EXECUTIVE SUMMARY

INDIAN OCEAN PANEL MEETING

Miami (USA), 20-22 November 1986 87-48

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1. New panel members have been appointed by PCOM. IOP recommends that W. Berger (replacing L. Tauxe) be invited to serve on the panel ; if he declines the panel suggests L. Peterson (RSMAS) or E. Vincent (France).

2. IOP considered the resolutions adopted by PCOM at his August meeting at Cornerbrook, the recommendations made by the thematic panels (LITHP, SOHP, TECP) at their last meeting and by the IOP-SOP Kerguelen Working Group and discussed a revised drilling program for the Western Indian Ocean (Legs 115 to 118), the Kerguelen Plateau (Legs 119 and 120), and the Eastern Indian Ocean (Legs 121 to 123).

2.1. WESTERN INDIAN OCEAN

*SWIR :* IOP examined the results of the recent site survey and recommends as first priority to locate and drill a "deep mantle hole" on the elevated central ridge at ~4700 m water depth, near the area where ultramafic rocks were dredged. If this first priority fails, IOP recommends drilling a transect of sites across the fossil trace of the fracture zone to the north of the northern spreading ridge.

*RED SEA :* IOP recommends *Resolution* do the final seismic line for the 17.5°N through site and suggests to drop the Sudanese Fan site. The program amounts to 39 days on site. If the Red Sea cannot be drilled, IOP still recommends as substitute the Intraplate Deformation program.

*NEOGENE :* IOP suggests that final site selection be made from the SCS processed lines and recommends that one of the Owen Ridge sites be deepened to basement. The program amounts to 50 days on site and 42 without the Gulf of Aden site.

*MAKRAN :* IOP notes that the program depends on the success of *Darwin* site survey and recommends to drill a transect of four holes (sites 2, 3, 4 and 5). The program requires 22 to 24 days on site and can be combined either with the Carbonate Saturation Profiles or Mascarene Plateau programs to form a complete leg.

*CARBONATE SATURATION PROFILES :* IOP notes that adequated site survey data are available and proposes on the basis of latitude and water depth a transect of four sites. The program requires 14 to 17 days on site.

*MASCARENE PLATEAU :* IOP recommends a program of three single-bit sites to address the major objectives. Site survey data will be obtained by *Darwin* in March 1987. IOP emphasizes that this program does not duplicate the 90°E Ridge program. The program requires about 17 days on site.

Considering these two programs IOP voted on which of these should be combined with the Makran : the result was a tie vote. IOP considers both programs to be excellent and recommends, if Makran cannot be drilled, to combine these two half leg programs into a full leg.

2.2. KERGUELEN PLATEAU

*KERGUELEN I AND II :* IOP endorses the conclusions of the IOP-SOP Kerguelen Working Group but notes that in some cases (central and southern Kerguelen Plateau) final sites have yet to be selected. Considering the presence of cherts in the sedimentary sections and thus the low probability of reaching basement in one or two sites, IOP recommends an additional basement site in the central or northern portion of the plateau.

2.3. EASTERN INDIAN OCEAN

*INTRAPLATE DEFORMATION* : IOP considers a program of five sites to be selected from the recent *Conrad* site survey. The program needs a full leg and IOP recommends that the northern 90°E Ridge site be picked up by the Argo Basin drilling program.

*BROKEN RIDGE* : IOP recommends six sites in a N-S transect on the center of the Broken Ridge to build up the pre- and post-rift sedimentary sections. Final site selection and drilling times will be made from the recent site survey data.

*90°E RIDGE* : To address the petrological, tectonic and paleoceanography objectives, IOP recommends a set of three sites spanning between 6°N and 29°S. Adequated site survey data are available. The program requires about 20 days on site and has to be combined for logistical reasons with two other drilling programs (Intraplate Deformation and Broken Ridge or Argo Basin and Broken Ridge).

*EXMOUTH PLATEAU/ARGO BASIN* : IOP identified three options concerning these programs.
. Assuming the Red Sea program stays on schedule and the Exmouth Plateau and Argo Basin objectives have to be drilled during one leg, IOP recommends 3 Exmouth Plateau sites and 1 Argo Basin site.

. Assuming the Red Sea program stays on schedule and the Exmouth Plateau and Argo Basin programs can be extended to a two-leg program, IOP recommends one Exmouth Plateau leg with 4 sites and one Argo Basin leg with two deep holes to achieve all the stratigraphic and basement objectives.

. Assuming the Red Sea program is not drilled, IOP recommends the two legs as described above ; this option addresses all the Exmouth Plateau and Argo Basin objectives without increasing the present Indian Ocean schedule.

3. Nominees for co-chief scientists for Indian Ocean legs have been updated.

4. Next meeting in March 1987 (Australia : Sydney, USA : L-DGO, U.K.).

# MINUTES OF THE INDIAN OCEAN PANEL MEETING

20-22 November, 1986

Miami, Florida

Members present :

A. Bosellini
J. Cochran
R. Duncan, Secretary
D. Falvey
J. Ludden
W. Prell
U. von Rad
R. Schlich, Chairman
R. Scrutton (Alternate)
J. Segawa

Absent :

J. Curray
J. Leggett, TECP
J. Sclater

Liaison members present :

C. Brenner, SSP
W. Hay, SOHP
C. Langmuir, LITHP
R. Larson, PCOM

Attending guests :

G. Brass
B. Clement, ODP-TAMU
D. Goldberg, ODP
L. Peterson
J. Weissel (21 Nov.)

The IOP began its meeting at RSMAS with a welcome from acting director Prof. Chris Harrison and host Gary Brass. Schlich introduced new panel members A. Bosellini (ESF), J. Ludden (Canada), R. Scrutton (U.K. alt. for R. White) and guests. We thank U. von Rad (retiring) for his help and contributions on this panel.

1. MINUTES OF THE PREVIOUS MEETING (STRASBOURG, 4-8 JULY)

R. Scrutton requested that the Executive Summary be changed to state that 280 km of MCS data will be fully processed by March 1987 in time for SSP review and proposed Makran drilling. U. von Rad noted that in item 8 on p. 10 "gas fields"

should be replaced by "commercial dry wells".
The minutes of the IOP Strasbourg meeting were accepted with these changes.

2. IOP MEMBERSHIP ROTATION

L. Keigwin has declined to replace L. Tauxe. IOP recommends that W. Berger be invited to fill this membership. If he declines we suggest L. Peterson (RSMAS) or E. Vincent (France).

3. REPORTS FROM LIAISONS

3.1. PCOM (R. Larson)

With regard to the Indian Ocean drilling plan the last PCOM meeting (Cornerbrook, Canada, 11-15 August) resolved that :

*SWIR*

. The second guide base should be on board the *Resolution* for use in stabilizing bare rock drilling.

. No oblique seismic experiment will be carried out due to time, effort, and cost considerations. A re-entry cone could be left to allow this experiment to be done at a later date.

. R. von Herzen and P. Robinson were chosen as co-chiefs.

*RED SEA*

. Clearance is still needed from Saudi Arabia and Egypt. The science operator is pursuing this and a final decision on whether this leg will be drilled is to be made at the next PCOM meeting (19 Jan.).

. J. Cochran and P. Guennoc were chosen as co-chiefs.

*INTRAPLATE/90°ER*

. Site surveys complete but not reviewed ; co-chiefs yet to be selected.

*NEOGENE*

. Site survey results presented.

. W. Prell and Niitsuma were selected as co-chiefs.

*MAKRAN*

. The IOP questions and recommendations were noted and TECP was asked to respond. TECP agreed with IOP that the Makran program should be 4 sites constituting a 1/2 leg. The result of a close vote by PCOM was to retain the Makran program as a full leg.

. J. Leggett and B. Haq were selected as co-chiefs.

*MASCARENE PLATEAU/CARBONATE SATURATION PROFILE*

. PCOM considered that Mascarene objectives duplicated the 90°ER objectives and so preferred the Carbonate Saturation Profile program as a 1/2 leg to combine with Makran.

*KERGUELEN I + II*

. The IOP-SOP Working Group formed by PCOM at its last meeting met at Rhode Island on 27/28 October 1986. PCOM decided again that the crew change will take place at Mauritius.

*BROKEN R/90°ER*

. Site surveys complete but not available ; no co-chiefs yet.

*EXMOUTH/ARGO BASIN*

. The extended, 2-leg program is still possible if the Red Sea is not drilled, particularly with strong LITHP support for the Argo Basin basement hole.

3.2. <u>EXCOM meeting</u>

. The U.S.S.R. will join ODP, probably in January, 1987, and representatives may then participate in subsequent panel meetings and scientific crew.

3.3. <u>LITHP (C. Langmuir)</u>

. Strongly endorses Leg 115, noting uncertainties about technical problems (esp. pogo sampling, depth limit on camera televiewer) ; some sites outside the fracture zone should be considered ; drilling into peridotite has greater probability of success than rubbly basalt or gabbro ; the hard rock guide base should be on the ship and ready to deploy for a deep penetration site.

. In general, basement holes should be drilled to 50 m or bit destruction.

. Recommends deepening the IOP-endorsed Argo Basin hole at M25 to at least 200 m penetration of basement as a geochemical reference hole for Sunda Arc volcanism.

. Mascarene Plateau, Kerguelen Plateau, and 90°ER basement objectives will be addressed in detail at the next (6-7 Jan.) meeting.

3.4. SOHP (W. Hay)

. Considered the Carbonate Saturation Profile drilling very important and votes this higher than additional drilling in the Argo Basin.

. Recommends adding the Carbonate Dissolution site (Maldives, A. Droxler proposal n° 183/B) to the Makran leg (see appendix 1).

. Noted uncertainties about hiatuses at Exmouth sites and recommended a deep penetration hole somewhere north of EP-5.

3.5. TECP (J. Leggett absent, no report available)

N. Pisias informed Schlich by letter that TECP has agreed with IOP recommendations of 4-site, 1/2 leg Makran program.

3.6. SSP (C. Brenner)

. Will review the new site survey data for SWIR, Neogene I, 90°ER, Broken R, and Intraplate programs at the next (13-14 Jan.) meeting.

. Prydz Bay could be a problem, having no cross-lines on the one available MCS line.

. Red Sea - Sudanese Fan site is out (not surveyed). 17.5°N site is not sufficiently surveyed ; all remaining sites look OK.

. Neogene I - site survey data look good to pick final sites ; Honimid site data not adequate - need to check additional U.S. and U.K. lines.

. Makran - dependant on MCS survey by *Darwin* (R. White).

. Carbonate Transect - existing data adequate except basement site objective at CARB-1.

. Mascarene - dependent on site survey by *Darwin* (A. Baxter).

. Kerguelen I + II - sites KHP-1, KHP-3 approved, northern sites look OK, central and southern site data yet to be fully processed.

. 90°ER, Broken R, Intraplate - awaiting finished site surveys.
. Exmouth/Argo - looks OK, awaiting final site selection.

4. REVIEW OF NEW DRILLING PROPOSALS

4.1. Maldive Carbonate Dissolution (Droxler proposal)
2 HPC sites are proposed to investigate the flux of dissolved carbonate into the water column ; this was previously considered favorably and has been revived by SOHP. The sites selected by Droxler on *Vema* and *Conrad* SCS lines are at the peaks of ridges and unlikely to contain continuous sections. More site selection work must be done. The IOP endorses SOHP recommendations that one or two sites be added to the Carbonate Saturation Profile program if time permits.

4.2. Oman Mesozoic sediments (Jansa proposal)
IOP rejects this proposal as immature, having no site surveys planned.

4.3. Indus Fan (Haq and Kolla proposal)
IOP rejects this proposal because of the high probability of incomplete stratigraphic section and the difficulty in dating clastic sediments. We considered and rejected very similar earlier proposals in favor of distal fan sites. We compared this with other programs to combine with Makran and rated the others higher priorities.

4.4. Seychelles Platform (Khanna proposal)
IOP rejects this proposal as immature, with no site surveys planned, and overly ambitions concerning large sedimentary sections to be drilled.

5. DOWNHOLE MEASUREMENTS INFORMATION (D. Goldberg)
We received information on time estimates and requirements/options for logging holes. These appear as Appendix 2 and should be used in constructing site drilling times.

## 6. REVISED DRILLING PLAN

We discussed revised programs for the Western Indian Ocean (Legs 115 to 118), the Eastern Indian Ocean (Legs 121 to 123) and the Kerguelen Plateau (Legs 119 and 120) and used these reviews to update the Indian Ocean program summaries, sent separately to PCOM for its August, 1986 meeting at Cornerbrook. We make the following recommendations :

### 6.1. Western Indian Ocean

*SWIR* – We examined the preliminary SEABEAM map of Atlantis II F.Z. and heard results from the site survey from R. Larson. We recommended as the first priority to locate and drill a "deep mantle hole" on the elevated central ridge at ∿ 4700 m water depth, near the area where ultramafic rocks were dredged ; use spot drilling to confirm the outcrop and camera televiewer to locate suitable site for hard rock guide base ; set guide base and drill as deep as possible in remaining time. If the first priority fails, we recommend drilling a transect of sites across the fossil trace of the fracture zone, to the north of the northern spreading ridge. We recommend standard logging and borehole televiewer as top priority, with temperature and packer experiments added if possible.

*RED SEA* – no revisions except logging estimates ; we recommend that *Resolution* do the final seismic line for the 17.5°N through site ; Sudanese Fan site has been dropped, all others are OK.

*NEOGENE* – final site selection will be made by W. Prell and G. Mountain from SCS processed lines. We recommend that one of the Owen Ridge sites be deepened to basement.

*MAKRAN* – We note that this program depends on the success of *Darwin* site survey. We estimate logging at sites 2, 3 and 5 will take 3 to 4 days, or 20 to 25 days total site time or half a full leg.

*CARBONATE SATURATION PROFILE - MASCARENE PLATEAU* - We considered each of these programs as half legs to combine with the Makran program. The Carbonate Saturation Program has received strong support from SOHP and has adequate site survey data. We estimate site time to be 14 days. If site M-3 of the Droxler proposal (Carbonate Dissolution) were added, this would make 17 days total.

The Mascarene program looks attractive with the addition of industry sampling from two deep wells into basement. Site survey data will come from the *Darwin* (March, 1987). This program does not duplicate the 90°ER program because a different time frame is to be sampled, two hotspot tracks are needed to establish Indian plate motion, and different geochemical objectives are addressed. This program would need also about 17 days total site time.

We voted on which of these two programs should be recommended to combine with Makran and the result was a tie vote, 4 to 4 (Duncan and Prell abstaining). We consider both programs to be excellent and a decision will have to be made on logistical considerations. If the Makran cannot be drilled we recommend that these two half programs be combined into a full leg. IOP still considers these two the best science combination of options.

*OPTION WITHOUT RED SEA* - If the Red Sea cannot be drilled we still recommend plan B from our last meeting ; that is, 116 - Intraplate Deformation, 117 - Neogene I, 118 - Makran plus Carbonate S.P. or Mascarene.

6.2. <u>Eastern Indian Ocean</u>

*INTRAPLATE DEFORMATION* - We recommend 5 sites selected from the Weissel survey to date deformation, investigate fault plane hydrology, and a distal Bengal Fan site. The revised site time for drilling and logging will need a full leg so the northern 90°ER site must be picked up by the Argo Basin drilling. See appendix 3 for revised co-chief recommendations.

*BROKEN RIDGE* - We recommend 6 sites in a N-S transect on the center of the Broken Ridge to build up the pre- and post-rift sedimentary sections. It appears unlikely that basement can be reached at any of the sites. Final site selection and drilling times can be made from the excellent site survey data. The southern two 90°ER sites have been surveyed and would be drilled as part of this leg. See Appendix 3 for revised co-chief recommendations.

*90°ER* - Three (1, 2 and 5 from previous program summary) are recommended for drilling. These have all been surveyed and await final site selection. For logistical reasons these 3 sites would be drilled in separate legs (121 and 123).

*EXMOUTH PLATEAU/ARGO BASIN* - We identified three options concerning these programs. (1) Assuming the Red Sea program stays on schedule the Exmouth Plateau and Argo Basin objectives would be drilled during one leg (EP-7, EP-10A, EP-2A and AAP-1B). (2) Since the LITHP has added their strong endorsement of the Argo Basin deep hole and adding extra basement penetration (re-entry hole) we feel the best option is to form one leg with Exmouth Plateau objectives (EP-7, EP-10A, EP-9B, EP-2A) and a second leg with two deep holes in the Argo Basin to achieve the stratigraphic (double-coring Jurassic - L. Cretaceous Tethyan section) and basement (geochemical reference hole) objectives. The northern 90°ER site would be picked up in this leg as well. (3) The Red Sea is not drilled and the two legs described above address the Exmouth/Argo objectives without increasing the present Indian Ocean schedule. See Appendix 3 for revised co-chief recommendations.

