CRUISE REPORT

RRS CHARLES DARWIN 4/85

17 May 1985 - 11 June 1985

G.K. Westbrook

CRUISE OBJECTIVES AND TECHNIQUES

The general aim of the cruise was to obtain geophysical data that would yield information on the formation of the continental margin on the western side of Hatton Bank, part of the Rockall Plateau. The area was chosen, because it appeared to be a simple continental margin with very little sediment cover to obscure structures in the crust beneath that are related to its formation. In particular, it was already known that seaward dipping reflectors in the basement were present in the area. These reflectors are produced by subaerial lava flows that were erupted during the formation of the margin, but whether they were erupted on to continental crust, oceanic coast or both is disputed by the different authors who have published hypotheses for the formation of this type of continental margin.

Particular questions that the project wished to answer are how does the crustal structure vary from continental to oceanic? Where is the outer edge of continental crust? Was the continental crust stretched and thinned before it finally broke, and if so do the dipping reflectors overlie structures associated with the stretching such as rotated fault blocks? Did the continental crust break sharply, and if so, is all the crust beneath the dipping reflectors essentially of oceanic origin, (i.e. formed by igneous processes subsequent to the break)? To address these questions, the cruise had two principal experimental objectives.

1. To obtain a cross sectional map of seismic velocity in the crust across the margin.

2. To image structures in the crust across the margin.

The techniques employed in cruise were:

Expanding Spread Profiles (ESPs)

In this technique two ships, one shooting the other recording, steam apart from a common midpoint at equal speed to keep the midpoint central throughout the experiment. The technique is good at resolving the change of seismic velocity with depth, but depends on being shot on a uniform structure to be successful. The Charles Darwin acted as the shooting ship in these experiments, and the Discovery, towing a 2.4km long streamer with 48 hydrophone sections, acted as the receiving ship. Four ESPs were shot with explosives, charge sizes increasing from 2.1 kg at the closest ranges to 100kg at ranges in excess of 90km, and four ESPs were shot with airguns (total capacity 3600 cu in at 1950 psi). The ESPs were shot parallel to the margin at different distances across it; the airgun ESPs being interleaved with the explosive ESPs. The role of these ESPs

was to establish the vertical variation in velocity at eight positions across the margin between oceanic and continental crust.

Cross Profile (Variable Offset Profile)

Crossing the margin perpendicularly and running through the midpoints of the ESPs was a cross profile along which five ocean-bottom seismometers were deployed. The ocean bottom seismic records built by Cambridge University had 3 seismometers, 1 vertical and 2 orthogonal horizontal, that rested on the seabed and 1 hydrophone. 4 of the recorders employed analogue FM recording, and 1 was a digital recorder. Explosive shots were fired along the whole length of the line by the Charles Darwin to be recorded by the seismometer. These ranged in size from 25kg to 400kg. In addition the Discovery steamed along the line at half the speed of the Darwin towing the multichannel streamer and crossing with Darwin near the centre. The purpose of this line was to provide recordings of many seismic rays crossing through the region of the crust of primary interest and obtain information on the lateral variations in velocity structure across the margin.

Synthetic Aperture Profiles (SAPs)

In these profiles in which one ship followed the other along track at a constant separation the aperture of the seismic reflection system was effectively doubled. The Discovery towing the multichannel streamer had a range of source-receiver offsets between 250m and 2600m. The Darwin following the Discovery with its airguns some 2500m behind the end of the streamer added another range of offsets of 2500m to 4850m. This was equivalent to the Discovery towing a streamer twice as long. Each ship fired its airguns alternately. The airguns on the Darwin were triggered remotely by the timing system on the Discovery using a short wave radio-link. Darwin's airgun array comprised 2 x 1000 + 2 x 300 + 160 cu in guns. Discovery's array comprised 1000 + 466 + 300 + 160 cu. in. guns. The reason for increasing the aperture is that the ability to resolve seismic velocities accurately is increased. The purpose of the SAPs was to image structures and to map velocity variations in the upper parts of the crust.

Single-Ship Multichannel Seismic Reflection Profiles

Reflection profiles were run along the ESPs and across them to give, with the SAP's and grid of seismic sections defining the structure of the upper part of the crust across the margin. In the cruise plan, the Charles Darwin was to have carried out profiling with a 12-channel streamer. In the event all the profiling was done by the Discovery.

Bathymetry, Gravity, Magnetics

The two ships built up a dense grid of lines of measurements of bathymetry gravity and magnetics to provide a more complete picture of the 3-dimensional structure of the crust across the margin. The gravity anomalies reflect variations in the density of the mantle as well as the crust. The magnetic anomalies can also be used to broadly date the oceanic crust.

Cross-Rockall Seismic Profile

An SAP was run across the entire Rockall Plateau, comprising the Hatton Bank, Hatton-Rockall basin and Rockall Bank, in the hope of imaging a section through the whole of the crust of this micro continent.

Rockall Trough

Two ESPs, one shot with explosives and one shot with airguns were shot in the same location in the centre of the Rockall Trough. The objective was to determine the crustal structure of the Trough which may be pure oceanic or stretched continental.

BRIEF NARRATIVE OF CRUISE

The Charles Darwin sailed from Ardrossan at 1900 on 17 May, and proceeded to the measured mile off the northeast coast of Arran to calibrate the log. On completion of calibration, the ship commenced passage to the work area via the North Channel. At 0800Z on 18 May logging of gravity and bathymetry was started, and logging of magnetics began at 1830Z on the same day.

During passage, a close approach to Rockall Island was made at 1220Z on 19 May. The western margin of the work area over oceanic crust west of the Hatton Bank was reached at 0800 on 20 May. During the forenoon, a digital ocean bottom seismometer (OBS) was deployed on the seabed for testing and shortline of ten 2.1kg shots were fired. The OBS was recovered at 1330 and at 1700 a series of profiles measuring bathymetry gravity and magnetics was begun running towards the SE. The general pattern of work for the Charles Darwin in the early part of the cruise was to undertake seismic work with explosives during daylight and to build up a grid of lines measuring bathymetry, gravity and magnetics during the night. Overnight, two OBSs were deployed either side of the midpoint of ESP1. This ESP was shot between 0905 and 1613 on 21 May, Darwin going NE. The two OBSs were recovered in the evening and a further OBS was deployed 5 miles SW of the midpoint of ESP2. Between 0823 and 1414 on 22 May, ESP2 was shot with explosives, Darwin going NE. The

