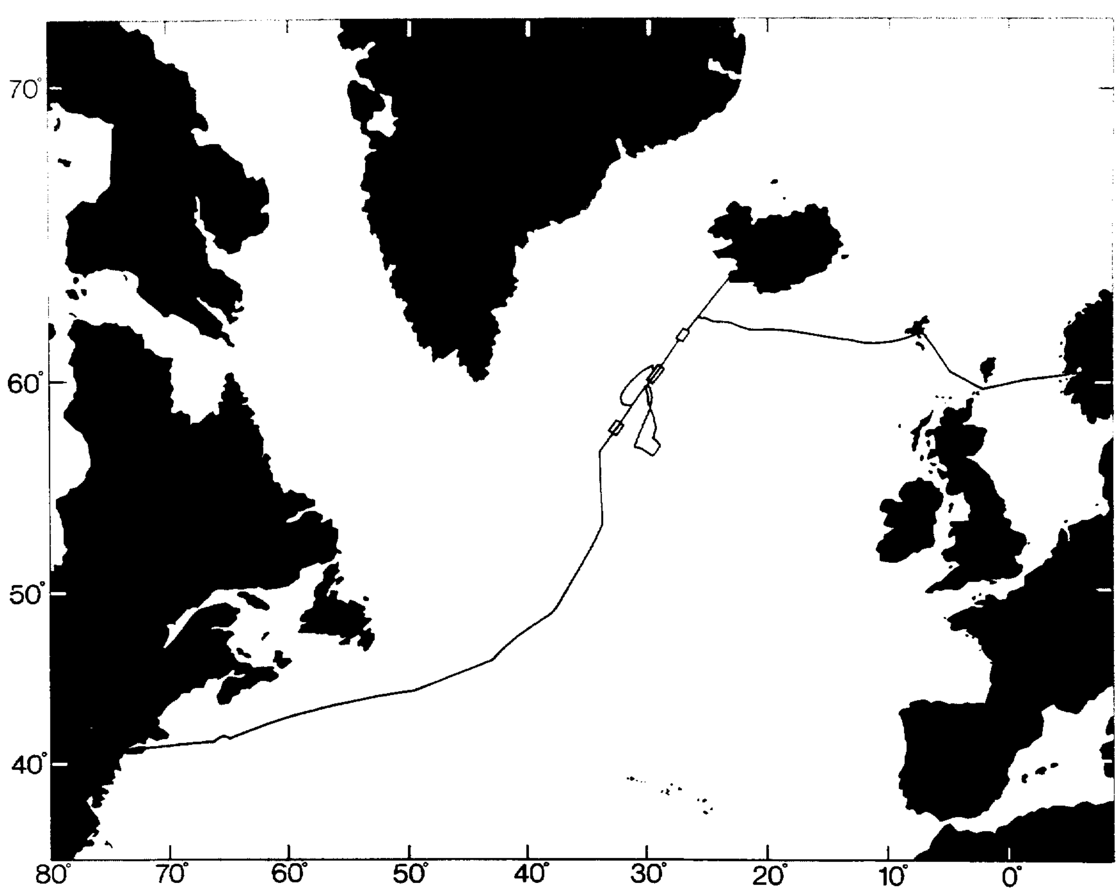
Institute of Oceanographic Sciences Deacon Laboratory

RV *Maurice Ewing* Cruise EW9008

29 Sep - 26 Oct 1990

Sidescan sonar and swath bathymetry investigations of the Reykjanes Ridge, southwest of Iceland

Cruise Report No 237 1993



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CRUISE REPORT NO. 237

RV *MAURICE EWING* CRUISE EW9008
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Sidescan sonar and swath bathymetry investigations
of the Reykjanes Ridge, southwest of Iceland

Principal Scientist
L M Parson

1993

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ABSTRACT

The major objectives of the *Maurice Ewing* EW9008 cruise were to use TOBI deeptow sidescan sonar recording and multibeam swath bathymetric mapping on the obliquely-spreading section of mid-Atlantic Ridge southwest of Iceland. Three areas of detailed study were selected along the axis to compare effects on tectonism and neovolcanism with distance from the Icelandic hotspot. Principal results suggest that arrays of en echelon Axial Volcanic Ridges form orthogonal to the spreading direction of 099° and oblique to the 036° average strike of the ridge. The detailed morphology of these ridges is one of hummocky, pillowed volcanic constructions. Sidescan images indicate that these Axial Volcanic Ridges undergo extension with faulting occurring orthogonal to the spreading direction almost immediately they become rapidly fragmented and are frequently unrecognisable outside of the axial valley. In the study area completed furthest from Iceland, ridge-parallel faulting dominates the flanks of the median valley, here some 10-12 km in width. Closer to the hotspot, however, our combination of deeptow sidescan, long-range (GLORIA) sidescan and swath bathymetry data shows that ridge-parallel faulting occurs at increasingly greater distances from the axis.

