FRANKLIN

National Facility
Oceanographic Research Vessel

Geophysics, geochemistry and sedimentology associated with a large inferred gas hydrate deposit, eastern Lord Howe Rise, Tasman Sea (FAUST 3, Geoscience Australia Cruise 232).

CRUISE SUMMARY

RV FRANKLIN

FR 09/01

Depart Brisbane 1045hrs, Tuesday 13 November 2001
Arrive Brisbane 0915hrs, Thursday 6 December 2001

Principal Investigators

Dr Neville Exon (Chief Scientist)
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Dr Gerald Dickens, School of Earth Sciences, James Cook University, Townsville*
Mr Peter Hill, Geoscience Australia, Canberra
Dr Yves Lafoy, Service des Mines et de l'Energie, New Caledonia
** Not aboard ship*

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Cruise Summary Authors

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Scientific objectives

Recent geophysical investigations indicate that much of the Fairway Basin (eastern Lord Howe Rise) in the Tasman Sea contains sediment diapirs, gas hydrate and probably free gas. Water depths are largely 1500-3200 m. The RV *Franklin* was used to:

- continue seismic mapping of basin sequences, sediment diapirs and bottom simulating reflectors (BSR, suggesting gas hydrate layers) within the Australian and New Caledonian/French seabed jurisdictions;
- core to help determine the origin and composition of gas on the Lord Howe Rise, especially in any identified seafloor structures above sediment diapirs;
- ground-truth seismic data by sampling older outcropping sequences;
- core to establish the composition, character and climate history of shallow sediment of Holocene and Pleistocene age.

Cruise objectives

About eighteen days were available for work in the study area. Most of the survey as planned consisted of ~3460 kilometres of seismic and magnetic profiling at 9 knots, using two airguns and a 600 m long, 24 channel solid streamer: ~3034 km in Australian territory and ~425 km in New Caledonian territory. The profiles in New Caledonian territory were designed to provide dredge targets in the east.

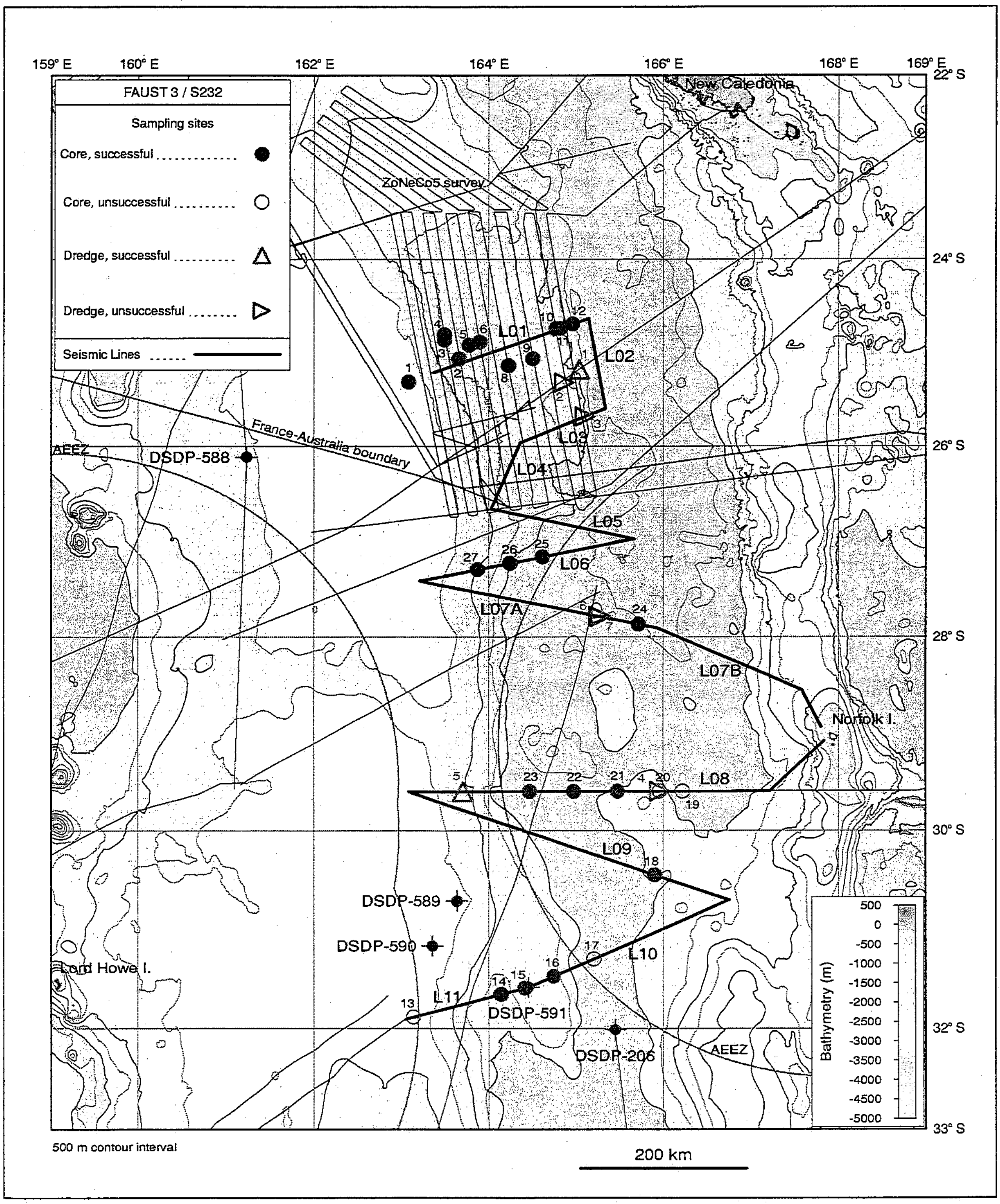
About 26 x 6 m gravity cores were to be described and sampled aboard for headspace gas, hydrocarbon isotopes and pore water: 14 cores in Australian territory and 9 in New Caledonian territory. About 16 dredge hauls or short gravity cores would be deployed for stratigraphic sampling of older targets. The dredging program was designed to elucidate geological history and to sample any Mn crusts.

Bathymetric transits between sampling stations were planned as 2020 km: 1500 km in Australian territory and 570 km in New Caledonian territory. Transits to and from Brisbane were estimated to total 2420 km.

This *FAUST 3* expedition was carried out cooperatively between Australia and New Caledonia/France, under the framework of the France-Australia FAUST agreement. Copies of all digital data in New Caledonian territory will be provided to the New Caledonian authorities.