OBS was recovered in the evening and another was deployed on ESP3. Bathymetry, gravity and magnetics were run overnight. The weather was too poor on 23 May to run ESP3. Another OBS was deployed on ESP3 and a short test line of five 2.1kg shots was carried out. In the early evenings, the two OBSs were retrieved, followed by more bathymetry, gravity and magnetics overnight. ESP4 was shot with explosives between 0823 and 1339 on 24 May, Darwin going SW. During the remainder of the day three 1000 cu.in. airguns were prepared and deployed. ESP3A (=5)* was shot with airguns between 0407 and 0934 on 25 May. Two OBSs were deployed on ESP3, and a shortened ESP3 was shot with only 2.1kg charges between 1455 and 1805. This was reduced from the intended full shoot because the weather after some improvement had worsened again and the streamer towed by Discovery was too noisy. The two OBSs were retrieved in the evening and another one deployed. Overnight, bathymetry, gravity and magnetics were measured. Between 0830 and 1428 on 26 May, ESPs (=3L) was shot with explosives. The weather had improved from the previous day. On 27 May, ESPs 2A (=6) and 1A (=7) were shot using airguns (3 x 1000 cu.in. + 2 x 300 cu.in.), and the OBS on ESP3 was retrieved. Bathymetry, gravity and magnetics were measured from 1845 on 27 May until 1330 on 28 May. A velocimeter dip was made in the southeast of the area and another trial deployment of an OBS was made with two 2.1kg test shots fired. Weather was bad this day with the wind gusting to Force 9 and it continued to be bad the next day, 29 May. Bathymetry, gravity and magnetics were measured from 1920 on 28 May until 0845 on 30 May. Deployment of five OBSs along the cross-profile began at its SE and at 0930 and finished at its NW and at 2056 on 30 May. Overnight more bathymetry, gravity and magnetics were measured and velocimeter dip was made at the NW end of the cross-profile at 0930 on 31 May. Between 1022 and 1950 the cross-profile (V08) was shot using explosives. Discovery was passed, steaming on a reciprocal course, at 1520. Shots of 400 kg size were detonated during this profile interspersed with 100kg and 25kg shots. Recovery of the OBSs commenced at 2050 and continued until 1030 on 1 June. Between 1830 on 1 June and 0130 on 3 June ESP 4A (=10) was shot and ESPs 1A (=1A), 2A (=6A), and 3A (=5A) were reshot. Reshooting of ESPs 1A, 2A and 3A was done because the weather conditions were poor when they were first shot, and also the streamer towed by Discovery had been rebalanced subsequently and was noticeably quieter. After, replacing a 1000 cu.in. chamber with a 160 cu.in. chamber and renewing a gunphone on another of the air guns, the first of the synthetic aperture profiles (SAP1) was started at 0620 on 3 June. Between then and 1100 on 5 June SAPs 1, 2, 3 and 4 were shot. Following a dogleg to bring the track on to the SE end of the explosives cross-profile, synthetic aperture profiling was continued across the Rockall-Hatton Basin, Rockall Bank and into the Rockall Trough, finishing at 2250 on 7 June at the midpoint of ESP C. Between 0015 and 0400

on 8 June ESP C (=11) was shot with airguns. An OBS was deployed 6 miles NNE of the midpoint of the ESP, and between 0802 and 1407 ESP C (=12) was shot with explosives. The OBS was recovered at 1918. In the evening, airgun towing depths were calibrated and the velocimeter was unsuccessfully deployed. Between 2224 and 0321 the next morning, 9 June, trials of a new pressure case for the OBSs were carried out. Several more hours were spent until 1200 on 9 June in unsuccessfully trying to get the velocimeter to work, before the Charles Darwin commenced passage to Falmouth. All geophysical logging finished at 2359 on 9 June. Falmouth was entered at 0800 on 11 June, and berthed at the Duchy Wharf shortly before 1000.

* The numbering of ESPs follow the numbers assigned to them in the cruise plan, "A" denoting an airgun ESP. During the cruise, however, ESPs were labelled on Discovery in a pseudo chronological order. Where these numbers differ from the original numbers they are given in brackets, e.g. ESP3A (=5).

CRUISE OPERATIONS

In general, the cruise went very well despite the period of bad weather. All of the major objectives were met. The major deficiency was that no 12-channel seismic reflection data was obtained by the RRS Charles Darwin. This resulted from a combination of two factors: firstly, the period of poor weather mentioned above; secondly, the time taken to get the ocean-bottom seismometers operational. Several deployments of the seismometers were required to iron out the faults in them. As this required the ship to be stationary and to carry out tight manoeuvres it was not possible to deploy the hydrophone streamer until the main phase of operations with the ocean-bottom seismometers had been completed, which in the event was too far delayed to allow time for seismic reflection profiling. The time expended was worthwhile, however, as they performed well on the explosive seismic profile shot across the western margin of the Hatton Bank. (A bar chart showing activity against date is Fig.1).

Equipment performance

The overall performance of the equipment was good; the air guns in particular, once deployed, were very reliable. Some of the problems encountered are given below.

Compressors:- The change-over solenoid controlling which of the two compressors led frequently stuck causing short-term reductions in pressure. The joint on the separator connecting the 2nd and 3rd stages of one compressor broke causing a leak that put the compressor out of action for

some hours. This fault occurred on Darwin Cruise 2/85 and the part that broke this time was a replacement. The flow-valve cut-out on the cooling water often shut down one of the compressors because of wear on its bearings.

Radio for shot firing and communications between the two ships:- This had many problems mainly stemming from the tranceiver on Discovery, although the set on Darwin did develop a fault in the output stage at one stage through poor connections. The principal problem encountered when using the system for remote firing of the airguns was the production of false triggers arising from noise breakthrough and spikes at the trailing edge of the transmitted square wave fire-pulse. This problem stemmed in some part from drift of the tuning, probably on both ships.

LORAN-C:- The Simrad receiver quite frequently jumped lanes or only acquired one station pair.

Gravimeter Level A Interface:- This broke down for seven hours on 7th June.

Sound Velocity Meter:- On the night of 8th June this developed a fault which occupied many hours in trying to correct. The problem was caused by a faulty capacitor, but in the meantime, through use with testing the pressure case on an ocean-bottom seismometer, the CTD cable developed an intermittent open circuit which prolonged the agony considerably.

Ship performance

The performance of the ship was good, but there were some problems. For several hours on 6th June the automatic pilot on the steering gear drifted off course by as much as 10° for several minutes at a time. The ship pitched quite strongly in rough weather and aft deck was often awash. Once awash, the water took a long time to clear from the deck.

There were some misunderstandings concerning manoeuvring of the ship between the bridge and some members of the ocean-bottom seismometer team during retrieval of the ocean-bottom seismometers. These probably arose from insufficient discussion of operations before they were undertaken, but in fact each retrieval operation was accomplished reasonably rapidly.

During the two-ship synthetic aperture seismic profiles, the tracks of the two ships were not always as close to those intended as they might have been. Darwin was following Discovery which did not always follow the desired track as closely as it should. This may stem in part from the lack of an operational transverse EM log in Discovery at the

time. Initially the watch-keepers on Discovery did not keep the watch-keepers on Darwin sufficiently well informed of changes in course and speed, sometimes making it difficult for Darwin to maintain her correct station. These matters improved during the cruise. The problems stemmed from the lack of a meeting of the officers and principal scientists of both at the beginning of the cruise to discuss the two-ship operations. This was a consequence of the ships sailing from different ports.

The scientific plot was found to be very uncomfortable in bad weather by most members of the scientific party, and it was fortunate that we did not operate any equipment in it. Problems arose from using the main laboratory for servicing the airguns, which conflicted with its other uses. Space was limited and access to the rear door was restricted.

