I.O.S.

MV FARNELLA
CRUISES 1/84 – 4/84

26 APRIL – 15 AUGUST 1984

GLORIA STUDIES OF THE EXCLUSIVE ECONOMIC ZONE OFF THE WESTERN UNITED STATES BETWEEN 30° 30′ AND 48° 30′N

CRUISE REPORT NO. 174
1985

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey, GU8 5UB.
(0428 - 79 - 4141)

(Director: Dr. A.S. Laughton FRS)

Bidston Observatory,
Birkenhead,
Merseyside, L43 7RA.
(051 - 653 - 8633)

(Assistant Director: Dr. D.E. Cartwright FRS)

Crossway,
Taunton,
Somerset, TA1 2DW.
(0823 - 86211)

(Assistant Director: M.J. Tucker)

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INSTITUTE OF OCEANOGRAPHIC SCIENCES

WORMLEY

MV FARNELLA

Cruises 1/84 - 4/84

26 April - 15 August 1984

GLORIA studies of the Exclusive Economic Zone off the western United States between 30°30' and 48°30'N

Principal Scientists

N.H. Kenyon and D.G. Masson

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Dr. Michael E. Field	Co-chief scientist	X			
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Dr. Paul R. Carlson	Geologist	X			
Dr. Richard N. Hey (SIO)	Geologist	X			
Dr. James V. Gardner	Co-chief scientist		X		
Dr. David S. McCulloch	Co-chief scientist		X		
Dr. Stephen L. Eittreim	Geologist		X		
Mr. Bruce M. Richmond	Geologist		X		
Mr. George B. Tate	Photographer		X		
Dr. David A. Cacchione	Co-chief scientist			X	
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Dr. Samuel H. Clarke	Geologist			X	
Mr. Bruce E. Jaffee	Geologist			X	
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Dr. Herman A. Karl	Co-chief scientist				X
Mr. Kris H. Johnson	Photographer				X
Mr. Tom Wiley	Geologist				X
Mr. Robert Kaylen	Geologist				X
IOS					
Mr. Neil H. Kenyon	Co-chief scientist	X			X
Dr. Douglas G. Masson	Co-chief scientist		X	X	
Dr. Michael L. Somers	GLORIA engineer	X			X
Mr. Brian J. Barrow	GLORIA engineer	X	X		
Mr. Timothy Probert	Shipboard computing	X	X		
Mr. Richard A. Phipps	Air-gun technician	X	X		
Mr. Chris Flewellen	Electronics technician	X			X
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Mr. Edward Lawson	Shipboard computing	X			
Mr. Malcolm Harris	GLORIA engineer		X	X	
Mr. Jon Campbell	GLORIA engineer		X	X	
Mr. Derek G. Bishop	Electronics technician		X	X	
Mr. Guy Rothwell	Geologist			X	X

SCIENTIFIC PERSONNEL continued		Leg 1	Leg 2	Leg 3	Leg 4
IOS					
Mr. Robin Bonner	Air-gun technician			X	X
Mr. Gareth Knight	Shipboard computing			X	
Mr. Ross Walker	GLORIA engineer				X
Mr. Edward Cooper	Shipboard computing				X

THE EEZ-SCAN PROGRAMME

EEZ-SCAN was a co-operative research programme between the United States Geological Survey (USGS) and the Institute of Oceanographic Sciences (IOS). The major aim of the programme was to undertake a reconnaissance survey of the entire United States exclusive economic zone (EEZ) adjacent to the western United States using the long-range sidescan sonar, GLORIA. The area covered by the survey extends from the Mexican to the Canadian Borders (32°30'N to 48°30'N) and from the continental shelf edge (in practice, the 400 m bathymetric contour) out to 200 nautical miles from the coast. In addition to GLORIA data, single-channel airgun seismic reflection profiles, 3.5 kHz and 10 kHz high-resolution profiles and magnetic anomaly profiles were continuously collected during the programme.

EEZ-SCAN was an outstanding success. A complete mosaic of overlapping sonographs of the entire EEZ area was produced and approximately 20,000 nautical miles of profile data were collected during some 100 days at sea (Fig. 1). Less than four days of survey time were lost because of failures in the GLORIA instrumentation and because of ship's engineering problems.

CRUISE NARRATIVE

LEG 1

Objectives

Leg 1 began a series of four cruises of EEZ-SCAN, a programme designed to provide continuous, overlapping long-range sidescan sonar coverage of the entire Exclusive Economic Zone of the western United States. The cruise was conducted aboard MV Farnella with a complement of both US and UK scientists and technical support staff. The Farnella departed from San Diego, California on 26 April 1984 and arrived at Long Beach, California on 21 May 1984. In 25 days at sea, 4,368 nautical miles of data, including sidescan (GLORIA), seismic reflection profiling (160 cu. in. airgun), high-resolution seismic-reflection profiling (3.5 kHz, 10 kHz) and magnetometer data were obtained (Fig. 2).

Specific objectives of Leg 1 were to:

1. Obtain overlapping sidescan sonar coverage from the US-Mexican Border (Latitude approximately 30°30'N) to Point Conception (Latitude approximately 34°30'N) and from the shelf edge seaward to the 200 nautical mile limit.
2. Survey as much of the bathymetrically-complex southern California Continental Borderland as possible by running track lines close together and orientating lines parallel to regional trends of ridges and island

platforms.

Narrative

Farnella sailed from San Diego at 1025 (all times are local) on April 26. Due to high winds and rough seas, the GLORIA vehicle could not be launched in open water (loose wraps in the spool might cause the tow cable to "bite" into the spool; sudden release of tension in response to the heavy swell might cause cable wraps to loosen) and we proceeded to the lee of San Clemente Island where the vehicle was launched at 2230. By 2300 data were being recorded and we began surveying. The vehicle was towed about 400 m behind the Farnella and about 45 m below the surface. Data from the first several hours of survey were overprinted with an electrical interference pattern; this initial problem was quickly solved by M. Somers and never reappeared.

