R.R.S. "Discovery"

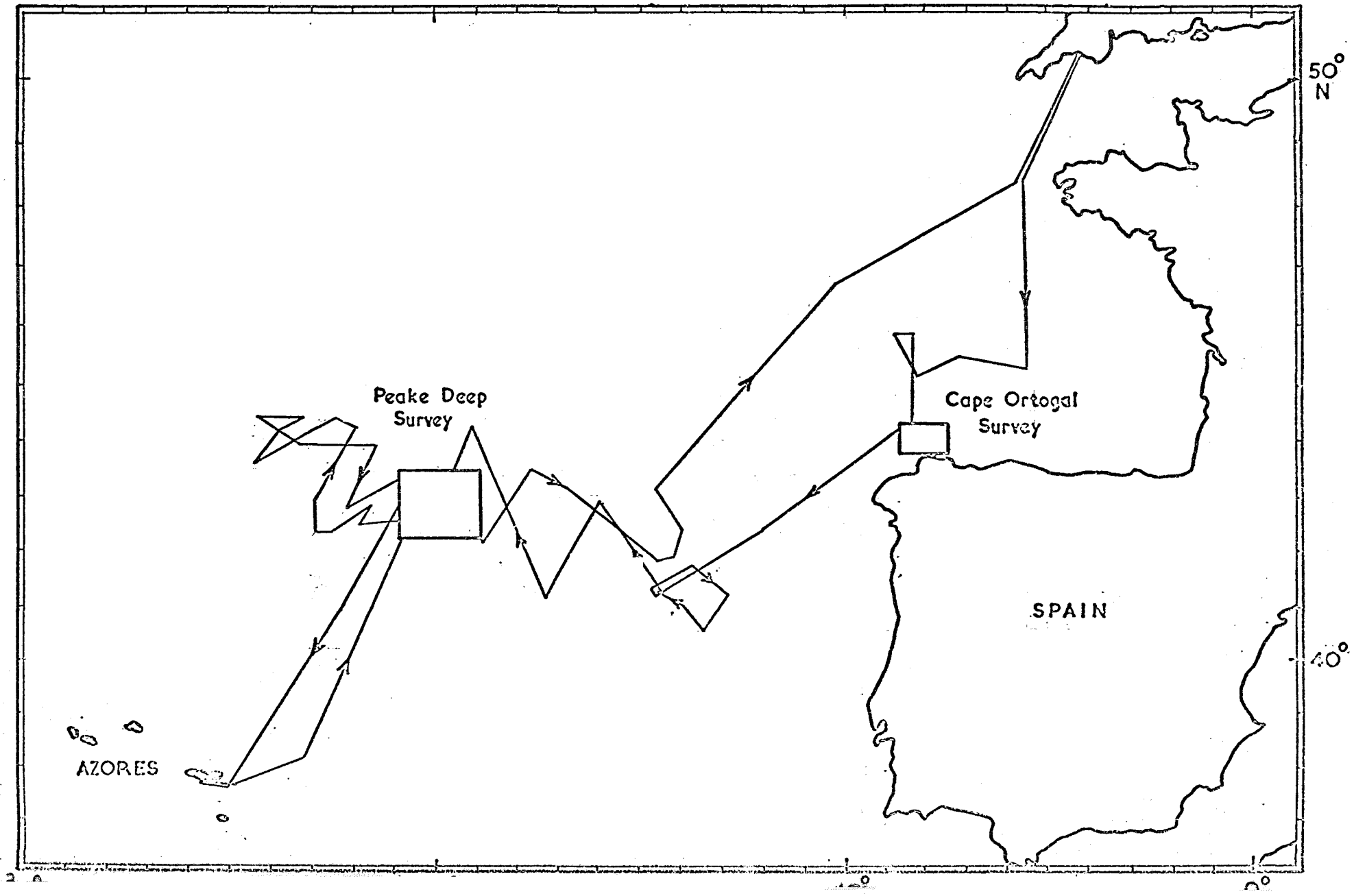
Cruise 4 Report

Feb. - March 1965

Geology and Geophysics in NE Atlantic

This report has been compiled from reports of proceedings, which contain the narrative of the two legs of the cruise, reports of individual projects prepared for O.N.R. Grant Contract N 62558-4293 and station lists. These reports have been written by Dr. M.N. Hill whose intention, before his death, was to prepare a detailed cruise report.

A.S. Laughton
National Institute of Oceanography
February 1966


Peake Deep
Survey
Cape Ortogal
Survey
SPAIN
AZORES
50°
N
40°

Dates

Departed Plymouth	2nd February 1965
Arrived Ponta Delgada, Azores	28th February
Departed Ponta Delgada	4th March
Arrived Plymouth	1st April

Personnel

Dr. M.N. Hill	Cambridge	(Geophysics)
Dr. A.S. Laughton	N.I.O.	
Dr. D.H. Matthews	Cambridge	(Geophysics)
Mr. D. Davies	Cambridge	(Geophysics)
Dr. J.R. Cann	Cambridge	(Min. and Pet.)
Mr. J.C. Cleverly	Cambridge	(Geophysics)
Mr. J. Sunderland	Cambridge	(Geophysics)
Mr. D.T. Pugh	Cambridge	(Geophysics)
Mr. J.G. Sclater	Cambridge	(Geophysics)
Mr. T. Davies	Cambridge	(Geology)
Mr. E.J.W. Jones	Cambridge	(Geophysics)
Mr. R.B. Whitmarsh	Cambridge	(Geophysics)
Mr. T. Vertue	Cambridge	(Geophysics)
Lt. F.H.F. Hinds	Hydrographic Department, R.N.	
Dr. S. Rusby	N.I.O.	
Mr. J. Jopling	N.I.O.	
Mr. J. Francis	N.I.O.	
Mr. N. Brewin	Monmouth Grammer School	
Mr. J. Walter	Marlborough College	

R.R.S. DISCOVERY,
at San Miguel
28th February, 1965

To Professor Sir Edward Bullard,
Department of Geodesy and Geophysics,
Cambridge University, England.

Herewith a Report of proceedings since we left Plymouth. Dates 2nd - 28th February 1965

(a) WEATHER

This has been the dominating force in what we have done; we have had about five days when the wind was less than force 5 to 6. For the rest of the time it has been blowing force 7 to 9, usually from the N.E. We have been obliged to heave-to on two occasions - on both we were underway and working within 24 hours. The type of work we could do was, however, restricted. For example, only one surface seismic station has been practicable.

