CARDIFF MARINE GEOSCIENCES

UNIVERSITY OF WALES COLLEGE OF CARDIFF
DEPARTMENT OF GEOLOGY

MARINE GEOSCIENCES RESEARCH GROUP
CRUISE REPORT NO. 1

R.R.S. DARWIN
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TOBI Sidescan and Other Surveys with Core Sampling on the Saharan Continental Rise, Northeast Atlantic Ocean.

Principal Scientist
Prof. Robert B. Kidd

1991

CONTENTS

TABLES:

FIGURES

SCIENTIFIC PERSONNEL

UNIVERSITY OF WALES, CARDIFF

KIDD, Robert B. (Principal Scientist)
WAKEFIELD, Simon J.
CRAMP, Adrian
MADDISON, David A.
ROBERTS, John A.
WRIGHT, Paul N.

INSTITUTE OF OCEANOGRAPHIC SCIENCES, DEACON LABORATORY
MASSON, Douglas.G.
WEAVER, Philip P.E.
FLEWELLEN, Christopher G.
ROUSE, Ian P.
EDGE, David

RESEARCH VESSEL SERVICES, BARRY
MASON, Peter J.
BOOTH, David G.
WYNAR, John
PHIPPS, Richard A.
DAVIES, Michael A.
DAY, Colin

INSTITUTO ESPANOL DE OCEANOGRAPHICA
ACOSTA J. (Spanish Observer)

SHIP'S PERSONNEL

HARDING, Michael A.	Master
BOURNE, Richard A.	Chief Officer
CLARKE, Jeremy L.	Second Officer
BURRIDGE, Paul A.	Third Officer
BAKER, Jeffrey G.L.	Radio Officer
ROWLANDS, David C.	Chief Engineer
GIMBER, Geoffrey	Second Engineer
ANDERSON, James A.	Third Engineer
EDGELL, Philip E.	Electrical Engineer
POOK, Glenn A.	Chief Petty Officer(Deck)
COOK, Stuart C.	Seaman
DEAN, Paul H.C.	Seaman
CRABB, Gary.	Seaman
BENNETT, Peter R.	Seaman
OLDS, Arthur E.	Seaman
HANLON, David J.	P.O.Motorman
PERRY, Clive K.	Cook Steward
SWENSON, Julian J.E.	Ship's Cook
ACTON Peter C.H.	Second Steward
JENKINS, David E.	Steward
ELLIOTT, Christopher J,	Steward

ITINERARY

Sailed Tenerife	11, February, 1991.
Arrived Tenerife	13,March, 1991.

CRUISE OBJECTIVES

The specific objectives of the UWCC cruise on RRS Darwin were as follows:

1. To improve our knowledge of the processes transporting sediments on continental margins; particularly with regard to the origin, pathways and ultimate destination of the sediments, and the differing roles played by sediment slides and debris flows versus turbidity currents.

2. To examine in detail the flow, erosional, and depositional processes associated with the Saharan Sediment Slide (Embley,1976) and its associated debris flows and the turbidity current channel systems on the Saharan continental rise.

3. To elucidate the timing of the flow events, and the extent to which the slide was a single or multi-phase event..

4. To determine the interactions between slide processes and turbidity current processes, and in particular the extent to which the slide generated turbidity currents.

The main tool to tackle these objectives was to be the TOBI sidescan and profiler which would be used in at least two detailed study areas on the continental rise that had been selected from existing GLORIA data. The surveys were to be bottom transponder-navigated and were to be supplemented by precisely navigated core sampling and bottom camera runs with the WASP vehicle.

Subsiduary objectives related to: studies of diagenetic processes in the upper few meters of pelagic sediments in this region of the North Atlantic basin, as part of UWCC's involvement in the B.O.F.S. community programme: and geotechnical investigations of slope stability around the Canaries.

NARRATIVE

Darwin sailed from Tenerife at 0900 on Sunday, 11th January; that is 0900/042 (All times henceforth GMT with Julian Day). Weather conditions were sunny with light winds and only slight swell and the ship headed south-south eastwards towards the startpoint of a projected airgun and 3.5kHz survey, which would take us into deep water on the edge of the Madeira Abyssal Plain (**Figure 1**).

Seismic Survey to Madiera Abyssal Plain: The PES and 3.5kHz fishes were launched at around 1100 as we left the Spanish 12-mile territorial limit. Boat drills and safety sessions were completed in the morning and early afternoon. The ship was slowed to 4 knots at 1300 for the launch of the airgun and hydrophone and there transpired a series of difficulties with the 160 cu in. airgun, including a badly scoured inner chamber and some damaged connections. The gun was launched and recovered twice more before it worked satisfactorily. This happened just as we reached Position A with the ship coming up to 8 knots survey speed.

Darwin turned on to a 282° course at 1900/042 to begin the first leg of survey towards Point B, through the "neck" of slide deposits southwest of Hierro island. Initially there were also problems with a 3.5kHz Raytheon recorder but this was replaced and the system was fully operational by the start of the survey at A.

By dawn on day 043 Darwin was well into survey mode with all watches operating. Weather conditions were cloudy to fine and clear, wind 350° at 5 knots and with a low swell. At 1050/042 the edge of a major debris flow, about 20m thick, was displayed on the 3.5kHz record. From comparisons with the recently completed, processed, regional GLORIA mosaic, this appeared to be the northern edge of a flow unit that passes south west of Hierro. After crossing the Discovery 188 TOBI survey area 4, the ship altered course at Point B to a northeasterly heading to traverse upslope over a supposed area of slide scars. The airgun failed at 1728/043 and was recovered, replaced and redeployed by 1848. Soon after this the ship altered course at Point D to run a survey line downslope and northwest, along the supposed axis of the main debris flow complex that reaches the abyssal plain.

Another airgun failure occurred at 0505 the following morning; again it was repaired and was working satisfactorily by 0546/044. The wind had been freshening through the night and by 0700 it was at 38 knots from the north (020°) with a sea state of force 5. It raised considerably over the next few hours reaching force 7 by midday. The upslope edge of a debris flow had been crossed, as planned, on both the upslope and downslope runs west of Hierro .

The ship turned into the wind at 1120/044 to run the line E-F and immediately began pitching and taking water over the bow. Soon afterwards the airgun was again off, this time for a compressor failure that lasted from1134 to1406. We slowed to 4 knots during these repairs and the ship rode the seas more kindly but when we came up to survey speed again we once again rode an uncomfortable course. Recognising that the ship was likely to roll badly over the final leg of the seismic survey line, the next-to-last waypoint was moved westwards such that after the turn at 2214/144 (Point F) we were on a 250° heading and the sea was on our aft port quarter. This made for a more acceptable motion but the airgun records were correspondingly noisy.

More compressor problems occurred at 0400/045 and the airgun was off until 0420. At this time the ship's speed was reduced to 7 knots to improve the seismic records. At dawn the weather remained squally with a sea state of 7 to 8. At 0703/045 the ship made its remaining course change in the survey at Point G and proceeded to run on a heading of around 280° towards the abyssal plain. Now the wind was on the beam and for the first few hours "Darwin" rolled uncomfortably. However, through the day the weather improved steadily and it became sunny in intervals, although still squally. Ship's speed was increased and plans were made for the station work at the end of the survey line. The 3.5 kHz records faithfully recorded subtle acoustic facies changes coincident with backscattering changes on the GLORIA mosaic.

At 0400/046 we passed through the end-point of the survey (H) and continued past it further on to the abyssal plain The 3.5kHz record showed that we had crossed the tip of the longest-run debris flow unit, at around 0230/045, and were now over stratified turbidite fill. The ship was turned between 0430 and 0457 to come back over Point H at 0530 on a reciprocal course. There we recovered the seismic gear at 4 knots and then hove to in order to exchange coring heads on the starboard side. The sea state was force 2 to 3 in light winds and overcast.

Winch and Cable Tests, Failure and Emergency Retrieval: At 0650 we launched the acoustic navigation fish for testing and also began the testing of the RVS winch and its 10km of conducting cable intended for use with TOBI. For test purposes the TOBI termination on this cable was shackled to a clump of about 500kg of anchor chain.and the test was begun with the ship underway but only at 1-2 knots. Because this was the same cable that had been used on the TOBI trials the previous February and portions were known to have been damaged and "bird-caged" in a winch tensioning incident on "Discovery", we wished to examine the state of the cable as it was paid out. The RVS winch had previously only been used at the base for spooling warps on and off ships. It had apparently been load tested there to 7.5 tons static before embarkation on "Darwin". The conducting cable already on the ship was considered unsuitable for TOBI, because of a narrow band width, and "Darwin's" ex-Shackleton winches were deemed unsuitable for the existing TOBI cable, because of their small size sheaves. The RVS engineers wished to gain experience controlling the "portable" winch and to check read-out indicators. We also wished to test the slave transponder of the acoustic navigation system which had failed to surmount interference problems on the Discovery cruise. Altogether the tests were considered necessary before deployment of TOBI on the end of the cable.

The winch trials began at 0714/046 and at the same time we began to rig the piston corer for the first coring station in the debris flow. The TOBI cable was now reeled in the opposite direction to Discovery's winch and so we were expecting the damaged section at around 3000 meters of wire out. Problems had arisen before we started the test in that both the wire out indicators and the dynamometer read-outs appeared not to be working. Trouble-shooting the previous evening had not completely sorted this problem. Initial pay-out showed that the wire-out indicators were indeed working but no measure of tension was obtainable from the dynamometers. The acoustic navigation transponder was clamped to the wire at 500m wire out in order to get ranges to it during the test

The first indications of cable damage were found at around 2000m wire out and these were marked with tape so that they could be inspected during future deployments. In some places a single wire strand had been broken and was missing over as much as 2-3 meters. Only some of the occurrences had been repaired by binding with wire but these repairs were those effected during the Discovery cruise; so no additional work had been done on the cable over the previous year. We rebound any broken strands with wire and marked these with tape also. We concluded that, since only single strands were missing, in patches over the 2000-3000 meter interval, the cable was in sufficient condition as long as it was regularly inspected during deployments. Any deterioration of the conducting cable would certainly be preceded by an electrical fault well before any serious effect on its structural integrity. The RVS engineers were now confident of the winch controls and only one of the dynamometer indicators was left to be fixed.

The winch was continued paying out to around 4300m, to continue the ranging tests on the transponder, and was then stopped. As soon as the engineers began to haul in at about 1200/046, the winch began making unusual noises ("as if it were straining against itself"). **At 1215/046, there occurred a total winch failure and the spooling gear completely collapsed.** It had been pulled forwards and sideways by a build-up of tension between the capstan winch and traction/storage winch. We were now: hove to in slight sea with 4000m+ of wire out, a navigation transponder deployed, and no way of hauling in!

The cable was stopped off to ensure safety on deck and various options were discussed ; the priorities being recovery of the cable complete and with no further damage, since the TOBI surveys represented over half of the cruise objectives, and recovery of the navigation transponder. Advice was sought by satellite-link telephone from RVS Barry. It was concluded: (1) that the hydraulic system of the motor drive should be thoroughly checked out to discover the source of the unusually low pump pressures recorded immediately prior to the breakdown; (2) that the spooling drum system should be partly cut away and replaced by a makeshift manual single spooling drum that would simply allow recovery of the cable: and (3) that some dynamometer readout must be rigged to ensure safety during recovery. By 1900/046 the RVS engineers had isolated a hydraulic valve that might be a likely cause of the pressure problems.

By 2300/047 only action (2) of the above had been successfully accomplished despite both the RVS and the ship's engineers being involved in the work and more advice being sought from specialists on the winch from ashore. The motor drive had been entirely stripped down and checked out but still pressures of only 100 bars were obtainable when the engine was driven. Over 240 bars would be needed just to recover the wire presently out. The stopped-off wire was still hung from the ship and the transponder signal was being detected but the weather was now worsening. Force 6 to 7 was the sea state at 2300 and it was expected to go to gale force 8 overnight.

Further advice was to be sought by telephone from shore but we were already examining options that might involve loss of the 4300 meters of cable presently out. RVS had advised against connecting this winch to other power packs aboard the ship. This would leave us only with the possibility of hauling in over the main coring warp or using the Darwin conducting cable after cutting the cable that was presently out. An urgent call was to be made to shore to ask for further help but also to alert them of the dire consequences for both this cruise and the following one in the event that the cable was cut too short for feasible TOBI operations operations or this winch could not be fixed either onboard or ashore in Tenerife.

Much of Day 048 was spent by the RVS engineers attempting various tests to investigate the cause of the pressure deficiency in the winch power unit and in frequent telephone conversation with shorebased personnel who were finding some difficulty in obtaining specialist advice over the weekend. Ultimately it became clear that linking up to an alternative power pack on board should be our next option for recovery of the cable and transponder and the shipboard engineers set about designing a possible configuration for approval by their superiors at the Base. The sea state continued at around 7 under cloudy skies. A FAX was sent by the Principal Scientist to the Superintendent, RVS, requesting further information on the original testing of the "portable" winch system.

On the morning of Day 049 a FAX of a proposed auxiliary power configuration was sent to RVS with a request for confirmation of approval from the shorebased mechanical engineers. Questions continued to be relayed from the Base over the original cause of the winch failure. At 1142/049 the Principal Scientist sent a telex stressing that the cable had now been hung off and stationary for 3 full days and was now becoming a definite safety concern. He requested urgent attention to approval of the auxilliary power arrangement. This was given at 1738 and the shipboard engineers set about coupling the auxilliary configuration from the GLORIA power pack.

