

CRUISE REPORT

SHIP UTILIZATION DATA

UNOLS
Rev. 83

SHIP NAME	ROBERT D. CONRAD	OPERATING INST.	LDGO OF COL. UNIV.
CRUISE (LEG) NO.	29-07	DATES	June 27-July 27, 1988
AREA OF OPERATIONS:	BARBADOS RIDGE	PORT CALLS:	DATES
		PLACE	DATES
DAYS AT SEA	30	Bridgetown	6-27-88
		Bridgetown	7-12-88
DAYS IN PORT	5	Bridgetown	7-13-88
		San Juan	7-27-88

WAS RESEARCH CONDUCTED IN FOREIGN WATERS? YES COUNTRY: FRANCE & BARBADOS

PRIMARY PROJECTS (those which govern the principal operations, area and movements of the ship)

PROJECT TITLE AND PRINCIPAL INVESTIGATOR	SPONSORING ACTIVITY	GRANT OR CONTRACT NUMBER	PARTICIPATING PERSONNEL (AS CODED ABOVE)
Barbados Accretionary Prism: A Seismic, Geothermal Geochemical Study of Fluid Expulsion Features Mark Langseth & Graham Westbrook	NSF	OCE-88-00799	
DISCIPLINE: Heat Flow			

ANCILLARY PROJECTS (which are accomplished on a not-to-interfere basis and contribute to the overall effectiveness of the cruise)

PROJECT TITLE AND PRINCIPAL INVESTIGATOR	SPONSORING ACTIVITY	GRANT OR CONTRACT NUMBER	PARTICIPATING PERSONNEL (AS CODED ABOVE)

SIGNATURE	<i>Mark Langseth</i>	CHIEF SCIENTIST	DATE	10-13-89
TOTAL SCIENTISTS	13	TOTAL TECHNICIANS	8	
TOTAL GRAD STUDENTS	1	TOTAL STUDENTS/OBSERVERS		

COST ALLOCATION DATA		
DAYS CHARGED	AGENCY OR ACTIVITY CHARGED	GRANT OR CONTRACT NO.
35	NSF	OCE-86-16405

ATTACH PAGE SIZE CRUISE TRACK
SIGNATURE *[Signature]* Institution Official DATE 10/17/89

5.	I. Ferguson	Scientist	British
6.	P. Henry	Scientist	France
7.	B. Jegot	Scientist	France
8.	S. Lallement	Scientist	France
9.	M. Mason	Scientist	British
10.	S. McPhail	Scientist	British
11.	C. Pierce	Scientist	British
12.	J. Raillard	Scientist	French
13.	P. Schuntheiss	Scientist	British
14.	R. Bartholomew	Technician	LDGO
15.	J. DiBernardo	Technician	LDGO
16.	S. Ferguson	Technician	URI
17.	R. Maiwiriwiri	Technician	LDGO
18.	J. Miller	Technician	URI
19.	E. Mills	Technician	British
20.	F. Robinson	Technician	LDGO
21.	J. Stennett	Technician	LDGO

Oct. 20, 1989

TO: Barbee, W.D. UNOLS
Hannigan, L. LDGO
Gerard, S. LDGO
✓Hayes, D. LDGO
Cox, L. LDGO
Lotti, R. LDGO
Kent, D. LDGO
Simpson, D. LDGO
Takahashi, T. LDGO
Science Officer CONRAD
Captain CONRAD

RESEARCH CRUISE REPORT

R/V ROBERT D. CONRAD 29-07

Attached is a copy of the cruise report for the above CONRAD
cruise.

Ann Burns
Marine Office

CRUISE REPORT
R/V ROBERT D CONRAD 2907
27 June - 27 July 1988
Barbados Ridge Complex

	Page No.
Synopsis of Operations and Cruise Objectives	2
Seabeam	4
Gravity	4
3.5 kHz Profiles	4
Seismic Reflection	4
Deep-Tow Seismic Reflection	5
Acoustic Navigation	6
Heat Flow	6
Pop-up Pore Pressure Instrument	7
Coring	9
Porewater Geochemistry	9
Summary	12
Brief Log of Cruise	13
Table of Stations	20
List of Scientific Staff	25
Track Chart for each leg	

SYNOPSIS OF OPERATIONS AND CRUISE OBJECTIVES

The general scientific objectives of the cruise were to investigate the outflow of fluids from the frontal region of the Barbados Ridge accretionary complex, to establish the distribution of fluid outflow, the chemistry of the fluids and the nature of the structural features that control and are influenced by fluid escape. Several techniques were employed during the cruise.

Deep-tow seismic and 3.5 kHz profiling:- detailed structural information on fluid outflow features.

Single channel conventional seismic profiling:- structural setting of individual outflow features.

Seabeam bathymetry:- detailed bathymetric maps of areas containing outflow features.

PUPPI (Pop Up Pore Pressure Instrument):- direct measurement of porewater pressure gradient beneath seafloor to establish outflow rates.

Heatflow:- detection of advective heat transport by outflow of fluids and thermal anomalies produced by warming effects of fluids.

Coring:- samples for porewater geochemistry and thermal conducting (in situ-conductivity was also measured using Cambridge heat-flow probe).

Acoustic navigation with seabed transponders:- provide accurate location of ship, deep-tow seismic streamer, heat flow probes, and corer.

The cruise was divided into two legs, because the deep-tow conductivity cable used for the deep-tow seismic reflection profiler could not be operated from the ship at the same time as the travel wire used for coring and heat flow, as only one winch suitable for either cable was available. In the first leg (28 June - 12 July, Bridgetown, Barbados to Bridgetown, Barbados), the deep-tow seismic profiler was employed in conjunction with Seabeam surface seismic reflection profiling with water guns and 3.5 kHz profiler, three PUPPIs were deployed and two acoustic navigation nets set down. In the second leg (13 July - 27 July, Bridgetown, Barbados to San Juan, Puerto Rico), heat flow was measured, cores were taken, three deployments and six retrievals of PUPPIs were made, and two more acoustic nets were established.

The operations were concentrated in six principal areas:

Area 1 was the location of the drill sites from DSDP Leg 78A and ODP Leg 110. It had preliminary heat flow measurements made in it from the Robert D Conrad in 1985, and in

1987 extensive heatflow measurements were taken from Le Suroit together with deep-tow high resolution sidescan sonar (SAR) and 3.5 kHz profiling. During the cruise 4 PUPPI deployments were made and coring carried out for porefluid geochemistry, together with further Seabeam and a watergun seismic profile. An acoustic navigation net was used.

Area 1A encloses the outer part of a two-ship seismic reflection line (C465) run across the accretionary wedge in 1985. The area was to have served as a control for Area 1, and have a heat flow profile measured across it. With loss of time in other areas only a Seabeam swath and watergun profile were made through Area 1A.

Area 2 which was the subject of intensive investigation with heatflow, Seabeam and watergun profiling in 1985, was investigated further with acoustically navigated heatflow to study detailed variation across the thrust-outcrop wedges that appear to be zones of fluid outflow. Two deep-tow seismic profiles were run to study the detailed structure of the thrust outcrop wedges.

Area 3 extends westward from Area 2 along a two ship seismic reflection line (C479-480) and terminates over a diapir in the eastern part of the forearc basin. Seabeam swaths and watergun seismic profiles were run in the area, and heatflow measurements were made to fill in gaps in the heatflow profile made in 1985 and extend it further west.

Area 4 is a region of extensive mud diapirism on the ocean floor in front of the accretionary wedge. It was noticed on a GLORIA sonograph in 1980, and Seabeam and surface watergun seismic reflection were run over it in 1985, but it was not until it was investigated with SAR and subsequently the Nautila in 1987 that the nature of this field of multiformed mud volcanoes and carbonate capped mounds was truly appreciated. Three deep-tow seismic lines, heatflow measurements and piston coring were conducted in the area, together with further Seabeam swaths and surface seismic reflection.

Area 2-4 The region between Areas 2 and 4, and around 4 was given complete coverage with Seabeam and watergun seismic profiling.

