OCEAN DRILLING PROGRAM

LEG 110 SCIENTIFIC PROSPECTUS

LESSER ANTILLES FOREARC

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INTRODUCTION

One general goal of modern geologic and geophysical research is to understand the varying mechanisms and conditions by which accretionary prisms develop. These prisms form by the transfer of material from one plate to another at convergent margins, and as such, represent the product of a major tectonic process. It is not clear, however, how growth by offscraping at the toe, underplating at the base, or deformation at the inner (arcward) front of accretionary prisms are apportioned in the forearc. Moreover, the mechanisms of each of these three modes of accretion and the conditions which promote or inhibit them are generally uncertain. Other major uncertainties in accretionary prism evolution are the amount and distribution of progressive deformation, the displacement paths in such deformation, and the configurational changes in forearc basins that reflect adjustments to prism growth.

Leg 110 drilling is planned to address the problems concerning the geohydrological and structural styles associated with an active accretionary margin by coring, logging, and performing a series of downhole experiments within the Barbados forearc. The Resolution is scheduled to sail from Bridgetown, Barbados, on June 27 and return on August 17, 1986. Three proposed drilling locations on the Lesser Antilles forearc form a transect of sites perpendicular to the accretionary front (Figures 1, 2, and 3). One other site, a reference hole located on the oceanic plate, will be drilled and logged. Results from drilling at these sites will complement results from DSDP Leg 78A, which drilled three sites in the same region during 1981 (Biju-Duval, Moore, et al., 1984).

GEOLOGICAL SETTING

The Lesser Antilles forearc forms the leading edge of the Caribbean plate, and lies above the west-descending slab of Atlantic oceanic lithosphere. Growth of the forearc probably began in early Cenozoic time, but an older origin cannot be disproven. The present convergence in the vicinity of Legs 78A and 110 drilling is nearly orthogonal at a rate of about 2 cm/yr (Minster and Jordan, 1978).

The Barbados prism is bounded by deformation fronts on its east and west sides (Westbrook, et al., 1984) (Figure 1). The outer deformation front is the active thrust fault on which a sediment packet is currently being transferred from the under-riding Atlantic plate to the over-riding prism toe. The western, or inner, deformation front separates the deformed Barbados Ridge complex from the undeformed Cenozoic forearc basin succession (>6 km thick) of the Tobago Trough.

The geometry of the top of the accretionary prism at the northern Barbados forearc is defined by a relatively steep lower slope within 50 km of the outer deformation front (Figure 2) and a shallower east-tilted, but highly irregular, upper slope to the west. The upper slope rises to a poorly defined crestal zone, the structural high of the prism. The structural high is underlain by rocks that accreted early in the history of the forearc, as

indicated at its only subaerial exposure, the island of Barbados (Speed, 1981).

In the drilling area, the subducted oceanic plate carries a pelagic to hemipelagic sedimentary section approximately 700 m thick with material as old as late Cretaceous (Biju-Duval, Moore, et al., 1984). The lower surface of the prism is defined by a detachment fault (décollement) along which Atlantic oceanic crust and a section of relatively undeformed, acoustically coherent strata, are underthrust beneath the prism. This detachment boundary is a significant component in the accretionary process. Fluid and thermal conditions along this boundary and associated thrust faults are certain to exert a major control on accretionary processes. A primary objective of Leg 110 is to study the geohydrological conditions existing at the décollement and related faults by drilling Sites LAF-1 and -2 (Figures 1, 2, and 3; Table 1).

STRUCTURAL AND GEOHYDROLOGICAL CHARACTERISTICS

The toe of the northern Barbados forearc has been particulary revealing with regards to understanding the accretionary process, primarily because the prism there is thin and easily penetrated by reflection profiling and because the region was the focus of DSDP Leg 78A drilling (Biju-Duval, Moore et al., 1982, 1984; Westbrook et al., 1982). DSDP Leg 78A drilling results indicate that the upper half of a 400 m thick hemipelagic section is offscraped at the deformation front whereas the lower half of the section is underthrust an unknown distance below the prism. The position of the detachment fault that separates the offscraped from the underthrust sediment is apparently stratigraphically controlled in an anomalously porous (75%) smectite mud lying between less porous (50%) mud, as indicated by physical properties data from the oceanic reference site (DSDP Site 543). This reference site was not logged during Leg 78A; during Leg 110 an adjacent hole (LAF-0) will be drilled, not cored, and logged to complete the reference data set (Figure 2; Table 1).

Numerical modelling (Shi and Wang, 1985; Ngokwey, 1984), mechanical models (Davis, 1984; Von Huene and Lee, 1983), and direct observation (Biju-Duval, Moore, et al., 1984) suggest that pore fluids are a principal factor controlling accretionary processes and associated structural styles. Fluids at near-lithostatic pressure were measured during Leg 78A at Site 542 in a thrust splaying off the décollement, implying that the detachment fault itself also probably contains overpressured fluids. Therefore, the separation of the sediment section into an offscraped and an underthrust section at the Barbados forearc is evidently controlled by an overpressured horizon. The underthrust section proceeds below the prism owing to reduction of effective stress at the base of the prism. Underthrusting will presumably continue as long as low effective stress conditions are maintained. In addition to overpressured fluids, the detachment zone and associated thrusts in the offscraped sequence are marked by foliated dewatered mud. Offscraped rocks away from the faults are inclined an average of 25° and have suffered a mean porosity loss of 10% relative to the oceanic reference section.

Anomalous temperatures (16° C) were measured in fluids near the décollement at Site 541. Evidently, warm fluids are migrating up the

detachment surface from greater depths because these temperatures exceed those expected from conductive heat flow. A recent surface heatflow survey carried out in the region of Legs 78A and 110 drilling revealed heat flow highs between Sites 541 and 542 and just seaward of the deformation front (Langseth et al., 1985). These heatflow anomalies can be explained by fluid migration along faults that surface nearby. Pore water studies suggest, however, that these fluids do not leak ubiquitously through the lower slope (Gieskes, et al., 1984). Apparently, pore water is expulsed through fault zones where the sediments have increased fracture permeability. Sensitive temperature measurements, packer experiments, and detailed pore water analyses planned for Leg 110 will attempt to determine the magnitude of fluid flow along faults and within the unfaulted sediment.

Assuming lithostatic pressure conditions exist at the level of the décollement, this would yield a lateral pressure gradient along the detachment zone of 1 mPa/km. The distribution of pressures across the Barbados forearc will be measured during Leg 110 at the reference site LAF-0, and on the prism at sites LAF-1, -2, and -3. These data will provide information of both the vertical and horizontal pressure gradients and structural deformation styles associated with this accretionary wedge, the décollement, and within the underlying undeformed oceanic sediments.

DRILLING PLAN

The Leg 110 drilling/coring program is scheduled for an area that was previously drilled on DSDP Leg 78A. For that reason, more is known about the region and its operational challenges than is normal for an ODP voyage. Experience at DSDP Sites 541 and 542 has shown that penetrating the overpressured detachment zone (or décollement) results in severe hole-cleaning problems and sticking of the drill string. A successful coring program for Leg 110 requires, therefore, isolating the overpressured zone behind casing to allow sampling and testing of the underlying formation.

The overall operational plans for drilling at each of the proposed sites are briefly summarized in Table 1. A very preliminary site occupation schedule is shown in Table 2. Due to the uncertainties of setting casing across the décollement, the time estimates shown may be completely revised and operations adjusted during the cruise. Drilling equipment and plans for Leg 110 support three alternatives for stabilizing the hole across the décollement. In addition to standard rotary and reentry systems, ODP will have a triple casing string, drill-in casing, and a downhole motor and under-reamer available for operations at LAF-1. Sites LAF-2 and -3 require only standard ODP operational systems since these are projected to penetrate to, or above, the décollement, respectively. LAF-0 will be drilled, but not cored, for logging and pressure measurements. Three additional sites have been included in this prospectus as alternates to the proposed program (Figure 4) (Appendix). Piston coring operations are recommended for these alternate sites.

Special experiments planned for Leg 110 include packer tests, pore pressure and fluid sampling, temperature measurements, and logging (including the borehole televiewer). A rotatable TAM packer will be on board for the

first time, in addition to a TAM straddle packer for testing of formation pore pressures and permeability. The Barnes/Uyeda tool will support pore fluid sampling, temperature measurements, and pore pressure measurements.

In order to answer some of the questions posed for this cruise, substantial whole-round sampling for pore water geochemistry and physical properties is envisioned. In consultation with the Information Handling Panel, therefore, special sampling arrangements have been made for this leg; however, the importance of the detailed biostratigraphic record is recognized and every effort will be made to accommodate the goals of the entire Program. An extensive porewater analysis program will be carried out to clearly identify pore fluid migration and diffusion. Five centimeter long, whole round samples and/or portions of split cores will be taken approximately every 10-15 meters in order to trace fluids through unfaulted and faulted sediments. Detailed geotechnical testing is also planned, including consolidation, triaxial, and creep tests. Two consolidation samples (10-cm whole-rounds), will be tested from each lithologic unit. Triaxial testing will be carried out on 10-15 cm long samples trimmed to approximately 2-3 cm diameter, thus leaving material for stratigraphic continuity. The triaxial samples, done in sets of four, will also be performed for each major lithostratigraphic unit for an estimated total of 8 sets. The creep test experiments will utilize 2-3 samples trimmed to triaxial sample dimensions.

