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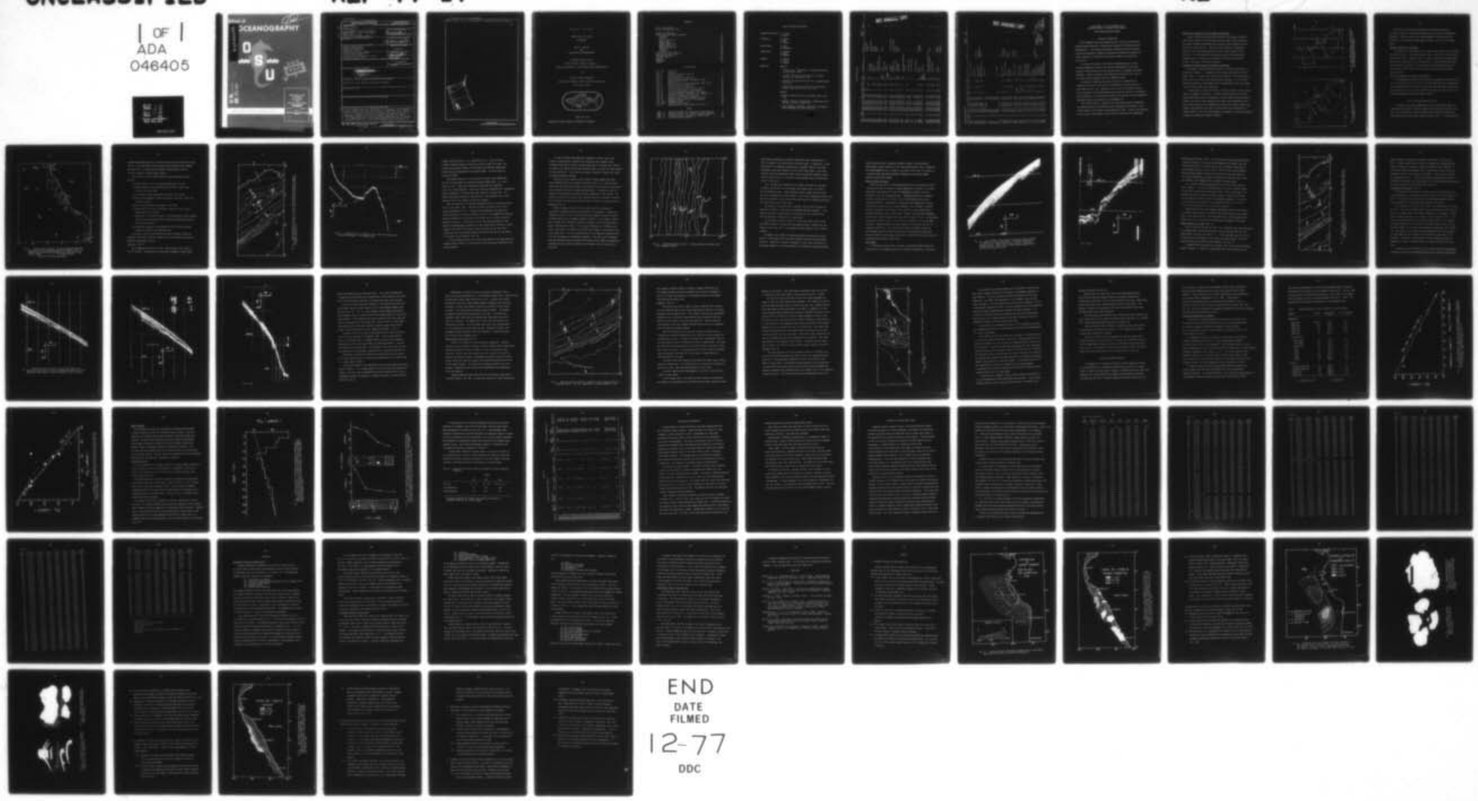

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WELOC Cruise '77, Leg 6

R/V WECOMA

May 21–June 18
1977

Callao, Peru to Balboa, Panama

Office of Naval Research
N00014-67-A-0369-0007
NR 083-102

Cruise Report Reference 77-17

August 1977

OREGON STATE UNIVERSITY

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (14) Ref-77-17	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* (6) WELOC CRUISE '77, LEG 6, R/V WECOMA MAY 21-JUNE 18, 1977. CALLAO, PERU TO BALBOA, PANAMA .		5. TYPE OF REPORT & PERIOD COVERED (9) Cruise Rept. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s) (15) N00014-67-A-0369-0007
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Oceanography Oregon State University Corvallis, OR 97331	278 26	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 083-102
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Ocean Science and Technology Division Arlington, Virginia 22217		12. REPORT DATE (11) 25 Aug 77 13. NUMBER OF PAGES (12) 74p.
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

Approved for public release; distribution unlimited

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The R/V WECOMA cruise leg 6 emphasized the field work of the marine geology research program on "Patterns and processes of continental margin sedimentation." This program constitutes a mesoscale study of processes controlling hemipelagic sediment distribution and composition beneath the coastal upwelling, non-upwelling and pelagic regimes of the equatorial East Pacific. It included field work of the optical oceanography group to help initiate cooperative research into a better understanding of the interrelation of

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ocean dynamics and the characteristics of suspended and bottom sediments.

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CRUISE REPORT

WELOC Cruise '77, Leg 6

R/V WECOMA

May 21 - June 18
1977
Callao/Peru to Balboa/Panama

Conducted as part of the

Office of Naval Research program on:

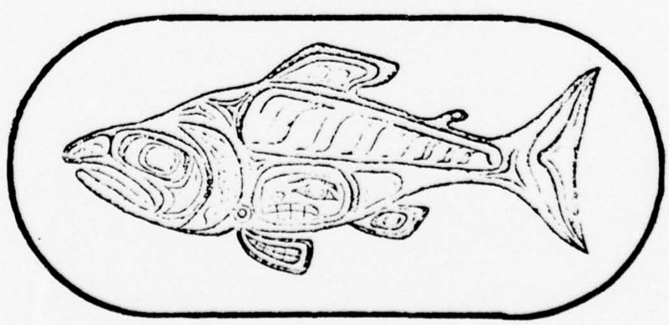
Patterns and processes of continental margin sedimentation

and

National Science Foundation

International Decade of Ocean Exploration program on:

Nazca Plate Project



August 25, 1977

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List of Cruise Participants

Co-Chief Scientists:	L. D. Kulm E. Suess
Scientists:	G. Keller H. Pak J. Thiede
Party Chiefs:	P. Kalk W. Schweller
Technicians:	M. Clauson M. Hower D. Menzies
Students:	C. Emerick R. Karlin C. Reimers
Observers:	<u>Leg 6 A</u>

T. Fonseca, Dept. Oceanografia, Universidad Catolica de Valparaiso, Chile

J. Carreno, Instituto Hidrografico de la Armada, Casilla 324, Valparaiso, Chile

C. Delgado, Instituto del Mar de Peru, Apartados 3734, Lima, Peru

J. Saldarriaga, Instituto Cientifica y Tecnologico Minero, Malecon Balta 758, Lima, Peru

<u>Leg 6 B</u>

A. Masias, Petroleos del Peru, Apartados 3126, Lima, Peru

J. Valdez, Direcion de Hidrografia y Navegacion de la Marina, La Punta, Callao, Peru

P. Lavi Zambrano, Instituto Cientifico y Tecnologico Minero Malecon Balta 758, Lima, Peru

List of Stations and Cores

Sample No.	Station No.	Latitude	Longitude	Water Depth (corr)	Type Sampler	Core Length (cm)	Core Status	Sediment/Rock Types	Comments	Interstitial Water Chemistry	Physical Properties
7706-1	1	12°54.0'S	76°51.0'W	148 m	RB		1c		composite sample		
7706-2	1	12°53.2'S	76°52.0'W	131 m	RB		2		washed, disturbed		
7706-3	2	12°56.3'S	76°57.4'W	304 m	RB	~70	1c,3		fish debris	X	X
7706-4	2	12°58.9'S	76°53.0'W	325 m	K	230	1abc;	black silty clay		X	X
7706-5	3	13°02.4'S	77°04.9'W	625 m	K		1c;	silt, silty sand	composite sample, 2 bags		
7706-6	3	13°02.4'S	77°04.9'W	701 m	K		1c;	silt, silty sand	disturbed		
7706-7	4	13°16.0'S	77°27.6'W	1774 m	G	few cms	1c	mudstone	disturbed		
7706-8	5	13°03.4'S	77°32.6'W	464 m	G	10	1c	silty clay	disturbed		
7706-9	6	13°01.0'S	77°19.0'W	1335 m	G	30	1c	--	washed down		
7706-10	7	13°09.0'S	77°15.0'W	1380 m	K	<100	1c	black-green silty clay	H_2S		
7706-11	7	13°09.0'S	77°14.0'W	1380 m	K	<100	1c	dark green silty clay & bivalves	--		
7706-12	8	13°13.0'S	77°20.0'W	1285 m	G	~120	2	--	--		
7706-13	9	13°26.0'S	77°40.0'W	3470 m	G	34	2 (bottom stored)	silty clay	disturbed		
7706-14	10	13°27.3'S	77°42.9'W	3521 m	K	~200	1abc	fine-grained sediment	--	X	X
7706-15	11	13°48.4'S	79°16.3'W	4581 m	K	300	2	silty clay			X
7706-16	12	15°38.2'S	81°14.8'W	4521 m	K	450	2 (top 150 cm) 1 (bottom 300 cm)	light tan clay			X
7706-17	13	17°29.2'S	84°18.0'W	4573 m	RB	40	2,3	soft brown mud	surface partially disturbed	X	X
7706-18	13	17°29.6'S	84°17.8'W	4462 m	K	270	1abc,4	brown clay	--	X	X
7706-19	14	22°14.3'S	79°30.7'W	4479 m	K	--	1c	mud, manganese nodules	2 bags clay; 1 bag nodules		
7706-20	15	23°01.4'S	73°44.7'W	3717 m	K	515	2,3	--	6 bags		
7706-21	16	23°14.7'S	71°43.7'W	4400 m	K	74	1abc,4	hard sediment, brown clay	bent barrel		X
7706-22	17	23°18.7'S	71°20.0'W	8080 m	K	120	1abc,4	olive gray clay	bent barrel	X	X
7706-23	18	23°18.7'S	71°10.4'W	6543 m	DR	--	bagged	pebbles & cobbles	6 bags		
		23°19.0'S	71°03.0'W	5066 m							
7706-24	19	23°19.2'S	71°07.7'W	5107 m	K	150	2,4	--	--		
7706-25	20	23°20.1'S	71°03.4'W	5047 m	DR		7 bags	siltstone, sandstone, manganese crusts			
		23°19.9'S	70°57.2'W	3995 m				igneous pebbles			
7706-	21	OPTICS									
7706-26	22	23°21.6'S	70°52.6'W	1600 m	K	100	2,4	--	--		X
7706-27	23	23°21.3'S	70°50.1'W	2893 m	DR	--	--	1 rounded metamorphic rock	--		
		23°20.7'S	70°47.7'W	2779 m							
7706-28	24	23°00.0'S	70°41.0'W	764 m	RB		1bc,4	black mud, sand, & carbonate	--		
7706-	25	OPTICS									
	26	22°53.5'S	70°38.2'W	360 m				--	--		
7706-29	27	22°10.6'S	70°52.1'W	4560 m	DR	--	1c	mudstone, manganese crusts	--		
		22°10.9'S	70°50.1'W	3814 m				--	--		
7706-30	28	16°42.0'S	73°24.2'W	2154 m	RB	25	1c	sand, silt	surface washed		
7706-31	29	16°17.6'S	73°53.6'W	645 m	RB	>40	1c,3	soupy mud	over penetrated	X	X
7706-32	29	16°17.4'S	73°53.9'W	645 m	K	150	1abc,4	--	--	X	X
7706-33	30	15°43.6'S	76°47.8'W	2967 m	K	305	1 (top 5 cm bagged) 2 (bottom 300 cm)	olive gray clay	--		X
7706-34	31	15°19.2'S	76°51.0'W	3316 m	K	210	2,4	--	--		X
7706-35	32	13°39.2'S	76°53.4'W	502 m	RB	17	1c,4	gravel, Mn crust, sandy mud, gray silty clay			
7706-36	33	13°37.3'S	76°50.5'W	370 m	RB	>40	1c,3	gray and brown silty clay, gravel	fish debris	X	X
7706-37	33	13°37.8'S	76°50.9'W	370 m	K	180	2,4	--	--		X
7706-38	34	13°12.0'S	77°15.1'W	1414 m	K	~100	1c,4	soupy dark brown clay	--		X
7706-39	35	11°15.1'S	77°57.4'W	186 m	RB	55	1c,3	--	--	X	X
7706-40	35	11°15.3'S	77°57.0'W	186 m	K	--	2,4	--	--		X
7706-41	36	11°20.6'S	70°07.0'W	411 m	K	--	2,4	--	fish debris		X
7706-42	36	11°20.6'S	70°07.0'W	411 m	RB	~60	1c,3	large tooth	fish debris	X	X
7706-43	37	11°24.6'S	78°13.8'W	584 m	RB	--	2	--	--		
7706-44	37	11°24.8'S	78°13.0'W	580 m	K	--	2	--	some carbonate	X	X

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Stations and Cores (continued)

Sample No.	Station No.	Latitude	Longitude	Water Depth (corr)	Type Sampler	Core Length (cm)	Core Status	Sediment/Rock Types	Comments	Interstitial Water Chemistry	Physical Properties
7706-45	38	11°26.6'S	78°17.2'W	810 m	RB	~40	2,4	--	--		
7706-46	39	11°40.9'S	78°30.6'W	2263 m	DR			sedimentary & metamorphic rocks	--		
		11°38.2'S	78°29.6'W	1639 m							
7706-47	40	11°40.2'S	78°25.8'W	1500 m	RB	~20	2,4	olive gray clay/sand	--		
7706-48	41	11°46.7'S	78°50.4'W	3749 m	DR	--	1c	dark meta. rock	--		
7706-49	42	11°16.6'S	79°05.9'W	3970 m	K	245	2,3	--	overpenetrated		X
7706-50	43	11°40.7'S	79°57.9'W	4902 m	K	330	1abc,3	olive gray/light brown clay	--		X
7706-51	44	9°44.6'S	79°24.3'W	259 m	RB	--	1c	green foram sand	composite sample		
7706-52	44	9°46.0'S	79°25.0'W	352 m	RB	20	1bc	green foram sand/mud	fish debris & PO_4 nodules		
7706-53	44	9°47.0'S	79°26.5'W	414 m	RB	24	1ac	foram sand with phosphorite (6 cm)	fish debris	X	
7706-	45	Dredge lost									
7706-54	45	9°03.7'S	79°56.2'W	502 m	DR	--	1c	sedimentary rocks	--		
		9°04.4'S	79°55.1'W	375 m							
7706-	46	OPTICS		216 m				--	--		
7706-	47	OPTICS		532 m				--	--		
7706-	48	OPTICS		1119 m				--	--		
7706-	49	OPTICS		1713 m				--	--		
7706-	50	OPTICS		2207 m				--	--		
7706-	51	OPTICS		3046 m				--	--		
7706-	52	OPTICS		4131 m				--	--		
7706-	53	OPTICS		6296 m	DR	--	1c	mud & 3 rock fragments	--		
7706-55	54	9°13.8'S	80°29.4'W	4330 m	DR			--	--		
	55							--	--		
7706-56	56	9° 0.3'S	80°16.9'W	2016 m	DR	--	1c	mud	no rocks		
7706-57	57	7°55.7'S	80°10.9'W	192 m	RB	24	1c,4	biogenic sand/shells	--	X	
7706-58	58	8°03.4'S	80°24.3'W	486 m	RB	~20	1c	sand	1/2 surface washed		
7706-59	59	8°03.2'S	80°22.9'W	430 m	DR	--	1c	sedimentary rocks, whale bones	fish teeth in rocks		
7706-60	60	8°03.7'S	80°25.9'W	830 m	RB	~30	1c	--	--		X
7706-61	60	8°03.7'S	80°25.9'W	838 m	K	~255	1abc,4	dark olive clay	bent barrel	X	X
7706-62	61	8°13.0'S	80°47.7'W	2670 m	K	260	2,3,4	green gray mud	top bagged	X	X
7706-63	62	8°16.9'S	80°55.4'W	4513 m	K	180	2,4	green gray mud	--		X
7706-	63	OPTICS						--	--		
7706-64	64	8°49.0'S	81°56.6'W	4404 m	K	>300	2,3	gray clay	over penetrated		X
7706-65	65	10°11.8'S	84°44.8'W	4500 m	PC		2	olive gray clay/brown clay	--		
7706-65	65	10°11.8'S	84°44.8'W	4500 m	G (4" trip core)	33	1c,2,3,4	--	0-30 cm bagged		
7706-66	66	10°00.7'S	87°58.6'W	4305 m	RB		1c,4	Mn brown clay & crusts	--	X	X
7706-67	66	10°01.4'S	87°57.9'W	4351 m	PC	869	2	light tan clay	--		
7706-67	66	10°01.4'S	87°57.9'W	4351 m	G (4" trip core)	147	1c,2	light tan clay/Mn nodule	--		
7706-68	67	4°49.1'S	88°30.7'W	3903 m	PC	1198	2	gray clay	--		
7706-68	67	4°49.1'S	88°30.7'W	3903 m	G (4")	153	1c,2	light brown clay/gray clay	--		
7706-69	69	4°12.0'S	85°20.4'W	3537 m	RB	33	1c	brown clay-carbonate	--	X	X
7706-70	69	4°12.9'S	85°19.7'W	3453 m	PC	1235	2,3	light gray calcareous ooze	--		
7706-70	69	4°12.9'S	85°10.7'W	3453 m	G (4")	139	1c,2,3	tan brown ooze/calc. ooze	--		
7706-71	75	3°40.9'S	82°30.3'W	3600 m	PC	1035	2	gray clay	--		
7706-71	75	3°40.9'S	82°30.3'W	3600 m	G (4")	160	1c,2,3	gray clay	--		
7706-72	79	3°31.2'S	81°38.5'W	3601 m	K	~357	1c,2,3	olive gray clay	--		
7706-73	80	3°29.4'S	81°29.0'W	2116 m	K	>300	1c,2,3	gray silty clay	--		
7706-74	81	3°45.4'S	81°24.3'W	713 m	RB	5	1c	compacted clay	sedimentary rocks		
7706-75	83	3°34.8'S	81°17.4'W	292 m	DR	--	1c	siltstone-conglomerate	rocks		
7706-76	84	3°34.7'S	81°00.1'W	365 m	RB	~35	2,4	olive gray clay	--		
7706-77	84	3°35.0'S	81°02.5'W	366 m	K	~225	2,4	olive gray silty clay	--		
7706-78	85	3°29.0'S	81°17.2'W	539 m	RB	35	2,4	silt and sandy silt	--		
7706-79	85	3°29.0'S	81°17.2'W	538 m	K	150	2,4	green mud/carbonate sand	--		
7706-80	86	3°27.6'S	81°04.0'W	360 m	DR	--	1c	sandstone, siltstone, claystone	--		

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Legend

Type sampler
RB = Reineck box corer
G = Gravity corer 4"
P = Piston corer
K = Kasten corer
DR = Dredge

Core status
1 = Opened
a = X-radiograph
b = Archive
c = Bagged samples
2 = Stored
3 = Overpenetrated
4 = Undisturbed surface

Cruise WELOC '77 of R/V WECOMA to the
Continental Margin off Western South America

Marine Geology General Report

Scientific Objectives

The R/V WECOMA cruise leg 6 emphasized the field work of the marine geology research program on "Patterns and processes of continental margin sedimentation". This program constitutes a mesoscale study of processes controlling hemipelagic sediment distribution and composition beneath the coastal upwelling, non-upwelling and pelagic regimes of the equatorial East Pacific.

It included field work of the optical oceanography group to help initiate cooperative research into a better understanding of the interrelation of ocean dynamics and the characteristics of suspended and bottom sediments. These two programs were funded during the 1977 fiscal year by the Office of Naval Research Grant No. N00014-76-C-0067.

In addition a dredging program was carried out to determine the lithologies and ages of rocks from the continental crystalline block of South America and of the sedimentary rocks from the continental slope to yield information on paleoenvironment settings and the history of lithospheric plate interaction. This program was funded by the National Science Foundation's IDOE Nazca Plate Project Grant No. OCE 76-05903 A 02.

This report contains a summary of the individual objectives comprising the research program on continental margin sedimentation followed by a narrative account of the findings along sampling profiles. Finally, the highlights of the cruise as they pertain to the scientific objectives are summarized.

Dispersal and composition of terrigenous constituents

Factors controlling the dispersal patterns of terrigenous sediments constituents adjacent to the South American continental block include surface water, mid-water and bottom layer transport, wind transport and composition of source material. These are further subject to topographic control of the slope-trench-abyssal plain and -ridge systems off Peru and Chile. It is believed that the regional extent of the hemipelagic sediment cover, its chemical, mineralogical and textural composition reflect the dominant sedimentary processes.

Production and preservation of biogenous constituents

The dispersal and compositional patterns of biogenous constituents in hemipelagic sediments -- in addition to the factors controlling the terrigenous input -- is dramatically affected by production in the surface water masses and preservation at the sediment water interface; i.e., by coastal and oceanic upwelling, water depths, calcite compensation level, O_2-minimum layer and rate of sediment accumulation.

To individually evaluate the effects of these conditions on the various groups of biogenous constituents a plankton sampling program of the major near-surface water masses was proposed, as was the study of nekton remains in rapidly accumulating slope sediments which might yield information on production and preservation of biogenous constituents on a higher trophic level. Further, the mechanisms and rates of mineralization and accumulation of organic matter in the various environments are thought to reflect the dominant processes of hemipelagic sediment formation.

