OCEAN DRILLING PROGRAM

LEG 115 SCIENTIFIC PROSPECTUS

MASCARENE PLATEAU - CARBONATE DISSOLUTION PROFILE

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# INTRODUCTION

The Indian Ocean was formed by a complex series of seafloor spreading events, starting with the rifting of Madagascar from Africa and continuing today with the asymmetric spreading on the Southeast Indian Ridge and the peculiarities of extremely slow spreading on the Southwest Indian Ridge. The origin and evolution of the major aseismic ridges, the Ninetyeast Ridge, the Chagos-Laccadive-Mascarene Ridge system, and the Kerguelen-Gaussberg Ridge, are integral parts of Indian Ocean development (Fisher et. al., 1967 and 1971).

The Chagos-Laccadive-Mascarene volcanic lineament is a major aseismic ridge system in the Central Indian Ocean basin. It connects young volcanic activity in the vicinity of Reunion Island with the massive, Cretaceous-Tertiary continental flood lavas in the Deccan Traps of India. This lineament parallels the remarkable Ninetyeast Ridge and the two together record the northward motion of the Indian subcontinent away from mantle-fixed hotspots near Reunion and Kerguelen Islands, respectively (Fig. 1).

The importance of aseismic ridges in understanding the structure, evolution, and paleoceanography of the Indian Ocean cannot be overestimated. These mainly volcanic features appear to record the fragmentation and dispersion of Gondwanaland away from mantle-fixed hotspots (Morgan, 1981; Duncan, 1981). Some aseismic ridges (Seychelles bank, Gaussberg Ridge?) may be continental remnants left behind during the rifting process, while others (Chagos-Laccadive-Mascarene and Ninetyeast Ridge) appear to connect hotspots to continental flood basalt activity (Mahoney et al., 1982, 1983). Geochemical analyses of basalts recovered from these ridges provide constraints on mantle composition and variability, and the melting processes which produce magmas in the ocean basins. These extremely long and topographically high features, which have sunk below sealevel, have influenced oceanic circulation and reflect the physical properties of the oceanic lithosphere in the Indian Ocean during the Cenozoic. Carbonate sediments on their margins also provide a complete record of vertical dissolution gradients.

Analysis of sediments and basalts recovered by drilling during Leg 115 will address the following scientific objectives:

(1) Determine basement crystallization ages along the Chagos-Laccadive-Mascarene Ridge system to document the proposed age-progressive nature of the volcanism for use in plate velocity and reconstruction studies.
(2) Determine the geochemical character of the basaltic rocks for comparison with basalts from the Deccan traps and Reunion/Mauritius/Rodrigues Islands, and to examine mantle melting processes and source variability through time.
(3) Measure paleolatitudes from sediments and basalts for comparison with the hotspot reference frame and to examine the timing and magnitude of proposed polar wander.
(4) Collect APC (advanced hydraulic piston coring) cores from widely varying bathymetric depths which record the Neogene history of equatorial surface productivity and vertical dissolution gradients.

Basement drilling objectives on the Mascarene Plateau are discussed below first, followed by a discussion of the paleoceanographic objectives.

JOIDES Resolution is scheduled to depart from Port Louis, Mauritius on May 21, 1987. The cruise will end in Colombo, Sri Lanka on July 2, 1987.

## MASCARENE PLATEAU DRILLING

Previous drilling at two DSDP sites on aseismic ridges in this region (Sites 219 and 237, Fig. 1) did not reach basement and thus did not address any of the questions related to the age, origin, and character of the volcanic rocks. These sites produced, however, valuable information about drilling conditions in the sedimentary section. Drilling at a third DSDP site (Site 238, Fig. 1) at the northeastern end of the Argo Fracture Zone and 300 km south of the Chagos-Laccadive Ridge did penetrate basement rocks. The typical ocean floor basalts that were recovered are not related geochemically to volcanism on the Chagos-Laccadive Ridge, and therefore are not useful in constraining plate velocities. Texaco, Inc. drilled two holes on top of the Mascarene Plateau in the Saya de Malha and Nazareth Banks which penetrated thick (>1000m) coral carbonate platforms before recovering basalts (Fig. 2). Both of these holes were dry. The basalts are available for radiometric and geochemical studies (Texaco, pers. comm., 1987). The oldest sediments at the Saya de Malha Bank hole are late Paleocene; at the Nazareth Bank hole they are Eocene.

The vessel is scheduled to drill three single-bit, rotary-cored sites (MP-1 through MP-3) into basement along the Mascarene Plateau, between Mauritius and Saya de Malha Bank (Fig. 3; Table 1). Sediment thickness varies between 200 and 300 m and water depths range from 2200 to 2800 m at these sites (Table 1).

### Age-Progressive Volcanism and Plate Reconstructions

The trend of the Ninetyeast and Chagos-Laccadive-Mascarene Ridges mark the path along which India has ridden north from the Southern Ocean to collide with Asia during Late Cretaceous and Tertiary times (Fig. 4). The Chagos-Laccadive-Mascarene Ridge system is the western lineament which stretches from the volcanically active island of Reunion to Mauritius, where it intersects the Rodrigues Ridge at a right angle, and finally to the Mascarene Plateau (Fig. 1). Active spreading on the Central Indian Ridge has separated this southern portion of the C-L-M Ridge system from the Chagos Plateau, Laccadive and Maldive Island chains and Deccan basalts of India to the north (McKenzie and Sclater, 1971).

Except for the young islands of Reunion (≤2 Ma; McDougall, 1971) and Mauritius (7-8 Ma; McDougall and Chamalaun, 1969) in the south and the extensive Deccan Traps (60-65 Ma; Kaneoka, 1980) in the north, we have no age control on eruption times along this major linear volcanic province. Age studies along the Ninetyeast Ridge show a clear age progression (Duncan, 1978), but for plate reconstructions we must have at least two dated lineaments to precisely define rotation poles for the Indian/Australian plate relative to the hotspot reference frame. Dating of basement from the Mascarene Plateau and Chagos-Laccadive Ridge is thus critical. Drilling on the Mascarene Plateau will not duplicate information gained from the planned drilling on the Ninetyeast Ridge as this ridge system is composed of 38 Ma volcanic rocks at its southern end, while the Mascarene Plateau apparently consists of basalts ranging from 35 Ma to the present (Reunion Island). Sampling and dating of both lineaments is required to determine plate motions over the mantle during Tertiary time. Given the geometry of these two lineaments and ages along them we can assess the data for use in plate reconstruction models based on fixed hotspots. The timing of the India-Asia collision can be predicted and compared with increasingly detailed models of Himalayan uplift and development of the Indus and Bengal Fans.

One very exciting development in the study of hotspot-generated volcanic lineaments (particularly in the Pacific Ocean) is the determination of "true polar wander." This is an old idea proposed originally to explain the apparent motion of the earth's surface with respect to the spin axis (e.g., glacial tillites in equatorial regions; coal deposits near the poles). The term now signifies any motion of the entire earth with respect to the rotational axis, presumably in response to changes in the principal moment of inertia (Goldreich and Toomre, 1969). A comparative study of paleomagnetically and hotspot-determined latitudes (e.g., Gordon and Cape, 1981) suggests that Pacific hotspots, and the mantle with them, have moved as much as 12° south during Cenozoic time. In this model, the whole earth moves with respect to its spin axis and the hotspots merely provide reference points. Thus if Pacific hotspots move south, those in the Indian Ocean move north. The best test of this model is at hotspot lineaments aligned north-south on a fast-moving plate, such as occurs in the Indian Ocean. Given the position of Gordon and Cape's (1981) true polar wander Euler pole (0°N, 115°E), the amount of <u>northward</u> motion of the Kerguelen and Reunion hotspots has been 10° to 15° in the last 60 to 70 million years. This should be easily resolvable through paleomagnetic measurements on both sediments and basalts recovered during drilling along either lineament. What is critical, however, is precisely dated locations along the Chagos-Laccadive-Mascarene volcanic system to allow plate reconstructions, in the hotspot reference frame, of the Indian Ocean through Late Cretaceous and Tertiary time.

## Upper Mantle Heterogeneity and Melting Processes

The earliest analyses of oceanic rocks showed that island and seamount chains and associated aseismic ridges are geochemically distinct from MORB's and were formed from different parts of the upper mantle and/or by different melting processes (Gast, 1968). A variety of new geochemical models of upper mantle structure and mantle-lithosphere interaction have been proposed to explain the differences in bulk-rock geochemistry. The Chagos-Laccadive-Mascarene lineament offers an especially attractive volcanic province for examining upper mantle variability and melting processes. At the southern end the islands of Reunion and Mauritius are built on oceanic lithosphere; at the northern end the Deccan flood basalts erupted through continental lithosphere. These endpoints are well characterized isotopically (White and Dupre, 1984; Mahoney et al., 1982; Fisk et al., 1987). It appears from these studies that the Deccan magmas formed by melting a mixture of MORB-type mantle and sub-continental lithosphere, while the basaltic rocks of Reunion and Mauritius are similar geochemically to magmas associated with hotspots. Geochemical analyses (Sr, Nb, Pb and trace elements) of basalt samples recovered from intermediate sections of this lineament during Leg 115 at Sites MP-1, MP-2 and MP-3 (or MP-3A; Fig. 3) will increase our understanding of the variability of the upper mantle magma source regions through time. This would allow a more quantitative assessment of the question of whether Deccan flood basalts were derived principally from a hotspot (mantle-plume) source, as is the case for Reunion, or whether this hotspot served largely as a source of heat to melt a chemically distinct subcontinental lithosphere from which the basalts were derived.

An interesting feature of this lineament is the Rodrigues Ridge which forms a perpendicular appendage on the Mascarene Plateau at its southern end near Mauritius (Fig. 1). Morgan (1978) suggested that this short east-west ridge formed along a transform fault by asthenospheric flow from the Reunion hotspot to the Central Indian Ridge. The Rodrigues Ridge should therefore be the same age as the island of Mauritius (i.e., >8 Ma). However, Rodrigues Island is much younger (about 1-2 Ma; Mcdougall, 1971), indicating that the whole ridge may actually be a young feature. In addition, it does not appear to be connected to the Central Indian Ridge towards the east. Sr and Nd isotopic systematics suggest that Rodrigues Island magmas were derived from a source very similar to that of Reunion Island (Baxter et al., 1985). The composition and the origin of the ridge and island remain a puzzle (Baxter et al., 1985; Fisk, 1983) which may be solved by drilling near its intersection with the Chagos-Laccadive-Mascarene lineament (Site MP-1; Fig. 3).

Of considerable interest to plate tectonic studies of the northwestern Indian Ocean is the southeastern limit of the Precambrian continental rocks forming the Seychelles Bank with the Saya de Malha Bank at the northern end of the Mascarene Plateau. Drilling on the center of this ridge at Site CARB-1 (Fig. 3) will identify its origin and examine the possible transition from continental to oceanic rocks. As mentioned earlier, the Chagos-Laccadive Ridge and the Mascarene Plateau were once a continuous volcanic lineament until seafloor spreading on the Central Indian Ridge separated them about 36 million years ago (McKenzie and Sclater, 1971). Drilling on the northeast flank of Nazareth Bank (Site MP-3, Fig. 3) will penetrate the western side of this rifted margin and provide information on the timing of rifting, sedimentary history, and petrologic character of this structure.

## PALEOCEANOGRAPHIC (CARBONATE DISSOLUTION) STUDIES

The construction of well constrained models of the deep-sea sediment budget and its changes through time and space are of critical importance if we are to understand the history of both global climate and ocean circulation. Such models can be established only by quantifying the processes which control the sediment budget. In the Indian Ocean, biogenically produced calcium carbonate has been the dominant component of sediments on the seafloor since the Mesozoic.

The accumulation of pelagic carbonate sediments in open ocean environments is primarily dependent on the rate of production and dissolution of foraminifers and calcareous nannoplankton. The productivity is determined by the availability of nutrients which, in turn, depends on the rate of supply of these elements from continental runoff and ocean circulation (e.g., vertical mixing, upwelling). In general, the rate of dissolution of calcium carbonate sediment is a function of the degree of calcite saturation in sea water at the sediment/water interface. Averaged globally, the degree of calcite saturation varies in order to balance the total carbonate budget. The oceanic circulation, and the underlying causes for its development and change, is therefore a key factor among the dissolution-related parameters. Deep-sea drilling has already established that fluctuations in dissolution rates in the Cenozoic are controlled by changes in productivity and carbonate concentration gradients (e.g., Heath et al., 1977).

The principal objective of the "carbonate dissolution profile" to be drilled during Leg 115 is the study of the interplay between the flux in carbonate production and the dissolution of this material as a function of water depth, as the shallow and deep water circulation and the climatic systems evolved during Neogene and Quaternary times. Drilling in the tropical Indian Ocean is aimed at significantly increasing our knowledge of the sediment-circulation-climate system on both a regional and global scale. It will ultimately form part of a network of depth transects that will enable us to examine the earth's carbonate budget through the Cenozoic.

The key to achieving this objective is to obtain a tightly spaced transect of continuous Neogene and Quaternary sediments from sites spanning a wide range of water depths. The requirements for such a transect also include the following:

(1) The sites should be located in a small geographic area to ensure that the pelagic rain to all sites is similar.
(2) The shallowest site should be located well above the depth of the calcite saturation horizon to ensure that little or no carbonate dissolution has occurred.
(3) The sites should cover a wide depth range so that a wide range of calcite saturation levels are represented. Depth intervals between sites should be similar, and the sites should be located both above and within present and past lysoclines and span present and past deep water mass boundaries.
(4) The sites should be located in an area with reasonably high sediment accumulation rates to ensure that high resolution studies are possible (e.g., detection of precessional cycles).

The northeastern flank of the Seychelles-Saya de Malha platform (Fig. 3) fulfills these requirements within the tropical Indian Ocean. Moreover, this drilling package is likely to produce the only high-resolution tropical stratigraphic sections from the Indian Ocean program. The four sites (CARB-1 through CARB-4) proposed will address a number of questions related to the evolution of the Neogene and Quaternary carbonate system. How has the carbonate system of the tropical Indian Ocean varied in response to changing climatic boundary conditions, changing glaciation levels and changing deep ocean circulation? Related questions include, how has surface productivity varied in response to climate and to the evolving physical geometry of the northern Indian Ocean? How do the sediments reflect the variation and interaction between surface production of biogenic carbonate and its dissolution at depth? The four sites will be double APC cored along a depth transect starting at a water depth of 1500 m between the Seychelles Bank and Saya de Malha Bank and deepening to 4600 m in the NW Indian Ocean Basin (Fig. 3; Table 1).

## Evolution of Shallow and Deep Water Circulation in the Northwestern Indian Ocean

Because the Indian Ocean has a unique geometry (no northern ocean) and a strong monsoonal circulation in the tropical atmosphere and ocean, some of the water masses and circulation patterns are distinctly different from those in the Atlantic and the Pacific. The complex system of submarine ridges divides the modern deep flow into separate circulation systems in the Wharton-Cocos Basins, Central Indian Basin, and the connected Madagascar, Mascarene and Somali Basins (Fig. 5; see also Reid and Lynn, 1971; Jacobs and Georgi, 1977). The evolution of this system can be traced through the study of its benthic faunas, which reflect deep water circulation changes, and planktonic faunas and floras, reflecting surface water changes. By studying gradients in $\delta^{18}O$ and $\delta^{13}C$ values, vertical and horizontal circulation patterns can be compared to other oceanic basin sites.

In terms of "deep" water mass changes, it is particularly important to establish how the intermediate and deep water masses responded to:

(1) The formation of a permanent ice cap in Antarctica during middle Miocene times.
(2) The onset of northern hemisphere glacial/interglacial cycles during late Pliocene times.
(3) The Miocene tectonic closing of the Tethyan seaway which connected the low-latitude Indo-Pacific and Atlantic regions.

In terms of shallow water mass changes, it is desirable to learn how the boundary between the Equatorial Water and the Central Water masses has fluctuated through time. Today, this boundary is located between the four CARB sites and the three MP sites. The retrieval of APC cores from the upper 200-250 m of the sedimentary column at Sites MP-1 through MP-3 will guarantee

(1) that sufficient latitudinal distance is covered in order to be able to monitor such surface water fluctuations;
(2) that these reconstructions can be based on equally good, high-quality material across the entire latitudinal span covered by Leg 115.

## Aragonite Dissolution (Maldive Islands)

Periplatform sediments deposited exclusively within the vicinity of shallow carbonate banks are unique environments in which to study climatically induced fluctuations of carbonate saturation levels within intermediate water masses. Besides coccoliths, planktonic/benthic foraminifers and pteropods, the periplatform carbonate ooze contains large amounts of needle-like, fine aragonite and some magnesium calcite in the form of skeletal fragments and micrite; both of which are produced in shallow carbonate environments. Because of their special mineralogy (aragonite and Mg-calcite), bank-derived sediments are susceptible to more rapid and shallower dissolution than the calcitic components - i.e., coccoliths and foraminifers.

Late Pleistocene aragonite cycles that occur within the fine (<62 $\mu$) fraction of the ooze appear to be related to climatic changes because of their high degree of correlation with the oxygen isotope record obtained from planktonic foraminifers. The variation through time in the preservation of bank-derived metastable aragonite can therefore be used to explain the observed aragonite cycles and hence fluctuations through time in carbonate saturation levels in intermediate water masses.