KEYWORDS

ATLNN
GLORIA
HOT SPOTS
ICELAND WATERS
"*MAURICE EWING*" - cruise(1990)(EW9008)
MID ATLANTIC RIDGE
REYKJANES RIDGE
SIDE SCAN SONAR
SWATH BATHYMETRY
TOBI

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PHILLIPS, David L.	Second Mate
CONNORS, Joseph M.	Third Mate
LARSON, Erik G.	Radio Officer
DUNNEY, William D.	Bosun
LUNDEKVAM, Oystein	A/B
MAIWIRIWIRI, Ropate	A/B
MARCHESE, Paul	A/B
SMITH, William G.	A/B
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PALONEY, Frank	O/S - Cook
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WALLA, Joseph E.	3rd Asst/Engineer
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NEWMAN, Gregory J.	Oiler
SPRUILL, Michael L.	Oiler
MOQO, Luke	Utility

ITINERARY

Departed	Bergen, Norway	29 September 1990	(Day 272)
Arrived	Newark, NJ, USA	26 October 1990	(Day 299)

OBJECTIVES

To use the TOBI deeptow sidescan sonar system, in conjunction with Hydrosweep data, to evaluate the relationship between volcanic and tectonic processes on the Reykjanes Ridge, the 800 km section of the slow-spreading Mid-Atlantic Ridge (MAR) southwest of Iceland.

To assess the detailed geometry of the axial volcanic zone of the Reykjanes Ridge, the style of ridge segmentation and its spatial and temporal variations as a function of distance from the Iceland "hot-spot".

Additional objectives were intended to be addressed during transit to the MAR, including survey lines to examine bedforms and sediment distributary systems through the Faeroe Bank and Faeroe Shetland Channels.

NARRATIVE

The scientific party boarded the *RV Maurice Ewing* on the 28 September 1990 (Day 272), after loading of the TOBI vehicle and supply containers had been completed during the previous three days. A gravity tie was completed at the dockside using a Lacoste and Romberg land gravity meter. The *Maurice Ewing* departed Bergen promptly at 0800Z 29 September in a gentle sea state and calm weather, and began its planned transit to the first of our principal survey sites (Area A), centred on the Reykjanes Ridge at 61°45'N, 26°45'W (Figure 1). We proceeded westwards through days 272 to 273, across the northern North Sea, within sight of a number of oil production platforms, and passing within a few miles of the East and West Frigg rigs. At 0400Z/273, we passed south of the Shetland Isles en route for the West Shetland shelf where we were scheduled to start the first of a number of Hydrosweep survey lines to be occupied within the Faeroe Bank and Faeroe Shetland Channels. At 1230Z/273, the magnetometer was deployed, and Hydrosweep, 3.5 kHz and 12 kHz surveying commenced. At the time of commencing the survey, however, news of a bereavement in one of the scientific party's family required the abandonment of the survey and his disembarkation at Torshavn, Faeroe Islands. After this diversion course was set to rejoin the Faeroe Bank Channel transit survey. The first line was occupied at 0834Z/274, following the completion of which, transit was made for the first principal survey area (Area A, Figure 2). A grid of ten Hydrosweep lines, with additional geophysical data collection, was occupied in this area to allow a 100% bathymetric coverage (Figure 3). Towards the end of day 276, it was clear that a further mid-cruise port-call was necessary due to the failing health of one of the ship's engineers, so at 2250Z/276, course was made for Reykjavik. The magnetometer was recovered by 0850Z/277 and watches suspended at 1200Z/277 for the duration of the portcall. After two of the engineers had disembarked by shore boat, we departed Reykjavik and logging recommenced at 2000Z/277. The magnetometer was streamed at 0439Z/278, and a further grid of lines was completed in Area A in preparation for the first TOBI deployment. By 1238Z/278 the magnetometer was recovered once again and the ship slowed to prepare for the first TOBI launch.

After deployment of the TOBI vehicle (completed at around 1400Z/278) and prior to deployment of the depressor weight, the system was tested and found to be open circuit somewhere in the umbilical cable. The vehicle was subsequently recovered for inspection by 1445Z/278. The problem was not immediately soluble, and we decided to abandon further deeptow work in Area A. Two XBT stations were occupied at 1416Z and 1505Z, after which course was set for Survey Area B, centred on 60°00'N, 29°30'W (Figure 2). The magnetometer was redeployed and logging recommenced at 1532Z/278. Between 2241Z/278 and 0959Z/280 a series of Hydrosweep lines was occupied in Area B, with one XBT station completed at 1904Z/279 (Figure 3). These survey lines complemented an earlier survey completed during a *Maurice Ewing* Cruise EW9004 transit to Reykjavik during the summer of 1990. At 1014Z/280 the ship was slowed and the magnetometer recovered in preparation for the second launch of TOBI. TOBI was launched and descending by 1139Z/278 and on line by 1200Z/278. TOBI operated faultlessly during the survey run and the real-time monitor allowed tight control using the Hydrosweep data without the necessity of laying a transponder array (Figure 4a). An impending storm, however, forced us to curtail the deeptow line and we started hauling at 2019Z/280 to recover the gear. TOBI was onboard by 2158Z/280 and we set course south-southeastwards to avoid the storm. The magnetometer was deployed and logging once more by 1126Z/281, en route to a fall-back survey area around the Marietta Seamounts (at 57°00'N, 28°30'W; Fig. 1). A series of NW-SE lines were provisionally programmed but the survey was once more abandoned at 2341Z/281 when weather conditions deteriorated still further and loss of Hydrosweep data became severe. A slow westerly transit took us once more towards the Reykjanes Ridge, which we rejoined at around 1400Z/283 to return to Area B for a second TOBI run.