Area 5 lies in south of the complex where the layer of accreted sediment is thick and composed primarily of turbidites. The accreted thrust slices are broadly folded with a thrust spacing of 3 to 4 km. Thrust-outcrop wedges are well developed and measurement of heatflow in 1987 showed heatflow from the first thrust-outcrop wedge to be about 40% higher than from the ocean floor or the first anticlinal crest. Heatflow measurements were made further landward over the 2nd and 3rd thrust-outcrop wedges and PUPPI deployments were made in the first thrust-outcrop wedge and anticline together with coring for porewater

geochemistry. Seabeam swaths and watergun seismic profiles were also made.

Seabeam

The Seabeam system on Conrad was operated for almost the whole of the first leg of the cruise. It was not used in the second leg of the cruise. Its performance was good. The system crashed twice for short periods and there were recurrent problems with interference from the 3.5 KHz transducer, which required vigilance from the scientific watchkeepers. The data were invaluable especially during Leg 2 for the siting of stations for heatflow, coring and PUPPIs. In addition to the normal bathymetry, several days of beam intensity data were recorded.

The broad coverage between Areas 2 and 4 showed major changes in the deformation of the accretionary wedge reflected in its bathymetry, with linear escarpments along the fronts of major thrust sheets and numerous mounds produced by mud diapirism. Results from the traverses in Area 3 and up to Areas 1 and 1A indicate major changes in the type and orientation of structures that were not known from seismic data and conventional bathymetry. A new field of diapirs was discovered at the foot of the wedge at 13°10'N.

Gravity

Gravity was measured using the Bell gravimeter throughout the cruise. Although the data are not immediately pertinent to the detailed investigation of water outflow, they have value in studies of the shape of the oceanic basement surface and density variations within the accretionary wedge.

3.5 kHz Profiler

The 3.5 kHz profiler was used throughout the cruise except during the operation of the deep-tow seismic system. It provided valuable data on the stratigraphy of the near-surface sediments, although its resolution of sharp lateral variation in structure was poor, because of the large water depth.

Seismic Reflection

The system on Conrad with two 80 cu in waterguns performed reliably with very few problems. Although the system is designed to tow at 9 knots, at this speed the records were considerably more noisy than those obtained at a speed of six knots, and over the accretionary complex they showed very little information beneath the sea bed when towed at the higher speed. The streamer tended to tow deep, as measured by the delay on the sea surface ghost, and when towed at 5 to 6 knots the tow cable needed to be shortened considerably to prevent the streamer towing excessively

deep. The depth of the waterguns was nominally 35 ft (10.7 m). This would not be optimal, given the frequency spectrum of the water gun, but the data indicated that they were probably towing more shallowly. Very good data were obtained on some of the slow speed runs at 2 knots or less when the deep-tow system was being used, but runs at slow speed with the sea on the quarter gave rather variable results.

Deep-Tow Seismic Reflection

The Cambridge deep-tow seismic streamer system was used with a watergun source at the surface and has its own 3.5 kHz profiler mounted on the weight stand at the head of the streamer. Before being used on the Conrad, the system had been modified to improve the tuning of the 3.5 kHz transducer and extend the range of filter settings. Although these modifications had been tested in the laboratory, the 3.5 kHz transducer did receive signals when first deployed. The fault was corrected and subsequently the 3.5 kHz transducer worked well. Unfortunately this was not true for the rest of the system. Of the eight deployments or attempted deployments, only two were carried through, one in Area 2 and one in Area 4, and on neither of these two did the seismic system work satisfactorily. In the earlier deployment in Area 4 the seismic system was too noisy for even the direct wave to be recorded clearly. This noise was not obviously of solely acoustic origin. In the later deployment in Area 2, the seismic system was working far better in detecting the seismic signal, but had strong 60 Hz interference.

A series of problems plagued the deep-two seismic system. These included water leakage into the preamplifier at the head of the streamer, damage to the plugs on the cable connecting the streamer to the main pressure case that houses most of the electronic systems caused by clumsy handling with a boat hook, damage to the cable connecting the streamer to the main pressure case by bending and chafing, water leakage into the longer (25 m) of the two streamers, and cut cables, damaged connectors and damaged pressure case for the pre-camp caused by entanglement with the ships screw.

Among the many individual problems besetting the system the principal fault was apparently low sensitivity to the seismic signal with high noise. The noise was worst during raising or lowering, but did not appear to be purely acoustic in origin. An airgun of 320 cu in capacity was used as a source for a short period to give a comparison with previous successful runs of the system. While the airgun gave better signal-to-noise than the watergun, it was not better than twice, and showed that the source was not a major problem. In the last and most successful deployment, 60 Hz noise was the main problem. This had probably been present all the time, but only showed itself when other sources of noise had been alleviated. This noise must have originated in the ship, but was being transmitted up the deep-two cable in frequency modulated form along with the seismic signal. All attempts to locate its source were unsuccessful. Even with the 60 Hz noise, the

signal-to-noise was better than on any previous deployment. In this deployment all the improvements to the circuiting for amplifying and filtering the seismic signal had been removed. It remains a possibility that with processing to suppress 60 Hz and its harmonics, some useful seismic data will be gained.

Towing from an A-frame at the ships side rather than from the stern, restricted the courses that could be run without danger of the tow cable rubbing against the ship's side.

Acoustic Navigation

An Oceano acoustic navigation system owned and operated by GENAVIR (IFREMER) of France was used on the cruise. Ten transponders were available to be used, of which one was used on the deep tow, the heatflow probes and the corer to provide the location of these devices as well as the ship. It had been the intention to make use of three transponders already deployed in Area 4 the previous year by Le Suroit, but unfortunately these transponders did not have sufficient power left in their batteries to be useful. Only one of them responded, and it died soon after. It was surmised that they had not been correctly switched off the previous year.

Two nets of three transponders each were deployed in Areas 1 and 4 in Leg 1, and once their operational cycle had been synchronised with the firing cycle of the waterguns, gave excellent service, locating the ship and deep tow up to 20 km away from the centre of the net. The third group of three transponders was deployed in Area 2 and Area 5 in Leg 2.

The system gave no serious trouble, although a circuit board in one of the Hewlett Packard computers controlling it failed and was replaced at the midcruise port call. All the transponders were retrieved.

The acoustic navigation system was essential for the detailed work conducted at the toe of the wedge in Areas 1, 2, 4 and 5.

Heatflow

Two heatflow systems were used, the Lamont-Doherty system, with thermistors attached to a core barrel or steel probe, and the Cambridge system, in which the thermistors are contained in a steel tube that acts as 'string' to the steel 'bow' that forms the strength member of the system. The Cambridge system also has small heating elements in the thermistor string and can make in-situ measurements of thermal conductivity. Both systems performed well. The Lamont system, after an initial problem with the sensitivity of the thermistors, suffered only its usual problem of progressive loss of individual thermistor measurements from wear and tear on the thermistors and

connectors each time the probe was stuck into the seabed.

The Cambridge system had more failures, but was more consistent while operating satisfactorily. Problems with the Cambridge system were an initially too high sensitivity of thermistors as with the Lamont system, leaks into the pot at the top of the thermistor string, a faulty connector breaking up under pressure, a leaky connector, and a spontaneous reset of the microprocessor controlling the measurement and recording sequence. Some difficulties were experienced in getting the system back into its launching cradle because of the motion between the ship and the probe.

The Cambridge system had the advantage over the Lamont system of slightly greater penetration, more closely spaced thermistors to better define the temperature profile, and in situ conductivity measurements. On the other hand, the Lamont system could be attached to a core barrel to give heat flow at precisely the same point as porewater geochemical measurements were made, and also through its sonic telemetry system the thermal gradients could be estimated in 'real time' giving great operational flexibility in the choice of the succeeding heatflow measurement sites. The availability of both systems was a great advantage and allowed long runs of heatflow measurements, interrupted only by the retrieval and development of each system.

Pop Up Pore Pressure Instrument

The objectives of the Pop Up Pore Pressure Instrument (PUPPI) programs was to determine the ambient differential pore pressure gradient within the sediments in different areas of the accretionary complex and to use this data to estimate the nature and rates of any pore water advection within the area. To achieve this objective, 6 PUPPI deployments were made using three instruments. PUPPI station Nos 1 and 2 (Area 5) were located in the first 'thrust outcrop wedge', at the toe of the complex, and at the top of the adjacent anticlinal fold respectively. PUPPI station Nos 3, 4 and 5 were all in Area 1 in the toe of the complex. PUPPI station Nos 3 and 4 were in locations of relatively high heatflow whereas No 5 was in a location of relatively low heat flow. PUPPI station No 6 was located approximately 3 miles East of the toe of the wedge in Area 1 and was considered to be a reference site.

