CRUISE REPORT

RRS JAMES CLARK ROSS 42

A Seismic Tomographic and Hydroacoustic Study of Ascension Island

2nd-18th May 1999

Montevideo-Ascension

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SUMMARY

The structure of the Earth's crust at oceanic volcanic islands is of interest for the information it provides both about the processes involved in the formation of these islands and about the rheology of the underlying oceanic lithosphere, which deforms in response to the island load. Since some of the acoustic energy from large underwater explosions is commonly coupled into the oceanic sound channel as so-called "T-phases", hydrophones around several such islands and broad-band seismic stations on the islands are being used for monitoring of the Comprehensive Test Ban Treaty. Cruise JR42 involved a four-day seismic experiment around the island of Ascension, a 4-km-high volcano some 90 km west of the Mid-Atlantic Ridge. During the experiment, a 6186 cu. in. airgun array was fired at one-minute intervals for about two days along a series of lines extending up to 45 km from the coast of the island. These shots were received by hydrophones and sonobuoys offshore and seismometers onshore.   The shots were used to locate and calibrate three permanently installed hydrophones, to study the coupling of seismic energy into the island slope, and to study the structure of the crust beneath the island. The experiment was funded by the US Department of Energy (through Lawrence Livermore National Laboratory (LLNL)), the US Office of Naval Research, the UK Natural Environment Research Council, the United Nations (through the Comprehensive Test Ban Treaty Office in Vienna), IFREMER's Centre de Brest, and funds held at the University of Southampton by T. A. Minshull. On the passage from Montevideo to Ascension Island, an unrelated scientific party conducted oceanographic measurements as part of the "Atlantic Meridional Transect".

SCIENTIFIC PARTY (seismic experiment)

Tim Minshull	SOC
Tim Owen	Cambridge
Mike Tuffin	SOC
Frauke Klingelhoefer	IFREMER, Brest
Donna Blackman (14th-18th May)	Scripps
Crispin Hollinshead (14th-18th May)	Scripps
Vicki Childers (14th-18th May)	NRL, Washington DC
Tony Cumming	RVS
Richard Phipps	RVS
Andy Tate	BAS
Neil Audley	BAS
Pat Cooper	BAS
Jeremy Robst	BAS

CREW

Jerry Burgan	Master
Graham Chapman	Chief Officer
Robin Kilroy	2nd Officer
Justin McCarthy	3rd Officer
John Summers	Deck Officer
Stephen Mee	Radio Officer
Duncan Anderson	Chief Engineer
Colin Smith	2nd Engineer
Rags MacAskill	3rd Engineer
Maurice Arber	4th Engineer
Douglas Trevett	Deck Engineer
Keith Rowe	Electrician
Kenneth Olley	Catering Officer
Colin Lang	Bosun
David Peck	Bosun's Mate
Martin Bowen	SG1
Chris Littlehales	SG1
David Taylor	SG1
George Dale	SG1
Luke Trussler	SG1
Richard Parsley	MG1
Erwin Allan	MG1
Daniel McManamy	Chief Cook
Tracey MacAskill	2nd Cook
Robert Heeney	2nd Steward
Derek Lee	Steward
Lee Jones	Steward
Michael Weirs	Steward
Sarah Taylor	Doctor

