I.O.S.

RRS SHACKLETON CRUISE 6/79

July 7th - July 31st 1979

SEISMIC STUDIES OF THE CONTINENT-OCEAN TRANSITION IN NORTH BISCAY

IOS CRUISE REPORT NO. 80

1979

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Institute of Oceanographic Sciences,
Brook Road,
Wormley, Godalming,
Surrey GU8 5UB

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DATES

Sailed Barry	July 7th, 1979
Arrived Brest	July 20th, 1979
Sailed Brest	July 21st, 1979
Arrived Barry	July 31st, 1979

PERSONNEL

			Leg 1	Leg 2
R. B. Whitmarsh	(PSO Leg 1)	IOS, Wormley	x	x
D. G. Roberts	(PSO Leg 2)	"		x
M. Charij		"	x	x
C. E. Davies		"	x	x
R. E. Kirk		"	x	x
J. J. Langford		"	x	on R. V. Resolution
P. R. Miles		"	x	
G. Aubert		COB, Brest	x	x
F. Avedik		"	x	x
R. Conogan		"	x	x
R. Perron		"	x	x
M. Beney		RVS, Barry	x	x
T. Colvin		"	x	x
S. Smith		"	x	x

Ship's Officers

Master	E. M. Bowen
Chief Officer	S. Mayl
Second Officer	T. Morse
Third Officer	G. Harries
Chief Engineer	F. C. Hammond
Second Engineer	D. Anderson
Third Engineer	J. Landry
Fourth Engineer	P. March
Radio Officer	N. Smerk
Electrical Officer	P. Sharpe
Purser/Catering Officer	P. Higginbottom

SUMMARY OF CRUISE INTENTIONS

The principal objective of the cruise was to study the transition from continental crust to oceanic crust beneath the continental margin in the South Western Approaches sometimes known as the Armorican margin of the Bay of Biscay. It was especially intended to examine the nature of the continent-ocean boundary and the variation in thickness and properties of the deep continental crust between the thick continental crust of the shelf and the thinned continental crust beneath the rise. The programme was to be jointly carried out by the Institute of Oceanographic Sciences (IOS), the Institut Francais du Petrole (IFP), and the Centre Oceanologique de Bretagne (COB). The programme was to be divided into two legs to be executed as follows:-

Leg 1. Seismic refraction studies (Barry to Brest)

Four seismic refraction lines were to be occupied on the continental margin using the pop-up bottom seismographs (PUBS) of IOS and the ocean bottom seismographs (OBS) of COB. The lines were provisionally located as follows:

	Positions		General Location	Sound source
Line 1	46°37'N	09°59'W	Oceanic crust	Airgun
	46°54'N	11°05'W		
Line 2	46°54'N	09°30'W	Thinned continental crust	Airgun
	47°15'N	10°35'W	beneath lower rise	
Line 3	49°01.0'N	08°33.5'W	From oceanic crust to continental shelf	Airgun and explosives
	46°22.0'N	11°00.0'W		
Line 4	48°04.51'N	07°52.41'W	Continental shelf	Airgun and explosives
	49°51.00'W	10°48.00'W		

The airgun system was to be either the 140 litre airgun of COB or 4 x 1000ins^3 airguns provided jointly by COB and by Research Vessel Services (RVS) for IOS. Explosives would also be used on the longer lines.

Leg 2. Two-ship multichannel seismic profiles (Brest to Barry)

Two ship seismic reflection profiles would be made by RRS Shackleton and RV Resolution using Shackleton's airguns and Resolution's 48-channel array along the refraction lines occupied during Leg 1 and as specified below:-

		Position
Line 1	Common depth point and 30-40km fixed offset	As above
Line 2	Common depth point and 30-40km fixed offset	As above
Line 3	Deep reflection, 5km offset	
Line 4	Deep reflection, 5km offset	
Line 3A	30-40km fixed offset between	46°22.00'N, 11°00'W and 47°40.00'N, 09°48'W

To achieve precise positioning of the two ships, it was proposed to install a range-range PULSE-8 receiver on both ships whilst in Brest.

Other Projects

1. Seismic reflection profiles

R. V. Resolution was to occupy 48-channel seismic profiles along all lines should time permit.

2. Gravity

Gravity measurements were to be made throughout the programme and especially along the refraction lines.

NARRATIVE

Leg 1

After a delay of 48 hours beyond the scheduled sailing date, caused by the time required to strengthen the stern A-frame and to fabricate and assemble the parts of a special stern winch needed to deploy airguns, firm plans were made to sail from Barry on the afternoon tide of July 7th (188). While final fitting of the winch was going on on the after-deck, 13 tons of Geophex explosive were unloaded from two British Rail wagons alongside the ship and stowed on board in the magazine. The pilot came aboard at 1500 and we cleared Barry breakwater at 1605. The electromagnetic log and the PES fish were deployed and we set course at full speed to Line 2. Clocks were retarded by one hour at midnight to GMT.

The following day (189) was spent in getting equipment working, particulary in preparing the 4 x 1000ins^3 airgun array suspended from a 3m long beam which was to be towed from the stern A-frame on a bridle. Next the four hoses and trigger cables were bundled together and at 1608 the ship slowed to conduct trials of the whole gun array. The hoses and leads were streamed from the port quarter and 150ft of towing warp paid out over the A-frame sheave. Bubble pulse period measurements were made to check on the gun depth at 4 knots and the guns were fired regularly for a trial period. Passage was resumed at 2137.