Prior to the deployment of the instruments, two wire tests were performed using the hydro winch and midships extending davit to test all the functions of the acoustic command systems, the release mechanisms, the pressure transducers and the solid state data loggers. The PUPPIs were constructed on a platform mounted aft of the starboard midship's davit on the 01 deck. This has about 4.5 metres of freeboard and enabled the PUPPI probes to be assembled vertically whilst underway. They were all launched using either the extending davit or the main crane without incidence (apart from a deluge of oil from a fractured hydraulic pipe during the launch of PUPPI 3). All the instruments apart from No 6 were deployed within range of the acoustic bottom

CRUISE REPORT
R/V ROBERT D CONRAD 2907
27 June - 27 July 1988
Barbados Ridge Complex

	Page No.
Synopsis of Operations and Cruise Objectives	2
Seabeam	4
Gravity	4
3.5 kHz Profiles	4
Seismic Reflection	4
Deep-Tow Seismic Reflection	5
Acoustic Navigation	6
Heat Flow	6
Pop-up Pore Pressure Instrument	7
Coring	9
Porewater Geochemistry	9
Summary	12
Brief Log of Cruise	13
Table of Stations	20
List of Scientific Staff	25
Track Chart for each leg	

navigation and surveyed in after deployment to accurately fix their sea floor positions. In general the instruments drifted about 100 m westwards during their free-fall. All instruments released from the sea floor without difficulty and were recovered on the starboard side using a grappling hook and the lift from the main crane onto the fantail.

In addition to the pore pressure record the deceleration profiles of the probe insertions provide some interesting data. Sharp decelerations occur during penetration at sites 4 and 6 which correlate well with each other. This contrasts with sites 2 and 3 which show relatively uniform deceleration profiles. The accelerometer failed to work at site 1 and over-ranged at site 5, presumably after striking an unusually stiff sediment.

An absolute pressure transducer with data logger was installed on PUPPI deployments 3 and 6 (logger VI). The intention was to record tidal pressure variations at the sea bed for comparison with the tidal cycles observed in the pore pressure measurements. The results were somewhat noisy, but good enough after averaging to show 12 and 24 hour tidal cycles. Results could be simply improved by increasing the duty cycle of the data collection (was 1 in 12) at the expense of battery duration. Unfortunately only very small pore pressure tidal cycles were observed during these deployments.

Laboratory determined sediment permeabilities and porosities are needed to calculate pore water advection velocities. However, the following summary gives a preliminary assessment of the observed pore pressure gradients and the direction of pore water flow.

PUPPI 1 - Thrust outcrop wedge, small +ve heatflow (HF) anomaly (Area 5). Penetrated 3-4 metres. Battery failure after about 8 days prevents an accurate assessment of any residual pore pressure.

PUPPI 2 - Top of anticlinal fold (Area 5). Penetrated 3.4 m. A positive pore pressure gradient of approximately 81 Pa/m was recorded indicating significant upward pervasive flow in the anticline. Small tidal cycles were observed on the lower port (about 3 metres below the mudline) indicating relatively low permeabilities.

PUPPI 3 - Toe of wedge, high HF (Area 1). Penetrated 4.3 m. A positive pore pressure gradient of approximately 21 Pa/m was recorded indicating a slow pervasive flow of pore waters.

PUPPI 4 - Toe of wedge, high HF (Area 1). Penetrated 4m. A large positive pore pressure gradient of approximately 77 Pa/m was recorded indicating a significant upward flow of pore waters.

PUPPI 5 - Toe of wedge, low HF (Area 1). This PUPPI hit something unusually stiff. It experienced decelerations of greater than 2g and only penetrated to about 1.2 m but remained upright. The insertion pore pressure record is complex which may be partly accounted for by a problem with the data logger. The problem with the data logger prevented any further data being collected after 3 days. Most importantly, the in situ zero calibration was not recorded.

PUPPI 6 - Reference site about 3 miles seaward of the wedge (Area 1). Penetrated 4.4 m. A large positive pore pressure gradient of approximately 81 Pa/m was recorded indicating a significant upward flow of pore waters.

Coring

There were eleven core stations. In addition to the information provided by the cores themselves on near surface sediment type and stratigraphy, the cores were taken to measure thermal conductivity, and to make measurements of the geochemistry of the porewater to detect fluid advection. Information on the porewater geochemistry is given in the following section.

All the cores were taken using one core barrel with the exception of the first in which two were used. In the first deployment the core barrels were strongly bent. From previous experience, the cause of this was suspected to be a resistant ash layer preventing further penetration by the corer, and subsequently only one barrel was used to avoid the problem.

All except one core station were successful in taking lengths of core between 4.1 m and 5.6 m. In the unsuccessful station, the trigger wire had become wrapped around the corer. A major limitation on the amount of coring done was, in practice, the number of qualified people actually available to run the coring winch and carry out other tasks in preparation and retrieval of the corer, which was only two.

Pore Water Geochemistry

The objectives of the geochemistry programme were three-fold: (1) to identify chemical reactions which might impart gradients into pore water profiles in the upper few meters of the sediment column; (2) to determine directions and rates of vertical advection inferred from modelling vertical profiles in these pore water gradients; and (3) to establish whether areas of rapid up- or down-flow are associated with local features of heatflow, pore pressure and topography (faulting).

Pore waters were extracted from 12 to 14 depths of four to six meter-long piston cores and their

trigger cores at ten sites. Pore waters were extracted at in situ temperatures with Manheim squeezers and were immediately filtered onboard ($0.4 \mu\text{m}$). 117 pore water samples were analysed onboard ship for salinity and dissolved chloride (Cl), sulfate (SO_4), silica (Si), fluoride (F), calcium (Ca), magnesium (Mg) and alkalinity (TA). Aliquots of these samples were sealed and returned to the lab at Lamont Doherty Geological Observatory for subsequent determinations of H_2O -isotopes (D/H, O-18 by P. Vrolik at Univ. Michigan), and for dissolved potassium, sodium, lithium, strontium, germanium and barium. In addition, we measured whole sediment resistivity at intervals along each core in order to estimate formation factors (corrections to diffusivities). Core segments and squeeze cakes were returned to Lamont for additional work (identification of ash layers and authigenic carbonates).

In general, we observed both strong and weak linear, and non-linear gradients in all measured pore water constituents. We presently recognize three classes of reactions responsible for the observations:

Reaction (1): Background organic diagenesis. Characterized by very weak positive (TA and often Ca) and negative (SO_4) gradients. Gradients are virtually linear since these sediments are poor in organic carbon: in situ oxidation reactions within the upper few meters are very slow, but slight curvature in the gradients cannot be inferred to be due solely to advection.

Reaction (2): Methane oxidation, mostly by sulfate reduction. The source of the methane is from below, within the complex, associated with lo-Cl formation waters. Characterized by positive gradients in TA, and negative gradients in Cl, F, SO_4 and Ca. Strengths of the gradients depends upon the depth at which the $\text{CH}_4 + \text{SO}_4$ reaction occurs. In general, curvature in the Ca- and Cl-gradients reflects advection rather than reaction since Cl is conservative and the carbonate-precipitation reaction is inferred to occur only at the CH_4 -oxidation horizon, which is generally below core recovery.

Reaction (3): Volcanic ash alteration. Weathering of sediment-hosted volcanic ash layers impart negative Mg-gradients and positive Ca-gradients to the pore water interval between the sediment-water interface and the ash layer. Curvature in these gradients above the top-most ash layer can be inferred due to advection rather than reaction.