The first four days of the cruise required continuous adjustment of track line locations. Weather was calm but, in the shallow regions of the borderland (~ 500 m) we could obtain useful data only out to a distance of about three nautical miles. This required repositioning of lines so as to obtain as complete coverage as possible. Early results from the GLORIA system showed intricate canyon and channel patterns of La Jolla, Newport and Redondo Canyons and very subtle reflectivity patterns on the floor of Santa Monica Basin. It became clear to the scientific staff that:

(a) the Loran-C navigation was providing very accurate and reliable positioning,
(b) that many small-scale features were being recorded by GLORIA, and
(c) that the shallowness, relief and variety of rock and sediment types of the borderland would result in an extremely complicated and incomplete mosaic.

On April 30 a problem developed in the A-D converter and no GLORIA image data was obtained from the starboard channel. We continued to survey while the problem was being identified and solved.

A water pipe in the engine room needed replacement on May 1. We completed a survey line, recovered the vehicle and hove to for repairs off Santa Catalina Island. Total down time was just under four hours. The weather and sea conditions continued to be good but the large number of fishing and naval boats in the area gave us concern; at one point we had to deviate 20° from our course and eventually pull completely off the line.

On May 2 we experienced moderately high winds (20 knots) and rough seas; as we were profiling into the weather our speed was reduced to about 6 to 6.5 knots. The weather conditions continued for several days and, as they were

being caused by a high-pressure system that appeared to be strengthening, we started thinking seriously about changing track-line orientation. Winds and seas were from the northwest; our entire survey was designed to be run on NW-SE courses so as to be oblique to major structural and depositional trends. By May 6 the winds had not abated significantly (peak winds reached 50 to 60 knots during the night) and the weather pattern appeared stable. The decision was made to run all deep-water lines west of Patton Escarpment on an east-west orientation so as to be beam on to the swell - easier on the equipment, harder on the crew.

We made our first transect into deep water and got our first glimpse of Arguello Fan on May 7. A well-developed channel-levee complex is present at the base of the slope and it appears that this system will be an exciting new feature to study. Little is known about the fan; it is intermediate in size - the smallest of the Pacific margin fans but larger than those in the adjacent southern California borderland. Magnetometer launched today. At 1410 all power was lost on board (apparently, a problem in switching over generators). The ship came to a complete stop, the magnetometer was lost and the GLORIA vehicle hung vertically below the ship. All systems back on 2.5 hours later. GLORIA was brought aboard at 1730 to allow a servo-motor controlling the variable pitch prop to be repaired. Unfortunately, the tow cable was found to be twisted from hanging dead in the water and IOS staff decided that a cable changeover was required. By 0500 on May 8 we were back on line gathering data after a loss of only 11.5 hours.

On May 9 it was discovered that the beam offset on GLORIA was not working. A corroded wire at the gantry termination was discovered and, after some disassembly and repair, we were back on line with only a 4.5 hour down period.

Winds and seas continued to be moderately rough throughout May. These conditions influenced to a degree the quality of data but, nonetheless, we continued to obtain exciting and significant new results. The deep sea adjacent to southern California contains many more volcanic ridges and seamounts than previously mapped and many of the seamounts have an identifiable central crater. The trend of volcanic ridges appears to be dominantly NE-SW. On May 11 a defective pin was located in the circuitry of the GLORIA recorder and we circled for five hours while the problem was corrected.

Force 9 conditions (winds 25-35 knots, gusting to 45 knots) on May 14 forced us again to reduce ship speed and consider abandoning our NW course on the Patton Ridge.

In the time allotted we could not complete our survey south to the Mexican border, primarily because the shallow water of the borderland required increased survey time (track lines were spaced at about 6 to 8 nautical miles, as compared to 16 nautical miles in deep water). The remaining survey lines will be covered at the completion of Leg 4. On May 20 we terminated our last deep water line and started towards port. On Monday May 21 the Farnella docked at the port of Long Beach to exchange scientific personnel and prepare for Leg 2.

LEG 2

Objectives

This cruise was the second in a series of four cruises of Programme EEZ-SCAN. The programme was designed to collect 100% coverage of the US west coast Exclusive Economic Zone from the shelf break out to 200 nautical miles, using GLORIA as the principal geophysical instrument. However, in addition to GLORIA, 160 in^3 airgun, 3.5 kHz, 10 kHz and magnetometer data were to be collected along the track lines.

The Programme

1. The main objective of this cruise was to use GLORIA to provide a reconnaissance survey of the area from Point Conception to Point Arena, central California (Fig. 1). This area includes the entire Monterey Fan, as well as the northern portion of Arguelo Fan and the entire Santa Lucia Escarpment.
2. We hoped that weather and sea state would allow us to run tracks at approximately 45° angles to the regional bathymetry in deep water and tracks parallel to the margin along the continental slope.

Narrative

Farnella sailed on time from Long Beach, California at 1000 (all times are local) on 23 May 1984. A short transit was required from Long Beach up to the northwestern corner of Santa Barbara Basin. We deployed the 3.5 and 10 kHz fishes at 1330 and GLORIA at 2000. All deployments went smoothly. By 2100 all systems were on and high-quality data were being collected. GLORIA was settled at 50-m depth about 400-m aft. Ship's speed was 8 knots.

Once we rounded Point Conception the script for the next three weeks was set; the winds were blowing 35 knots (Force 8). We surveyed Ascension Canyon

on the pre-arranged track of NW but soon decided that this course was not optimum for the equipment. The decision was made on May 24 to replot all survey lines seaward of the continental slope as east-west lines. These courses put the ship beam on to the swell but reduced wear and tear on the GLORIA cable. By 1500 on May 24 the weather was Force 9 and we were heading westerly.

Once we crossed the western edge of the California Current, the sea and air temperature increased and the wind dropped to about 20 knots. We decided to continue to run east-west tracks over the deep Monterey Fan and await calm seas to attempt a survey of the continental slope. All systems were continuing to produce top-quality data.

We were expecting to find meanders on lower Monterey Fan, similar to those found on Amazon fan, but were disappointed. No meanders, other than the one surveyed over 30 years ago by Fran Shepard, occur in Monterey Channel but we were surprised to find very large-scale bedforms covering the southern two-thirds of Monterey Fan. The bedforms have wavelengths of about 1.5 km and wave heights of from 5 to 15 m. Lively debates as to the origin of the bedforms kept us occupied for several days but no consensus was arrived at.