### 6.3. Kerguelen Plateau

*KERGUELEN I AND II* - IOP endorses the minutes of the Working Group (W. Prell), noting that final sites in some cases have yet to be selected and flexibility must be maintained in the two legs due to weather considerations. The presence of cherts in the sedimentary sections needs to be factored into drilling times and technical planning. The science operator is requested to study ways to minimize this problem. IOP notes the low probability of reaching basement in 1 or 2 sites and recommends consideration of an additional basement site in the central or northern portion of the plateau. IOP asks that the science operator calculate more accurate drilling, logging and transit times from the present sites selected.

7. NOMINATION FOR CO-CHIEF SCIENTISTS FOR INDIAN OCEAN LEGS

Co-chief nominations have been made for legs 115 through 118.
Revised co-chief recommendations are given in appendix 3 for the subsequent legs.

8. LIAISON MEMBERS TO UPCOMING PANEL MEETINGS

LITHP (6,7 January, U.K.) :
We request that J. Ludden be invited to attend as IOP liaison.

SOHP (9,10,11 March, Menlo Park) :
We will be represented by W. Hay who is SOHP liaison to IOP.

TECP :
To be appointed at our next meeting.

9. COSOD-II

We discussed the importance of our individual contributions to the COSOD-II meeting and document with regard to future drilling in the Indian Ocean. R. Schlich will circulate COSOD-II information from R. Larson to IOP members to focus thinking on global themes of specific Indian Ocean interest.

10. NEXT MEETING

We request that PCOM approve our next meeting for Sydney, Australia, in the first week of March, 1987. As an alternate we request Palisades, N.Y. (L-DGO). A third possibility would be meeting in the U.K. following an invitation from R. White to Schlich prior to Christmas.

# APPENDIX 1

## Maldives Carbonate Dissolution Site

One aspect of paleo-oceanography which has been especially difficult to investigate is the nature of intermediate water masses. Because these water masses include the changes in ocean chemistry which cause undersaturation with respect to aragonite, variations of the aragonite content with age can provide new insights into ancient water mass structure. Droxler, Baker, and Williams (Proposal 183/B) have proposed drilling on the Maldive Ridge to recover continuous Neogene sequences of periplatform oozes - rich in aragonite derived from shallow carbonate banks. These sequences would provide a record of climatic-change-induced variations in the rate of supply from shallow banks as well as fluctuations of the carbonate saturation level in intermediate water masses, recorded as variations in the aragonite-low Mg calcite-high Mg calcite ratios. Although a depth transect of three sites spanning the aragonite dissolution zone is preferable, the SOHP recognized that the stratigraphic sequence at a single site located at a depth within the dissolution interval should record temporal changes in the nature of the intermediate water masses and offer new insight into the structure of the Indian Ocean during the Neogene. Accordingly the SOHP has requested that one site in the Maldives be added to the carbonate dissolution program proposed by L. Peterson.

After the SOHP meeting in late October, Droxler has attempted to select new sites on the southern Maldive Ridge which would be logistically more convenient, but the prints of the seismic records received from the Site Survey Office do not show sufficient detail to insure proper site selection at this time. He will be asked to reexamine the seismic records and nearby cores to propose an optimal site or sites.

# APPENDIX 2

## ODP logging

The most commonly run logs in ODP, the Schlumberger tools, are combined into multiple-tool strings for efficiency of operation. We presently operate three standard tool combinations : the seismic-stratigraphy, the lithoporosity and the geochemical combinations. Three lowerings are required to obtain this suite of logs in each ODP hole having greater than 400 m penetration. The total time for this operation can be calculated using the site water depth (WD) and sediment penetration (SD) and the logging time curves in the table below. The standard package of logs usually requires about 36 hours of rig-time depending on the sediment and water depths.

The seismic stratigraphic combination measures directly the compressional-wave sound speed in the formation and indirectly measures the two variables most often affecting velocity : porosity and clay content. The lithoporosity combination measures formation porosity and density as well as an estimate of the proportions of primary radioactive elements U, K, and Th. The geochemical combination tool has the ability to measure relative concentrations of seven other elements : Si, Ca, Fe, S, Al, Mn, HCl. In addition, a sonde measuring vector magnetic field, hole azimuts and deviation can be run with either lithoporosity or geochemical combinations.

Additional lowerings of Schlumberger and L-DGO logging tools can provide unique information in addition to the standard logging package. The dual lateroleg measures resistivity accurately in highly resistive formations, such as basalts. The borehole acoustic televiewer is employed to detect and evaluate fractures and bedding intersecting the borehole wall. The 12-channel sonic sonde records waveforms which allow the determination of compressional, shear, and stonely wave velocities, as well as energy and frequency content, useful to differentiate complex structural environments and for synthetic seismograms. The additional times required for these lowerings can be calculated using the appropriate logging time from the table attached.

Other in situ measurements, such as vertical seismic profiling (VSP), precision temperature logging, permeability-packer experiments, and dipmeter (high resolution resistivities) can be run using the wireline logging equipment on the *Resolution*. A rough time estimate is 12 hours per lowering for these measurements. Further information on the use and appropriateness of all available downhole measurements at each I.O. site has been recommended by the DMP and collated by the Borehole Research Group at L-DGO. Also consult the ODP Wireline Logging Manual for detailed log descriptions.

## Logging time equations

| | |
|---|---|
| "Standard" Schlumberger | t = 11.7 + .0018 x WD + .0145 x SD |
| Litjoporosity Combo. | t = 1.6 + .0009 x WD + .0058 x SD |
| Dual Laterolog | t = 1.7 + .0009 x WD + .0045 x SD |
| Multichannel Sonic | t = 1.5 + .0009 x WD + .0081 x SD |
| Borehole Televiewer | t = 1.7 + .0009 x WD + .0045 x SD + .0091 x LI |

*WD : Water Depth*
*SD : Sediment Penetration*
*LI : Logged Interval*
*t : time (hour)*

# APPENDIX 3

Revised nominations for co-chief scientists : IOP

| | U.S. | non-U.S. |
|---|---|---|
| 115<br>SWIR | R. von Herzen | P. Robinson (Can.) |
| 116<br>Red Sea | J. Cochran | P. Guennoc (Fr.) |
| 117<br>Neogene | W. Prell | Niitsuma (J.) |
| 118<br>. Makran<br>. Carb. S.P.<br>. Masc. P. | <br>B. Haq<br>L. Peterson, W. Curry<br>R. Duncan, R. Fisher | <br>J. Leggett (U.K.)<br>H. Thirstein (ESF), A. Baxter (U.K.)<br>A. Baxter (U.K.) |
| 119 & 120<br>Kerguelen | W. Berggren, R. Wise,<br>J. Hays | R. Schlich (Fr.), D. Falvey (Aust.), K. Perch-Nielsen (ESF), L. Leclaire (Fr.), H. Schrader (ESF), M. Coffin (Aust.) |
| 121<br>Broken R. | J. Sclater, J. Weissel,<br>R. Duncan, J. Curray | J. Pierce (Can.), R. Herb (ESF) |
| 122<br>Intraplate | J. Curray, J. Cochran | R. Herb (ESF), R. Scrutton (U.K.) |
| 123<br>Exmouth Pl. | J. Mutter, R. Larson | U. von Rad (D.), N. Exon (Aust.), P. Williamson (Aust.) |
| 124<br>Argo Basin | C. Langmuir | F. Gradstein (Can.), J. Ludden (Can.), J. Honnorez (Fr.) |

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# SUMMARY OF THE SOUTHWEST INDIAN RIDGE

# FRACTURE ZONE DRILLING PROGRAM

The Southwest Indian Ridge is the slowest spreading end member accessible for study of the development of ocean crust and fracture zones of the world's oceanic ridges. Its characteristics include the highest density of large relief fracture zones with the greatest abundance of ultramafic rocks of any oceanic ridge system in the world.

## DRILLING OBJECTIVES

Viewed theoretically, there could be many important drilling objectives in the vicinity of the Atlantis II transform. The site survey, however, revealed the total absence of sediment ponds within the transform, and probable thick rubble sequences on the floor of the transform make successful drilling of the basement there highly unlikely, especially since the depths > 6000 m preclude use of the TV camera system on the drill ship. It is also not clear what short, single bit holes in rubble would reveal scientifically, even if they could be accomplished. In view of these considerations, we propose that the prime objective be to obtain core samples and logs from a single site drilled as deeply as possible into the axis of the median ridge in the center of the Atlantis II transform valley. This ridge is hypothesized to be a hydrated (serpentinized) mantle diapir and to mark the principal zone of transform fault deformation. The recovered samples will test the serpentine diapir hypothesis, potentially allowing study of mantle petrology and its alteration characteristics, as well as the deformation characteristics of a zone of primary fault motion. The logging program will emphasize the standard Schlumberger logging tools and the borehole televiewer with temperature and packer measurements as secondary programs.

Rough time estimates based on bare rock guidebase deployment on Leg 106 indicate that ideal weather and seafloor conditions might allow guidebase deployment in a minimum of 15 days, leaving a maximum of 18 days for drilling and logging the deep hole. Weather delays and an extended survey prior to guidebase deployment will shorten drilling and logging time by an unpredictable amount.

Failing this prime objective, the fall back option is to otbain a transect of single bit holes to map basement petrology changes across the fracture zone extension of the active transform north of the northern spreading center / transform intersection.

PROPOSED SITES

The prime site is located at the axis of the median ridge in the transform at about 32°32'S, 57°03'E. Water depth is about 4700 m. This is near the southern end of the continuous segment of the 100 km long median ridge and is flanked by lineated, transform valley floors about 5700 m deep. It is likely that this site has igneous rock outcropping at the surface and requires use of a bare rock guidebase to stabilize the bottom of the drill string.

The secondary transect of sites begins in a fracture zone valley along strike to the north from the transform median ridge and extends to the ENE into another broad shallow valley that is an along strike extension of the scalloped wall that bounds the east side of the transform. The first valley is 5000 m deep, probably sediment free, and located at about 31°36'S, 57°03'E. The second, broader valley is 4200 m deep, contains sediment, is the site of a heat flow survey and is located at about 31°34'S, 57°10'E.

STATUS OF SITE SURVEY

Conrad 27-09 conducted a detailed Sea Beam, dredging and coring survey of the Atlantis II transform in October 1986. The Sea Beam bathymetry outlines the detailed morphology of the transform and its fracture zone extension to the north as well as the adjacent spreading centers and lineated magnetic anomaly patterns. Four dredges were recovered from the median tectonic ridge that contain a mixture of gabbro, diabase, and peridotite with varying levels of serpentinization. The prime site is located where a dredge recovered entirely ultramafic rocks. The secondary transect to the north is also well imaged by Sea Beam with the along strike transform valley appearing to be sediment free on a 3.5 KHz pinger lowering. The valley to the ENE contains at least enough sediment to accomodate a heat flow survey.

The prime, bare rock re-entry site will require additional surveying with down pipe TV and sonar scanning to locate a site flat enough to deploy the bare rock guidebase. An unsupported bare rock spud-in should also be attempted prior to guidebase deployment as a preliminary penetration test.

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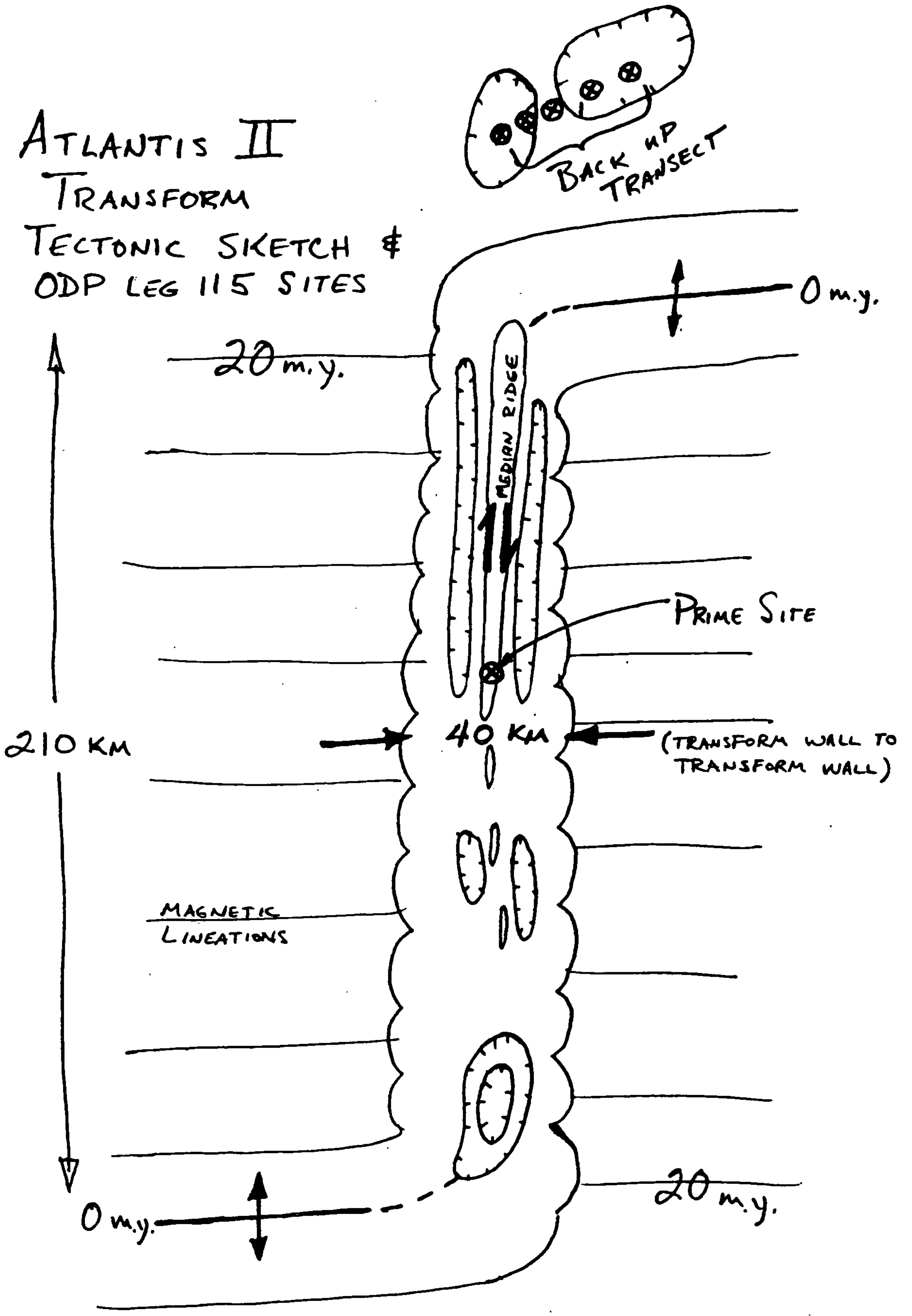
Further detail is available from the following proposals : JOIDES n° 89/B (H. Dick), JOIDES n° 186/F (R. von Herzen), and JOIDES n° 89/B Revised (H. Dick, et al).

22 November 1986

# Atlantis II Transform Tectonic Sketch & ODP Leg 115 Sites



# SUMMARY OF THE RED SEA DRILLING PROGRAM

The Red Sea Working Group proposed a drilling program following their meeting at Brest in September, 1985. The program presented here is a modification of that program based in time constraints and site survey realities that have since developed.

## DRILLING OBJECTIVES

The Red Sea is an attractive location to study the processes of lithospheric rifting, the early development of a "passive" continental margin and the initiation of seafloor spreading because these processes are currently occuring there. Major rifting began near the Oligocene-Miocene boundary and organized seafloor spreading began about 5 mybp in the southern Red Sea. The northern Red Sea, however, is still undergoing late stage continental rifting. The spreading center is propagating northward allowing different stages in the transition to be examined.

The drilling program is built around a number of themes. Two of these involve drilling a series of holes into young oceanic basement in the south and the deeps of the Central and North Red Sea. These two are :

- Evolution of the lithosphere through the transition from continental rifting to seafloor spreading as expressed by the nature of the igneous rocks produced at different stages in this process.

- Hydrothermal activity and metallogenesis. The Red Sea offers an opportunity to establish a "natural laboratory" in an active low temperature hydrothermal system, to investigate nature of circulating fluids, fluid-hot rock interactions metallogenesis and the basement alteration.

The other theme is related to Miocene and Holocene paleoenvironments and paleo-oceanography. The particular objective is a study of Red Sea sapropels. This is developed in a double HPC hole designed to sample the post-Miocene (post-evaporite) sedimentary section.

## PROPOSED SITES

The sites proposed are as follows :

Site RS-1 will be drilled near the outer edge of the axial trough in the first seafloor spreading cell to develop in the southern Red Sea. The primary objective is to obtain a section of the first oceanic crust generated at the Red Sea spreading center. A second objective is to obtain a sedimentary section to compliment those obtained further north to form a latitudinal transect.

Site RS-2a, RS-2b and RS-2c are alternative sites in the Nereus Deep, the furthest north seafloor spreading cell of the Red Sea spreading center. The objectives are to obtain a section of oceanic crust from an isolated cell not yet completely linked to the spreading center, and to study spreading center metallogenesis and fluid-rock interactions in an active hydrothermal system.

