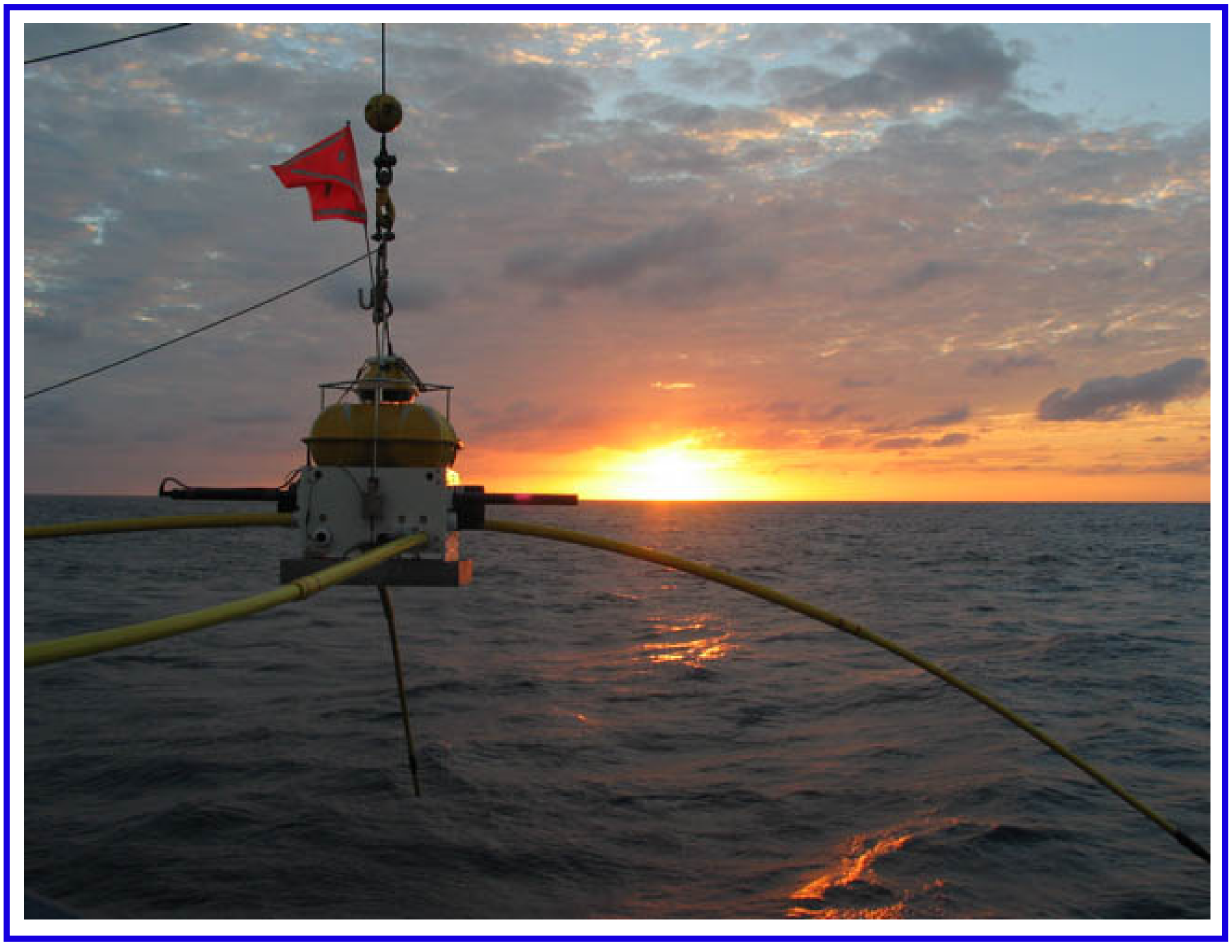
Constraining the Magmatic Budget of the EPR at 9°N Using Broadband Marine MT

R.V. Roger Revelle, February 9th – March 9th 2004

NSF OCE-02-41597

Cruise Report

Kerry Key and Steven Constable



Summary

The object of this RIDGE2000 funded experiment is to map the hydrothermal circulation systems removing heat from the mid-ocean ridge magma chambers, quantify the total amount of melt in the crustal magma chamber, and examine the relationship between mantle melting and crustal melt accumulation. Because electrical conductivity is a strong function of fluid content and temperature, whether magma or seawater, we used electromagnetic methods to accomplish these goals. Two techniques were used:

a) Marine magnetotelluric (MT) method. A seafloor instrument records natural variations in Earth's electric and magnetic fields for 2 days to 2 weeks. When processed, these data can be used to obtain images of seafloor conductivity up to hundreds of kilometers deep.

b) Marine controlled source EM (CSEM) sounding. An EM transmitter is deeptowed close to the seafloor to provide a man-made source of EM energy. The seafloor recorders monitor the transmitted electric fields, which provide similar information to the MT method except that (i) the CSEM method has better resolution at shallow depths and (ii) the CSEM method is better at measuring resistive (c.f. conductive) rocks.

The seafloor recorders for the MT and CSEM parts of the experiment are identical. The new broadband MT/CSEM instrument developed at Scripps Institution of Oceanography and used extensively by the petroleum industry allows resolution of electrical conductivity structure at much shallower depths than traditional MT instrument systems. Forty such instruments were taken on this experiment, and we commissioned a new second-generation deeptowed EM transmitter. In total, we collected 69 MT sites and approximately 1300 receiver-hours of CSEM data at the Ridge 2000 integrated study site (ISS) on the East Pacific Rise (EPR) at 9°50′N and along a supporting larger aperture MT transect at 9°30′N.

See also http://marineemlab.ucsd.edu/Projects/EPR2004

Research Objectives

Extensive seismic and compliance data collected along the East Pacific Rise south of the Clipperton Fracture Zone have in part constrained structural contrasts, but ambiguities in the extent and amount of melting in the crust and upper mantle still persist. Additionally, new questions have arisen about the role of hydrothermal circulation in the removal of heat from the crust and in determining the distribution of partial melt. A pilot experiment at 9°50′N demonstrated the ability of the new SIO broadband MT instrument to image conductivity structure in both the crust and shallow mantle. We proposed a small aperture (30 km) transect of densely spaced MT sites across the ridge at the ISS "bull's eye" focus area at 9°50′N to image the electrical conductivity structure in the crust and shallow mantle in the vicinity of the ridge axis. A larger aperture (200km) MT transect across the ridge at 9°30′N was proposed to target both crustal and upper mantle conductivity structures. The large aperture transect is positioned to the south to avoid 3D structure associated with both the Lamont seamonts and the Clipperton transform. We proposed to take a total of 40 instruments and collect 60 sites on a single cruise leg; in the event we deployed 40 instruments 72 times to recover 69 MT data sets, as well as collected bonus CSEM data along the southern line.