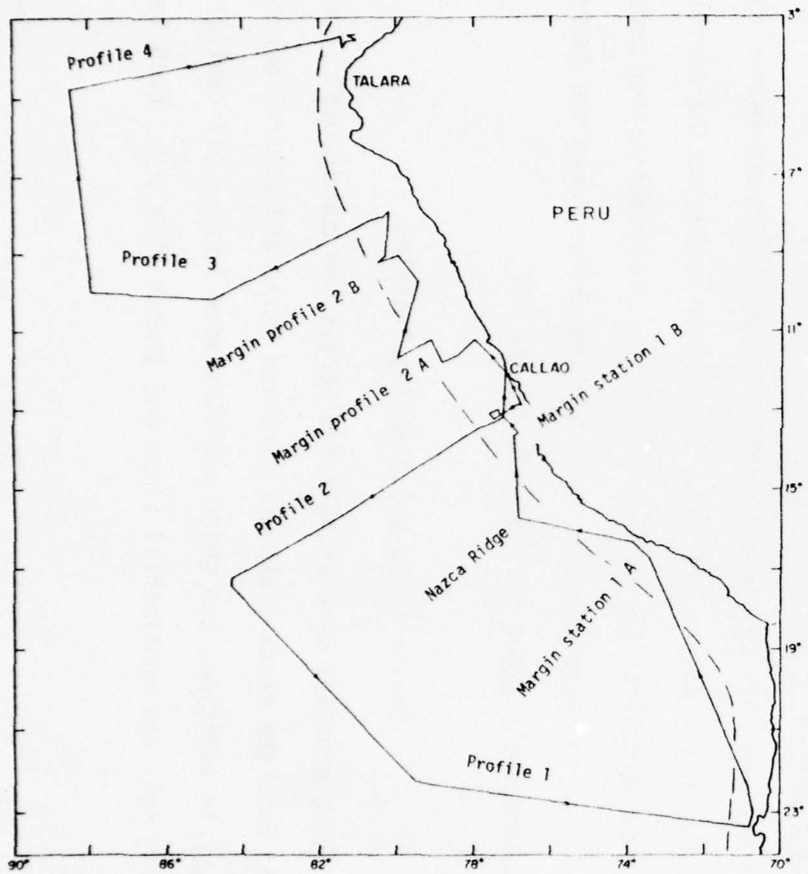


Fig. 1a. Track line of R/V WECOMA during Leg 6 of WELOC Cruise '77.

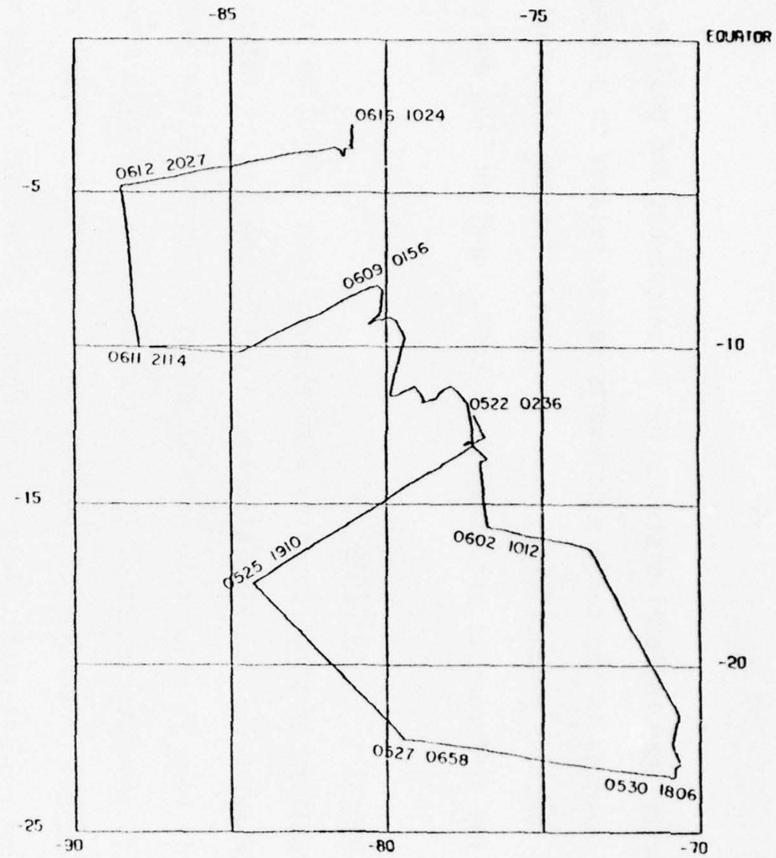


Fig. 1b. Annotated trackline. First four digits are month and date and second four digits are time selected at turn points.

Similarily, the regional distribution of calcareous and opaline microfossil species in the surface sediments may be related to oceanographic parameters. Besides productivity, these parameters include dissolution, oxidation, and differential preservation of $CaCO_3$, opaline SiO_2 and organic matter.

Physical properties of sediments

The stability of slope deposits also asserts some control on the sediment's distribution pattern. The high biogenous input in the area of intense coastal upwelling off Peru is thought to have a unique influence on the geotechnical and stability characteristics of these deposits. Shear-strength measurements and bulk physical properties of fresh sediments from beneath upwelling and non-upwelling regimes might yield information on these physical sediment characteristics.

Optical measurements in water masses off Peru

Field measurements designed to determine the suspended matter distribution in the various water masses off Peru, to further determine the microstructure of the bottom nepheloid layer and to relate the suspended matter concentration and composition to characteristic sediment properties, were the tasks of the optical oceanography group during WELOC cruise '77.

Cruise Track and Sampling Profiles

Four long profiles were established across the continental slope, the trench and onto the Nazca Plate off northern Chile and central-northern Peru (Fig. 1a,b). In addition, two short profiles were located off central Peru transecting only the continental slope and trench (Fig. 2). Each long profile

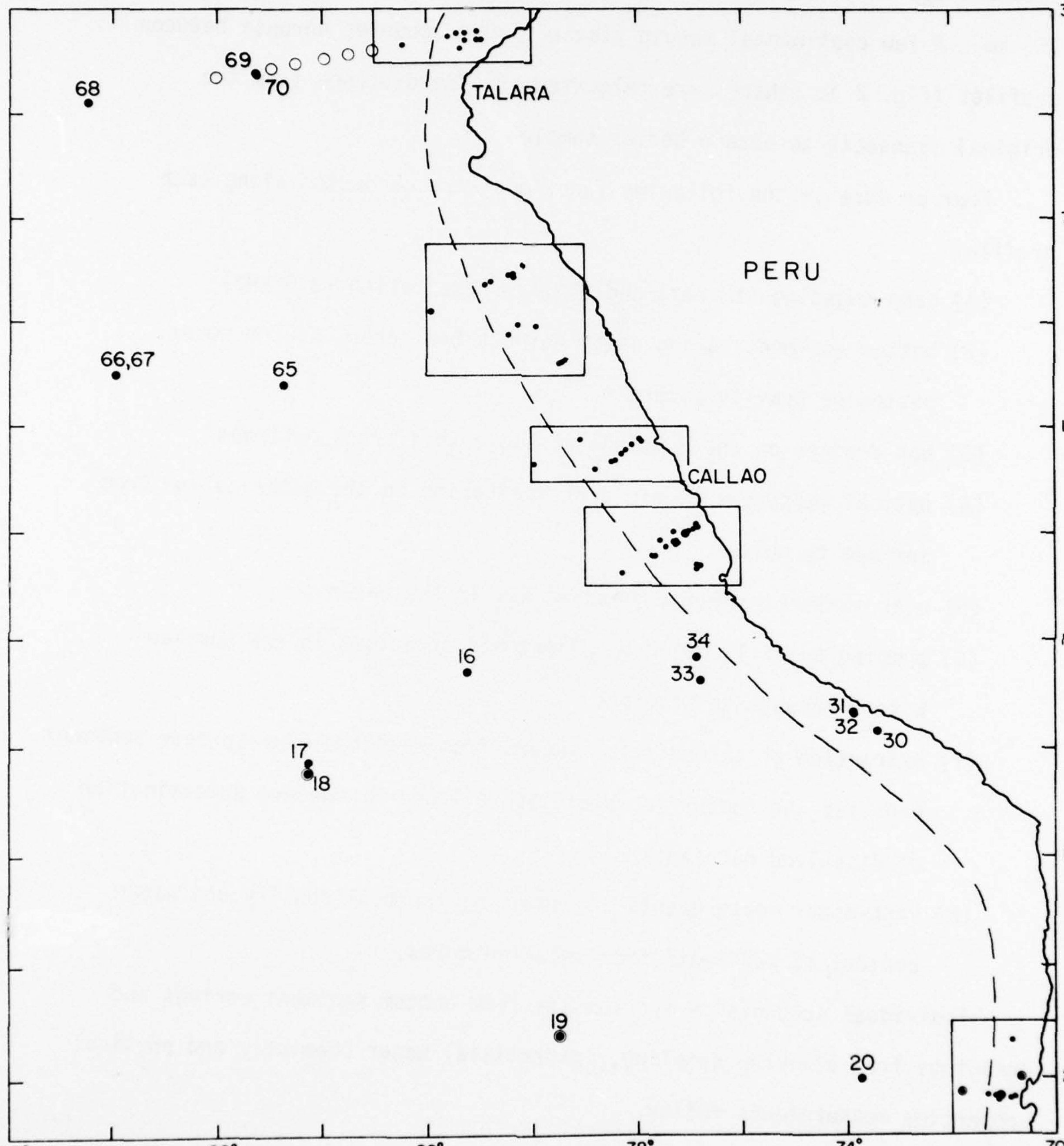


Fig. 2 Stations along profiles 1 to 4 and locations of detailed survey areas across continental margin. The numbers refer to sediment cores outside the detailed survey areas and are <u>not</u> station numbers. O = optics stations (See List of Stations and Cores.)

extended approximately 800 km to the west and each short profile only about 150 km. A few continental margin stations were occupied enroute between profiles (Fig. 2); others were relocated at some distance from the original transects to obtain better samples.

Four or more of the following functions were conducted along each profile:

(1) echo sounding (12 kHz) and shallow penetration (3.5 kHz)

(2) bottom sediment coring using Reineck box corer, Kasten corer, piston or gravity corers

(3) box dredges on the continental slope-shelf rock outcrops

(4) optical measurements of light scattering in the water column from surface to bottom

(5) near surface radiance measurements in the water

(6) pumping and filtration of planktonic organisms in the surface waters enroute to stations

(7) extraction of interstitial waters from selected near-surface sediment profiles and subsurface profiles followed by onboard determination of dissolved nutrients

(8) vane-shear measurements and sampling for bulk density and water content of sediments from selected cores.

Individual accounts of the results from bottom sediment corings and dredgings from plankton sampling, interstitial water chemistry and physical properties measurements follow.

Profile 2 (Fig. 3)

Leg 6 commenced with profile 2 after leaving Callao, Peru on May 21, 1977 at 2100 GMT. Three Reineck box cores were attempted in water depths

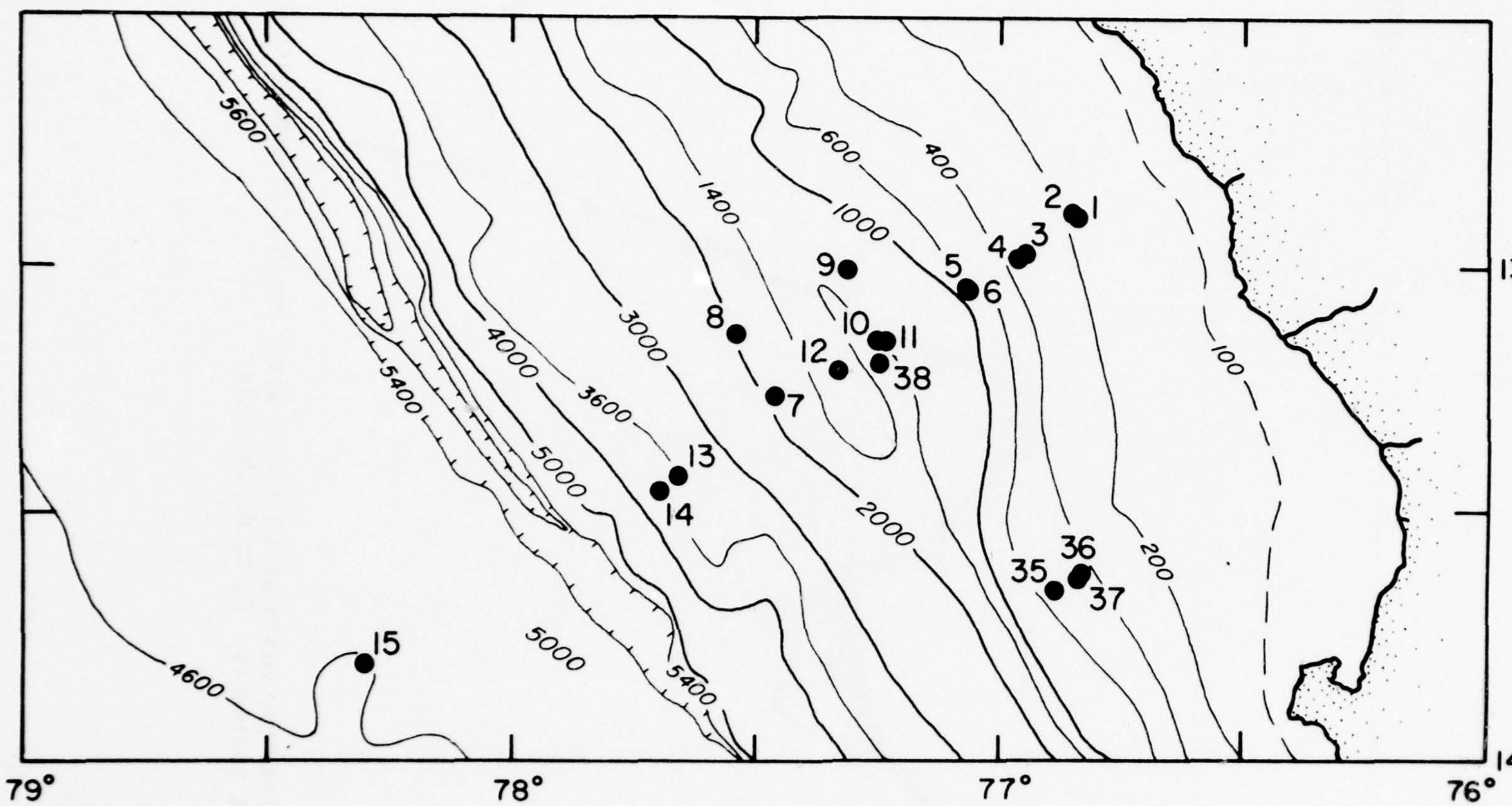


Fig. 3 Detailed section of profile 2 across the continental margin off central Peru with intraslope basin (see Fig. 3 a); cores 35-37 are from Margin Stations 1 B south (see p. 18).

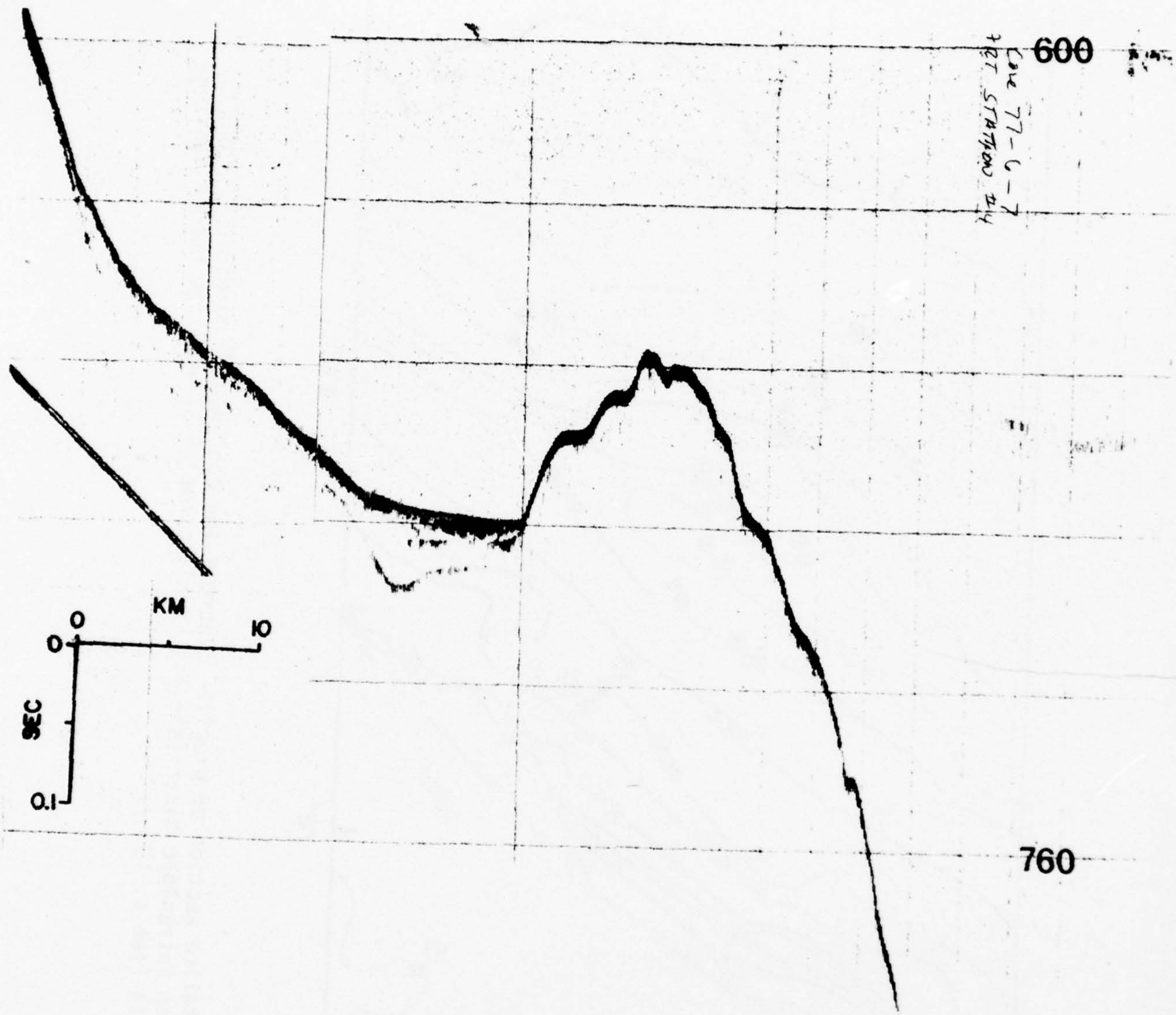


Fig 3a. Intraslope basin at 1400 m of water depth with acoustically transparent sediments. Fm to depth scale.

ranging from 148 to 304 m, i.e., cores 7706-1,-2,-3. The first core yielded a composite sample of dark gray to black, organic-rich mud. The second one was washed slightly at the surface but otherwise undisturbed and the third over-penetrated to the weight stand. The third core contained fish debris.

Three Kasten cores and a 4-inch gravity core were taken between 325 and 701 m of water depth to bracket the oxygen minimum zone, i.e., cores 7706-4,-5,-6,-7. Most cores consisted of disturbed dark gray/black silty clay or hard mudstone. Kasten core 7706-4 was processed for X-radiographs, physical properties and interstitial water chemistry on board ship. The rather steep upper continental slope has only a thin sediment cover as evidenced by the 3.5 kHz records and the core recovery.

Next an acoustically well defined sedimentary basin was sampled at about 1400 m on the middle slope. Sediment thickness according to the 3.5 kHz record approached 25 to 75 m. Several cores attempted in the center and around the margins of the basin (7706-8,-9,-10,-11,-12) produced less than one meter of sediment each consisting of dark green silty clay and free H_2S was detected in one core. The rather stiff clay and spongy appearance of the deposits precluded deeper penetration of the coring devices and even a second attempt in the center of the basin during the latter part of the cruise yielded only 100 cm of sediment despite the addition of 400 lbs. more weight to the Kasten corer (7706-38). (Fig. 3a)

A 4-inch diameter gravity core, 7706-13, was taken on the steep lower continental slope at 3470 m; it consisted of silty clay and was disturbed in the coring operation.

In order to compare the hemipelagic sediments on either side of the trench a 2 m Kasten core (7706-14) was collected on the lowermost slope landward of the trench in 3621 m of water depth and a 4.5 Kasten core (7706-15) was taken on the seaward side of the trench at 4581 m at nearly the same distance from the trench axis. Core 7706-14 was opened on board for interstitial water and physical property analyses.

Light tan clay was cored at station 7706-16 midway between the trench and the western most cores located on the Nazca Plate (i.e., 7706-17 and 18). These cores contained pelagic brown clay and were both processed for interstitial water extraction and physical property measurements. A gradient in the components of the hemipelagic sediments should be apparent in this profile. The western most station of profile 2 was reached on May 25 at 1253 GMT (17°29.6'S, 84°17.8'W) then followed by 379 nautical miles of transit to sampling profile 1.

Profile 1 (Fig. 4)

Pelagic sediments cored in the Chile Basin form a thin blanket of acoustically transparent material draping the hilly topography. Kasten core (7706-19) at 22°14.3'S and 79°30.7'W at the most westward station of profile 1 contained brown clay and abundant manganese nodules at a water depth of 4497 m. Next a Kasten core (7706-20) was taken at a depth of 3717 m and about 240 km west of the Peru-Chile Trench. This core was stored and its lithologies not noted. Core 7706-21 at 4400 m was collected just seaward of the trench on the outer trench swell. The 74 cm long bent Kasten core contained indurated brown clay with no evidence of hemipelagic sediments. Olive gray clay interbedded with sand turbidites were cored within the trench axis at 8080 m and apparently represent the most seaward occurrence of terrigenous sand, silt and clay in this area.

