Mar 22, 1988

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RESEARCH CRUISE REPORT

R/V ROBERT D. CONRAD 28-10

Attached is a copy of a cruise report for the above CONRAD cruise.

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CRUISE REPORT

RC 28-10

BLAKE-SPUR FRACTURE ZONE TWO-SHIP MCS EXPERIMENT

RV CONRAD AND RRS DISCOVERY

NOV/DEC 1987

CO-CHIEF SCIENTISTS

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1. Cruise Objectives

During the ONR-sponsored North Atlantic Transect experiment in 1979 a remarkable two-ship, wide aperture multichannel seismic reflection profile (NAT Line 15) was collected across 115-165 my old crust in the western North Atlantic about 500 km southwest of Bermuda (NAT Study Group, 1985; see Fig. 1). This profile, oriented obliquely (10-25^{o}) to the spreading direction, crossed several small fracture zones including the Blake-Spur fracture zone (BSFZ). The resulting seismic reflection data provide a unique image of the structure of oceanic crust including very continuous Moho reflections, steeply dipping, lower crustal reflections, and a shallow subhorizontal reflector about 1 sec below igneous basement (Fig. 2). The origin of these reflectors and their geological significance remain controversial. Mutter et al. (1985) related variations in crustal thickness and intracrustal reflectors along this profile to the presence of small-offset fracture zones. The strong shallow reflector beneath the BSFZ was interpreted by Mutter, Detrick et al. (1984) as Moho, suggesting anomalously thin crust is present beneath this small-offset fracture zone. McCarthy et al. (in press) have interpreted the steeply dipping lower crustal reflections as cumulate layering indicative of a relic magma chamber and argue that the crust may actually thicken beneath the BSFZ.

The interpretation of NAT Line 15 is hampered by the lack of good control on the seismic velocity structure and the one-dimensional perspective on variations in crustal structure provided by a single profile. To address these problems and improve our understanding of oceanic crustal structure in the western North Atlantic, L-DGO, URI and Cambridge University, with support from the U.S. Office of Naval Research and the N.E.R.C. in the U.K., carried out a two-ship multichannel seismic experiment in the Blake-Spur area in Nov.-Dec. 1987. The objectives of this experiment were to: (1) use the two-ship Expanding Spread Profile (ESP) technique to determine variations in crustal and upper mantle velocity over the BSFZ and the adjacent crust, and (2) use CDP and wide aperture profiling techniques and observed free-air gravity anomalies to map the three-dimensional variation in crustal structure along and across the ribbon of crust bordering the BSFZ.

2. Experimental techniques and equipment

The two ships participating in this experiment were the R/V ROBERT D. CONRAD of L-DGO and the RRS DISCOVERY of Cambridge University. Both ships were equipped with multichannel seismic systems. Although DISCOVERY recorded some CDP and wide aperture reflection data, it was primarily used to record data for the ESP experiments.

CONRAD served as the shooting ship during the ESPs and simultaneously recorded CDP reflection data. The ESPs were typically shot out to ranges of >60 km and were usually recorded on both the inbound and outbound legs, effectively resulting in two experiments on each profile. After the completion of the two-ship work, CONRAD remained in the survey area and collected about 1500 km of additional single ship CDP reflection data. CONRAD was equipped with a 3-km-long, 240-channel digital streamer and a 10-gun, 6000 cu.in. airgun source array. This was the first leg on which the new Digicon DSS-240 digital streamer and seismic acquisition system were used, although the equipment had been tested on a short shakedown cruise (RC 25-09) immediately prior to this leg. Two new Price 300 scfm compressors were also installed on the ship as part of this system upgrade.

The airgun source array employed in this experiment has been described by Diebold (1987) and is shown in Figure 3. It consists of 10 guns which are deployed in two subarrays. Eight of the guns are towed from two 60 ft (~18 m) truss-style booms that are swung out by two 4-in. rams. The remaining two guns (#5 and 6) are towed from trolleys extending aft of the main boom stanchions. The airguns are Bolt Associates 1500-Cs and are nominally fired at 2000 psi at a depth of about 30 ft. (10 m). On the ESP profiles shot during this leg the array configuration shown in Fig. 3 was employed. Chamber sizes ranged from 365 cu.in. to 825 cu.in. with a total array volume of 5821 cu.in. (96 L) which was fired on a 40 sec cycle. During single ship CDP profiling the two largest guns in this array (#5 and 6) were replaced with smaller chambers (260 cu.in. and 350 cu.in., respectively) resulting in a total array volume of 4846 cu.in. which was typically fired every 22 sec (CDP lines 103, 109 and 110 were shot with a 30 sec pop rate).

The DSS-240 receiving system used on this leg was recently acquired by L-DGO from the ARCO Resolution. The receiving array consists of a 3-km-long digital streamer with 240-channels and 12.5 m group lengths. The array configuration is shown in Figure 4. It consists of a 100-m armored lead-in cable, two 100-m inactive sections, a 50-m stretch section and sixty 50-m active sections each consisting of four 12.5-m groups. Electronically controllable birds and depth indicators were located on every fourth section and four 4-m compass sections were positioned along the array. The streamer was typically towed at a depth of about 30 ft. (10 m). The seismic data were recorded on high-density (6250 bpi) tape with a 4-ms sampling interval in SEG-Y format. A record length of 15-sec was used on the CDP reflection profiles recorded by CONRAD during the ESPs and on the wide aperture profile (WACDP 1); otherwise a 12-sec record length was used.

For the two-ship work, CONRAD was equipped with the Miniranger and Raydist ranging systems, as well as a Trisponder ranging system provided by Discovery. The antenna geometry relative to the CONRAD airguns and first active streamer section are shown in Fig. 4. Ranging information was recorded on the logger tapes along with course and speed information, and Transit and GPS satellite fixes. Gravity (BGM-3 gravimeter) and magnetics were also routinely recorded throughout the leg. During the ESPs CONRAD shots were received on DISCOVERY's 2.4-km, 48-channel streamer. The ESP data were recorded at 4-msec with a 38-sec record length. DISCOVERY also recorded four CDP reflection profiles (lines 101, 102, 104 and 106) as well as the intermediate-range offsets on the wide aperture profile WACDP 1. For more details on the DISCOVERY multichannel seismic system see the DISCOVERY cruise report.

3. Summary of Experiment

Figure 5 shows a track chart of the single-ship and two-ship MCS data acquired during the 1987 Blake-Spur experiment. In the 19 days spent on-site, a total of 18 ESPs were obtained (including one, ESP 5, which was shot twice) and over 3000 km of single ship CDP reflection data. Conrad alone fired 55,555 shots and recorded 999 magnetic tapes worth of data. The monitor records suggest that, in general, the data quality is extremely good and we have every reason to believe that we have obtained an outstanding data set to address the problems outlined above.

Eight closely-spaced ESPs were shot along and immediately adjacent to the BSFZ (ESPs 1-7, 13) in order to constrain the variations in crustal structure across this small-offset fracture zone (Fig. 6). We attempted to position ESPs 1 and 2 on normal crust immediately south of the fracture zone, ESP 3 in the southern fracture zone trough, ESPs 4 and 13 on the fracture zone ridge, ESP 5 in the northern fracture zone trough, and ESPs 6 and 7 on normal crust immediately north of the fracture zone. This plan was based on the assumption that the fracture zone would have a relatively simple basement expression similar to that shown on NAT Line 15. We found, however, that the basement topography associated with the BSFZ varies significantly along-strike and the tectonic setting of the ESPs described above will have to be re-examined after a careful synthesis and correlation of all of the CDP reflection profiles collected in this area. Poor weather also hampered operations during the shooting of several of these ESPs. Five somewhat more widely-spaced ESPs (8-12) were shot parallel to the BSFZ on "normal" oceanic crust north of the fracture zone. These ESPs were designed to constrain variations in crustal structure across a ribbon of crust bounded by two fracture zones. The variations in basement topography observed on WACDP 1, shot through the mid-points of these ESPs, suggests there might be a small, previously unmapped fracture zone near the location of ESP 9 (Fig. 6). A careful examination of the magnetics collected during the survey should be able to verify this. The remaining five ESPs obtained on this leg (ESPs 14-18) were shot along isochrons between anomalies M16 and M25 and were designed primarily to investigate age-dependent variations in crustal structure. Two of these ESPs (17 an 18) were specifically located in areas where NAT Line 15 had suggested the presence of prominent intra-crustal reflections (Fig. 2).

Over 3000 km of 240-channel CDP reflection data were acquired by CONRAD during this experiment providing an unprecedented data set with which to examine the three-dimensional structural variability of oceanic crust. Ten new reflection profiles were obtained across the BSFZ, including three long 150-km profiles (WACDP 1, CDP lines 119 and 121) that extend across the entire ribbon of crust from the Blake-Spur to the unnamed fracture zone to the north. In addition to these profiles, two 250-km-long CDP reflection lines were obtained along a flow line on normal crust north of the Blake-Spur covering crust ranging in age form 140-153 my. Finally, 57 sonobuoys were deployed along the CDP and ESP profiles to provide additional constraints on the variations in crustal velocity structure.

4. Cruise Narrative

CONRAD sailed from Bermuda at 1600Z (1200L) on 11 Nov. 1987 and arrived in Miami on 5 Dec. 1987 at approximately 1300Z. In this section the operations on RC 28-10 are briefly summarized.

After leaving Bermuda, CONRAD headed at full steam for 29°N, 69°W. The main lab watch was begun at 1200Z on 12 Nov. (JD 316) and by evening we were recording gravity, magnetics, PDR and the data logger was running smoothly. DISCOVERY, which had left Bermuda at 1400Z on the 10th, planned to shoot CDP lines 101 and 104 (see Fig. 5) to establish the location of the Blake-Spur fracture zone and proposed a rendezvous at 26.4°N and 69.01°W.