The following objectives will be addressed by drilling the Neogene carbonate sections at sites MLD-1 and MLD-2 near the Maldive Islands (Figure 6):

(1) To derive a detailed oxygen and carbon isotope stratigraphy for the Neogene given the expected high rates of accumulation of periplatform ooze and to test the integrity of correlations with the Pleistocene isotope record.
(2) To determine the interaction between sea level fluctuations and carbonate off-bank transport and to test the highstand carbonate theory (interglacial high sedimentation rates and turbidite high occurrence) established in the Bahamas.
(3) To determine the effects of monsoonal circulation in the Northern Indian Ocean on carbonate dissolution and production.
(4) To estimate the influx of terrigenous components at different water depths.
(5) To decipher the effects of diagenesis on metastable aragonite and Mg-calcite.

## Stratigraphy

The collection of Neogene and Quaternary APC material from MP-1, MP-2, MP-3 and the four CARB sites will make possible the development of a high-resolution biostratigraphy (based on calcareous and siliceous microfossils) for the low-latitude Indian Ocean. There is still room for much improvement regarding the precise sequencing of--or relative distance between--biostratigraphic species events, both within and between microfossil groups. Once adequate magnetostratigraphic sequences are established, we can then transform the biostratigraphic information into an accurate biochronology.

Despite the fact that much effort has been made in establishing high-quality magnetostratigraphic records from deep-sea sediments, we still do not possess a single continuous Miocene record from a low latitude environment. This lack of an adequate biochronologic record makes it difficult to assess the rates of many of the important processes which characterized the development of the Miocene deep-sea environment. This magneto- biochronologic problem will be addressed at the MP-1, MP-2, MP-3 and CARB sites. The recovery of a number of APC cored sections from a relatively small area is ideal for this purpose because it should assure the recovery of the complete stratigraphic section. Moreover, APC coring of the MP sites will allow magnetostratigraphic studies which are based on inclination and are therefore not critically dependent on core orientation.

## DRILLING PLAN AND PRIORITIES

The current drilling plan includes two main programs: penetration and recovery of volcanic basement rocks on the Mascarene Plateau (Sites MP-1 through MP-3) and recovery of complete and undisturbed sediments by APC coring along a paleoceanographic depth transect consisting of four sites (CARB-1 to CARB-4). The drilling objectives described above will be addressed during 42 days of operations. The estimated drilling time will be divided between the basement and the paleoceanographic objectives (Tables 2A and 2B).

Sites MP-1, MP-2 and MP-3 will penetrate 50 m into the basement using the rotary coring system (RCB) and provide basaltic rocks for radiometric age measurements, geochemical analyses and paleolatitude determinations. The timing of volcanism along the Rodrigues Ridge may be observed in the recovered sediments. Sediments should also reveal the subsidence history and environment of deposition. Basaltic rocks at MP-3 (or MP-3A) will be dated and analyzed to determine mantle source compositions for magmas. The subsidence history and rifting of the Mascarene Plateau from the Chagos Bank should be recorded in the sediments.

Sites CARB-1, -2, -3, and -4 (or 1A, 2A, and 4A, B, C) will be located within the narrowest possible latitudinal range and spaced at nearly equal depth increments between 1500 m and 4000 m water depth. These sites will be double cored using the APC and XCB coring systems (Table 1).

If time permits the first addition to the drilling program will be to deepen site CARB-1 to determine the nature and age of the basement. This will increase our understanding of the origin and past position of the Seychelles Bank. Sediments will reveal the Cenozoic subsidence history and paleoenvironment of deposition. Finally, if time remains at the end of the program an intermediate depth site in the Maldive Islands (MLD-2 as the first priority) will be APC-cored to examine the history of aragonite dissolution.

Logging with standard Schlumberger tools will take place at the three deepest sites (MP-2, MP-3, and CARB-1).

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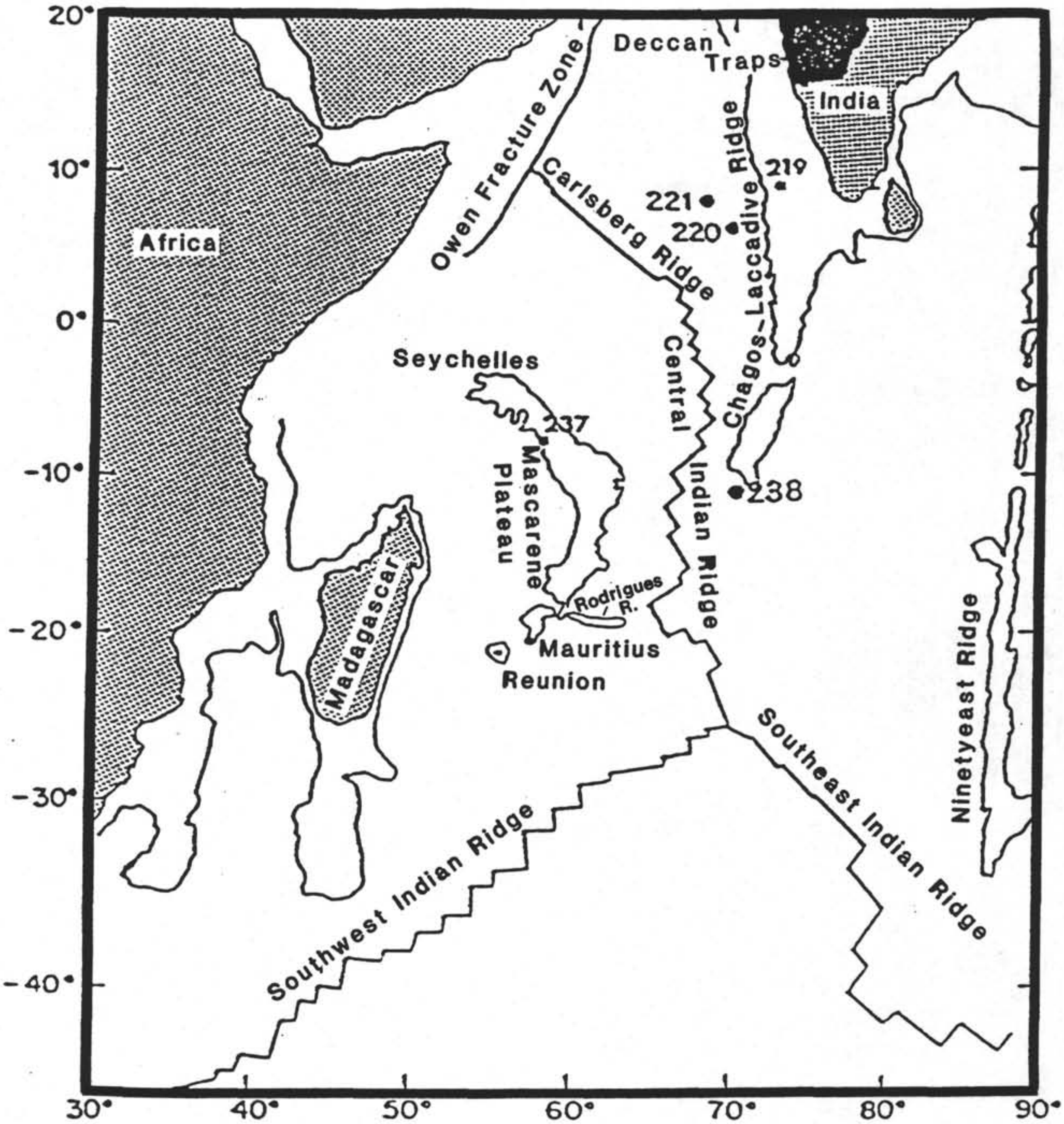



Fig. 1. Chagos-Laccadive-Mascarene Ridge system in the western Indian Ocean. Numbers indicate DSDP sites. Deccan Traps are located at the northern end of the ridge.

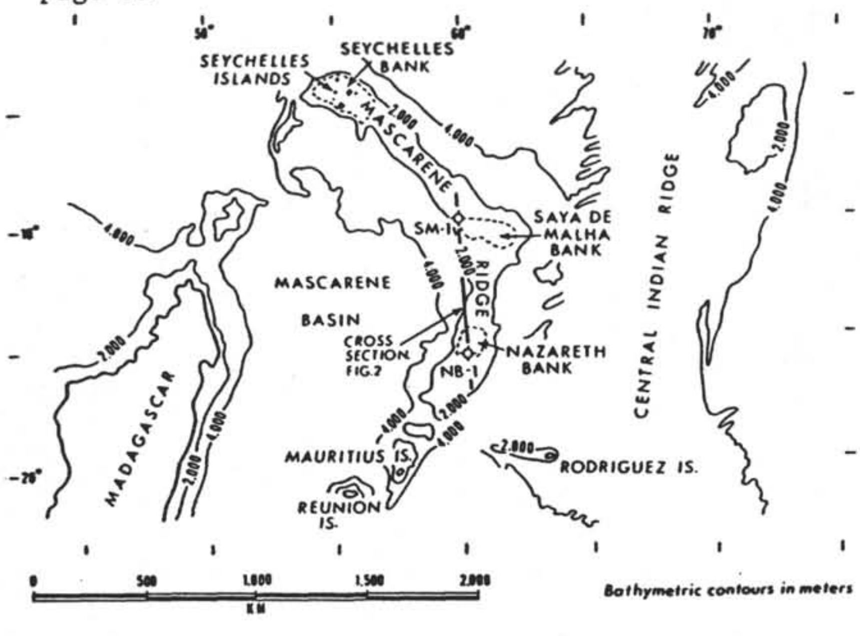



Fig. 2A. Mascarene Plateau with the sites of two dry holes (SM-1 and NB-1) drilled by Texaco Inc. (from Meyerhoff and Kamen-Kaye, 1981)

| Interval (m) | Age | Reported Depositional Environment |
|---|---|---|
| 0-100 | Quaternary | Reef carbonates |
| 100-1,249 | Pliocene | Reef carbonates |
| | Miocene | Reef carbonates |
| | Late Oligocene | Reef carbonates |
| 1,249-1,323 | Early Oligocene or Late Eocene | Shallow marine |
| 1,323-1,506 | Late Eocene | Shallow marine |
| 1,506-2,146 | Middle Eocene | Near reefal grading downward to more open marine |
| 2,146-2,347 | Early Eocene | Open marine |
| 2,347-2,432 | Late Paleocene | Near reefal grading downward to bioclastic |
| 2,432-3,264 TD | Unknown (K-Ar dates are late Oligocene to middle Miocene) | Volcanic rocks, mainly basalt; no sedimentary intercalations. A few ash(?) beds with zeolites |

Fig. 2B. Summary of well SM-1 on the Saya de Malha Bank.

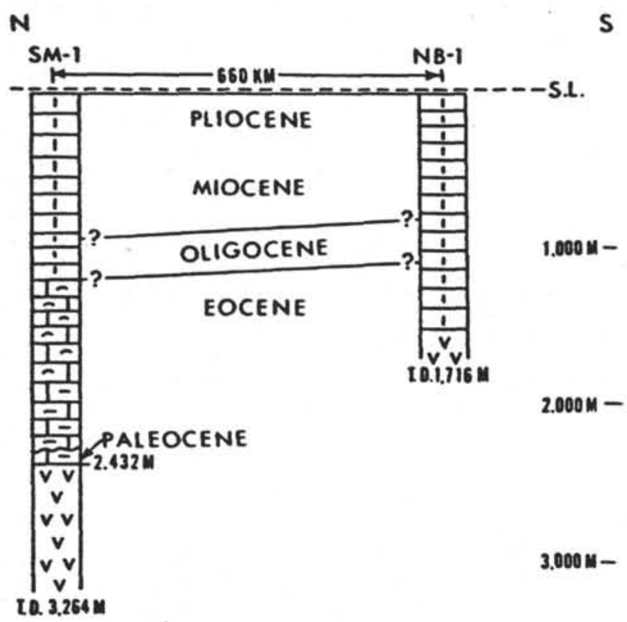
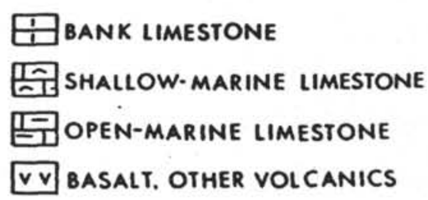



Fig. 2C. Culumnar sections of exploratory wells SM-1 and NB-1.



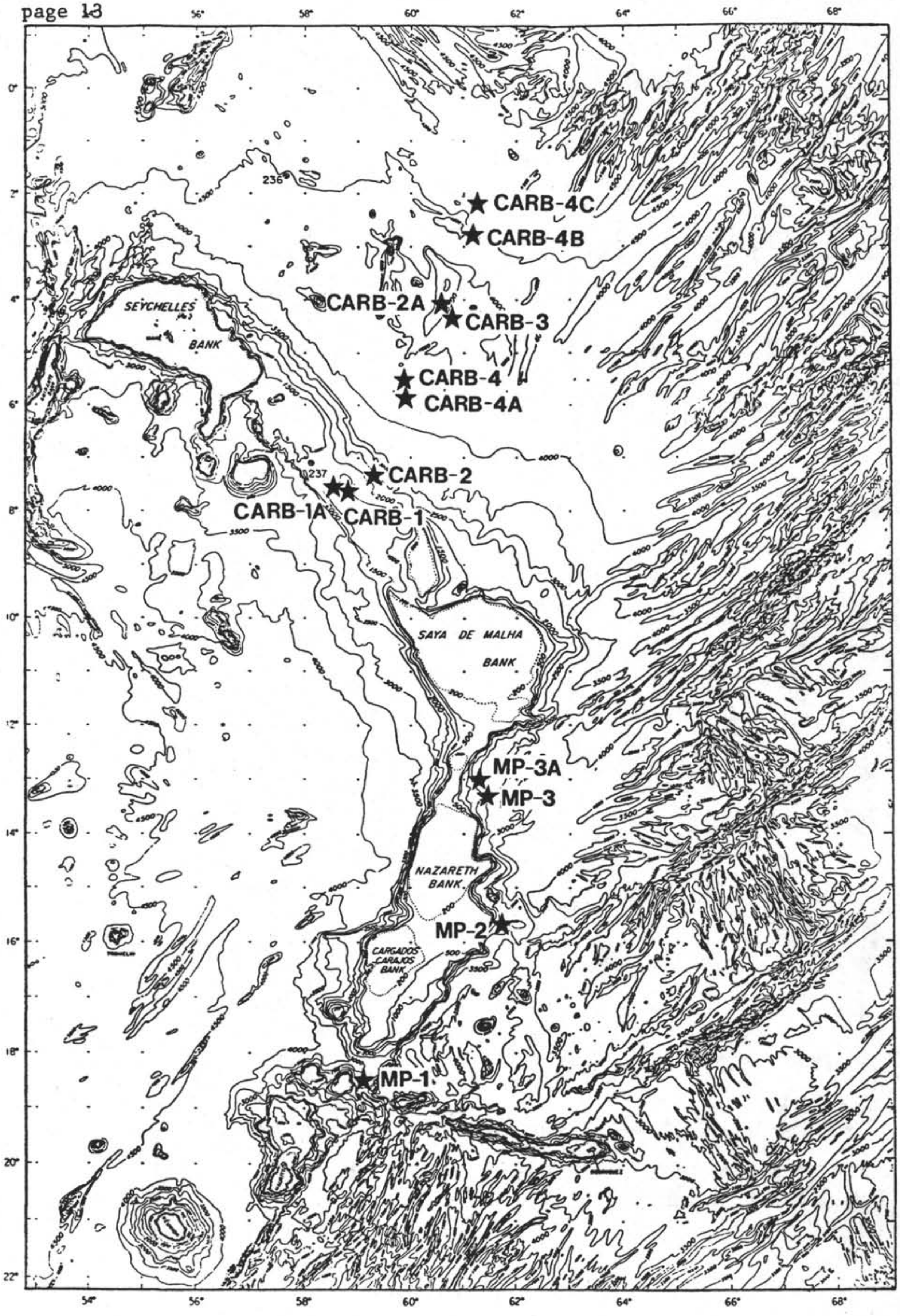



Fig. 3. Location of proposed ODP drill sites for the Mascarene Plateau, Leg 115. (after Fisher et al., 1974)