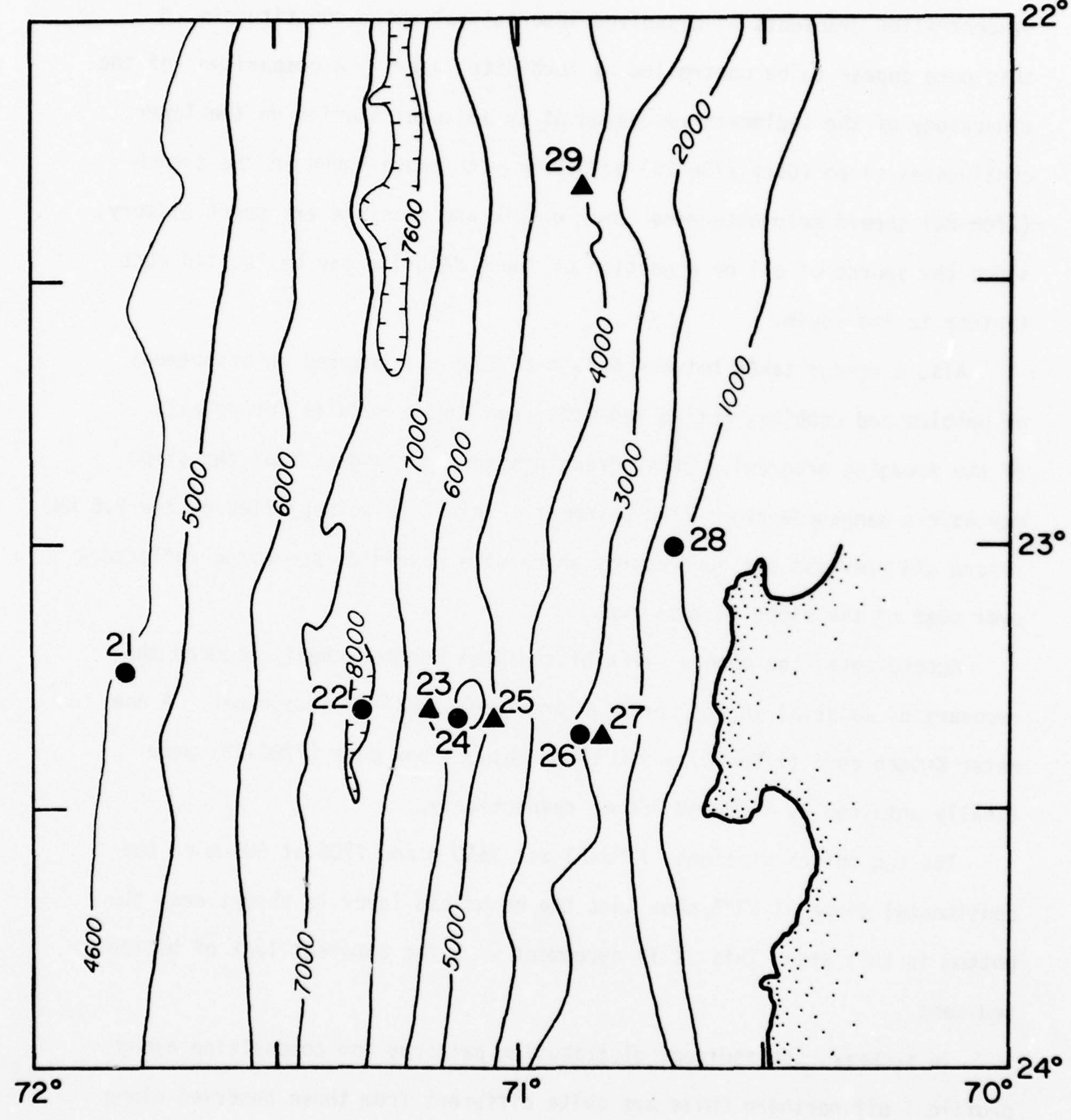


Fig. 4 Detailed section of profile 1 across margin off northern Chile
▲ = dredging stations.

Concentration gradients of dissolved interstitial water constituents in this core appear to be controlled by turbidite layers. A comparison of the mineralogy of the sediments recovered at an adjacent station on the lower continental slope (Core 7706-24) at 5197 m with those found in the trench (7706-22) should help determine their origin and possible transport history, since the source of all or a portion of these deposits may be located much farther to the south.

Also a dredge taken between 6543 m to 5066 m recovered an assortment of pebbles and cobbles, but no sediment (see dredge results for details of the dredging program). Other dredgings further suggest that the slope may have a manganese-crust-like pavement. This is also supported by the 3.5 kHz record and previous air gun records which were devoid of subbottom reflectors over most of the slope in this area.

Accordingly, the general lack of sediment cover markedly reduced the recovery of material in the cores or precluded sampling altogether. A one meter Kasten core (7706-26) and a 15 cm Reineck box core (7706-28) were finally obtained at 1600 and 764 m, respectively.

The two optics stations, 7706-21 at 3650 m and 7706 at 500 m on the continental slope at 23°S, show that the nepheloid layer is absent near the bottom in this area. This is in agreement with the apparent lack of bottom sediment.

In summary, the sediment distribution patterns and composition along profile 1 off northern Chile are quite different from those observed along profile 2. Upwelling is absent or negligible in this area; the sources of terrigenous material are limited because of the ephemeral streams associated with the Atacama Desert; manganese pavements suggest low sedimentation rates and/or current winnowing of the fine-grained material that is deposited; the bottom nepheloid layer is absent; the acoustic data shows no evidence of a sediment cover; and most hemipelagic sediments do not extend seaward beyond the Peru-Chile Trench.

Margin station 1A (south)

After leaving profile 1 and traversing NNE along the continental margin, a decision was made to attempt to recover hemipelagic sediments on the upper continental slope between 23°S and 12°S regardless of whether they are located on any of the standard profiles. A Reineck box core was attempted at 2154 m of water depth at 16°42.0'S and 73°24.2'W with 25 cm of sand recovered (7706-30). Subsequently a topographic basin mapped by a previous survey did not materialize, but rather appeared to be a channel. A second basin was surveyed at 16°25'S and 73°35'W at 600 m of water depth with no sediment indicated on the 3.5 kHz record. However, sediments were recovered to the NW on a ledge located at 645 m and 16°17.6'S and 73°53.6 W. At this site a Reineck core (7706-31) and a 1.5 m Kasten core (7706-32) of silty clay were recovered. Abundant benthic fauna was apparent in the Reineck box core to a depth of about 10 cm. The portion of the upper continental slope with this sediment cover lies within the main part of the upwelling region and within the depths of the oxygen minimum zone. Interstitial waters and physical properties were analyzed in both cores.

Nazca Ridge

In traversing further north to Callao, a decision was made to take two Kasten cores on the landward extension of the Nazca Ridge where it intersects

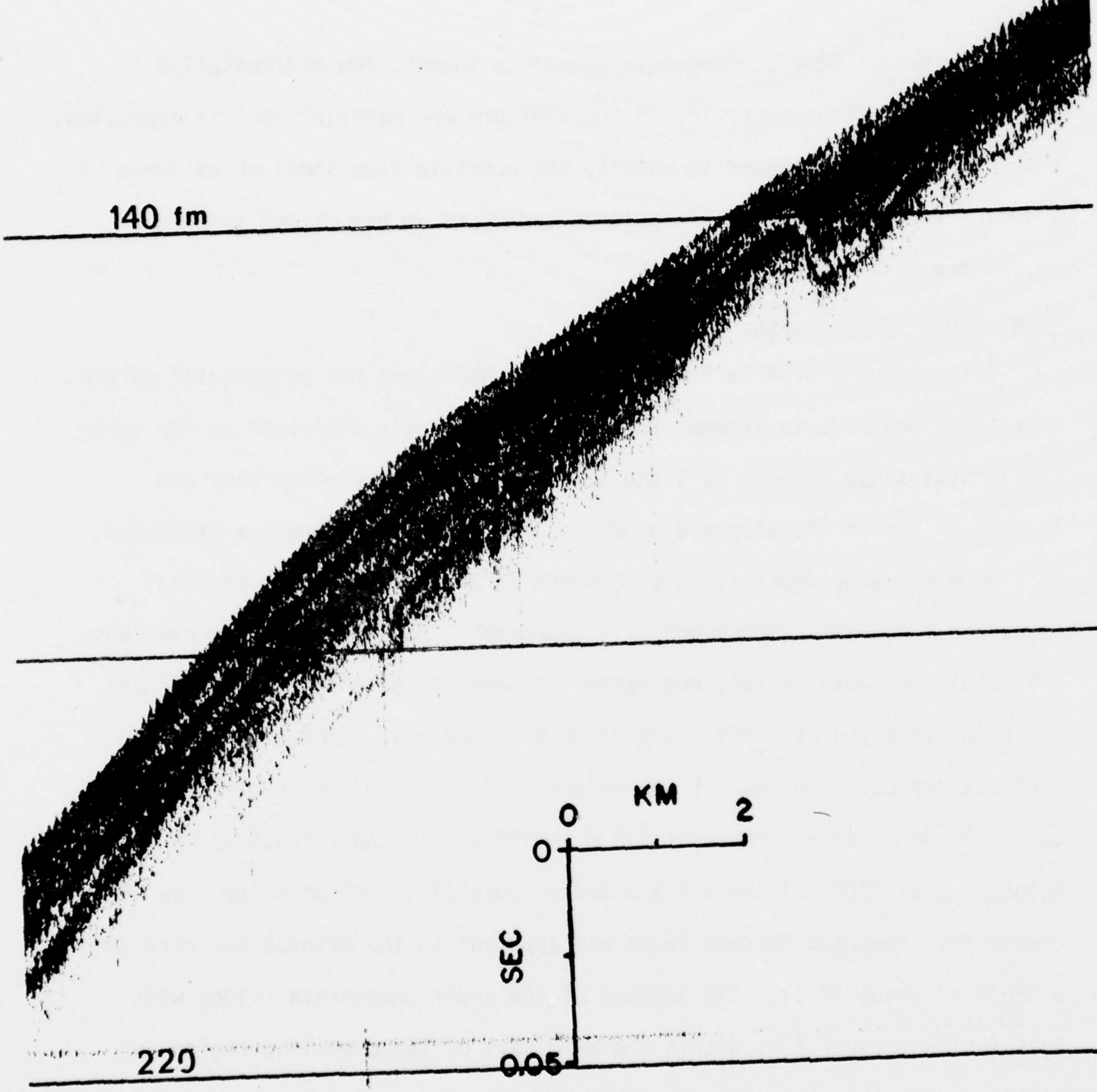
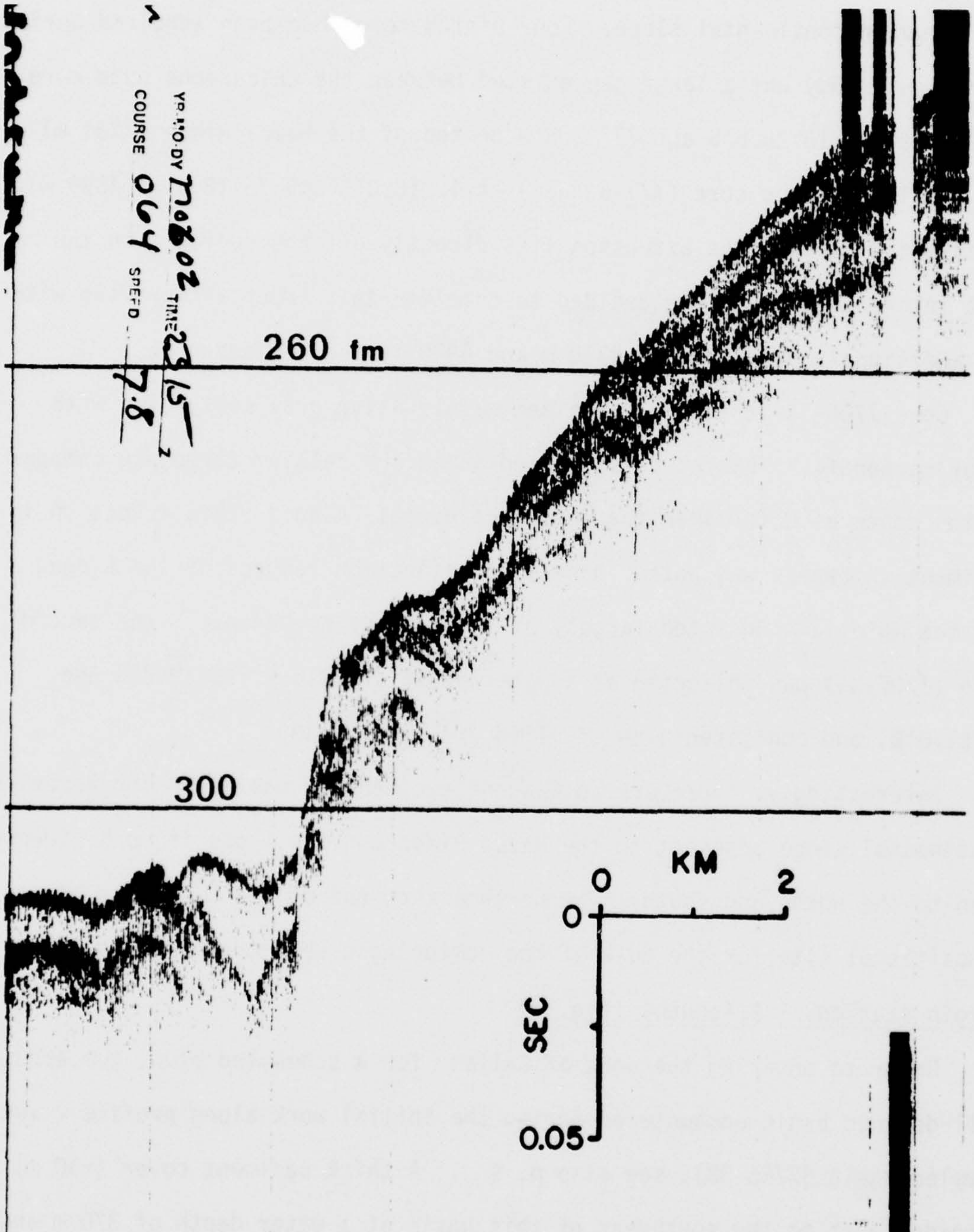


Fig. 5 Thick sediment cover of dark olive gray to black, organic-rich deposits on upper slope <600 m. Subbottom topography apparently controls depositional sites of similar "upwelling" sediment patches. Below 600 m of water depth evidence for reworking and erosion was found.



YR.MO.DY 710602 TIME 2315
COURSE 064 SPEED 7.8
260 fm
300
0 KM 2
0
SEC
0.05

Fig. 5 cont.

the Peruvian continental slope. Four piston cores had been acquired during a previous study but a large gap existed between the calcareous ooze core (Y71-6-12) at 16°26.6'S and 77°33.8'W on top of the Nazca Ridge (2734 m) and the lower slope core (Y71-6, -24) at 15°16.0'S and 76°18.8'W (4899 m). Because the Nazca Ridge extension lies directly off the region with the most intense upwelling, we decided to complete this important profile with two additional cores between 2700 m and 4900 m of water depth.

Core 7706-33 at 2967 m contained mainly olive gray silty clay with minor carbonate. This core is located above the calcium carbonate compensation depth as determined for the Nazca Ridge. Also a rapid reduction in sediment thickness was noted in seismic reflection records of the Ridge, yet the material consisted largely of terrigenous components. The second core (7706-34) was collected at a water depth of 3316 m (15°19.2'S and 76°51.0'W) and consisted also of olive gray silty clay.

Interestingly, there are no Neogene sedimentary basins on the Peruvian continental slope adjacent to the Nazca Ridge and the slope is much steeper than to the north and south. The northeastern end of the Ridge may be the depositional site for the bulk of the hemipelagic sediments in this area.

<u>Margin stations 1 B (south)</u> (Fig. 3)

Prior to entering the port of Callao for a scheduled stop, the acoustically well-defined basin encountered during the initial work along profile 2 was sampled again (7706-38), see also p. 9 . A thick sediment cover (>30 m) was recorded just to the southeast of this basin at a water depth of 370 m and sampled by Reineck and Kasten coring (7706-36, -37) (Fig. 5).

It appeared that the extent of this organic-rich silty clay with abundant benthic organisms is limited to a water depth <600 m and constitutes one of

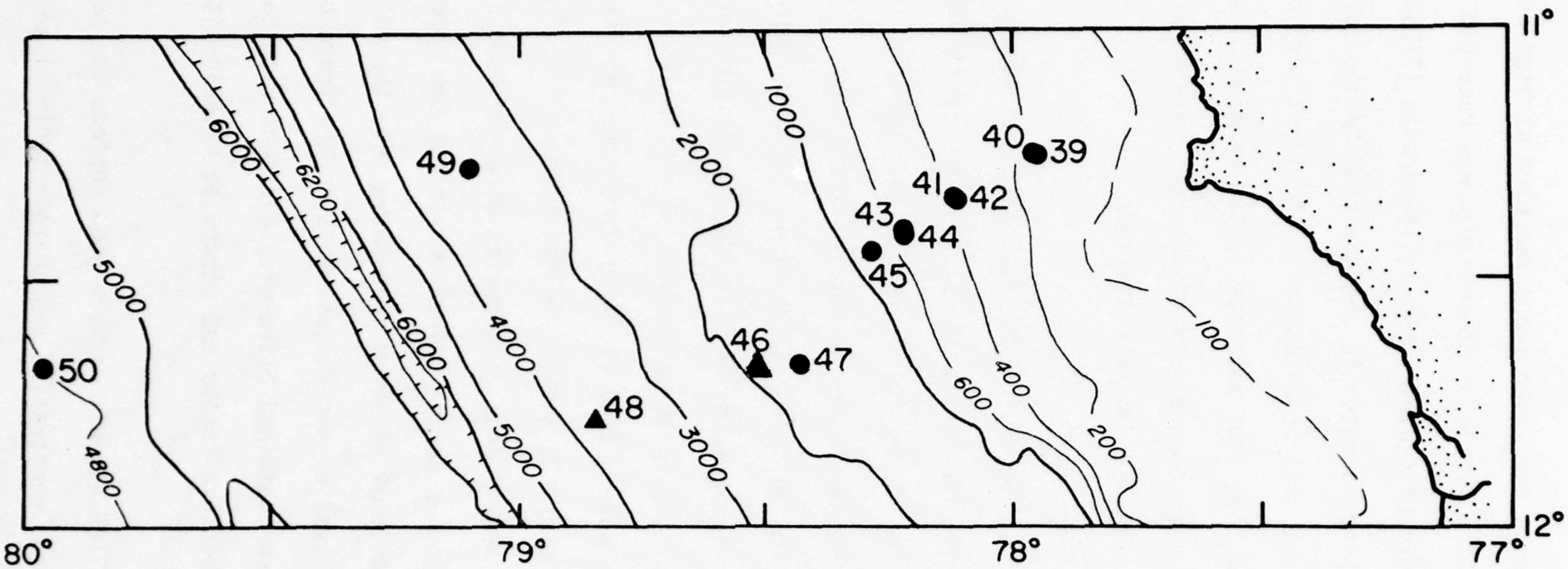


Fig. 6 Margin profile 2 A; the lower slope stations (cores 7706-49, -50) are shifted northward because of lack of sediment cover along original track line; ▲ = dredging site.

several patches of sediment on the upper slope reaching as high as the shelf. At water depths >600 m little or no sediment was recorded and core recovery limited to a mixture of gravelly mud and Mn-crusts (7706-35). A similar distribution was observed later to the north of Callao during the second part of the cruise and will be discussed. The first part of Leg 6 was completed by June 2. A port stop was made on the morning of June 3 at 1300 GMT for refueling and maintenance work on the refrigerated container used for sample storage and interstitial water extraction.

Margin profile 2 A (north) (Fig. 6)

After leaving Callao on June 4 at 0800 local time the second part of Leg 6 commenced with corings along the short profile 2 A (north) between 11° and 12° S to study the nature of the margin hemipelagic deposits beneath intense upwelling and those immediately seaward of the trench.

Both a Reineck box (7706-39) and a Kasten core (7706-40) were collected at 186 m. The former over-penetrated into the dark-gray olive colored silty mud rich in organic matter; the latter recovered >3 m of sediment. Another pair of Reineck and Kasten cores (7706-41, -42) were taken at 411 m. The Reineck over-penetrated again, the Kasten yielded approx. 3 m of sediment. Fish debris were found in both cores; lithologies were the same as on the previous station. At 580 m the coring operation yielded two cores 7706-43, -44. The problem of the Reineck box over-penetrating into the soft organic rich sediments had been solved by some adjustments on the frame of the equipment. The Kasten core contained olive-gray sediment with calcium carbonate in clusters of benthic forams and otherwise organic-rich silty clay.

A Reineck box core (7706-46) with a very good surface was subsequently collected at 810 m but short penetration and coarser sediment texture than

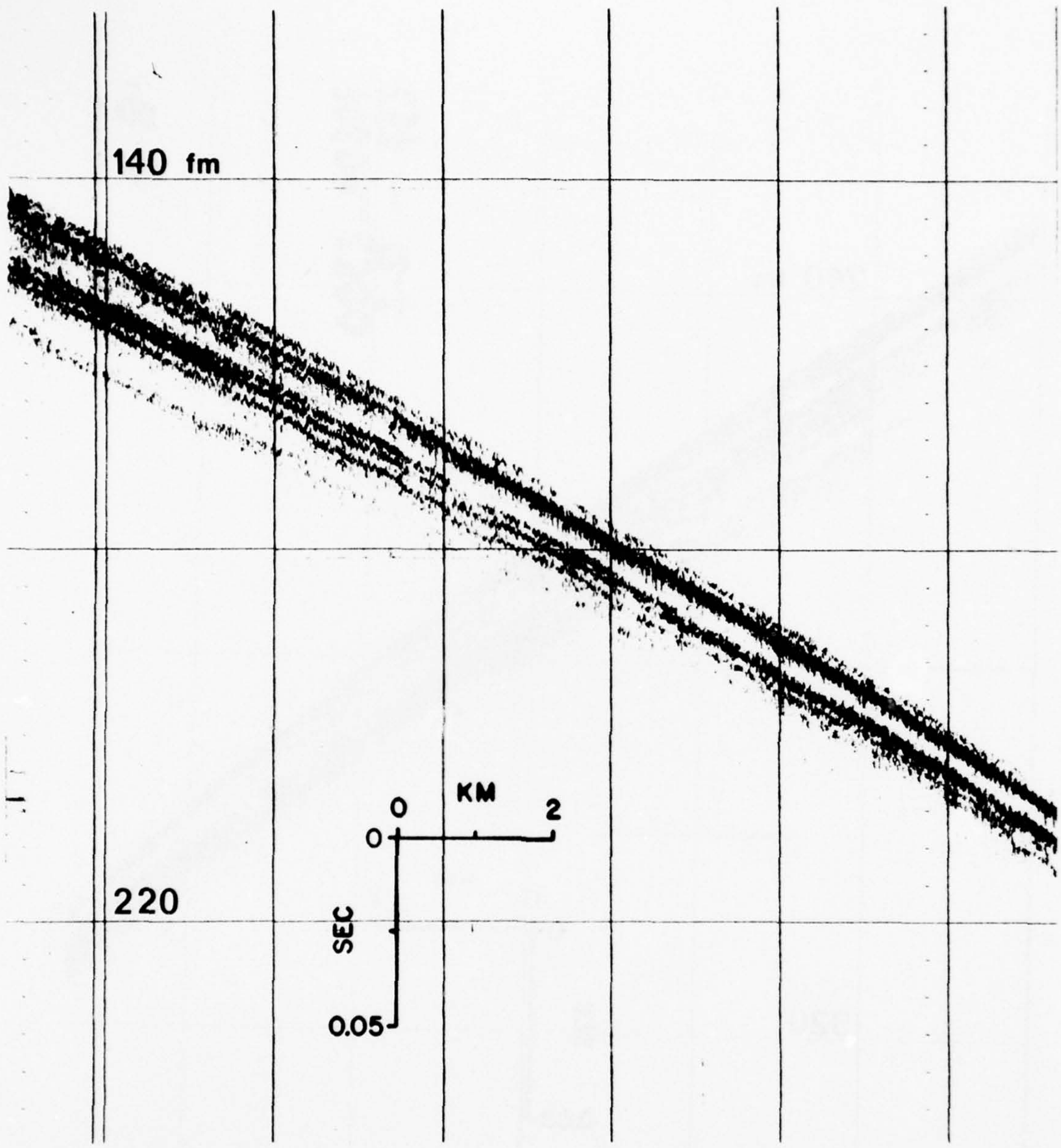


Fig. 7 Sediment cover of dark olive-gray to black organic-rich deposits on upper slope (< 600 m), abundant fish debris and faint laminations were observed, sand was recovered at 810 m of depth.