We began to deploy the streamer at about 1230Z on 13 Nov. (just after breakfast). A problem was found in a memory board of the DSS-240. After this problem was repaired, deployment went relatively slowly as several sections had to be topped up with oil, additional weight (~36 lbs) added to the front end of the streamer, and two cannisters and one compass section replaced. However, by 1930Z the streamer was in the water. Meanwhile, White had reported from DISCOVERY that they found the BSFZ surprisingly far north on line 101, possibly indicating a more easterly trend if the location of the NAT crossing is correct. We decide to shoot line 103 while DISCOVERY completed her work. Recording began at about 2100Z on the 13th, firing ~4000 cu.in. at 2000 psi every 30 sec using the two new compressors on the 01 deck. The two 01 deck compressors both experienced problems - one blew a head gasket, the other sucked air into its cooling system, both within a few hours of initial operation. Both problems were fixable although these compressors continued to have problems throughout the leg.

Although the fracture zone trough was apparent on line 103, no fracture zone ridge was observed. After speaking with White on DISCOVERY we decided to extend the reconnaissance survey to better constrain the fracture zone location. DISCOVERY shot line 104 north to about 27°36'N then turned east and shot south on line 102, while CONRAD ran west on line 109 to about 70° 27.5'W then south on line 110 (Fig. 5). This gave five crossings of the BSFZ to establish its location and trend. We also agreed to shift the midpoints of the fracture zone-parallel ESPs about five miles NW since the location of the BSFZ on line 101 appeared to be anomalous. This shifts the survey closer to the NAT line. The DSS-240 crashed twice on line 110, once due to a loss of ship's power. The streamer leader had to be pulled during this 15 min power outage because the ship slowed to a near stop. No fracture zone ridge was again seen on line 110. In general, the reconnaissance survey suggests that the BSFZ is located somewhat north (~10 km) of the position inferred from the magnetics, although it seems to have the same trend. The basement expression of the fracture zone appears to be quite variable along-strike ranging from the trough-ridge-trough morphology seen on NAT Line 15 (101, 104) to a broad trough with minor flanking highs (102, 103, 110).

Line 110 was completed at 1920Z on 14 Nov. and both ships moved into position to begin ESP 1 at 2300Z. This and subsequent ESPs were shot using the 5821 cu.in. airgun array shown in Fig. 3. Shooting interval was 40s; CONRAD initially recorded a 12 sec record, DISCOVERY a 38 sec record (CONRAD later switched to recording 15-sec records). After some initial confusion over shot synchronization, the first ESP proceeded fairly routinely. Some problems were experienced with the DSS-240 in switching between tape drives; at one point (0146-0157Z 15 Nov.) all three drives were down. The ship speeds were mismatched and the crossing point was displaced from the intended point. We were unable to communicate via VHF radio to DISCOVERY from the main lab; this problem existed for the entire leg and we had to rely on the bridge VHF radios on both ships for communication.

ESP 2 shooting began at 0930Z 15 Nov., the mid-point was at 1315Z and the last shot was fired at 1800Z. This ESP generally went well although CONRAD was at one point almost 2 nm north of the intended line. Again there was a large differential in ship's speed. Routine launching of sonobuoys by both ships on the inbound leg began on this ESP.

ESP 3 shooting began at 1937Z 15 Nov. after some confusion over the start time. The ESP went fairly routinely, although more tape drive problems were experienced near the end of line (after 0124Z 16 Nov.). At 0131Z 11 shots were missed; no tape 107 or 108. The symptom is many "read after write" errors which become so frequent that the DSS-240 eventually crashes. After some experimentation, the problem was eventually solved by routine cleaning of the tape heads after every tape change. By the end of ESP 3 the seas were becoming quite heavy with winds in excess of 30 kts.

ESP 4 did not start off well. On approach to the start of the line a major DSS-240 problem was found suggesting errors in the memory buffer where the data is temporarily stored prior to being written to tape. Jim Smith checked out the problem, but the diagnostics gave unfamiliar error messages. The system was eventually rebooted, but only after we were already 48 min down the line. As we approached the mid-point DISCOVERY informed us that they were almost one hour late getting to their start point. The mid-point was therefore shifted to the west and the line shot out to 0301Z 16 Nov. The record length was increased to 15 sec on this and all subsequent ESPs to record sonobuoys to the maximum range possible. The weather continued to worsen and the data quality recorded by both ships deteriorated.

ESP 5 shooting began routinely at 1442Z 16 Nov., but shortly after beginning the line DISCOVERY reported that it had lost 39 of its 96 groups due to an open circuit in their stretch section (caused by towing the streamer too fast in heavy weather). We agreed to break off the line after the midpoint at 1901Z so they could carry out repairs. Meanwhile, Jim Smith continued to investigate the memory buffer problems in the DSS-240. He was still unable to isolate the problem, although Digicon advises that since good data is seen on the SCS monitor and the galvanometer camera it is "likely" the data is being recorded ok. ESP 5 was restarted at 0403Z 17 Nov. as both ships shot the outbound leg of the profile. Heavy seas and 25-30 kt winds cause problems on both ships; it is difficult to maintain a constant speed and the streamer fluctuates wildly in depth. This is a very marginal ESP which was subsequently reshot (ESP 5A).

ESP 6 began at 1126Z 17 Nov. and was fairly routine except for a brief failure of the steering motor on CONRAD at 1525Z. The ship changed heading by 150° before corrective measures were taken and it was 1536Z before the ship was back on course. The maggy was turned off for a short period during this time. ESP 6 was completed at 1919Z 17 Nov. During the transits between ESPs the DSS-240 was taken down to run diagnostics. Only one of the two input buffers was working which could create a problem for normal CDP profiling since the shot cycle time is too short for the buffer to be flushed.

ESPs 7-11 were collected under steadily improving weather conditions and were relatively routine. At the ESP 8 midpoint DISCOVERY nearly ran over our tailbuoy after a close (~0.2 nm) crossing. This was apparently because the ships were not on reciprocal courses during the crossing. Better communication between the bridges on subsequent ESPs resulted in close crossings (~.3-.4 nm) without incidents of this kind. Sporadic problems continued with the Telex tape drives, especially when changing tapes. Jim Smith found some chafed and crimped wires on one input buffer board and with them repaired the system was able to operate with two input buffers. On ESP 7 the magnetometer readings were very noisy and the data may be unreliable.

DISCOVERY had a major problem with their seismic recording system on ESP 12 and it was not properly recorded. On the inbound shooting leg they recorded only a single channel analogue monitor record. Although we originally planned to break off this line at the midpoint, they were able to get one tape drive working and so they recorded the outbound shooting leg, missing about 7 shots at each tape change. They later found the problem was with a tape with an EOF mark about 8' into the tape - the recording system was ok.

After completing ESP 12 at 1622Z on 20 Nov., the two ships formed up to shoot a wide aperture profile (WACDP 1 in Fig. 5) through the midpoints of ESPs 1-12. For this profile DISCOVERY was the lead ship with CONRAD maintaining a ship-to-ship separation of 5800 m. With this geometry the first offset (CONRAD shooting and receiving) covers the ranges 0.32-3.32 km; the second offset (CONRAD shooting, DISCOVERY receiving) covers the ranges from 3.32 to 5.72 km; and the third offset (DISCOVERY shooting, CONRAD receiving) covers the ranges from 6.186-9.186 km. The gap between the 2nd and 3rd offsets is unavoidable and is equal to the sum of the gun-to-streamer separation of the two ships (466 m in this case). The ships shot alternatively every 40 sec and recorded 15-sec records during the wide aperture profile.

Recording for WACDP 1 began at 2336Z on 20 Nov. DISCOVERY had problems with wide power fluctuations in their main engine soon after the line started and again later along the line. As a result DISCOVERY broke off the wide aperture line at 2000Z on 21 Nov., about three hours before the end of the line. They later found the problem was due to the power drain of the air compressors on the main engine. CONRAD continued shooting this line as a normal CDP profile to the original endpoint, switching first to a 30-sec pop rate, then down to 20 sec. It was found that with the available compressors we could not fire a 5800 cu.in. array at 2000 psi every 20 sec. Thus the firing interval was increased back to 30 sec. In subsequent single ship CDP profiling we were forced to use a slightly smaller airgun array (~4800 cu.in.).

WACDP 1 proved to be an excellent profile with a well-defined BSFZ and evidence for two fracture zones to the north - one just north of ESP 12, and a second, previously unidentified fracture zone near ESP 9 (Fig. 6). Some intracrustal reflections were also seen on the single channel monitor record beneath the ridge that forms the southern part of the BSFZ. Because of the problems in shooting ESPs 3-6 we had not really sampled this crust. Thus we decided that our highest priority should be to reshoot ESP 5 (located in the trough of the BSFZ) and obtain a new ESP (13) between the ESPs 3 and 4 on the fracture zone ridge.

The reshoot of ESP 5 (called ESP 5A) began at 0550Z on 22 Nov. and was successfully completed by 1412Z. ESP 13 was also shot as planned. On ESP 13 a problem developed with the data logging system and navigation, Miniranger and Raydist data were not properly recorded on logger tape 9 (the data were, however, recorded on disk).

We next began a series of five ESPs north of the BSFZ oriented NE-SW, parallel to the magnetic lineations (see Fig. 5). To save time in starting ESP 14 CONRAD began shooting from south to north along the ESP line while DISCOVERY transited across to a point a few miles north of the intended midpoint. Thus only the outbound portion of the ESP was recorded by DISCOVERY, although CONRAD recorded a CDP line along the entire profile.