	Inferred Reactions	Inferred Adv'n	Comments
PC1	Shallow (>4 m) CH ₄ -ox'n & Ash alteration	Up ≤ 20 mm/yr (?)	Strong TA, F, Ca, Mg, SO ₄ & weak Cl gradients
PC2	Shallow (>4 m) CH ₄ -ox'n & Ash alteration	Up ~ 20 mm/yr	Strong Ta, F, Ca, Mg, SO ₄ gradients
PC3	CH ₄ -oxidation @ 4.5 m; Ash alteration @ ~ 5 m	Up 15-20 mm/yr	Strong Ta, F, C, Mg, SO ₄ & weak Cl gradients
PC5	Background diagenesis Deep Ash or Basement Alteration (> 100 m)	(?)	No Cl, F, SO ₄ & weak Ca Mg, TA Gradients = Linear
PC6	CH ₄ -ox'n @ 90 cm; Ash alteration at about 6 m	Up ~ 8 mm/yr	Strong gradients in all; Top of mud volcano
PC7	Background Diagenesis	Down (?)	Very weak gradients; Nearly linear
PC8	Background Diagenesis Very deep (>100 m) Ash or basement alteration	(?)	Very weak gradients; Nearly linear; No Cl, F gradients
PC9	Background Diagenesis Very Deep (>100 m) Ash	(?) (?)	Very weak gradients; nearly linear, weak Cl gradient
PC10	Background Diagenesis Very deep (> 100 m) Ash or Basement Alteration	Up (?)	Ref Site: very weak gradients = linear; no Cl gradient
PC11	Background Diagenesis Ash Alteration in upper 40 cm		Ash layer - 34 cm; weak non- linear gradients = reaction. No Cl gradient

Summary

The cruise was a successful one. With the exception of the deep-towed seismic reflection system, all the equipment worked well. The Seabeam bathymetry and seismic reflection profiles provided new information on the variation of structure in the accretionary complex and located new fields of diapiric activity. Preliminary evaluation of the data from the Lamont heatflow probe shows that the whole region of the mud volcanoes in Area 4 is one of high heat flow, which at about 80 mW/m^2 is greater than expected from ocean crust of Late Cretaceous age and 35 mW/m^2 is greater than measurements on the ocean floor in Area 5, and also shows that heatflow in Area 3, 110 km west of the front of the wedge, is about 'normal', ie 55 mW/m^2 . The use of the PUPPIs and porewater geochemistry successfully demonstrated water flow out of the sea bed in the region of the toe of the wedge. There was clear agreement between the two techniques in Area 5, but in Area 1 the PUPPI measurements indicated quite strong outflow where porewater geochemistry showed little evidence of outflow. The results are at present only preliminary and the reasons for the apparent conflict are currently being explored.

G K Westbrook November 1988

BRIEF LOG RV ROBERT D. CONRAD CRUISE RC2907 BARBADOS RIDGE

Monday 27 June 1988

- 1524 Departed from Bridgetown, Barbados.
- 1740 Began Seabeam mapping along track to Area 5.
- 2245 Water-gun seismic profiling with Seabeam commenced.

Tuesday 28 June 1988

- 0900 Finished track from Barbados with water gun and Seabeam.
- 1030 Tested two Pop Up Pore Pressure Instruments (PUPPIs).
- 1400 Ran Seabeam to location for deployment of deep-tow seismic streamer.
- 2000 Preparation for deployment of deep-tow begun.
- 2153 Deep-tow deployed. Systems tested at depth of 200m with water gun firing, and then lowered to 2820m. Signals from streamer lost and 3.5 kHz transducer in deep-tow did not pick up returned signal.

Wednesday 29 June 1988

- 0500 Deep-tow recovered.
- 0648 Deployed PUPPI in thrust-outcrop wedge at foot of accretionary wedge.
- 0810 Seabeam swaths commenced.
- 1250 Water-gun seismic profiling added to Seabeam.
- 1954 Finished seismic profiling.
- 2047 PUPPI deployed in crest of first major anticline at foot of accretionary wedge.
- 2206 Seabeam swath to deep-tow deployment location.
- 2355 Began preparation for deep-tow deployment.

Thursday 30 June 1988

- 0100 Deep-tow deployment broken off before putting in water, because of failure of power circuits in instrument while under test on deck.
- 0130 Seabeam swaths started.
- 0500 Water-gun seismic profiling added to Seabeam. Courses made to Area 4, going through potential mud-diapir targets on ocean floor and accretionary wedge.
- 1910 Finished Seabeam and water guns.
- 1935 Began to set up acoustic beacon network in Area 4 by trying to switch on three acoustic beacons deployed by Le Surcit in 1987. Only one beacon responded. Three more beacons were deployed.

Friday 1 July 1988

- 0300 Calibration of acoustic net in Area 4 undertaken.
- 0800 Seabeam and water-gun seismics commenced on lines to east of

Area 4.

Deep-tow deployed, but became entangled in ship's propellor while acoustic beacon was being fixed to the cable. System was retrieved and brought back aboard with some damage to it.

1500 Commenced Seabeam and water-gun seismics in box between Area 4 and Area 5.

Saturday 2 July 1988

0045 Retrieved seismic streamer and water guns.

0100 Deployed deep-tow. Cable was let out to 3714 m before deployment was stopped because of loss of carrier signal. The 3.5 kHz transducer in the deep-tow worked very well, but the amplitude of the signal from the deep-tow streamer was very low. Another problem was that it was not possible for the ship to make a southerly course, because the deep-tow cable towed from the A-frame on the starboard side led beneath the ship's hull and was in danger of scraping against it as the length of cable paid out increased.

0700 Deep-tow retrieved.

0700 Began wire test of the third PUPPI.

0830 Test of PUPPI successfully completed.

1219 Recommenced Seabeam and water-gun seismic lines in box between Areas 4 and 2.

Sunday 3 July 1988

0100 Continued Seabeam and water-gun seismic lines. Join to earlier survey to north completed, and coverage extended to south.

0740 Started to pressure test small pressure vessel at front of deep-tow streamer on hydrographic wire. Vessel lowered to 4600 m.

Monday 4 July 1988

0220 Finished pressure test, which was successful.

0335 Recommenced Seabeam and water-gun seismic survey in area south and east of mud volcano field.

0954 Deployed deep-tow at 13 44 N 57 38 W on northerly course to cross mud volcano field. 3.5 kHz transducer working well, but response of streamer still poor. Deep-tow run was continued using one water gun and towing the near-surface seismic streamer with all its tow-cable and weighted section on board.

Tuesday 5 July 1988

0113 Deep-tow run, as such, finished, deployment continued at 2 knots while a total length of 8300 m of cable was streamed to improve lay of cable in winch when it was reeled in.
Deep-tow recovered.

0443 Commenced Seabeam and water-gun seismic lines, four of them at 6 knots over mud volcano field, and a further three across the

mud volcano at 14 20 N.

Wednesday 6 July 1988

Continued Seabeam and water-gun seismic lines in northwestern part of Area 2 until

2000 Deployed deep-tow going east along two-ship multichannel seismic line Conrad 480, at Lat. 14 22.5 N. A 320 cu. in. air gun was also used as a source. Signal to noise was still poor. Several changes in ship's speed and towing depth were made in an attempt to find the cause of the noise. With 4033 m of wire out the seismic channel of the deep-tow failed, apparently due to a break in the circuit.

Thursday 7 July 1988

0330 Deep-tow retrieved. Its streamer was found to have water in it.
0408 With surface streamer and water gun deployed, Seabeam and seismic profiles were recommenced in the west of Area 2.
2200 Deep-tow deployed at 14 22.5 N on two-ship seismic line 480, going east. There was a severe problem with 60 Hz noise on the seismic channel.
2250 Deep-tow retrieved and more Seabeam and seismic profiling begun.

Friday 8 July 1988

0730 Deep-tow deployed on line 480 going west from toe of accretionary wedge. System working well except for 60 Hz noise on seismic channel, although this was less severe than before. The ship was unable to hold a course to the west, because of a northward current setting the ship over the tow cable. A northwestward course was adopted. After the northwest course, an eastward course was followed.

Saturday 9 July 1988

0750 Deep-tow retrieved.
0830 Commenced Seabeam and water-gun seismic reflection on line to and along Area 3. Westward course continued until end of day.
2340 Commenced small survey of diapir in eastern margin of forearc basin.

Sunday 10 July 1988

0243 Commenced eastward track along Area 3.
0853 Commenced track northward to Area 1.
1742 Deployment of acoustic transponder net in Area 1 begun.
2324 Calibration of acoustic transponder net completed.

Monday 11 July 1988

- 051 Deployed third PUPPI in Area 1.
- 0208 Recommended Seabeam and water-gun seismic profiles, on track through Area 1, northward to Area 1A, through Area 1A, and then southward towards Barbados.
- 1700 Stopped water-gun seismic profiling.