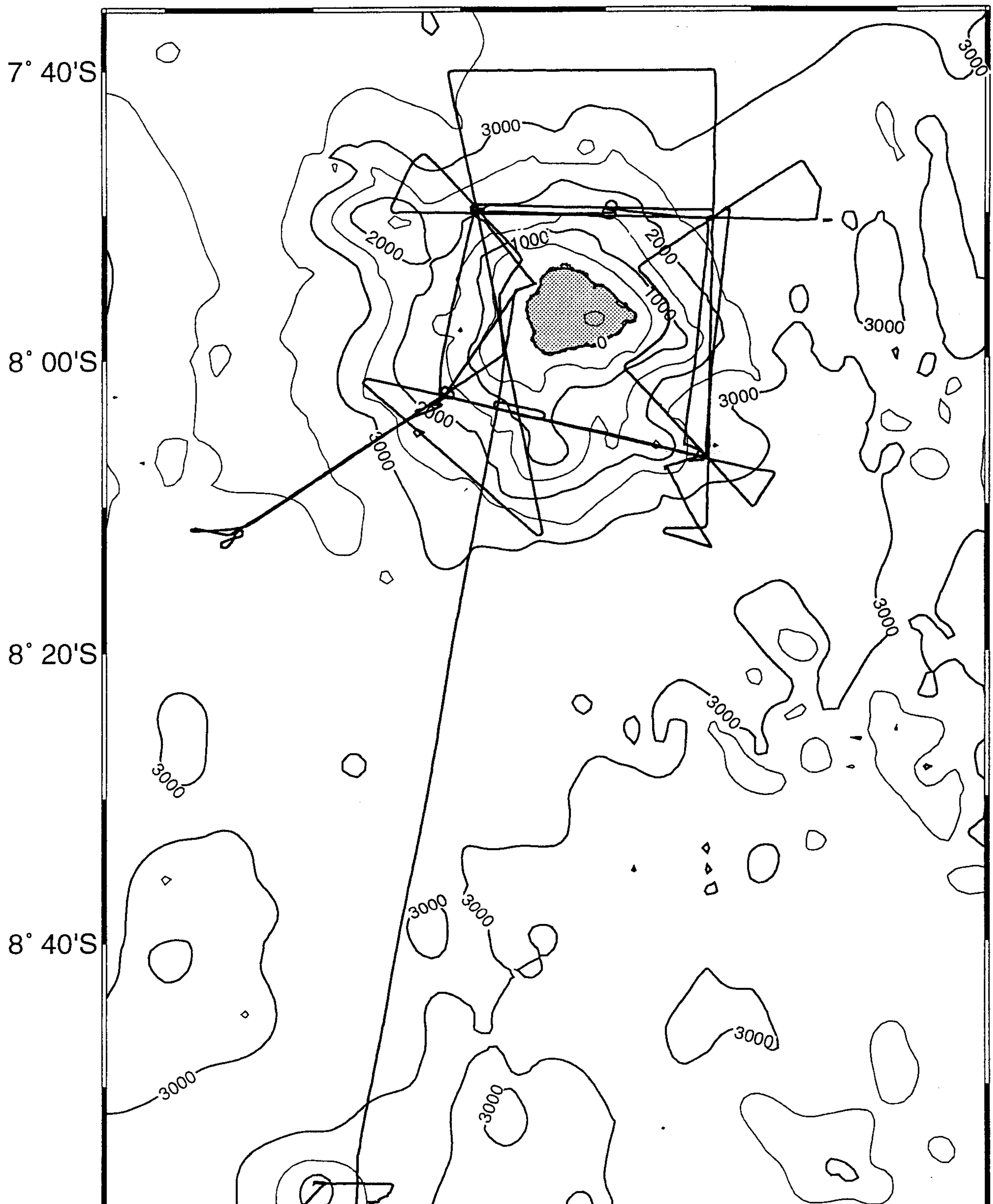
SHIP AND RVS/BAS EQUIPMENT PERFORMANCE

The ship and equipment supplied by RVS and BAS performed well throughout, and excellent and dedicated support was supplied by the RVS and BAS technicians. There was no downtime or loss of signal amplitude at all during the seismic experiment due to airgun, compressor or airgun control system failure, and the SAQ digital acquisition system never crashed. The following problems were noted:

1. The lack of functioning EM or Doppler log meant that the officer of the watch had no measure of speed through the water available, which caused some delays when coming onto station to deploy overside transducers, etc. Since the RVS software for producing MGD77 final navigation/underway data files and track plots depends on an input from one of these logs, standard track plots were also not available. The inability to replace these systems without going into dry dock appears to be a severe limitation.

2. The Simrad EM500 echosounder gave a poor paper record and no digital record when steaming on certain headings due to aeriation beneath the hull. Bathymetric data are of fundamental importance for geophysical work and such data loss is a serious problem; the location of transducers for the proposed swath bathymetric system will need careful consideration.

3. Disposable sonobuoys can provide very useful data to long ranges on *RRS James Clark Ross* due to the availability of a particularly high site for installation of VHF aerials. However, setting up and running the sonobuoy data acquisition system remains a time-consuming and delicate task, since the limited dynamic range of the SAQ means that input signal levels must be adjusted rather precisely for good results. A more consistent data quality could be obtained if VHF aerials with low-loss cabling were permanently installed, if the aged analogue amplifiers and filters available were replaced by more modern systems, and if the whole system was available as an integrated package.



Ship's track for entire experiment, overlain on bathymetry

CRUISE NARRATIVE

Sunday 2nd May (JD 122)

The ship departed Montevideo on time at 1600 local time (1900 GMT). Prior to departure, three aerials were installed on the main mast to act as sonobuoy receivers.

Monday 3rd May-Wednesday 12th May (JD 123-132)

Passage continued toward Ascension Island, with short daily stops for oceanographic work. Low-loss cables were run to the three mast aerials. The Reftek airgun triggering system and shot time logger were set up and tested in the UIC lab, along with the three radio receivers, two analogue bandpass filters, the SAQ data acquisition system, and a signal generator and oscilloscope for test purposes. The 11-airgun array was also serviced and prepared, the Cambridge GPS clock was set up and the clock drift on the two Cambridge Minidobs was monitored for several days.

Thursday 13th May (JD 133)

We arrived on station near the US MILS hydrophone ASC-26 at 1846. After a short flotation test of one Minidobs, which showed that it floated the right way up and with the flag and light visible, a single 1000 cu. in. airgun was deployed. A series of calibration shots commenced at 1934, and the first timed shot was at 1940:00 approximately 3 km west of ASC-26. A pair of 6 km orthogonal lines were shot through the nominal position of ASC-26, mainly at 5 knts; this survey was completed at 2147. We then accelerated to 6 knts and continued shooting on a track towards Ascension Island. Two sonobuoys were launched on this track to test the acquisition system.

