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AN OPERATIONAL SUMMARY OF THE BERMEX81-V3 EXPERIMENT: 17-19 SEP--ETC(U)
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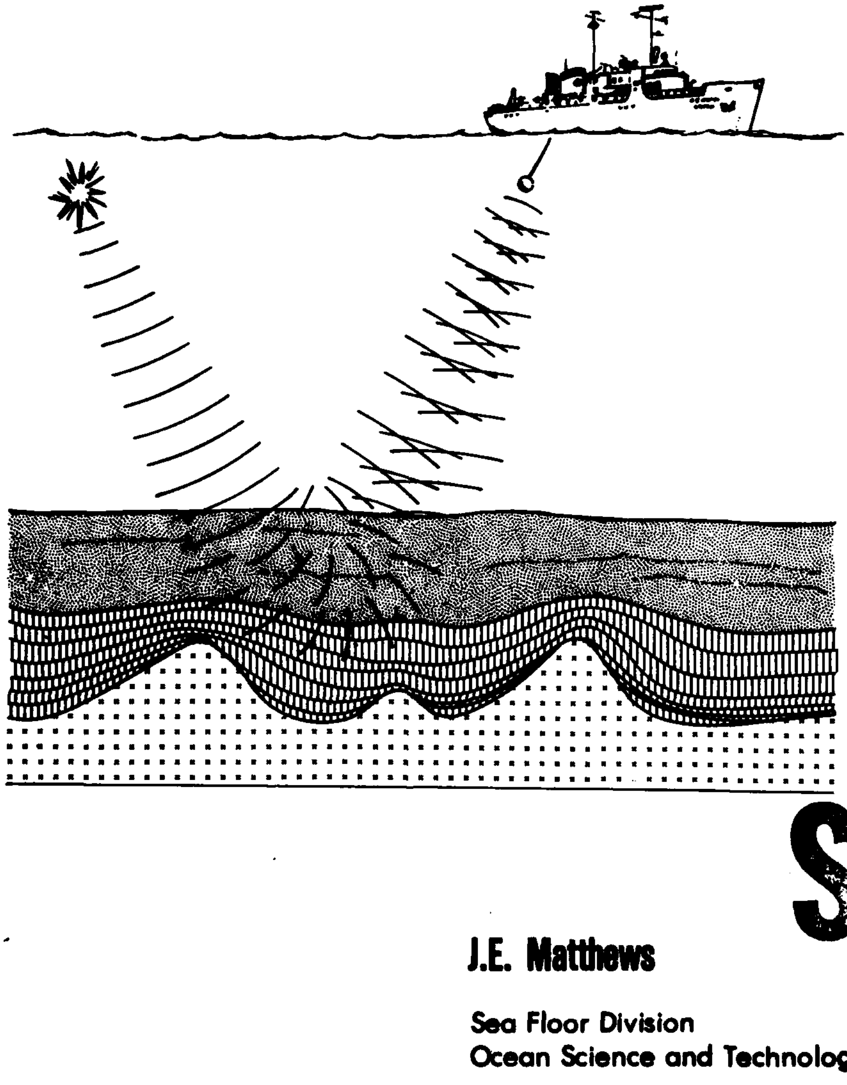
Naval Ocean Research and Development Activity
NSTL Station, Mississippi 39529

An Operational Summary of the BERMEX81-V3 Experiment: 17-19 September 1981



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July 1982

ABSTRACT

During September 1981, a vertical array of eight hydrophones (VEDABS) was moored in deep water to the south of the island of Bermuda for engineering tests. While the array was in the water, a series of deep, large, explosive charges were detonated and acoustic projector towed on a radial away from the array. This report documents the generalized experimental design, array characteristics, and operational aspects of the experiment.

ACKNOWLEDGEMENTS

I am greatly indebted to Randy Jacobson, Oregon State University, and Norman Lombard, Naval Ocean Research and Development Activity, for their assistance in the "field." I am also indebted to Bob Rumph of the Naval Underwater Systems Center, Tudor Hill, Bermuda, for his assistance both ashore and in the field. The Naval Electronics System Command, Code 612-Bottom Interaction Block, provided funding for the data collection. The Surveillance Environmental Acoustics Support Project (SEAS) allowed me to collect the data during their engineering tests of the array, and provided funding for publications of this report, which documents the operation.

CONTENTS

ILLUSTRATIONS

TABLES

AN OPERATIONAL SUMMARY OF THE BERMEX81-V3 EXPERIMENT: 17-19 SEPTEMBER 1981

I. INTRODUCTION

This report describes the experimental design, system characteristics, and field procedures of one portion of the BERMEX81 Exercise, specifically, the V3 leg of 17-19 September 1981. This experiment was designed in 1976 by NORDA Code 362 to measure the velocity and attenuation of compressional waves as a function of depth below the sea floor. Data was to be collected in three sedimentary provinces (abyssal plain turbidites, pelagic carbonates, and hemipelagic carbonates) of the Venezuelan Basin, Caribbean Sea. The source-receiver geometry and shooting procedures have remained unchanged; however, the receiving system and geographic location were significantly changed.

Two attempts at data collection (1979 and 1980) were to utilize the Versatile Experimental Kevlar Array (VEKA-3B), a two-hydrophone, vertically moored system with an RF telemetry link to shipboard recording equipment. Both attempts failed due to external factors (collision at sea, loss of main propulsion system, theft of critical electronic circuit boards, and other calamities). The experiment was then revised and rescheduled for an area of thick pelagic carbonate sediment south of the Island of Bermuda. The revised experiment would utilize the Versatile Experimental Data Acquisition Buoy System (VEDABS) with a vertical array of hydrophones. The VEDABS, designed and fabricated by NORDA Code 353, was scheduled to undergo a field test and evaluation during September and October 1981. This report is a summary of the V3 leg of that exercise.

The exercise was conducted aboard USNS BARTLETT (T-AGOR-13) was scheduled to sail from Bermuda on 9 September, but was delayed until 17 September because four hurricanes (Emily, Floyd, Gert, and Harvey) passed within 150 nautical miles of the operation area during a ten-day period. The VEDABS was deployed 17 September and followed by an SV/STD cast, the explosive shot run and projector tow were conducted 18 September, and the VEDABS was recovered 19 September. Figure 1 shows the bathymetry of the Bermuda region with the VEDABS location, shot run, and projector tow tracks superimposed.

II. EXPERIMENTAL DESIGN

The experimental design consisted of a deep hydrophone and deep explosive charges to record the bottom interactive acoustic arrivals and the direct "water" path separated in time from each other, from the surface reflection, and from subsequent surface/bottom multiple reflections. The arrival structure (time-distance relationship of multipaths) can be easily calculated from analytic functions for an isovelocity water column over a sea floor of constant velocity gradient. Figure 2 shows the travel paths of interest, velocity structure of the simplified model, and the necessary equations to compute the time-distance curves for such a model. Figure 3 shows the calculated time-distance curves corresponding to a 3000 m source and receiver in 4500 m of isovelocity water (1500 m/s), over thick sediment with a velocity gradient of 1.0 sec^{-1}.

From these calculations, based upon a simplified model, it can be seen that the deep refracted bottom arrival and direct "water" arrival could be easily separated (windowed in time) for this experimental configuration.

Therefore, 3000 m depth detonated explosive charges and the 3000 m hydrophone of the receiving array deployed in 4500 m of water in the area of thick pelagic sediment south of the Island of Bermuda met the experimental requirements.