Tuesday 12 July 1988

- 0117 Extended Seabeam survey of diapir in eastern flank of forearc basin.
- 0252 Stopped Seabeam.
- 1718 Arrived Bridgetown, Barbados to change over the deep-tow conducting cable for trawl wire. The reel to take the conducting cable was not ready until late morning (local time), and wire winding was delayed. Further delay resulted from absence of crane operators after 1600 (local time), to change reels on the wire winding machine.

Wednesday 13 July 1988

- 1918 Departed Bridgetown, Barbados after completing change of wires. Made course for Area 5.

Thursday 14 July 1988

- 3905 Commenced deploying acoustic beacon net in Area 5
- 1735 Finished calibration of acoustic beacon net.
- 1 53 Started to survey the positions of PUPPIs 1 and 2 relative to the acoustic beacon net.
- 1844 PUPPI 2 retrieved.
- 1 43 Further location of PUPPI 1 carried out.
- 2030 PUPPI 1 retrieved.

Friday 15 July 1988

- 3234 Started first piston core station 1 (2 pipes plus heat-flow sta.1) in Area 5.
- 3300 Piston core 1 retrieved. Core barrel bent to 35 degrees. Considerable flow-in.
- 3 20 Second heat-flow station in Area 1 commenced with Cambridge system. Sensitivity of thermistors was set too high and temperature of near bottom water was cooler than expected, so thermistor recordings went out of range. The probe was brought back to the surface. Also, a leak developed in the pressure vessel at the top of the thermistor string.
- 1216 Cambridge heat-flow probe redeployed. System worked well, and the measurements were continued for the rest of the day.

Saturday 16 July 1988

Heat flow continued until

0855 Heat-flow probe retrieved at end of station 2A-M.
1105 Core station 2 commenced (1 pipe plus heat-flow sta.3).
1445 Core station 2 finished successfully.
1535 Core station 3 commenced (1 pipe).
1740 Core station 3 finished successfully.
1755 Began retrieval of acoustic beacon network.
2052 Finished retrieval of acoustic beacons.
2105 Transit to Area 1.

Sunday 17 July 1988

1630 Dropped PUPPI 4 in area of high heat flow on the accretionary wedge in Area 1, and surveyed seabed positions of PUPPIs 3 and 4.
2050 Retrieved PUPPI 3.
2153 Started core station 4 (1 pipe with heat flow sta.4).

Monday 18 July 1988

0114 Retrieved core 4. Trigger wire had become tangled around core barrel, and did not work properly, resulting in very poor penetration.
0210 PUPPI 5 deployed.
0325 Core station 5 commenced (1 pipe).
0627 Core station 5 finished. Good core taken in area of high heat flow on accretionary wedge.
0736 PUPPI 6 deployed.
0818 Commenced transit to Area 4.
2200 Deployed Lamont heat-flow probe in Area 4. Brought back to surface at 2240 to remedy faulty thermistor.
2324 Lamont heat-flow probe deployed again on heat flow station 5.

Tuesday 19 July 1988

Heat-flow station 5A-G continued until:-

1200 Heat-flow probe recovered.
1325 Core station 6 (1 pipe) begun.
1608 Core 6 retrieved. Core contained gas which burned with blue flame when lit.
1732 Heat-flow station 6 started with Cambridge probe.

Wednesday 20 July 1988

0102 Heat-flow probe stopped recording thermistor values.
0215 Heat-flow probe retrieved, to end station 6A-D.
0400 Heat-flow probe redeployed on station 7.

Thursday 21 July 1988

- 1331 Heat-flow probe recovered, at end of station 7A-K.
- 0140 Core station 7 (1 pipe plus heat-flow sta. 8) begun.
- 0225 Core 7 recovered.
- 0336 Heat-flow station 9 commenced, with Lamont heat-flow probe.
- 0952 Heat-flow station 9A-E finished.
- 0956 Began recovery of acoustic beacons in Area 4.
- 1048 Completed recovery of the 3 acoustic beacons and began transit to Area 2.
- 1722 Began deployment of acoustic beacons in Area 2.
- 2030 Finished deployment and calibration of acoustic navigation net.
- 2228 Core station 8 (1 pipe plus heat-flow sta. 10) begun.

Friday 22 July 1988

- 0044 Core 8 recovered.
- 0135 Core station 9 (1 pipe plus heat-flow sta. 11) begun.
- 0419 Core 9 recovered.
- 0516 Commenced heat-flow station 12 with Cambridge probe.
- 0700 Heat-flow station 12 interrupted, because the system stopped transmitting. Probe was brought to surface.
- 0950 Recommenced heat-flow station 12.
- 1730 Heat-flow station 12A-P finished.

Saturday 23 July 1988

- 0610 Commenced heat-flow station 13 with Lamont probe.
- 0738 Heat-flow station 13A-H finished.
- 0818 Began to retrieve acoustic navigation network.
- 1055 Third, and last, transponder of net retrieved.
- 1300 Started transit to Area 3.
- 1900 Commenced heat-flow station 14 in Area 3 with Cambridge probe.

Sunday 24 July 1988

- 0300 Finished heat-flow station 14A-E.
- 0517 Commenced heat-flow station 15 with Lamont probe farther west in Area 3.
- 0616 Finished heat-flow station 15A-D.
- 0616 Started transit to Area 1.
- 0905 Began core station 10 (1 pipe plus heat-flow sta. 16) in Area 1. PUPPI 6 released from seabed while corer in bottom.
- 1240 Retrieved core 10.
- 1300 PUPPI 6 retrieved.

Monday 25 July 1988

0030 Began survey of seabed position of PUPPI 5.
0111 Finished PUPPI survey.
0130 Began core station 11 (1 pipe plus heat-flow sta. 17).
Released PUPPI 5 while core was being brought to the surface.
0530 Core 11 retrieved.
0651 PUPPI 5 retrieved.
0700 Started release of PUPPI 4, but malfunction of deck unit delayed
release until 0733.
0946 PUPPI 4 retrieved, and recovery of acoustic beacons begun.
1330 Last of the acoustic beacons retrieved, and passage to San Juan,
Puerto Rico commenced.

Tuesday 26 July 1988

On passage to San Juan, Puerto Rico.

Wednesday 27 July 1988

1215 Arrived at San Juan, Puerto Rico. Cruise ended.

NOTE all times are GMT (Z) unless stated otherwise.

Station Summary for Conrad 29-07
Barbados to Puerto Rico
June 27 - July 27 1988

Station Number	Date	Time GMT	Position		Comments
			Latitude	Longitude	
<u>PUPPI</u>					
PUPPI-1	Jun 29	06 48	12 18.463	57 28.727	(GPS). Deployed on thrust outcrop wedge
		07 24	12 18.657	57 28.645	Landed
PUPPI-1	Jul 14	23 30			Retrieved
PUPPI-2	Jun 29	20 47	12 18.912	57 29.633	Sat Deployed
		21 32	12 19.029	57 29.718	Landed on anticline
PUPPI-2	Jul 14	18 44			Retrieved
PUPPI-3	Jul 11	0051	15 31.948	58 41.907	(GPS 2 Sat.)
		01 30	15 32.026	58 41.858	Landed in toe of wedge. High HF
PUPPI-3	Jul 17	20 50			Retrieved
PUPPI-4	Jul 17	16 31	15 31.903	58 42.258	Deployed in toe of wedge. High HF
		17 10	15 31.892	58 42.302	Landed
PUPPI-4	Jul 25	09 46			Retrieved
PUPPI-5	Jul 18	02 10	15 31.986	58 41.992	Deployed in toe of wedge. Low HF
		02 56	15 31.999	58 42.053	Landed
PUPPI-5	Jul 25	06 51			Retrieved
PUPPI-6	Jul 18	07 36	15 31.989	58 38.457	Deployed at Ref site east of wedge
		08 13	15 31.988	58 38.513	Position assumes westward drift
PUPPI-6	Jul 24	23 20			Retrieved

Heat Flow

HF-1	Jul 15	02 00	12 19.032	57 29.544	L-DGO Instrument on core #1
HF2-A	Jul 15	13 38	12 18.611	57 31.311	Cambridge Instr.
HF2-B	"	14 50	12 18.651	57 31.095	"
HF2-C	"	16 00	12 18.530	57 30.863	"
HF2-D	"	17 11	12 18.554	57 30.596	"
HF2-E	"	18 18	12 18.515	57 30.435	"
HF2-F	"	19 29	12 18.533	57 30.270	"
HF2-G	"	20.36	12 18.472	57 30.083	"
HF2-H	"	23.20	12 18.837	57 32.491	"
HF2-I	Jul 16	01 10	12 18.632	57 31.915	"