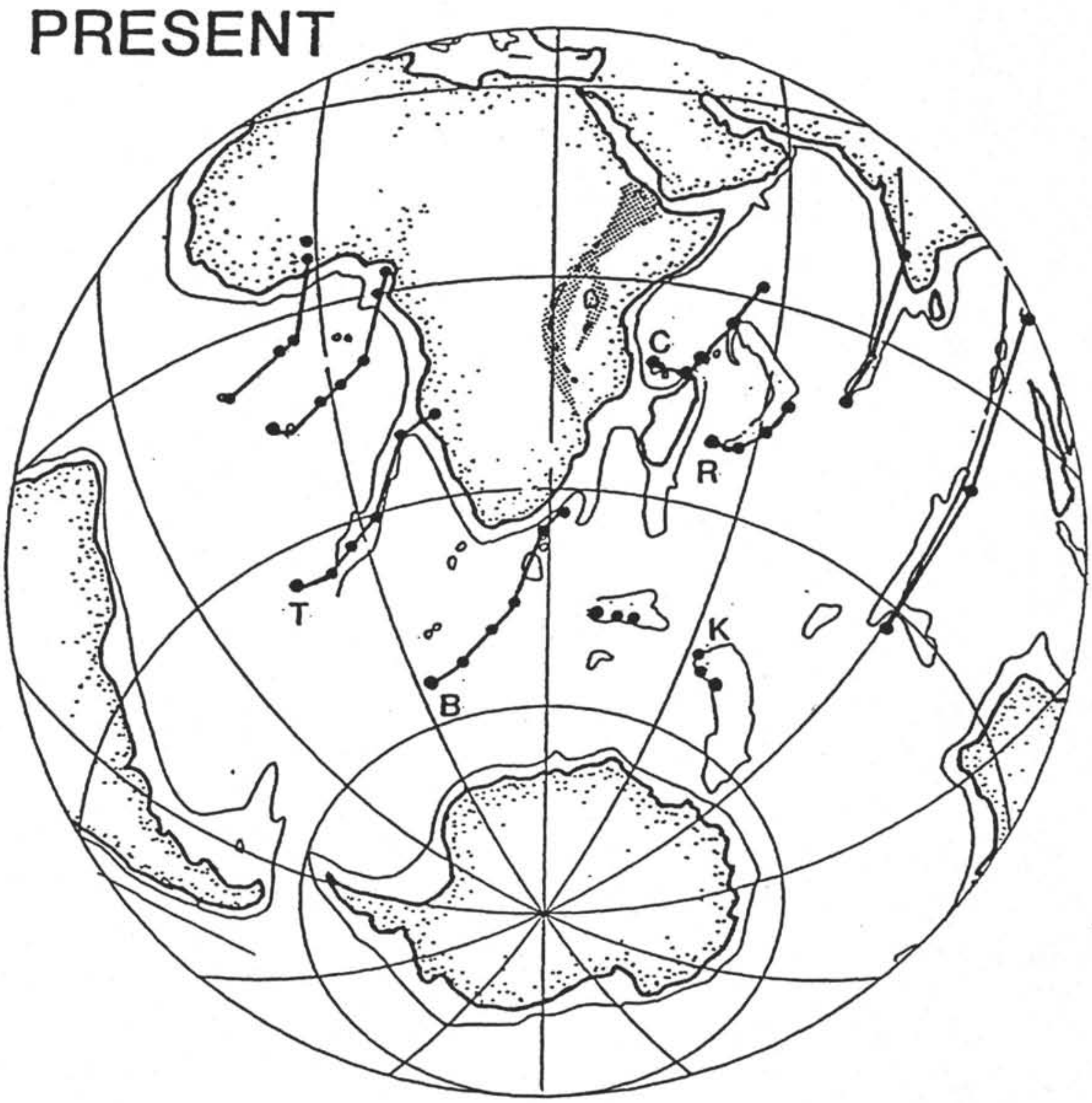



Fig.4 . Predicted hotspot tracks and the present-day distribution of aseismic ridges in the Indian and South Atlantic Oceans. Letters refer to Reunion (R), Comores (C), Kerguelen (K), Bouvet (B), and Tristan (T) hotspots. From Emerick (1985).

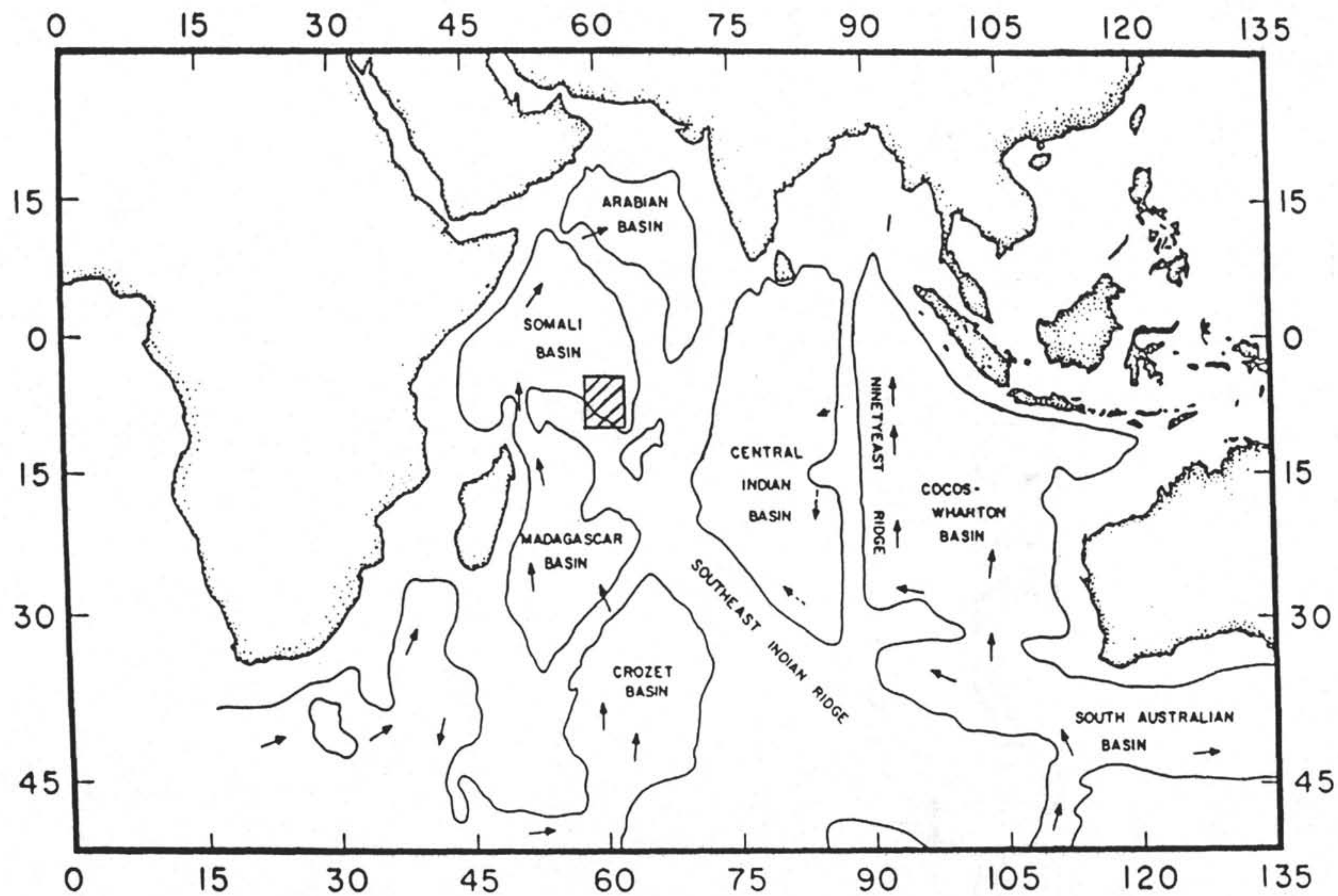



Figure 5: Index map of major basins and ridges in the Indian Ocean, including an approximation of the 4 km isobath (after Wyrtki, 1971). Arrows indicate generalized modern flow paths of bottom water entering the Indian Ocean. Hachured box delineates the northeastern margin of the Mascarene Plateau, the proposed target area for a low-latitude HPC depth transect.

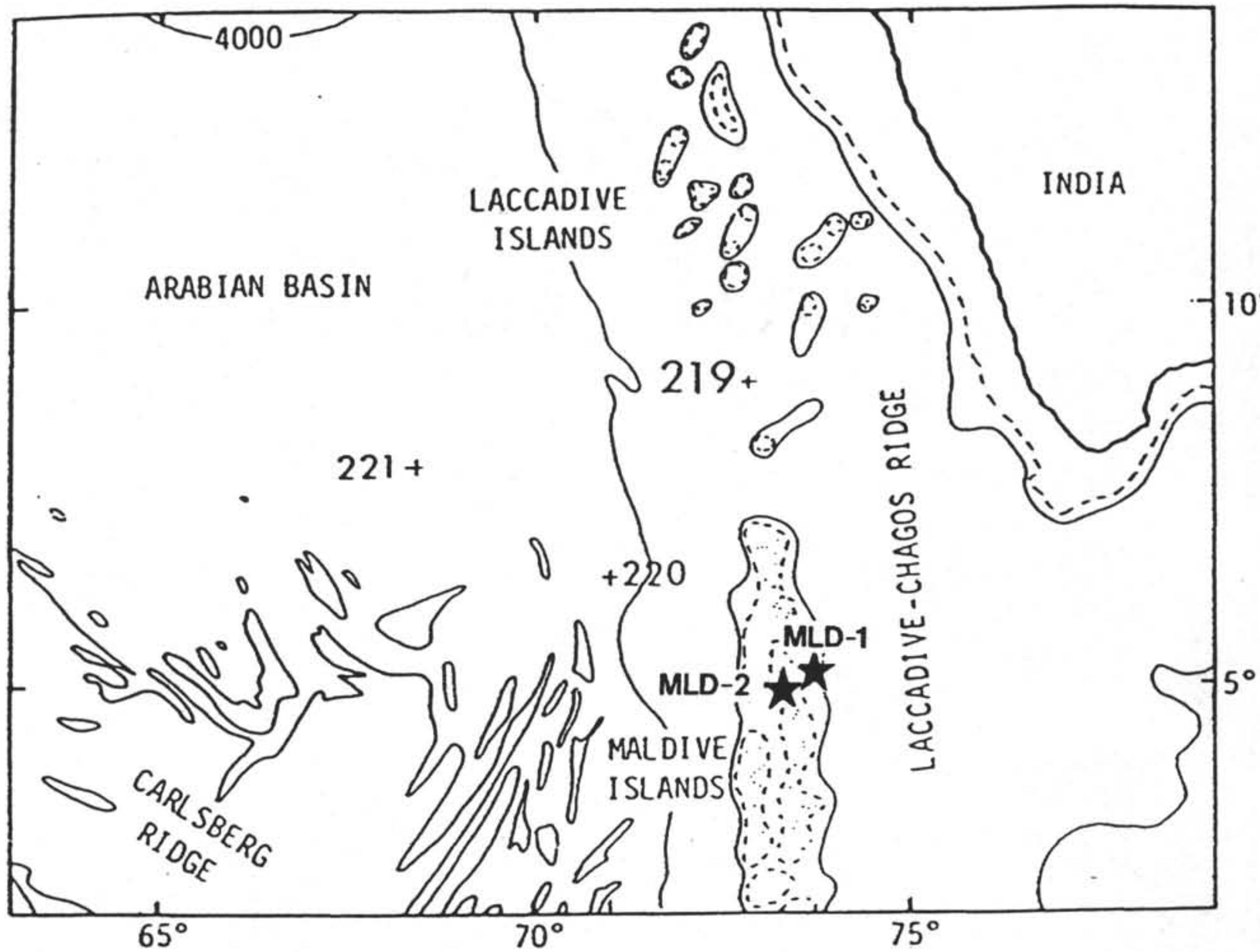



**Fig. 6.** Location of proposed ODP drilling sites MLD-1 and MLD-2 in the Maldive Islands. (after Laughton et al., 1971)

TABLE 1: LOCATION OF PROPOSED SITES FOR LEG 115

| SITE | LOCATION | WATER DEPTH (M) | PENETRATION SEDIMENT (M) | BASEMENT (M) | OPERATIONS |
|---|---|---|---|---|---|
| MP-1 | 18° 25.5'S<br>59° 09.0'E | 2714 | 170 | 50 | APC/RCB |
| MP-2 | 15° 36.5'S<br>61° 45.5'E | 2650 | 250 | 50 | APC/RCB<br>Logging |
| MP-3 | 13° 10.0'S<br>61° 23.0'E | 2240 | 280 | 50 | APC/RCB<br>Logging |
| MP-3A | 12° 54.0'S<br>61° 17.0'E | 2350 | 300 | 50 | APC/RCB<br>Logging |
| CARB-1 | 07° 36.0'S<br>58° 58.5'E | 1496 | 280 | 50 | double APC/XCB<br>RCB; Logging |
| CARB-1A | 07° 37.0'S<br>58° 47.0'E | 1410 | 250 | 50 | double APC/XCB<br>RCB; Logging |
| CARB-2 | 07° 16.5'S<br>59° 18.0'E | 2400 | 250 | -- | double APC/XCB |
| CARB-2A | 04° 00.0'S<br>60° 31.0'E | 3180 | 250 | -- | double APC/XCB |
| CARB-3 | 04° 19.0'S<br>60° 49.0'E | 3800 | 250 | -- | double APC/XCB |
| CARB-4 | 05° 25.2'S<br>59° 56.4'E | 4075 | 250 | -- | double APC/XCB |
| CARB-4A | 05° 43.2'S<br>59° 56.5'E | 4060 | 250 | -- | double APC/XCB |
| CARB-4B | 02° 39.6'S<br>61° 10.8'E | 4350 | 250 | -- | double APC/XCB |
| CARB-4C | 02° 09.0'S<br>61° 21.6'E | 4630 | 250 | -- | double APC/XCB |
| MLD-1 | 04° 56.0'S<br>73° 17.0'E | 520 | 250 | -- | double APC/XCB |
| MLD-2 | 05° 12.5'N<br>73° 44.0'E | 1500 | 250 | -- | double APC/XCB |

TABLE 2A: PROPOSED LEG 115 DRILLING PROGRAM

| Site | Location | Travel Time (days) | Time at Site (days) | Date (approximate) |
|---|---|---|---|---|
| Depart: | Port Louis Mauritius | | | May 21, 1987 |
| Transit | | 0.5 | | |
| MP-1 | 18° 25.5'S 59° 09.0'E | | 2.8 | May 25, 1987 |
| Transit: | | 0.9 | | |
| MP-2 | 15° 36.5'S 61° 45.5'E | | 4.8 | |
| Transit: | | 0.6 | | |
| MP-3 | 13° 10.0'S 61° 23.0'E | | 4.7 | |
| Transit: | | 1.5 | | |
| CARB-1 | 07° 36.0'S 58° 58.5'E | | 4.7 | |
| Transit: | | 0.1 | | |
| CARB-2 | 07° 16.5'S 59° 18.0'E | | 1.7 | |
| Transit: | | 0.8 | | |
| CARB-3 | 04° 19.0'S 60° 49.0'E | | 2.6 | |
| Transit: | | 0.4 | | |
| CARB-4 | 05° 25.2'S 59° 56.4'E | | 2.8 | |
| Transit: | | 4.3 | | |
| MLD-2 | 05° 12.5'N 73° 44.0'E | | 1.5 | |
| Transit: | | 1.6 | | |
| Arrive: | Colombo, Sri Lanka | | | July 2, 1987 |
| | | 10.7 | 25.6 | * 36.3 Days |

* 36 operational days estimated (out of total of 42 days).

* (Includes 4.5 days if MP-2, MP-3, and CARB-1 logged)

TABLE 2B: PROPOSED LEG 115 DRILLING PROGRAM

ALTERNATE SITES

| | Location | Drilling Time (days) |
|---|---|---|
| MP-3A | 12° 54.0'S<br>61° 17.0'E | 3.6 |
| CARB-1A | 07° 37.0'S<br>58° 47.0'E | 1.3 |
| CARB-2A | 04° 00.0'S<br>60° 31.0'E | 1.9 |
| CARB-4A | 05° 43.2'S<br>59° 56.5'E | 2.6 |
| CARB-4B | 02° 39.6'S<br>61° 10.8'E | 2.7 |
| CARB-4C | 02° 09.0'S<br>61° 21.6'E | 2.8 |
| MLD-1 | 04° 56.0'N<br>73° 17.0'E | 1.5 |

SITE NUMBER: MP-1 (Intersection of Rodrigues Ridge and Mascarene Plateau).

POSITION: $18^{o}$ 25.5'S
$59^{o}$ 09.0'E

SEDIMENT THICKNESS: 170 m

WATER DEPTH: 2714 m

PRIORITY: 1

PROPOSED DRILLING PROGRAM: APC to 150 m, then single bit, RCB coring 50 m into basement.

SEISMIC RECORD: R.R.S. Darwin, March 1987 at 2030.

