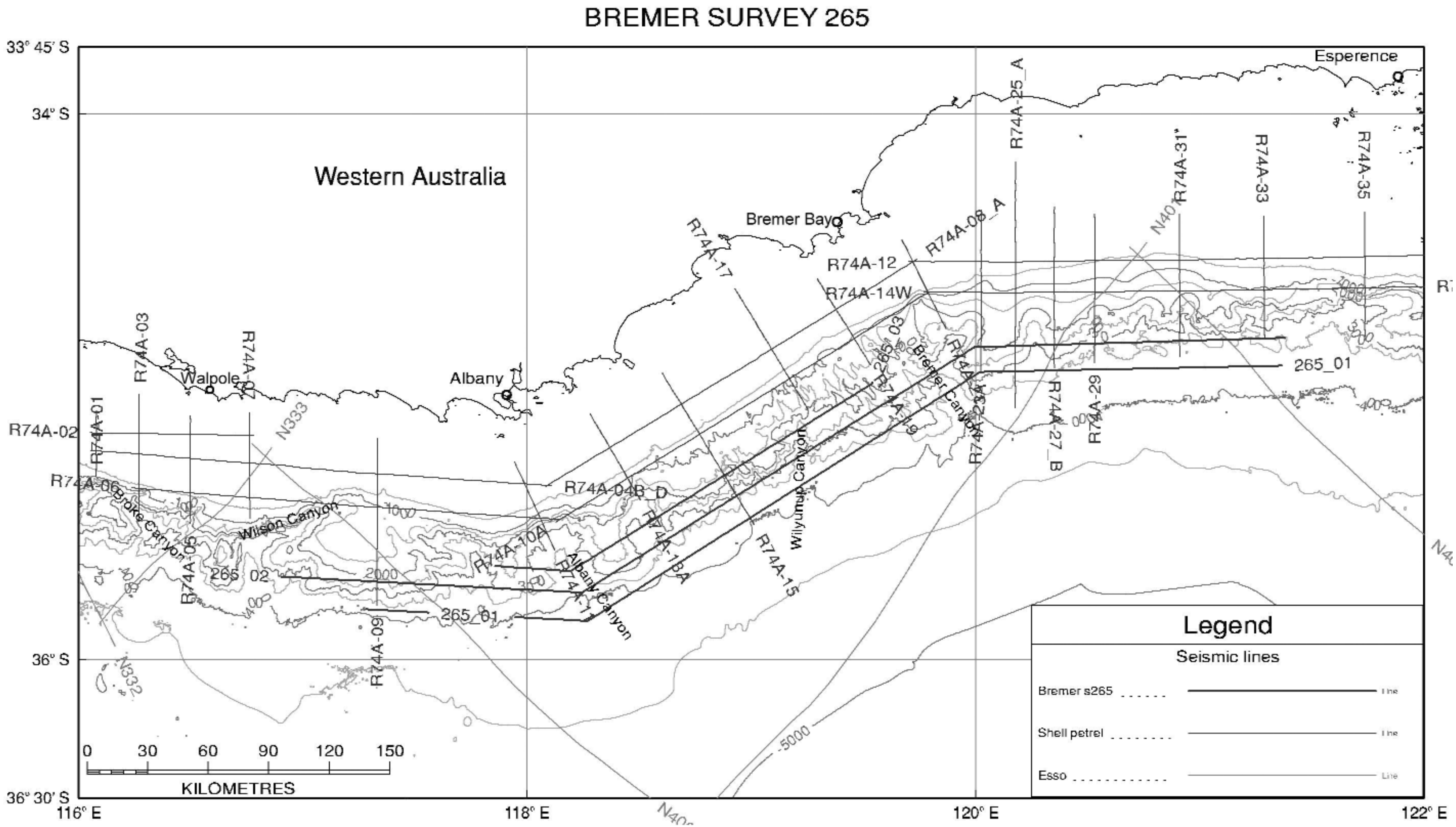

Figure 1. Map showing bathymetry, and new and existing seismic lines.

