May 7, 1987

TO:

Barbee, W.D.	-	UNOLS
Dudley, J.	-	LDGO
Gerard, S.	-	LDGO
✓Hayes, D.	-	LDGO
Cox, L.	-	LDGO
Lotti, R.	-	LDGO
Raleigh, B.	-	LDGO
Ruddiman, W.	-	LDGO
Ryan, W.F.B.	-	LDGO
Sykes, L.R.	-	LDGO
Takahashi, T.	-	LDGO
Science Officer	-	CONRAD
Captain	-	CONRAD

RESEARCH CRUISE REPORT

R/V ROBERT D. CONRAD 27-04

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

Ann Burns

Ann Burns
Marine Office

Enc.

BROWN UNIVERSITY Providence, Rhode Island • 02912

DEPARTMENT OF GEOLOGICAL SCIENCES
401 863-3221, 3338, 3339

PRELIMINARY REPORT OF RC27-04

SHIP NAME:	R.V. ROBERT CONRAD
OPERATING INSTITUTION:	LAMONT-DOHERTY GEOLOGICAL OBSERVATORY, COLUMBIA UNIVERSITY
DATES:	14-5-86 TO 16-6-86
PROJECT TITLE:	VARIATION OF MONSOONAL UPWELLING
CHIEF SCIENTIST:	DR. WARREN L. PRELL, BROWN UNIVERSITY
CLEARANCE COUNTRIES:	OMAN
FOREIGN PARTICIPANTS:	NONE
PORT CALLS:	COLOMBO TO COLOMBO, SRI LANKA
SCIENTIFIC PROGRAM:	SUMMARY

To study the history of monsoonal upwelling in the western Arabian Sea by obtaining sediment samples from a variety of depositional environments and water depths. Samples (see table in attached report) were obtained from the Indus Fan, the Owen Ridge, and the Oman Margin. Geophysical surveys were also conducted to help identify sites for scientific drilling as part of the international Ocean Drilling Program. See attached cruise report for detailed information.

DATA AND SAMPLES COLLECTED:

TYPE	CUSTODIAN
Single Channel Seismics[1]	LDGO
Gravity[1]	LDGO
Magnetics[1]	LDGO
Seabeam Bathymetry[1]	URI/BROWN
3.5Khz Profiles[1]	LDGO
Sediment Cores[1,2]	LDGO

LDGO - Lamont-Doherty Geological Observatory
URI - University of Rhode Island
[1]See attached track charts.
[2]See attached table for locations and core lengths.

INFORMATION ADDRESSES:

Dr. Warren L. Prell, Department of Geological Sciences, Brown University, Providence, Rhode Island 02912-1846, USA

Dr. Gregory Mountain, Lamont-Doherty Geological Observatory, Palisades, New York 10964, USA

AVAILABILITY AND DELIVERY OF DATA RESULTS AND REPORTS:

A cruise summary is attached and includes detailed track charts of all surveys and a complete listing of the location, depth, and type of each sediment sample recovered. As noted above, all geophysical data (with the exception of the Seabeam data) is archived at LDGO and is available upon request. All sediment samples are also archived and curated at LDGO.

Results and conclusions arising from the research conducted on this cruise will be published in the normal scientific literature and in the Initial Reports of the Ocean Drilling Program. Individual results will be submitted for publication as soon as they are completed. I expect that the first results will be submitted in 1988-1989 and that additional results will follow over the next five years. Copies of all publications and reports will be sent upon completion.

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DEPARTMENT OF GEOLOGICAL SCIENCES
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PRELIMINARY CRUISE REPORT

ROBERT CONRAD 27-04

EVOLUTION OF MONSOONAL UPWELLING

Introduction and Background

The western Arabian Sea is characterized by extremely strong seasonal upwelling that is associated with the Indian Ocean summer monsoon. The goal of this research and the associated cruise was to develop a data base and conceptual framework for interpreting the long-term evolution of the Indian Ocean monsoon and its associated upwelling system. The primary objective of cruise RC27-04 were to obtain geophysical surveys of the Oman Margin, the Owen Ridge, and the western-most Indus Fan to identify sites for recovering continuous sections of Neogene sediments for the study of the evolution of monsoonal upwelling and to clarify the structure and history of the Oman Margin and the Owen Ridge. A second objective was to obtain transects of sediment cores over a variety of water depths from both the Oman Margin and the Owen Ridge to enable us to reconstruct the variability of Late Quaternary monsoonal upwelling.

Cruise RC27-Leg 4, aboard Lamont-Doherty Geological Observatory's RV Robert Conrad, departed Colombo, Sri Lanka at 0630 on 14 May, 1986, spent 34 days at sea and returned to Colombo at 0600 on 16 June, 1986. A track chart for the entire cruise is attached as Figure 1 and a list of participants is given in Table 1. Below, I summarize the data acquisition and preliminary results from the cruise and post-cruise activity.

Preliminary Results from Cruise RC27-04

Oman Margin. - Our survey of the Oman Margin was concentrated between 17°30'N and 18°30'N and between 57°30'E and 58°00'E (see Figure 2). Within this area, we collected 1400 kilometers of continuous Seabeam, single channel seismic, 3.5 Khz seismic, gravity, and magnetic data. Due to the shallow water depths (1000 m or less) the Seabeam swath was very narrow and complete bathymetric mapping was impossible. However, the seismic data clearly deliniated the morphology and structure of the margin. We found that the northern part of the study area contained numerous sharp V-shaped canyons whereas much of the the southern part was a smooth depositional platform or terrace about 800 meters deep. This platform is a sedimentary basin bounded on the shoreward side by relatively steep slopes from about 200 m to 600 m and on the seaward side from 1000 m to 2000 m (see Figure 3A). Sonobouy data indicate that this basin has up to 2400 m of sediment and is bounded on the seaward edge by distinct diapiric-type structures (See Figure 3). A seismic strike line (Figure 3B) along the center of this slope-shelf basin reveals relatively undisturbed, flat lying sediments that are good coring sites for expanded Quaternary sections. We completed 37 coring stations in the study area using the piston core, a giant gravity core, and a box core. The location of cores is shown in Figure 2. The distribution of cores with water depth is shown in Figure 4. A summary of the water depth, coordinates, and recovery for each core is given in Table 2. We found that the sediments of the sedimentary basin were mixtures of carbonate and terrigenous silty components with alternating layers of darker (more organic) and lighter (less organic) sediments. Preliminary analysis of one core at about 800 m depth reveals variable carbonate contents of 20 to 40 percent (see Figure 13). We found no direct evidence of extended anoxia as all of the box cores were clearly oxygenated and bioturbated. We also obtained two hydrographic stations off the margin to establish the temperature, salinity, and oxygen composition of the water column and to identify the oxygen minima zone. These data are shown in Figure 5 along with the water depth of cores collected from the Oman Margin. Future study of the longer sediment cores should provide the basis for establishing variations in the oxygen minima zone.

Owen Ridge. - Our survey of the Owen Ridge was concentrated between 59^{o}E and 60^{o}E and between 59^{o}40E and 16^{o}40E. The track chart for the Owen Ridge survey (Figure 6) shows that we obtained about 2000 kilometers of Seabeam, seismic, gravity, and magnetic data. Our track density gave about 70% coverage for Seabeam data and provided an excellent bathymetric chart of the complex Owen Ridge. A portion of the machine contoured bathymetric map is attached

(Figure 7) as an example of the complex erosional surface on the westward flank of the Owen Ridge. The combination of the Seabeam data along with the seismic reflection and 3.5 Khz seismic data provided an excellent data base to establish structure of the Owen Ridge, the location of continuous sediment sections, and the complex evolution of this fracture zone ridge. Attached are partial records of the processed seismic data to illustrate the complexity of the ridge and potential ODP coring locations. Figure 8 illustrates a typical dip line (see Figure 6 for location) showing the sediments to be tilted and onlapping onto the Owen Ridge basement. Some disturbance in the upper most sediment section is apparent but is not clearly defined in the dip lines. Figure 9 illustrates the crestal portion of the Owen Ridge and the location of a drilling site proposed to obtain an expanded Neogene section. The reflector at about 0.45 seconds depth is thought to be approximately middle Miocene on the basis of correlation to DSDP Site 224. We have located several sites similar to the one in Figure 9 for obtaining complete Neogene sections from the Owen Ridge. Figure 10 illustrates a strike line (see Figure 6 for location) showing the erosional(?) valleys in the upper sediments and the deeper sediment structures onlapping basement. These data are being used to locate an appropriate site to recover the reflector stratigraphy and establish the age relationships of the older sediments onlapping the Owen Ridge. These age relationships will the be traced into the Oman Basin in order to provide age constraints on the origin of that basin.

We obtained 23 cores from the Owen Ridge at a wide variety of water depths. The location of cores is shown in Figure 6 and their water depth and recovery is shown in Figure 11. Table 2 gives a listing of the location, water depth, and recovery of each core site. Sediments from the Owen Ridge were predominantly calcareous and showed slight alternations of carbonate content and colors.

