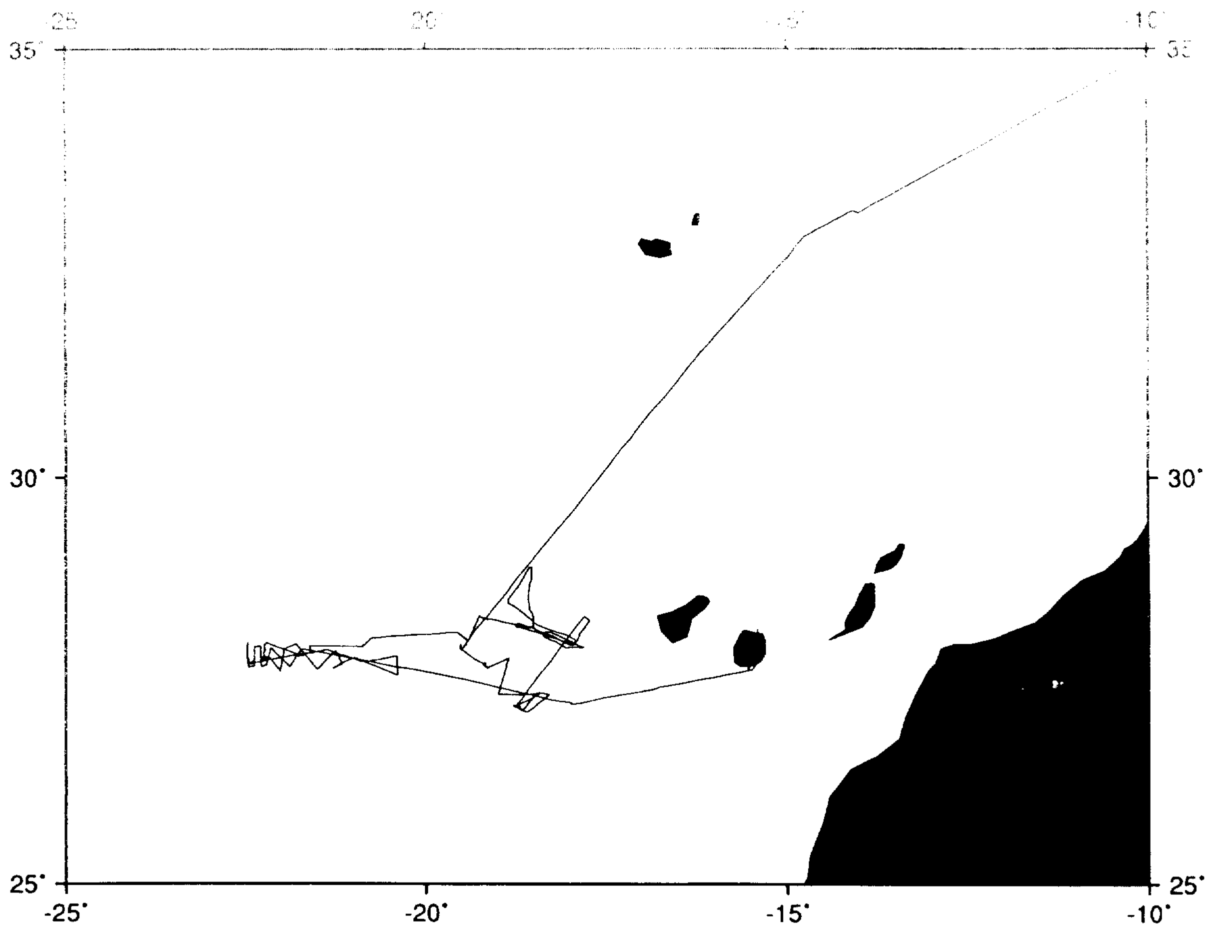
Institute of Oceanographic Sciences Deacon Laboratory

RRS *Discovery* Cruise 205

10 Nov - 07 Dec 1993

TOBI surveys and coring of debris flows west of the Canaries

Cruise Report No 239 1994



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CRUISE REPORT NO. 239

RRS *DISCOVERY* CRUISE 205
10 NOV - 07 DEC 1993

TOBI surveys and coring of debris flows west of the Canaries

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ABSTRACT

The major objective of the cruise was to collect TOBI sidescan sonar and profiler data and sediment cores from the distal part of the Saharan Debris flow deposit and the proximal area (slide scar) of the Canary Debris Flow. Subsidiary objectives included instrument trials to test the new scatterometer instrument on TOBI and the completion of a coring transect along the axis of the 'Agadir' sedimentary basin, southeast of Madeira.

Discovery sailed from Las Palmas, Canary Islands on the 10th November, 1993, and arrived at Cadiz, Spain on the 7th December. Approximately 800 track km of TOBI data and 12 sediment cores were collected. Some 9.5 days were allocated to TOBI operations, 5.25 days to coring, and 3.25 days to scatterometer trials. The remaining time was used up in passage to and from the working area and between sites. 3.5 kHz data was collected along most of the passage tracks.

The main achievements of the cruise were:

(i) The collection of a swath of TOBI data across the snout of the Saharan Debris Flow deposit and a suite of cores to sample the various acoustic facies seen on that swath. One core penetrated the flow and should allow us to obtain an accurate date for flow emplacement.

(ii) The collection of a mosaic of TOBI lines in the Canary Debris Flow source area. This proved our earlier interpretation of the source area based on GLORIA data and provided much new evidence for the mechanisms of failure.

