EW0112 Cruise Report

Victoria, Mahe, Seychelles to Freemantle, Australia, 6-23 October, 2001

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Goal. The purpose of our work is to produce acoustic signals at various locations in the Indian Ocean basin so that the nature of sound propagation, and losses, can be documented. One goal is to determine what types of topography are conducive to using large, shallow sources that require that energy be scattered off the seafloor into the SoFar channel, for basin scale propagation. Another goal is to determine the range at which small, deep imploding sources can be detected at distant receivers. The acoustic sources consist of a large array of airguns, imploding glass spheres, and a triggered imploding cylinder. The receivers are permanently installed hydrophones that are part of the International Monitoring System that is overseen by the Comprehensive Test-Ban Treaty Office of the United Nations. Each hydrophone station consists of 3 instruments. Two stations are deployed in the vicinity of Diego Garcia, on the east and west slopes of Chagos platform. One station is installed off Cape Leeuwin, SW Australia.

Daily Summary.

OCTOBER *times local; julian day in parentheses; * clock change 1 hr forward; italics- stn unsuccessful*

Sun	Mon	Tues	Wed	Thurs	Fri	Sat
air#= airgun shotline	imp#= imploder stn	sph#= LLNL sphere stn			**5** arrive Seychelles	**6** depart Seychelles
7 (280) air1 2130	**8 (281)** air2 0500 *imp1 0800* air3 2000	**9 (282)** air4 0830 imp2 0800	**10 (283)** *imp3 0800* air5 0900 sph1 1000 xbt1	**11 (284)*** sph2 1900 air6 2000 xbt2 imp4 2130 sph3 2230	**12 (285)** transit	**13 (286)** imp5 0900 *xbt3* sph4 1000
14 (287) transit	**15 (288)*** transit	**16 (289)** air7 0700 air8 1800	**17 (290)** transit	**18 (291)** transit	**19 (292)*** air9 0830 imp6 1030	**20 (293)*** transit & weather
21 (294) imp7 1500 *sph5 1600*	**22 (295)** transit	**23**				

Personnel.

Captain Jim O'Loughlin
1st Bert Thurston
2nd Bob Beauregard
3rd Meredith Mecketsy
Bosun David Philbrick
AB Wake Walker
AB Bryan Ruegg
AB Robert Ewing
AB Liz Scanland
OS Bear

Chief Eng. Steve Pica
1st Paul Morris
3rd Ryan Weber
3rd Chris Rooney
Oiler G Fernando Uribe
Leslie Strickland
Daniel Lee
Electrician John Schwartz
Steward Ryan Dennis
Cook John Batchelor
Utility Luk Moqo

Chief Sci. Donna Blackman
Allan Sauter
Erica Key
Sci officer Chris Leidhold
Guns: Johnny DiBernardo
John Byrne
Justin Walsh
Hamish Gordon
All around Ted Koczynski
Computing Ethan Gold
Chief Safety Mike Rawson

Logistics. Funding is provided by DOE contract #ROA0101-44. The cruise was initially scheduled for Oct 26-Nov 10 but when the leg before ours was shifted from the Gulf of Aden to Western Australia, our dates were moved forward. Permission to make the initially planned stop in Diego Garcia was denied due to heightened military activity so we were not able to include SUS charges in our suite of sources. We were able to airfreight (Kintetsu Shipping via Britsh Airways, San Diego, Gatwick, Seychelles) the MPL/SIO imploder and associated supplies, and five of the LLNL glass spheres, with a single trigger mechanism and frame, in time for the new cruise departure date. LLNL was not ready to ship the multi-sphere instruments in time so we plan to have these onboard for a couple stations on the following leg (Driscoll et al., Exmouth Plateau). Allan Sauter traveled from San Diego via Singapore & Mauritius; Donna Blackman traveled via Gatwick and Paris. Our LLNL colleagues were unable to get travel approved, due to a combination of shortened timeframe and federal restrictions during the aftermath of the Sept 11 attacks in the US, so they did not participate in the cruise.

Instruments.

Airgun array. The 'standard' Ewing array of 20 airguns is used. Figure 1 shows the layout of the array and the gun sizes. Total volume of the array is 8465 cubic inches. The shot interval was varied from 57 - 173 seconds, these odd times being chosen to eliminate the chance of other souces in the Indian Ocean 'stepping on' our signals as they arrive at the Diego Garcia and Cape Leeuwin hydrophones. Previous analysis of the hydrophone data suggested that industry work does occur at times. Each shooting period lasted about 30 minutes and the intended shots were preceded by a couple minutes of warmup shots at 20-40s interval and were followed by a couple bleed off shots at 40 s.