We could have used the magnetometer on the airgun lines if we had had another towing point that would have kept the sensor and cable clear of the airguns.

PRELIMINARY ASSESSMENT OF RESULTS

For the two-ship seismic work the Charles Darwin was the shooting ship, and so all the information concerning the quality of the seismic data came from the Discovery. (See report on Discovery Cruise 155 by R.S.White) Now that most of these data have undergone replay and some processing it is known that they are of generally good quality, but some of the ESPs were noisy in part and that the noise affected different parts of the streamer on different shots very often. The cause of this noise was predominantly produced by the effect of the swell upon the hydrophone streamer towed by Discovery which was not balanced as well as it could have been. The streamer was rebalanced prior to the SAPs and was quieter subsequently. All the explosive ESPs gave sufficiently good records for the Moho depth to be determined. The ranges to which seismic arrivals could be clearly identified on the airgun ESPs was much more limited (40 km), and the Moho could only be determined from the most oceanward of them. They did, however, give much higher resolution of the structure in the upper part of the crust than the explosive ESPs. The SAPs show the dipping reflector sequence and the sediments above them very well. Deeper reflectors are not well shown with only a few vague feature occurring on each section.

PARTICIPANTS IN CRUISE 4/85 OF RRS CHARLES DARWIN

SHIPS OFFICERS AND CREW

P.H. Warne	Master
K.O. Avery	Chief Officer
J.K. Seymour	2nd Officer
T.J. Boult	3rd Officer
D. Brooks	Radio Officer
C.S. Storrier	Chief Engineer
G.M. Batten	2nd Engineer
A.P. Grattidge	3rd Engineer
P.G. Parker	Electrical Engineer
F.S. Williams	CPO (Deck)
P. Biggs	Seaman 1A
P.R. Jones	Seaman 1A
K.L. King	Seaman 1B
M. MacKenzie	Seaman 1A
S.C. Francis	Seaman 1A
C.L. Williams	Cook/Steward
C. Gallimore	Ships Cook
S.P. Bannister	2nd Steward
P. Blagdon	Steward
J. McDonald	Steward
J.A. Gillespie	Motorman 1A

SCIENTIFIC PARTY

G.K. Westbrook	Principal Scientist, Birmingham University
P.J. Barton	Leader of ocean bottom seismometer team Cambridge University
E.B. Cooper	RVS
T.P. Furey	University College Galway Irish Observer
R. Hopkin	RVS
D.A. Jones	RVS
J.R. Leonard	Cambridge University
M.R.G. MacCormack	Cambridge University
J.V. Morgan	Cambridge University
T.R.E. Owen	Cambridge University
C.N. Prescott	Durham University
K.G. Robertson	RVS
M.C. Sinha	Cambridge University
S.J. Smith	RVS
D.J. Spurlock	Explosives Consultant
J.P. Strangward	RVS
P.R. Uniyal	Cambridge University
I.J. Wilson	RVS

Analysis and interpretation of data from the two-ship experiment has been conducted by:-

G K Westbrook	Department of Geological Sciences University of Birmingham
P J Barton	Department of Earth Sciences University of Cambridge
S R Fowler	"
M Joppen	"
J V Morgan	"
G D Spence	"
R S White	"
M H P Bott	Department of Geological Sciences University of Durham
A N Bowen	"
C N Prescott	"

FIGURES

1 Bar chart of scientific activity against date.

2 Preliminary cross section of Hatton Margin derived from the results of the seismic experiments.

3 Seismic structure of the crust midway across the Hatton Margin.

4 Brute-stack seismic reflection section from part of Synthetic Aperture seismic reflection Profile number 2.

TRACK CHARTS

1 Synthetic Aperture Profiles in the main survey area and across the Rockall Plateau, and the Expanding Spread Profile in the Rockall Trough.

2 Track of RRS Charles Darwin in the main survey area. (All track have gravity date.)

3 Track of both the RRS Charles Darwin and the RRS Discovery in the main survey area.

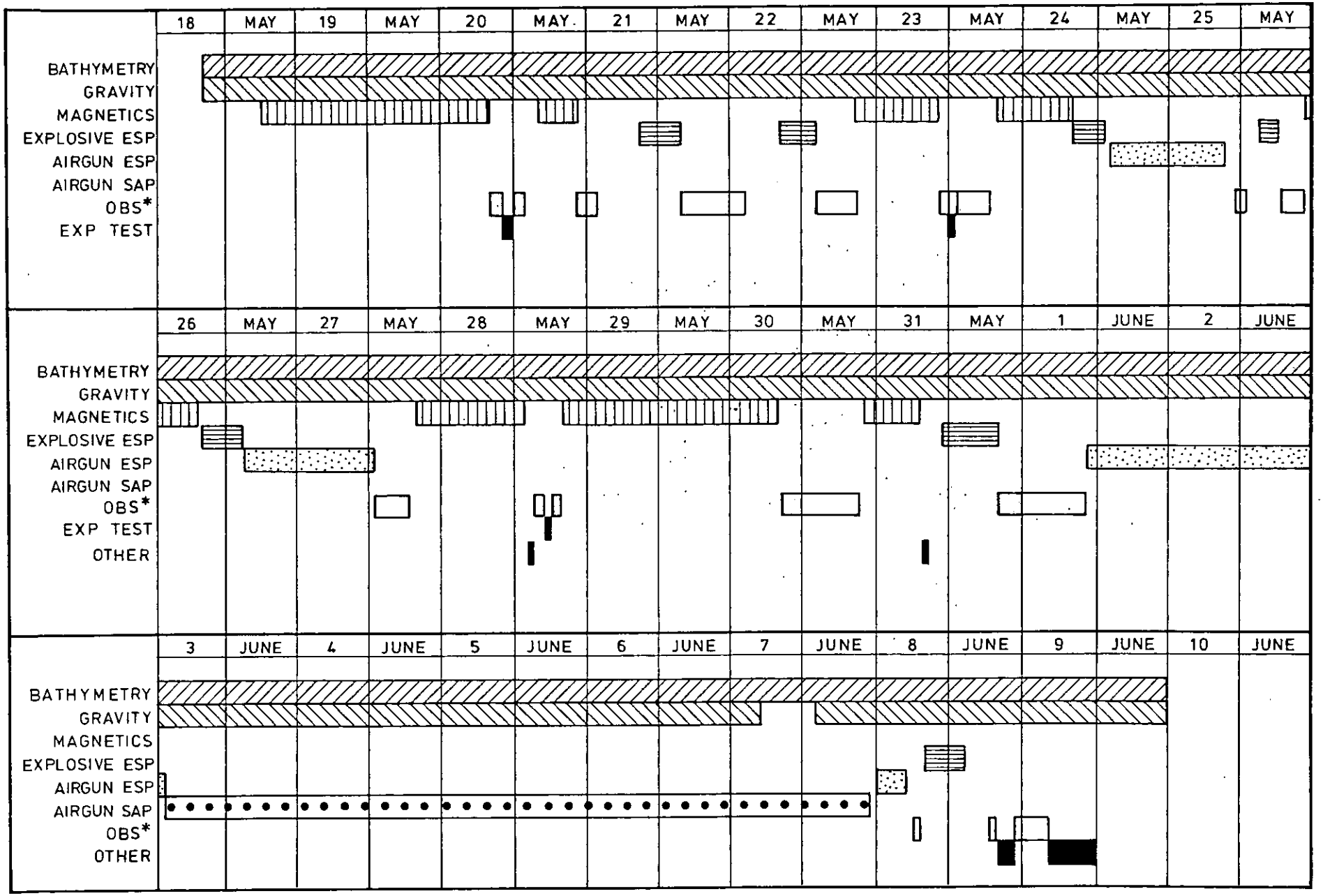
4 Synthetic Aperture Profiles in the main survey area.