The setting up of the alternative power supply took well into Day 050; still the ship was hove to in a sea state of 6 to 7 under cloudy skies. We began hauling in the cable at 1526/050, initially very slowly at less than 1.5m/sec. No significant structural damage appeared to have taken place to the cable. No wire strand breaks were seen where it had gone through the spooling gear at the point of collapse, where it had been stopped off wlth the clamp (although it was compressed here), or where it had been stationary through the A-frame sheave. Hauling in was speeded up at around 1500m wire-out and the transponder was removed at 500m wire-out. **All was inboard at 2300/050.**

Coring the Debris Flow Termination: We had drifted over 60 nm northeastwards during the 4.5 days of winch problems and so we began a 3.5kHz survey back to the location of our first projected coring sites at the "nose" of the longest-run debris flow identified by GLORIA (Simm & Kidd,1984; Kidd et al.,1987). We wished to locate part of the northern edge of the debris flow at around 31°N and so we traversed due south and through a triangular arrangement of way-points inserted to locate the boundary on the 3.5kHz records (**Figure 2**). We then sailed southwestwards to piston core site, **CD56-1-P1**, arriving on site at 1230/051. The weather was by now sunny and clear and the ship was hove to in a moderate swell. This 3-barrel piston core was inboard by 1730 but, because the hydrostatic release on the trigger arm had flooded, the corer had not triggered. It had hit the bottom and keeled over, bending the two lower barrels. About 0.5 meters of core was recovered, mostly mud but with about 1 cm of fine sand in the base and in the core catcher. (Lift-off position was Lat: 30° 48.3' N; Long. 23° 57.7'W; w.d. 5360m) It was decided to try for another core here, this time a 2-barrel piston corer, but to bring the ship back to the south because we had drifted about 2nm before CD56-1-P1 got to the bottom.

CD56-2-P1 was launched at 1957/151 and came aboard at 0030/052. Pull-out had been at Lat. 30° 45.6'N; Long.23° 58.3'W; w.d. 5360m. This was full almost to the core-weight and a stiff mixture of lithologies were visible in the core catcher, along with black volcanic glass fragments. Total recovery was 5.9m. We were fairly certain that we had sampled the debris flow.

The ship then traversed to the west on to the "stratified turbidites"of the abyssal plain with a view to obtaining a 'turbidite stratigraphy' and to investigate the relationship between debris flow and turbidite. Here (**CD56-3-P1**) we rigged for a 4-barrel piston core and the corer was launched at 0304. A weak pull-out occurred at position Lat.30° 46.04'N; 29°09.97'W; w.d.5368m and the corer was inboard at 0733/052. It had penetrated right to the core-head and 3 of the 4 barrels were full, with only 10cms or so of sediment in the top barrel. Total recovery 9.0m. (Apparently we had recovered as intended the top three or four MAP turbidites of Weaver et al.,1987).

What was required now was a core in the feather-edge of the debris flow that would penetrate through it and into turbidite below for dating purposes. The ship was positioned to the east about half-way between the previous two cores. A 4-barrel corer was launched at1322/052. At pull-out the position was 30°48.15'N; 24°02.83'W; w.d.5361m. The corer, **CD56-4-P1**, was inboard at 1600/052 and 9.2m had been recovered. Apparently the sequence was mostly turbidite but with a thick sand in section two. We were now concerned that we may have missed the end of the debris flow and so moved about 2miles further east. This 4-barrel piston corer, **CD56-5-P1** was launched at 1750 and was recovered at 2230. The pull-out at 2032 was at position 30°48.3'N; 24°01.1'W; w.d. 5361m. We had apparently recovered 3 full barrels and a small amount of sediment in the top barrel. (Total recovery was eventually recorded as 7.14m.). The sequence looked very similar to that in CD56-4 and again we were left wondering whether we had indeed penetrated through the feather edge, although we were well to the east of the debris flow boundary as mapped from GLORIA.

We now returned to the approximate position of the debris flow recovery at site CD56-2 and here we planned obtaining a bulk sample with the Kasten corer. A 2-meter Kasten corer was launched at 0014/053. This penetrated the bottom and was pulled-out at 0224/053: position 30°45.71'N; 23° 58.38'W; w.d. 5360m. The core, **CD56-6-K1**, was inboard at 0421/053 and contained almost 2m of recovery. largely turbidite that was assumed to lie on top of the debris flow. We decided to progress with our coring program planned for the pelagic "black hole site" reserving the possiblity that we might return to the debris flow termination for a last attempt at deeper penetration.

Pelagic Coring for Geochemical Studies: The ship was underway at 0447/053 for a short 3.5kHz survey to the southeast that would confirm a boundary in our mapping. We arrived on site CD56-7 at 0834/053 and a 2-meter Kasten corer was launched at 0852. In the meantime, it had been found that the mixture of Kasten coring equipment that had been supplied did not all fit together and we anticipated problems in turn-around times when intensively Kasten coring. Also the RVS engineers had been carrying out further winch tests on the advice of the shorebased engineering group and the results of these were dispatched to Barry.

CD56-7-K1 was inboard at 1254/053 and was an almost full barrel (1.9m) of pelagic marls and clays with fine-grained turbidites, an identical sequence to Shackleton Cr.86 core 15, that was also located on this hill (Kidd et al.,1985). Its pull-out located it at 30° 21.7'N; 23° 34.9'W. We then proceeded to take a single-spade box core, **CD56-7-B1** (0.43m recovery) and a further 2-meter Kasten core, **CD56-7-K2**, as near as possible to these coordinates to satisfy the needs of the geochemical and geotechnical sampling programmes. Samples were taken for the IOSDL Biology Group from the box corer.

The weather was sunny throughout day 053 and the sea calm and with a low swell. Morale was steadily improving as we planned a modified programme of coring and camera work at three of the existing TOBI sites using the acoustic navigation system, along with further 3.5kHz surveys and coring back towards the Canaries.

CD56-7-K2 was secured inboard at 2333/053 and had recovered an identical sequence to 7-K1, although with slightly better recovery (2.0m). The ship then traversed northwards and downslope to a location dislaying an 'acoustically-speckled facies' on the GLORIA mosaic, which contrasts markedly with the 'solid black' displayed at our previous site 7. A 2-meter Kasten corer was launched and this penetrated the bottom at 0320/054. The pull-out location for **CD56-8-K1** was 30°32.02'N; 23°34.80'W. The pelagic sequence in this 1.83m core appeared the same as in CD56-7 but the turbidite units seemed to be either missing or thinned in comparison. This is the opposite of what we had expected at this bathymetrically lower level. Also no turbidite interval seemed obviously related to the edge of the debris flow just to the north.

Return to the Debris Flow Termination: Once the corer was secure we traversed northeastwards back to the tip of the debris flow to attempt a bulk 4-meter Kasten sampling of the debris flow, now known from shipboard P-wave logging of our previous cores to be below at least 3m of turbidite. We would also attempt a 4-barrel piston core east of our previous sites to try for full recovery of the debris flow unit.

We hove to on station **CD56-9-K1** at 0850/054 and launched the 4-meter Kasten corer. This pulled-out at 1109 (30°46.04'N; 25°56.98'W; w.d.5359m) and was inboard by 1244. Once opened the Kasten corer revealed, in the lower half meter of barrel and in the catcher, a spectacular and very stiff top to the debris flow ; this coming below a sequence of pelagic units and the generally very soft A and B turbidites of the MAP sequence (Total recovery 2.2m). While some set about sampling this core on deck, others rigged a 4-barrel piston corer. **CD56-9-P1** was launched at 1500 and was triggered at 1716 into the bottom.(location 30°45.95'N; 23°56.97'W; w.d. 5359m). We then found that we could not pull-out and the ship was effectively anchored into the bottom. We recorded over 10 ton hauling load on the coring winch and the ship was heeling over to starboard but we were still unable to pull-out. After some manoeuvring of the ship and a number of attempts at pull-out up to 9 tons, the Principal Scientist and Captain decided on a further major pull when we were certain the ship was vertically over the corer. This was to be indicated by the separation of the pinger signal, the wire angle and our GPS navigation. At a load of 12.5 tons the corer eventually 'pulled-out' at 1755. At 1945 the remains of the warp termination came aboard. The termination had broken as designed when it passed its safe-working-load and the corer had remained in the bottom and had been lost! (Although the ship was now free, there was a general feeling of great disappointment:- a full piston corer assembly had been lost possibly curtailling our future programme and the Saharan debris flow had foiled "Dr. Debris" once again!)

Another core-head was positioned in the launching bucket, all deck equipment was made secure and we set sail at 2015 for an overnight 3.5kHz survey to TOBI site 2, which had been surveyed by the "Discovery " cruise in 1990 (Masson et al.,1990). In the apparent absence of a TOBI capability ourselves, we planned follow-up coring and camera work here with acoustic navigation.

Transponder-navigated Coring and Camera Surveys at TOBI Site 2: The morning broke with the wind at 10 knots, slight sea, low swell and cloudy skies with showers. We were on-site to begin laying the beacons for the acoustic navigation net at 1336/055. By the end of the day four of the six transponders were in place towards completing a 15km square grid over a portion of a turbidity current channel that had been detected on the 1990 TOBI survey. We had spent much of the day creating a blown-up grid on which was placed a cross-over of two anamorphosed TOBI swaths replayed at 1:25,000 scale at 41°N. The plan was to make an overlay of the surveyed-in beacon position grid, with the margins of the channel plotted on it from our survey records, and then to locate the channel margins shown on the the TOBI swaths in relation to the overlay. By this means, we would have the TOBI coverage located relative to the beacon net.

The laying of the transponder beacons took until 0125 on Day 056. We then began a tight echo-sounder survey at 5 knots designed to cross the channel on five occasions and to survey-in the transponders out to the edges of a 12km box (**Figure 3**). This was complete by 1129/056. That morning the wind was at 5 knots, there was a rippled sea and low swell and skies were cloudy and clear. Whilst we carried out a computer calibration and obtained plots of our acoustically-navigated track, we launched a 2-meter Kasten corer at 1136 with a pinger on the warp at 50m wire-out and a transponder at 200m. Once we had relocated the TOBI sonographs in relation to the acoustic net we began to reposition the ship. We found that we were over 1km from our target selected on the lip of the northern channel levee. This meant that the ship had to move through the target and then back over it. This manoever brought the corer transponder towards the target more slowly than the ship had moved. With the ship now stationary over the target, we dropped the corer into the bottom from 150m up. A weak pull-out occurred at 1504 at precise location 30°31.6863'N; 21°09.3680'W; w.d. 4879m, which was 116m from the target. Unfortunately the corer (**CD56-10-K1**) came up almost empty because one of the catcher doors had not closed. This was presumed to be because of an excess of electrical tape used in pinning back the triggering paddles. About 25cm of sample was later bagged.

We relaunched the corer at 1718/056 and it reached bottom at 1916. At pull-out the precise position of **CD56-10-K2** was 30°31.7255'N; 21°09.3257'W; w.d.4873m. The corer was secure inboard at ~2100 but still there was little recovery (0.3m). We decided to stay at the same site and try the single-spade box corer. This was launched at 2130 and was in the bottom at 0107/057. The pull-out registered 6 tons and **CD56-10-B1** had a recorded position of 30°31.715'N; 21°09.344'W; w.d. 4875m. When it was brought aboard the box corer was two-thirds full but contained no sand as might have been expected (recovery 0.4m).

We then moved to the base of the northern channel wall and deployed box corer **CD56-11-B1** at 0312/057. This came aboard at 0855 and contained 35cm of soupy turbidite top, over a foram sand and dark stiff silty claystone layer at the base. The precise location obtained at pull-out had been 30°31.4927'N; 21°10.008'W; w.d. 4892m. It was felt that we could get a Kasten corer to penetrate further here and so we elected to launch **CD56-11-K1** at 0901/057. This was at the bottom at 1113 but there was only a weak pull-out. (position 30°31.5174'N; 21°09.9804'W; w.d. 4898m; 26m from target). No more was recovered with the Kasten corer(0.42m) than the box: again the dark claystone layer was at the base.

We now moved to the channel axis and, suspecting that there may be more likelihood of sand here, we launched box corer **CD56-12-B1** at 1140. This corer was on the bottom at 1620 and was inboard at ~1830. Despite a weak pull-out it was almost full on recovery and contained a black sand layer in the base (0.40m recovery). It had been precisely located

24m from target at location 30°30.9891'N; 21°09.0166'W; w.d. 4888m. Resolving to return to sample the channel axis, we moved on to place a transect of core sites on the southern channel wall where the 1990 TOBI survey had detected slump folds.

The first site over the slump folds, **CD56-13-K1**, was at the base of slope. This Kasten corer now had the heavier of the two core-heads on it. and was launched at 1933/057. It penetrated the bottom at 2152 and pull-out occurred at 2154. The precise position was given as 30°30.7328'N; 21°06.1520'W; w.d. 4871m; 41m off target. When inboard at 2340 and opened, this core was found to be 0.9m long and contained a thick black sand unit (thought to be equivalent to the B-turbidite of the MAP sequence).

We then moved to the mid-slope site amongst the slump folds and launched another Kasten corer at 0130/058. This core was taken at 0355 and resulted in a 5 ton pull-out. **CD56-14-K1** was precisely positioned at 30°30.6362'N; 21°06.1461'W; w.d.4865m. It was brought inboard at 0550 and was found to be two-thirds full (1.74m). Again, when we opened it, there was a black sand graded unit.