(iii) The collection of cores from the middle part of the Saharan Debris Flow, over an area surveyed with TOBI in 1990. Key acoustic facies, such as the lateral ridges, rafted blocks and 'woodgrain' facies area previously identified, were sampled.

(v) The successful trials of the scatterometer.

KEYWORDS

ATLNEAFR
CANARY DEBRIS FLOW
CANARY ISLAND WATERS
CORING
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SCATTEROMETER
SEDIMENT SAMPLING
SIDESCAN SONAR
TOBI
TURBIDITES

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CONTENTS

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ITINERARY

Sailed Las Palmas, Canary Islands	10th November, 1993
Arrived Cadiz, Spain	7th December, 1993

CRUISE OBJECTIVES

The major objective of the cruise was to collect TOBI sidescan sonar and profiler data and sediment cores from the distal part of the Saharan Sediment Slide and the proximal area (slide scar) of the Canary Slide. Subsidiary objectives included instrument trials to test the new scatterometer instrument on TOBI and completion of a coring transect along the axis of the 'Agadir' sedimentary basin southeast of Madeira.

The aims of collecting TOBI and core data from the Saharan Slide were:

(i) to investigate in more detail the spectacular flow fabric imaged during a previous reconnaissance survey of a small part of the Saharan Slide, with the objective of understanding the mechanics of its formation.

(ii) to investigate how the flow fabric might change downslope, and to examine what this might tell us about slide mechanisms.

(iii) to compare the fabrics of the Saharan and Canary Slides, and to investigate what this might tell us about the flow characteristics of the two slides.

The aims of collecting TOBI data from the slide scar area of the Canary Slide were:

(i) to investigate possible failure mechanisms, such as rotational block faulting, slip on slope-parallel bedding planes or detachment of the whole sediment cover from the underlying bedrock.

(ii) to see whether blocks gradually disintegrate as they move downslope or whether the whole slide mass fluidises in place and then flows downslope.

(iii) to look for clues as to the triggering mechanisms, such as fluid escape structures or evidence for submarine volcanic eruptions, and to investigate whether the slide is related to the collapse of part of the island of Hierro.

The scatterometer trials were designed to prove the concept of the scatterometer in deep water, as part of a contract to the DRA, although it was also hoped that data useful for seabed classification might also be collected.

Coring in the 'Agadir' Basin southeast of Madeira was a continuation of our long standing programme to look at sediment transport patterns to the Madeira Abyssal Plain. This would fill a crucial gap in our existing core coverage and allow us to investigate the evolution of flows as they passed through this basin en route to the Madeira Abyssal Plain

NARRATIVE

After a 12 hr delay to enable cruise preparation work to be completed, *Discovery* left Las Palmas at 1700/314 GMT (= local time) and set course for the start of a preliminary 3.5 kHz survey which was to be undertaken en route to the first TOBI survey area. This point, south of the island of Hierro, was reached at 0930/315, and the 3.5 and 10 kHz fish were deployed between 0930 and 1130/315. The 3.5 kHz immediately proved extremely noisy and experiments with ship's speed were carried out between 1200-1400/315 to find the cause. It was quickly discovered that the problem was due to propeller noise, picked up because the fish was being towed from a point too far aft. The records varied from very poor to useless at speeds above 4 Kt. Because of this problem the preliminary survey was shortened and a more direct route to the first TOBI area was chosen, so that the later part of the survey could be carried out at a lower speed without losing time overall. The 3.5 kHz survey was completed at 2040/316, enabling a first TOBI survey line to be chosen.

Wire testing of the scatterometer electronics tube and hydrophone then began, with deployment starting at 2145/316. This was completed at 0200/317, after which the ship moved to the start of the first TOBI station. While the ship was hove to prior to TOBI deployment, the 3.5 kHz fish was moved to the forward towing point (0800-1000/317). Deployment of TOBI began at 1015/317 and was completed by 1130. TOBI logging began at 1410/317. Despite 3.5 kHz profile evidence which suggested that a debris flow lay at or near the seafloor, no evidence was seen on the sidescan data until 1400/318, when an obvious debris flow front was crossed. Debris flow structures similar to, but much subdued relative to those seen on a previous TOBI run obtained during *Discovery* cruise 188, were observed over the next 40 hr as the ship followed an general easterly course. However, since the sidescan observations were showing few previously unobserved debris flow structures, it was decided to terminate TOBI run 1 at 0630/320. Despite some problems in maintaining the back tension on the winch, TOBI was recovered and secured by 1100. A series of 3.5 kHz survey lines following the debris flow to the west were then run during passage back to the first of a series of coring sites chosen to sample the major acoustic facies seen on the sidescan images. Considerable trouble with the 3.5 kHz profiler was solved by replacing the Raytheon linescan recorder with an EPC during this survey.

The first coring site (D12616), designed to sample the high-penetration parallel-bedded acoustic facies seen on 3.5 kHz records, was reached at 0800/321 (Table 1). The 9 m corer was deployed by 1000/320 and recovered at 1425. Results were excellent with 7.7 m of piston core and a full trigger core recovered. The core appeared to consist of interbedded pelagic sediments and volcaniclastic turbidites.