We arrived at the west end of Line 2 at 1010/190. One OBS (ocean-bottom seismograph) and one PUBS (pop-up bottom seismograph) were laid at each end of the line and a single PUBS at the centre. During this operation a coupling broke on one of the ship's three alternators thus reducing the power available for the bow thruster. No spare was available on board but the decision was made to continue work. We began to deploy the airgun array at 2310 and the first shot was fied at 0002/191. Shots were fired from east to west at 4 knots every 2 minutes. Firing finished at 1230/191. During the afternoon the satellite Navigator power supply burnt out and was replaced by a spare unit. The first two OBS and PUBS were recovered by 1920 but the central PUBS surfaced in moonlight close to a brightly lit fleet of tuna boats and with a faulty flashing light. At the same time an as-yet undiagnosed fault in the RDF aerial lead on the ship prevented us obtaining a radio fix on the PUBS. At first light a systematic search was begun. After 2½ hours the search was abandoned but immediately afterwards the errant PUBS was spotted 3 miles from where it had surfaced. The remaining two buoys were recovered without incident by 1312/192 whereupon we set course for the east end of Line 1.

An OBS was laid at the east end of Line 1 at 1729/192 followed by two PUBS at the centre of the line, one of which was laid at the west end of the line and the first gun shot was fired at 0310/193. Shots were fired from west to east at 4 knots and 2 minute intervals until 1658. Buoy recovery began immediately and, except for an RDF search in darkness due to a further faulty flashing light, passed without incident being completed by 1030/194.

At 1048 we were underway to the south end of Line 3 arriving there at 1704. Three PUBS and one OBS were laid at intervals from south to north along the line. The next OBS position lay over the continental slope and a short bathymetric survey was required in order to choose a suitable site. While this OBS was being deployed however, the ballast weight released and fell into the water. A fault attributable to irreparable damage caused by an exploded battery on the previous station was eventually found to be the cause, thus reducing the number of available OBS to three. After a further survey an OBS was laid at last at 1054/195. The last OBS was laid on the shelf close to the edge. Guns were deployed at 1621 and the first of a long series of north to south shots was fired at 1656. This series included groups of "stacking" shots fired while the ship turned full circle in 20 minutes to enable subsequent digital summing of seismic traces. At 1911 between the third and fourth group an experimental 8-day recording PUBS was laid while underway at 1 knot.

Early the next day a message was received forbidding us to fire explosives as planned the following day. Although this unexpected order struck at the whole scientific basis of Line 3 it was clear that we were subject to events outside our control and plans were rapidly made to re-design the second half of the experiment. Consequently when the first set of gun shots ended at 0419/197 we steamed to the south end of the line and began to fire further stacking gun shots as we returned northwards. These ended at 2100/197 when we began the lengthy business of recovering the seven ocean bottom seismographs.

During the night of 197/198 the Satellite Navigator receiver broke down again and one PUBS had to be relocated on dead reckoning alone. As dawn broke it revealed a glassy sea which during the day enabled us to see a variety of marine life including a solitary turtle. Buoy recovery ended on the shelf at 0220/199 whereupon we set course for the east end of Line 4. Further Satellite Navigator difficulties raised concern over the navigation of the line but fortunately we found the drilling rig Pentagone in position over the Glazenn wellhead close to where we planned to lay our seismographs. Two PUBS and an OBS were laid relative to the rig using radar at ranges in excess of 5 miles to avoid the noise of the rig itself. This was finished by 1210/199 when we got underway at full speed to the west end of the line.

We were on course heading back to the east at full speed at first light next morning ready for the first explosion shot scheduled for 0500/200. A single 12.5Kg warning shot was fired first and followed shortly after by the first of a series of 300Kg suspended shots. Following the misfire of shot 4, presumed to be caused by the charge sinking too deep due to too rapid deflation of the punctured surface float, the size of bleed hole in the floats was reduced without further misfires occurring. At 1000, just after a 300Kg charge had been deployed, a hydraulic motor in the steering gear failed causing the ship to temporarily lose steerage. The fault was rectified and after a short steerage trial shooting was resumed at 1035, with 150Kg shots. The remainder of the line passed without incident. Charge sizes were reduced as we neared the OBS/PUBS, the last shot being at 1640 close to the UK/France fishing limit boundary. Recovery of the PUBS and OBS was rapid due to the good radar navigation relative to the rig and to the shallow water and was completed by 2040/200. Immediately afterwards the PES fish was recovered, thereby ending scientific watchkeeping, and we set course at full speed for Brest.

The Brest pilot came aboard at 0905/201 and we were tied up alongside by 1054, next to the RV Resolution which had arrived the previous day. The COB OBS equipment and 140 litre airgun were unloaded. A new coupling was also fitted to the damaged alternator during the port stop.

R. B. Whitmarsh

Leg 2

Whilst in Brest, P. R. Miles left Shackleton and J. J. Langford transferred to RV Resolution. D. G. Roberts joined Shackleton. During July 20th (201), the PULSE-8 navaid was installed by Decca engineers and in the late evening a meeting was held with the Institut Francais du Petrole to discuss the seismic reflection programme for the second leg and to finalise the positions of the two ship seismic reflection profiles. RV Resolution departed Brest at 0600/202. RRS Shackleton departed Brest at 1600/202, having been delayed by one hour because of the late arrival of a Decca engineer from London with new RHO/3 cassette tapes and of the need to completely re-rig the airgun hose and trigger lead bundle. The intention was for RV Resolution to occupy a conventional multichannel seismic profile along Line 2 prior to the arrival of RRS Shackleton and for the ships to then rendezvous to begin the two ship programme. Shortly after leaving Brest, we were repeatedly buzzed by a single engined French maritime reconnaissance aircraft. The PES fish was streamed at 1830Z/202 and the log deployed at the same time. Whilst on transit to the end of Line 2 the opportunity was taken to evaluate the plotting programs and setting-up procedures of the PULSE-8 RHO/3 system. We reached the southeast end of Line 2 at about 1454Z and then proceeded northwards to rendezvous with Resolution at 1850Z/203. The Zodiac dinghy was lowered to transfer the new RHO/3 tapes to Resolution and was recovered at 1925Z when we set course southeast for point B to begin the common-depth-point experiment. During the course of our transit, an assessment was made of the maximum radio range of the time break transmitter installed on Shackleton, which was found to be about 40Km. On this basis we agreed to use this range for the CDP experiment as the initial separation of the two ships. R.T. and VHF communication procedures were also tested during this period. RRS Shackleton arrived at the southeastern end of Line 2 at 0200Z/204 and commenced firing at shot-point 23 (SP23) proceeding to the northwest and passing Resolution at about 0400Z/204. PULSE-8 signals were erratic throughout much of this period presumably because of the poor nighttime propagation at this long range from the Master and Slave stations. At 0725Z, the Line was completed and the airguns recovered by 0830Z when we altered course southeastward to rendezvous with Resolution for the 30km fixed distance experiment. Resolution was passed at about 1000Z when it was agreed to fix the two ship distance at 30km. We altered course NW and at 1341Z the airguns were streamed. Airgun firing began at 1423Z and both ships (Shackleton leading) proceeded southeast down Line 2 completing the two ship fixed distance profile at 2030Z (SP250) when speed was reduced to recover the airguns. At 2136Z, course was set for the SE end of Line 1. In view of the generally poor PULSE-8 reception between 2300 and 0400Z hours, it was agreed to delay the start of the CDP profile until the anticipated improvement in reception at 0400, and to open radio communications at 0500Z/205. Meanwhile Resolution would proceed northwestward shooting a conventional multichannel seismic profile along Line 1 during this overnight period.