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TABLE 1
LEG 110 OCEAN DRILLING PROGRAM
LESSER ANTILLES FOREARC

Location of Proposed Sites

SITE No.	LATITUDE	LONGITUDE	WATER DEPTH	MAX. PENETRA.	OPERATIONS	PRIMARY OBJECTIVES
LAF-0	15°30'N	58°38'W	5000	900	Wash/log	Establish logged oceanic reference site.
LAF-1	15°30'N	58°44'W	5025	860	HPC/XCB/Re-entry Logging, Special Experiments	Penetrate and sample décollement; structural, geotechnical, and hydrogeologic character of accretionary wedge.
LAF-2	15°31'N	58°46'W	4800	850	HPC/XCB/RCB Logging, Special Experiments	Structural, geotechnical, and hydrogeologic character of accretionary wedge.
LAF-3	15°30'N	58°54'W	4275	500	HPC/XCB/RCB Logging, Special Experiments	Structural, geotechnical, and hydrogeologic character of accretionary wedge.
*LAF-3A	15°31'N	58°49'W	4650	600	HPC/XCB/RCB Logging Special Experiments	Structural, geotechnical, and hydrogeologic character of accretionary wedge.
*LAF-4	14°20'N	57°53'W	4400	600	HPC/XCB/RCB Logging	Accretion style, structural geology.
*LAF-5	14°20'N	57°46'W	5200	400	HPC/XCB/RCB Logging	Accretion style, folds, thrusts.
*LAF-6	12°48'N	60°05'W	2200	700	HPC/XCB/RCB Logging	Forearc basin Accretion

* Alternate Sites

TABLE 2
LEG 110 OCEAN DRILLING PROGRAM
SITE OCCUPATION SCHEDULE

SITE	LOCATION	TRAVEL TIME (Days)	ON SITE OPERATIONS (Days)	DEPARTURE DATE (Approximate)
	DEPART: Bridgetown, Barbados			27 June 1986
	Underway:	1		
LAF-1	15°30'N 58°44'W		27	25 July 1986
LAF-2	15°31'N 58°46'W		14	9 Aug 1986
LAF-3	15°30'N 58°54'W		7	15 Aug 1986
LAF-0	15°30'N 58°38'W		3	17 Aug 1986
	Underway:	0.6		
	ARRIVE: Bridgetown, Barbados			17 Aug 1986
		1.4	51	

ALTERNATE SITES

LAF-3A	15°31'N 58°49'W		9	
LAF-4	14°20'N 57°53'W		8	
LAF-5	14°20'N 57°46'W		8	
LAF-6	12°48'N 60°05'W		6	

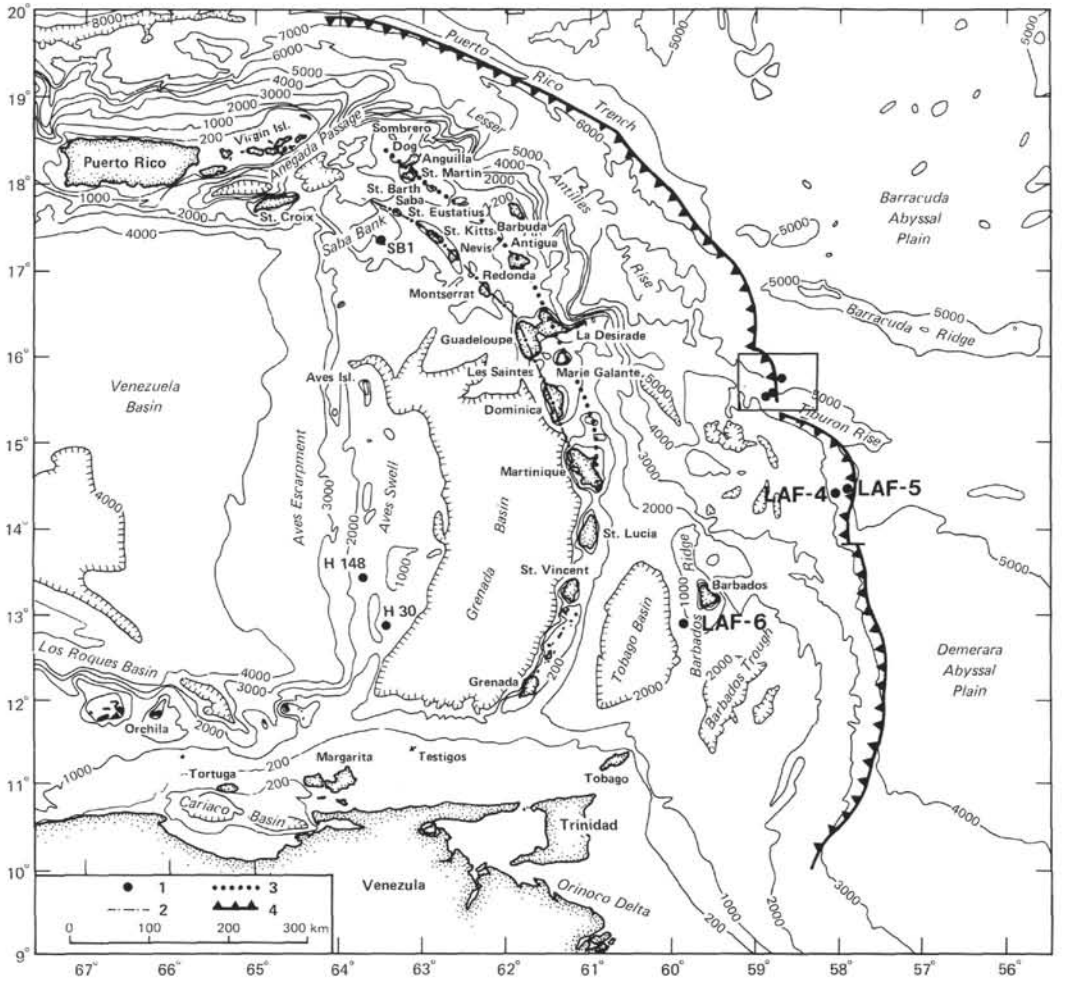


Figure 1. Eastern Caribbean. (Bathymetry [isobaths: 200m and every 1000m] is slightly modified from Case and Holcombe [1980]). Square insert is location of DSDP Leg 78A drilling and proposed ODP Leg 110 operations area.

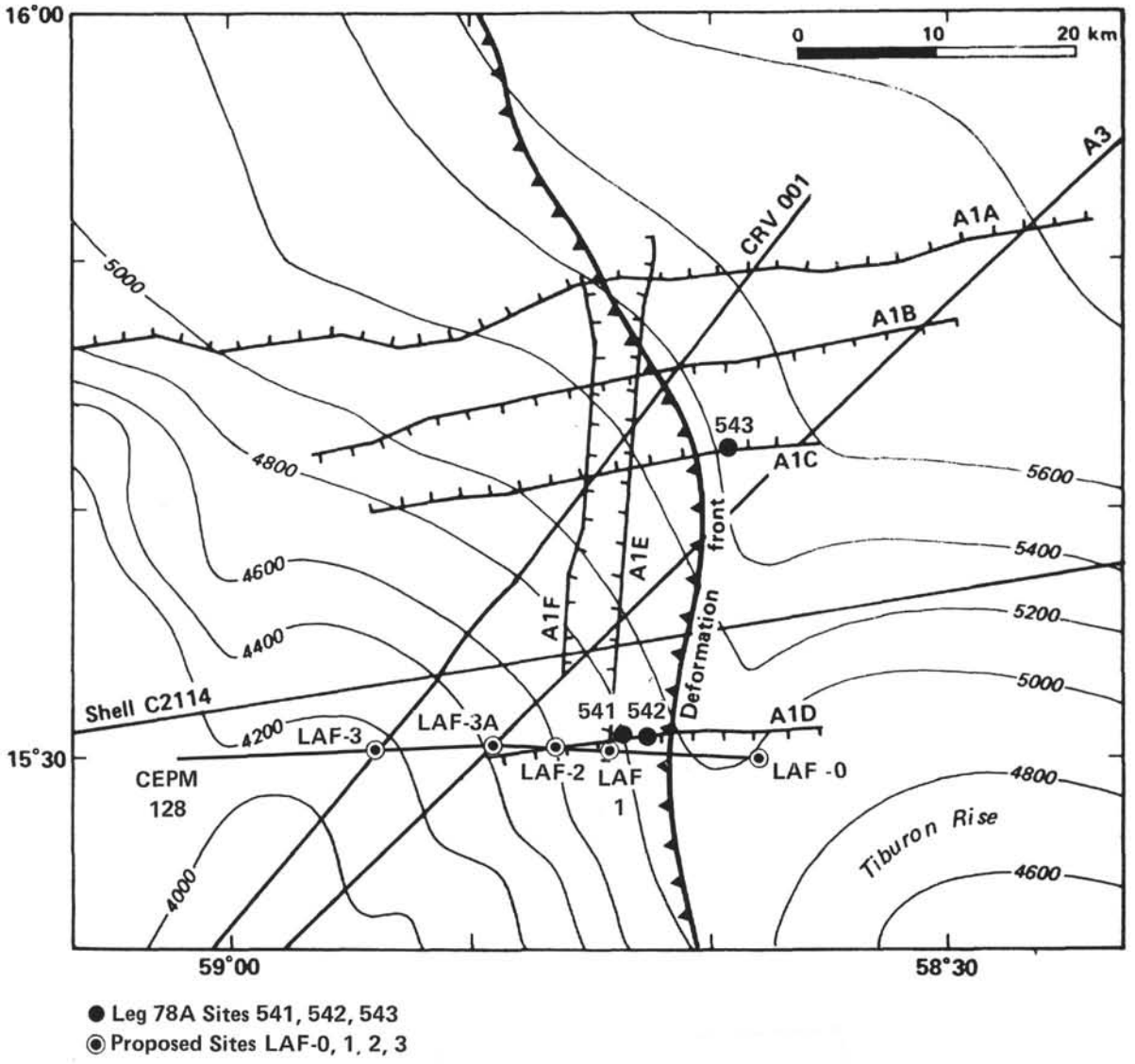


Figure 2. Detailed location of proposed sites for ODP Leg 110 drilling, position of the previously drilled DSDP Leg 78A holes, bathymetry (meters), and track lines of available seismic reflection profiles. See inset in Figure 1 for map location. (Slightly modified from Moore, Biju-Duval, Natland, et al., 1984).