The second core site (D12617), designed to sample an area of zero penetration on the 3.5 kHz profiles but no apparent structure on TOBI sidescan records, was reached at about 1600/320 and the corer was deployed at 1637. The bottom was reached at 1903/320. However, despite pulling at up to 12.5 tonnes, it proved impossible to pull out the corer. During the next 19.5 hr, the ship manoeuvred around the core site, applying variable pull on the corer. After contacting RVS, permission was given to apply a pull of up to 14 tonnes, but even this failed to dislodge it. Eventually, at 1429/321, to the surprise of all, the corer came free at a pull of little over 12 tonnes, while we were manoeuvring around the core site. However, it still had some fight in it, and, while hauling in, the winch stopped. A frustrating 24 hr followed, before the trouble was traced to a faulty pressure switch. The corer was finally brought aboard at 1650/323. Forty-eight hours and thirteen minutes, probably the world record for a core station. The bottom two sections were badly bent, with only some 2 m of core in the bottom section. There were no real clues as to why the pull-out had been so difficult, because twenty four hours in the water column had washed all trace of sediment from the outside of the corer.

Undaunted, we proceeded to our third core station (D12618), designed to sample the debris flow. This was reached at 2030/323 and the corer was deployed by 2247. The corer hit bottom at 0057/324 and the station was completed without incident at 0347/324. An excellent 8.5 m core was recovered.

The corer, shortened to two barrels (6 m) because of the anticipation of coring sand at this site, was deployed at the fourth core site (D12619) at 0620/324. It was designed to sample the apron of low-backscatter material seen immediately adjacent to the debris flow deposit. It reached the bottom at 0803, and an abnormally high pull-out of 10 tonnes was recorded. The corer was recovered at 1010 and was found to contain about 5 m of sediment.

The fifth core site (D126200) was also occupied using the short 6 m configuration. It was designed to sample the high-backscatter material ahead of the debris flow. The corer was deployed at 1239/324 and reached the bottom at 1430. Despite a high pull-out of over 10.5 tonnes, the corer was recovered at 1640 without incident. 4.1 m of sediment was obtained.

The sixth core site was reached at 1815 and the corer was deployed by 1903/324. A three barrel corer was used at this site, situated on the debris flow deposit. The corer reached the bottom at 2111/324, although only a very weak pull out was recorded. However, a 7.9 m core was recovered when the corer was brought on board at 2324/324. This was the final core of the sequence, and following its recovery, the coring wire was taken off the traction winch and replaced with the conducting cable, so that testing of the scatterometer could begin. The cable change was completed at 0230/325, after which we steamed to the TOBI deployment site.

TOBI deployment began at 0800/325, at the site where R.R.S. *Charles Darwin* had surveyed a 25 x 25 km box with its swath bathymetry just a few days before. It was hoped that the swath data would help in the interpretation of any scatterometer data collected. TOBI deployment was completed by 0930, and 500 m of wire was paid out for initial testing of the scatterometer. With the system apparently operational, a full depth deployment was begun, but almost immediately communication with the scatterometer was lost and the deployment was abandoned. TOBI was recovered by 1400/325. It was decided to move some 70 nautical miles to the east while tests on the scatterometer were carried out, so that the lost time could be made use of in passage to the next TOBI survey site. In the meantime, the scatterometer was checked on deck and was apparently operating normally. The second deployment began at 2030/325, and again all seemed to be operating at 500 m. A bottom return from the scatterometer was detected at a range of 3500 m, but shortly after, at 2325/325, a continuous noise appeared on the hydrophone. At this point it was decided that tests would be continued for a short time overnight, but that the vehicle would be brought back to the surface for recovery at 0800/326. The scatterometer electronics tube could then be removed for further testing onboard, while TOBI was redeployed to continue survey work.

TOBI was recovered by 0900/326 and prepared for relaunch by 1100. The aim of this survey was to image the upper part of the Canary Slide and to look for evidence that it was related to the collapse of Hierro island. Launch was completed by 1135/326 and deployment to full depth began. For the next 19 hr we completed a track up the slide imaging spectacular rafted blocks in excess of 6 km in diameter. However, overnight the weather deteriorated, and by 0640/327 it proved impossible to keep *Discovery* on an easterly course. Wire was hauled in, and a turn made into the wind to ride out the bad weather, with the wind now gusting to 50 Kt. At 1930/327 the wind was still averaging close to 30 Kt, but the sea had decreased to a state where the survey could be continued, albeit only on a northerly track, into the wind. Although this took us away from our preferred study area, it was decided to continue in this way overnight, in the hope that the weather would improve. Logging recommenced at 1930/327. By morning, the sea had decreased to an extent where we could turn back toward the study area, the turn being completed by 1400/328.

A track was then completed toward the southwest, back onto the Canary Debris Flow, before we once again turned to run up the flow at 2300/229, picking up the track which we had been forced to abandon some 30 hr earlier. Between 2300/329 and 0700/331, two parallel tracks were run across the Canary Slide Scar, in a direction perpendicular to the slope. These showed a variety of slip planes and small rotational faults, with a tendency for the degree of chaos associated with the slide to increase downslope. Large (up to 1 km across), apparently randomly scattered blocks of volcanic rock (?) were observed to cover a large area west of Hierro Island. Evidence for the method of emplacement of these blocks was lacking.

The evidence collected between days 329 and early 331 suggested that further sidescan data was required to pinpoint the source of sediment failures in the area immediately north of Hierro. At 0700/331 TOBI was recovered, and we steamed back towards the island. TOBI was relaunched at 1500/331 when we began the first of two E-W survey lines north of the island. These were followed by a northeasterly line toward La Palma, completed at 0800/333. TOBI was then recovered by 1040/333, prior to steaming some 80 miles to the southwest, for the next TOBI deployment southwest of Hierro.