The motion of the ship has been much greater than we had hitherto experienced in this ship but apart from causing discomfort did not cause interference with scientific work, except with the coring programme as discussed below.

(b) NARRATIVE

We left Plymouth at 1630 on February 2nd and once south of the Eddystone we began the familiar gravity calibration run south from the Eddystone towards Ushant. The run was extended to pass over other submarine pendulum stations in the Bay of Biscay.

At a point about half way across the Bay we stopped to stretch the coring winch wire and test various pressure containers. This was accomplished without much difficulty; it was, however, apparent that the badly worn traversing rollers on the coring winch would have to be replaced after only a few more lowerings.

On February 4th the ship reached the position for the beginning of a coring programme on the abyssal plain, and this programme proceeded with some shifting of subsequent positions to the west for 6 cores. In between the first and second cores a wing traversing roller from the trawl winch was swopped over with a coring roller in which the ball race had broken. No cores were obtained; this was partly because of premature release of the trigger mechanism in the high seas and winds but probably, more important, because of the hardness of the bottom.

On February 6th this programme was abandoned and a course was set for a survey with echo-sounder, magnetometer and gravity meter of an area on the continental slope and shelf off the N. Coast of Spain. This survey, conducted in high winds from the North and East, was completed on 9th February. It included the investigation of a suspect off-shore bank, which proved to be non-existent.

Gale force winds precluded station work so a course was set from Cape Finisterre towards Galicia Bank and Swallow Bank. It was intended to resume coring in the Iberian abyssal plain if the weather permitted. However, there was no respite and Swallow Bank was reached early in the morning of 11th February. The ship then, in the N.E. gale, turned to the N.W. for a run up to an area including Antaltair seamount and Peake Deep, both in the foothills of the Mid-Atlantic Ridge. The ship, after turning, began rolling heavily and caused lubrication trouble in the main engines. We were forced to heave-to. By dawn the wind had moderated somewhat and daylight was spent with trying out the reflection-shooting air gun and towed hydrophone array. Moderate success was achieved in the rough seas. By evening the wind and sea had moderated sufficiently for a change of plan. A programme of coring in the S.E. Iberian Plain was arranged. This programme began a.m. on 12th February; the first core was unsuccessful but thereafter a sequence of 12 satisfactory cores was obtained in moderate weather. Two dan-buoys were laid for this programme; all were successfully moored. During the programme the brake blocks on the coring winch had to be replaced. They had been badly worn on Cruise 2 of DISCOVERY.

The coring on the two dan-buoys was completed and various other tests of equipment made by mid-day on 15th February, and in fair weather a course was set for the Swallow Bank area. A further successful core was obtained in the S.E. corner of this area.

On 16th February a dan-buoy was laid just to the East of Swallow Bank and a bottom seismic experiment undertaken. This failed to produce useful results but was instrumentally revealing. In the evening the dan-buoy was recovered and a zig-zag course set for Peake Deep. On 17th February the wind started rising again and by 18th February was force 8 to 9 from the S.E. However, the underway measuring instruments continued to function satisfactorily. Early in the morning of 19th February the weather was such that the ship hove-to until shortly after midnight on 20th February, when the survey run to Peake Deep started once again. We laid a dan-buoy in the evening on the ridge at the southern boundary of Peake Deep and after an unsuccessful camera station we started a survey run based on the dan-buoy. This buoy had a flashing beacon on it which could be seen at ranges greater than 6 miles. On the morning of 21st February we started dredging and had a good haul of serpentinite-like rocks.

Another dan-buoy was laid to the South of the first in a deep parallel with Peake Deep. Again this was successful with a haul of - somewhat unexpectedly - soft limestones. This dredge station was followed by a bottom camera station near the shallower dan-buoy and a good collection of photographs obtained showing many loose boulders near the top of the ridge.

Early on 22nd February a survey run was made to fix the dan-buoys relative to one another and to extend the survey area. An inboard electronic failure of the sounder caused curtailment of this run and early in the morning, with force 6 to 7 winds from the N.E. a further dredge station was made which produced a small load of stones. This station was followed by a coring station in the deep to the south of Peake Deep. A premature release resulted in no core being obtained,

but there was a heat flow result. In the late evening, a further survey was made of the area. The next dredge station (on February 23rd) was abortive but a coring station was successfully completed after yesterday's failure. During the night there was a further survey run. By then the area was becoming fairly well known to us.

A further dredge station on February 24th produced one stone - probably an erratic and in the early afternoon we laid the third dan-buoy in the area in the bottom of Peake Deep. 6300 m. of mooring was required. This was followed by a fixing run back to the other buoys and a successful core was taken near the buoy. A camera station followed and a satisfactory collection of pictures was obtained on the cliff between the two earlier laid buoys. Surprisingly, the photographs were mostly of sediment. A survey run on the new dan-buoy was completed in the early morning and a bottom seismic station begun. Again unsatisfactory results were obtained although all nine charges fired. The ground wave arrivals were weak.

For the first day for some time the weather was calm so it was decided to lay the sono-buoys at the western end of Peake Deep and shoot through the night to the west and then recover the buoys. This all went well, although the ground wave arrivals were not as strong as had been hoped. The sono-buoy recovery started at first light on 26th February and was completed by 0900. A dredge station followed and a load of altered igneous rocks obtained.

The dan-buoys were raised and the few spare hours left before passage to San Miguel were used in further tests with the air gun and a survey run to the N.W.

On 27th February we were full away to San Miguel with three engines and a strong to gale force quartering wind. Somewhat uncomfortably we made a high speed. We made our landfall early in the morning of February 28th and were alongside in Ponta Delgada by 1100 hours on that day.

(c) GRAVITY

As far as it is possible to tell at this stage of the expedition, the Dutch meter has worked more satisfactorily than our own meter on other ships. The servo mechanism has proved good. In some sea states on particular courses the excursions of the Enograph were excessive but, in general and in spite of very rough weather we believe that we have been measuring gravity. In no small measure this is a result of the platform's performance; it appears to be more satisfactory than that belonging to Cambridge.

A gravity connexion has been made by air to Santa Maria with the Worden meter. It was unnecessary to make two such connexions; the uncertainty appears to be no greater than 0.4 mgal.