Friday 14th May (JD 134)

Shooting was terminated at 0550 and the gun recovered on deck at 0616. At 0730 we arrived at the anchorage at Clarence Bay, and at 0830 Donna Blackman, Vicki Childers and Crispin Hollinshead boarded the ship from a launch. The ship got underway to the first OBH site at 0915. The two Minidobs had both been set to start recording at 0800, and both crashed when they tried to write to disk due to an incorrect battery voltage. A short bathymetric survey around the first proposed site revealed no severe slopes, and the ship arrived on site at 1032. At 1103 the first Minidobs (29) was finally ready for deployment and it was in the water at 1104. The descent was followed to around 1500 m depth, after which no reliable range readings could be obtained, partly because of the high noise level of the ship.

In transit to the second OBH site, a figure-of-eight calibration loop was conducted for the shipboard thee-component magnetometer. We arrived on site at 1354 and deployment of the first Scripps OBH (Maggie) began at 1356 with the anchor weight. 4800 ft of rope was then paid out, before releasing the OBH itself at 1437. Again the acoustics were disrupted by noise from the ship. At 1526, about 2 km to the northwest, the first glass sphere, a thin-walled sphere with no mechanism attached, was lowered into the water on the trawl warp over the stern A-frame. A total of 2200 m of wire was paid out with no implosion apparent, but later a possible implosion was reported when about 1700 m of wire was out. The sphere had indeed disappeared when the end of the wire came on deck at 1636.

The second Minidobs (27) was deployed at 1834 and successfully followed to the seabed with the Oceano transducer and deck unit; the transducer was this time located further forward and the ship's echosounder and some thrusters were switched off to minimise noise. Ranging was also attempted with the Marine Acoustics transducer and deck unit; this performed very poorly. We arrived at the fourth OBH position at 2111 and the anchor weight of Scripps OBH Lisa was in the water at 2127. 2400 ft of rope was paid out, and the OBH was released at 2146. The second glass sphere, a Benthos sphere with a mechanism to puncture it at about 750 m depth, was lowered from the stern A-frame into the water at 2223, about 2 km from OBH Lisa. The sphere was lowered to 1000 m and then recovered on deck at 2259; the mechanism had operated but the sphere, though holed, had not collapsed. We then steamed to the near the start of the first line for airgun deployment.

Saturday 15th May (JD 135)

Deployment of the full airgun array commenced at 0035. Deployment proceeded without incident except for an oil leak from the port Effer crane which occurred during deployment of the port beam and resulted in an oil spill on deck. By 0203, all eleven guns were in the water. Calibration shots (on the Reftek PC clock) began at 0230 with the ship at 4 knts, but two airgun hydrophones appeared not to be receiving any signal. The first timed shot with the full array was at 0300:00, and the first sonobuoy was deployed at 0321. At 0350:42, one of the 700 cu. in. guns was manually triggered to check that it was still firing. The gun hydrophone problem was eventually traced to some incorrect wiring from the lab to the port umbilical winch, and all hydrophones were working at 0424. Shooting with all guns continued through the day. At 1913 we passed over OBH site 2 and a single 1000 cu. in. gun was fired for five shots around this time, with the ship at 5 knts to calibrate the source used for the survey around ASC-26. At 2130 the third imploding sphere, with a redesigned bolt to penetrate it, was dropped from the port quarter, followed immediately by a sonobuoy. At 2140 the guns were switched off, and at 2147 a possible implosion was heard on the sonobuoy receiver, though the signal was weak. At 2156 the guns were switched on again.

Sunday 16th May (JD 136)

Airgun shooting continued. At 1112, near ASC-23, all guns except for a single 1000 cu. in. gun were switched off, and the ship's speed was increased to 5 knts, for a series of calibration shots as we passed ASC-23 and ASC-24. The full array was switched on again at 1145 once we had passed ASC-24, and we looped around to repeat these shots at 4 knts with the full airgun array so that there was no break in the line. Around 1432 we passed over OBH site 4 and again a single 1000 cu. in. gun was fired for five shots around this time, with a ship's speed of 5 knts, for further calibration. Shooting with the full array then continued for the rest of the day.

Monday 17th May (JD 137)

Airgun shooting continued. Around 1100 the ship suddenly slowed to 2.5 knts for a few minutes due to finger trouble in the engine room, and airgun depths increased by up to ~10 m. The BAS recoverable sonobuoy was launched at 1459 as we passed over OBH site 3. At 1600 the tomographic survey was completed; this was followed by a series of 8 shots at five-minute intervals with the full airgun array for T-phase calibration. Airgun recovery began at 1648 and was completed at 1807. We then steamed back to recover the BAS sonobuoy, which was on board at 1916.