The next TOBI site was reached at 1900/333, and TOBI, with the scatterometer refitted, was deployed by 2015. It was immediately apparent that the scatterometer was not triggering. However, it was decided to carry on with the deployment for a short run across the Saharan Debris Flow, with the aim of recovering late the next day for a final attempt to persuade the scatterometer to work. Even this objective had to be abandoned, however, when at 2245/333, it was realised that the port side of the sidescan was not operational. Hauling began immediately, and TOBI was recovered by 0200/334. It was then discovered that one section of the port sidescan transducer had flooded, and this was removed from the array.

Repairs to the scatterometer continued until 1200/334, and TOBI was redeployed by 1300/334. Survey depth was reached by 1600 and data was collected until 1835/334 when all systems on the vehicle failed. During the deployment the scatterometer appeared to be transmitting, but no bottom returns were received. TOBI was brought to the surface at 2200/334 and was secure on deck by 2245. It was then decided that we would move to coring operations, so the cable was changed and a short transit to the first coring station was undertaken overnight.

The first core station of this second series (D12622) was designed to sample the middle reaches of the Saharan Debris Flow deposit. The corer was deployed at 0840/335, and reached the bottom at 1040. Despite a very gentle pullout, an almost full 8 m core was recovered, coming onboard at 1300/335.

The second core site (D12623), at which we were to attempt to core a large rafted block, was reached at 1430/335, and the corer was deployed by 1450. The bottom was reached at 1640/335, and a moderate pull out was observed. On recovery at 1830/335, an almost full 8 m core was retrieved.

The third core site (D12624), where the lateral ridge of the debris flow was to be sampled, was reached at 2100/335 and the corer was deployed at 2122. The corer reached the bottom at 2327 and a pull out of 7.7 t was observed as the corer was lifted off the bottom. The corer reached the surface and was recovered by 0230/336. Again, a nearly full 8.4 m core was recovered.

The fourth core station (D12625) was aimed at sampling the 'background' sedimentation on the insular slope adjacent to the debris flow, with the hope of being able to obtain information to aid in dating the flow. The corer was deployed at 0412/336 and reached the bottom at 0602/336. An unusual double pull out reaching a maximum of 8.1 t was observed. The corer reached the surface at 0800/336, when it was discovered that the double pull out observed earlier was a consequence of the corer being bent. A thick coarse volcanic sand, which probably prevented penetration of the corer, appeared to be the cause of the damage. Although part of the core was lost because we were unable to extract it from the bent barrels, 5.5 m of core was recovered.

Because of the time needed to rebuild the damaged corer, it was decided to end coring in the area west of Hierro, and to proceed northward to the next coring site in the area southeast of Madeira. The 3.5 kHz fish was recovered at 0930/336 to allow us to proceed at maximum speed. However, an oil leak problem in the ship's stern gland, which had begun earlier in the cruise, worsened dramatically due to ship motion, particularly at speeds over 8 Kt. The ship was forced to reduce speed to 8 Kt, increasing the time required for passage to Cadiz by some 50%, and drastically reducing the time remaining for scientific work. A short TOBI dip, for a final scatterometer trial, was planned for the few remaining working hours.

However, overnight, the northeasterly sea and swell died away, and it was possible to increase speed to between 10 and 11 Kt. This allowed two coring sites in the basin southwest of Madeira to be occupied. The aim of these sites was to test the provenance of specific Madeira Abyssal Plain turbidites which were believed to have passed to the plain through this basin. The first site (D12626) was reached at 1530/337, when the 3.5 kHz fish was redeployed. The corer was launched at 1615, and reached the seabed at 1817. A pullout of 7.6 t was recorded and the corer was recovered by 2020. 6.7 m of sediment was obtained. Passage to the next coring site was begun immediately. This site (D12627) was reached at 0530/338 and the corer was launched at 0610. It reached the seabed at 0806/338 and a large pull out of 9.5 t was recorded. The corer returned to the surface at 0940 when the middle section was again found to be bent. The lower barrel contained a thick shelly sand, which had apparently stopped penetration and caused the corer to bend. Again, part of the core was lost because we were unable to extract it from the bent barrels, but 3.8 m of core was recovered.

Following recovery of the corer, *Discovery* continued to make passage to the northeast while the cable was changed for the final TOBI dip. TOBI was launched at 1325/338 and was run across the sill at the southwest end of the Seine Abyssal Plain for the next 17 hr, while scatterometer trials were carried out. Good results were obtained from the scatterometer using the profiler as a receiver. Scans through a variety of angles and at different frequencies were possible. No evidence for sediment flow over the sill was seen in the sidescan data. Finally, at 0630/339, we began to haul TOBI back to the surface, and it was secured onboard by 1000/339. The 3.5 kHz fish was also recovered at this time. *Discovery* began passage to Cadiz at 1030/339 and docked at 1000/340.

PISTON CORING

A total of twelve piston cores were taken by a combined team of IOSDL scientists and RVS technical staff, with the assistance of the *Discovery* crew. Because of the varied and unpredictable nature of the debris flow sediments in the area, the cores were restricted to a maximum of three barrels. This later proved to be a wise decision since three out of twelve cores were bent on recovery. Core D12617 reached a maximum allowable load for the coring warp without moving. Eventually after 19 hr of steaming around the core site, the corer pulled out and a bent core was recovered. Cores D12625 and D12627 both appear to have bent after hitting coarse sandy units and under penetrating.

Unfortunately, the present winch system does not easily allow the insertion of a pennant and weak link; had there been one and the corer remained stuck in the seabed at site D12617, this would have saved 4000 m of coring warp. The addition of an auxiliary winch would allow stopping off and the insertion of a weak link above the coring system. This should be considered for future coring on *Discovery*.