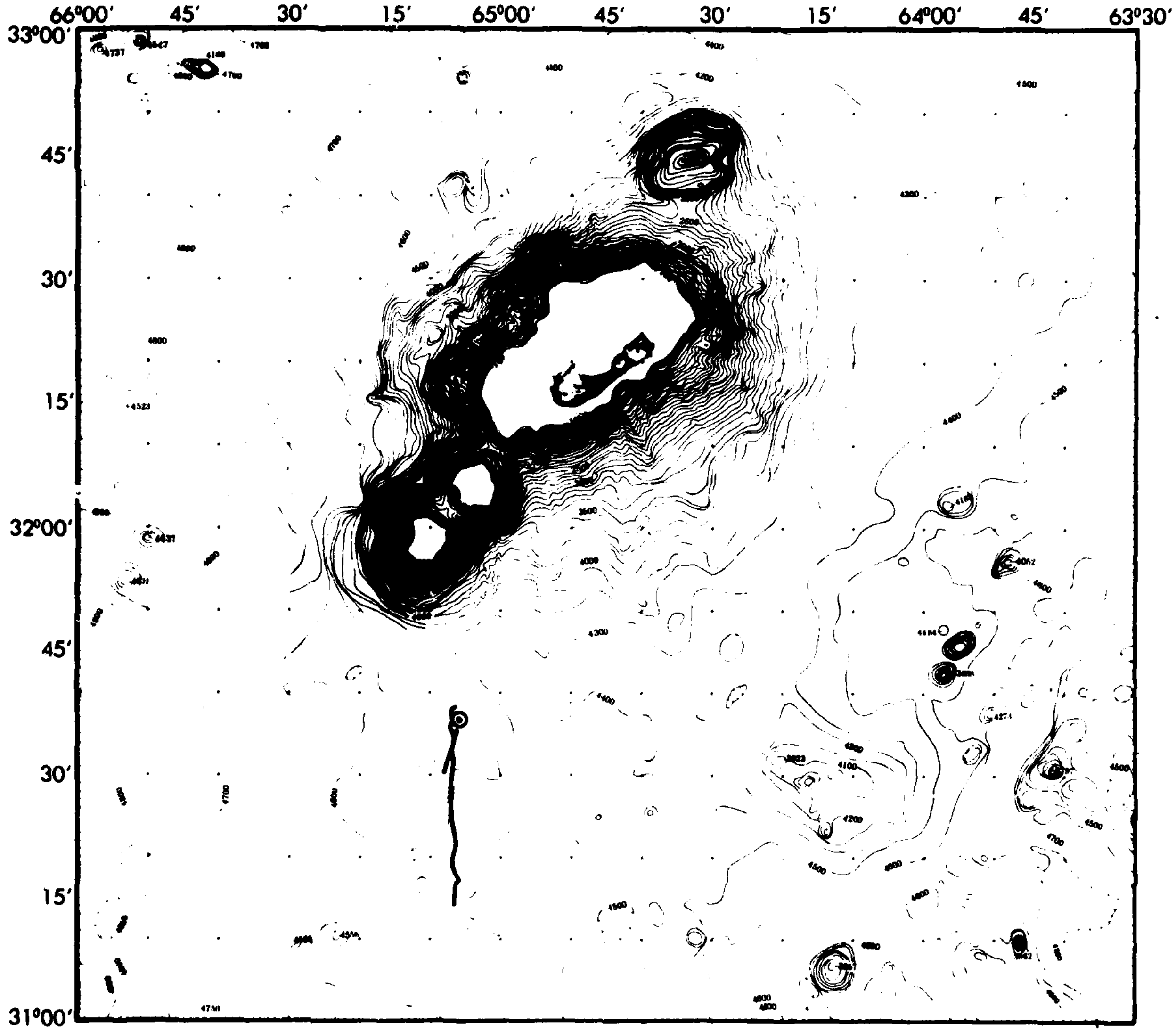
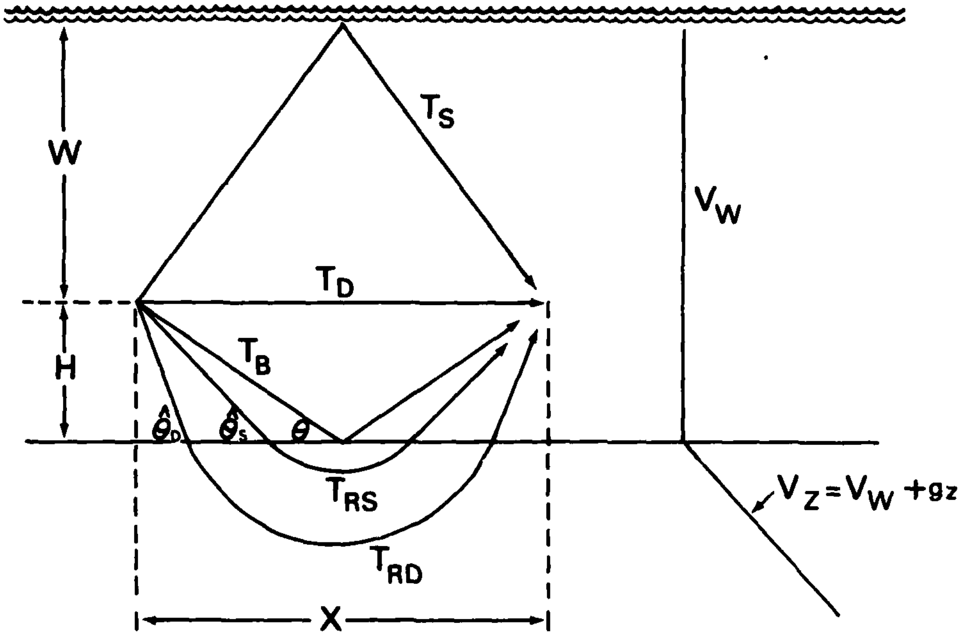


Figure 1. Bathymetry of Bermuda Seamount and vicinity with VEDABS location (⊙) and ship tracks (—)



TRAVEL TIME EQUATIONS:

$$T_D = X/V_W$$

$$T_S = 2\sqrt{\left(\frac{X}{2}\right)^2 + W^2}/V_W$$

$$T_B = 2\sqrt{\left(\frac{X}{2}\right)^2 + H^2}/V_W$$

$$\tan\hat{\theta} = \frac{Xg \pm g\sqrt{X^2 - \frac{16V_WH}{g}}}{4V_W}$$

$$\tan\hat{\theta} = 1/2\sqrt{\frac{gH}{V_W}}$$

$$T_R = 2H/V_W \sin\hat{\theta} + \frac{2}{g}\ln\left[1/\sin(90-\hat{\theta}) + \sqrt{1/\sin^2(90-\hat{\theta}) - 1}\right.$$

$$X_C = 4H\Big/\sqrt{\frac{gH}{V_W}}$$

Figure 2. Geometry of experiment with acoustic travel paths

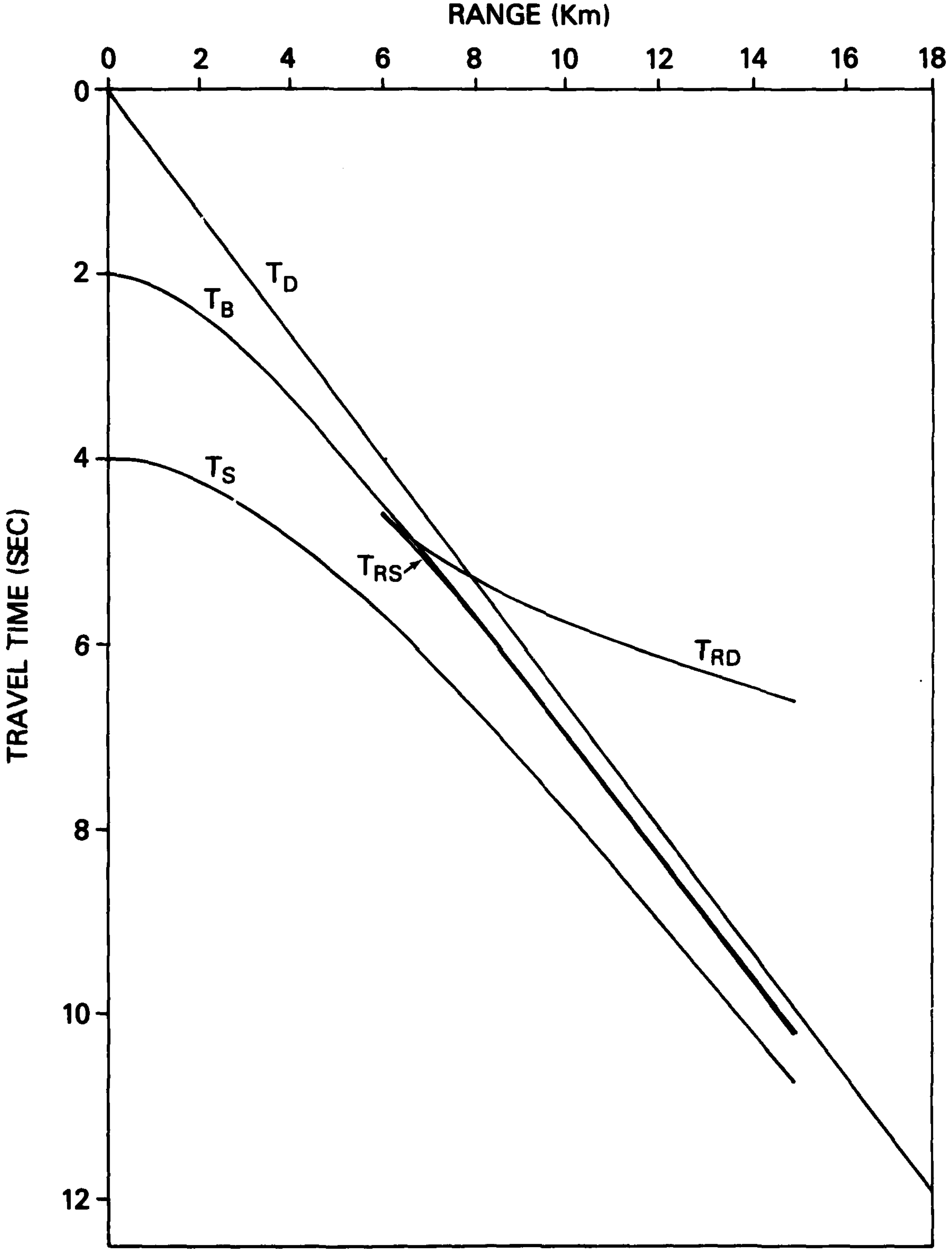


Figure 3. Time-distance relationships for travel paths of Figure 2

III. ESTIMATION OF EXPLOSIVE ACOUSTIC CHARACTERISTICS

There is little published information specifically dealing with the acoustical characteristics of large, deep underwater TNT detonations. Gaspin and Schuler (1971) empirically show that the peak acoustical pressure is a function of charge size and distance from the detonation, and not detonation depth. However, the period of oscillation of the bubble generated (bubble pulse period), which controls the detonations frequency content, is a function of charge size and depth of detonation. Their empirical relationships are:

$$P_0 = 2.08 \times 10^4 \left(W^{1/3}/R\right)^{1.13}$$

$$T_1 = \frac{4.34W^{1/3}}{Z^{5/6}}$$

$$T_2 = \frac{3.06W^{1/3}}{Z^{5/6}}$$

where

P_0 = peak pressure in psi
T_1 = first bubble pulse period in seconds
T_2 = second bubble pulse period in seconds
R = shot range in feet
W = charge weight in pounds
Z = detonation depth in feet + 33

It is clear that to obtain a low frequency signal from deep explosive charges, large charges must be used. Table 1 shows the computed peak pressure and first bubble pulse period for the charge weights of interest. The pressure levels at ranges of 2 and 4 km were computed by subtracting a spherical spreading loss from the one yard pressure level. Absorption at 100 Hz over these ranges was considered insignificant (Thorp, 1967).