ESP 14 was completed at 1421Z on 23 Nov. and both ships steamed west to the endpoints of ESP 15. CONRAD recorded a CDP line (111) enroute. Because time was running short (DISCOVERY had to depart for Nassau late on Nov. 25), it was agreed to half-shoot both ESPs 15 and 16 and relocate 16 so as to be on CDP line 110 collected during our reconnaissance survey. ESP 15 was carried out as planned and completed at 0100Z 24 Nov. In transiting to ESP 16 CONRAD recorded a CDP profile (line 112) and we attempted to have DISCOVERY record the CONRAD shots while following a parallel course ~20 km to the north. This novel experiment did not work out too well since the DSS-240 was down for over 2 hrs at the end of ESP 15 and both ships were strongly set to the south by currents resulting in some major course adjustments enroute. This strong southward set also created a problem in shooting ESP 16 since the midpoint was shifted far south of its intended location. As we turned onto ESP 16 CONRAD also experienced a main engine failure at 0630Z 24 Nov. and we were on one engine at less than 3 kts for about one hour. DISCOVERY tried to match our slower speed, but the Captain requested we turn off the guns between 0655Z and 0729Z. Full power was restored at 0750Z near the crossing, however this ESP was not one of our best efforts.

After running a number of diagnostic tests and consulting with Digicon engineers, Jim Smith concluded that the problems associated with the DSS-240 appear to have affected only the auxiliary channels on which the sonobuoy and true-time signals have been recorded, not the seismic reflection data. The auxiliary channel data may be difficult, but not impossible, to recover. For the remainder of the leg only analogue (paper) sonobuoy records were recorded.

ESPs 17 and 18 were located along or near portions of NAT Line 15 that show well-developed intracrustal reflections (see Fig. 2). Both ESPs were shot without incident and ESP 18 was completed by 0000Z on the 26th. Rough seas prevented a rendezvous. The DISCOVERY recovered its gear and departed for Nassau, ending the very successful two-ship portion of our experiment.

At the end of ESP 18 we began recovery of the streamer to recharge batteries on the streamer birds and to replace a few bad sections and/or cannisters. The first compass section was moved to an active bird location and three cans were replaced including can 10 which appeared to have imploded during retrieval operations. On examination it showed several dents and scratches suggesting it had collided with something hard. Other evidence that the tail end of the streamer had collided with something were scratches and dents on several other cans and the damage sustained by the tailbuoy (it was found upside down with one fin broken off and the chain weight missing). Once the streamer was aboard it showed a failure either at can 63, the slip rings or in the leader - it turned out to be a problem with the slip ring seating. The re-deployment of the streamer began again about 0900Z on Thanksgiving morning and was completed by about 1400Z. It took a while to steam back to the midpoint of ESP 18 where CDP line 115 began at 1554Z. Later this same afternoon a lavish Thanksgiving dinner was enjoyed by all.

In the seven days of survey time left after the departure of DISCOVERY, our highest priority was to collect two long (~250 km) flowline profiles tieing ESP 18 to the main survey area and two 150-km-long profiles across the BSFZ along ESPs 14 and 15. All these lines were shot with a 4846 cu.in. airgun array firing every 22 sec. This array differs from the one used for the ESPs (Fig. 3) in that gun 5 is 260 cu.in. and gun 6 is a 350 cu.in. Twelve second records were recorded. Sonobuoys were deployed regularly along all of these profiles.

Line 115 was completed by 0520Z on 28 Nov. without experiencing any significant problems. Four successful sonobuoys (SB 38-41) were recorded along this profile. The northernmost part of line 116 was shot with a smaller volume airgun array while compressor maintenance was carried out. The full array was back on-line by 0657Z. Line 116 was completed by 1100Z on 28 Nov. and line 117 was started at 1111Z. At 1303Z, about 2 hours into this line, the system crashed with the diagnostics indicating a problem with can 55. On retrieving the streamer we found that section 56 was attached by only one of its three strain members (can 55 was ok). This section was replaced and the streamer was re-deployed and line 117 was resumed at 1516Z (called 117A). It seems likely that the incident on Nov. 25th that caused the damage to the tail end of the streamer and the tailbuoy may also have over-stressed this section that eventually broke three days later.

Line 117A was completed at 0134Z on Nov. 29th and we turned south on line 118 to obtain a crossing of the BSFZ between line 110 and NAT Line 15. This line had a basement structure that was quite unexpected with a major basement high (seamount?) at the northern end of the profile and no obvious topographic expression for the BSFZ.

Line 119, shot from south to north, was begun at 1339Z 29 Nov. This line was shot without incident and three excellent sonobuoys (SB 43, 44 and 46) were recorded. We turned onto line 120 at 0732Z on the 30th, doing some compressor maintenance just after the turn. The next long N-S profile, line 121, was begun at 1254Z. At 1522Z, less than three hours into this line, there was a failure of the data logging system. This was followed almost immediately by another failure of the steering motor at 1545Z. The acquisition system was brought down and the guns turned off as the ship swung through a broad 270^{o} turn to port. This brought the ship over our previous track, but fortunately the turn was broad enough that the tailbuoy had already passed. Line 121 (now called 121A) was resumed at 1830Z and was completed at 1420Z on Dec 1st without further incident.

With the completion of line 121 we ran on a northwesterly course, obliquely crossing the BSFZ, in order to tie in with line 117 and complete the southern flowline transect. No data was acquired for the first three hours on this track while compressor and airgun maintenance were carried out and a broken airgun tow cable was repaired. Recording on line 122 finally began at 1723Z 1 Dec and the line was completed by 2235Z.

We turned onto line 123, the western portion of the southern flowline transect, at 2343Z. Some problems were experienced with gun 6, but beyond that the line went smoothly. Four good sonobuoys (SB 52-55) were deployed. Line 123, and the Blake-Spur fracture zone experiment, were completed at 2309Z on Dec. 2nd with shot 55,555 which was recorded on tape 999. The streamer was recovered and on the way in one section was replaced that had sustained shark damage. Three additional compass sections (giving a total of seven) were added to the streamer. The tailbuoy (upside down again) was pulled aboard at 0453Z on the 3rd, and we got underway immediately for Miami. During this transit the PDR and gravimeter were run, but no magnetics were collected.

Conrad arrived in Miami, ending RC 28-10, at 1300Z on Saturday Dec. 5th.

5. Comments and Recommendations

The cruise was generally successful in achieving the objectives outlined above. Although it was not possible to arrange the schedules of the two research vessels to allow them to be together in the area for the entire duration of the experiment, sufficient time was available that our highest priority objectives were achieved. We took as our major task the collection of ESP data and were able to obtain 19 ESPs of which one is a re-shoot. This is about the total number we had hoped to collect. The principal compromise was that we were required to substantially reduce the amount of WACDP data collected. We had originally planned to obtain five lines crossing from the BSFZ to the fracture zone to the north plus one flow line profile in WACDP mode. As described above we were only able to obtain one line of WACDP data which was run through the mid-points of the main transect of ESPs 1 to 12. It is not possible, at this stage, to determine whether this has seriously compromised our science objectives.

The length of the cruise was extended from 22 to 24 days in order to incorporate time for shakedown of the new MCS equipment. This was done because it was not possible to conduct shakedown operations for the time period we had hoped between New York and Bermuda due to the requirement to meet DISCOVERY's scheduled port stay in Bermuda. The guns were never actually fired, and consequently it was not possible to test the DSS-240 data recording system during the shakedown leg. The shakedown work comprised final compressor installation, rigging of airguns, testing electronic components of the streamer, and balancing the streamer for towing at 40 feet depth. It is difficult to estimate how much time was lost during RC28-10 on work that could and should have been done on a shakedown leg. However, it certainly exceeds the 48 hours added to the leg. Unfortunately the shakedown-type problems that occurred on RC28-10 happened during the first two weeks when the equipment was being operated for the first time; that is, during two-ship operations. Time lost here could not be recovered due to DISCOVERY's requirement to leave the work area on 25 November. Had the equipment been thoroughly tested prior to RC28-10, the single ship lines 119 and 121 could have been collected as WACDP lines as planned.

By the end of the leg most systems were operating routinely. The following are a few recommendations that we feel would improve the operations and help obtain better quality data.

1) Streamer: Given that this was the streamer's first outing it performed extremely well. It proved somewhat difficult to balance during shakedown and presently cannot be towed above about 4.6 knots without bringing up the head of the streamer. A total of six cans were replaced, one due to implosion, the others from failure, and two sections were replaced both due to damage -- one from shark bites and the other from broken strain members. The latter apparently occurred on 25 November, at the same time the cannister imploded and several other cans were badly scraped and dented when the streamer apparently struck a submerged object (likely a wire line and/or chain) during retrieval. This rate of failure of cannisters and section damage is probably a little above what would normally be expected.

The present tailbuoy cannot be seen visually during daylight or on radar in even quite moderate seas. An active beacon should be attached to a sturdy mast on the tailbuoy to ensure that it can be easily located. This is necessary to ensure safe, close crossings at ESP midpoints, but also to help locate the streamer if it is lost. The tailbuoy is the primary means of locating a lost streamer -- a few thousand dollars invested in an active beacon is good insurance.

2) DSS-240: The system is now working normally and can be easily monitored by one watchstander, who can also take care of tape changes. The watchstanding staff can be reduced from six to three. The system does not support the recording of sonobuoys, but can do so with a modest upgrade available from Digicon. We recorded sonobuoys on paper only during the leg. Many were of excellent quality and would have made a fine digital data set if recording was possible. This upgrade should be made as soon as possible.

3) MCS display and "on-line" processing: The present system matches an advanced streamer and recording system with a graphic display capability that was unsuitable even for the DFS IV/analogue streamer

system. It is highly desirable that we develop a modest capability to read and process the data and display profiles at sea. Only the most basic data handling need be considered to begin with. The simple ability to filter, AGC and display a single channel monitor at a chosen scale would be quite an advance over the present system. A brute stack from a simple "geometric" gather should also be possible. We appreciate that the system to be installed by Dale Chayes in Miami is a first step in this direction though it is initially focussed more on the problem of quality control. This comment is made to re-iterate that the goal of achieving on-line display for science purposes should be retained with some priority.