(d) MAGNETISM

After the first attempts at using the Birmingham magnetometer it was abandoned through towed fish failure and through inboard electronic failure. The towed fish failure could be mended aboard, but efforts to repair the inboard electronic failure proved to be useless; the fault or faults could not be traced. A representative of the manufacturers arrived in Ponta Delgada and in-so-far that we can test the instrument alongside it is now in working order.

The modified Cambridge magnetometer has worked throughout the cruise and not more than a few minutes' recording time has been lost.

(e) CONTINUOUS SEISMIC PROFILING

The compressor for the seismic gun and its associated equipment was hastily tested before leaving Plymouth. There have been a number of difficulties which can probably be resolved in the next half of the expedition. First, there was trouble in the air gun with seizing of metal to metal with the particular alloy which was used. This has involved much machining organized most ably by the Chief Engineer. Secondly, there has been leakage of air from the gun just before firing.

Troubles with the long towed hydrophone array have been fixed. These were largely electrical. No difficulty has been experienced with the compressor.

(f) ECHO-SOUNDING

Good records have been obtained from the sounder apart from a brief period of inboard electronic trouble.

(g) HEAT FLOW

Numerous heat flow results have been obtained, although the battering that the probes have received in entering turbidity current deposits explains the lack of results available in the abyssal plains of the Eastern Atlantic.

(h) PHOTOGRAPHY

Three stations have been occupied with the simple camera with new lenses. From two of these, photographs with excellent resolution have been obtained. Photography has been confined to areas of dredge hauls. In order to receive the camera pings clearly a hydrophone has been lowered to about 25 m. on the midships winch. This has also been useful for "pinger" listening.

(i) GENERAL

The expedition has had the maximum possible co-operation from the Captain, the Chief Engineer and their staffs. There has been no complaint about the apparently whimsical way in which the scientific programme has had to be altered to suit the vagaries of the weather. The engineering Department has worked hard to maintain the scientific equipment and deck machinery at the same time as coping with their usual engine room maintenance. The R.N. Survey Officer on the scientific staff has, as on previous occasions, provided service of inestimable value to the detailed survey work which has been undertaken.

(j) SUMMARY

Passage: Plymouth to San Miguel: 2nd Feb. - 28th Feb. 1965

Distance steamed:....3458 miles

Stations occupied:... 36

(Coring..... 23)
(Dredging..... 6)
(Camera..... 3)
(Bottom seismic..... 2)
(Water bottle ..... 1)
(Surface seismic.... 1)

M.N. Hill
Principal Scientist

O.N.R. CONTRACT N62558 - 4293

Herewith a Report of Proceedings on the Second Leg of Cruise 4 of R.R.S. DISCOVERY, February - April, 1965

1. WEATHER

As on the First Leg of the Expedition, the weather dominated the work that could be undertaken and it was only during the few days of the outward bound passage to the area of investigation and during the days when we were homeward bound that there was any continuous, reasonably calm weather. On many days the wind was between moderate gale and storm force and the ship was hove to in severe gale and storm force winds for a total of 103 hours during the month of March.

It was, however, satisfying to find that much of the work could continue in moderate gale and gale force winds.

2. NARRATIVE

The ship left Ponta Delgada in the Azores in the afternoon of 4th March and a course was set to Peake Deep. Full speed was made with three engines in operation, but a heavy northerly swell retarded the ship somewhat and she was pitching violently. The underway scientific apparatus was working satisfactorily.

In the early morning of 6th March, the ship was approaching Peake Deep but no sights had been obtained during the night due to overcast weather, and the position of the ship had to be established by the echo sounder and magnetometer. In mid-morning the position was found in the Deep which lies parallel with Peake Deep but to the south, where a dan buoy was laid. Attempts were then made at reflection profiling but these were unsatisfactory; the air gun was producing an unsatisfactory sound level. These attempts were abandoned in the late afternoon and a coring and heatflow station was started to the north of the dan buoy. By 10 p.m. the corer was inboard and a good core had been obtained and a satisfactory heatflow result. While the corer was being reassembled a small survey run was made to establish in detail the position of the dan buoy, and shortly after midnight on 7th March another station, with the corer and heatflow apparatus, was started and successfully completed by 3 a.m. During this station the wind had been rising and, although it was hoped that another coring station could be made, this proved impossible and the

ship was hove to until 3 o'clock in the afternoon. By then the wind had moderated although there was a very heavy swell which caused the trigger release mechanism to fail. Surprisingly, however, a reasonably long core and a satisfactory heatflow result were obtained.

It was then decided to lay another dan buoy at the east end of Peake Deep. This dan buoy was successfully moored by midnight on the 7th/8th March, and a night survey run was made to locate it. This survey run was completed by 9 o'clock in the morning of 8th March when a dredge station was started. This station took us four hours and only one rock was obtained. The dredge came up fouled with the heavy chain attached to its fore end.

The next operation was to test the container for the National Institute of Oceanography's buoyant camera. No internal works were put into the camera case. This was just as well since the camera case was missing on recovery of the 3,000 fathoms of wire. An attempt was made immediately to locate the case which should have surfaced, but shortly before midnight this search was abandoned for the night, and a survey run was started. This survey run continued until mid-day on 9th March when further attempts were made to find the missing camera case. After a further four hours this search was abandoned.

In the late afternoon, bottom seismic operations were begun. Nine charges were laid on the bottom: of these, eight fired satisfactorily. The recorder and associated equipment was inboard shortly before midnight and a further night survey run was made. This survey continued until about 7 o'clock when a surface seismic station was begun over Peake Deep. Twenty-four charges were fired, of which the largest was 100 lb. Throughout the station the wind was rising, but reasonable results were obtained. The sonoradio buoys were inboard by the late afternoon when the wind had risen to severe gale force and the ship was hove to. On this occasion there was a rapid moderation of the wind and before midnight a further dan buoy was laid on the ridge separating the two Deeps. The weather was very rough but it was possible to dredge. A good haul of sixteen rocks was obtained but, as soon as the dredge was inboard, it was necessary for the ship to heave to until the morning of 12th March when again dredging could be started. Before noon the dredge was inboard with a considerable load of rocks including one weighing about $1\frac{1}{2}$ cwt. Almost immediately further dredging was started but the weather was such that very poor control could be maintained of the ship's movement relative to the dan buoy and the ship continuously moved down-slope in-