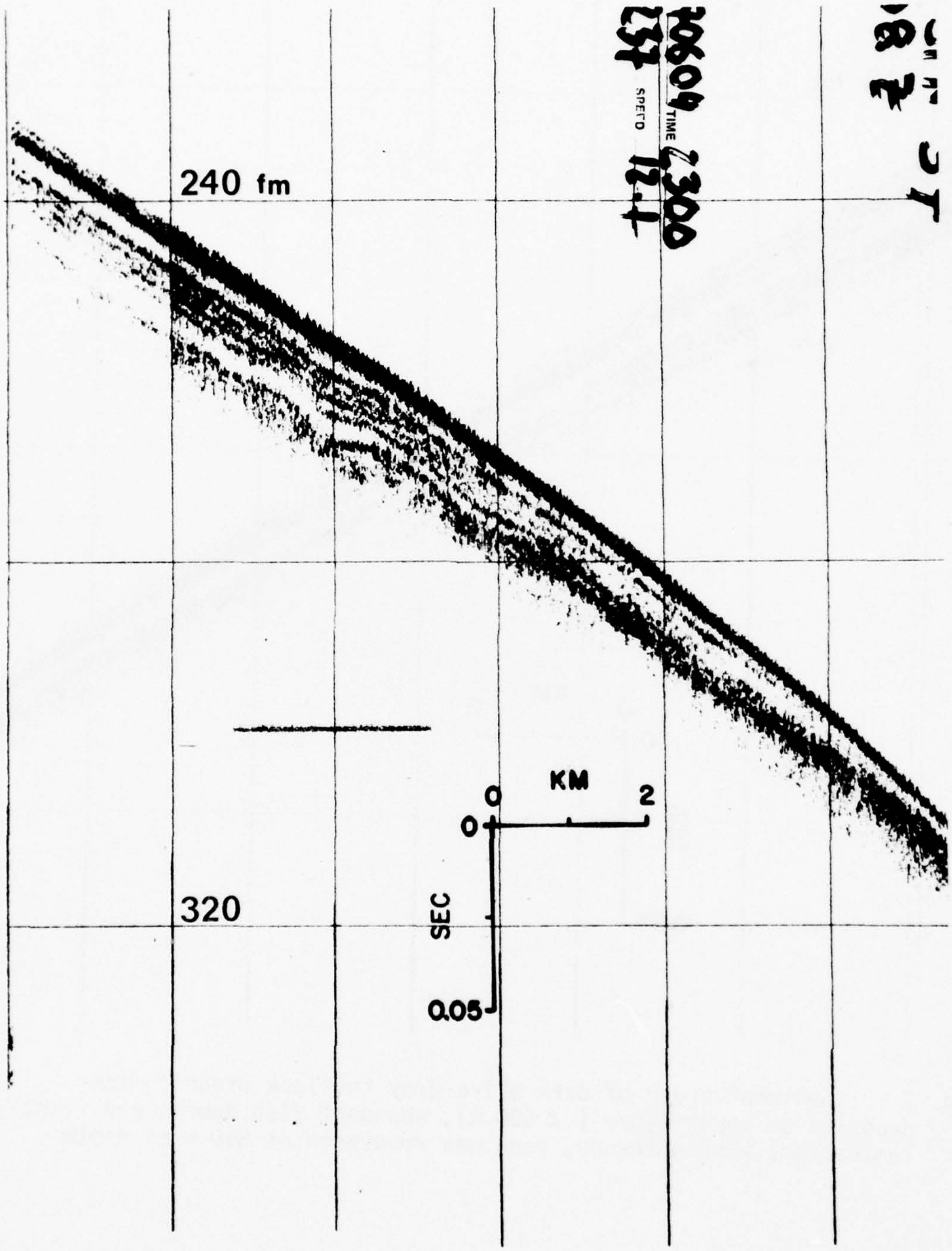


Fig. 7 cont.

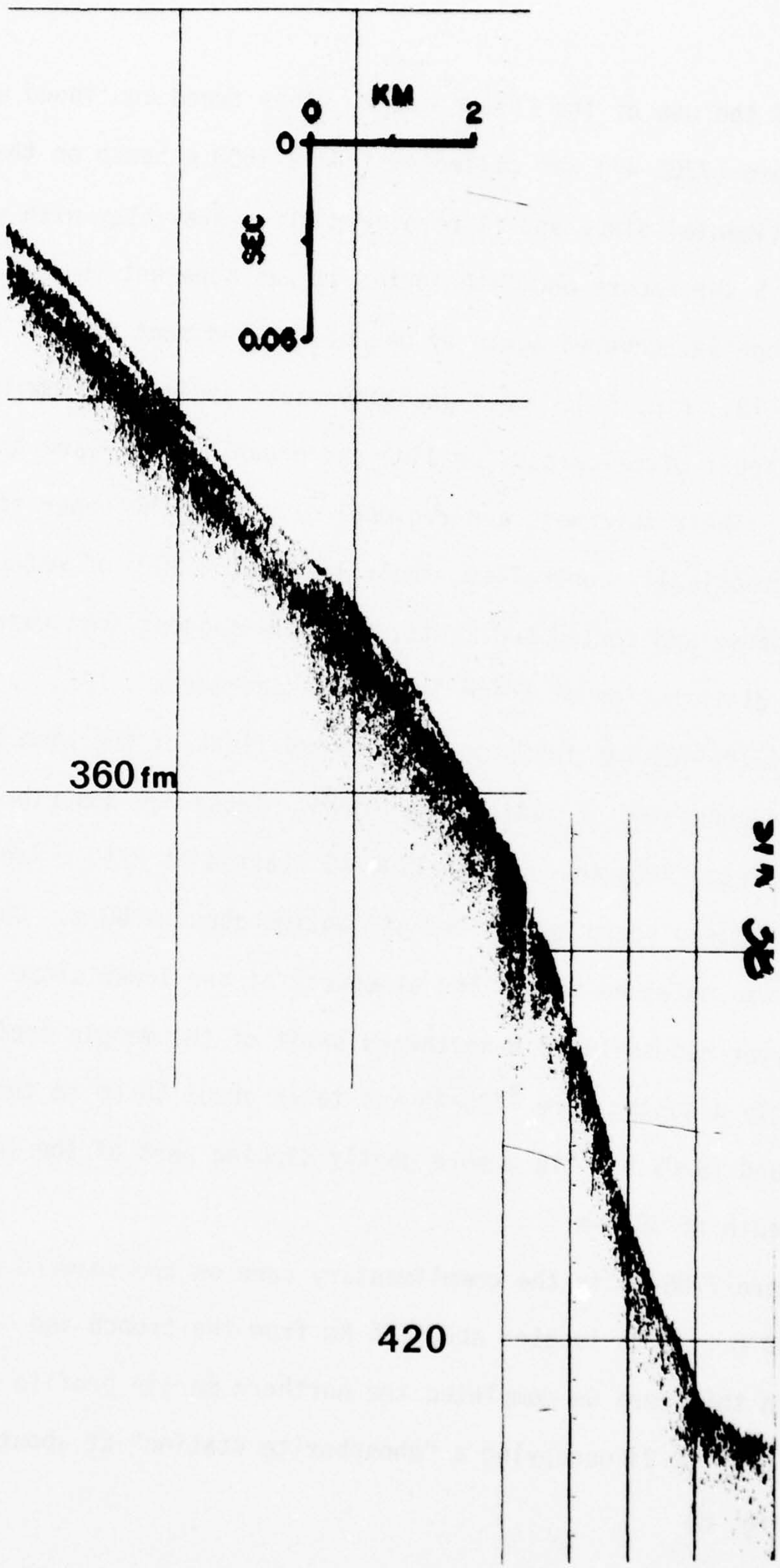


Fig. 7 cont.

before precluded the use of the Kasten corer. This trend continued when a Reineck box core (7706-47) was collected from a 1500 m bench on the middle part of the continental slope and it recovered olive gray clay with sand.

From the 3.5 kHz record and lithologies it was apparent that this part of the upper slope was covered again by one of the sediment patches noted earlier (see p. 19, Fig. 5). Most probably rapid sediment accumulation, high biogenous input of calcareous opaline and organic matter are typical for these deposits. Their thickness and regional extent on the upper slope and shelf are topographically controlled, their limit at ~600 m of water depth indicated by coarse and sorted sediments, strongly suggest some current control on the distribution of these "upwelling sediments". (Fig. 7)

A dredge (7706-46) was taken on the seaward flank of the Lima Basin at 2246-1623 m and consisted of sedimentary rocks. These are described in detail on the Dredge Program. Dredge 7706-48 started at 3749 m landward, proceeding up a steep scarp and lifted off bottom about 3000 m. Only one rock specimen was obtained here. The steepness of the lower slope and lack of sediment cover necessitated a northward shift of the margin profile 2 A.

Accordingly a Kasten core 7706-49 was taken about 50 km to the north at 11°16.6'S and 79°05.9'W in a more gently dipping part of the lower slope at a water depth of 3970 m.

Kasten core 7706-50 is the complimentary core on the seaward side of the trench at 4902 m. It is located about 75 km from the trench and opposite of 7706-49. With this core we completed the northern margin profile 2 A and proceeded to profile 2 B occupying a "phosphorite station" at about 9°46.0'S, 79°25.0'W. (Fig. 8)

Phosphorites are known to occur on the upper continental slope at about 10°S latitude (Baturin et al., 1975; Burnett & Veeh, 1977). Station 44 was occupied over a depth range from 259 m to 414 m. A Reineck core 7706-51 was taken at 259 m and a badly washed composite biogenous sand sample was recovered. At 352 m water depth a Reineck core 7706-52 of 20 cm length was taken. The surface was disturbed by washing slightly. Lithologies included olive-green foram sand and dark olive mud. Fish debris and phosphatic black concretions and cemented sand concretions occurred at the 5-17 cm interval. In deeper water at 414 m the final Reineck core 7706-53 was collected. The olive green foram sand cover had diminished to <10 cm underlain by olive green hard mud. Abundant fish debris and phosphorites were recovered at the facies boundary. Interstitial water was extracted from 2 Reineck cores.

Margin profile 2 B (north) (Fig. 8)

Profile 2 B located at 9°S had two primary objectives: dredging outcrops on the continental slope and a series of eight closely spaced optics stations extending from 200 m to 5000 m; it was only about 85 km long. The optics stations were run consecutively over a period of 18 hours to minimize the temporal changes in suspended particulates across the margin. Dredge 7706-54 was taken at a depth of 380 m where the entire box was lost on the rugged outcrops. The station was reoccupied at 250 m and a full dredge of sedimentary rocks and partially metamorphosed hard sedimentary rocks was obtained.

Dredging commenced again along profile 2 B starting at about 4479 m (stations 7706-54, -55, -56). No rocks were recovered in three attempts and

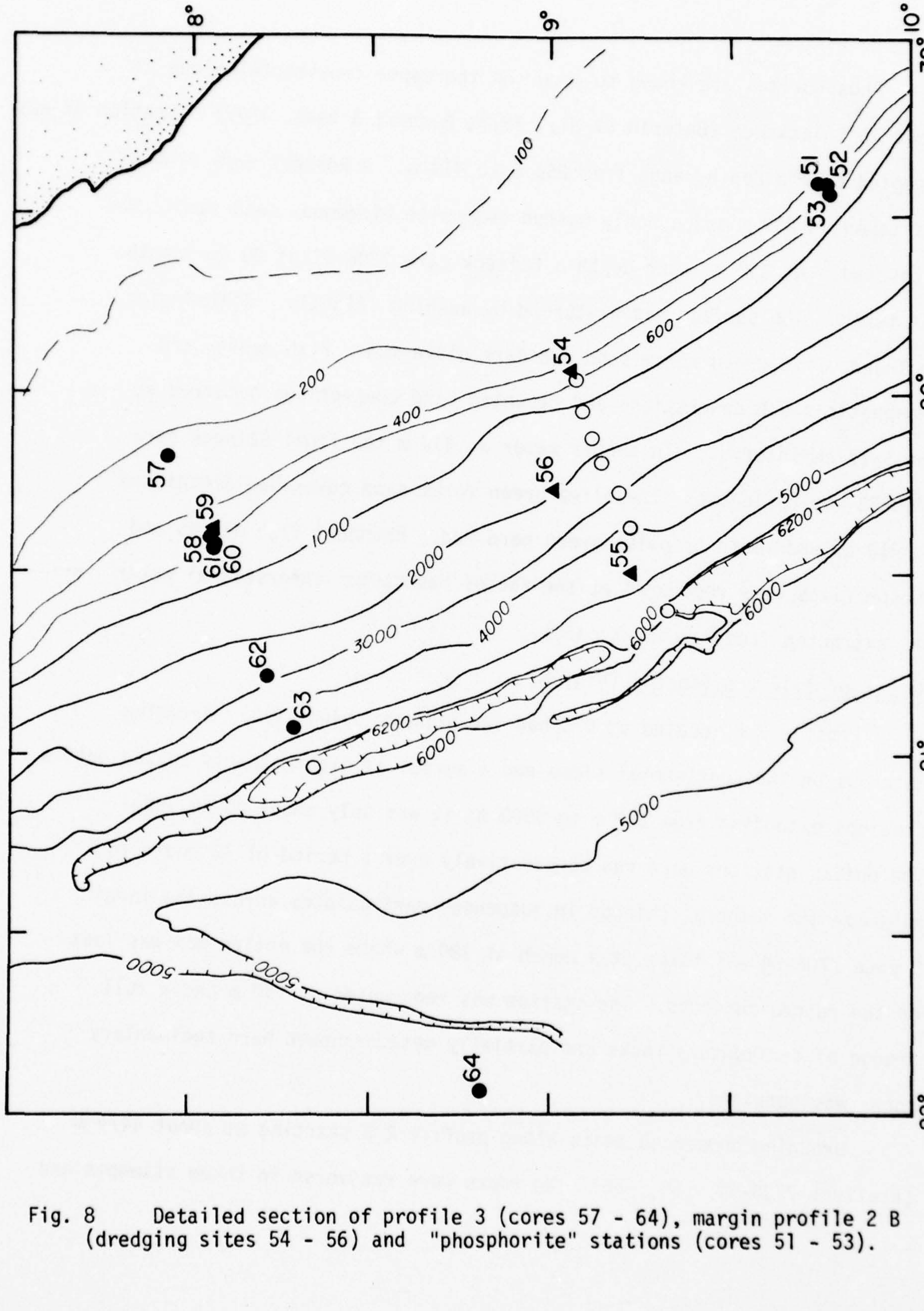


Fig. 8 Detailed section of profile 3 (cores 57 - 64), margin profile 2 B (dredging sites 54 - 56) and "phosphorite" stations (cores 51 - 53).

only composite sediment samples collected in dredges 7706-55 and -56. All dredging attempts were then terminated and the vessel proceeded to profile 3 to begin the sampling of the sediments across the continental slope and onto the Nazca Plate.

Profile 3 (Fig. 8)

Station work on profile 3 began on June 9, 0030 GMT with a Reineck box core (7706-57) taken at 192 m water depth which yielded 24 cm of green biogenous sand with shell debris. The surface of the core was undisturbed. Another box core (7706-58) of sandy material was collected at 486 m and one-half of the surface of the core was washed out. Then an excellent rock exposure at 430 m was dredged (7706-59) and a full bag of sedimentary rocks retrieved (see Dredge Program).

Just to the seaward side of the rock exposure a Reineck box core (7706-60) was recovered containing 35 cm of olive gray silty sediment with an undisturbed surface. A Kasten core (7706-61) was subsequently taken at the same location (8°03.7'S, 80°25.9'W) at 890 m of water depth. The barrel was bent and some washing occurred in the bent section of the core at about 100 cm from the surface. The *in situ* interstitial water sampler was tested here and attached to the exterior of the barrel; it worked perfectly, yielding about 15 ml of water.

Two Kasten cores were obtained on the middle and lower slope at 2670 m and 4513 m respectively. Core 7706-62 was 317 cm long and core 7706-63 was about 180 cm long. Both contained green-gray to olive clay.

An optics station was run subsequently in the axis of the trench at 7000 m of water depth.

To the seaward side of the trench at 4404 m Kasten core 7706-64 was positioned as the counterpart of core 7706-63 on the lower continental slope landward of the trench. Olive gray mud was obtained at that site similar in lithology to other cores taken in the area by Prince et al. (1974).

For the first time during this cruise piston coring equipment was rigged in order to recover Nazca Plate sediments. Core 7706-65 was 1012 cm long and penetrated about 298 cm of light olive gray clay, abruptly passing into light brown to dark brown pelagic clay below. It appears as if the facies boundary between hemipelagic and pelagic sediments was cored at this location (10°11.8'S,84°44.8'W); moving farther westward to 10°00.7'S and 87°58.6'W, we took a Reineck box core at 4305 m (7706-66) and obtained 8 cm of light brown clay with manganese crusts and micro-nodules on the surface underlain by 25 cm of brown clay rich in siliceous ooze. The piston corer (7706-67) recovered 869 cm of the same material at the same site but the auxillary gravity core over penetrated. Interstitial water composition and physical sediment properties were determined on core 7706-66. With these cores profile 3 was completed after 70 hours. Following this the vessel was in transit for 22 hours to reach the most seaward station of profile 4.

<u>Profile 4</u> (Fig. 9)

The first sampling station was reached on June 12 at 1940 GMT and a piston core 7706-68 recovered with 1198 cm of gray clay suggesting that we were still in the hemipelagic sediments at 4°49.1'S and 88°30.7'W and 3903 m of water depth. The westward flowing equatorial current apparently is transporting terrigenous clays in this direction diluting somewhat the biogenic components being produced here at the southern limit of the equatorial productivity zone. The 4-inch gravity core over penetrated at this site.

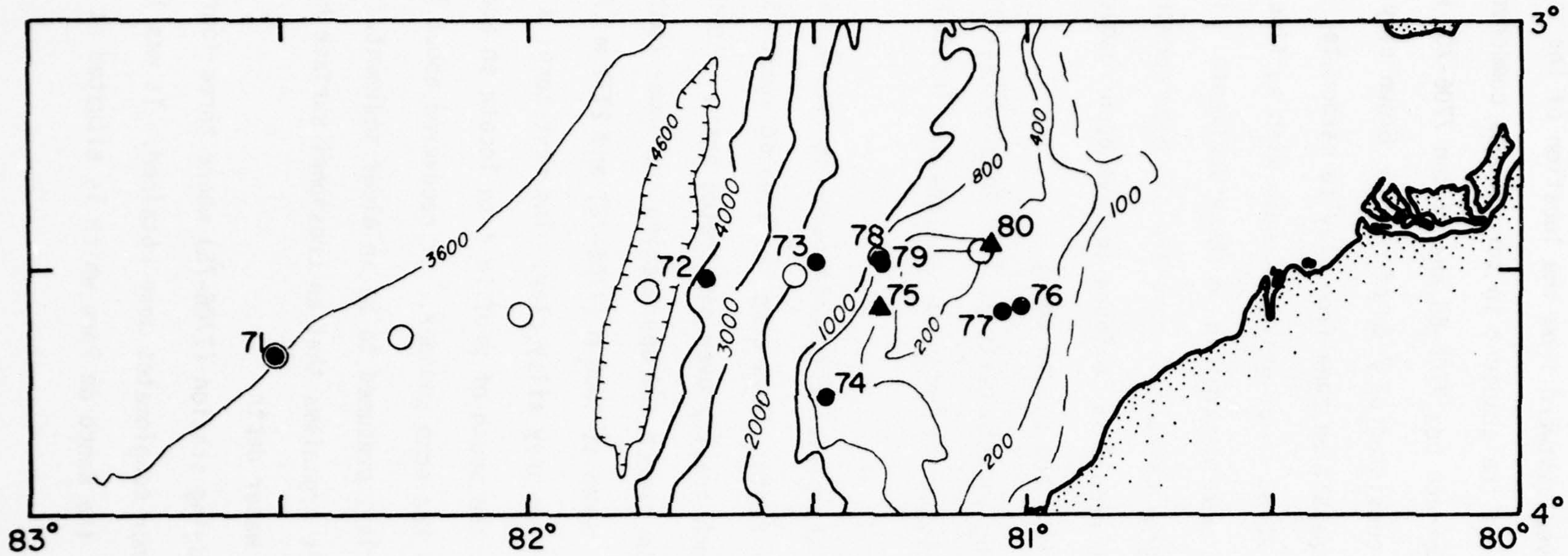


Fig. 9 Detailed section of profile 4, O = optics stations, Δ = dredging sites Banco de Peru.

The next station was moved eastward from the location of the original plan to get a better estimate of the gradient in terrigenous components in these deposits. Two cores, Reineck box 7706-69 and piston 7706-70, were taken here. The former core consisted of 7 cm of medium brown clay and little carbonate, a 7-10 cm transition zone from clay to carbonate, 10-20 cm of bioturbated carbonate and 20-33 cm of gray carbonate with sulfide mottling. Interstitial water components were determined on these sediments. The piston core contained light gray calcareous ooze and had over penetrated past the fins, yet a complete record is believed to have been recovered between the Reineck-, auxilliary and piston cores.

An extensive optics program with casts at 1/2° longitudinal distance was completed along profile 4; the majority of stations was located between 82° and 86° W longitude.

Core 7706-71 was the last piston core collected; it recovered 1188 cm of gray clay at 3600 m water depth. This core is situated about 70 km seaward of the trench; the 4-inch gravity over penetrated again into the very soft sediments. Crossing the trench and approaching the lower continental slope two Kasten cores were taken at 3600 m (7706-72) and 2117 m (7706-73). Both recovered >300 cm of olive gray silty clay. The next core, a Reineck box 7706-74, was shifted to the south of profile 4 to locate an acceptable sediment cover with the 3.5 kHz echo sounder. It recovered about 5 cm of well compacted olive gray clay, presumed to be an older sediment.
It appeared from the benthic organisms that an erosional surface had been recovered here at 713 m of water depth.