4) "On-line" navigation: During this leg we were entirely dependent on the bridge for navigational data. Without Sea Beam running there is no display of track information in the lab. Again we appreciate that it is a goal of current system revisions to have a navigation reduction capability on-board, and that we are close to that objective. The more nearly "real time" this is, the better. Presumably the DR track could be displayed on-line in nearly real time while a reduced track having corrected navigation would be a day or so behind. Gravity and magnetics along track 24 hours after acquisition would have been extremely valuable during this leg.

5) Compressors and airguns: The new compressor proved far more troublesome than anticipated and a large investment in man hours was required to bring them into routine operational condition by the end of the leg. Jay Ardai has prepared a separate attached performance evaluation. It recommends an augmentation to the present airgun mechanics staff to cope with the work load increase caused by the upgrade from four to ten airguns, and three to five compressors. Fortunately this staff increase is offset by the need for three less watchstanders so that MCS budgets should not be effected in this way.

We cannot shoot the entire 6000 cu.in. gun array at 2000 psi at the desired CDP repetition rate of 20 sec or less with the current air capability. This could be achieved by upgrading one of the older compressors to 300 SCFM. This is highly recommended.

6) VHF radios on bridge and in lab: Both are entirely inadequate in power and reliability. We had no lab-to-lab radio contact throughout

the two-ship work on RC28-10 and the limited range and frequent failure of the bridge radios caused several ESPs to be poorly executed because the ships were unable to communicate in time to compensate for navigational problems caused by currents, etc. These radios must be upgraded.

7) Science space: Apart from the Chief Scientist's stateroom there is no space provided on the vessel for the chief scientist to use for laying out maps etc. needed for the good conduct of science operations. Space is at a premium on CONRAD and very little is underutilized. Only the "lower lab" seems to be somewhat underused. It is difficult to imagine how suitable space could be created, but the good conduct of an investigation often demands substantial real-time decision making about track modification. The chief scientist has nowhere on the vessel to go to consult the sorts of information needed to make such decisions in a reasonable manner, nor even to make notes and keep basic records. Laying out any data recorded during the leg for inspection is quiet impossible - we were forced to use the tables in the mess for this purpose. A science work area must be made available.

6. References

Diebold, J. B., 1987, A new airgun array for Conrad, EOS, 68, 155.

Klitgord, K. D. and H. Schouten, 1986, Plate kinematics of the central Atlantic, in The Western North Atlantic Region, DNAG vol. M, eds. P. R. Vogt and B. E. Tucholke, Boulder, CO.

Mutter, J. C., R. S. Detrick, and the NAT Study Group, 1984, Multichannel seismic evidence for anomalously thin crust at the Blake-Spur fracture zone, Geology, 12, 534.

Mutter, J. C., and the NAT Study Group, 1985, Multichannel seismic images of the oceanic crust's internal structure: Evidence for a magma chamber beneath the Mesozoic Mid-Atlantic Ridge, Geology, 13, 629.

NAT Study Group, 1985, North Atlantic Transect: A two-ship, wide-aperture multichannel seismic investigation of the oceanic crust in the western North Atlantic, J. Geophys. Res., 90, 10,321.

Sundvik, M., R. L. Larson, and R. S. Detrick, 1984, Rough-smooth basement boundary in the western North Atlantic basin: Evidence for a seafloor-spreading origin, Geology, 12, 31.

7. APPENDIX I

Compressor Use RC28-10

Compressors on the CONRAD are of two types. Installed in the engine room are three 200 SCFM Price units, two driven by Detroit Diesel 6-71 engines and one unit driven by a 200-HP electric motor. Two additional units were added in Piermont in the fall of 1987 of 300 SCFM capacity each. These units are designated by numbers assigned as follows:

No. 1 Diesel Stb. Forward
No. 2 Diesel Stb. Aft
No. 3 Electric Port Aft
No. 4 Diesel Stb. 01 Deck
No. 5 Diesel Port 01 Deck

Operating hours on each compressor after initial testing:

No. 1 202.9
No. 2 291.7
No. 3 65.3
No. 4 313.5
No. 5 247.6

Compressor No. 1

Trouble free during whole cruise; only routine maintenance required.

Compressor No. 2

Warped fourth stage cylinder head changed to stop slight air leak at 43.5 operating hours. No other problems requiring unscheduled downtime.

Compressor No. 3

Broken third stage gauge line at 15.5 hours; replaced. Only routine maintenance.

Compressor No. 4

Blown head gasket with two stuck fourth stage valves at 5 hours. Intake valve cracked third stage 18.1 hours. Speed control shaft friction too loose 43.3 hours. Third stage cylinder base bolts tightened to stop oil leaks 144 hours. Oil filter on booster block split - emergency shutdown, filter replaced 217.0 hours. Third stage valve spring broken 249.0 hours. Third stage discharge line broken; replaced 259.0 hours. Third stage discharge line broken again; replaced with flex line from A-200 unit and hard pipe 263.5 hours.

Compressor No. 5

Metal chip in fourth stage discharge valve 22.1 hours. Engine water temp high - heat exchanger acid cleaned 54.6 hours. Fourth stage base bolts tightened to reduce oil leaks. Pinhole leak in fourth stage compressor heat exchange 134.5 hours; found to be bronze rather than stainless steel. Replaced at 172.5 hours.

From the preceding summaries it can be seen that the original A-200 units installed in the engine room had a much better service record than the new units installed on the 01 deck. Some of the problems experienced on the new units are probably due to dirt left in the intercoolers from manufacture, causing stuck and broken valves, but use of bronze intercoolers in the third and fourth stage is not a good idea for long-term use. Even though the stainless units do not cool as well as the bronze units, the additional life is well worth the expense, at least on the fourth stage. The broken oil filter that also resulted in extensive damage to compressor no. 4 was traced to a mis-machined oil filter base that was replaced in Miami. This should eliminate this problem.

Three different oils for the compressors are currently being carried on the CONRAD. Both AGM and Exxon Synesstic 100 were tried. The AGM quickly broke down in the 200 units. The high pressure blocks were changed to Synesstic and were able to run 100 to 150 hours between changes. The 300 units started without breakdown. It is not known yet whether this is due to cooler operating temperatures or the fact that these units are equipped with oil filters. Also the oiling system is better, which is less stressful to the oil. Whatever the reason, the Exxon product seems to be the best for the compressors.

The air shock isolation system used on the 01 deck units worked very well. Two side bags were replaced on the transit to Bermuda due to chafing. Rolls up to 30 degrees were taken with the units operating without hitting the bump stops. The perceived noise level in the main lab was extremely low and not objectionable. Further improvements to this system would be the addition of orifice plugs to further increase the pitch stiffness.

A potential problem that should be addressed soon is the addition of an alarm/shutdown system for the 300 SCFM units. With the compressors now separated by two decks and 100 feet the ability to catch a potential problem is not great before it becomes a major repair job. This should be a major priority for any upgrading of the compressor system.

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TABLE 1 SCIENTIFIC PARTY

John Mutter	L-DGO	Co-chief scientist
Bob Detrick	URI	Co-chief scientist
Jose Ardai	L-DGO	
Ginger Barth	L-DGO	
Robert Blaes	L-DGO	
John Dibernardo	L-DGO	
Rene Forman	L-DGO	
Carlos Gutierrez	L-DGO	
Martin Iltzsche	L-DGO	
Steve LaBrecque	L-DGO	
Ropate Maiwiriwiri	L-DGO	
Ellen Morris	URI	
Kevin Newman	L-DGO	
Tim Nolan	L-DOG	
Beth Rees	URI	
Mark Richardson	URI	
Bill Robinson	L-DGO	
Jim Smith	L-DGO	
Joe Stennett	L-DGO	

Patrick Roberge, Captain

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TABLE 2 CDP AND WACDP PROFILES

CDP Number	Line Number	Start Date/ Time	Start Position	End Date/ Time	End Position	Data Tape #	Log Tape #
103	683	2130Z 13 Nov 87	26°35.600'N 70°05.654'W	0700Z 14 Nov 87	27°17.044'N 69°46.276'W	2-23	2
109	684	0701Z 14 Nov 87	27°15.097'N 69°46.635'W	1437Z 14 Nov 87	27°28.752'N 70°26.571'W	24-42	2
110	685	1556Z 14 Nov 87	27°23.845'N 70°29.530'W	1920Z 14 Nov 87	27°07.050'N 70°35.723'W	43-51	2
ESP 1	686	2300Z 14 Nov 87	26°59.836'N 70°23.421'W	0732Z 15 Nov 87	26°46.121'N 69°42.033'W	52-78	4
ESP 2	687	0930Z 15 Nov 87	26°52.116'N 69°44.473'W	1800Z 15 Nov 87	27°03.611'N 70°22.285'W	79-93	4
ESP 3	688	1937Z 15 Nov 87	27°07.345'N 70°18.312'W	0301Z 16 Nov 87	26°55.307'N 69°42.584'W	95-112	4
ESP 4	689	0518Z 16 Nov 87	27°00.032'N 69°45.664'W	1144Z 16 Nov 87	27°10.150'N 70°16.501'W	113-126	4/5
ESP 5 INBOUND	690	1442Z 16 Nov 87	27°14.108'N 70°15.494'W	1901Z 16 Nov 87	27°07.544'N 69°59.967'W	127-136	5
ESP 5 OUTBOUND	691	0403Z 17 Nov 87	27°08.406'N 69°58.083'W	0821Z 17 Nov 87	27°01.393'W 69°38.522'W	136-146	5
ESP 6	692	1126Z 17 Nov 87	27°06.003'N 69°39.357'W	1919Z 17 Nov 87	27°17.214'N 70°15.770'W	147-165	5
ESP 7	693	2248Z 17 Nov 87	27°20.754'N 70°12.646'W	0532Z 18 Nov 87	27°10.901'N 69°40.248'W	166-180	6
ESP 8	694	0902Z 18 Nov 87	27°16.447'N 69°33.506'W	1700Z 18 Nov 87	27°30.215'N 70°13.787'W	181-198	6
ESP 9	695	2100Z 18 Nov 87	27°39.927'N 70°06.201'W	0516Z 19 Nov 87	27°27.357'N 69°26.981'W	199-217	7
ESP 10	696	0900Z 19 Nov 87	27°39.496'N 69°25.306'W	1632Z 19 Nov 87	27°52.810'N 70°03.894'W	218-235	7/8
ESP 11	697	2100Z 19 Nov 87	28°02.011'N 69°56.405'W	0442Z 20 Nov 87	27°50.113'N 69°16.783'W	236-253	8/9