At the upslope end of the transect of the southern channel wall was site **CD56-15-K1** and here we recovered an almost full 2-meter Kasten barrel. The corer was launched at 0630 and pull-out was at 0909. The precise position was 30°30.2142'N; 21°06.1957W; w.d. 4858m. The opened core was 2.1m long and contained a number of turbidite and pelagic units (perhaps representing a time span as far back as isotope stage 13) but no sand units. Clearly this was not an obvious overbank levee sequence but it did present an opportunity to date the building of the levees by returning later and trying for a long piston core.

At this stage we had too much core inboard to process through the laboratory so we began a camera station, **CD56-C1**, at 1241/058. A south-to-north run across the slump folds was planned, continuing across the channel and onto the other levee. It took some hours to precisely position WASP at the southern end of the trackline which was to run 30°29.9'N; 21°07.15'W to 30°32.0'N; 21°06.65'W, and the IOSDL technicians were intermittently making tests on the electrical cable as it was run out. Eventually we traversed the complete line almost perfectly in a navigational sense but we were unsure when we began hauling-in at 2228 whether the camera's flash unit had worked, because no indication was received on the pinger monitor. The camera was inboard at 0040/059 and subsequently we learned that the camera unit itself had worked but the flash unit had indeed not functioned correctly, resulting in no photographs.

We then moved to a site in the channel axis for another attempt to get deeper in the sequence there, this time with the increased weight of the other Kasten corer-head. The corer was launched at 0200/059 and was in the seabed at 0400. The precise position for **CD56-16-K1** was 30°31.321'N; 21°06.000'W; w.d. 4886m. When the corer was on deck, it was found to be almost empty (0.1m recovery) but with the dark silty claystone again apparently the cause of the lack of penetration in this channel axis.
A further axis site was attempted about a mile to the west, this time with

the box corer **CD56-17-B1** was launched at 0645/059 and was in the seabed at 0921. Only a weak pull-out was observed but, when inboard at 1127, it was found to be over half-full (0.28m recovery). The precise position was 30°31.095'N; 21°06.8396'W; w.d.4887m and again the claystone made up the basal layer.

We then switched to piston coring; firstly to get a longer record at the southern levee site and secondly to try to penetrate the basal unit of the channel; preferably in the strange 'lumpy' acoustic facies detected by TOBI at the base of the northern channel wall. At 0800 there was a slight sea, moderate swell and it was cloudy to fine and clear. The first piston core was to be a 4-barrel length on a return to the levee site, **CD56-15-P1**. Because the loss of the piston corer previously had left us with incomplete coring systems of either RVS or IOSDL type, this corer was made up with a mix of barrels of RVS stainless steel (top two) and IOSDL drillpipe steel. Some drilling of screw-holes was necessary. During launching, however, when the corer was taken to vertical in the holding bucket its two lower (IOSDL) barrels dropped off and were lost! It was concluded on recovery of the remainder of the corer that the grub-screws in the new holes had been insufficiently tightened. The second launch at this site went smoothly and the corer was in the water at 1440. (During the deployment we were visited by two fin whales, one of which was estimated at over 30ft long as it approached to within 10 yards of the port side). The corer triggered into the seabed at 1644 and there followed a 7 ton pull-out. The precise position was given as 30°30.1886'N; 21°06.0546W. When inboard at 1840 and dismantled, the recovery was found to be 9.40 meters. P-wave logging later revealed only a thin layer of sand near the top, perhaps equivalent to the thin laminae of sand in the Kasten core from the same site.

Renewed Possibilities for TOBI Operations: During that evening, the IOSDL technicians came up with the intriguing possibility that TOBI could be operated on the RVS conducting cable that was on the ship's own winch. This route had previously been discounted because the cable was deemed to be incapable of sustaining the voltages required to trigger TOBI down the wire from the ship. Their tests on the cable at various stages of wire-out during the WASP deployment had suggested that the cable might be capable of transmitting all the necessary incoming data for TOBI sidescan, profiler and monitoring of vehicle behavior. But it still could not transmit the trigger pulses and they had an idea that this problem could be overcome by having TOBI trigger itself automatically every 4 seconds. They needed a test dip with TOBI simply to wet the transducers and run about an hour of tests. The PSO readily agreed to this proposal, since there was still time left on the cruise to conduct our prime objective a full 5-day TOBI survey as an extension to the 1990 TOBI Site 3, as well as the necessary 5 days of follow-up transponder-navigated coring and camera work.

Continued Coring at TOBI Site 2: The next site within the acoustic network at TOBI Site 2 was at the base of the northern channel wall and we rigged for a 2-barrel piston core, **CD56-18-P1**. The corer was launched at

2057; it was in the bottom at 2311 and registered a 6.2 ton pull-out. The precise position was 30°31.4041'; 21°09.9977'; w.d. 4891m; and was 8.4m off target! This corer was inboard at 0052/060 and recovery was 3.8m. When the sections were P-wave logged a 2m sand layer was detected. This confirmed our view that all the previous box and Kasten cores in the channel axis had penetrated only as far as a thick sand layer.

We now moved less than 4nm to the southwest to a site in a bright area of high acoustic backscatter seen on the TOBI sonographs. A 2-barrel Kasten corer (**CD56-19-K1**) was launched at 0823 and was inboard at 1200 after a 6ton pull-out (location 30^0 29.999'; 21^0 04.95'). However there was no recovery and we subsequently tried a box corer. **CD56-19-B1** was launched at 0823/060, penetrated bottom at 1104, pulled-out at 6tons at 1106 and was inboard at 1200 (precise position 30°30'N; 21^0 04.9'W 05.1153W; w.d. 4855m). The box was half-full (0.28m recover) and a thin sand horizon at the base had clearly impaired penetration. This sand was now suspected as being the cause of the higher backscatter but we would have to investigate a lower backscatter area to the west to confirm this interpretation.

TOBI Testing: Next came the short test dip for TOBI signal reception. We launched the vehicle using the conductor cable simply for lift and streamed it aft of the ship on the vehicle's umbilical rope connection. The launch was at 1414/060 into a moderate swell and slight sea with "whitecaps"; the wind was 11 knots but it was sunny and clear. These tests of the incoming signal proved positive and the vehicle was recovered at 1545. (The good news was very welcome on St. David's Day!)
[Some discussion ensued on the recorded safe working load of this cable and its discrepancy with our shipboard calculations of the loads that we might expect whilst towing TOBI with 8km of cable-out. The PSO contacted RVS by telephone to request details of their calculations before our now-projected deployment at Site 3 on Monday pm.]

Continued Coring at TOBI Site 2: We now moved to site CD56-12 in the channel axis again. Our success at the base of the northern channel wall had prompted us to try a 2-barrel piston corer in the channel axis. The corer was launched at 1830 and was triggered into the seabed at 2122. Despite a 10 ton hauling load we failed to pull-out. A second pull at 9.5 tons indicated that we were 'anchored' again as we had been in the debris flow when the other piston corer was lost. We elected first to have the ship take up a position directly over the transponder on the wire. This could now be accomplished with an order of magnitude better accuracy because of the acoustic navigation. A pull of 10 tons at this point again failed to free the corer. Next we moved the ship to a range of 1km from the target and, keeping the tension at 9.5 tons, we proceeded to navigate the ship around the edge of the 1km range circle as displayed on our acoustic navigation monitor screens. At 2205 the load dropped off and we began hauling-in, left now to wonder whether we still had the corer on the end of the wire! We had completed a process analagous to removing a fence post by a circular motion combined with vertical pulls - all

2259/060 and apart from a slight bend in the lower barrel it had suffered no damage. A full lower barrel contained 3.0m of sediment, the top appearing to be a coarse sand mixed with mud and almost certainly indicating some disturbance. The core catcher contained a greenish brown sandstone associated with a white hard chalk. When extruded from the catcher the boundary between these two lithologies was very sharp and dipping steeply and we thought it might possibly be a clast boundary (debris flow?). Under the microscope the broken surfaces of the sandstone suggested that it might be volcanogenic; little biogenic material was evident. The core catcher contained nothing.

We now moved to our last core site within the TOBI Site 2 acoustic net: **CD56-20-K1.** This site is on the "interference fringes" area, a patch of generally weak acoustic backscatter with wavy 'fringes' displayed on the TOBI sonographs. The 2-barrel Kasten corer was launched at 0129/061, was in the seabed at 0327 and pulled-out at 6 tons. The precise position was 30° 28.9983'N; 21°07.0053'W; w.d. 4857m. The corer was inboard at 0521 but it contained only a few tens of centimeters of muddy sediment: once again no sand recovered from the weak backscatter areas. The cause of the lack of recovery was thought to be pre-triggering of one of the catcher doors.

The coring complete, we now ran a short 3.5kHz line over the net to the northern side of the channel where we began retrieving the beacons with Beacon A, at 0625/061.

Saturday 2nd March (061) dawned as a beautiful day: slight sea (force 3), low swell and light winds; clear and sunny. While the RVS technicians and deck crews continued to recover the beacons, the TOBI technicians prepared their vehicle for deployment next morning. The RVS engineers continued to work on the portable winch so that it could be used just to launch TOBI, and the coring teams took a well-earned rest in the sunshine.

We recovered our last beacon at 1630/061 and began a 3.5kHz run to the location of GLORIA calibration core site, S86-7 (Kidd et al., 1985), to the north of TOBI Site 3. We then prepared a plan for a ~10km square beacon net around this core site and located the net at the mid-point of an extension to the original TOBI survey made up of four swaths 30nm long. These overlapping swaths were drawn up over photographic blow-ups of the GLORIA mosaic at a scale of 1 : 59666 @ 41°N. We planned to deploy five beacons initially and then, if necessary, extend the net southwards later, with our remaining three beacons, onto the original TOBI coverage.

Surveys to Extend TOBI Site 3: The first beacon for the TOBI Site 3 extension was laid at 2316 and the last was complete at 0605/062. The net was surveyed-in by 1034 with three ~6nm cross lines run at 5 knots (Figure 4). We then ran southeastwards at 10kts to 5nm beyond the end of our projected northern TOBI line. On arriving there at 1237, we turned northwestwards for a TOBI deployment into the wind and sea . The wind was 24 knots and there was a very heavy swell.

TOBI was lifted into the water at 1325/062 using the beleaguered RVS portable winch and kept floating about 100m astern on its umbilical cable while the switch was made to the ship's conducting cable deployed over the central sheave of the aft A-frame. The depressor weight was connected and deployed and we began to pay-out cable. Unfortunately at 1400 we had to recover the depressor weight because of a faulty termination. The termination was rebuilt and the depressor re-deployed by 2039. This time the winch had paid-out to almost 1000m before a fault was detected again at the depressor and we had to recover it once more. This time all seemed well when tested when the winch was stopped at 200m wire-out and we were able to press ahead and lower TOBI to within 400m of the seabed. At the same time, we attempted to get the ship and vehicle back on the eastern end of the northern line that was planned to run just south of the seamount on the "Calibration Site". By now the weather and sea state were deteriorating rapidly and we counted ourselves fortunate to have TOBI launched successfully before it would have been impossible due to sea conditions.

We were on line at 0400/063 and beginning to collect reasonable, although not yet optimal, TOBI sidescan data; however, the profiler data was already unusually good. Line 1 was followed until 1630 with good outer range images of the seamount recorded mid-line and indications of a channel near the end of the line on the port side. The turn was head-to-wind and was accomplished by running NW towards an intersection with the next survey line (Figure 4), whilst hauling in about 1000m of wire in order to raise the vehicle sufficiently for a relatively rapid turn back to the SW. The turn took 4.5 hours in total and we were on line 2 by 2200.

During the previous day, there had been general concern amongst the engineering staff aboard about welding cracks on the RVS portable winch that had been noted during and after the TOBI deployment. These now appeared to be flexing as the vessel rolled! One set were at the join of the winch drum pillar mounting-blocks with the base-plate while a second set were around the join of the winch drum axle and the drum cheek-plates. The winch drum was secured with chains to the deck and then wedged to prevent further lateral movement. Advice emanating from RVS via telex was that the winch should not be used any more on this trip; but this now did not take account of the need to finally recover TOBI in a straight 2-3ton lift on to the after-deck. [The advice was later amended with the suggestion that further welding could secure the winch sufficiently for recovery!]

TOBI Line 2 was followed until1600/063. Near the start of the line we observed two spectacular cross-cutting channels at the edge but largely within the debris flow. Further SE the major debris flow boundary seen on GLORIA was weak on TOBI suggesting it is at depth. In mid-line, we were passing through the northern end of the acoustic net and were able to see that the vehicle was tracking very well along the planned line, even though the ship's track was offset.

The turn at the end of Line 2 was much more difficult. By now the wind had gone around to northerly and the sea state was force 7-8. Again we hauled the vehicle in 1000m during an extension of the line but as we made the relatively sharp turn to starboard the vessel rolled violently. We were back on line by 0200/064; the turn having taken 10 hours. As the ship reached the end of line, TOBI had been within range of the seabed for up to 2 hours. We were imaging a seabed with a blocky and streaky surface interpreted as debris flow. Soon after this we began getting good images of a channel, presumably on the surface of the debris flow, that ran continuously into the acoustic net.

At 0800/064 the wind was at 27 knots with a rough sea and heavy quarterly swell and skies.were cloudy. We were already expressing concern that the bad weather might force us to run TOBI longer than intended because recovery could be difficult. By the time we reached the end of Line 3 at 0700/065, the seas were up to force 8 and rising and we were forced to extend the line until daybreak because of the likely difficulties of turning beam-on in such conditions. In the event, this particular turn was not made until 0800 and we were not back on the originally- planned survey line until 2100/066.