RRS Shackleton stood by the southeast end of Line 1 to await radio contact with Resolution which was eventually re-established by steaming northwestward along Line 1 until VHF contact could be made at 0850Z. There had been a misunderstanding of radio communications procedure and a regular schedule was then instituted to avoid further long breaks. At 0850Z/205, Shackleton set course southeastward towards the start of the line and commenced streaming the airguns at 0940Z. The CDP profile began at 1016Z. During the period of this profile, and indeed for much of the preceding day, no satellite fixes were received, apparently because of radio frequency interference from the time break transmitter. Missing fixes for this period were calculated from the PULSE-8 data. The common depth point profile was completed at 1906Z when the guns were brought inboard and we set course 112° at full speed to begin the fixed distance experiment. At 2247Z/205, speed was reduced to 3 knots to stream the airguns and the 30km fixed distance profile began at 0000Z/206 and was completed at 0630Z after profiling for a further 100 shotpoints (20km). The airguns were recovered at 0702Z and course was set for the southern end of Line 3. At 1130Z/206, we reduced speed close to SP75 to await the arrival of Resolution. Whilst awaiting Resolution, the PULSE-8 system experienced progressively larger drifts that eventually increased to about 14. 00 microseconds. Use of the manual correction programme failed to reduce the drift. Aided by the Decca engineer who was in VHF contact, we attempted to regain the correct values by changing the rubidium clocks but ultimately master and slaves were lost completely. Efforts to re-achieve lock met with little success. Interface checks showed the receivers were operating correctly. At 1237Z we therefore decided to proceed northward toward stronger signals to re-achieve lock. Meanwhile, Resolution was to occupy a conventional multichannel seismic profile along Line 3A. Between 0800 and 1200, the data logger failed to record data because of misthreading of the tape. The PULSE-8 system was realigned at 1640Z. Shackleton reached point 3A' at 0112Z/207 where we had to await the arrival of Resolution. R. T. contact was established at 0214Z/207 and VHF contact at 0525Z. To save lost time, Resolution led Shackleton along the fixed distance (30km) profile. The profile was started at 0620Z along a heading of 205° with the objective of crossing the continent-ocean boundary. The profile continued throughout the day and was completed at 0252Z/208. At the end of the profile, two airguns were not operating and at 0343Z speed was reduced to recover the airguns. The fault was traced to broken trigger leads. Repairs were completed by 0650Z and at 0703Z we altered course onto the line beginning the profile at 0838Z with Shackleton as the lead ship. At 0925Z all remaining detonators were dumped and detonated. Between 1900 and 2000Z, successive sets of 0 and 10° were found to be necessary possibly reflecting 'tide rips' observed on the sea surface. The profile continued overnight without incident. At 0640Z/209 however, the PULSE-8 track plotter stopped and both calculator outputs indicated a 'memory overflow'. The failure was eventually traced to a pedestal jump of about 3 microseconds. By 0945Z the

PULSE-8 system was again operational, Shackleton having maintained station on Resolution using radar in the intervening period. It was found difficult to re-establish the pre-plot for a variety of reasons but this was eventually done. At 1635Z the PULSE-8 systems on both Resolution and Shackleton failed due to an electrical storm. Difficulty in realigning the system was compounded by the cessation of master transmissions between 1839 and 2009Z. The system was realigned at about 2030Z but after the completion of the 5km fixed distance profile at 1913Z/209. At 2030Z, course was set westward to carry out a shortened 5km fixed distance profile along Line 4, reducing speed to bring the airguns in board for a routine check. Passage to the end of Line 4 was delayed by thick fog. At 0302/210 the airguns were deployed but the start of the profile was delayed by discrepancies between the relative position of Shackleton and Resolution as given by radar and PULSE-8. Some time was occupied in realigning the Shackleton PULSE-8 system. At 0455 both ships reached the end of Line 4 and the final 5km fixed distance multichannel seismic reflection profile began along a heading of 122°. The profile was completed at 0100Z/211 within sight of the Pentagone oil rig and speed was reduced to recover the airguns and PES fish. At 0230Z, course was set for Barry. RRS Shackleton docked Barry at 0900Z/212.

The cruise was very successful and was blessed by calm weather throughout, emphasising the importance of choosing the optimum time of year to carry out this type of study.

All refraction lines were completed except for the reversal of Line 4 on the shelf due to time constraints and all five two-ship multichannel reflection profiles were completed successfully. There were continued problems with contamination of the diesel fuel supply to the auxiliary generator that were eventually cleared up by repeated flushing of the system. Difficulties with the PULSE-8 system are referred to below.

Finally, it is a pleasure to thank Captain E. M. Bowen, the officers and crew of RRS Shackleton for their help, and, by no means least, the scientists for their careful and enthusiastic work throughout the cruise.