At 1435Z/283 the magnetometer was once more turned off and recovered. An XBT station was occupied at 1507Z/283 and TOBI was launched at 1558Z. At 1835Z/283 the TOBI data acquisition suddenly failed. The slip-rings on the deeptow winch were found to have burnt out and a replacement set were fitted during a looping track which returned to the break-off point in the survey by 2324Z/283. Our line through Area B towards the northeast was completed by 1725Z/284 when we turned to follow a reciprocal deeptow survey track (Figure 4a). An XBT station was occupied at 1744Z/284. This second deeptow run was abandoned at 0146Z/285 due to the approach of further inclement weather and TOBI was recovered and onboard by 0400Z/285. A northwesterly course was then set to run from the storm. It was decided to continue with surveying, even though we were well off our target areas, so the magnetometer was deployed at 0427Z/285. The poor weather prevented us from getting back to the Ridge to the south of Area B until 1230Z/286, at which point we headed northeast back to Area B. Progress towards the north, however, became slower and slower until 2330/286 when we again decided to end further work in Area B and a southwesterly course was set down the Reykjanes Ridge towards Area C (centred on 58°00'N, 32°30'W, Figure 2). The KSS-30 gravimeter stopped once again at 1000Z/287, one of the many occasions during the poor weather conditions. Two reconnaissance lines through the axial zone were completed by 1420Z/287 and the ship slowed to prepare for a third and final TOBI run. The magnetometer was recovered by 1435Z/287. TOBI was deployed by 1550Z/287 and a northwesterly deeptow track was run until 1348Z/288 when a reciprocal course was occupied until the end of the TOBI survey at 1604Z/288. An XBT station was occupied at 2220Z/287. Recovery of the TOBI system started at 1400Z/289 and TOBI was safely inboard by 1446Z/289 (Figure 4b). We were up to survey speed by 1502Z/289 with the magnetometer streamed and logging by 1525Z.

Between 1534Z/289 and 0856Z/291, a series of parallel NW-SE lines was occupied to complete an 80-85% Hydrosweep coverage of a box of approximately one degree square (Figure 3, 4b). Hydrosweep surveying of Area C was terminated at 0900Z/291, and we made course for Newark. Logging of data continued throughout the next day of our passage down the central portion of the Mid-Atlantic Ridge (Figure 1). We arrived in Newark at 1000Z on the 26th October, earlier than anticipated, following further detours to avoid approaching bad weather.

NAVIGATION

In all, nine shipboard navigation systems were in operation during the survey. These comprised two Global Positioning Systems linked to an Rb-atomic clock, two Transit satellite receivers, LORAN C, Internav (a form of Loran), Northstar, and a Furuno doppler navigation system. These permanent ship systems were augmented by an RVS GPS receiver onboard as a stand alone unit for use with the transponder navigation. In general GPS allowed us more than 20 hours coverage each day and the Internav Loran provided the best coverage for the gaps. An accurate and continuous navigation source was required for Hydrosweep operations and either GPS or satellite dead reckoning was used after this. Loran was unsuitable for the cruise. The RVS GPS receiver was not supported by an atomic clock, and yet over a 24-hour period provided significantly greater coverage. This was probably due to its automatic re-initialisation process which was not available in the ship's systems.

GRAVIMETERS

Two units were operated throughout the cruise, a BGM system and a KSS-30 system. The BGM produced consistently good data throughout the survey, despite some persistent and severe weather problems. The KSS-30 was less reliable and was prone to shut down on many occasions. Faulty sensors were suspected.

MAGNETOMETER

A proton precession magnetometer was towed some 200 m behind the ship throughout the survey. Deployment/recovery was through a block mounted as part of the airgun array supports and was satisfactorily completed at survey speeds. Signal-to-noise ratios were in general good throughout, with a few periods of excessive noise, the source of which was not traced. Overall magnetometer operation was relatively trouble-free throughout the cruise.

COMPUTING

Two MASSCOMP computers were used to log and process survey data. One was operated by the Lamont-Doherty Geological Observatory and logged all geophysical parameters as well as navigation. The other was run by University of Rhode Island North East Consortium for Oceanographic Research (URI NECOR) and this logged and processed Hydrosweep data and navigation only, as part of the processing arrangement between LDGO and URI. This second system controlled real-time plotting of Hydrosweep data. Remote terminals were available throughout the ship to enable links to the ship system. The

Hydrosweep data was broadcast on an Ethernet circuit into which the LDGO and URI systems were linked. During the cruise, an Apollo workstation brought on by one of the scientific party was successfully linked into the Ethernet broadcast and was used to extract Hydrosweep data for processing.

TRANSPONDER NAVIGATION

The RVS 10 kHz "OCEANO" acoustic navigation system was kept on standby during the cruise, but was not used. It was intended that it should be used as guidance for TOBI and/or WASP photo sledge stations. It was recognised, however, that the deeptow system would complete coverage of the area of the proposed transponder net very rapidly (within a few hours). Furthermore, the additional length of time required to locate the transponder net accurately at the start of the survey and that required for its recovery at the end of the survey could total more than 2 days. It was thus decided to attempt to navigate the deeptow survey in this extreme terrain using the swath bathymetry compilations made during the earlier Hydrosweep reconnaissance. We found we were able to "fly" the deeptow vehicle with a high degree of accuracy and safety by matching topography from the Hydrosweep to patterns of acoustic backscatter on TOBI records. We were thus able to save the time we had allocated to the deployment of the transponders and offset this against our time lost due to bad weather. Our provisionally programmed camera sledge work was also abandoned as a result of the serious reduction in prime survey time due to enforced port calls and poor weather conditions.