Of the remaining seven straight cores, 65.9 m of core was recovered from a maximum to 75 m. This was an average of 88% full cores, an excellent recovery rate. confirming the freefall and chain lengths figures below as correct.

On recovery all of the cores were logged using the IOSDL P-Wave logger and stored in the ship's sample cold store at 4° C.

Table 1. Piston Core freefall wire and chain lengths.

Number of barrels (length)	Freefall length (m)	Chain length (m)
2 (7.5 m)	4.5	10
3 (10.5 m)	7.5	16

TOBI / SCATTEROMETER

There were two objectives for the TOBI system on this cruise: to provide 30 kHz sidescan imagery and sub-bottom profile records to satisfy the cruise scientific objectives, and to provide a platform and communications link to enable trials for the scatterometer (a wide bandwidth, non-linear steerable acoustic system) currently being developed at IOSDL. It was hoped that realisation of the latter could be achieved at the same time as, and without detriment to, the former, although provisions were made to ballast the vehicle for operation in either configuration.

During the cruise a total of 8 deployments were made and for all but the first, lasting 3 days, the vehicle was fitted with the scatterometer hardware and for runs 2, 6, 7 and 8 the scatterometer electronics were also included. The vehicle was in the water for a little under 11 days covering about 800 km of trackline.

Sidescan and Profiler.

Although the sidescan imagery was for the most part of an acceptable quality, the sidescan performance was intermittently degraded by a few problems with the vehicle. During Run 1 the time varied gain (TVG), which should increase over the 4 s swath period to compensate for acoustic losses, periodically operated with some other time constant and had to be reset on each occasion using the modem link. This resulted in occasional short periods of bad data although it is hoped that these can be processed out in future replays. The problem was cured before the next run.

The port sidescan showed increasing spiky noise over the next few deployments until it failed altogether on Run 6. It was found that one of the five sections had flooded through a connector. This section was removed for the next deployment, giving a small but not unacceptable loss of resolution. Luckily only limited damage was caused internally and it was repaired to be replaced for Run 8. Run 7 had to be terminated after a short circuit appeared on the cable after 10 hours. This was eventually traced to an insulation failure on a wire within the swivel assembly. Run 8 was primarily a scatterometer trial but the sidescan data again showed spiky noise on the port side. On recovery it was discovered that another connector had leaked. However this time the water had not penetrated the acoustic array and the problem was readily repaired.

The plug failure was worrying and although to date this type of connector has been very reliable they were ageing and a policy of early replacement will be adopted. A contributory factor may well have been the fact that fitting and removal of the scatterometer system was an awkward task involving possible accidental stress on these connectors. More attention should be paid to this problem in the future.

The profiler worked faultlessly throughout and provided excellent records.

Scatterometer trials.

The scatterometer is an instrument that can generate, over a wide range of frequencies, a narrow and electronically steerable acoustic beam using a non-linear acoustic array. Its purpose is to help with the characterisation of different types of sea-floor by observing how backscatter varies with grazing angle and frequency. The non-linear transmitting array, receiving hydrophone and electronics tube were mounted on the TOBI vehicle, which also provided the instrument with the power trigger signals and data links that it required.

This was the first trial for the transducer and hydrophone following only very limited previous experience with the transmitter electronics. The objectives of the trial were:

a) To establish a data link between the scatterometer and ship via the TOBI controller.
b) To test the transmit, receive and steering electronics.
c) To establish proper working of the non-linear array.
d) To establish proper working of the receiving hydrophone.

The first deployment revealed that the listening hydrophone was unstable and generating a high level of modulated signal on the cable. This caused breakthrough on the modem and made communicating with the micro-controller impossible. It was also discovered that the scatterometer was generating multiple pulses when triggered. By the fourth deployment these problems had been resolved, though it had been decided that the profiler transducer array should be used to listen for the scatterometer backscatter signals. The vehicle had only just reached its working altitude and the scatterometer was being reprogrammed to scan through a higher range of frequencies when the short-circuit in the swivel happened. The fifth deployment was successful. As the vehicle descended, the scatterometer was set to scan through 40° and cycle through frequencies 1 to 11 kHz. Surface echoes were seen on the profiler record as the vehicle approached 3000 m depth and these were clearly due to scatterometer transmissions. Once the vehicle was at about 400 m altitude strong echoes were seen from the bottom and the profiler transmission was turned off for the next 9 hours and the scatterometer was logged as if it were the profiler. During this time it was possible to steer the beam through a variety of angles, but not to change the frequency much away from 9 kHz.

It was unfortunate that there was such a high level of cross-talk between profiler and modem as it made communicating between scatterometer and micro-controller very tricky.

COMPUTING

The requirements for this cruise was primarily to provide navigation. To this end the following instruments were logged:

Chernikeef electro-magnetic log providing both fore/aft and port/starboard speed;

Gyro for heading;

Trimble GPS for position fixing approximately once a second;

MX1107 for position fixing using Transit Satellites.