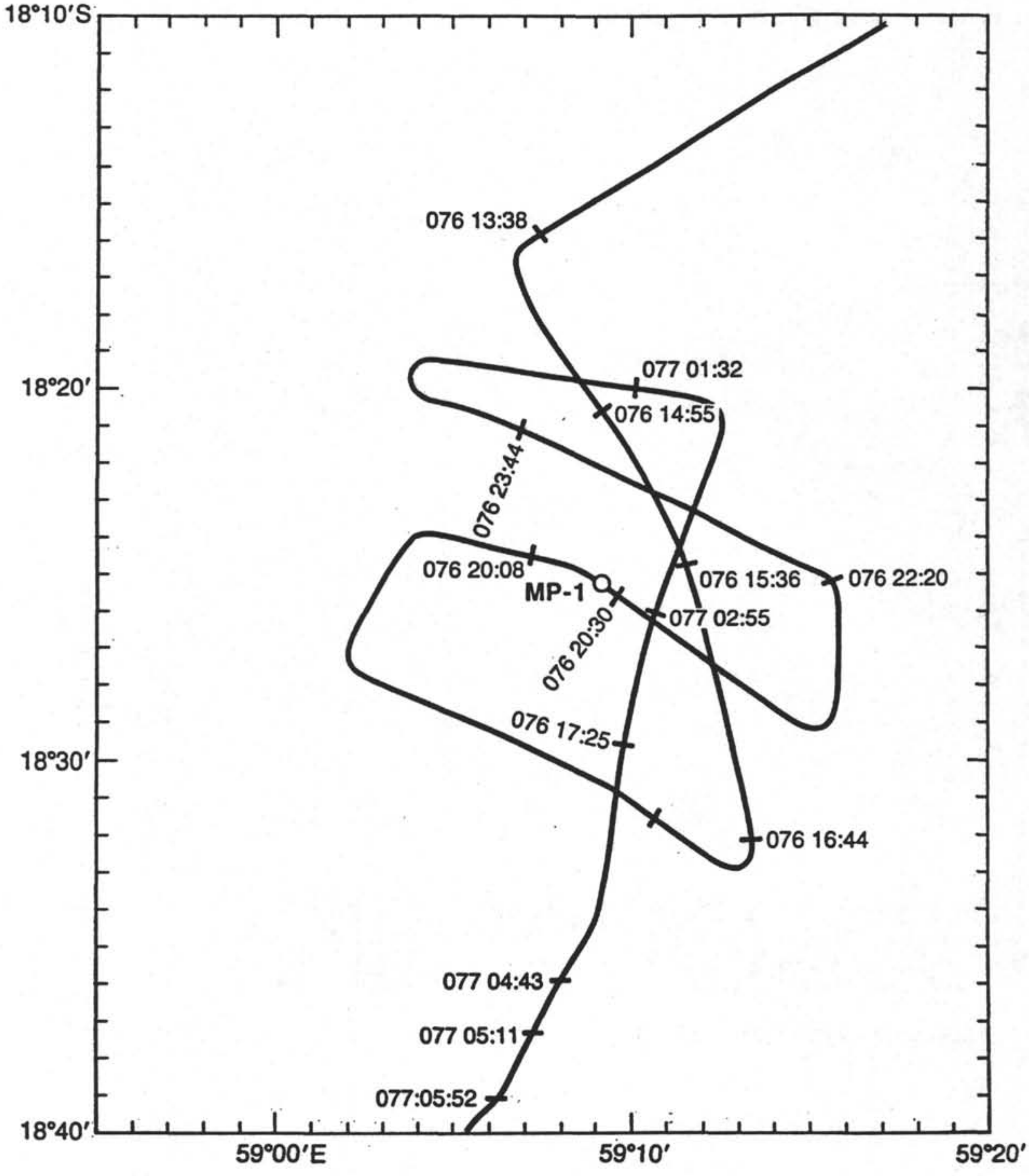
HEAT FLOW: No

LOGGING: No

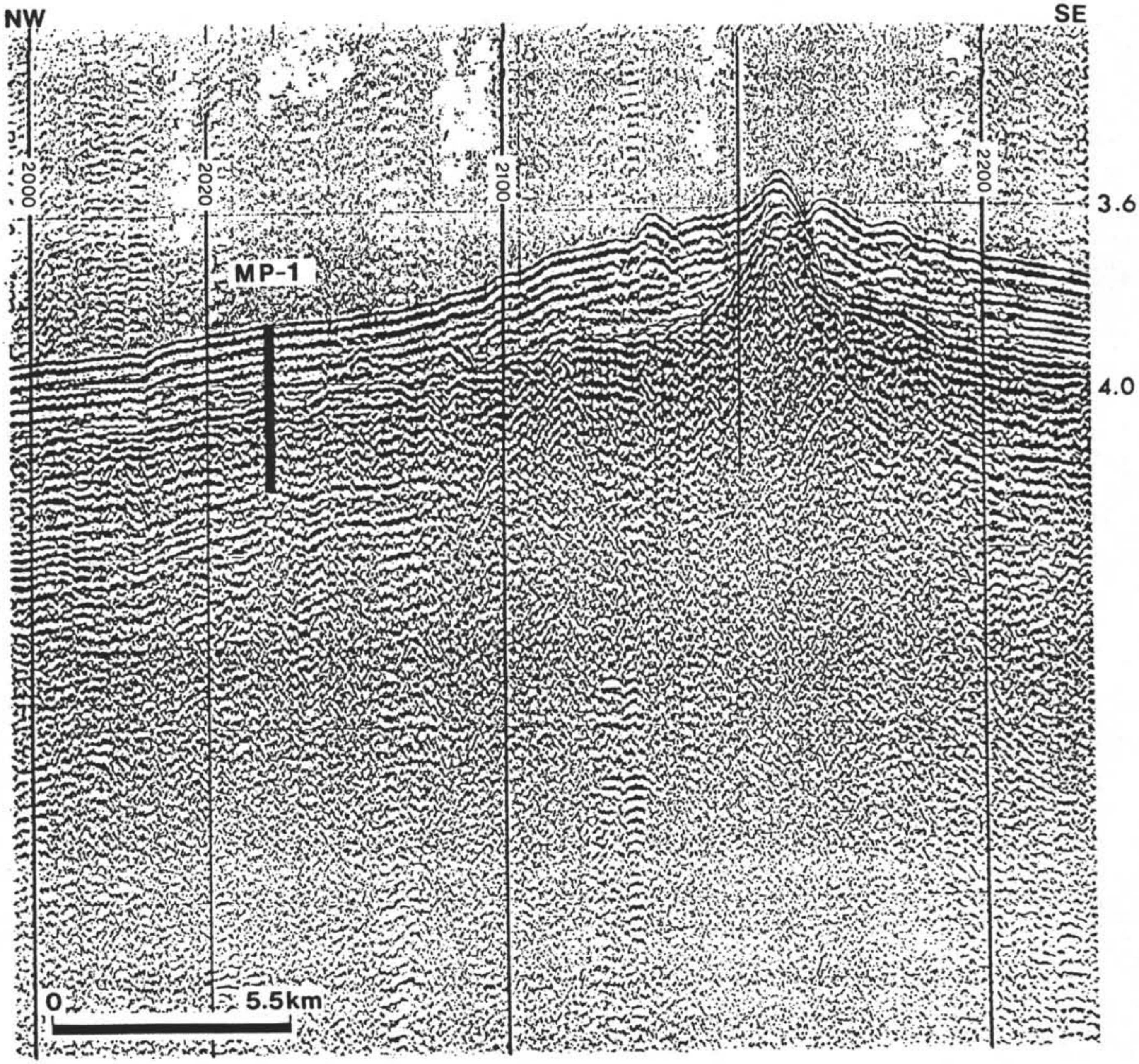
OBJECTIVES: (1) Geochemical analysis and dating of basaltic rocks for comparison with other oceanic hotspots and to determine paleolatitudes, respectively
(2) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.

BASEMENT TYPE: Basalt




R.R.S. Darwin seismic survey line for Site MP-1.


NW
SE
2000
2020
2100
2200
3.6
4.0
MP-1
0
5.5km

SITE NUMBER: MP-2 (S.E. boundary of Nazareth Bank, Mascarene Plateau)

POSITION: 15° 36.5'S
61° 45.5'E

SEDIMENT THICKNESS: 250 m

WATER DEPTH: 2650 m

PRIORITY: 1

PROPOSED DRILLING PROGRAM: APC to 150 m, then single bit, RCB coring 50 m into basement.

SEISMIC RECORD: R.R.S. Darwin, March 1987 at 1250.

HEAT FLOW: No

LOGGING: Standard Schlumberger tool combination: seismic stratigraphic, litho-porosity and geochemical.

OBJECTIVES: (1) Geochemical analysis and dating of basaltic rocks for comparison with other oceanic hotspots and to determine paleolatitudes, respectively
(2) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.

BASEMENT TYPE: Basalt

SITE NUMBER: MP-3 (N. margin Nazareth Bank, Mascarene Plateau)

POSITION: 13° 10'S
61° 23'E

SEDIMENT THICKNESS: 280 M

WATER DEPTH: 2240 M

PRIORITY: 1

PROPOSED DRILLING PROGRAM: APC to 150 m, then single bit, RCB coring 50 m into basement.

SEISMIC RECORD: R.R.S. Darwin, March 1987 at 0440.

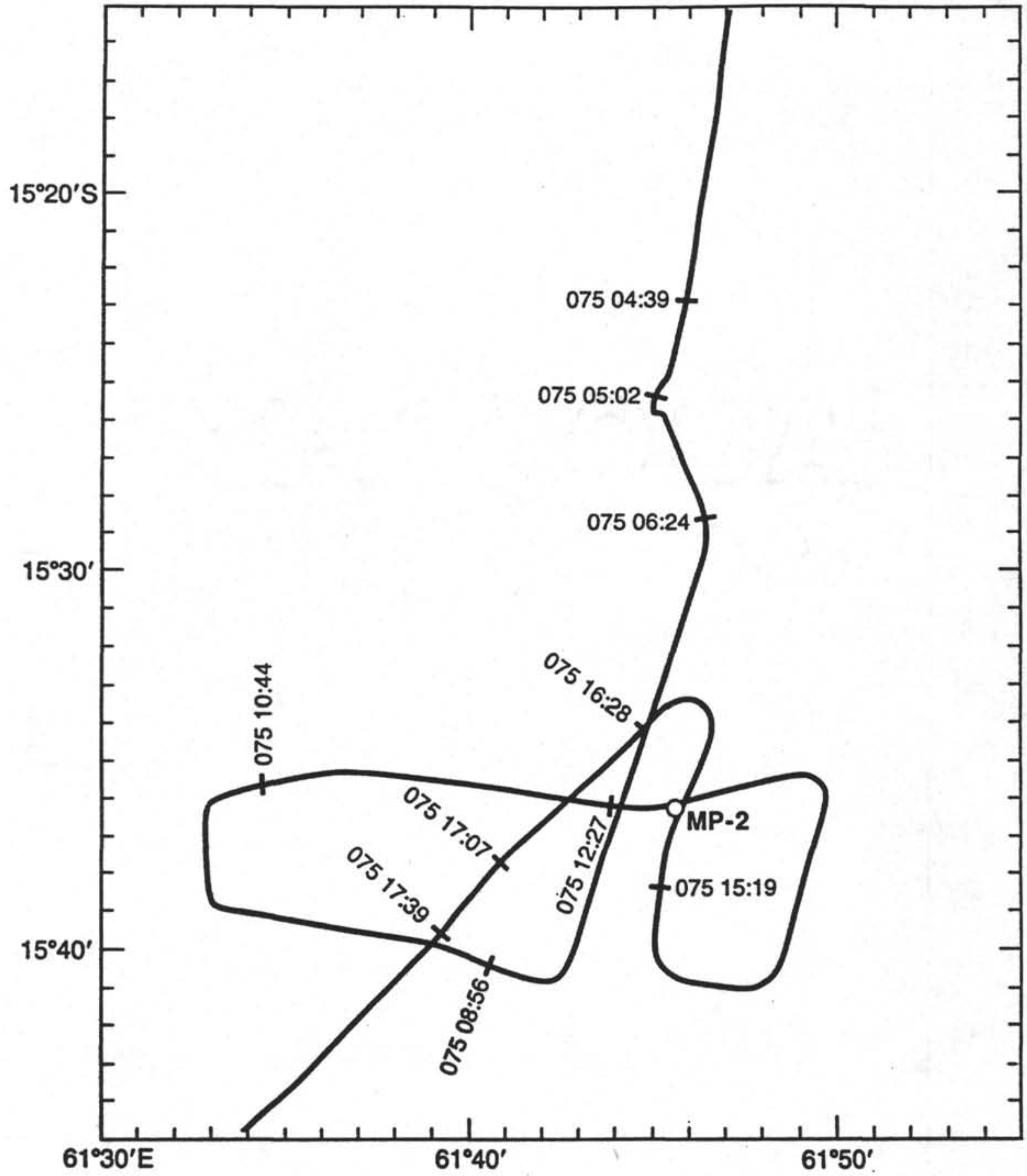
HEAT FLOW: NO

LOGGING: Standard Schlumberger tool combination: seismic stratigraphic, litho-porosity and geochemical.

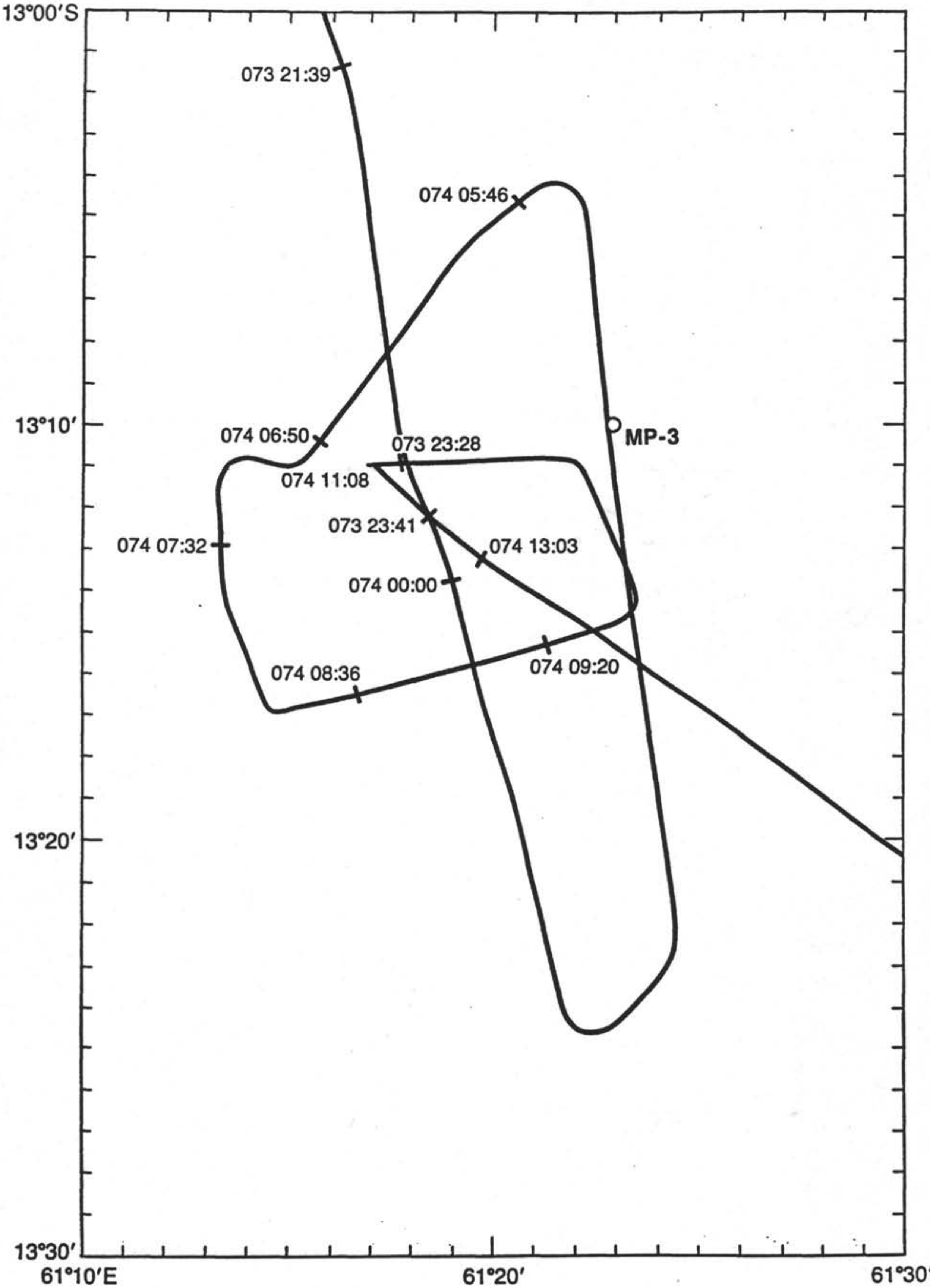
OBJECTIVES: (1) Geochemical analysis and dating of basaltic rocks for comparison with other oceanic hotspots and to determine paleolatitudes, respectively
(2) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.