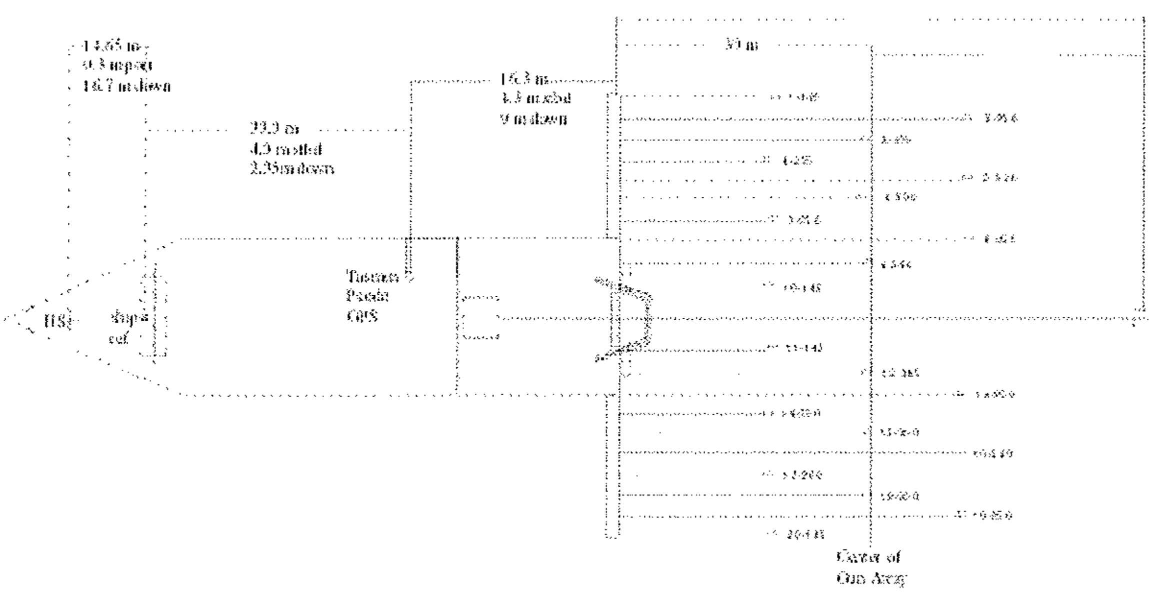


Figure 1. Diagram of the airgun array used for EW0112. Gun sizes follow the gun number and are in cubic inches. The ships reference, corresponding to the Master location in the Spectra header file is noted by 'ship ref'. This diagram also suggests where the implosion sources are relative to the GPS antenna (P-Code) since the CTD winch wire enters the water just outboard and behind the booth on top of which the (Tasmon) GPS is mounted.

MPL/SIO Imploder. The ~900 lb imploder was developed by Allan Sauter, in collaboration with LeRoy Dorman. We used the cylindrical configuration which operates by using the available hydrostatic pressure at depth to mechanically open an empty 20-liter cylinder upon electrical command. Displaced water fills the cylinder, generating an acoustical signal. The instrument is lowered by .322 CTD cable to the firing depth, indicated by the winch wire readout, and then triggered in the lab by a GPS 1 second pulse.

LLNL Glass Spheres. The imploding glass sphere developed at LLNL consists of a sealed piston chamber attached below a secured 22 liter glass sphere. An anchor is mounted at the base and we added additional weight after the first lowering. The thin-walled glass sphere - called a closed flask by the manufacturer CGS, Konte Glass Co., NJ- can withstand pressures found at over 1000m depth. It is lowered by the CTD cable to depth until a small (~2cm dia) burst plate breaks. This opens a passageway for seawater into one side of the piston chamber. We used 2 different pressure rated disks (1010PSI, and 500PSI). After one breaks, the high-pressure seawater pushes the piston towards the glass sphere, causing an extruding "T" bar to strike and break the sphere. Water rushes in from all sides towards the center of the sphere causing a negatively polarized pressure signal at our hydrophone which lasts ~20ms for the deeper implosions and ~30ms for the shallower ones. This signal is followed by a high positively polarized pressure pulse which matches the sudden deceleration of the water and broken glass when it all meets at the center.

Hydrophone and Recording System. We recorded all the implosions on a TEAC RD-145T 16-track using a calibrated (-194dB re 1V/uPa) Ball hydrophone of unknown manufacture. The hydrophone was deployed from the ships deck, just aft (~2 m) of the CTD wire. Shackles were attached to the cable to add weight but at some stations the cable was not particularly vertical in the water. The TEAC recorder and a preamplifier recorded 4 channels to DAT tape: 1) raw hydrophone data ; 2) GPS clock pulse; 3) hydrophone signal amplified x 10, low-pass filtered *(see readme files in science/0112 directories for details of each station. Drop off was 24dB/octave with corner at either 20 or 40kHz);* 4) amplification factor of 100. The sample rate was set to either 24000 (tape speed of 1) or 48000 (tape speed x 2) for the stations. The signals could be heard real time in several cases, either at the ship hull or on the TEAC speaker. For a couple stations the signal was not loud enough to be heard (or other noise masked it) but a mark on the 3.5 recording indicated the signal. We usually turned the 3.5 transmitter off during expected signal times but left the receiver on.

XBT. Sippican Ocean Systems T-5 with 1830 m capability were deployed at the first four LLNL Sphere stations. Data was received down to 1200-1400 m.