Key issues addressed by this project are:

> What is the distribution, vertical extent and volume fraction of melt present in the mid to lower crust? Although recent seismic and compliance experiments have in part addressed these questions, the results do not unambiguously resolve the physical properties of the melt/rock mix. By using seismic and compliance results as constraints on the geometry of structures in the mid to lower crust, MT data can help constrain the amount of connected melt present. The dense transect of MT sites near the ridge axis at the ISS "bull's eye" focus area (9°50′N) will delineate the region of crust containing partial melt, and constrain the total amount of connected melt present.

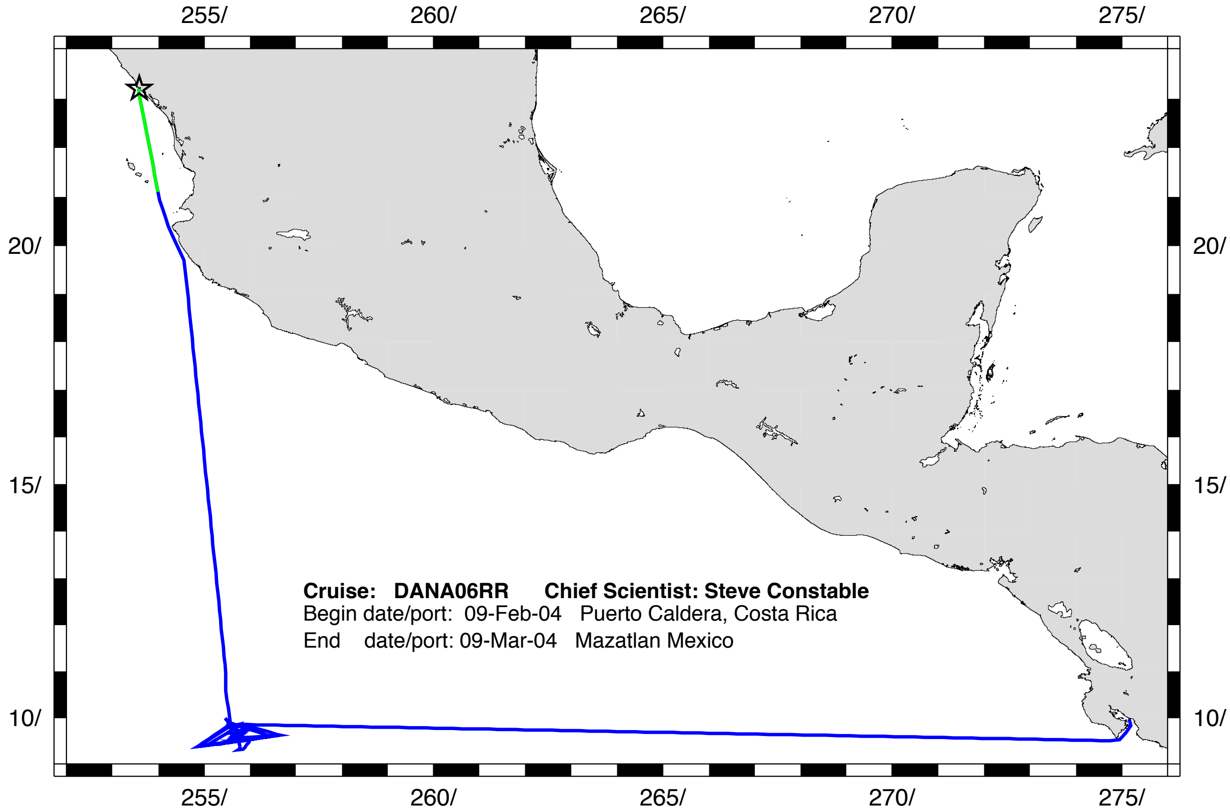


Figure 1. Hourly underway locations.

> To what extent does hydrothermal circulation play a role in heat removal from the crust? What link(s) exists between the hydrothermal activity and crustal magma at the ridge axis? How does hydrothermal circulation affect the lateral extent of the crustal melt? To address these questions we will use MT data to provide constraints on lateral conductivity variations in the crust near the mid-ocean ridge, from which we will infer temperature, porosity and permeability variations in the region surrounding the mid to lower crustal melt accumulations at 9°50′N.
>
> To what extent is melt accumulating at the base of the crust? Does a relatively thin layer of concentrated melt pond at the base of the crust, or does melt accumulate from a broader region of the mantle? The wide aperture line of MT sites up to 100 km from the ridge axis at 9°30′N will distinguish between these hypotheses.
>
> What, if any, connection exists between the crustal melt accumulations and the region of decompression melting deeper in the mantle? Again, the wide aperture line of MT sites will allow us to place constraints on the delivery of melt to the ridge by the crust-mantle system.

Electrical conductivity images of the crust and upper mantle from this experiment will complement existing results from other geophysical methods used at this segment of the EPR (seismic refraction/ reflection, compliance and gravity). Estimates of the amount and distribution of partial melt in both the crust and upper mantle, and of the temperature, porosity and permeability structure of the crust will provide useful constraints on the nature of the complex magmatic system, and will support the interpretation of a wide variety of other Ridge 2000 EPR ISS experiments.