D. G. Roberts

PROJECT REPORTS

1. Pop-up bottom seismographs (PUBS)

Three standard and one prototype (8-day recording) PUBS were deployed over four seismic refraction lines. The standard recorders, used on the previous cruises, have been improved by the addition of a spool braking mechanism. This prevents the full tape spool being revolved by vibration which sometimes previously led to the tape jamming. A solenoid now releases the mechanism as soon as the PUBS starts to record.

The new eight day recording PUBS was completed during the cruise and used in the final two refraction lines. It has a slowed down tape deck running at about 15/256 inches/second and modified frequency modulators to cope with the reduced recorded bandwidth. This was the first stage in the development of a long term recording PUBS.

Other experiments with the PUBS during the refraction lines were the addition of a heavy steel ballast weight and the use of a small spherical hydrophone. The extra ballast weight was used in an attempt to improve the coupling of the PUBS to the seafloor thereby to improve the geophone performance. A spherical hydrophone was used to replace the standard hydrophone in one PUBS where its higher sensitivity should improve the signal to noise of the PUBS.

Unfortunately the PUBS on which both these modifications were first tried failed to record as the pivoted tape deck motor became disengaged from the flywheel it was supposed to drive. This was probably due to the greater impact with the seabed due to the steel ballast weight. The same PUBS was deployed with the same modifications after minor tape-deck adjustment later in the cruise and worked perfectly.

The eight day recording PUBS failed to record on its first deployment due to a wiring fault in a switch-on delay logic card. This was successfully deployed in the final refraction line.

Recovery of the PUBS was made difficult in a few cases by unreliable flashing lights and by a badly corroded shipboard radio DF aerial cable. The faulty cable was replaced and the radio was used very effectively in the recovery of two PUBS that came up at night with inoperative lights. The directional aerial was so good that the ship was able to steer to within 40-50 metres of the PUBS. Also during the PUBS recovery the hull mounted MS28 echo-sounder transducer seemed to show the acoustic transponder better on the Mufax display than when the towed fish was used. The fish seemed to be very noisy at lower speeds and during manoeuvering.

We used four one thousand cubic inch airguns for the first time as a sound source and the PUBS recorded ground waves from them out to about 90km.

Despite these minor problems, eleven PUBS deployments and recoveries were made in less than fourteen days and nine data tapes were obtained.

R. E. Kirk

J. J. Langford

2. Ocean bottom seismographs (OBS)

Our group of four from the Centre Oceanologique de Bretagne operated mainly the Ocean Bottom Seismographs (OBS), the Girodin compressor, which supplied the airgun array, and the timing of different events (shots, synchronising OBS, etc.) from our programmer clock.

The "operational headquarters" of the OBSs was the port side of the foredeck. The four assemblies were prepared here for launchings, which took place on the starboard-side. The transport of the 18ft high instruments (the sphere is decoupled from the instrumental structure by nylon ropes) on the rolling ship was quite an achievement. We were lucky that the weather remained fair to good during the entire cruise, otherwise the open deck maintenance of the instruments would have become impossible. (None of the ships I have worked on provides sufficient covered deck space!) Altogether nine launches and recoveries were made. It turned out to be advisable to do this with the support of a good Satellite Fix. The time spent looking for a surfaced instrument is very often much more than the time waiting for fixes. The instruments performed satisfactorily. Two failures occurred: a broken reduction gear in a release motor (changed); a main connector shorted due to acid which leaked from a battery, and the sinker weight dropped off whilst launching on Line 3.

The descent and ascent rate of the instruments were respectively 1.9 and 1.1 meter/sec.

During the acoustic tracking of the instruments the bad quality of the acoustic link was noted, most likely due to a high environmental noise level (viz Shackleton's screw). Nevertheless further investigation to assess the reason is needed.

After recovery of the instruments, the tapes were played back at 32 times the initial speed and the results were displayed on an EPC graphic recorder.

On Lines 1 and 2, on several records the seismic signal could be followed until the end of profiles (ca. 90kms).

Based on EPC plots the first velocity determinations for Lines 1 and 2 tend to show a different upper crustal structure under the respective profiles.

On Line 1, positioned over presumed "oceanic crust", the velocities observed in the upper crust are 7.1 and 7.8 km/s while under Profile 2, positioned over possibly attenuated continental crust, the velocities are 6.3 and 8.2 km/s. Observed velocities in the 9.0 - 9.5 km/s range most likely indicate dipping of the Moho interface.

The airgun array (4 x 1000^3) fired at optimum depth seems to be sufficient to obtain representative arrivals to a depth of about 12-15km.

The hook-up of the Girodin and ship's compressors was straightforward and did not cause any trouble. The on-deck 125 KVA-electrical generator, providing power for the Girodin compressor, failed several times (blocked fuel filters of the diesel engine). A radical cleaning of these filters solved the problem.

In conclusion, we hope that these joint cruises between Institutions will tend to become more and more frequent.

F. Avedik

3. Two-ship multichannel seismic reflection profiles

During Leg 2, a series of two ship multichannel seismic reflection profiles was occupied along the refraction lines occupied during Leg 1. In addition, R. V. Resolution occupied conventional 48-trace multichannel seismic profiles along Lines 1, 2 and 3A.

Although various separations between the two ships were used, Shackleton acted as the shooting ship throughout firing 4 x $1000in^3$ airguns at 80 second intervals at 2000 psi. The airgun array was towed at a depth of about 115 ft at speeds between 5 and 6 knots. Shot instants were transmitted to Resolution using a time-break transmitter kindly loaned by Societe Nationale de Petrole d'Aquitaine and the reflected and refracted waves received on a 48-trace streamer (50m between traces) and recorded to 20 seconds. Beyond the range of the time break transmitter, shots were recorded using previously synchronised clocks. To maintain common depth points, it was critical to maintain the relative positions of the two ships to within 200m at speeds of 5kts. To achieve this a PULSE-8/RHO-3 system had been placed on board both ships for the leg. Pre-plots generated by the 3-pattern seismic tracking program computed shot number separation so that both ships could easily manoeuvre to the start of the profiles and maintain the required relative position during the course of the profile. During the profiles, the VHF radio facilitated inter-ship communications and was used to relay the shot position of Resolution. Speed was then adjusted on Shackleton to maintain the required separation of the two ships. During profiles with a separation of 5km an extra and more frequent check was made on separation using radar. Shot separations were normally recorded every 15 minutes. Accurate tracking along the profile was maintained by frequent adjustments to the ship's autopilot. The relative offline position of the ship from the pre-plotted line was given in the printout of the HP 98155 computer.