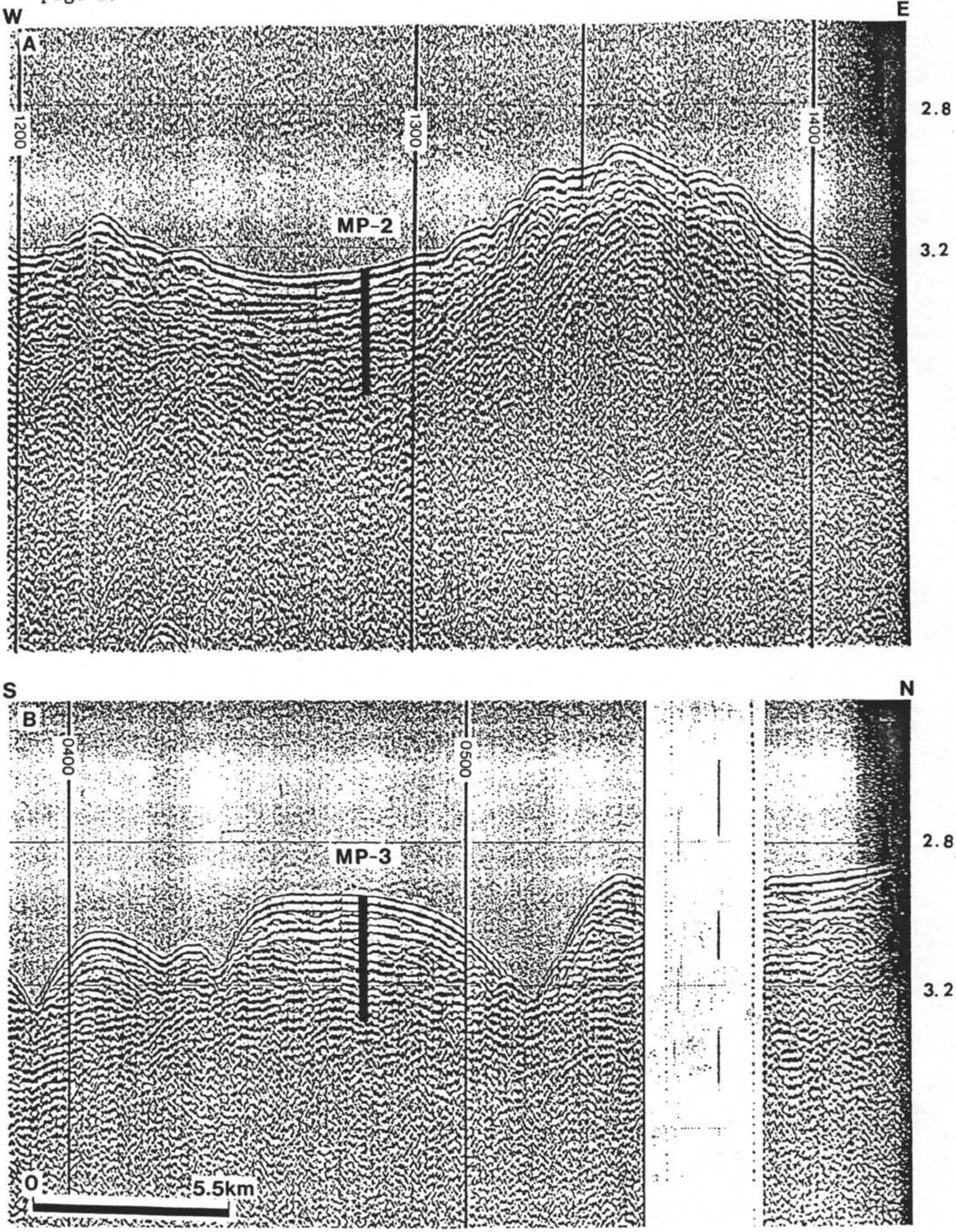
BASEMENT TYPE: Basalt




R.R.S. Darwin seismic survey line for Site MP-2.




R.R.S. Darwin seismic survey line for Site MP-3.


W
E
A
1200
1300
1400
2.8
MP-2
3.2
S
N
B
0400
0500
2.8
MP-3
3.2
0
5.5km

SITE NUMBER: MP-3A (N. margin Nazareth Bank, Mascarene Plateau)

POSITION: $12^{o}$ 54'S
$61^{o}$ 17'E

SEDIMENT THICKNESS: 300 m

WATER DEPTH: 2350 m

PRIORITY: 1 (Alternate)

PROPOSED DRILLING PROGRAM: APC to 150 m, then single bit, RCB coring 50 m into basement.

SEISMIC RECORD: R.R.S. Darwin, March 1987 at 1725.

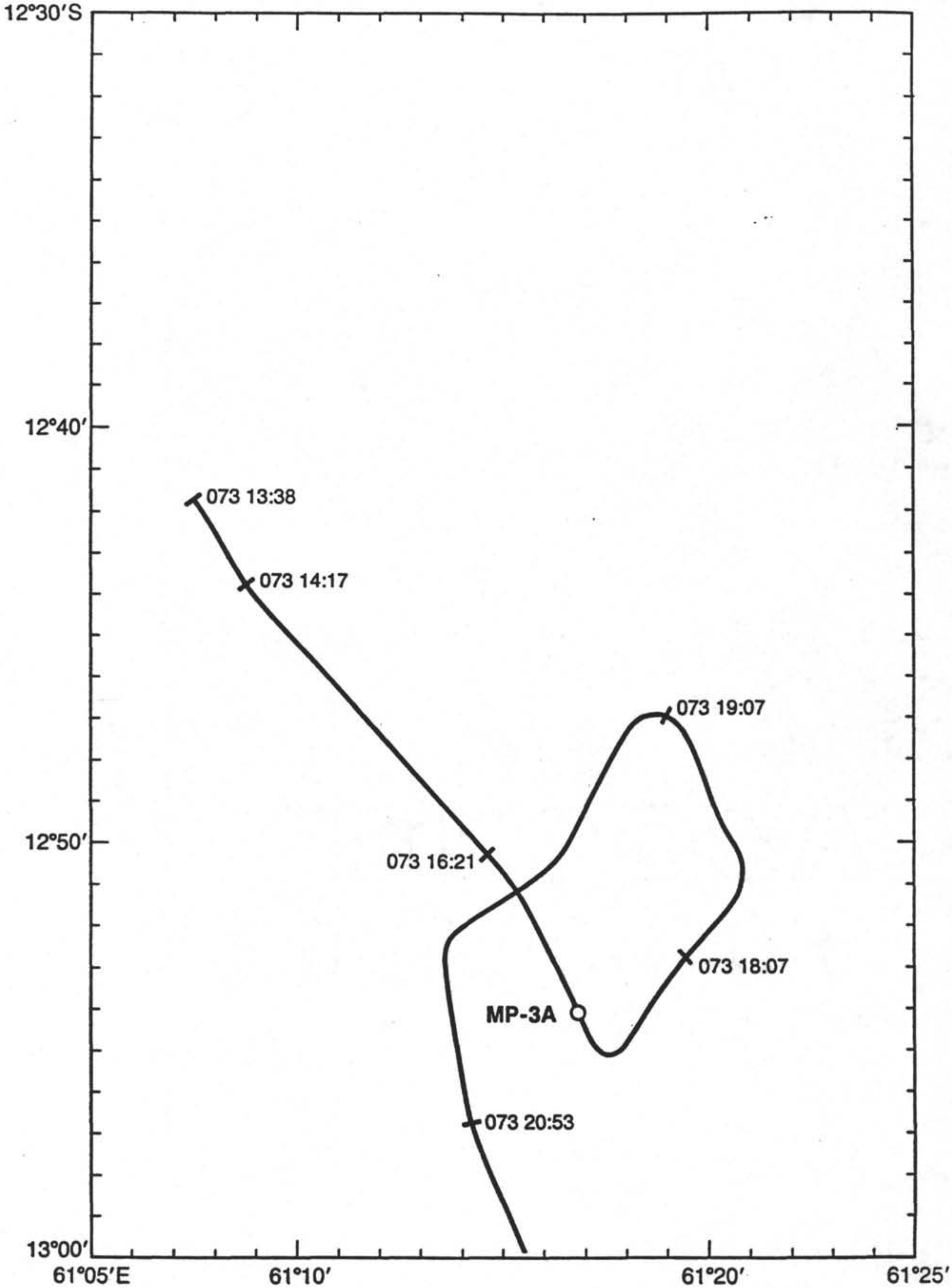
HEAT FLOW: No

LOGGING: Standard Schlumberger tool combination: seismic stratigraphic, litho-porosity and geochemical.

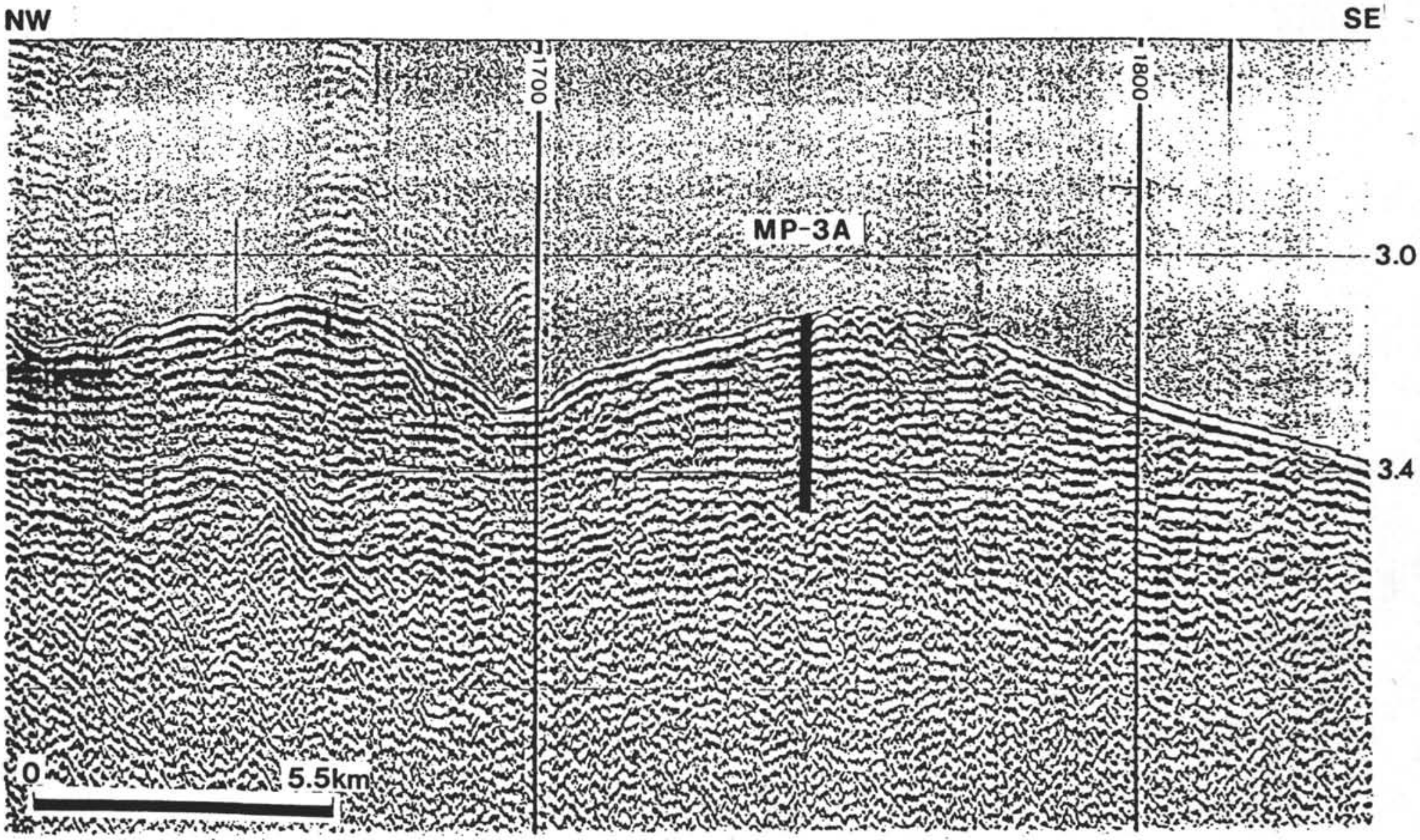
OBJECTIVES: (1) Geochemical analysis and dating of basaltic rocks for comparison with other oceanic hotspots and to determine paleolatitudes, respectively
(2) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.

BASEMENT TYPE: Basalt




R.R.S. Darwin seismic survey line for Site MP-3A.


NW
SE
1700
1800
MP-3A
3.0
3.4
0
5.5km

SITE NUMBER: CARB-1 (Mascarene Plateau on saddle between the Seychelles and Saya de Malha Bank)

POSITION: $07^{o}$ 36.0'S $58^{o}$ 58.5'E

SEDIMENT THICKNESS: 280 m

WATER DEPTH: 1496 m

PRIORITY: 1

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters, then RCB about 50 m into basement.

SEISMIC RECORD: R.R.S. Darwin March 1987 at 0025.

HEAT FLOW: No

LOGGING: Standard Schlumberger tool combination: seismic stratigraphic, litho-porosity and geochemical.

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.
(2) Geochemical analysis and dating of basaltic rocks for comparison with other oceanic hotspots and to determine paleolatitudes, respectively.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.

BASEMENT TYPE: Basalt

SITE NUMBER: CARB-2 (Mascarene Plateau on saddle between Seychelles and Saya de Malha Bank)

POSITION: 07° 16.5'S
59° 18.0'E

SEDIMENT THICKNESS: 410 m

WATER DEPTH: 2400 m

PRIORITY: 1

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters.

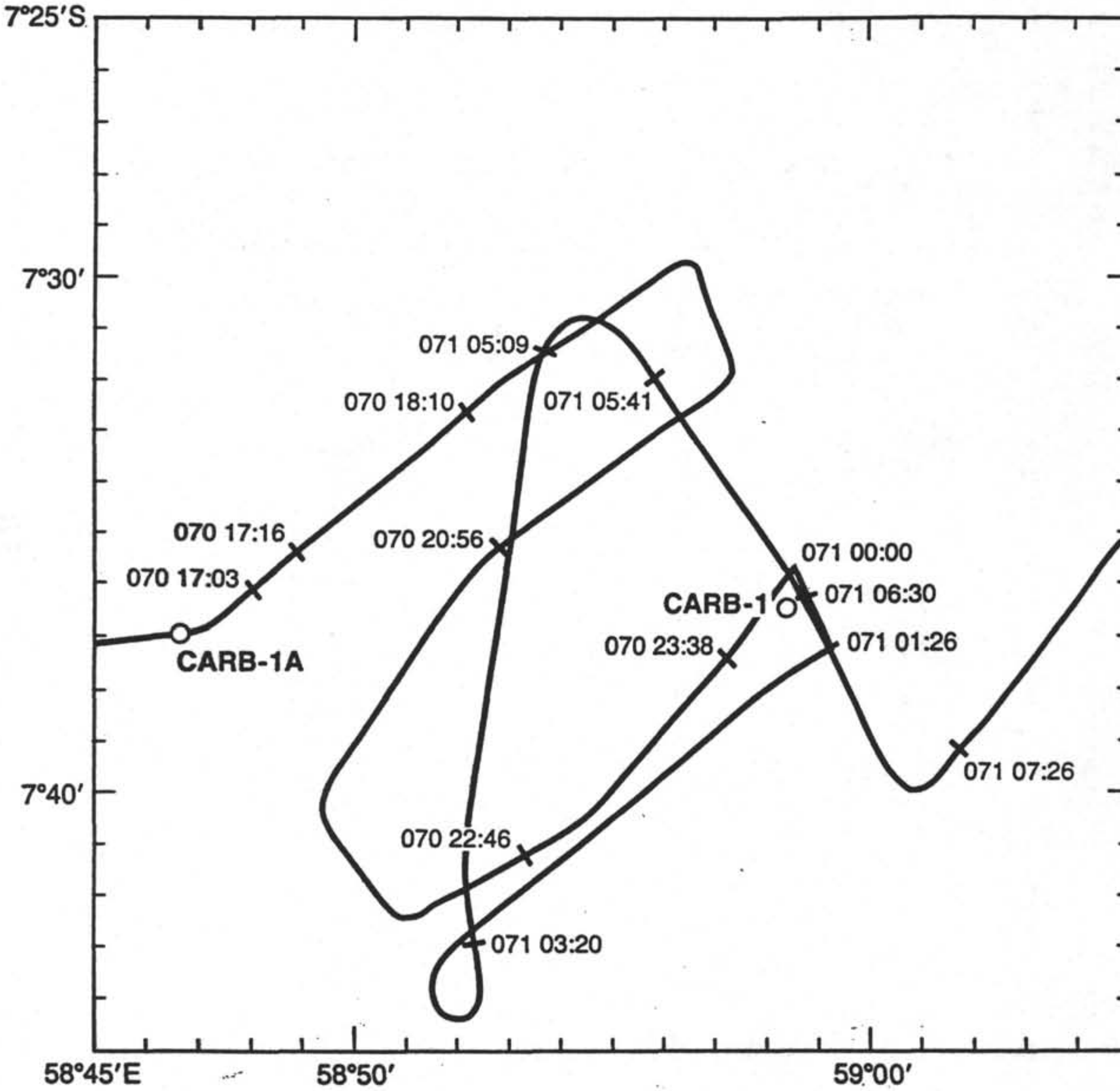
SEISMIC RECORD: R.R.S. Darwin March 1987 at 1150.

