

Thomas G. Thompson TN121

23 February – 12 March, 2001

APPLE

Anisotropy and Physics of the Pacific Lithosphere Experiment

OCE-0002381

Preliminary Cruise Report

March 11, 2001

1. Summary

The purpose of this experiment is to study electrical anisotropy in the crust and mantle of the Pacific oceanic lithosphere and asthenosphere. By using a combination of controlled source EM (CSEM) sounding, in which a deep-towed EM transmitter broadcasts energy to seafloor electric field recorders, and magnetotelluric (MT) sounding, a method utilizing time variations in Earth's natural magnetic field, electrical conductivity structure can be studied from depths of a few hundred meters down to the lower mantle. We expect electrical anisotropy (a direction dependence of conductivity) in the sheeted dikes of the crust, in the fabric of the lower crust and mantle imprinted during lithosphere formation at mid-ocean ridges, and in the plastic asthenospheric mantle being actively deformed as a result of current plate motion. A quantitative model of electrical properties with depth will lead to a better understanding of the physics of electrical conduction in the deep Earth, and also a better estimate of the depth over which the asthenosphere is deforming.

This cruise (TN121), leg 1 of a two leg project, had as its primary task the collection of CSEM and broadband MT data. Ten long period MT instruments were left on the seafloor, 6 at the main survey site and 4 on the transit back to San Diego (to evaluate the effect of the coast on the MT fields). These instruments will be recovered from the New Horizon in August 2001 during the second leg.

In terms of ship use and data collection, the objectives of the project were well met. The deep-towed transmitter worked almost perfectly, with only about 6 hours consumed in initial commissioning and maintenance. The fiber optic deep-tow wire and winch, installed in San Diego for this cruise, worked extremely well. All seafloor instruments recovered good quality data, with the exception of one instrument that failed to leave the seafloor; the instrument is communicating via acoustics and we will make further attempts at recovery in August. Meanwhile, this MT recorder was deployed to provide redundancy in a key location occupied by other, working, instruments and so its potential loss will have very small impact on the project.

Although the project should prove to be an unqualified success, because of limited shiptime we did have to cut the amount of transmitter towing to the bare minimum required to achieve the scientific objectives. Indeed, even this was obtained only through an aggressive recovery schedule that at one point had four instruments in the water column at the same time. The principal reasons for this were a delayed sailing date caused by the late arrival of the Thompson in San Diego, where we needed to install the deep-tow winch and transmitter, and several days lost to weather. The weather contingency in the original science plan was unable to accommodate this cumulative loss of time.

2. Personnel

This project brings together the expertise of scientists at four institutions; Mark Everett at Texas A&M University (modelling), Lucy MacGregor and colleagues at Southampton University (CSEM transmitter and CSEM interpretation), Antony White and colleagues at Flinders/Adelaide Universities in South Australia (long period MT equipment, MT interpretation), and Steven Constable of Scripps Institution of Oceanography (project coordination, CSEM and MT receivers and interpretation).

Personnel on board ship were:

SIO:

| | |
|------------------|---------------------------------|
| Steven Constable | chief scientist |
| Monika Korte | postdoctoral scientist/observer |
| Kerry Key | graduate student |
| Jim Behrens | graduate student |
| Gary Austin | winch engineer |
| Lisl Lewis | marine MT technician |

University of Southampton:

| | |
|------------------|----------------------|
| Lucy MacGregor | co-chief scientist |
| Neville Barker | graduate student |
| Dhananjai Pandey | graduate student |
| Jennifer Rust | transmitter engineer |

Flinders University:

| | |
|---------------|------------------|
| Adrian Costar | graduate student |
|---------------|------------------|

Shipboard technical support was provided by Robert Hagg and Bill Martin. Antony White of Flinders University and Peter Mason of Southampton University assisted with instrument preparation and mobilization in San Diego.

3. Instrumentation

The deep-tow transmitter requires a fiber optic cable in order to handle the communications channel separately from the high voltage supply. Since the Thompson is not currently equipped with such a cable, a **portable winch facility** provided by SIO was installed on the main deck. The facility consisted of a Dynacon storage winch and slip rings, traction unit, slack tensioner (heave compensator), and hydraulic power supply, along with approximately 9000 m of .680" fiber optic electromechanical cable, borrowed from the R.V. Revelle. This was the first time this facility was used aboard ship, and three days were spent in port installing, terminating, and testing the winch system.