Indus Fan. -

We obtained several east/west crossings of the Indus Fan and completed a brief survey of a channel system on the western most part of the Indus Fan (see Figure 12 for cruise track). The Seabeam and seismic data revealed a general lack of strong reflectors on the broad levies of the meandering channel. A core obtained from the western-most levy appeared to be predominantly fine-grained sediment with no obvious sand layers.

Post-Cruise Results

Sediment data. - Five piston cores were sampled aboard the Conrad. The remainder of the cores have been returned to Lamont-Doherty Geological Observatory and are now awaiting to be opened, described, and curated. For all shipboard samples, we have completed initial sample processing, calcium carbonate stratigraphy, and have several cores ready for obtaining stable isotope stratigraphy. The calcium carbonate stratigraphy (Figure 13) from the Owen Ridge is consistent with other Indian Ocean cores we have previously analyzed. On the basis of this stratigraphy, we estimate that core RC27-61 extends back about 400,000 years. If confirmed by isotopic stratigraphy, we will have achieved one of our objectives - that of obtaining a long time series for study of monsoonal variations in the late Pleistocene. The calcium carbonate stratigraphy can be clearly correlated to the lower slopes of the Oman Margin (RC27-24 at 1400 m), but losses its distinctive pattern on the upper slope platform (RC67-12).

Two biostratigraphic datums (see Figure 13) provide a tentative correlation between cores in these three depositional environments. The combination of carbonate stratigraphy and biostratigraphy indicates that accumulation rates vary from about 3 cm/kyr on the Owen Ridge to about 15 cm/kyr on the slope basin.

Examination of surface sediment samples across the Owen Margin slope indicates that the carbonate content (about 50%) consists of shells of recent benthic and planktonic organisms as opposed to detrital origin. Siliceous microfossils are rare and very fragmented in these sediments and quantitative species counts are unlikely to be made in surface sediments. Coarse silt and fine sand sized terrigenous particles are common in all slope sediments. Preliminary analyses reveal that upper and lower slope sediments contain from 2.0 to 3.5% organic carbon whereas the midslope samples contain as much as 5.5 to 6.5% organic carbon. Sediments from the Owen Ridge are characteristic pelagic carbonate oozes with moderately preserved diatoms and reasonably well-preserved radiolarian assembleges that are similar to those of the tropical Pacific. We expect the radiolarian assemblages to provide quantitative estimates of past paleoenvironments along with the planktonic and benthic foraminifera.

In conjuction with John King and Jan Bloemedale at the University of Rhode Island Graduate School of Oceanography, we have obtained magnetic susceptability measurements on portions of ten sediment cores. Although preliminary, these data seem to show systematic susceptability variations that are consistent with available carbonate data. We are encouraged that the magnetic susceptability data may provide a rapid index of the lithic variation in these cores and we plan to pursue this methodology.

Seismic data. - Greg Mountain (Lamont-Doherty Geological Observatory) completed initial processing of all seismic data from the Oman Margin, the Owen Ridge, and the Indus Fan. These data were reviewed by the Site Survey Panel Ocean Drilling Program and were judged as more than adequate to select appropriate drilling sites. Greg Mountain and I have been evaluating seismic data and are in the process of finalizing the selection of ODP drilling sites for Leg 117 of the Ocean Drilling Program. These sites will be presented to the Indian Ocean Panel at their next meeting.

TABLE 1

CRUISE PARTICIPANTS

DR. WARREN PRELL	Brown	Chief Scientist
DR. GREGORY MOUNTAIN	L-DGO	Co-Chief Scientist
DR. SAM GERARD	L-DGO	Hydraulic Engineer
DR. JON OVERPECK	L-DGO	Watchstander
DR. LARRY PETERSON	Miami	Watchstander
MR. WILL HOWARD	WHOI	Watchstander
MR. BOB BREYNAERT	Brown	Watchstander
MR. JOHN FARRELL	Brown	Watchstander
MR. STEVE CLEMENS	Brown	Watchstander
MR. DAVE ANDERSON	Brown	Watchstander
MS. LISA DUBOIS	Brown	Watchstander
MR. NEAL DRISCOLL	URI	Seismic Technician
MR. HARRY VAN SANTFORD	L-DGO	Electronics Technician
MR. STEVE LABRECQUE	L-DGO	Electronics Technician
MR. KURT FEIGL	L-DGO	Navigational Technician
MR. FRANK ROBINSON	L-DGO	Winch Operator
MR. JOHN FREITAG	URI	SEABEAM Technician
MR. PETER LEMMOND	URI	SEABEAM Technician
MR. MARTIN ILTSZCHE	L-DGO	Water Gun Technician
MR. ROPATE QUALI	L-DGO	Coring Bos'n

TABLE 2

STATION DATA

STATION		DAY/TIME	LATITUDE	LONGITUDE	DEPTH (m)	RECOVERY
2	H-1	140/10:59	17 29.5	58 02.8	2020	8BOT,0-600
3	H-2	140/14:30	17 30.3	58 03.5	2092	8BOT,600-2000
4	C-2PC	145/06:34	17 41.6	57 52.6	1474	5.94M
5	C-3GGC	145/08:17	17 40.5	57 53.0	1473	0.00
6	C-4PC	145/11:17	17 38.6	57 43.9	1276	5.93M
7	C-5GGC	145/12:43	17 38.7	57 42.9	1275	0.00
8	C-6GGC	145/15:14	17 37.7	57 43.0	1275	0.28M
9	C-7PC	145/17:43	17 42.9	57 37.6	965	10.10M
10	C-8GGC	145/19:14	17 42.6	57 37.3	957	1.02M
11	C-9PC	145/21:13	17 46.7	57 37.3	891	10.38M
12	C-10GGC	145/22:23	17 45.8	57 39.5	889	1.23M
13	C-11PC	146/00:43	17 53.7	57 34.8	861	11.04M
14	C-12PC	146/04:09	18 03.8	57 37.0	788	11.63M
15	C-13PC	146/07:25	18 14.6	57 41.0	689	10.34M
16	C-14PC	146/12:12	18 15.2	57 39.3	590	10.92M
17	C-15GGC	146/14:10	18 15.6	57 39.2	579	0.00
18	C-16PC	146/16:30	18 16.1	57 37.8	479	10.26M
19	C-17PC	146/20.10	18 16.6	57 37.6	438	9.81M
20	C-18GGC	146/21:57	18 17.8	57 38.6	452	0.59M
21	C-19PC	146/23:51	18 17.4	57 38.6	459	5.77M
22	C-20PC	147/02:31	18 16.1	57 33.4	296	5.43M
23	C-21PC	147/05:41	18 06.6	57 31.8	569	12.03M
24	C-22PC	147/11:44	18 04.2	57 33.8	749	11.25M
25	C-23PC	147/15:16	17 59.7	57 35.4	815	10.83M
26	C-24PC	147/19:40	17 43.1	57 49.2	1416	11.74M
27	C-25PC	147/22:27	17 37.6	57 39.9	1347	10.50M
28	C-26PC	148/00:52	17 40.7	57 39.9	1064	11.21M
29	C-27BOX	148/08:04	17 54.5	57 35.5	860	0.56M
30	C-28GGC	148/12:03	17 54.2	57 35.4	866	2.78M
31	C-29BOX	148/14:43	17 53.1	57 37.3	868	0.00
32	C-30BOX	148/18:47	18 13.0	57 41.0	698	0.51M
33	C-31GGC	148/20:09	18 12.8	57 41.1	707	2.68M
34	C-32GGC	148/22:30	18 14.3	57 38.7	601	0.00
35	C-33BOX	148/23:35	18 13.5	57 38.8	630	0.49M
36	H-3	149/01:10	18 12.6	57 38.9	688	8BOT,0-600
37	C-34GGC	149/03:45	18 13.9	57 35.0	509	0.00
38	C-35BOX	149/04:48	18 14.0	57 35.9	498	0.42M
39	C-36TW	149/07:56	18 19.5	57 30.1	185	0.00
40	C-37TW	149/08:22	18 20.5	57 31.2	188	0.00
41	C-38TW	149/09:08	18 19.7	57 33.5	247	0.15M
42	C-39GGC	156/07:48	16 37.2	59 51.9	1889	3.05M
43+	C-40PC	156/09:23	16 37.2	59 52.1	1890	11.40M
44+	C-41GGC	156/12:31	16 31.7	59 47.3	2052	2.01M
45	C-42PC	156/13:55	16 31.1	59 47.0	2044	11.11M
46	C-43GGC	156/16:49	16 36.2	59 46.0	2159	2.45M
47	C-44PC	156/18:37	16 36.2	59 46.0	2159	11.75M
48	C-45GGC	156/21:21	16 36.0	59 40.8	2406	2.88M
49	C-46PC	156/23:37	16 38.8	59 42.7	2441	10.65M
50	C-74GGC	157/02:13	16 38.2	59 41.5	2530	2.89M
51	C-48PC	157/03:52	16 38.1	59 41.3	2545	11.79M
52	C-49GGC	157/06:12	16 39.1	59 39.1	2686	2.94M
53+	C-50PC	157/08:04	16 40.2	59 39.6	2707	12.07M
54	C-51GGC	157/11:22	16 42.2	59 36.0	2918	2.68M
55	C-52PC	157/13:22	16 40.8	59 35.9	2985	11.89M
56	C-53GGC	157/18:08	16 32.3	59 27.3	3258*	2.37M
57	C-54PC	157/20:31	16 32.1	59 27.3	3275	11.76M
58+	C-55GGC	158/00:14	16 28.6	59 21.2	3392	2.72M
59	C-56PC	158/02:47	16 29.0	59 20.7	3405	11.59M
60	C-57GGC	158/06:20	16 20.9	59 17.6	3490	2.92M
61	C-58PC	158/08:28	16 22.0	59 11.2	3484	11.84M
62	C-59BOX	158/12:07	16 22.0	59 10.9	3488	0.00
63	C-60GGC	158/21:04	16 36.8	59 51.5	1887	0.93M
64	C-61PC	159/06:08	16 39.5	59 31.4	1893	15.97M
65	C-62PC	159/21:22	16 09.6	60 40.8	3997	11.78M