The reciprocal of the detonations bubble pulse period is its spectral peak frequency. Christian (1967) investigated the source spectra of deep underwater explosions, and determined that the spectrum fell off at a rate of 8 dB/octave on either side of this peak. Christian used a slightly different equation for computing the spectral peak frequency, but the results agree with the above equation to within one hertz.

Table 1. Explosive Characteristics

	TNT Charge Weight		
	55 lbs	110 lbs	220 lbs
Po (psi) @ 1 yd	2.719×10^4	3.531×10^4	4.584×10^4
Po (dB//μPa) @ 1 yd	285.3	287.6	289.9
T_1 (sec)	.0076	.0096	.0121
f(Hz)=1/T_1	130.9	103.9	82.5
Po (psi) @ 2 km	12.4	16.2	21.0
Po (dB//μPa) @ 2 km	218.5	220.8	223.1
Po (psi) @ 4 km	6.2	8.1	10.5

IV. VEDABS ARRAY CHARACTERISTICS

The Versatile Experimental Data Acquisition Buoy System (VEDABS) is a self-contained data recording system in a pressure housing. The system will accept eight separate hydrophone inputs, and will record each input at three different gain settings on an analog tape recorder, along with ancillary time codes and reference tones. During the BERMEX81-V3 experiment, the VEDABS was used to record the output of a moored, eight-element vertical hydrophone array. The hydrophones were configured at a 500 m spacing, and therefore did not constitute an array in the sense of a beamformer, but provided sensors distributed through the water column. Figure 4 shows the configuration diagrammatically; the hydrophones are numbered and their depths indicated.

Figure 5 shows the VEDABS system block diagram for a single hydrophone. All hydrophone channels are electronically identical except for the optional C1 capacitor built into the hydrophone and the settings of the variable gain preamplifiers. The hydrophones are USRD Type H78A built by the Naval Research Laboratory, Underwater Sound Reference Detachment (Tims, 1979). Each hydrophone has a built-in 20 dB current-mode preamplifier which clips at -6 dB//1v with a recove [illegible] time of 60 μs. This arrangement can drive up to 9200 m of No. 24 AWG twisted-pair [illegible] ble over a frequency range of 10 Hz to 10 kHz. The preamplifier input is prot [illegible] d by a pair of diodes set to clip at 1.0 v peak-to-peak. The inclusion of the C1 [illegible] acitor, in parallel with the hydrophone crystal, decreases the sensitivity of t [illegible] ydrophone. In the experimental configuration three different sensitivities were [illegible] -181, -196, and -201 dB//v/μPa, the first being the crystal alone, the latte [illegible] o having a C1 capacitor.

The resistors (40 Ω and 2.14k Ω) produce a -35 dB drop in the signal level, followed by a 20 dB gain preamplifier. The signal level entering the pre-emphasis circuit is thus 5 dB above the hydrophone crystal output (accounting also for the C1 capacitor). The pre-emphasis circuit was designed to compensate for the fall-off in oceanic acoustic ambient noise with increasing frequency. The pre-emphasis added consists of an 8.8 dB gain in the 0-30 Hz range, with an increasing gain of 6 dB/octave at frequencies above 30 Hz. After pre-emphasis, the signal is input to three parallel variable gain preamplifiers (0-54 dB in 6 dB steps). The three signals are then passed through three low pass filters (F1, F2 and F3), set at a 500 Hz cutoff. Finally, the three signals are mixed (in a 0 dB gain preamplifier) with a 1785 Hz, 600 mv peak-to-peak carrier tone which has a high-amplitude marker every 256 cycles. These three mixed signals are then put on 1 inch, 28 channel analog tape by a Bell and Howell Model 1428 tape drive operating at 0.2 ips. Table 2 lists the tape recorder channels and the data recorded on them, including the variable gain preamplifier settings.

V. EXPLOSIVE SHOT RUN

The objective of the explosive shot run was to detonate a series of large (55-220 lb) TNT charges on a radial from the VEDABS array with a horizontal spacing of approximately 500 meters. The charges were to be detonated at a depth of 3000 m. To achieve this, MK-94 SUS set for 3048 m were used to detonate 55 lb TNT blocks which were banded to the SUS. The engineers responsible for the VEDABS deployment were concerned that large charges close to the array could emplode the glass spheres used