HF2-J	"	02 32	12 18.579	57 31.589	"
HF2-K	"	05 00	12 18.922	57 33.570	"
HF2-L	"	06 18	12 18.897	57 33.242	"
HF2-M	"	07 33	12 18.863	57 32.898	"
HF-3	Jul 16	11 02	12 19.041	57 29.749	Grad = 60.7 on core #2
HF-4	Jul 18	21 53	15 31.964	58 42.258	Snagged trig. line on core #4
HF5-A	Jul 19	00 47	13.48.626	58 45.734	Grad = 90
HF5-B	"	03 02	-	-	Fell over
HF5-C	"	03 08	13 49.200	57 44.952	Grad = 80
HF5-D	"	05 28	13 49.539	57 44.361	Grad = 98
HF5-E	"	07 11	13 49.906	57 44.375	Grad = 89
HF5-F	"	09 08	13 50.190	57 43.910	Grad = 96
HF5-G	"	10 36	13 50.340	57 43.640	Grad =
HF6-A	Jul 19	21 32	13 50.661	57 43.259	Cambridge Inst
HF6-B	"	22 14	13 50.811	57 43.119	"
HF6-C	"	22 51	13 50.733	57 43.297	"
HF6-D	Jul 20	00 47	13 51.036	57 43.470	"
HF7-A	Jul 20	05 31	13 51.079	57 43.784	"
HF7-B	"	07 14	13 51.286	57 43.897	"
HF7-C	"	08 46	13 51.891	57 43.901	"
HF7-D	"	10 42	13 51.387	57 44.522	"
HF7-E	"	12 17	13 51.204	57 44.694	"
HF7-F	"	13 47	13 51.404	57 44.994	"
HF7-G	"	15 11	13 51.577	57 45.373	"
HF7-H	"	16 42	13 51.589	57 45.524	"
HF7-I	"	17 51	13 51.495	57 45.653	"
HF7-J	"	20 04	13 51.740	57 45.874	"
HF7-K	"	22 27	13 52.561	57 44.797	"
HF-8	Jul 21	03 00	13 51.865	57 45.965	Grad = 72 on core #7

HF9-A	Jul 21	06 55	13 50.302	57 43.670	Grad = 96
HF9-B	"	06 59	13 50.346	57 43.614	Grad = 90
HF9-C	"	07 30	13 50.383	57 43.645	Grad = 91 or 101
HF9-D	"	08 30	13 50.622	57 43.478	Grad = 99
HF9-E	"	08 41	13 50.587	57 43.440	Grad = 133 ?
HF-10	Jul 21	23 19	14 22.690	57 44.613	On core #8
HF-11	Jul 22	02 50	14 22.388	57 44.130	On core #9
HF-12A	Jul 22	06 39	14 22.908	57 47.082	Cambridge Inst.
HF-12B	"	08 02	14 22.512	57 46.747	"
HF-12C	"	09 19	14 22.554	57 46.517	"
HF-12D	"	10 35	14 22.429	57 46.061	Aborted-poor signal
HF-12E	"	10 44	14 22.453	57 46.018	
HF-12F	"	11 41	14 22.49	57 45.67	Abort-poor signal
HF-12G	"	12 00	14 22.490	57 45.614	"
HF-12H	"	13 09	14 22.492	57 45.270	"
HF-12I	"	14 11	14 22.511	57 44.903	Fell over
HF-12J	"	14 20	14 22.510	57 44.849	"
HF-12K	"	15 17	14 22.509	57 44.505	"
HF-12L	"	16 04	14 22.509	57 44.505	Fell over
HF-12M	"	16 13	14 22.516	57 44.227	"
HF-12N	"	16 44	14 22 545	57 44.150	Abort-No signal
HF-12O	"	21 09	14 22.475	57 44.150	"
HF-12P	Jul 22	22 08	14 22.485	57 44.028	"
HF-13A	Jul 23	01 27	14 22.475	57 43.986	Grad = 56
HF-13B	"	02 05	14 22.409	57 43.859	Grad = 60
HF-13C	"	02 44	14 22.463	57 43.701	Fell over
HF-13D	"	02 50	14 22.482	57 43.658	Grad = 56
HF-13E	"	03 54	14 22.494	57 43.253	Fell over
HF-13F	"	04 00	14 22.497	57 43.234	Grad = 55
HF-13G	"	05 40	14 22.529	57 42.470	Grad = 54

HF-13H	Jul 23	06 19	14 22.540	57 42.459	Grad = 59
HF-14A	Jul 23	19 21	14 23.261	58 32.319	Cambridge Inst.
HF-14B	"	20 16	14 23.090	58 32.197	"
HF-14C	"	23 02	14 22.687	58 33.929	"
HF-14D	"	00 44	14 22.626	58 33.534	"
HF-14E	Jul 24	01 41	14 22.251	58 34.975	"
HF-15A	Jul 24	07 01	14 22.398	58 48.147	Grad = 62
HF-15B	"	08 07	14 22.635	58 48.557	Grad = 49
HF-15C	"	09 17	14 22.476	58 48.874	Grad = 70
HF-15D	Jul 24	10 15	14 22.131	58 48.648	Grad = 67
HF-16	Jul 24	20 35	15 32.057	58 38.502	Grad = 82 on core #10
HF-17	Jul 25	03 03	15 31.963	58 41.968	Grad = 84 on core #11

Station Number	Date	Time GMT	Position Latitude	Longitude	Comments
Piston Cores					
No length (m)					
01 (9.6)	Jul 15	02 00	12 19.032	57 29.544	2-piper core bent. In anticline Area 5
02 (5.6)	Jul 16	11 02	12 19.041	57 29.749	In anticline area 5
03 (5.0)	Jul 16	15 35	12 18.592	57 28.619	No heat flow. In thrust outcrop wedge, Area 5
04 (0)	Jul 18	21 53	15 31.964	58 42.258	Snagged trig. line
05 (4.1)	Jul 18	03 25	15 31.916	58 42.238	No heat flow. In toe of wedge, Area 1.
06 (4.3)	Jul 19	13 25	13 50.397	57 43.719	Mud volcano, Area 4. No heat flow
07 (4.6)	Jul 21	03 00	13 51.865	57 45.965	In toe of wedge near thrust outcrop, Area 4.
08 (4.1)	Jul 21	23 19	14 22.690	57 44.613	In toe of thrust outcrop wedge, Area 2
09 (4.6)	Jul 22	02 50	14 22.388	57 44.130	At foot of thrust outcrop wedge, Area 2
10 (4.6)	Jul 24	20 35	15 32.057	58 38.502	In Ref site east of wedge, Area 1
11 (5.6)	Jul 25	03 03	15 31.963	58 41.968	In toe of wedge, Area 1

SCIENTIFIC STAFF FOR THE CONRAD CRUISE 2907

Leg 1		Leg 2	
1	Graham Westbrook (Birmingham)	Co-Chief	Graham Westbrook (Birmingham) Co-Chief
2	Marcus Langseth (Lamont)	Co-Chief	Marcus Langseth (Lamont) Co-Chief
3	Jenny Collier (Cambridge)	Deep Tow	Christine Peirce (Cambridge) Heatflow
4	Christine Peirce (Cambridge)	Deep Tow	Jenny Collier (Cambridge) Heatflow
5	Ted Mills (Birmingham/Cambridge)	Deep Tow	Innes Ferguson (Birmingham) Sci Watch
6	Innes Ferguson (Birmingham)	Sci Watch	Philip Froelich (Lamont) Geochem
7	Peter Schultheiss (IOS)	PUPPI	Rick Mortlock (Lamont) Geochem
8	Steve McPhail (IOS)	PUPPI	Jane Warger (Lamont) Geochem
9	Melvin Mason (Cambridge)	Deep Tow	Mike Hobart (Lamont) Heatflow
10	Seigfried Lallemand (ENS)	Sci Watch	Tim Owen (Cambridge) Heatflow
11	Pierre Henry (ENS)	Sci Watch	Peter Schultheiss (IOS) PUPPI
12	Joyce Miller (Rhode Island)	Seabeam	Steve McPhail (IOS) PUPPI
13	Scott Ferguson (Rhode Island)	Seabeam	Siegfried Lallemand (ENS) Sci Watch
14	Frank Robinson (Lamont)	Dep Sci Off	Pierre Henry (ENS) Sci Watch
15	John Dibernardo (Lamont)	Watergun	Frank Robinson Sci Officer
16	Rick Bartholemew (Lamont)	Computer	Rick Bartholemew (Lamont) Computer
17	Bernard Jegot (IFREMER)	Bot Nav	Bernard Jegot (IFREMER) Bot Nav
18	Jean-Michel Raillard (IFREMER)	Bot Nav	Jean-Michel Raillard (IFREMER) Bot Nav
19	Nancy Breen (Lamont)	Sci Watch	Nancy Breen (Lamont) Sci Watch
20	Joe Stennett (Lamont)	Sci Off	John Dibernardo (Lamont) Watergun