After a short passage, communication was established with Minidobs 27 at 1956 and a release command was sent. The OBH rose to a slant range of 260 m at 2124 and the flashing light was spotted at the surface, but then it disappeared and the slant range began to increase again. We assumed that it was being carried away by surface currents, and there followed a series of manoevres aimed at locating the OBH and chasing it downstream. However, the slant range increased each time and eventually we realised that it had probably taken in some water and sunk back to the seabed again; the OBH was finally abandoned at 2316.

Tuesday 18th May (JD 138)

The Scripps OBH Maggie was released at 0050, spotted at the surface at 0123 and on board at 0145. The release command was sent to Minidobs 29 at 0318, it was spotted at the surface at 0415 and on board at 0427. Scripps OBH Lisa was released at 0541, spotted at the surface at 0612 and on board at 0626. A second shipboard magnetometer calibration figure-of-eight was conducted between 0639 and 0719, and the ship then headed directly for the Clarence Bay anchorage. The scientific party disembarked at 1030 after backing up data and packing up equipment through the night.

NAVIGATION

Scientific navigation was from Trimble and Ashtech GPS units located on the Bridge, with a continuous satellite link for differential corrections. Both systems were logged. The accuracy of the system is sufficiently high that the main positional uncertainty comes from variations in the relative location of, for example, the airguns relative to the GPS aerial as the ship pitches and rolls.

DATA LOGGING

Underway data were logged using the RVS Level A, B and C system, time tagged with times from the ships master clock, which was slightly (< 1 s) fast with respect to Universal Time. The ship's position was logged once per second.

ECHOSOUNDER

Bathymetry was logged from a Simrad 12 kHz echosounder run from the Bridge. All logged depths assumed a water velocity of 1500 m/s. Bathymetry was also recorded on a paper record on the Bridge. Some bathymetric data were lost when the Simrad was switched off to avoid interference with acoustic transponders during OBH deployments and not switched on again. The logged data show larger gaps; the logging system was not properly restarted when the Simrad was restarted. Further logged data was lost on day 317 when the Simrad signal was intermittent and the automatic picker failed. Fortunately, the paper record covers most logged data gaps and can be read with an accuracy of 10-20 m.

MAGNETOMETER

No towed magnetometer was used during the experiment, to allow tighter turns and avoid entanglement of sonobuoys, but the ship was equipped with the BAS shipboard three-component magnetometer, consisting of a Bartington Instruments

MAG-03 fluxgate magnetometer and a logging PC. Calibration loops for the magnetometer were conducted at the beginning and end of the seismic experiment.

TRIGGERING

The triggering system for the seismic data acquisition was as follows:

1) A free-running oscillator was started up at the previous shot instant.
2) This oscillator ran for 59.5 s, then passed an enabling pulse to the Reftek gun controller.
3) The Reftek and SAQ system were triggered on the next second mark (i.e. on the exact minute of UT).
4) The airguns were synchronised to fire 50 ms later.

A system had been set up to log the shot time via a Level A, but on the first (single gun) shooting run the shot number was interpreted as 9999 throughout. Therefore during the main survey, shot times (i.e., triggers) were logged instead on a separate PC against the PC clock, which was approximately 1 minute and 20 seconds fast throughout the survey. This record allows each shot to be indentified unambiguously with a particular minute.

AIRGUN ARRAY

The airgun array consisted of 11 guns with a total volume of 6186 cu. in., towed at a nominal depth of 20 m, with the centre of the array approximately 59 m from the stern and 116 m from the GPS aerial. At this depth the modelled peak-to-peak amplitude was 95 bar.m unfiltered and 32 bar.m when minimum phase Butterworth bandpass filtered with corner frequencies of 1, 3, 10 and 15 Hz. The modelled source signature had a strong bubble pulse, but this was not considered a problem since we were not attempting to record reflection data. The towing arrangement consisted of three 7 m beams with three guns each, and two single guns. The beams were supported from hippo buoys by 25 m lengths of rope, while the single airguns were just towed from the strength members of their umbilicals. The airguns on the beams settled at around 22 m depth, but at 4 knts the single guns were at around 10 m depth due to their shorter umbilicals. During the initial shooting run with a single 1000 cu. in. gun, at 5 knts the gun settled at 8 m depth, while at 6 knts it was at about 4 m depth. The single gun was also used for various calibration shots; details are given in Table 1; and the array geometry is shown in Fig. 1.

The ship was equipped with four Hamworthy compressors with a capacity of 327 cfm each, able to supply up to 4200 cu. in. of air at about 1950 psi per minute. With a shot interval of 60 s, the full array required only two compressors, but all four compressors were used in turn. The nominal shot interval for the main experiment was around 125 m for a ship's speed of 4 knots.