stead of upslope. By late afternoon the dredge was inboard, empty. By this time we were out of contact with the dan buoy, and an immediate search was made for it. It was found two hours later. By then, gale force winds were blowing and the night survey run was selected to avoid having the ship beam on to the sea. This survey run continued until 4.30 a.m. when a camera station was started near where the latest successful dredge haul had been obtained. Numerous pictures of the sea floor were taken; quite a number of these showed rock outcrops. This station was completed by breakfast time, and a further dredge station was begun. After three hours' dredging, the dredge was recovered, once again empty, and at noon coring was started on the top of the slope between the two Deeps. Once again the trigger release mechanism failed because of the high seas but a heatflow result was obtained. There was no core. The dan buoy that had been laid on the ridge was then recovered and in calm weather the ship set off to the flat area north of Peake Deep for a surface sonobuoy station. For this station a dan buoy was laid in 4,500 metres of water. By late evening this buoy was successfully moored and shortly before midnight the first charge was fired. Shooting continued all night and at 8.15 a.m. on the 14th March, we were proceeding to recover the sonobuoys in reasonably calm weather. There was some difficulty in locating the sonobuoys. However, satisfactory results were obtained. By 4 o'clock in the afternoon the dan buoy which had been laid the previous night had been recovered and the ship was steaming back to the dan buoy which had been moored a week before at the east end of Peake Deep. During the passage to this buoy the wind rose to severe gale force but the dan buoy was located and recovered in heavy rain and high winds. In spite of the weather a survey run was started but was abandoned at 2 a.m. on 15th March. After breakfast the weather started to moderate and the survey was continued. This survey was supposed to end close to the dan buoy laid nine days before in the Deep to the south of Peake Deep. On the run up to the supposed position, an object was sighted by radar and no dan buoy could be located where it could have been expected. A run was made back to the object previously sighted on the radar and was found to be the dan buoy which had broken adrift.

In the late afternoon of 15th March another dan buoy was laid in the middle of the plain to the south of Peake Deep and a bottom seismic station was started. Nine charges were laid on the bottom and eight fired successfully. Poor results were obtained from this station due to malfunctioning of electronics. At 7 o'clock in the morning the sonobuoys were laid in the Deep to the south of Peake Deep, in a wind that was rather high for this kind of work. The wind continued to rise throughout the day and by the time the last sonobuoy had been recovered in the late afternoon, there were storm force winds and the ship had to heave to. During the

night of 16th/17th March the wind moderated considerably and we were able to get underway by 6 o'clock in the morning. A further core was obtained on the northern boundary of the Deep to the south of Peake Deep and a successful heatflow measurement was made. In the late afternoon of 17th March the dan buoy was recovered and another one laid at the southern edge of the Deep to the south of Peake Deep. As soon as it was moored, dredging started on a very steep slope and about 3 o'clock in the morning the dredge was inboard with four good rocks in it that had been broken from the bottom.

The ship then steamed to an area some 20 miles to the south for sonobuoy work. Four buoys were laid and satisfactory results were obtained. During the afternoon the wind was freshening, but a coring station was successfully made in the neighbourhood of the sonobuoy work. By 9 o'clock on the evening of 18th March the corer was inboard and a course was set back to the dan buoy that had been moored the previous day. A camera station was made near this dan buoy in the position where the rocks had been obtained from the bottom. This camera station was completed by 4 o'clock in the morning of 19th March but by then the wind was rising and the intended sonobuoy station was abandoned. In high winds a small survey was made around the dan buoy to locate it accurately and this survey was completed by the late afternoon. By then it was apparent that the dan buoy was adrift in severe gale force winds. It was recovered and it was then decided to make a long zig-zag run to the westwards, towards Antialtair Seamount, but after a few hours this zig-zag run had to be abandoned in severe gale force winds that continued until mid-afternoon of 20th March, when the survey was resumed in strong winds. In the late afternoon the wind had started rising again and by 9 o'clock in the evening the vessel was once again hove to in severe gale storm force winds. These high winds continued throughout 21st March and it was not until 7 o'clock in the morning of 22nd March that the survey to the westwards could be continued. However, shortly before midnight on that day storm force winds with a rapidly falling barometer resulted in the ship heaving to. Early in the morning of 23rd March the barometer started rising as rapidly as it had fallen and the wind moderated to gale force and the survey was continued in high winds throughout that day. The motion of the ship was particularly violent.

On 24th March the survey was again continuing with, at times, gale force winds. By then the ship was on the return zig-zag track to Peake Deep and a dan buoy was laid on 25th March in the Deep south of Peake Deep. It had been intended to use the sonobuoys but, because of gale

force winds this idea was abandoned. However, a dan buoy was moored and a bottom seismic station was attempted. Nine charges were laid on the sea floor in gale force winds. It was expected that they would be on a flat plain. However, the water shoaled during the laying of the charges and it was thought that the dan buoy was adrift. The recorder array was therefore towed back to where the depth was correct for the first charge that had been laid. This operation resulted in the hydrophone cable becoming snarled up with the main warp and on recovery all the electric cables had to be cut adrift in order to remove the instruments.

A survey on the dan buoy showed that it was not adrift after all, but that we had not understood the topography of the area adequately. Meanwhile, the weather was moderating and it was decided to lay another dan buoy on the ridge immediately to the south of Peake Deep and to do a sonoradio buoy station. The first shot was fired shortly after breakfast and the sonobuoys were recovered by late afternoon. These buoys had been laid near the dan buoy which was not located as the other buoys were being recovered. However, three hours later, it was found adrift with its moorings parted at the upper end.

Later in the night of 26th March a course was laid for the north end of the Iberian Plain for coring operations and on 27th March the ship was steaming all day with the underway scientific apparatus functioning satisfactorily and the weather improving steadily. The position for coring was reached in the early morning of 28th March and during this day and 29th March seven successful coring and heatflow stations were made. This programme of coring was completed just before noon on 29th March and a course was laid for Plymouth.

On 31st March the ship was west of Ushant and was stopped in order that echo sounder and magnetometer fishes could be recovered and a run made on the familiar line from Ushant to the Eddystone. In mid-afternoon of 31st March a rendezvous was made with the new Canadian Survey Ship the HUDSON which required one of our gravity meter gyroscopes. HUDSON was to be at sea for some days before joining DISCOVERY in Bristol and the opportunity was taken to transfer one of the scientists from DISCOVERY to the HUDSON.

