OCEAN DRILLING PROGRAM

LEG 117 SCIENTIFIC PROSPECTUS

OMAN MARGIN/NEOGENE PACKAGE

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INTRODUCTION

The Arabian coast off Oman, the Owen Ridge, and the Indus fan will be investigated during ODP Leg 117 in August through October 1987 (Fig. 1). The two major scientific objectives that will be addressed during this cruise are the evolution of the Indian Ocean summer monsoon and the history and origin of Owen Ridge as it relates to the evolution of the SE Oman continental margin.

The southwest monsoon is counted among the dominant components of global climate. The evolution of this primary atmospheric feature since the Neogene has had tremendous impact on the evolution of atmospheric and oceanographic circulation not only on the regional monsoonal winds of the northern Indian Ocean, but also on the paleoclimate of tropical Africa, the whole of Asia, and possibly North America. According to atmospheric modelling experiments, the most important factors controlling the intensity of the southwest monsoon are the topography of surrounding land masses and variations in solar radiation (Hahn and Manabe, 1975; Kutzbach, 1981; Kutzbach and Guetter, 1986; Prell and Kutzbach, in press). While the characteristics and causes of this annual phenomenon are generally understood -- they will be outlined in brief below -- the longer term evolution and intensity of the monsoon is difficult to reconstruct and extrapolate to geologic times prior to 150 thousand years ago.

The temporal and causal link between Himalayan uplift and monsoonal evolution will be explored by reconstructing the depositional history of the Indus catch basin. One of two proposed sites in the mid Indus fan (target sites IN-1 and IN-2) will enable calculation of the rates of clastic deposition, which can be correlated to periods of uplift by a bio- and magnetostratigraphic chronology of the fan evolution obtained from intercalated pelagic intervals.

The tectonic origin of Owen Ridge and Basin and the history of the Oman coast have been discussed by Whitmarsh (1979). Recently, Stein and Cochran (1984) have equated the rifted margins of Kenya and Somalia, where India and Madagascar split from the plates of Africa and Arabia during the middle Jurassic, to the passive margin history off Oman. This analogy postulates the occurrence of oceanic crust of Jurassic or Early Cretaceous age beneath Owen Basin sediments. Recently obtained site survey data (R/V Robert Conrad) suggest a younger age (younger than Paleogene) for sediments from the Owen Basin, however, and thus suggest a different mechanism and tectonic history (Mountain and Prell, 1987). A new tectonic model that is outlined below will be tested by scientific drilling during Leg 117.

PREVIOUS WORK

The Modern Monsoon and Upwelling in the Northern Indian Ocean

At present, the near-surface winds of the Arabian Sea typically change from southwesterly to northeasterly direction on a seasonal basis. During the winter, cooling over Asia develops a high pressure cell that leads to a northeasterly wind flow from Asia over the Arabian Sea (Hastenrath and Lamb, 1979; Hastenrath, 1985; Figs. 2a and 2b). During summer months, this pattern is reversed because summer heating creates an intense low pressure zone centered around 30^{o}N over the Tibetan Plateau (Fig. 3). During this season, the southern Indian Ocean acts as a high pressure cell, and the meridional pressure gradient is large enough to produce considerable wind speeds from a southwesterly direction over the Arabian Sea (Hastenrath and Lamb, 1979; Hastenrath, 1985; Fig. 2b). Winds parallel to the Arabian coast induce coastal upwelling in shelf and upper slope areas, because Ekman flow transports water off shore perpendicular to the prevailing wind direction, and thus promotes upwelling of subsurface, nutrient-rich and cooler water to the surface (Hastenrath and Lamb, 1979; Wyrtki, 1971). The response of the Arabian Sea to the monsoon winds is clearly observed in the sea-surface temperature (SST) patterns during the summer, a time of expected high SST. Typically, these patterns display zones of upwelling water with low temperatures (22-23^{o}C) along the coast of Africa and Arabia and grade to higher temperatures (27-28^{o}C) in the central Arabian Sea (Prell and Streeter, 1982). Nutrient concentrations covary significantly with SST, as does primary productivity (Krey and Babenerd, 1976). Thus, a direct and coherent link is established between monsoonal wind intensity, the intensity of coastal upwelling, biogenic productivity, and sediment input into the sedimentary column underlying areas of coastal upwelling.

Sedimentary Response to Coastal Upwelling

The response of modern planktonic assemblages to the phenomenon of coastal upwelling off Oman has been mapped (Prell and Streeter, 1982). In other areas, such as the Benguela and NW African upwelling centers, the increase of siliceous over carbonate primary productivity and the ratio of carbonate to opal in sediments can be employed to reconstruct general conditions of nutrient make-up and temperature. However, this pattern is not so clear off Oman. Here, the changing intensities of upwelling may be reconstructed by examining certain key species of foraminifera and radiolaria (Prell and Streeter, 1982; Prell, 1984). For example, studies of upper Quaternary sediments have shown that good faunal records of monsoonal upwelling are preserved for the last 150 k.y. on the shallow portions (< 2000 m water depth) of the western Arabian Sea, particularly on the Owen Ridge. Studies of these sediments suggest that monsoonal upwelling was stronger at about 9 k.y. and weaker at 18 k.y. and that its variation shows a 23-k.y. periodicity that is related to the seasonal distribution of solar radiation (Prell, 1984). These records only extend to the late Pleistocene because of limits in recovery and penetration of conventional sampling methods. Furthermore, geochemical indicators (Cd/Ca and P/Ca ratios) are known to reflect the composition of source waters and the extent of primary productivity in the upwelling plume. Thus, the spatially and temporarily restricted phenomenon of coastal upwelling may be traced by investigating these parameters, and variations in the history of monsoonal upwelling can be reconstructed in considerable detail.

Aside from the biogenic component, sediment in the NW Indian Ocean contains significant amount of eolian dust (Prospero, 1981; Spencer et al., 1982). The amount of aerosol from erosion of east African highlands and the input of these eolian clastics into the Arabian Sea is an independent measure of wind intensity through time.

High oxygen demand during microbial remineralization of primary produced organic matter in the water column results in an oxygen minimum zone, located between 200 and 1000 m water depth, in which dissolved oxygen is almost depleted (Spencer et al., 1982). Where the oxygen minimum zone impinges on the margin, the sediments are deposited under suboxic to anoxic conditions (von Stackelberg, 1972). Ideally, the organic carbon-rich muds are undisturbed by benthic organisms and are laminated in annual varve-type laminations of a few millimeters thickness. However, the survey cruise (R/V Robert Conrad) to this area did not recover laminated sediments in its box cores. Organic carbon concentrations are high (2-6%), however, and sedimentation rates in piston cores range up to 150 m/m.y. Intense microbial remineralization of the fresh organic matter during early diagenesis creates chemical environments which are rarely found in normal marine sediments of low organic carbon content and low sedimentation rate. Sulfate reduction, phosphate and ammonia release, and methane production during microbial consumption of the organic matter result in the diagenetic neoformation of a characteristic suite of minerals. The assemblage of dolomites with characteristic isotopic fingerprints, phosphorites, and cherts can be used to constrain input and conditions of diagenesis.

Tectonic Evolution of the Oman Margin

Site survey data obtained during 1986 reveal little more than 1.5 seconds two-way travel time (about 1500 m) of sediment filling Owen Basin, which is less than half the sediment thickness in the presumably analogous Somali Basin. Results of DSDP Leg 23 provided approximate ages of prominent seismic reflectors on Owen Ridge that can be traced into this relatively thin sedimentary infill of the basin; this correlation suggests that the basin is no older than latest Cretaceous. Leg 117 will continuously core and log the sequence reflectors on the Owen Ridge down to acoustic basement. Thus, the age and nature of basement will be revealed, as will the nature and accumulation rates of the older sediment in the region, and the uplift history of Owen Ridge. From preliminary interpretations of the survey data, we think that today's ridge area was a catch basin for turbidites until well into the Miocene, when large-scale plate reorganization in the NW Indian Ocean occurred. Uplift of the ridge may coincide with the early stages of rifting in the Gulf of Aden.

Seismic profiles of the margin reveal an abrupt and linear hinge zone near the 500 m isobath which trends parallel to the regional trend of the coastline. This may well be the ocean/continent boundary. Drilling near the 1500 m isobath should encounter Tertiary strata resting on tholeiitic basalt, if the margin was formed by shearing in the latest Cretaceous. The Jurassic passive margin model would predict older sediments overlying crust of continental origin.

Prior DSDP Sites

Extended stratigraphic records were recovered during DSDP Leg 23 that drilled and spot cored two sites (223 and 224) west of the Owen Fracture zone between 15°N and 20°N. The following paragraph renders stratigraphic relationships in Site 223 and 224 as described in the respective site chapters (Whitmarsh, Weser, Ross et al., 1974).

DSDP Site 223 is located over the continental rise off the coast of Oman (Fig. 1b) and recovered a basal igneous unit (717-740 meters below sea floor (mbsf)) of trachybasalt and hyaloclastic breccia suggestive of deposition in water depths not exceeding 800 m. Sedimentary Unit IV of late Paleocene to Eocene age is composed of barren brown montmorillonite claystone (657-717 mbsf) and is considered to be a product of basalt alteration of volcanic basement. Sedimentary Unit III (560-657 mbsf) of Eocene age is composed of gray detrital silty clay-rich nannofossil chalk and zeolitic radiolaria-rich claystone. Sedimentary Unit II (455-560 mbsf) is Oligocene to middle Miocene in age. It is composed of silty and clay-rich nannofossil chalk with minor admixtures of terrigenous and micritic carbonate particles. Carbonate content reaches up to 90% in Sedimentary Unit II, which in the lower part displays faint laminations. Sedimentary Unit I (0-455 mbsf) consists of nannofossil ooze rich in silt, as well as chalk, siltstone, and nannofossil-rich diatomite. The age of this unit ranges from the middle Miocene to Holocene. The initiation of upwelling is thought to occur in the middle Miocene and is signalled by occurrence of significant amounts of siliceous microfossils.

DSDP Site 224 was drilled on the western flank of Owen Ridge close to proposed site OR-3 and OR-4 of Leg 117 (Figures 1b and 1c). Igneous rocks (lamprophyres) at the base of the section are older than early Eocene. These black, fine-grained rocks may be derived from a dike or intrusive sill and are overlain by about 107 m of nannofossil-rich claystone, nannofossil chalk and micarb-rich clay of late Paleocene age. Nannofossil-rich detrital claystone with zeolite- and radiolarian-rich claystone of early to middle Eocene age grades into white nannofossil chalk deposited during the late Eocene to the Oligocene and early Miocene. The onset of monsoonal upwelling is thought to coincide with the appearance of siliceous microfossils and an increase in the amount of organic carbon deposited in alternating sequences of silty nannofossil chalks, diatom-rich detrital nannofossil chalks, and nannofossil diatomites of middle Miocene to Holocene age.

DRILLING OBJECTIVES

The drilling proposal for the northwestern Indian Ocean has become known informally as the "M4 Leg," the four M's standing for "Monsoon, Mountains, Milankovitch, Man." These topics are interrelated because the evolution of the monsoonal circulation and concomitant humanoid migration and evolution are, in part, a response to tectonic uplift of the Himalayas and orbital forcing of global climate. A Neogene record of global climate, monsoonal intensity, and the evolution of the Himalayas will be recovered from the rapidly accumulating and largely undisturbed biogenic and eolian sediments of Owen Ridge, the Oman margin, and the clastic sequences of the Indus deep-sea fan. To achieve these objectives, our sites must recover several hundred meters of continuous and undisturbed sediments. Besides the objectives related to deciphering the record of the SW monsoon and the evolution of the Himalayas, several other objectives have been identified that extend the scope of Leg 117 to the following suite of objectives:

1) What is the history of Neogene monsoonal upwelling as recorded in sediments of the northern Indian Ocean and how does it vary in response to changing radiation budgets caused by changes in the earth's orbit around the sun and tectonic evolution of Central Asia?

2) How did changes in monsoonal intensity and glacio-eustatic sealevel fluctuations affect the sedimentary facies of organic carbon-rich biogenic and eolian sediments deposited on the Arabian margin? What is the extent of diagenesis, i.e., dolomite and phosphorite formation, in the sediments deposited in the oxygen minimum zone between 200 and 1000 m water depth? Does pore water chemistry give an indication of evaporitic hydrological regimes in the subsurface of the Oman Shelf?

3) What is the record of paleoceanographic circulation and origin of intermediate water flowing out of the Red Sea?

4) How does the mid Indus fan record the uplift of the Tibet-Himalayan complex, the depositional history of fluvial sediments in Pakistan, and erosion of coastal deposits in climatic and sealevel cycles?

5) What is the tectonic origin and uplift history of Owen Ridge, and what is the tectonic history of the Oman Basin and the continental margin east of the Masirah anticline composed of continental basement?

OPERATIONS PLAN

Fifteen sites have been identified to meet the above objectives (Table 1 and Fig. 1). They constitute prime and backup sites, and not all will be drilled during the 56 days of Leg 117, of which 17 days will be necessary for the transits from Colombo/Sri Lanka to the operational area and to Port Louis/Mauritius for the Leg 118 portcall, leaving 39 days of operations in the area. Estimated operation time on sites is given in Table 1.

Target site IN-1 will be drilled first after the transit of estimated 7.4 days from Colombo. This single site on the Indus fan will be drilled to 500 mbsf or to refusal of the bit, whichever occurs first. Logging with a standard Schlumberger program is expected. Target site IN-2 is a backup site that will not be drilled if target site IN-1 is successful.

Working towards the shallow sites on the Oman margin, targets on the Owen Ridge will be addressed after the fan site. Targets OR-1 to OR-3 are located to recover extended Neogene sediment sections on the ridge, a location that should be free of turbidites and laterally transported sediment. Target sites OR-1 and OR-2 will penetrate 425 m and 550 m, respectively, with APC/XCB tools; target site OR-4 aims at providing a complete section of sediments that span the time prior to Owen Ridge uplift to Recent. OR-4 may be washed down to equivalent total depth of OR-3 and rotary cored to the prominent basal reflector. At this site, a vertical seismic profiling experiment will be carried out in addition to standard logging experiments.

Nine target sites have been identified on the Oman margin. These locations span water depths of 300-1410 m in order to bracket the zone of sediments deposited under the oxygen minimum in the water column. Logging with a special high-resolution resistivity tool on three sites (OR-1, OR-2, OM-9) will attempt to monitor cyclicity in the sedimentary section. OM-10 will drill the oldest sediments overlying basement on the Oman margin by rotary coring to basement.

Transit to Port Louis/Mauritius will require about 9.4 days of steaming.

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Table 1: Location of proposed sites and time estimates

SITE	LATTITUDE	LONGITUDE	WATER DEPTH (m)	TARGET DEPTH (m)	PRIORITY	OPERATIONS	TIME ON SITE (days)
Colombo/Sri Lanka						Transit	7.4
IN-1	16°07.6'N	60°44.4'E	4000	500*	1	DOUBLE APC/XCB	5.6
IN-2	16°12.9'N	60°43.2'E	4000	500*	3	DOUBLE APC/XCB	5.6
OR-1	16°41.0'N	59°51.9'E	1940	425*	1	DOUBLE APC/XCB	3.0
OR-2	16°37.3'N	59°47.6'E	2010	550*	1	DOUBLE APC/XCB	3.4
OR-3	16°36.2'N	59°42.2'E	2430	425*	1	DOUBLE APC/XCB	3.2
OR-4	16°28.0'N	59°42.2'E	2380	1150*	1	RCB	11.9
OM-1	18°03.3'N	57°36.6'E	800	700*	1	DOUBLE APC/XCB	3.4
OM-2	18°14.9'N	57°40.1'E	675	340	2	DOUBLE APC/XCB	1.3
OM-3	18°27.5'N	57°47.0'E	570	270	2	DOUBLE APC/XCB	1.0
OM-4	18°29.0'N	57°42.6'E	360	250	1	DOUBLE APC/XCB	1.0
OM-5	17°48.7'N	57°22.0'E	300	200	1	DOUBLE APC/XCB	1.0
OM-6	17°46.2'N	57°35.3'E	890	300	2	DOUBLE APC/XCB	1.3
OM-8	17°41.0'N	57°49.6'E	1400	340	1	DOUBLE APC/XCB	1.5
OM-9	17°42.7'N	57°50.0'E	1400	400	3	DOUBLE APC/XCB	1.5
OM-10	17°38.9'N	57°57.0'E	1350	340	1	RCB	1.5
Port Louis/Mauritius						Transit	9.4
						Total Days	63.0
					without	IN-2, OM-9	55.9

APC= Advanced Hydraulic Piston Corer
XCB = Advanced Hydraulic Piston Corer with Extended Core Barrel
RCB = Rotary Core Barrel

* = Logging

IN-2, OM-9 are backup sites of low priority and will not be drilled if prime sites are successful.