After shake down problems during Line 2, this procedure worked well. Fortunately failure of the PULSE-8 system took place between the two-ship profiles or during the 5km offset experiments when radar was used instead to maintain positions.

Three types of two-ship multichannel seismic profile were made during Leg 2:

i) Common Depth Point Profiles (Lines 1 and 2)

To make these profiles, the two ships steamed toward each other from an initial separation of 40km passing each other at the centre point and proceeding towards opposite ends of the line. The initial separation for Line 1 was based on the effective 40km range of the time-break transmitter but during Line 2 was extended for a further 100 shot points (20km) using synchronised clocks on Resolution and Shackleton. The profile provided both refraction and wide angle reflection data. Preliminary analysis of the data recorded on Resolution show a similar velocity structure to that observed by the OBS system during Leg 1.

ii) 30km fixed distance profiles (Lines 1, 2, and 3A)

To make these profiles, the ships steamed along the entire length of Lines 1, 2 and 3A maintaining a fixed separation of 150 shot points (30km) using the PULSE-8/RHO-3 system. The fixed distance of 30km was chosen on the basis of the refraction results obtained during Leg 1. The intention of the experiment was to obtain continuous interval velocity data for the lower crust and in particular to examine the continent-ocean transition crossed on Line 3A. Until the data recorded on Resolution is fully processed, it will not be possible to assess the results.

iii) 5km fixed distance profiles (Lines 3 and 4)

To make these profiles the two ships steamed along the entire length of Line 3 and along most of Line 4 maintaining a fixed separation of 25 shot points (5km) using both radar and the PULSE-8/RHO-3 system. The intention of this experiment was to use a large aperture array to look at deep reflections originating in the lower parts of the oceanic crust and continental crust with specific reference to the continent-ocean transition. Until the data recorded on Resolution is fully processed, it will not be possible to fully assess the results.

D. G. Roberts

4. PULSE-8/RHO-3 Radio location system

During the two-ship multichannel seismic reflection experiments RV Resolution and RRS Shackleton were positioned using the PULSE-8/RHO-3 radio location system. This system, which was installed on the ships in Brest, had been rented to ensure precise relative positioning of the two ships over the ground when beyond line of sight. Precise positioning of shot points would considerably aid subsequent processing of the reflection data.

The PULSE-8 system, which is based on the established LORAN-C system, was originally developed for use over medium ranges of less than five hundred miles in applications which require unambiguous position determination for twenty-four hours a day with consistent repeatability of better than fifty metres. The system consists of three or more shorebased transmitting stations containing timing and monitoring equipment to synchronise the transmitters thereby producing a precisely controlled pattern of radio signals which are generally used in the hyperbolic mode but can also be used in the range-range mode. PULSE-8 is a pulsed low frequency radio navigation system. Long ranges are made possible by the low propagation losses of the 100 KHz frequency used and therefore by the ability to use relatively long base lines between the stations in a chain.

Equipment supplied by Sea Surveys Ltd. consisted of two PULSE-8 receivers, a Rubidium Beam frequency standard, two Hewlett-Packard 98155 computers interfaced with a Hewlett-Packard X-Y plotter and PULSE-8 receiver to compute track and drift corrections respectively.

The Rubidium Beam frequency standard is used to provide a stable 5 MHz signal to the receiver to maintain the accurate position of 'the pedestal pulse' generated within the receiver. The standard PULSE-8 hyperbolic receiver has a three range facility printed circuit board. Controls on this board allow the pedestal to be set and the drift rate of the Rubidium as seen against the Master Station. Rubidium to be corrected as necessary. The drift controls are set up to the number of seconds and the positive or negative sense over which a correction of 10 nanoseconds is required to compensate for the pre-determined on board Rubidium drift. Further controls are the slew control and rate and selection switch for either RHO-3 or Hyperbolic working. The displays show range from three stations when in the RHO-3 mode. The HP 9815 computer system is an integral part of the PULSE-8/RHO-3 system and contains software which carries out the following functions:-

1. Re-establishes receiver pedestal in the case of long term power failure on board or station malfunction: this is intended to obviate the need to return to a known location

to re-establish the pedestal.

2. To carry out a constant monitor of the Rubidium drift rate to ensure the constant correction to the receiver of that drift. Facilities are available to input this in manual or automatic modes. Prints indicate drift values and indicate also when manual correction is necessary.

3. To provide on-line tracking and plotting based on three-patterns least-squares positioning. A variety of presentations was available of which the three-pattern seismic pre-plot programme was used the most extensively. This programme showed the line run at small scale to show progress on the line and the same line skewed on the grid and plotted as a parallel track annotated with shot point numbers at a scale of 1:10,000 for use in tracking. The print-out showed fix number, northings and eastings, residuals and distance off-line.

Performance of PULSE-8 system

The PULSE-8/RHO-3 system was set up on board Shackleton in Brest on 20th July by Decca engineers. Two scientists had previously been briefly instructed in the use of the equipment by Sea Surveys Ltd. A Decca engineer sailed on board Resolution. New updated RHO-3 tapes for Resolution and Shackleton arrived just before sailing. One of these tapes was subsequently found to have been corrupted, either on transcription or during transit to Brest.

A preliminary assessment of the system was made during the passage down the Rade de Brest using a pre-plot. No major problems were encountered. However, during the night of 203/204 large drift corrections were frequently experienced requiring manual correction. Corrections were typically of the order of 0. 25-0. 55 microseconds at night but during the day corrections of -0. 03 to +0. 04 microseconds were normally experienced. These corrections were in general larger at the extreme ranges encountered on Line 1 and the southern end of Line 3. In practice manual corrections to the drift programme were found to be necessary every six or so " 4 x 500 " readings (approximately every $1\frac{1}{2}$ hours) and more frequently at night.