C = CORE; PC = PISTON CORE; GGC = GIANT GRAVITY CORE; BOX = BOX CORE (SOUTAR); TW = TRIGGER GRAVITY CORE; H = HYDROGRAPHIC CAST

ALL CORE LENGTHS ARE CORRECTED FOR VOIDS AND SHORT SECTIONS. AN * INDICATES THAT 3.5KHZ DEPTH, WIRE OUT, AND PINGER DEPTHS DID NOT AGREE. A + AFTER THE SHIP STATION INDICATES A SURFACE PLANKTON TOW.

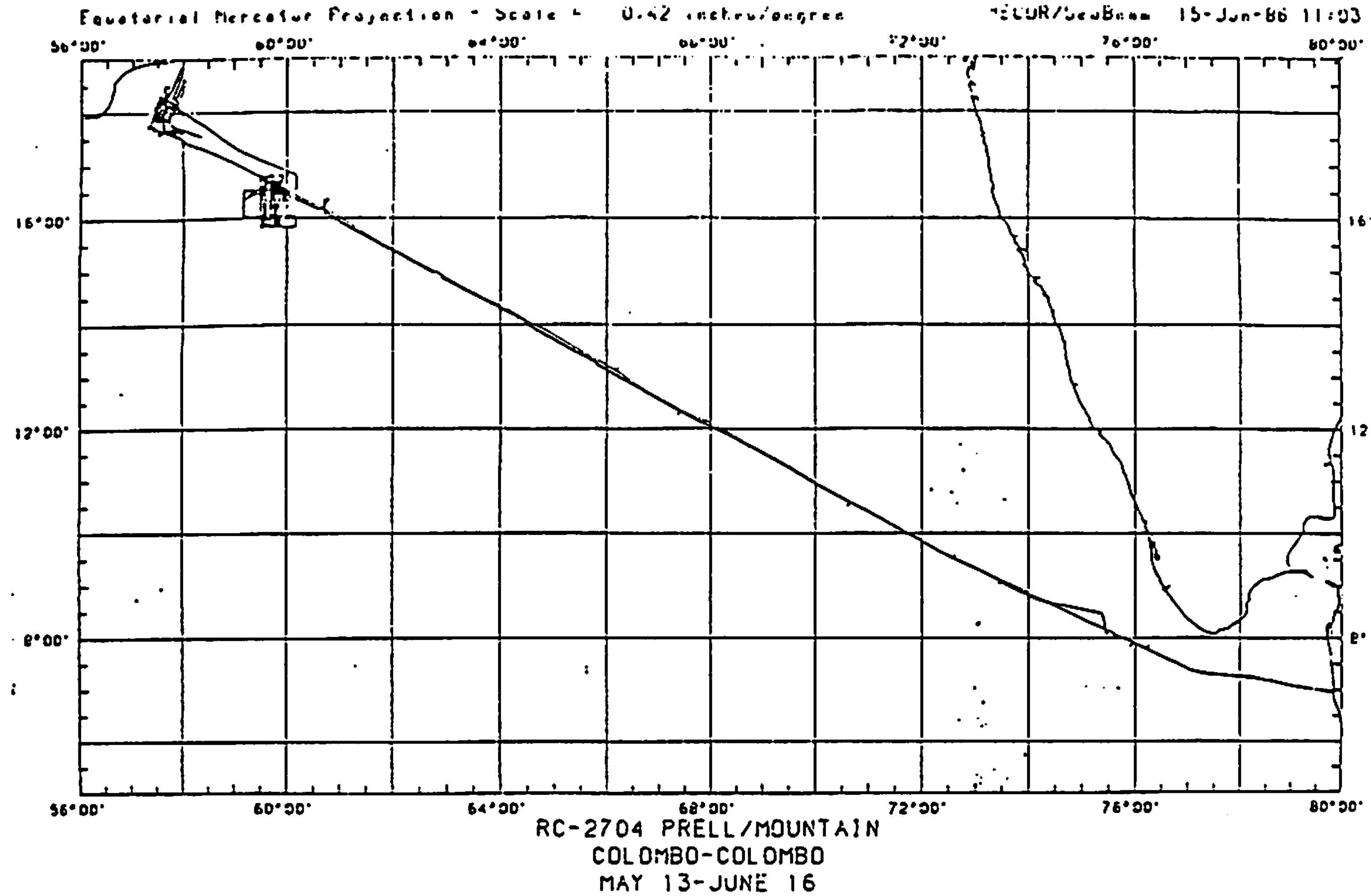

Figure 1. Track chart for Robert Conrad Cruise 27-04.

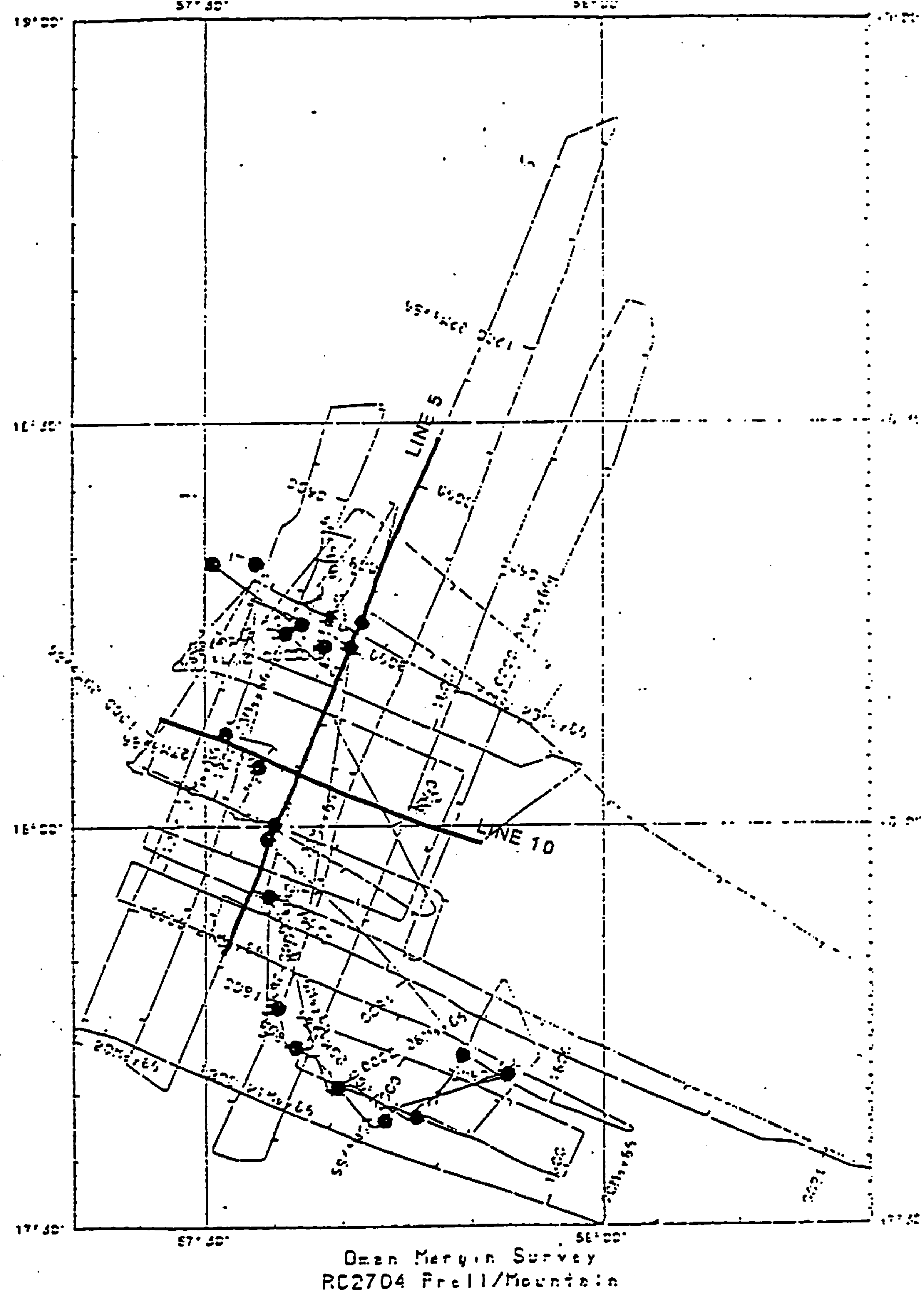

Figure 2. Track chart for Oman Margin survey. Location of sediment cores are shown by black dots. Seismic lines 10 (Figure 3b) and 5 (Figure 3a) are shown as heavy lines.