Table 2: Locations of proposed sites on seismic lines

Site	Line	Date	Time	Crossline	Date	Time	Remarks
IN-1	49	6-09	0000	---	---	---	
IN-2	48	6-08	1435	---	---	---	
OR-1	40	6-03	2010	46	6-05	0436	North of line
OR-2	38	6-03	0745	1	5-19	2047	
OR-3	35	6-02	1440	46	6-05	0236	
OR-4	35	6-02	1352	45	6-04	2120	
OM-1	5	5-22	0310	10	5-22	1407	SW of line
OM-2	13	6-05	0124	---	---	---	
OM-3	5	5-22	0618	---	---	---	
OM-4	4	5-21	0518	---	---	---	
OM-5	3	5-20	2322	---	---	---	
OM-6	6	5-22	1805	18	5-24	1402	SW of line
OM-8	20	5-25	0035	---	---	---	
OM-9	19	5-24	1845	---	---	---	
OM-10	19	5-24	1752	---	---	---	

All lines were obtained during Site Survey cruise RC27-Leg 4 of R/V Robert Conrad (May 14, 1986 to June 16, 1986)

FIGURE CAPTIONS

Figure 1: a) Location of ODP Leg 117 operations areas in the NW Indian Ocean. Bathymetyrtic contours in meters.
b) Topography and location of DSDP sites and proposed ODP sites on the Oman margin, the mid Indus Fan, and Owen Ridge. Due to bathymetric revisions during the site survey cruise (RC27-Leg 4 of R/V Robert Conrad), water depth given for some sites do not agree with base-map bathymetry.
c) Track chart and position of proposed sites on seismic lines obtained during site survey cruise RC27-Leg4 of R/V Robert Conrad for Owen Ridge sites.
d) Track chart and position of proposed sites on seismic lines obtained during site survey cruise RC27-Leg4 of R/V Robert Conrad for Oman margin sites.

Figure 2: Seasonal boundary conditions and atmospheric circulation in the northern Indian Ocean and Asia.
a) modern January, b) modern August
Shaded area is the Tibetan Plateau and Himalayas.
Arrows denote dominant wind directions. Sea surface temperatures of the Indian Ocean are given in ^{o}C. In area of coastal upwelling off Arabia and Somalia, sea surface temperatures are between 22^{o} and 24^{o} C. Redrawn after Prell and Streeter (1982).

Figure 3: Boundary conditions of monsoonal atmospheric and oceanographic circulation in the NW Indian Ocean during the summer monsoon. Heating of air masses over the Himalaya/Tibetan Plateau complex creates a low-pressure cell which induces intense north-easterly winds in the lower atmosphere over the NW Indian Ocean. mb= atmospheric pressure in millibars, SST= sea surface temperature in ^{o}C. Redrawn after Prell and Streeter (1982).

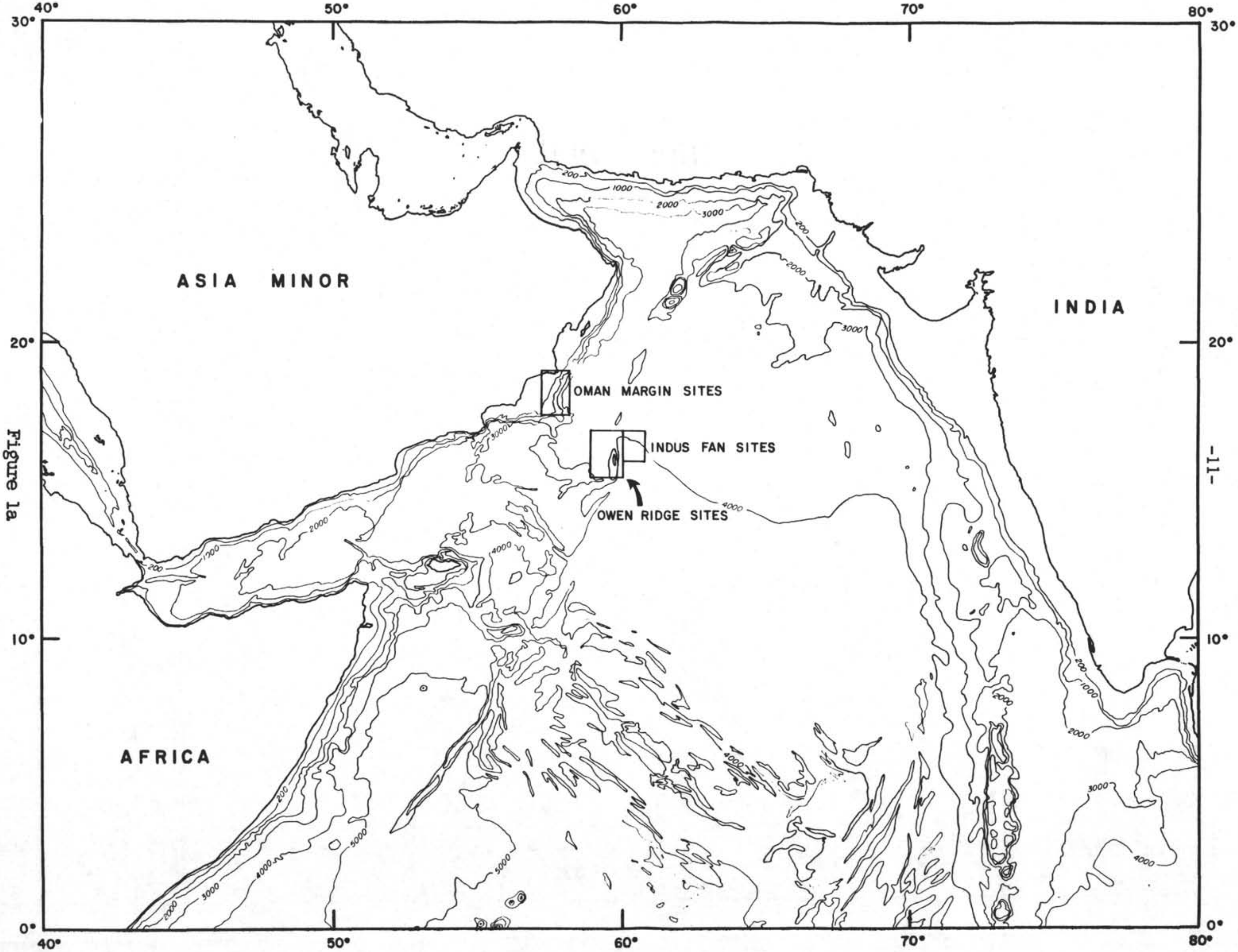

40°
50°
60°
70°
80°
30°
20°
10°
0°
ASIA MINOR
INDIA
AFRICA
OMAN MARGIN SITES
INDUS FAN SITES
OWEN RIDGE SITES
200
1000
2000
3000
4000
5000

Figure 1a

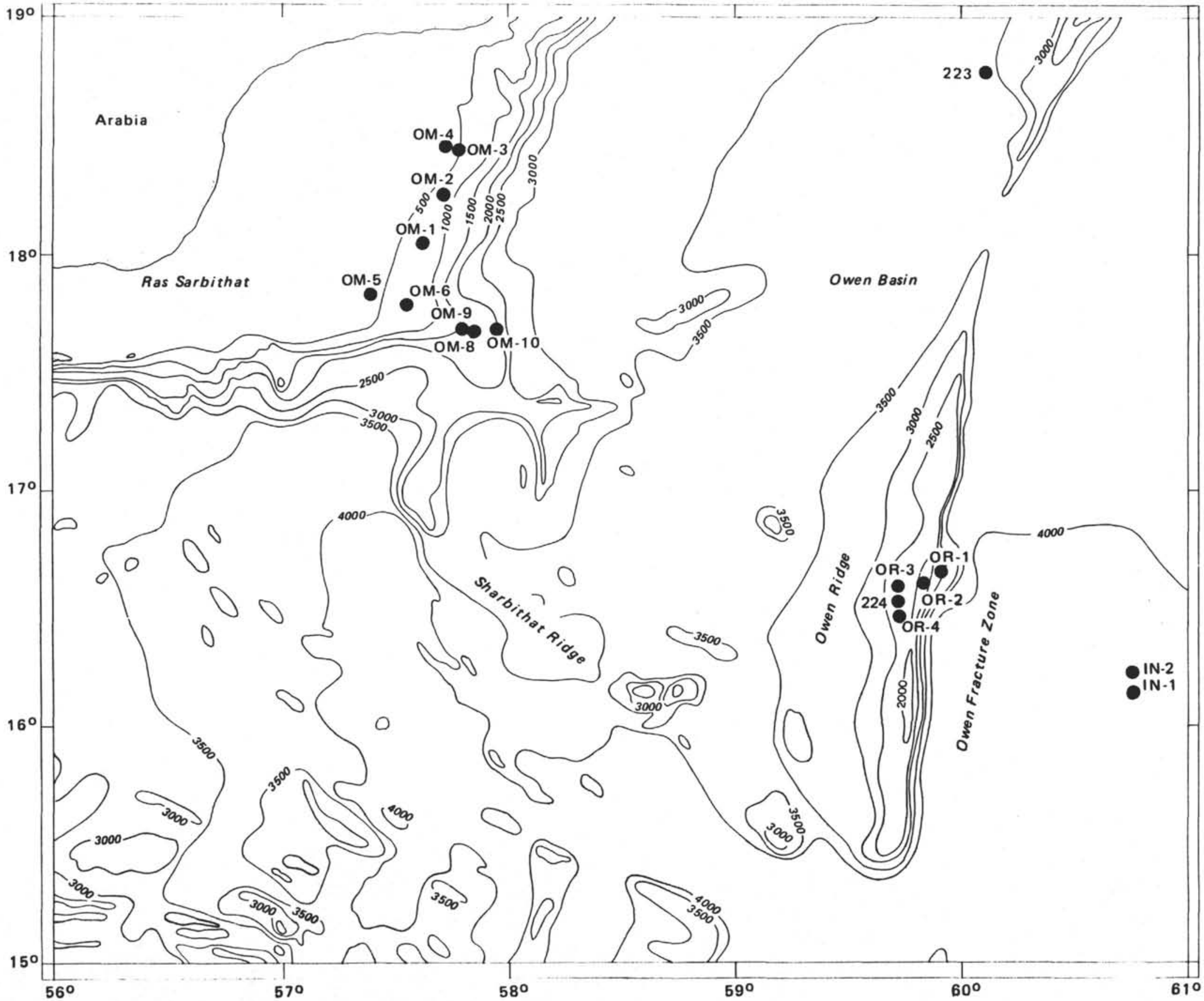
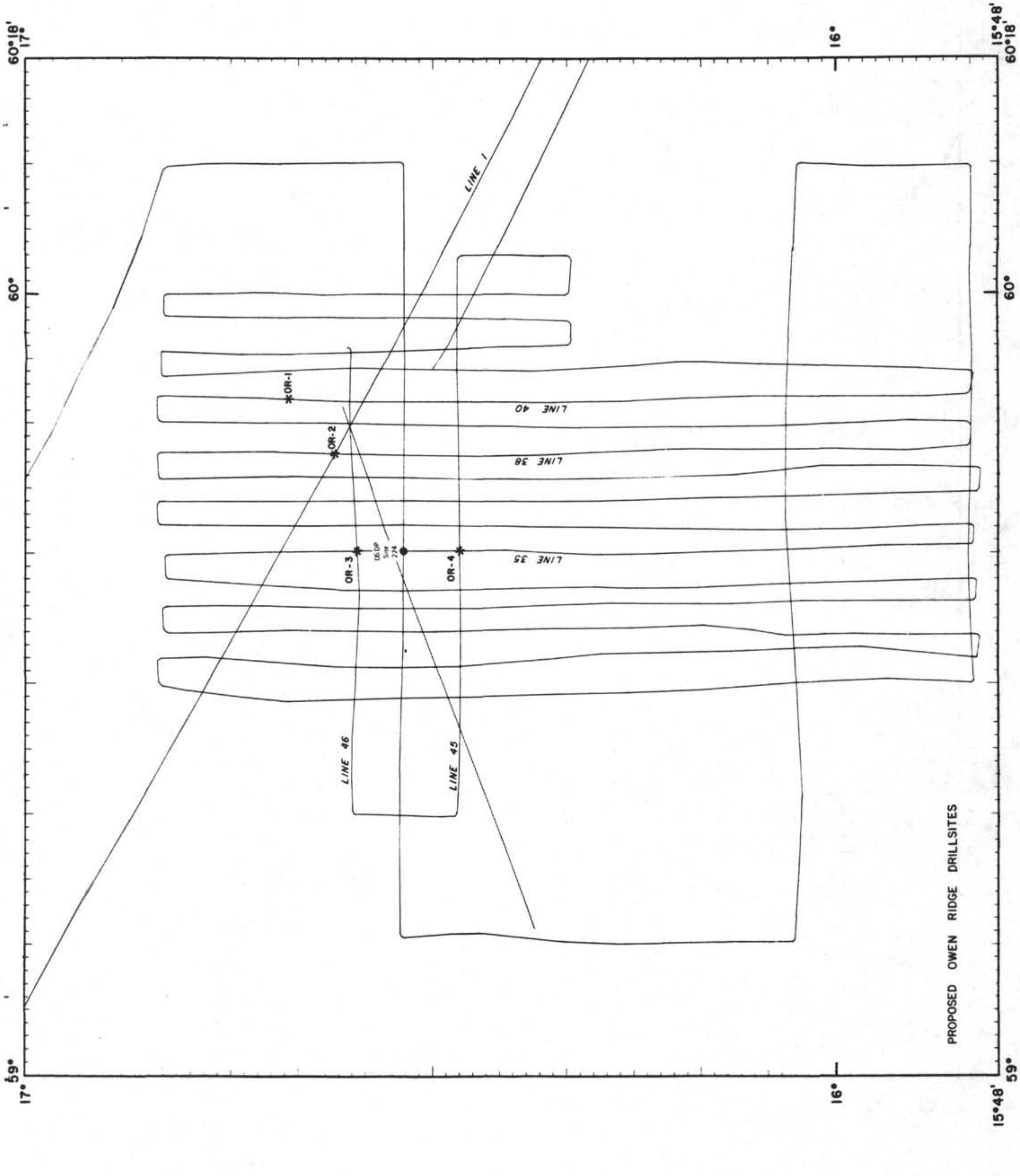

19°
18°
17°
16°
15°
56°
57°
58°
59°
60°
61°
Arabia
Ras Sarbithat
OM-4
OM-3
OM-2
OM-1
OM-5
OM-6
OM-9
OM-8
OM-10
500
1000
1500
2000
2500
3000
3500
4000
223
Owen Basin
Sharbithat Ridge
Owen Ridge
Owen Fracture Zone
OR-1
OR-2
OR-3
OR-4
224
IN-2
IN-1

Figure 1b



60°18'
17°
16°
15°48'
60°
59°
LINE 1
LINE 40
LINE 38
LINE 35
LINE 46
LINE 45
OR-1
OR-2
OR-3
OR-4
PROPOSED OWEN RIDGE DRILLSITES