The predicted displacement of the offset voltage was not observed when the corrections were made in automatic mode. The cause of this is not known. Cross-referenced positions with Resolution gave residuals of about 12m at this time.

The PULSE-8/RHO-3 system worked very well indeed bearing in mind the extreme range of the survey area. One specific criticism of the system is the almost complete lack of documentation and diagnostics. We had been given to understand by Sea Surveys Ltd. that such documentation was available and given the short training obviated the requirement for a Decca engineer. Much of the time lost could have been minimised if documentation and diagnostics had been available. There was no handover by the installing engineers, and only the unexpected arrival of Mr. Mike Brooks from England gave us the opportunity to have a good run through the system before sailing that was most useful. Of the four new RHO-3 tapes brought by Mr. Brooks, two were found to be corrupted in first use suggesting poor transcription of the software. In sorting out the major problems with the system we were forced to rely heavily on the Decca engineer on Resolution. He proved most helpful despite the difficulty of re-aligning the system using RT and VHF communications.

In conclusion the PULSE-8/RHO-3 system has proven itself to be a precise navigation aid that fulfilled the accuracy requirements for this two-ship experiment. The system failed completely on three separate occasions. At about 1130Z/206 progressively larger drifts that increased alternately to values of 14. 00 were experienced. Use of the manual correction programme failed to achieve any improvement. Eventually the Rubidium 'A' clock was replaced by the Rubidium 'B' clock. In this process lock was inadvertently lost on master and all slaves. The problem of clocking was aggravated by our position and extreme range from slave 5. Lock was eventually regained after steaming northward towards stronger signals. Total loss of time on this occasion was about 5 hours. On the second occasion at 0645/209, the HP 98155 interfaced with the HP plotter stopped indicating a memory overflow followed shortly afterward by the other calculator. Tapes and calculators were changed over but to no avail. The trouble was eventually traced to a pedestal jump of 3000 microseconds. Lock was reachieved at 0945Z/209 by switching to hyperbolic mode and then back to RHO-3 mode. During the third failure at 1635Z/209 all master and slave lights came on. This failure was associated with an electrical storm. Re-alignment was delayed by a break in transmission from the master between 1839 and 2000Z/209. Lock was finally achieved by 2030Z/209. For future use it is recommended that a Decca engineer be placed on board ship and/or comprehensive user-oriented documentation is provided.

D. G. Roberts

R. B. Whitmarsh

5. Gravity Measurements

Gravity was measured using the La Coste and Romberg Meter S86. No downtime of data was encountered with the exception of that caused by an A. C. power failure during Leg 1. A four minute filter was used and the gravity values were logged on the data logger. The La Coste was tied in to land observations at Barry. On the ship's return an as-yet unexplained discrepancy of 6 mgals was observed.

M. Beney

6. Data Logger

The logger was used to record the following parameters: ship's speed through the water, both in the forward and athwartships direction from a two-component E. M. log, the ship's head from a gyro compass and gravity from a La Coste and Romberg gravitymeter S86.

The data logger proved to be reliable stopping only twice for short periods because of the failure of the A. C. power supply and possibly because of interference by radio transmission.

The data was routinely processed by the IBM 1130, which was used to provide daily track charts and track charts annotated with depth and Free Air gravity anomaly. Additional charts were provided as required. On Leg 2 because of problems with the Magnavox Satellite Navigator, fixes for the processing were taken and recalculated from the PULSE-8 Navaid system.

T. Colvin

M. Beney

7. Satellite Navigation System

Generally, the system was reliable, exceptions being a problem with the power supply and interference.

During Leg 1 part of the power supply overheated and was replaced. On Leg 2 the time-break transmitter caused interference on the high channel so that poor quality fixes only could be obtained using the low channel alone.

(The time-break transmitter transmitted on 130MHz and the high channel on the Satellite Navigator receiver is tuned for approximately 400MHz.)

T. Colvin

M. Beney

8. Airgun systems

Throughout the cruise, 4 x 1000 ins^3 Bolt airguns were towed from a 3 m beam spaced along the beam at 1 m intervals. This configuration, based on previous experience on Shackleton, proved successful despite the cramped conditions on the afterdeck and became quite easy after some practice in deploying the array. Weather conditions were good throughout the cruise, precluding a realistic assessment of deployment and recovery.

During the first leg of the cruise, the seismic refraction experiments required a survey speed of 4 kts. At this speed, the weight of the towing beam and airguns was sufficient to maintain the array at the required depth of 120 ft. During the second leg the required depth of 120 ft at a higher tow speed of 5-6 kts was achieved by attaching a 250 kg weight to the centre of the beam. As the higher speed was thought likely to put extra strain on the air lines, a rope was used to reduce the tension along the airgun hose and trigger lead bundle. As this rope damaged the trigger cables, it was eventually discarded without any obvious ill effects.

The performance of the Bolt airguns continued to be very reliable and apart from routine cleaning of air filters and repairs to damaged cables, nothing was needed in the way of repairs.

During the first leg, the firing rate was 2 minutes at 2000 psi and 80 seconds at 2000 psi during the second leg.

S. Smith

9. Air compressors

The generator supplied to power the Girodin compressor had dirty fuel tanks and stopped frequently because of blocked fuel lines during the early stages of the cruise. The fuel system had therefore to be cleaned frequently. The tanks were eventually purged by repeated flushing of the dirt and water and afterwards the performance of the generator improved radically.

The ship's Reavell VHP36 compressors performed reliably and apart from routine maintenance required no attention.

The Girodin compressor supplied by the Centre Oceanologique de Bretagne was housed in a container on the fore-deck. Power was supplied by a 125 KVA diesel generator, also on the fore-deck. The Girodin was a very impressive machine with an extremely flexible performance. It easily supplied the required back-up to the ship's compressors.