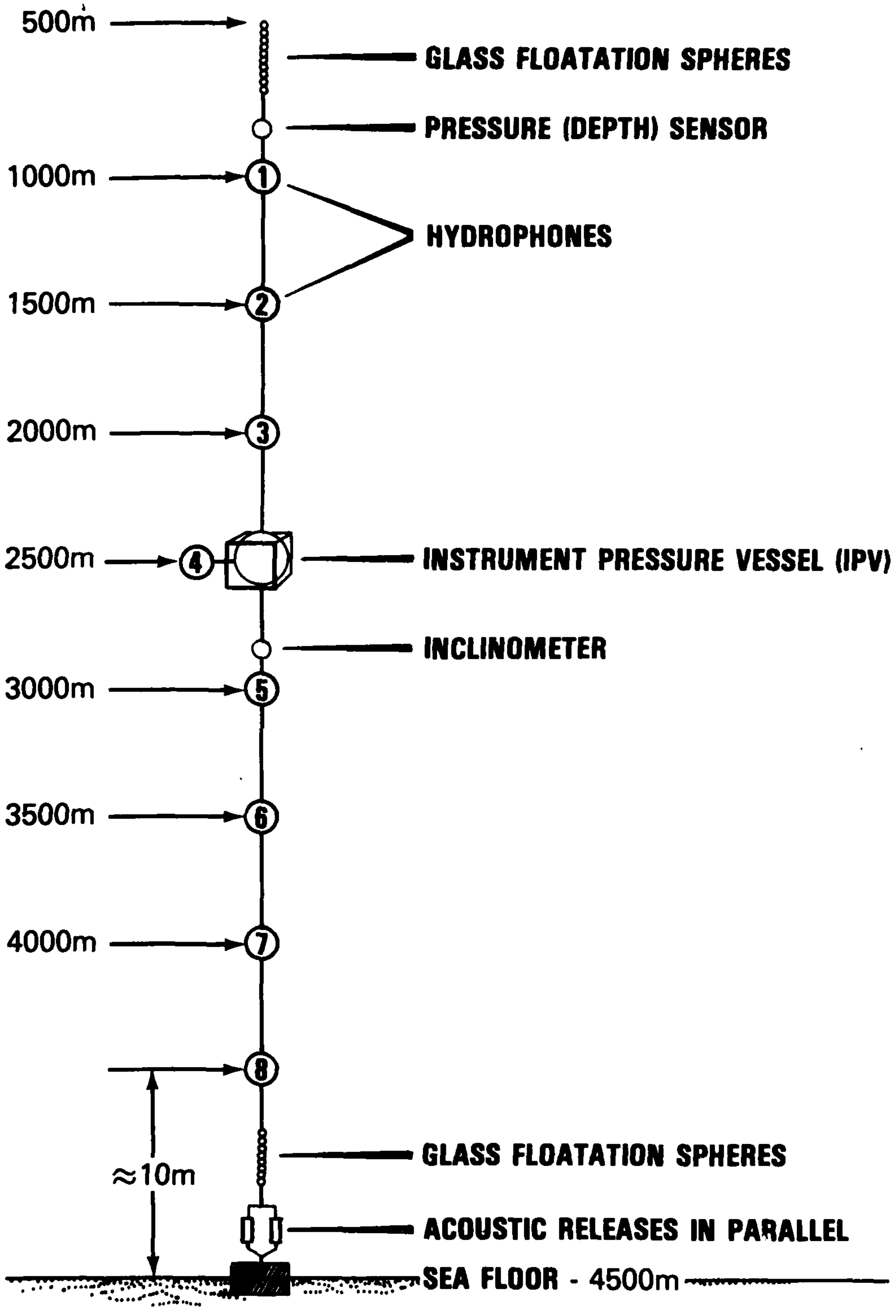


Figure 4. VEDABS BERMEX81-V3 configuration

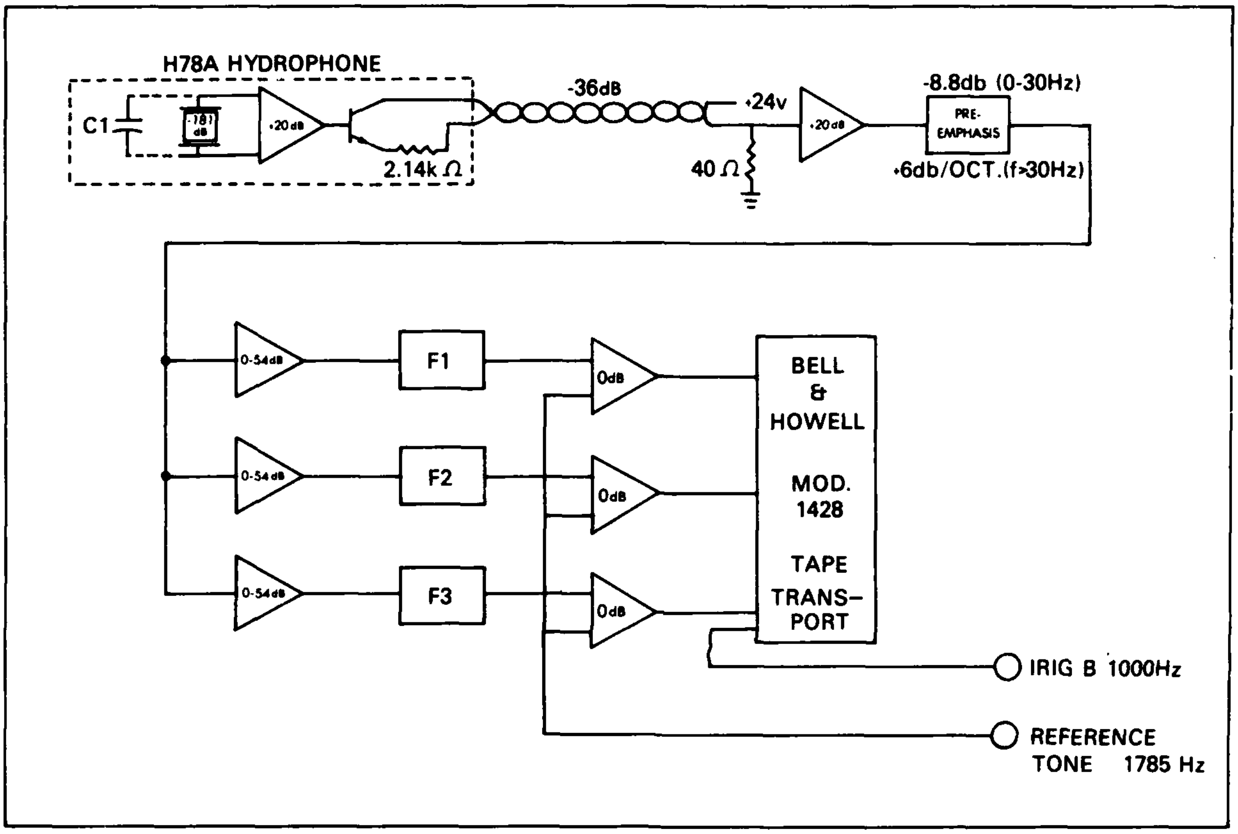


Figure 5. VEDABS system configuration

Table 2. Tape Recorder Configuration

Tape Recorder Channel	Hydrophone Number - Sensitivity (dB//v/μPa)	Variable Preamplifier Gain (dB//1v)	Other
1	1-181	24	
2	1-181	36	
3	1-181	48	
4	2-201	12	
5	2-201	30	
6	2-201	48	
7	3-181	24	
8	3-181	36	
9	3-181	48	
10	4-196	6	
11	4-196	24	
12	4-196	42	
13			1560 Hz Servo tone
14			IRIG B 1000 Hz time code
15			1560 Hz Servo tone
16	5-196	6	
17	5-196	18	
18	5-196	30	
19	6-181	24	
20	6-181	36	
21	6-181	48	
22	7-181	24	
23	7-181	36	
24	7-181	48	
25	8-196	6	
26	8-196	24	
27			IRIG B 1000 Hz time code
28	8-196	42	

for array floatation.* The shot run, therefore, started with 55 lb charges and progressed to 110 lb and 220 lb charges as source-receiver range was increased to alleviate these fears.

A MK-94 SUS with its streamlined shape should sink to a depth of 3000 m in approximately 6.5 minutes, but with the addition of 1-4 TNT blocks, the sink time was estimated to be at least 30 minutes. It was also estimated that with two shooters making up charges and two seamen breaking explosives out of the magazine, at least 10 minutes would be required to make up each charge. It was, therefore, decided that a one-knot speed with shots at 15 minute intervals was operationally feasible, would preclude more than 2-3 charges in the water at any given time, and would minimize the quantity of explosive on the fantail.

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*NOTE: Table 1 which indicates the pressure wave from the 220 lb charge at 2 km, is less than 1.0% above the ambient hydrostatic pressure. Thus, the safety factor of the glass spheres is adequate for these conditions.

East-west courses the previous night indicated a northerly, and somewhat westerly, drift could be anticipated even though the wind was three knots out of the southwest. A southerly shot course was desired to ensure thick sediments away from the Bermuda pedestal, which precluded a simple drift shot run. A decision was made to steer 180° while making 50 rpm, hoping the drift would reduce the ship's speed of advance (SOA) to one knot.

The navigational system available was a Magnavox MX-1102 satellite system with gyroscope course input and manual speed input. An improper speed input to the satellite receiver and a series of very high angle and very low angle satellite passes for several hours prior to the operation resulted in an unreliable dead reckoning (DR) position for the ship. VEDABS had no surface marker. The ship was therefore maneuvered toward the array by repeated ranging on the array's acoustic release devices. Finally the ship was brought dead in the water (DIW) to track and compute a 1249 GMT satellite pass. After obtaining this fix, the ship came to course 135° and sailed at 7.5 knots for 10 minutes to reposition for the shot run. A 1330 GMT fix was obtained while DIW, after which the ship swung to a course of 180° making 50 rpm, and the first shot was dropped at 1400 GMT (1100 ADT). At 1544 GMT the "shaft turns" were reduced to 30 rpm and the last charge was dropped at 2000 GMT.

Figure 6 shows the satellite fixes and adjusted navigation for the shot run, plotted on a Mercator projection at a scale of 32 inches per degree of longitude. All times are GMT and the number in parenthesis indicates the maximum altitude in degrees of the satellite pass. All fixes were accepted by the satellite computer to update the DR except the ones at 1550.6* and 1804.1. This was because they fell outside the 10°-80° altitude range considered acceptable for position update. Probably the major cause of error in satellite positioning of a moving receiver is a north-south error in SOA (Stansell, 1978). For satellite passes above 55°-60°, the longitude error increases rapidly for N-S errors in SOA. The MX-1102 had a one knot speed entered for the duration of the run and yielded a 1.89 knot SOA between the 1405.4 and 1515.4 fixes, and a 0.61 knot SOA between the 1738.6 and 1927.0 fixes. These speed errors could result in an error of 0.2-0.4 nautical miles in longitude while only slightly affecting the latitude. This error is, however, not easily separable because of the least squares fitting of residuals in the position computation; errors are distributed between latitude and longitude to produce an error ellipse.

Thus, the navigational adjustment consisted of (1) initiating the shot run between the 1330.3 and 1405.4 fixes to account for a wide turn made while coming from DIW to one knot (50 rpm); (2) accepting the 1515.4 and 1738.6 fixes; and (3) weighting the track between the 1927.0 and 1949.3 fixes, with extra weight going to the 1927.0 fix, which should have significantly less longitudinal error because of satellite pass elevation. The result is a straight course of 195° from initiation (1400 GMT) to the 1544 GMT speed change, and a straight course of 200.5° from the speed change to the termination of the run at 2000 GMT. The first leg had an estimated SOA of 1.88 knots, the second leg had an estimated SOA of 0.70 knots. The apparent 5° course change at 1544 GMT results from the speed change which altered the drift. Table 3 lists the positions of the VEDABS array and satellite fixes taken during the shot run. Table 4 lists the times of shots in the water, charge size, times the shot was heard aboard ship, and the approximate range from each shot to the VEDABS array.

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*NOTE: The numeral to the right of the decimal is time past the minute rounded to the nearest tenth minute.