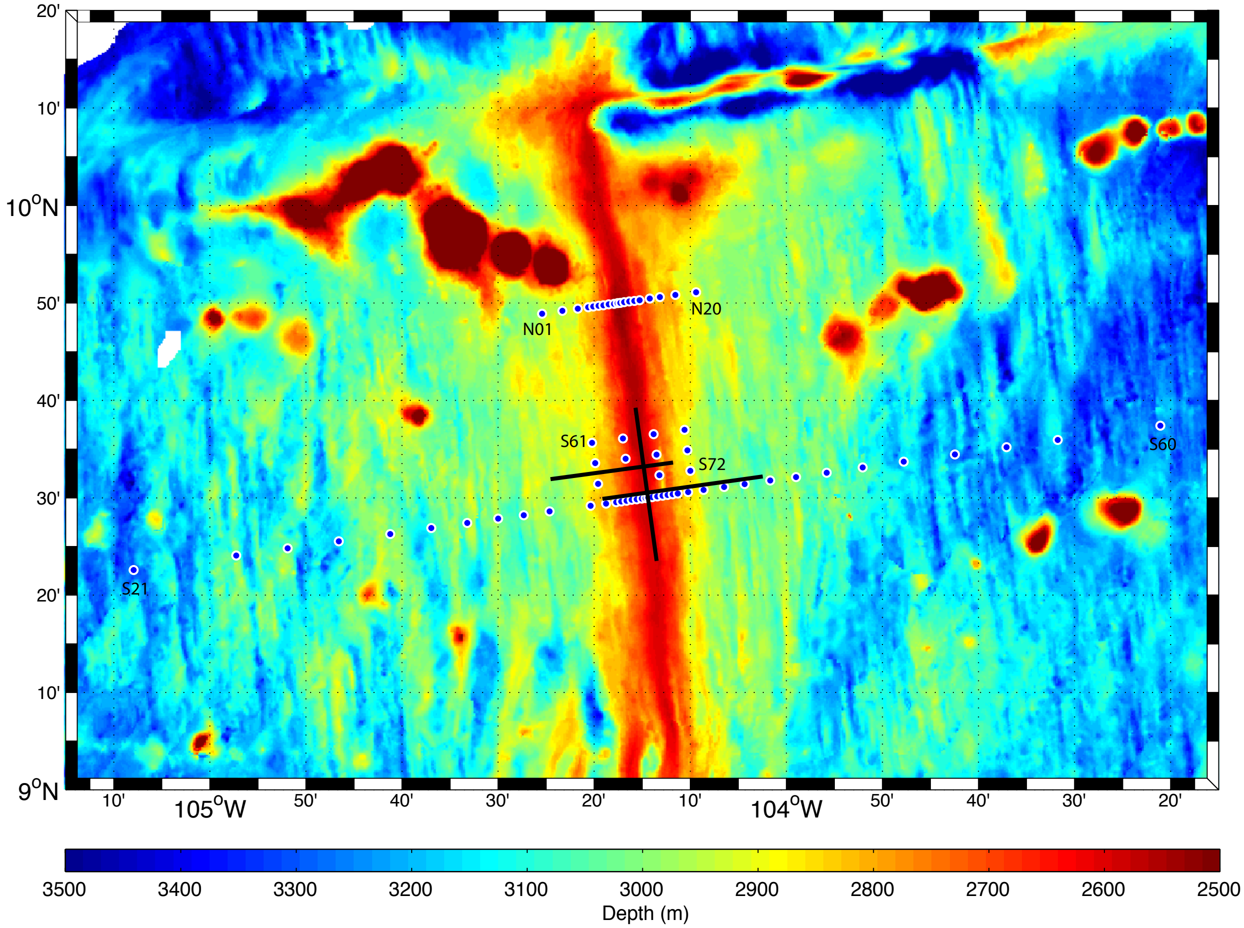


Figure 2. Map of deployment stations (circles) and CSEM tows (solid lines).

Mobilization and Logistics

Given the large inventory of equipment and anchors, we originally requested a San Diego–San Diego leg for this cruise. The inevitable compromises of ship scheduling resulted in a Puerto Caldera (Costa Rica) to Mazatlan (Mexico) leg, very early in the project cycle (within a couple of months of funding). This had plusses and minuses. A clear advantage is that data are collected early on, leaving more time for processing, inversion, interpretation, and paper writing. The time spent at sea was reduced from over 40 days to less than 30 days. Perhaps most importantly, we were insulated from later uncertainties in the UNOLS 2004 ship schedules forced by budgetary issues.

The downside was that equipment and personnel had to get to Costa Rica. The 15 tonnes of concrete anchors required by our operations turned out to be much less of a problem than anticipated. As a result of our operations with the petroleum industry, we have made marine EM anchors a global commodity, and 70 anchors were made for us by Craig Group International Mooring Systems in Aberdeen, Scotland, and shipped to Costa Rica for about the same cost as producing the anchors in San Diego.

The scientific equipment proved to be a little more difficult. The only shipping company working the Pacific side of central America cancelled 3 consecutive scheduled runs, leaving us with a shipping schedule that put the gear into Costa Rica one day after the Revelle was due to leave (assuming that this was not also cancelled, which we considered highly probable). Consequently, we had to air freight 13 tonnes of equipment. The air freight itself proved to be quite economical, although the cost of producing the packing crates for 40 seafloor instruments was considerable.

Finally, we needed the coaxial .680” deeptow wire, rather than the fiber optic cable that was then installed on the Revelle, so SIO ship operations needed to send a container of cable and spooling gear to the ship. They were able to meet an earlier schedule for an Atlantic side delivery and transshipment overland in Costa Rica, something we were not prepared to do with scientific gear.

The good news is that equipment, anchors, and cable all made it to the Revelle on time and in good condition, in no small part because of the excellent services of our agent, Vasile Tudoran.

Another issue was that Dan Fornari and the Atlantis were scheduled to work in exactly the same area of the EPR at about the same time as we were. Through negotiation prior to the cruises, we arranged to spend all our port days at the beginning of our cruise, which not only facilitated loading, but offset our operations as much as possible from that of the Alvin and Atlantis. This was possible because Peter Lonsdale, who had the Mazatlan – San Diego leg, kindly agreed to allow us to leave our gear aboard ship, saving us both time and money. The agreed plan was for the Atlantis to finish operations at $9°50'$ in time for our arrival and deployment of instruments there. As it happened, the Atlantis experienced delays in operations and had to extend its cruise to carry out further operations at $9°50'$, as well as $9°30'$ and places in between. We managed to accommodate this by disabling the acoustic systems on the 20 instruments deployed at $9°50'$ so that Alvin could operate without acoustic interference while we continued operations at $9°30'$. We carried out evasive maneuvers until the Atlantis completed its work–had we managed to bring up our deeptowed EM transmitter immediately, this would have resulted in some loss of time for us, but as it happened we were busy preparing this brand new instrument for deployment.

Efficient use of ship time was achieved by dividing the personnel into two 12 hour shifts for around-the-clock operations (see shift list appendix). Each shift was led by an experienced Scripps scientist capable of mitigating most situations (Key and Behrens) and consisted of at least 4 other persons to carry out the deployments and recoveries. Crane operations were carried out partially by the ResTech (Colt) and by various members of the ships crew during the ResTech’s off time. With two shifts and the availability of a crane operator 24 hours a day we were able to achieve an average time of about 1.8 hours per deployment and per recovery. Deployment and recovery have become routine for our EM receiver (over 1000 deployments to date) and so Constable was able to concentrate his efforts on preparing the deep-towed EM transmitter and overseeing the shipboard operations. During the deep-tow operations watches were formed for the winch control and for monitoring deep-tow vital signs. Constable, Key and Behrens oversaw the deep-tow operations while the other personnel took turns at 30 minute “flying” sessions at the winch control station.

Instrumentation

Receivers

Forty modern, state of the art, seafloor electromagnetic recorders constituted the core facility of this project. These instruments were developed and built over the last decade or so with petroleum industry sponsorship, and have a shared heritage with the Scripps ocean-bottom hydrophone now in the NSF’s Ocean Bottom Seismometer Instrument Pool. Each instrument is fitted with a pair of orthogonal 10 m dipoles for electric field measurements, and a pair of orthogonal induction coil magnetometers as magnetic field sensors. A brief list of specifications follows:

Channels	8 (MkIII), 4 (MkII)
ADC	24 bit
ADC noise floor	10^{-13} V^2/Hz at 0.01 Hz to nyquist
Power consumption	450 mW (4 channels at 32 Hz sampling)
Maximum sample rate	1,000 Hz on 4 (Mk III) channels or 2 (Mk II)
Time base drift	1 - 5 ms/day, correctable to < 1 ms
E and B amplifiers	Chopper-stabilized