S. Smith

Table 1 Station Position List

STATION NO.	END POINTS		RECEIVER			SOURCE
			TYPE	POSITION	DEPTH (m)	
6791	LINE 2 WEST 47°15.2'N 10°31.9'W	EAST 46°52.7'N 09°29.0'W	OBS DIANE PUBS2 PUBS4 PUBS3 OBS JULIE	47°15.2'N 10°31.9'W 47°14.7'N 10°30.4'W 47°04.4'N 10°01.9'W 46°52.9'N 09°29.6'W 46°52.7'N 09°29.0'W	4500 4490 4465 4185 4175	4 x 1000ins^3 airguns at 120 secs intervals, 2000 psi.
6792	LINE 1 WEST 46°54.6'N 11°05.5'W	EAST 46°37.0'N 09°58.0'W	OBS ISIS PUBS3 PUBS4 OBS DIANE	46°37.0'N 09°58.0'W 46°46.0'N 10°33.4'W 46°46.3'N 10°34.3'W 46°54.6'N 11°05.5'W	4640 4700 4705 4735	
6793	LINE 3 NORTH 48°01.9'N 09°45.5'W	SOUTH 46°51.52'N 10°32.59'W	PUBS4 PUBS3 PUBS2 OBS ISIS OBS JULIE OBS ESTHER PUBS5	46°52.9'N 10°32.7'W 47°10.5'N 10°20.5'W 47°23.5'N 10°11.8'W 47°36.4'N 10°02.4'W 48°01.9'N 09°45.5'W 48°44.0'N 09°09.3'W 47°16.3'N 10°14.7'W	4685 4500 4270 4210 1790 169 4326	
6794	LINE 4 NORTH 49°15.0'N 10°49.0'W	SOUTH 48°12.0'N 08°10.0'W	OBS ESTHER PUBS2 PUBS5	48°06.7'N 07°57.7'W 48°07.3'N 07°59.4'W 48°09.9'N 08°01.0'W	188 175 186	10 x 300 Kg shots 10 x 150 Kg shots 5 x 50 Kg shots 1 x 12.5 Kg shot

Table 2 Two Ship Seismic Reflection Profiles

PROFILE NO.	TYPE	TIME FROM	TIME TO	CO-ORDINATES		POSITION ON MARGIN	COMMENTS
6/79/2-1	Common Depth Point	0200/204	0725/204	47°17'N 09°50'W	47°03'N 10°39'W	Continental rise/ thinned continental crust	Along refraction station 6792
6/79/2-2	30km Fixed Offset	1423/204	2030/204	10°39'W	46°59.3'N 09°48.6'W	Continental rise/ thinned continental crust	Along refraction station 6792
6/79/1-1	Common Depth Point	1016/205	1820/205	46°40.3'N 10°15.4'W	46°55.2'N 11°06.8'W	Oceanic crust	Along refraction station 6791
6/79/1-2	30km Fixed Offset	0050/206	0629/206	46°43.7'N 10°25.7'W	46°55.6'N 11°11.1'W	Oceanic crust	Along refraction station 6791
6/79/3-A	30km Fixed Offset	0620/208	0252/208	47°50.9'N 09°48.1'W	46°21.8'N 10°51.9'W	Traverse across continent-ocean transition to lower slope	Along refraction station 6793
6/79/3	5km Fixed Offset	0833/208	1913/209	48°15.7'N 10°58.0'W	48°35.4'N 09°06.4'W	Traverse from oceanic crust to shelf	Along refraction station 6793
6/79/4	5km Fixed Offset	0455/210	0100/211	48°58.2'N 10°04.1'W	48°07.6'N 07°57.6'W	Traverse along Line 4	Along refraction station 6794

NB: A 4 x 1000in^3 airgun array firing at 80 second intervals at 2000 psi was used throughout.