The **deep-towed EM transmitter** (DASI) system provided by Southampton University consists of a deep towed package and neutrally buoyant electrode streamer, with power, control, and communications provided by a ship-board high voltage power supply unit.

Seafloor instrument systems provide various types of electric and magnetic recording capabilities:

ELFs (SIO) provide 3 types of data on 7 channels; (a) two channels of 32 Hz high frequency E-field recordings of the CSEM transmitter signals on two orthogonal, 10 m antennae, (b) two channels of 0.5 Hz low frequency E-field recording for long period MT data on the same antennae, and (c) a fluxgate (low frequency) 3-axis magnetometer supplied by Flinders and mounted in one of the two 17” glass flotation balls.

LCheapo MT recorders (SIO) record 4 channels of data; two channels of 125 Hz high frequency E-field recordings of both the CSEM transmitter signals and high frequency MT data on two orthogonal, 10 m antennae, and two channels of high frequency magnetic data from orthogonal, horizontal, induction coil sensors.

Flinders’ long period MT instruments record 2 channels of horizontal long period E-field data on orthogonal 10 m antennae, and 3 channels of long period B-field data on fluxgate magnetometers.

LEMs (Long-wire ElectroMagnetic recorders, SIO) record 2 channels of high frequency CSEM electric field data on 200 m long antennae for increased sensitivity (but only in one direction). They are made using either an ELF logging unit, recording at 32 Hz, or an LCheapo sampling at 125 Hz. In this application, two pair of LEMs were deployed in both N–S and E–W orientations. LEMs are deployed by streaming the antenna wire behind the ship (moving at 4 kts), attaching the antenna wire to the instrument/anchor sled assembly, and lowering the instrument package to the seafloor while a reduced ship’s speed of 2 kts keeps the antenna streamed behind the instrument. The instrument is connected to the end of the towing wire via a down-wire acoustic echo-sounder and release unit. When the acoustic system shows that the package is close to the seafloor (within about 10 m), it is released from the cable by a command to the down-wire release mechanism.

The two ELF-type LEMs were recovered and fitted with Flinders fluxgate magnetometers, for redeployment as long period MT instruments during the transit back to San Diego.

The instruments used in this experiment are summarized as follows. Redeployment of the two ELF-LEMs, and multiple uses for certain loggers, increased the effective number of instruments over the 18 physical units that were taken to sea.

| Instrument type | number | CSEM | High-f MT | Low-f MT |
|-----------------|--------|------|-----------|----------|
| CSEM ELF | 5 | + | | + |
| LCheapo MT | 6 | + | + | |
| Flinders | 2 | | | + |
| LEM | 4 | + | | |
| MT ELF | 3 | | | + |
| total | 20 | 15 | 6 | 10 |

4. Survey Design

The survey location (Figure 1) was chosen so that (a) the fossil spreading direction was distinct from current plate motion (b) it was logistically convenient for operation out of San Diego and (c) the water was not