Figure 1c

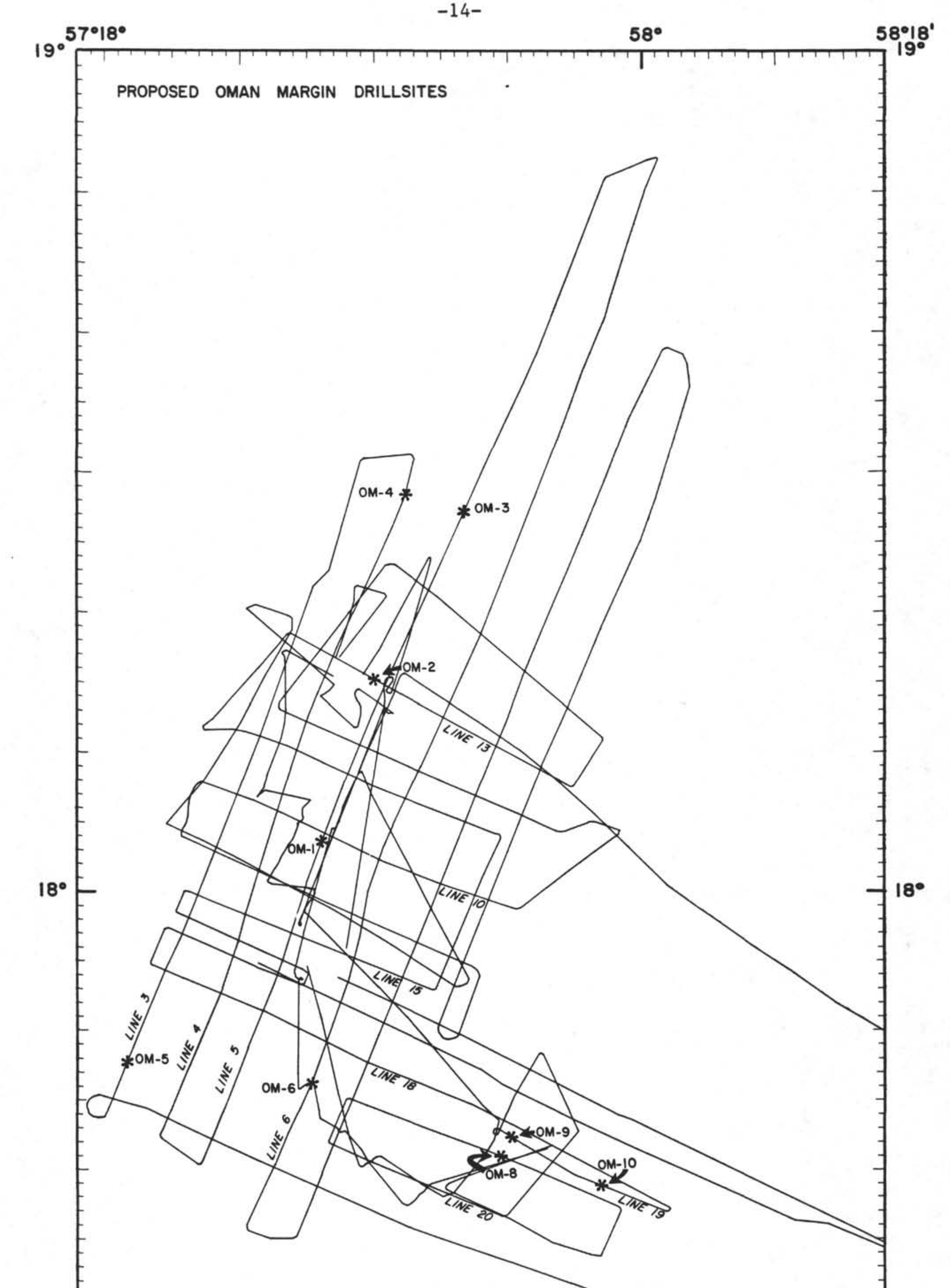

57°18°
58°
58°18'
19°
19°
PROPOSED OMAN MARGIN DRILLSITES
OM-4
OM-3
OM-2
LINE 13
OM-1
LINE 10
18°
18°
LINE 15
LINE 3
OM-5
LINE 4
LINE 5
OM-6
LINE 18
LINE 6
OM-9
OM-10
OM-8
LINE 19
LINE 20
17°30'
17°30'
57°18'
58°
58°18'

Figure 1d

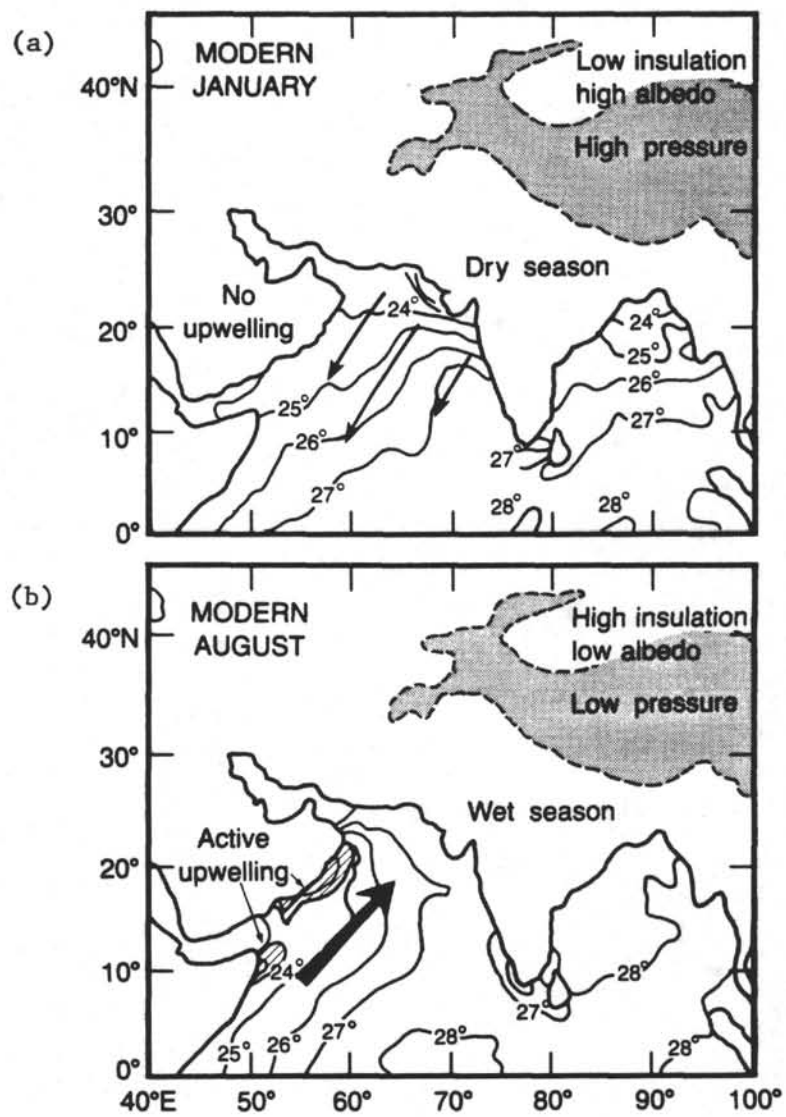
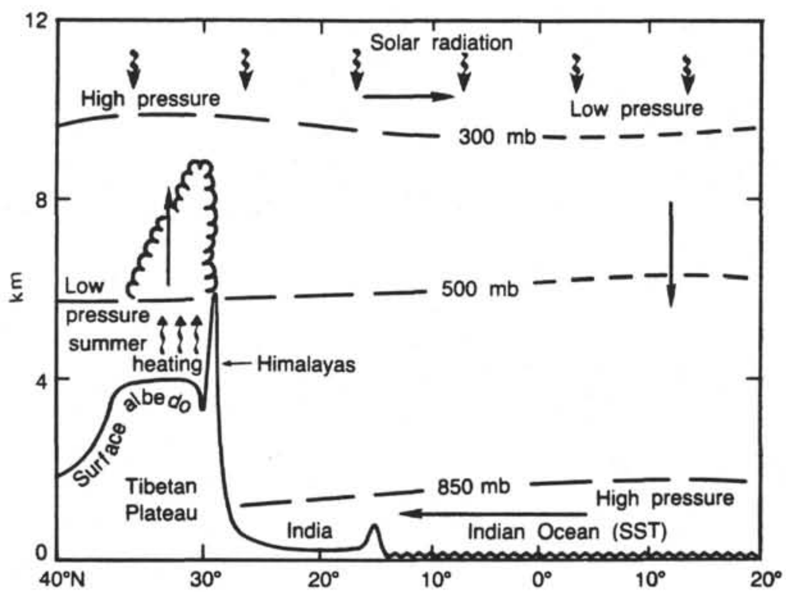

(a)
MODERN
JANUARY
Low insulation
high albedo
High pressure
Dry season
No
upwelling
24°
25°
26°
27°
28°
40°N
30°
20°
10°
0°
(b)
MODERN
AUGUST
High insulation
low albedo
Low pressure
Wet season
Active
upwelling
24°
25°
26°
27°
28°
40°N
30°
20°
10°
0°
40°E
50°
60°
70°
80°
90°
100°

Figure 2



12
8
4
0
km
Solar radiation
High pressure
Low pressure
300 mb
Low
pressure
500 mb
summer
heating
Himalayas
Surface albedo
Tibetan
Plateau
850 mb
High pressure
India
Indian Ocean (SST)
40°N
30°
20°
10°
0°
10°
20°

Figure 3

SITE NUMBER: IN-1
IN-2

TRANSIT FROM PREVIOUS SITE: 7.4 DAYS

POSITION: 16°07.6'N/60°44.4'E (IN-1)
16°12.9'N/60°43.2'E (IN-2)

SEDIMENT THICKNESS: >2,000 m

WATER DEPTH: 4000m

PRIORITY: 1 (IN-1)
3 (IN-2)

PROPOSED DRILLING PROGRAM: Double APC/XCB to 500 mbsf

SEISMIC RECORD: RV Robert Conrad #49, 06-09-86, 0000 hours (IN-1)
#48, 06-08-86, 1435 hours (IN-2)

HEAT FLOW: Yes

ORIENTED CORES: Yes

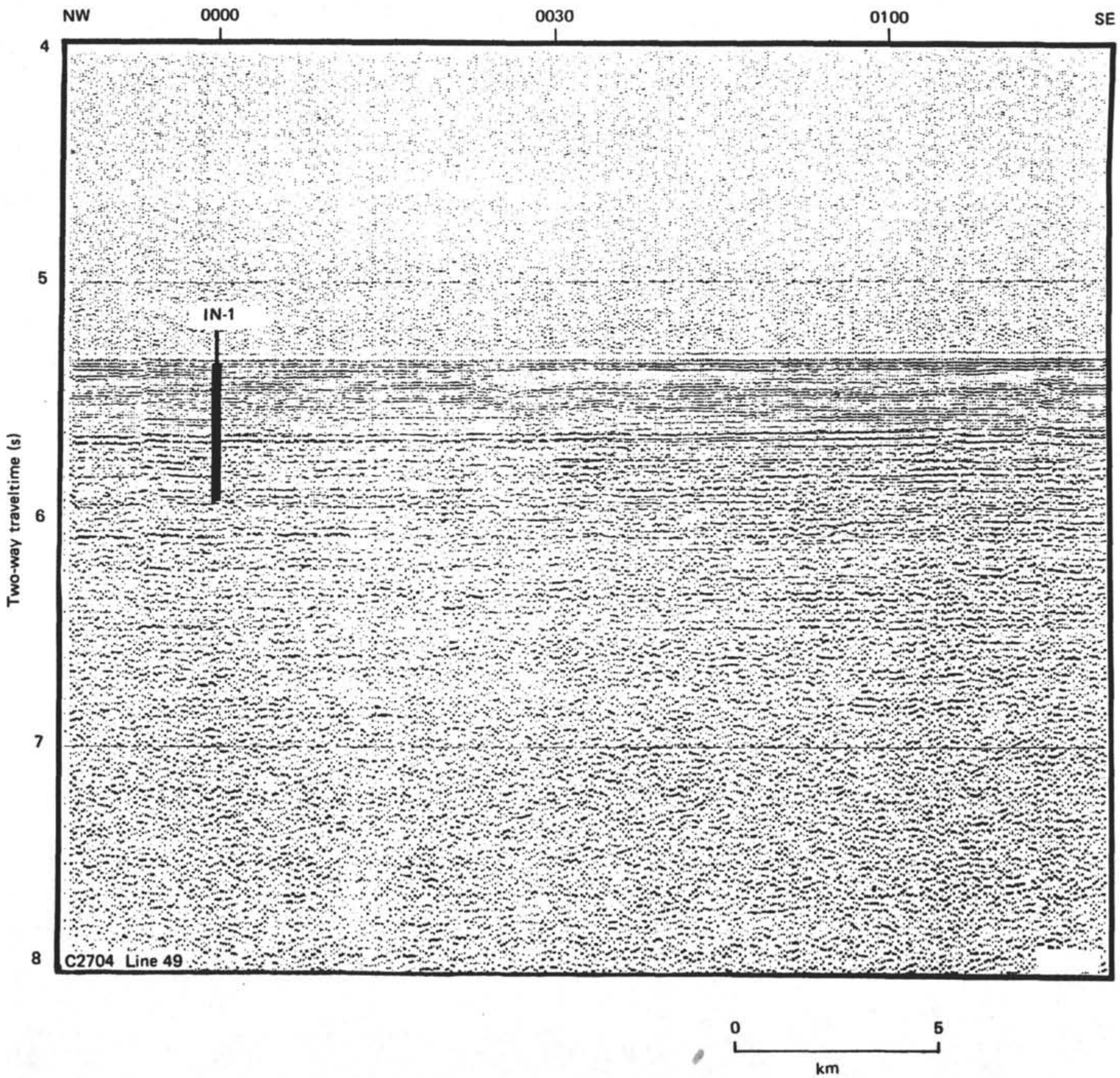
LOGGING: Yes (Standard)

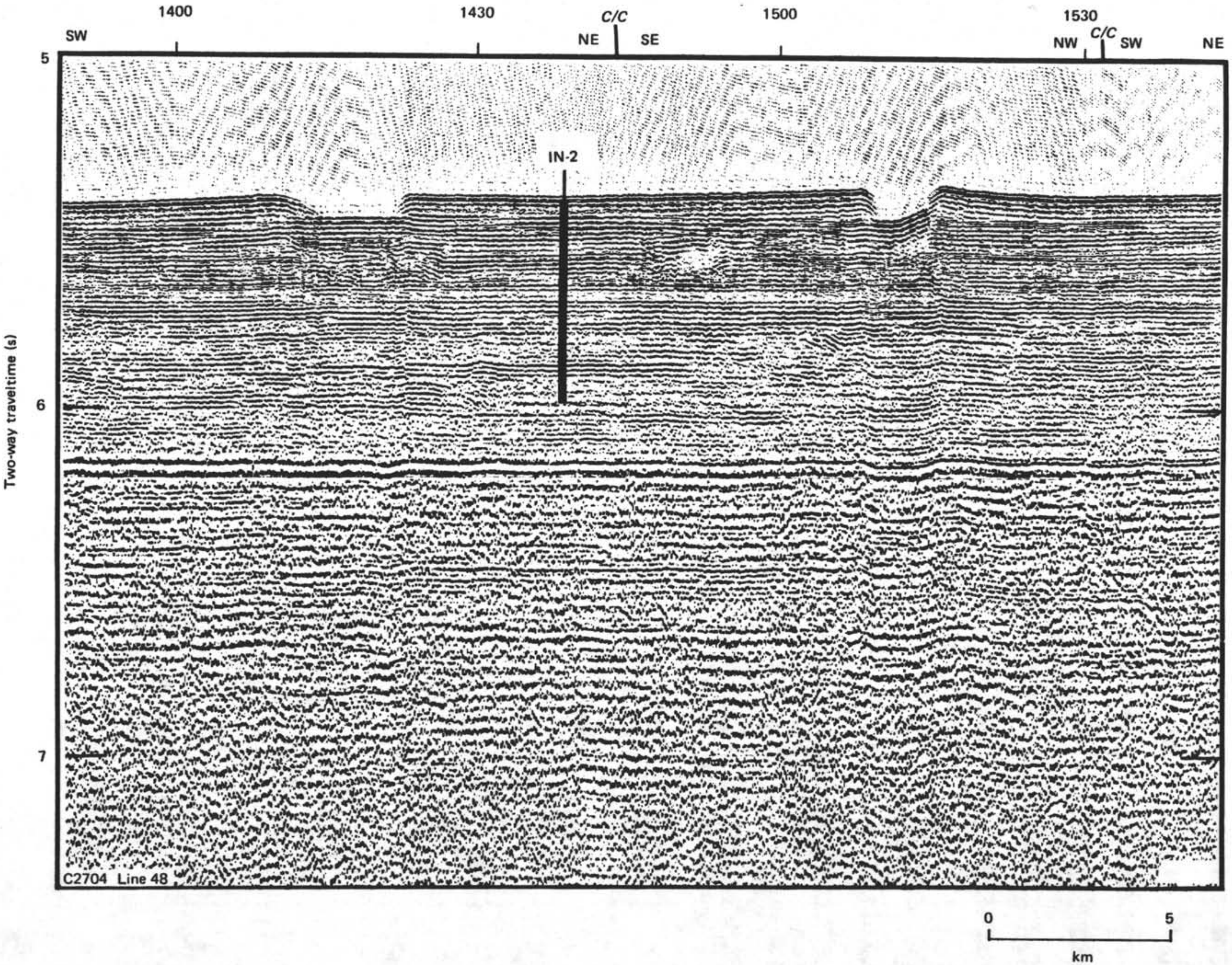
WATER SAMPLER: Yes

OBJECTIVES: Determine the history of uplift and erosion of the Tibet/Himalayan Complex by investigating depositional rates of the distal Indus Fan and intercalated pelagic sediments.

SEDIMENT TYPE: Claystones/clays, mudstones/muds and marlstones/marls (overbank deposits similar to those found at DSDP Sites 223 & 222).

REMARKS: Operations time limited to 6 days.