HEAT FLOW: No

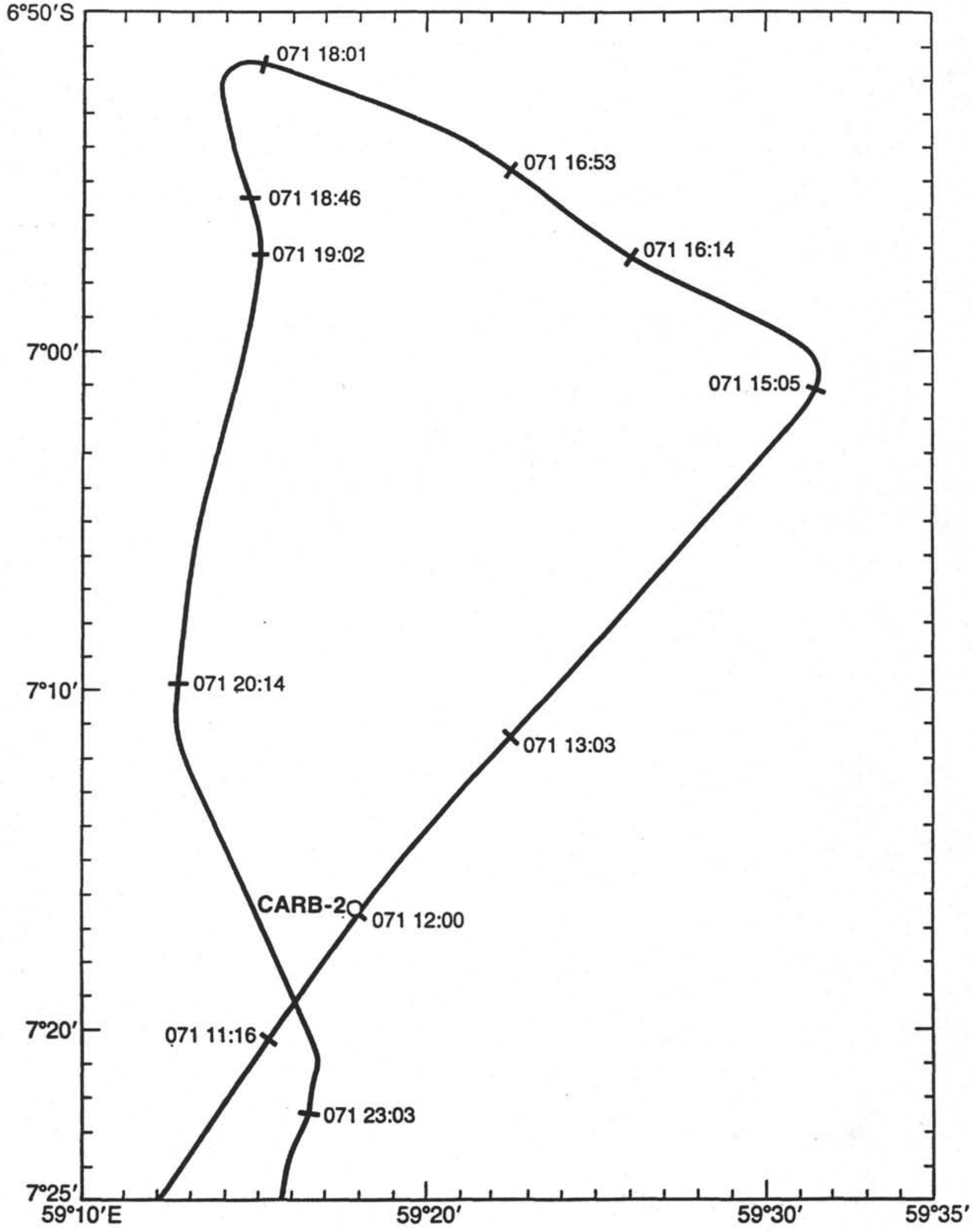
LOGGING: No

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

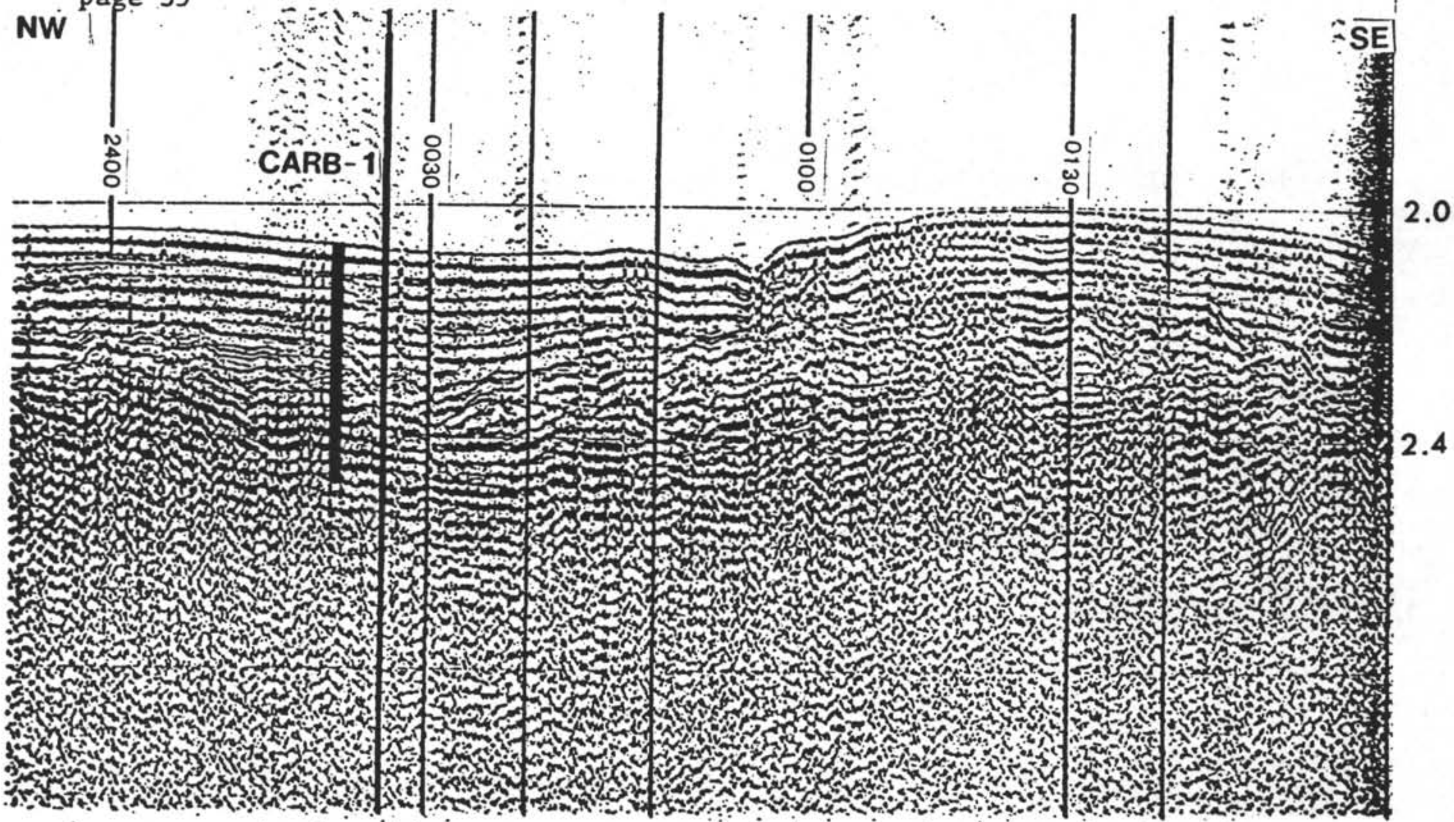
SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.

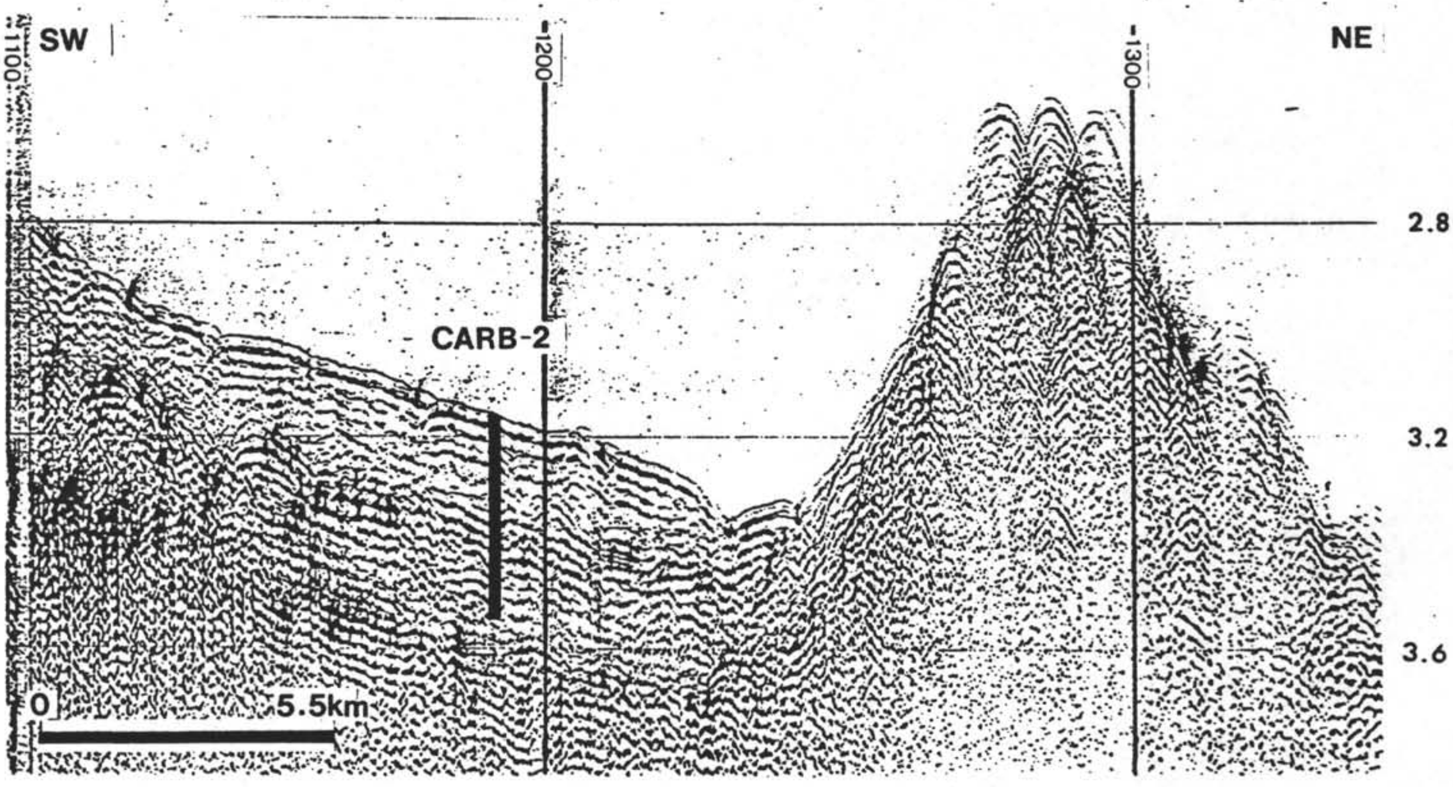



R.R.S. Darwin seismic survey line for Site CARB-1 and CARB-1A.




R.R.S. Darwin seismic survey line for Site CARB-2.


NW
SE
2400
CARB-1
0030
0100
0130
2.0
2.4


SW
NE
1100
1200
1300
CARB-2
2.8
3.2
3.6
0
5.5km

SITE NUMBER: CARB-1A (Mascarene Plateau on saddle between Seychelles and Saya de Malha Bank)

POSITION: 07° 37'S
58° 47'E

SEDIMENT THICKNESS: 400 m

WATER DEPTH: 1410 m

PRIORITY: 1 (Alternate)

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters, then RCB about 50 m into basement.

SEISMIC RECORD: R.R.S. Darwin March 1987 at 1710.

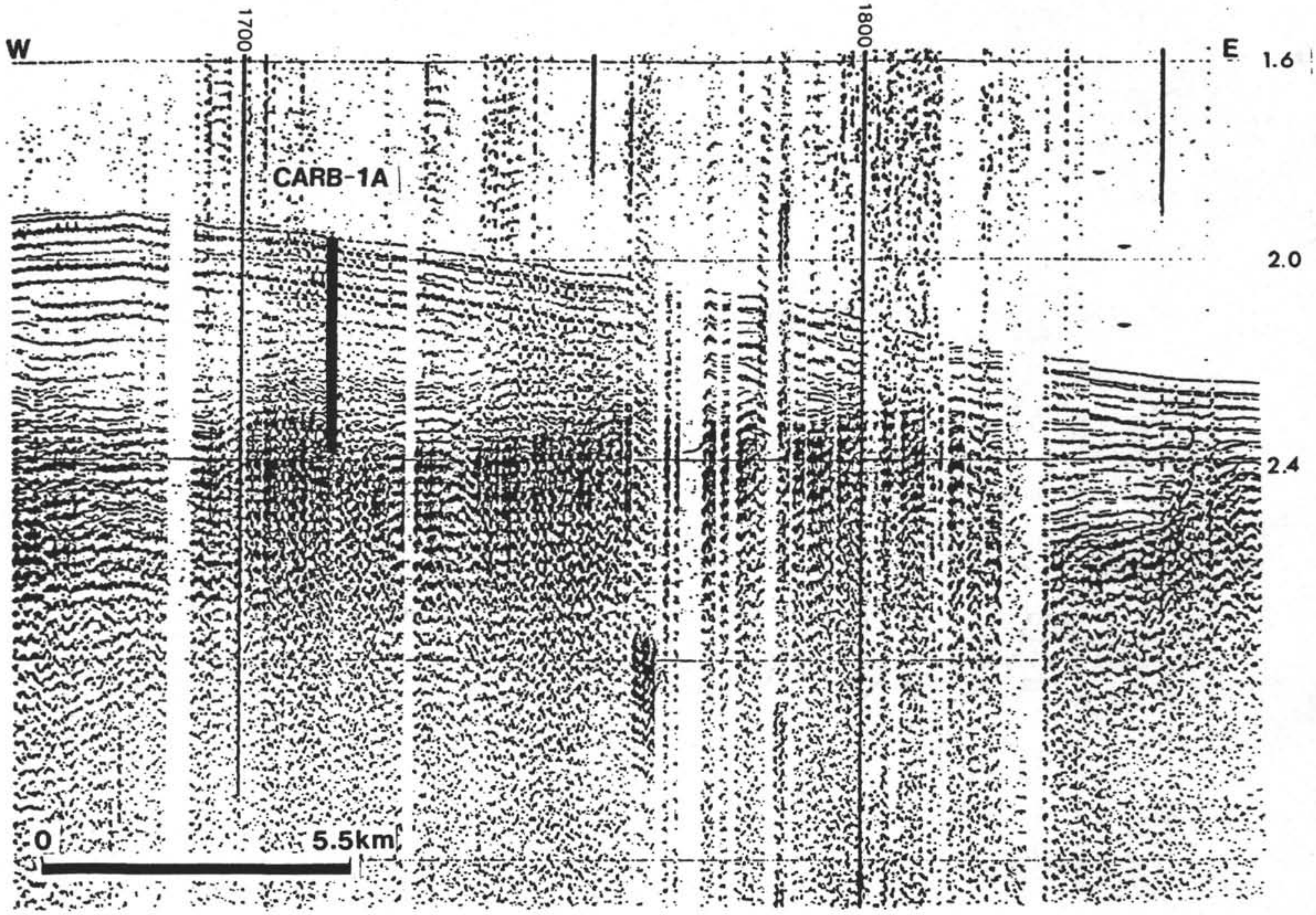
HEAT FLOW: No

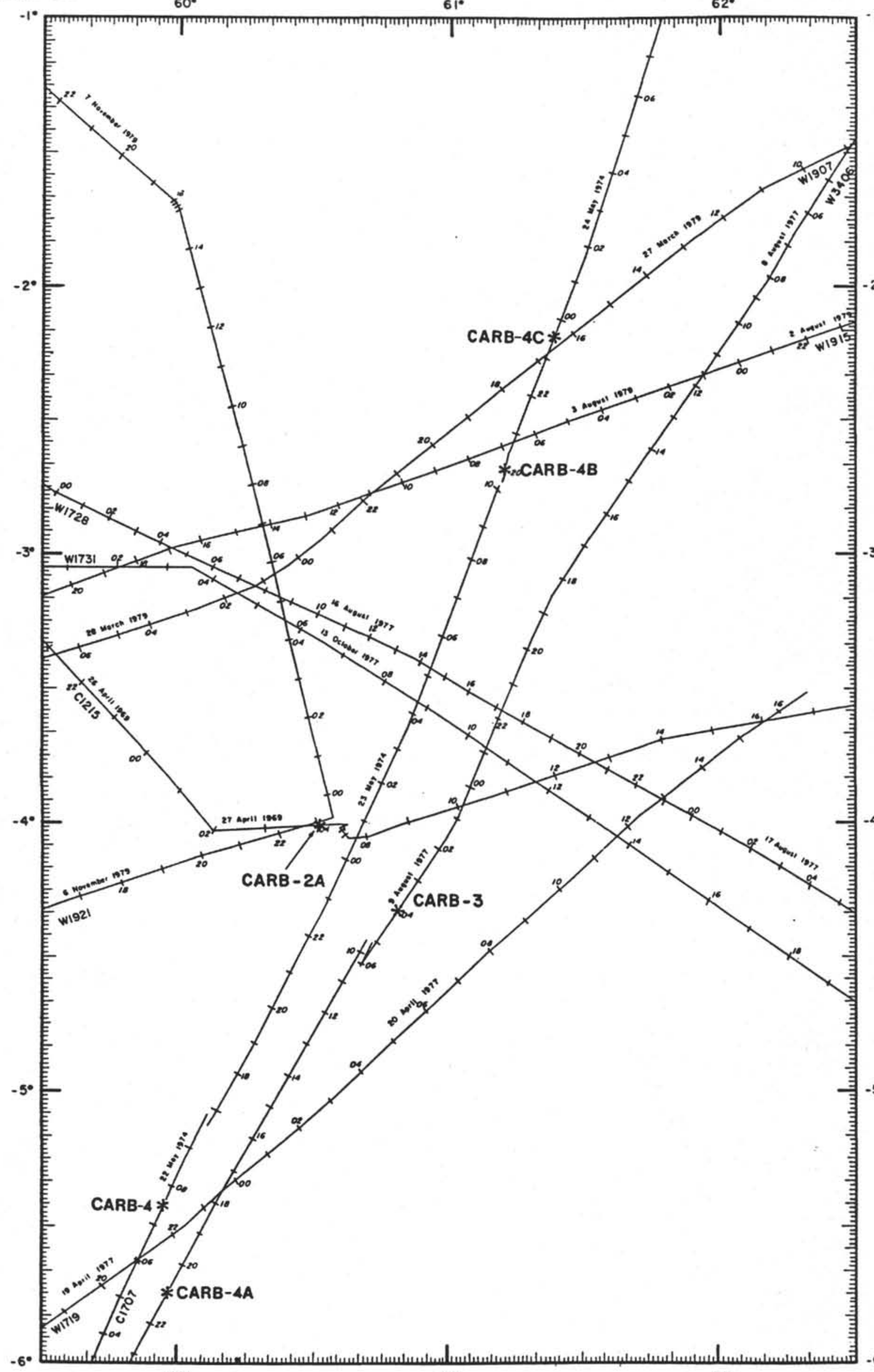
LOGGING: Standard Schlumberger tool combination: seismic stratigraphic, litho-porosity and geochemical.