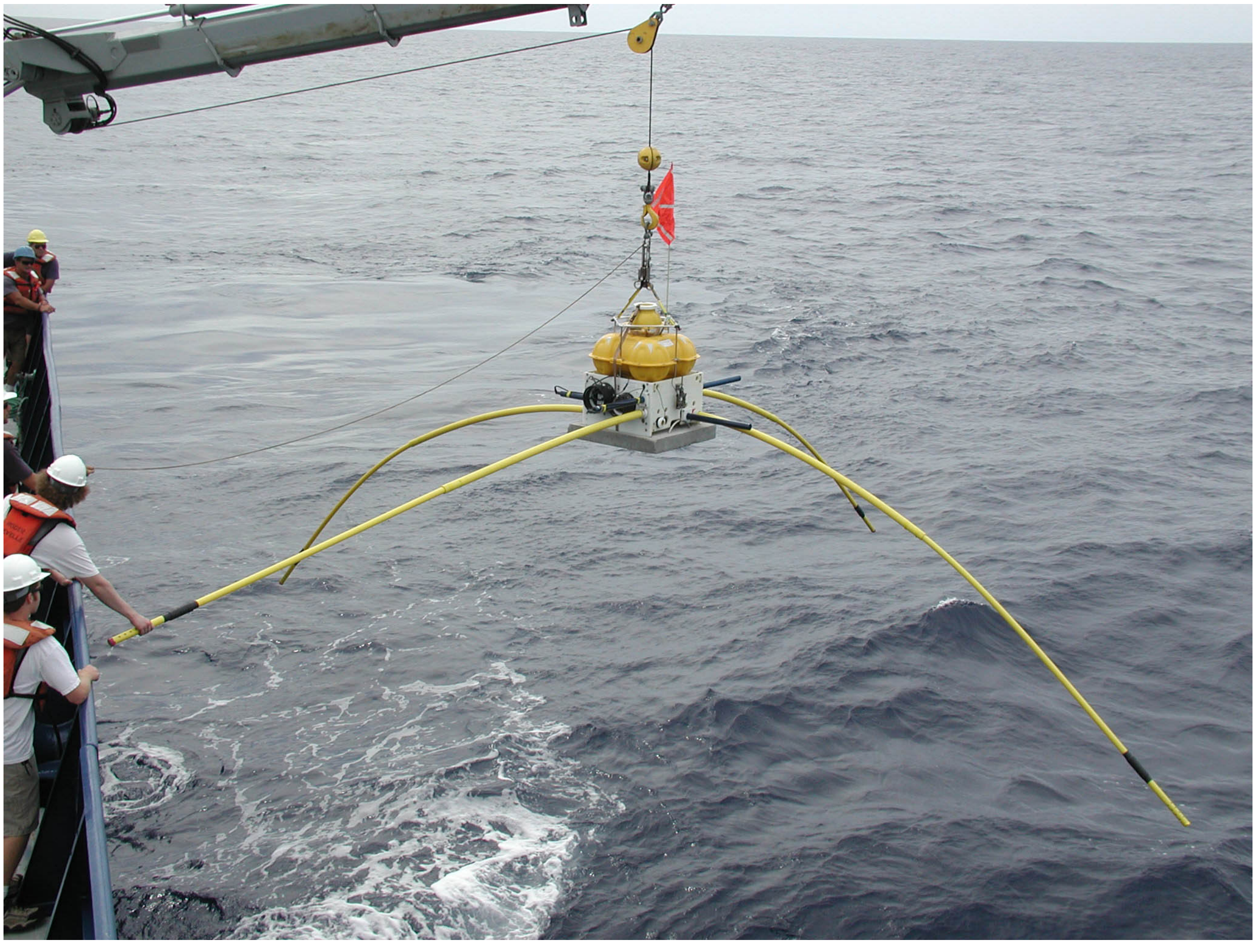


Figure 3. Seafloor EM receiver being deployed over the starboard side of the Revelle.

Bandwidth	10,000 s to 1,000 Hz
E sensors	AgCl electrodes
Voltage noise floor	10^{-18} V^2/Hz at 1 Hz
E-field noise floor on 10m antenna	10^{-10} V/m/$\sqrt{\text{Hz}}$ at 1 Hz
B sensors	Multi-turn, mu-metal core
B noise floor	10^{-8} nT^2/Hz at 1 Hz
Weight of assembly in air	125 kg
in water	-14 kg
Endurance on one set of Li batteries	2 months
Data capacity	1 Gbyte (Mk III), 20 Gbyte (Mk II)
Depth rating	6,000 m
Acoustic navigation/release	SIO custom (SIO) or EG&G (Industry)
Long term loss rate	<1% per deployment
Deployments to date	>1,000

The fleet of forty instruments we used was remarkably uniform in construction, with no differences of significance in performance. Minor differences of configuration that will become important during data processing are:

a) Sample rates of both 32.25 and 62.5 Hz were used..

b) The Mk II and Mk III instruments have slightly different least count values on the ADC.

c) There were two lengths of magnetometer coils used, which differ by a simple gain factor.

d) There were two types of E-field amplifier used, which differ in long period response.

These variations will be fully documented during data distribution.

The performance of the instruments was, overall, excellent. One instrument (Goanna, site S31) failed to respond during recovery, and probably either released prematurely or was destroyed by a glass ball implosion. One instrument (Bunyip, site N16) leaked water but luckily still managed to return to the surface. We kept this instrument in service by replacing the data logger with a spare unit. One instrument failed to start recording on the second deployment (Camel, site S70). A couple of other instruments had single unusable channels of data. However, this leaves 69 MT data sets for 72 deployments with the loss of only one instrument, which is, as stated, excellent. We note that the proposal was to collect only 60 sites of MT data.

Data quality was as good as one can expect in this environment. Virtually all instruments exhibited some noise associated with motion of the magnetometers on the rocky seafloor, but virtually all of these had periods when data were clean enough to process. Similarly, most instruments occasionally suffered from spikes followed by exponential decay ('shark fins') in the electric field data, for reasons that are still not understood. Raw magnetic field records are not particularly impressive to look at, as the magnetic field is very weak in deep water over resistive seafloor, but there was abundant magnetic field activity (minor storms) and decimated data can be quite clean (Figure 4).

Scripps Undersea Electromagnetic Source Instrument

During the past two years at SIO we have been working on building SUESI, a second-generation EM transmitter, again under petroleum industry sponsorship. One complicating factor with this cruise is that our industry colleagues requested use of the instrument we constructed in 2003 (#1) for use in Atlantic Ocean operations. They did provide funding to build a second unit (#2), but construction only started in December 2003. By the time we had to ship the instrument for this cruise, there were still several days work left to do. We went along with this situation because there was a reasonable expectation that the second instrument would be built on time, and our proposal was to collect MT data, with the collection of CSEM data mentioned only as a possibility if the transmitter unit was available in time.