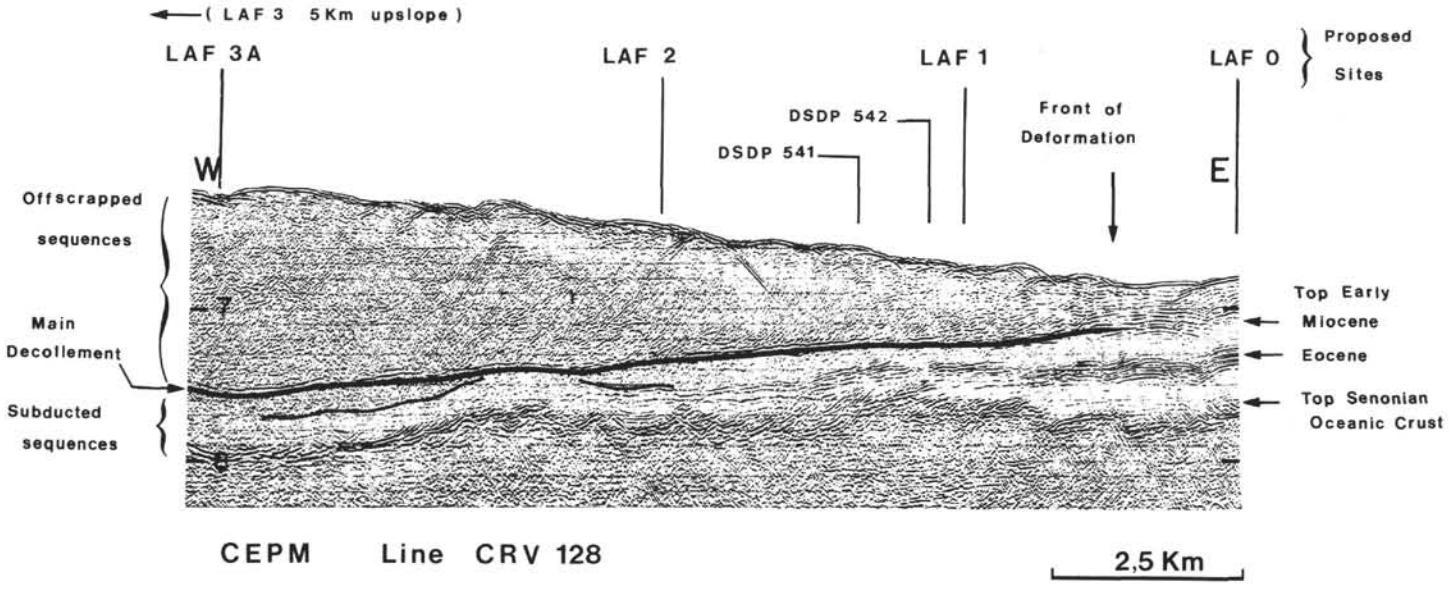


Figure 3. Multichannel seismic profile (time section) across the Barbados forearc with local geologic features and location of proposed drillsites. (See Figures 1 and 2 for location of profile).

SITE NUMBER: LAF-0 (Lesser Antilles Forearc)

POSITION: $15^{o}30'N$ $58^{o}38'W$ SEDIMENT THICKNESS: 900 m

WATER DEPTH: 5000 m PRIORITY: 1

PROPOSED DRILLING PROGRAM: Wash to basement (Note: Cored previously)

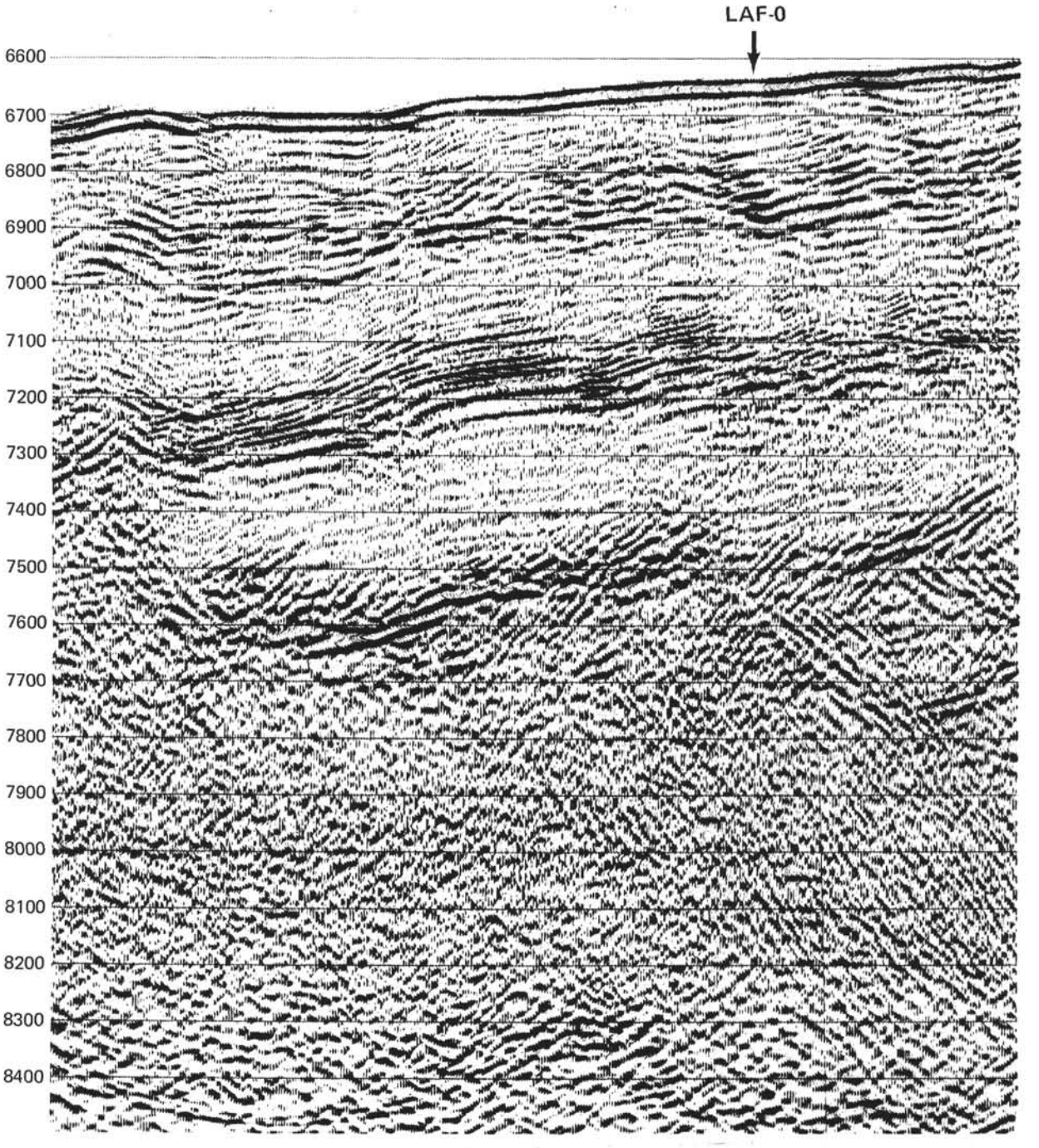
SEISMIC RECORD: CEPM 128, S.P. 25

HEAT FLOW: Yes LOGGING: Yes

PACKER EXPERIMENTS: Yes

OBJECTIVES: 1) Establish a reference hole in the oceanic sediment section adjacent to the LAF-1, 2 and 3 transect to measure physical and hydrological properties of sediment prior to apparent deformation.

SEDIMENT TYPE:
0-200 m : Quaternary to middle Miocene pelagic mud and mudstone.
200-500 m : Early Miocene to Eocene (?) radiolarian clay.
500-900 m : Eocene to Cretaceous pelagic clay.


LAF-0
6600
6700
6800
6900
7000
7100
7200
7300
7400
7500
7600
7700
7800
7900
8000
8100
8200
8300
8400

SITE NUMBER: LAF-1 (Northern Barbados Ridge)

POSITION: 15°30'N 58°44'W SEDIMENT THICKNESS: 850 m

WATER DEPTH: 5025 m PRIORITY: 1

PROPOSED DRILLING PROGRAM: Three holes as follows;

1) APC (oriented)/XCB : 420 m (Décollement at 400 m)
2) RCB (wash) / Packer : 420 m
3) Re-entry / RCB : 860 m