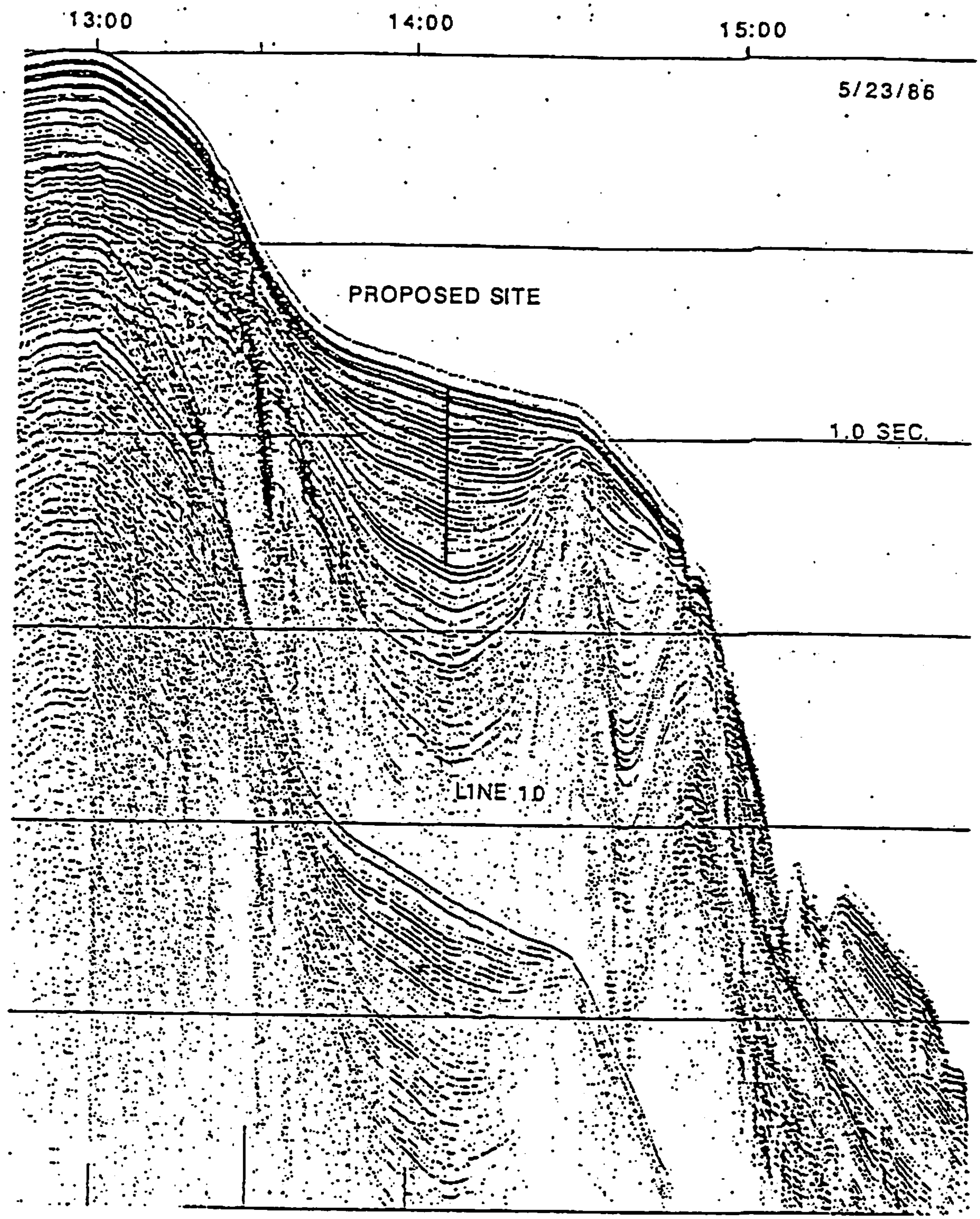

Figure 3a. A dip section (seismic line 10) across the Oman Margin illustrating the upper slope sedimentary basin and diapiric structures of the outer slope. ODP coring sites will be proposed for the center for the sedimentary basin. See Figure 2 for location of line 10.

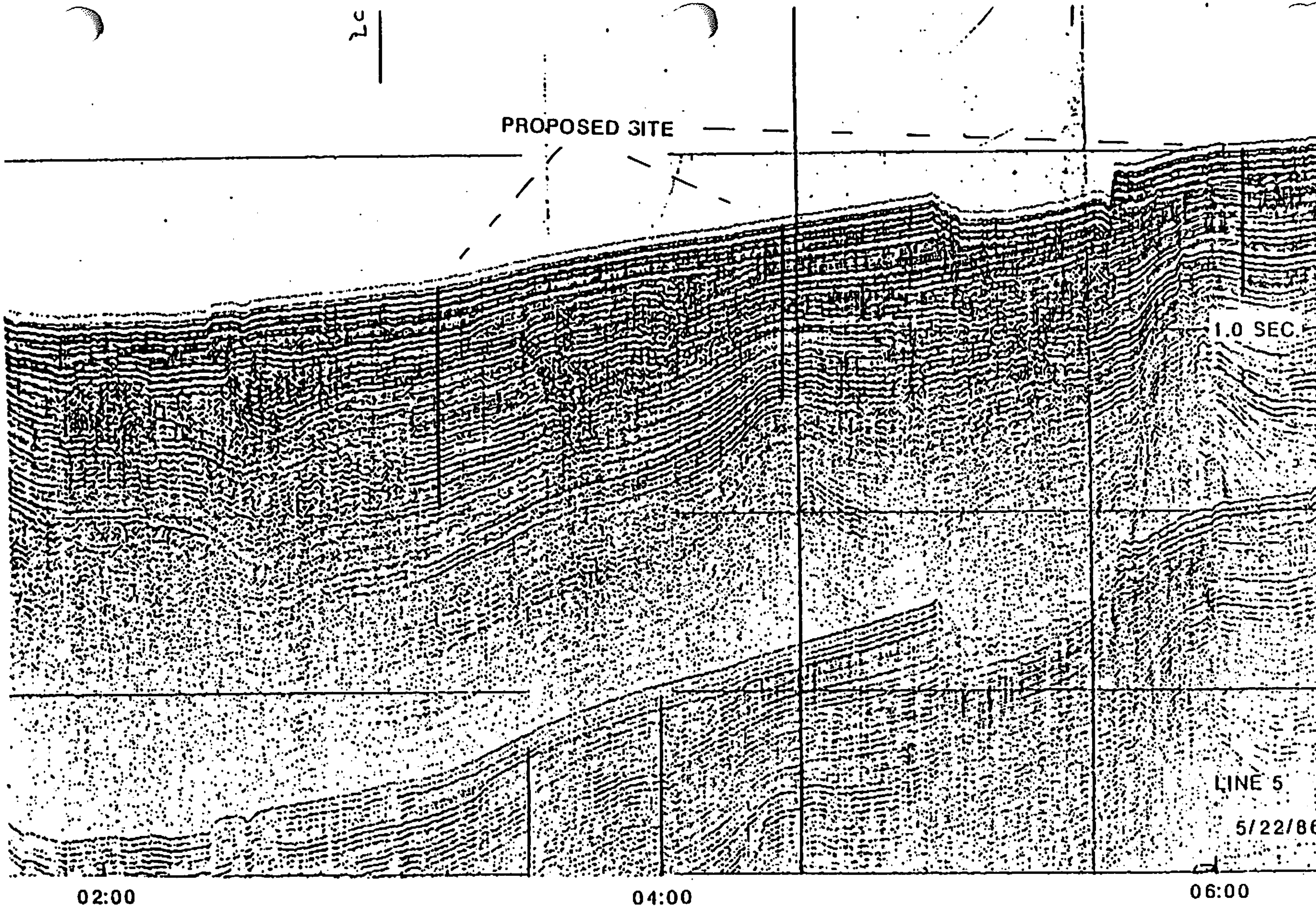

Figure 3b. A strike section (seismic line 5) along the upper slope sedimentary basin. Discordant reflectors probably represent turbidite or slump deposits. Several areas appear suitable for obtaining relatively expanded Plio-Pleistocene sediment sections. See Figure 2 for location of line 5.