Site RS-3 is located in Bannock Deep, the furthest south of the non-seafloor spreading northern Red Sea type deeps. The main objective is to obtain a section of igneous rocks generated just prior to the beginning of organized seafloor spreading.

Site RS-4 is located in Shaban (or Jean Charcot) Deep in the northern Red Sea. The objective is to obtain a section of the igneous rocks created early in the development of a nucleation point, well before the beginning of seafloor spreading.

Site RS-5a is located on the southwest side of Mabahiss Deep, an isolated seafloor spreading cell in the northern Red Sea that did not propagate ; the purpose of this site is to obtain a section of the crust generated at this seafloor spreading cell.

Site RS-5b is located on the northeastern side of Mabahiss Deep. The principal objectives at this site are to investigate the nature of the unusual appearing Plio-Quaternary sequence and the timing of motion on the tilted fault blocks that appear to underlie this area.

Site RS-6a and site RS-6b are alternative sites in the main trough away from the igneous intrusions in the deeps. The objective is to study the organic rich sapropel layers in the post Miocene section to look at the effects of variations in monsoonal strength on the Paleoceanography in the Red Sea. A second objective is to study the termination of evaporites and the establishment of an open marine sequence.

The details of the sites are given in the table following. The 17°N site may not be able to be drilled for site survey reasons (see below). If so, the time allowed for that site could be used either for the Gulf of Aden hominoid site or for deepening the Nereus Deep site. Nereus Deep is a priority site and enough time should be taken to do it properly. If additional time is needed, it is suggested that one of the Mabahiss Deep sites be eliminated.

Red Sea Drilling Program

| Site - Location | Water Depth (m) | Penetration (m) Total | Penetration (m) Basm't | Operations | Time on site (day) Total | Time on site (day) Logging |
|---|---|---|---|---|---|---|
| RS-1 17°N-18°N<br>17°39'N - 40°27.3'E | 1750 | 500 | 100 | rotary core | 7 | 1+ |
| RS-2a Nereus Deep<br>23°13.2'N - 37°12'E | 2370 | 350 | 300 | rotary core<br>re-entry<br>full logging | 8+ | 2- |
| RS-2b Nereus Deep<br>23°11.7'N - 37°14.2'E | 2370 | 350 | 300 | same as RS-2a | 8+ | 2- |
| RS-2c Nereus Deep<br>23°10.35'N - 37°11.1'E | 2325 | 350 | 300 | same as RS-2a | 8+ | 2- |
| RS-3 Bannock Deep<br>23°41'N - 36°35'E | 1500 | 200 | 100 | rotary core | 5 | 1+ |
| RS-4 Shaban Deep<br>26°12.4N - 35°21.1E | 1480 | 200 | 100 | rotary core | 5 | 1+ |
| RS-5a Mabahiss Deep SW<br>25°16.4'N - 36°01'E | 1000-1100 | 300 | 100 | rotary core | 4 | 1 |
| RS-5b Mabahiss Deep NE<br>25°17.1'N - 36°12.5'E | 1480 | 600 | 100 | rotary core | 5 | 1 |
| RS-6a Main Trough<br>24°37.5'N - 36°30'E | 1050 | 200-300 | - | double HPC | 5 | - |
| RS-6b Main Trough<br>24°45'N - 36°10'E | 1100 | 200-300 | - | double HPC | 5 | - |

The program (drilling and logging), including the 17°N site, the Nereus Deep site, the Bannock Deep site, the Shaban site, the two Mahabiss sites, and the Main Trough site, amounts to 39 days. RS-2b, RS-2c, and RS-6b are alternate sites.

STATUS OF SITE SURVEYS

Sites RS4, RS5 (a+b) and RS6 (a+b) are selected on the basis of BRGM-IFREMER Seabeam and SCS seismic surveys and the sites have been approved. RS2 (a, b and c) have available BRGM-IFREMER Seabeam survey, a Scripps Deep-Tow survey and italian SCS seismic data. RS3 is based on italian SCS seismic data. RS1 has available a Scripps Deep-Tow line and the possibility of a German Seabeam line in January, 1987 on *Meteor*. There is no acceptable seismic line and little prospect of acquiring a line prior to drilling. IOP recommends that *Joides Resolution* be allowed to run a line just prior to drilling, with well defined criteria for what constitutes an acceptable site.

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Further details on each of the sites is available from the report of the Red Sea Working Group meeting in September, 1985 at Brest, France. Also see the following proposals : PCOM n°3/B (P. Guennoc), n° 86/B (E. Bonatti), n°117/B (J. Cochran), n° 120/B (R. Zierenberg et al.), n°140/B (G. Pautot and P. Guennoc), n°215/B (M. Richardson and M. Arthur).

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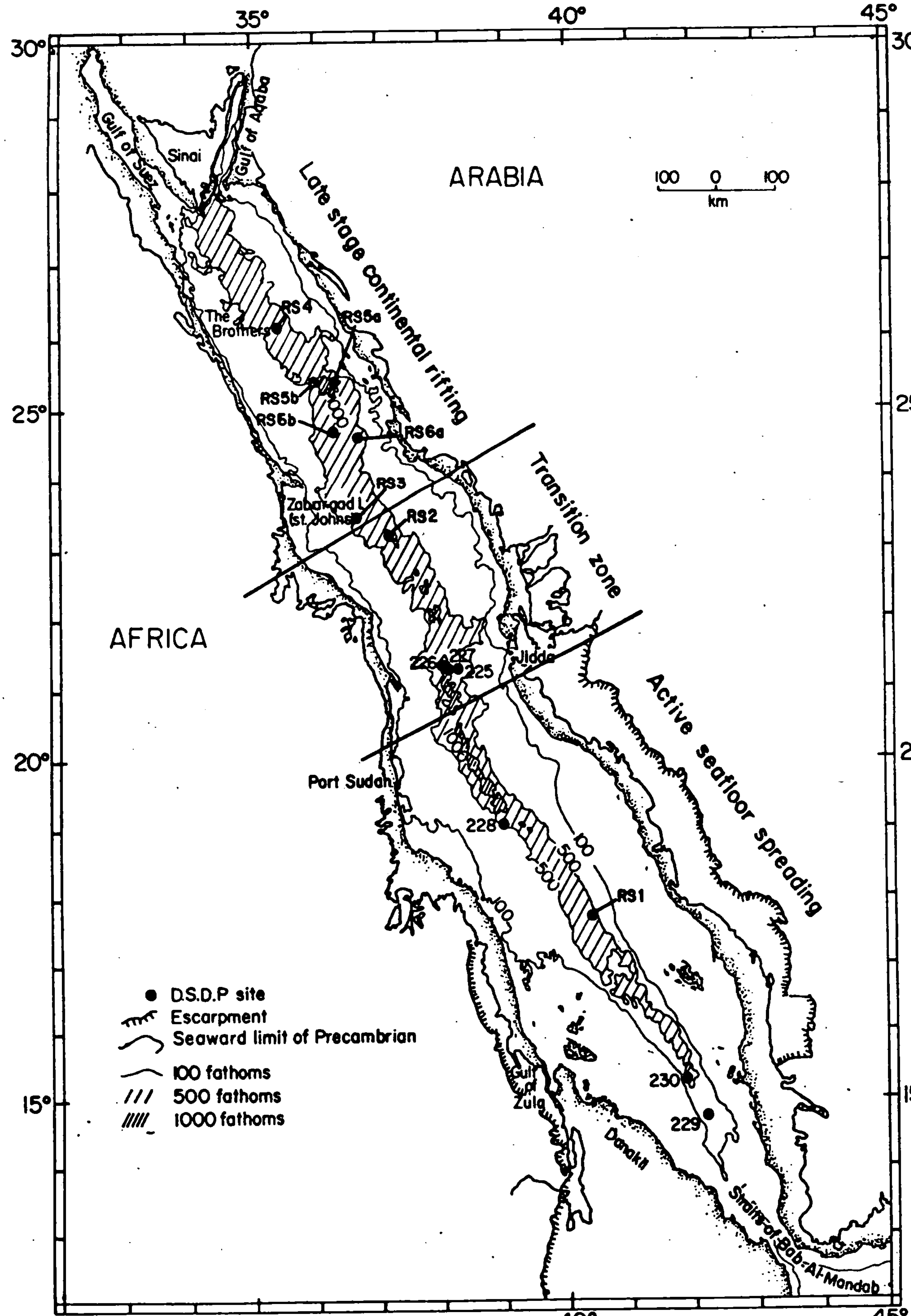

35°
40°
45°
30°
25°
20°
15°
ARABIA
AFRICA
100 0 100
km
Sinai
Gulf of Suez
Gulf of Aqaba
Late stage continental rifting
Transition zone
Active seafloor spreading
The Brothers
RS4
RS5a
RS5b
RS6a
RS3
RS2
Zabargad I. (st. Johns)
226
227
225
Jidda
Port Sudan
228
RS1
230
229
Gulf of Zula
Danakil
Straits of Bab-Al-Mandab
D.S.D.P site
Escarpment
Seaward limit of Precambrian
100 fathoms
500 fathoms
1000 fathoms

# SUMMARY OF DRILLING PROGRAM TO UNDERSTAND THE NEOGENE EVOLUTION OF THE INDIAN OCEAN MONSOON AND ITS RELATION TO MILANKOVITCH RADIATION CHANGES, MOUNTAIN BUILDING, AND EVOLUTION OF MAN

The paleoclimatic history of tropical Africa, the northern Indian Ocean, and southern Asia is dominated by the evolution of the Indian Ocean Monsoon. The monsoon circulation causes seasonal upwelling along Arabia, transports terrestrial dust into the Arabian Sea, and controls the precipitation budget of tropical Africa and southern Asia. Long term variation of these climatic and geologic processes reflect changes in external boundary conditions, such as the solar radiation budget of the Northern Hemisphere i.e., Milankovitch orbital cycles) and internal boundary conditions, such as the elevation of the Tibetan Plateau and the extent of global glaciation. Hence, the coastal upwelling, the productivity of the Arabian Sea, the eolian transport, the growth of the Indus Fan, the history of the oxygen minima zone, and the vegetation history of the surrounding continents are all affected by the evolution and intensity of the Indian Summer Monsoon. This confluence of atmospheric, oceanic, and geologic processes gives rise to a number of important problems that can be uniquely addressed by drilling in the northwestern Indian Ocean.

## DRILLING OBJECTIVES

The major topics and objectives include :

- What is the history of Neogene monsoonal upwelling and how does it vary in response to changing radiation budgets ? The role and evolution of the Indian Monsoon as a major component of the global climate is a major unanswered question in paleoceanography/paleoclimatology.

- What is the depositional and diagenetic history of the highly organic rich sediments deposited in the oxygen minima zone (OMZ) beneath the zone of proximal upwelling ? These sediments may contain annual laminations (such as the gulf of California) which will address questions of interannual and decadal variability and stability of the OMZ.

- How does the growth of the Indus Fan record the uplift of the Tibet-Himalayan complex, the depositional history of the fluvial Siwaliks of Pakistan, and climate related changes in eustatic sea level .

- How is the uplift of the Owen Ridge related to the formation of the Owen Basin and the Miocene changes in spreading ?

- How is the evolution of hominid/hominoids related to climate changes caused by the uplift of mountains and changes in monsoonal precipitation ?

PROPOSED SITES

To address these problems, we propose an integrated transect of seven sites in the Western Arabian Sea and a possible additional site in the Gulf of Aden. Briefly, these are :

1. Oman Margin sites (NP-1, 2, 3)
A double HPC depth transect along the upper slope that crosses the oxygen minima zone and within the zone of proximal upwelling. Sediments are about 50 % pelagic carbonates, organic rich and may contain annual laminations (altough Holocene sediments do not contain them). Due to high accumulation rates, penetration of 200 m is expected to obtain only Plio-Pleistocene age sediments. Sites will be located around the relatively flat terrace (Figure 1, average depth about 900 m) at about 500 m, 1000 m, and 1500 m. The site survey found good sediment sections at each depth and this range spans the lower oxygen minima zone. If possible the two deeper holes will be logged.

2. Owen Ridge sites (NP-4, 5, 6)
Three HPC/XCB sites to obtain a Late Neogene high resolution history (around 10 Ma) of upwelling and eolian deposition related to the Indian Ocean summer monsoon and the early history of the Owen Ridge. Sites are located within the upwelling zone but above the effects of bottom processes on the margin and Indus Fan.

The site survey identified numerous possible sites (at various water depths) for the monsoon-evolution sites NP-4 and NP-5 (Figure 2). The site survey also identified a seismic stratigraphy and series of major slump valleys that can be utilized to understand the early evolution of the Owen Ridge and possibly its relation to the Owen Basin. Site NP-6 will be selected to maximize the recovery of the reflector sequence related to uplift of the ridge by utilizing the slump scar geometry. All holes will be logged. At least one site should contain a VSP.

3. Indus Fan sites (NP-7)
One HPC/XCB site on the westernmost midfan region to obtain a relatively continuous record of fine grained sediments that record the growth history of the fan. The site is to be located away from major channels on midfan to avoid sand lobes in the distal fan.

The site survey found small channels in the western midfan (Figure 3) but no evidence of major sand deposits in the seismic data (strong sub-bottom reflectors) or in the piston core taken on the levee. This site will be logged.

4. Gulf of Aden (NP-8)
One HPC/XCB to recover the sequence of terrestrial components, such as pollen and volcanic ash, originating in East Africa and blown into the Gulf of Aden by monsoonal winds within a well dated bio-magneto-stratigraphy) marine sediments. Comparison of the marine and continental paleoclimate data with the stratigraphy of hominid deposits is expected to give insights into the role of large scale climate changes in hominid and mammalian evolution

The details of the sites are given in the table following.

Neogene Drilling Program

| Site - Location | Water Depth (m) | Penetration (m) Total | Penetration (m) Bsm't | Operations | Time on site (day) Total | Time on site (day) Logging |
|---|---|---|---|---|---|---|
| NP-1 Oman Margin 17°30'N - 57°45'E | 500 | 200 | - | Double HPC | 1.0 | - |
| NP-2 Oman Margin 17°30'N - 57°45'E | 1000 | 200 | - | Double HPC | 2.5 | 1.5 |
| NP-3 Oman Margin 17°30'N - 57°45'E | 1500 | 200 | - | Double HPC | 3.0 | 1.5 |
| NP-4 Owen Ridge 16°N - 60°E | 2500 | 500 | - | HPC/XCB Double HPC | 8.0 | 1.5 |
| NP-5 Owen Ridge 16°N - 60°E | 3000 | 500 | - | HPC/XCB Double HPC | 8.0 | 1.5 |
| NP-6 Owen Ridge 16°N - 60°E | 3500 | 500 | - | HPC/XCB Double HPC | 8.5 | 2.0 |
| NP-7 Indus Fan 16°N - 61°E | 4000 | 600 | - | HPC/XCB Double HPC | 11.0 | 1.5 |
| NP-8 Gulf of Aden 12°N - 47°E | 2000 | 600 | - | HPC/XCB Double HPC | 8.0 | 1.5 |

The program (drilling and logging) amounts to 42 days without site NP-8 and 50 days with NP-8.

STATUS OF SITE SURVEY

The site survey has been completed and additional information will be submitted to the ODP data bank for SSP. Additional work by *RRS Charles Darwin* and *R/V Marion Dufresne* on the Indus Fan will be completed early 1987. Survey data still needed for NP-8 (Gulf of Aden).

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Further detail is available from the following proposals : PCOM n°93/B (W. Prell) for the Oman Margin sites ; n°94/B (W. Prell) for the Owen Ridge sites ; n°78/B (V. Kolla), 96/B (G. de V Klein) for the Indus Fan sites ; n°118/B (J. Kennett et al.) for the Gulf of Aden site.