In addition the output from the Simrad 500 echosounder and Winch monitoring system were also logged. The GPS positions were carefully screened, after the first large scale plot that was produced showed up numerous steps in the track which could not possibly have happened. These mainly occurred during the TOBI runs when the ship's speed was below 2 Kt. At normal passage speeds these tended to get smoothed over by the processing programs. It was also observed that there was a 10 to 12 second cyclic wave form modulating the values for latitude and longitude. These were reduced by averaging both the latitude and longitude over a 10 second sampling period. The results of this average together with the dead-reckoning positions produced from the ship's speed and heading were used to produce a corrected navigation position every 30 seconds. During the course of the cruise, the outboard echosounder transducer was replaced by the 3.5 kHz pinger and echosounding relied on the hull mounted transducer. This caused a severe degradation of the received signal such that digitising of the depth by the echosounder was not reliable when the ship was rolling. It also suffered with interference from the TOBI signal and when the winches were running. As a result there were large periods when there was no suitable data to log. The uncorrected depth data was averaged over a 30 second period and a correction applied based on the Carters table. A small portion of the TOBI data was transferred to one of the Sun workstations from the networked TOBI replay PC and an attempt made to display the pictures on the Sun workstation screen. A suite of programs originally written by Scott Garland of Boise State University on board the RRS *Charles Darwin* in February 1992 was used to convert the TOBI data into a format suitable for displaying. There were a number of problems in achieving this, amongst them being the vast amount of data generated and the lack of memory in the Suns to cope with it. Eventually by reducing the size of the data arrays containing the image it was possible to display them and produce a hard copy. Rather more time was spent in extracting the magnetics data and a program now exists which allows this data to be accessed and processed by the onboard computing system.

Navigation plots were produced, mainly for the TOBI runs at a scale of 1:50,000 for 41° N. The final data set was produced in a 'dxfmt' format at a 30 seconds interval on a cartridge tape.

RESULTS

A successful cruise during which some 800 km of TOBI data and 12 sediment cores were collected. Some 9.5 days were allocated to TOBI operations, 5.25 days to coring, and 3.25 days to scatterometer trials. The remaining time was used up in passage to and from the working area and in passage between sites. 3.5 kHz data was collected along most of the passage tracks. About 0.5 days were lost due bad weather.

The main achievements of the cruise were:

(i) The collection of a swath of TOBI data across the snout of the Saharan Debris flow deposit and the collection of a suite of cores to sample the various acoustic facies seen on that swath. The P-wave log of one core near the debris flow snout suggests that the core penetrated the flow. If this is the case we should be able to obtain an accurate date for the flow emplacement.

(ii) The collection of a mosaic of TOBI lines in the Canary Debris Flow source area. This proved our earlier interpretation of the source area based on GLORIA data and provided much new evidence for the mechanisms of failure. A large field of presumed volcanic debris, with some fragments in excess of 1 km across and several hundred meters high, was observed north of the island of Hierro. This appears to relate to the partial collapse of the island, but is not related to the Canary Debris Flow.

(iii) The collection of cores from the middle part of the Saharan Debris Flow, over an area surveyed with TOBI in 1990. Key acoustic facies, such as the lateral ridges, rafted blocks and 'woodgrain' fabric area previously identified were sampled.

(iv) The collection of cores from the 'Agadir' Basin, southeast of Madeira, which should allow us to test our existing models of turbidite transport through the area.

(v) The successful trials of the scatterometer.

Table 2. Piston Core Stations

Station	Latitiude	Longitude	Water Depth (uncorr. m)	Core Length (m)	Trigger Core (m)	Comments
D12616	27° 46.76'N	22° 17.68'W	4849	7.7	1.2	High-penetration, parallel bedded 3.5 kHz facies
D12617	27° 48.09'N	22° 14.89'W	4849	1.8*	1.2	No 3.5 kHz penetration + featureless TOBI record. Top of core (1-2 m?) lost in bent barrels
D12618	27° 50.01'N	21° 43.36'W	4791	8.5	0.8	Debris flow (3.5 kHz + TOBI)
D12619	27° 50.11'N	21° 46.71'W	4815	5.3	1.2	Immediately in front of debris flow tip. No 3.5 kHz penetration + low backscatter TOBI record
D12620	27° 50.17'N	21° 47.58'W	4809	4.1	0.8	Immediately in front of debris flow tip. No 3.5 kHz penetration + high backscatter TOBI record
D12621	27° 52.76'N	21° 35.50'W	4780	7.9	0.8	Saharan Debris flow
D12622	27° 41.83'N	19° 09.78'W	4182	8.0	1.2	Saharan Debris Flow
D12623	27° 43.10'N	19° 12.01'W	4177	8.0	1.1	Rafted block in Saharan Debris Flow
D12624	27° 56.27'N	19° 32.02'W	4273	8.4	0.8	Lateral ridge of Saharan Debris Flow
D12625	27° 57.62'N	19° 31.07'W	4318	5.5*	1.2	Slope sediments north of Saharan Debris Flow. Corer bent, 4.2 m recovered above bend. About 1.4 m of core lost in top of lower barrel. 1.3 m recovered below bend.
D12626	31° 30.05'N	16° 11.96'W	4405	6.7	0.8	Basin plain southwest of Madeira (Agadir Basin)
D12627	32° 35.98'N	15° 00.17'W	4358	3.8*	0.8	Basin plain (Agadir Basin) below sill to Seine Abyssal Plain. Corer bent in middle section. About 1 m of core top lost.