On May 27 the weather improved to the point where we decided to attempt to survey the continental slope. The sea continued to calm and we were able to completely insonify the entire continental slope and upper continental rise from Point Conception to Point Arena before the weather degraded. The weather permitted us to achieve almost 100% coverage of upper Monterey Canyon as well as Santa Lucia Escarpment. The ocean was almost isothermal from top to bottom and the acoustic propagation was very favourable.

On May 29 we began to get a very noisy 3.5 kHz record. Speculation was that something was fouled around the tow cable. We also became aware of a "striping" on the anamorphosed photographs that was being produced by the anamorphic camera. We started a series of tests to isolate the cause of this camera nuisance.

May 30 brought 15 to 20 knot winds so we decided to break off the survey line and retrieve the 3.5 kHz fish to check out the noise problem. The fish was brought up within about one foot of the surface and appeared OK but the noise was still present so it was recovered and found to have a loose cover plate. After securing the cover plate the fish was redeployed. The weather forecast was horrifying but we decided to try to finish the last line of the continental slope before resuming east-west lines.

May 31 brought 20-knot winds and 10-ft seas so we broke off the continental

slope lines and resumed our east-west surveys. We found surface faults in the vicinity of Sur Canyon and a large (structurally controlled??) meander on Sur Canyon. Pronounced gullying off the Farallon Escarpment appears to be headward erosion and not sediment controlled. The GLORIA data continue to be very high quality. The one disappointment of the day was that the CALCOMP plotter died. Tests showed a defective circuit board for which no spare was carried. This meant an end to navigation plots and all plots for the remainder of the cruise had to be done by hand.

Early June brought only foul weather with the ship rolling 20°; this continued to the end of the Leg. However, the sonographs and seismic data continued to pour in and, at times, provide heated debates. Seventeen uncharted seamounts were located and informally named, some of which are at least 1500-m high.

On June 2 the engine room required a complete shutdown to repair a water pipe. GLORIA was retrieved, the pipe was repaired, and GLORIA was redeployed with only a 5.5 hour loss. Recovery and redeployment went very smoothly even though the wind was 25 to 30 knots and the sea was 12 to 15 ft.

The northern part of the area began to show Monterey Fan sediment onlapping an older surface. The older surface may be Delgada Fan sediment or basin sediment. Also, the large bedforms begin to become less pronounced in the northern region. The cause of the bedforms continue to be the topic that generated the liveliest debate.

On June 11 the 3.5 kHz record began to show a 20-Hz noise. The data were still very good but the noise was a nuisance. GLORIA had some problem with gain during the night that appeared to be a gain increase across both port and starboard channels. The gain increase eventually disappeared from the starboard channel. It looked to be an intermittent problem and was impossible to track down. We surveyed a large depositional feature that resembled a suprafan located north of Monterey Fan. Speculation is that it is the active deposition lobe of Delgada Fan. Noyo Canyon appears as a perched levee-channel complex built up several hundred metres above the level of the basin. It is very different looking from anything related to Monterey Fan.

We realised that we would not survey to the latitude of Pioneer Fracture Zone, a realisation that was disappointing to many of us. However, as the end of the survey approached, we realised that we had achieved virtually 100% coverage of the entire region covered. GLORIA and the seismic systems all performed above expectations and all of the data are very high quality. On

June 12 the weather stayed at 30-knot winds and 10- to 15-ft seas and we quietly debated when to retrieve the gear for our transit to San Francisco. We completed our last line in the late afternoon, retrieved all the gear, and commenced our transit before dark.

We arrived at the pier in San Francisco at 0800 on June 13, much relieved to get off the rolling platform and on to something stable.

Scientific Results

Over 44,000 mi^2 were surveyed with GLORIA and over 3800 n mi of seismic data were collected (Fig. 3). The average survey speed was about 8 knots. The cruise consisted of 504 hours at sea during which 474.5 hours of data were collected.

The entire Monterey Fan was surveyed and the acoustic stratigraphy appears to represent a period of pelagic sedimentation followed by an erosional event and then the sediment from Monterey Fan. The surface of Monterey Fan is covered by large bedforms whose origin is unknown at this time, although they appear to be abyssal sediment waves. Monterey Channel has a large, previously-surveyed meander that is controlled by a north-south-trending fault. Monterey Fan onlaps basin sediment to the west and south and Delgada Fan sediment to the north.

The type of gullying along the continental slope apears to be directly related to the nature of the basement rocks along the margin. Franciscan rocks along the margin north of San Francisco are more intensely gulled than are the Salinian granitics along the Big Sur margin.

Taney Seamounts, a series of four very large (10-km summit diameter) seamounts, have caldera summits that resemble either explosive calderas or collapse features. The seamounts are formed on Oligocene crust but are very different from any other seamounts on Oligocene crust in the region. Taney Seamounts are much larger than any other seamounts in the region and their origin will require extensive study.

We were able to compare the quality of the GLORIA data collected from upper Monterey Fan with SEABEAM data collected by NOAA from the same area. We could clearly identify all features on GLORIA data that were contoured at 10-m intervals on SEABEAM but, in addition, we could see subtle features on GLORIA that were very confusing on SEABEAM. Our unanimous consensus was that the two systems together provide a very thorough data set but, if one had the use of only one of the two systems, we would choose GLORIA sonography.

LEG 3

Objectives

The main objective of Leg 3 was to obtain GLORIA coverage of the EEZ between Point Arena (39°N) and Coos Bay (43°20'N) off the Oregon and northern Californian coast (Fig. 1). This area includes much of Delgada Fan, the Mendocino Fracture Zone, the Gorda Ridge seafloor spreading centre and the convergent plate boundary west of Oregon.

Narrative

Farnella sailed from San Francisco at 1000 (local time) on June 15. Repairs to the CALCOMP plotter by a shore-based engineer had been completed the previous day. The 3.5 kHz and 10 kHz fishes were deployed at 1500 in good weather with calm seas. GLORIA and the seismic reflection profiling system were deployed between 2000 and 2200 in rapidly worsening weather conditions. Overnight, N to NNW winds reached 40-50 knots and heavy seas were encountered. An E-W survey track direction was dictated by the wind direction in order to minimise wear on the GLORIA cable.