Cruise Track

Figure 1. Cruise track FR09/2001



Results

Partly new nomenclature for this region is used here:

- *Lord Howe Rise* for the broad basement ridge in water shallower than 1500 m, in the west of the area
- *New Caledonia Basin* for the sedimentary and morphological basin in water generally deeper than 3600 m, in the east of the area
- *Central Fairway Basin* for the shallower part of the sedimentary basin between the Lord Howe Rise and the New Caledonia Basin, which lies north of 26°40'S and is generally in water less than 3000 m deep
- *South Fairway Basin* for the deeper part of the sedimentary basin between the Lord Howe Rise and the New Caledonia Basin, which lies south of 26°40'S and is generally in water more than 3000 m deep. To the south it is limited by the generally high area between the East Lord Howe Rise Spur and the West Norfolk Ridge at ~31°30'S.
- *Fairway Ridge* for the northwest-trending basement ridge west of New Caledonia and north of ~23°30'S separating the North Fairway Basin and the New Caledonia Basin
- *Northern West Norfolk Ridge* for intermittent north-south ridge between Central and South Fairway Basin and New Caledonia Basin
- *East Lord Howe Spur* for bathymetric ridge extending ESE from Lord Howe Rise through DSDP Site 591. Separates Fairway Basin from a basin to the south.

The cruise plan was changed drastically:

- Major problems with the hired diesel compressor caused 12 days to be taken for a seismic program reduced by ~10%, rather than the 9 days planned.
- The need to go to Norfolk Island for compressor spares substantially changed the layout of the reduced seismic program.
- The increased time taken for the seismic program reduced the time for sampling and associated transits to 6 days rather than the 9 days planned.

We were blessed by good weather. The logistical results of the cruise are summarised in Table 1, and the seismic results are documented in Table 2. Almost all the down time was due to problems with the hired diesel seismic compressor, and most of it was concentrated in the first six seismic lines (~945 km). These profiles took six days to record, at a very low average of 6.5 km/hour. The last five seismic lines (~1850 km) also took six days to record, at an average of 13 km/hour. In New Caledonian waters we acquired 480 km of seismic data in 3.5 days of profiling, a miserable average of 6 km/hour, compared to the planned 425 km. In Australian waters we acquired 2315 km of seismic data in 8.5 days, an average of 11 km/hour, much better than in New Caledonian waters because the compressor problems were being overcome. This compared to the planned 2870 km of data in Australian waters at 15 km/hour in 7.6 days. Ship's speed was reduced at times due to rougher sea conditions.

The sampling results are summarised for New Caledonian territory in Table 3, and for Australian territory in Table 4. The 26 Quaternary cores taken matched the cruise plan, and all but four were successful. The successful cores recovered foram-bearing nanno ooze and nanno ooze, in water depths of 1297-3517. Average recovery was 360 cm, and total recovery 80 m. Two of the four unsuccessful cores (two of which were also repeated) failed to penetrate current-swept foram sand in shallower water (1200 m), or foram sand turbidites in deep water (3320 m). Such sands require the use of a piston corer. Another Quaternary core failed when the core catcher failed, and the final core failure was an attempt to recover basement rock.

The seven dredges were far fewer than planned, because of time constraints and the fact that most possible hard rock targets were only marginally suitable. In fact, only two of them succeeded, one in recovering volcaniclastic basement and the other Neogene chalk.

Despite the problems, the cruise was an overall success and its results will allow us to meet the pre-cruise scientific objectives (shipboard success in %)

- continue seismic mapping of basin sequences, sediment diapirs and bottom simulating reflectors: 80% success
- ground-truth seismic data using samples taken from older outcropping sequences: 20% success
- help determine the origin and composition of gas from cores: 90% success
- establish the composition, character and climate history of shallow sediment from cores: 90% success

The equipment used is listed in Appendix 1. The seismic profiles were acquired at an average speed (while actually profiling) of 15 km/hour or 8 knots, with a 300 m cable rather than the planned 600 m cable. They were processed aboard ship and proved to be of excellent quality. The coring program was a success, with the cores being split, described and sampled aboard ship. The dredging program was drastically reduced to save time, but some interesting hauls were recovered, described and sampled.

New Caledonian seismic survey

This survey started in the north (~25°10'S) and ended in the south (~26°40'S). The results are summarised in Table 2. The seismic survey in New Caledonian waters was plagued by problems with the hired Charge-Air DC330/2000 diesel compressor. Acquiring the 480 km of data (Figure 1) took nearly three days as compared to the planned one day, mainly because of compressor breakdowns, but also partly because the optimal towing speed proved to be 8 rather than 9 knots.

Line 1, 205 km long and from west to east, generally shows 2 seconds of penetration. It starts in 1800 m water depth on the Lord Howe Rise (LHR), passes through the Fairway Basin (FB), and finishes in 3500 m water depth in the New Caledonia Basin (NCB). It is characterised by very strong reflectors in the mid-Cainozoic that are often unconformably overlain by the younger sequence, diapiric structures and large scale folding, volcanics at depth, and some evidence of BSRs and possible flat spots. The eastern margin of the FB is marked by a high basement block with as little as 50 metres of overlying younger sediments. The older sedimentary section onlaps basement and shows some broad gentle folding. The section thickens off the basement high into the New Caledonia Basin.

Line 2, 110 km long and from north to south in the New Caledonia Basin, shows a very flat sea floor at 3500 m. A basement high in the north is 0.8 seconds below seabed. Basement drops southward about 1 second along an assumed fault zone, and there an older sequence onlaps the high. Further south, basement gradually shallows to 0.5 seconds below sea bed, toward the culmination of a large basement high to the west.

Line 3, 107 km long, rose from east to west out of the New Caledonian Basin up into the Central Fairway Basin, the sea bed shallowing from 3500 m deep to 2600 m deep. In the short section across the NCB there is initially about 1 second of section above basement. The older section thins westward to the foot of the northern West Norfolk Ridge but the transparent younger section maintains its 0.4 second thickness. The scarp of the northern West Norfolk Ridge is lightly sedimented and ~600 m high, and is underlain by a local basement high. Beyond the first high, folded sediments are unconformably overlain by a transparent younger section which is ~0.4 second thick across the northern West Norfolk Ridge and FB. A second basement high is possibly planated and is immediately overlain by a thin bedded section, which thickens westward into the FB where the total section above basement (?volcanic) is 1.5 seconds thick. At the western end of the line the total section is at least 2 seconds thick. Some folding and diapirs occur.

Line 4, 95 km long, runs from north to south in the southernmost Central Fairway Basin, shallowing from 2600 m to 2100 m. Total sediment thickness reaches 2.5 seconds in places, with a transparent sequence 0.4 seconds thick overlying a bedded sequence that contains numerous folded and diapiric structures. The largest of these structures rises ~1 second at the southern end of the line, where even the sea bed is irregular. The southernmost third of this line is in Australian jurisdiction.