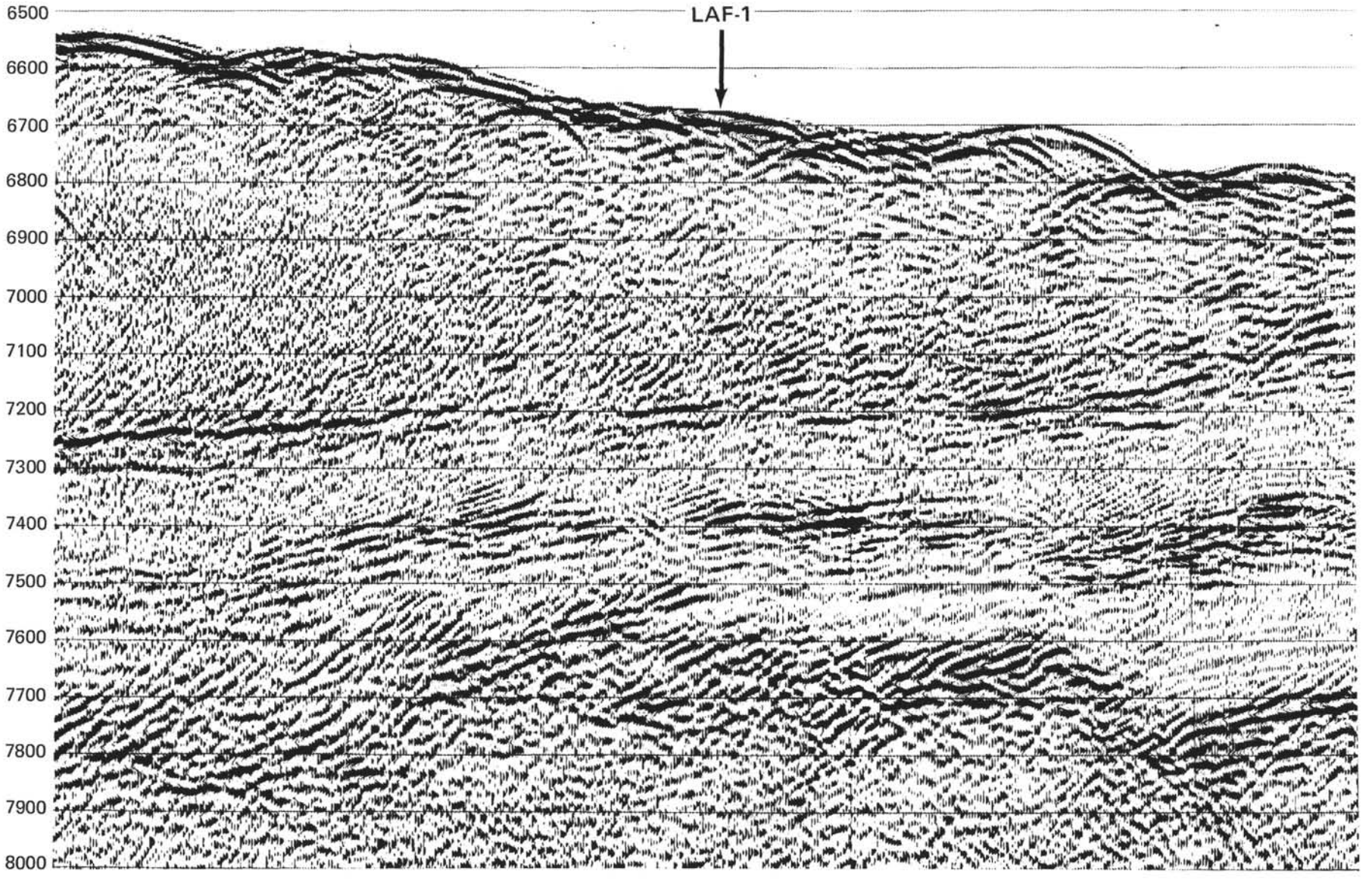
SEISMIC RECORD: CEPM 128, S.P. 410 at crossing with Line AIE.
Located near DSDP Site 541.

HEAT FLOW: Yes LOGGING: Yes

PACKER EXPERIMENTS: Yes

OBJECTIVES:
1) Measure pressure, temperature and pore fluid characteristics above, below and at the décollement;
2) Complete penetration and sampling of the lithologic section of accretionary toe;
3) Determine sequence of structural features related to accretionary processes;
4) Tephrachronology.

SEDIMENT TYPE:
0-450 m : Offscraped sequence of Quaternary and middle Miocene hemipelagic mud.
450-850 m : Underthrust sequence of early Miocene to Cretaceous pelagic mud.
850-860 m : Oceanic basalt.


LAF-1
6500
6600
6700
6800
6900
7000
7100
7200
7300
7400
7500
7600
7700
7800
7900
8000

SITE NUMBER: LAF-2 (Northern Barbados Ridge)

POSITION: $15^{o}31'N$ $58^{o}46'W$ SEDIMENT THICKNESS: 1300 m

WATER DEPTH: 4800 m PRIORITY: 1

PROPOSED DRILLING PROGRAM: Two holes as follows;

1) APC (oriented)/XCB : 850 m (Decollement at 800 m)
2) RCB (wash) / Packer : 850 m

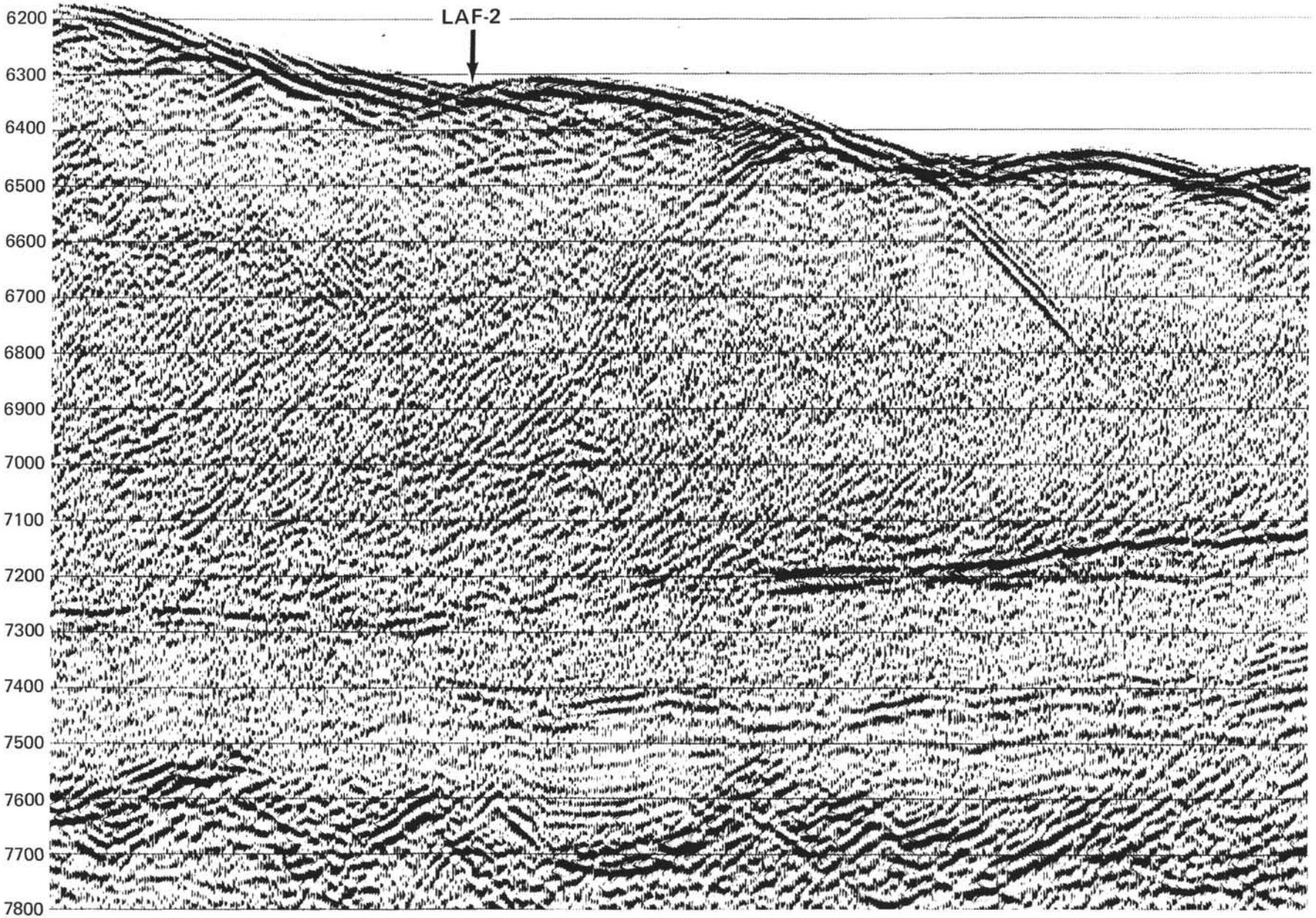
SEISMIC RECORD: CEPM 128, S.P. 630 at crossline A1D.

HEAT FLOW: Yes LOGGING: Yes

PACKER EXPERIMENTS: Yes

OBJECTIVES:
1) Study structural features, geotechnical properties, temperatures, pore pressures and fluids in offscraped sequence above and at the décollement.
2) Combine results with LAF-1 to establish lateral gradients in accretionary process.
3) Test whether faults upslope from the accretionary toe are active fluid conduits.

SEDIMENT TYPE:
0-850 m : Offscraped sequence of Quaternary to Miocene hemipelagic mud.
Below 850 m : Underthrust pelagic mud.


LAF-2
6200
6300
6400
6500
6600
6700
6800
6900
7000
7100
7200
7300
7400
7500
7600
7700
7800

SITE NUMBER: LAF-3 (Northern Barbados Ridge)

POSITION: 15°30'N 58°54'W

SEDIMENT THICKNESS: 2000 m

WATER DEPTH: 4275 m

PRIORITY: 1

PROPOSED DRILLING PROGRAM: Two holes as follows;

1) APC (oriented)/XCB : 500 m
2) RCB (wash) / Packer : 500 m

SEISMIC RECORD: CEPM 128, S.P. 1170 at crossline CRV 001.