Hydrosweep. The multibeam sonar system operates at 14-15 kHz frequency. The Hydrosweep was operated in Deep Water Survey mode, generally 90 degrees. Several times over the deep basin (~ 5000 m depths), the system lost tracking and garbage values along a very narrow swath were recorded. Going to 120 degree swath and playing with gains sometimes brought it back; other times selecting 'stop' in the Multibeam Control window, waiting for 'standby' notice and then selecting 'start' seemed to be necessary. The center beam value from this system is used to key the 3.5 sonar window so this can lead to loss of both data streams (and precludes using the 3.5 to help choose appropriate min/max depths for Hydrosweep.

Additional Underway Data Collected. Gravity (Bell BGM-3), magnetics (Varian V-75 Magnetometer), seasurface T/S (the latter overseen by Erica Key from Rosenstiel). The magnetometer became very noise on jd290 (10/17/01), a couple tries to fix connections failed to improve it so it was brought onboard at the next airgun site and the major surgery ensued, taking much of the remainder of the trip.

Data Processing.
Shot positions: Initially the usual processing scheme for the shot time/location logging was having problems since we had no tailbuoy info to provide it. This was sorted out in time for our second shooting period on jd281 so those, and all subsequent, shot positions have the offset between the ships reference and the center of the gun array incorporated (Spectra). For jd 280 & 281a, I calculated source location from the raw Spectra header information. For each shot number, the GPS1 location is logged, I computed the source offset (sourceoff.f) which accounts for the 55 m distance from GPS antenna to center of array and a 3 m cross-beam offset (Figure 1). Table 1 also includes the seafloor depth at the shots from the shotlog.ewing file in /data/reduction/0112/clean/.

Implosions: Data were recorded on TEAC tape with tape speed usually (except imp2 and sph1) set at x2. Quantization factor for the 20V range at 16 bit was 0.0025. Data were downloaded using QuickVu; a starting tape count was specified and the length of data desired. Format is converted from TEAC to ASCII in this step. Ftp transfer of these files to the UNIX system allowed use of matlab to plot/pick direct and seasurface reflected arrival times. t0 for each source was calculated using hydrophone depth (determined from time difference of the main peak in direct and seasurface reflected pulses) and wireout reading from winch. The matlab pick times are accurate to 0.001 s and the wireout reading is probably within a couple m (except for imp6). Source location was obtained by interpolating the smoothed nav (1 minute records) position to t0. Source time/location information were entered in a 'shotinfo.* file in the relevant /export/home/science/0112/* subdirectory, where * is air(gun), sph(ere), or imp(loder).

Hydrosweep: mbsystem was used to process the swath bathymetry data. For the airgun shooting regions, a section starting 1 hr before the shots and ending 1 hr afterwards was extracted from the /data/raw/0112/0112ds2.d* directories. The processing sequence and parameters:

```
mbcopy -F183 -I  -O
mbgrid -C2.0 -E100/100 -I -Oair* -P3  (speed ~ 4 kts so -P5 too much)
pltgrd  (to view unedited data)
mbclean -Q -X(10-15) -C(2.0-2.5) -I
mbedit (hand edit files for further noise)
mbvelocitytool (choose swath file in center of region) > d*.svp
edit *.par (c/SVPMODE 0/SVPMODE 1/ and c/SVPFILE to d*.svp)
mbprocess -I
mbgrid -I(*p.mb183) -E100/100 -P3 -Oair*
pltgrd (to view at page size)
```

For daily plots of swath bathymetry, only automated editing was done. A plot of the undedited data was produced at page scale and then a version with mbedit -X10 -P5 -E250/250 was gridded up. Both page and map scales were printed. The scripts for each day are dod280, dod281 ... dod294

Initial Results.

Airguns shots. The airguns worked well for all the deployments. Gun #4 on the stbd side initially had a faulty sensor so we could not evaluate its signal but were sure that it was firing. No audible out-of-tune was evident. This was fixed by jd282. The gun depth sensor system was running for 281b shots and all subsequent shots. We tried using long lines between the guns and floats to allow them to sink to 15 m but at the reasonable, safe tow speed of 3.8 kts they rode at 11-12 m depths, some being as shallow as 9 m at times along the shotlines. The lines were later shortened to decrease problems during deployment and this did not affect the gun depths. Only once did the shot manager process hang up during a shooting period- power was cycled on the top processor and it restarted just fine. No shots were lost since this occurred during the switchover from manual to Spectra firing.

Catherine de Groot-Hedlin analyzed Diego Garcia and Cape Leeuwin hydrophone data onshore at Scripps. Shots from some days were seen clearly without filtering, other shots were visible when data were bandpassed 5-10 Hz.