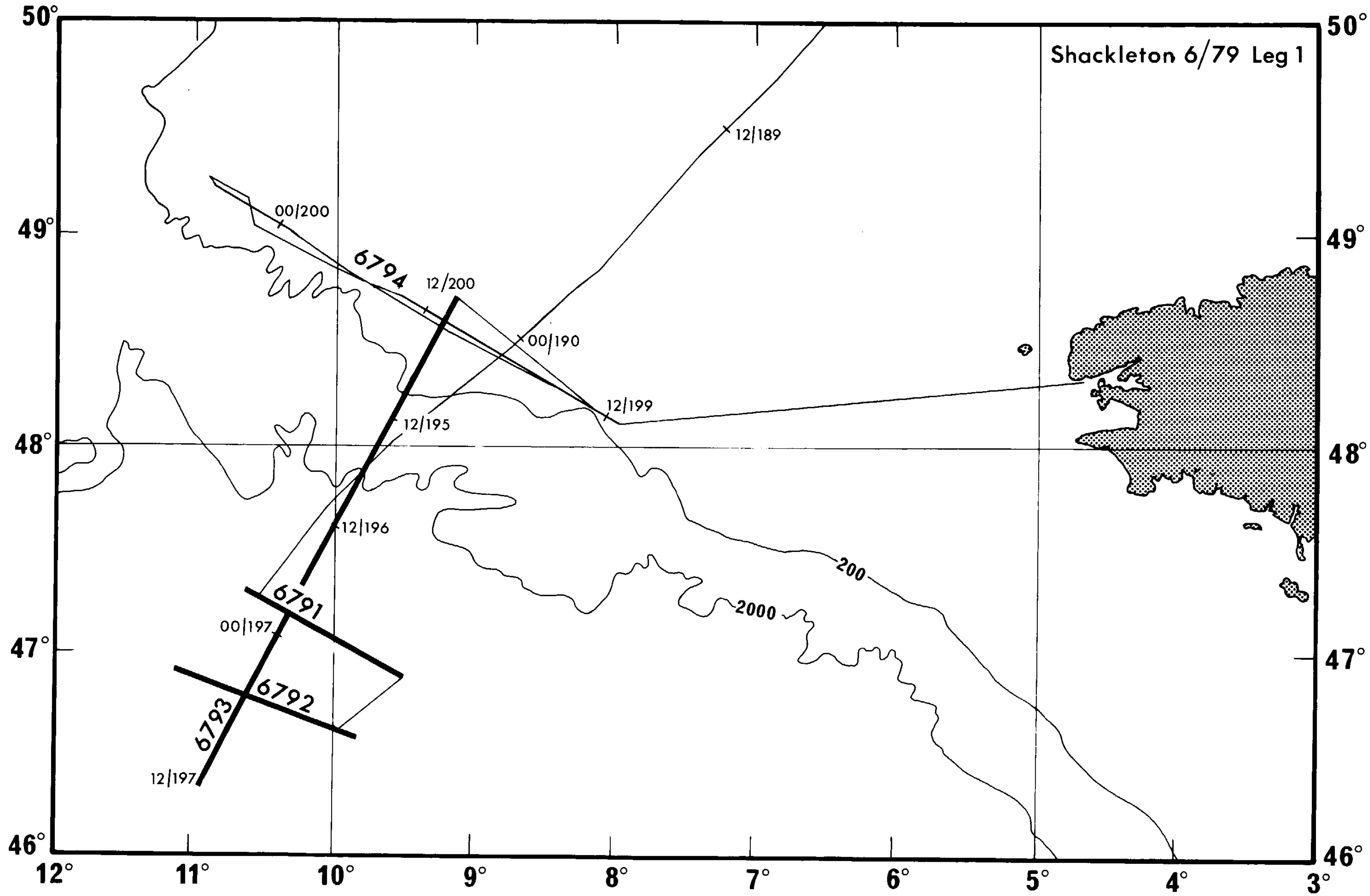

Fig. 1 Track chart for Leg 1. Regions with closely spaced overlapping tracks are shown by thick lines.

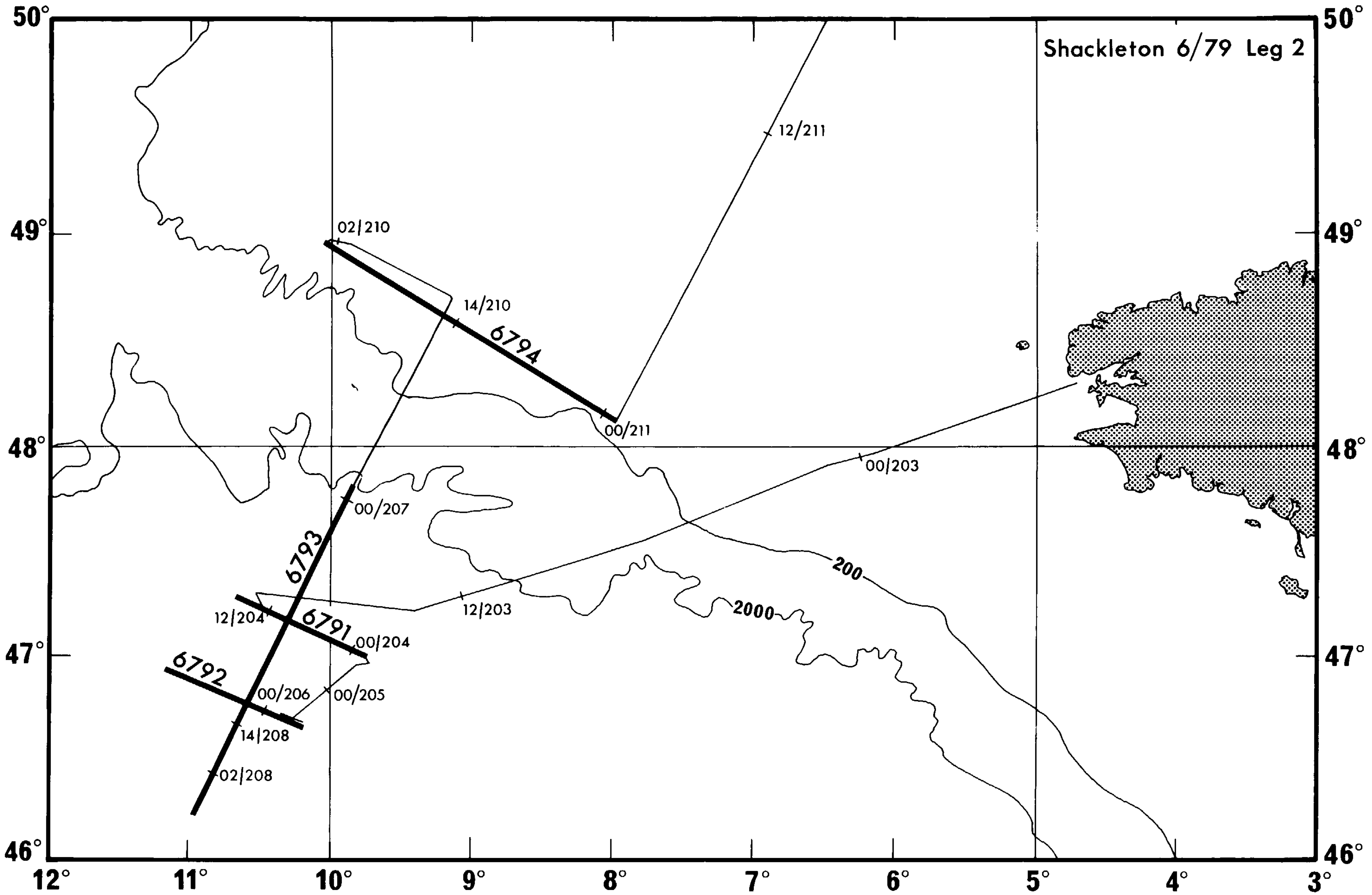

Fig. 2 Track chart for Leg 2. Regions with closely spaced overlapping tracks are shown by thick lines.

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59	FEB 1974	14
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87	OCT 1977	58
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