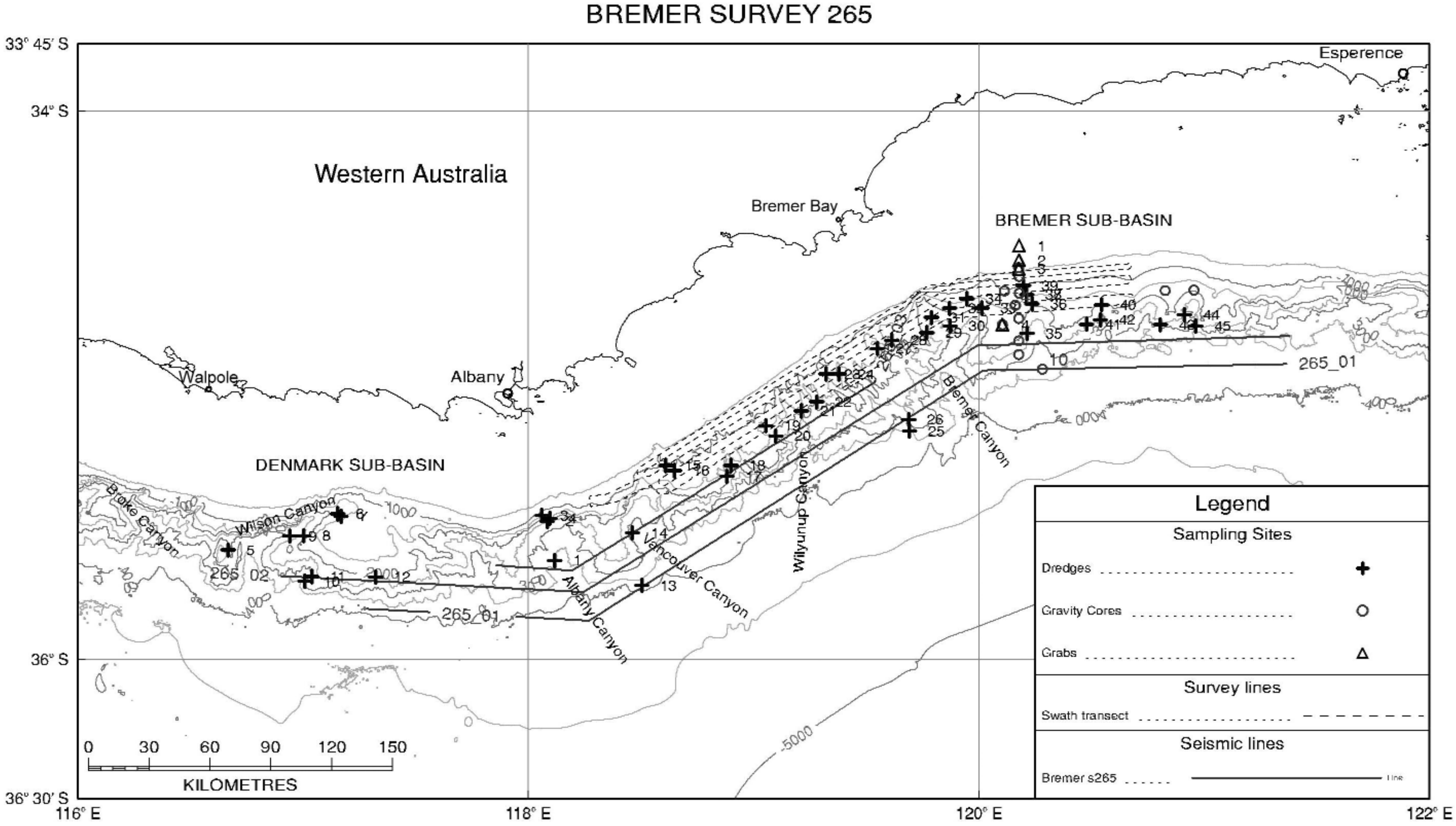

Figure 2. Map showing bathymetry, new seismic lines and swath traces, dredge and core sites.