Station 83 was a dredging station (7706-75) where three-fourths of a bag of siltstones with minor conglomates were obtained. It was located along the western flank of the Banco de Peru which is situated at the shoreward extension of profile 4.

Moving across this bank into a broad, well-developed depression paralleling the bank and adjacent shore, we recovered a Reineck core 7706-76, and a Kasten core 7706-77, with olive-gray silty clay. Both coring barrels were nearly full; the water depth at this site was 366 m. The absence of organic-rich sediments of the type cored farther south inside the upwelling area was most conspicuous.

The vessel then sailed westward across the bank and took a Reineck core and a Kasten core at 540 m along the seaward flank of the bank (i.e., 7706-78, -79). Both contained biogenous sand and olive-green silt.

The final sampling site (7706-80) was among the large rock outcrops on the eastern side of the Banco de Peru. A full dredge bag of largely siltsone and sandstone was recovered.

With this station the vessel completed the sampling program after spending 107 hours on the last profile. On June 16 at 0730 GMT course was set for Panama where we docked on June 18 at 1700 GMT and terminated this part of Leg 6. The position at 0°00' Lat. was crossed at 80°57.7'W with due respect paid the solemn mysteries of the ancient order of the deep.

Interstitial Water Chemistry

The composition of interstitial waters of marine sediments provides an indispensable tool in determining mineralization reactions of organic matter or other incipient chemical changes in sediments soon after deposition. Generally the limited sample size of water from conventional extraction procedures and the loss of unstable compounds soon after extraction, such as with ammonia, carbon dioxide and hydrogen sulfide impose considerable analytical and methodological restrictions when dealing with pore water chemistry. These restrictions are further complicated by the "temperature-of squeezing" effect (Mangelsdorf et al., 1969). These workers found that the concentrations of conservative constituents, K, Mg, Na, Ca and Cl as well as those involved in mineralization reactions, NH_3, SiO_2, CO_2, PO_4, are either decreased or increased by temperature sensitive ion-exchange and dissolution precipitation equilibria.

Extraction and analytical procedures

At present it is generally believed that the above limitations can be overcome by extracting the interstitial fluids at in situ temperatures, by specially adapted microanalytical methods, and by performing all of the essential analytical determinations on board ship within hours after sediment collection.

We attempted to meet these conditions by performing the extractions inside a refrigerated van at 5°C ± 2. Also large-diameter pressure-filtration units of 30 cm were employed for rapid extraction and all critical nutrient determinations were carried out directly on board ship by standard seawater techniques (Grasshoff, 1976) (Table I p. 31). The large-diameter coring equipment, Reineck corer and Kasten corer, yielded large volumes of interstitial waters of up to 500 ml and allowed for close sample spacing near the sediment surface or at facies boundaries, where gradients are critical.

In addition a newly acquired in situ interstitial water sampler was used to compare the efficiency and reliability of the low temperature squeezing procedure. It was found (Table II , p.37) that the in situ sampled and cold-squeezed interstitial waters did not differ significantly in their

SiO_2 and NH_3 concentrations but that the warm-squeezed sampler exhibited considerable gain and loss of these compounds, respectively. The PO_4 in the in situ sampler was affected by the presence of iron oxides in the sampler, which are known to sorb all dissolved phosphate (Bray et al., 1973). The concentrations of the major constituents will be determined later.

Table I Selected sediment cores for interstitial water analyses.

Regime	Core No.	Water Depth (m)	No. of Samples
Hemipelagic			
Upwelling	7706-39	186 m	10 R
Upwelling	-04	325 m	6 K
Upwelling	-36	370 m	10 R
Upwelling	-42	411 m	13 R
Upwelling	-14	3961 m	7 K
Non-upwelling			
Shelf-break	-57	192 m	4 R
Shelf-break	-52	352 m	1 R
Shelf-break	-53	414 m	4 R
Slope	-31	650 m	11 K
Slope	-32	650 m	4 K
Slope	-61	838 m	8 K
Slope	-60	2670 m	7 R
Trench	-22	8080 m	9 K
Pelagic			
Carbonate ooze/clay	-69	3903 m	11 R
Siliceous ooze/clay	-66	4305 m	9 R
Brown clay	-17	4500 m	9 R
Brown clay	-18	4500 m	7 K

R = Reineck box core K = Kasten core

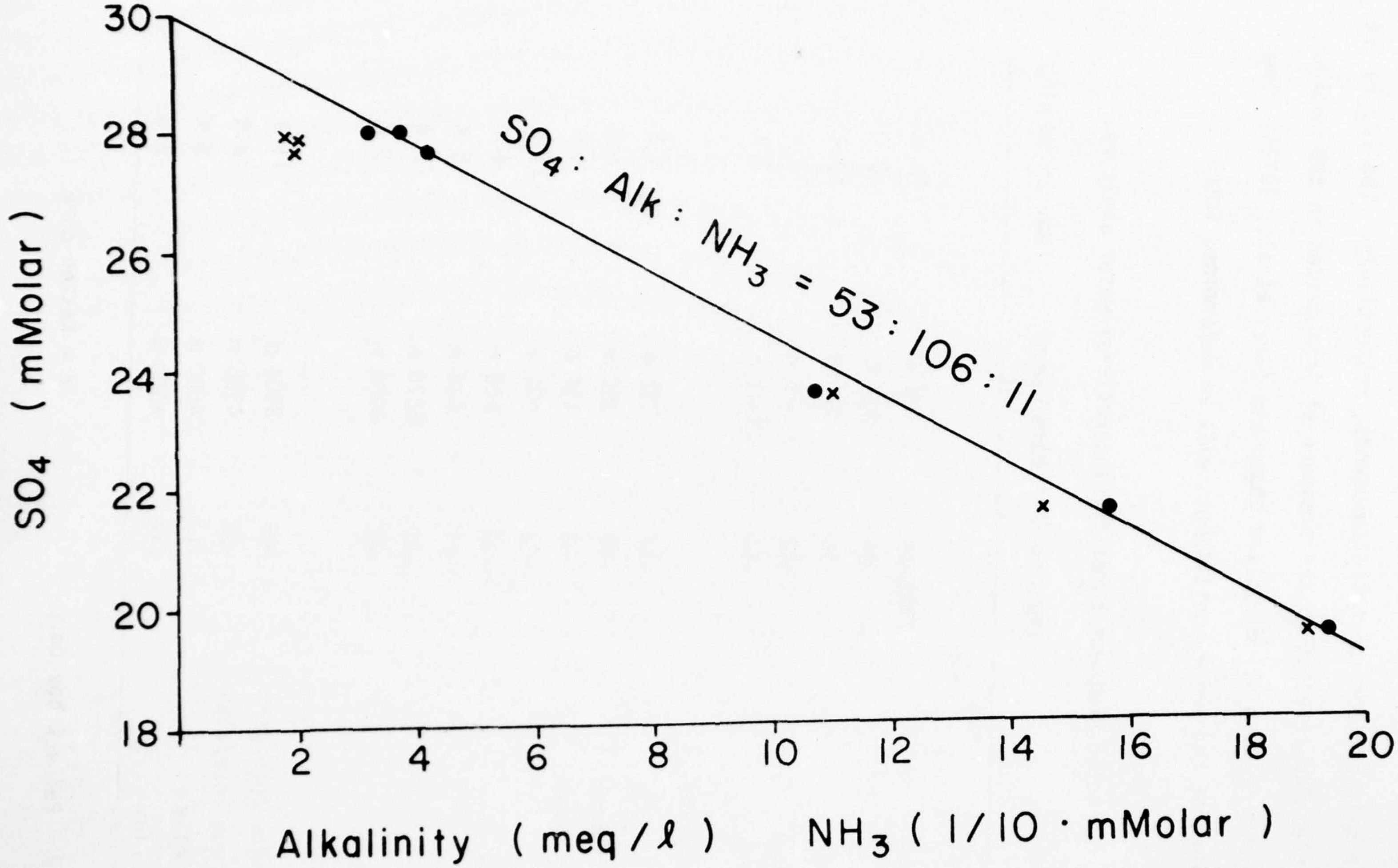


Fig. 10 Sulfate reduction, ammonia and alkalinity production in interstitial waters from Core 7706-14. Concentrations result from bacterial decomposition of organic matter as indicated by molar ratios of

SO_4 : Alk. : NH_3 = -53 : 106 : 11

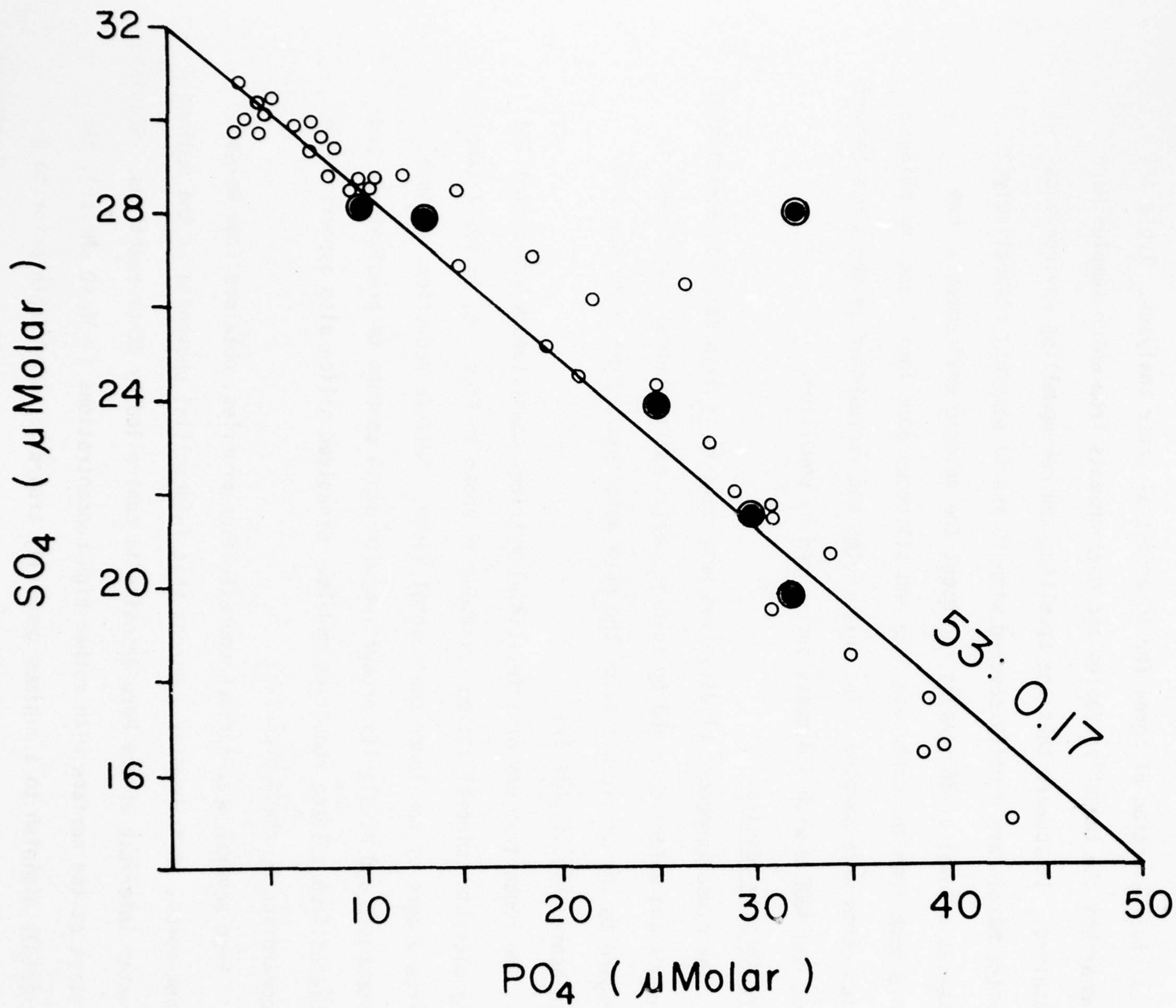


Fig. 11 Dissolved sulfate and phosphate in core 7706-14 (●) also conform to bacterial sulfate reduction model except for near-surface sample, high PO_4 indicates different source.

Sample coverage

The time-consuming extraction and analytical procedures necessitated a careful selection of cores for interstitial water analyses. Table III summarizes the tentative facies and environments from which samples were obtained. It appears that the upwelling and non-upwelling environments on the margin are equally covered with 46 and 47 samples, respectively; whereas a total of 36 samples represent the pelagic environment. One core each from the carbonate ooze and siliceous ooze facies and two pelagic clay cores were sampled. The only regime not represented is the slope between 400 and 4000 m with sediments influenced by upwelling.

Preliminary results

The close agreement of dissolved nutrients in *in situ* sampled interstitial waters and waters obtained by cold-squeezing is considered significant in regard to the applicability of the pore water extraction technique used on board ship. (Table IV)

The concentrations of interstitial nutrient constituents are controlled by microbial mineralization reactions as shown in Figs. 10, 11 for 7 samples from a core of the lower continental slope. Sulfate reduction, ammonia, phosphate and alkalinity production with depth conform to gradients as predicted from sulfate reduction models. Dissolved silica also appears to be controlled by these processes.

From several near-surface concentration profiles, obtained from Reineck box cores, it is however apparent that interstitial phosphate at the sediment/water interface of the Peru deposits is controlled by other reactions. Gradients start at the surface with rather high concentrations ($\approx$30-40 μMolar), then rapidly diminish to a minimum generally around 15 cm of depth prior to a renewed increase with increasing depth, such as typically shown by core 7706-31 (Fig. 12).

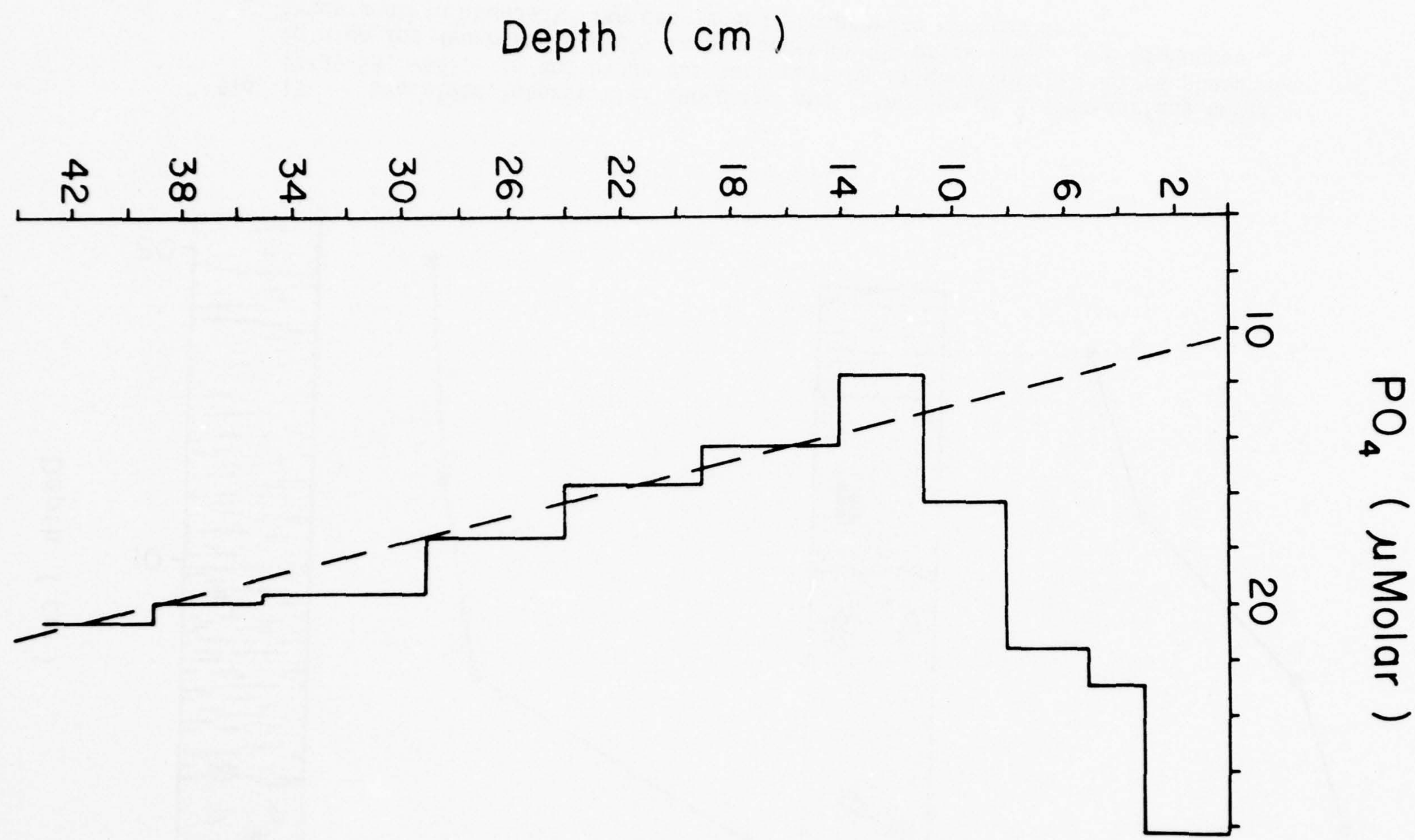


Fig. 12 Dissolved interstitial phosphate concentration changes with depth in Core 7706-31 (R). Line indicates regeneration of phosphate from bacterial decomposition of organic matter. Near-surafce samples show large excess of dissolved phosphate probably from dissolution of biogenic phosphatic debris.

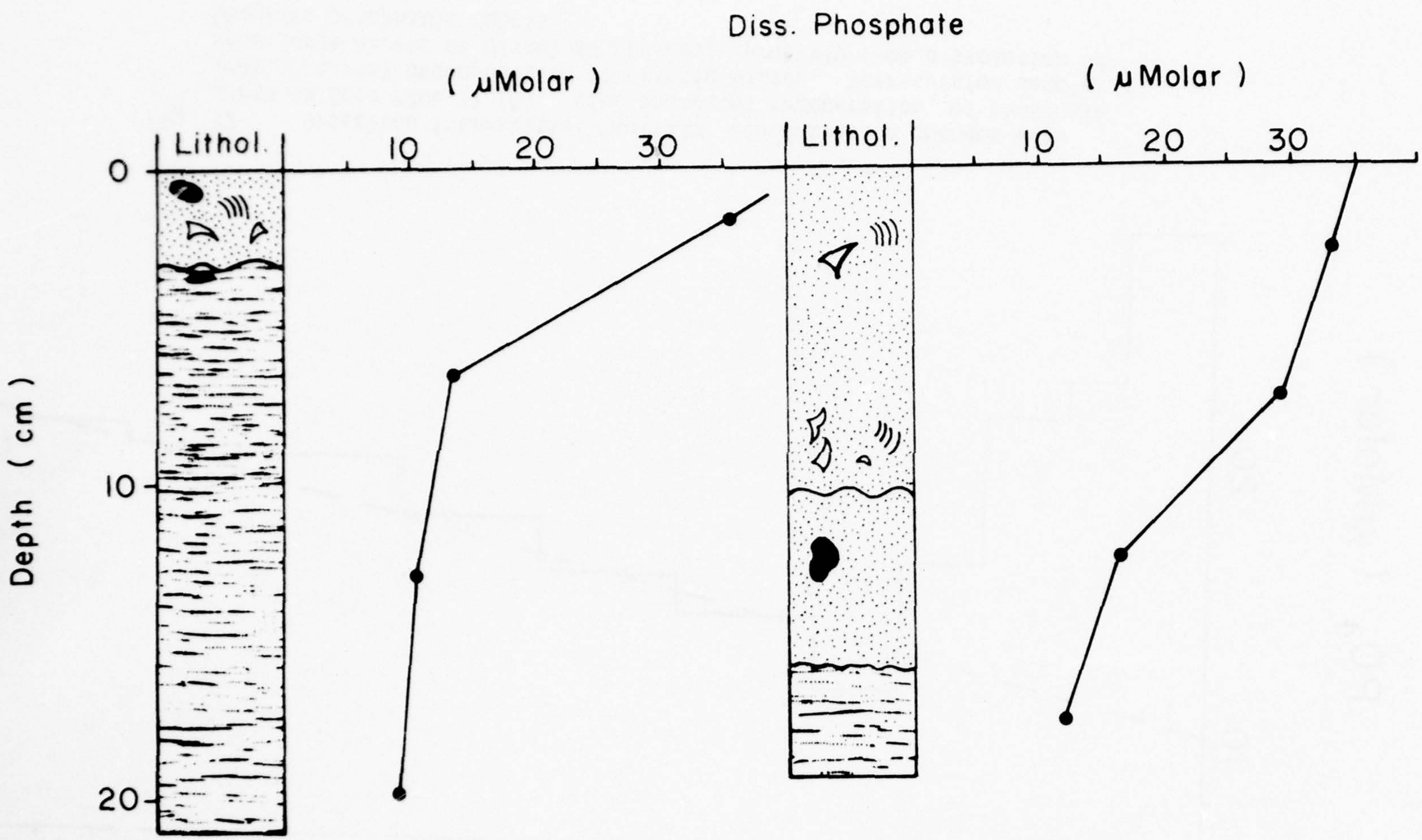


Fig. 13 Dissolved interstitial phosphate and lithology of 2 near-surface cores (7706-53, -57). In the biogenous sand portion of each core dissolved phosphate is high and decreases rapidly in the underlaying silty clay. The biogenous sands contain abundant fish debris and phosphorite concretions.

An interesting case of dissolved phosphate distribution was further observed in 2 biogenous sand cores from the upper slope and shelf region where phosphorites are known to occur (Fig. 13). Here extremely high phosphate concentrations prevailed throughout the arenaceous deposits, whereas at the facies boundary with the underlying silty clay they rapidly decreased. What appeared to be phosphorite nodules were observed at the boundary thus probably control total dissolved phosphate contents in conjunction with incongruent dissolution of phosphatic fish debris.

The pore water chemistry of pelagic deposits was typically found to be influenced not by microbial sulfate reduction but rather by dissolution reactions of calcium carbonate and biogenic silica and inorganic reactions involving clay minerals and minor constituents of the pore waters.

Table II. Comparison of nutrient analyses obtained by different sampling techniques.