Specifications for SUESI are as follows:

Dipole moment at full power	50,000 Am (Mk II), 10,000 Am (Mk I)
Square wave zero- peak current	200 A (Mk II)
Tow cable	Standard 0.680” (17 mm) UNOLS copper coaxial
Tow cable voltage	2000 V RMS/400 Hz
Input power supply	30 kVA, 208 - 480 VAC, 3-phase
Telemetry	9600 baud bidirectional on copper
Noise floor of system with SIO recorder	10^{-15} V/m per Am
Output frequency	DC to 100 Hz, GPS stabilized
Depth rating:	6,000 m
Top-side interface	Serial port / Labview GUI

It turned out to be quite a struggle to build an entire deeptow EM transmitter in two months (which shouldn't come as a surprise), and we spent the first two weeks of the cruise finishing building and debugging the system (during which MT operations were carried out). We managed to produce an operating system in time to collect an extensive pilot data set over the $9^\circ 30'$ area (unfortunately, by the time we had a working system running, the seafloor instruments had been recovered from the $9^\circ 50'$ ISS area, although Alvin operations

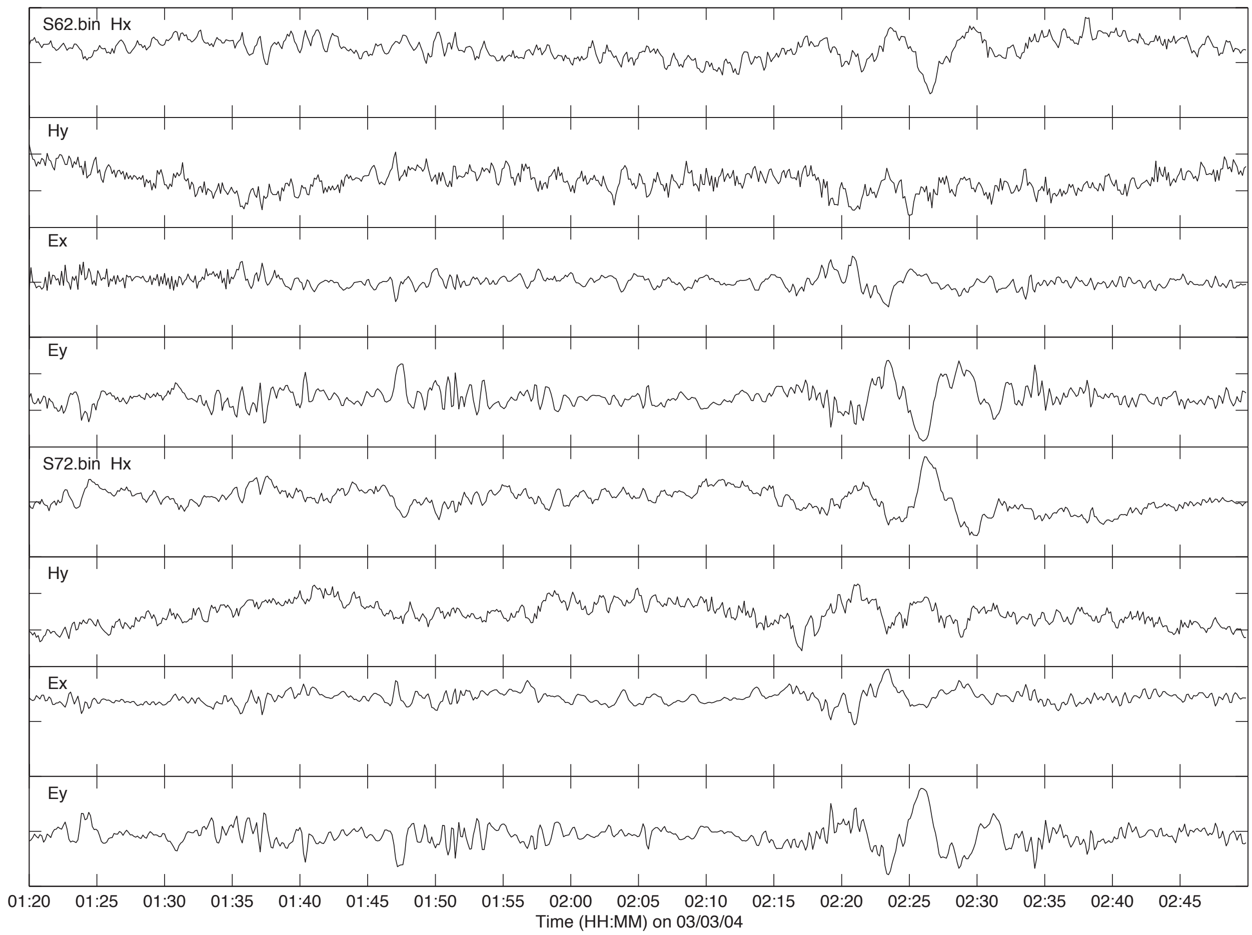


Figure 4. Example of MT data collected on two instruments, deployed at sites S62 and S72, decimated to 0.125 Hz.

in this area would in fact have made scheduling a tow difficult). Some compromises had to be made in order to accomplish these goals, the most significant of which was lack of depth measurements from our Parocscientific pressure gauge. We collected data from the following tows:

#	Description	Start		Stop		Time	10^3 Am
1	W–E at 9°50′	055:04:19	9°29.47 104°22.27	055:07:50	9°29.96 104°18.70	3.52 h	20.2
2	W–E at 9°50′	058:01:10	9°29.49 104°21.96	058:02:51	9°29.64 104°20.86	1.68 h	22.0
3	W–E at 9°50′	059:16:25	9°29.89 104°19.14	060:06:08	9°32.21 104°02.44	13.72 h	22.2
4	S–N ridge	060:16:26	9°23.51 104°13.50	061:05:40	9°39.25 104°15.69	12.23	15.0
5	W–E 3D grid	061:12:41	9°31.92 104°24.54	061:23:46	9°33.63 104°11.79	11.08	15.6

The start and stop positions of the tows are for the ship, not the deeptow, which is approximately 2 km behind the vessel. The start and stop times are times when the transmitter was running and within 120 m of the seafloor (i.e. times during which we collected data on the receivers), and not the full times of the deeptow operations. The last column is the output current times the antenna length (200 m for tows 1–3, 90 m for tows 4 and 5). To obtain dipole moments at the fundamental frequency of 2 Hz, multiply this number by 1.273. Because this was the first use of this new instrument, we operated at less than full power in order to maximize instrument reliability and data collection. This proved to be a wise move, since after the experiment we discovered that our topside transformer was overheating because of insufficient air flow, and would have expired early in the cruise had we had operated at full load.