5 Explosive Expanding Spread Profiles and Cross-Profile in the main survey area.

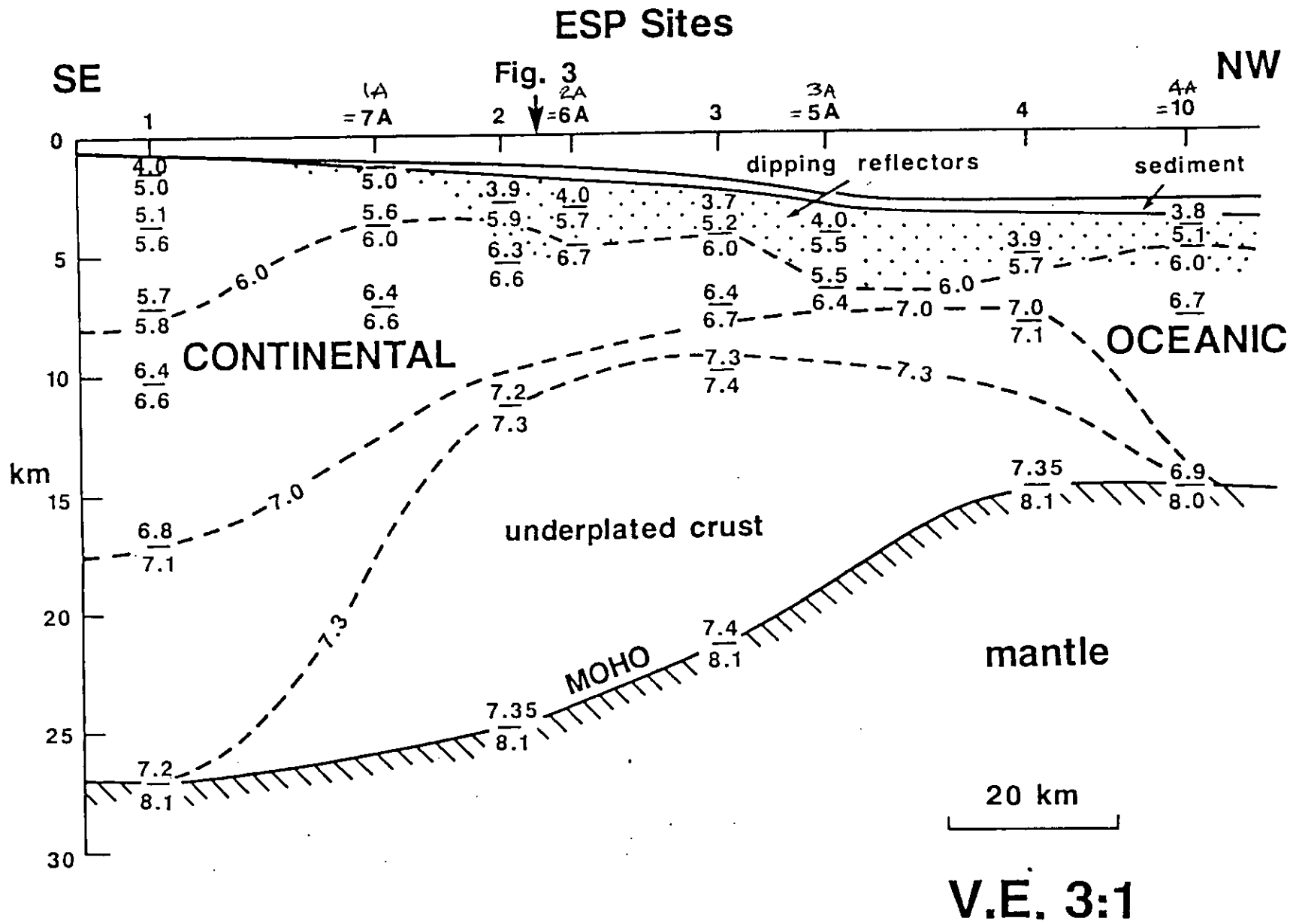
6 Airgun Expanding Spread Profiles in the main survey area.