	μ Molar		
	PO_4	SiO_2	NH_3
"in situ"	< 1. ± 1*	137 ± 10	57.4 ± 0.5
"cold-squeezing"	13.	143	55.6
"warm-squeezing"	18.	175	48.1

*dissolved phosphate was removed from solution by sorption to suspended flakes of rust inside sampler.

Table III

Core No.	No. of Samples	Alkalinity Sulfate	Silica	Ammonia	Phosphate	Carbon	Bulk Density	Water Content	Shear Strength	Sensitivity
	Interstitial Water Chemistry						Physical Properties *)			
7706-3	2	X	X	X	X	X	X(P)	X(P)	X(P)(1)	--
7706-4	7	X	X	X	X	X	X	X	X(6)	X(4)
7706-14	6	X	X	X	X	X	X	X	X(5)	X(4)
7706-15							·	·	·(2)	·(1)
7706-16							X	X	X(7)	X(6)
7706-17	10	X	X	X	X	X	X	X	X(11)	--
7707-18	7	X	X	X	X	X	X	X	X(6)	X(4)
7706-21							X	X	--	--
7706-22	9	X	X	X	X	X	X	X	X(7)	X(3)
7706-26							·	·	·(2)	·(1)
7706-31	11	X	X	X	X		X	X	X(9)	X(2)
7706-32	4	X	X	X	X		X	X	X(5)	X(3)
7706-33	1	X	X	X	X		·	·	·(2)	--
7706-34	1	X	X	X	X		·	·	·(2)	--
7706-36	10	X	X	X	X	X	X	X	X(8)	X(3)
7706-37							·	·	·(2)	·(1)
7706-38							X	X	X(5)	X(4)
7706-39	13	X	X	X	X	X	X	X	--	--
7706-40							·	·	·(2)	·(1)
7706-41							·	·	·(2)	·(1)
7706-42	10	X	X	X	X	X	X	X	--	--
7706-44							·	·	·(2)	·(1)
7706-49							·	·	·(2)	·(1)
7706-50							X	X	X(6)	X(5)
7706-52	1	X	X	X	X	X				
7706-53	5	X	X	X	X	X				
7706-57	4		X		X	X				
7706-60	7		X	X	X	X	X	X	X(10)	X(4)
7706-61	9		X	X	X	X	X	X	X(5)	X(4)
7706-62							--	--	·(2)	·(1)
7706-63							·	·	·(2)	·(1)
7706-64							·	·	·(5)	·(2)
7706-66	9	X	X	X	X	X	X	X	X(8)	X(3)
7706-69	11	X	X	X	X	X	X	X	--	--

*) Legend physical properties only: X = analyzed entire core, · = analyzed core catcher only
P = partially completed, ( ) = number of samples

Mass Physical Properties

A limited number of Kasten and Reineck cores were opened aboard ship for interstitial water analyses. These cores were also tested for shear strength at varying intervals as well as subsampled for shore based determinations of bulk density, water content and primary sedimentary structures (X-radiography). The large cross-sectional area of the cores (Kasten 15x15, Reineck 20x30) provided excellent samples for the study of geotechnical properties due to the minimum degree of sampling disturbance. Open burrows frequently found in the cores attest to their relatively undisturbed condition. The shipboard tests and subsampling procedures were carried out effectively and the results are considered to be of very high quality. The procedures used aboard ship are outlined below.

Bulk density and water content: Thin-walled stainless steel cylinders (2.9x1.9 cm) were used to subsample the opened cores aboard ship (see Table II) for bulk density and water content. The volume of sediment obtained by this means was transferred to a plastic vial which was sealed against moisture loss for later weighing. The sealed vials were stored and transported to the lab at 4-5°C. A total of 258 subsamples for bulk density and water content were taken during the cruise. The unopened cores will be subsampled at OSU to determine the same properties.

Shear strength: A miniature laboratory vane shear apparatus (Wykeham Farrance) with a 1.9x1.2 cm vane, and a shearing rate of 60 degrees per minute was used for shear strength determinations aboard ship. The shearing apparatus was mounted in such a way that measurements were made directly in the Reineck box before the sediment was removed. Sediment was extruded (3-4 cm) from the box after each test. This mode of vane shear measurement provided the least disturbed sediment and thus the highest quality data.

Shear tests on Kasten cores were made on intact invervals (8-10 cm thick) removed from the core and sheared by the vane without further subsampling or handling, a very effective procedure.

Remolded shear strength was determined on a representative number of intervals (64) in order to obtain values for sensitivity of the sediment. A total of 198 vane shear tests were made during the cruise.

Direct shear: For the purpose of making direct shear tests at Oregon State University, complete intervals (15 cm thick) from two Kasten cores were removed and carefully packaged in such a way as to not disturb the sediment or to cause moisture loss. Both samples were kept under refrigeration until their testing at OSU. The majority of the direct shear tests will be made on those cores not opened during the cruise.

Sedimentary structures: *Complete sections, top to bottom of all the* Kasten cores opened and of one Reineck box core were collected in plastic trays (100x15x1.3 cm), sealed in plastic sleeves, and refrigerated for later X-radiography. A compass mounted on the coring stand was so designed as to lock its reading in place when the corer penetrated the sea floor. This has provided the means by which the core was then oriented relative to north.

Plankton of Surface Water Masses

Biogenous remains produced by shell- and skeleton-bearing plankton and nekton organisms are a major component of the pelagic and hemipelagic sediments deposited under and around the fertile surface water masses of the southeast Pacific upwelling region off South America. The quantitative as well as qualitative regional distribution of these faunal and floral biocoenoses (= standing stocks) are indicative of one of the major controls for the composition of the output of biogenic particles (thanatocoenoses) which then have to cross the water column and the benthic boundary before becoming members of the sediment particle assemblages (taphocoenoses). The nature and composition of these biocoenoses have never been studied in a comprehensive way in this region despite large marine geology sampling programs and despite the past and present intensive interest in the biologic systems of the fertile surface water masses of the South Pacific eastern boundary current.

Because we will use distributional patterns and accumulation rates of biogenic particles in our sediment cores to decipher the temporal and spatial dynamics of this eastern boundary current system, we wanted to understand the regional distributions of the standing stocks of some major sediment-particle-producing floral and faunal plankton and nekton components. The limited time frame of the cruise did not allow us to set up a separate plankton sampling program with conventional tows which would have consumed valuable shiptime. Rather we decided to sample the near-surface water masses continuously by means of a seawater pump and a filter system which allowed collection of the desired organisms en route through an inlet in the ship's hull 4 m below the water surface. The filter system collected all organisms larger than 150 μm (the same grain diameter will also be used for a major part of the micropaleontological sediment studies) at a flow rate of approximately 20 gal/min. Most of the samples were collected from the filter after approximately 2 h of pumping, or -- where advisable between stations along the South American continental margin -- after somewhat shorter intervals (though these were never less than one hour). Therefore most samples represent parts of the ship trackline which might be up to 30-40 nautical miles long. Although this can be expected to blur details of the regional distributions, this method is known to average out the small scale regional patchiness of the faunal and floral distribution.

Samples from this filter system have been taken for several purposes and they have been treated therefore in different ways:

(1) The majority of the samples have been preserved with formaldehyde buffered with sodium borate to prevent calcite and aragonite dissolution. These samples will be used to study the distributions of the important shell- and skeleton producing organisms. These samples will allow us to establish quasi-synoptic (in terms of a time slice representing a southern hemisphere fall situation) spatial distribution of diatoms, planktonic foraminifers, radiolarians, pelagic gastropods and of microplanktonic larvae of benthic molluscs in the subtropical and tropical eastern boundary current along the starved active continental margin of the South Pacific.

(2) A minor set of samples have been reserved for geochemical measurements for comparison with similar results obtained from the pelagic and hemipelagic sediments which have been deposited below these fertile surface water masses. These samples have been preserved with mercuric chloride.

A total of 220 samples have been filtered from more than 600,000 gallons of seawater (see Table IV for all relevant station data).

Table IV. Plankton sampling stations.

Sample no.	Date, local time	Date, local time	Pos. °S start	Pos. °W start	Pos. °S end	Pos. °W end	Volume (gallons)
	May						
1		22, 01.00	in port		12°54.0'	76°51.0'	~ 11,000[1]
2	22, 04.55	22, 05.50	12°53.2'	76°52.0'	12°58.3'	76°57.4'	1210
3	22, 12.18	22, 13.20	12°58.9'	76°58.0'	13°02.4'	77°04.9'	1286
4	22, 15.45	22, 19.30	13°02.4'	77°04.9'	13°16.0'	77°27.6'	3981
5	22, 20.00	22, 22.45	13°16.0'	77°27.6'	13°01.1'	77°19.1'	1980
6	23, 00.10	23, 01.30	13°01.1'	77°19.1'	13°18.0'	77°08.0	1716
7	23, 01.40	23, 03.05	13°18.0'	77°08.0'	13°09.0'	77°15.0'	1808
8	23, 06.25	23, 07.30	13°09.8'	77°14.1'	13°13.8'	77°20.1'	1406
9	23, 08.30	23, 09.50	13°13.8'	77°20.1'	13°23.3'	77°35.4'	1747
10	23, 10.00	23, 11.15	13°24.6'	77°37.6'	13°26.2'	77°40.0'	1667
11	23, 15.20	23, 17.55	13°27.3'	77°42.0'	13°48.4'	78°18.3'	3263
12	23, 23.40	24, 01.25	13°48.4'	78°18.3'	14°02.7'	78°39.0'	2356
13	24, 01.32	24, 03.40	14°03.7'	78°40.5'	14°19.0'	79°07.2'	2708
14	24, 03.50	24, 05.20	14°20.1'	79°09.8'	14°30.9'	79°29.5'	1936
15	24, 05.30	24, 07.00	14°32.9'	79°32.2'	14°44.3'	79°50.4'	1990
16	24, 07.10	24, 09.45	14°45.6'	79°52.5'	15°06.2'	80°24.4'	3558
17	24, 09.55	24, 11.40	15°07.9'	80°26.4'	15°21.7'	80°48.4'	2197
18	24, 11.50	24, 13.50	15°23.6'	80°51.4'	15°38.2'	81°14.8'	2596[2]
19	24, 17.30	24, 19.05	15°38.2'	81°14.8'	15°51.6'	81°36.7'	1941
20	24, 19.20	24, 21.10	15°53.5'	81°40.0'	16°07.4'	82°03.8'	1807[3]
21	24, 21.30	24, 23.15	16°10.05'	82°08.2'	16°22.6'	82°31.7'	2284
22	24, 23.34	25, 01.30	16°25.3'	82°36.0'	16°39.8'	82°58.6'	2529
23	25, 01.45	25, 03.45	16°42.5'	83°02.9'	16°58.1'	83°26.6'	2642
24	25, 03.55	25, 05.43	17°00.0'	83°28.8'	17°13.3'	83°51.5'	2317
25	25, 05.55	25, 08.00	17°15.1'	83°54.4'	17°29.2'	84°18.1'	2745
26	25, 18.20	25, 20.35	17°35.8'	84°11.9'	17°58.4'	83°49.7'	2919
27	25, 20.50	25, 23.05	18°00.5'	83°47.6'	18°22.5'	83°25.4'	2913
28	25, 23.12	26, 01.00	18°23.8'	83°24.1'	18°42.6'	83°04.5'	2407
29	26, 01.15	26, 03.00	18°44.3'	83°02.7'	19°01.2'	82°45.6'	2188
30	26, 03.05	26, 05.20	19°02.9'	82°42.7'	19°25.9'	82°22.3'	2920
31	26, 05.35	26, 07.38	19°28.1'	82°20.0'	19°48.0'	81°59.0'	2635
32	26, 07.50	26, 09.40	19°50.0'	81°56.9'	20°06.7'	81°38.7'	2353
33	26, 09.55	26, 11.50	20°09.2'	81°36.2'	20°29.3'	81°16.4'	2566
34	26, 12.07	26, 13.55	20°32.0'	81°13.6'	20°50.1'	80°59.1'	2397
35	26, 14.00	26, 16.15	20°50.1'	80°59.1'	21°13.0'	80°30.0'	2431
36	26, 16.30	26, 18.30	21°15.7'	80°28.0'	21°36.8'	80°06.6'	2652
37	26, 18.33	26, 20.35	21°36.8'	80°06.6'	21°58.6'	79°44.1'	2897
38	26, 21.00	26, 23.00	22°01.1'	79°40.4'	22°14.7'	79°28.7'	1963
39	27, 09.30	27, 13.30	22°14.3'	79°30.7'	22°22.0'	78°19.6'	5241

Table IV cont.

Sample no.	Date, local time	Date, local time	Pos. °S start	Pos. °W start	Pos. °S end	Pos. °W end	Volume (gallons)
40	27, 13.35	27, 15.30	22°20.0'	78°19.6'	22°26.7'	77°48.3'	2783
41	27, 16.30	27, 18.00	22°26.7'	77°48.3'	22°31.6'	77°14.7'	2900
42	27, 18.15	27, 20.40	22°31.3'	77°11.4'	22°38.1'	76°34.5'	3179
43	27, 20.55	27, 23.05	22°38.5'	76°31.8'	22°41.9'	75°59.0'	2954
44	27, 23.18	28, 01.25	22°42.4'	75°55.9'	22°48.1'	75°23.9'	2802
45	28, 01.40	28, 03.45	22°48.2'	75°20.2'	22°53.8'	74°49.2'	2751
46	28, 05.53	28, 08.50	22°58.6'	74°16.2'	23°01.9'	73°44.7'	3889
47	28, 08.55	28, 10.12	23°01.9'	73°44.7'	23°01.9'	73°44.7'	1685[4]
48	28, 10.17	28, 12.25	23°01.9'	73°44.7'	23°06.3'	73°07.8'	2745
49	28, 12.40	28, 14.10	23°06.7'	73°04.4'	23°09.4'	72°39.8'	2032
50	28, 14.20	28, 15.45	23°09.7'	72°36.9'	23°12.0'	72°14.6'	1864
51	28, 15.55	28, 17.35	23°12.3'	72°11.8'	23°14.7'	71°48.7'	2196
52	28, 21.30	28, 23.45	23°15.1'	71°48.8'	23°18.3'	71°22.0'	2592
53	29, 00.00	29, 01.20	23°18.5	71°24.4'	23°18.7'	71°20.0'	1833
54	29, 04.05	29, 05.30	23°18.5'	71°19.4'	23°18.1'	71°18.3'	1840
55	29, 05.45	29, 08.45	23°18.1'	71°18.3'	23°18.1'	71°18.3'	3909
56	29, 08.55	29, 12.35	23°18.1'	71°18.1'	23°19.0'	71°08.0'	4825
57	29, 16.00	29, 18.00	23°20.0'	71°06.6'	23°20.1'	71°01.9'	2911
58	29, 18.30	29, 21.15	23°20.1'	71°01.3'	23°20.2'	70°58.8'	3758
59	30, 01.10	30, 03.00	23°20.1'	70°57.1'	23°21.5'	70°53.6'	2392
60	30,	30, 14.00	23°16.6'	70°46.9'	23°16.6'	70°46.9'	120
61	30, 14.00	30, 15.55	23°16.6'	70°46.9'	22°59.8'	70°40.3'	2368
62	30, 17.40	30, 19.30	23°00.1'	70°40.1'	22°59.5'	70°38.2'	2334
63	30, 20.15	30, 21.40	22°59.5'	70°38.2'	22°43.0'	70°44.3'	1636
64	30, 21.50	30, 23.05	22°39.4'	70.45.9'	22°20.0'	70°53.0'	2348
65	31, 01.05	31, 04.00	22°19.4'	70°52.7'	22°19.0'	70°49.7'	3482
66	31, 04.05	31, 05.45	22°19.1'	70°49.7'	21°56.0'	70°46.5'	2148
67	31, 05.55	31, 08.05	21°13.4'	70°46.0'	21°33.1'	70°37.7'	2876
68	31, 08.20	31, 10.15	21°33.1'	70°35.6'	21°15.4'	70°49.9'	2334
69	31, 10.20	31, 12.10	21°15.4'	70°49.9'	20°53.2'	71°02.9'	2563
70	no sample No. 70						
71	31, 12.20	31, 14.35	20°53.2'	71°02.9'	20°20.0'	71°22.2'	3087
72	31, 14.40	31, 16.25	20°20.0'	71°22.2'	19°59.4'	71°34.1	2217
73	31, 16.40	31, 18.27	19°55.8'	71°36.3'	19°33.4'	71°48.7'	2343
74	31, 18.43	31, 20.25	19°29.6'	71°50.9'	19°08.1'	72°02.2'	2195
75	31, 20.38	31, 22.25	19°04.8'	72°03.9'	18°44.4'	72°16.1'	2326
76	31, 22.35	01, 00.40	18°42.5'	72°17.1'	18°14.4'	72°32.6'	2723
77	June 01, 00.50	01, 02.45	18°11.1'	72°33.5'	17°47.5'	72°46.7'	2493
78	01, 03.00	01, 05.00	17°44.1'	72°48.7'	17°19.8'	73°04.0'	2598
79	01, 05.05	01, 07.05	17°17.5'	73°05.2'	16°52.5'	73°20.5'	2640
80	01, 07.20	01, 09.05	16°49.8'	73°22.1'	16°42.0'	73°24.2'	2375

Table IV cont.

Sample no.	Date, local time	Date, local time	Pos. °S start	Pos. °W start	Pos. °S end	Pos. °W end	Volume (gallons)
81	01, 10.30	01, 13.00	16°40.2'	73°23.4'	16°22.7'	73°35.1'	3430
82	01, 13.10	01, 14.45	16°21.8'	73°37.5'	16°17.8'	73°54.5'	1932
83	01, 16.30	01, 19.10	16°17.6'	73°53.6'	16°09.4'	74°35.0'	3514
84	01, 19.25	01, 21.30	16°08.8'	74°38.5'	16°02.8'	75°13.1'	2756
85	01, 21.45	01, 23.30	16°02.2'	75°16.4'	15°57.3'	75°41.6'	2174
86	01, 23.45	02, 02.00	15°56.7'	75°45.1'	15°48.1'	76°18.2'	2928
87	02, 02.15	02, 04.00	15°40.1'	76°21.2'	14°44.1'	76°47.9'	2302
88	02, 06.00	02, 08.20	14°44.1'	76°47.9'	15°19.5'	76°49.9'	2973
89	02, 09.50	02, 13.30	15°19.5'	76°49.9'	14°39.0'	76°55.9'	3366
90	02, 13.30	12, 15.30	14°39.0'	76°55.9'	13°56.2'	76°59.5'	3856
91	12, 15.30	02, 17.45	13°56.2'	76°59.5'	13°39.2'	76°53.4'	2968
92	02, 18.15	02, 19.15	13°40.2'	76°53.0'	13°37.8'	76°50.9'	1118
93	02, 20.55	02, 23.00	13°37.8'	76°50.9'	13°21.2'	77°01.8'	2835
94	02, 23.15	03, 01.20	13°19.2'	77°04.5'	13°11.8'	77°15.2'	2795
95	03, 02.40	03, 04.30	13°11.8'	77°15.2'	12°45.6'	77°16.4'	2308
96	03, 04.35	03, 06.00	12°45.6'	77°16.4'	12°22.2'	77°17.2'	1750
Port call in Callao 03, 08.00 - 04, 08.00							
97	04, 10.35	04, 12.40	12°02.5'	77°15.5'	11°49.3'	77°42.4'	3767[5]
98	04, 13.00	04, 14.30	11°26.3'	77°43.9'	11°15.3'	77°57.8'	2001
99	04, 15.20	04, 16.30	11°15.3'	77°57.8'	11°20.6'	78°07.0'	1535
100	05, 00.30	05, 03.15	11°39.9'	78°26.1'	11°43.1'	78°33.0'	3654
101	05, 03.30	05, 05.40	11°43.1'	78°33.0'	11°38.2'	78°29.6'	2873
102	05, 10.15	05, 13.15	11°40.2'	78°28.5'	11°49.1'	78°55.1'	3935
103	05, 13.25	05, 16.00	11°49.1'	78°55.1'	11°45.9'	78°48.4'	3285
104	05, 16.15	05, 19.10	11°45.2'	78°48.1'	11°44.1'	78°47.2'	3748
105	05, 19.25	05, 22.10	11°43.7'	78°47.5'	11°15.7'	79°06.7'	3656
106	05, 22.12	06, 00.15	11°15.7'	79°06.7'	11°15.7'	79°06.7'	2665
107	06, 01.10	06, 04.00	11°15.7'	79°06.7'	11°33.9'	79°43.2'	3783
108	06, 04.05	06, 05.45	11°33.9'	79°43.2'	11°40.7'	79°57.5'	2093
109	06, 05.55	06, 08.20	11°40.7'	79°57.5'	11°40.7'	79°57.5'	3052
110	06, 09.15	06, 12.25	11°37.5'	79°56.6'	10°51.4'	79°43.1'	4100
111	06, 12.40	06, 15.40	10°48.2'	79°42.2'	10°05.8'	79°31.1'	3848
112	06, 15.50	06, 17.30	10°02.2'	79°30.2'	09°44.3'	79°24.0'	2008
113	06, 20.15	06, 22.00	09°42.2'	79°26.3'	09°18.6'	79°35.9'	2234
114	06, 22.05	07, 00.10	09°18.6'	79°35.9'	09°06.1'	79°47.6'	2683
115	07, 00.13	07, 04.00	09°06.1'	79°47.6'	09°03.9'	79°58.1'	4944
116	07, 04.05	07, 06.35	09°03.3'	79°58.1'	09°03.9'	79°58.1'	3133
117	07, 06.35	07, 08.00	09°03.9'	79°58.1'	09°03.2'	79°56.3'	1647
118	07, 08.30	07, 10.45	09°03.9'	79°58.1'	09°06.1'	80°08.2'	3024
119	07, 11.00	07, 13.10	09°06.2'	80°08.3'	09°08.9'	80°17.5'	2851
120	07, 14.50	07, 16.50	09°09.2'	80°21.5'	09°09.3'	80°24.8'	2504

Table IV cont.