NW
0000
0030
0100
SE
4
5
6
7
8
Two-way traveltime (s)
IN-1
C2704 Line 49
0
5
km


1400
1430
C/C
1500
1530
C/C
SW
NE
SE
NW
SW
NE
5
6
7
Two-way traveltime (s)
IN-2
C2704 Line 48
0
5
km

SITE NUMBER: OR-1

TRANSIT FROM PREVIOUS SITE: 5.0 hrs

POSITION: 16^{O}41.0'N/59^{O}51.9'E   SEDIMENT THICKNESS: 800m

WATER DEPTH: 1940m   PRIORITY: 1

PROPOSED DRILLING PROGRAM: Double APC/XCB to 425 mbsf

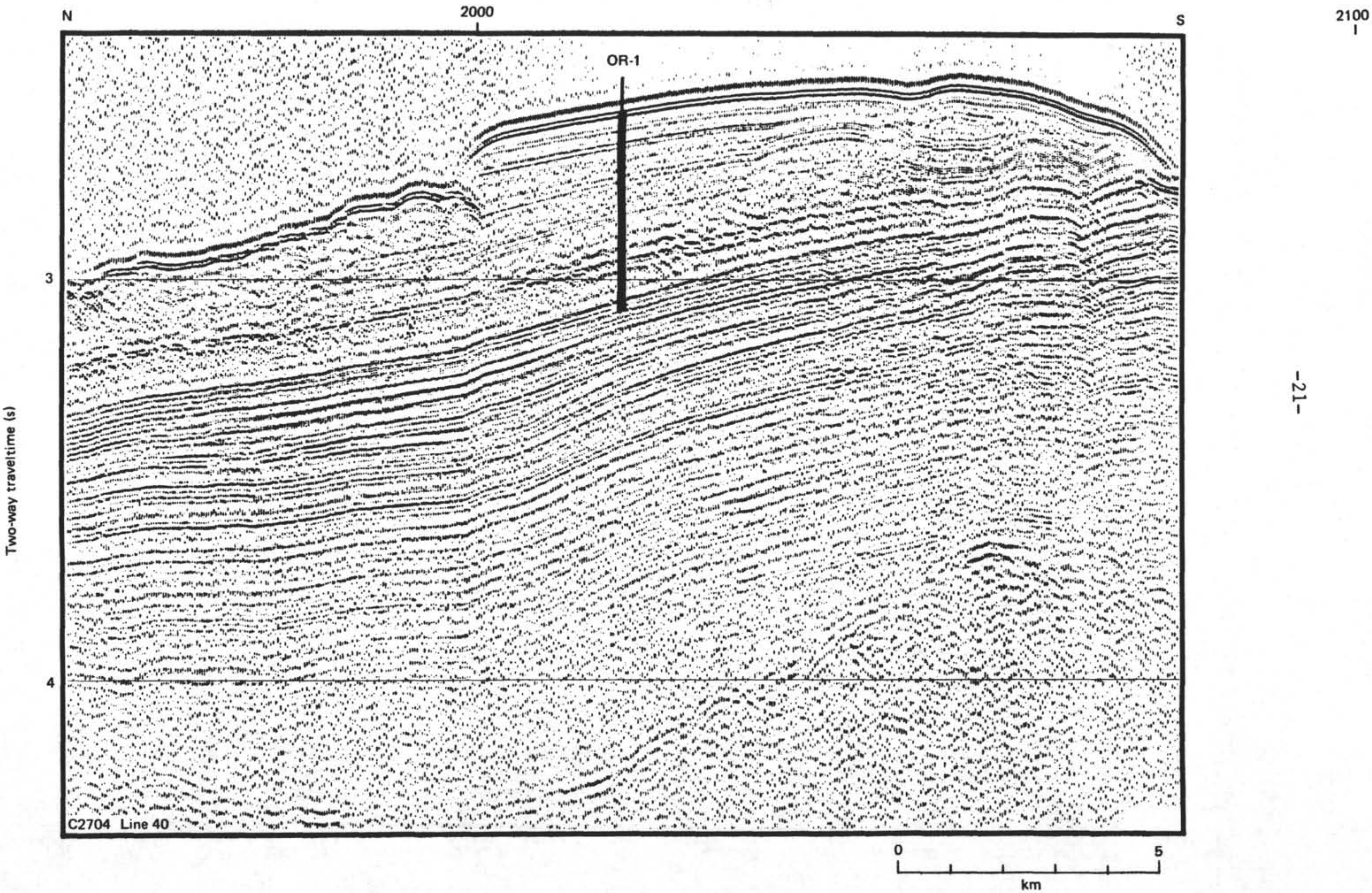
SEISMIC RECORD: RV Robert Conrad Line 40, 06-03-87, 2010 hours
and north of Line 46, 06-05-87, 0436 hours

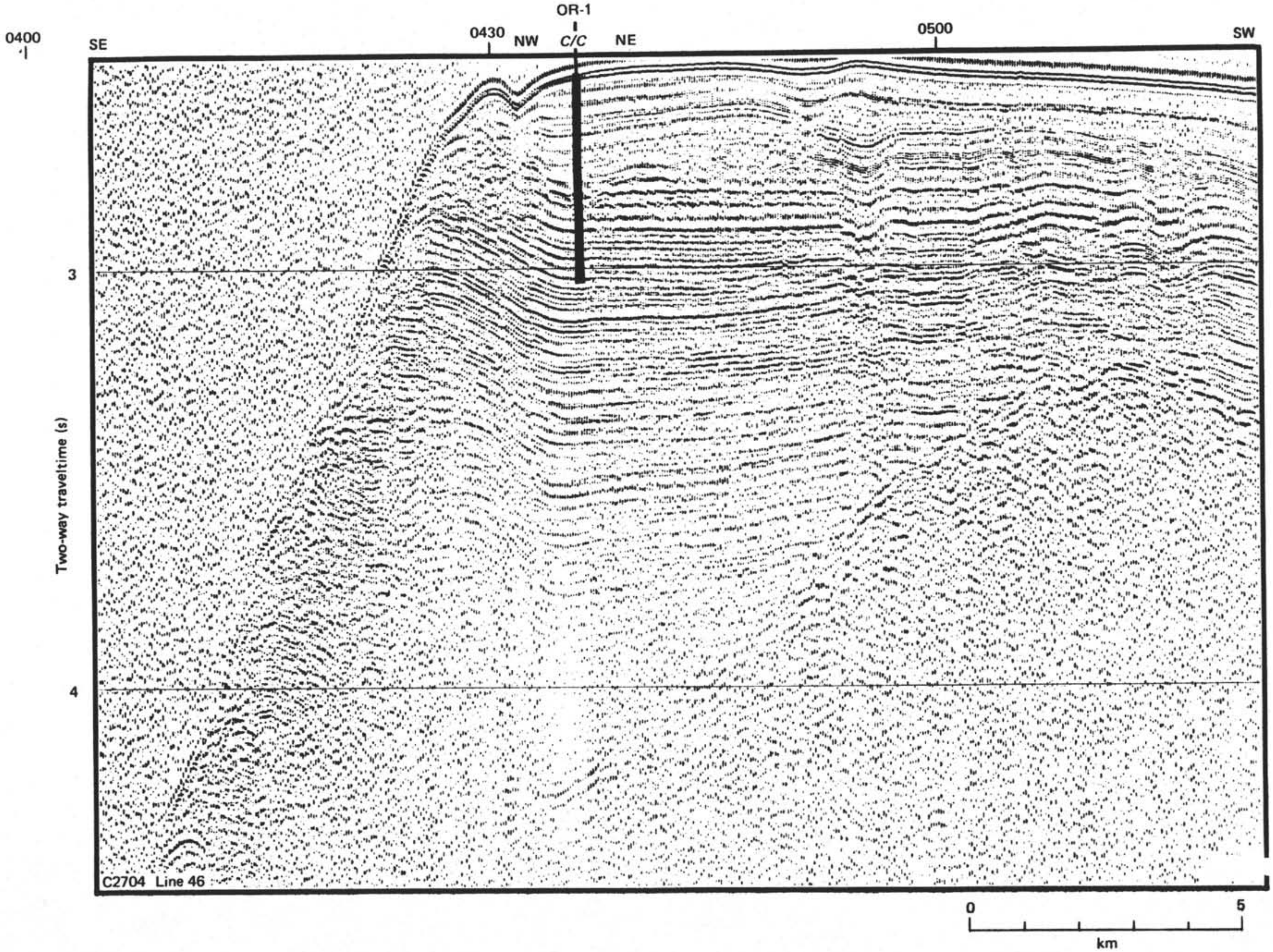
HEAT FLOW: Yes   ORIENTED CORES: Yes

LOGGING: Yes (Standard)   WATER SAMPLER: Yes

OBJECTIVES: Recover a continuous and undisturbed Neogene pelagic sequence deposited under the influence of monsoon-driven upwelling and eolian transport over Owen Ridge.

SEDIMENT TYPE: Calcareous oozes and marls, calcareous mudstones and silty mudstones of middle to late Miocene to Pleistocene age.


N
2000
S
2100
OR-1
3
4
Two-way traveltime (s)
C2704 Line 40
0
5
km


OR-1
0400
SE
0430
NW
C/C
NE
0500
SW
3
4
Two-way traveltime (s)
C2704 Line 46
0
5
km

SITE NUMBER: OR-2

TRANSIT FROM PREVIOUS SITE: 0.5 hrs

POSITION: 16°37.3'N/59°47.6'E SEDIMENT THICKNESS: 500m

WATER DEPTH: 2010m PRIORITY: 1

PROPOSED DRILLING PROGRAM: Double APC/XCB to 550 mbsf

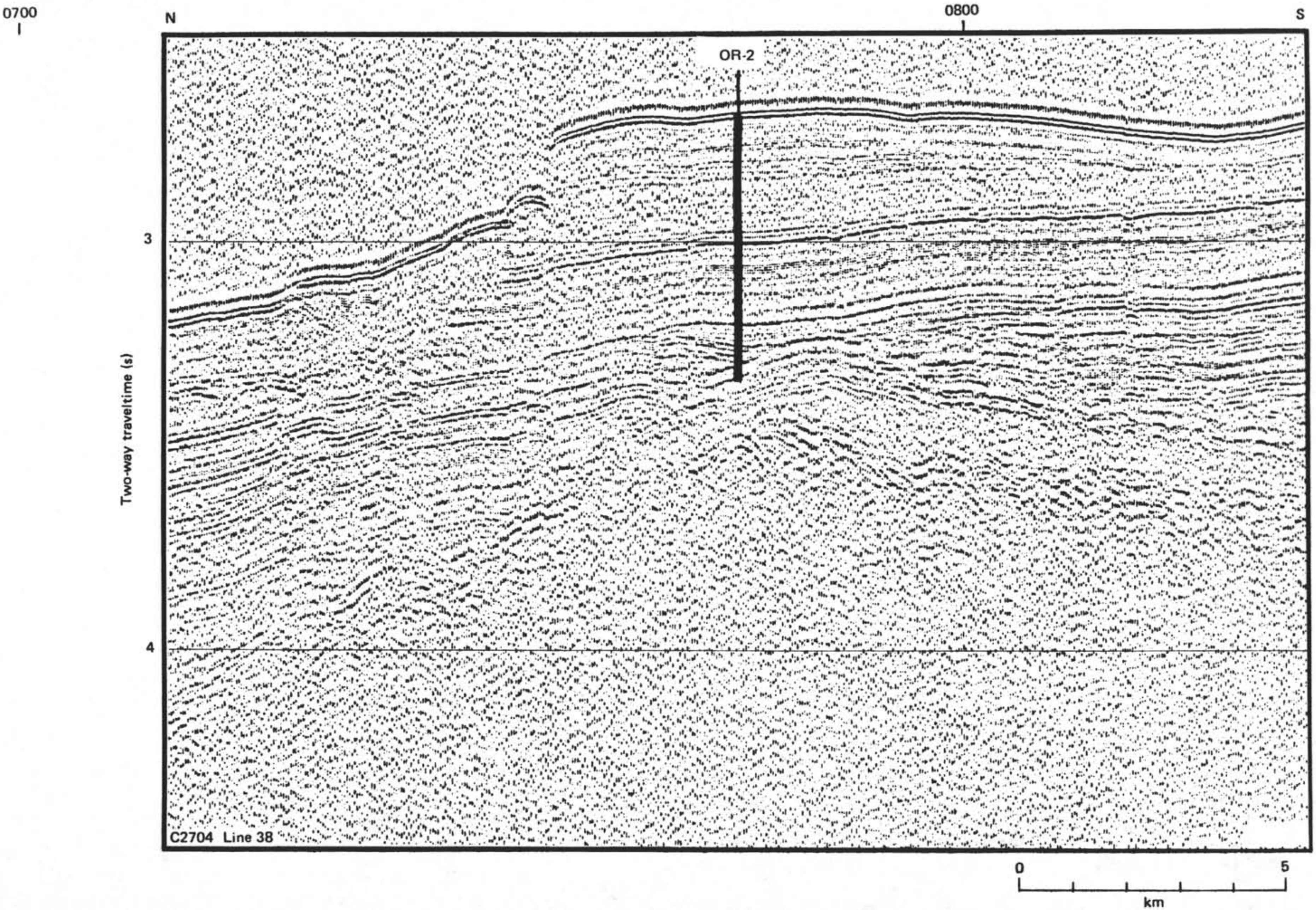
SEISMIC RECORD: RV Robert Conrad Line 38, 6-03-87, 0745 hours
and west of Line 1, 5-19-87, 2047 hours

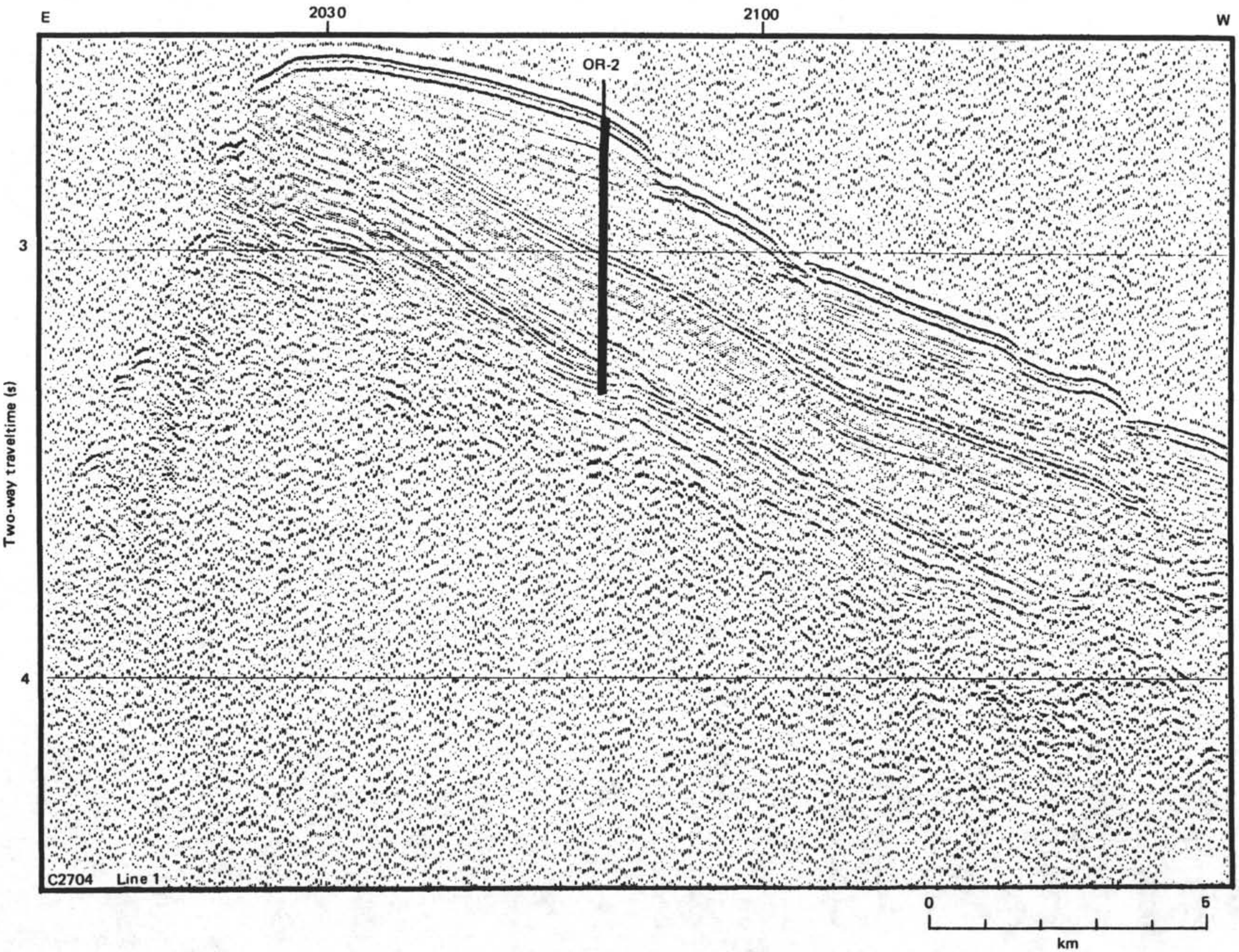
HEAT FLOW: Yes ORIENTED CORES: Yes

LOGGING: Yes (Standard) WATER SAMPLER: Yes

OBJECTIVES: Recover a continuous and undisturbed Neogene pelagic sequence deposited under the influence of monsoon-driven upwelling and eolian transport over Owen Ridge.