After the usual exchange of pleasantries, passage for Plymouth was resumed and at 1 o'clock in the morning of 1st April the ship anchored in Plymouth Sound. She entered Millbay Docks in the late afternoon of that day.

(a) Seismic refraction exploration. The operations were severely hampered by weather, and, as has often been noted before, it was the launching and picking up of buoys that proved the difficulty. Once the buoys were in the water their performance was nearly independent of weather conditions. Six seismic profiles were shot and they are enumerated in Table 1. Sonoradio buoys and internally recording buoys were used on all stations; the general procedure being to use three of the former and two of the latter, which are now well integrated into the seismic system.

TABLE 1

Station	Date	Position	Reversed ?
5618	25/26 Feb.	Peake Deep	No
5625	10th March	Peake Deep	No
5632	13/14 March	N. of Peake Deep	Yes
5634	16th March	Freene Deep	No
5637	18th March	S. of Freene Deep	No
5641	26th March	Inter-Deep ridge	Yes

The profiles were intended to give a broad structural view of the area around the two deeps, and, accordingly, the lines were sited in the two deeps, on the ridge between and on the northern and southern flanks. The results are noted elsewhere.

The only innovation from the instrumentation point of view was the use of a large tape recorder to store the radio buoy data for use at a later date. It seems unlikely at the moment that further use can be made of the data from this cruise, but much has been learned of tape recording techniques.

It cannot be maintained that seismic refraction shooting was a complete success during the cruise. Quite apart from the difficulties imposed by the weather, equipment troubles were considerable for two reasons: first, much of the equipment is ready for replacement and needed continuous attention; secondly, there were not the opportunities for continuous seismic effort on alternate days that keeps the team in its best condition.

In order to attempt both to improve the instrumentation and to make a system that might be more weather-independent, plans are well advanced for:

(i) a new set of sono-radio buoys
(ii) an ocean bottom seismic system
(This is mentioned under 3(c))

Thus this cruise may well be notable from the seismic point of view for the rethinking it generated on the future of sea seismics.

(b) Seismic reflection profiling. The first tests of the seismic profiling system were carried out at intervals during the two months of the cruise. The recently constructed pneumatic gun has shown itself to be promising as a sound source although several defects have been made apparent in its present design. With the gun being towed at speeds of up to five knots, air at 3,000 pounds/sq. inch was delivered to the gun from an air compressor in the steering compartment of the ship and suddenly released into the water at intervals of fifteen seconds.

The twenty foot long, ten element, towed hydrophone array has not proved to be as sensitive as is required for receiving reflected sound from the sediment layers beneath the sea floor. Various attempts have been made to increase the signal: noise ratio. However, it is clear that better design and more testing of equipment is required before a reliable reflection profiling apparatus can become operational.

(c) Bottom seismics. Five stations were occupied during the cruise, only one of which may yield information about sediment velocities. The first four failed for various reasons, but mainly owing to electronic difficulties. When these were overcome, difficulty in ship manoeuvring and control of the gear (attached to a cable) at depth further hampered the experiments. Eventually, however, one station was successfully completed from which it is hoped to extract some sediment velocity data.

The problems of ship manoeuvring and instrument laying were such as to initiate interest in a new design of ocean bottom gear. In this it is proposed that each transducer head should protrude from a recording tube containing a tape recorder. Each such tube would be allowed to free-fall to the sea-bed and after recording seismic arrivals a ballast release mechanism (e.g. explosive bolt) would operate allowing the tube which must possess positive buoyancy, to be attached to a float and slowly surface. Homing of the ship would be by means of a flashing beacon and/or a radio beacon, as successfully used already on DISCOVERY cruises.

Further advantages of this system would be that variations in the array configuration are possible and that surface explosions beyond a critical range from the receivers, could be let off by the operating ship to augment arrivals from layer 2. Work is progressing satisfactorily in the manufacture of such a system.

(d) Coring. A total of 36 coring stations were worked during the cruise of which twenty-five were successful. Both piston and free-fall gravity coring techniques were employed and the cores were extruded and rough logged on board ship as soon as they had been taken. Details of the

Late on the 31st March, the principal scientist was found to have pneumonia and was taken, as soon as the ship berthed, to the Royal Naval Hospital.

M.N. Hill

coring stations are given in Table 2. Where coring failed it was usually due to either hardness or incoherence of the bottom sediment or to premature release of the trigger mechanism while lowering. Premature release could be, in most cases, attributed to the ship pitching and causing the hydraulic trigger mechanism release to surge up and down. Coring was carried out in conditions up to wind force 8 and clearly, in such conditions, premature releases somewhat unexpectedly occur; improvement in the design of the trigger mechanism is required for rough weather use.

One of the objects of the coring programme had been to collect a suite of gravity cores containing samples of turbidite material from the Biscay Abyssal Plain. However, after six unsuccessful attempts, this programme was abandoned. Turbidity samples were subsequently obtained with a piston corer from two regions in the Iberian Abyssal Plain.

The general features of the cores taken on the cruise are summarised below. Stations 5591-5602 form a line of twelve piston cores running across the foot of the fan at the mouth of the ~~St-Nazaire~~ Nazaré submarine canyon. The cores consist largely of graded turbidite layers varying in thickness from 10 cm to 60 cm, as many as seven layers being found in a single core. The turbidite material is commonly a green-black sand grading up into a smooth green-grey clay. The intervening layers of "pelagic" sediment are brown, white and pale green clays, highly disturbed by burrow-mottling.

Nine of the twelve cores terminate in an exceptionally coarse, black sand characterised by large flakes of mica, up to 0.5 cm across. Preliminary examination suggested that correlation between these twelve cores is quite possible.

5603 is a single core taken further from the mouth of the canyon. It contains turbidite material, but as might be expected, the turbidite layers here are generally finer, though not markedly thinner, than in the previous cores.

Cores number from 5611 to 5638 were taken in the Peake Deep region. 5613, 5620-5622 and 5635 were taken from Freene Deep in connexion with an experiment to measure a heat flow profile from the edge of the deep into the centre. The sediments in these cores are brown, white, and, occasionally, green clays with abundant foraminifera. Four of the cores terminate in a white stiff clay, apparently devoid of foraminifera. Near the bottom of each core are three layers of coarse foraminifera, the thickest layer being 15 cm thick. These are interpreted as turbidites of locally derived material from the surrounding slopes and their grouping into one short section of the cores might indicate small local turbidity

currents triggered by some small earthquake. A similar coarse layer is found in the top 50 cm of each core. Bed by bed correlation between these cores is possible.