Shot line start/end (shot# increment breaks with change in shot interval)

year	jd	hr:mn:second	shot#	latitude	longitude	leg	depth	rate	line#
2001	280	19:14:39.999	100	S 7 46.0868	E 59 41.6034	ew0112	2108.3	97s	air1
2001	280	19:27:35.999	108	S 7 46.2564	E 59 42.4617	ew0112	2145.4		
2001	280	19:31:03.375	110	S 7 46.3031	E 59 42.6993	ew0112	2188.5	173s	
2001	280	19:44:13.375	116	S 0 -0.0292	E 0 -0.0049	ew0112	2280.8		
2001	281	02:32:53.411	130	S 8 8.3307	E 60 30.3786	ew0112	2649.0	127s	air2
2001	281	03:03:45.411	148	S 8 9.5059	E 60 32.0760	ew0112	2653.0		
2001	281	14:52:49.474	155	S 09 06.4333	E 061 58.4864	ew0112	2391.2	173s	air3
2001	281	17:17:37.484	165	S 09 14.7308	E 062 11.4880	ew0112	2717.2		
2001	282	05:22:24.000	175	S 10 12.1857	E 063 40.8958	ew0112	3538.9	57s	air4
		05:31:54							
2001	282	05:38:24.549	196	S 10 12.7565	E 063 41.7686	ew0112	3522.8	173s	
2001	282	05:55:42.549	202	S 10 13.3549	E 063 42.6965	ew0112	3660.3		
2001	283	04:33:50.667	215	S 12 01.7703	E 066 30.6457	ew0112	2965.0	127s	air5
2001	283	05:03:28.667	229	S 12 02.6314	E 066 32.2139	ew0112	3328.2		
2001	284	15:34:15.846	235	S 14 48.3162	E 071 19.5013	ew0112	4850.1	173s	air6
2001	284	16:03:05.846	245	S 14 49.4959	E 071 20.8279	ew0112	4874.2		
2001	289	02:11:58.395	255	S 22 55.5129	E 087 02.8481	ew0112	3371.5	127s	air7
2001	289	02:43:43.395	270	S 22 54.6634	E 087 00.8697	ew0112	3453.2		
2001	289	02:45:60.000	275	S 22 54.6063	E 087 00.7298	ew0112	3447.2	57s	
2001	289	02:57:24.000	287	S 22 54.3071	E 087 00.0353	ew0112	3552.4		
2001	289	12:28:36.867	290	S 23 25.0296	E 088 11.3103	ew0112	2984.4	173s	air8
2001	289	12:57:26.867	300	S 23 25.5766	E 088 13.3527	ew0112	3242.7		
2001	289	12:59:10.000	305	S 23 25.6098	E 088 13.4722	ew0112	3234.6	57s	
2001	289	13:04:52.000	311	S 23 25.7197	E 088 13.8682	ew0112	3107.4		
2001	292:02:10:59.915		000317	S 27 33.2231	E 098 51.5828	ew0112	2717.6	57s	air9
2001	292:02:32:50.915		000340	S 27 33.7219	E 098 53.0368	ew0112	2797.8		
2001	292:02:35:54.918		000345	S 27 33.7915	E 098 53.2368	ew0112	2807.8	127s	
2001	292:02:46:29.918		000350	S 27 34.0405	E 098 53.9444	ew0112	2836.9		