LMP

TOBI OPERATIONS

The primary use for TOBI on this cruise was to carry out an acoustic survey over sections of the Reykjanes Ridge using its narrow beam 30 kHz sidescan system. In addition the vehicle was fitted with a 7.5 kHz sonar array for bottom profiling, a tri-axial magnetometer, a transmissometer and a thermistor probe. The latter two items had been recently installed with the aim of detecting hydrothermal activity from plume signature in the water column. For monitoring vehicle attitude, pitch, roll and pressure sensors were fitted along with a compass. The two-component EM log was not available on this occasion. An acoustic transponder which could have been used as part of the acoustic navigation system was also incorporated but, in practice, it was there only as an emergency beacon.

The ship was fitted with a Lebua direct storage winch containing about 6000 m of 0.68 inch double armoured coaxial tow cable of a type not previously used with the TOBI system but which caused no problems. Launching of the vehicle was achieved through an "A" frame on the stern using an auxiliary block mounted alongside the main towing sheave and the ship's capstan to lift the vehicle clear of the deck. Four control lines were used to prevent excessive swing but a certain amount of difficulty was encountered due to insufficient reach of the "A" frame, requiring some juggling to get TOBI clear of the stern. The umbilical was paid out and recovered using a hydrophone streamer winch which, in the event, was not powerful enough to ensure proper control at all times. Four deployments and recoveries were made in moderate sea conditions without serious damage to equipment or personnel (launch methods on the previous two ships used for TOBI operations would not have allowed TOBI to have been deployed in the same sea conditions). The poor control over the winch used to deploy the umbilical probably contributed to the failure of the its conductor at a splice during the first launch. It was realised, following closer inspection, that the failure of the conductor was partly due to damage sustained on the previous cruise. The failure, however required a complete umbilical change before attempting the second launch which, along with the third and fourth, resulted in successful tows. During tests after the umbilical change a sudden loss of signal was traced to a failure of the slip rings on the main winch which were subsequently replaced by a set removed from the CTD winch. Shortly after the third launch these also failed and in the absence of a further spare, a makeshift but successful assembly had to be rigged from a combination of parts of the failed systems and parts of the TOBI swivel.

Over the period of the three successful launches TOBI covered a total of 192 miles in 91 hours, at an average speed of 2.1 knots (Figure 4). This was a speed of about 0.6 knots faster than achieved on previous cruises and was made possible by the comparatively shallow water (2300 m maximum compared with 5000 m maximum on previous runs). It is interesting to note that, although sea conditions were rougher than previously experienced, the "dropouts" caused by vehicle pitch induced by ship heave were noticeably less, a result of the greater speed and/or the shorter tow length.

All the instrumentation performed satisfactorily with the exception of the magnetometer which, due to an untraceable fault, registered the z-component permanently off scale. Minor problems were encountered with the logging system. Write errors occurred on an occasion which was attributable to a faulty optical cartridge and difficulties were encountered with entering commands through the system keyboard after initialisation following the start of a new cartridge.

NM, IR

HYDROSWEEP OPERATIONS

The Hydrosweep system is a hull-mounted, formed beam, swath mapping sonar built and fitted by Krupp-Atlas Electronic of Bremen, Germany. Data is generated for 59 beams (across track samples) to cover a swath width of 90° (approximately twice water depth). Hydrosweep data collected on the *Maurice Ewing* seems to be very subject to noise manifest as highly irregular isobaths. This is related to several things: weather, the estimated slope qualifier (designed to filter anomalously high slope cycles, i.e. spurious noise), the sound velocity and the character of the bottom.

Hydrosweep seems to be very subject to weather-induced noise and spurious depth values which are not always rejected. It is possible that the windowing algorithms are not as robust as they need to be. There are three positions for the slope qualifier: Off - no slopes rejected; Half - slopes over 50% rejected; Full - slopes over 20% rejected. To minimize noise, the full slope correction should be selected, but this also rejects some real data, particularly in the type of terrain which we were surveying. Although our early opinion was that the slope qualifier should be switched off in order to avoid rejection of the steep slopes characteristic of mid-ocean ridge topography, in practice there was too much noise to allow this. We therefore ran the slope qualifier for much of the time in the Half (50%) mode.

Another area which aroused much debate was the unsuitability of, and the potential inaccuracies in, sound velocity values used in correcting bathymetry. In the early part of cruise EW9008, we were seeing extreme "tunnel" effects and "W"s on sea-bottoms of flat, sedimented character. It was suspected that the "tunnel" effects were partially caused by inaccuracies in the automatic sound velocity corrections. When an alternative sound velocity was entered, such as that generated using data from an XBT probe, the tunnel effect was significantly reduced. In addition we found that contours were at different levels when passing over a single area several times; this was undoubtedly caused by inconsistent sound velocity corrections.

The effect of all this noise is that data processing is very time-consuming for Hydrosweep. This is particularly because of the rejection of noise from the data. An automatic and/or gridded interactive noise editor would be vital for use in processing of Hydrosweep data. Data processing of all survey areas and preliminary map production, however, were completed during the cruise. The survey areas overlapped unprocessed data from the previous EW9004 transit leg and Days 197-200 from EW9004 were processed and combined with EW9008 data.