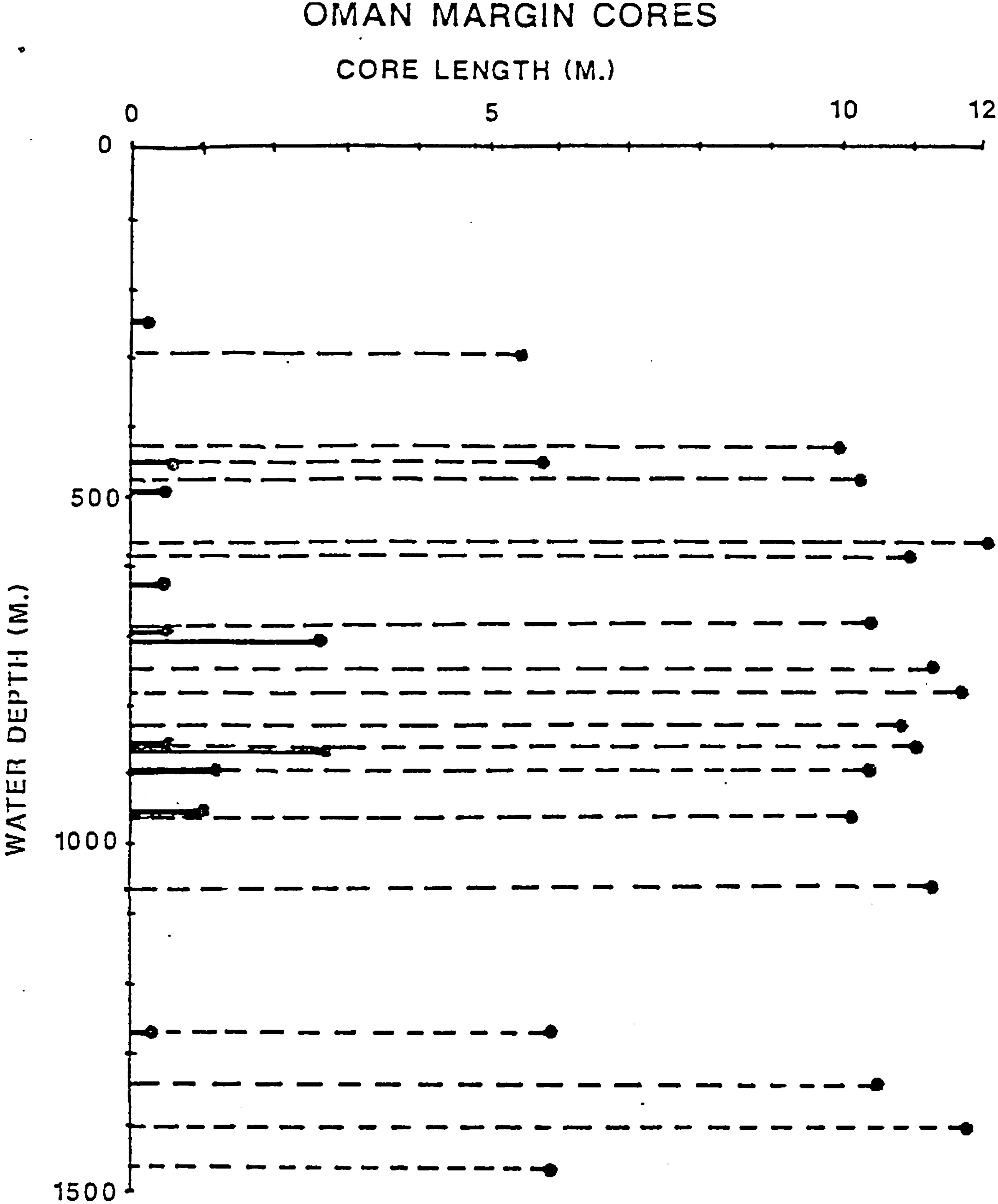

Figure 4. A summary of Oman Margin box cores, giant gravity cores, and piston cores (dashed lines) as a function of water depth. Detailed location and recovery data are given in Table 2.

Oxygen Profiles

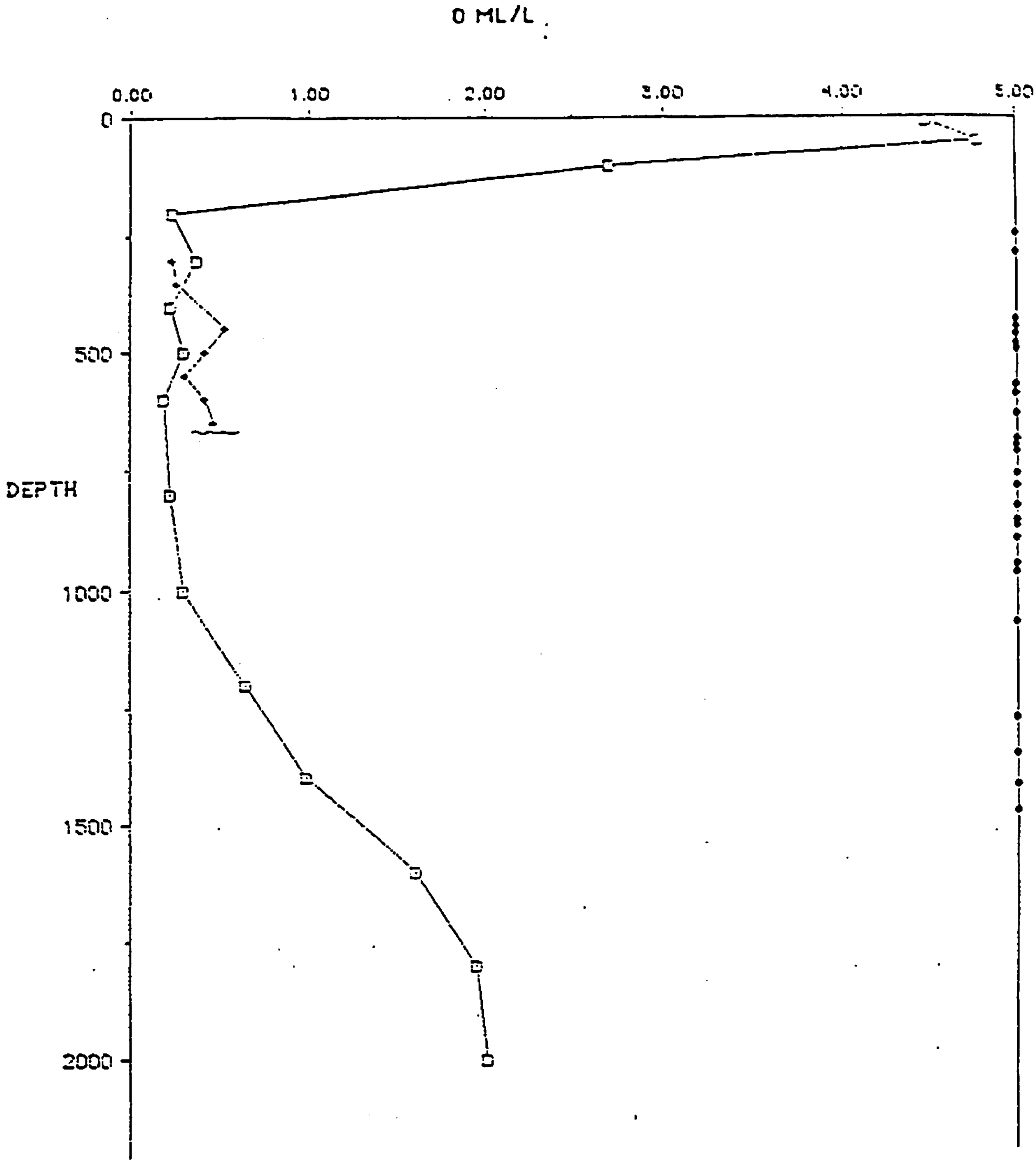

Figure 5. Profiles of oxygen content of the water column on and adjacent to the Oman Margin. The oxygen minimazone is clearly dilineated between about 200 meters and 1000 meters. Dots on the right-hand margin show the relationship of the various cores to the zone of low oxygen.