Table 1: Seismic sources

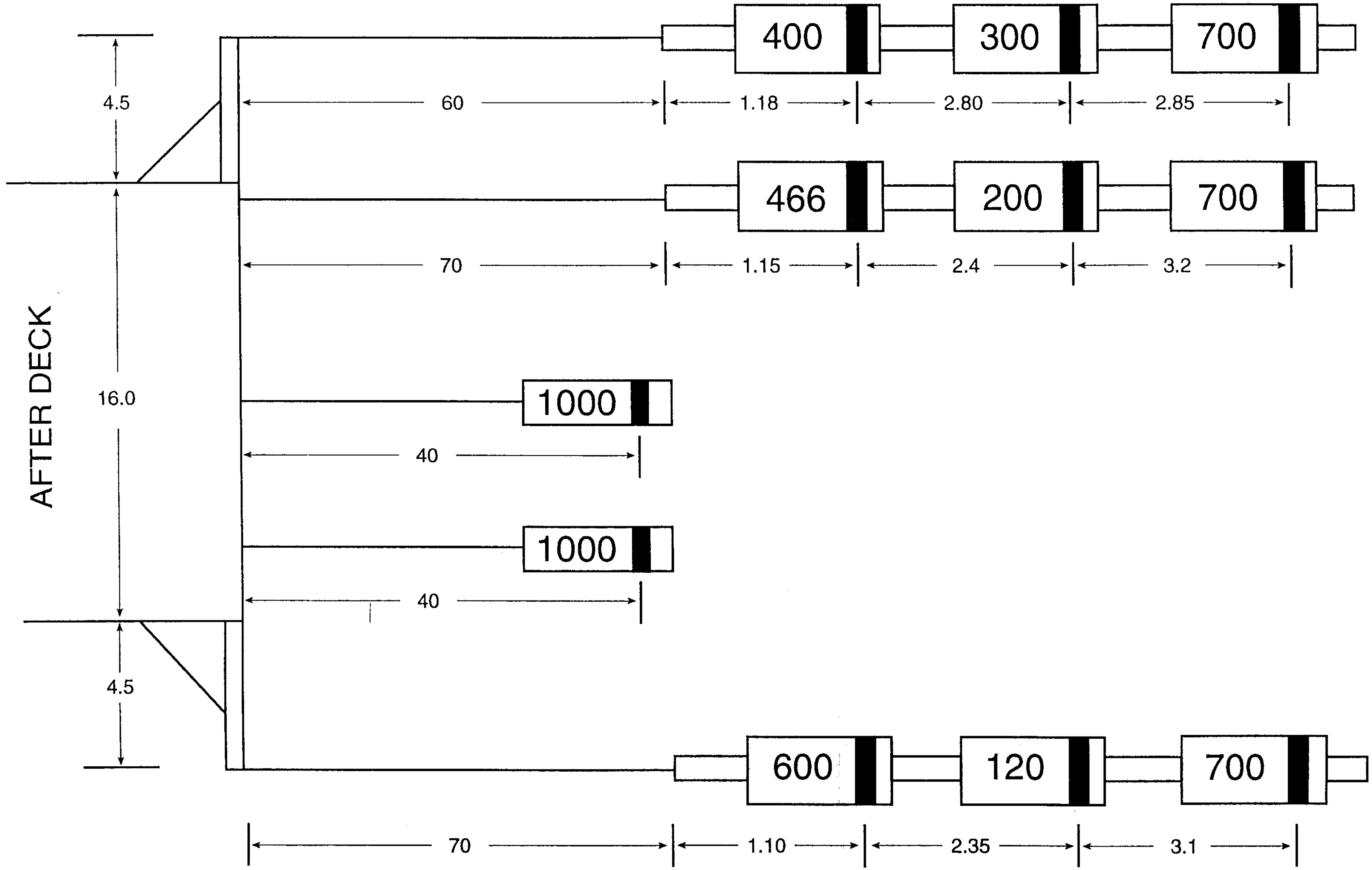
Time	Shot No.	Array volume (cu. in.)	Speed (knts)	Mean Gun Depth (m)	Mean Distance Astern (m)
1934/133-1939/133	0 (test)	1000	2-4	23-10	37
1940/133-2004/133	9001-9015	1000	4-5	Unknown	37

2005/133-2147/133	9016-9118	1000	5	5-7	37
2147/133-2152/133	9119-9124	1000	5-6	4-5	37
2153/133-0550/134	9125-9602	1000	6	4-5	37
0230/135-0259/135	0 (test)	Variable	4	18-20	59
0300/135-1907/135	1-968	6186	4	18-20	59
1908/135-1910/135	969-971	6186	4-5	Variable	59
1911/135-1915/135	972-976	1000	5	7	40
1916/135-1920/135	977-981	6186	5-4	Variable	59
1921/135-2140/135	982-1121	6186	4	18-20	59
2156/135-1106/136	1122-1912	6186	4	18-20	59
1107/136-1111/136	1913-1917	6186	4-5	Variable	59
1112/136-1145/136	1918-1951	1000	5	7	40
1146/136-1148/136	1952-1954	6186	5-4	Variable	59
1149/136-1419/136	1955-2105	6186	4	18-20	59
1420/136-1429/136	2106-2115	6186	4-5	Variable	59
1430/136-1434/136	2116-2120	1000	5	8	40
1435/136-1438/136	2121-2124	6186	5-4	Variable	59
1439/136-1059/137	2125-3345	6186	4	18-20	59
1100/137-1104/137	3346-3350	6186	2.5-4	>25	<59
1105/137-1600/137	3351-3646	6186	4	18-20	59
1605/137-1640/137	3647-3654	Source as above, but 5 minute shot interval			