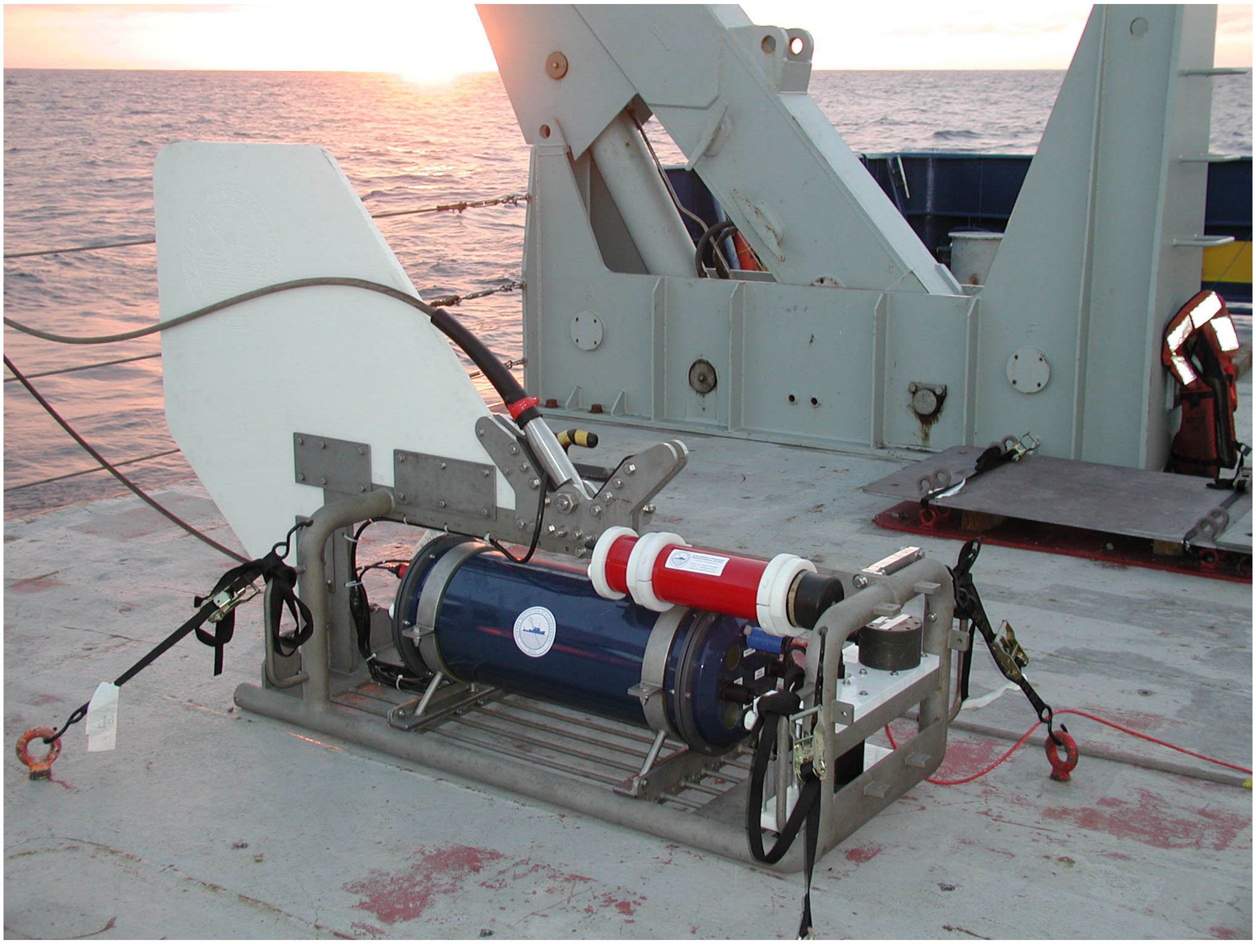


Figure 5. Scripps Undersea Electromagnetic Source Instrument, on deck ready for deployment.

We used some of the time spent debugging the transmitter system to move instruments which had already collected 9 days of MT data on the far edges of the wide aperture line to a small 3D grid over the ridge, thereby ensuring that the maximum number of instruments (about 30) were in range of the transmitter during tows 3 to 5. We operated the transmitter for about 3 days to provide 44 hours of transmission near the seafloor, and all together collected about 1,300 receiver–hours of CSEM data. In spite of operating the transmitter at reduced functionality, data quality is excellent (Figure 6). The is largely a result of the good amplitude and phase control of the transmitter system, obtained by stabilizing the 400 Hz power using a GPS time standard.

If the equipment was fully operational at the beginning of the cruise, we could have collected about 2 more days of data. However, given that the only comparable CSEM experiment collected 318 receiver–hours of much poorer quality data (1995 in the Lau Basin), this pilot experiment represents a significant step forward in the state of the art for mid-ocean ridge CSEM work.

A Personal Note

This is an experiment that one of us (SC) has been trying to carry out for at least a decade. The wait has been worthwhile. We have accomplished what is probably the largest marine EM survey carried out to date. At least three industrial marine MT operations have collected of order 100 MT sites, although distributed over two or more prospects. The use of CSEM to characterize petroleum drilling targets has resulted in numerous