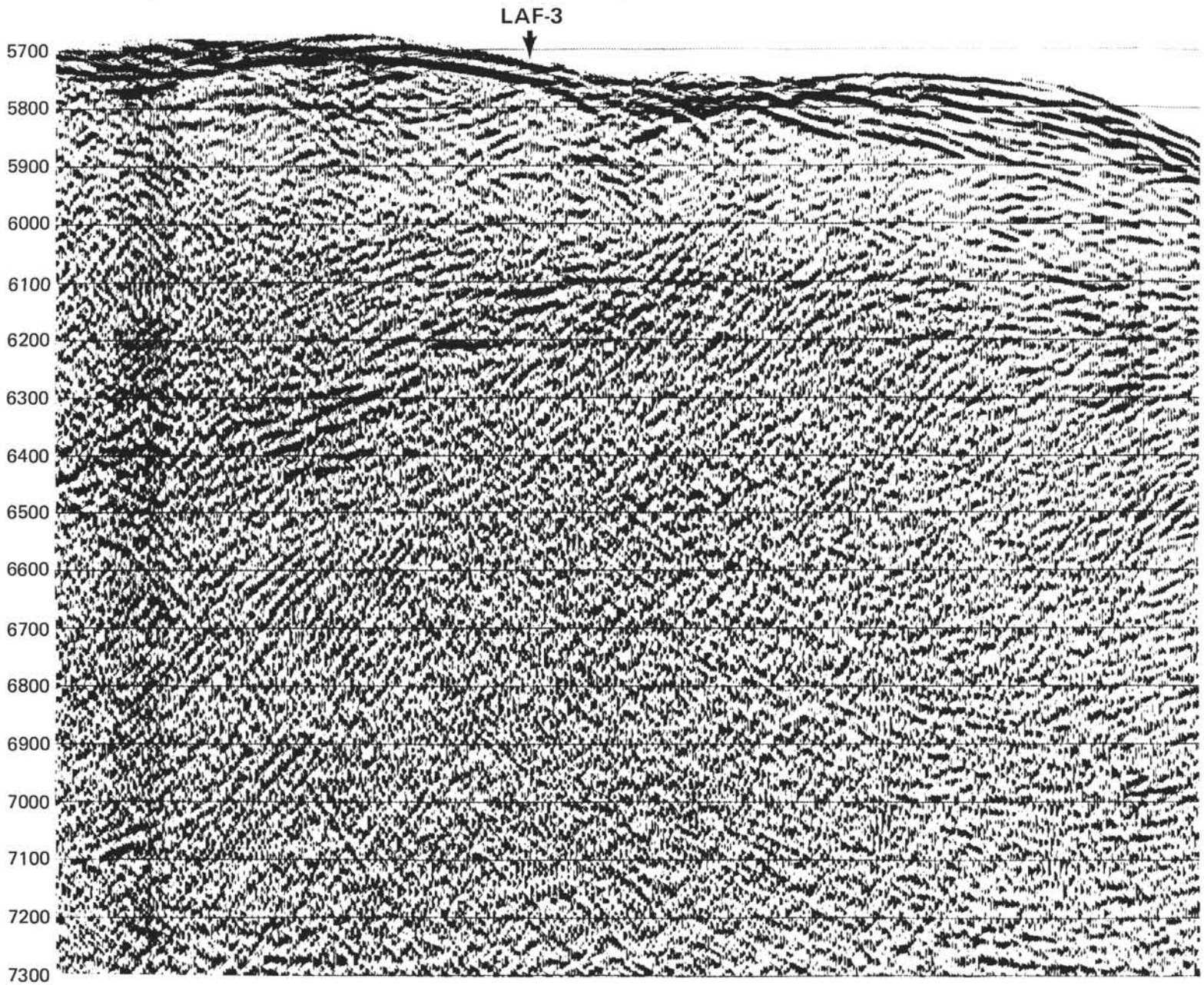
HEAT FLOW: Yes

LOGGING: Yes

PACKER EXPERIMENTS: Yes

OBJECTIVES: 1) Same as LAF-2.
2) Test for fluid migration in lower section of landward dipping reflectors.

SEDIMENT TYPE: 0-500 m : Offscraped sequence of Quaternary to Miocene hemipelagic mud.
Below 500 m : Underthrust pelagic mud.


LAF-3
5700
5800
5900
6000
6100
6200
6300
6400
6500
6600
6700
6800
6900
7000
7100
7200
7300

SITE NUMBER: LAF-3A (Northern Barbados Ridge)

POSITION: 15°31'N 58°49'W

SEDIMENT THICKNESS: 1600 m

WATER DEPTH: 4650 m

PRIORITY: 2

PROPOSED DRILLING PROGRAM:
Two holes as follows;

1) APC (oriented)/XCB : 600 m
2) RCB (wash) / Packer : 600 m

SEISMIC RECORD:
CEPM 128, S.P. 930 at crossline A3.

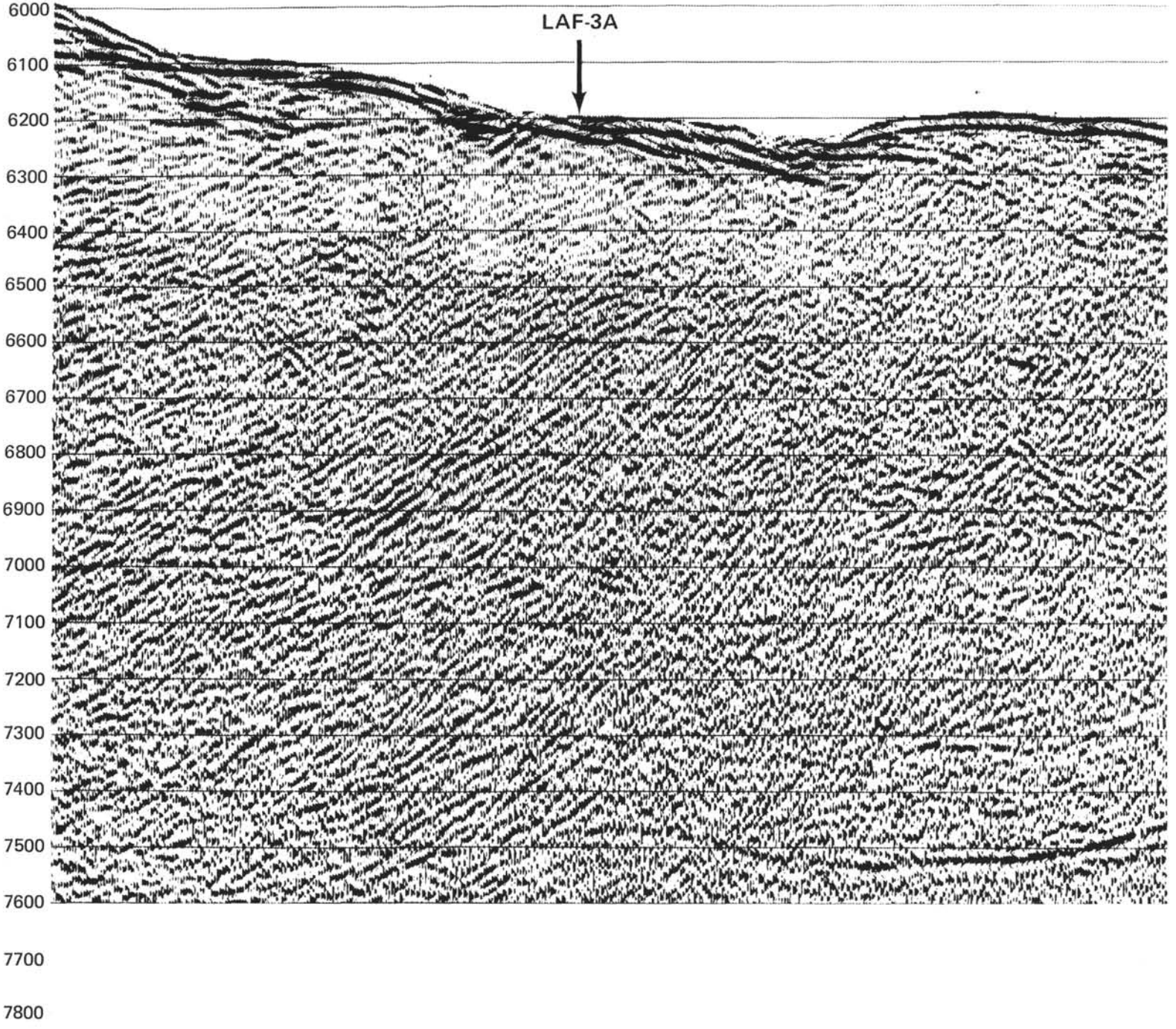
HEAT FLOW: Yes

LOGGING: Yes

PACKER EXPERIMENTS: Yes

OBJECTIVES:
Same as LAF-3.

SEDIMENT TYPE:
Offscraped sequence of Quaternary to Miocene hemipelagic mud.