Lamont and URI jointly processed the navigation data. Using Lamont-generated statistical analysis plots of GPS, and course and speed data plus URI track plots comparing all data sources, appropriate GPS, Internav and Transit satellites were selected and navigation tracks calculated. URI and Lamont operators independently calculated a navigation track using the agreed set of fixes. After comparing the calculated tracks with gravity (Lamont) and Hydrosweep data (URI), modifications to the fixes were made and a final track was calculated. In order of priority, we generally used continuous GPS where available, then Internav (if available and calibrated to GPS) and then Transit satellites. The Furuno was found to be suspect and very noisy and was used for reference only.

SUMMARY

The cruise was a success, despite some unfortunate weather conditions - our three survey areas were in the path of five of the 1990 'named' hurricanes, Josephine through to Nana. The TOBI sidescan sonar data was the first to be collected from a mid-ocean ridge terrain and was spectacular both scientifically and in its quality. The Hydrosweep swath bathymetry data suffered significantly in the rough seas, but overall the compilations were more than adequate to navigate TOBI and subsequently to ensure satisfactory digital merging of data sets. It was clear during the cruise that the combined geophysical records we had acquired were to provide many answers to many questions about the interaction and temporal relationship between volcanic and tectonic processes at slow spreading mid-ocean ridges.

ACKNOWLEDGEMENTS

On behalf of the scientific crew of the *Maurice Ewing* Cruise EW9008, I would like to thank the officers and crew for their efforts to ensure we collected the fullest possible data set under trying weather conditions. At all times the professionalism of the ship's party was exemplary and a credit to Lamont Doherty Geological Observatory. I would also like to express my gratitude to the US and UK scientific bodies, the National Science Foundation and Natural Environment Research Council, for their assistance in securing the ship swap arrangement which led to this cruise, and finally to Mike Rawson for his helpfulness and forbearance in overseeing the operation from a distance.

FIGURE 1

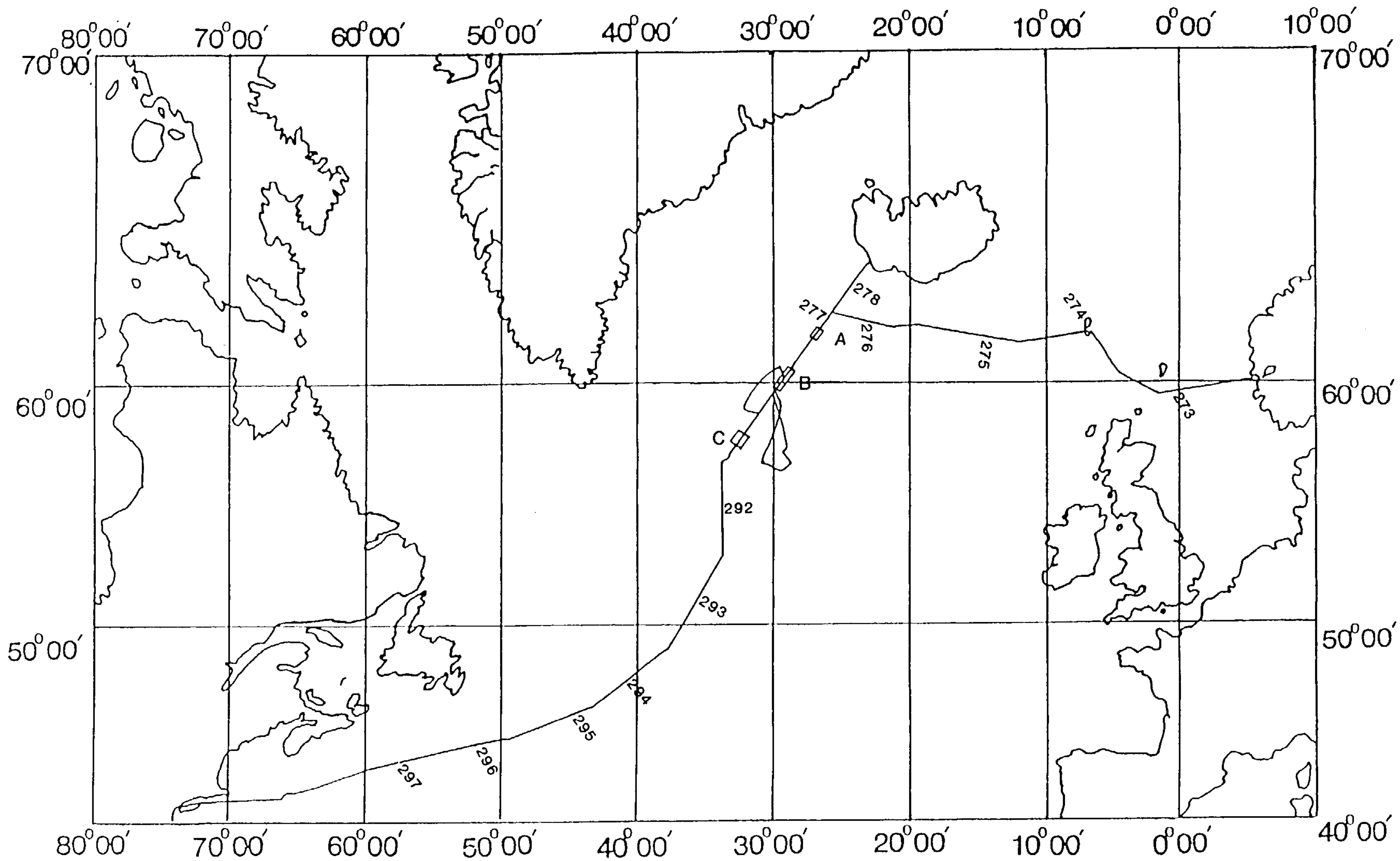


Figure 1: Track chart of *RV Maurice Ewing* Cruise EW9008, 29 Sep-26 Oct 1990. Julian days are numbered along track. Detailed study area A, B and C located SW of Iceland.