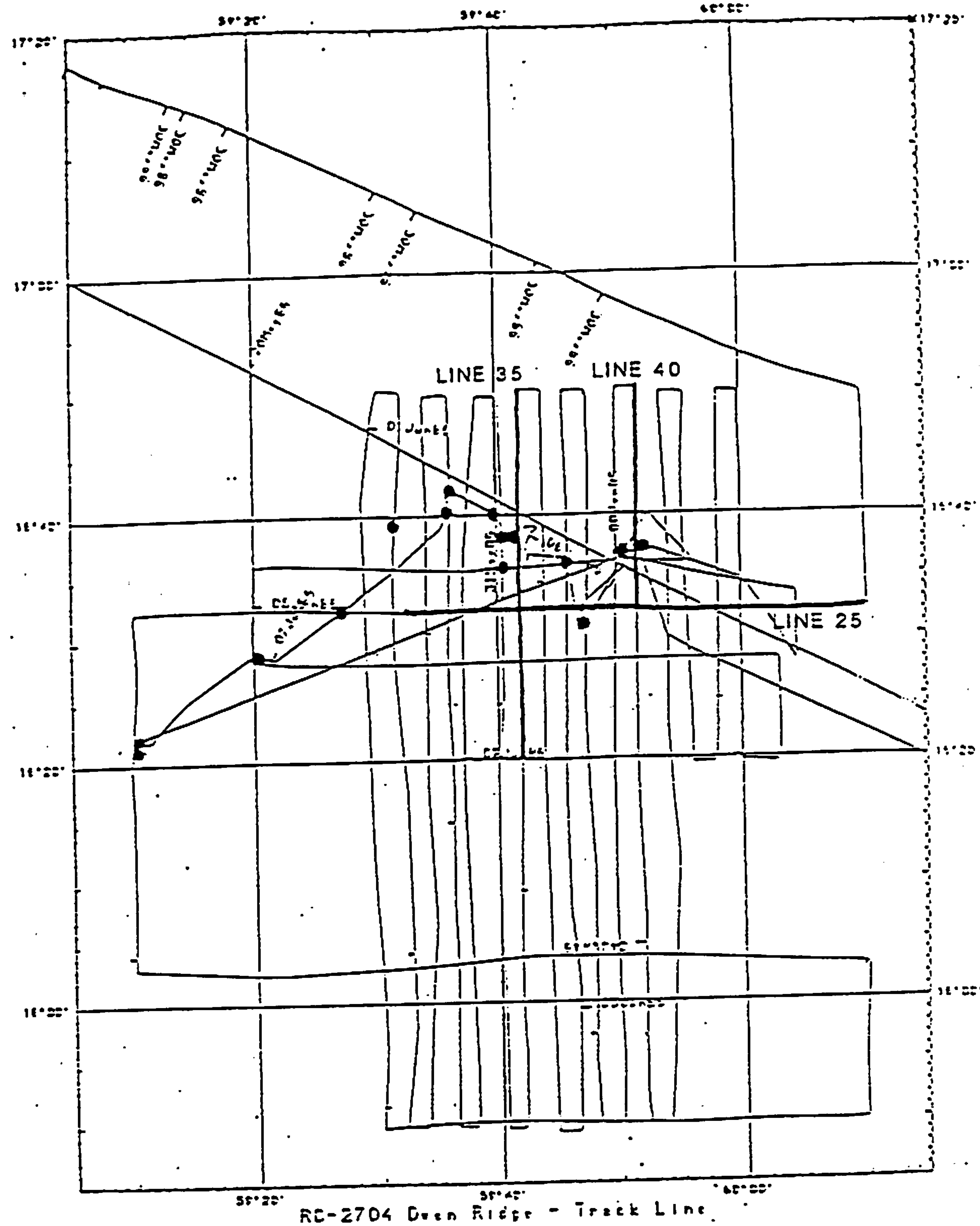

Figure 6. Summary track chart for the Owen Ridge survey. Location of sediment cores are shown as dots and seismic lines 25, 35, and 40 are shown as heavy lines.

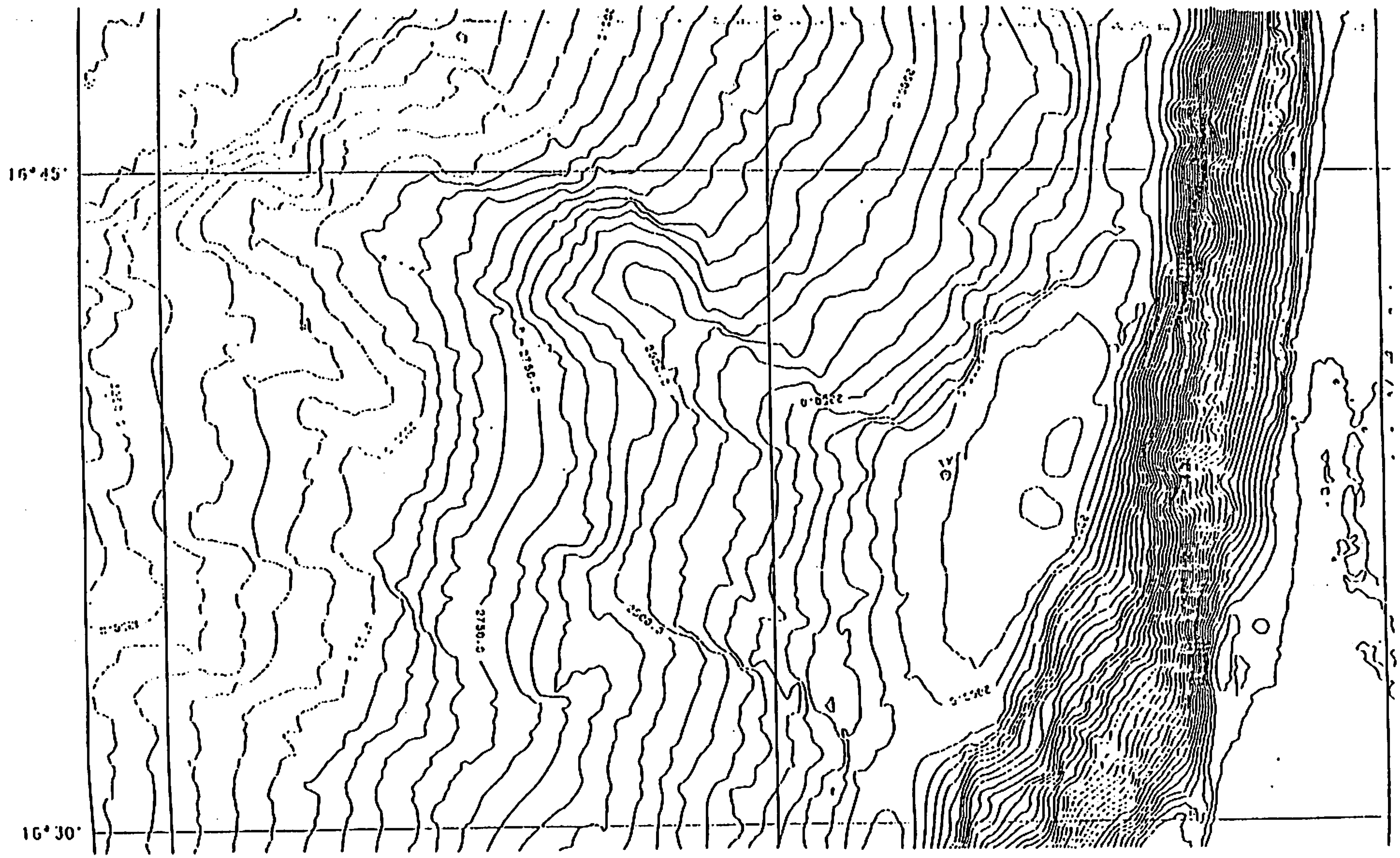

Figure 7. A portion of the machine contoured data from our Seabeam survey of the Owen Ridge. Swath coverage was approximately 60 to 70 percent over most of this area. This portion clearly shows the steep east-facing scarp, the broad crestal region, and the complex valley system on the westerward flank of the Owen Ridge.