By 0800/067 the gale had moved eastwards and we were making good progress towards the end of the TOBI survey. The wind had dropped to 6 knots, the sea was rippled with a moderate swell and the skies were cloudy, but cleared to sunshine by mid-day. The end of Line 4 was reached by the ship at around1100 and by the vehicle at 1100. We then began hauling-in the 8000m+ of cable for TOBI recovery in the late afternoon in beautiful sunshine but still a heavy swell. The recovery went exceedingly well. The depressor weight was recovered at 1545 and the TOBI vehicle was inboard and secure by 1625/067.

Transponder-navigated Coring and Camera Work within the TOBI Site 3 Extension: We now set off westwards to the acoustic net at 10 knots. The first core was to be with the Kasten corer at the same location as Shackleton 126 gravity core S126-8, which in 1982 had recovered near-surface debris flow. We were on station for **CD56-21-K1** at 2046/067 and the corer was launched quickly. The corer was at the bottom at 2319 but on recovery at 0130 was empty, despite both catcher doors having closed. There had been very little pull-out noted. We suspected that the corer had not succeeded in penetrating a hard substrate and had simply rolled over because there was sediment on the outside of the barrel. The station was repeated with a 2-barrel piston corer launched at 0415/068. This corer, **CD56-21-P1**, was in the bottom at 0643 and a pull-out of 6.5 tons was recorded at 0645. (Acoustic location fix: 30°36.6943'N; 22°24.5238'W; w.d. 5057m.). On recovery the core was just over 3m long and appeared to have a mix of coarse sand, mud and hard white chalk within it, taken as indicative of debris flow.

We now moved to one of two channels that appeared on the TOBI sidescan record to run together at a confluence in the south of the acoustic net. The first to be cored appeared not to be infilled but to be sitting on top of the debris flow. **CD56-22-P1** was a 2-barrel piston corer launched at 1020/068. The sea was almost calm with a gentle broad swell but we were getting frequent rain squalls. This corer was in the seabed at 1218 and despite a relatively weak pull-out was recovered at 1435 with its lower barrel almost full. The precise location was 30°34.5372'N; 22°5352'W; w.d. 5058m, similar in depth to the previous site. We then moved to the second channel, this one seemingly infilled, and launched a 2-barrel piston corer at 1510. This was in the seabed at 1714 but, despite an attempted pull-out to 10 tons, we failed to retrieve it. We again used our technique that had successfully removed our other 'anchored' corers, namely to steam the ship in an arc 1km away from the core location keeping a tension of 9 tons on the warp. Again our patience was rewarded and the corer pulled-out at 1909 (location: 30°36.107'N; 22°23.6296'W; w.d. 5068m). It was inboard at 2120 and was made secure before a 6nm traverse to the deployment point for a WASP camera run. The corer lower barrel had been sharply bent but we were still able to remove a full 3m liner section from it.

The camera station, **CD56-C2,** began in the southeast of the acoustic net at 2250/068 and was near-bottom by 0100/069 for a run towards the western channel confluence. Its monitor signals showed that, although it could be made to flash as the vehicle moved above and below the camera's 18m threshold for focussing, there was no regular triggering of flashes at the 32 sec interval required by the camera. We decided to progress with the survey, even though the photographs would at best be taken only every 2-3 minutes which was the optimum that we could hope for from the hauling and paying-out of the winch. However, by around 0315, the flash unit appeared to be entirely inoperable and it was decided to end the station. The WASP was inboard and secure by 0500 and operations to recover the acoustic beacons were begun at 0700. All beacons were inboard by 1350/069.

Continental Slope Coring for Geotechnical Studies: We now set off eastwards to begin collection of a Kasten core transect on the western slope of the Canaries for the geotechnical slope stability programme. By 1400/069 the vessel was underway at 12 knots towards the base of the insular slope at 29°N; 19°W. Because of the fair conditions and calm sea, we were still able to collect useable 3.5kHz records at this speed.

The ship arrived at site **CD56-24-K1** at 0655/070 and hove-to for deployment of the 2-meter Kasten corer. This location was just upslope of the edge of the debris flow area, as mapped earlier from GLORIA and 3.5kHz, and was over an area of sediment waves. The corer was on the bottom at 0842 but there was a weak"pull-out". On recovery the catcher doors had not activated and there was no core. The corer was re-launched at 1055 and pulled-out from the seabed at 1230. (location: 29°01.53'N; 19°00.54'W; w.d.4386m). On recovery this corer was almost full with stiff muds and sands. We then transitted upslope over the sediment wave field until we reached more rugged topography at around 3400m w.d.
A reciprocal turn took us back on our track and we selected an upslope site for the end of the geotechnical transect. A 2-meter Kasten corer, **CD56-25-K1,** was launched at 2009 and penetrated the seabed at 2139. This had a good pull-out and, when inboard at 2255, was found to be full (location 28°47.83'N; 18°14.90'W; w.d.3364m). This time the stiff muds contained shell and coral debris intermixed with basalt clasts and pumice.

Our last Kasten core site in the transect was selected from the 3.5 kHz record on a large sediment wave. The 2-meter corer, **CD56-26-K1** was launched at 0107/071 and penetrated the seabed at 0247. On recovery, this again was almost full with stiff muds and contained volcaniclastic sand horizons that had primary apparent dips of up to 30 degrees.

We now moved our investigations to the source area of what we were now calling 'the Canary Slide' (Masson et al, in press) and selected a site downslope to the southwest, where we recognised the edge of the debris flow adjacent to the sediment wave field. A 2-barrel piston corer , **CD56-27-P1,** was launched at 0700/071 and this was in the seabed by 0833. This was recovered at 1010 with sediment in both barrels, although it clearly had penetrated both muds and basalt gravels. (location 28°37.8'N; 18°50. 5'W; w.d. 4280m)

Our last station was selected upslope on a Discovery188 GLORIA line. This 2-barrel piston corer, **CD56-28-P1,** was launched at 1231/071 and penetrated the seabed at 1359 (location: 28°33.18'N; 18°30.887'W). The corer was inboard at 1518 having recovered a 4m core.

We completed our programme with a short 3.5kHz survey of the upslope area towards the perceived source of the "Canary Slide". All scientific watches were ended at 1630 when we hove-to west of Palma island to recover the 3.5kHz and PES fishes. The ship arrived in Santa de Tenerife harbour at 0900 the following morning (072).

TOBI OPERATIONS AND PROCESSING (IR/CF)

The equipment on TOBI (Towed Ocean Bottom Instrument) for this cruise comprised the 30 kHz double-sided sidescan sonar, the 7.5 kHz sub-bottom profiler, the tri-axis fluxgate magnetometer, a thermistor temperature probe, a dual axis E-M log and the vehicle attitude sensors (depth, heading, pitch and roll),

New equipment to be used for the first time included a pressure-balanced E-M log head, erasable optical cartridges for data logging and a computer display for digital data.

When it became apparent that the deck mounted winch system would not be fully operational for the remainder of the cruise, attention shifted to the possibility of using the ship's conducting cable. This cable is significantly different to the deck winch cable in that it only has a single conductor and uses the armouring as the return path. The deck winch cable uses a coaxial cable as the conductor and return resulting in far superior electrical characteristics. The most serious problem with the ship's cable was the high attenuation of high (about 100 kHz) frequency signals. Also, as the armouring is used as the return, it was thought that the cable characteristics could change depending on the wire out.

An impedance test carried out during the first WASP run suggested that the attenuation characteristic did not change appreciably with wire out. An attenuation test was carried out on the cable after WASP was back aboard. The results of the test are shown in the table below, along with a similar test on the deck winch cable for comparison.

Frequency (kHz)	Ship's Conducting Cable (13 mm) Attenuation (dB)[1]	Deck Winch System (0.68") Attenuation (dB)[2]
1	8.0	6.4
2	8.0	6.4
5	9.1	5.0
10	13.0	6.0
20	20.4	7.1
30	26.7	8.4
40	32.8	9.4
50	38.4	10.5
60	44.4	11.5
70	48.0	12.6
80	50.5	13.6
90	54.0	14.7
100	60.0	15.7

Notes

1. Terminated with 60
2. Terminated with 50

From this test it was concluded that the profiler, sidescan and DPSK digital data could be transmitted up the cable with suitable modifications to the vehicle and deck electronics. However, the high frequency (80, 90 & 100 kHz) trigger tones vital to the synchronisation of the system would be highly attenuated and result in very unreliable operation.

The solution adopted used an accurate four second pulse, derived from the vehicle's digital data timing system, to trigger both the profiler and sidescan in a free running mode. This trigger pulse was then derived accurately on the ship from the digital data's frame synchronisation pulses.

The new system was tested on day 060. This was carried out in vats to prevent any possible damage to the transducers or power amplifiers. The vehicle was deployed and towed on the umbilical. Electrical connection was via the conducting cable and umbilical. A broken wire in the vehicle's electronics prevented digital data being transmitted but good signals from the sidescan and profiler were encouraging. The vehicle was recovered and the fault repaired.

The ship's conducting cable was reterminated to suit the TOBI swivel prior to a full deployment on day 062.

The vehicle was launched using the deck mounted winch system at about 1325. On turning on the power to the vehicle a short circuit was encountered. On recovery of the depressor weight the fault was traced to a short in the mechanical termination to the cable. The termination was remade and the depressor deployed. This time the vehicle turned on correctly but after paying out 900 m of wire another short circuit occurred. The depressor was recovered and the short traced to the electrical termination of the conducting cable. This was repaired and the depressor redeployed at about 2330.

The system suffered a couple of early problems. Firstly, when acoustic contact was made with the bottom the signal levels of the profiler and sidescan were very low. This was due in part to the ship's cable but mostly due to the fact that TOBI had previously been used over very rocky terrain which gave very large signal returns compared to the sediment in the area under investigation. The problem was cured by adjusting amplified gains in the respective receivers. The second problem was on of data synchronisation. The hardware solution to the problem of deriving the four second trigger pulse was found to be unreliable due to spurious pulses entering the system. A software solution was adopted. Although not ideal, this system was used for the remainder of the run. All problems were solved during the first 16 hours of deployment. Thereafter TOBI operated well for the rest of its 113 hour run. The vehicle was recovered at about 1625 on day 065.

The weather was the main factor in determining the quality of the TOBI sidescan records. For most of the run the wind was above force 6 with gusts up to force 10. Under these conditions the pitching movement of the ship is transmitted to the vehicle causing the sidescan to transmit and receive in different vehicle attitudes resulting in dark lines (low signal) appearing on the record.

Average speed over the ground and wire out were 1.6 knts and 7000 m for the legs into the wind and 1.9 knts and 8500 m for the downwind legs, the vehicle flying at a depth of about 4600-4700 m in both cases. The better quality records were achieved during the downwind legs due to either the ship pitching less or, more likely, the extra speed and wire out having a damping effect on the vehicle motion.

The profiler, with its wider downward looking beam pattern, was unaffected by the motion and gave excellent results throughout.

The digital data system worked reliably but the calibrations used for the E-M log and temperature probe displays need to be investigated.

During the 113 hour deployment a total of 200 nautical miles of seabed were suveyed at an average speed of 1.77 knts. Approximately 2200 sq kms of seabed were surveyed with the sidescan.

Processing: As this was the first time that erasable optical discs were used for logging TOBI data, a problem occurring during change-over of drives had to be corrected. After one cartridge was logged with many losses of synchronisation, it was decided to use the logging program itself to lock on to 4 Hz pulses. It has a 3.95 second dead-time once triggered and generates a profiler trigger pulse that could be used as the 4 second master pulse to trigger dry paper recorders and oscilloscope. The result was stable synchronisation except at cartridge change-over time.

Processor programs originally written to ready from WORM drives were adapted to read from erasable drives instead. Two addition features were added to the program that generates anamorphically corrected files:-

a) To produce an unscaled record similar to the real-time monitor record.

b) To detect the worst drop-outs that occur during pitching and increase their amplitude. This was only partially effective since during pitching the side-scan beams are looking in the wrong direction. Before the vehicle was launched, data from Discovery 188 was replayed anamorphically corrected to match GLORIA enlargements and, after much massaging, profiler records from TOBI runs 2, 3 and 4 of that cruise were recovered.

In order to cope with the loss of synchronisation, especially at the beginning of the run, a diagnostic program was adapted. This program was modified so that data in the sidescan and profiler arrays could be rotated by increments of 0.25 sec. and written back to the cartridge. The water-column value used during profiler replaying could be edited using the program.

During the run anamorphically corrected records were generated to build a mosaic as soon as each cartridge became available and subsequently replayed again after some massaging at 3 different scales. Profiles were produced for the whole run though a lot of editing is still required to offset the effects of loss of correct attitude values.

WASP OPERATIONS (DE)

The WASP (Wide Angle Survey Photography) system comprises a 35 mm *Benthos* camera, *Camera Alive* twin-head flash unit and an IOS 10 kHz telemeter and control unit. It is designed to be operated at a height of between 7 and 18 meters above the seabed. A 35 kHz altitude transducer provides an accurate indication of height-above-the-seabed and triggers the camera automatically when within a pre-set window. The deck system consisted of an IOS-developed "waterfall" display operating on an IBM PC attached to the 10 kHz echo-sounder fish. This provided a clear, user friendly method of displaying and measuring the telemetered signals. (On Cruise 56 this system was soon adopted for all coring operations to monitor the corer height off the seabed.)