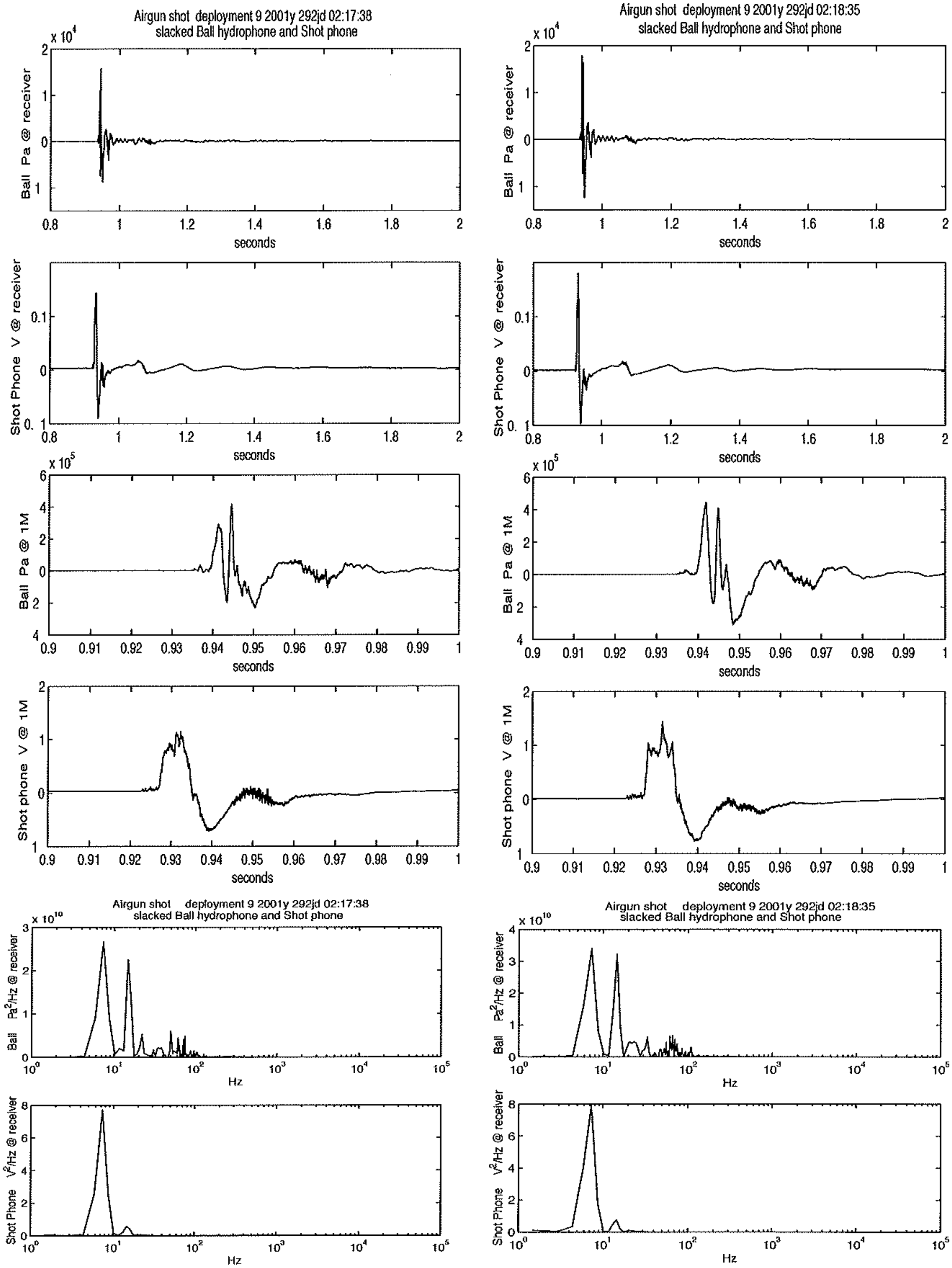


Figure 2. Recordings of two airgun array shots on the Ball and Shot hydrophones and their spectra.

Weather precluded our shooting a final site at Dirck Hartog Ridge.

A near-source recording of a few shots was accomplished during the final shooting line. Figure 2 shows a comparison of the signal on the Ball hydrophone and the ship's Shot Hydrophone. The TEAC setup was:

- Channel 1 - Ball hydrophone (no gain)
- Channel 2 - GPS second pulse
- Channel 3 - Ball hydrophone passed through an ITHAC model 4302 Amplifier set to x1 gain, and low-passed with a 24dB/octave, 40KHz corner frequency filter. The output of this was fed into a resistor voltage divider to attenuate the original Ch 1 signal by 12.
- Channel 4 - Ewing Shot hydrophone passed through an Ithaco model 4302 Amplifier set to x10 gain and low-passed with a 24dB/octave, 40Khz corner frequency filter.

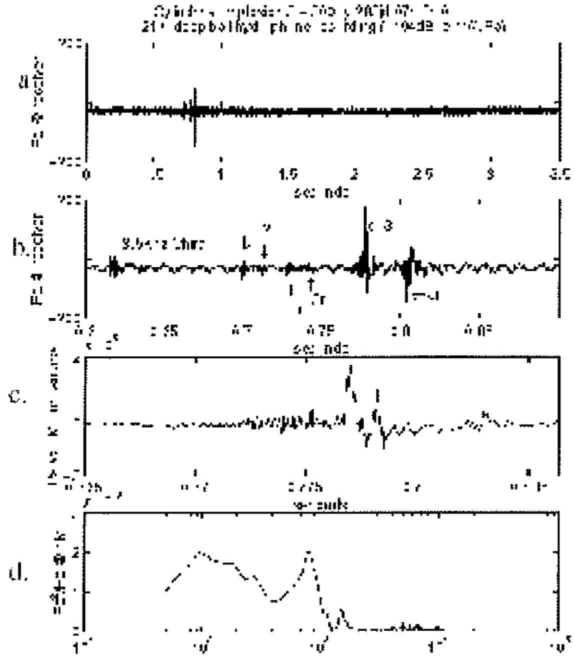
For shots 1 thru 3, the ball hydrophone line was payed out fast during the firing to minimize towing noise. We estimate that the ball hydrophone was about 30 meters ahead of the trailing array. The shot hydrophone was towed steadily behind the ship about 8 meters ahead of the array.

The Shot phone is uncalibrated. A delay between the first arrivals on the Shot phone with respect to the Ball hydrophone of ~.0123 seconds gives a distance offset of 18.5 meters between the 2 hydrophones (1500m/S water vel). The spectra in the lower panels of Figure 2 include the visible ringing coda on the Shot hydrophone record.