TABLE 2 (Cont'd)

CDP Number	Line Number	Start Date/ Time	Start Position	End Date/ Time	End Position	Data Tape #	Log Tape #
ESP 12	698	0810Z 20 Nov 87	27°58.874'N 69°15.976'W	1622Z 20 Nov 87	28°10.693'N 69°56.594'W	254-271	9
WACDP 1	699	2336Z 20 Nov 87	28°24.348'N 69°26.375'W	2303Z 21 Nov 87	26°47.433'N 70°06.970'W	272-370	9
ESP 5A	700	0551Z 22 Nov 87	27°04.050'N 69°45.930W	1412Z 22 Nov 87	27°16.474N 70°25.392'W	371-388	9
ESP 13	701	1600Z 22 Nov 87	27°11.983N 70°23.630'W	0029Z 23 Nov 87	26°59.188'N 69°48.746'W	389-404	-
ESP 14	702	0533Z 23 Nov 87	27°03.236'N 69°47.843'W	1421 23 Nov 87	27°39.283'N 69°31.834'W	405-424	10
111	703	1600Z 23 Nov 87	27°43.190'N 69°38.534'W	2001Z 23 Nov 87	27°43.549'N 69°57.170'W	425-436	10
ESP 15 INBOUND	704	2006Z 23 Nov 87	27°43.757'N 69°57.067'W	0100Z 24 Nov 87	27°24.565'N 70°04.927'W	437-448	11
112	705	0326Z 24 Nov 87	27°24.082'N 70°16.147'W	0612Z 24 Nov 87	27°26.673'N 70°28.770'W	449-453	11
ESP 16 OUTBOUND	706	0630Z 24 Nov 87	27°27.734'N 70°29.070'W	1100Z 24 Nov 87	27°44.605'N 70°23.629'W	454-460	11
113	707	1108Z 24 Nov 87	27°45.797'N 70°24.106'W	2051Z 24 Nov 87	28°08.490'N 71°02.017'W	461-484	11
ESP 17	708	2054Z 24 Nov 87	28°08.195'N 71°02.323'W	0450Z 25 Nov 87	27°40.365'N 71°23.975'W	485-498	11
114	709	0530Z 25 Nov 87	27°40.640'N 71°26.724'W	1350Z 25 Nov 87	28°10.338'N 71°49.351'W	499-517	11
ESP 18	710	1617Z 25 Nov 87	28°19.140'N 71°45.136'W	0002Z 26 Nov 87	28°48.555'N 71°26.615'W	518-534	11
115	711	1554Z 26 Nov 87	28°37.104'N 71°40.185'W	0520Z 28 Nov 87	27°37.159'N 69°02.348'W	535-654	11-13
116	712	0527Z 28 Nov 87	27°36.814'N 69°02.669'W	1100Z 28 Nov 87	27°13.164'N 69°12.796'W	655-672	13
117	713	1111Z 28 Nov 87	27°12.941'N 69°13.847'W	1300Z 28 Nov 87	27°14.713'N 69°23.371'W	673-678	13

TABLE 2 (Cont'd)

CDP Number	Line Number	Start Date/ Time	Start Position	End Date/ Time	End Position	Data Tape #	Log Tape #
117A	714	1516Z 28 Nov 87	27°16.205'N 69°32.301'W	0134Z 29 Nov 87	27°29.692'N 70°14.851'W	679-711	13
118	715	0138Z 29 Nov 87	27°29.483'N 70°14.944'W	1026Z 29 Nov 87	26°57.171'N 70°29.551'W	712-739	13
119	716	1339Z 29 Nov 87	26°54.600'N 70°27.200'W	0732Z 30 Nov 87	28°20.906'N 69°42.877'W	740-802	13
120	717	0854Z 30 Nov 87	28°18.923'N 69°36.345'W	1250Z 30 Nov 87	28°12.927'N 69°18.154'W	803-815	13
121	718	1254Z 30 Nov 87	28°12.927'N 69°18.154'W	1541Z 30 Nov 87	28°02.249'N 69°23.421'W	816-824	13-14
121A	719	1830Z 30 Nov 87	28°02.574'N 69°23.830'W	1420Z 01 Dec 87	26°45.422'N 69°55.830'W	825-894	15
122	720	1723Z 01 Dec 87	26°59.920'N 70°01.573'W	2235Z 01 Dec 87	27°28.830'N 70°11.833'W	895-916	15
123	721	2343Z 01 Dec 87	27°29.237'N 70°12.292'W	2309Z 02 Dec 87	28°26.178'N 71°56.131'W	917-999	15

RC 28-10

TABLE 3 Sonobuoys

Number/Ship	Buoy Position	Line	Start Date/Time	End Date/Time	Data Tape
3D	26°50.200'N 69°54.400'W	ESP 1	0102Z 15 Nov 87		58,
4D	26°58.600'N 70°07.700'W	ESP 2	1207Z 15 Nov 87	1800Z 15 Nov 87	83,93
5C	27°04.800'N 70°12.000'N	ESP 3	2100Z 15 Nov 87	0300Z 16 Nov 87	97,112
6D	26°59.500'N 69°55.100'W	ESP 3	2204Z 15 Nov 87	0300Z 16 Nov 87	99,112
7C	27°02.338'N 69°53.171'W	ESP 4	0644Z 16 Nov 87	1144Z 16 Nov 87	116,126
8D	27°06.200'N 70°03.100'W	ESP 4	0749Z 16 Nov 87	1144Z 16 Nov 87	116,126
9C	27°06.800'N 69°53.200'W	ESP 5	0510Z 17 Nov 87	0821Z 17 Nov 87	139,146
10C	27°08.400'N 69°46.900'W	ESP 6	1303Z 17 Nov 87	1433Z 17 Nov 87	151,155
11D		ESP 6	1405Z 17 Nov 87	1919Z 17 Nov 87	154,165
12C	27°11.500'N 69°55.200'W	ESP 6	1444Z 17 Nov 87	1700Z 17 Nov 87	156,160
13C	27°19.200'N 70°04.900'W	ESP 7	0132Z 18 Nov 87	0532Z 18 Nov 87	168,180
14D		ESP 7	0050Z 18 Nov 87	0532Z 18 Nov 87	170,180
15D	27°24.200'N 69°57.300'W	ESP 8	1145Z 18 Nov 87	1700Z 18 Nov 87	186,198
16C	27°21.600'N 69°49.100'W	ESP 8	1203Z 18 Nov 87	1700Z 18 Nov 87	187,198
17C	27°37.800'N 69°57.500'W	ESP 9	2234Z 18 Nov 87	0516Z 19 Nov 87	202,217
18D	27°32.100'N 69°42.100'W	ESP 9	2245Z 18 Nov 87	0516Z 19 Nov 87	203,217

TABLE 3 (cont'd)

Number/Ship	Buoy Position	Line	Start Date/Time	End Date/Time	Data Tape
19C	27°41.900'N 69°32.200'W	ESP 10	1023Z 19 Nov 87	1632Z 19 Nov 87	221,235
20D		ESP 10	1120Z 19 Nov 87	1632Z 19 Nov 87	223,235
21D		ESP 11	2226Z 19 Nov 87	0442Z 20 Nov 87	239,253
22C	27°59.400'N 69°47.300'W	ESP 11	2244Z 19 Nov 87	0442Z 20 Nov 87	239,253
23C	28°01.546'N 69°23.100'W	ESP 12	0942Z 20 Nov 87	1622Z 20 Nov 87	257,271
24D	28°08.000'N 69°42.600'W	ESP 12	1033Z 20 Nov 87	1622Z 20 Nov 87	259,271
25D (No Good)		WACDP 1	1330Z 21 Nov 87	1350Z 21 Nov 87	333,334
26D		WACDP 1	1356Z 21 Nov 87	2303Z 21 Nov 87	335,370
27C	27°06.600'N 69°53.200'W	ESP 5A	0730Z 22 Nov 87	1412Z 22 Nov 87	374,388
28D	27°11.800'N 70°08.100'W	ESP 5A	0833Z 22 Nov 87	1412Z 22 Nov 87	376,388
29C	27°08.200'N 70°15.800'W	ESP 13	1834Z 22 Nov 87	0029Z 23 Nov 87	392,404
30D	27°02.800'N 69°54.800'W	ESP 13	1859Z 22 Nov 87	0029Z 23 Nov 87	393,404
31C	27°07.600'N 69°46.300'W	ESP 14	0200 23 Nov 87	1421Z 23 Nov 87	408,424
32C	27°43.800'N 69°41.700'W	111	1629Z 23 Nov 87	1908Z 23 Nov 87	426,433
33C	27°37.800'N 70°00.800'W	ESP 15	2139Z 23 Nov 87	0100Z 24 Nov 87	440,448
34C	27°56.600'N 70°42.800'W	113	1547Z 24 Nov 87	2042Z 24 Nov 87	None (Paper Record)
35C	28°02.300'N 71°06.200'W	ESP 17	2236Z 24 Nov 87	0450Z 25 Nov 87	None (Paper Record)