Severe weather conditions persisted throughout June 16 to 18, during which an E-W survey direction was maintained. Two hours of seismic reflection profiling (SRP) data were lost in the early hours of the 16th and early part of the 17th due to failure of a compressor fan motor. Weather gradually improved through June 19 and 20, with winds decreasing to 20-25 knots, but heavy seas necessitated that the east-west survey direction be maintained. At 0100 on the 19th, the SRP logging system failed, although the SRP data could still be displayed in real time. Despite considerable effort over the following few days, the lack of a complete spare set of printed current boards made it impossible to repair the system and eventually it was concluded that digital SRP logging would have to be abandoned for Leg 3. To counter this, an extra EPC recorder was added to the SRP system so that three versions of the SRP profile, each with different filter settings, could be displayed simultaneously. In the evening of the 19th four hours of SRP data was lost because of a leaking high pressure hose and because of problems with the wave-shaping kit fitted to the airgun. Profiling was eventually continued without the wave-shaping kit being fitted to the airgun.

By 0900 on June 20, the weather had moderated considerably and it was decided to begin running the N-S to NW-SE orientated survey lines over the continental slope. Between 0900 on June 20 and 1900 on June 22, lines were run

between Point Arena (39N) and the Mendocino FZ (40.5N). Good sonographs were obtained over the heads of Noyo and Vizcaino Canyons during this period. On completion of the southern part of the slope parallel survey planned for Leg 3, and with two to three days of good weather forecast, it was decided to continue north on slope parallel survey lines. At 1920 on the 22nd the Mendocino Fracture Zone was crossed; during the next 2.5 days complete sonograph coverage of the entire continental slope between Cape Mendocino (40.5°N) and Coos Bay (43°N) was achieved from four long N-S trending survey lines. Spectacular sonographs of the continental slope were obtained, showing abundant evidence for deformation and shale diapirism.

At 1100 on June 20, the Mendocino FZ was crossed on a southerly heading as Farnella returned to pick up the E-W survey pattern at 39°40'N. Between 1920 on June 25 and 1930 on June 28, four long E-W lines were run in good weather with winds of 10-15 knots and calm seas. The latter two E-W lines gave north and south-looking views of the Mendocino FZ. Clear evidence of extensional faulting was seen where the southern end of the Escanaba Trough was crossed between 0700 and 1000 on June 28. The trace of the Mendocino transform fault was also seen on the northern side of the Mendocino Ridge.

At 1930 on June 28 we began our survey of the ocean basin north of the Mendocino FZ using NE-SW orientated lines. This appeared to be the optimum survey direction, given the prevailing NW winds encountered during the earlier part of the survey and the N-S to NNE-SSW trend of the oceanic basement associated with the Gorda Ridge. The Gorda Fan area was surveyed on this heading between 1930 on June 28 and 2015 on June 30. However, worsening weather between 0800 and 2015 on the 30th, with 30-40 knot winds and 15 ft seas from the north, eventually forced Farnella back on to an E-W course to minimise wear on the GLORIA cable. This E-W course was not ideal for the Gorda Ridge survey, given the N-S trend of the seafloor fabric, but had to be maintained to the end of Leg 3 on July 8 due to persistent strong winds and heavy seas from the NW to NNE.

At around 0930 on July 2, it was noticed that the GLORIA vehicle heading indicator was giving erratic readings. Cable damage due to the persistent bad weather durings Legs 2 and 3 was diagnosed and a cable change was clearly required. However, heavy seas were still running, preventing an immediate recovery of the GLORIA vehicle, and it was decided to finish the westerly survey line being run at the time in the hope of finding better weather farther from the coast. The end of the line was reached at 1500 on July 2, and all gear was

recovered without difficulty by 1600, despite winds of 20-30 knots and a confused N to NW swell. Farnella then headed for the coast in an attempt to find sheltered waters, because a stable and spray-free working environment is required for the cable change.

Sheltered water under the lee of Point St. George, at 41 45N on the California coast, was reached at 1200 hours on July 3. The cable change was then completed in the excellent time of eight hours, and Farnella was underway for the survey area by 2030 hours. The shelf edge was reached at 2200 hours, but launching was delayed because of heavy seas. By first light on July 4 the seas had moderated slightly and, although conditions were not ideal, it was decided to deploy the survey equipment. Potentially serious damage to the GLORIA vehicle and cable was narrowly avoided when the cable became snagged on the gantry during launching; fortunately, the cable freed itself within a few seconds, with some chaffing of the outer sheath of the cable the only apparent damage. All the equipment was deployed by 0700, and GLORIA was operational by 0720.

Between 0720 on July 4 and 0740 on July 8, five further E-W survey lines were occupied between 41 30N and 42 40N. During this period the weather was extremely bad with winds ranging from 30 to 60 knots. Despite this, the data continued to be of high quality. The final survey line was completed at 0740 on July 8 and all survey gear was inboard by 0900. Farnella docked in Coos Bay at 0900 hours on July 9.

Scientific Results

The average survey speed during Leg 3 was 8 knots. Approximately 64,000 square miles were surveyed with GLORIA and 4050 n miles of profile data collected during some 500 hours of surveying (Fig. 4).

The early part of Leg 3 surveyed the proximal part of Delgada Fan. An important discovery here is that the main fan channel is derived from Vizcaino Canyon and that Noyo Canyon does not feed into the fan channel complex. A previously unknown fan channel trending westward from near the top of Delgada Fan was also seen.

On the north side of Mendocino Ridge, the trace of the Mendocino Fracture Zone can be clearly seen over a distance of over 100 miles between the southern end of Escanaba Trough and the continental margin. On the north side of Mendocino Ridge, Mendocino Canyon is a spectacular meandering channel extending from the continental slope to 125°40'W. Profile data across Escanaba Trough

shows evidence of extensional faulting.

Along the continental slope north of the Mendocino Ridge, sonographs showed abundant evidence of compressional tectonics. The deformation front at the base of the continental slope is a striking feature marked by a series of en echelon anticlinal folds which rise abruptly from the flat, sediment-covered basin floor to the west. Shale diapirs, possibly exploiting anticlinal axes, are common on the mid- and upper slope. Many canyons cut the continental slope in this area; some cut through the rough terrain caused by folding, while the paths of others are clearly controlled by it.

Continuous bad weather during the latter part of Leg 3 meant that the survey lines over Gorda Ridge had to be run in an E-W direction. This was not ideal, given the N-S to NNE-SSW trend of the oceanic fabric in this area. Nevertheless, it is clear that the northwards increasing spreading rate along Gorda Ridge has resulted in an extremely complex, fan-shaped spreading fabric.