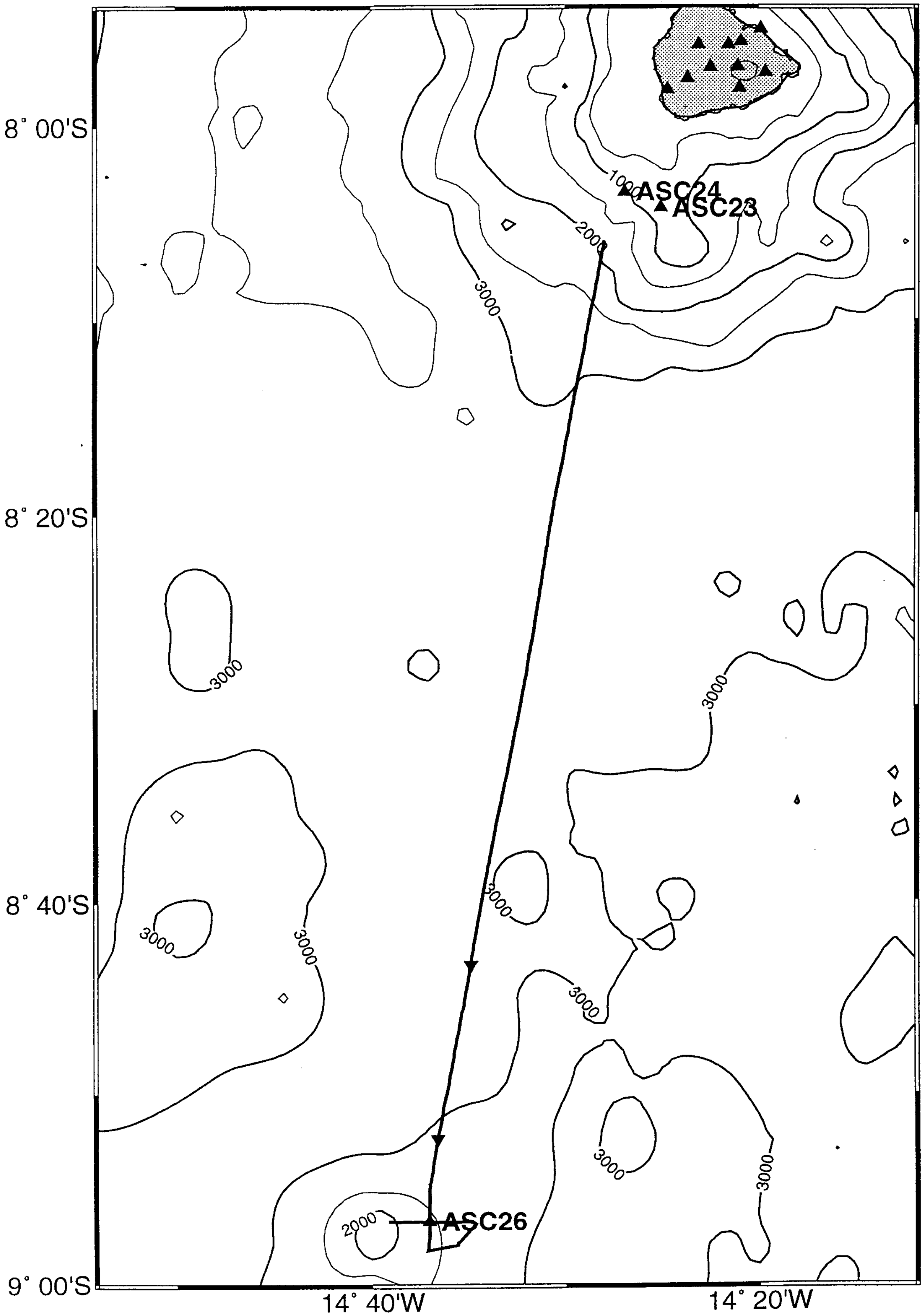
NB Mean source depth is approximate; individual gun and beam depths were logged and can be used if an accurate measure is required.