5615 was taken in Peake Deep itself and shows the same type of sediments and general succession as in the deep to the south, though the sections differ in detail.

5638 was taken on the crest of the ridge south of the two deeps and, not surprisingly, shows no evidence of turbidity current deposition, the core consisting of grey and brown foram-rich clays, burrow mottled throughout. It is hoped that a detailed palaeontological examination of this core can be carried out soon.

Cores 5642 to 5648 form the least successful series of cores taken. They were taken from the northern part of the Iberian Abyssal Plain in an attempt to obtain samples of turbidite material from this region, presumably material that has come through Theta Gap, for comparison with material from the cores taken from further south, earlier in the cruise. The bottom proved to consist of very hard-packed sand. This effectively stopped the corer and two core barrels were seriously bent in taking cores here. The cores that were obtained consisted of very sloppy coarse green-black sand, with a thin layer of green clay overlain by brown mottled clay at the top, and seem to be sections of a single turbidite layer very close to the surface. At first sight the sediments seem little different from those found in the earlier suite of cores from the Iberian Abyssal Plain but it is hoped that a detailed mineralogical examination will show distinct differences between them.

TABLE 2

CORING STATIONS - R.R.S. DISCOVERY
CRUISE 4 (Feb. - Mar. 1965)

Station No.	Date	Time on Bottom	Latitude (North)	Longitude (West)	Depth (m)	Core Length (cm)	Type of core
5584	4/2	0920	45 36	7 16	4841	-	G
5585	4/2	2000	45 44	7 21	4833	-	G
5586	5/2	1130	45 33	7 23	4850	-	G
5587	5/2	1459	45 34	7 22	4848	-	G
5588	6/2	0920	45 50	8 39	4654	-	G

Table 2 (continued) G = gravity; P = piston

Station No.	Date	Time on Bottom	Latitude (North)	Longitude (West)	Depth (m)	Core Length (cm)	Type of core
5589	6/2	1640	45 53	8 28	4844	-	G
5590	12/2	0905	41 08	12 57	5322	-	G
5591	12/2	1506	41 12	12 52	5322	340	P
5592	12/2	2237	41 10	12 53	5324	290	P
5593	13/2	0220	41 07	12 54	5324	245	P
5594	13/2	0618	41 03	12 58	5324	260	P
5595	13/2	1403	40 57	13 06	5333	252	P
5596	13/2	1755	40 53	13 08	5333	175	P
5597	13/2	2145	40 50	13 10	5329	160	P
5598	14/2	0200	40 47	13 14	5331	85	P
5599	14/2	2231	40 36	13 23	5333	265	P
5600	15/2	0215	40 34	13 27	5338	143	P
5601	15/2	0538	40 31½	13 28	5338	160	P
5602	15/2	0929	40 29	13 30	5338	195	P
5603	15/2	2230	41 01	13 57	5340	267	P
5611	22/2	1745	42 48	20 17	5340	-	P
5613	23/2	1628	42 47½	20 17	5326	284	G
5615	24/2	1739	43 07½	19 55½	5930	347	G
5620	6/3	2030	42 49½	20 16	5338	340	G
5621	7/3	0143	42 46½	20 17	5338	353	G
5622	7/3	1625	42 50	20 17	5338	280	G
5631	13/3	1332	42 51	19 58	2838	-	G
5635	17/3	0948	42 50½	20 15	5314	285	G
5638	18/3	2001	42 26	20 28	4113	236	G
5642	28/3	0749	41 52	14 30	5325	150	P
5643	28/3	1211	41 53	14 21½	5326	227	P
5644	28/3	1628	41 54	14 14	5326	80	P
5645	28/3	2250	42 13	14 01	5322	-	P
5646	29/2	0210	42 15	14 04	5321	280	P
5647	29/3	0600	42 15	14 02	5318	-	P
5648	29/3	0915	42 15½	14 01	5322	200	P

(e) Heat flow. Fourteen successful heat flow measurements were taken on the cruise. The first five were obtained during a line of twelve piston cores taken in the southern half of the Iberian Abyssal Plain. A profile of eight closely spaced heat flow stations in and around the deep south of Peake Deep investigated the effects of rapidly varying topography and sediment thickness upon the surface flow of heat. One final measurement

was obtained during the coring programme in the northern half of the Iberian Abyssal Plain. Though no outstandingly high values were obtained a measurement considerably lower than the mean oceanic value of 1.5 μcal./sq.cm/sec. was obtained on the ridge just south of Peake Deep.

The outrigger fin type of apparatus used on this cruise worked satisfactorily during the experiment in the deep south of Peake Deep. Unfortunately, in the Iberian Abyssal Plain only five successful measurements were made in eleven lowerings. The hardness of the thick sandy turbidite layers in the top few feet of sediment not only prevented the core barrel from penetrating more than a few feet but also, on most lowerings, damaged the lowermost probe. This cruise has shown that though the outrigger-fin type of apparatus is satisfactory for measurements taken in cores of soft pelagic sediments it is inadequate for measuring the flow of heat in regions of well compacted sediments. For these regions a heavy, specially strengthened Bullard-type cylindrical probe apparatus would give greater penetration and be less susceptible to damage. It would, however, have the disadvantage of not obtaining samples of the sea floor.

(f) Dredging. Twelve dredge stations were occupied on the cruise, all of them lying in the Peake Deep area, and nine were successful. This is a much higher rate of success than has been usual in the past, and can perhaps be attributed to the greater care taken in dredging, the lack of strong local currents and the use of the new small dredges.

The equipment used was often varied, but without noticeable effect on the results of dredging. The first four stations (three successful) were made with a length of chain rigged between the end of the wire and the dredge bag. For the next three stations, all successful, a grapnel was fastened between the chain and the dredge consisting of an iron bar to which were bolted arms about 50 cm. long sticking out in all directions. Unfortunately the welded stops which prevented the arms from swinging freely gave way after three hauls, and the grapnel was not used again. In the last five stations the apparatus was similar to that used in the first four, except that a short length of chain was attached to the end of the dredge bag; three of these attempts were successful and brought in some of the best hauls. The usefulness of the grapnel was thus not well established, but it would seem desirable to rebuild it and attempt to use it again. Weak links were incorporated in the dredge set up for the first time on this cruise; they never broke, but neither did the dredge get seriously snagged up, so no information was obtained on their merits.