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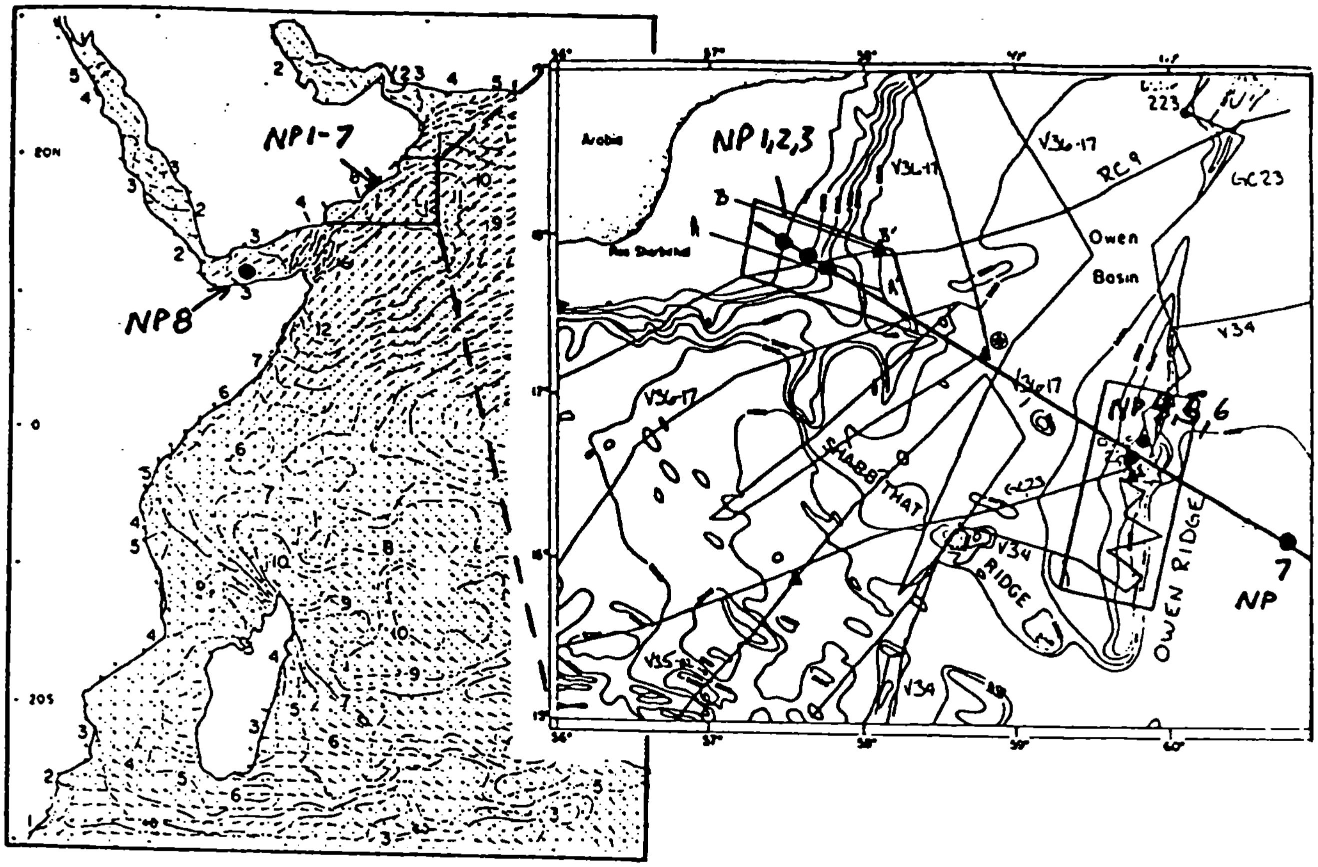


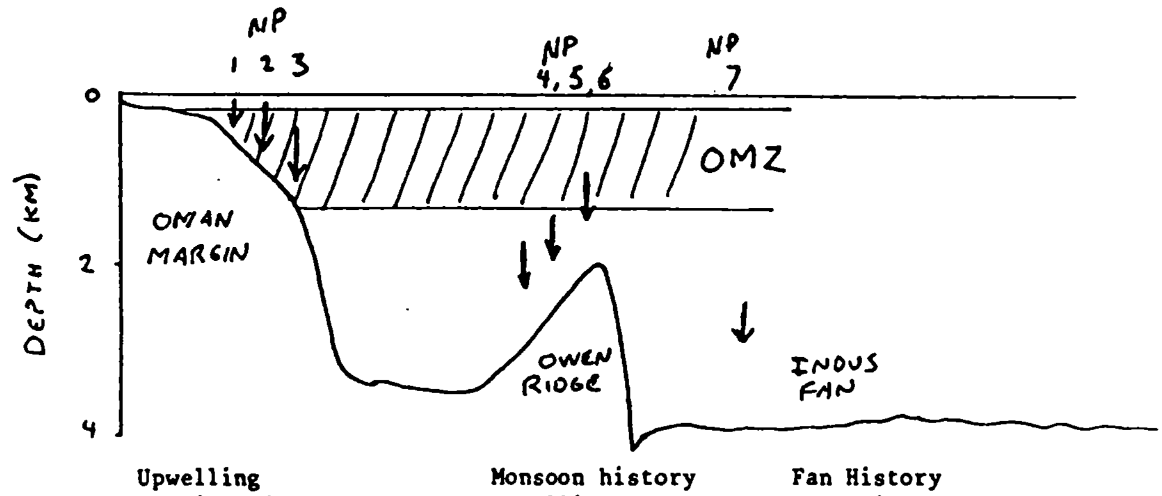


| | | |
|---|---|---|
| Upwelling | Monsoon history | Fan History |
| Anoxic sed | Upwelling | Upwelling |
| Eolian organic | Eolian pelagic | Climate response |

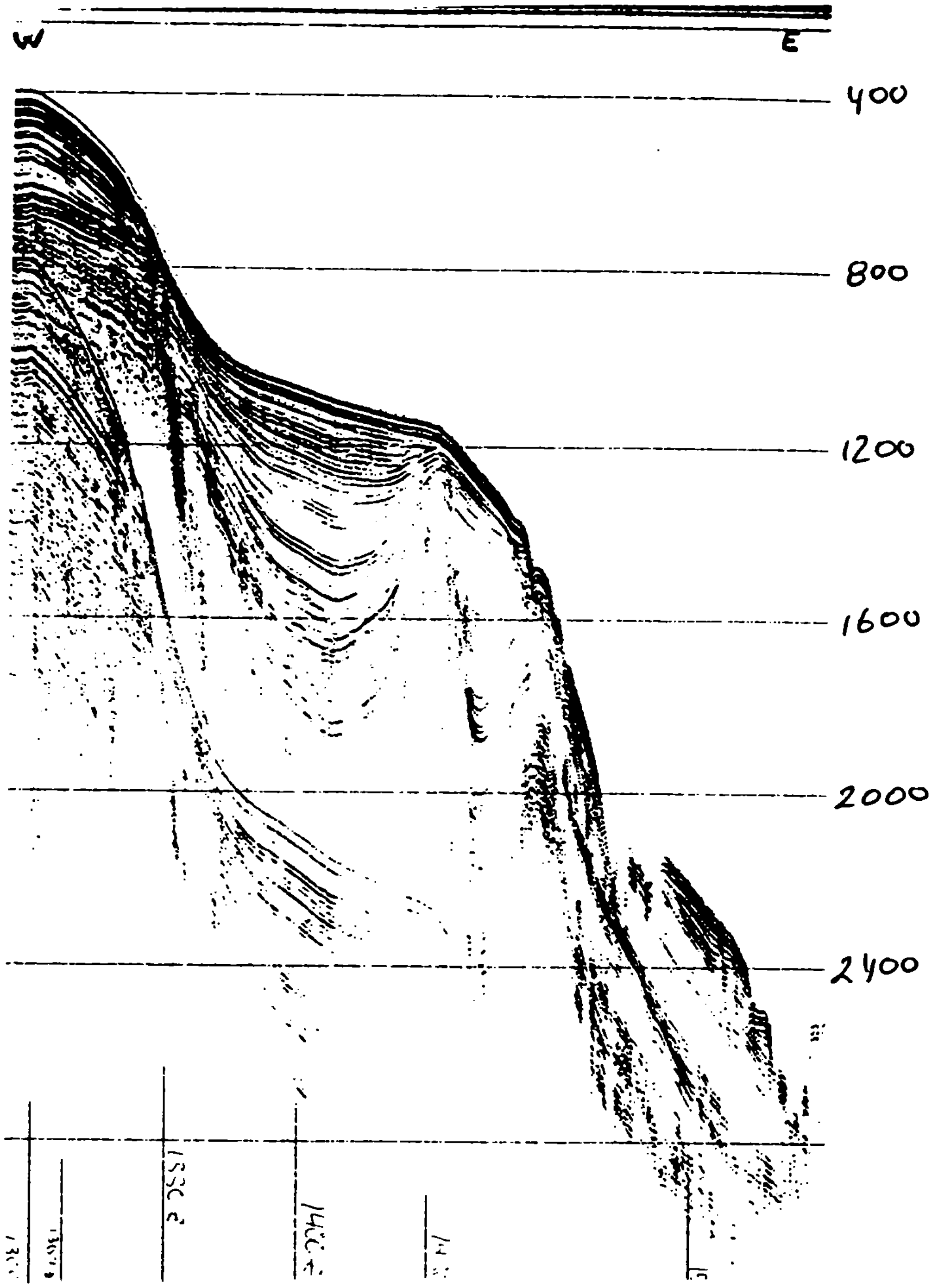


Figure 1 : Oman Margin (NP-1,2,3)
Sites to be located around deep terrace at about 1000 m. Structures off profile provide continuous sediment cover at ∿ 1600 m water depth.

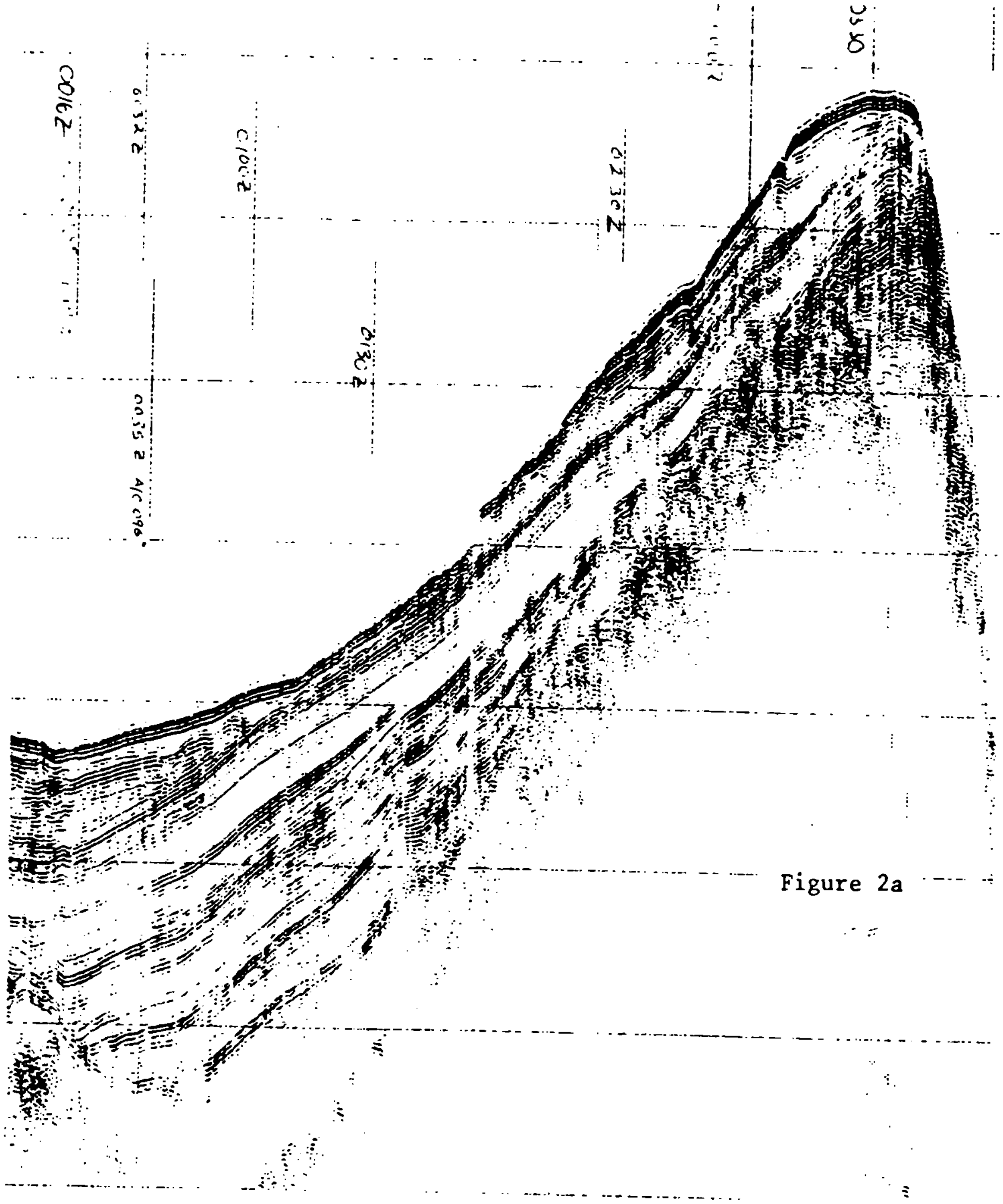


Figure 2 : Owen Ridge (NP-4,5,6)
Dip section (A) and strike sections (B) of RC 27-04 site survey show representative sites for monsoon history sites (NP-4,5) and Owen Ridge evolution site (NP-6). Former sites will be selected to obtain continuous Neogene sections and the latter to recover the deeper reflector sequence.