* Part of core lost; unable to extract it from bent barrels

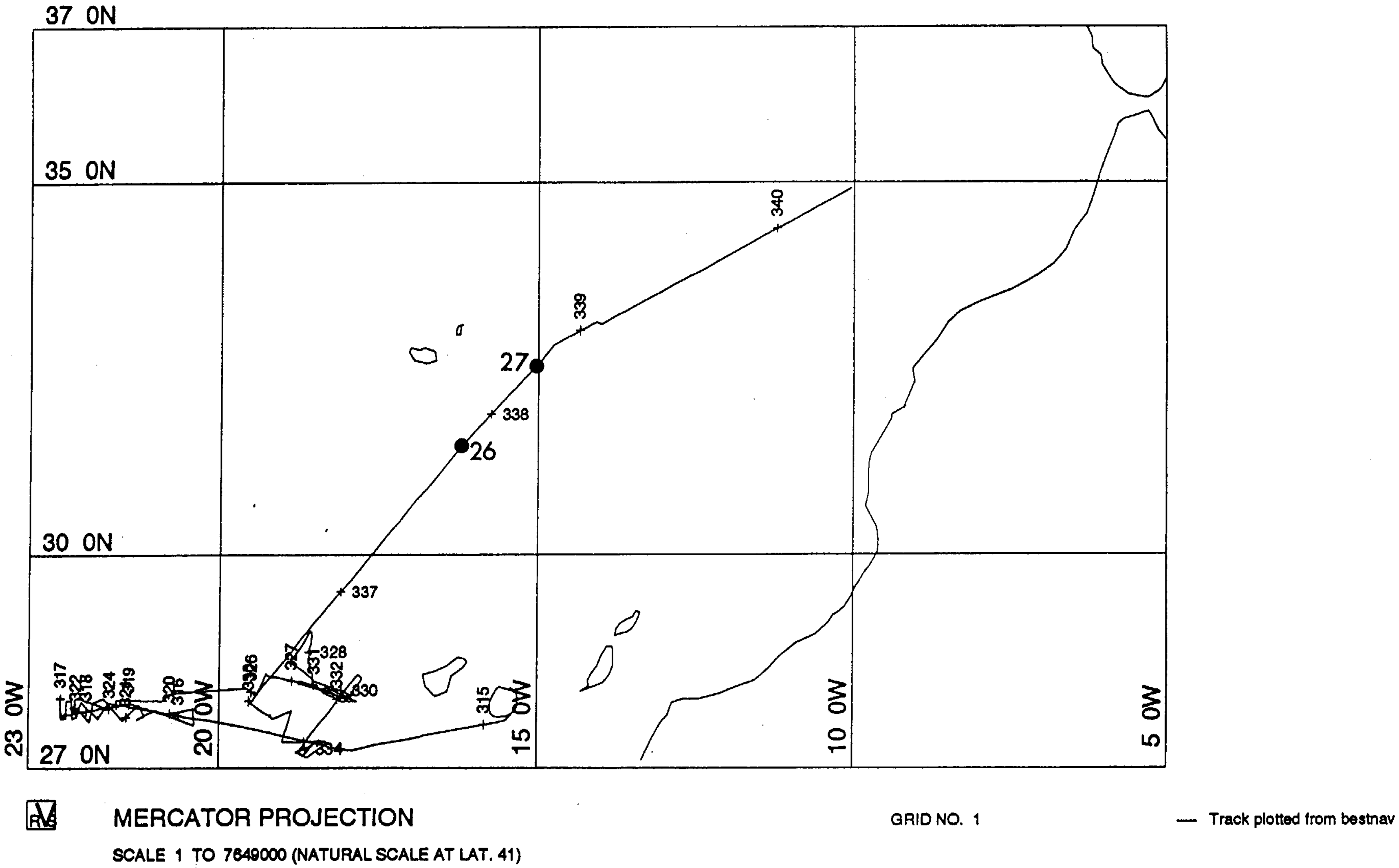


Figure 1. Track plot for *Discovery* Cruise 205, 10 Nov - 07 Dec 1993. Numbers 315 to 340 are Julian day numbers at midnight. Filled dots show location of core stations D12626 and D12627 (Table 2).