By far the greater number of the rocks obtained belong to the class of altered indurated tuffs, calcareous tuffs and altered basalt lavas that D.H. Matthews has studied in detail and which probably form an important part of Layer 2. Specimens of serpentinite, with gabbro and anorthosite, were present in two hauls, and may represent outcrops of thin slices of Layer 3 thrust into the normally outcropping Layer 2. In one haul were lumps of brecciated altered basalt, perhaps showing the presence of near-by faulting. Manganese coating was present on many of the tuff specimens and at times was so thick that the rock was better called a manganese nodule. Several erratics were recovered and some of them showed well developed glacial striae.

The dredging programme on this cruise has been unprecedentedly successful, and dredging shows signs of becoming not a chore carried out in the hope that sooner or later luck will hold, but a technique that may be used systematically to obtain some idea of the composition of the ocean bed.

(g) Underway observations. Continuous underway echo sounding, magnetic and gravity observations were routinely taken during the cruise, and these are in various stages of processing at the moment. They will add considerably to the large corpus of knowledge we already possess on the North Atlantic.

(h) Bottom photography (the responsibility of A.S. Laughton of the National Institute of Oceanography). Four camera stations were held in areas where there were successful dredge hauls. They were stations 5609, 5616, 5629 and 5639. The photographs were taken with a newly designed underwater lens and a higher powered electronic flash unit. This resulted in improved resolution and higher definition.

Station 5609 was situated on the crest of the ridge in 1800 fm., between Peake Deep and the deep to the South and 5619, in 2450 fm., was on the south facing cliff, both being approximately along the line taken by dredge stations 5614 and 5619. Station 5609 showed rock outcrops either partially sediment covered or nearly bare; others showed boulders lying on sediment that was sometimes rippled. Sixty-six pictures were taken. At station 5616 some seventy pictures were taken; only six of which showed rocks.

Station 5629, in 1400 fm., was on the crest of the ridge, fifteen miles further east than the stations mentioned above and near dredge station 5627. Three pictures show rock outcrops and one a loose boulder.

Otherwise they all showed fine sediment covered in places by small rock fragments and sometimes by dense accumulations of gravel-sized material possibly organic in origin. Seventy pictures were obtained.

Station 5639 in 2600 fm. was meant to be on the dredge station 5636 on the slope of the cliff bounding the deep to the South of Peake Deep; this object was not achieved, since the dan buoy locating the station dragged its moorings and consequently the station was held further north in deeper water at the foot of the northern slope. Some thirty-two pictures show sediment disturbed by burrows.

CRUISE 4

STATION SUMMARY

Total number of stations occupied 65

Bottom seismics 5
Single ship refraction seismics 6
Rock dredge 12
Underwater camera 5
Core and heat flow 29
Core 7

Total time spent on stations ..... 13 days 7 hours

KEY TO STATION LIST (ATTACHED)

D.L.H.	Large heavy dredge
U.C.	Underwater camera
C.H.F.	Core and heat flow
S.S.	Seismics - surface refraction
S.B.	Seismics - bottom refraction
W.B.	Water bottle

1. In seismics, the mean centre of the buoy line is given if DISCOVERY moved during station
2. Depths are to the nearest five fathoms
3. Dan buoy number is given when used on station

CRUISE 4

Station No.	Type	Date 1965	Time (L.M.T.)	Position	D.B.	Depth U.C.F.	Depth C.F.	(M)	
5584	C.H.F.	4 Feb.	0650 - 1047	45°36'N 07°16'W	-	2562	2647	4841	No core
5585	C.H.F.	4 Feb.	1800 - 2130	45°44'N 07°21'W	-	2559	2643	4833	No core
5586	C.H.F.	5 Feb.	1020 - 1250	45°33'N 07°23'W	-	2567	2652	4850	No core
5587	C.H.F.	5 Feb.	1330 - 2245	45°34'N 07°22'W	-	2566	2651	4848	No core: testing reflection Equip.
5588	C.H.F.	6 Feb.	0735 - 1030	45°50'N 08°39'W	-	2569	2654	4854	Pre mature release: no core
5589	C.H.F.	6 Feb.	1447 - 1904	45°53'N 08°28'W	-	2564	2649	4844	No core
5590	C.H.F.	12 Feb.	0703 - 1040	41°08'N 12°57'W	-	2814	2910	5323	No core
5591	Core	12 Feb.	1330 - 1850	41°12'N 12°52'W	I	2814	2910	5323	Piston core successful. Two graded turbidite layers and smooth mottled clay
5592	C.H.F.	12 Feb.	2035 - 0005	41°10'N 12°53'W	I	2815	2911	5324	Core successful. Five turbidite layers, very coarse micaceous sand

Cruise 4 (contd)

Station No.	Type	Date 1965	Time (L.M.T.)	Position	D.B.	Depth U.C.F.	Depth C.F.	(M)	
5593	C.H.F.	13 Feb.	0043 - 0340	41°07'N 12°54'W	I	2815	2911	5324	Core successful. Six turbidite layers graded sand to clay
5594	C.H.F.	13 Feb.	0445 - 0852	41°03'N 12°58'W	I	2815	2911	5324	Core successful. Five turbidite layers graded sand silt to clay
5595	Core	13 Feb.	1100 - 1520	40°57'N 13°06'W	II	2820	2916	5333	Core successful. Two graded turbidite layers graded sand to clay, below these green/grey clay.
5596	C.H.F.	13 Feb.	1555 - 1920	40°53'N 13°08'W	-	2820	2916	5333	Heat flow result. Core successful. Three turbidite layers; lower layer very coarse sand
5597	Core	13 Feb.	2000 - 2300	40°50'N 13°10'W	-	2818	2914	5329	Core successful. Four turbidite layers, fine sand to clay
5598	C.H.F.	14 Feb.	0025 - 0330	40°47'N 13°14'W	-	2820	2916	5331	Heat flow result. Brown and green clay to coarse green/black sand
5599	Core	14 Feb.	2055 - 2400	40°36'N 13°23'W	III	2821	2917	5333	Core successful. Smooth, mottled brown and cream clay
5600	C.H.F.	15 Feb.	0033 - 0330	40°34'N 13°27'W	-	2823	2919	5338	Heat flow result. Core successful Two turbidite layers separated by green/brown smooth clay