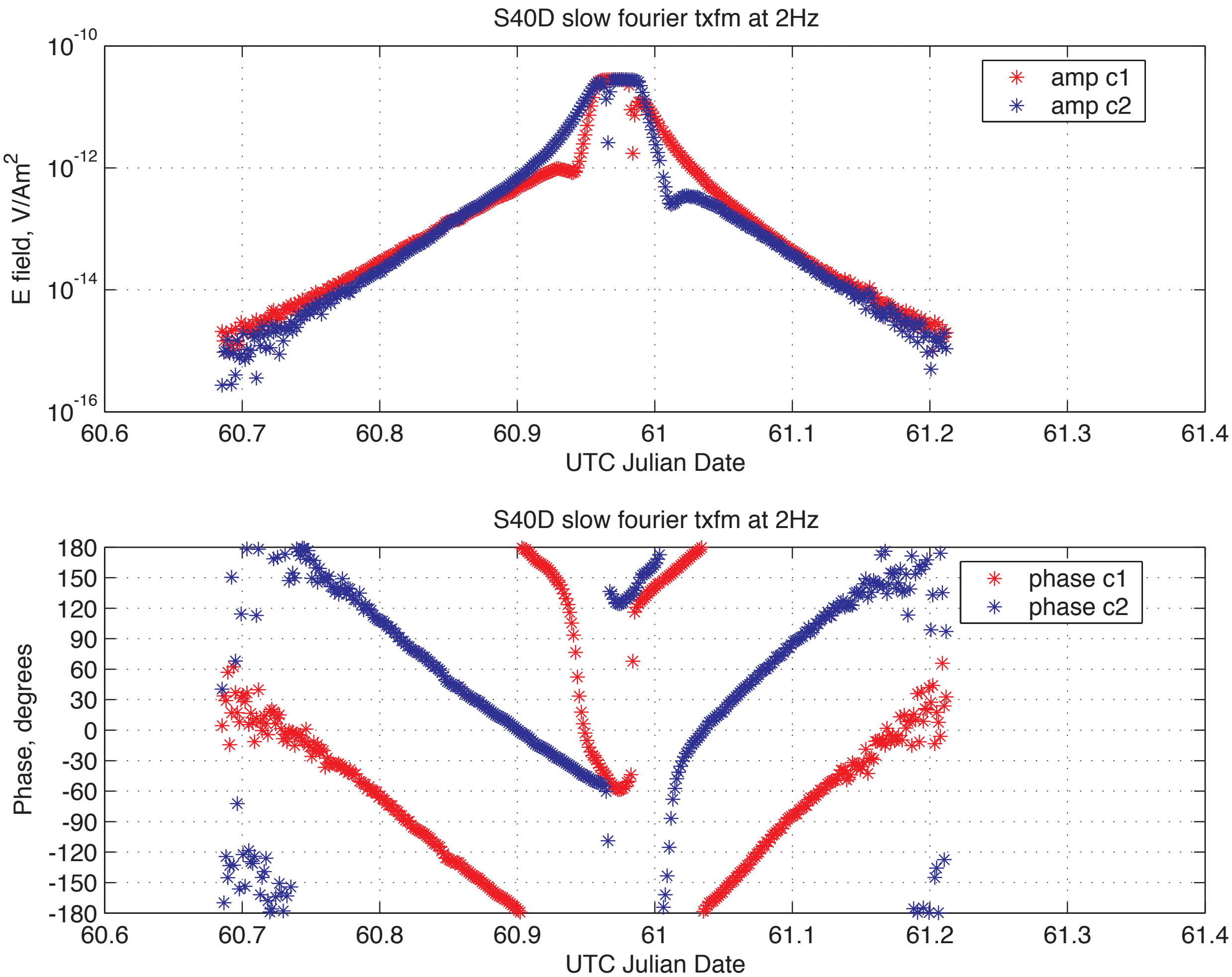


Figure 6. Controlled source transmission from the entire tow 4 into Bandicoot, site S40. Note the excellent stability in amplitude and phase, and noise floor of 10^{-15} V/m/Am. The time axis of 0.5 days corresponds to about 30 km.

CSEM data sets that are at least as large as the one we have collected. (All these have used SIO equipment or SIO clones.) However, the extent of the combined MT and CSEM data collected here is probably unique. Most importantly, in terms of deepwater *academic* projects, this is not only the largest experiment of this type, but it is so by almost an order of magnitude.

Thanks to the industrial sponsors that have supported marine EM at Scripps, we have developed and built a fleet of instruments that has no peer within the academic community. Thanks to the students and technicians who have worked with me over the years, and came on this cruise, our daily productivity was huge; it has become routine to deploy, and even recover, instruments at a rate of up to one per hour. It has become expected that instruments return and collect good data– anything else is an anomaly.

And thanks to Jacques, for we truly could not have done this without him.

I feel immensely grateful to have been able to carry out this work. Almost certainly, the science that will come out of this enormous data set will be spectacular. Thank you everyone.

S.C.

Appendix

Cruise Personnel

Steve Constable	Scripps Inst. Oceanography	Chief Scientist
Kerry Key	Scripps Inst. Oceanography	Co-Chief Scientist
James Behrens	Scripps Inst. Oceanography	Student
Chester Weiss	Sandia National Laboratories	Scientist
Graham Heinson	Adelaide University, Australia	Scientist
Lucrezia Terzi	Milan Univ., Italy	Student
Joshua King	Texas A&M	Student
Goren Boran	Flinders Unviersity, Australia	Student
Chris Armerding	Scripps Inst. Oceanography	Technician
Patricia Cheng	Scripps Inst. Oceanography	Technician
Garth Engelhorn	Scripps Inst. Oceanography	Technician
Anthony Massarweh	Scripps Inst. Oceanography	Adventurer
Geof Howe	AOA Geomarine Operations	Engineer
Kelly Callaway	AOA Geomarine Operations	Engineer
Cambria Colt	Scripps Inst. Oceanography	Res Tech

Shift List

12pm-12am	12 am -12 pm	SUESI Team
Key	Behrens	Constable
Heinson	Engelhorn	Howe
Weiss	Terzi	Calllaway
King	Boren	
Cheng	Massarweh	
Armerding		

Daily Log

2nd Feb.	Revelle arrives in port Puerto Caldera.
3rd	Loading.
4th	Loading.
5th	Loading.
6th	Loading and instrument prep.
7th	Loading and instrument prep.
8th	Last personnel arrive.
9th	Underway on schedule at 16:00.
10th	Transit to station.
11th	Transit to station.
12th	Transit to station.
13th	14:00 arrive on station. Start deployments at $9^\circ 50'$.
14th	Deployments at $9^\circ 50'$. Transit to $9^\circ 30'$.
15th	Deployments at $9^\circ 30'$.
16th	Deployments at $9^\circ 30'$.
17th	Acoustic nav., transmitter prep. and mag. tow.
18th	Transmitter prep. and mag. tow.
19 th	Transmitter prep. and mag. tow.

20th	Recover 10 instruments at 9°50′ and transit to 9°30′.
21st	Deploy 10 instruments at 9°30′ and transit to 9°50′.
22nd	Recover 10 instruments at 9°50′ and transit to 9°30′.
22th	Deploy 10 instruments at 9°30′.
23th	Deploy instruments. Transmitter Tow 1.
24th	Recover instruments.
25th	Recover instruments.
26th	Recover instruments. Start redeployment.
27th	Deploy instruments. Transmitter Tow 2.
28th	Transmitter Tow 3.
29th	Transmitter Tow 4.
1st March	Transmitter Tow 5.
2nd	Start final instrument recovery.
3rd	Recover instruments.
4th	Recover instruments.
5th	Attempt Goanna recovery; leave station 08:00.
6th	Transit to Mazatlan.
7th	Transit to Mazatlan.
8th	Arrive Mazatlan. No offloading.