LEG 4

Objectives

The primary objective of Leg 4 of programme EEZ-SCAN was to construct a sonograph mosaic of the entire seafloor in water depth greater than 500 m within the US Exclusive Economic Zone (EEZ) off Oregon and Washington (Fig. 1). The survey was extended westward beyond the 200-nm limit of the EEZ where necessary to include the Juan de Fuca Ridge. Also, coverage was planned to extend into Canadian territory, perhaps to 49°north, to obtain a complete picture of certain geologic features.

The primary surveying instrument used was GLORIA, a unique long-range sidescanning sonar system. Additional geophysical data were collected with airgun and transducer seismic-reflection profiling systems and with a magnetometer, in order to aid our interpretation of the sonograph data.

Narrative

The cruise began at 0900 (local time) on 11 July 1984 when the research vessel Farnella left Coos Bay, Oregon. The plan was to begin surveying along the uppermost continental slope and work westward into deep water along approximately north-south tracklines, which would give the optimum insonification of most geologic features in the area.

We were greeted by flat seas as we left Coos Bay, a condition that would prevail during most of the cruise. The geophysical systems were deployed at

1300 and we began our initial, northerly-trending trackline slightly seaward of the continental shelf break. All systems performed well and we soon began to construct our mosaic and identify the clearly-displayed physiographic features. The records that we produced on board ship, in addition to slant-range and anamorphically-corrected sonographs, included 10-kHz bathymetric and 3.5-kHz high-resolution profiles, airgun profiles displayed at unfiltered 50-150 Hz and 15-80 Hz settings, and analogue magnetic field measurements. XBT drops were made routinely once a day and the data telemetered to the National Atmospheric and Oceanic Administration.

After surveying the continental slope off northern Washington, we first entered Canadian waters on July 14 where we insonified part of the Nitinat Fan and the submarine canyons that feed it. We decided to postpone any further work north of the US border until after all of the planned area south of the border was completed. This proved to be a prudent choice because accumulated small delays in our schedule barely allowed us to complete the US territory with the additional coverage of a small part of middle Juan de Fuca Ridge.

Our first equipment failure occurred on July 15 when we had to suspend operations for five hours in order to track down and replace a faulty transistor in one of GLORIA's starboard amplifiers. (This was the only failure of the GLORIA system during the entire cruise.) We manouevred in a circular course during repairs so that no insonification coverage was missed. Further equipment failure occurred on July 19 when a bearing on the airgun compressor seized and five hours were spent making a new one and installing it. We continued surveying during the repairs. Trouble with the airguns themselves occurred on July 21 and 23 and we missed a small amount of seismic-reflection coverage.

The only other significant interruption of surveying operations occurred on July 28. A few days earlier we discovered that our supply of developer for the negatives of the sonograph photographs had been depleted. Arrangements were made for the US Navy to fly additional developer to us from their air base at Moffett Field in California. A successful air drop was made as we rendezvous-ed with the P-3 Orion at 1500, about 300 km off the coast of Oregon. A total of eight hours surveying time was lost preparing for the drop and retrieving the developer.

On July 21, when we were in the southeast corner of our survey area, the seas became rough and dictated that we change to an east-west, trough-parallel course that would avoid pitch-induced stresses in GLORIA's conductor cable. This was a fortuitous circumstance because this put us on a favourable track to

survey the Blanco fracture zone which trends west-northwest. During the remainder of the cruise we surveyed north-south across Cascadia Abyssal Plain and Juan de Fuca Ridge and east-west across Blanco Fracture Zone and northern Gorda Ridge (Fig. 5).

Surveying of the Oregon-Washington EEZ was completed on August 8. According to a pre-arranged plan with Leg 1, 2 and 3 scientists, we began a southward track to survey a single line along the approximate outer limit of the EEZ from the Canadian to the Mexican border as we made way to our final destination, the port of San Diego, California. The final few days of the cruise were spent filling in some of the Leg 1 area close to the Mexican border and among the Channel Islands.

During the cruise, the splendid sunny weather and calm seas generated much enthusiasm for on-deck exercise. Daily jump-rope and calisthenic exercises were performed by several of the scientific crew. Addtionally, there was a regular, pre-supper volleyball game. The British scientific and ship crew members engaged in a few spirited cricket matches, and an elimination bowling tournament was held. Indoor activity included repeated showing of many favourite movies and two lengthy and challenging quizzes that were hotly contested as the scientists vied for the prizes and prestige bestowed upon the winner.

The Farnella docked in San Diego at 0900 on August 15 after insonifying a total of about 90,000 n miles^2 along 6,500 n miles of trackline. Meeting the ship at the dock were several representatives of the US Geological Survey, the British Institute of Oceanographic Sciences, and J. Marr & Sons (the ship's owner). A variety of post-cruise activities and festivities occupied the next two days. An open house for the public and the press was held on August 16. Stories of the successful EEZ-SCAN programme appeared in several newspapers and on local television. Mr. J. Marr graciously hosted a dinner party for the scientists, programme participants and guests on the night of August 16. The highlight of the activities occurred on August 17 when William Clark, US Secretary of the Interior, visited the Farnella for a special briefing and viewing of the shipboard sonograph mosaics.

Scientific Results

The first-order geologic features surveyed in the Oregon-Washington EEZ include the continental slope, the Cascadia Abyssal Plain, the northern end of the Gorda Ridge, the Blanco Fracture Zone and the Juan de Fuca Ridge. Sonographs of the continental slope off Oregon show a number of linear accretionary ridges that are typical of subducting convergent continental margins. Submarine canyons on this portion of the continental slope are small to obscure whereas, to the north along the Washington margin, several major canyons with densely-gullied side walls and a flat floor deeply-incise the upper continental slope. The canyons become indistinct on the lower slope where there are accretionary ridges surrounded by a blanket of sediment that probably was deposited from sheet and overbank flows from the canyons.

Nitinat and Astoria deep-sea fans cover Cascadia abyssal plain. Constructional channel-levee complexes as well as erosional channels form a complex drainage system on the surface of these large sediment bodies. Most of the channels appear to be relict but the through-going Cascadia, Astoria and Willapa channels have a connectin with submarine canyons and probably are active. Fields of sediment waves are present within channels, on levees and in interchannel areas.