TABLE 3 (cont'd)

Number/Ship	Buoy Position	Line	Start Date/Time	End Date/Time	Data Tape
36D	27°44.900'N 71°18.900'W	ESP 17	2300Z 24 Nov 87 2300Z 24 Nov 87	No end time (Not Recorded)	
37C	28°24.900'N 71°41.000'W	ESP 18	1740Z 25 Nov 87	0002Z 26 Nov 87	None (Paper Record)
38C	28°32.000'N 71°39.800'W	115	1836Z 26 Nov 87	0000Z? 27 Nov 87	None (Paper Record)
39C	28°26.700'N 70°55.900'W	115	0331Z 27 Nov 87	0711Z 27 Nov 87	None (Paper Record)
40C	28°07.600'N 70°33.600'W	115	0802Z 27 Nov 87	1453Z 27 Nov 87	None (Paper Record)
41C	27°52.900'N 69°42.000'W	115	1957Z 27 Nov 87	0030Z 28 Nov 87	None (Paper Record)
42C	27°26.900'N 70°16.100'W	118	0226Z 29 Nov 87	0604Z 29 Nov 87	None (Paper Record)
43C	26°57.900'N 70°16.200'W	119	1418Z 29 Nov 87	1822Z 29 Nov 87	None (Paper Record)
44C	27°19.300'N 70°07.800'W	119	1830Z 29 Nov 87	2228Z 29 Nov 87	None (Paper Record)
45C	27°40.900'N 69°57.800'W	119	2312Z 29 Nov 87	2352Z 29 Nov 87	Bad After 30 mins
46C	27°44.600'N 69°56.300'W	119	0000Z 30 Nov 87	0700Z 30 Nov 87	None (Paper Record)
47C	28°18.700'N 69°36.700'W	120	0903Z 30 Nov 87	1300Z 30 Nov 87	None (Paper Record)
48C	28°05.200'N 69°21.800'W	121A Off 2545Z & back on 1807Z (see log)	1451Z 30 Nov 87	2201Z 30 Nov 87	None (Paper Record)
49C	27°47.200'N 69°29.100'W	121A	2204Z 30 Nov 87	0324Z 01 Dec 87	None (Paper Record)
50C	27°27.300'N 69°37.700'W	121A	0329Z 01 Dec 87	0857Z 01 Dec 87	None (Paper Record)

TABLE 3 (cont'd)

Number/Ship	Buoy Position	Line	Start Date/Time	End Date/Time	Data Tape
51C	27°06.800'N 69°46.700'W	121A	0858Z 01 Dec 87	1352Z 01 Dec 87	None (Paper Record)
52C	27°29.800'N 70°14.500'W	123	0015Z 02 Dec 87	0454Z 02 Dec 87	None (Paper Record)
53C	27°36.500'N 70°36.500'W	123	0456Z 02 Dec 87	0838Z 02 Dec 87	None (Paper Record)
54C	27°43.200'N 70°54.000'W	123	0843Z 02 Dec 87	1309Z 02 Dec 87	None (Paper Record)
55C	27°57.100'N 71°13.000'W	123	1313Z 02 Dec 87	1714Z 02 Dec 87	None (Paper Record)
56C	28°02.300'N 71°31.400'W	123	1718Z 02 Dec 87	2045Z 02 Dec 87	None (Paper Record)
57C	28°09.800'N 71°46.100'W	123	2047Z 02 Dec 87	2120Z 02 Dec 87	None (Paper Record)

Figure Captions

Figure 1 - Map of western North Atlantic showing location of NAT line 15 and Blake-Spur fracture zone (BSFZ) experiment. Magnetic anomalies are from Klitgord and Schouten (1986); location of rough-smooth boundary from Sundvik et al. (1984).

Figure 2 - Line drawing interpretation of NAT line 15 from McCarthy et al. (in press). Location of ESPs obtained during the BSFZ experiment are shown for reference.

Figure 3 - RC28-10 - airgun source array geometry.

Figure 4 - RC28-10 - DSS-240 streamer configuration and antenna geometry.

Figure 5 - RC28-10 cruise track superimposed on magnetic base map showing location of ESPs, CDP lines, and sonobuoys obtained during the BSFZ experiment.

Figure 6 - Line drawing of single channel monitor record from WACDP 1 showing location of BSFZ, Northern fracture zone (NFZ) of Mutter et al. (1985) and a new fracture zone discovered between the BSFZ and NFZ which we call the White Horse fracture zone (WHFZ). The locations of ESPs 1-13 are shown for reference.