7 Track along which magnetic anomalies were measured in the main survey area.

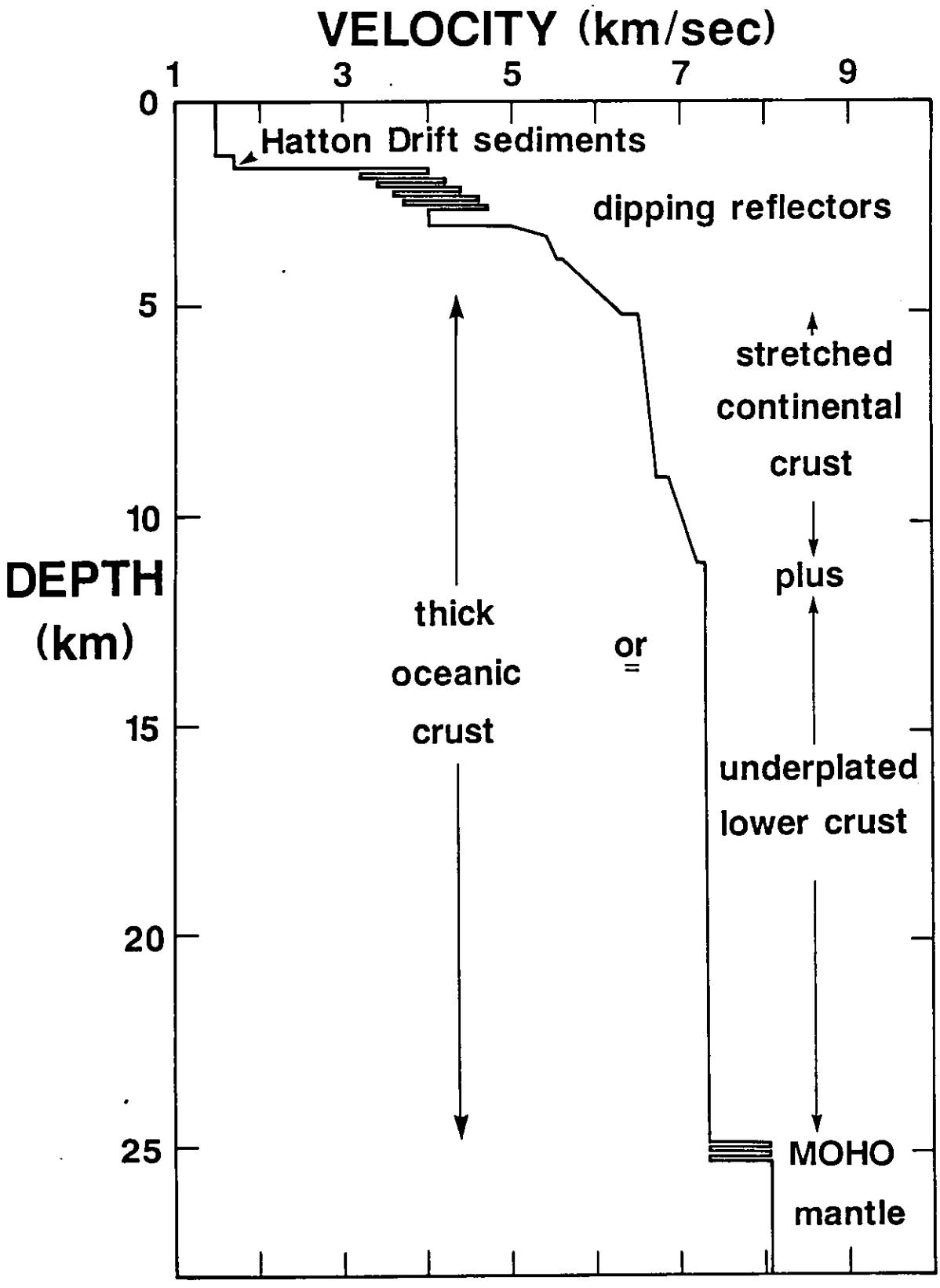
CHART OF SCIENTIFIC ACTIVITY AGAINST DATE FOR
CHARLES DARWIN CRUISE 4/85



OBS* - OBS DEPLOYMENT / RETRIEVAL



Preliminary cross section of the Hatton continental margin derived from the seismic results of the two-ship experiment.



Seismic velocity structure of the crust from midway across the Hatton margin.
Upper structure from airgun ESP2A (=6A)
Lower structure from explosive ESP2.

Example of brute-stack two-ship seismic reflection section from SAP2.

DURHAM UNIVERSITY
SEISMIC PRØCESSING

SAP2 STACK 003 LINE : 2

SYSTEM PARAMETERS

*** FIELD DATA

AREA:	HATTØN BANK
ACQUIRED:	DISCØVERY CRUISE 155/85 - DARWIN CRUISE 4/85
RECØRDING SYSTEM:	N.E.R.C. SERCEL SN 358 D.M.C.S.A.S.
RECØRDING GEØMETRY:	48 CHANNELS AT 50 METRE SPACING
SHØT INTERVAL:	100 METRES
SAMPLING INTERVAL:	4 MS

*** DEMULTIPLEX

SEG-B TØ SEG-Y

*** SØRT

ABSØLUTE LØCATIØN CMP-SØRTED:

FØLD:	48 (NØMINAL); 52 TRACES PER BIN (MAX)
BIN INTERVAL:	50 METRES

*** PRE-STACK PRØCESSING

TIME BREAK CØRRECTIØN:	
SØURCE/RECEIVER DEPTH CØRRECTIØN:	
BAND PASS FILTER:	LØW TAPER 5 HZ
	LØW CUT 5 HZ
	HIGH CUT 70 HZ
	HIGH TAPER 55 HZ
AUTØMATIC RANGE CØRRECTIØN:	
PREDICTIVE DECØN:	ACTIVE 2000MS; GAP SEA-FLØØR CØNSISTENT; APPLIED TRACES 1-25 IN GATHER; 1% WHITENING.
NMØ APPLIED:	RESAMPLED AT 1MS.
MUTE APPLIED:	LINEAR WITH ØFFSET

*** STACK

TRACES INCLUDED:	1 - 52
TRACE WEIGHTING:	CMPS 1- 840 NØNE
	CMPS 841-1400 BY RØØT ØFFSET
	CMPS 1401-2640 BY ØFFSET

*** PØST-STACK PRØCESSING:

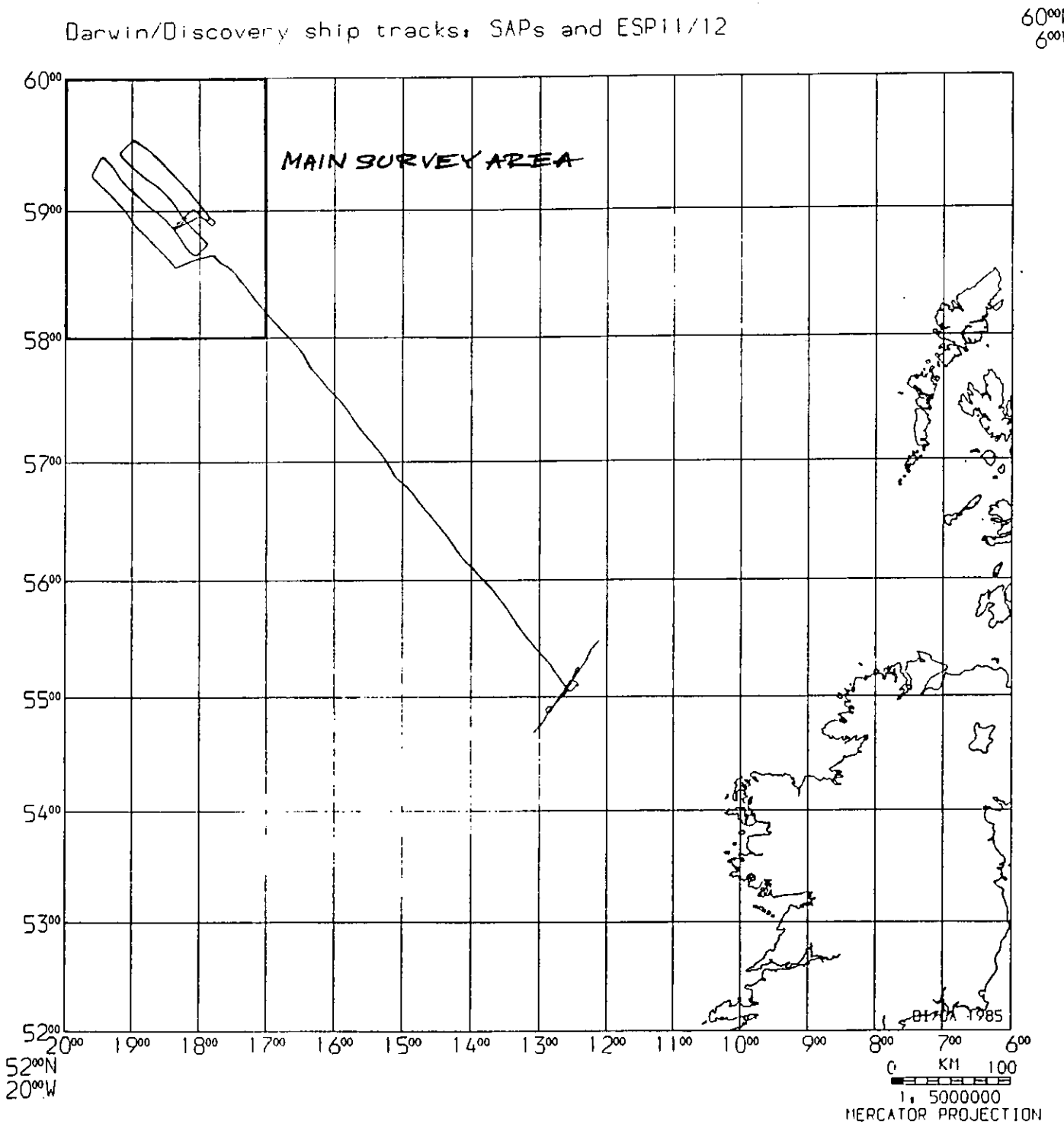
PREDICTIVE DECØN:	ACTIVE 4000MS; GAP SEAFLØØR CØNSISTENT; ACF START @ MULTIPLE; TRAMP APPLIED; 1% WHITENING
MUTE:	TØ SEA FLØØR