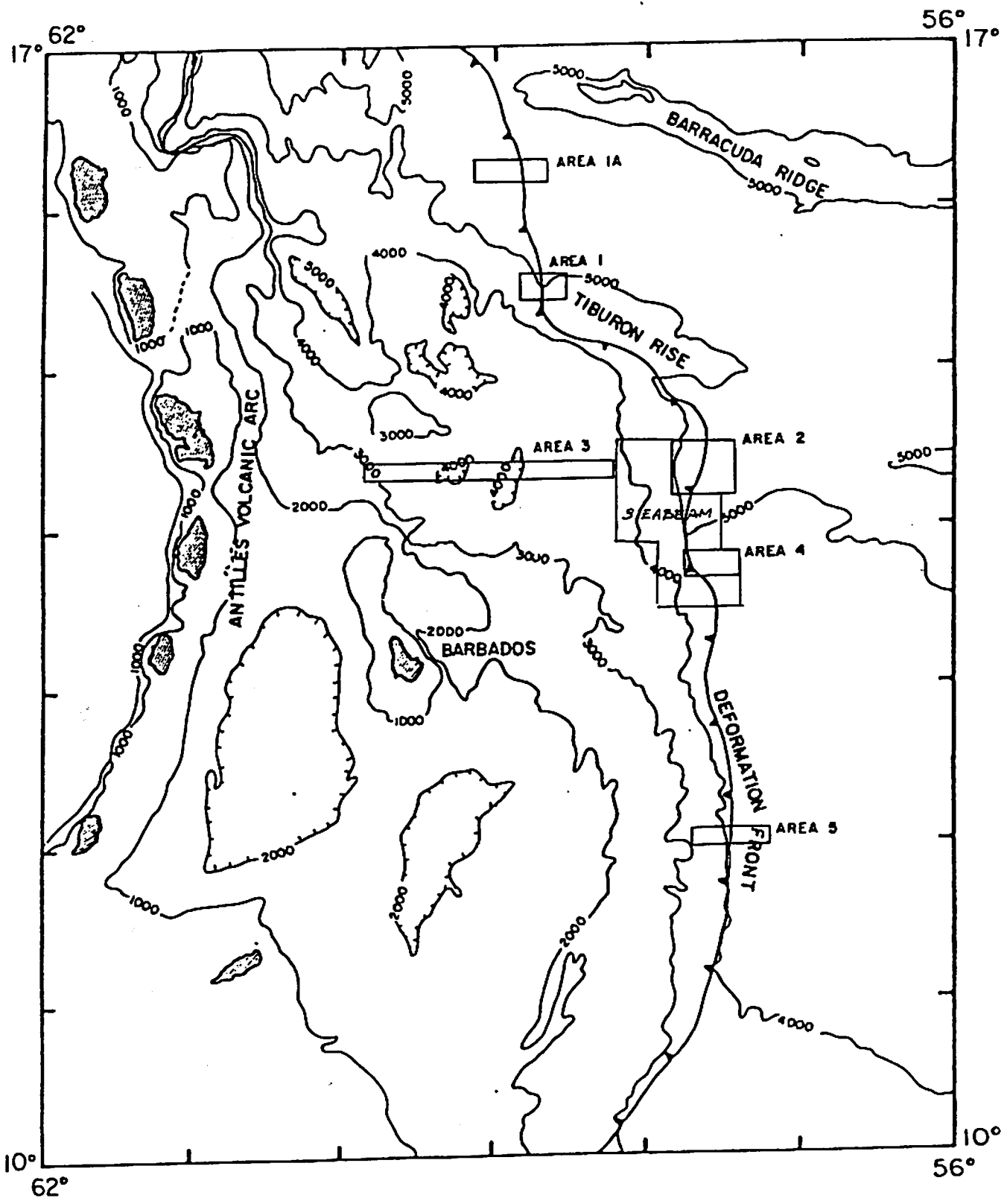


Figure 1. Map of the Barbados Ridge Complex showing areas of surveys.