WASP was deployed on 27th February and 10th March with an *Oceano* transponder attached to the front of the frame. This, when operated with the seabed net provided good positional fixes.
On both deployments a fault occurred.

On the first there was no flash indication when operating at the seabed. During recovery, with the 35 kHz detecting a surface-reflection, the flash indication reappeared but at half the pre-set repetition rate.
On inspection the camera had operated normally and had wound on half of the film. Test strips of the film were developed and the results were consistent with there having been no flash operation. The flash unit control board was found to be malfunctioning and was replaced with a spare.

On the second deployment, the system again appeared to malfunction at the seabed. The system provided occasional flash indications and eventually stopped. This time it did not recover at the surface, which aided diagnosis. Again the camera had operated correctly, winding on the anticipated amount of film. On developing the film it was found that approximately 70 seabed photographs had been taken. This however did not correlate with the number of flash indications received. The system was inspected and an intermittent fault with the camera flash trigger connector was found. This answered the question of why the flash stopped altogether.

There were no further operations with WASP on Cruise 56. The system was prepared for operation on the following cruise, 57, with better results: two successful deployments and 1100 photographs taken!

ACOUSTIC NAVIGATION SYSTEM (DB)

The RVS *Oceano* acoustic navigation system was used at two study areas with six transponders used at the first and five at the second. The table below gives the position of the transponders. At both sites only "relative" calibration was carried out. The resulting rms error after calibration was less than 1 metre in both cases, with absolute errors of less than 70 metres.

No problems were encountered during the operation of the system during WASP and coring operations. When operating with TOBI, continuous fixing was not possible because the remote transponder lost lock with the acoustic navigation system; however enough positions for TOBI were achieved to give a reasonable track plot of the vehicle. Ranges of over 17km were achieved. Some positioning was possible with the 3.5 kHz sounder running. In the past this has not been possible. However, for continuous positioning the 3.5 kHz must be off.

All the transponders released first time (at ranges of over 6km) and were recovered by the ship with no problems.

Transponder positions:

Xpdr	Latitude	Longitude	Easting	Northing
Study Area (TOBI Site 2)				
A (919)	30° 32.63367N	21° 10.88788W	770399.73	3382437.42
B (920)	30° 33.83521N	21° 8.83664W	773624.60	384740.54
C (921)	30° 32.53042N	21° 5.94405W	778312.76	3382447.35
D (922)	30° 29.97888N	21° 5.80650W	778654.25	3377737.50
E (923)	30° 28.39444N	21° 9.00691W	773606.48	3374678.75
F (924)	30° 29.95636N	21° 11.44696W	769628.75	3377467.32
Study Area (TOBI Site 3 Extension)				
A (924)	30° 37.45190N	22° 18.75861W	661724.86	3389168.18
B (923)	30° 38.28740N	22° 22.46395W	655782.77	3390624.42
C (922)	30° 36.40018N	22° 24.22662W	653016.60	3387097.76
D (921)	30° 33.37138N	22° 21.52661W	657412.52	3381564.63
E (920)	30° 34.67514N	22° 18.82323W	661698.49	3384036.95

The UTM Central Meridian for both sites is -24 degrees (West)

Remote Xpdrs used - TOBI (361-50) & Coring + WASP (918)

AIRGUN, 3.5kHz AND PES SYSTEMS (DGM)

Seismic Profiling: The seismic profiling system was run for 3.5 days at the beginning of the cruise in order to obtain an extended longitudinal profile downslope through the study area (Figure 1). A two channel hydrophone and a 160in^3 airgun were used, the latter because this was the smallest gun to which a waveshape kit could be fitted. The data was displayed in real time on a *Waverley* recorder and recorded in both analogue and digital form. The system performed only moderately well, with six breakdowns due to airgun or compressor failure in the 3.5 day operational period.

3.5kHz Profiling: The 3.5kHz profiler was run almost continuously during the cruise (see **Table 1**), with only short breaks when it was interfering with the acoustic navigation. Although one setting on the programmer could not be used, the system worked well and good quality records were obtained throughout.

Echo-sounding: The *Simrad* 10kHz PES profiler was used throughout the cruise. Use of the colour printer was curtailed about two-thirds through the cruise because no spare ink cartridges were available, after which hard copy was produced using a *Waverley* recorder. The use of two different sound velocities, 1480m/s on the real-time screen and printer and 1500m on the digital read-out and computer archive, is a highly confusing anomaly which should be corrected at the earliest possible date. It results in a hard copy from the printer showing a depth which is different to that logged by the computer, and effectively renders the hard copy useless for anything other than qualitative studies. The potential for confusion in post-cruise studies is considerable.

NAVIGATION AND DATA LOGGING (PJM)

The shipboard computing system was used to log data and to display it in various formats as required by the scientists on board. The networked PC was used for report writing and printing documents that were written on other machines.

The following parameters were logged:-

Ships Log (EM±LOG)
Ships Compass (BIN±GYRO)
Transit position (MX1107)
Global position (GPS)
Simrad depth (ECHO)
Acoustic navigation (AC±NAV)

Some navigational data was lost during the cruise when one of the Cambridge Ring nodes stopped on a couple of occasions and once when the logger failed. Unfortunately these failures were not noticed immediately for various reasons.

Other than the above problems the system ran successfully for the duration of the cruise. Data from several cruises that had previously worked in this area were loaded into the system.
Charts were produced integrating the old and new data together with station identification. Two DXFMT tapes and a TAR format cartridge were given to the Principal Scientist at the end of the cruise.

CORING OPERATIONS

Lithostratigraphy (DM/PPEW):

A total of 28 stations were visited during cruise CD56 at which a total of 38 coring attempts were made: - 18 for Kasten cores, 14 for Piston cores and 6 for Box cores (see **Table 2 &3**). Coring operations were carried out in four main areas-

Area 1 at the termination of the debris flow at 30°45' to 30°49' N. and 23°50' to 24° 05' W;

Area 2 around the seamount at 30°21' to 30°32' N. and 23° 34' to 23°35' W;

Area 3 on TOBI Site 2 at 30°28' to 30°33' N. and 21°04' to 21°11' W (all cores acoustically-navigated):

Area 4 on the TOBI Site 3 Extension in the area 30°34' to 30°37' N. and 22°22' to 22°25' W (again all cores acoustically navigated);

Area 5 on the insular slope west of the Canaries and 29°01' to 28°33'N and 19°01' to 18°14'W.

The Kasten corers used had 2m. or 4m. length barrels. The 2-m barrels had been modified to allow improved sub-sampling as described in Zangger and McCave(1990). Once recovered they were opened and described by logging and photography. Archive D-tubes and X-ray slabs (0.33m. in length) were taken and either geochemical or geotechnical sampling was carried out (see below). Because the Kasten cores could be described and sampled on recovery, and because they displayed a greater length of the sediment column than the box cores, they provided the basis of our initial shipboard stratigraphy for each of the areas.

In Area 1 a mainly pelagic sequence appears interupted by up to three turbidites. CD-56-9-K1, the longest 4m-Kasten corer, contained a debris flow at its base (2.0m.).

Area 2 cores around the flank of the seamount display possibly as many as 8 thin turbidite units interbedded with pelagic sediments (marls, oozes and clays). These thin turbidites generally show sharp bases and 'normal' grading.

Area 3 cores were precisely-navigated to a number of locations in and around a channel. Little penetration was obtained from Kasten cores in the channel axis itself. Cores from the northern and southern channel walls and levees display a pelagic sequence interbedded with turbidites, but here the cores also show a distinctive layer of coarse volcaniclastics with 'normal' grading and cross lamination (occuring between 0.41 and 0.74 m in CD56-13-K1). The thickness of the pelagic sequence increased as we cored away from the channel axis and up the channel walls, which may indicate a relatively inactive channel with little overbank deposition

Area 5 cores, taken on the slope west of the island of Hierro, comprised a mix of Kasten and piston cores. The opened Kastens contain dark brown/black turbidite(?) units interbedded with lighter coloured pelagic sediments.

The RVS/UMEL single-spade box corer worked very well. Box cores recovered were opened to reveal a seawater/sediment interface which often displayed the effects of bioturbation, such as the spoke burrow on the surface of CD56-19-B1. Sample tubes were then emplaced and one side of the box core was removed to reveal the sedimentary column. This surface was logged and sampled using X-ray slab containers. Box core sites were mainly in Area 3 and suggested that the dark volcanic sand was restricted, as a lag deposit(?), to the channel axis itself. Box cores from the channel walls displayed a generally pelagic sequence.

The Piston corers used on Cruise 56 were deployed with 2, 3 or 4 barrels (each 3m. in length). On recovery the 3m core liners were cut into 1.5m. sections and sealed; so no shipboard description was possible. All piston cores were logged using the IOSDL P-wave logger, however, and this gave us an initial insight to their stratigraphy. Logs were plotted with a velocity range of 1400-1800 m/s. Most of the piston cores showed a number of sections with a high P-wave velocities, thought to represent sandy units; only CD56-15-P1 showed little variation. **Figure 5** shows a P-wave log for CD56-4-P1.

All of the core samples were stored aboard ship at around 4° C until off-loading at Barry for the refridgerated UWCC core store.

Geotechnics (JR/AC):

Possibly the most important feature of the geotechnical work on Cruise 56 was the sampling procedure adopted for the Kasten cores to ensure as little disturbance as possible to the samples before shorebased round of measurements. The Darwin 56 Kasten and box cores were to be sampled for a range of physical determinations, including shear strength, water content, and rheological properties, and for X-radiography to determine structure. In addition, the samples once tested ashore were to be used for grain size, XRD, XRF and SEM analyses. Archive sections of all cores were to be retained for reference. The sampling procedure for the Kasten cores is outlined in Figure 6 and is modified from that suggested by Zangger & McCave (1990).

Aboard ship shear strength was measured soon after opening the Kasten cores using a vane shear apparatus. The exposed surface was cleaned, photographed and then shear strength readings were taken at 5 to 10 cm intervals dependent upon lithology and visual structure. Sub-samples (20cc vol.) were taken to coincide with the vane shear measurements and would later be used to determine water content, grain-size, clay mineral and major and minor element composition. Archive sections were then taken at a lower level in the cut surface using 1 metre lengths of plastic electrical trunking (supplied by RS Components, Corby, UK). The remaining sedimentary material was then raised in the corer, cleaned and X-ray slabs (33 x 15 x 2.5 cm) were taken along the core. These were labeled and sealed for subsequent X-radiographic analysis at the Department of Earth Sciences, Cambridge. The remaining material in the Kasten core was raised and circular PVC slabs, 11 cm in diameter, were taken, sealed and stored at 4°C ready for rheological analysis in Cardiff.

The geotechnical sub-sampling of the Box cores consisted of taking as many 11cm circular PVC slabs as were possible down the core. These samples were sealed, labeled and stored at 4°C for subsequent rheological analysis. Again, 20cc sub-samples were taken to determine water content, grain-size clay composition and major and minor element composition .

The redesigned Kasten corer is a vast improvement on its predecessor. Sub-sampling is simple, as is the turn round time for redeployment of the corer. We would make a some further comments and suggestions that relate to geotechnical work in particular:

1. RVS should have available Kasten core barrels of lengths 2m to 10 m;

2. We should look to the possibility of producing a larger volume Kasten barrel - say 30cm square. This would enable additional multidisciplinary sub-sampling to take place from the same core;

3. A heavier corer weight stand might result in increased penetration of sandy sediments but there remains a requirement in the UK for a deep-water vibrocoring system capable of recovering core lengths of 10m or more.

Geochemistry (PW/SJW):

The aims of the geochemical studies were twofold:

(1) To obtain further pore water samples to augment the sample set collected previously as part of the benthic component of the UK Community Programme BOFS;

(2) To investigate the notion that channel/debris flow deposits have characteristic diagenetic signatures when compared with abyssal plain turbidites.

The change in the relative amounts of the pore water nitrogen species through denitrification and the change in the oxidation states of the iron and manganese will give some indication of the rate of diagenesis occurring within, and also the redox state of the sediments sampled.

Geochemical samples were obtained from both box cores and Kasten cores. The box corer used, the "SMBA/UMEL" type, worked magnificently, providing six excellent surface cores of 30 to 40cm penetration. The integrity of the interface was impressively demonstrated by tracks of benthic organisms.

The box cores were subcored immediately on deck by pushing core liner tubes into the sediment interface. The sub-cores were then geochemically processed and archived in the ship's C.T. lab at 4°C by slicing the 10cm i.d. subcore in a nitrogen-filled glove bag apparatus. The 1cm sections were taken contiguously over the first 10cm or so of core depth and then as dictated by the lithostratigraphy. The number of samples collected for pore water extraction was limited to 24 due to the time taken to process each core. Any intermediate sections were bagged and stored cool. The rest were sealed and centrifuged at 4°C, 3000 rpm for 30 minutes. The resultant pore waters were drawn off and filtered through 5um and 0.2um disposable filters, and stored in two bottles. One, for nitrogen species determination, was pickled with 3ul $HgCl_2$/ml, whilst the other, for Si, P, Fe and Mn analysis, was acidified to 1% v/v 6M Aristar HCl. The residual solids were bagged and stored cool.

Three of the Kasten cores were sampled by using 60ml syringes to extract sediment plugs from the core. These were placed in nitrogen-filled plastic bags in the glove bag apparatus and then processed in exactly the same manner as the box core samples.