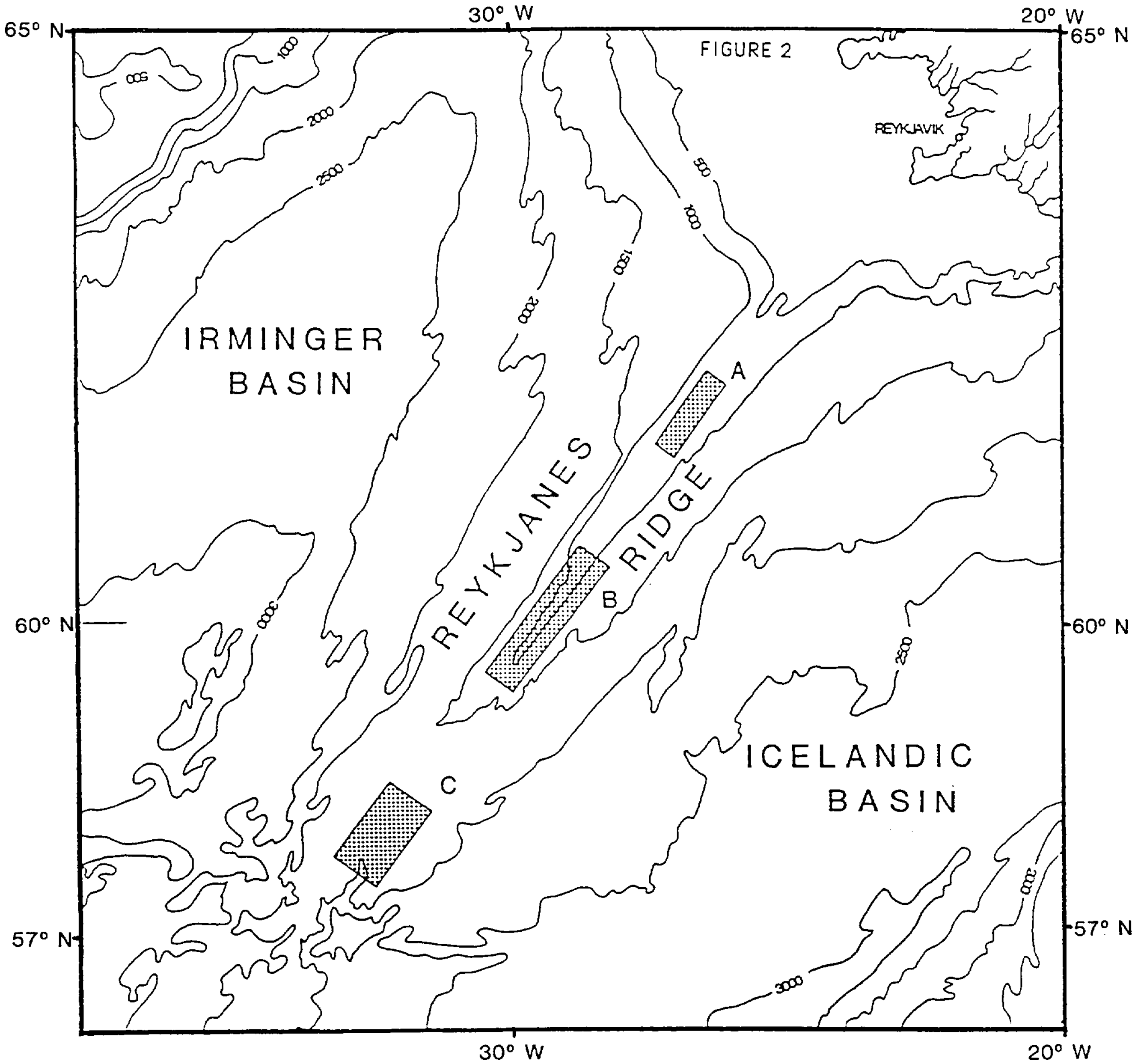


Figure 2: Simplified bathymetry of the Reykjanes Ridge. Stippled boxes locate the detailed Survey Areas A, B and C.