Blanco Fracture zone is bounded on its northeast and southwest sides by linear volcanic ridges and by faults, separated by a predominantly flat, sediment-covered area approximately 15-km wide. Cascadia Channel appears to cut through the zone in a westerly direction.

Gorda Ridge abuts the southwest side of Blanco Fracture Zone and the spreading axis occurs near the east end of the zone. The block-faulted basement ridges have a pronounced curvature towards the spreading axis near the fracture zone. Similar curvature occurs on the southern end of Juan de Fuca Ridge, although the radius of curvature is substantially larger than for Gorda Ridge. The basement ridges associated with both spreading centres become increasingly buried by abyssal-plain sediment farther from the axis.

The physiography of the middle section of Juan de Fuca Ridge is complicated by the presence of many circular volcanic centres and probable associated lava flows that partially-to-totally obscure the ridge and valley forms seen elsewhere. The ridges visible in this section are offset in a right-lateral sense. Occasional seamounts are present outside this middle section, most notable of which are the Vance and Thompson seamounts.

SUMMARY STATISTICS OF GLORIA RECORDING, EEZ-SCAN 1984

LEG	SEA-TIME HOURS	SURVEY TIME HOURS (including downtime)	GLORIA DOWNTIME HOURS (all causes)	% TIME ON LINE	APPROXIMATE AREA INSONIFIED (nautical miles^2)
1	576	556	30.5	94.5	41,000
2	519	492	3.5	99.3	46,000
3	574	537	40	92.6	49,000
4	840	822	17	97.9	90,000
ALL LEGS	2,509	2,407	91	96.2	226,000

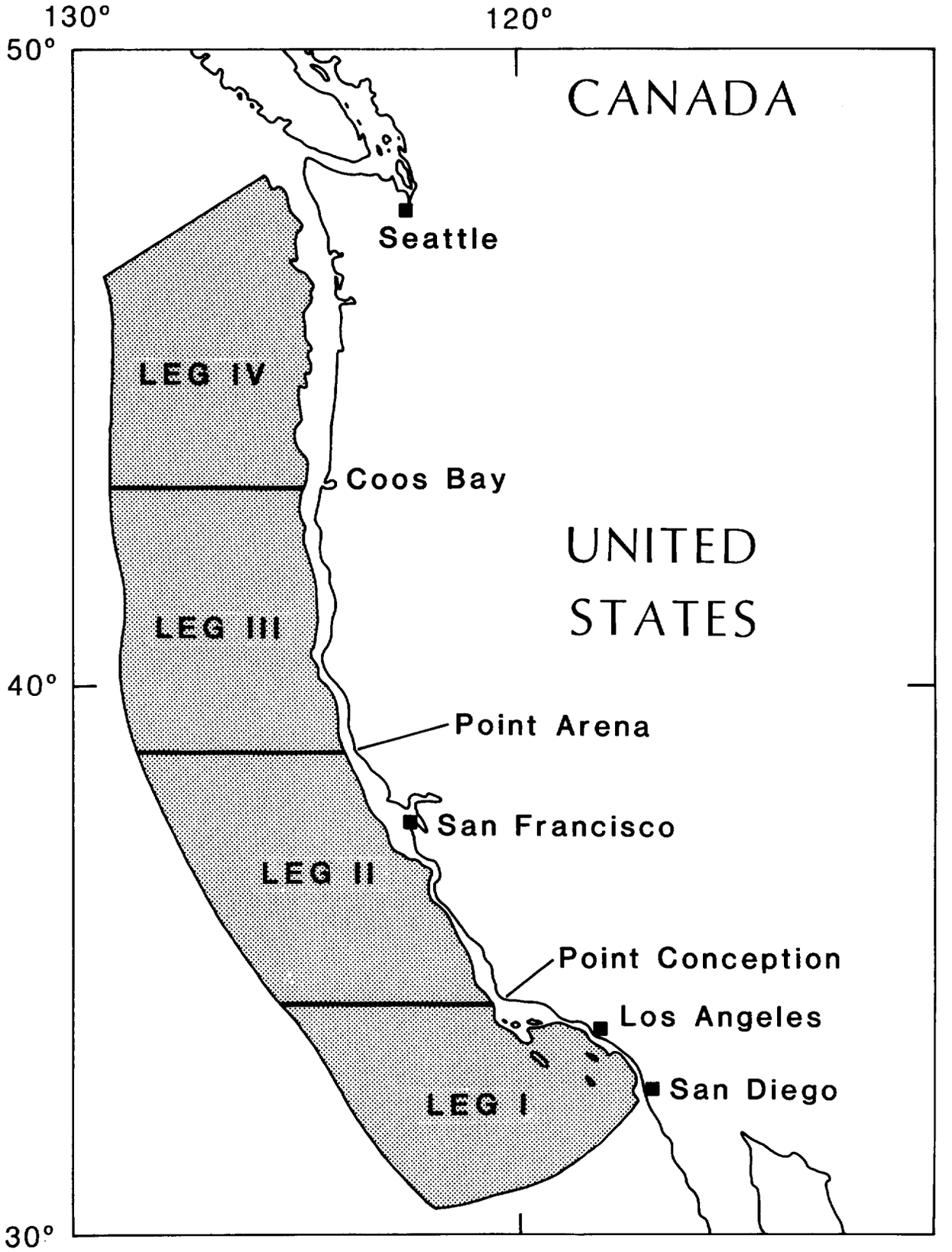


Fig. 1: GLORIA survey areas for FARNELLA cruises 1/84 to 4/84.