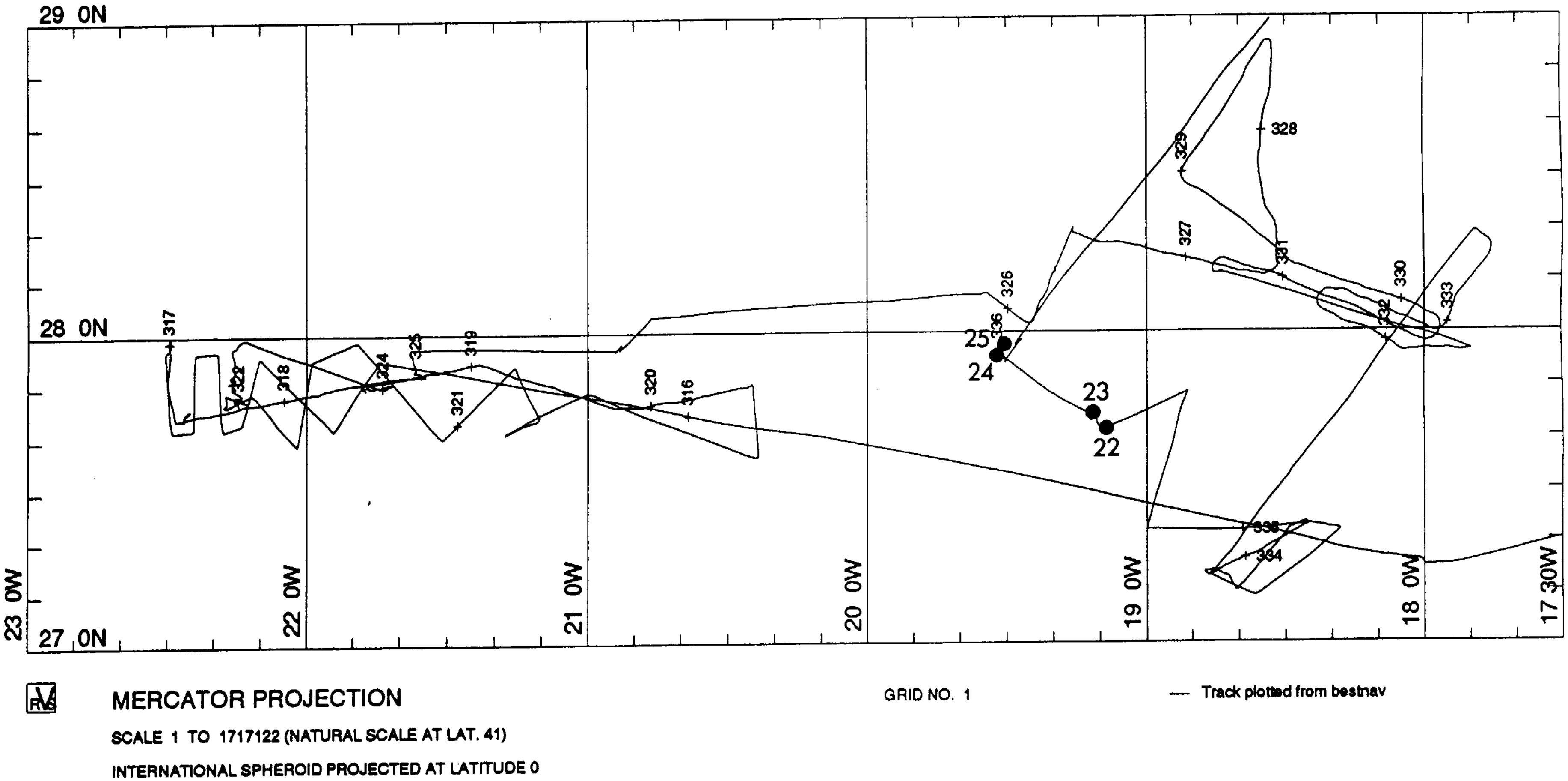
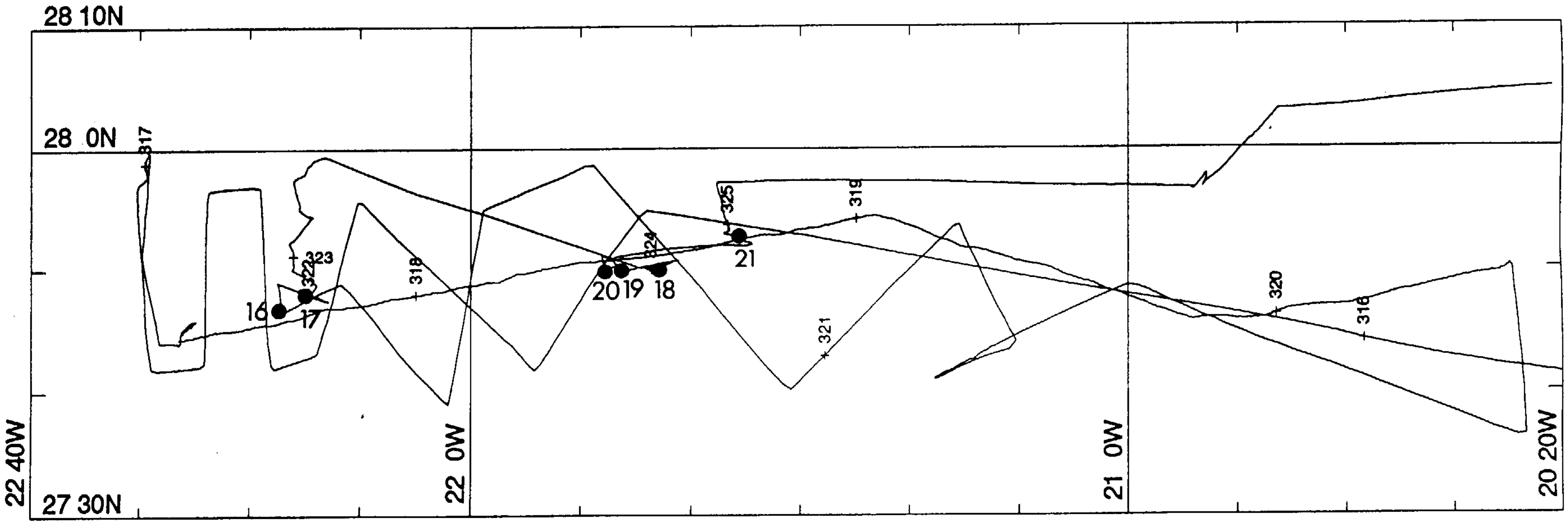


Figure 2. Track plot for *Discovery* Cruise 205 in main study area west of the Canary Islands. Numbers 316 to 336 are Julian day numbers at midnight. Filled dots show location of core stations D126<u>22</u> to D126<u>25</u> (Table 2).



MERCATOR PROJECTION

SCALE 1 TO 764900 (NATURAL SCALE AT LAT. 41)

INTERNATIONAL SPHEROID PROJECTED AT LATITUDE 0

GRID NO. 1

— Track plotted from bestnav

Figure 3. Detail of track plot of *Discovery* Cruise 205 in the area of the Saharan Debris Flow snout. Numbers 316 to 325 are Julian day numbers at midnight. Filled dots show location of core stations D126<u>16</u> to D126<u>21</u> (Table 2).