LAF-3A
6000
6100
6200
6300
6400
6500
6600
6700
6800
6900
7000
7100
7200
7300
7400
7500
7600
7700
7800

APPENDIX OF PROPOSED ALTERNATES SITES

LAF-4
LAF-5
LAF-6

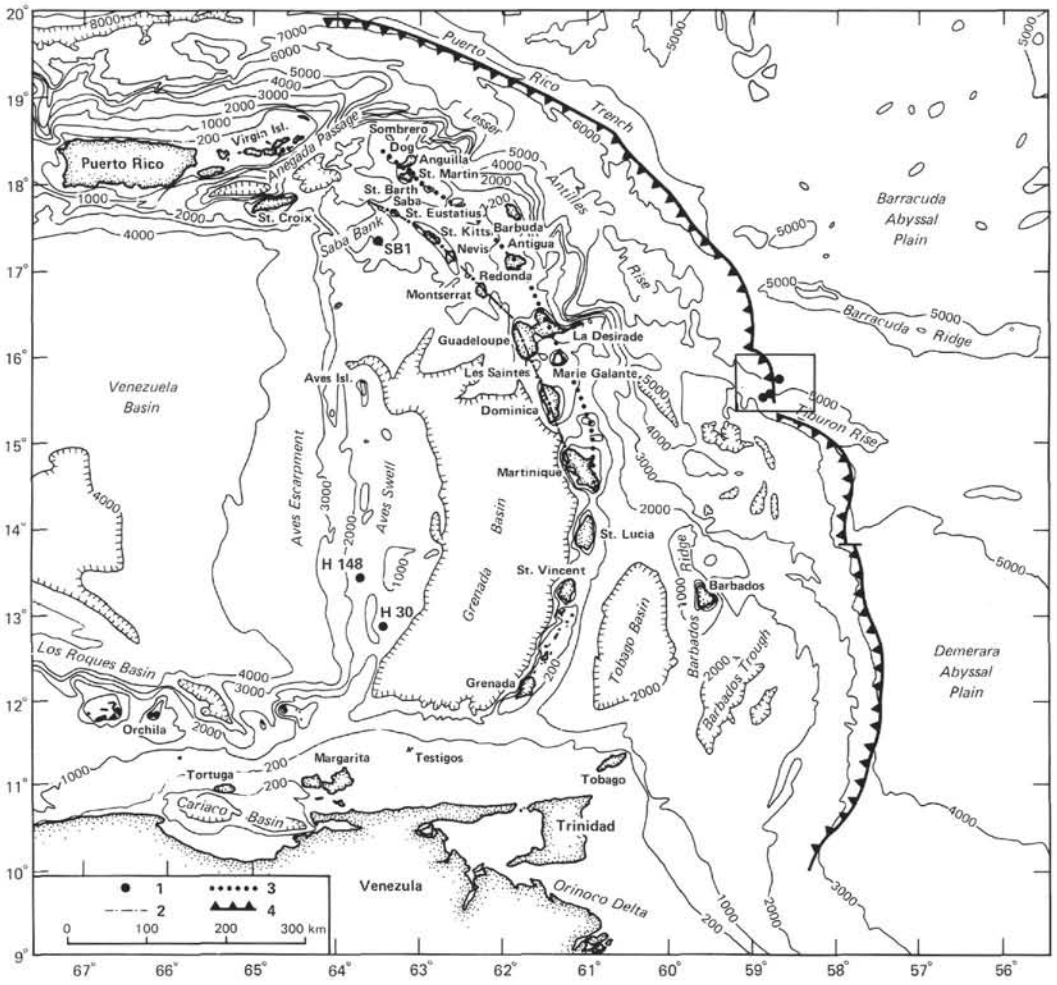


Figure 4. Location of Priority 3 drillsites proposed for ODP Leg 110. (Map slightly modified from Case and Holcombe, 1980).

SITE NUMBER: LAF-4 (Lesser Antilles Forearc)

POSITION: $14^{o}20'N$ $57^{o}53'W$ SEDIMENT THICKNESS: 4000 m

WATER DEPTH: 4400 m PRIORITY: 3

PROPOSED DRILLING PROGRAM:

Option 1 : APC/XCB to 600 m.
Option 2 : RCB, single bit if necessary.

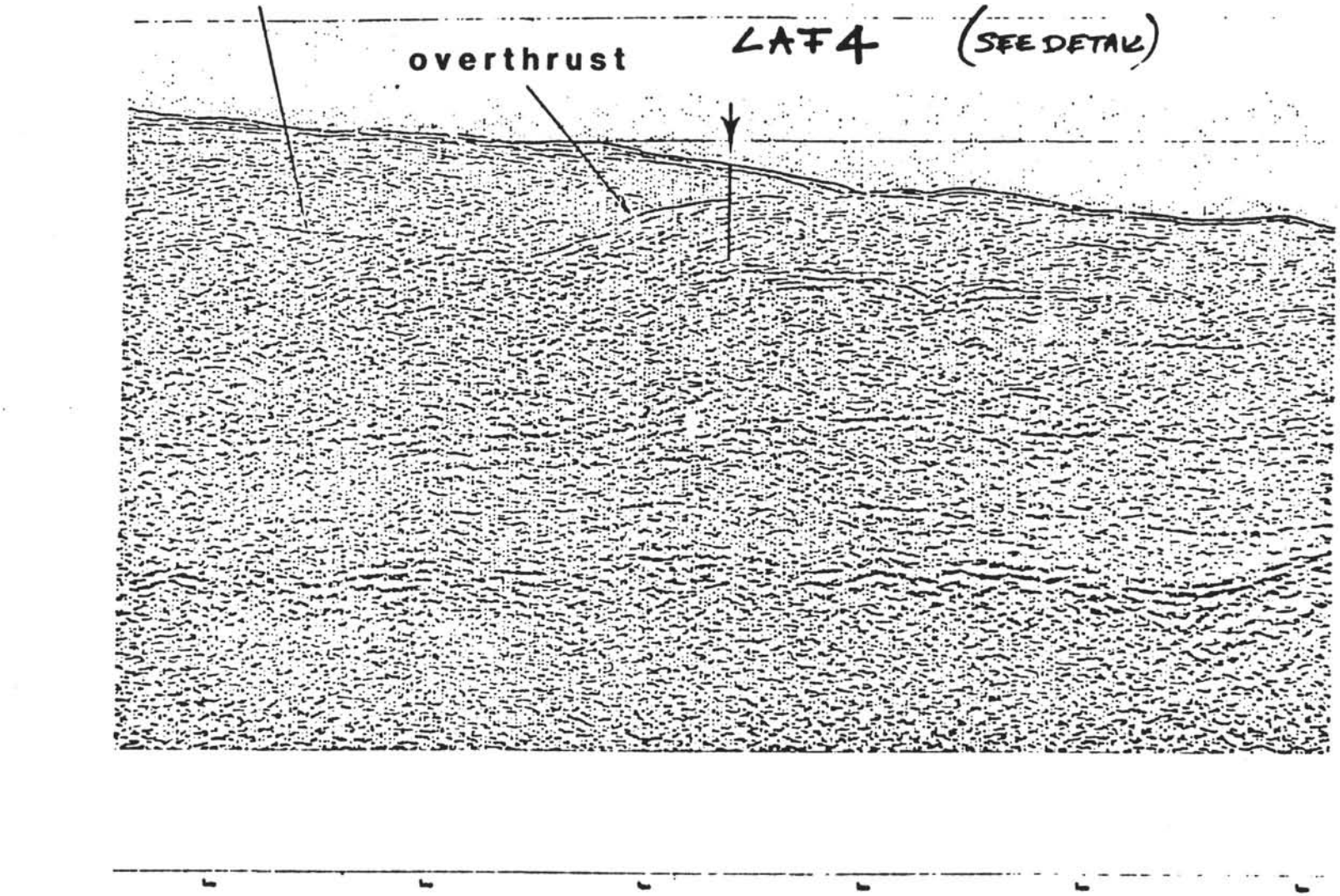
SEISMIC RECORD: D109-9, S.P. 540

HEAT FLOW: Yes LOGGING: Yes

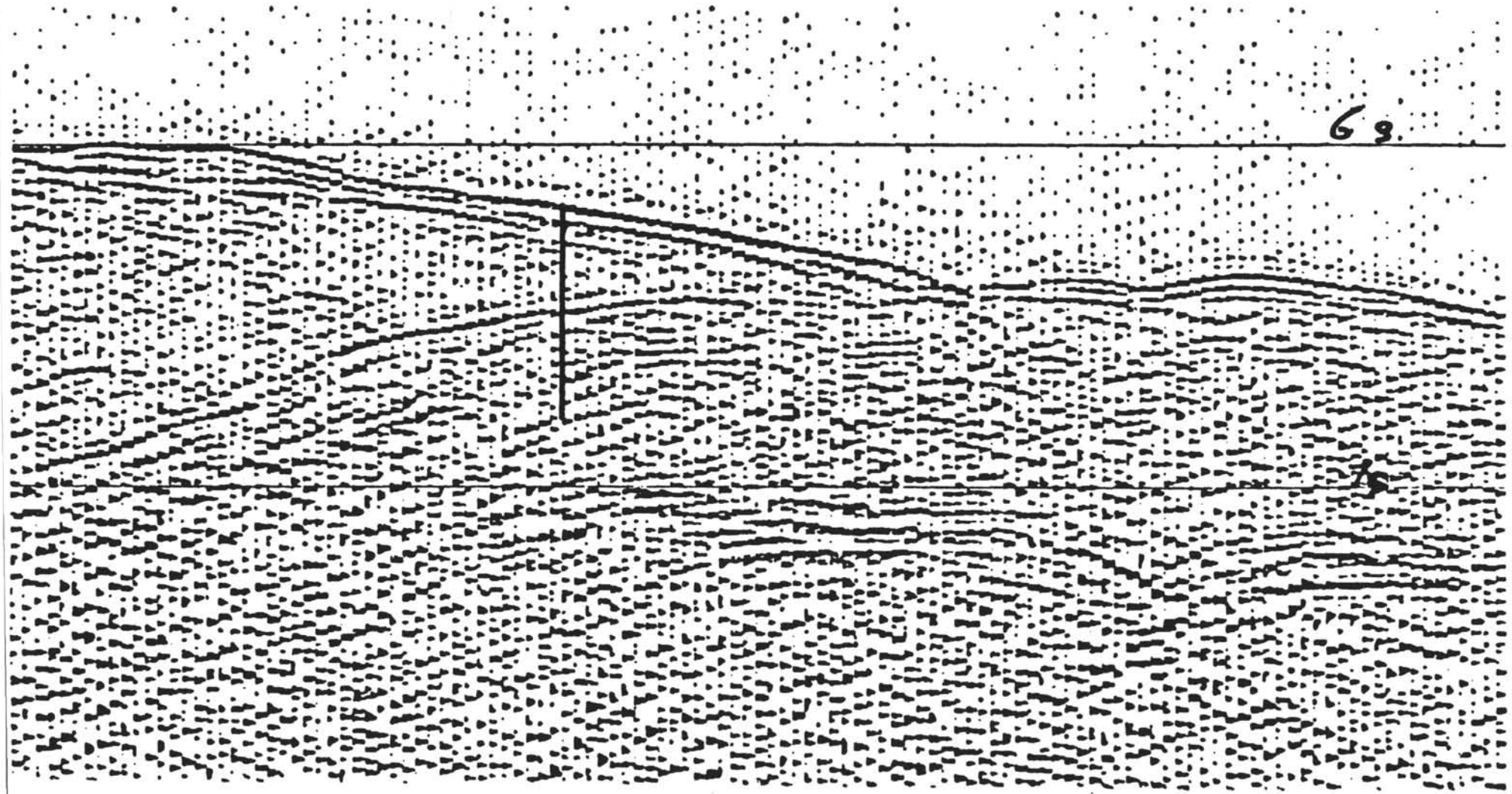
PACKER EXPERIMENTS: No

OBJECTIVES:
1) Study hydrogeology and structural characteristics of accretionary wedge.
2) Determine amount of displacement on décollement in gentle folding and thrusting setting.
3) Estimate quantity of lost material from front of thrust.