Imploder. The MPL/SIO imploding cylinder was used at 7 stations and near-source recordings were obtained. An electrical connection failure prevented the gun from triggering at the first station and an unknown problem resulted in no evident signal for the third station, although the gun had triggered. All other stations were successful. The recordings show that the source is repeatable and has 3 separate arrivals. We suggest the following events as the probable causes (see Figures 3-6). Arrival 1 is generated by the release pin as it strikes the brass manifold cap, after release. Arrival 2 is generated when water finishes filling the 1st stage prior to piston movement. It should be remembered that pressure is equivalent to a force (mass times acceleration) per unit area. Therefore, when a mass of water is abruptly stopped by coming into contact with a barrier, the pressure wave generated will be large. Or at least, in this case, large enough to be seen by our hydrophone. The resulting pressure on the inner piston face forces a piston to move, pulling the endcap off of the main cylinder. The high frequency signal which preceeds the main arrival #3 for 6 milliseconds is most likely caused by turbulent filling of the main cylinder. Arrival 3, the largest, is generated when the cylinder is completely filled. It is consistently around 2×10^5 Pa re 1m. We suspect the second peak following arrival 3 is a tube resonance since its time delay from the main arrival is roughly the cylinder length divided by the water velocity.

Imploder Source Information

year	jd	hr:mn:sec	stn	latitude	longitude	water(m)	source
2001	282	07:18:09.12	imp2	S 10 15.0479	E 063 45.0703	3807	1000 m
2001	283	03:29:10	imp3	S 12 00.495	E 066 28.536	3376	1000
2001	284	18:00:50.14	imp4	S 14 46.026	E 071 17.117	4623	1000
2001	286	04:30:50.13	imp5	S 17 41.2828	E 076 26.2046	5042	1200
2001	292	04:00:30.1	imp6	S 27 27.0660	E 098 33.9000	3772	1230?
2001	294	07:27:15.11	imp7	S 30 21.4746	E 108 20.2620	5291	1000



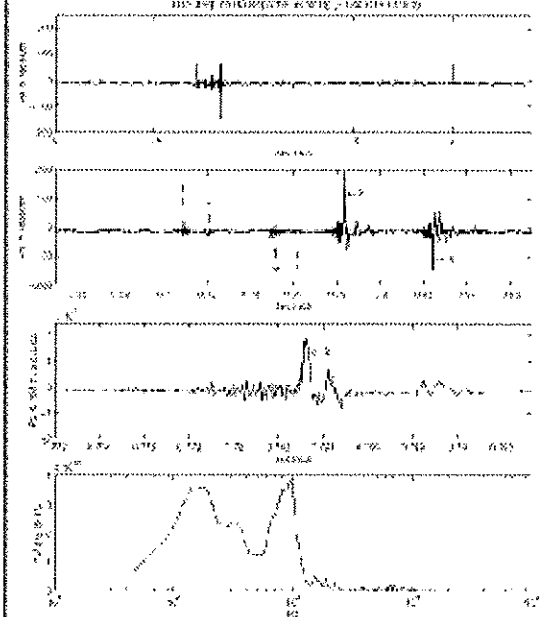


Figure 3. (a) The implosive signal for a 1000 meter source. (b) Different arrivals - the 3.5Khz ship's down-looking sonar arrives first in this record. Arrow 1 shows the first sound generated by the cylindrical imploder - probably the release pin striking the manifold cap. Arrow 2 points to a second arrival, probably related to the hydraulic infilling of the imploder's piston chamber. The arrival labeled 3 is the signal related to filling the main chamber. The features labeled 1r, 2r, and 3r are sea surface reflections and the time offset between direct and reflected pulse of .0276 seconds gives a hydrophone depth of 20.5 meters (at 1500 m/s). (c) Main arrival multiplied by 1000-20.5 to correct for geometric propagation loss. The amplitude plotted reflects the signal strength 1 meter from the source. Spacing of the 2 main peaks around .777 - .778 seconds is about .00135 seconds, which corresponds to a spectral peak around 740 Hz. (d) Power Spectral Density of (c).

Figure 4. Hydrophone recording of imp4. (see caption Figure 3). This source was triggered at the same depth as imp2.

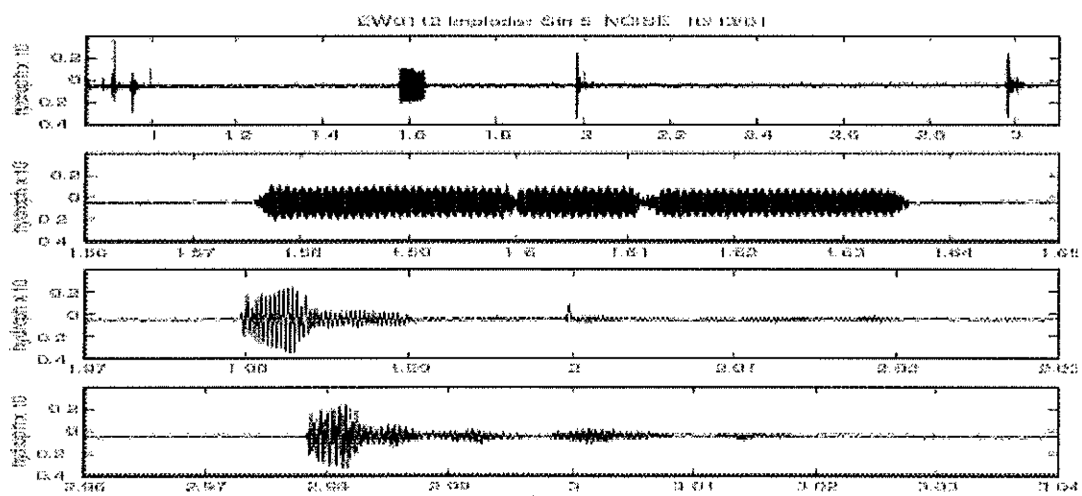


Figure 5. Recording of imp5, the first set of direct and reflected arrivals on the top panel, and subsequent arrivals of hydrosweep pulse (15 kHz, duration ~.036 sec) and the 3.5 pinger (duration ~ 10msec).