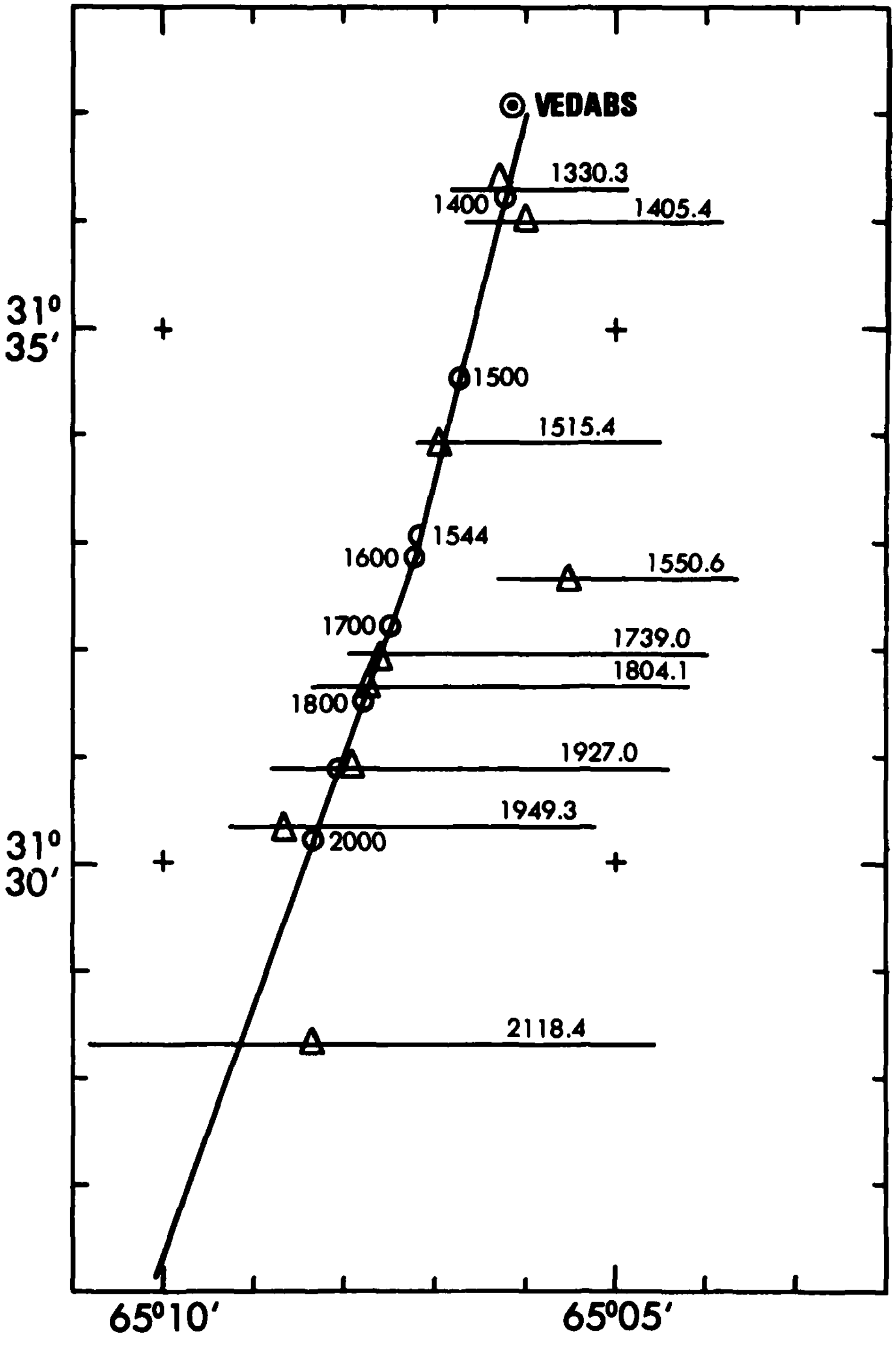

Figure 6. Navigational track of explosive shot run

Table 3. VEDABS and Satellite Positions Associated with Shot Run

Time/ Place	Latitude	Longitude	Satellite Elevation/Iteration/Dopplers
VEDABS*	31°-37.1'	65°-06.3'	
1330:28	31°-36.30'	65°-06.26'	40/2/33
1405:39	31°-36.53'	65°-05.94'	12/2/24
1515:39	31°-33.96'	65°-06.93'	21/2/28
1550:57	31°-32.67'	65°-05.54'	81/3/28
1738:57	31°-31.90'	65°-07.60'	53/2/34
1804:14	31°-31.63'	65°-07.81'	6/2/20
1927:04	31°-30.89'	65°-07.91'	22/2/33
1949:32	31°-30.68'	65°-08.66'	63/2/34
2118:42	31°-28.33'	65°-08.41'	10/2/19

*NOTE: The position of the VEDABS array is based upon repeated DR and satellite positions taken during the operation.

Table 4. Shooting schedule, detonation times (determined by ear from shooting ship), water depth (at time of drop), and range from VEDABS array (estimated from navigation)

Shot No.	Drop Time (GMT)	Charge Weight (lbs)	Detonation Time (GMT)	Water Depth Sonic/Corrected (m)	Range to VEDABS (km)
1	1400	55	1440:53	4528/4566	1.6
2	1415	55	1453:28	4528/4566	2.3
3	1430	55	1507:34	4528/4566	3.1
4	1445	55	1524:41	4526/4564	3.9
5	1500	110	1540:52	4524/4562	4.8
6	1515	110	1553:34	4521/4559	5.6
7	1530	110	1609:57	4519/4557	6.4
8	1545	110	1624:33	4511/4549	7.1
9	1600	110	1640:05	4509/4547	7.9
10	1615	110	1654:27	4506/4544	8.2
11	1630	110	1706:17	4506/4544	8.6
12	1645	110	1727:15	4506/4544	8.9
13	1700	110	DUD	4506/4544	9.2
14	1715	110	1755:40	4506/4544	9.4
15	1730	110	1809:45	4506/4544	9.8
16	1745	110	1825:33	4506/4544	10.2
17	1800	110	1840:41	4506/4544	10.5
18	1815	110	1856:38	4504/4542	10.9
19	1830	110	1910:43	4504/4542	11.1
20	1845	110	1926:32	4504/4542	11.4
21	1900	110	1941:58	4504/4542	11.8
22	1915	110	1955:55	4504/4542	12.1
23	1930	110	2010:58	4504/4542	12.4
24	1945	220	2017:17	4506/4544	12.7
25	2000	220	2032:19	4508/4546	13.1

VI. PROJECTOR TOW

On the evening of 18 September 1981 the R/V ERLINE, operated by the Tudor Hill Laboratory of the Naval Underwater Systems Center (NUSC), conducted a CW projector tow. The projector was a BTS9092, and is described in Table 5, which is quoted directly from Paragraph 5 and Table C-3 of Appendix C of SEAS (1981).

The tow commenced at 2315 GMT 18 September at a position of 31°-37.4'N and 65°-06.7'W, which is approximately 0.9 kilometers northwest of the VEDABS V3 Site. ERLINE steamed due south at four knots for approximately seven hours towing the source. Figure 7 presents a navigational plot provided by Tudor Hill, and is based upon LORAN C navigation. Appendix A presents a copy of the relevant portion of the R/V ERLINE navigational log, which lists the LORAN rates and pertinent course and speed changes as well as the ON-OFF times of the projector. Also included from the log is a resistance reading in ohms (DEPTH-ohms) which can be used to determine the depth of the projector. Appendix A includes a depth-resistance plot with a linear fit for interpolation of the actual projector depth.

The projector tow was not the primary experimental objective; thus, a complete reconstruction of the tow is not presented. However, the necessary information for such a reconstruction is presented.

Table 5. BTS 9029 Projector Characteristics

The BTS 9029 projector is an omnidirectional CW sound source consisting of a Honeywell KX-90G and a Honeywell HX-29 sound source. Only one power transformer is used in the BTS 9029 and consequently only one of the sources, HX-90G or HX-29, can be operated at one time. Selection of which source is to be used is made on deck prior to deployment. Switching between the HX-90G and HX-29 when deployed is not possible. The BTS 9029 tow body utilizes the nose and tail sections of a MK35 torpedo. Operational parameters of the BTS 9029 are presented in Table C-3.

The BTS 9029 system was fully calibrated in May 1981 and the calibration subsequently reported by NUSC.

	HX-90G	HX290
Number of Bars		6
Resonant Frequency, f_r	325 Hz	165 Hz
Source Level at f_r dB//μPa	195	186
Maximum Operating Depth*	1400 ft	700 ft
Maximum Tow Speed#	4.5 knots	4.5 knots
Active Body Dimensions		
Length	20 in	23 in
Diameter	20 in	10 in
Weight in Air	400 lbs	176 lbs
Weight of Tow Body and Transformer	~625 lbs	
Length of Tow Body	~8 ft	

*Operational depth will be more nearly 300 feet.
#Maximum tow speed increases with decreasing depth.