A total of 196 pore water and 64 non-pore water samples were obtained from 1.94m of box core and 9.16m of Kasten core (Table 4). Core stations 7, 15 and 19 will provide data relating primarily to the first aim of this study, the BOFS objectives. In addition, 7.5cm diameter subcores were taken and retained intact from all box core samples, plus extra 10cm diameter subcores from sites 12 and 17.

PRINCIPAL RESULTS AND CONCLUSIONS

The main objectives of Cruise CD56 were to carry out deep-towed TOBI sidescan and profiler surveys over locations on the Saharan Continental Rise that had been previously surveyed with long-range sidescan sonar, GLORIA. These TOBI surveys were to be the basis for acoustically-navigated core sampling stations and WASP near-bottom camera surveys. At least two areas were to be tackled in this way, taking marine geological investigations "to the field outcrop scale".

In the event, problems with the RVS portable winch curtailed the TOBI effort and forced us to modify our programme. Shipboard electronic modifications to the TOBI system by the IOSDL technicians ultimately allowed its use in one area for a 4-day survey, which we followed up with 3 coring sites and a partially successful WASP camera survey. We were, however, able to mount a full transponder-navigated coring programme before this over a previously-surveyed TOBI site which involved 11 successful core samples and salvaged some of the prime objective work.

Secondary objectives of the cruise were well served. A coring transect of six piston and Kasten cores was successfully completed at the edge of the Madiera Abyssal Plain for studies of the frequency of sediment mass wasting and of the relationship between debris flow and turbidity current processes. On the flanks of an oceanic seamount, we collected two Kasten cores and two box cores as part of the Cardiff group's involvement in the BOFS programme; and on the western insular slope of the Canaries we collected three Kasten cores and two piston cores for a geotechnical study of slope sediment stability.

Throughout the cruise we collected 3.5kHz profiles and collated these with previously-collected GLORIA and 3.5kHz survey data. This mapping, together with the calibrations afforded by the sampling during this cruise, has allowed us to recognise multiple sources for the debris flows of the lower Saharan continental rise (Masson et al., in press). The most prominent debris flow area that we have been studying, which we now call "the Canary Slide", has its source not in the"Saharan Slide Scar" of Embley (1976) but further north on the volcanic slopes west of Palma and Hierro islands.

ACKNOWLEDGEMENTS

The performance of the Ship's officer's and crew, and of the RVS and IOSDL technical support teams, was outstanding during RRS Charles Darwin Cruise 56: this report section affords the science group the opportunity to thank them.

Captain Harding is thanked in particular for his support and enthusiasm for all aspects of our scientific effort during an operationally difficult cruise. The deck officers are commended for the way they handled our unusual requirements for TOBI and WASP surveys and for precise navigation of corers to targets in the acoustic nets. The deck crew was the best I have sailed with in over a dozen cruises on NERC ships and the catering staff served up without exception the best food that most of us have sampled courtesy of NERC. The RVS technicians are thanked for their hard work particularly over the first half of the cruise during the period of winch problems. In the end, their determination won through when the winch cable was retrieved using auxilliary systems and we were able to get on with the cruise. The IOSDL technicians saved one of the prime cruise objectives by their modification of the TOBI triggering system and we thank them for their dogged perseverence.

The UWCC geochemists are indebted to Sarah Colley of IOSDL for the loan of the framework supports for the glove bags and other material assets.

Staff of the Department of Earth Sciences, University of Cambridge are thanked for their advice in the use of the modified Kasten corer for our geotechnical and geochemical requirements and for subsequent post-cruise assistance with X-radiography of core samples at Cambridge.

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TABLE 1. RRS Charles Darwin Cruise 56: Survey data.

	START	END	TIME hrs. : mins	DIST n.m.	DIST k.m.
AIRGUN					
	2000/042	2308/042	3 : 08	28	52
	0000/043	0953/043	9 : 50	90	167
	1335/043	1740/043	4 : 05	35	65
	1900/043	1135/044	16 : 35	135	250
	1405/046	0530/046	39 : 30	295	546
			TOTAL	**583**	**1080**
PES	1130/042	2040/046	105 : 10	728	1348
	2300/050	2015/054	93 : 15	251	465
	2015/054	1630/061	164 : 15	320	593
	1630/061	1400/069	189 : 30	396	733
	1400/069	1630/071	50 : 30	330	611
			TOTAL	**2025**	**3750**
3.5kHz*	1700/042	0702/046	86 : 20	683	1265
	2300/050	2015/054	93 : 15	245	453
	2015/054	0245/056	30 : 30	182	337
	0520/061	1630/061	11 : 10	28	52
	1630/061	0600/062	13 : 30	86	159
	1030/062	1400/069	171 : 30	286	530
	1400/069	1630/071	50 : 30	330	611
			TOTAL	**1840**	**3407**
WASP	1200/058	0036/058	12 : 36	14	26
	2240/068	0530/069	6 : 40	8	15
			TOTAL	**22**	**41**
TOBI	2330/062	0530/067	113 : 00	**200**	**370**

* 3.5kHz turned off periodically during acoustic navigation

TABLE 2. Station list for CD56.

STATION NO.	START	END	LAT (N)	LONG (W)	DEPTH (m)
CD56-1-1P	1240/051	1736/051	30° 48.3'	23° 57.7'	5360
CD56-2-1P	1900/051	0038/052	30° 45.6'	23° 58.3'	5360
CD56-3-1P	0150/052	0803/052	30° 46.04'	24° 9.97'	5360
CD56-4-1P	0930/052	1613/052	30° 48.15'	24° 02.83'	5360
CD56-5-1P	1653/052	2246/052	30° 48.3'	24° 01.1'	5360
CD56-6-1K	0005/053	0447/053	30° 45.71'	23° 58.38'	5360
CD56-7-1K	0827/053	1254/053	30° 21.7'	23° 34.9'	5266
CD56-7-1B	1305/053	1849/053	30° 21.71'	23° 34.96'	5266
CD56-7-2K	1919/053	2340/053	30° 21.68'	23° 34.89'	5267
CD56-8-1K	0107/054	0532/054	30° 32.02'	23° 34.88'	5360
CD56-9-1K	0848/054	1245/054	30° 46.05'	23° 56.98'	5359
CD56-9-1P	1500/054	2015/054	30° 45.95'	23° 56.97'	5359
CD56-10-1K	1129/056	1647/056	30° 31.663'	21° 09.454'	4879
CD56-10-2K	1718/056	2054/056	30° 31.722'	21° 09.372'	4873
CD56-10-1B	2129/056	0308/057	30° 31.733'	21° 09.222'	4875
CD56-11-1B	0357/057	0840/057	30° 31.502'	21° 09.999'	4892
CD56-11-1K	0900/057	1300/057	30° 31.5'	21° 10.1'	4891
CD56-12-1B	1339/057	1827/057	30° 30.978'	21° 08.892'	4888
CD56-13-1K	1930/057	2340/057	30° 30.710'	21° 06.156'	4871
CD56-14-IK	0100/058	0606/058	30° 30.677'	21° 06.107'	4865
CD56-15-1K	0622/058	1048/058	30° 30.257'	21° 06.245'	4858
CD56-C1	1200/058		30° 30.29.9'	21° 07.15'	4861
		0036/059	30° 32.0'	21° 06.65'	4860
CD56-16-1K	0154/059	0613/059	30° 31.183'	21° 06.181'	4886
CD56-17-1B	0645/059	1125/059	30° 31.1'	21° 06.9'	4887
CD56-15-1P	1311/059	1850/059	30° 30.182'	21° 06.097'	4857
CD56-18-1P	2045/059	0200/060	30° 31.4'	21° 08.9'	4891
CD56-19-1K	0330/060	0720/060	30° 29.999'	21° 04.95'	4850
CD56-19-1B	0820/060	1257/060	30° 30.0'	21° 04.9'	4855
CD56-12-1P	1656/060	2359/060	30° 31.0'	21° 09.1'	4891
CD56-20-1K	0114/061	0516/061	30° 28.991'	21° 07.043'	4857
CD56-TOBI	1240/062		30° 32.04'	21° 07.043'	4979
		1710/067	30° 23.4'	21° 58.3'	4969
CD56-21-1K	2043/067	0112/068	30° 36.8'	22° 24.17'	5057
CD56-21-1P	0112/068	0905/068	30° 36.7'	22° 24.49'	5057
CD56-22-1P	1000/068	1430/068	30° 34.535'	22° 22.529'	5058
CD56-23-1P	1500/068	2117/068	30° 36.156'	22° 23.81'	5068
CD56-C2	2234/068		30° 33.0'	22° 19.0'	5049
		0553/069	30° 37.0'	22° 25.5	
CD56-24-1K	0654/070	1015/070	29° 00.14'	19° 00.31'	4377
CD56-24-2K	1046/070	1351/070	29° 01.424'	19° 00.529'	4377
CD56-25-1K	2008/070	2256/070	28° 47.83'	18° 14.9'	3364
CD56-26-1K	0113/071	0425/071	28° 52.118'	18° 32.162'	4103
CD56-27-1P	0644/071	1015/071	28° 37.8'	18° 50.5'	4280
CD56-28-1P	1220/071	1530/071	28° 33.14'	18° 31.29'	4042

Table 2 Station list for CD56.

TABLE 3. Core listing for Cruise 56.

CORE	LAT (N)	LONG (W)	DEPTH (m)	COMMENTS
CD56-1-P1	30° 48.3'	23° 57.7'	5360	did not trigger
CD56-2-P1	30° 45.6'	23° 53.8'	5360	5.8m core
CD56-3-P1	30° 48.6'	24° 04.2'	5420	9.0m core
CD56-4-P1	30° 48.15'	24° 04.83'	5420	9.1m core
CD56-5-P1	30° 48.3'	24° 01.1'	5420	7.14m core
CD56-6-K1	30° 45.71'	23° 53.38'	5360	1.94m core
CD56-7-K1	30° 21.7'	23° 34.9'	5266	1.98m core
CD56-7-B1	30° 21.71'	23° 34.96'	5266	0.43m core
CD56-7-K2	30° 21.68'	23° 34.89'	5267	1.84m core
CD56-8-K1	30° 32.02'	23° 34.84'	5360	1.83m core
CD56-9-K1	30° 46.04'	23° 56.98'	5359	2.2m core
CD56-9-P1	30° 45.95'	23° 56.97'	5359	corer lost
CD56-10-K1*	30° 31.6863'	21° 09.3680'	4879	core catcher only (0.1m)
CD56-10-K2*	30° 31.7255'	21° 09.3257'	4873	core catcher only (0.25m)
CD56-10-B1*	30° 31.7150'	21° 09.3443'	4875	0.36m core
CD56-11-B1*	30° 31.4927'	21° 10.0008'	4892	0.31m core
CD56-11-K1*	30° 31.5174'	21° 09.9804'	4891	0.42m core
CD56-12-B1*	30° 30.9891'	21° 09.0166'	4888	0.42m core
CD56-12-P1*	30° 30.9827'	21° 08.9955'	4891	3.0m core
CD56-13-K1*	30° 30.7328'	21° 06.1502'	4871	1.00m core
CD56-14-K1*	30° 30.6362'	21° 06.1461'	4865	1.74m core
CD56-15-K1*	30° 30.2142'	21° 06.1957'	4858	2.04m core
CD56-15-P1*	30° 30.1886'	21° 06.0546'	4857	9.37m core
CD56-16-K1*	30° 31.1321'	21° 06.0000'	4886	empty
CD56-17-B1*	30° 31.0950'	21° 06.8396'	4887	0.27m core
CD56-18-P1*	30° 31.4041'	21° 08.9977'	4891	3.8m core
CD56-19-K1*	30° 29.9862'	21° 04.9398'	4850	empty
CD56-19-B1*	30° 29.9827'	21° 05.1153'	4855	0.28m core
CD56-20-K1*	30° 28.9983'	21° 07.0053'	4857	0.45m core
CD56-21-K1*	30° 36.6942'	22° 24.5320'	5057	empty
CD56-21-P1*	30° 36.6943'	22° 24.5238'	5057	2.82m core
CD56-22-P1*	30° 34.5372'	22° 22.5352'	5058	2.56m core
CD56-23-P1*	30° 36.1073'	22° 23.6296'	5068	1.94m core
CD56-24-K1	29° 00.14'	19° 00.31'	4377	empty
CD56-24-K2	29° 01.43'	19° 00.31'	4377	2.14m.core
CD56-25-K1	28° 47.83'	18° 14.90'	3364	1.72m core
CD56-26-K1	28° 52.11'	18° 32.17'	4103	1.36m core
CD56-27-P1	28° 37.80'	18° 50.50'	4280	2.80m core
CD56-28-P1	28° 33.14'	18° 31.29'	4042	4.50m core

Table 3 List of core stations for CD56. Acoustically navigated cores are shown by *.

TABLE 3. List of core stations for CD56.