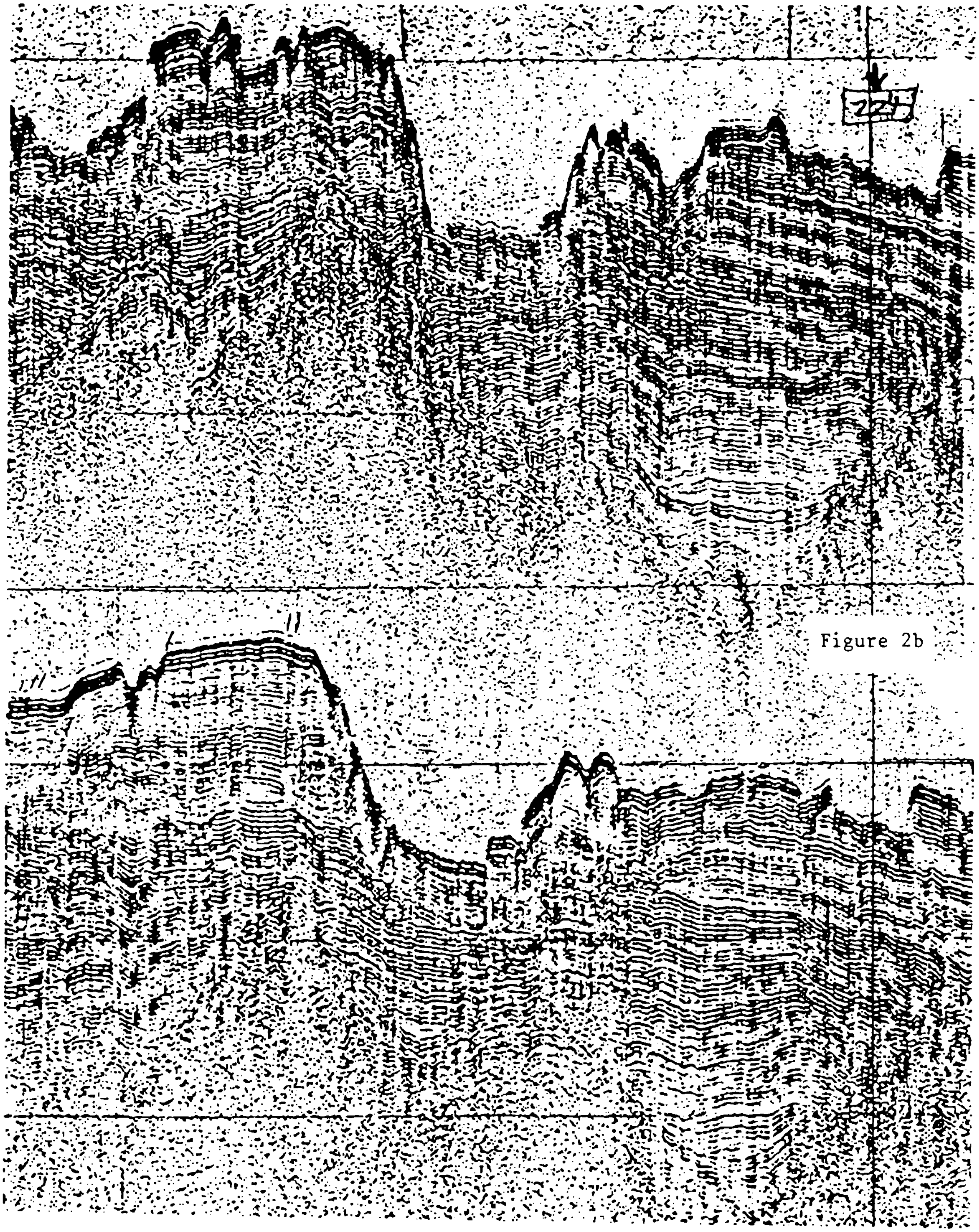


Figure 2b

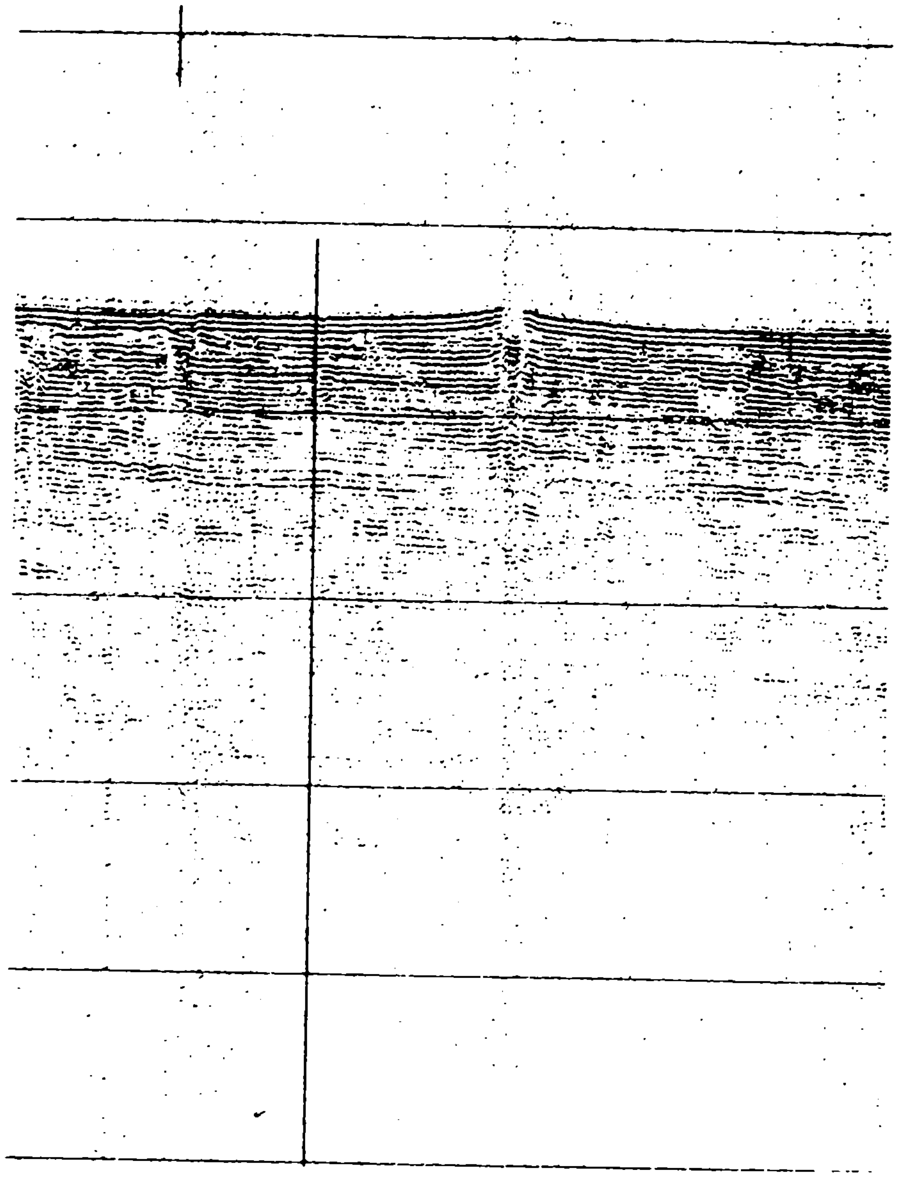

Figure 3 : Indus Fan (NP-7)
RC 27-04 monitor profile of western mid fan at about 16°N, 61°E. Compared to Mississipi Fan profiles the Western Indus Fan levee sequences show little evidence of massive sand-channel deposits.

# SUMMARY OF THE MAKRAN FORE-ARC (PAKISTAN) DRILLING PROGRAM

The Makran active margin is the widest currently-subduction fore-arc (Fig. 1). In Pakistan, the arc-trench gap measures up to 600 km. The fore-arc basin is now emergent, and some two-thirds of the accretionary complex is exposed in the arid Makran hills of Baluchistan (Western Pakistan and Eastern Iran). Emergent accretionary complexes on currently active margins are rare, and usually of very limited extent (eg Barbados, Andaman-Nicobar islands, Kodiak).

Existing seismic data (Cambridge University single-channel profiles and Shell and Marathon multichannel lines, Fig. 1 and 2) show relatively simple fold-thrust packages of sediment apparently accreted from the abyssal plain. On the lower part of the slope these form linear ridges of considerable east-west continuity. Behind the ridges, back-tilted, ponded linear slope-basins record the deformation and uplift history of the lower slope. Upslope from the linear-ridge domain lies a terrace indented by submarine canyons and a narrow shelf.

## DRILLING OBJECTIVES

- In a transect of four holes up the lower slope establish the detailed biostigraphy of the Neogene and Quaternary to document accretion and uplift rates, to study the processes of deformation, and the patterns of sedimentation in the early stages of development of the accretionary prism.

- To drill through three decollement thrusts to shallow depth ; to sample, and contrast, in-situ fluid pressures and fluid compositions.

- For the first time in active margin drilling, to combine drilling results from the onshore part of an accretionary complex with data from its exposed TIME-EQUIVALENT onshore portion. Specifically, to compare the Quaternary history of tectonics and sedimentation on the slope with the Quaternary record, and the record of analogous Neogene processes, preserved in the superbly exposed coastal Makran.

## PROPOSED SITES

All sites are in a north-south transect off Gwadar, Pakistan. Alternative analogous sites are available off Pasni, Pakistan 100 km to the east should the Gwadar sites prove to be too close to the Iran border for ease of clearance. The *Darwin* MCS lines will include coverage of both alternatives, lines D and L in figure 1. All holes are to be logged. Indeed logging is particularly important at thrust sites (2,3 and 5) where packer experiments are required above, below and in the thrust. The faster wireline packer should be available for this leg.

Following a recommendation from Tectonic Panel, endorsement from Planning Committee, and discussions by the Indian Ocean Panel, the program now comprises four drilling sites.

MAK-2 is located 200-400 m north (upslope) of the "deformation front". The objectives at this site are to penetrate the basal thrust, to record fluid pressures and compositions, and to study the style of the earliest deformation (400 m of drilling in 3200 m water depth).

MAK-3 is located 8 km upslope, near base of second thrust-fold ridge. The objectives at this site are to penetrate the second thrust, to determine the rate of deformation and to record fluid pressures and compositions (400 m of drilling in 2300 m water depth).

MAK-4 is located inboard flank of second fold-thrust ridge. The objectives at this site are to determine the uplift history, and the relationship between ponded slope sediment and folded substrate (350 m of drilling in 2300 m water depth).

MAK-5 is located 37 km upslope, near base of sixth fold-thrust ridge. The objectives at this site are to determine the rate and type of deformation, plus the amount of displacement, and to record fluid pressures and compositions (400 m of drilling in 2000 m water depth).

The details of the sites are given in the table below.

| Site - Location | Water Depth (m) | Penetration (m) | | Operations | Time on site (day) | |
|---|---|---|---|---|---|---|
| | | Total | Bsm't | | Total | Logging |
| MAK-2 Makran 24°10'N - 62°31'E | 3200 | 400 | - | HPC/XCB | 7.5+ | 3.5+ |
| MAK-3 Makran 24°14'N - 62°30'E | 2300 | 400 | - | HPC/XCB | 6.5+ | 3.5+ |
| MAK-4 Makran 24°16'N - 62°29'E | 2300 | 350 | - | HPC/XCB | 3.5 | 1 |
| MAK-5 Makran 24°30'N - 62°27'E | 2000 | 400 | - | HPC/XCB | 5.5+ | 3.5+ |

The program (drilling and logging) requires 23 to 24 days on site. All drilling times are based on the old TAMU drilling tables and may be reduced by up to 2 days with revised drilling tables. The program can be combined either with the Carbonate Saturation Profiles or Mascarene Plateau to form a complete leg.

STATUS OF SITE SURVEY

R. White is collecting (Nov.-Dec., 1986) on board *Darwin* MCS data over the proposed sites. He is also carrying out deep-tow, high resolution seismic profiling, a piston core transect across the slope and crustal seismic refraction in a land-sea experiment. NERC has agreed to fund the processing of 280 km of MCS data to at least the brute stack stage (T. Francis, pers. comm.) within two months of the magnetic tapes returning to the United Kingdom. These data should be available by March, 1987. 280 km of profiles cover both transect locations and some cross lines.

Existing SCS data show that gas hydrates are common in the upper 500 m of sediment, with a strong bottom simulating reflector (BSR) at the underlying free-gas contact : this produces a strong safety constraint. Proposed drilling does not exceed 400 m, however there is also evidence of localized shale diapirism and slumping.

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Further detail is available from the following proposal : PCOM n°55/B (J.K. Leggett and R. White).

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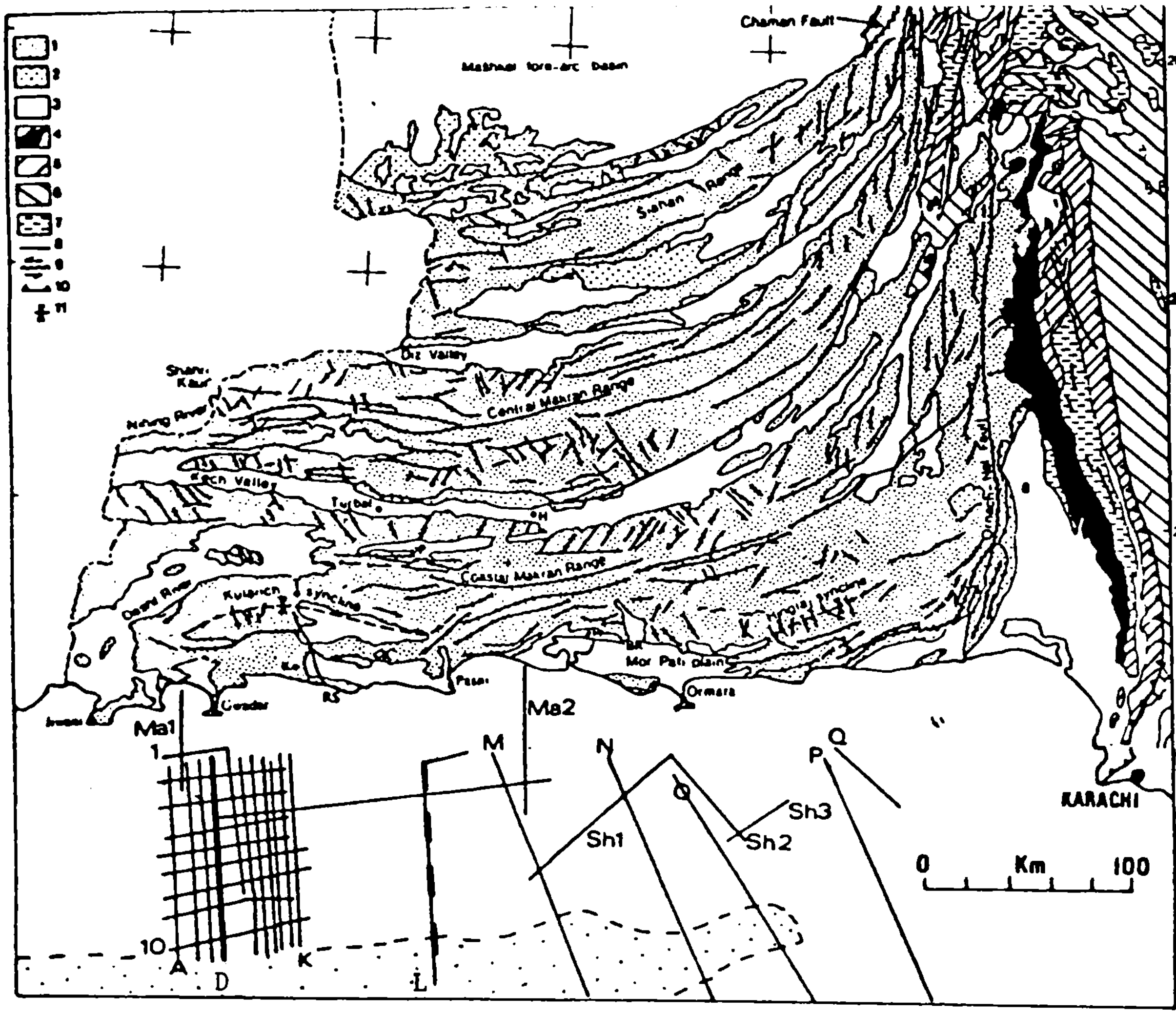


Figure 1 : Tectonic map of southern Baluchistan (after Geological Survey of Pakistan 1/2000 000 tectonic map of Pakistan) and offshore seismic coverage.

Tectonostratigraphic units (MAKRAN UNITS) : 1) Eocene (?) - Pliocene deep-to shallow-marine strata ; 2) M-U Pleistocene, continental in north, shallow marine on coast ; 3) U. Pleistocene-Recent (intra montane basins and coastal plain). UNITS E OF ORNACH-NAL FAULT (for further details and definitions see Tectonic Map of Pakistan) ; 4) Ophiolitic rocks ; 5) Rocks affected by "late Himalayan" orogeny ; 6) Rocks affected by "middle Himalayan" orogeny ; 7) "Pre-orogenic" units.

Structural features :

8) Faults (undifferentiated) ; 9) Principal coastal synclines.

Place names :

B) Bela ; BR) Basol River ; H) Hoshab ; K) Kappar ; M) Makola ; P) Pidarak ; RS) Ras Shahid ; T) Talar.

Seismic data currently available :
Ma1,2 : Marathon profiles
Sh1,2,3 : Shell profiles
Grid South of Gwadar : Cambridge single channel profiles.
Dashed line is approximate north margin of abyssal plain.

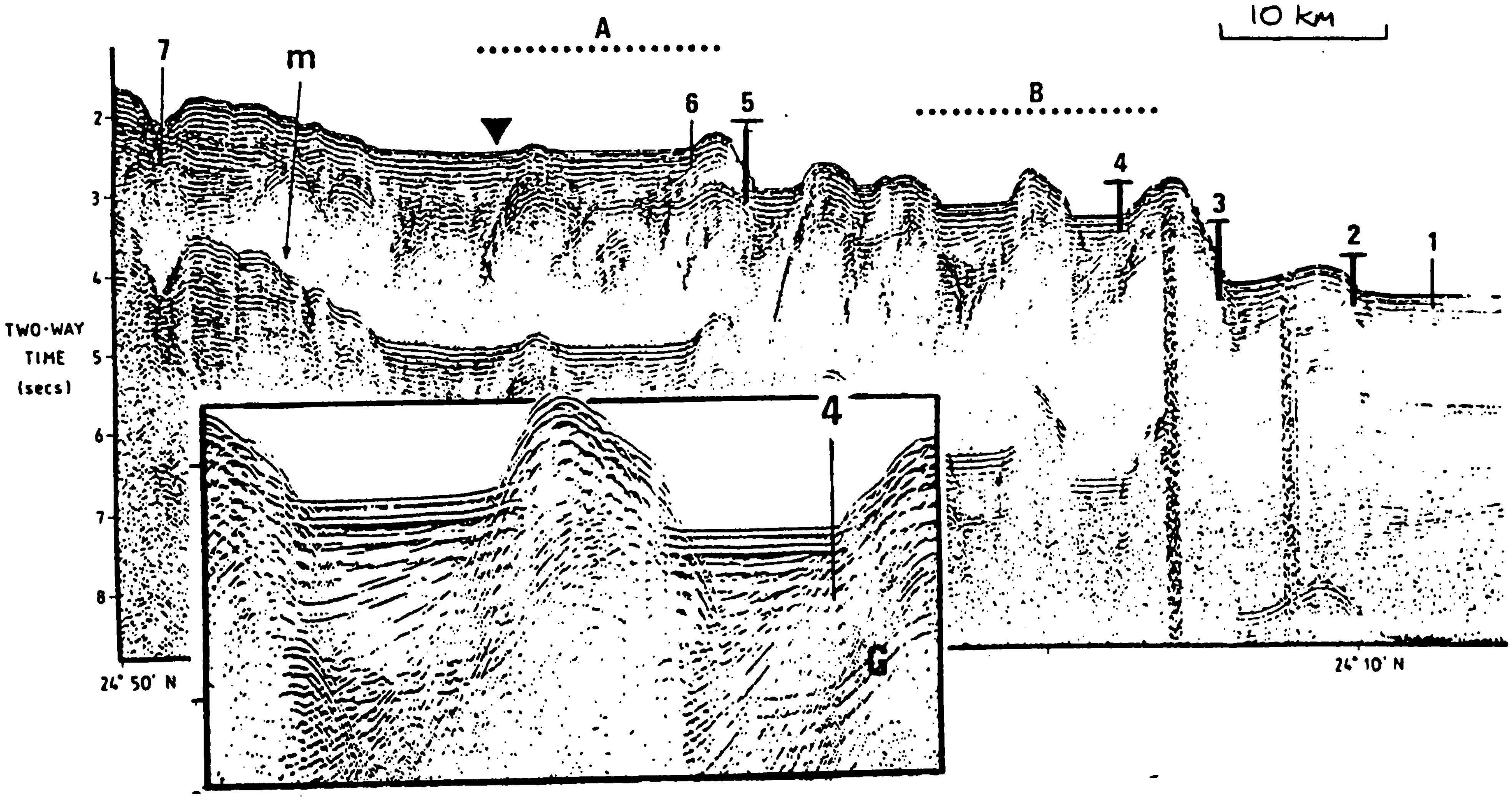


Figure 2 : Cambridge profile D (see Fig. 1 for location) and proposed ODP sites.
M : Mu' 'ola: A,B : Detailed enlargements of slope basins. Inverted triangle : cross-line 5. Vertical exaggeratio
at sea of approximately 7:1 ; Enlargement B : note easing dip with depth in interfold sediments ; BSR.