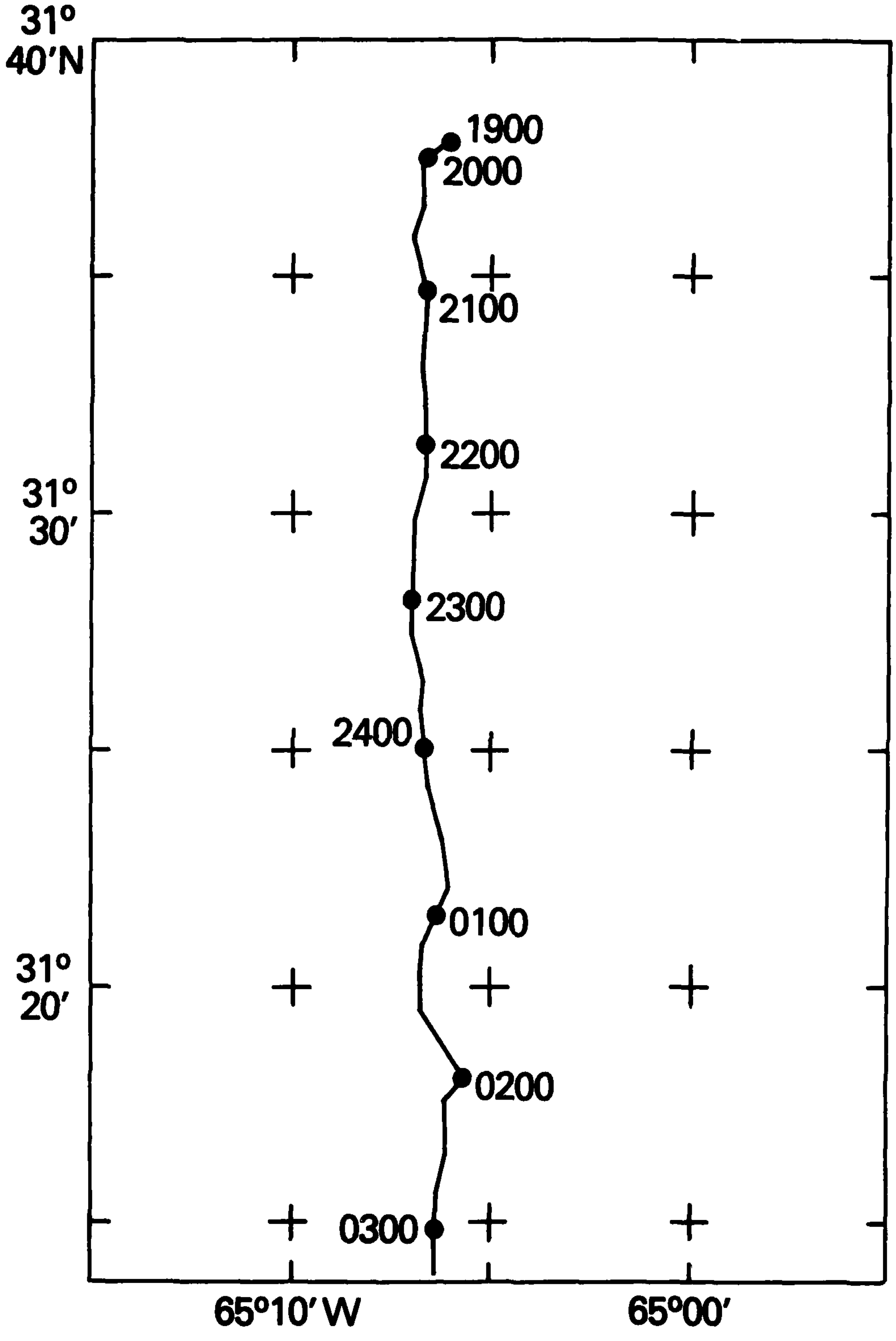

Figure 7. ERLINE HX 2990 tow track, 18-19 Sept 1981

VII. OCEANOGRAPHIC SUMMARY

Between 0245 GMT and 0545 GMT 18 September, a deep SV/STD cast was taken using the ship's equipment (Bissett-Burman, Inc.). The corrected cast depth was 4432 m according to instrument output, and the sonic depth of the bottom was 4409 m, which, when corrected with the integrated velocity profile, is 4446 m. The sound speed sensor was yielding erratic readings averaging 100 m/s too low for sea water of 27.5°C. The other sensors seemed to be functioning properly. Table 6 tabulates a series of "computed" sound speed values automatically determined from temperature, salinity and depth by the system. These values are plotted in Figure 8. To verify that conditions did not change appreciably during the operation, expendable bathythermographs (XBT's) were dropped. Figure 9 and Table 7 present the results of a 1200 GMT XBT taken 18 September, soon after the beginning of the shot run. During the experiment, the weather remained fair and unchanged, with scattered clouds and a less than five knot wind out of the southwest.

Table 6. Sound speed versus depth from SV/STD cast at 31°-37.1'N 65°-03.2'W

Sound Speed Depth (m)	Sound Speed (m/s)	Depth (m)	Sound Speed (m/s)
0.1	1542.1	1101.5	1492.3
5.2	1541.8	1203.4	1491.8
10.4	1541.2	1279.9*	1491.2
15.2	1541.7	1298.2	1491.5
20.0+	1540.5	1402.0	1491.9
24.8	1534.6	1500.2	1492.8
30.4	1531.9	1747.2	1495.7
39.6	1528.9	1998.2	1498.8
50.0	1528.7	2248.6	1502.3
74.8	1524.6	2498.1	1505.4
101.2	1523.2	2748.6	1508.8
124.5	1521.9	3000.2	1512.1
149.3	1521.6	3251.5	1515.6
199.1	1521.4	3501.1	1519.4
249.5	1521.6	3749.2	1523.5
299.6	1522.1	3996.9	1527.9
349.7	1522.4	4248.2	1532.4
399.9	1522.5	4432.0#	1535.8
450.0	1522.0		
500.5	1520.5		
550.5	1517.7		
599.4	1515.2		
650.8	1512.8		
699.6	1509.6		
750.8	1506.0		
800.3	1502.8		
900.1	1497.3		
999.7	1493.5		