Figure 6. Time series and spectra of Imploder stations. Left panels: imp5 with source depth 1200m; middle panels: imp6, source @ ~1230m; right panels: imp7, source @ 1000m. t=0 is set at the even second closest to the arrivals shown. See caption for Figure 3 for arrival description.

Spheres. Four of the five spheres were completely successful and at least two of these were recorded at Diego Garcia, as determined by Phil Harben at LLNL. At the fifth station (sph5), the ram broke a hole in the sphere but the glass did not shatter so there was not an implosion. A small signal was recorded on the hydrophone and the 3.5 sonar receiver. The sphere did fill with water through the 0.5 x 2 inch hole where the ram protruded into the sphere.

When the seawater rushes into a smashed sphere a negatively polarized pressure signal is recorded at our hydrophone which lasts ~20ms for the deeper implosions and ~30ms for the shallower ones. This signal is followed by a high positively polarized pressure pulse which matches the sudden deceleration of the water and broken glass when it all meets at the center. This pulse is 2×10^6 Pa re 1m for the 320m implosion, and 4×10^6 for the 680m implosions. A small, quickly damped bubble pulse ringing can be seen trailing the main pulse.

Sphere Source Information

year	jd	hr:mn:sec	stn	latitude	longitude	water	source
2001	283	06:25:12.39	sph1	S 12 3.8883	E 66 34.5404	3636	680 m
2001	284	14:24:54.5	sph2	S 14 46.0701	E 71 17.0669	4623	320
2001	284	18:48:00.73	sph3	S 14 46.0624	E 71 17.2791	4640	670
2001	286	05:17:07.82	sph4	S 17 41.4825	E 76 26.2167	5037	670
2001	294	08:03:39.7	sph5	S 30 21.8861	E 108 20.0393	5292	340

Figure 7. Recordings of two sphere implosions. Left panels show sph1 with 680 m deep source; right panels show sph2 where source depth is 320 m.