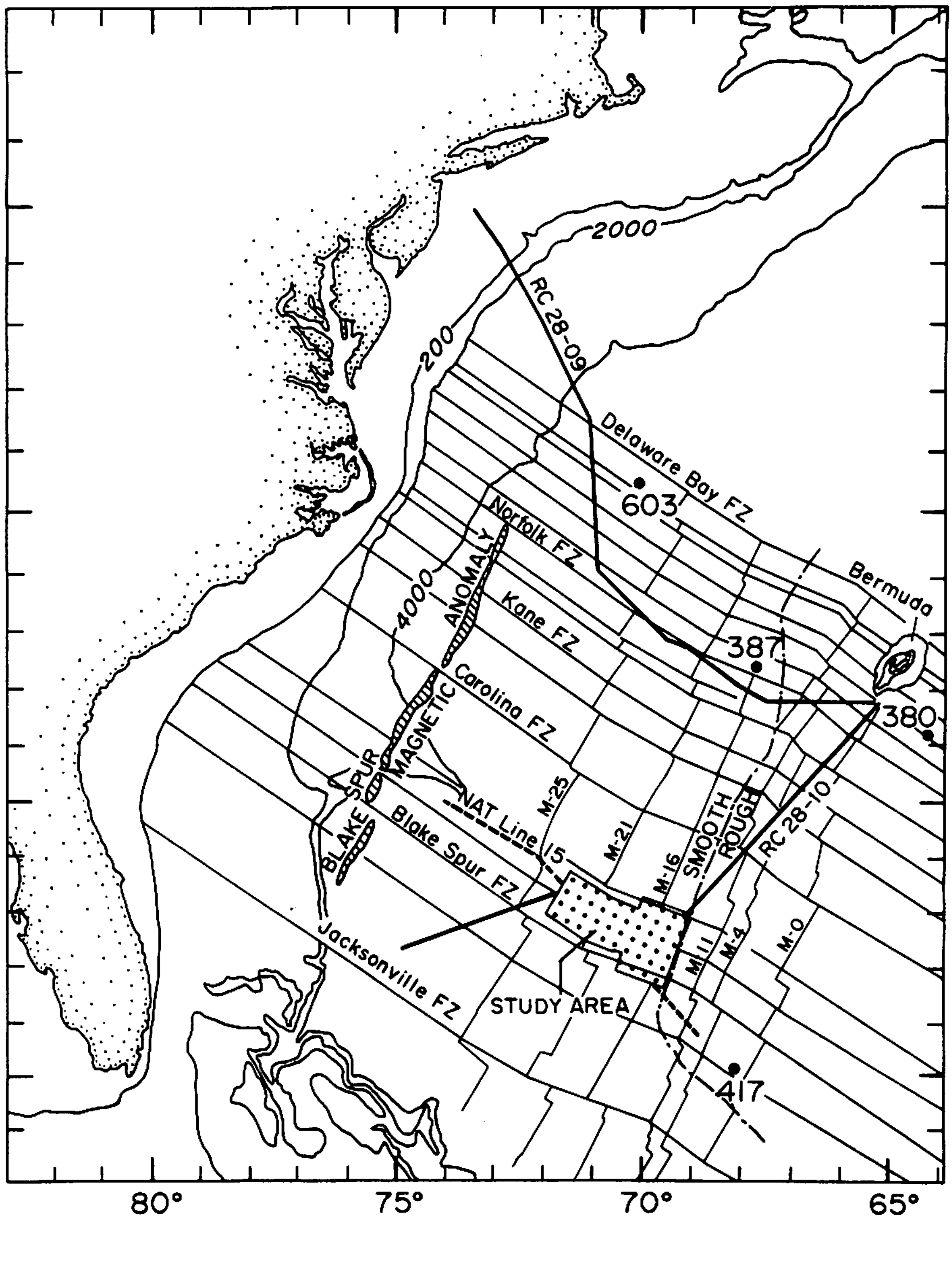
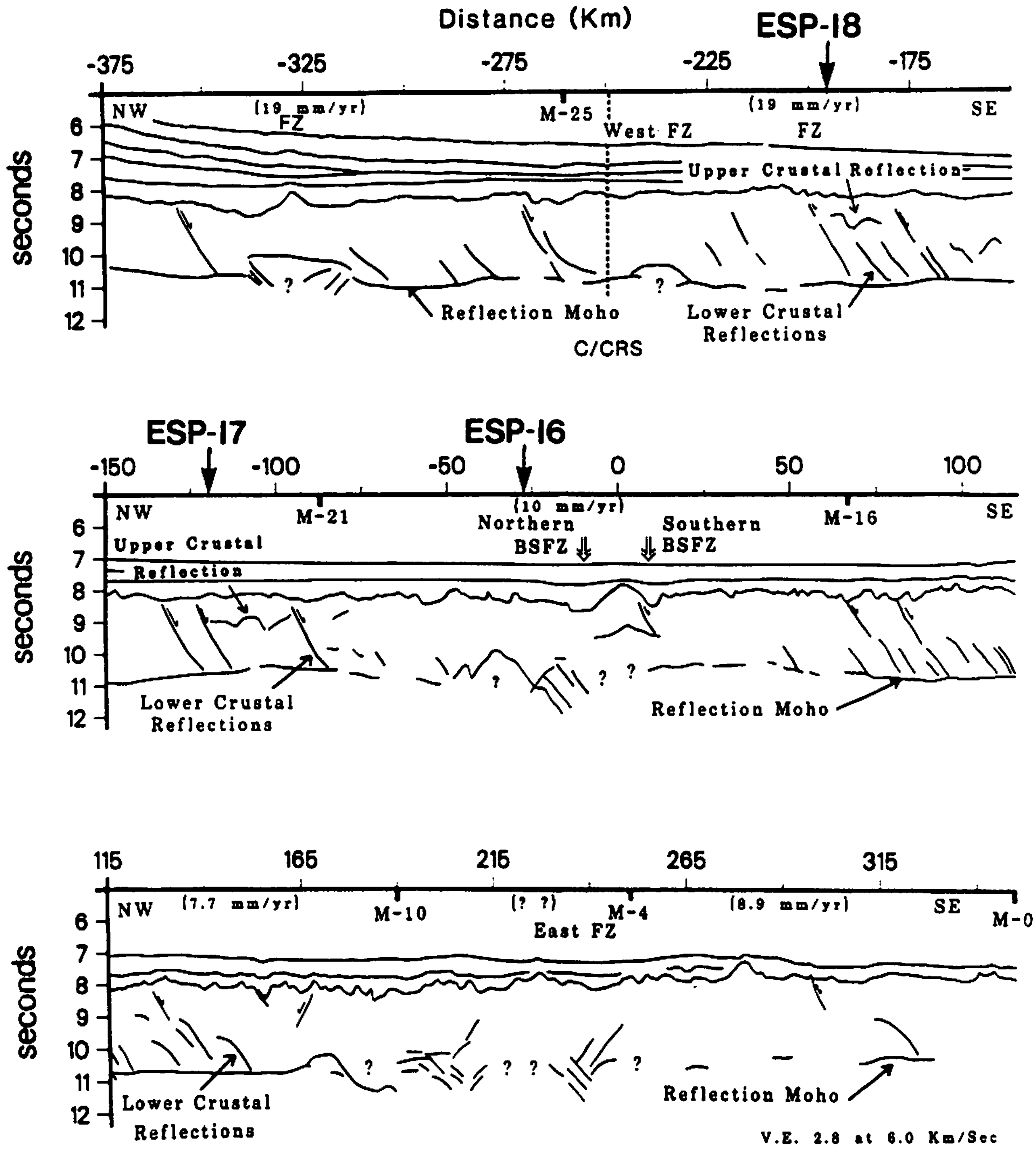
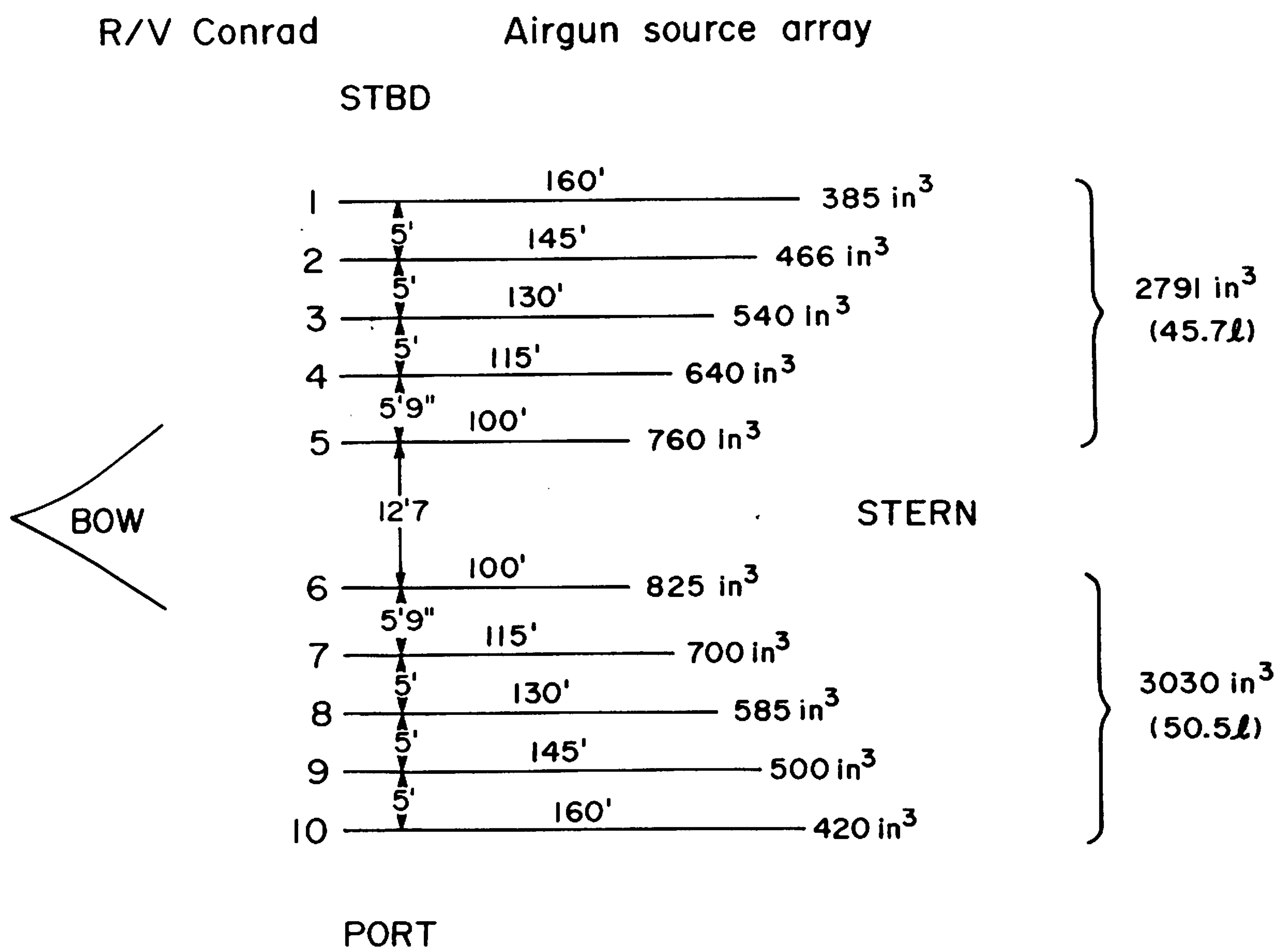

40°
35°
30°
25°
80°
75°
70°
65°
2000
200
4000
RC 28-09
RC 28-10
Delaware Bay FZ
603
Norfolk FZ
Bermuda
Kane FZ
387
380
Carolina FZ
BLAKE SPUR MAGNETIC ANOMALY
NAT Line 15
Blake Spur FZ
M-25
M-21
M-16
M-11
M-4
M-0
SMOOTH
ROUGH
Jacksonville FZ
STUDY AREA
417

Fig. 1



Distance (Km)
ESP-18
-375
-325
-275
-225
-175
NW
(19 mm/yr)
FZ
M-25
West FZ
(19 mm/yr)
FZ
SE
Upper Crustal Reflection
seconds
6
7
8
9
10
11
12
Reflection Moho
Lower Crustal
Reflections
C/CRS
ESP-17
ESP-16
-150
-100
-50
0
50
100
NW
M-21
(10 mm/yr)
Northern
BSFZ
Southern
BSFZ
M-16
SE
Upper Crustal
Reflection
Lower Crustal
Reflections
Reflection Moho
115
165
215
265
315
NW
(7.7 mm/yr)
M-10
(? ?)
East FZ
M-4
(8.9 mm/yr)
SE
M-0
Lower Crustal
Reflections
Reflection Moho
V.E. 2.8 at 6.0 Km/Sec

Fig. 2



R/V Conrad
Airgun source array
STBD
1
2
3
4
5
6
7
8
9
10
160'
145'
130'
115'
100'
100'
115'
130'
145'
160'
5'
5'
5'
5'9"
12'7
5'9"
5'
5'
5'
385 in3
466 in3
540 in3
640 in3
760 in3
825 in3
700 in3
585 in3
500 in3
420 in3
2791 in3
(45.7ℓ)
3030 in3
(50.5ℓ)
BOW
STERN
PORT