SEDIMENT TYPE: Calcareous ooze and marls, calcareous mudstones and silty mudstones.


0700
N
0800
S
OR-2
3
4
Two-way traveltime (s)
C2704 Line 38
0
5
km


E
2030
2100
W
OR-2
3
4
Two-way traveltime (s)
C2704 Line 1
0
5
km

SITE NUMBER: OR-3

TRANSIT FROM PREVIOUS SITE: 0.5 hrs

POSITION: $16^{O}36.2'N/59^{O}42.2'E$ SEDIMENT THICKNESS: 400m

WATER DEPTH: 2430m PRIORITY: 1

PROPOSED DRILLING PROGRAM: DOUBLE APC/XCB to 425 mbsf

SEISMIC RECORD: RV Robert Conrad Line 35, 6-02-87, 1440 hours
and Line 46, 6-05-87, 0236 hours

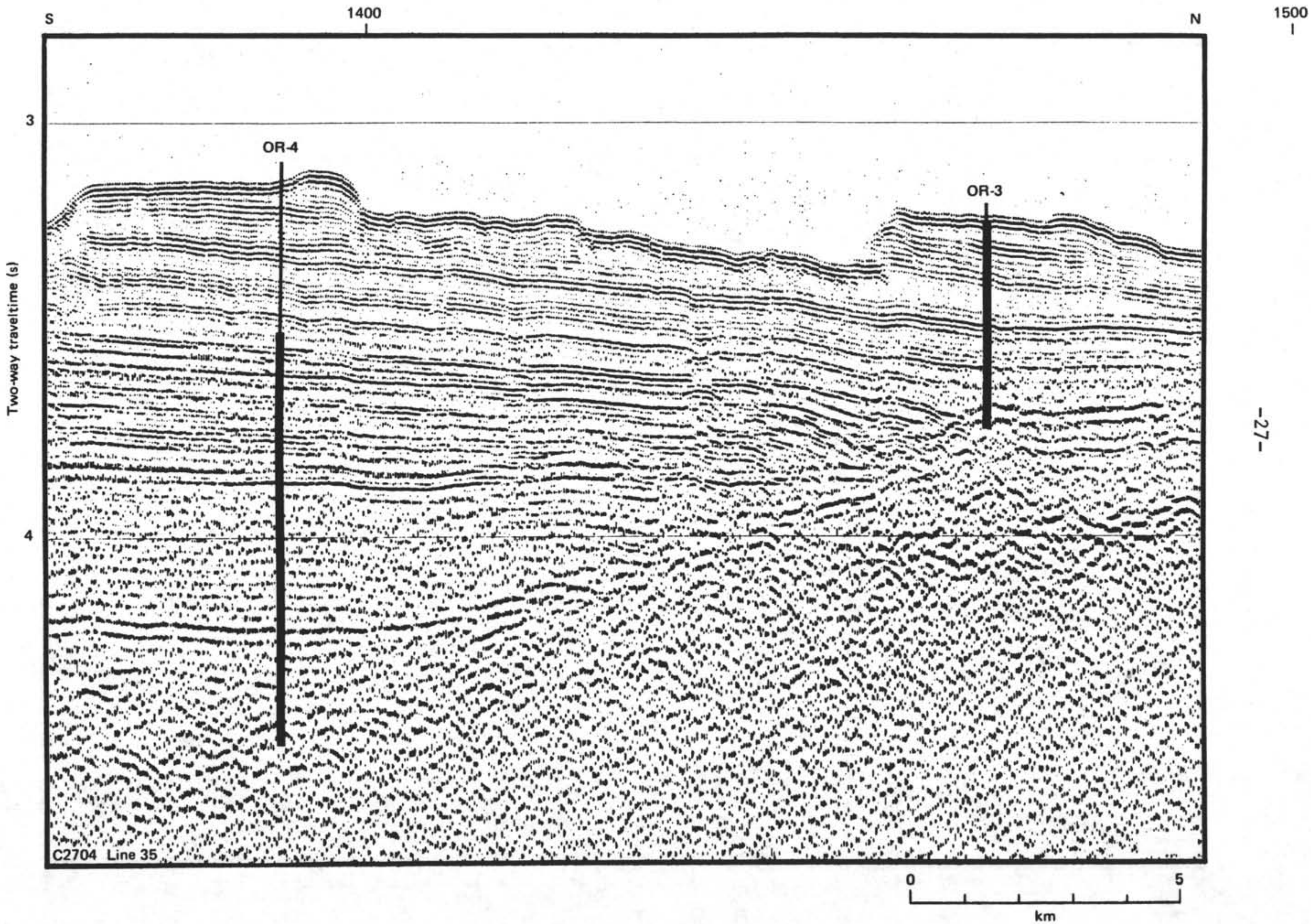
HEAT FLOW: Yes ORIENTED CORES: Yes

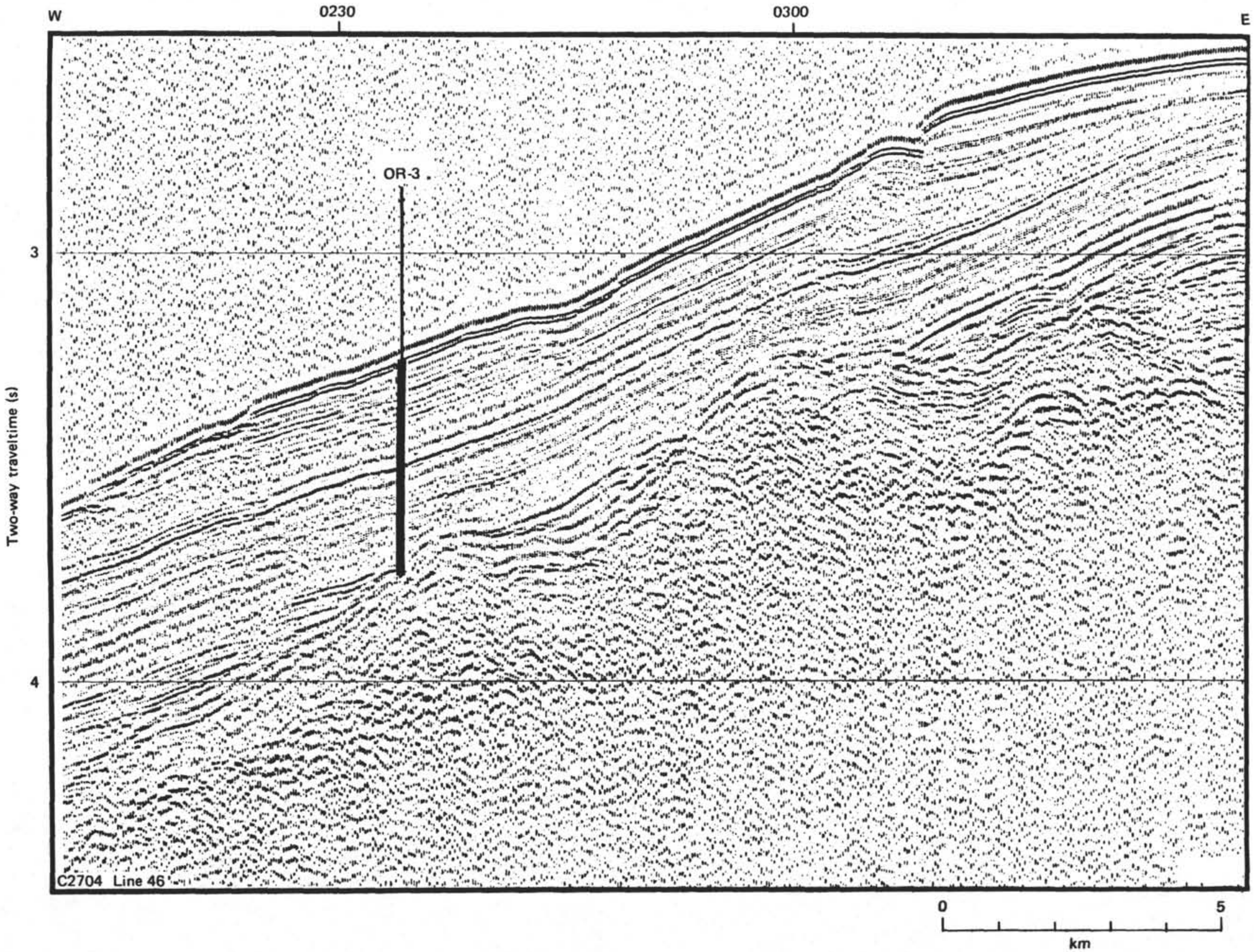
LOGGING: Yes (standard) WATER SAMPLER: Yes

OBJECTIVES: Recover a continuous and undisturbed Neogene pelagic sequence deposited under the influence of monsoon-driven upwelling and eolian transport over Owen Ridge.

SEDIMENT TYPE: Calcareous ooze and marls, calcareous mudstones and silty mustones.

REMARKS: Near DSDP Site 224. Site will be drilled in conjunction with target site OR-4.


S
1400
N
1500
3
4
Two-way traveltime (s)
OR-4
OR-3
C2704 Line 35
0
5
km


W
0230
0300
E
OR-3
3
4
Two-way traveltime (s)
C2704 Line 46
0
5
km

SITE NUMBER: OR-4

TRANSIT FROM PREVIOUS SITE: 0.5 hrs

POSITION: 16°28.0'N/59°42.2'E   SEDIMENT THICKNESS: 1000m

WATER DEPTH: 2380m   PRIORITY: 1

PROPOSED DRILLING PROGRAM: RCB to 1150 mbsf

SEISMIC RECORD: RV Robert Conrad Line 35, 6-02-87, 1352 hours
and Line 45, 6-04-87, 2120 hours

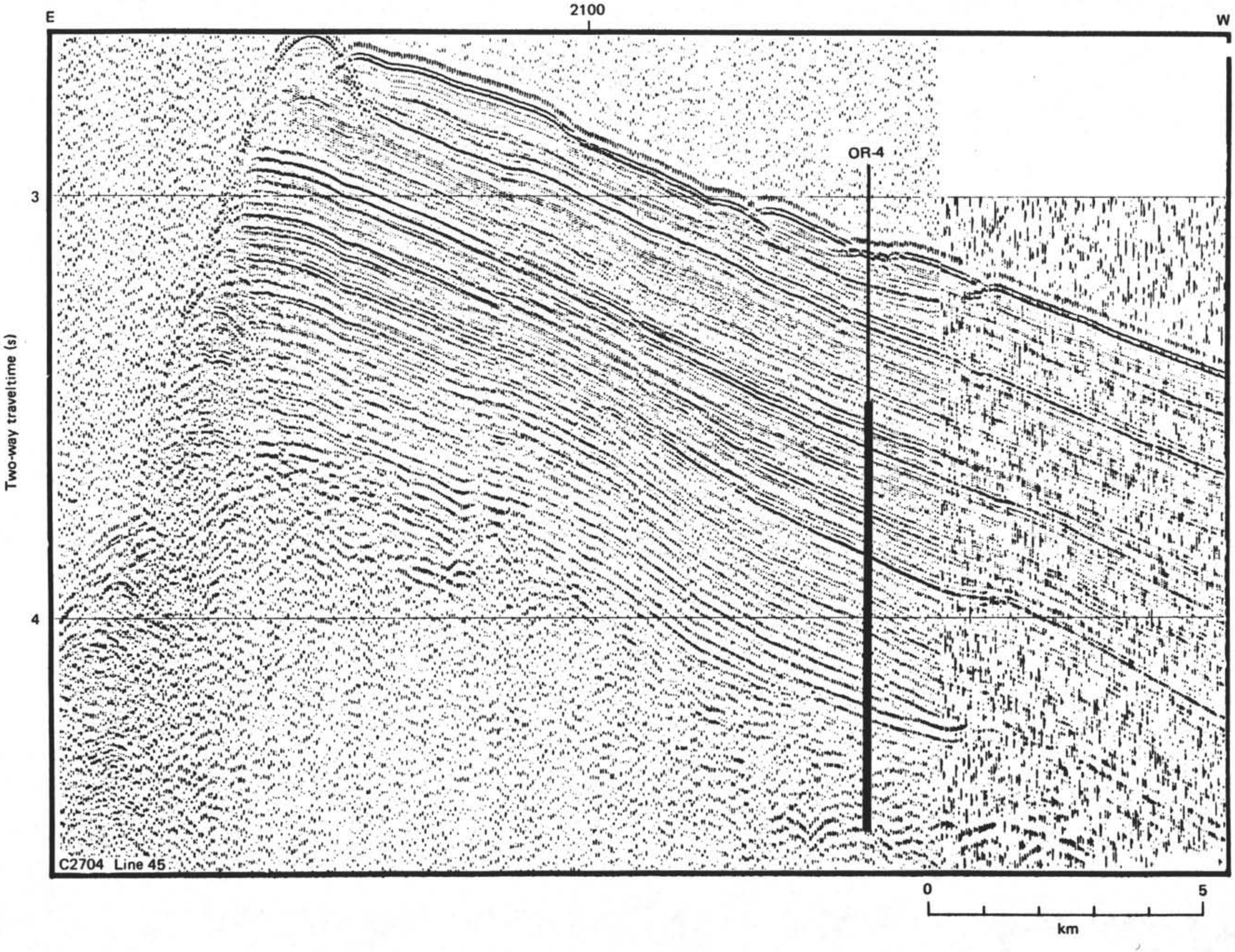
HEAT FLOW: Yes   ORIENTED CORES: Yes

LOGGING: Yes with VSP   WATER SAMPLER: No

OBJECTIVES: Recover a continuous sequence of reflectors onlapping on the Owen Ridge to date the uplift history of the ridge and relate the uplife to the age of the Oman Basin. Recover basement.

SEDIMENT TYPE: Calcareous ooze and marls, dolomites, calcareous mudstones and silty mudstones, turbidites, basalt(?).

REMARKS: Wash to equivalent strata of total depth for Site OR-3, continue coring to establish overlap between sites, drill to basement. A vertical seismic profiling (VSP) experiment will be carried out.



E
2100
W
OR-4
3
4
Two-way traveltime (s)
C2704 Line 45
0
5
km

SITE NUMBER: OM-1

TRANSIT FROM PREVIOUS SITE: 16.0 hrs

POSITION: 18°03.3'N/57°36.6'E SEDIMENT THICKNESS: >3000 m

WATER DEPTH: 800 m PRIORITY: 1

PROPOSED DRILLING PROGRAM: DOUBLE APC/XCB to 700 mbsf, with possibility of third hole.