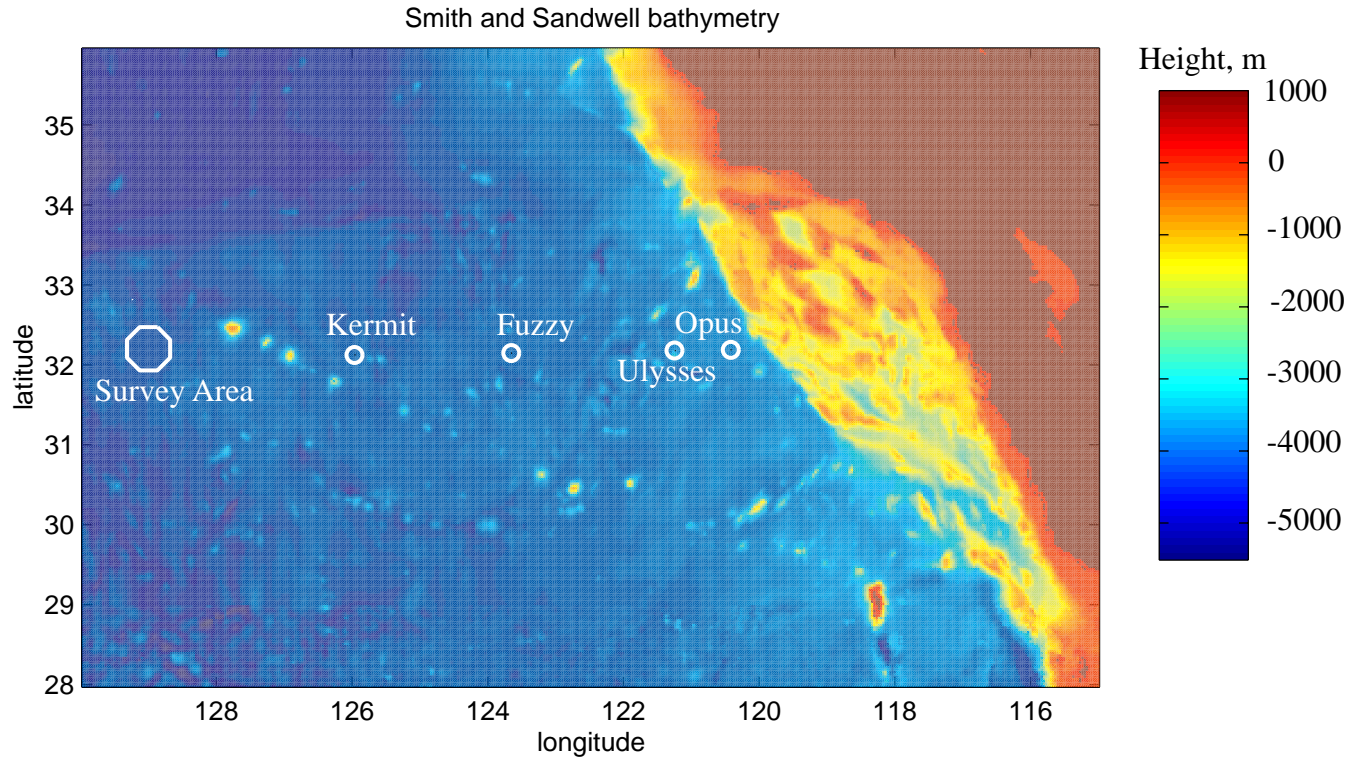


Figure 1: Survey location, showing main survey area and locations of additional long period MT instruments (Kermit, Fuzzy, Ulysses, and Opus).

particularly deep.

The proposal called for concentric 5 km and 30 km transmitter circles to be towed around the center of the research experiment (the CORE), two radial tows to 50 km radius, and a 50 km radius 1/8 circle tow. Given the loss of shiptime, the plan was altered to emphasize data collection from the 30 km tow and a radial tow to 75 km. Bad weather (35–40 kt winds and 15–20' seas) forced further modification when we had to abandon the 30 km circle 1/2-way and head into the wind only. Fortunately, this resulted in a 15 km radius 1/2 circle around one instrument (A) and a useful radial tow of range 30–75 km, before weather stopped operations completely for over a day.

The instrument layout was designed to (a) maximize redundancy and sensitivity in the central core, where two redundant pairs of LEMs and three other CSEM receivers were deployed and (b) maximize the number of short-range radial geometries whilst simultaneously monitoring transmitter coupling from short range by deploying 8 instruments on the perimeter of the 30 km radius circle. This was slightly modified during the cruise to avoid towing directly over the perimeter instruments, as such short-range data is only sensitive to seawater conductivity.

Instrument locations and way points are tabulated below. The UTM central meridian is 129°W.