SEDIMENT TYPE:
0-300 m : Overthrust Neogene hemipelagic mud and fine-grained turbidites.
300-600 m : Underthrust hemipelagic sediment and fine-grained turbidites.


base of gas hydrate
overthrust
LAT 4
(SEE DETAIL)

LAF 4



SITE NUMBER: LAF-5 (Lesser Antilles Forearc)

POSITION: $14^{o}20'N$ $57^{o}46'W$ SEDIMENT THICKNESS: 3000 m

WATER DEPTH: 5200 m PRIORITY: 3

PROPOSED DRILLING PROGRAM:

Option 1 : APC/XCB to 400 m.
Option 2 : RCB, single bit if necessary.

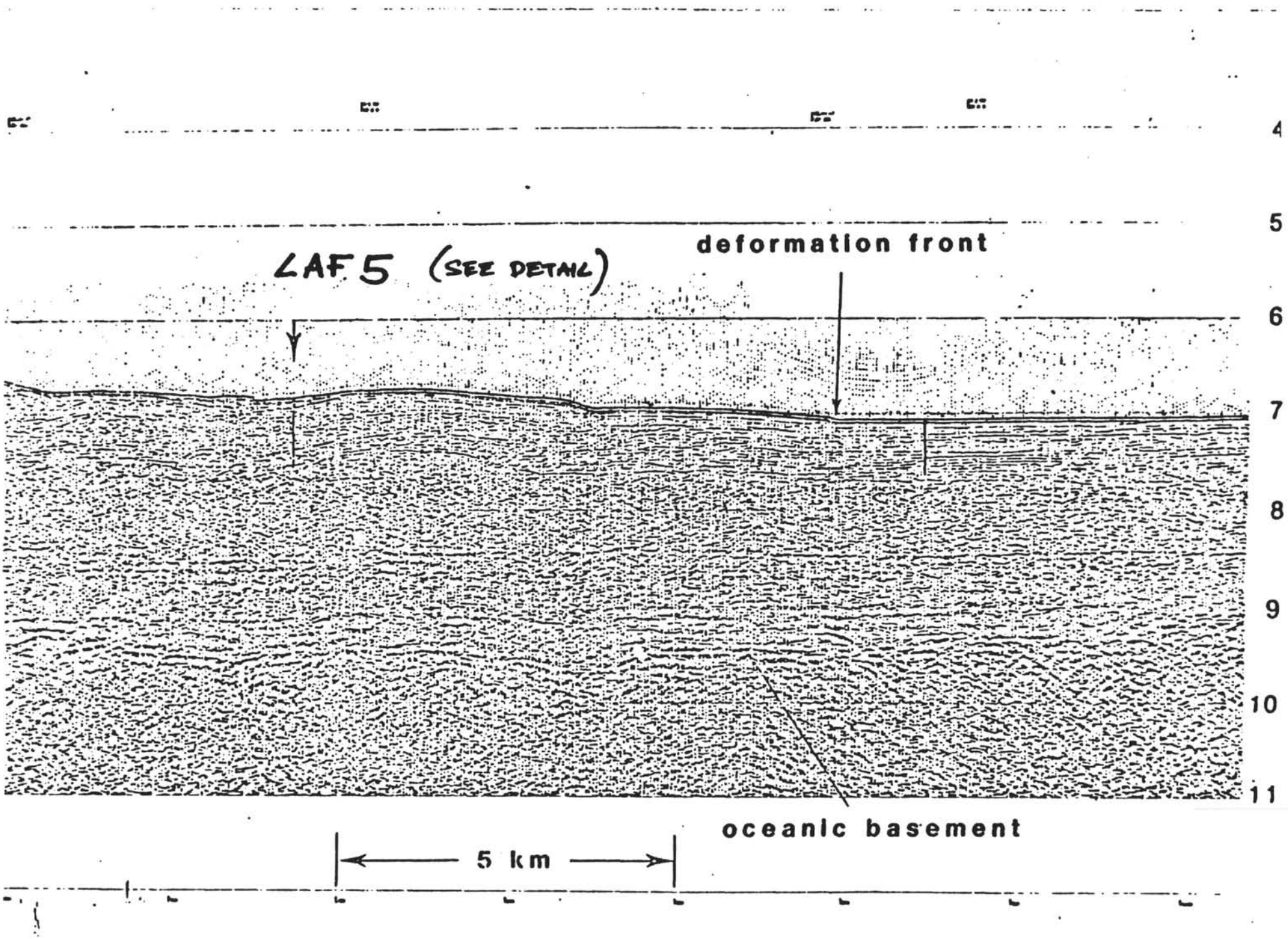
SEISMIC RECORD: D 109-9, S.P. 750

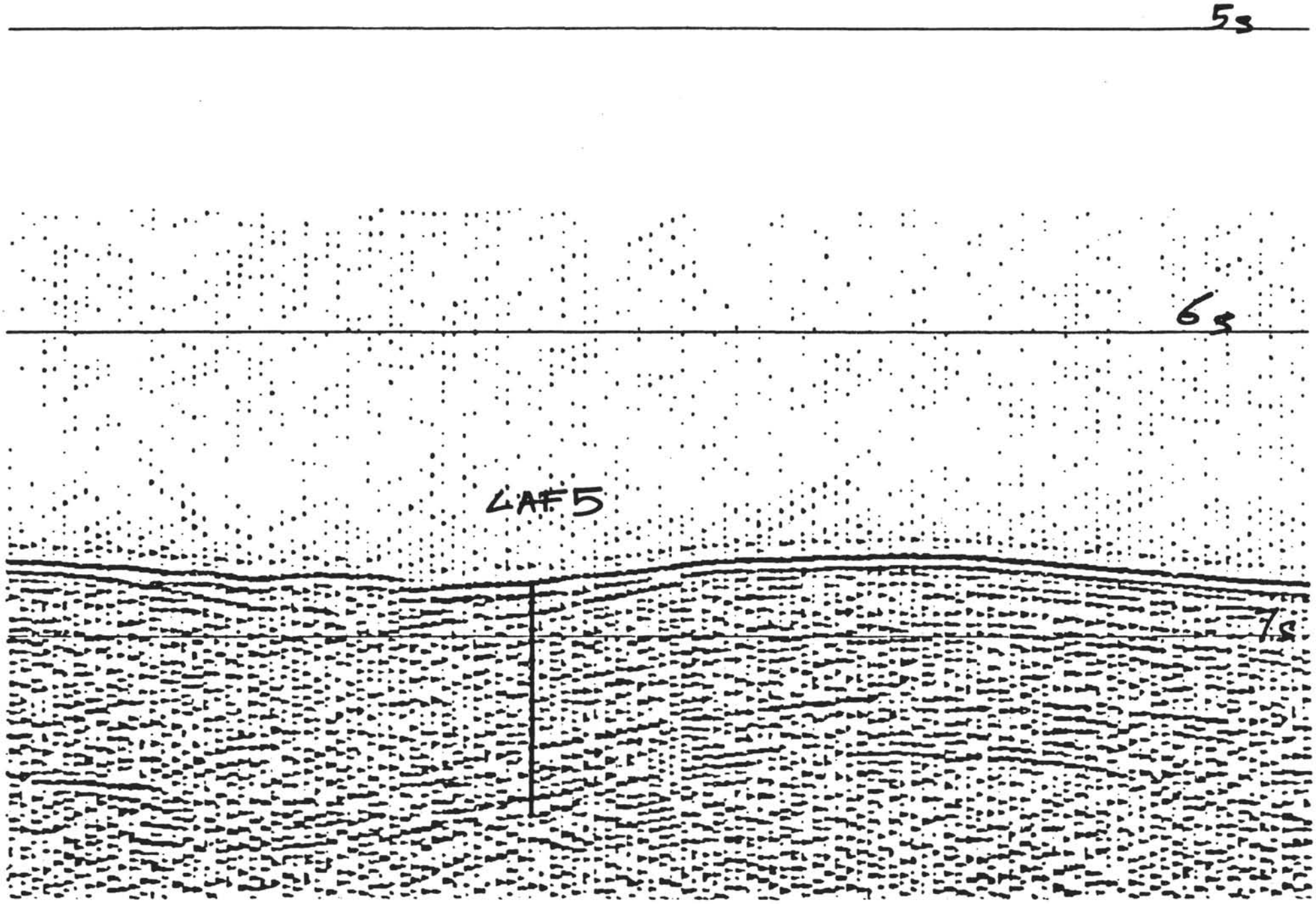
HEAT FLOW: Yes LOGGING: Yes

PACKER EXPERIMENTS: No

OBJECTIVES:
1) Tied with LAF-4 for thrust studies;
2) Determine sedimentary character of fold infill; i.e., slump, drape, etc.;
3) Calibrate seismic stratigraphy.