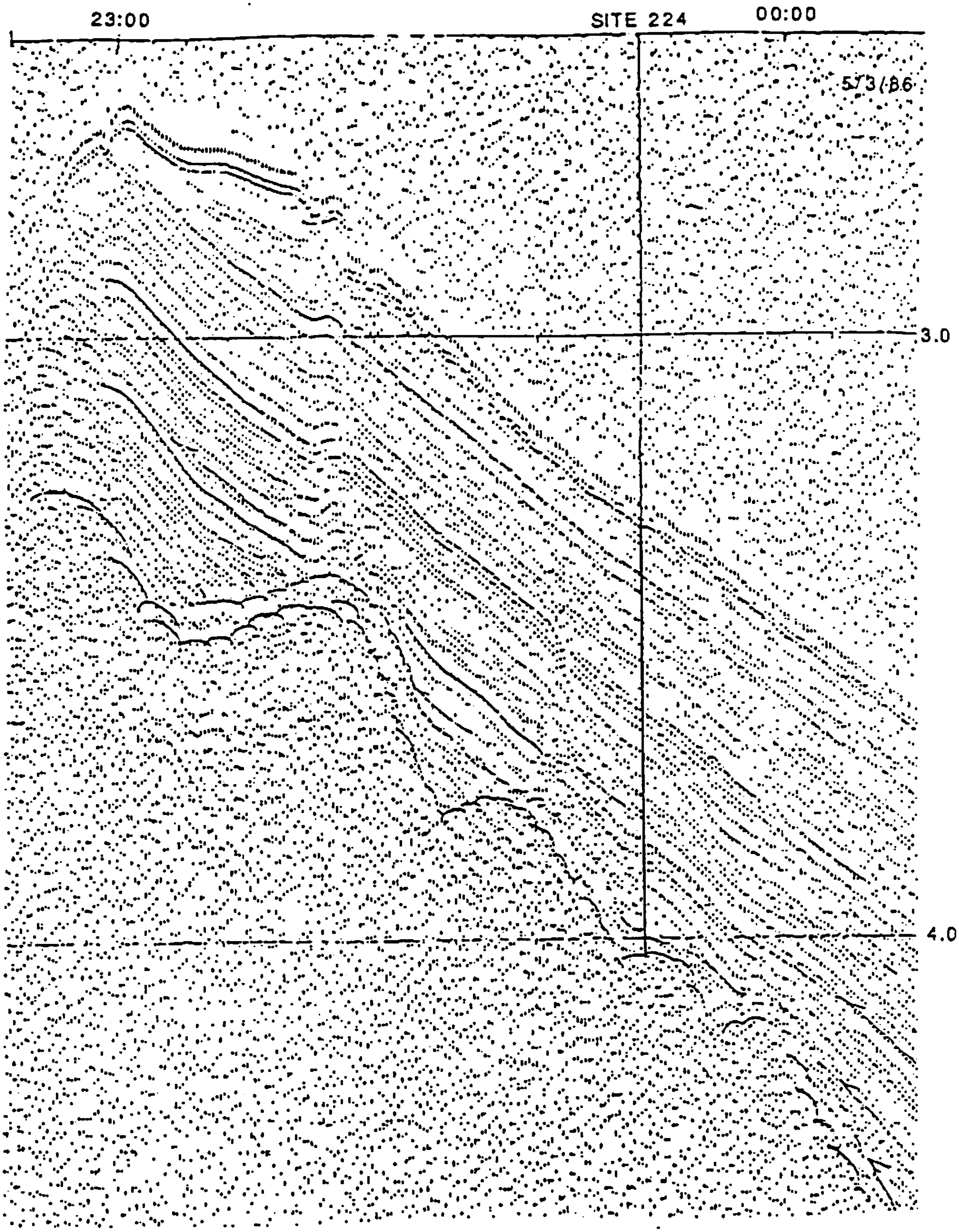

Figure 8. A partial dip section (seismic line 25 - see Figure 6 for location) using the processed single-channel digital data. Basement was clearly dilineated. This line nearly intersects DSDP Site 224.

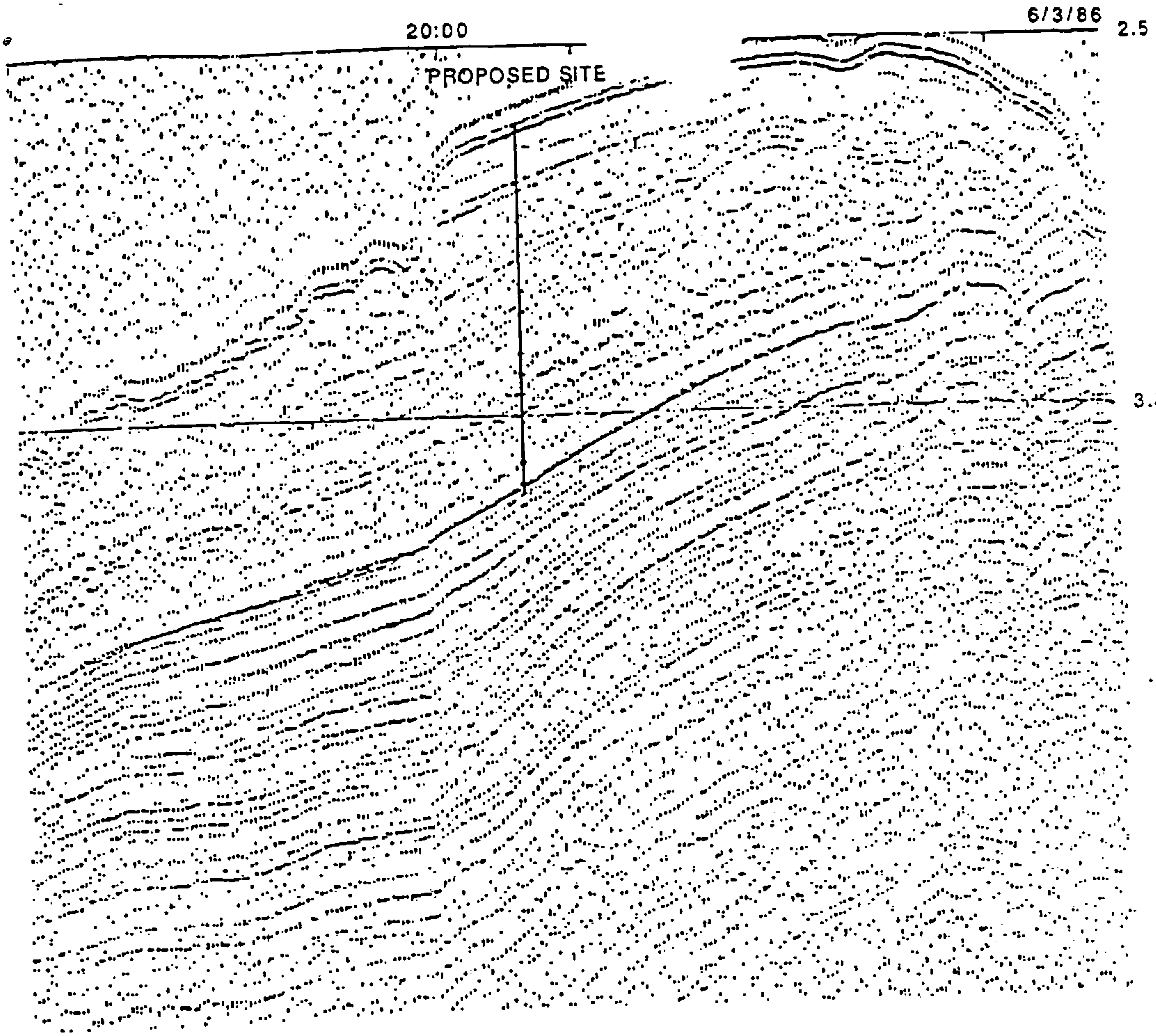

Figure 9. A partial dip section (seismic line 40) using the processed data to show the existence of expanded Neogene sections near the crest of the Owen Ridge. Sites such as this will be proposed as primary coring locations for the Owen Ridge. See Figure 2 for the location of seismic line 40.

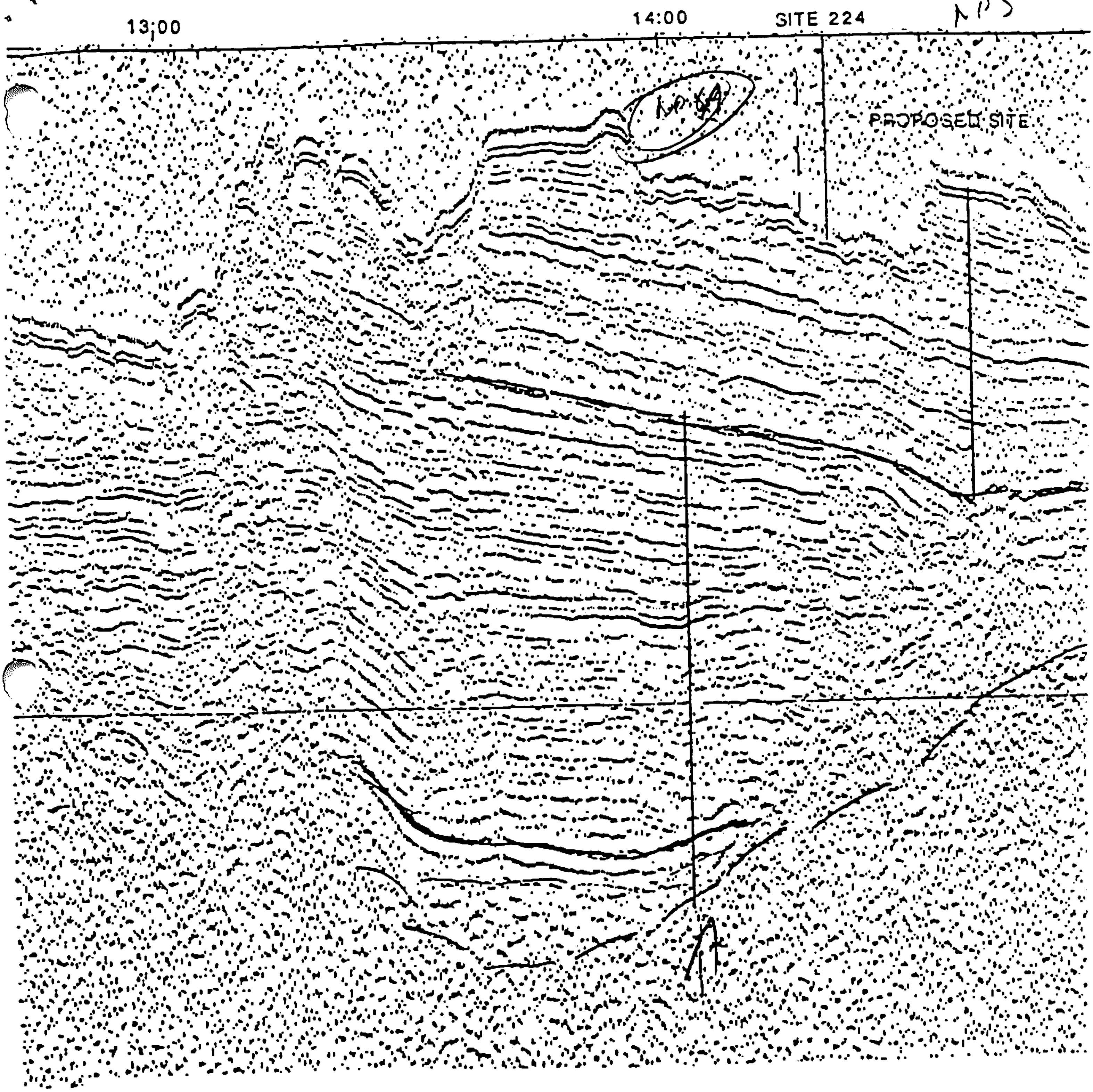

Figure 10. A portion of the strike section (seismic line 35) using the processed single-channel data. This section illustrates the erosional(?) valleys along the western flank of the Owen Ridge and the deep sequence of reflectors that onlap onto Owen Ridge basement. These data will be used to propose recovering both the expanded Neogene section and also the earlier section that contains the prominent reflector sequence.