+ Layer depth
* Sound channel axis
# Bottom of cast

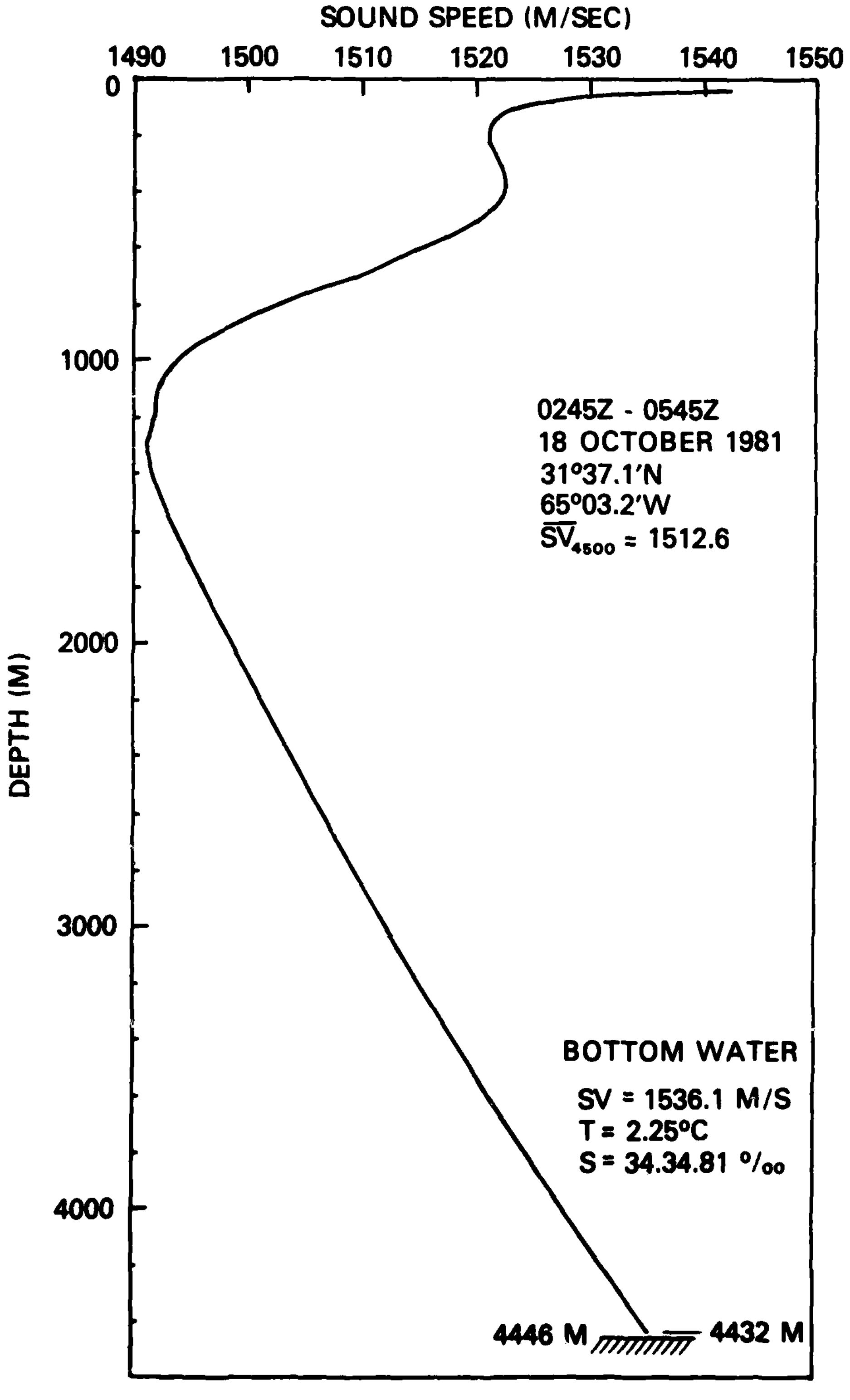

Figure 8. Water column sound speed versus depth

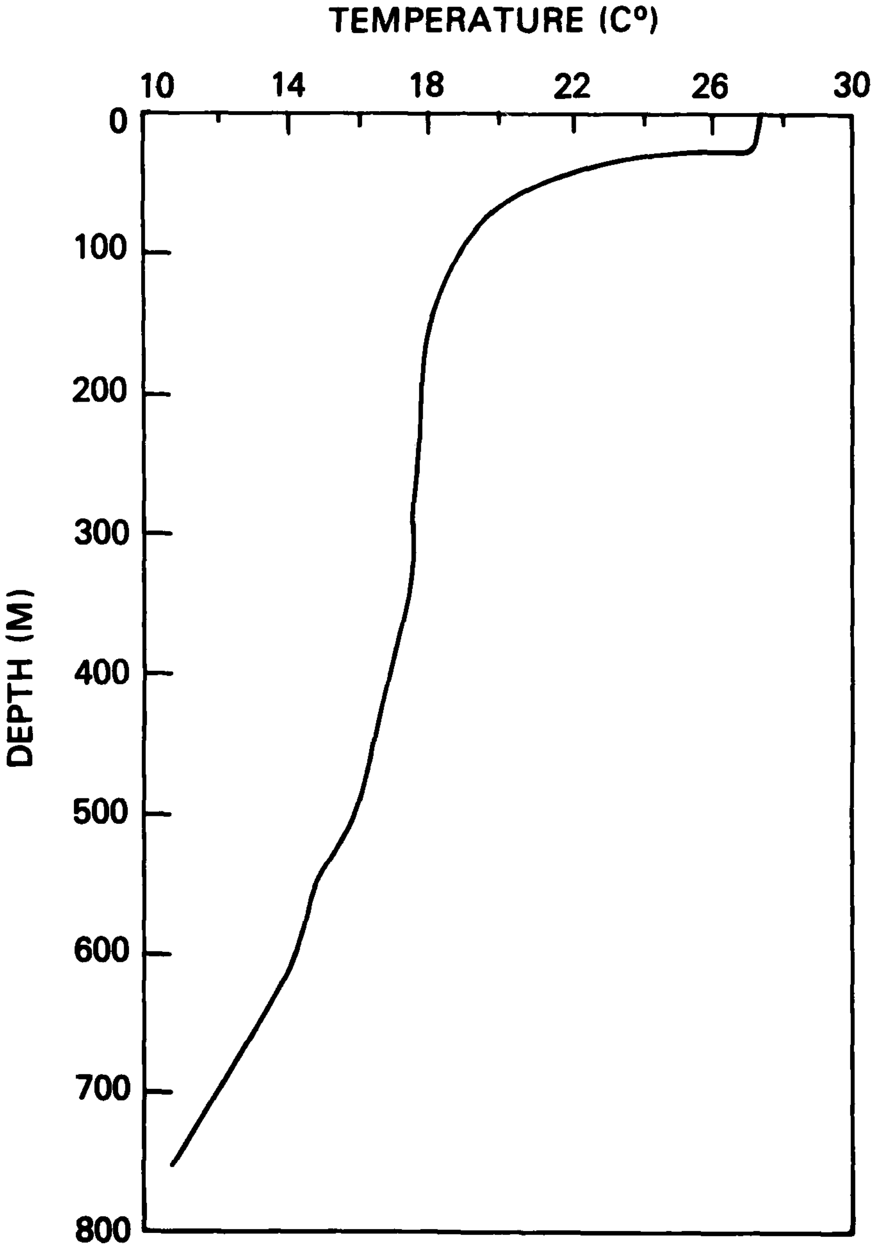

Figure 9. Temperature versus depth from XBT drop taken during experiment

Table 7. Temperature-depth points picked from 1200Z XBT of 18 September

Depth (m)	Temperature (C°)
0.	27.5
24.	27.3
30.	24.0
40.	22.0
50.	21.0
75.	19.5
100.	19.0
150.	18.1
200.	17.9
250.	17.8
300.	17.6
350.	17.5
400.	17.0
450.	16.5
500.	16.0
550.	14.9
600.	14.3
650.	13.2
700.	12.0
750.	10.8

Figure 8 shows a small sound channel with an axis at approximately 200 m depth, and a large, well-developed sound channel (typical of deep oceanic regions) with an axis depth of approximately 1280 m. This is a rather typical velocity structure for the vicinity of Bermuda during late summer, and has been documented in the literature (Worthington, 1959). The temperature plot of Figure 9 explains this velocity structure. During the winter season, cooling and storm activity in the Sargasso Sea form a near surface mixed layer of 18°C water which extends to depths of 300 m. During the summer season, the layer persists, but its upper portion is warmed. Thus, during late summer there commonly exists a shallow isothermal layer (20-28 m thick based upon XBT's during this three-day experiment) below which is a seasonal thermocline between the surface layer (27.5°C and 36.95‰ salinity) and the residual isothermal layer from the winter season. Below approximately 300 m is the permanent thermocline to the sound channel axis at approximately 1280 m. Below this depth the temperature stabilizes at a near constant temperature with a bottom temperature (in deep water) of 2.25°C (34.81‰ salinity.)

On 19 September, during and after recovery of VEDABS, the winds began to increase and the surface isothermal layer thickened to 28 m as determined by XBT drops.

VIII. GEOLOGICAL/GEOPHYSICAL SUMMARY AND GEOACOUSTIC MODEL

The seismic stratigraphy and its interpretation of the area around the V-3 site has been described in detail by Bowles (1980). Approximately 1.0-1.5 seconds (two-way time) of transparent and/or acoustically stratified material overlies an acoustic basement. Within this interval is a prominent reflecting horizon, which has been designated A to distinguish it from the broadly distributed (and similar)

North Atlantic Horizon A. Correlation with lithologies cored in the nearby DSDP hole 386 (31°-11.2'N, 64°-14.9'W) indicate that Horizon A^V is a sequence of volcanogenic turbidites of late Eocene to middle Oligocene age.

Below A^V is a sequence termed by Bowles, as the "lower stratified layer." DSDP data indicate this layer probably consists of siliceous and carbonate turbidites. The carbonate material was probably redeposited from local topographic highs, while the siliceous material has been postulated to represent remnants of an abyssal plain which predates the uplift of the Bermuda Rise (Ewing et al., 1969).

Above A^V is a layer of relatively transparent material approximately 0.5-0.6 seconds thick. This uppermost layer is interpreted to be rather uniform pelagic carbonate sediment. Near the Bermuda pedestal are sporadic occurrences of layering on the seismic records. These are interpreted as local turbidity deposits derived from the pelagic carbonate sediments on the Bermuda pedestal. Although not all of the transducer elements on BARTLETT were working, the 3.5 kHz record shows weak stratification indicative of sediment layering. Weak stratification of this type on seismic records, however, is common in pelagic carbonate sediments, and does not necessarily imply turbidite layers.

Johnson et al. (1978) have estimated the compressional wave velocity functions for pelagic carbonate sediments in the Pacific Ocean. Their regression equations for instantaneous (Vi) and mean ($\overline{V}$) velocity versus one-way travel time are:

$$Vi = 1.56 + 2.97t$$
$$\overline{V} = 1.56 + 1.49t$$

and the velocity-depth regression equation is:

$$V(z) = 1.56 + 1.40z$$

Houtz (1980) summarized North Atlantic seismic interval velocities and found a 2.0 km/s average for Bermuda Rise sediment of less than 1.0 sec thickness. This velocity would correspond to only a 0.30 sec sediment thickness according to the above mean velocity equation. Houtz averaged 27 interval velocities, but did not list the actual velocities or thickness of his data. DSDP hole 386 penetrated to basalt and cored almost continuously. Correlation of cored depths with seismic reflection records yielded the following interval velocities:

Table 8. Seismic interval velocities

Layer	Depth (m)	Velocity (km/s)
Upper Stratified Layer	0	
		1.74
Horizon A^V	156	
		1.94
	320	
		1.75
Lower	408	
Stratified Layer		1.91
	630	
		1.92
	964	
basalt		

These values are similar to those of DSDP hole 387 to the west. The measured core velocities of these holes were highly variable, which is indicative of interbedded ooze and chalk. Based upon the Houtz and DSDP data it is felt that the Johnson regression equations probably predict velocities too high for the Bermuda Rise carbonate sediments. However, in the absence of specific velocity-depth functions for this region, the above function of Johnson et al. (1978) is suggested.

An initial velocity (Vo) was determined by averaging measured core velocities (unpublished NAVOCEANO data) corrected to <u>in situ</u>, from the top meter of six nearby gravity cores. This yielded 1501.7 m/s which was substituted for the higher (1560.0 m/s) value of the Johnson equation. Other geoacoustic parameters can be estimated from this modified velocity-depth equation in the manner of Hamilton (1980). These procedures were used to construct the regional geoacoustic model presented in Table 10. The footnotes to the table reference the origin of each parameter and its variation with depth below the sea floor.

Table 9. Geoacoustic model for a thick carbonate sequence based upon Hamilton (1980)

Layer Material	Depth (m)	Velocity Vp(1)	(m/s) Vs(2)	Attenuation kp(3)	ks(4)	Density (g/cc)(5)
Sea Surface	---------	----------	--------	--------	--------	------------
Bottom Water	4500.	1459.				1.037
Sea Floor	---------	----------	--------	--------	--------	------------
Carbonate Sediment	0	1502.	77.	.0045	15.0	1.51
	25	1537.	212.	.0060	20.0	1.55
	50	1572.	302.	.0075	25.0	1.59
	75	1607.	342.	.0090	30.0	1.63
	100	1642.	382.	.0110	36.7	1.67
	150	1712.	424.	.0130	43.3	1.75
	200	1782.	459.	.0150	50.0	1.83
	250	1852.	499.	.0170	56.7	1.91
	300	1922.	544.	.0190	63.3	1.99
	400	2062.	647.	.0190	63.3	2.09
	500	2202.	733.	.0160	53.3	2.16
	600	2342.	780.	.0123	41.0	2.21
	700	2482.	827.	.0106	35.3	2.24
	800	2622.	873.	.0105	35.0	2.27
	1000	2902.	966.	.0105	35.0	2.30

(1) Vp - Compressional wave velocities were computed from the equation

$$V_p = 1.502 + 1.40z$$

which is modified from Johnson et al. (1978), as stated in the text.