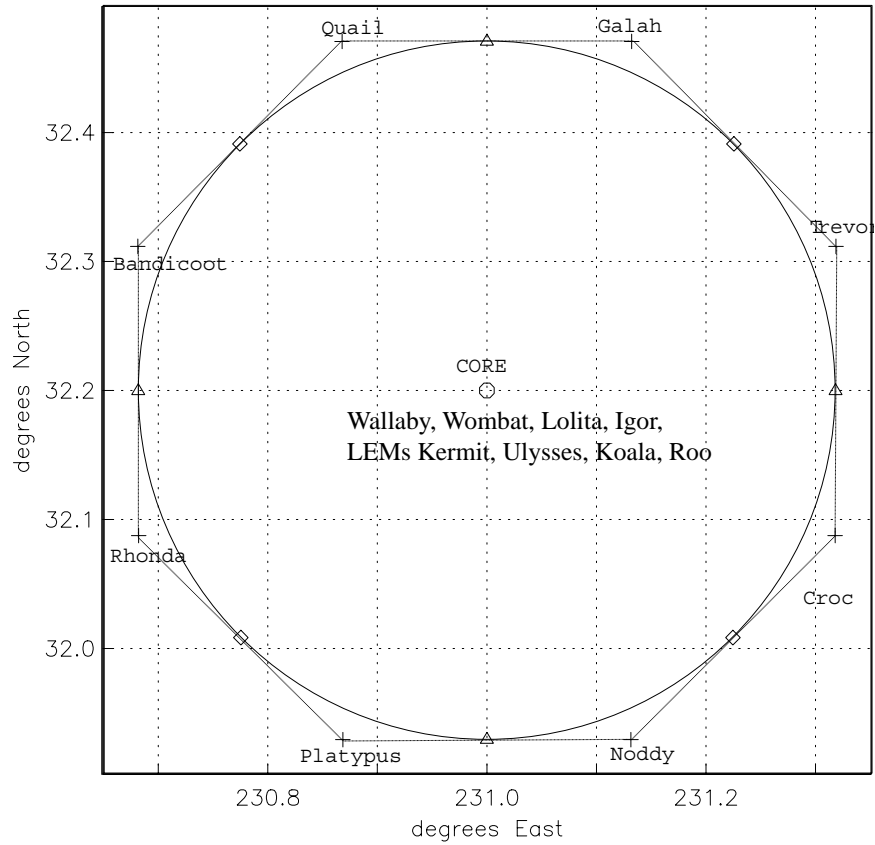


Figure 2: Survey layout.

| CORE: | UTM East | UTM North | latitude | W longitude |
|------------------|----------|-----------|------------|-------------|
| LCheapo Wallaby | 500000 | 3562604 | 32° 12.000 | 129° 0.000 |
| LCheapo Wombat | 500000 | 3562604 | 32° 12.000 | 129° 0.000 |
| ELF Lolita | 500000 | 3562604 | 32° 12.000 | 129° 0.000 |
| Flinders MT Igor | 500000 | 3562604 | 32° 12.000 | 129° 0.000 |
| E-W LEM Roo | | | 32° 11.75 | 128° 59.88 |
| E-W LEM Ulysses | | | 32° 11.75 | 128° 59.66 |
| N-S LEM Koala | | | 32° 11.65 | 129° 0.0 |
| N-S LEM Kermit | | | 32° 11.50 | 129° 0.0 |

Circle Way points:

| | UTM East | UTM North | latitude | E longitude |
|---|----------|-----------|------------|-------------|
| 1 | 500000 | 3592604 | 32° 28.238 | 231° 0.000 |
| 2 | 521213 | 3583817 | 32° 23.470 | 231° 13.532 |
| 3 | 530000 | 3562604 | 32° 11.976 | 231° 19.098 |
| 4 | 521213 | 3541391 | 32° 0.505 | 231° 13.477 |
| 5 | 500000 | 3532604 | 31° 55.761 | 231° 0.000 |
| 6 | 478787 | 3541391 | 32° 0.505 | 230° 46.523 |

| | | | | |
|---|--------|---------|-------------|--------------|
| 7 | 470000 | 3562604 | 32 - 11.976 | 230 - 40.902 |
| 8 | 478787 | 3583817 | 32 - 23.470 | 230 - 46.468 |

| Instrument locations on 30 km circle: | dec. latitude | E longitude | latitude | E longitude |
|---------------------------------------|---------------|-------------|-------------|--------------|
| A: ELF Quail | 32.4706 | 230.8678 | 32 - 28.234 | 230 - 52.066 |
| B: LCheapo Galah | 32.4706 | 231.1322 | 32 - 28.234 | 231 - 7.934 |
| C: ELF Trevor | 32.3117 | 231.3187 | 32 - 18.702 | 231 - 19.122 |
| D: LCheapo Croc | 32.0875 | 231.3179 | 32 - 5.250 | 231 - 19.075 |
| E: ELF Noddy | 31.9293 | 231.1315 | 31 - 55.757 | 231 - 7.888 |
| F: LCheapo Platypus | 31.9293 | 230.8685 | 31 - 55.757 | 230 - 52.112 |
| G: ELF Rhonda | 32.0875 | 230.6821 | 32 - 5.250 | 230 - 40.925 |
| H: LCheapo Bandicoot | 32.3117 | 230.6813 | 32 - 18.702 | 230 - 40.878 |

| Instrument locations on transit: | latitude | W longitude |
|----------------------------------|-------------|--------------|
| 1: ELF Kermit | 32 - 7.407 | 125 - 57.781 |
| 2: Flinders MT Fuzzy | 32 - 8.708 | 123 - 39.548 |
| 3: ELF Ulysses | 32 - 10.52 | 121 - 14.55 |
| 4: ELF Opus | 32 - 11.327 | 120 - 25.281 |