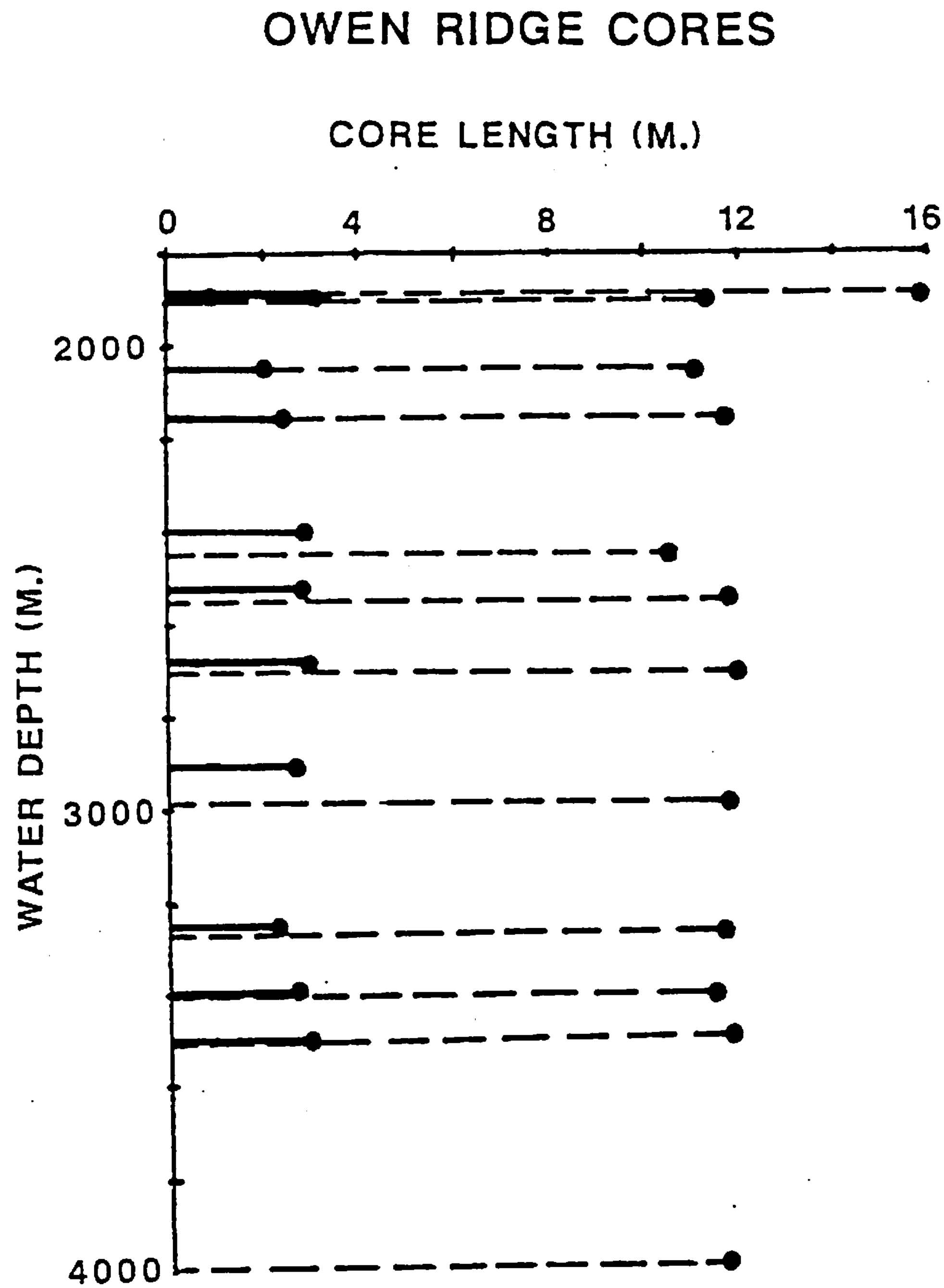

Figure 11. The distribution of recovery in Owen Ridge cores (dashed lines are piston cores) versus water depth. This sequence of cores should allow us to accurately reconstruct the variations of carbonate preservation as a function of water depth.

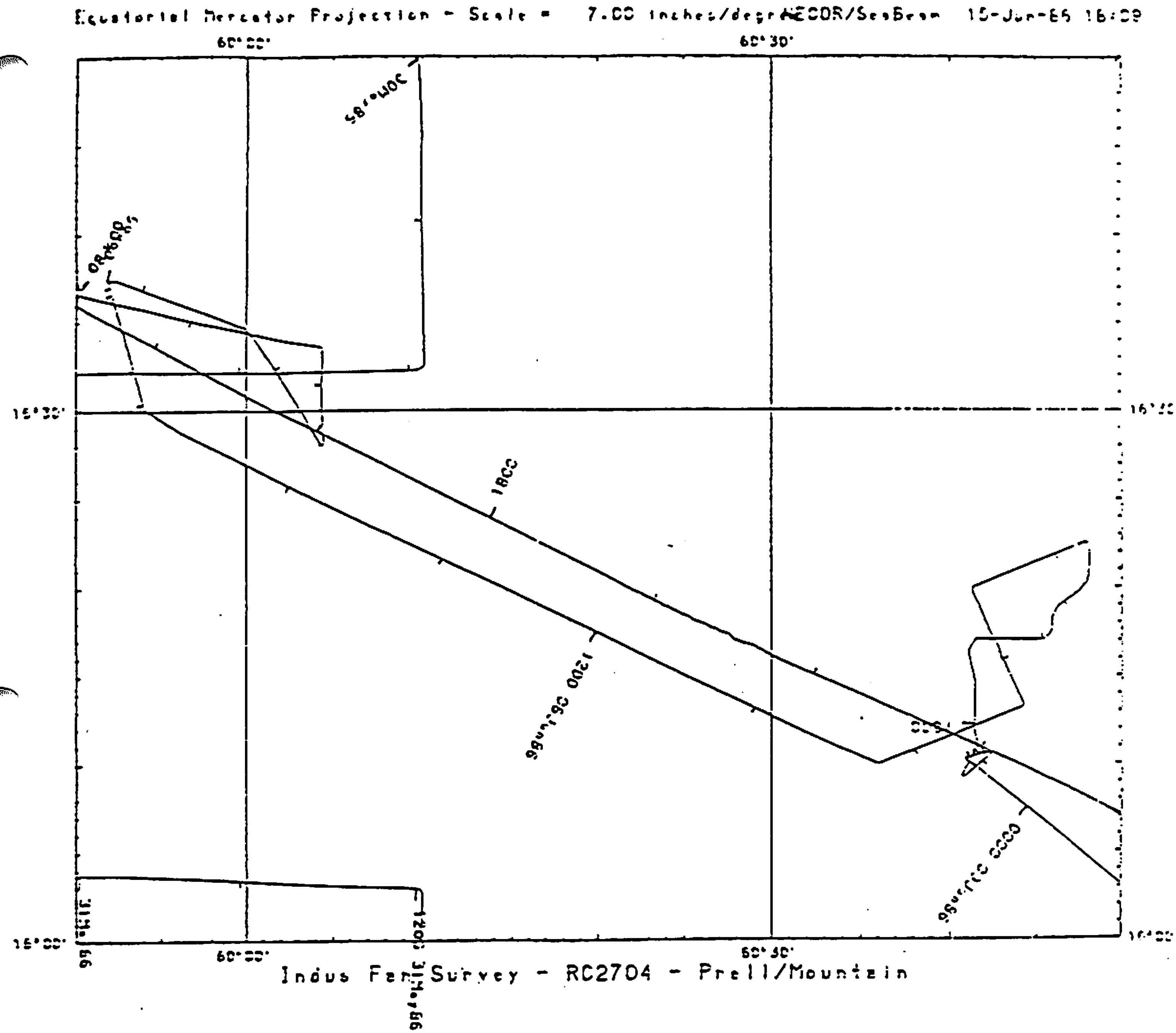

Figure 12. A summary track chart for crossings and survey of the western-most Indus Fan.