SEISMIC RECORD: RV Robert Conrad Line 5, 5-22-87, 0310 hours and southwest of Line 10, 5-22-87, 1407 hours

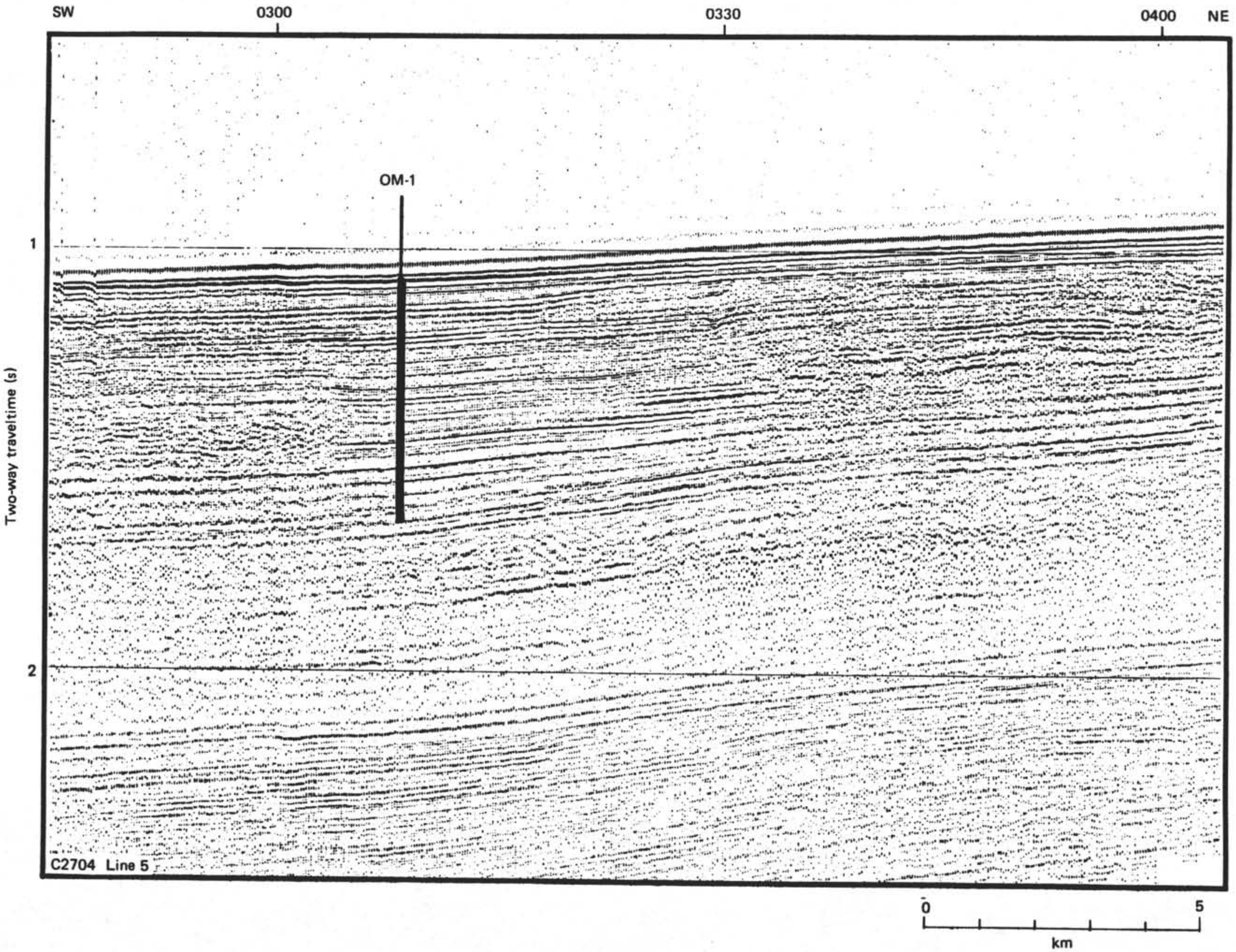
HEAT FLOW: Yes ORIENTED CORES: Yes

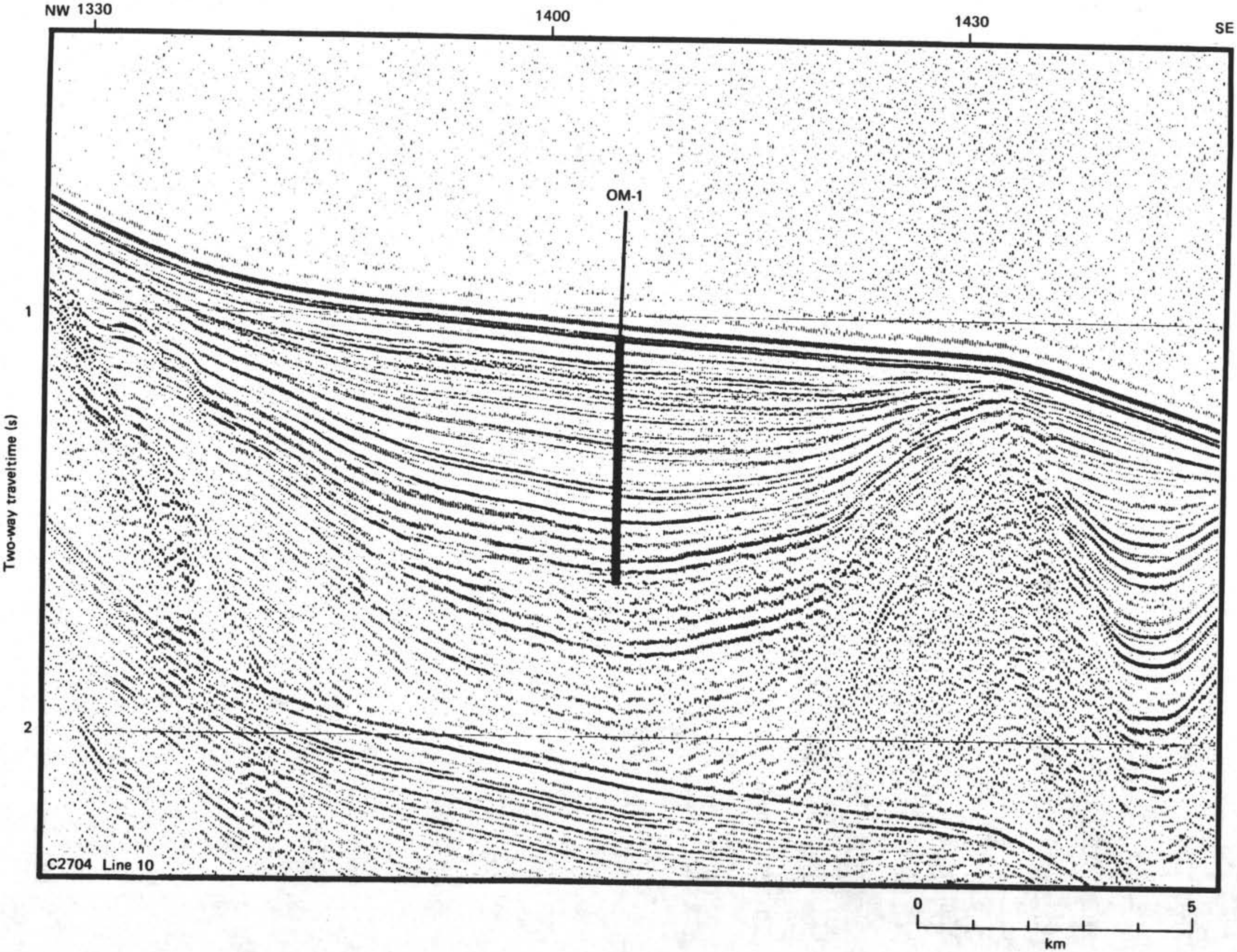
LOGGING: Yes (standard) WATER SAMPLER: Yes

OBJECTIVES: Recover a continuous, high-resolution, undisturbed Plio-Pleistocene sequence of organic-rich sediment deposited under the proximal monsoon-driven coastal upwelling on the Oman Margin.

SEDIMENT TYPE: Calcareous ooze and marls, calcareous mudstones and silty mudstones.

REMARKS: Possibly duplicate/triplicate entire section depending on quality/quantity of recovery.


SW
0300
0330
0400
NE
OM-1
1
2
Two-way traveltime (s)
C2704 Line 5
0
5
km


NW 1330
1400
1430
SE
OM-1
Two-way traveltime (s)
1
2
C2704 Line 10
0
5
km

SITE NUMBER: OM-2

TRANSIT FROM PREVIOUS SITE: 0.5 hrs

POSITION: $18^{O}14.9'N/57^{O}40.1'E$ SEDIMENT THICKNESS: 600m

WATER DEPTH: 675 m PRIORITY: 2

PROPOSED DRILLING PROGRAM: DOUBLE APC/XCB to 340 mbsf

SEISMIC RECORD: RV Robert Conrad Line 13, 6-05-87, 0124 hours

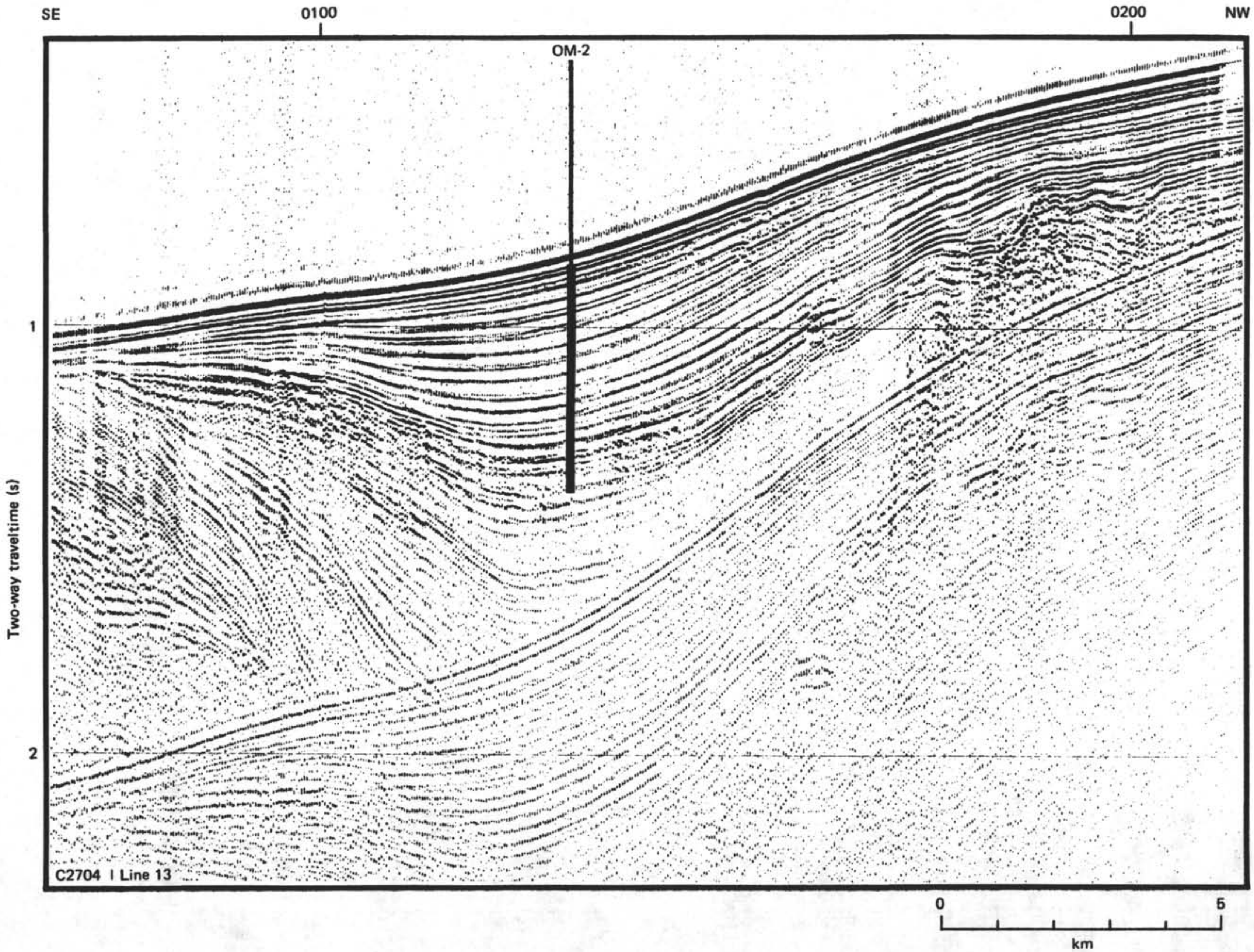
HEAT FLOW: Yes ORIENTED CORES: Yes

LOGGING: Yes (standard) WATER SAMPLER: Yes

OBJECTIVES: Recover a continuous, high-resolution, undisturbed Plio-Pleistocene sequence of organic-rich sediment deposited under the proximal monsoon-driven coastal upwelling on the Oman Margin.

SEDIMENT TYPE: Calcareous ooze and marls, calcareous mudstones and silty mudstones.

REMARKS: Lower accumulation rate than at site OM-1, backup to OM-1.


SE
0100
0200
NW
OM-2
Two-way traveltime (s)
1
2
C2704 I Line 13
0
5
km

SITE NUMBER: OM-3

TRANSIT FROM PREVIOUS SITE: 0.5 hrs

POSITION: 18°27.5'N/57°47.0'E SEDIMENT THICKNESS: >700 m

WATER DEPTH: 570m PRIORITY: 2

PROPOSED DRILLING PROGRAM: DOUBLE APC/XCB to 270 mbsf

SEISMIC RECORD: RV Robert Conrad Line 5, 5-22-87, 0618 hours

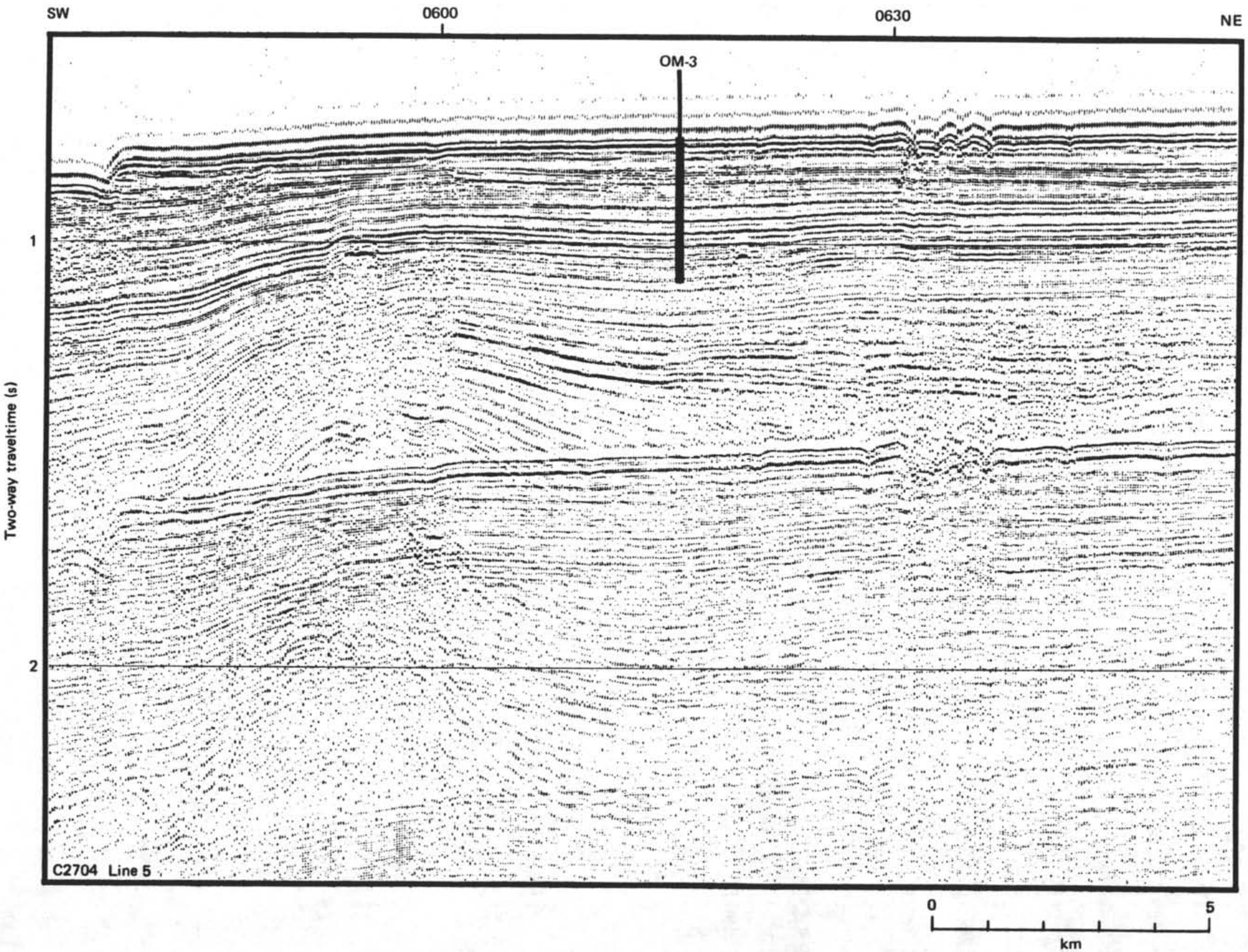
HEAT FLOW: Yes ORIENTED CORES: Yes

LOGGING: Yes (Standard) WATER SAMPLER: Yes

OBJECTIVES: Recover a continuous, high-resolution, undisturbed Plio-Pleistocene sequence of organic-rich sediment deposited under the proximal monsoon-driven coastal upwelling on the Oman Margin.

SEDIMENT TYPE: Calcareous ooze and marls, calcareous mudstones and silty mudstones.

REMARKS: Lower accumulation rate than OM-1 and OM-2. Backup site.