5. Shiptime Utilization and Daily Log

Shiptime had to be budgeted very carefully, as the late arrival of the Thompson in San Diego, coupled with the need for 3 work days to install the winch, resulted in a sailing date of afternoon 23rd February, rather than morning of the 21st as scheduled.

| | | |
|---------|----------|---|
| 21 Feb | 10:00 | Thompson arrives Nimitz Marine Facility; winch installation commences |
| 22 | | Winch installation |
| 23 | | Winch installation |
| | 16:00 | Leave San Diego |
| 24 | | Transit to station |
| 25 | midnight | Arrive on station; commence deployments |
| 26 | | Deploy ELFs and broadband MT |
| 27 | | Deploy LEMs |
| 28 | | Deploy LEMs |
| 1 March | midday | Deploy DASI deeptow transmitter |
| 2 | | DASI tows; West circle started |
| 3 | 12:00 | Weather forces into-the-wind operation only |
| 4 | | Radial tow into wind |
| 5 | 04:00 | DASI stops transmitting due to weather |
| 6 | 06:00 | DASI recovered; head South |
| | 21:00 | transmission restarted East circle |
| 7 | | DASI tows |
| 8 | 09:30 | Start recovery |

| | | |
|----|-------|----------------------------|
| 9 | 22:20 | leave station |
| 10 | | transit and deploy |
| 11 | | transit and deploy |
| 12 | 08:00 | arrive San Diego |
| 13 | 08:00 | Thompson departs San Diego |

Weather played a critical role in the experiment. The Thompson handles weather extremely well, and we made the transit and many of the instrument deployments in winds up to 30 kt. DASI transmissions started in some of the best weather of the cruise (winds less than 20 kt), but on the 3rd March winds forced the ship off the planned E–W segment of the circle and towards the South. Winds progressively veered around through westerlys to winds from the North/Northwest. We were able to adapt to this well, achieving an unplanned semi-circular tow around the instrument at A (Quail) and then on a quasi-radial tow to the NW. We had planned on a SW radial tow to avoid the seamounts in the NW, and indeed a combination of rough bottom terrain and high winds and seas forced a termination of transmission early on the 5th March. Weather prevented recovery of DASI and resumption of transmitter tows until the evening of the 6th.

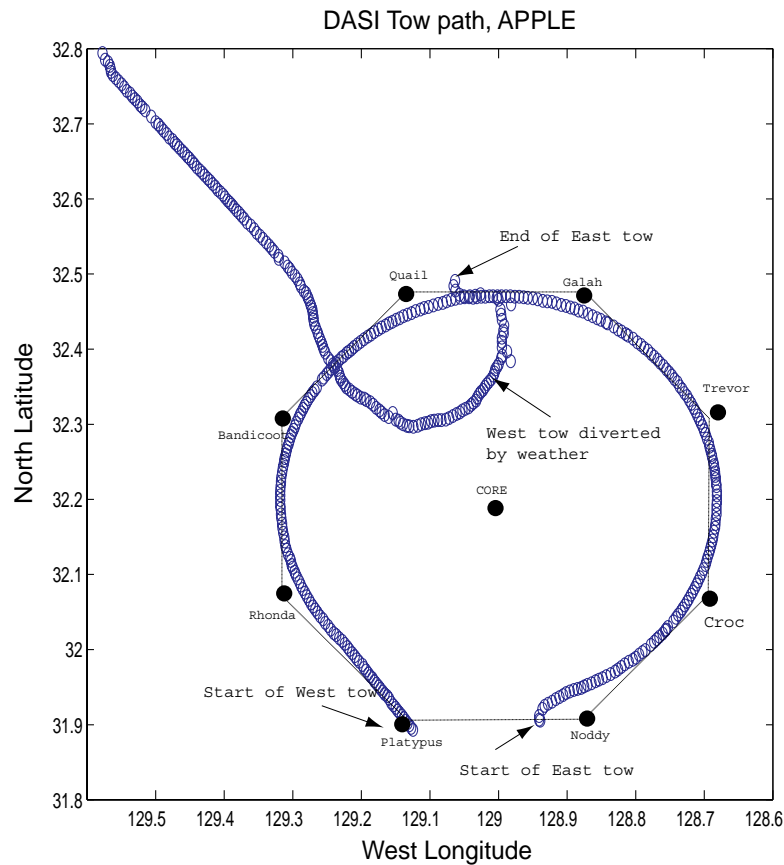


Figure 2: Path followed by ship during DASI transmitter tow.