*** DISPLAY

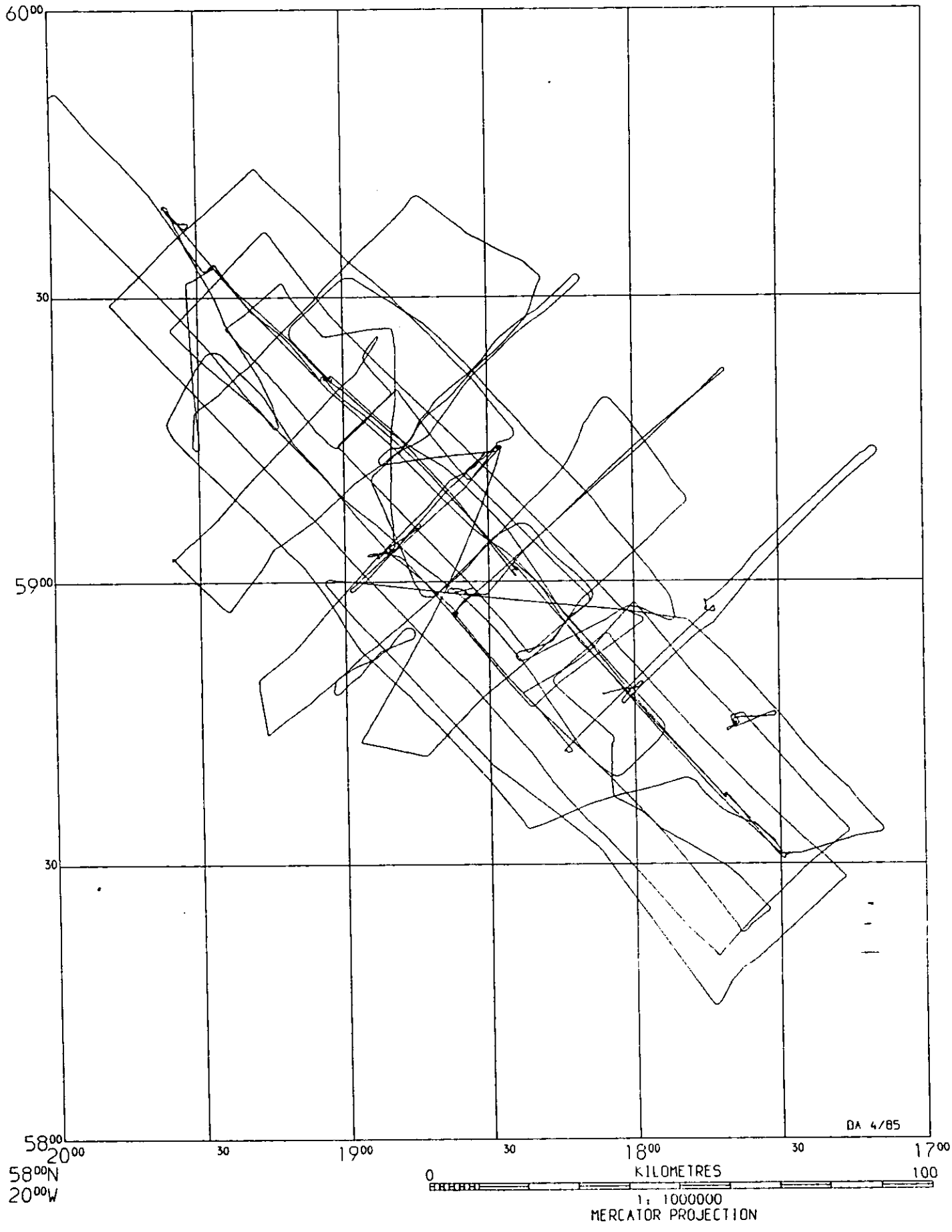
GAIN:	AGC
TRACE SPACING:	0.03 INCHES
PØSITIVE LØBE SHADED:	