CORE	LAT (N)	LONG (W)	DEPTH (m)	COMMENTS
CD56-1-1P	30° 48.3'	23° 57.7'	5360	did not trigger (0.4m)
CD56-2-1P	30° 45.6'	23° 58.3'	5360	5.8m core
CD56-3-1P	30° 46.04'	24° 9.97'	5360	9.0m core
CD56-4-1P	30° 48.15'	24° 02.83'	5360	9.1m core
CD56-5-1P	30° 48.3'	24° 01.1'	5360	8.64m core
CD56-6-1K	30° 45.71'	23° 58.38'	5360	1.94m core
CD56-7-1K	30° 21.7'	23° 34.9'	5266	1.86m core
CD56-7-1B	30° 21.71'	23° 34.96'	5266	0.43m core
CD56-7-2K	30° 21.68'	23° 34.89'	5267	1.97m core
CD56-8-1K	30° 32.02'	23° 34.88'	5360	1.83m core
CD56-9-1K	30° 46.05'	23° 56.98'	5359	2.2m core
CD56-9-1P	30° 45.95'	23° 56.97'	5359	corer lost
CD56-10-1K*	30° 31.6863'	21° 09.3680'	4879	core catcher only (0.1m)
CD56-10-2K*	30° 31.7255'	21° 09.3257'	4873	core catcher only (0.25m)
CD56-10-1B*	30° 31.7150'	21° 09.3443'	4875	0.36m core
CD56-11-1B*	30° 31.4927'	21° 10.0008'	4892	0.35m core
CD56-11-1K*	30° 31.5174'	21° 09.9804'	4891	0.42m core
CD56-12-1B*	30° 30.9891'	21° 09.0166'	4888	0.42m core
CD56-12-1P*	30° 30.9899'	21° 08.9955'	4891	3.0m core
CD56-13-1K*	30° 30.7328'	21° 06.1502'	4871	0.9m core
CD56-14-IK*	30° 30.6362'	21° 06.1461'	4865	1.74m core
CD56-15-1K*	30° 30.2142'	21° 06.1957'	4858	2.04m core
CD56-15-1P*	30° 30.1886'	21° 06.0546'	4857	9.37m core
CD56-16-1K*	30° 31.1321'	21° 06.0000'	4886	empty
CD56-17-1B*	30° 31.0950'	21° 06.8396'	4887	0.28m core
CD56-18-1P*	30° 31.4041'	21° 08.9977'	4891	3.8m core
CD56-19-1K*	30° 29.9862'	21° 04.9398'	4850	empty
CD56-19-1B*	30° 29.9827'	21° 05.1153'	4855	0.28m core
CD56-20-1K*	30° 28.9983'	21° 07.0053'	4857	0.45m core
CD56-21-1K*	30° 36.6942'	22° 24.5320'	5057	empty
CD56-21-1P*	30° 36.6943'	22° 24.5238'	5057	2.82m core
CD56-22-1P*	30° 34.5372'	22° 22.5352'	5058	2.6m core
CD56-23-1P*	30° 36.1073'	22° 23.6296'	5068	1.94m core
CD56-24-1K	29° 00.14'	19° 00.31'	4377	empty
CD56-24-2K	29° 01.424'	19° 00.529'	4377	2.14m core
CD56-25-1K	28° 47.83'	18° 14.90'	3364	1.73m core
CD56-26-1K	28° 52.118'	18° 32.162'	4103	1.37m core
CD56-27-1P	28° 37.80'	18° 50.50'	4280	2.80m core
CD56-28-1P	28° 33.14'	18° 31.29'	4042	4.4m core

Table 3 List of core stations for CD56. Acoustically navigated cores are shown by *.

TABLE 4. Pore water samples taken on CD56

Core Ref. No.	Water Depth (m)	Core Length (cm)	No of PW Samples	No of Sed. Samples
CD56-7-K1	5266	181	24	0
CD56-7-B1	5267	42	22	9
CD56-9-K1	5359	214	16	0
CD56-10-K1	4875	36	23	13
CD56-11-B1	4892	32	15	17
CD56-12-B1*	4888	27	0	0
CD56-15-K1	4858	176	24	0
CD56-17-B1	4887	27	21	6
CD56-19-B1	4855	30	21	9
CD56-24-K2	4386	179	15	0
CD56-25-K1	3364	166	15	0

* Archive Core.

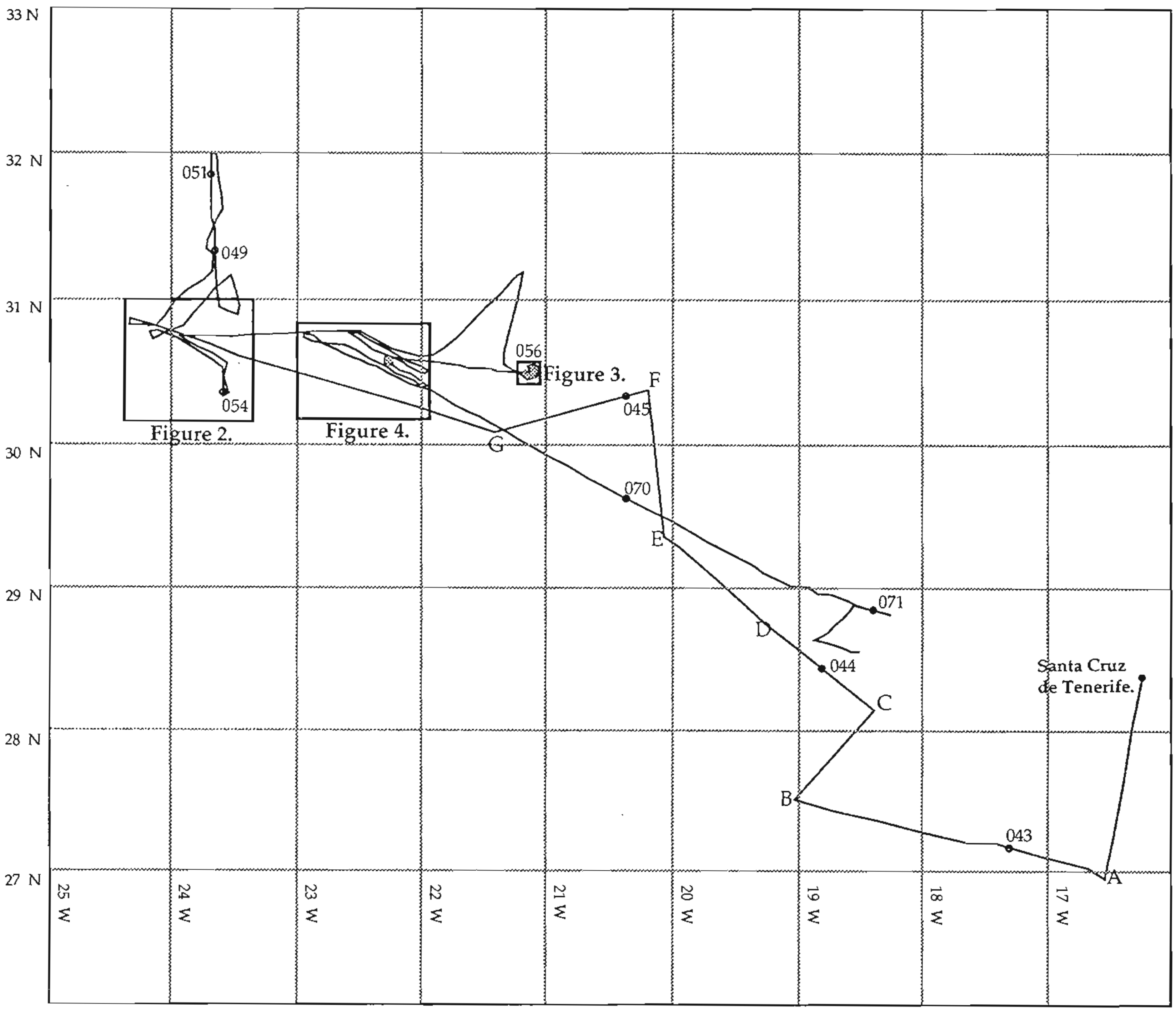


FIGURE 1.
Track Chart:
R.R.S. Charles
Darwin, Cruise
56. Feb/Mar
1991.

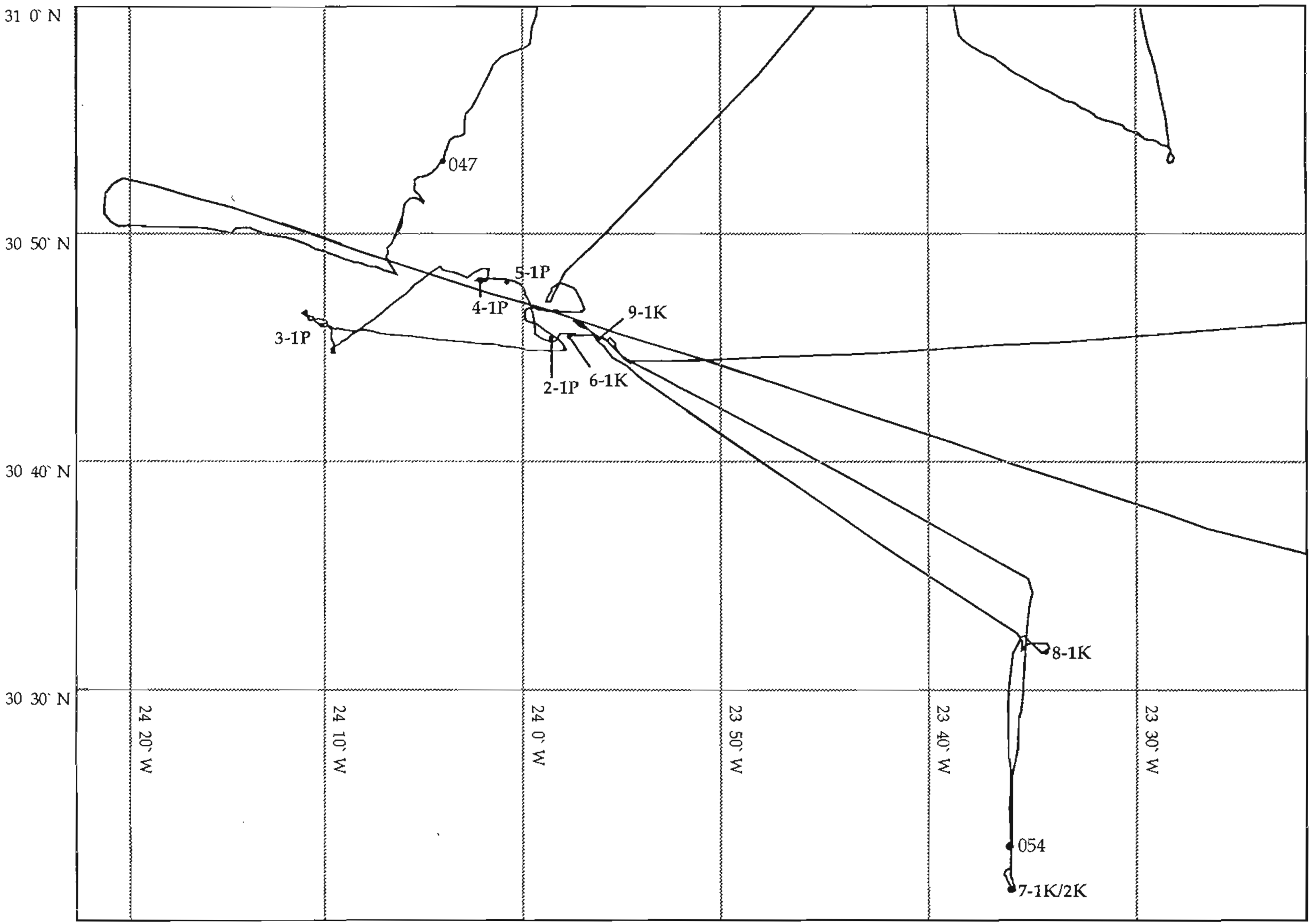
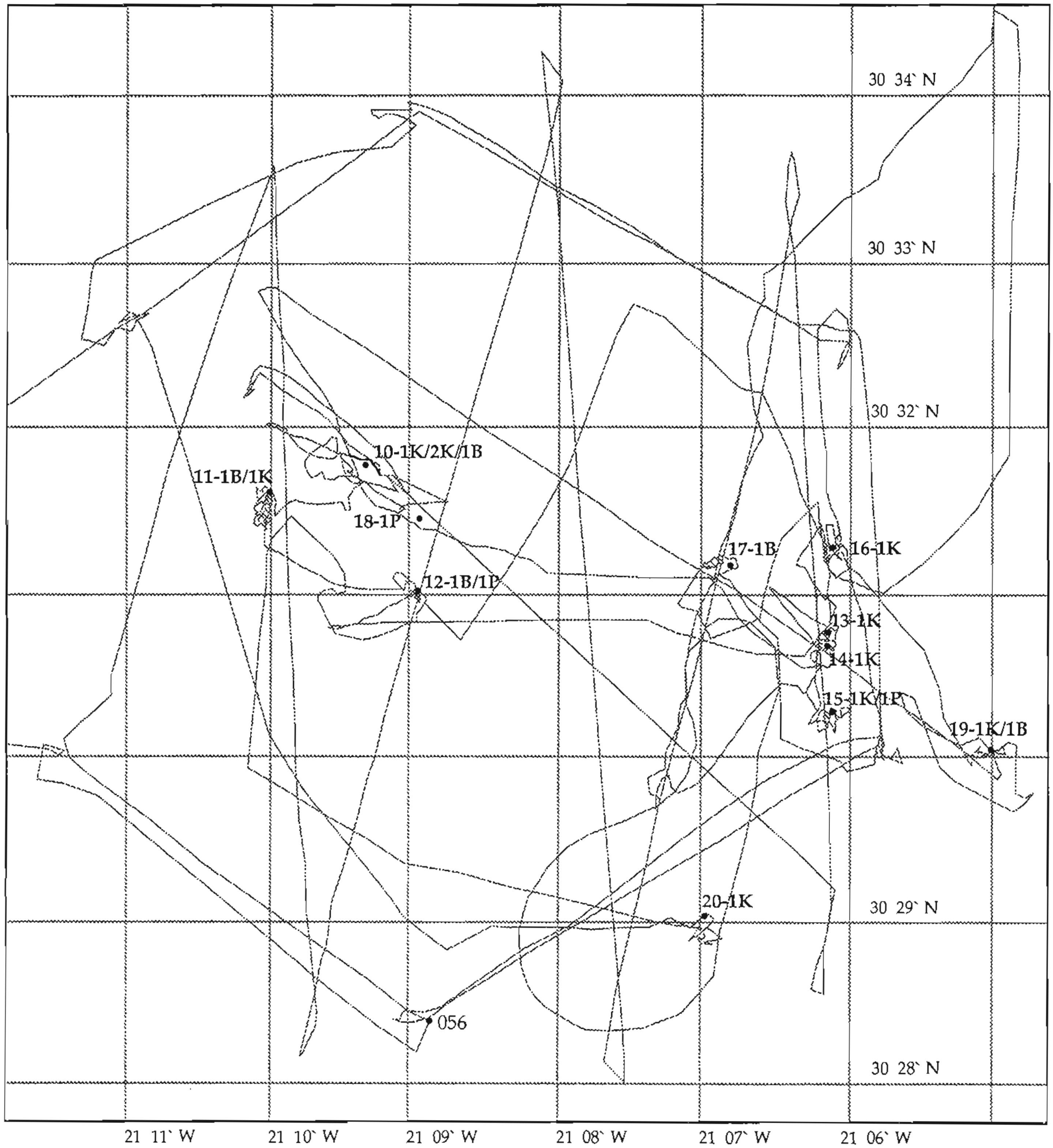


FIGURE 2. Tracks and stations at the edge of the Madeira Abyssal Plain.