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.
(2) Geochemical analysis and dating of basaltic rocks for comparison with other oceanic hotspots and to determine paleolatitudes, respectively.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.

BASEMENT TYPE: Basalt


W
1700
1800
E
1.6
CARB-1A
2.0
2.4
0
5.5km



60°
61°
62°
-1°
-2°
-3°
-4°
-5°
-6°
CARB-4C
CARB-4B
CARB-2A
CARB-3
CARB-4
CARB-4A
W1907
W3406
W1915
W1728
W1731
C1215
W1921
W1719
C1707
7 November 1979
24 May 1974
27 March 1979
8 August 1977
2 August 1979
3 August 1979
28 March 1979
16 August 1977
13 October 1977
25 April 1969
27 April 1969
6 November 1979
23 May 1974
9 August 1977
17 August 1977
20 April 1977
22 May 1974
19 April 1977

SITE NUMBER: CARB-2A (On Maddingley Rise, north of Mascarene Plateau)

POSITION: 04° 00'S
60° 31'E

SEDIMENT THICKNESS: 350 m

WATER DEPTH: 3180 m

PRIORITY: 1 (Alternate)

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters.

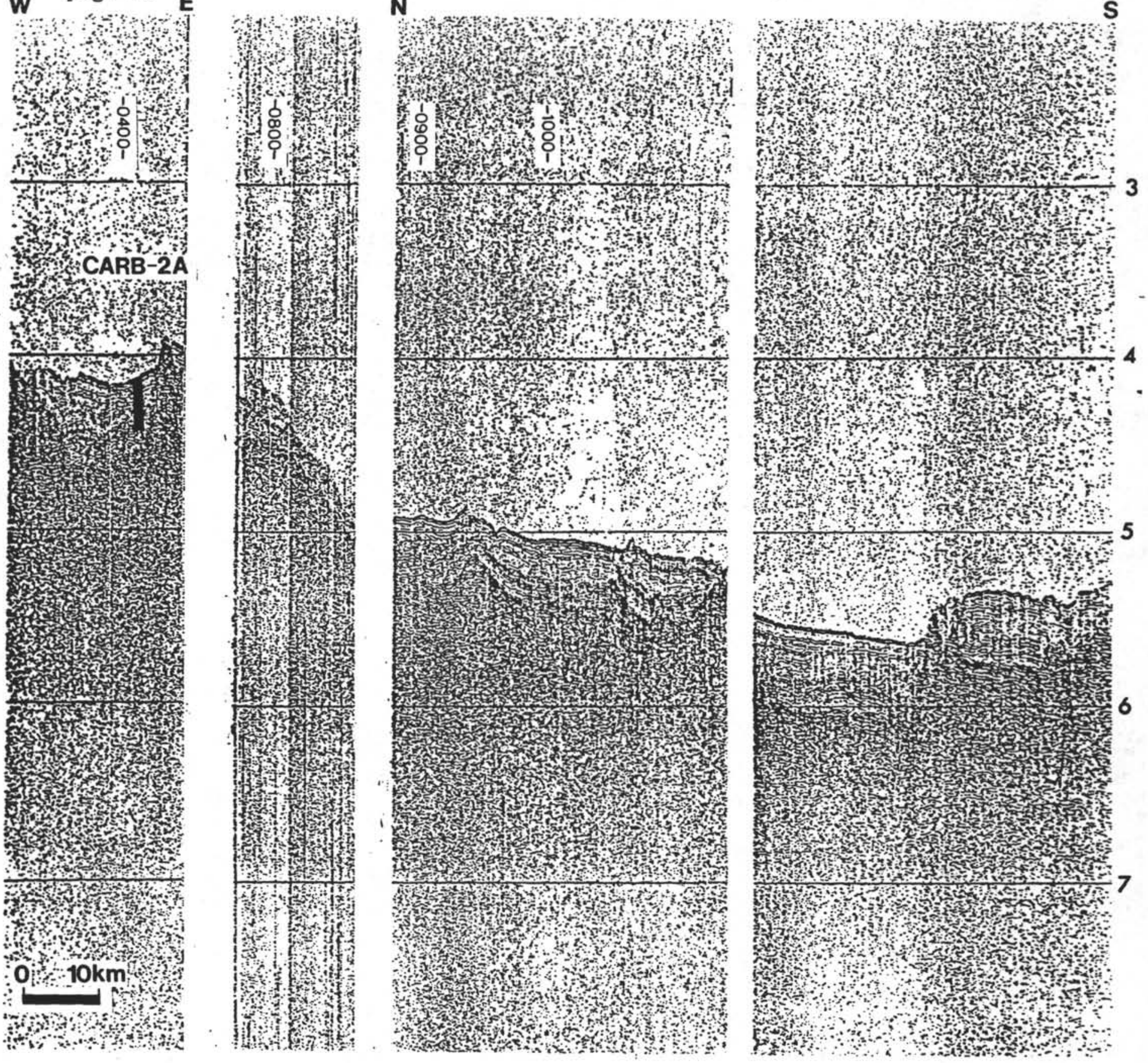
SEISMIC RECORD: Conrad 1215, 27 April 1969 at 0400 Z. Near Wilkes 921, 6 November 1979 at 2255 Z.

HEAT FLOW: No

LOGGING: No

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.


W
E
N
S
-0400-
-0800-
-0900-
-1000-
CARB-2A
3
4
5
6
7
0
10km

SITE NUMBER: CARB-3 (On Maddingley Rise, north of Mascarene Plateau)

POSITION: 04° 19'S
60° 49'E

SEDIMENT THICKNESS: 400 m

WATER DEPTH: 3800 m

PRIORITY: 1

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters.

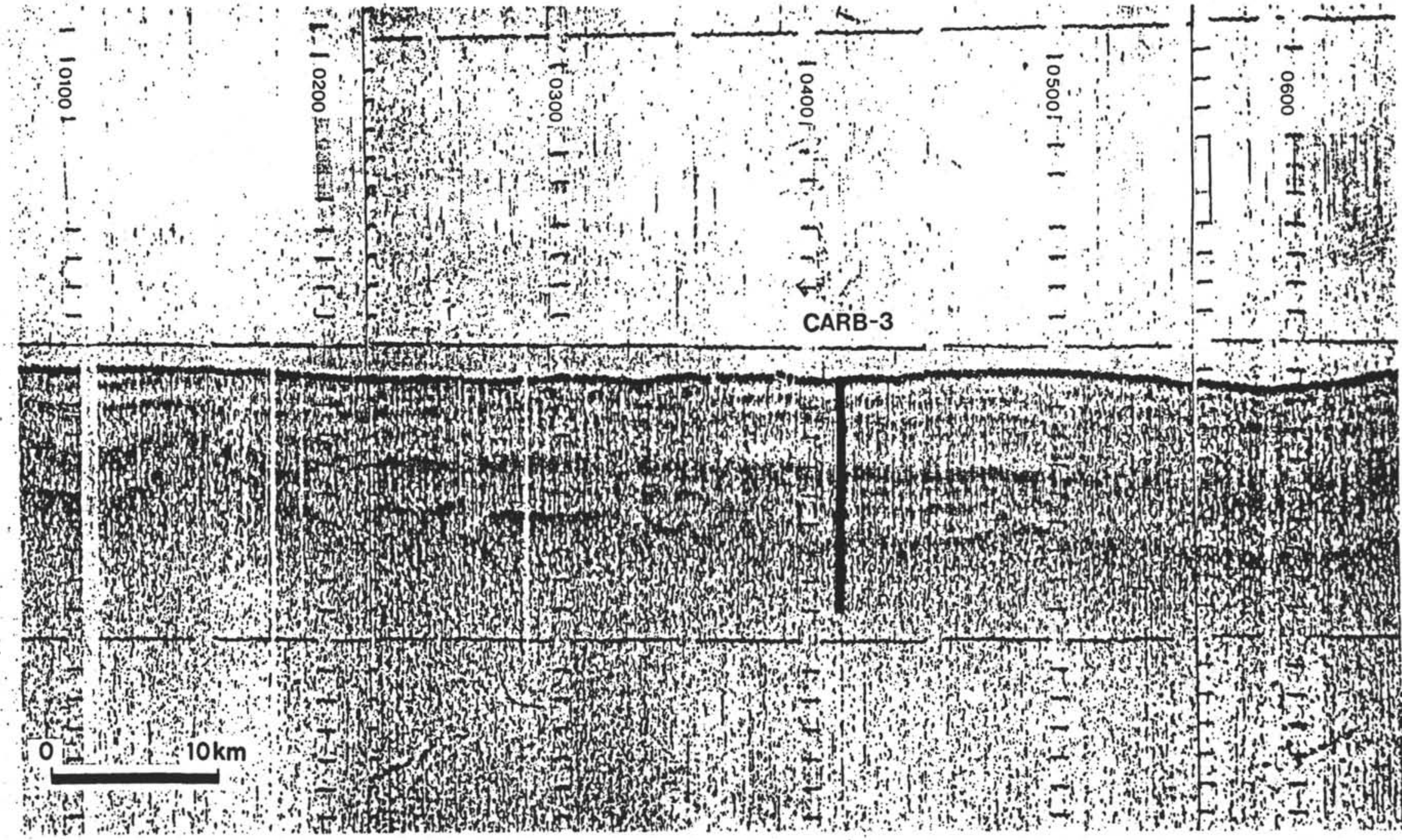
SEISMIC RECORD: Vema 3406, 9 August, 1977, at 0400 Z.

HEAT FLOW: No

LOGGING: No

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.


0100
0200
0300
0400
0500
0600
4
5
6
CARB-3
0
10km

SITE NUMBER: CARB-4 (S.W. boundary of Maddingley Rise)

POSITION: 05° 25.2'S
59° 56.4'E

SEDIMENT THICKNESS: >400 m

WATER DEPTH: 4075 m

PRIORITY: 1

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters.

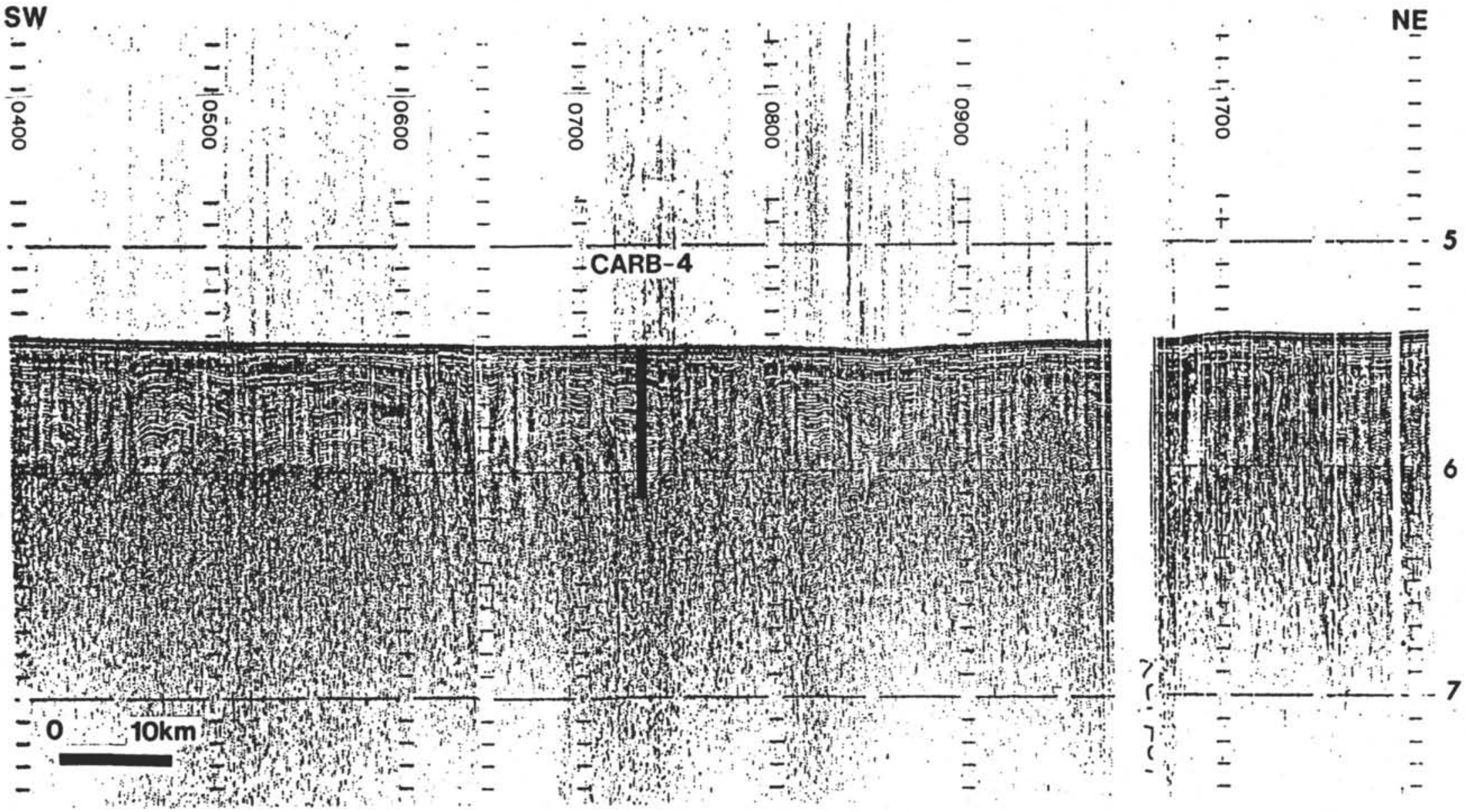
SEISMIC RECORD: Conrad 1707, May 22, 1974 at 730.

HEAT FLOW: No

LOGGING: No

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate sections.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.


SW
NE
0400
0500
0600
0700
0800
0900
1700
CARB-4
5
6
7
0
10km

SITE NUMBER: CARB-4A (S.W. boundary of Maddingley Rise)

POSITION: 05° 43.2'S
59° 56.5'E

SEDIMENT THICKNESS: 500 m

WATER DEPTH: 4060 m

PRIORITY: 1 (Alternate)

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters.

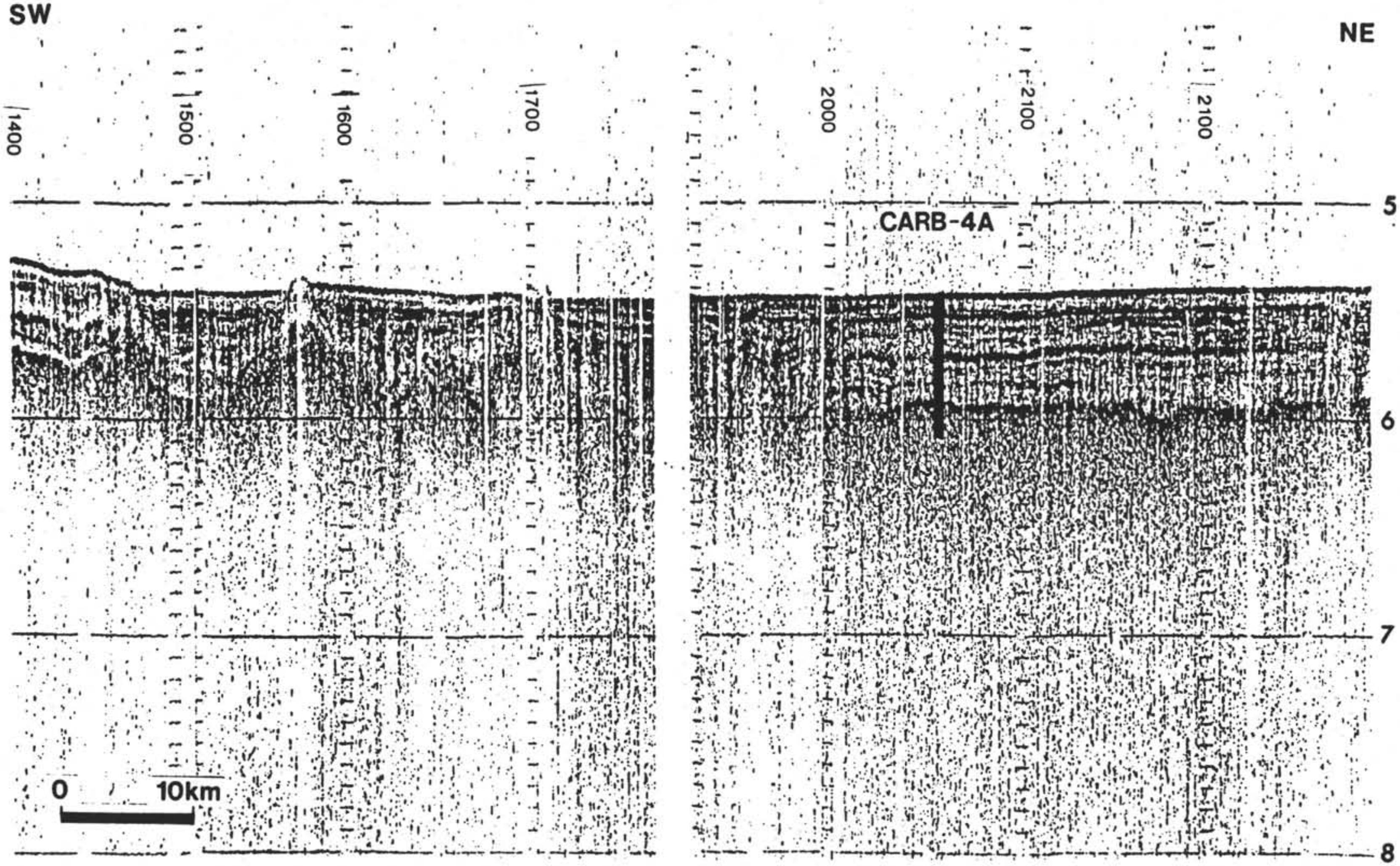
SEISMIC RECORD: Vema 3406, August 9, 1977 at 2045.