IMPLODING GLASS SPHERES

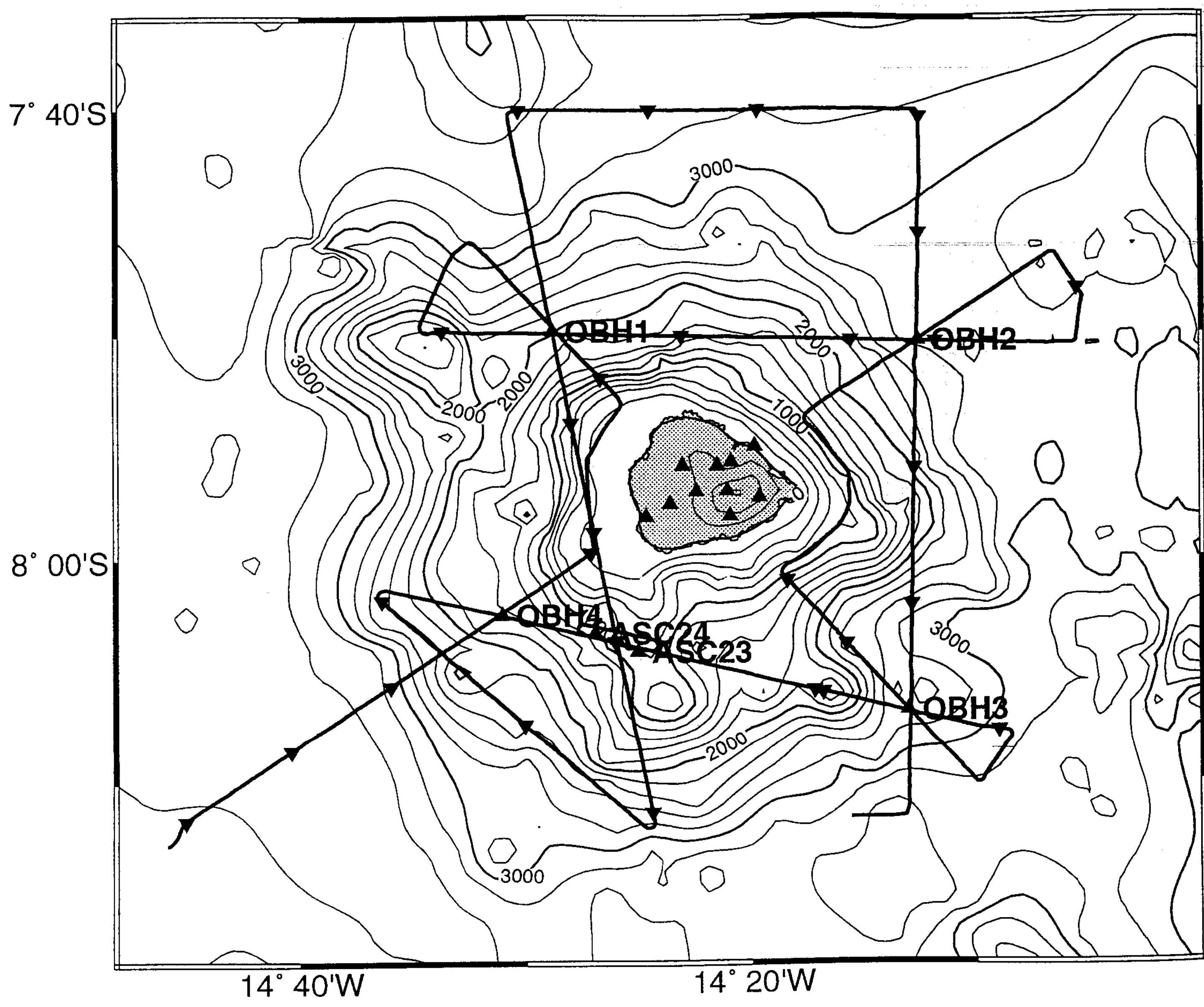
Three imploding glass sphere sources were fabricated for the cruise by LLNL (Table 2). These were designed to put acoustic energy directly into the centre of the sound channel at 700-800 m depth, since the use of explosives on the cruise was impossible due to logistical constraints. Two were ordinary Benthos glass spheres with a pressure-triggered mechanism designed to puncture the sphere at an ambient pressure of 75 atmospheres; the third was a thin-walled sphere which was expected to implode spontaneously at a similar depth. The thin-walled sphere appeared to be the most successful, but some data analysis is required before the usefulness of these sources can be assessed.



Schematic diagram of airgun array. Nominal towing depth was 20m, with single guns at 10m. Airgun chamber sizes are in cu in., distances in m.