New Caledonian sampling

Results are summarised in Table 3. Sample locations (Figure 1) were defined by 3.5 kHz echosounder and seismic data from the ZoNéCo 5 program, and by new FR9/01 seismic data (Table 2). The 11 core stations were in water 1297-3515 m deep, and the three dredge stations in water 2450-3300 m deep. 41 metres of sediment were recovered from the cores, with no failures. Their length varied from 305 to 455 cm and averaged 370 cm. The cores were described and sampled aboard for headspace gas, hydrocarbon isotopes and pore water. They consisted largely of brownish foram-bearing nannofossil ooze, grading downward to white in some cases. The three dredge hauls yielded Neogene chalk in DR1, nothing in DR2, which snapped off on hard outcrop, and Quaternary ooze in DR3.

Australian seismic survey

This survey also started in the north (~26°40'S) and ended in the south (~31°50'S). The results are summarised in Table 2. The seismic survey in Australian waters was also plagued by problems with the hired diesel compressor. **Line 5**, 187 km long, runs ESE from the southernmost Central Fairway Basin to the easternmost part of the South Fairway Basin, and across the northern West Norfolk Ridge. The water depth increases from 2100 m to 3600 m. The maximum sediment thickness is ~2 seconds, with an upper transparent section 0.4 seconds thick and a lower bedded section containing folding and diapirs. The northern West Norfolk Ridge has a surface expression of 150 m, and basement below it comes to within ~0.5 seconds of the sea bed. Sea bed drops 150 m into the New Caledonia Basin to a flat 3600 m, but the section remains similar there except that flows or sills disguise basement at the eastern end of the line.

Line 6, 242 km long, runs WSW from the westernmost New Caledonia Basin across the South Fairway Basin to the edge of the Lord Howe Rise. The water depth decreases from 3600 m to 1300 m. In the east the sedimentary section is 1-1.5 seconds thick. The upper transparent section is 0.4 seconds thick. The entire section is disturbed along the northern West Norfolk Ridge, with folding and diapirism apparent throughout, and with surface relief in the transparent material of as much as 200 m. In the deepest part of the South Fairway Basin the section is almost 2 seconds thick with two large diapirs, one of which has surface expression. On the slope up to the Lord Howe Rise the surface and deeper sections undulate and small, and occasionally large, diapirs are present. The section decreases from 2 seconds to 1 second thick up the slope. On the easternmost Lord Howe Rise the basement comes to within 0.3 seconds of the surface and is unconformably overlain by transparent sediments. The unconformity appears to be subaerial and is unconformbly underlain by a wedge of sediments up to 0.8 seconds thick in a local half graben.

Line 7 runs 560 km ESE from the Lord Howe Rise to the Norfolk Ridge. On the LHR it is very near Line 6 and shows similar features, indicating north-south structural trends. The section thickens down-slope from 1200 m water depth into the axis of the South Fairway Basin 3300 m deep, where the section is two seconds thick, folded and cut by diapirs, some of which affect the surface. Here the northern West Norfolk Ridge consists of two basement highs, the larger of which dams the Fairway Basin, rising 600 m above the Fairway Basin and 1000 m above the New Caledonia Basin. Basement is exposed on the eastern flank of the larger, western high, and the transparent sequence is up to 0.4 seconds thick.

In the New Caledonia Basin, the Line 7 section is ~1.5 seconds thick, with its base characterised by either flat reflective basement or by highs of diffuse material. The sedimentary section is largely flat-lying, with some areas of folding and diapirism. The upper sequence, up to 0.5 seconds thick, is transparent on both sides of the basin, but well-bedded in the basin centre. The sea floor is flat-lying at 3600 m in the centre of the basin, above the well-bedded sequence. As the sea floor rises toward the Norfolk Ridge, basement is not apparent, probably because of volcanic strata in the mid-Tertiary. The sea floor is cut into the young sediments, probably by canyons, with perhaps some slumping of the upper sequence. Near the Norfolk Ridge is a large free-standing volcano or guyot rising to within 900 m of the surface. Younger sediments fill its caldera, which is at least 17 km across. This volcano is part of a north-south chain apparent in satellite gravity data. Small satellite cones east of the main volcano give way to a sedimentary section ~1.2 seconds thick. This section in turn gives way to the hard volcanic outcrop of the pedestal of Norfolk Island in 500 m water depth. The pedestal is planated at about 75 m below sea level.

Line 8 to the west is 550 km long, and extends from the Norfolk Ridge to the eastern flank of Lord Howe Rise. West of the planated pedestal at about 700 m water depth, a sedimentary section at least 0.5 seconds thick thickens westward into the New Caledonia Basin. The upper, flat-lying sedimentary sequence is up to 1.6 seconds thick and overlies large bulges of weakly reflective material. Basement is not readily apparent. The flat-lying sequence consists of a lower, largely transparent part, and an upper part unconformably overlying the lower. As on Line 7, the upper sequence is more transparent on the margins, and is well-bedded in the flat central basin where the water depth is 3200 m. On the eastern side of the basin, the generally transparent sequence contains some volcanics and is canyoned and slumped, and perhaps reworked as contourites. On the western side of the basin the transparent sequence is more disturbed than the synchronous well-bedded material further east.

On Line 8, the New Caledonia Basin is terminated westward by a basement ridge, a northern extension of the West Norfolk Ridge, which outcrops and rises to within 2400 m of sea level. This ridge towers above a broad rise extending westward for 90 km and falling slowly to 3000 m below sea level. The rise consists of two sequences, cut by another high in acoustic basement in its midst. The lower sequence is strongly reflective, folded and faulted, with a maximum revealed thickness of 0.5 seconds. The upper, also deformed, sequence is generally transparent and ~0.6 seconds thick. Seafloor above it is irregular. The lower folded sequence drops away westward beneath the South Fairway Basin to at least 1.7 seconds below the sea bed, which is flat-lying and 3400 m below sea level. In the basin, flat-lying sediments are only weakly reflective at depth, but the top 0.4 seconds of section is strongly reflective.

Line 9 runs 370 km ESE from the eastern flank of the Lord Howe Rise 1300 m deep to the South end of the New Caledonia Basin 3000 m deep. On the rise at the western end of the line, basement is planated and lies 0.5 seconds deep. It deepens rapidly to 2 seconds deep for over 50 km in a basin, before rising to 1.1 seconds deep in a large marginal block on the easternmost rise. In the basin 1 second of transparent section lies between the basement blocks. About 0.5 seconds of younger well-bedded section overlaps onto the blocks and is overlain by 0.5 seconds of transparent sequence. Two diapirs are apparent. The three sequences thicken down the slope into the Fairway Basin where they reach 1.7 seconds thick. In the central flat part of the basin ~3400 m deep, the two lower sequences give way to one transparent sequence, and the upper sequence becomes well-bedded, presumably by the addition of turbidites. Several large diapirs are present, including one that appears to have eroded away the underside of the upper well-bedded sequence. A basement high in the northern extension of the West Norfolk Ridge rises 400 m above the Fairway Basin and the New Caledonia Basin to the east. It is planated and capped by 200 m of eroded transparent sequence. The New Caledonia Basin is about 3000 m deep. The sedimentary sequence is up to 1.6 seconds thick and fairly transparent. It is cut by large diapirs, some of which bow the sea bed upward.