6. Scientific Equipment Performance

The **portable winch system** worked well, and the new instrumented A-frame block (which was relatively light-weight) and slack tensioner allowed operations to continue into weather conditions that would have otherwise shut us down. The wire-out and speed sensors on the A-frame block became damaged and failed fairly early into the cruise, but we were able to use the corresponding indicators on the traction winch, relying on the block only for tension monitoring. Maximum wire out was 6014 m and maximum tension was about 10,000 lbs. One incident is worthy of note; the bolts holding the traction winch sheaves to the bearing assembly worked loose the first time we carried out a sustained haul in of the instrument. Indeed, it was the sound of a bolt falling to the deck that alerted the winch operator to the problem. The bolts were re-tightened and provided no trouble for the remainder of the cruise.

The **deep-tow EM transmitter** performed well. Installation was straightforward, with no problems associated either with connecting to the slip rings on the winch or with the termination of the wire. Three hours were lost during the initial commissioning and first deployment, during which time it was discovered that the winch and DASI could not both run off the same 480 VAC power circuit without the protection system of the deep-tow power supply tripping. The problem was solved temporarily by putting an additional generator on line, allowing paying out of wire to commence, during which time clean 480 VAC power was run to the laboratory and provided a permanent solution. The only other down time associated with the transmitter was associated with a broken cable on the near electrode. This was discovered during the redeployment of DASI after the weather down time, and was almost certainly caused by the need to tow the instrument for an extended length of time in rough weather before a safe recovery was possible. A spare cable was at hand, and the diagnosis and repair only consumed 3 hours.

Deployment of the **seafloor instruments systems** went well, despite less than hospitable weather, with the exception of one LEM deployment that had to be repeated when the package broke free from the end of the deep-tow wire (we used the ship's 0.680" coaxial wire for the LEM deployments). During the initial lowering of the instrument package into the water, the winch operator payed out cable at 30m/minute, far too fast when there is not yet a load on the cable and faster than the 20m/minute that we normally use for deployments. When the wire was recovered it was discovered that the release package was torn apart, and it appears that a tangle developed during the initial deployment, putting a side, rather than in-line, load on the release. Fortunately, the problem was spotted on the acoustic system in time to release the instrument before the anchor/instrument/antenna assembly piled onto the seafloor. A spare release unit, anchor, antenna, and electrodes were all available to repeat the deployment, but at a loss of 6 hours of work.

In order to maximize transmitter tow time after the bad weather relented, an aggressive recovery schedule was initiated that at one time had 4 of the core instruments rising in the water at one time. This did, however, gain us several hours of shiptime, and worked well, except that one instrument (LCheapo MT instrument Wallaby, in the core) failed to lift off the seafloor even after acknowledging repeated release commands. Since the instruments are equipped with redundant release mechanisms, both of which are tested immediately prior to deployment, likely possibilities are reduced to a flooded logger pressure case or a tangle with another instrument or the stray line and its own anchor. Time permitting, we will attempt a dragging recovery of this instrument during the recovery cruise, but since this instrument was a duplication of instrument Wombat,

which recovered excellent data, the experiment is not compromised by this loss.

All recovered instruments operated correctly and collected data.

7. Performance of Ship's Equipment

The Thompson proved to be an excellent vessel for this project, particularly because it rides well in bad weather. We had only 3 days without white-caps, and many days with wind speeds over 30 kts, so this was more than an issue of comfort, but rather a significant factor in how much science could be accomplished.

The on-board computer, navigation, mechanical and electrical systems offered a good level of support, and worked well for the duration of the cruise. The tracking of the transmitter tow lines and station holding during deployments was spectacular, with the ship typically within 10 m (often less) of the desired position. The ship's crew, engineers, and resident technicians were responsive and provided much help. The only negative associated with the ship was the late arrival in San Diego, which wiped out the weather contingency built into the science schedule and eventually compromised the amount of science that we could get done when the weather did end up costing us time.

Whilst the ship's support for this cruise was more than satisfactory, recommendations for improvements in ship's equipment would include the ability for the bridge to set, choose, and display waypoints in the navigation system, rather than having to phone the resident technicians for changes to be made in the computer lab 3 decks below (even for a simple zoom in/zoom out operation). Ideally, one should have the ability for the scientists to have a display in the lab using different parameters than the bridge is using (e.g. the bridge typically would like to be at a large scale, so that the ship's orientation and actual course made good could be distinguished, whilst for scientific purposes the ship's position with respect to the various instrument locations is more useful). A postscript wide-bed plotter would be useful for making charts and maps.