Sample no.	Date, local time	Date, local time	Pos. °S start	Pos. °W start	Pos. °S end	Pos. °W end	Volume (gallons)
121	07, 17.00	07, 19.15	09°09.3'	80°24.8'	09°17.7'	80°34.5'	2897
122	07, 19.30	07, 21.00	09°17.7'	80°34.1'	09°17.7'	80°34.1'	1954
123	07, 21.05	08, 01.00	09°17.7'	80°34.1'	09°11.7'	80°28.8'	4903
124	08, 01.05	08, 02.40	09°17.7'	80°28.8'	09°07.8'	80°23.3'	1913
125	08, 02.45	08, 04.32	09°07.8'	80°23.3'	09°07.8'	80°23.3'	2304
126	08, 04.37	08, 06.22	09°07.8'	80°23.3'	09°07.8'	80°23.3'	2177
127	08, 06.25	08, 08.05	09°07.8'	80°23.3'	09°01.1'	80°13.7'	2139
128	08, 08.20	08, 12.00	09°01.4'	80°14.8'	08°58.6'	80°15.3'	4575
129	08, 12.10	08, 13.05	08°58.6'	80°15.3'	08°58.6'	80°15.3'	1126
130	08, 13.20	08, 16.55	08°58.6'	80°13.3'	08°14.0'	80°09.1'	4492
131	08, 17.15	08, 19.30	08°09.3'	80°11.6'	07°55.7	80°10.9'	2727
132	08, 20.25	08, 21.35	07°57.0'	80°13.6'	08°03.4'	80°24.3'	1483
133	08, 22.30	09, 00.10	08°02.9'	30°22.4'	08°02.9'	80°22.4'	2172
134	09, 00.15	09, 03.10	08°02.9'	80°22.4'	08°05.4'	80°30.3'	3659
135	09, 03.15	09, 05.30	08°05.4'	80°30.3'	08°13.0'	80°47.7'	2625
136	09, 05.35	09, 06.40	08°13.0'	80°47.7'	08°13.0'	80°47.7'	1246[6]
137	09, 07.25	09, 10.40	08°13.0'	80°47.7'	08°17.2'	80°55.5'	4179
138	09, 11.35	09, 13.35	08°17.2'	80°55.5'	08°19.9'	80°59.7'	2456
139	09, 13.45	09, 16.15	08°19.9'	80°59.7'	08°19.9'	80°59.7'	3179
140	09, 16.25	09, 18.35	08°19.9'	80°59.7'	08°32.0'	81°28.5'	2699
141	09, 18.45	09, 20.35	08°33.4'	81°31.3'	08°47.6'	81°55.3'	2258
142	09, 20.40	09, 22.40	08°47.6'	81°55.3'	08°49.0'	81°56.6'	2524
143	10, 00.00	10, 02.03	08°49.0'	81°56.6'	09°02.6'	82°21.7'	2583
ES-1	10, 02.05	10, 03.00	09°02.6'	82°21.7'	09°08.4'	82°36.4'	1184
144	10, 03.05	10, 04.45	09°08.4'	82°36.4'	09°15.7'	82°57.6'	2108
ES-2	10, 04.50	10, 05.50	09°15.7'	82°57.6'	09°24.0'	83°12.0'	1263
145	10, 05.53	10, 08.00	09°24.0'	83°12.0'	09°37.9'	83°40.6'	2703
146	10, 08.10	10, 10.10	09°38.9'	83°42.6'	09°42.5'	83°48.8'	2397
ES-3	10, 10.15	10, 11.70	09°42.5'	83°48.8'	09°42.5'	83°48.8'	1232
147	10, 11.25	10, 14.05	09°42.5'	83°48.8'	10°00.3'	84°22.9'	3217
148	10, 14.15	10, 18.05	10°01.1'	84°24.6'	10°11.8'	84°44.8'	4739
ES-4	10, 18.15	10, 19.45	10°11.8'	84°44.8'	10°11.8'	84°44.8'	1813
149	10, 19.55	10, 21.55	10°11.8'	84°44.8'	10°13.0'	84°57.7'	2514
150	10, 22.05	11, 00.00	10°12.9'	84°59.6'	10°10.8'	85°27.1'	2331
151	11, 00.08	11, 02.18	10°10.8'	85°27.1'	10°07.7'	85°58.7'	2767
152	11, 02.22	11, 04.24	10°07.7'	85°58.7'	10°06.0'	86°27.4'	2553
153	11, 04.27	11, 06.15	10°06.0'	86°27.4'	10°04.1'	86°55.8'	2325
154	11, 06.18	11, 09.05	10°04.1'	86°55.8'	10°01.2'	87°36.4'	3657
155	11, 09.15	11, 12.15	10°01.1'	87°38.5'	10°01.3'	87°57.3'	3892
ES-5	11, 12.20	11, 15.05	10°01.3'	87°57.3'	10°01.3'	87°57.3'	3421
156	11, 15.10	11, 20.20	10°01.3'	87°57.3'	09°11.1'	88°02.2'	6596

Table IV cont.

Sample no.	Date, local time	Date, local time	Pos. °S start	Pos. °W start	Pos. °S end	Pos. °W end	Volume (gallons)
157	11, 20.25	11, 23.25	09°11.1'	88°02.2'	08°27.1'	88°08.4'	3841
158	11, 23.30	12, 01.37	08°27.1'	88°08.4'	07°57.2'	88°12.9'	2718
159	12, 01.40	12, 05.00	07°57.2'	88°12.9'	07°09.6'	88°15.7'	4280
160	12, 05.10	12, 07.15	07°09.6'	88°15.7'	06°35.4'	88°19.3'	2941
161	12, 07.25	12, 09.50	06°35.4'	88°19.3'	05°58.0'	88°22.0'	3095
162	12, 09.53	12, 12.10	05°58.0'	88°22.0'	05°24.6'	88°26.0'	2930
163	12, 12.15	12, 14.15	05°24.6'	88°26.0'	04°55.2'	88°29.9'	2571
164	12, 14.20	12, 16.15	04°55.2'	88°29.9'	04°49.1'	88°30.7'	2539
ES-6	12, 16.20	12, 17.20	04°49.1'	88°30.7'	04°49.1'	88°30.7'	1385
165	12, 17.20	12, 19.50	04°49.1'	88°30.7'	04°43.8'	87°58.4'	2945
166	12, 19.53	12, 22.00	04°43.8'	87°58.4'	04°38.2'	87°28.9'	2754
167	12, 22.03	13, 00.02	04°38.2'	87°28.9'	04°31.6'	87°00.6'	2576
168	13, 00.07	13, 02.05	04°31.6'	87°00.6'	04°26.8'	86°31.8'	3031
169	13, 02.10	13, 04.08	04°26.8'	86°31.8'	04°19.7'	86°02.8'	3030
170	13, 04.08	13, 06.05	04°19.7'	86°02.8'	04°18.4'	86°00.2	1498
171	13, 08.13	13, 10.10	04°13.9'	85°34.9'	04°11.8'	85°20.9'	2439
172	13, 10.17	13, 12.35	04°11.8'	85°20.9'	04°12.9'	85°19.8'	3011
ES-7	13, 12.40	13, 13.50	04°12.9'	85°19.8'	04°12.9'	85°19.8'	1572
173	13, 14.05	13, 16.10	04°12.9'	85°19.8'	04°10.2'	84°58.3'	2592
174	13, 16.15	13, 18.00	04°10.2'	84°58.3'	04°07.2'	84°49.5'	2261
175	13, 18.05	13, 20.40	04°07.2'	84°49.5'	04°02.7'	84°29.8'	3240
176	13, 20.45	13, 23.00	04°02.7'	84°29.8'	03°58.0'	84°06.4'	2933
177	13, 23.05	14, 01.20	03°58.0'	84°06.4'	03°56.0'	83°58.9'	2850
178	14, 01.25	14, 03.23	03°56.0'	83°58.9'	03°51.3'	83°32.8'	2547
179	14, 03.27	14, 06.13	03°51.3'	83°32.8'	03°47.4'	83°10.6'	3528
180	14, 06.16	14, 08.13	03°47.4'	83°10.6'	03°44.9'	83°03.1'	2446
181	14, 08.20	14, 11.20	03°44.9'	83°03.1'	03°41.8'	82°33.6'	3851
ES-8	14, 11.25	14, 15.45	03°41.8'	82°33.6'	03°40.8'	82°30.3'	5959
182	14, 16.17	14, 19.17	03°40.8'	82°30.3'	03°38.1'	82°16.1'	3859
183	14, 19.20	14, 21.15	03°38.1'	82°16.1'	03°36.2'	82°00.1'	2473
184	14, 21.17	14, 23.20	03°36.2'	82°00.1'	03°34.2'	81°51.0'	2677
185	14, 23.22	15, 01.13	03°34.2'	81°51.0'	03°31.2'	81°36.8'	2320
ES-9	15, 01.16	15, 04.08	03°31.2'	81°36.8'	03°31.3'	81°38.2'	3689
186	15, 04.12	15, 06.15	03°31.3'	81°38.5'	03°29.4'	81°29.0'	2456
187	15, 08.05	15, 10.40	03°29.4'	81°29.0'	03°45.4'	81°24.3'	3156
ES-10	15, 10.45	15, 12.45	03°45.4'	81°24.3'	03°46.8'	81°19.3'	2477
188	15, 12.50	15, 15.50	03°46.8'	81°19.3'	03°34.8'	81°17.4'	3621
189	15, 16.10	15, 19.00	03°34.8'	81°17.4'	03°34.7'	81°00.1'	3447
190	15, 19.00	15, 20.45	03°34.7'	81°00.1'	03°35.0'	81°02.4'	2107
ES-11	15, 20.50	15, 23.10	03°35.0'	81°02.4'	03°29.2'	81°17.2'	2797
191	15, 23.15	16, 01.32	03°29.2'	81°17.2'	03°28.5'	81°05.7'	2833

Table IV cont.

Sample no.	Date, local time	Date, local time	Pos. °S start	Pos. °W start	Pos. °S end	Pos. °W end	Volume (gallons)
192	16, 02.33	16, 04.23	03°28.5'	81°05.7'	02°59.9'	81°06.3'	2246
193	16, 04.26	16, 06.45	02°59.9'	81°06.3'	02°25.8'	81°08.0'	2935
194	16, 06.47	16, 09.06	02°25.8'	81°08.0'	01°53.7'	81°09.9'	2728
195	16, 09.20	16, 11.10	01°53.7'	81°09.9'	01°32.5'	81°10.9'	2280
ES-12	16, 11.13	16, 13.10	01°32.5'	81°10.9'	00°29.7'	81°02.2'	2304
196	16, 15.20	16, 16.05	00°29.7'	81°02.2'	00°17.8'	81°00.8'	822
197	16, 16.10	16, 17.18	00°17.8'	81°00.8'	00°00.0'	80°57.7'	1399
			Pos. °N		Pos. °N		
198	16, 17.20	16, 19.22	00°00.0	80°57.7'	00°27.7'	80°52.1'	2458
199	16, 19.25	16, 21.20	00°27.7'	80°52.1'	00°55.9'	80°47.3'	2313
200	16, 21.22	16, 23.20	00°55.9'	80°47.3'	01°22.6'	80°41.1'	2295
ES-13	16, 23.23	17, 01.45	01°22.6'	80°41.1'	01°55.0'	80°36.2'	2888
201	17, 01.48	17, 04.05	01°55.0'	80°36.2'	02°28.7'	80°32.0'	2758
202	17, 04.10	17, 06.55	02°28.7'	80°32.0'	03°09.1'	80°25.6'	3353
203	17, 07.00	7, 08.20	03°09.1'	80°25.6'	03°28.6'	80°22.2'	1528
204	17, 08.22	17, 10.15	03°28.6'	80°22.2'	03°51.4'	80°21.1'	2187
205	17, 10.16	17, 12.00	03°51.4'	80°21.1'	04°23.0'	80°16.0'	2046
ES-14	17, 12.05	17, 14.30	04°23.0'	80°16.0'	05°02.3'	80°08.4'	2959
206	17, 14.33	17, 16.45	05°02.3'	80°08.4	05°33.0'	80°34.1'	2696
207	17, 16.50	17, 19.00	05°33.0'	80°34.1'	06°02.0'	79°56.2'	2526
208	17, 19.00	17, 21.30	06°02.0'	79°56.2'	06°37.6'	79°49.9'	3008
209	17, 21.35	17, 23.30	06°37.6'	79°49.9'	07°02.4'	79°46.2	2291
210	17, 23.33	18, 01.40	07°02.4'	79°46.2'	07°26.8'	79°49.1'	2773
ES-15	18, 01.42	18, 03.35	07°26.8'	79°49.4'	07°55.1'	79°40.1'	2079
211	18, 03.35	18, 05.50	07°55.1'	79°40.1'	08°28.9'	79°33.1'	2639
212	18, 05.55	18, 07.35	08°28.9'	79°33.1'	08°52.2'	79°49.4'	2015

[1]Local time = Z-5 hours.

[2]Fire station during this sample; no formaldehyde.

[3]Pumping started 25 min. later.

[4]Pumped on station.

[5]One sample after port call; not all collected because sieve was clogged with algae.

[6]Not preserved.

Dredgings

Continental slope off northern Chile

Dredging commenced off northern Chile at 23°18.7'S and 71°10.4'W at a water depth of 6534 meters and terminated at 23°19.0'S and 71°08.0'W at 5066 meters (see List of Stations, p. IV and Fig. 4). The dredge haul (7706-23) contained a mixture of lithologies:

(1) siltstones and mudstones
(2) crystalline rocks including quartzite and acid igneous rocks
(3) assorted rounded pebbles
(4) manganese crusts
(5) unconsolidated sediments.

The rounded character of some of the crystalline rocks raises the question as to whether they were recovered from outcrops on the sea floor or whether they were carried into the area by rivers or by ice rafting. There are no rivers draining the coast from the Atacama Desert today or apparently during the last few million years. Furthermore, no ice rafted debris is noted in Pleistocene cores from the adjacent Nazca Plate. The sedimentary rocks seem to be from outcrops -- several are encrusted with manganese.

The second dredge haul (7706-25) encountered the bottom at 23°20.1'S and 71°03.4'W at a depth of 5047 (Fig. 4). It lifted off the bottom at 23°19.9'S and 70°57.2'W at 3995 m. This sampling contained a much larger volume of rocks than the previous one and consisted mainly of sedimentary rocks, i.e., siltstone and sandstone, manganese crusts and minor amounts of igneous pebbles. One large siltstone boulder was recovered that appears to have come from an outcrop on the sea floor at this site. As in the previous dredge the igneous rocks are rounded and their origin is questionable. The sedimentary rocks apparently are representative of the slope environment.

A third dredge (7706-27) was dragged up the continental slope from 23°21.3'S and 76°50.1'W at 2893 m to 23°20.7'S and 70°47.7'W at 2779 m (Fig. 4). One well rounded metamorphic rock of unknown composition was obtained at this site. This sample is of questionable origin with regard to the continental slope setting because of its rounded character.

The fourth dredge, (7706-29) was positioned to the north of the previous profile at 22°19.6'S and 70°52.1'W at 4660 m and extended up slope to 22°18.9'S and 70°50.1'W at 3814 m (Fig. 4). Several sedimentary rocks, including medium gray mudstones, olive gray mudstones and tan gray mudstones, and manganese crusts were recovered. In some specimens the manganese coated the mudstones. These sedimentary rocks probably originated on the continental slope.

After these attempts at dredging the continental slope off northern Chile and the observations that the slope is rather smooth and generally covered with manganese crusts, we decided to terminate the dredging activities in this area and move to the targets off central Peru.

Continental slope off central Peru

Here the first dredge haul (7706-46) was obtained along the seaward side of the Lima Basin which is the most prominent sedimentary basin on the upper continental slope (fore-arc basin) as described by Masias (1976) and Kulm et al., (1977). This basin is about 35-40 km wide and has at least 2 km of sediment. The dredge was positioned on a steep scarp that projects seaward from about 1600-2400 m water depth (see Fig. 6). The dredge's position was 11°40.9'S and 78°29.6'W at 2263 m and was dragged up slope to position 11°38.2'S and 78°29.6'W at 1639 m. The main lithologies recovered were:

(1) siltstones
(2) pebble conglomerates
(3) mudstone and chertified siltstone
(4) minor metamorphic rocks including a breccia
(5) metamorphic rocks of unknown composition.

This dredge haul comprised a total of 197 separate samples. Although most of the sedimentary rocks are hard and well consolidated, a few soft black siltstones and light tan siltstones are present. Ages may be obtained on these softer rocks using benthic forams.

Dredge 7706-48 was taken on the middle slope at 3749 m water depth located at 11°46.7'S and 78°50.4'W, and to the seaward of dredge haul 7706-46 (Fig. 6). Only one hard rock specimen consisting of indurated dark-greenish gray sediment or meta-sediment was recovered. It was bored extensively by benthic organisms of possible shallow water origin.

The vessel then moved to the 9°S latitude profile to commence dredging off central Peru. The station was a narrow ridge that rises steeply to the seaward side of the edge of the continental shelf and presumably shallows to about 25 m near the surface according to the Peruvian bathymetric charts. However, no such shallow water depths were encountered after a 2-mile link survey. Dredge 7706-54 was lost at position 9°04.25'S and 79°57'W at 380 m water depth (Fig. 8). It pulled about 11,000 lbs before breaking the weak line and breakaway chains.

Dredge 7706-54 was lowered again at 9°03.7'S and 79°56.2'W at a depth of 250 m and terminated at 9°04.4'S and 79°55.1'W at 202 m (Fig. 8). The area dredged was the seaward side of the highest point on the structural ridge rising steeply out of the uppermost continental slope. A trough occurs between this ridge and the edge of the shelf. A full bag of rocks was recovered which consisted primarily of metamorphic rocks and meta-sediments. Specific lithologies are:

(1) cherts
(2) chertified siltstones
(3) dark black siltstones
(4) conglomerates
(5) calcareous siltstones and sandstones.

The main question is whether the rocks recovered originate from the Lima Basin or from the outer shelf high.

Three dredge hauls were attempted on the lower and middle slope along the 9°S profiles starting at 4500 m and terminating at 1800 m. The first dredge haul 7706-55 was located at 9°13.8'S and 80°29.4'W and touched bottom at 4479 m (Fig. 8). It recovered mud and three small rock fragments of unknown composition. The second dredge 7706-56 (A) at station 55 started at position 9°08.8'S and 80°24.7'W at about 3000 m and came to the surface empty. The third dredge 7706-56 (B) was positioned at 8°58.6'S and 80°15.2'W at 2016 m to 1730 m. It was plugged with unconsolidated sediment; no rocks were recovered.

Dredge 7706-59 was located on the landward side of the northern part of the Lima Basin along the profile at 8°S latitude (see Fig. 8). It was positioned at 8°03.2'S and 80°22.9'W at 430 m. A full bag of rocks was obtained; lithologies were dominantly sedimentary rocks and included:

(1) chertified siltstone
(2) dark black siltstones
(3) fine-grained conglomerates and siltstones
(4) laminated siltstones
(5) coarse-grained conglomerates
(6) pebbly conglomerates
(7) black sandy conglomerates
(8) fragments of whale bones.

Several rocks had fish teeth embedded; these may be useful in dating the rocks.

In summary, the central Peru dredges at 9°S and 8°S are different from one another in that metamorphic rocks were recovered at 9°S just seaward of the outer continental shelf structural high which trends parallel to the margin in a NW-SE direction. Two oil wells drilled about 30 km landward of the dredge site on the structural high obtained Mio-Oligocene sedimentary sequences overlying crystalline rocks of possible Paleozoic age. On the other hand the dredge at 8°S consisted of sedimentary rocks which occur on the landward side of the Lima Basin. This is the first discovery of sedimentary rocks in this area seaward of the structural high.

Continental slope off northern Peru

Two dredge hauls were taken off Talara, Peru on the Banco de Peru to determine the nature of lithologies on the outer shelf structural high in this area. The Progreso Basin, which is a late Cenozoic sedimentary basin, lies between the structural high and the coastline. The first dredge, 7706-75, was full of sedimentary rocks which consisted mainly of gray siltstones and minor pebble and blocky conglomerates. These rocks were dredged from an outcrop at a water depth of about 292 m on the seaward side of the structural high. The dredge site is located at 3°34.8'S and 80° 17.4'W (Fig. 9).

The second dredge 7706-80, obtained a full bag of sedimentary rocks from the flank of a large hill protruding from the main part of the structural high (Fig. 9). The water depth was about 360 m and the site is located on the NE part of the Banco de Peru on the landward side of the bank. Lithologies included very fine sandstones, gray siltstones and one sample of claystone. The bulk of the dredged material seems to consist of very fine sandstones and gray siltstones.

In summary, sedimentary rocks were also recovered from the structural high off Talara (northern Peru). If this high has an underlying crystalline basement, it was not detected in these two dredge hauls.

References

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Summary

A. Sediment distribution and composition

Results obtained thus far concern the variability of the hemipelagic sediment cover on the continental margin off Peru and Chile; the following observations summarize this pattern (Fig. 14):

(1) In the southern part of the area of investigation (at ≈23°S) little hemipelagic cover was found on the margin and none on the Nazca Plate. The slope walls were covered with Mn-oxide crusts and rock outcrops. Pelagic sediments on the plate, immediately westward of the trench, consisted of indurated red and brown clay.

(2) The only hemipelagic sediments recovered in the area were interlayered with trench turbidites, the sources of both are not immediately obvious but they are most probably derived from the southern and central part off Chile.

(3) Further to the north a continuous hemipelagic sediment cover extends from the margin seaward to about 81°W at 18°S latitude indicating a progressive westward extension when approaching the equator.

(4) This pattern covers the NE nose of the Nazca Ridge in an area and at a water depth -- above the calcite compensation level -- where up to now only biogenous carbonates had been reported.