SW
0600
0630
NE
OM-3
1
2
Two-way traveltime (s)
C2704 Line 5
0
5
km

SITE NUMBER: OM-4

TRANSIT FROM PREVIOUS SITE: 0.5 hrs

POSITION: $18^{o}29.0'N/57^{o}42.6'E$ SEDIMENT THICKNESS: >500 m

WATER DEPTH: 360m PRIORITY: 1

PROPOSED DRILLING PROGRAM: DOUBLE APC/XCB to 250 mbsf

SEISMIC RECORD: RV Robert Conrad Line 4, 5-21-87, 0518 hours

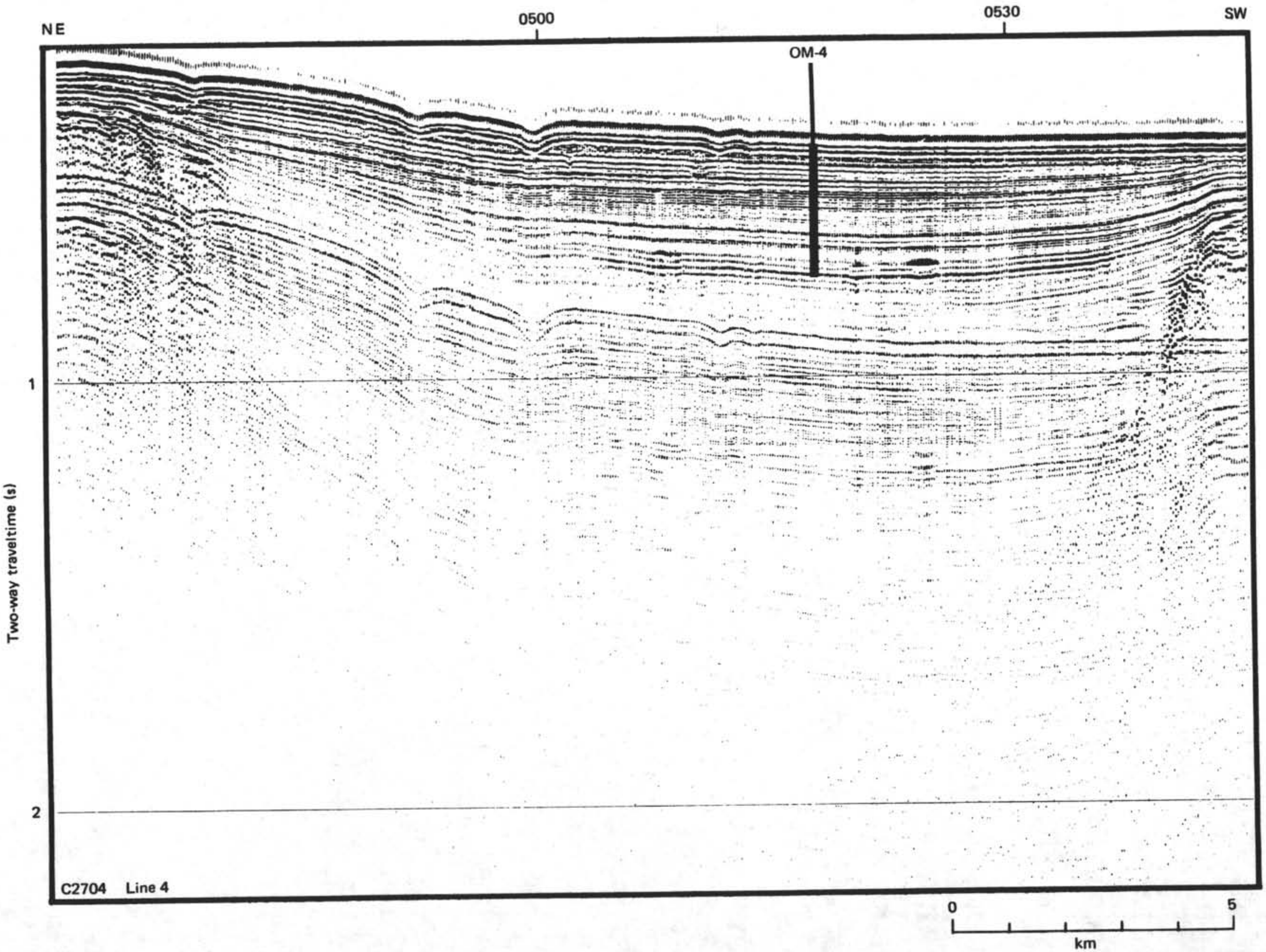
HEAT FLOW: Yes ORIENTED CORES: Yes

LOGGING: Yes (standard) WATER SAMPLER: Yes

OBJECTIVES: Recover a shallow continuous, high-resolution, undisturbed Plio-Pleistocene sequence of organic-rich sediment deposited under the proximal monsoon-driven coastal upwelling on the Oman Margin.

SEDIMENT TYPE: Calcareous ooze and marls, calcareous mudstones and silty mudstones.

REMARKS: Shallowest site thought to have expanded section in Quaternary. "Bright Spot" at target depth 1 km to southwest.


NE
0500
0530
SW
OM-4
1
2
Two-way traveltime (s)
C2704 Line 4
0
5
km

<u>SITE NUMBER</u>: OM-5

<u>TRANSIT FROM PREVIOUS SITE</u>: 5.0 hrs from OM-4

<u>POSITION</u>: 17°48.7'N/57°22.0'E

<u>SEDIMENT THICKNESS</u>: 200 m

<u>WATER DEPTH</u>: 300m

<u>PRIORITY</u>: 1

<u>PROPOSED DRILLING PROGRAM</u>: DOUBLE APC/XCB to 200 mbsf (possible RCB)

<u>SEISMIC RECORD</u>: RV Robert Conrad Line 3, 5-20-87, 2322 hours

<u>HEAT FLOW</u>: Yes

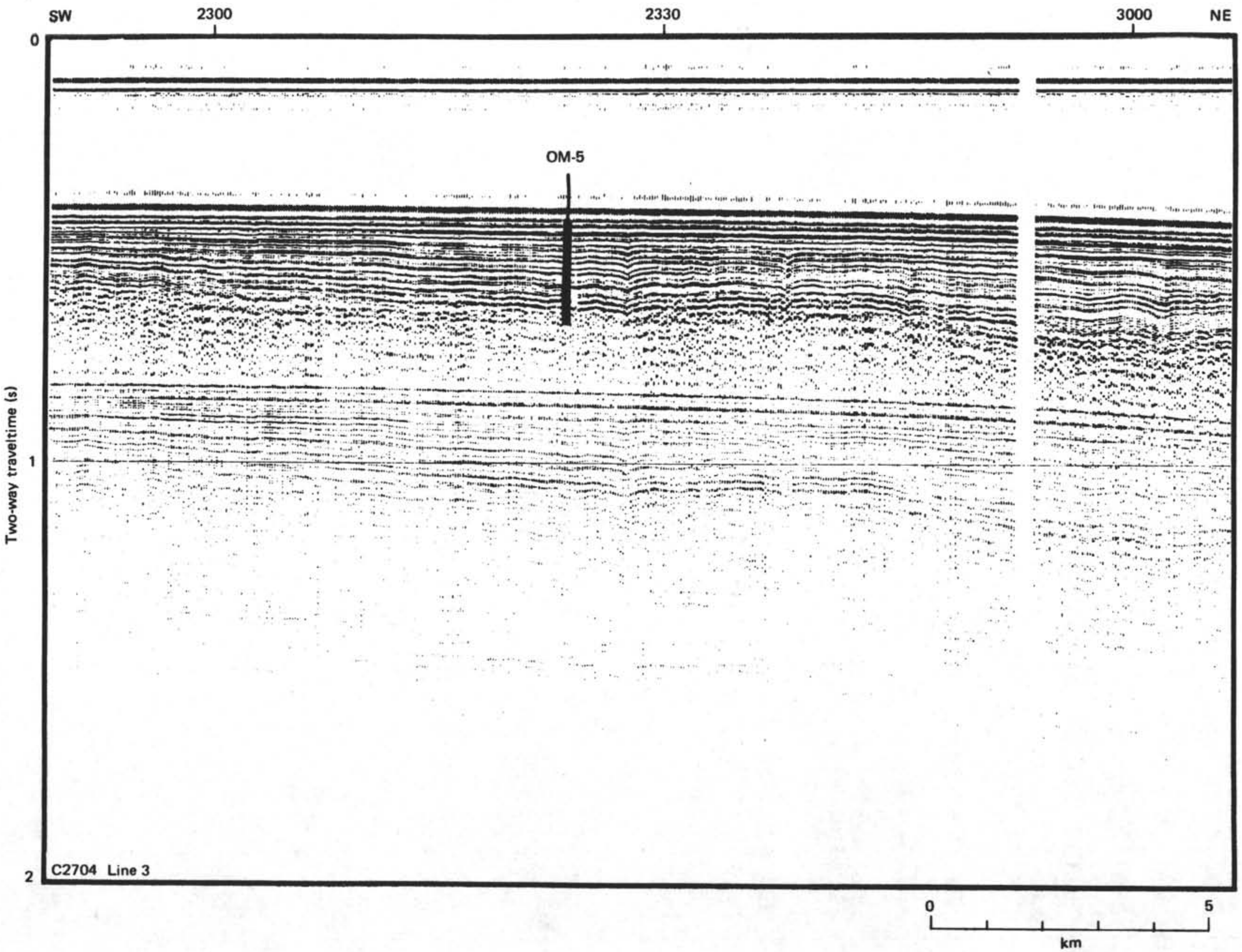
<u>ORIENTED CORES</u>: Yes

<u>LOGGING</u>: Yes (standard)

<u>WATER SAMPLER</u>: Yes

<u>OBJECTIVES</u>: Recover shallow sediments overlying shallow basement (thought to be ophiolite thrusts). Obtain section of ophiolite series.

<u>SEDIMENT TYPE</u>: Calcareous ooze, marls, and limestones; calcareous mudstones, silty mudstones, and clastics (overlying ophiolite?).



SW
2300
2330
3000
NE
0
1
2
Two-way traveltime (s)
OM-5
C2704 Line 3
0
5
km

SITE NUMBER: OM-6

TRANSIT FROM PREVIOUS SITE: 1.0 hrs

POSITION: 17°46.2'N/57°35.3'E SEDIMENT THICKNESS: >1000 m

WATER DEPTH: 890 m PRIORITY: 2

PROPOSED DRILLING PROGRAM: DOUBLE APC/XCB to 300 mbsf

SEISMIC RECORD: RV Robert Conrad Line 6, 5-22-87, 1805 hours
and southwest of Line 18, 5-24-87, 1402 hours

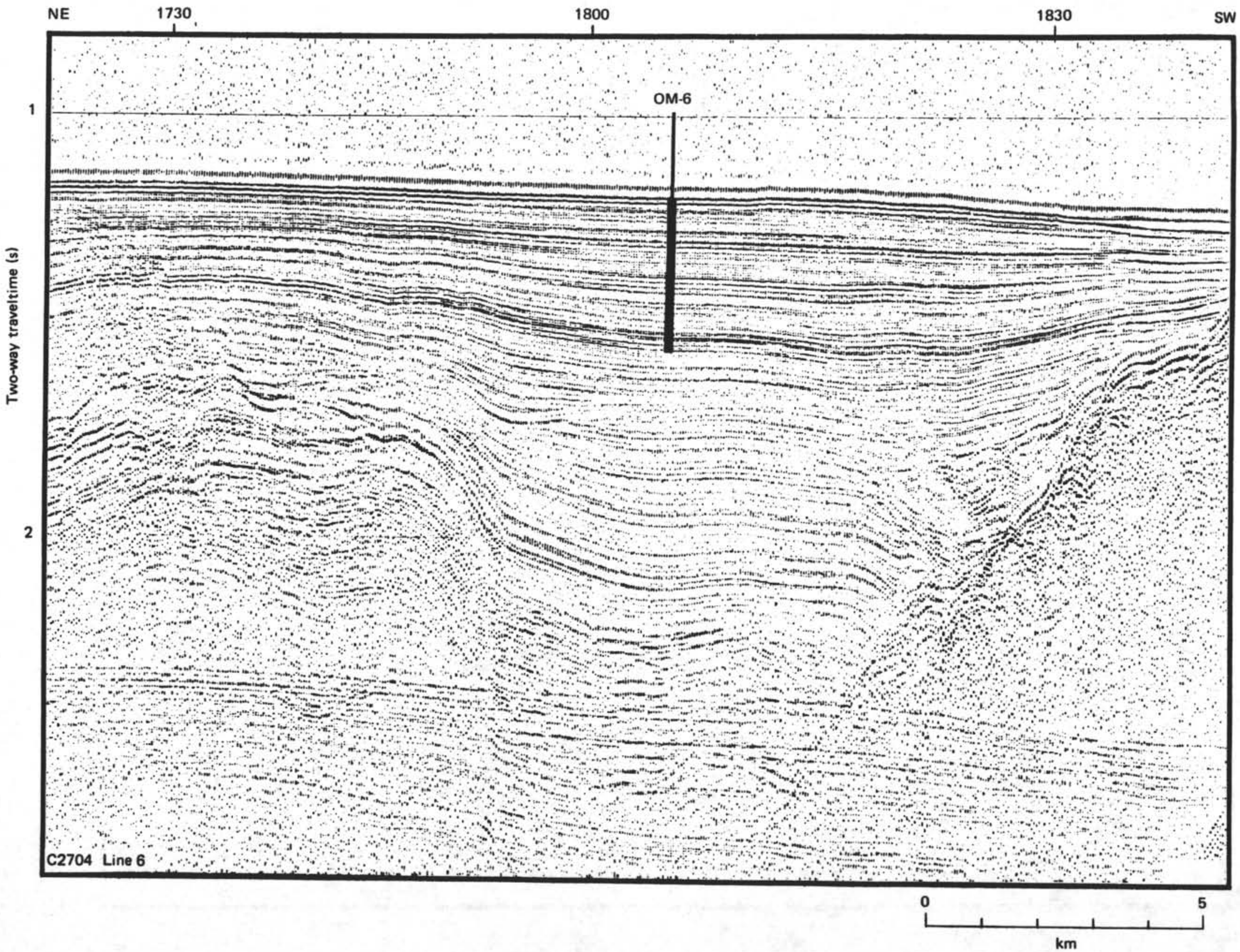
HEAT FLOW: Yes ORIENTED CORES: Yes

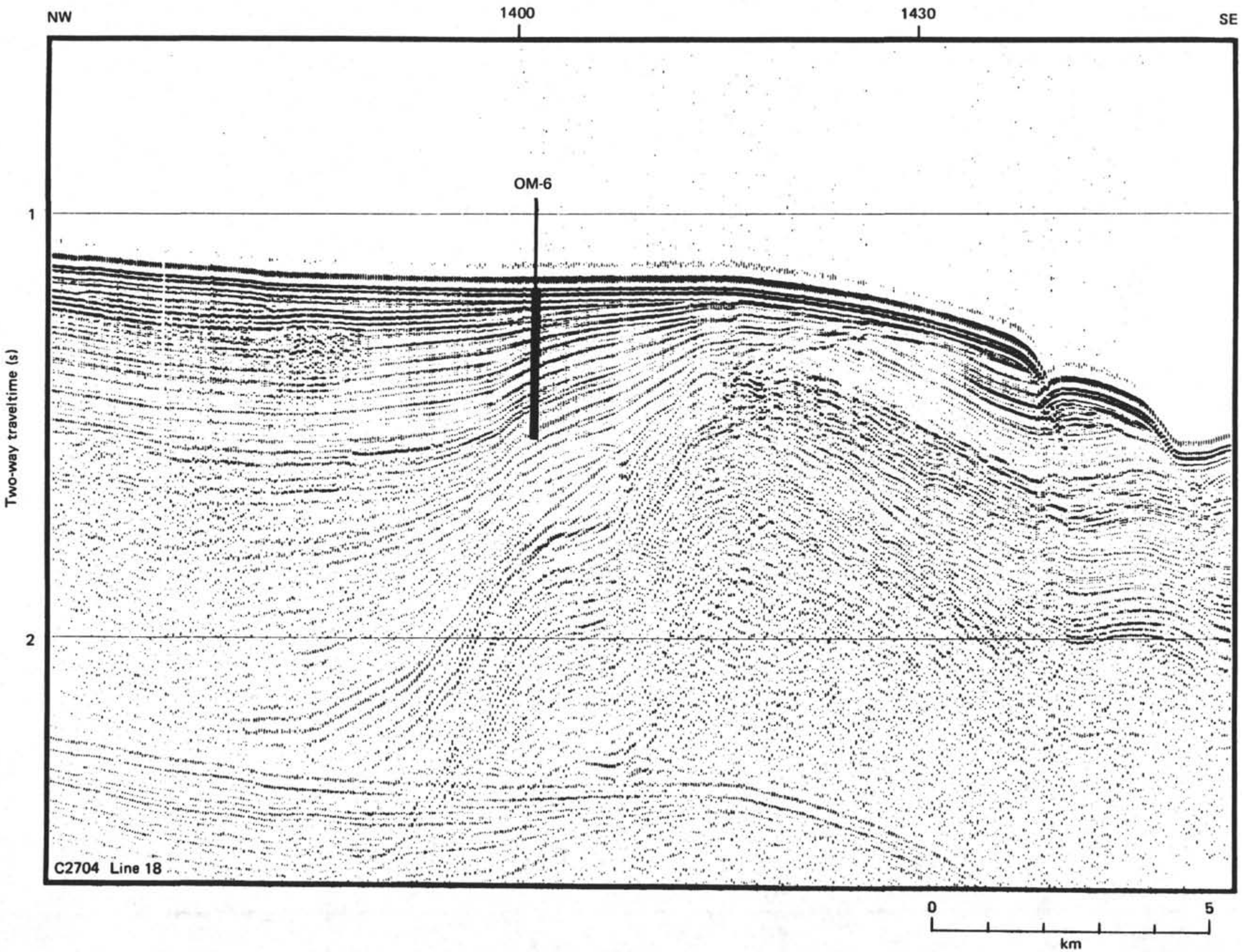
LOGGING: Yes (standard) WATER SAMPLER: Yes

OBJECTIVES: Recover a continuous, high-resolution, undisturbed Plio-Pleistocene sequence of organic-rich sediment deposited under the proximal monsoon-driven coastal upwelling on the Oman Margin.