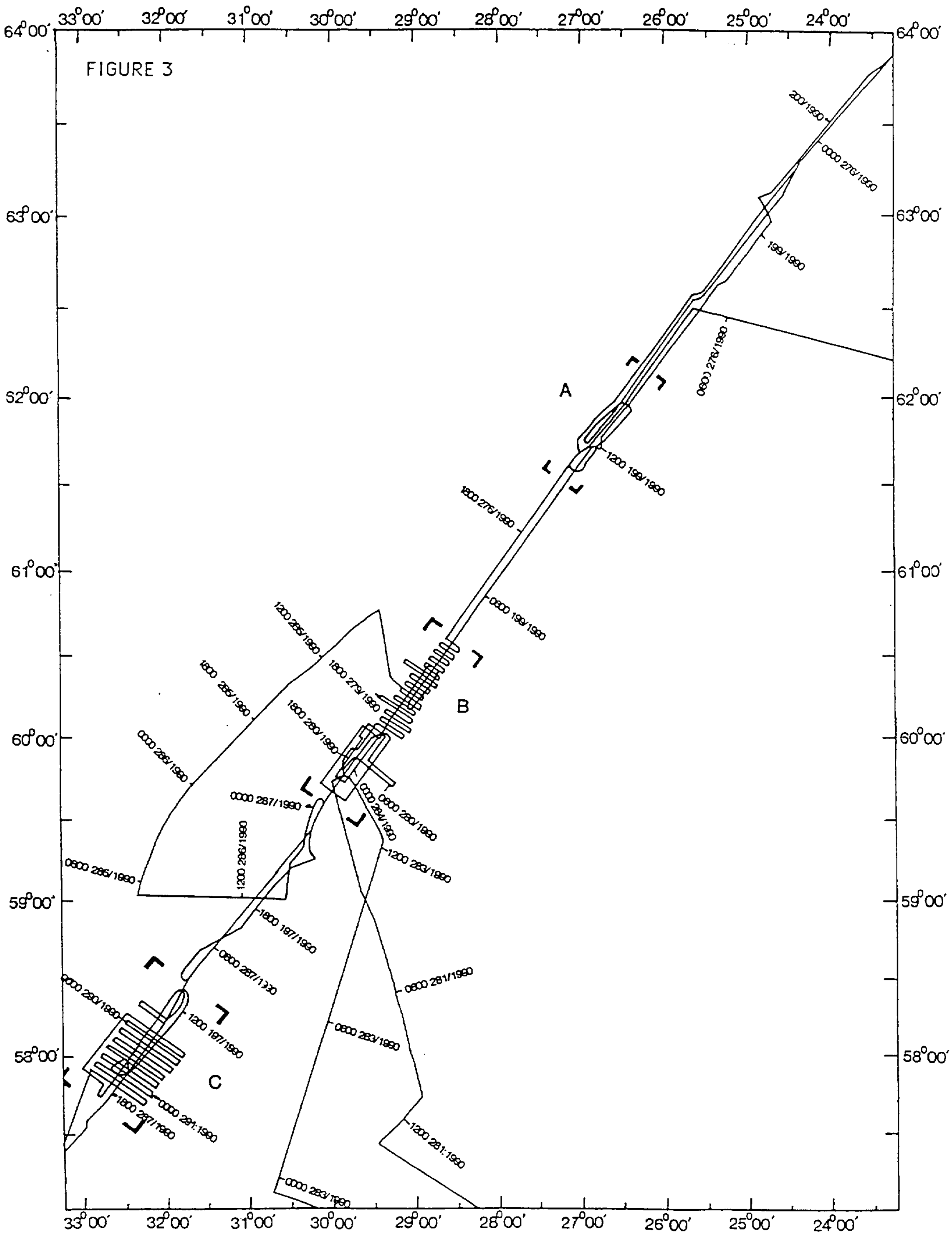
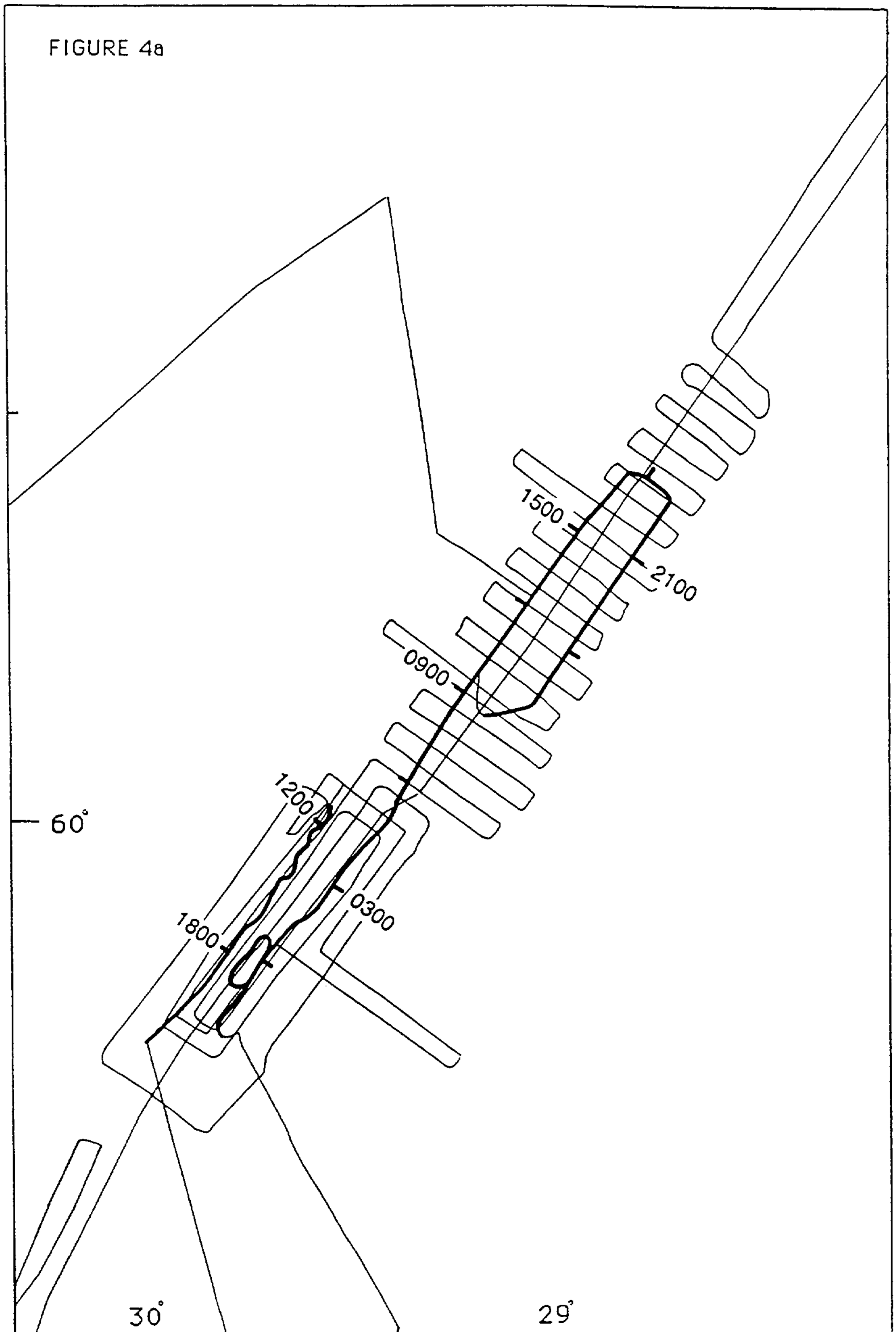