Instrument positions

		Position			Wake up (UTC)		Release (UTC)	
Instrument	Site	Latitude	Longitude	Depth	Date	Time	Date	Time
Magpie	N01	9°48.887	104°25.435	2940	02/14/04	20:00:00	02/20/04	6:38:00
Joey	N02	9°49.185	104°23.299	2955	02/14/04	20:00:00	02/20/04	10:15:00
Possum	N03	9°49.344	104°21.762	2831	02/14/04	20:00:00	02/22/04	3:26:54
Wombat	N04	9°49.557	104°20.627	2816	02/14/04	20:00:00	02/20/04	14:01:00
Croc	N05	9°49.6091	104°20.1341	2793	02/14/04	20:00:00	02/22/04	6:23:00
Bandicoot	N06	9°49.705	104°19.558	2741	02/14/04	14:00:00	02/20/04	15:11:00
Wallaby	N07	9°49.779	104°19.026	2606	02/14/04	14:00:00	02/22/04	7:48:00
Quindal	N08	9°49.851	104°18.489	2613	02/14/04	14:00:00	02/20/04	16:59:00
Tazz	N09	9°49.925	104°17.959	2550	02/14/04	14:00:00	02/22/04	9:26:10
Lerp	N10	9°49.982	104°17.553	2528	02/14/04	14:00:00	02/20/04	18:16:00
Roo	N11	9°50.019	104°17.287	2520	02/14/04	8:00:00	02/22/04	10:33:00
Fruitbat	N12	9°50.0830	104°16.8881	2535	02/14/04	8:00:00	02/20/04	19:45:00
Kookaburra	N13	9°50.1579	104°16.3541	2565	02/14/04	8:00:00	02/22/04	12:27:00
Wobbygong	N14	9°50.2529	104°15.8318	2580	02/14/04	8:00:00	02/20/04	21:15:00
Mantis	N15	9°50.3058	104°15.290	2692	02/14/04	8:00:00	02/22/04	13:55:00
Bunyip	N16	9°50.371	104°14.748	2688	02/14/04	8:00:00	02/20/04	22:33:00
Bogong	N17	9°50.4431	104°14.2126	2730	02/14/04	2:00:00	02/22/04	15:48:00
Emu	N18	9°50.5908	104°13.1440	2790	02/14/04	2:00:00	02/21/04	1:54:00
Dugite	N19	9°50.8135	104°11.5410	2797	02/14/04	2:00:00	02/22/04	17:37:00
Spitfire	N20	9°51.1095	104°09.4032	2885	02/14/04	2:00:00	02/22/04	19:29:00
Corella	S21	9°22.6026	105°07.9470	3232	02/15/04	9:00:00	02/22/04	15:23:00
Magpie	S22	9°24.072	104°57.255	2933	02/21/04	19:00:00	03/05/04	1:59:00
Cassowary	S23	9°24.814	104°51.910	3000	02/15/04	9:00:00	02/24/04	20:17:00
Joey	S24	9°25.559	104°46.567	3041	02/21/04	19:00:00	03/04/04	21:40:00
Camel	S25	9°26.230	104°41.220	3030	02/15/04	9:00:00	02/24/04	23:56:00
Wombat	S26	9°26.892	104°36.951	3003	02/21/04	19:00:00	03/04/04	20:48:00
Devil	S27	9°27.607	104°33.206	2347	02/15/04	19:00:00	02/25/04	4:10:00

Wobbygong	S28	9°27.858	104°29.992	2920	02/21/04	19:00:00	03/04/04	16:50:00
Rabbit	S29	9°28.221	104°27.327	3018	02/15/04	13:00:00	02/25/04	8:13:00
Emu	S30	9°28.589	104°24.656	2947	02/21/04	19:00:00	03/04/04	16:10:00
Goanna	S31	9°28.888	104°22.520	2925	02/15/04	19:00:00	03/05/04	n/a
Cocky	S32	9°29.185	104°20.379	2843	02/22/04	7:00:00	03/03/04	18:16:00
Stingray	S33	9°29.408	104°18.787	2730	02/16/04	5:00:00	03/03/04	16:33:00
Lerp	S34	9°29.557	104°17.709	2779	02/22/04	7:00:00	03/03/04	14:52:00
Quokka	S35	9°29.629	104°17.172	2711	02/16/04	5:00:00	03/03/04	14:29:00
Fruitbat	S36	9°29.704	104°16.640	2677	02/22/04	7:00:00	03/03/04	13:57:00
Taipan	S37	9°29.780	104°16.100	2656	02/16/04	5:00:00	03/03/04	12:57:00
Quindal	S38	9°29.874	104°15.582	2602	02/22/04	7:00:00	03/03/04	11:57:00
Galah	S39	9°29.933	104°15.026	2583	02/16/04	5:00:00	02/25/04	6:23:00
Bandicoot	S40	9°29.974	104°14.640	2580	02/22/04	7:00:00	03/03/04	10:42:00
Rosella	S41	9°30.017	104°14.376	2569	02/16/04	5:00:00	02/25/04	14:15:00
Tazz	S42	9°30.0759	104°13.9658	2422	02/23/04	22:00:00	03/03/04	9:56:00
Glider	S43	9°30.141	104°13.433	2661	02/16/04	5:00:00	03/03/04	9:21:00
Croc	S44	9°30.222	104°12.897	2680	02/23/04	22:00:00	03/03/04	0:58:00
Lorrie	S45	9°30.2970	104°12.3631	2704	02/16/04	5:00:00	03/04/04	7:05:00
Roo	S46	9°30.379	104°11.837	2670	02/23/04	22:00:00	03/03/04	5:57:00
Bullant	S47	9°30.444	104°11.294	2762	02/16/04	5:00:00	03/03/04	3:58:00
Spitfire	S48	9°30.594	104°10.238	2831	02/23/04	22:00:00	03/03/04	2:20:00
Shark	S49	9°30.815	104°8.622	2873	02/16/04	5:00:00	03/03/04	1:46:00
Wallaby	S50	9°31.111	104°06.483	2981	02/23/04	22:00:00	03/02/04	22:00:00
Platypus	S51	9°31.408	104°04.348	2973	02/16/04	17:00:00	02/25/04	17:47:00
Bogong	S52	9°31.784	104°01.674	3015	02/23/04	22:00:00	03/02/04	21:09:00
Occie	S53	9°32.149	103°59.002	2943	02/16/04	17:00:00	02/25/04	19:16:00
Mantis	S54	9°32.594	103°55.807	3045	02/23/04	12:00:00	03/02/04	16:51:00
Dingo	S55	9°33.122	103°52.058	3075	02/16/04	17:00:00	02/25/04	23:28:00
Kookaburra	S56	9°33.698	103°47.776	3093	02/23/04	12:00:00	03/02/04	15:25:00
Skink	S57	9°34.444	103°42.435	3153	02/16/04	17:00:00	02/26/04	3:38:00
Dugite	S58	9°35.2061	103°37.1052	3104	02/23/04	12:00:00	03/02/04	10:57:00
Echidna	S59	9°35.923	103°31.746	3154	02/16/04	17:00:00	02/26/04	8:22:00
Possum	S60	9°37.413	103°21.065	3210	02/23/04	12:00:00	03/02/04	6:29:00
Dingo	S61	9°35.643	104°20.220	2865	02/27/04	7:00:00	03/03/04	22:15:00
Skink	S62	9°36.102	104°17.005	2685	02/27/04	7:00:00	03/03/04	23:44:00
Echidna	S63	9°36.5453	104°13.7981	2643	02/27/04	1:00:00	03/04/04	8:06:00
Occie	S64	9°36.987	104°10.589	2871	02/27/04	1:00:00	03/04/04	9:47:00
Platypus	S65	9°33.548	104°19.908	2760	02/27/04	7:00:00	03/03/04	20:10:00
Rosella	S66	9°33.993	104°16.704	2655	02/27/04	1:00:00	03/04/04	0:20:00
Galah	S67	9°34.437	104°13.502	2658	02/27/04	1:00:00	03/04/04	4:40:00
Rabbit	S68	9°34.876	104°10.286	2907	02/27/04	1:00:00	03/04/04	9:24:00
Cassowary	S69	9°31.442	104°19.610	2850	02/27/04	7:00:00	03/03/04	18:49:00
Camel	S70	9°31.886	104°16.405	2655	02/27/94	1:00:00	03/04/04	3:33:00
Devil	S71	9°31.330	104°13.198	2655	02/27/04	1:00:00	03/04/04	4:05:00
Corella	S72	9°32.775	104°09.990	2835	02/27/04	1:00:00	03/04/04	11:42:00