Line 10 runs 241 km WSW from the southernmost New Caledonia Basin to DSDP Site 591, where latest Early Miocene chalk is at total depth of 500 m below sea floor. The small part of the New Caledonia Basin that was surveyed is flat, ~2900 m deep, and underlain by at least 1.4 seconds of largely transparent section above faulted basement. The broad northern extension of the West Norfolk Ridge is 100 km across and about 2700 m deep. An irregular volcanic surface lies 0.6-1.3 seconds below the sea bed. Most of the overlying sequence is transparent, but the upper 0.3 seconds contains some bedding in a broad depression, and another bedded sequence 0.2 seconds thick lies about 0.7 seconds deep. The western side of the ridge drops 600 m down into the Fairway Basin about ~3300 m deep and 75 km wide. The sedimentary section is up to 1.6 seconds thick and largely transparent. An upper well-bedded section thickens into the basin from 0.1 to 0.3 seconds, and probably contains foram sand turbidites on the evidence of GC17. The broad East Lord Howe Spur (new name) extends SSE from the Fairway Basin, and here it is 75 km wide and ~2100 m deep. Basement lies 1-1.6 seconds below sea bed. The upper section is transparent and 0.5 seconds thick; it is underlain by a well-bedded section 0.2-0.3 seconds thick that may be volcanogenic. A BSR occurs 0.6 seconds below sea bed and there are several small diapiric structures. DSDP Site 591 lies at the western end of the line and the western side of the ridge, where the BSR is no longer apparent.

Line 11 runs 138 km WSW, from ODP Site 591 on the western side of the SSE-trending ridge, up onto the Lord Howe Rise. Core GC15 was taken above a deep diapir a couple of kilometres from DSDP Site 591. A fault-bounded graben, 30 km wide and ~2700 m deep, trends NNW and separates the East Lord Howe Spur from the Fairway Basin. It contains up to 1.8 seconds of moderately bedded and generally flat-lying sedimentary section. A deep diapir is overlain by a surface mound and a shallow flat spot, and that location was cored by GC14. West of the graben the Fairway Basin extends about 45 km upslope toward the Lord Howe Rise. Basement is visible only in places, and is up to 2.2 seconds deep. The sedimentary section is largely transparent, with a bedded section 0-6-0.8 seconds deep. At least one diapir is visible at depth. Basement is upthrown 0.5 seconds at ~1650 m water depth to 1.2 seconds below sea bed, where the Lord Howe Rise begins 50 km from the end of the line. It rises steadily westward to 0.5 seconds below sea bed in water ~1350 m deep at the end of the line, the shallower part being planated, presumably by wave action. The older sequences onlap the rising basement westward, with only the upper sequence (probably Miocene and younger) overlying planated basement. The lower part of this sequence is well-bedded and the upper part transparent. Near the end of the line GC13 contains foram sand.

Australian sampling

The sampling was carried out from south (~31°50'S) to north (~27°15'S). Results are summarised in Table 4. The work was split into three areas based on the new seismic profiles, starting in the south. The Late Quaternary cores will enable us to study the composition, character and climate history of the region over nearly eight degrees of latitude including the New Caledonian cores. Pale brown, yellow and pale grey colours dominate north of 28°S; darker grey and olive are interbedded with such colours south of 29°S. This suggests purely oxidising conditions in the north, but fluctuations in redox conditions in the south, probably related to variable inflow of bottom water through time.

Southern area: Cores GC13-17 were taken on seismic Lines 11 and 10, running ENE from the Lord Howe Rise. Core GC13, located on the eastern Lord Howe Rise at the end of seismic Line 11, recovered only 10 cm of foram sand in 1188 m of water, indicating current activity at that depth. The seismic profile suggests firm bottom. Further ENE along Line 11, GC14 was sited on a slight rise in the transparent sediments in the flat bottom of a 25 km wide half graben, which runs ESE from the flank of the Lord Howe Rise, southwest of the East Lord Howe Spur. The graben opens out southward, and is not part of the Fairway Basin. On seismic evidence the core site was above a shallow 'flat spot' and a deep diapir. It recovered 5.19 m of nanno ooze in 2726 m of water. GC15, on the western side of the East Lord Howe Spur, recovered 2.46 m of ooze from transparent strata in 2147 m of water. This was above a diapir that rises to ~0.3 seconds of the surface near ODP Site 591. GC16, also in transparent strata above a small diapir and fault on the eastern side of the same ridge, recovered 3.2 m of foram nanno ooze from 2089 m of water. GC17, in the flat base of the Fairway Basin, recovered only traces of foram sand and ooze from 3320 m of water. The seismic profile shows well-bedded sediments near the surface, suggesting that the corer was stopped by foram sand turbidites. These cores from south of 31°S were more reduced than those recovered from New Caledonian territory north of 25°S, with a brownish oxidised layer less than 1 m thick, above pale olive, brown and white oozes.

110 kilometres northeast of GC17, on Line 9, lies a lightly sedimented basement high on the northern extension of the West Norfolk Ridge. **GC18** recovered 240 cm of nanno ooze from the high in water 2590 m deep, but no basement rocks.

Central area: After a transit of 100 km to the north, a series of stations were taken along seismic Line 8, from east to west. Core **GC19** was attempted in highly reflective bottom, in generally transparent sediments above a subsurface and seabed rise, in the flat southern New Caledonia Basin on Line 8. It failed when the tines of the core catcher sheared. Further west is a lightly sedimented basement high on the eastern flank of the northern extension of the West Norfolk Ridge which was the subject of two failed stations. Core **GC20** skidded off outcrop on the western flank of the high in water 2483 m deep, with no recovery. Dredge **DR4**, taken up the western basement slope from water depths of 2580 to 2420 m, recovered only foram nanno ooze. Core **GC21** was taken above a deep diapir in transparent ooze on the western part of the ridge, and recovered 400 cm of nanno ooze. Core **GC22** was located above a deep diapir in the flat bottom of the eastern part of the Fairway Basin. It was taken at 3405 m in a fairly reflective surface layer, and recovered 445 cm of pale grey nannofossil ooze. Core **GC23** was located in the flat bottom of the western part of the Fairway Basin. It was taken in water 3390 m deep, in a fairly reflective surface layer above a broad deep diapir, and recovered 433 cm of multicoloured nannofossil ooze. Dredge **DR5**, taken east to west on a rugged basement high, on the trend of the Vening-Meinesz Fracture Zone on the eastern edge of the Lord Howe Rise, recovered volcaniclastic rocks and manganese crust from water 1700 m deep.