SEDIMENT TYPE: Calcareous ooze and marls, calcareous mudstones and silty mudstones.

REMARKS: Location has accumulation rate similar to OM-1.


NE
1730
1800
1830
SW
OM-6
1
2
Two-way traveltime (s)
C2704 Line 6
0
5
km


NW
1400
1430
SE
OM-6
1
2
Two-way traveltime (s)
C2704 Line 18
0
5
km

<u>SITE NUMBER</u>: OM-8

<u>TRANSIT FROM PREVIOUS SITE</u>: 1.0 hrs

<u>POSITION</u>: 17°41.0'N/57°49.6'E <u>SEDIMENT THICKNESS</u>: >400 m

<u>WATER DEPTH</u>: 1400 m <u>PRIORITY</u>: 1

<u>PROPOSED DRILLING PROGRAM</u>: DOUBLE APC/XCB to 340 mbsf

<u>SEISMIC RECORD</u>: RV Robert Conrad Line 20, 5-25-87, 0035 hours

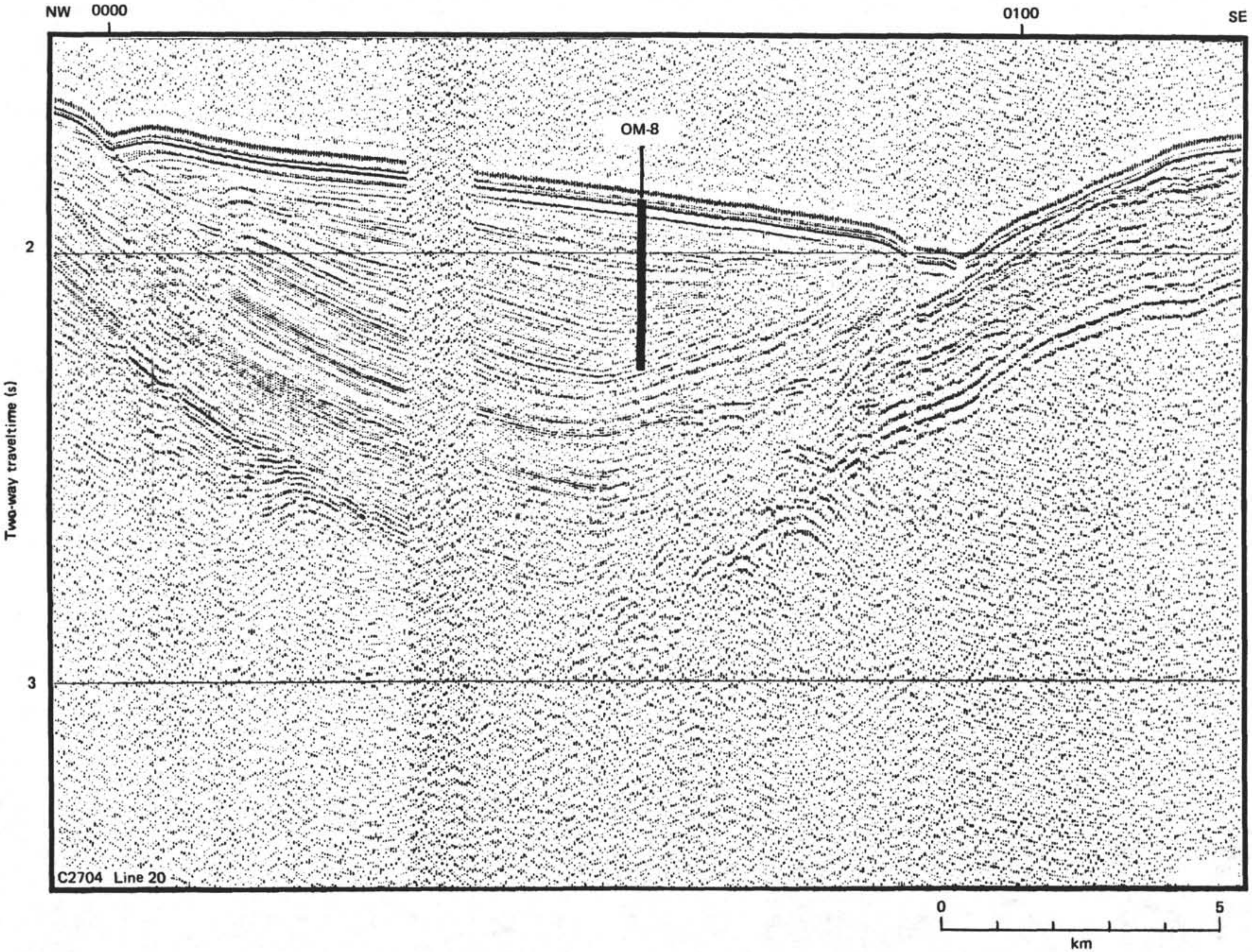
<u>HEAT FLOW</u>: Yes <u>ORIENTED CORES</u>: Yes

<u>LOGGING</u>: Yes (standard) <u>WATER SAMPLER</u>: Yes

<u>OBJECTIVES</u>: Recover a continuous and undisturbed late Neogene sequence deposited on the deeper part of the margin under the proximal monsoon-driven coastal upwelling over Oman Margin.

<u>SEDIMENT TYPE</u>: Calcareous ooze and marls, calcareous mudstones and silty mudstones.

<u>REMARKS</u>: Piston cores show more pelagic sediments compared to OM-1.


NW
0000
0100
SE
OM-8
2
3
Two-way traveltime (s)
C2704 Line 20
0
5
km

SITE NUMBER: OM-9

TRANSIT FROM PREVIOUS SITE: 0.5 hrs

POSITION: 17°42.7'N/57°50.0'E   SEDIMENT THICKNESS: >800 m

WATER DEPTH: 1400 m   PRIORITY: 3 (after OM-8)

PROPOSED DRILLING PROGRAM: DOUBLE APC/XCB to 400 mbsf

SEISMIC RECORD: RV Robert Conrad Line 19, 5-24-87, 1845 hours

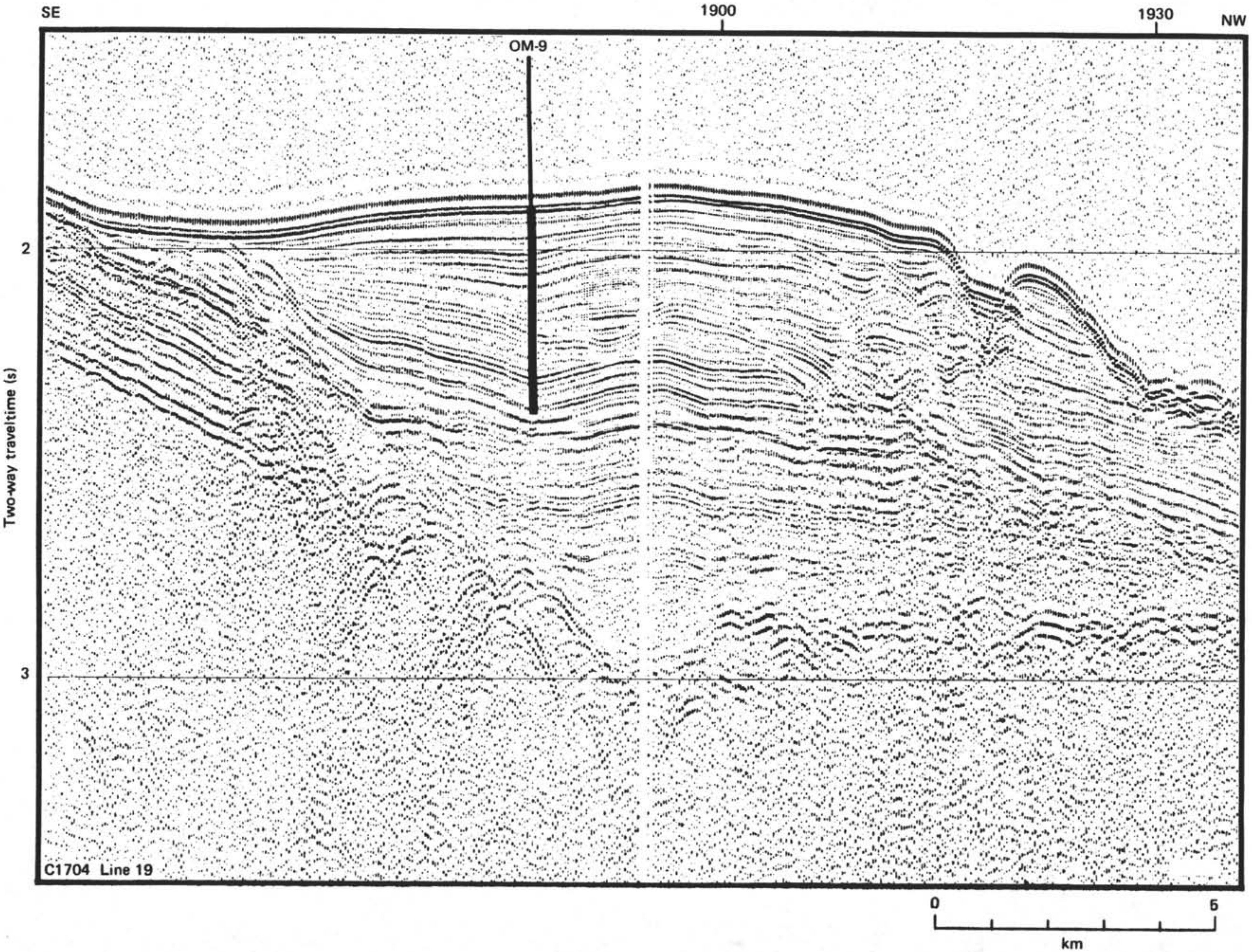
HEAT FLOW: Yes   ORIENTED CORES: Yes

LOGGING: Yes (standard)   WATER SAMPLER: Yes

OBJECTIVES: Recover a continuous and undisturbed late Neogene sequence deposited on the deeper part of the margin under the proximal monsoon-driven coastal upwelling over Oman Margin.

SEDIMENT TYPE: Calcareous ooze and marls, calcareous mudstones and silty mudstones.

REMARKS: Piston cores show more pelagic sediments compared to OM-1.


SE
1900
1930
NW
OM-9
2
3
Two-way traveltime (s)
C1704 Line 19
0
5
km

SITE NUMBER: OM-10

TRANSIT FROM PREVIOUS SITE: 0.5 hrs

POSITION: 17°38.9'N/57°57.0'E SEDIMENT THICKNESS: 400 m

WATER DEPTH: 1350 m PRIORITY: 1

PROPOSED DRILLING PROGRAM: RCB to 340 mbsf

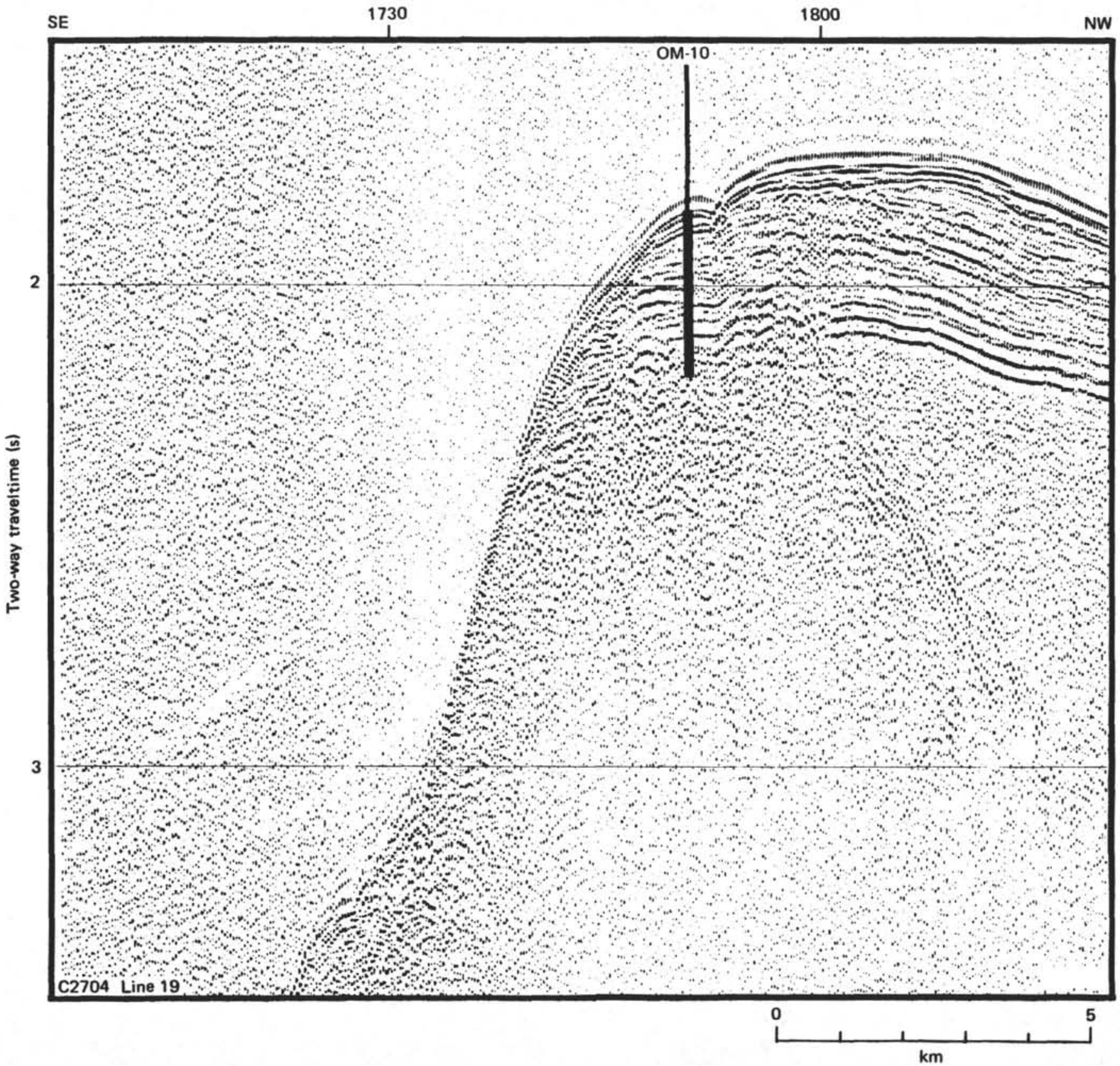
SEISMIC RECORD: RV Robert Conrad Line 19, 5-24-87, 1752 hours

HEAT FLOW: Yes ORIENTED CORES: Yes

LOGGING: Yes (standard) WATER SAMPLER: Yes

OBJECTIVES: Recover the sediment sequence deposited on the outer basement structure thought to be an ophiolite thrust.

SEDIMENT TYPE: Calcareous ooze, marls, and limestones, calcareous mudstones and silty mudstones.


SE
1730
1800
NW
OM-10
2
3
Two-way traveltime (s)
C2704 Line 19
0
5
km

OCEAN DRILLING PROGRAM LEG 117
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L-DGO Logging Scientist:	RICH JARRARD Borehole Research Group Lamont-Doherty Geological Observatory Palisades, NY 10964
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