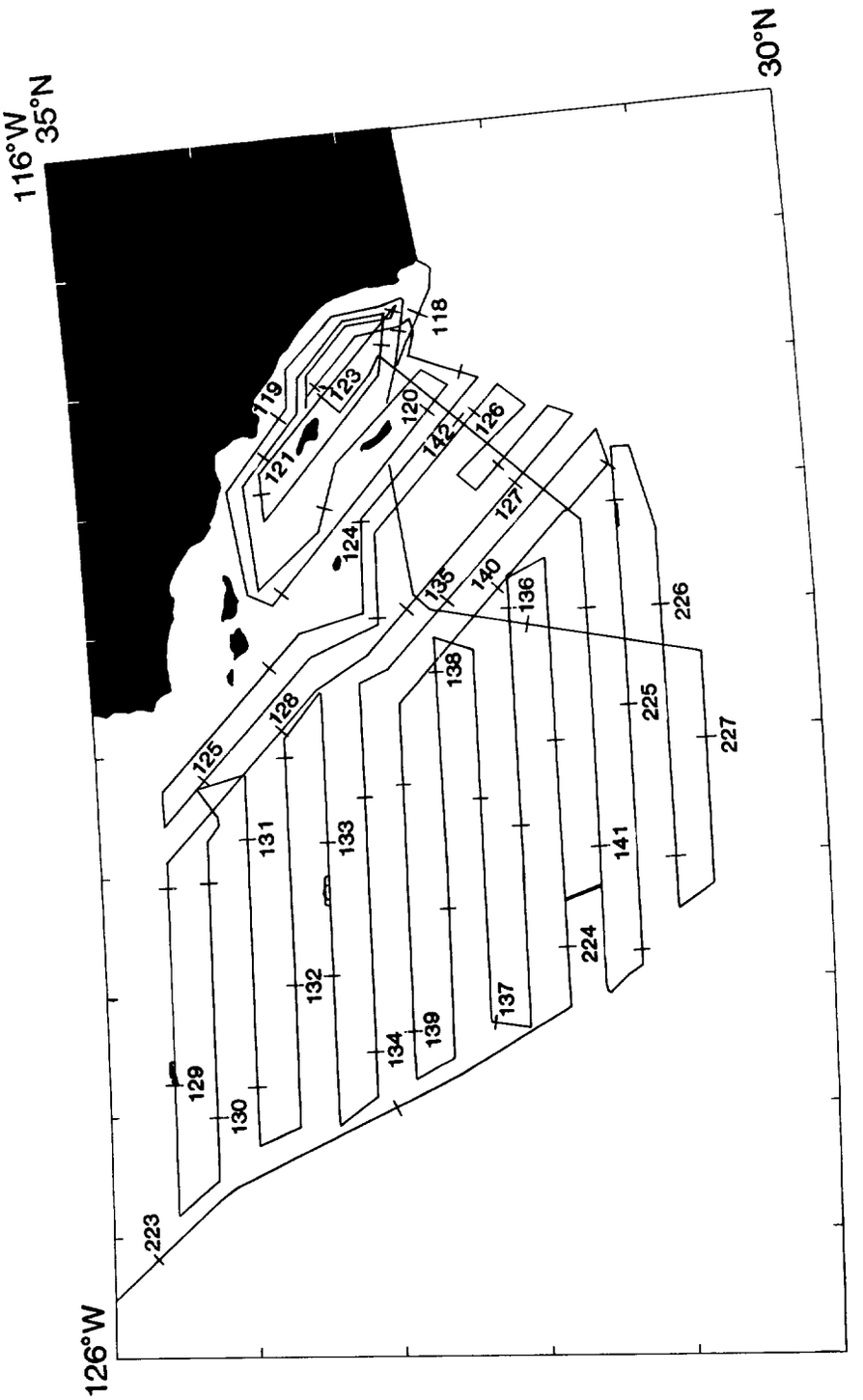


Fig. 2: Track chart for FARNELLA cruise 1/84.

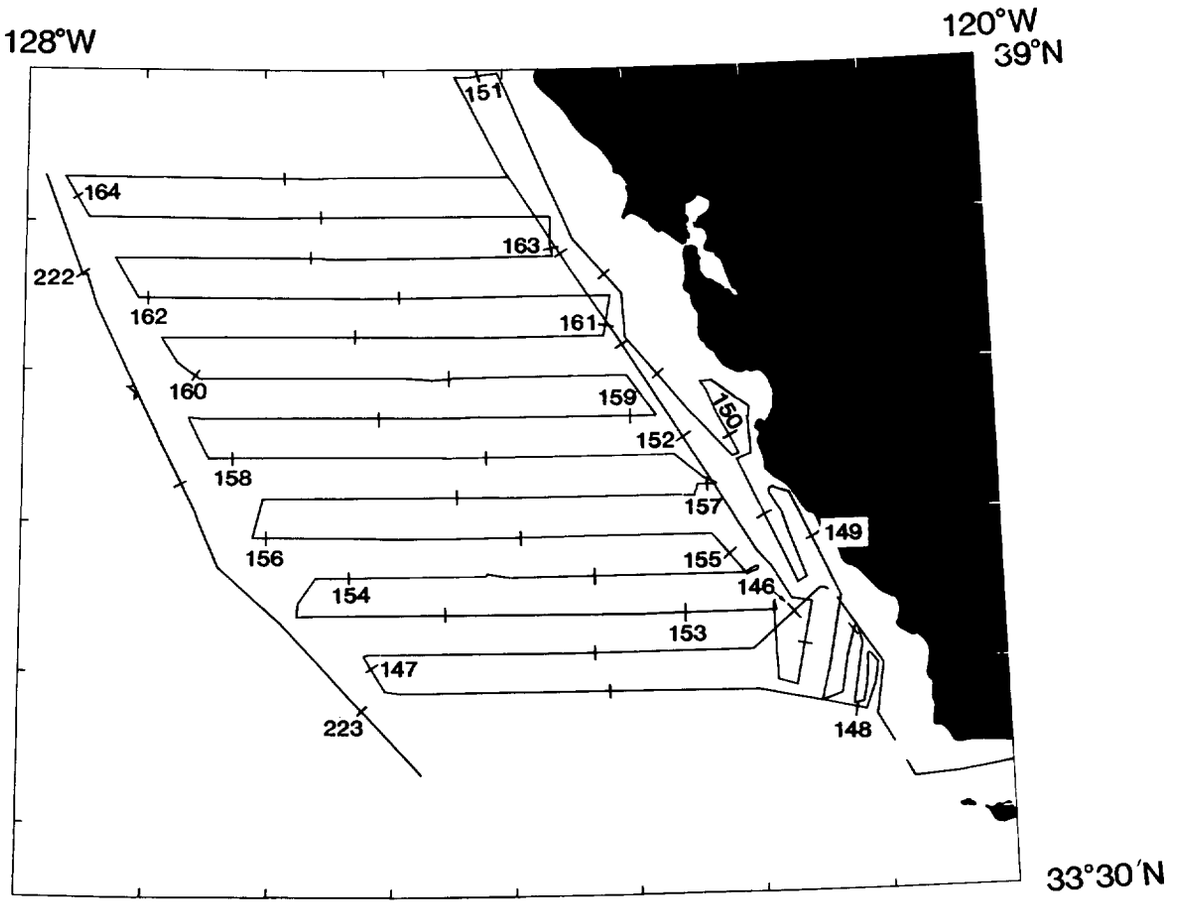
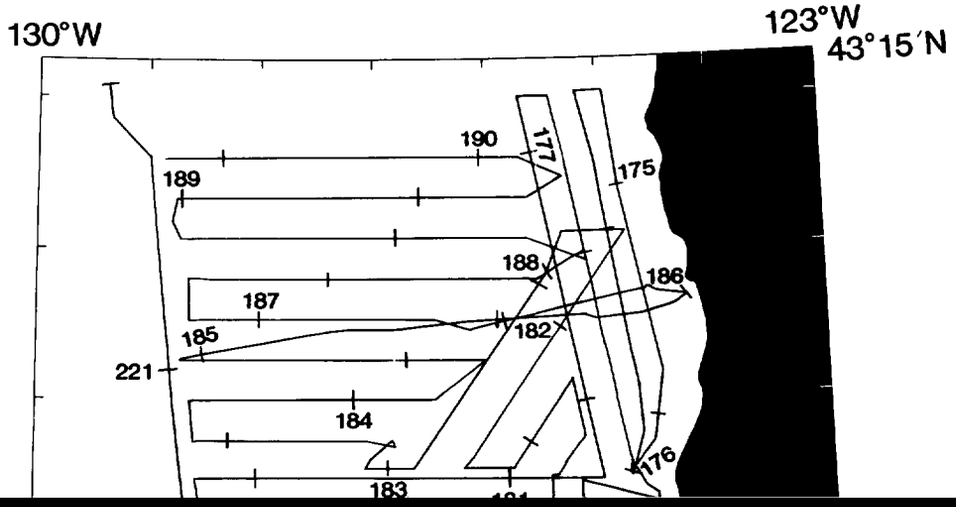