Northern area: After a 270 km transit northeast, Core **GC24** was taken in moderately transparent sediment in the flat depression of the New Caledonia Basin on seismic Line 7. This was on a bulge in the sea floor above a deep diapir and a BSR. It recovered 226 cm of pale brown and pale yellow nanno ooze from 3450 m water depth. Dredges **DR6** and **DR 7** were planned to sample the eastern slope of basement high on the northern West Norfolk Ridge. Dredge DR6 sampled the slope in water depths of 3080-2840 m and contained only nanno ooze. Dredge DR7 sampled the slope in water depths of 3280-3100 m and also contained only nanno ooze. Apparently the slopes were thinly blanketed in ooze. After a transit of 145 km to the northwest to seismic Line 6, three cores were taken westward along it. Core **GC25** was taken in transparent sediments on a seafloor bulge rising 50 m above the generally flat seafloor of the eastern Fairway Basin. It is in water 3239 metres deep above a diapir, which is at least 500 m across at depth and may reach the surface. It recovered 407 cm of nanno ooze. Core **GC26** was taken in water 2935 m deep, in transparent sediments in the Fairway Basin, at the base of the slope up to the Lord Howe Rise. It lies on a 50 m rise above sea bed, and above a near-seabed diapir at least 500 m across and fault-bounded to the west. It recovered 377 cm of nanno ooze. Core **GC27** was taken in water 1866 m deep, in weakly bedded sediments on the slope of the westernmost Fairway Basin. It lies above a near-surface diapir at least 300 m across. It recovered 248 cm of nanno ooze.

Cruise Narrative

We departed from Brisbane at 1045 local time on 13 November (0045 on Julian Day 317) and headed down the Brisbane River and into Moreton Bay on a bright sunny day with a moderate breeze in our face. Once in the open sea we made 10-11 knots over the ground at a heading of 80°, into a current from the northeast. Around 1800 we deployed the new Geoscience Australia magnetometer in the hope of getting a magnetic profile across the Tasman Basin. With no response from the equipment, it was hauled in for overhaul at 2300.

On 14 November, we were still underway to the first station and refining our plans. During the day, from 1230 until 1430, a CTD cast and several XBT casts were carried out at the one station, to compare data sets. At 1800, tests showed a break in the magnetometer cable and it was cut beyond the break and re-terminated, leaving the cable 50 m shorter at 200 m long. The cable was redeployed at 2300 and worked well as we climbed the western flank of Lord Howe Rise. The magnetometer was now 150 m behind the ship at the end of the neutrally buoyant cable.

New Caledonian sampling and seismic survey

At 2300 on 15 November (1100 on Julian Day 319) we deployed the 6 m gravity corer in 1300 m water depth on the eastern flank of Lord Howe Rise in New Caledonian territory. We recovered 450 cm of light grey to very pale brown nannofossil ooze, with decreasing forams and increasing stiffness down the core. Early on 16 November we deployed the seismic system in good weather on the long seismic Line 1 to the east across the Fairway Basin. The system consisted on a hired compressor, two GI airguns suspended from a rail beneath a buoy, and a 300m long, 24 channel *Stealtharray* solid seismic cable. This system towed well at 8 knots. A 40 minute ship's engine failure around 0300 on 16 November necessitated pulling the seismic cable in by hand. Seismic surveying recommenced after a long turn (Line 1, part 2), but was cut short by a compressor failure at 1030, caused by rust, dirt and water in its fuel tank. Another short period of seismic acquisition was ended by more dirt in the filter at 1415.

At 1800 on 16 November we decided to stop waiting on seismic acquisition and started coring in the Fairway Basin. GC2 recovered 369 m of pale nannofossil ooze at 2130, and then we took cores GC3-6, and GC8-9, consisting of similar sediments in cores of similar length. The cores were split, described and sampled for headspace gas, hydrocarbon isotopes and pore water. This coring program ended at 1850 on 17 November, and we headed back westward to complete seismic Line 1.

Craig Wintle and the ship's engineers had jury rigged the diesel motor that drives the compressor to take clean fuel from a 200 litre drum, and a test of several hours suggested that this was likely to be a success. It involved hand pumping of fuel for 10 minutes every 2 hours, but worked. At 2245 on 17 November we reached the area for the continuation of seismic Line 1 (part 3) and started to deploy the seismic gear. At 0030 on 18 November the first shot was fired. The 205 km long Line 1 was completed at 1245 on 18 November and seismic Line 2 to the south in the New Caledonia Basin was started at 1330. Shortly afterward the bearings failed of a pulley tensioning the six belts connecting the motor and the compressor, and seismic acquisition stopped. Profiling recommenced at 1630 after the bearings were replaced, and the 110 km long Line 2 was completed at 0100 on 19 November.

Seismic Line 3 to the west up the eastern flank of the Lord Howe Rise started at 0130 on 19 November and was terminated at 0230. The drive belts between the diesel motor and the compressor had burnt out, as had the bearings of the tensioning pulley for the belts. The ship's engines failed from 0500 to 0830. Email discussions started with ships' agents in Noumea and the supplier of the equipment in Australia about sourcing and delivery of diesel/compressor spares. To reduce the pressure on the single mechanical technician, and to do useful work while repairs continued, we returned to seismic Line 1 to attempt to sample older sediments on the buried basement block just west of the New Caledonia Basin. Cores GC10-12 were taken between 1800 on November 19 and 1300 on November 20.

The vessel then headed south about 60 km to dredge the northern end of a large basement block west of the New Caledonia Basin. Two dredges were attempted between 0400 and 1330 on 20 November. DR1 was successful in recovering Neogene chalks. DR2 lost the dredge to some hard outcrop. DR3 was attempted between 1600 and 1900 in the central part of the block, 50 km south, and recovered only ooze. At 2100 seismic profiling recommenced on Line 3 running to the west, and this 107 km long profile was completed with only minor further problems at 0650 on 21 November. Seismic Line 4 to the SSW, 95 km long, commenced at 0700 and was completed at 8 knots at 1240. This took us out of New Caledonian territory 1.7 days later than originally planned.

Australian seismic survey

After a turn during which the compressor was checked and adjusted, seismic **Line 5** to the ESE commenced at 0230 on 21 November. The 187 km long line was finally completed at 0430 on 22 November, and then the compressor belts shredded again. They are operating at a temperature of 140°C, which is much higher than one would expect. We again discussed the option of going to Norfolk Island to pick up spares if the remaining two sets of belts failed, and asked Steve Dutton in Canberra to pursue spares and air transport more vigorously. At 1000 we started seismic **Line 6** to the WSW, but the compressor failed again at 1200 because of fuel problems. At 1430 the line recommenced and it continued with minor problems until 0300 on 23 November when firstly the airguns needed attention, and secondly the compressor threw off a belt. Profiling recommenced at

0800 but at 1115 dirty fuel caused another delay. Line 6, 242 km long, was finally completed at 1515 on 23 November. The compressor was checked on the turn and a leaking seal on the second stage was replaced. The airguns were also recovered to fix an air leak. During the day arrangements were made to fly spares to Norfolk Island for collection at the end of the next seismic line, including heavier duty belts.