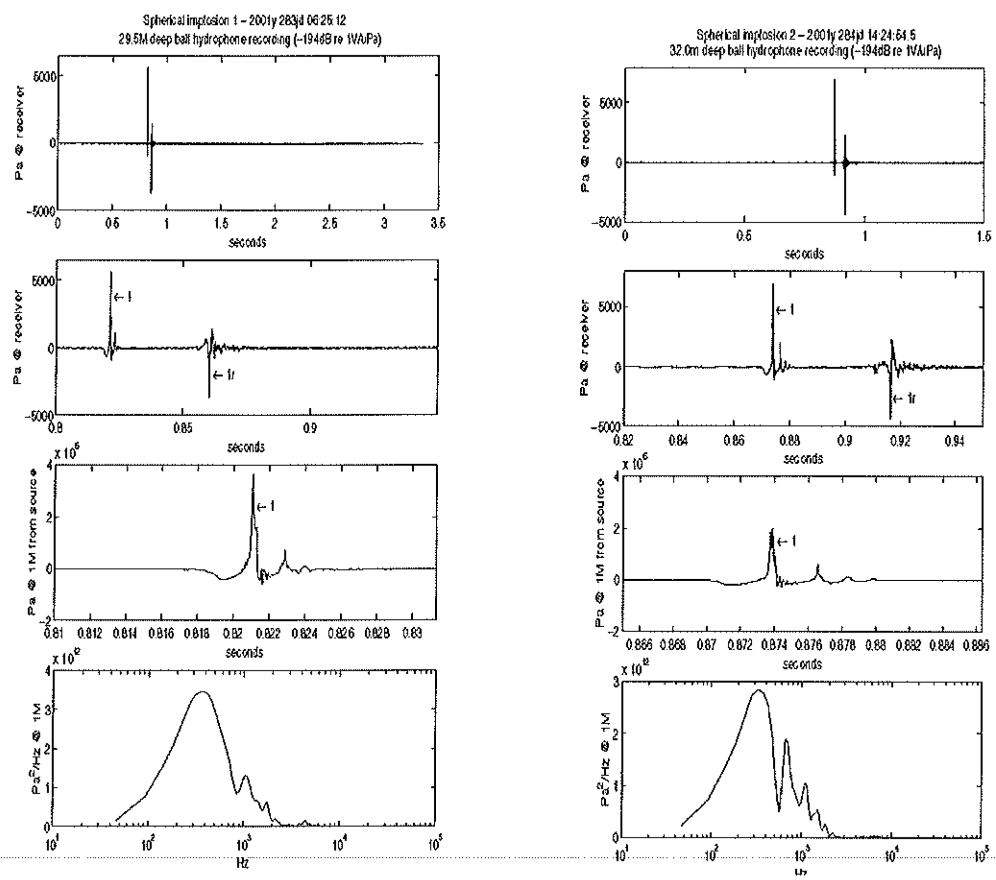


Figure 8. Hydrophone recordings of glass sphere signals. Left panels: sph3 @ 650m depth; middle panels: sph4 @ 670 m depth; right panels: sph5 @ 340 m depth - not a full implosion. Unlike the typical sph3 and sph4 signals, the sph5 signal is very small amplitude due to the fact that the glass didnt fully break. The 15kHz signal (2) following the puncture signal (1) is probably a seafloor reflected hydrosweep pulse.

The fact that both the cylindrical and spherical imploders have nearly identical volumes might seem at odds with fact that the spherical implosions produce 20 times larger signals than the cylindrical. However, considering the peak signals in both cases are produced by sudden decelerations, and that the infilling time for the sphere is much shorter than for the imploder, it makes sense to expect larger decelerations and bigger peak signals for the sphere. The smooth, down-going sinusoidal signal preceding the spherical imploder peak contrasts with the high-frequency chatter that precedes the cylindrical imploder peak. This indicates smooth, optimally-laminar inward flow following the breaking of the sphere and a more turbulent flow after the opening of the cylinder.

Breaking the sphere produces a larger, cleaner pulse than pulling the endcap off the equal-volume cylinder. In a past experiment, with a different configuration for the cylindrical firing mechanism, we have successfully used a timing pulse to break a sphere on the seafloor. Therefore, we might be tempted to abandon any use of a cylindrical geometry but for one potential advantage over the breaking of spheres. It is much more likely that a cylindrical geometry can be developed into a down-wire repeatable source - a deep watergun. Apart from hydrophone calibration work, this device would have multiple applications in seafloor research and in the oil industry. However, it is first necessary to increase the signal output from the cylinder. Analysis of this trip's data has suggested a way to accomplish this. Instead of pulling water into a void to create a signal, we could reconfigure the first stage of the imploder to push water out of an open chamber. The sudden deceleration of the water when the pusher reached the stops would create the peak signal. This is essentially how a watergun works, only we would use hydrostatic pressure to do the work of pushing the water instead of relying on compressed gas.

Hydrosweep:

The page-size maps of the 9 airgun shooting sites illustrate the variety of seafloor character in these source regions. The shallowest site, *air1*, averages ~2200 m and slopes towards the N, between Seychelles and Saya de Malha banks. A steeper N slope characterizes the *air2* site but depths are greater, averaging 2700 m. On the edge of Saya de Malha bank, the *air3* site slopes from 2500-2900m to the SE. Smoother seafloor characterizes the *air4* site which is about half way between Saya de Malha bank and the Central Indian Ridge at depths of ~3700m. On the east flank of the CIR, the *air5* site took advantage of the steep slopes of a topographic high rising to 2900m. In the open basin, the *air6* site was in an area where depths are ~4700m but a flat basin reaching 5000 m is included. Two sites on the 90E Ridge were used for airgun shooting. On the western side, *air7* took advantage of a moderate slope between 3400 and 3700 m depth. The Fisher map did not indicate the shallowness of the ridge on our track, we measured depths as shallow as 2500 m to the N of our track. As the ridge began to drop off to the east, we shot *air8* at ~2900-3200 m depths. The final site, *air9*, that we were able to shoot at was north of Gulden Draak Knoll where a north protruding finger shallowed to ~2700 m and then dropped rapidly down to the east.

For the most part the seafloor topography followed the current contour map by Bob Fisher (SIO) but we did recognize a couple shallow ridges and areas of deep, but rough seafloor. These are sketched onto our (50% reduced) copy of the contour maps and they are clear in the daily hydrosweep plots at 81°10'E, 81°45'E and 104°30'E.

XBT Information.

year	jd	hr:mn	#	latitude	longitude	depth	surface T
2001	283	07:00	xbt1	12 07.736S	66 41.580E	3525m	25.9C
2001	284	17:00	xbt2	14 50.871S	71 22.41 E	4507	24.6
2001	292	04:00	xbt4	27 43.229S	99 20.42 E	2987	19.1

Archive Data:

TEAC Dat tapes:

T1- imp1
T2- imp2, imp3, sph1
T3- sph2, imp4, sph3
T4- imp5, sph4
T5- imp6
T6- airgun shots
T7- imp7, sph5

UNIX files

CD1 (dkb) for HSdailyproc.tar, msystem files for daily hydrosweep
CD2 (dkb) for other files from /export/home/science/0112
CD1 (allan) UNIX files without hydrosweep and pictures
CD2 (allan) /export/home/science/0112

shipboard data

DAT tape

3.5 kHz paper record

4 rolls