Cruise 4 (contd)

Station No.	Type	Date 1965	Time (L.M.T.)	Position	D.B.	Depth U.C.F.	Depth C.F.	(M)	
5601	Core	15 Feb.	0425 - 0700	40°31'.5N 13°28' W	-	2823	2919	5338	Core successful. Two turbidites graded sand to clay
5602	C.H.F.	15 Feb.	0800 - 1140	40°29' N 13°30' W	-	2823	2919	5338	Heat flow result. Core. Two turbidite layers graded sand to clay
5603	C.H.F.	15 Feb.	2035 - 2400	41°01' N 13°57' W	-	2824	2920	5340	No heat flow result. Core, five layers of silty clay graded upwards from coarse to fine.
5604	S.B.	16 Feb.	1300 - 2045	41°19' N 14°26'.5W	IV	2824	2920	5340	No results. Eight charges laid on 303°T: three fired
5605	W.B.	16 Feb.	2335 - 0145	41°19' N 14°26'.5W	-	2680	2770	5065	Two casts down to 1600 M
5606	U.C.	20 Feb.	1755 - 2400	42°57'.5N 20°15' W	V	2280	2350	4298	No results. Electrical failure
5607	D.L.H.	21 Feb.	1005 - 1430	42°54' N 20°08'.5W	-	1750	1798	3288	Good collection. Manganese encrusted serpentinite blocks and erratics
5608	D.L.H.	21 Feb.	1635 - 2045	42°52' N 20°16'.5W	VI	2338	2411	4409	Tuffs, limestones and erratics

Cruise 4 (contd)

Station No.	Type	Date 1965	Time (L.M.T.)	Position	D.B.	Depth U.C.F.	Depth C.F.	(M)	
5609	U.C.	21 Feb.	2100 - 0100	42°54' N 20°16' W	-	1804	1854	3391	Many pictures showing out-cropping rocks and boulders
5610	D.L.H.	22 Feb.	1000 - 1315	42°51' N 20°16'.5W	VI	2456	2540	4645	Two metamorphosed basalts one weathered basalt one erratic
5611	C.H.F.	22 Feb.	1610 - 1920	42°48' N 20°17' W	VI	2816	2915	5333	Heat flow result; premature release
5612	D.L.H.	23 Feb.	0910 - 1400	42°53' N 20°16' W	V	2073	2134	3903	Dredge empty
5613	C.H.F.	23 Feb.	1500 - 1750	42°47'.5N 20°17' W	VII	2814	2913	5321	Heat flow results. Core: brown and grey/green clays. Two layers of foraminiferal sand
5614	D.L.H.	24 Feb.	0910 - 1225	42°53'.5N 20°16' W	V	2025	2083	3809	One erratic
5615	C.H.F.	24 Feb.	1535 - 1912	43°07'.5N 19°55'.5W	VII	3138	3257	5933	Heat flow results
5616	U.C.	24 Feb.	2128 - 0053	42°53'.5N 20°16' W	VI	2444	2522	4612	Successful mainly pictures of soft bottom, some loose rocks. Fifty-five pictures

Cruise 4 (contd)

Station No.	Type	Date 1965	Time (L.M.T.)	Position	D.B.	Depth U.C.F.	Depth C.F.	(M)	
5617	S.B.	25 Feb.	0904 - 1650	43°17' N 19°58' W	VII	3140	3259	5960	Nine charges on 074°T; all fired. No ground waves
5618	S.S.	25 Feb.	2017 - 0850	43°05' N 20°13' W	VII	3126	3256	5954	Five buoys, ten shots on 092°T. Results satisfactory
5619	D.L.H.	26 Feb.	1010 - 1420	42°54' N 20°15' W	V	1780	1829	3345	Good haul; tuffs, limestones erratics
5620	C.H.F.	6 Mar.	1900 - 2155	42°49'.5N 20°16' W	VIII	2818	2917	5336	Heat flow result: core: brown/ grey clay four graded layers of foraminiferal sand
5621	C.H.F.	7 Mar.	0000 - 0315	42°46'.5N 20°17' W	VIII	2819	2918	5338	Heat flow result; core; brown/ grey clay with four layers of foraminiferal sand
5622	C.H.F.	7 Mar.	1457 - 1755	42°50' N 20°17' W	VIII	2818	2917	5336	Heat flow result; core; brown/ grey clay with four layers of foraminiferal sand
5623	D.L.H.	8 Mar.	0937 - 1340	43°07'.5N 19°39'.5W	IX	1950	2006	3869	Only one rock; weathered basalt
5624	S.B.	9 Mar.	1625 - 2325	43°04' N 19°47' W	IX	3139	3258	5956	Nine charges laid on 270°T Eight charges fired. Very noisy records

Cruise 4 (contd)

Station No.	Type	Date 1965	Time (L.M.T.)	Position	D.B.	Depth U.C.F.	Depth C.F.	(M)	
5625	S.S.	10 Mar.	0826 - 1620	43°06' N 19°52' W	IX	3126	3256	5954	Five buoys and twenty-seven shots on 272°T. Good results
5626	D.L.H.	11 Mar.	1325 - 1640	42°50'.8N 19°59'.5W	X	1407	1447	2646	Good haul; sixteen rocks. Tuffs, limestones, erratics
5627	D.L.H.	12 Mar.	0907 - 1132	42°51'.5N 19°56' W	X	1432	1472	2692	Good haul of rocks; one weighed 1.5 cwt. and was a block of tuff. Other manganese encrusted tuffs and limestones
5628	D.L.H.	12 Mar.	1206 - 1620	42°50' N 19°56' W	X	1660	1706	3120	Dredge empty
5629	U.C.	13 Mar.	0555 - 0847	42°50'.5N 19°56' W	X	1438	1474	2696	Numerous pictures; mainly sediment with some rock outcrops. Forty-eight pictures
5630	D.L.H.	13 Mar.	0930 - 1201	42°52'.5N 19°58'.5W	X	1572	1613	2950	Dredge empty
5631	C.H.F.	13 Mar.	1212 - 1418	42°51' N 19°58' W	X	1507	1545	2826	Heat flow result; core catcher sample only
5632	S.S.	13 Mar./ 14 Mar.	2040 - 1120	43°25' N 19°55' W	XI	2123	2188	4000	Five buoys and thirty-five shots on 272°T; line reversed good results