At 1820 on 23 November, seismic **Line 7** to the ESE started. It continued without problems until 0745 on 24 November, when dirty fuel caused a brief failure. It was decided to continue the line to Norfolk Island, and the remainder of the program was modified accordingly. Only minor further stoppages occurred on 24 November with the vessel recording at 8 knots and data quality being good. The same applied on 25 November until we terminated the line off Norfolk Island at 1200 and pulled in the seismic gear. Spare parts such as belts, bearings and oil filters for the diesel compressor were transferred to the vessel by boat, and we started seismic **Line 8** to the southwest at 1600, and later west at 2330. It was designed to join the western end of east-west *Rig Seismic* seismic line 177/LHRNR-C, southwest of Norfolk Island. The 550 km long line ended on the morning of 27 November.

Seismic **Line 9** to the ESE commenced at 0840 on 27 November. After early problems, with the computer acquisition system locking up and with tape drives, there were no major problems on this 370 km long line. The magnetometer failed at 1200 and was restarted at 1800. The line ended at 1315 on 28 November. Seismic **Line 10** to the WSW commenced at 1430 on 28 November. It was designed to tie DSDP Site 591. The magnetometer failed when brought in for the loop before this line, but was brought back into action fairly quickly. Seismic Line 10, 241 km long, ended at 0610 on 29 November. Seismic **Line 11** to the WSW commenced at DSDP Site 591 at 0625
Seismic Line 11, 139 km long was completed on the easternmost Lord Howe Rise at 1530 on 29 November, tying to *Rig Seismic* line 46/6. This ended the seismic program and all the equipment was aboard and stowed away by 1700 on 29 November. Unfortunately, the tail assembly of the magnetometer was damaged during recovery.

Australian sampling program

Southern area: Core GC13 was attempted twice in 1188 m of water on the eastern Lord Howe Rise at the end of seismic Line 11 between 1710 and 1915 on 29 November. Only 10 cm of foram sand was recovered, indicating current activity at that depth. We then headed ENE back along Lines 11 and 10, into the southernmost Fairway Basin for a concerted sampling program. GC14 recovered 5.19 m of nanno ooze from 2726 m of water at 0130 on 30 November. GC15 recovered 2.46 m of ooze from 2147 m of water at 0430. GC16 recovered 3.2 m of foram ooze from 2089 m of water at 0750. GC17 failed the first time, recovering only traces of foram sand and ooze from 3320 m of water at 1156. A second attempt at 1347 also failed.

Then northeast to seismic Line 9, where GC18 recovered 240 cm of nanno ooze from a lightly sedimented basement high in water 2590 m deep, at 2140 on 30 November.

Central area: After a transit of 100 km to the north, Core GC19 was taken at 0440 on 1 December in the flat southern New Caledonia Basin on Line 8. It failed, but the sheared fingers of the core catcher showed that it had penetrated. We then moved west along seismic Line 8, to a lightly sedimented basement high on the eastern flank of the northern extension of the West Norfolk Ridge. On the evidence of damage to the core cutter, Core GC20 skidded off the outcrop in water 2483 m deep at 0740. Dredge DR4, taken west to east up the basement slope from water depths of 2580 to 2420 m, recovered only foram nanno ooze, and left the station at 1045. Core GC21, in transparent ooze on the western part of the ridge, was taken at 1620 in a water depth of 2818 m, and recovered 400 cm of nanno ooze. Core GC22 was located in the flat bottom of the eastern part of the Fairway Basin. It was taken at 2140 on 1 December in water 3405 m deep, in a fairly reflective surface layer, and recovered 445 cm of multicoloured nannofossil ooze. Core GC23 was located in the flat bottom of the western part of the Fairway Basin. It was taken at 0110 on 2 December in water 3390 m deep, in a fairly reflective surface layer, and recovered 433 cm of multicoloured nannofossil ooze. Dredge DR5, taken east to west on rugged basement, recovered volcaniclastic rocks and manganese crust at 0700 from water 1700 m deep on the eastern edge of the Lord Howe Rise.

Northern area: After a 270 km transit northeast, Core GC24 was taken at 2220 on 2 December in moderately transparent sediment in the flat depression of the New Caledonia Basin, on seismic Line 7. It recovered 226 cm of pale brown and pale yellow nanno ooze from 3450 m water depth. Dredges DR6 and DR7 were planned to sample the eastern slope of basement high on the northern West Norfolk Ridge. Dredge DR6 sampled the slope in water depths of 3080-2840 m and recovered only nanno ooze at 0500 on 3 December. Dredge DR7 sampled the slope in water depths of 3280-3100 m and recovered only nanno ooze at 0830. After a transit of 145 km to the northwest to seismic Line 6, Core GC25 was taken in transparent sediments at 1430 and recovered 407 cm of nanno ooze. Core GC26 was taken at 1810 in transparent sediments in the Fairway Basin at the foot of the Lord Howe Rise slope, in water 2935 m deep. It recovered 377 cm of nanno ooze. Core GC27 was taken in water 1866 m deep, in weakly bedded sediments on the slope of the westernmost Fairway Basin. It recovered 248 cm of nanno ooze at 2130. The core was on deck at 2150 on 3 December, and we set course for Brisbane with the magnetometer deployed. The magnetometer could not be made to operate, and was hauled in at 2250.

On 4 and 5 December, much time was taken up in report writing, scientific discussions and a final science meeting, and packing up samples and equipment. Two short engine stoppages slowed us down, but otherwise the return to Brisbane went uneventfully. Late on 3 December coring ended, and we berthed at 0915 on the morning of 6 December, and all samples and some equipment were despatched to Canberra. Equipment for the non-seismic Geoscience Australia cruise FR1/02, to sail in January, was left aboard.

Summary

The results of the cruise are summarised in Tables 1-4 and Figure 1. Despite major problems with the hired seismic compressor, the cruise was a success, and its results will allow us to meet most of our pre-cruise objectives. From west to east, the geological history of eastern Lord Howe Rise, Fairway Basin, northern West Norfolk Ridge, New Caledonia Basin and Norfolk Ridge is important to studying a poorly understood and globally significant Southwest Pacific story of Cretaceous and Cainozoic subduction and back-arc rifting. The nine new seismic profiles across the Fairway Basin, and the four profiles that entered the previously unknown southern part of the New Caledonia Basin, will help to elucidate the history of a complex region of ribbon continents and deep ocean basins. Sediment diapirs and a sporadic BSR occur in both basins, suggesting that both have some petroleum potential.

Before this cruise, the Fairway Basin had been proven to exist as a distinct sedimentary basin along the eastern side of the Lord Howe Rise for 550 km, from 22°S to 26°40'S; now it has been shown to extend another 500 km to 31°30'S. It is a roughly north-south basin about 1050 km long, and about 150 km wide. We can now split it into three parts:
The northwest trending *North Fairway Basin* from 22°S to 23°30'S

The north-south trending *Central Fairway Basin* from 23°30'S to 26°40'S
The north-south trending, largely deeper water *South Fairway Basin* from 26°40'S to 31°30'S.