Initial single gun shooting, overlain on bathymetry
Triangles mark MILS hydrophones and land stations
Inverted triangles mark sonobuoy locations



Main shooting track, overlain on bathymetry. Triangles mark hydrophones and land stations
Inverted triangles mark sonobuoy locations

Table 2: Imploding glass spheres

Sphere	Type	Time of implosion	Latitude S	Longitude W
1	Thin-walled	~1558/134	7°49.7’	14°11.7’
2	Benthos	~2240/134?	8°3.1’	14°32.0’
3	Benthos	~2147/135	7°46.9’	14°6.1’

OCEAN BOTTOM HYDROPHONES

Two “Minidobs” ocean bottom hydrophones (OBHs) from Cambridge and two “LCHEAPO” OBHs from Scripps were deployed on the cruise. The Cambridge instruments consisted of a single 17” glass sphere instrument housing with an external flashing light, a 10” strayline sphere, a burnt-wire acoustic release, and a 45 kg anchor weight. Hydrophone data were logged on a hard disk and the instrument clocks were checked against an external GPS standard before and after deployment. The Scripps instruments consisted of a 14.6 cm aluminium tube housing the data logger and a separate tube for the acoustic release (also with a burnt-wire mechanism), with a float frame consisting of three glass spheres, and a 35 kg anchor weight. The logger used a fixed gain postamplifier and a gain-ranging preamplifier. The logger, amplifier and sensor systems were powered by lithium oxyhalide cells. Timing was provided by a custom low-power oscillator with an accuracy of about one part in 10^8. Clocks were synchronised to the GPS standard prior to deployment, with an initial timing accurate to 1-10 μs, and checked against the GPS clock after recovery.

The Cambridge instruments were deployed with 2 m of rope between the anchor weight and the OBH, while the Scripps instruments were deployed on mooring lines above the seabed (4800 ft of rope for Maggie; 2400 ft for Lisa) to record the calibrated far-field source signature, which was particularly important for the hydroacoustic studies. OBH depths in Table 3 are estimated by subtracting the mooring line length from the water depth. Timing of both types of instruments was synchronised relative to Universal Time using GPS clocks. Data were also recorded at the US MILS (Missile Impact Location System) hydrophones ASC-23, ASC-24 and ASC-26, installed permanently on the seabed. The MILS hydropones are connected by seabed cable to Ascension Island and data is transmitted by satellite to the AFTAC monitoring centre in Arlington, Virginia.

Table 3: Ocean Bottom Hydrophones

Type	Name	Drop Time	Latitude S	Longitude W	Depth (m)
MILS	ASC-23	-	8º04.18’	14º25.05’	836
MILS	ASC-24	-	8º03.34’	14º26.94’	772
MILS	ASC-26	-	8º56.70’	14º37.01’	1662
Cambridge	27	1834:54/134	8º06.80	14º13.00’	3003
Cambridge	29	1104:02/134	7º49.84	14º28.88’	2008
Scripps	Maggie	1437:33/134	7º50.30’	14º12.60’	1382
Scripps	Lisa	2146:45/134	8º02.50’	14º31.10’	914

LAND STATIONS

Receivers on land were deployed by Phil Harben (LLNL), Don Rock (LLNL) and Tom Sandoval (Los Alamos), with assistance from Marta Galindo Arrantz (CTBT Office observer). Receivers consisted of Sprengnether three-component model S-6000 seismometers with a natural period of 2 Hz, and Reftek acquisition systems. One of the stations (ACH) had only horizontal components. Land station locations are listed in Table 4.

Table 4: Land Stations

Station	Latitude S	Longitude W	Altitude (m)
APP	7º58.157'	14º24.693'	18
ACH	7º57.586'	14º23.546'	230
APS	7º57.039'	14º22.464'	173
AVC	7º55.709'	14º20.908'	182
AAS	7º55.035'	14º19.874'	36
OBG	7º55.877'	14º23.087'	104
GMP	7º57.007'	14º21.081'	664
DAP	7º57.292'	14º19.643'	529
SEC	7º58.096'	14º20.970'	339
SBC	7º55.875'	14º21.547'	207

SONOBUOYS

Thirty-one Sparton Electronics AN/SSQ-57A sonobuoys were deployed on the cruise. Signals were received on two ICOM IC-R7000 and one IC-R8500 VHF receivers, using aft-facing aeriels installed on the main mast, 28 m above the sea surface, at the beginning of the cruise, and low loss cabling down to the UIC Lab. Signals were digitally recorded on the RVS SAQ four-channel acquisition system, recording in SEGY format on the hard disk, with one file per shot. The SAQ was set up to record 40 s records per shot at a 4 ms sample interval. The three channels were displayed on two Waverley recorders and the SAQ monitor. Two analogue bandpass filters were available and were set at 2-100 Hz (to give an effective passband of around 3-70 Hz) and used for SAQ channels 1 and 2; the output from the third receiver was fed directly into channel 3 of the SAQ, so had only the 125 Hz anti-alias filter applied. Sonobuoys were launched by hand from the quarters; generally on the port side, since there was only one airgun beam on the port side, but on the starboard side when the ship's heading was significantly to starboard of the course made good. One sonobuoy (#20) failed to function, one (#16) lost its hydrophone, and one (#28) had a weak signal perhaps due to a faulty transmitter. The remainder recorded water waves to at least 30 km range. Unfortunately, subsequent data display showed that signal levels were insufficient (or noise levels too high) to detect energy turning in the crust beyond 15-20 km range, but the information from shorter range will still provide very useful constraints on upper-mid crustal structure. The BAS internally recording sonobuoy was also deployed, mainly for test purposes. Deployments are summarised in Table 5.