(5) A strong seaward gradient of the diminishing hemipelagic sediment cover was cored in a profile on the Nazca Plate ranging from < 0.5 m at 87°W to 3-4 m at 84°W; other records indicate >30 m of hemipelagics further to the east

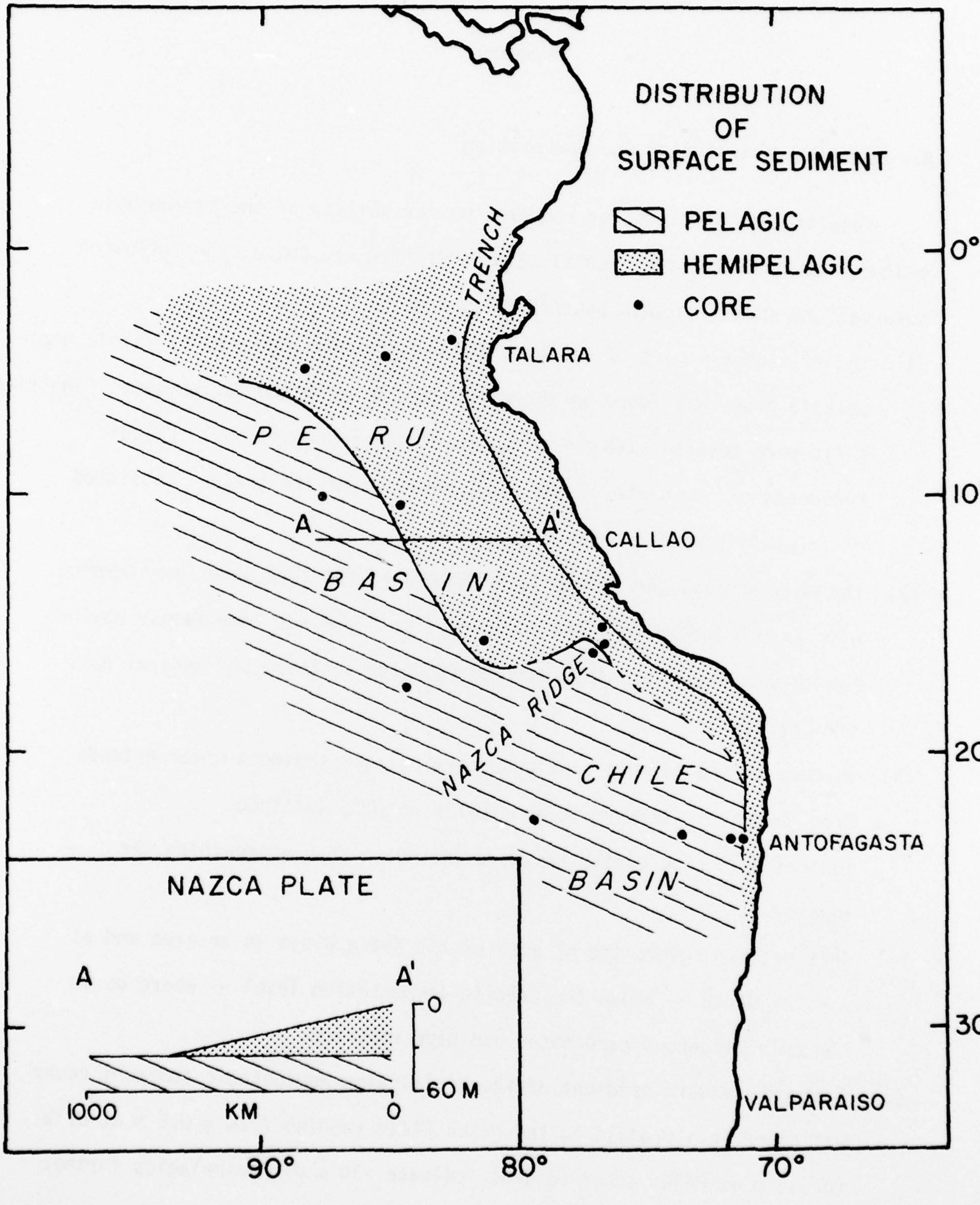

Fig. 14 Regional extent of hemipelagic sediment cover on continental margin and oceanic plate off central South America.

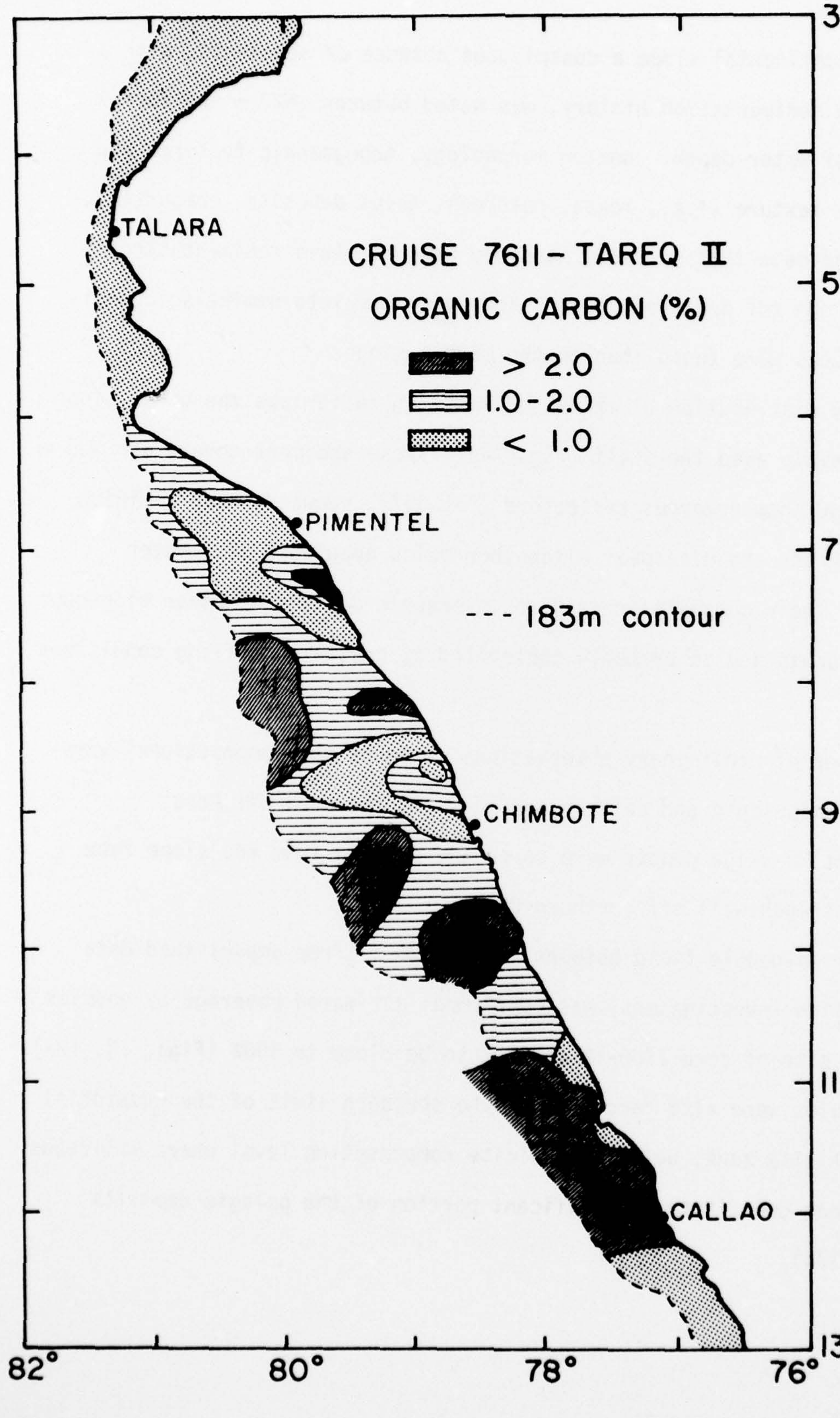

Fig. 15 Organic carbon in shelf sediments off Peru indicating patchy distribution of sediments influenced by upwelling. The same pattern is found with upper slope sediments. This figure is based on unpublished data (60 samples) kindly provided by C. Delgado, Instituto del Mar, Peru.

(6) On the continental slope a conspicuous absence of sediments, with a complete sedimentation history, was noted between >600 m and approx. 3000 m of water depth. Bottom morphology, topographic features and sediment texture (i.e., moats, outcrops, talus deposits, compaction, etc.) indicate that currents possibly dominate this sedimentation regime. On the upper and lower slope more complete hemipelagic sediment covers were found than on the middle slope.

(7) *A patchy distribution of thick sediments characterizes* the upper slope and possibly also the shelf (Fig. 15). These sediment covers are >30 m thick and show numerous reflectors (Fig. 5,7), seawards they diminish in thickness and disappear altogether below about 600 m of water depth. Their composition is high in organic carbon and other biogenous constituents and is probably controlled by coastal upwelling conditions.

A second group of preliminary observations concerns the compositional variability of hemipelagic and pelagic sediments in the area off Peru:

(1) Abundant Mn-oxide crusts were cored and dredged from the slope face of the trench wall off northern Chile.

(2) A major Mn-nodule field between 22° and 26°S (from unpublished data by Russian investigators) was confirmed; estimated coverage by nodules at the site of core 7706-19 appears to be close to 100% (Figs. 16, 17a).

(3) Mn-nodules were also recovered at the southern limit of the equatorial productivity zone, below the calcite compensation level where siliceous skeletons constitute a significant portion of the pelagic deposits (Fig. 17b).

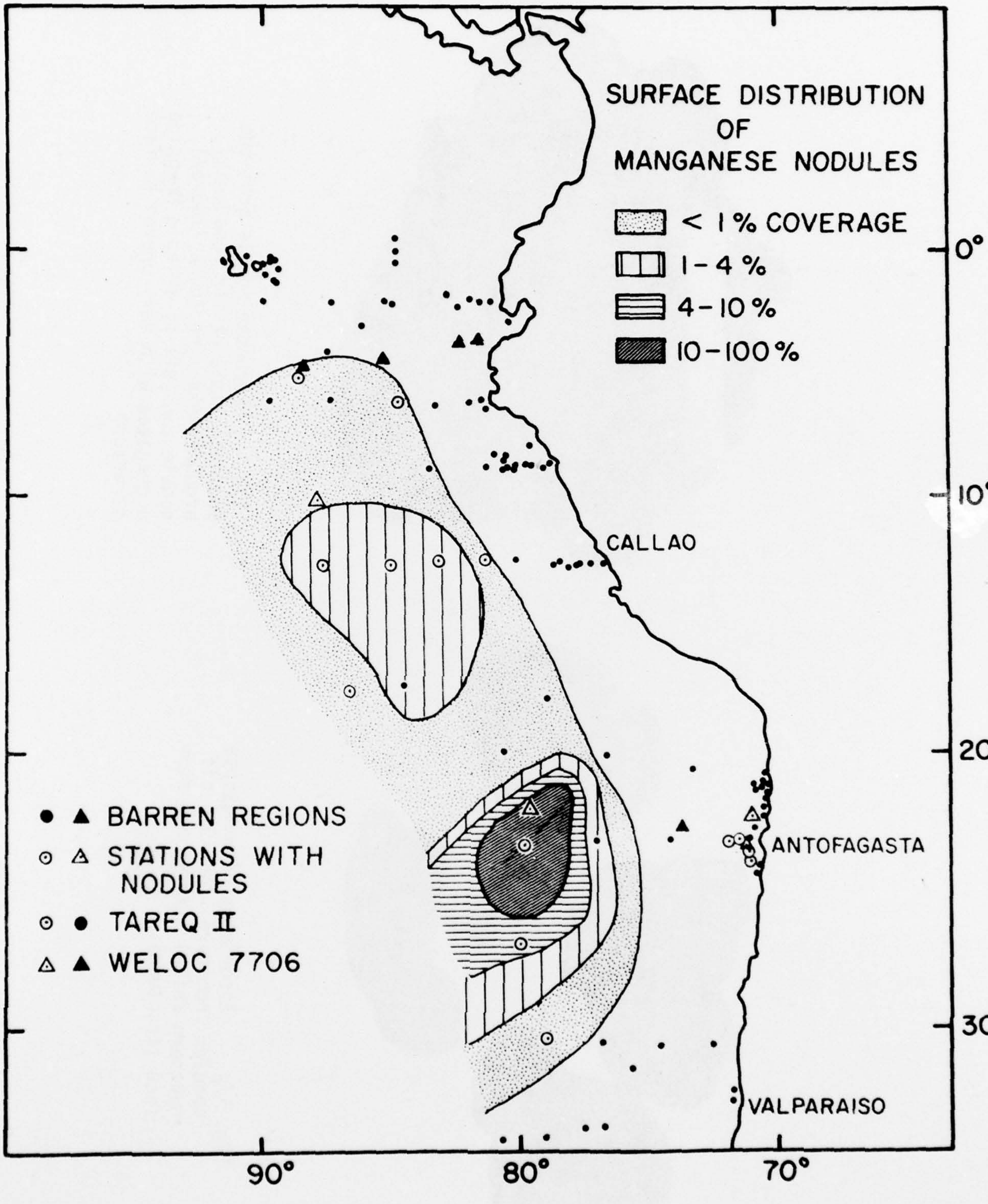

Fig. 16 Manganese nodule dsitribution in surface sediments of Peru and Chile Basin. Nodule field at 22° S was sampled by Core 7706-19. This map is based on data gathered by the USSR R/V Academico Kurtchakov; H.M. Saidova (1971), Trudy Inst. Okean.

Fig. 17a   Assortment of manganese nodules from core 7706-19 (off northern Chile) with smooth sur= face structures.

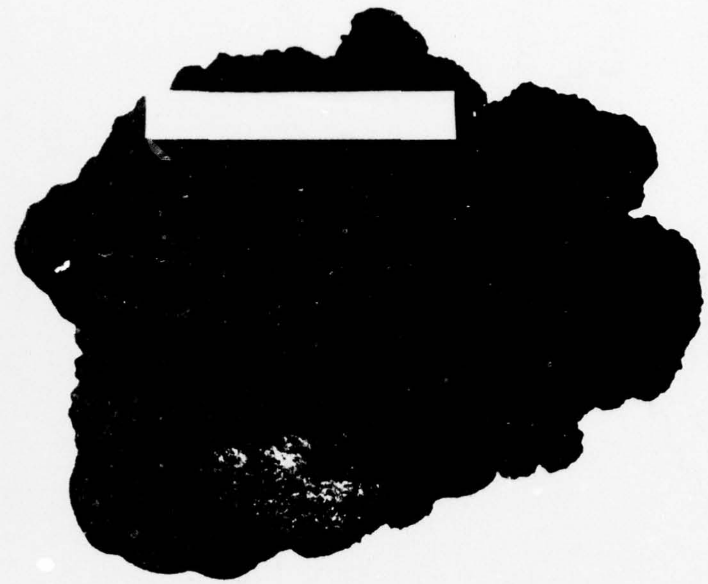

Fig. 17b   Manganese nodule from the southern limit of the equatorial productivity zone (core 7706-67), nodule consists of friable Mn-oxide aggregates with very uneven surface structure

Fig. 17c Fish debris from black, reducing silty clay of upper continental slope off central Peru, cores 7706-39, -42.

Fig. 17d Phosphatic concretions from biogenous sands of upper slope deposits, cores 7706-53,-57.

(4) The composition of organic rich, strongly reducing (upper slope deposits) with abundant fish debris and vaguely discernable laminations appears to be controlled by biogenous input from coastal upwelling (Fig. 17c).

(5) Phosphorite (?) nodules, phosphatic (?) cemented arenaceous particles, phosphatic fish debris in biogenous sands on the upper slope and near the shelf-break characterize a second sedimentary facies reflecting coastal upwelling; organic carbon contents appear to be low (Figs. 17d,18).

(6) Visual inspection of terrigenous cores from the slope showed an abundance of benthic foraminifera useful for correlation and time series analyses.

(7) The low carbonate contents of the 2 Nazca Plate cores at 2937 m and 3316 m of water depth reflect either strong terrigenous input from across the trench or require a reassessment of the calcite compensation level at this location.

B. The shipboard results from interstitial water chemical analyses deal with methods of water extraction, microbial sulfate reduction processes and a unique -- still speculative -- control of dissolved phosphate in upper slope sediments:

(1) Agreement in dissolved nutrient analyses was obtained between in situ sampled water and interstitial samples extracted by cold-squeezing technique.

(2) Sulfate, ammonia, alkalinity and phosphate concentrations conform to gradients as predicted from microbial sulfate reduction models; dissolved silica also appears to be controlled by these reactions. (Figs. 10 & 11).

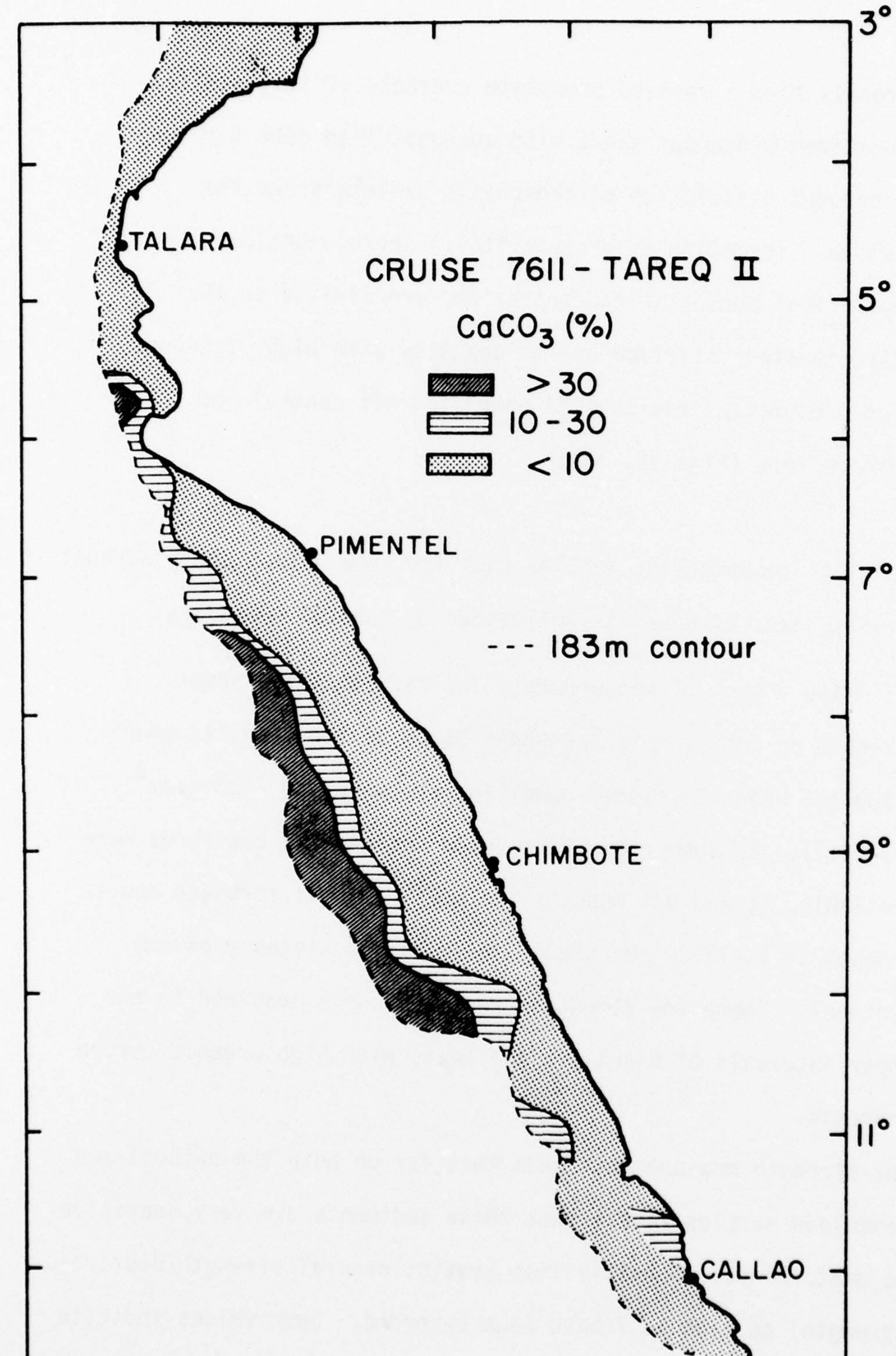

Fig. 18 $CaCO_3$ contents of arenaceous shelf deposits off Peru, in area of high biogenous $CaCO_3$ (30%) abundant phosphorite concretions. This figure is based in unpublished data (60 samples) kindly provided by C. Delgado, Inst. del Mar, Peru.

(3) Extremely high dissolved phosphate contents of interstitial waters from biogenous sands with abundant fish debris suggest incongruent dissolution of phosphatic skeletons and the possible formation of phosphorites. These anomalous interstitial phosphate concentrations are limited to the sediment-water interface and to deposits with high biogenous input presumably from coastal upwelling off central and northern Peru (Figs. 12, 13).

C. Evaluation of geotechnical properties thus far show unique shear strength and sensitivity data of deposits influenced by coastal upwelling:

(1) A limited number of measurements indicate that the shear strength or cohesion in the upper 50 cm of the deposits underlying the area of intense upwelling are very low ($<20\ g/cm^2$ (.3 psi)). In some cases, even when undisturbed box cores were available, it was not possible to measure shear strength above a depth of 10-15 cm because of the fluid consistency of the sediment. These low strengths resemble those measured in the upper intervals of Black Sea sediments with high organic carbon contents.

(2) The strength measurements made thus far on both the natural and remoulded samples reveal that these sediments are very sensitive to disturbance. Sensitivities (ratio: natural strength/disturbed strength) as high as 7 have been recorded. Such values indicate that a sediment may lose up to 85% of its strength when disturbed.

Submarine sediments commonly display sensitivities of 2 to 4. The high sensitivities from the Peru-Chile continental margin are greater than those measured in the highly organic Black Sea deposits.

D. Preliminary evaluation of optical measurements delineate the spatial variations of light transmission and hydrographic parameters.

(1) The maximum clarity (or minimum turbidity) below the variable surface layer is very uniform although its depth may vary in time and space; light transmission of the clean deep water off Peru is similar to that of off Oregon.

(2) Particle input from the coastal upwelling is represented by a marked maximum turbidity of about 100 ~150 m in thickness and at a depth of about 200 m. This maximum is well defined, but it dissipates rapidly beyond the trench.

(3) Bottom nepheloid layers are ubiquitous, and their vertical structure is strongly influenced by bottom topography.

(4) Southward extension of the equatorial undercurrent is observed in both temperature and light transmission.

E. Dredging activities recovered largely sedimentary rocks from the continental slopes off Chile and Peru. The uplift or subsidence history of the basin can be determined from benthic foraminiferal assemblages in these rocks and related to the structural framework of the region.

(1) The Chile margin at 22-24°S is acoustically opaque and covered with a thin manganese pavement. Lithologies include siltstone

and mudstone, presumably from rock outcrops on the slope, manganese crusts and rounded crystalline rocks of questionable origin.

(2) Lithologies recovered from the lower part of the Lima fore-arc basin (1600-2400 m) at 11°40'S include siltstone, mudstone, conglomerate and minor breccia which are similar to the lithologies recovered in 1972 from the upper part of the basin at about 900-1200 m.

(3) Lithologies recovered just seaward of the outer shelf structural high at 8°S and 9°S, which is composed of metamorphic rocks with a thin covering of early to late Cenozoic sedimentary rocks, consist of dark black siltstone, sandstone and conglomerate. Most of these rocks are very dense and hard and may be meta-sediments.

(4) The outer shelf structural high, Banco de Peru, off Talara consists mainly of siltstone and sandstone with minor conglomerate. If this high has an underlying crystalline core its rocks do not appear to be exposed on the bank.