Figure 3: Detailed track chart of the main survey Areas A, B, C. Times and Julian days are posted every six hours.



Figures 4a & b: Location of TOBI survey lines within Areas B and C.

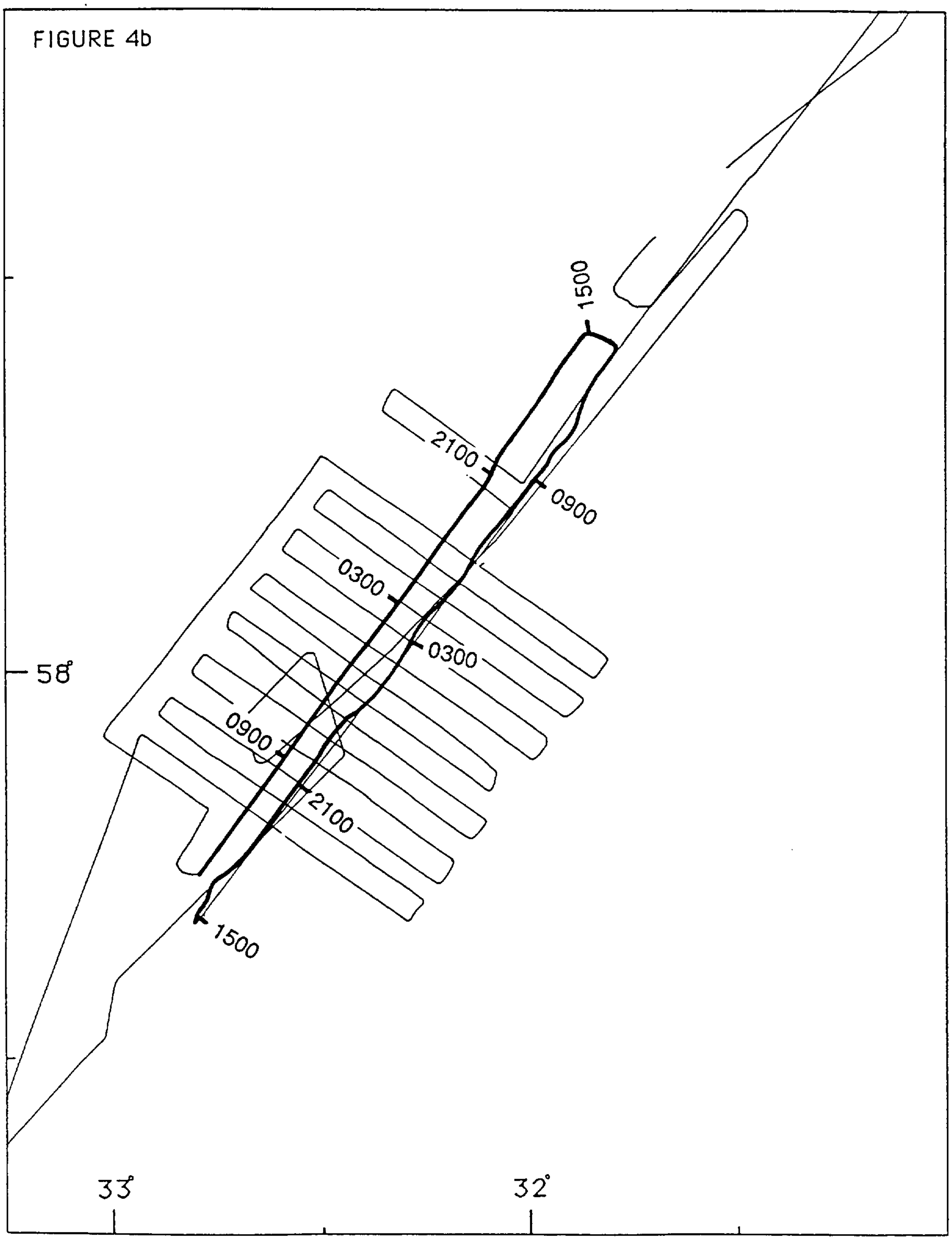


FIGURE 4b
1500
2100
0900
0300
0300
58°
0900
2100
1500
33°
32°