FIGURE 3. Stations and tracks on "Channel Site",
TOBI Site 2.



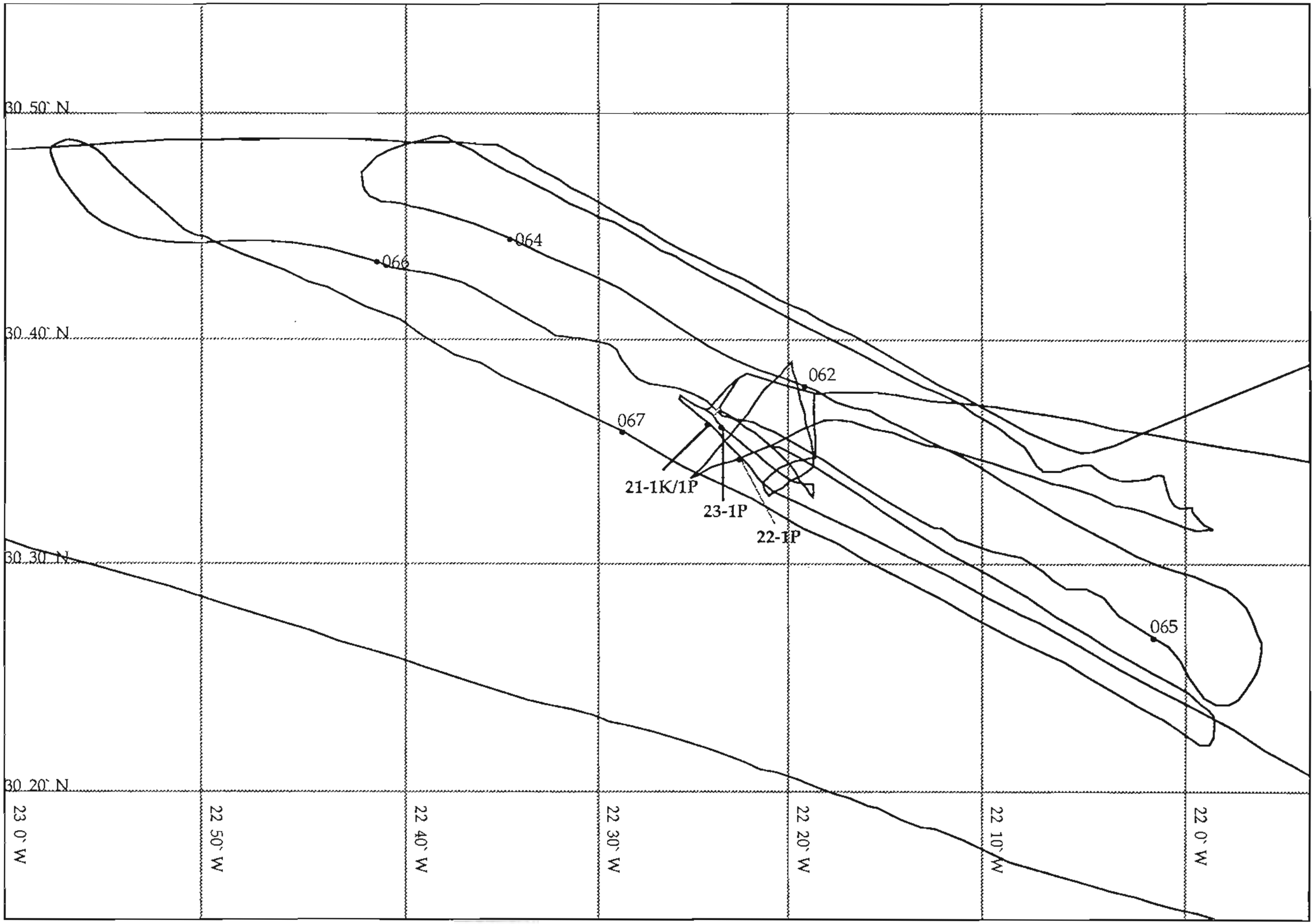


FIGURE 4. Tracks and stations on "Calibration Site", TOBI Site 3 Extension.

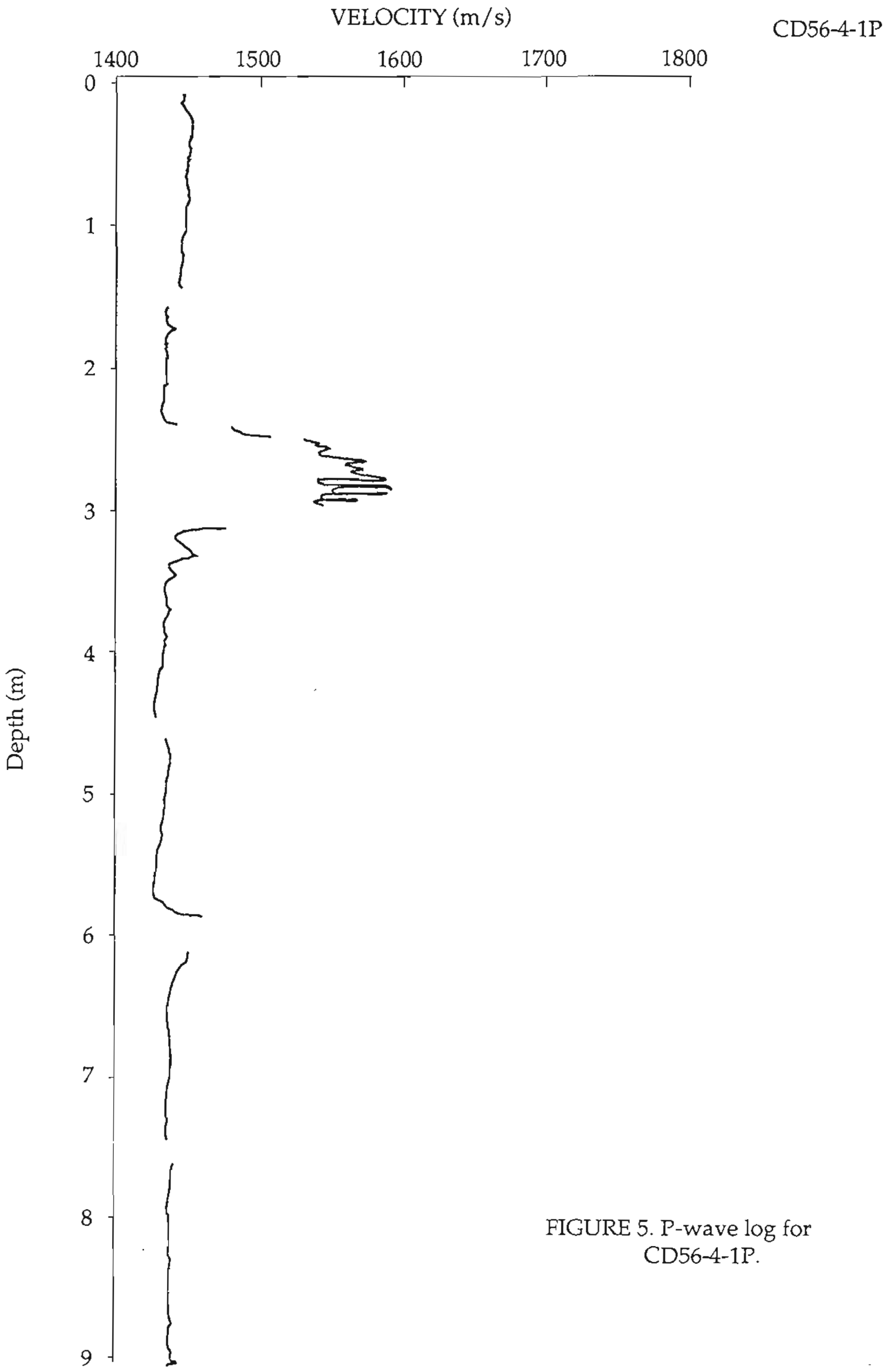


FIGURE 5. P-wave log for CD56-4-1P.

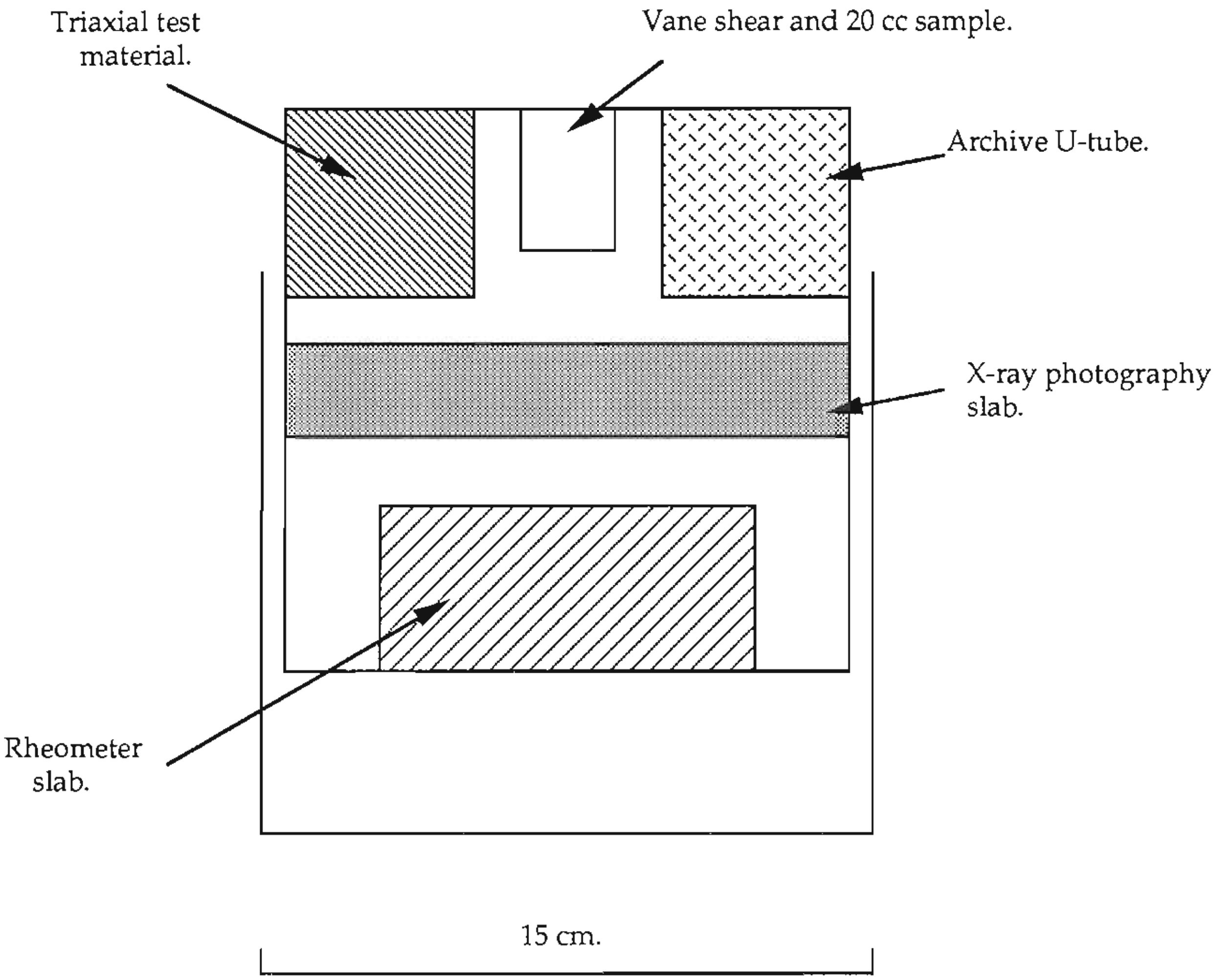


FIGURE 6. Cross section of Kastenlot core sub-sampling procedure on Cruise 56 (modified from Zangger and McCave 1990).