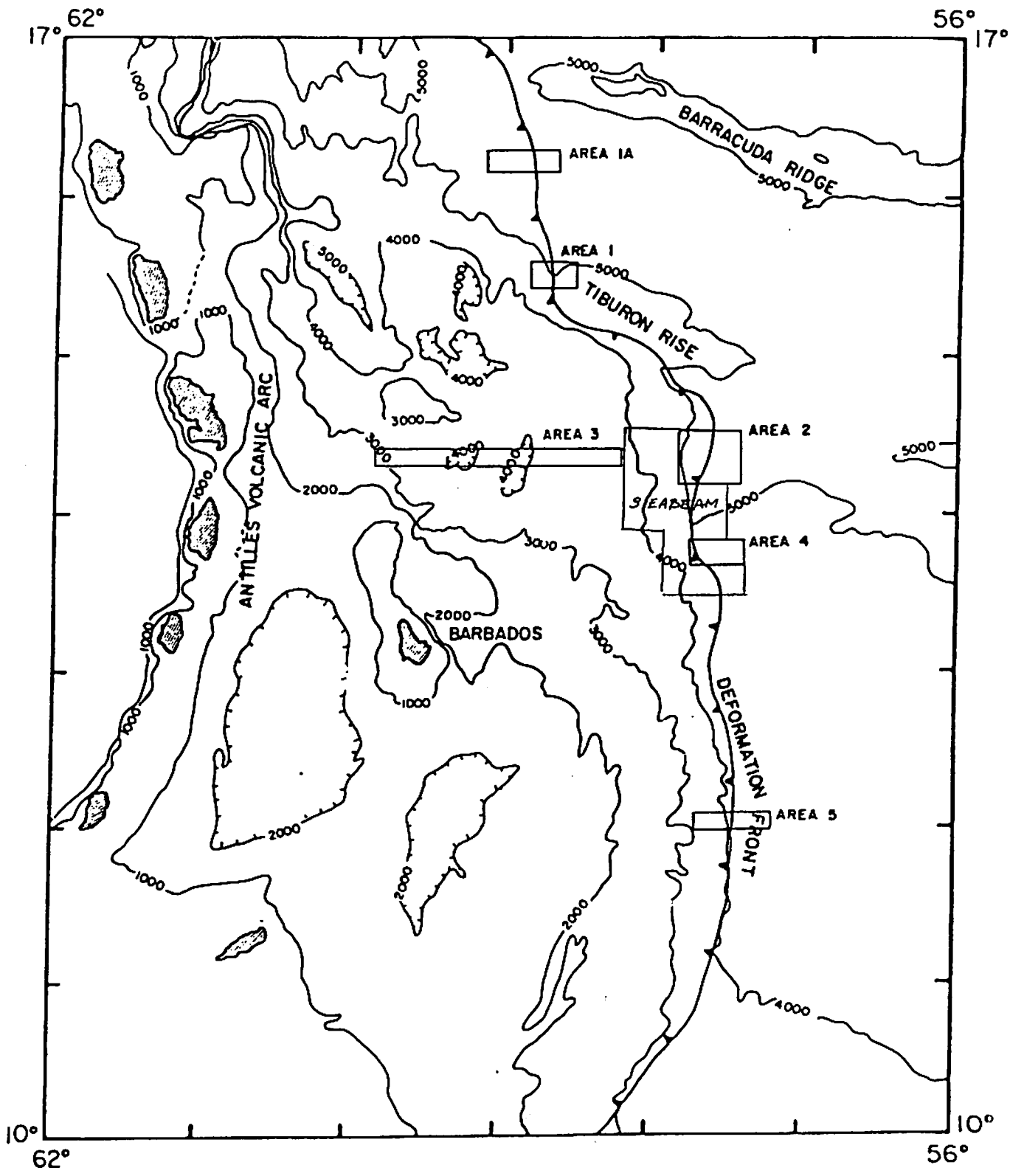
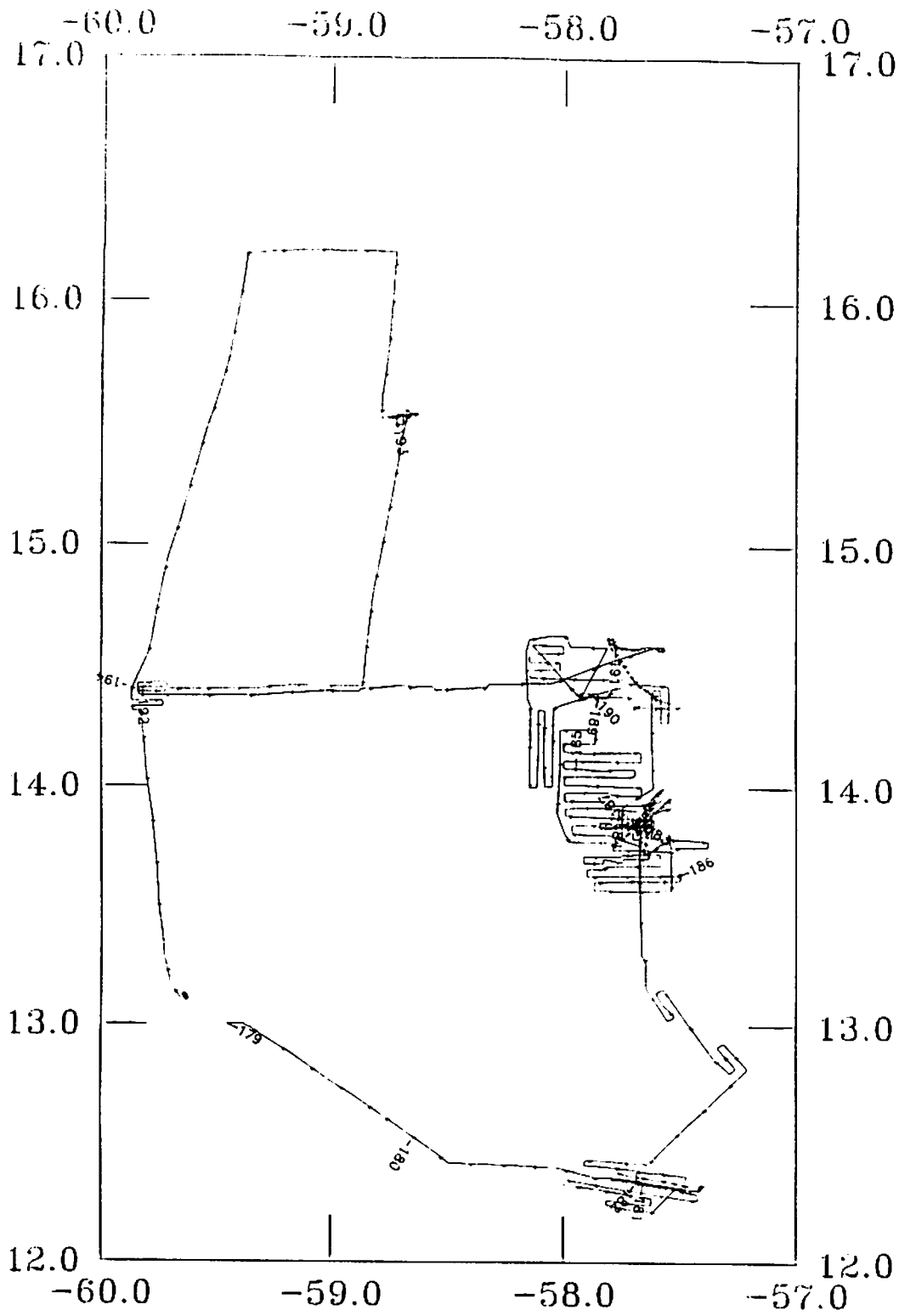
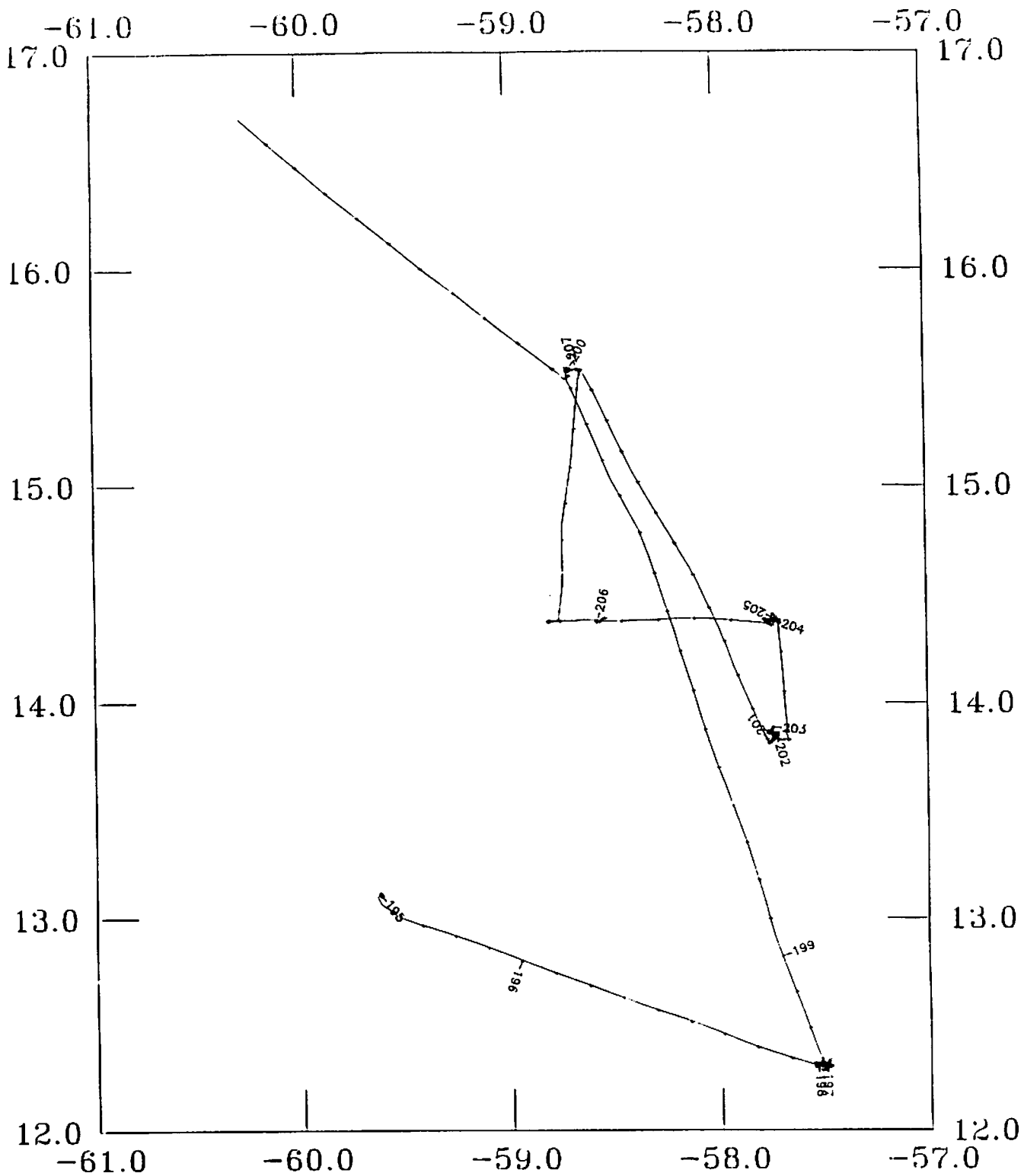


Figure 1. Map of the Barbados Ridge Complex showing areas of surveys.



RC2907 Leg 1
27 JUNE - 12 JULY 1988



RC2907 Leg 2
 13 JULY - 27 JULY 1988