(2) Vs - Shear wave velocities were computed from the below equations taken from Hamilton (1980).

$$\begin{array}{ll} Vs = 3.884\ Vp - 5.757 & 1.512 < Vp \leq 1.555 \\ Vs = 1.137\ Vp - 1.485 & 1.555 < Vp \leq 1.650 \\ Vs = 0.78\ \ Vp - 0.962 & 1.650 < Vp \leq 2.150 \end{array}$$

The last equation yields a Vs/Vp ratio of 0.333 for Vp = 2.150, this ratio was held constant for all higher Vp velocities.

(3) kp - Compressional wave attenuation constant was scaled from the "low" attenuation profile (Mitchell and Focke, 1980).

(4) ks - Shear wave attenuation constant starts with an initial value of ks=15.0 at z=0, and varies with depth as a proportion to the compressional wave attenuation in the manner of Hamilton (1980).

$$ks(z) = 15.0 kp(z)/kp(z=0)$$

(5) ρ-Sediment bulk density was computed from the compressional wave velocity by the equation

$$\rho = 1.135Vp - .19$$

where Vp is the compressional wave velocity in km/s after Hamilton (1978). For the density of limestone however he recommends using the equation shown below.

$$\rho = 2.351 - 7.497\ Vp^{-4.656}$$

In the present case, the first equation was used until the two functions crossed at a depth of 300 m, the second equation was then used for the deeper estimates.

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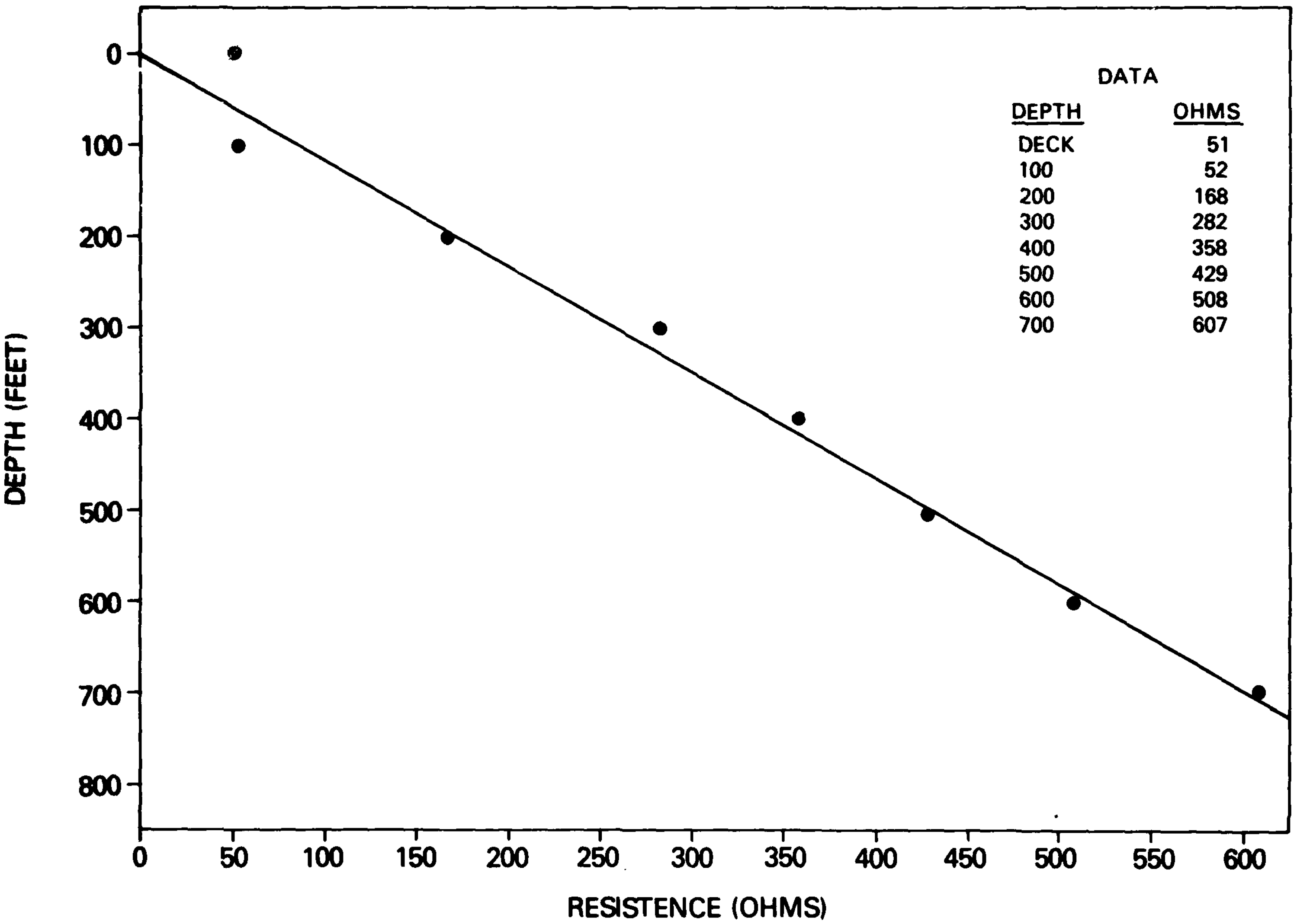
APPENDIX - R/V ERLINE Navigational Log and BTS9092 Projector Depth-Resistance Curve

TIME LOCAL	WHISKEY	YANKEE	DEPTH-ohms	COURSE, SPEED, REMARKS
1625	14044.6	41075.1		c/s 195°T 11.5 knots
1723	14069.6	41027.5		
1834	14100.6	40969.1		
1846	14106.6	40957.8		c/s 195°T 11.5 knots Bartlett D/A 13.3 nm
1855	14109.9	40951.9		
1857				on station
1900	14110.4	40951.1		XBT launched
1913	14110.5	40951.1	365 482	HX2990 down 600 ft HX2990 down 650 ft sonar reads 142 meters
2000			254	Comex 180°T 4 knots
2015	14112.3	40948.8		finish event sequencer programming signal levels 166.67 Hz, + 30 dBV 333.33 Hz, + 30 dBV 475 Hz, + 30 dBV
2030	14113.2	40946.1		
2045	14114.7	40943.4		
2100	14115.2	40940.3	254	10 nm North of USNS BARTLETT
2130	14117.3	40935.2		USNS BARTLETT 7.4 nm 183°T
2145	14118.1	40932.4		event sequencer clock fast by 10 minutes
2200	14119.0	40929.9	264	USNS BARTLETT 3.0 nm 300°T reset event sequencer clock
2210	14119.7	40928.0		change course to 185°T
2230	14121.4	40924.7	269	USNS BARTLETT 4.45 nm 240°T
2245	14122.5	40922.0		
2300	14123.7	40918.8	269	USNS BARTLETT 8.35 nm 230°T
2315	14124.5	40916.6		
2330	14125.0	40914.0		XBT launched
2345	1415.8	40912.0		
2400	14126.5	40909.5	275	USNS BARTLETT 15.0 nm 230°T
0015	14127.3	40906.9		
0030	14127.6	40904.5	274	course 185°T
0033				source off-problem with event sequencer
0045	14128.4	40901.4		
0058				source off
0100	14129.7	40899.1		
0103				source on

TIME LOCAL	WHISKEY	YANKEE	DEPTH-ohms	COURSE, SPEED, REMARKS
0115	14131.3	40896.5	277	
0120				course 180°T
0130	14132.2	40894.3	275	
0145	14132.9	40892.1		
1052				noticed source off
0153			275	source back on
0200	14132.0	40889.6		
0215	14133.6	40887.4	274	
0220				course 185°T
0230	14134.7	40884.1		
0242				source off - turned back on
0245	14136.3	40881.0		
0255-0302				source off
0303	14137.6	40877.7	272	
0315	14138.4	40875.5		
0330	14139.8	40873.0	270	Finex-secure source
0340				XBT launched
0600	14113.9	40932.0		underway toward USNS BARTLETT
0630	14110.9	40941.2		
0700	14108.2	40951.9		underway toward Annex

CALIBRATION OF HX 2990 DEPTH SENSOR SEPTEMBER 1981



DATA

DEPTH	OHMS
DECK	51
100	52
200	168
300	282
400	358
500	429
600	508
700	607

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During September 1981, a vertical array of eight hydrophones (VEDABS) was moored in deep water to the south of the island of Bermuda for engineering tests. While the array was in the water, a series of deep, large, explosive charges were detonated and acoustic projector towed on a radial away from the array. This report documents the generalized experimental design, array characteristics, and operational aspects of the experiment.

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