TRACK CHARTS

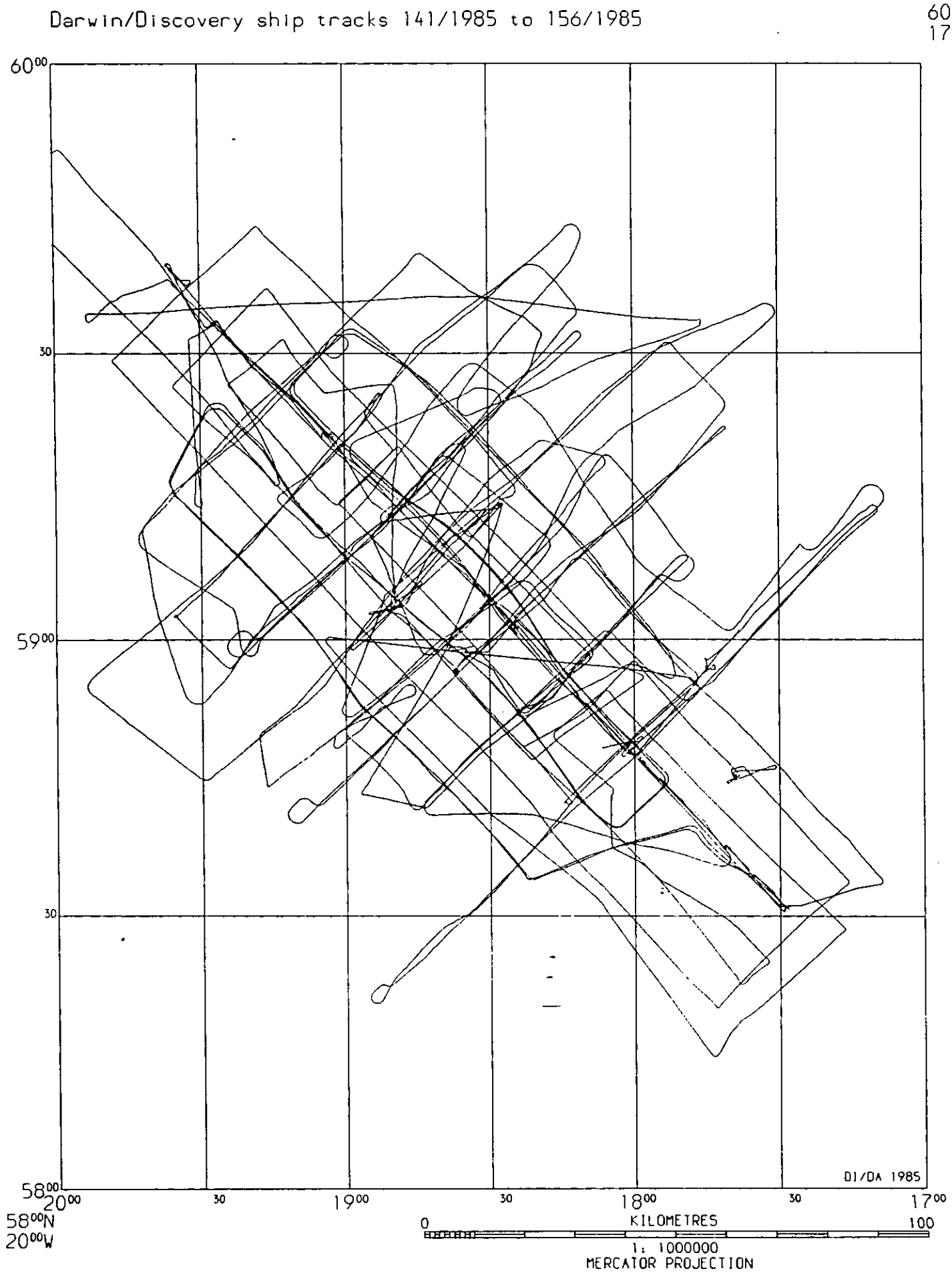
Darwin/Discovery ship tracks: SAPs and ESP11/12



Darwin ship track 141/1985 to 156/1985



Darwin/Discovery ship tracks 141/1985 to 156/1985



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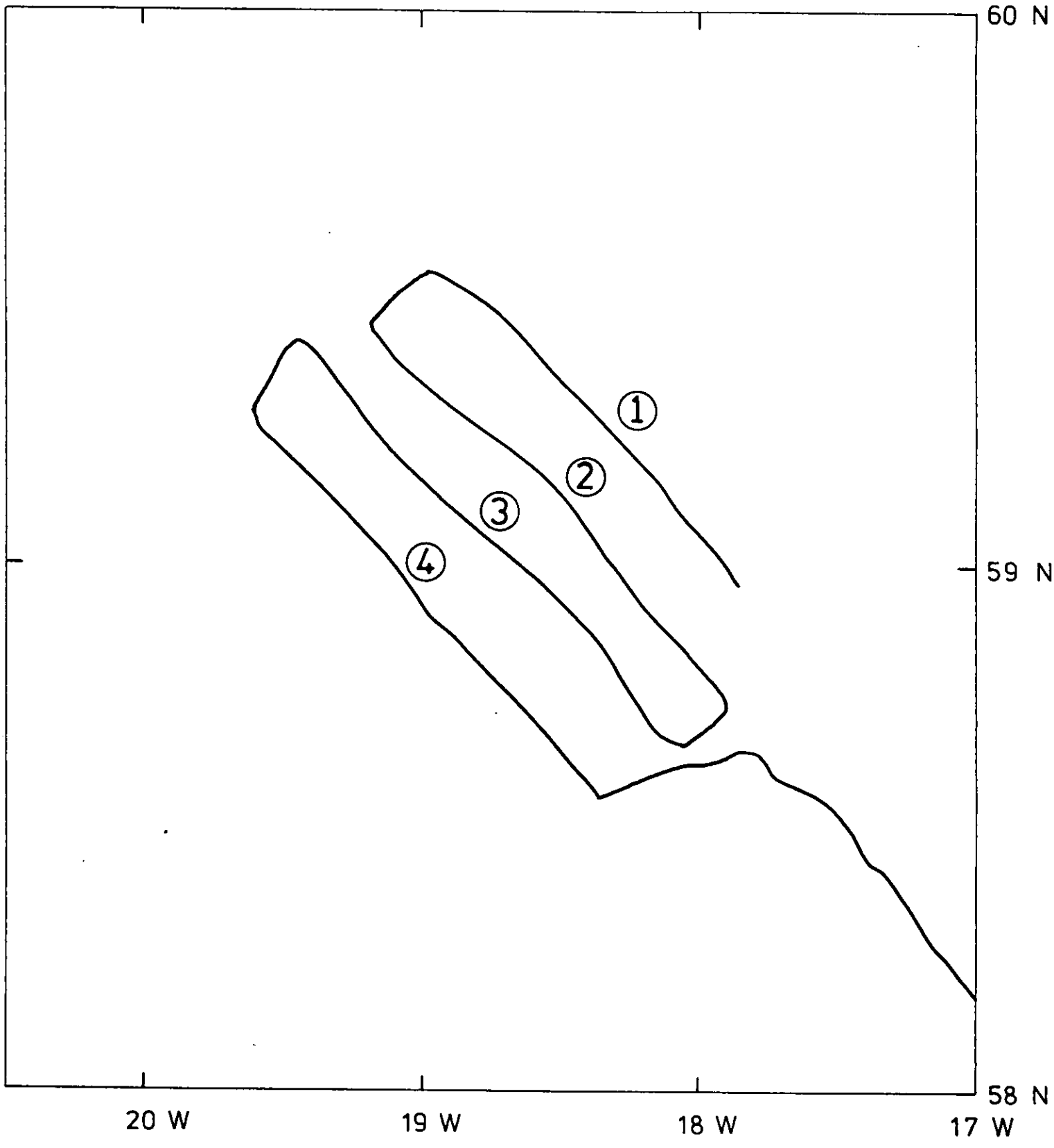
SYNTHETIC APERTURE PROFILES