The seismic program gave us 2795 km of 24 channel profiles, which shipboard processing showed were of excellent quality. In the Central Fairway Basin in the north (largely in New Caledonian jurisdiction), it provided two new east-west cross-sections to add to the existing few, and found more diapirs, evidence of a bottom-simulating reflector (BSR) indicating the presence of gas hydrates, and young faulting. In short, it increased our knowledge of a part of the basin known to have petroleum potential.

In the south, the seismic profiling has provided six east-west multichannel cross-sections in an area of Australian jurisdiction, where there were none. These show that the deeper water, north-south extending depression south of 26°20'S is indeed a southern extension of the Fairway Basin, with the main difference probably being thinner continental crust. It is limited by the Lord Howe Rise to the west and the northern extension of the West Norfolk Ridge to the east, and is roughly 700 km long and 100 km wide. Thus it has an area of 70,000 km², about the size of Tasmania, and about 40% of it lies within the Norfolk Island EEZ. It contains sediments more than 2 seconds thick in places, shallow and deep diapirs (especially common north of 29°S), and a BSR in some regions. Water depths are 1200 m to 3600 m. Clearly, the South Fairway Basin has some petroleum potential, although the apparent maximum thickness of sediment <3 km) in the small part of the basin that we surveyed does reduce its potential.

Foram-bearing nanno ooze and nanno ooze were recovered in 22 successful cores, in water depths of 1297-3517 m. These gravity cores averaged 360 cm long (and totalled 80 m), compared to the piston cores of *L'Atalante* in the north and central Fairway Basin in 1998, which averaged 630 cm. The much higher velocity of a piston corer (~5 times as high) is a huge advantage in penetrating firm oozes like those in this region, and makes coring of foram sands quite feasible. Thus piston coring should become a standard deepwater operation when the larger *Southern Surveyor* replaces the *Franklin*. Nevertheless, the present set of Late Quaternary cores will enable us to study the composition, character and climate history of the region over nearly eight degrees of latitude. Colour changes in the cores suggest purely oxidising conditions in the north, but fluctuations in redox conditions in the south, probably related to inflow of varied bottom water through time. The core samples taken aboard will also help us to address the composition of any gas hydrates at depth, and petroleum potential in general, by determining the origin and composition of any enclosed gas, and the nature of pore water variations.

The seven dredges were far fewer than planned, because of time constraints and the fact that most possible hard rock targets were only marginally suitable. The much heavier dredges deployable from *Southern Surveyor* will greatly improve Australia's deepwater dredging capability. Two of the dredges succeeded, one in recovering volcaniclastic basement and the other Neogene chalk. The basement rocks may help us better understand the nature of the Vening-Meinesz Fracture Zone, a northwest-trending feature of regional significance.

Already the cruise data have improved our understanding of the geological history of an important part of the Southwest Pacific, and the nature and petroleum potential of the Fairway Basin. When worked up, they will shed light on many aspects of a complex and interesting offshore region.

Scientific Personnel

Neville Exon	Geoscience Australia	Chief Scientist, Geology
Peter Hill	Geoscience Australia	Geophysicist
Yves Lafoy	Service des Mines, New Caledonia	Geoscientist
Melissa Fellows	Geoscience Australia	Sedimentologist
Kirsten Perry	James Cook University	Sedimentologist (PhD Student)
Patrick Mitts	Moss Landing Marine Labs, USA	Geochemist (Masters student)
Jon Stratton	Geoscience Australia	Geological technician
Lyndon O'Grady	Geoscience Australia	Geological technician
Craig Wintle	Geoscience Australia	Mechanical technician
David Holdway	Geoscience Australia	Electronics technician
Lindsay Pender	CSIRO Marine Research	Computing
Stephen Thomas	CSIRO Marine Research	Electronics

Marine Crew

Ian Taylor	Master
Arthur Staron	Chief Officer
John Boyes	2nd Officer
Gordon Gore	Chief Engineer
Gregory Pearce	1st Engineer
Hugh McCormick	Electrical Engineer
Malcolm McDougall	Bosun
Tony Hearne	Able Seaman
Graham McDougall	Able Seaman
Louis Jacomas	Able Seaman
Howard (Danny) Davies	Greaser
Marc Sweeney	Chief Cook
Bernard Sorenson	2nd Cook
Shaun McQuaid	Chief Steward

We are very grateful to the Master, Ian Taylor, and his maritime crew for their wholehearted support and professional seamanship throughout the cruise, and especially to the engineers, Gordon Gore and Greg Pearce, for their wonderful support to Craig Wintle in overcoming numerous problems with the diesel compressor. The deck crew, led by bosun Malcolm McDougall, were helpful at all times. The excellent food kept spirits high. We thank the CSIRO Marine Division staff of Lindsay Pender and Steve Thomas for ensuring that all the necessary scientific support was provided. The Geoscience Australia technical group did an excellent job, and was led well by Jon Stratton; especial mention must be made of Craig Wintle in his ultimately successful struggles with the recalcitrant compressor.

Table 1. Data gathered on Cruise FR09/2001

Data type	Results
Seismic profiles	2795 km of 24 channel (3 fold) data
Magnetic profiles	~2400 km of data (163 hours)
Bathymetric profiles	~7400 km of data (acquired throughout voyage)
Gravity cores	26 total: 22 successful, total 80 m, average 360 cm
Dredges	7 total: 2 successful

Table 2. Seismic line statistics

Line	Start WP (lat/long)		End WP (lat/long)		Intermediate WP(s)	Length (km)
FB-01	25 12.5S	163 22.1E	24 35.8S	165 09.0E		205
FB-02	24 35.7S	165 08.3E	25 35.6S	165 20.1E		110
FB-03	25 35.6S	165 20.1E	25 57.6S	164 21.0E		107
FB-04	25 57.5S	164 21.2E	26 39.6S	164 01.5E		95
FB-05	26 39.5S	164 01.6E	26 58.4S	165 39.9E		187
FB-06	26 58.4S	165 39.9E	27 24.9S	163 12.4E		242
FB-07A	27 24.8S	163 12.7E	27 54.4S	165 56.2E		269
FB-07B	27 54.4S	165 56.2E	28 56.1S	167 48.1E		291
FB-08A	29 04.7S	167 49.9E	29 35.6S	167 12.8E		80
FB-08B	29 35.6S	167 12.8E	29 36.0S	163 05.0E		460
FB-09	29 36.0S	163 05.0E	30 42.0S	166 45.0E		370
FB-10	30 42.0S	166 45.0E	31 35.1S	164 26.9E	DSDP 591B	241
FB-11	31 35.1S	164 26.9E	31 54.3E	163 02.7E		138

Total kilometres = 2795
New Caledonian kilometres = 480
Australian kilometres = 2315