Fig. 3: Track chart for FARNELLA cruise 2/84.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123°W
43°15′N
190
177
175
189
188
186
187
182
185
221
184
176
183

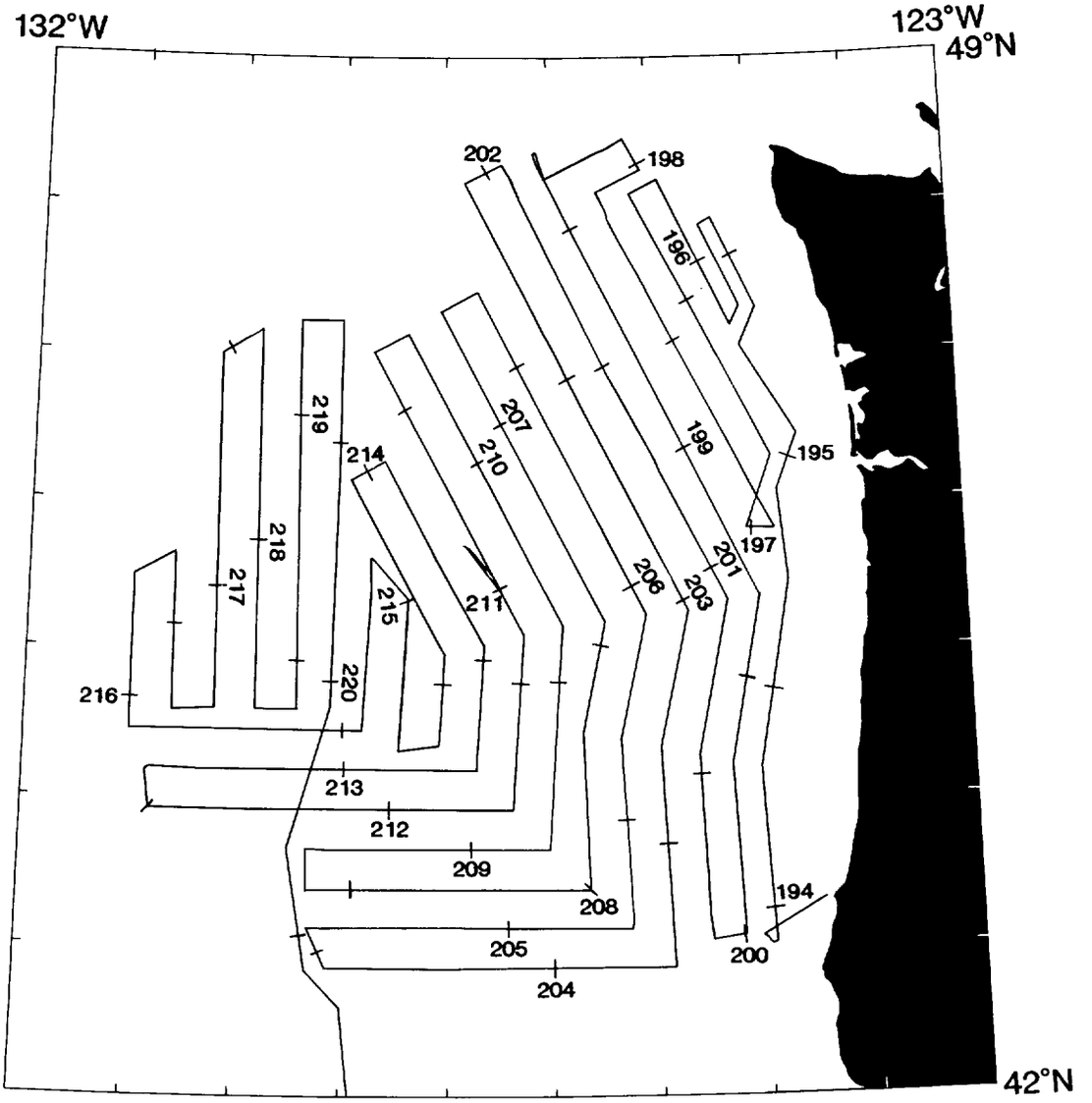

Fig. 5: Track chart for FARNELLA cruise 4/84.