HEAT FLOW: No

LOGGING: No

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.


SW
NE
1400
1500
1600
1700
2000
2100
2100
CARB-4A
5
6
7
8
0
10km

SITE NUMBER: CARB-4B (Relatively smooth seafloor north of Madingley Rise)

POSITION: 02° 39.6'S
61° 10.8'E

SEDIMENT THICKNESS: 400 m

WATER DEPTH: 4350 m

PRIORITY: 1 (Alternate)

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters.

SEISMIC RECORD: Conrad 1707, May 1974 at 1930, near Wilkes 915, 23 May 1974.

HEAT FLOW: No

LOGGING: No

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.

SITE NUMBER: CARB-4C (Relatively smooth seafloor north of Madingley Rise)

POSITION: 02° 09.0'S
61° 21.6'E

SEDIMENT THICKNESS: 400 m

WATER DEPTH: 4630 m

PRIORITY: 1 (Alternate)

PROPOSED DRILLING PROGRAM: Double APC/XCB to 250 meters.

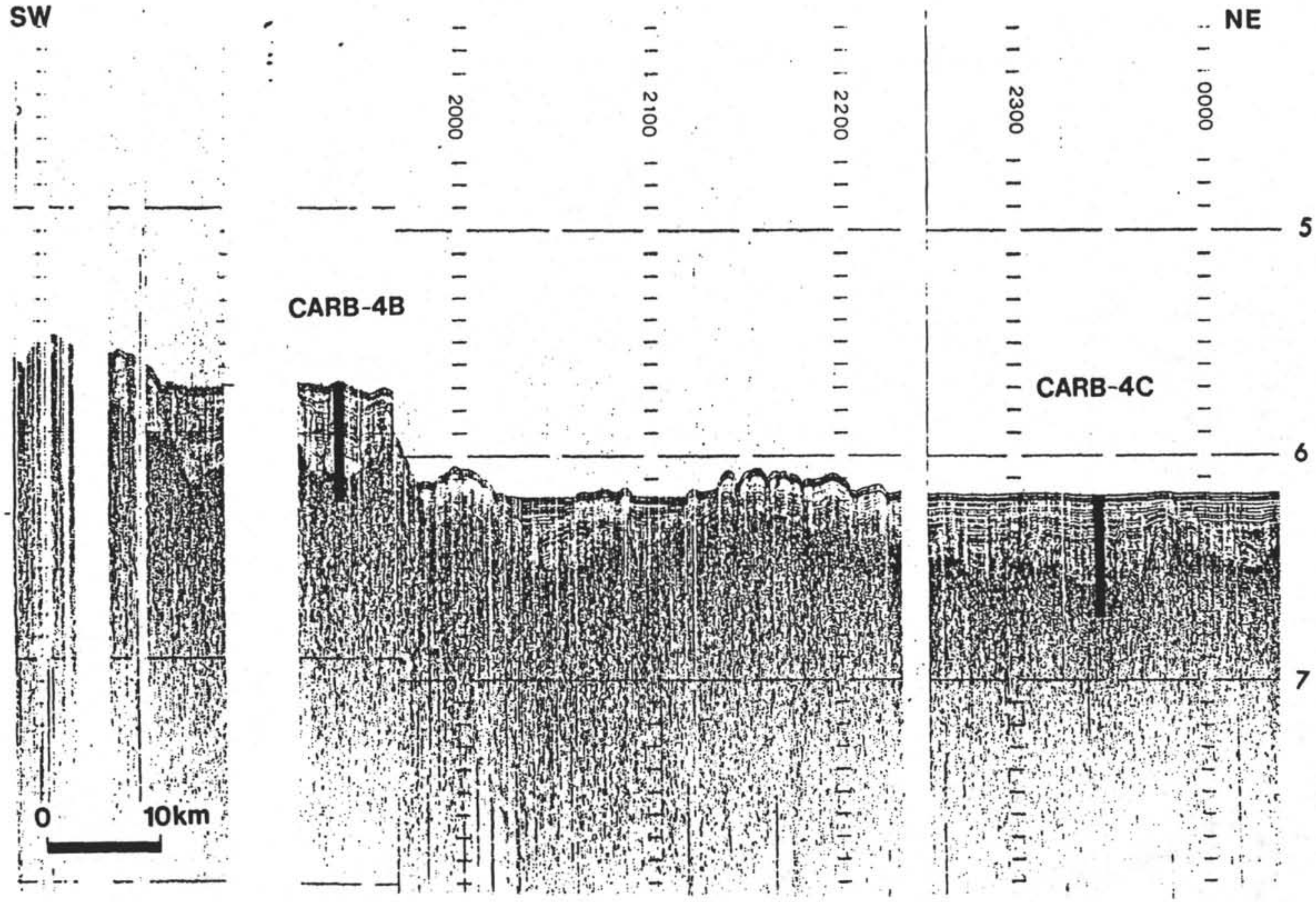
SEISMIC RECORD: Conrad 1707, May 1974 at 2330 Z, near Wilkes 907, 27 March, 1979 at 16252.

HEAT FLOW: No

LOGGING: No

OBJECTIVES: (1) High-resolution magnetostratigraphy, biostratigraphy, and dissolution studies of the Neogene and Quaternary carbonate system.

SEDIMENT TYPE: Carbonate ooze plus minor volcanoclastic sediments.


SW
NE
2000
2100
2200
2300
0000
5
6
7
CARB-4B
CARB-4C
0
10km

SITE NUMBER: MDL-1 (Maldives Archipelago)

POSITION: 04° 56'N
73° 17'E

SEDIMENT THICKNESS: >200 m

WATER DEPTH: 520 m

PRIORITY: 2 (Alternate)

PROPOSED DRILLING PROGRAM: Double APC/XCB to about 200 meters

SEISMIC RECORD: ELF line MLD-7307 (Sp. 1036) and ELF line MLD-763 (Sp. 80). Near Wilkes 827, 17 September 1978 at 0440 and Vema 2902, 20 December 1971 at 1725.

HEAT FLOW: No

LOGGING: No

OBJECTIVES: Record of climatically induced changes in carbonate saturation levels as recorded in aragonite sediments; for comparison with Pleistocene aragonite cycles in the Bahamas.

SEDIMENT TYPE: Periplatform carbonate ooze.

SITE NUMBER: MLD-2 (Maldives Archipelago)

POSITION: 05° 12.5'N
73° 44.0'E

SEDIMENT THICKNESS: >200 m

WATER DEPTH: 1500 m

PRIORITY: 2

PROPOSED DRILLING PROGRAM: Double APC/XCB to about 200 meters

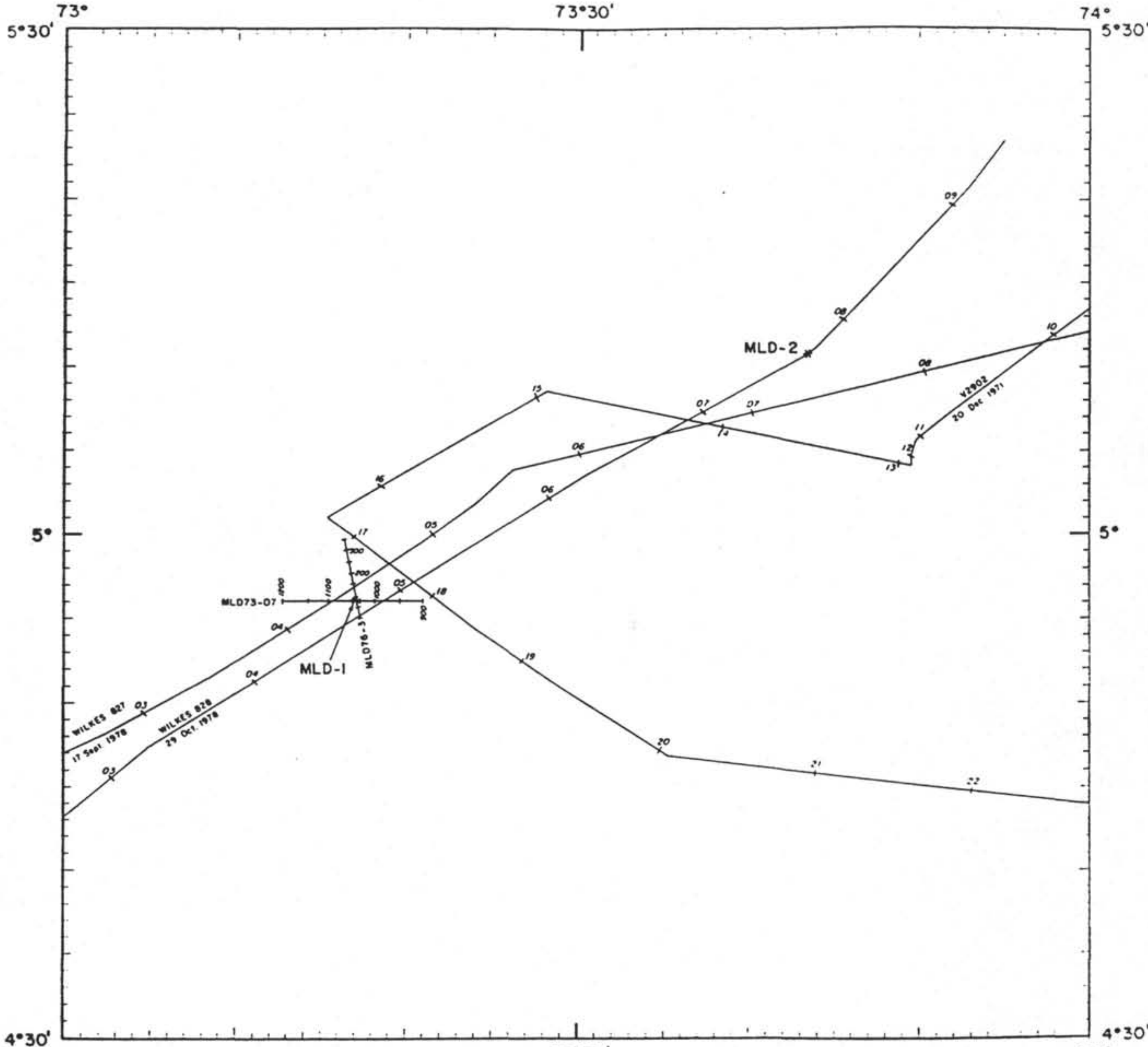
SEISMIC RECORD: Wilkes 828 line, 17 September 1978, at 0748 Z.

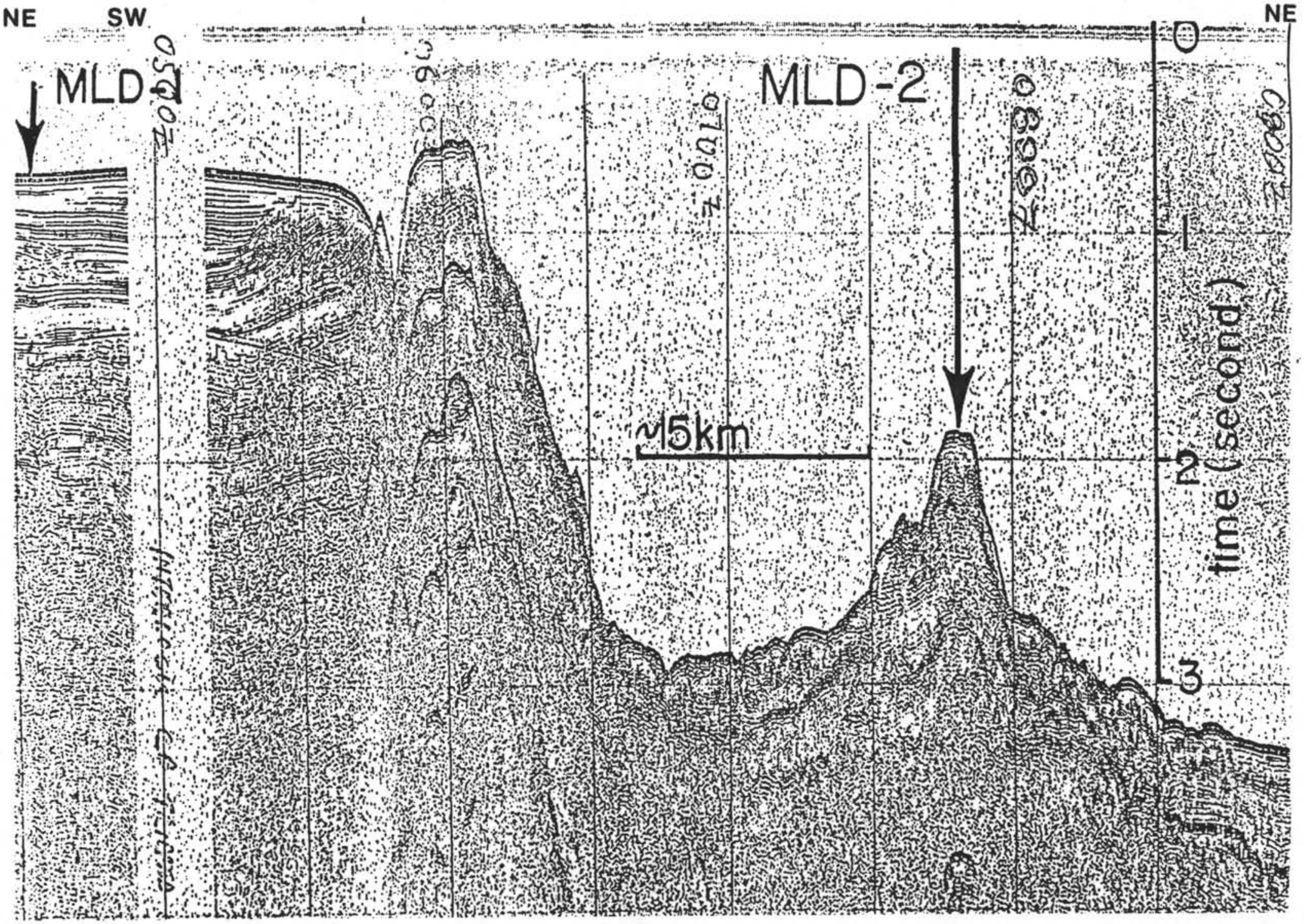
HEAT FLOW: No

LOGGING: No

OBJECTIVES: Record of climatically induced changes in carbonate saturation levels as recorded in aragonite seiments; for comparison with Pleistocene aragonite cycles in the Bahamas.

SEDIMENT TYPE: Periplatform carbonate ooze.


73°
73°30'
74°
5°30'
5°
4°30'
MLD-1
MLD-2
MLD73-07
MLD76-3
WILKES 827
17 Sept 1978
WILKES 828
29 Oct 1978
V2902
20 Dec 1971


NE
SW
MLD-1
MLD-2
NE
~15km
0
1
2
3
time (second)

# SHIPBOARD PARTICIPANTS

## OCEAN DRILLING PROGRAM LEG 115

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| Engineer:<br>(Special tools) | MARK ROBINSON<br>Ocean Drilling Program<br>Texas A&M University<br>College Station, TX |
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| Lab Officer: | B. W. HAMLIN<br>Ocean Drilling Program<br>Texas A&M University<br>College Station, TX |
| Yeoperson: | DAWN WRIGHT<br>Ocean Drilling Program<br>Texas A&M University<br>College Station, TX |
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| Electronics Technician: | DWIGHT MOSSMAN<br>Ocean Drilling Program<br>Texas A&M University<br>College Station, TX |
| Electronics Technician: | JIM BRIGGS<br>Ocean Drilling Program<br>Texas A&M University<br>College Station, TX |
| Chemistry Technician: | KATIE TAUXE<br>Ocean Drilling Program<br>Texas A&M University<br>College Station, TX |

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| Magnetics Technician: | JOHN TAUXE<br>Ocean Drilling Program<br>Texas A&M University<br>College Station, TX |
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| Marine Technician: | ANGELO CAMERLENGHI<br>Ocean Drilling Program<br>Texas A&M University<br>College Station, TX |