# SUMMARY OF THE CARBONATE SATURATION PROFILES AND DEEP CIRCULATION OF THE EQUATORIAL INDIAN OCEAN DRILLING PROGRAM

This study is part of a global effort to quantify and model the controls on carbonate saturation profiles (as recorded by lysocline and compensation depths), basin to basin fractionation of carbonate and carbon isotopes, and deep circulation. The key to these efforts is monitoring the flux of sediment components as a function of both water depth (to calculate gradients) and time. A depth transect that constrains vertical movement of carbonate, isotopic and water mass boundaries is the fundamental requirement of this study. A global network of these depth transects is required to quantify global circulation patterns.

A transect of HPC's spanning a wide range of depth on the northeastern flank of the Seychelle's Bank can make substantial contributions to a number of major problems in the fields of marine geochemistry, surface and deep water paleoceanography, paleoclimatology, and marine ecology. The key to calculating meaningful fluxes of carbonate and other sediment components is a tightly spaced transect of continuous Neogene sediments spanning a wide bathymetric range. The requirements for such a transect include : i) a small geographic area to insure that the pelagic rain to all sites is similar ; ii) a wide water depth range so that samples are located both above and within present and past sedimentary lysoclines and span present and past deep water mass boundaries ; iii) a location in an area with reasonably high accumulation rates so that high resolution studies are possible.

The northeast flank of the Seychelles platform best fulfills these requirements within the Indian Ocean. A series of HPC cores at this location could address several specific questions and problems.

## DRILLING OBJECTIVES

- Evolution of the Neogene carbonate system.

How have carbonate saturation profiles changed in the Neogene ? For example, if the depth gradients of carbonate composition and fluxes can be calculated along with the thickness of the lysocline from the depth transect, then models such as those given in Broecker and Peng can be used to estimate the effects of pelagic rain rate and carbonate ion saturation in controlling the carbonate boundaries.

Related questions include : how has the carbonate system of the tropical Indian Ocean varied in response to changing climatic boundary conditions, changing glaciation levels, and changing deep circulation ; how has surface productivity varied ? Resolution of these questions requires one to know : i) the depth gradients of carbonate and noncarbonate fluxes ; ii) the geometry of the sedimentary lysocline through time ; iii) the pelagic rain composition and rate (input) ; iv) high resolution chronology.

From these variables (which can only be obtained from a bathymetric transect), the dynamic features of the carbonate system can be reconstructed. These reconstructions can be used to constrain models of the carbonate system and thus to test fundamental assumptions on the controls of the carbonate system.

- Evolution of shallow and deep water circulation in the Indian Ocean
Because the Indian Ocean has a unique geometry (i.e. 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 the Atlantic and the Pacific. The evolution of this system can be traced through study of its benthic faunas (reflecting deep water mass changes), planktonic faunas (which reflect surface water circulation), and its vertical and horizontal circulation by comparing the $\delta^{18}O$ and $\delta^{13}C$ gradients in comparison with other sites in the Indian Ocean and in other oceans. Likewise, the variability of the carbonate system (above) also reflects the circulation pattern. Knowledge of the vertical and horizontal patterns through the Neogene would give great insight into the dynamics of both the tropical Indian Ocean and the global ocean. In addition, direct comparison of the equatorial sediments to those of the Arabian Sea monsoonal upwelling sequence (Neogene drilling program) would provide a better measure of the temporal and spatial response of the Indian Ocean to past changes in the monsoonal circulation. Again, these objectives can only be accomplished by work within a high resolution-time framework.

PROPOSED SITES

A transect of four sites is proposed on the basis of latitude, water depth, and location of suitable sequences of pelagic sediments for HPC sites. Details of these sites are given in the table below.

| Site - Location | Water Depth (m) | Penetration (m) Total | Bsm't | Operations | Time on site (day) Total | logging |
|---|---|---|---|---|---|---|
| CARB-1<br>7°30'S - 59°00'E | 1600 | 250 | 50(?) | Double HPC/<br>XCB<br>Single bit(?) | 2.5 | - |
| CARB-2<br>4°00'S - 60°30'E | 3000 | 250 | - | Double HPC/<br>XCB | 3.5 | - |
| CARB-3<br>4°20'S - 60°50'E | 3800 | 250 | - | Double HPC/<br>XCB | 3.5 | - |
| CARB-4<br>2°12'S - 61°25'E | 4600 | 250 | - | Double HPC/<br>XCB | 4.0 | - |

The program amounts to 13.5 days without basement drilling at site CARB-1 and without logging. We estimate that the transect objectives can be met with four double HPC-XCB sites with penetration of about 250 meters, with the option of additional single bit coring to basement at site CARB-1 to address objectives of the Mascarene Plateau drilling program. The drilling time estimates presented here were provided by Dr. Jack Baldauf and TAMU engineers based on their extensive HPC experience aboard Leg 108. Time estimates for each site, in addition to double HPC/XCB to 250 m, include time for locating and coming on site, and time for one complete drill string round trip. The estimate for site CARB 1 does not include time required for single bit coring if the basement objectives are combined with the sediment objectives of this program. Site time estimates also do not include logging time. While logging is not likely to be required, at these sites, the seismic stratigraphic geochemical logging program and the lithoporosity logging would be desirable if time permits. For both logging programs, an additional allotment of about 30-31 hours would be required per site.

This Neogene Carbonate Program can be combined with either the Makran or Mascarene Plateau Programs to form a complete leg. The depth transect to study the Neogene evolution of the pelagic carbonate system and deep circulation of the equatorial Indian Ocean represents the modern approach to understanding these systems. The program concentrates on depth gradients, which change substantially during the Neogene, and quantitative high resolution reconstruction of carbonate, silica, and terrigenous fluxes into the sediment. Such data are needed to properly constrain models of the carbonate system and can only be obtained within the framework of a high resolution depth transect.

STATUS OF SITE SURVEY

At present, adequate single channel seismic data (including cross tracks) exist for all four of the proposed sites for a purely sediment program. The *Darwin* is scheduled to be in this general area from December, 1986 until August, 1987. We anticipate that the *Darwin* could easily obtain cross tracks of seismic data in critical areas, if deemed necessary by the Site Survey Panel. Such survey data is almost surely to be required in the vicinity of CARB-1 if basement objectives are to be sought in this hole.

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Further detail is available from the following proposals: PCOM n°97/B (L. Peterson), n°173/B (P. Patriat, E. Vincent, G. Jacquart), n°226/B (L. Peterson, W. Prell).

22 November, 1986

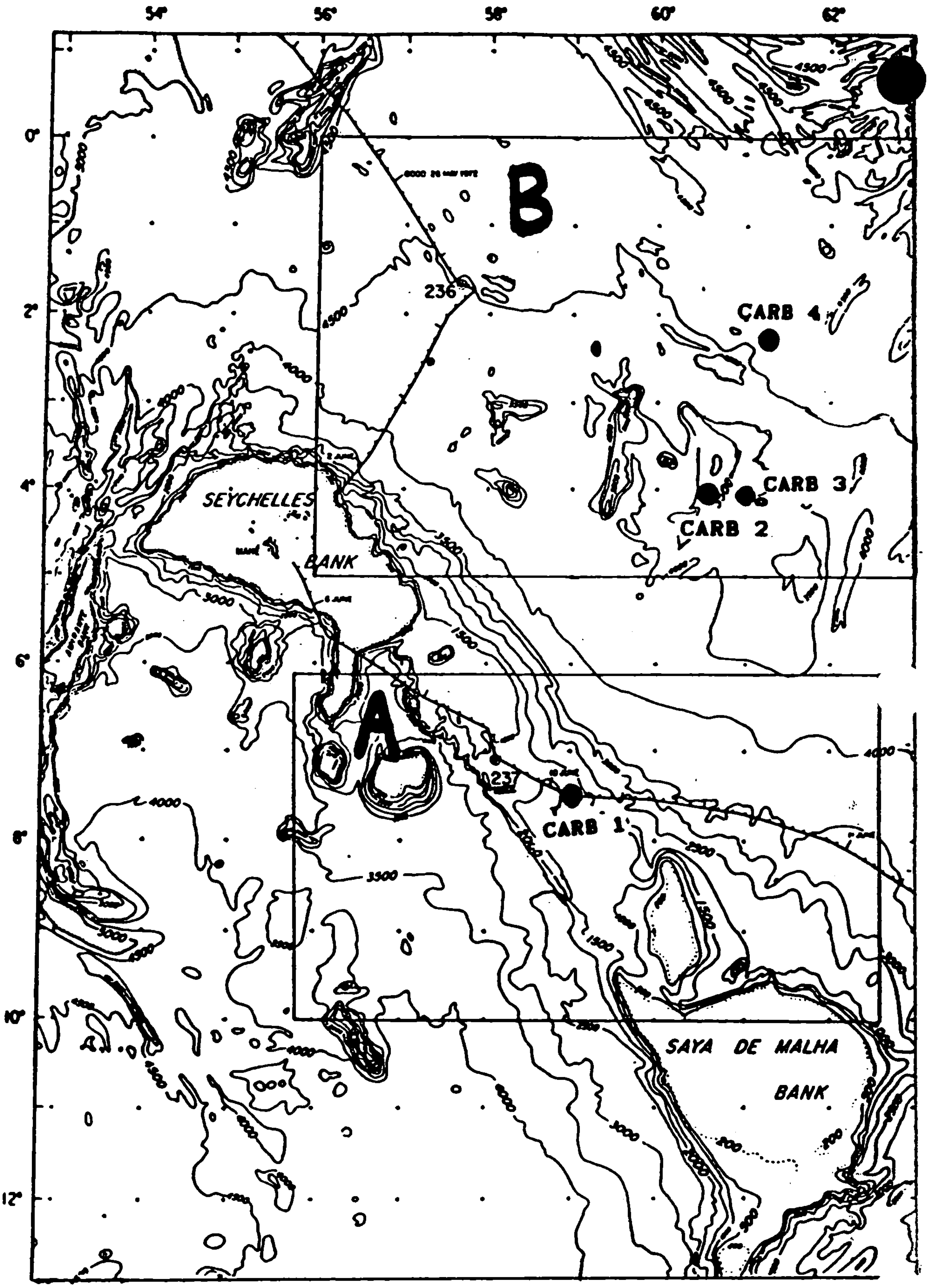


Figure 1 : Regional bathymetry of the Seychelles Bank showing the location of proposed HPC sites. See Figure 2 for available seismic profiles from boxes A and B.

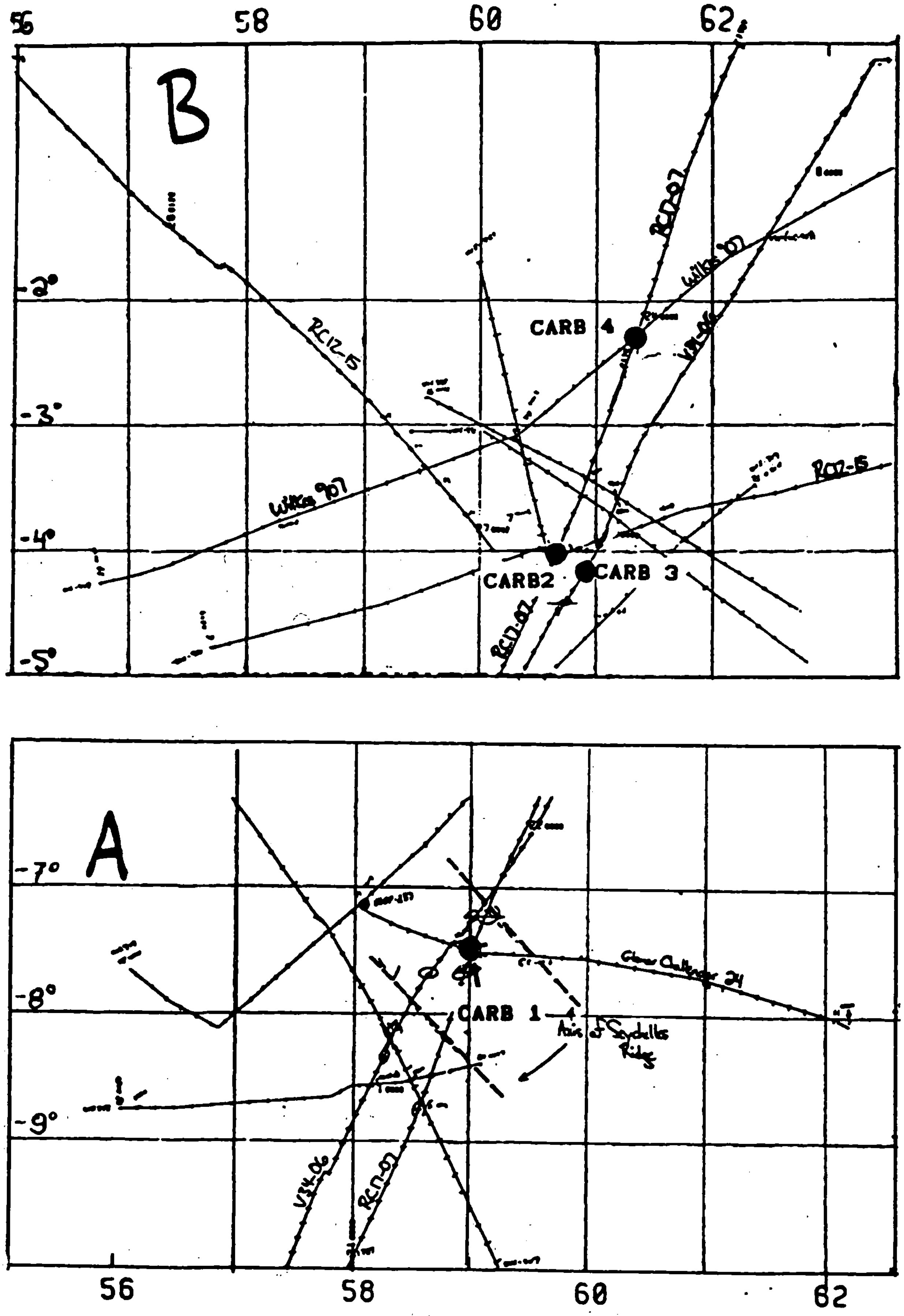


Figure 2 : Track lines of past cruises from which seismic data is available.

# SUMMARY OF THE MASCARENE PLATEAU DRILLING PROGRAM

The Mascarene volcanic lineament is a major "aseismic" ridge system in the Central Indian Ocean Basin. It connects, with the Chagos-Laccadive Ridge, young volcanic activity in the vicinity of Reunion Island with the massive accumulation of continental flood lavas in the Deccan Traps, erupted at the Cretaceous/Tertiary transition. 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.

## DRILLING OBJECTIVES

Drilling on the Mascarene Plateau will meet specific objectives which can be summarized as follows :

- To document the probable age progression in volcanic activity from north to south which records the motion of the Indian plate and, more recently, the Somali plate over the Reunion hotspot ;
- To investigate the geochemical variation of magmas erupted over the hotspot, from Deccan Traps-type flood basalts to central, oceanic island volcanism ;
- To describe the nature of the crust beneath the volcanic and limestone plateform (continental fragment ? or entirely volcanic ?) and its subsidence history ;
- To examine the nature of rifting on the margin of a volcanic plateau, and the phenomenon of channeled flow from an off-ridge hotspot.

A program of three single-bit sites should address these objectives.

## PROPOSED SITES

MP-1 : Intersection of the Mascarene Plateau and the Rodriguez Ridge. Investigate channeled flow from hotspot toward spreading ridge through magma mixing observed in basalt compositions ; age and geochemistry of basaltic rocks.

MP-2 : Northern margin of the Cargados Carajos Bank. Age and geochemistry of basalts, possible evidence of continental material in basalt compositions ; subsidence history in sediments.

MP-3 : Northeastern margin of the Nazareth Bank. Age and geochemistry of basalts, nature of rifting away from the Chagos Bank ; subsidence history.

The details of the sites are given in the table following.

Mascarene Plateau Drilling Program

| Site - Location | Water Depth (m) | Penetration (m) | | Operations | Time on site (day) | |
|---|---|---|---|---|---|---|
| | | Total | Bsm't | | Total | Logging |
| MP-1 Mascarene Plateau 18°45'S - 59°05'E | 2000 | 250(?) | 50 | Rot. single bit to destruction | 5.5 | 1.5 |
| MP-2 Cargados Bank 15°30'S - 59°40'E | 2500 | 350(?) | 50 | Rot. single bit to destruction | 5.5 | 1.5 |
| MP-3 Nazareth Bank 13°30'S - 61°30'E | 2700 | 450(?) | 50 | Rot. single bit to destruction | 6.5 | 1.5 |

Total times on site are only estimates. The logging includes standard and BHTV. The program (drilling and logging) requires 17 to 18 days on site and can be combined either with the Makran or Carbonate Saturation Profiles to form a complete leg.

Paleomagnetic measurements would be made on sediments and basalts to determine paleolatitudes with age to compare hotspot and geomagnetic reference frames and assess true polar wander through Tertiary time.