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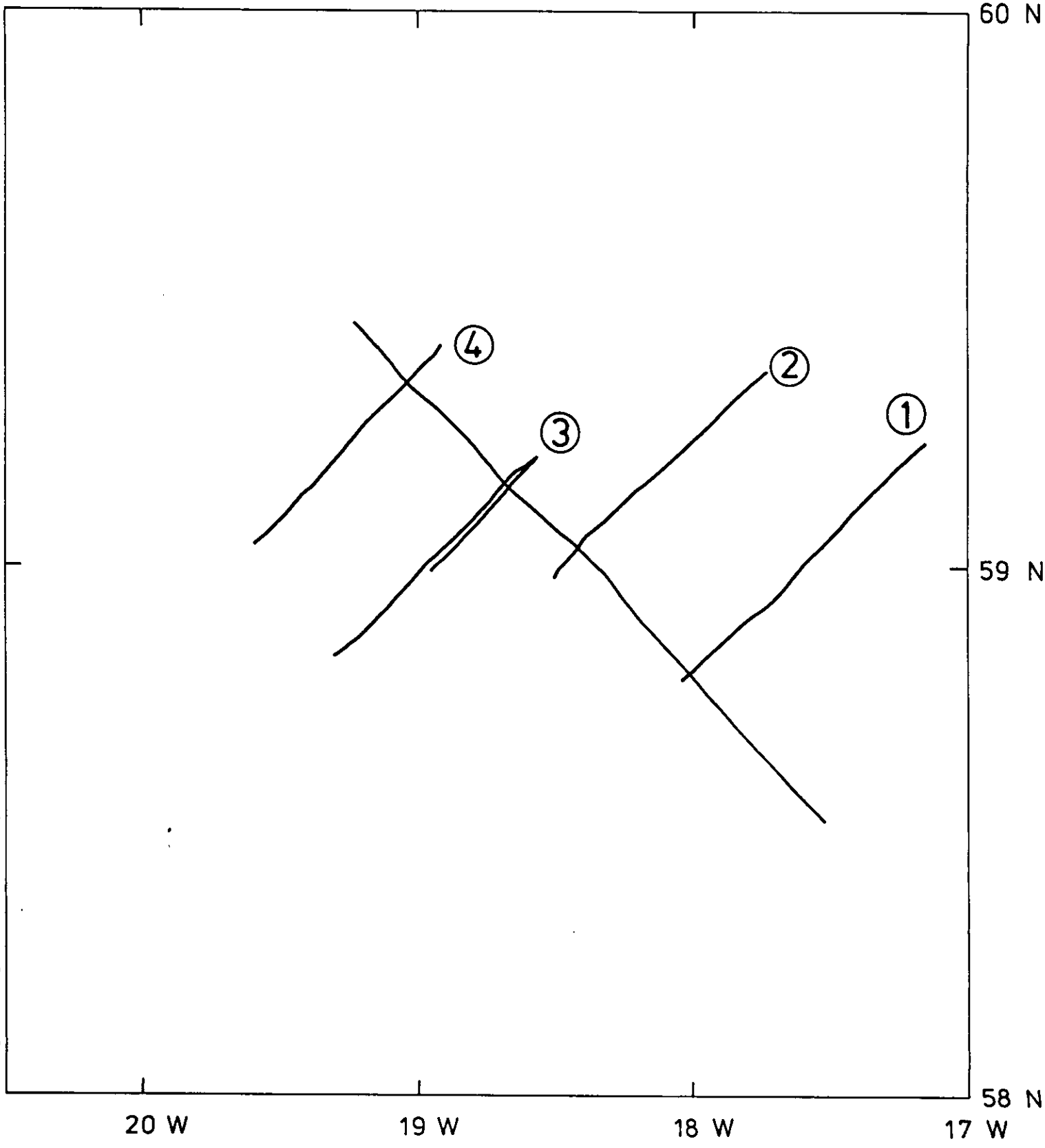
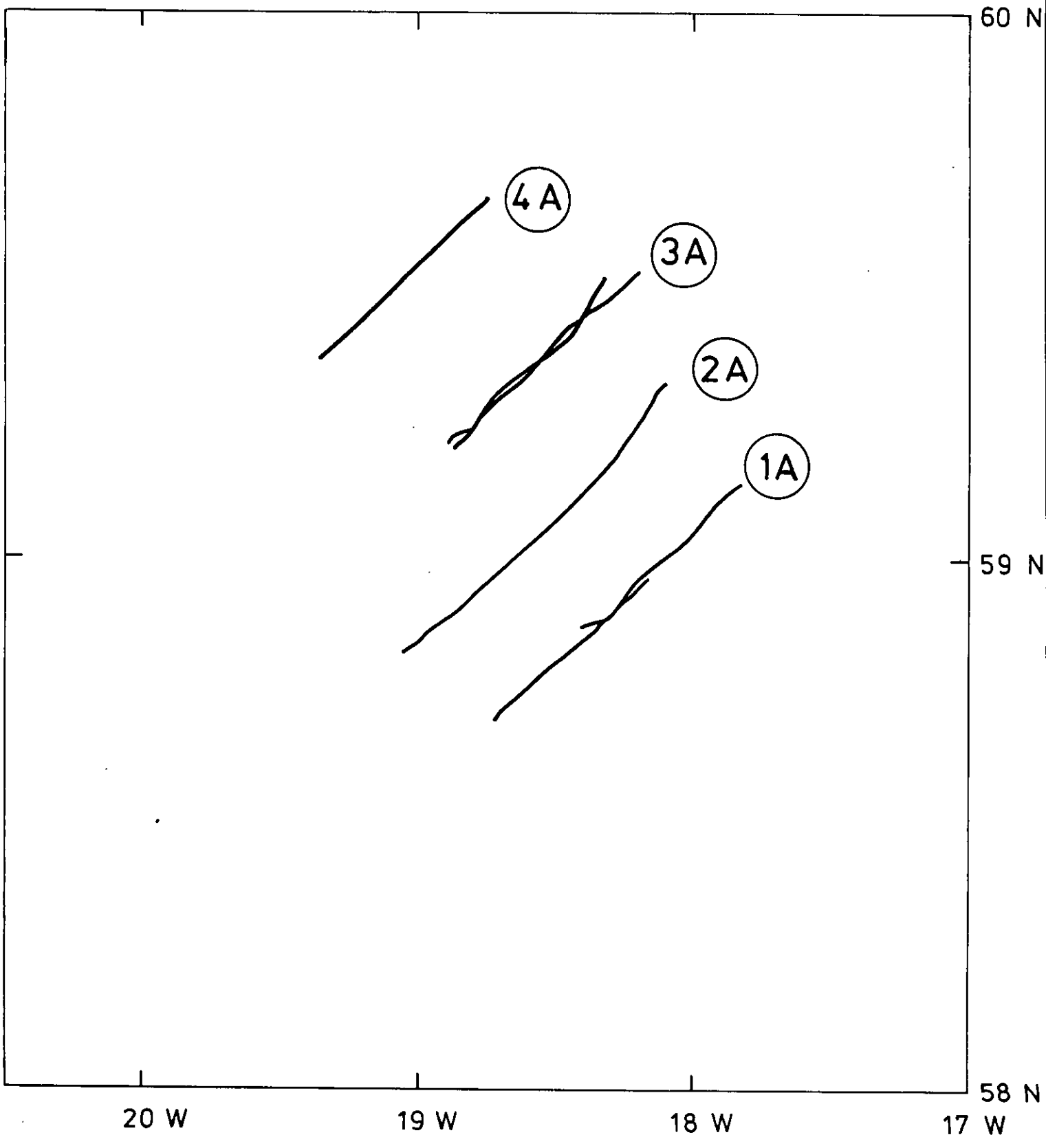
EXPLOSIVE ESPS
AND CROSS PROFILE (VARIABLE OFFSET)



CHARLES DARWIN CRUISE 4/85

AIR GUN ESPS



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MAGNETICS TRACK