DSDP 591B = 31°35.06S, 164°26.92E

Table 3. Cores and dredges in New Caledonian jurisdiction

Core	Latitude	Longitude	Depth (m)	Recov. (cm) or (kg)	Description	Echofacies
GC01	25°18.67	163°04.75	1297	450	Pale foram-bearing nanno ooze	N/A
GC02	25°03.71	163°40.02	2635	369	Pale brown foram-bearing nanno ooze	1a
GC03	24°51.70	163°30.09	2522	339	Pale brown foram-bearing nanno ooze	DpBSR + 1b
GC04	24°48.18	163°29.99	2586	329	Pale foram-bearing nanno ooze	DS + 1b
GC05	24°54.98	163°46.75	2706	305	Pale brown foram-bearing nanno ooze	DpBSR + 1a
GC06	24°53.00	163°53.98	2764	338	Pale foram-bearing nanno ooze	DD + 1a
GC07	24°18.60	164°03.60	2835	N/A	Not attempted	DD + 1a + PM
GC08	25°08.10	164°13.50	2700	369	Pale foram-bearing nanno ooze (repeat section from 328 cm)	DD + 1b + PM
GC09	25°03.71	164°30.05	2840	350	Pale brown foram-bearing nanno ooze	DpBSR + 1a
GC10	24°44.33	164°46.14	2580	445	Pale brown foram-bearing nanno ooze	
GC11	24°44.28	164°49.13	2820	350	Pale brown foram-bearing nanno ooze	
GC12	24°41.39	164°57.83	3517	455	Brown foram-bearing nanno ooze	
DR01	25°11 25°11	165°02 165°01	3300-3150	30 kg	Pale orange to white chalk, ooze, pumice	
DR02	25°19	164°51	2450	0 kg	Lost dredge after strong bite (>4 tonnes)	
DR03	25°40.6	165°06.9	3130	3 kg	Quaternary ooze only	

Total recovery: 41 metres of core, so average is 370 cm

Seismic:
DS: sub-surface diapir
DpBSR: Diapir piercing the BSR
DD: Deep diapir

Echofacies (3.5 kHz):
1a: Layered, flat (long wave amplitude)
1b: Layered, wavy (short wave amplitude)
PM: possible pock mark

Table 4. Cores and dredges in Australian jurisdiction

Core	Latitude (S)	Longitude (E)	Depth (m)	Recov. (cm) or (kg)	Description	Line – shot point	Target
GC13 *	31 53.0	163 08.0	1188	10 cm	Pale olive muddy foram sand		PO
GC14	31 39.35	164 08.47	2720	519 cm	0-16 cm: pale brown foram-rich nanno ooze. 16-496: olive to white nanno ooze. 496-519: repeat 0-16.	L110-615	PO
GC15	31 35.59	164 24.64	2140	246 cm	0-90 cm: pale brown & light grey nanno ooze. 90-246 cm: pale yellow & white nanno ooze	L1101-85	DSDP 591 DD
GC16	31 28.49	164 44.53	2100	320 cm	0-29 cm: pale brown & light grey foram-rich nanno ooze. 29-320: light grey & pale olive nanno ooze	L1001 B-4207	MD, F, PM
GC17 *	31 17.94	165 12.46	3320	None	Traces of foram sand	L1001 B-3240	PO
GC18	30 26.87	165 54.33	2590	240 cm	Interbedded v pale brown & light grey foram-bearing nanno ooze	L902 C-6310	BR, WNR
GC19	29 35.74	166 13.33	2905	None	Fingers torn off core catcher	L802 B-3140	DD, NCB
GC20	29 35.75	165 57.65	2483	None	Bounced off hard rock, core cutter damaged. Ooze traces.	L802 B-3722	BR
DR4	29 35.75 29 35.75	165 57.00 165 58.05	2565-2400	10 kg	Nibbles only. Pale grey foram nanno ooze with some pyritised forams. Very minor pumice.	L802 B-3744-3707	BR W>E
GC21	29 35.78	165 28.60	2810	400 cm	0-290 cm: pale brown & yellow foram-bearing nanno ooze. 290-400 cm: repeat of top section	L802 B-4800	DD, WNR
GC22	29 35.86	164 58.51	3405	445 cm	Multicoloured nanno ooze, with distinct beds 20-30 cm thick: white, pale yellow, pale & dark greenish grey.	L802 B-5916	DD
GC23	29 35.88	164 27.77	3392	433 cm	Multicoloured nanno ooze, with distinct beds 20-40 cm thick: yellow, yellowish brown, pale & dark greenish grey.	L804-2-1062	DD

DR5	29 35.9	163 42.68 163 42.06	~1700	5 kg	Basaltic volcaniclastic rocks: hyaloclastite, hyaloclastite breccia, minor basalt. Mn crusts to 3 cm thick	L805-2744-2767	BR
GC24	27 52.02	165 43.00	3450	266 cm	Pale brown & pale yellow nanno ooze	L703-107	SB, DNS, BSR, NCB
DR6	27 47.17 27 46.98	165 16.34 165 15.18	3080-2840	5 kg	Very pale brown nanno ooze. Very minor pumice	L702-854-810	BR, WNR E>W
DR7	27 47.36 27 47.19	165 17.36 165 16.41	3280-3100	5 kg	Very pale brown nanno ooze.	L702-895-860	BR, WNR E>W
GC25	27 09.78	164 36.54	3239	407 cm	0-359 cm: pale brown & pale yellow nanno ooze. 359-407: repeat section	604-272	DNS, SB
GC26	27 13.74	164 14.43	2935	377 cm	Pale yellow, pale brown & greenish grey nanno ooze	604-1107	DNS
GC27	27 17.67	163 52.50	1875	248 cm	Pale brown, pale yellow, light grey & white nanno ooze	605-1976	SB, DNS

Station repeated once.
Total recovery: 39 metres of core, so average is 354 cm

Seismic:
DNS: near-surface diapir
DpBSR: Diapir piercing the BSR
DD: Deep diapir
MD: Minor diapir
F: Fault
PM: pock mark
SB: surface bulge
PO: palaeo-oceanography
BSR: Bottom simulating reflector
BR: basement ridge
WNR: West Norfolk Ridge
WNCB: West New Caledonia Basin

APPENDIX 1. KEY EQUIPMENT

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 450 m long, with 300 m active section and 24 channels
Plotter for seismic profiles and sampling locations
Seismic processing work station
MMC *Seaspy Overhauser* magnetometer and towing winch
Gravity corer, 1 tonne, for 6m cores
Dredges, chain bag and pipe
Refrigerated container for cores
Benches in CTD laboratory
Rock saw
Core splitter
Equipment for gas sampling
Equipment for pore water sampling equipment from Moss Landing Marine Labs
Ship's winches, and deck machinery
Coring cradle
DGPS navigation
Scientific echosounder (12 kHz)