These sites will also provide the necessary age documentation for comparison with Ninetyeast Ridge age progression for plate tectonic reconstructions in the hotspot reference frame. These data will allow precise determination of the collision history of India with Asia through Tertiary time.

Drilling on the Mascarene Plateau does not duplicate Ninetyeast Ridge objectives :

- In order to define Cenozoic motion of the Indian plate in the hotspot reference frame at least two hotspot lineaments must be dated to determine a series of rotation poles and angular velocities. Different periods of time within the Cenozoic are recorded on the two traces. The Ninetyeast Ridge covers 115 Ma (Rajmahal Traps, eastern India) to 38 Ma (southern end) ; between 38 Ma and the present the hotspot has been under the nearly motionless Antarctic plate where it has produced the Kerguelen Plateau. The western hotspot trace runs from the Deccan Traps (65 Ma) to present day activity at Reunion Island. Thus the only way to obtain direct information on plate motion between 38 Ma and the present is to sample the Mascarene Plateau. Precise reconstruction of the Indian plate throughout the Cenozoic, for defining the collision history of India with Asia and discerning True Polar Wander, requires sampling and dating on both lineaments.

- Geochemical and petrological studies at the endpoints of the Mascarene-Chagos-Laccadive lineament (which are the Deccan Traps in western India and the islands of Reunion and Mauritius) are more "mature" than equivalent studies of the Ninetyeast Ridge. In particular, isotopic work on the Deccan flood basalts has shown that melts have been contributed from the sub-continental, the sub-oceanic and hotspot mantle sources. The Rajmahal Traps which begin the Ninetyeast Ridge are much less well exposed and geochemical work has not progressed as far. Hence, the compositions of recovered basement samples from the Mascarene Plateau will be more easily interpreted in terms of already defined mantle source endmembers and mixing models developed from these studies. Ultimately, the Ninetyeast Ridge sampling will supply a similar record of mantle heterogeneity and melting/mixing processes. Kerguelen, which lies over the hotspot responsible for the Ninetyeast Ridge, has dramatically different isotopic compositions from Reunion, so comparison of the two lineaments will reveal an extra dimension -that of the variability of hotspots within the same ocean basin through time.

- Drilled basement rocks from two industry wells on the northern end of the Mascarene Plateau have just been made available by Texaco. These penetrated 830 m and 200 m of basalts at 10°S, 60°E and 15°S, 60.5°E, respectively. Together with the proposed three basement sites (ODP drilling) and the subaerial locations (Deccan and volcanic islands) this would be one of the best sampled aseismic (hotspot) ridges yet.

STATUS OF SITE SURVEY

Site survey grids will be done by *Darwin* (March, 1987), including high resolution SCS, 3.5 Khz, gravity and magnetics. Basement definition and sediment thickness are required, slumping and steep slopes have to be avoided.

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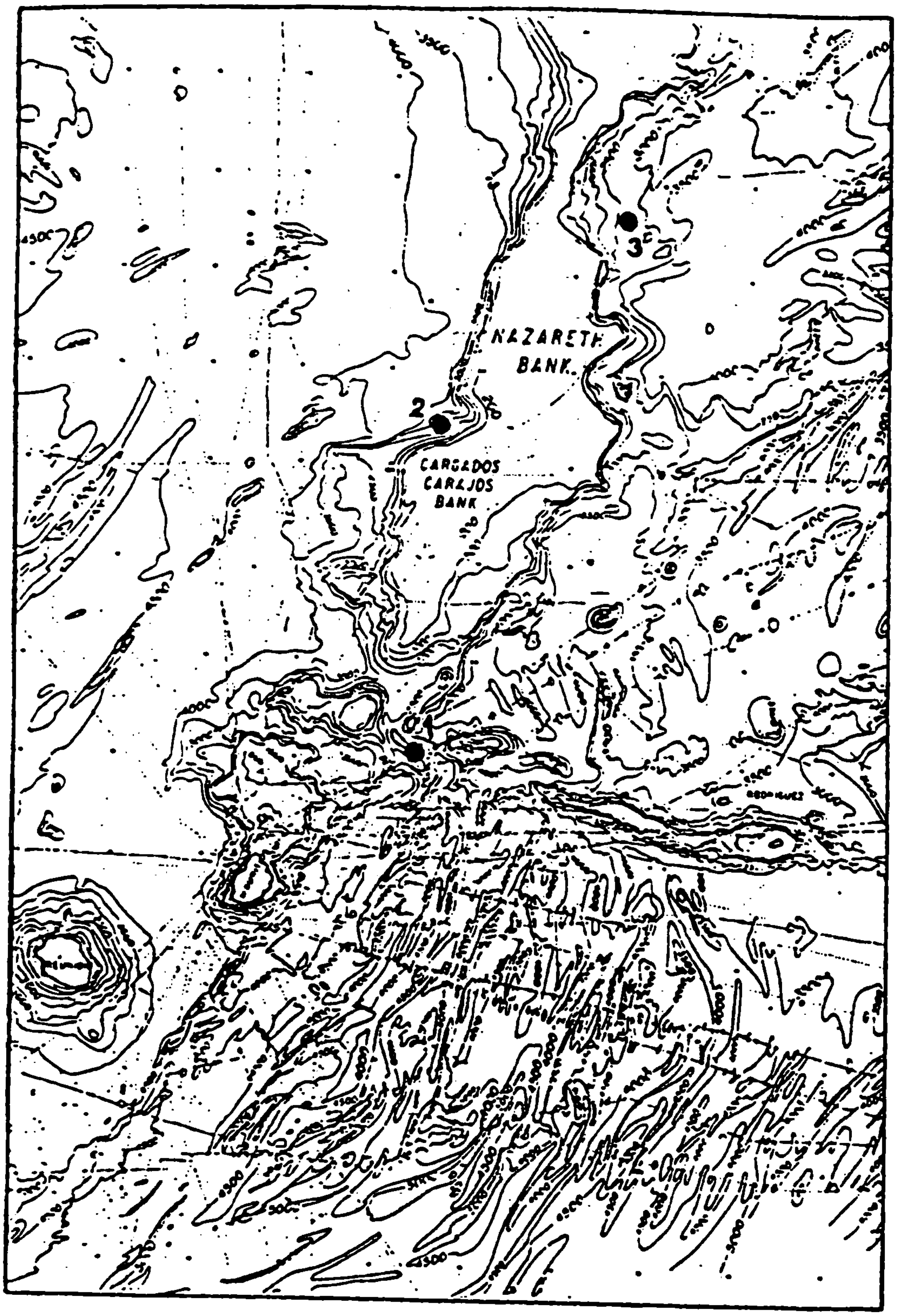
Further detail is available from the following proposal : PCOM n° 88/B (R. Duncan et al.).

22 November, 1986


NAZARETH
BANK
2
CARGADOS
CARAJOS
BANK
3

# SUMMARY OF THE KERGUELEN PLATEAU/PRYDZ BAY DRILLING PROGRAM

The Kerguelen Plateau is the largest oceanic plateau in the world. It extends over 2000 km from 46°S to 64°S in a northwest-southeast direction. The feature is between 200 and 600 km wide, and stands 2 to 4 km above the adjacent Cretaceous to earliest Tertiary seafloor. Kerguelen and Heard islands are exposed on the shallower northern sector, which has an average water depth of 1000 m and which is characterized by a deep sedimentary basin (over 3000 m of sediments) located just southeast of Kerguelen Island. The central sector, including a large east-west trending spur, the Elan Bank, has irregular topography and also contains a major sedimentary basin, the Raggat Basin, covered by over 4000 m of sediments of late Cretaceous to Recent age. Water depths vary from 1000 to 3000 m. The southern sector extends from Banzare Bank to a 3500 m deep saddle separating the plateau from the antarctic margin. Sediments in that sector are generally thin. The origin and crustal structure of the basement rocks of the plateau is obscure with some workers considering it to be oceanic, others continental. A multiple origin is also possible, with a continental southern sector and an oceanic hotspot northern sector.

Prydz Bay lies on the antarctic continental margin south of the Kerguelen Plateau and includes the Amery Ice Shelf. Over 4000 m of Tertiary to Mesozo sediments occur in a seaward dippening sequence at waterdepth of 500 to 800 m. This section contains both the India-Antarctica breakup history as well as the glacial and climatic history of Antarctica.

The Indian Ocean Panel, the Southern Ocean Panel, and the IOP-SOP Kerguelen Working Group have proposed a two-leg drilling program on the Kerguelen Plateau and in Prydz Bay which jointly tackles the problems of the origin and tectonic history of the plateau and the paleoclimatic and paleoceanographic history of the Southern Ocean from the Antarctic Margin to the convergence.

## DRILLING OBJECTIVES

The major objectives include :

- The nature and age of basement on the northern, central and southern sectors of the Kerguelen Plateau. Sufficient penetration into basement (∿50 m) should be achieved to clearly decide between the different modes of origin.

- The nature and age of the various sedimentary sequences occuring on all three sectors of the plateau.

- The pre- and post-breakup history and subsidence of the plateau and the relationship with basement type and origin.

- The evolution of antarctic climate and oceanic fronts, including the polar front and subtropical convergence.

- The evolution of water masses and their paleocirculation.

PROPOSED SITES

For the northern sector of the Kerguelen Plateau four sites have been selected.

Site KHP1 to sample Neogene (S1 and S2) sequences including the major discordance (A) in the deep sedimentary basin southeast of Kerguelen Island (910 m of drilling in 660 m water depth).

Site KHP3 to sample the major discordance (A) and Eocene to Cretaceous (I1 and I2) sequences and basement in the deep sedimentary basin southeast of Kerguelen (1700 m+ of drilling in 570 m water depth).

Site KHP4 alt to sample basement. Site KHP4A is an alternate basement site to site KHP3 (750 m of drilling in 990 m water depth).

Site KHP5 to sample deep water Neogene sequences including the major discordance (740 m of drilling in 2310 m water depth).

For the central and southern sectors of the Kerguelen Plateau, eight sites have been proposed :

Site SKP1 to sample sedimentary units and basement in the central sector of the plateau (450 m of drilling in 1700 m water depth).

Site SKP2 to sample Neogene sedimentary units in the Raggatt Basin including the major unconformity (700 to 1100 m of drilling in 1700 m water depth).

Site SKP3 to sample Paleogene and Mesozoic sedimentary units in the Raggatt Basin including major unconformities (1300 m of drilling in 1500 m water depth).

Site SKP4 to sample sedimentary units and basement on the Western Banzare Bank (400 m of drilling in 1200 m water depth for SKP4A).

Site SKP5 to sample sedimentary units and basement on the Eastern Banzare Bank (650 m of drilling in 1400 m water depth).

Site SKP6 to sample intermediate depth sedimentary units and basement at the southernmost end of the southern sector of the plateau (500 m drilling in 2300 m water depth for SKP6A).

Site SKP7 to sample deep water sediments on the eastern flank of the southern sector of the plateau (600 m of drilling in 4100 m water depth for SKP7A).

Site SKP8 to sample deepwater sediments on the eastern Kerguelen sediment ridge in the southern sector of the plateau (700 to 950 m drilling in 3900 m water depth).

The details of the sites are given in the table following.

## Kerguelen Plateau Drilling Program

| Site - Location | Water Depth (m) | Penetration (m) Total | Bsm't | Operations | Time on site(day) Total | Logging |
|---|---|---|---|---|---|---|
| KHP1 N. Kerg.Pl. 49°22.4'S-71°39.3'E | 660 | 910 | - | HPC/Rot. | 7 | |
| KHP3 N.Kerg.Pl. 50°14.0'S-73°02.7'E | 570 | 1700 | 30 | Re-entry HPC/Rot. | 18 | |
| KHP4A N.Kerg.Pl. 49°10.8'S-72°05.9'E | 990 | 750 | 50 | Rotary | (6) | |
| KHP5 N.Kerg.Pl 48°56.9'S-72°46.2'E | 2310 | 740 | - | HPC/Rot. | | |
| SKP1 C.Kerg.Pl. 54°48.8'S-76°47.4'E | 1600 | 450 | 50 | HPC/Rot. | | |
| SKP2 Raggatt Basin 57°48.9'S-79°55.8'E | 1700 | 700+ | - | HPC/Rot. | 6+ | |
| SKP3 Raggatt Basin 58°07.6'S-78°11.4'E | 1500 | 1300 | 50 | Re-entry HPC/Rot. | 15 | |
| SKP4A Banzare Bank 58°43.0'S-76°24.4'E | 1200 | 400 | 50 | HPC/Rot. | 5 | |
| SKP5 Banzare Bank 59°34.5'S-82°43.0'E | 1400 | 650 | 50 | HPC/Rot. | | |
| SKP6A S.Kerg.Pl. 62°44.0'S-83°05.2'E | 2300 | 500 | 50 | HPC/Rot. | 5 | |
| SKP7A Labuan Basin 59°32.0'S-85°49.5'E | 4100 | 600 | - | HPC/Rot. | | |
| SKP8 Labuan Basin 61°17.8'S-86°46.7'E | 3900 | 700+ | - | HPC/Rot. | 6+ | |

*Times on sites are estimates made by the IOP-SOP Kerguelen Working Group at his October 27, 1986 meeting.*

To establish the origin of the Kerguelen Plateau and to understand its Mesozoic and Paleogene history of subsidence, rifting, erosion, and how the late Mesozoic-early Tertiary ocean responded to changes of Antarctic climates, the IOP-SOP Kerguelen Working Group has selected sites KHP3/4A, SKP3, SKP4A and SKP6A. To establish the evolution from pre-Glacial to Glacial climates in East Antarctica and to understand the role of changing climates in the meridional and vertical evolution of water masses and their associated biota in the Southern Ocean, the IOP-SOP Kerguelen Working Group has selected, in addition to four Prydz Bay sites (PB1 to PB4), sites KHP1, SKP2, SKP8 and wish to consider an additional site SKP9 to fill the objectives of the depth transect.

Two drilling legs, 119 and 120, have been considered by PCOM to achieve the Kerguelen/Prydz Bay drilling program. The program as suggested by the IOP-SOP Kerguelen Working Group requires 86 days on site. These estimates need further scrutiny by the ODP Science Operator. Deeper Paleogene and Cretaceous sedimentary, tectonic and basement objectives are mostly incorporated into leg 119 in the northern and central Kerguelen Plateau (KHP1, KHP3/4, SKP3, SKP4A representing 45 days on site). It includes two re-entry sites with drilling depths of 1650 m and 1300 m subbottom. Problems with cherts are also expected. Leg 120 incorporates most of the paleoceanographic objectives in the central and southern Kerguelen Plateau and Prydz Bay (SKP2, SKP6A, SKP8, SKP9, PB1, PB2, PB3, PB4 representing 41 days on site). Ice problems might be expected here.

Final selection of the central and southern Kerguelen Plateau sites will only be possible after completion of processing of the recent acquired MCS data.

## STATUS OF SITE SURVEY

The site survey has been completed for all the Kerguelen Plateau sites (Marion Dufresne cruise 26, 1981 ; Rig Seismic cruise 02, 1985 ; Marion Dufresne cruise 47, 1986). Seismic data processing is completed for all the northern Kerguelen Plateau sites and will be finished early 1987 for all the central and southern Kerguelen Plateau sites.

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Further detail is available from the following proposals : PCOM n°136/C (R. Schlich, M. Munschy, L. Leclaire, F. Froehlich), 185/C (M. Coffin, J. Colwell), and XXX/C (R. Schlich, M. Munschy, J. Colwell, H. Davies).