Fig. 3

R/V Conrad Streamer configuration and antenna geometry

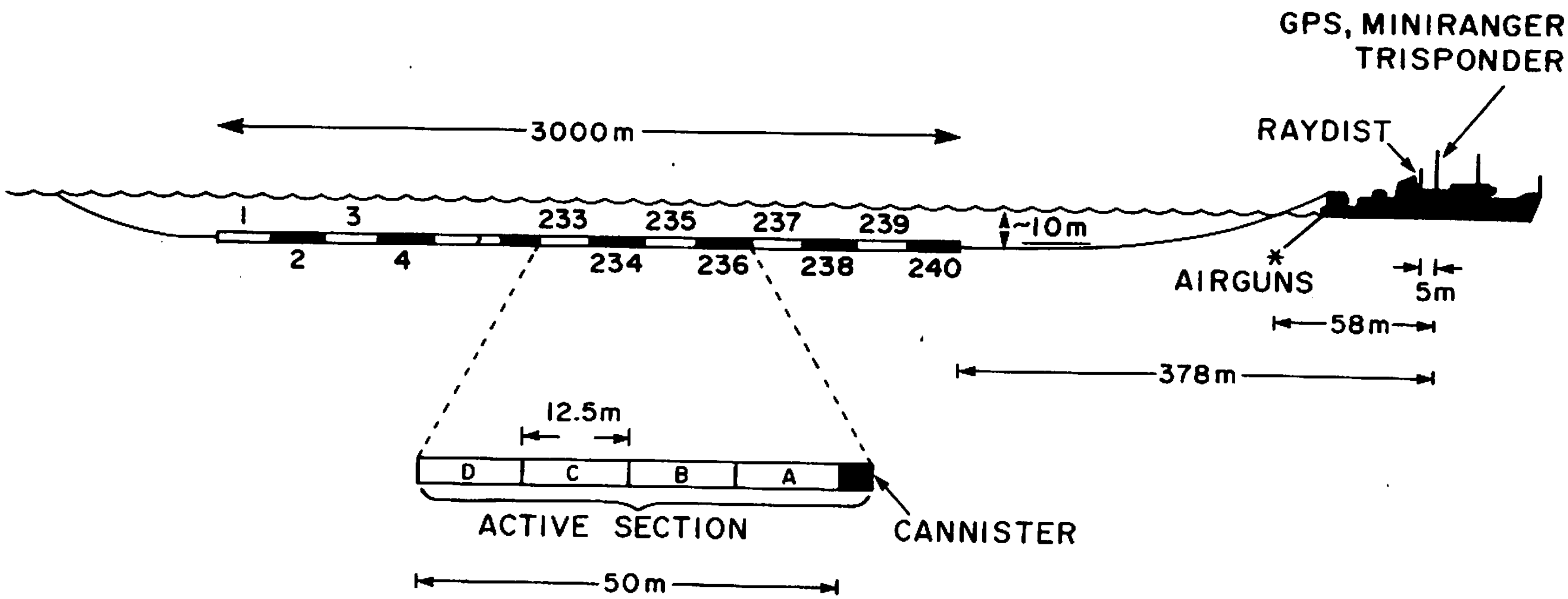
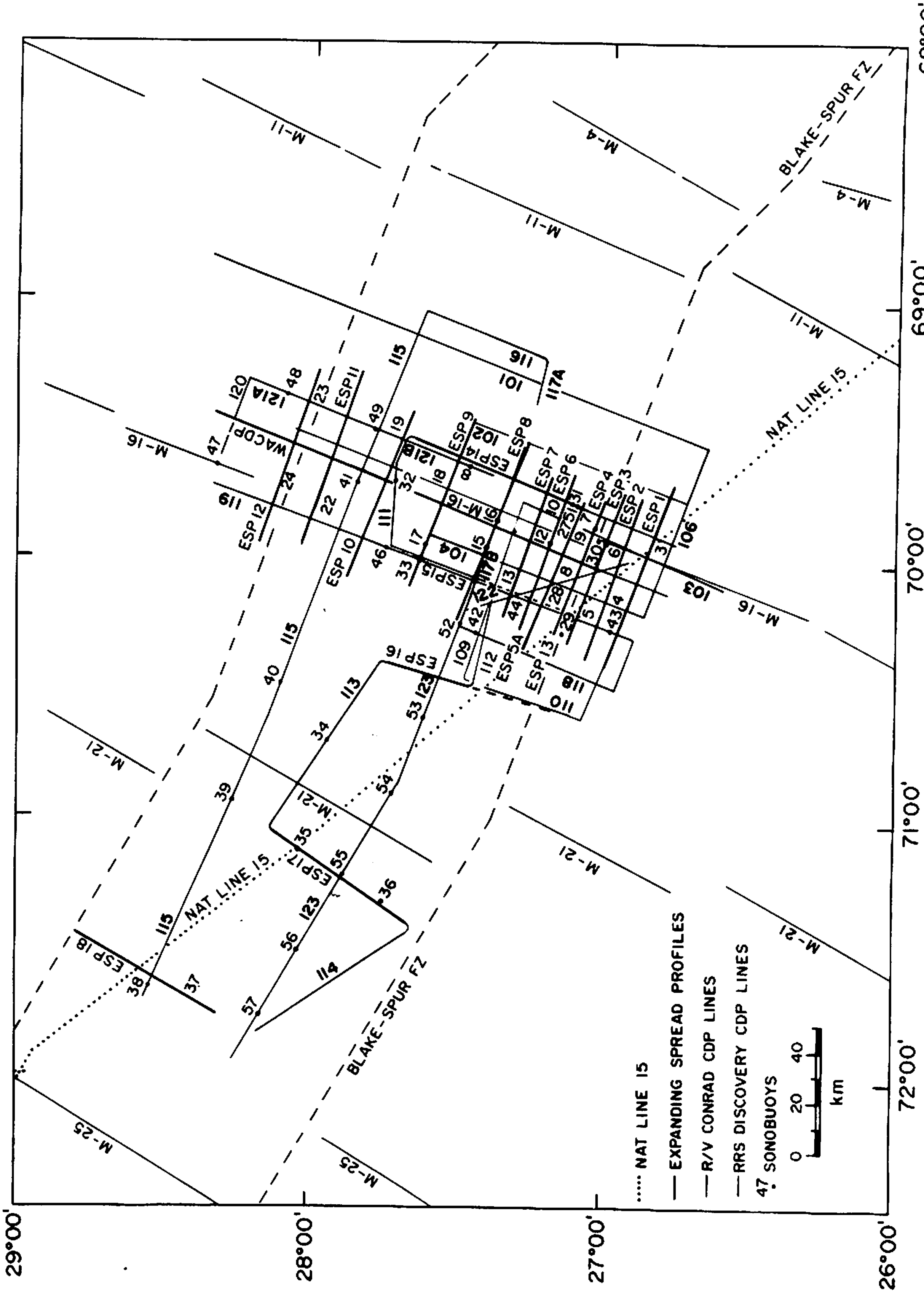


Fig. 4



NAT LINE 15
EXPANDING SPREAD PROFILES
R/V CONRAD CDP LINES
RRS DISCOVERY CDP LINES
47 SONOBUOYS
0 20 40
km
BLAKE-SPUR FZ
M-4
M-11
M-16
M-21
M-25
29°00'
28°00'
27°00'
26°00'
68°00'
69°00'
70°00'
71°00'
72°00'

Fig. 5

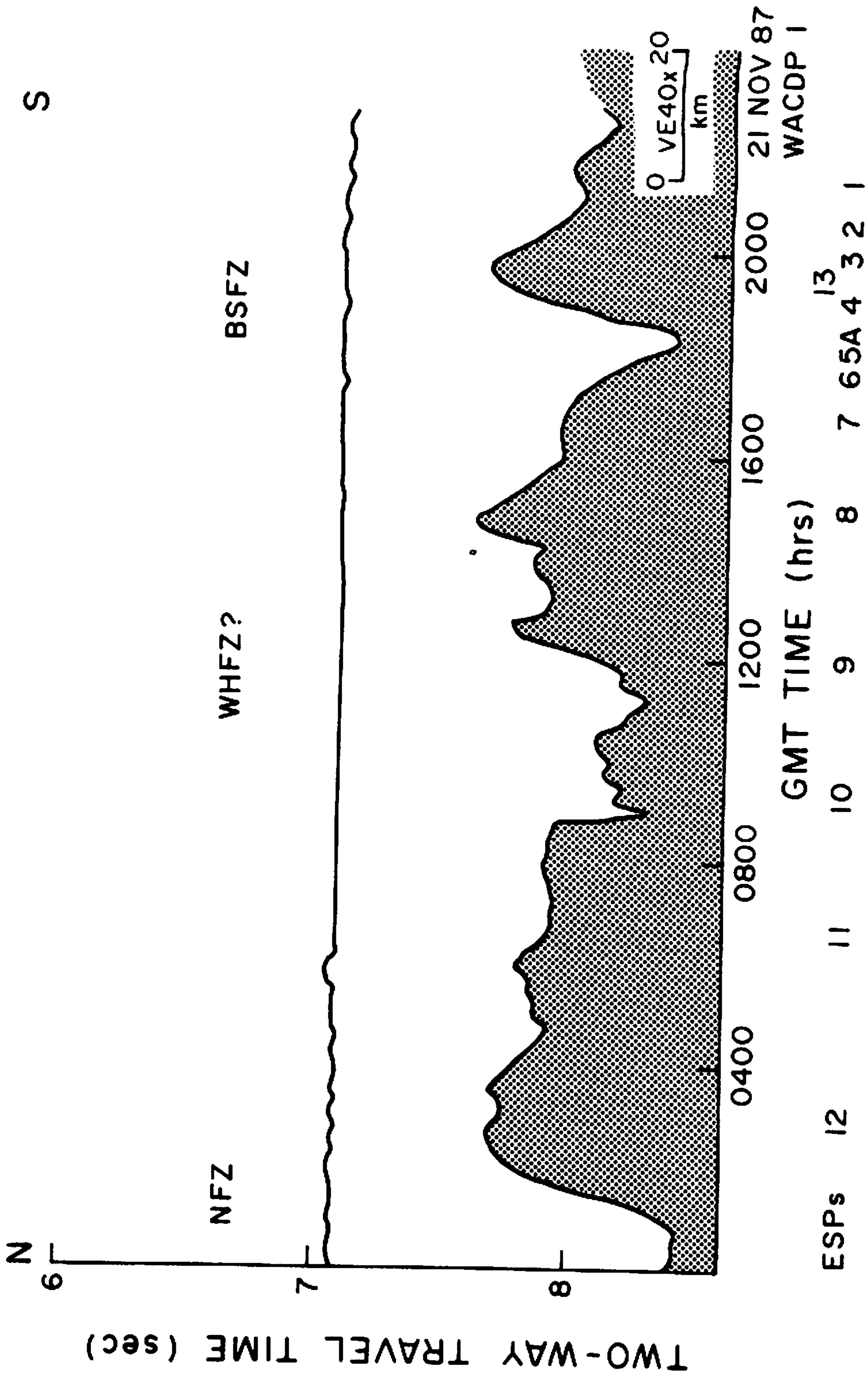

S
N
NFZ
WHFZ?
BSFZ
TWO-WAY TRAVEL TIME (sec)
6
7
8
0400
0800
1200
1600
2000
GMT TIME (hrs)
ESPs 12 11 10 9 8 7 65A 4 13 3 2 1
0 VE40x 20
km
21 NOV 87
WACDP I

Fig. 6