SEDIMENT TYPE: 0-400 m : Quaternary to Pliocene (?) pelagic and hemipelagic mud and fine-grained turbidites.


4
5
deformation front
LAF 5 (SEE DETAIL)
6
7
8
9
10
11
oceanic basement
5 km


5s
6s
LAF5
7s

SITE NUMBER: LAF-6 (Lesser Antilles Forearc)

POSITION: 12°48'N 60°05'W

SEDIMENT THICKNESS: 6000 m

WATER DEPTH: 2200 m

PRIORITY: 3

PROPOSED DRILLING PROGRAM:

Option 1 : APC/XCB to 700 m.
Option 2 : RCB, single bit if necessary.

SEISMIC RECORD: At intersection of Lines CEPM 107 and 212.

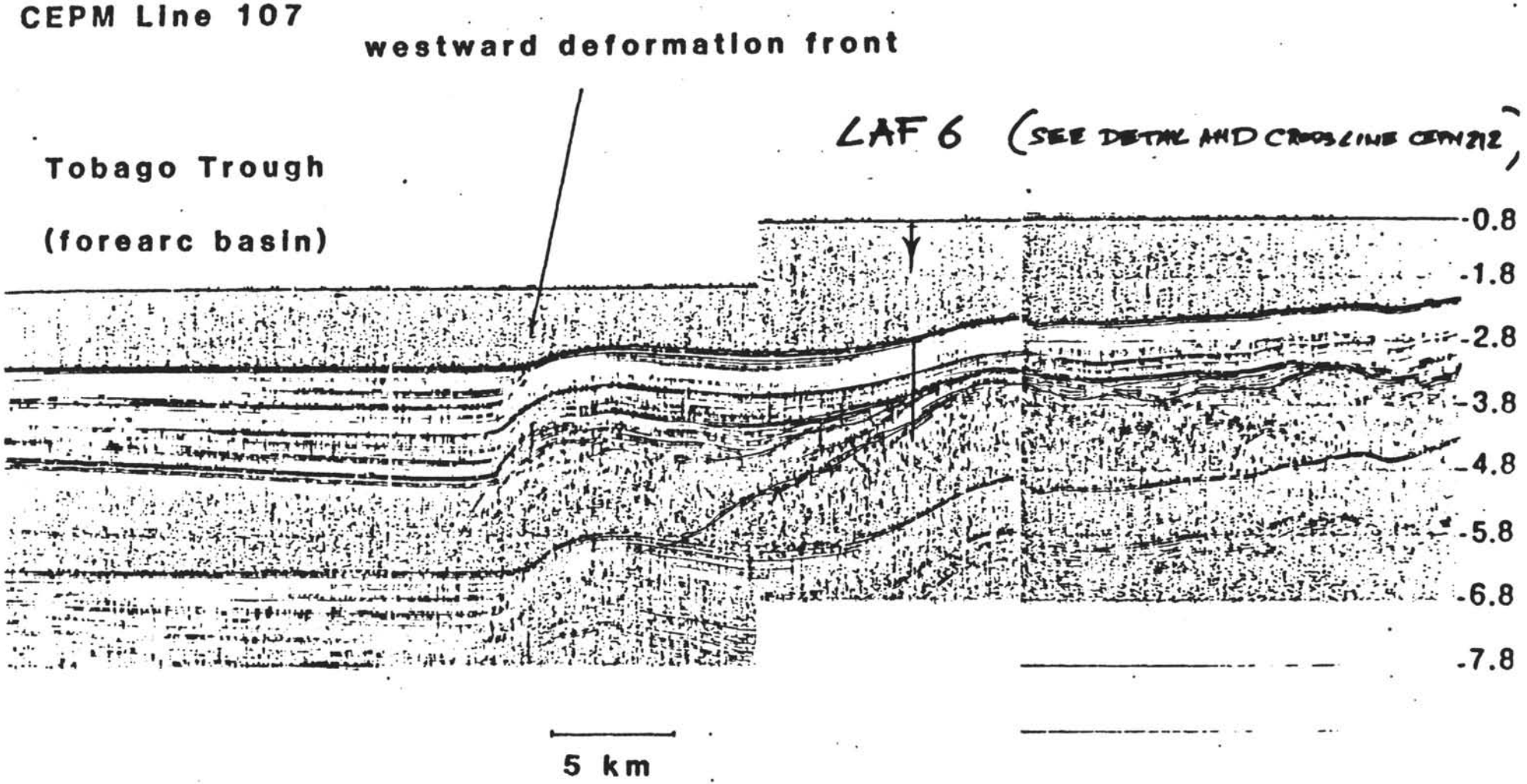
HEAT FLOW: Yes

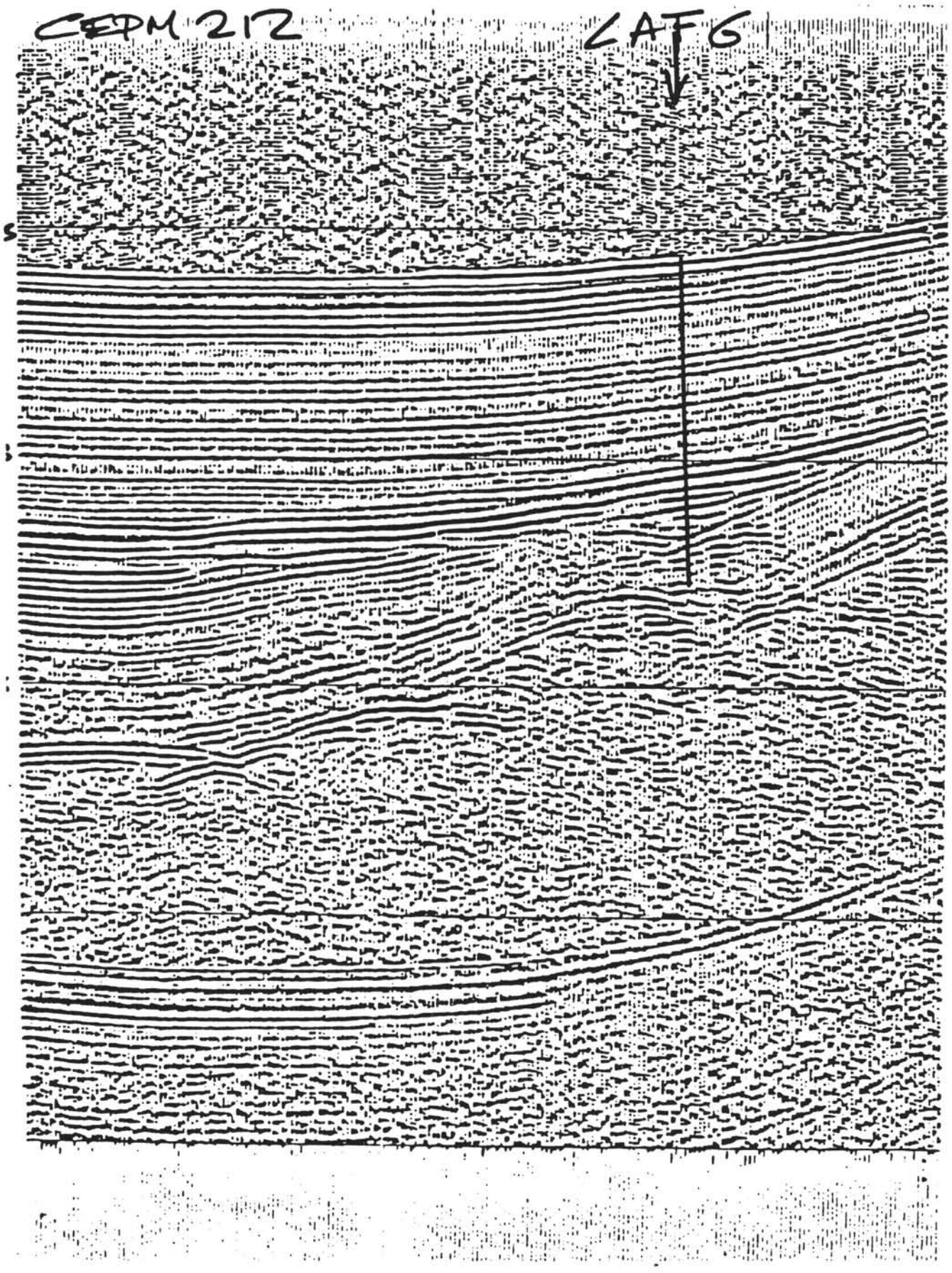
LOGGING: Yes

PACKER EXPERIMENTS: No

OBJECTIVES:
1) Sample gently folded post-Miocene sequence to establish history of deformation in forearc basin sediments.
2) Study hydrogeology and structural geology of forearc basin deformation.
3) Document tephrachronology of southern Lesser Antilles.

SEDIMENT TYPE: 0-700 m : Quaternary to Pliocene pelagic and hemipelagic mud, fine-grained turbidites, and possibly some sand layers.


CEPM Line 107
westward deformation front
LAF 6 (SEE DETAIL AND CROSSLINE CENTRE)
Tobago Trough
(forearc basin)
-0.8
-1.8
-2.8
-3.8
-4.8
-5.8
-6.8
-7.8
5 km


CEPM 212
LATG

OCEAN DRILLING PROGRAM LEG 110
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