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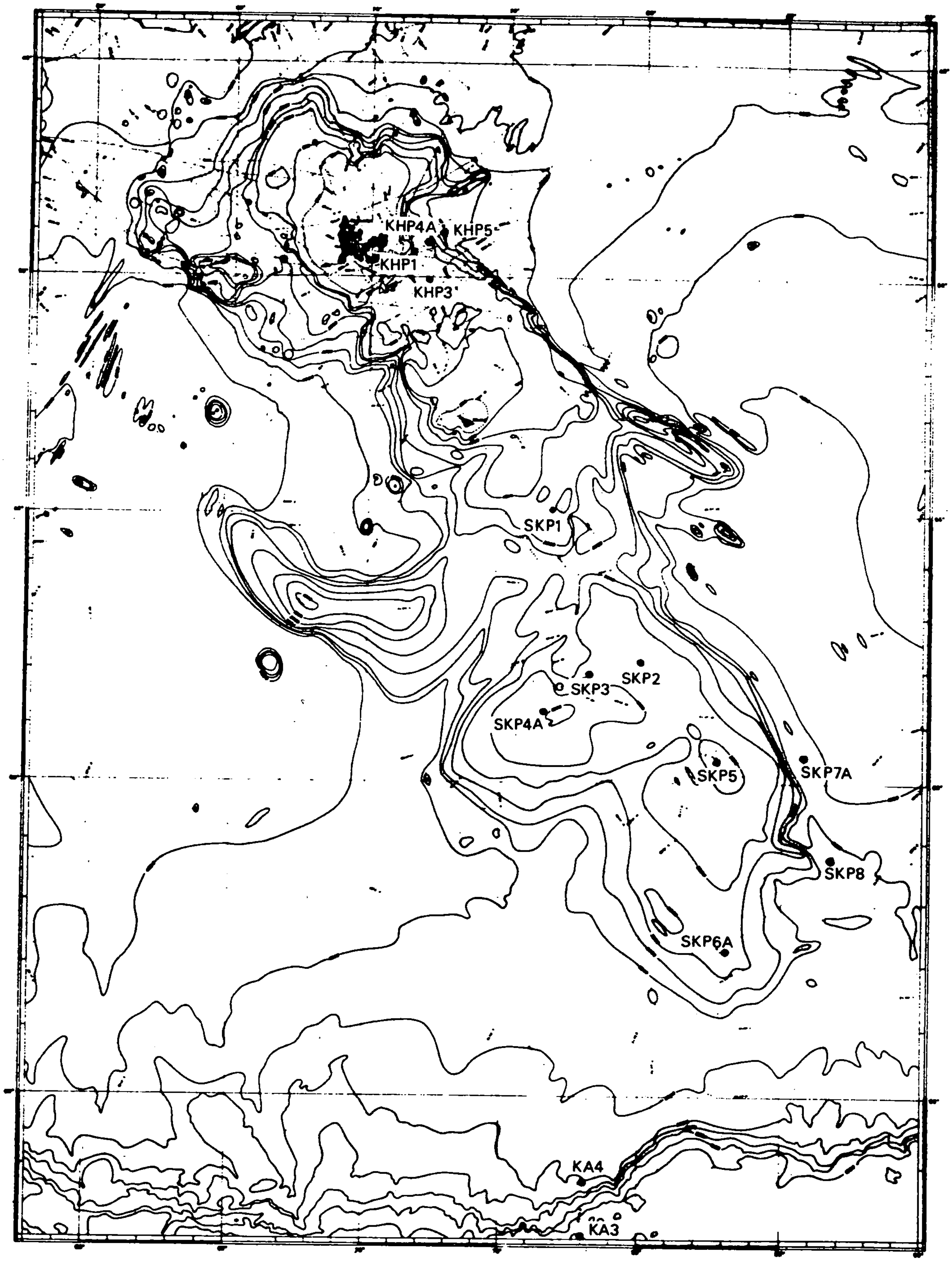
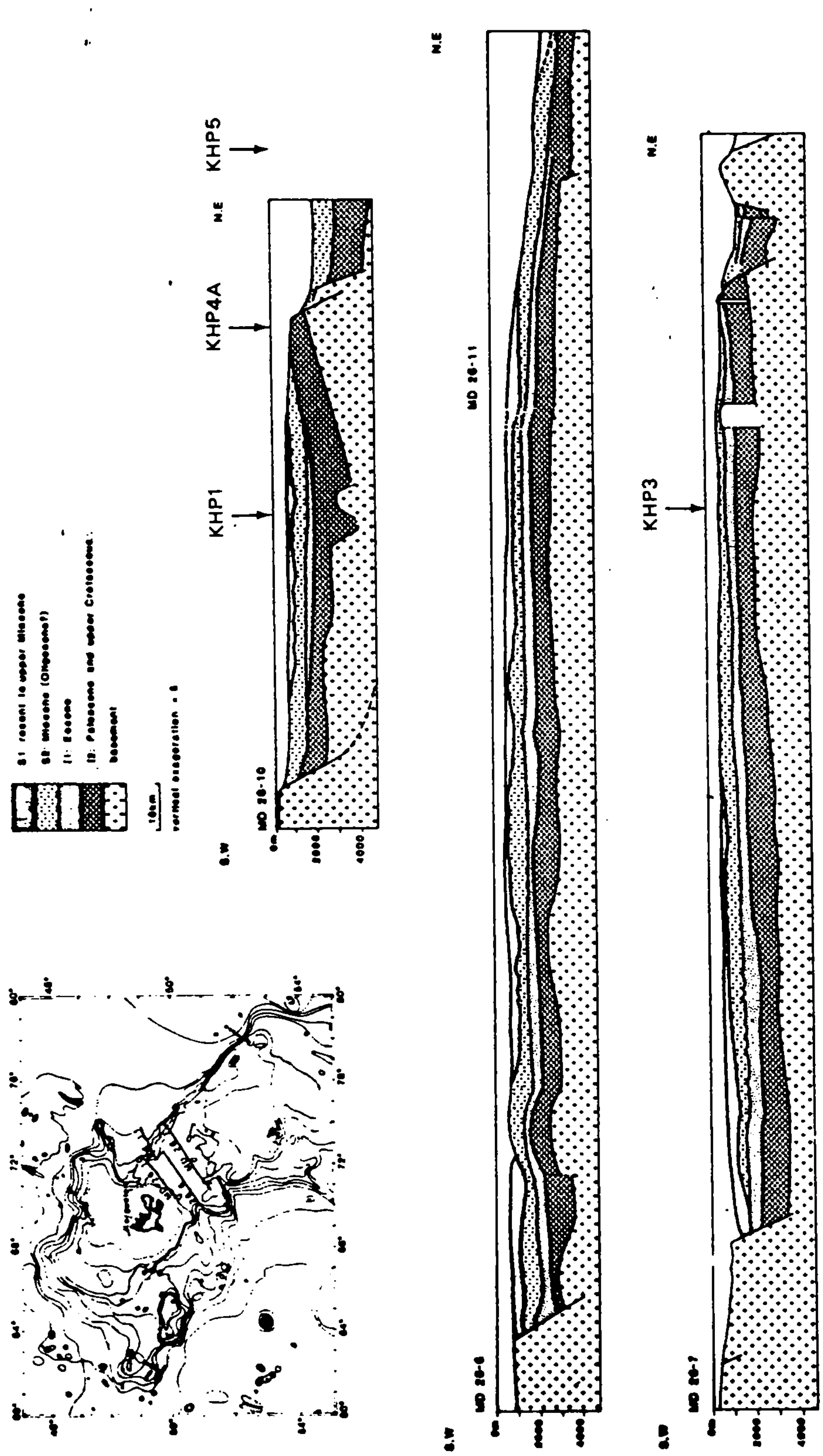
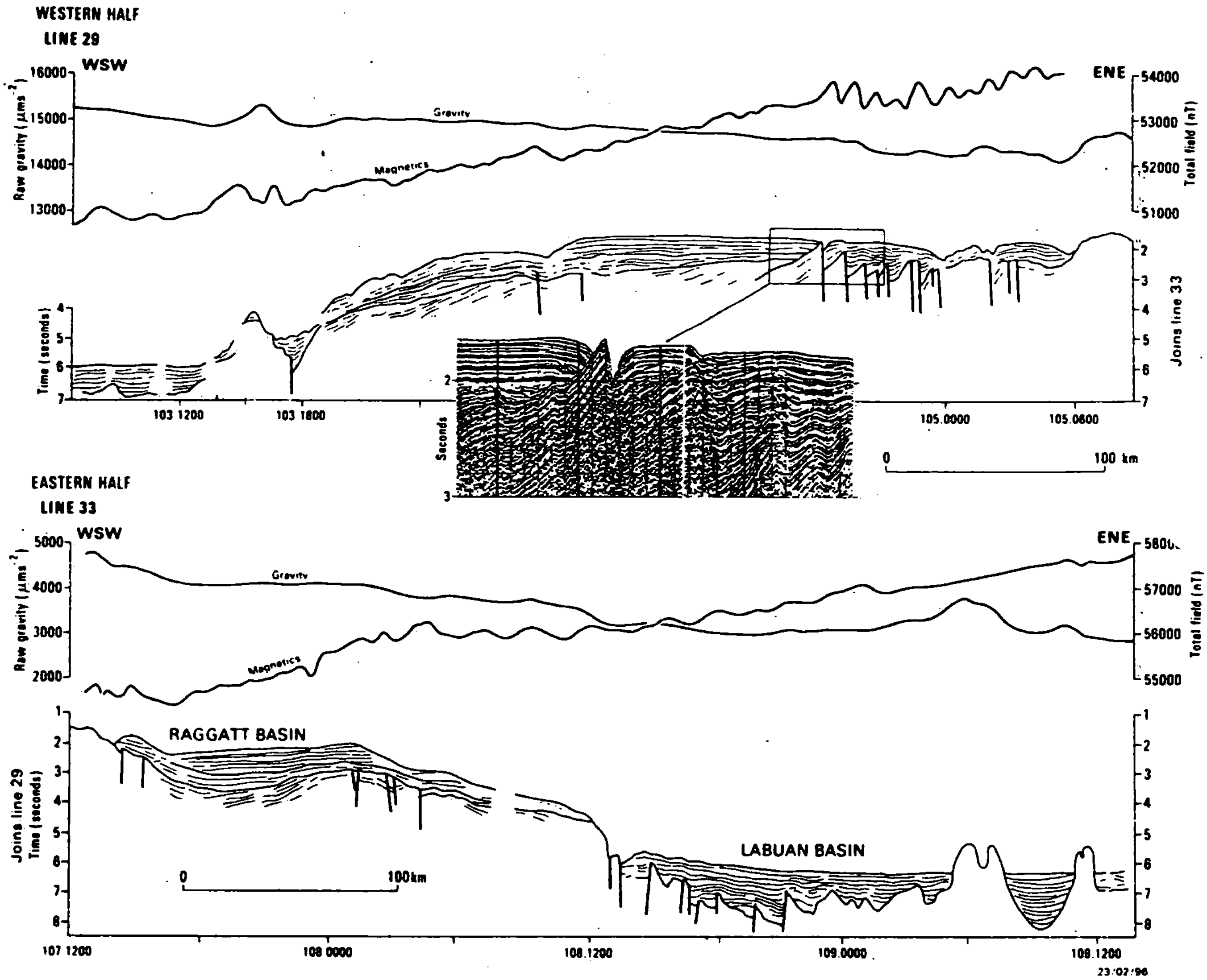

KHP4A
KHP5
KHP1
KHP3
SKP1
SKP2
SKP3
SKP4A
SKP5
SKP7A
SKP8
SKP6A
KA4
KA3




Cross sections at about 50° S of the Kerguelen Plateau (northern sector) derived from seismic interpretation with locations of sites KHP 1, KHP 3, KHP 4A and KHP 5.




Cross sections at about 59°S of the Kerguelen Plateau (southern sector) derived from preliminary seismic interpretation.

# SUMMARY OF THE INTRAPLATE DEFORMATION DRILLING PROGRAM

*This program will be sent later*

SUMMARY OF THE BROKEN RIDGE

DRILLING PROGRAM

*This program will be sent later*

# SUMMARY OF THE NINETYEAST RIDGE DRILLING PROGRAM

This study combines the two major regional objectives of the collision history of India with respect to Asia and the geochemical evolution of magmas associated with the Kerguelen hot-spot track. These objectives will be addressed by drilling at three sites on the 90°E Ridge.

## DRILLING OBJECTIVES

i) Petrological

From a geochemical perspective the Indian Ocean floor is especially interesting due to the presence of an isotopically distinct "end-member" composition which is defined by magmas erupted at Kerguelen Island. By drilling basement at three sites along the 90°E Ridge, in combination with existing data from DSDP sites 216, 214, 253, and 254, it will be possible to constrain the processes which create heterogeneities in the oceanic crust and the length of time that such heterogeneities can exist in a convecting mantle.

ii) Tectonic

Drilling a north-south transect of the 90°E Ridge will provide samples for a high-resolution study of the northward motion of India with respect to Asia. It will be possible to relate changes in plate velocity to the onset of the Himalayan orogeny and tectonic events in Southern China. Current data indicate that the Indian Ocean plate slowed down by a factor of three after colliding with Eurasia.

iii) Paleceanography

In addition to the two major objectives the north-south transect, with a total of 35° latitude extent, will be used to detect climatic and paleoceanographic changes such as a record of the aeolian transport from Western Australia through the Tertiary.

## PROPOSED SITES

The sites proposed are numbered from north to south ; they correspond to the original selected sites 90ER-1,2, and 5. All have the same objectives : basalt geochemistry, northward motion, paleoenvironment.

Details of these sites are given in the table following.

## NINETYEAST RIDGE DRILLING PROGRAM

| Site - Location | Water Depth (m) | Penetration (m) | | Operations | Time on site (day) | |
|---|---|---|---|---|---|---|
| | | Total | Bsm't | | Total | Logging |
| 90ER-1 (North) 6°N - 90°E | 2500 | 750(?) | 50 | Rotary core | 9.5+ | 1.5+ |
| 90ER-2 (Central) 16°30'S - 88°E | 1800 | 450(?) | 50 | Rotary core | 6.5- | 1.5- |
| 90ER-5 (South) 29°S - 87°30'E | 2300 | 250(?) | 50 | Rotary core | 4.5- | 1.5- |

Total times on site are still estimates which have to be adjusted according to the results of the recent site surveys. The program (drilling and loggin requires about 20 days on site and has to be combined with two other drillin programs in the Eastern Indian Ocean (Intraplate Deformation and Broken Ridge or Broken Ridge and Argo Basin).

STATUS OF SITE SURVEY

Site 90ER-1 was surveyed by J. Curray in July, 1986 from the *Conrad*. Sites 90ER-2 and 90ER-5 were surveyed by J. Sclater and J. Weissel in subsequent *Conrad* cruises in August and September, 1986 respectively.

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Further details is available from the following proposals : PCOM n°98/B (Rea), n°116/B (Oberhänsli and Herb), n°150/B (Frey and Sclater), n°196/B (Pierce).

Five DSDP holes have been drilled on the Ninetyeast Ridge in 1972. Site 216 (01°28'N, 90°12'E), site 214 (11°20'S, 88°43'E), site 253 (24°53'S, 88°22'E), and site 254 (30°58'S, 87°54'E) have reached and sampled basement.

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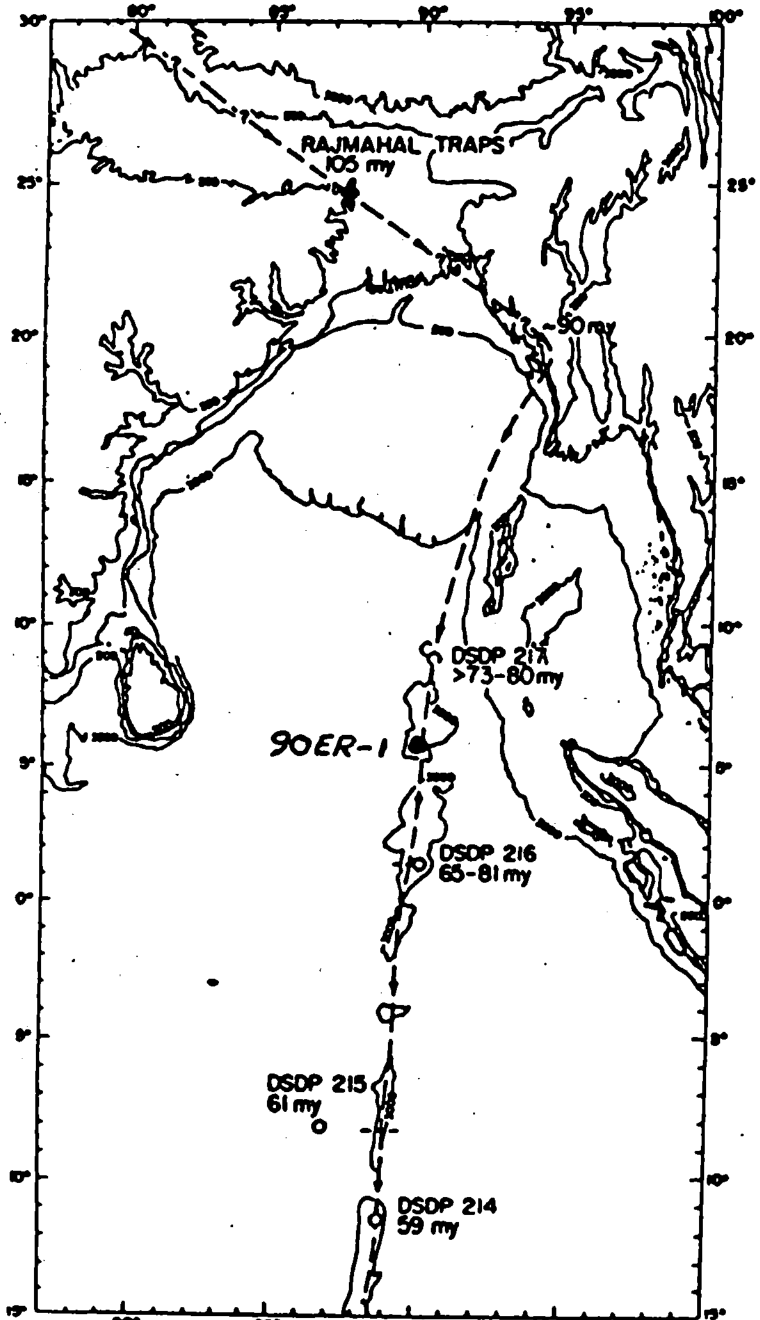
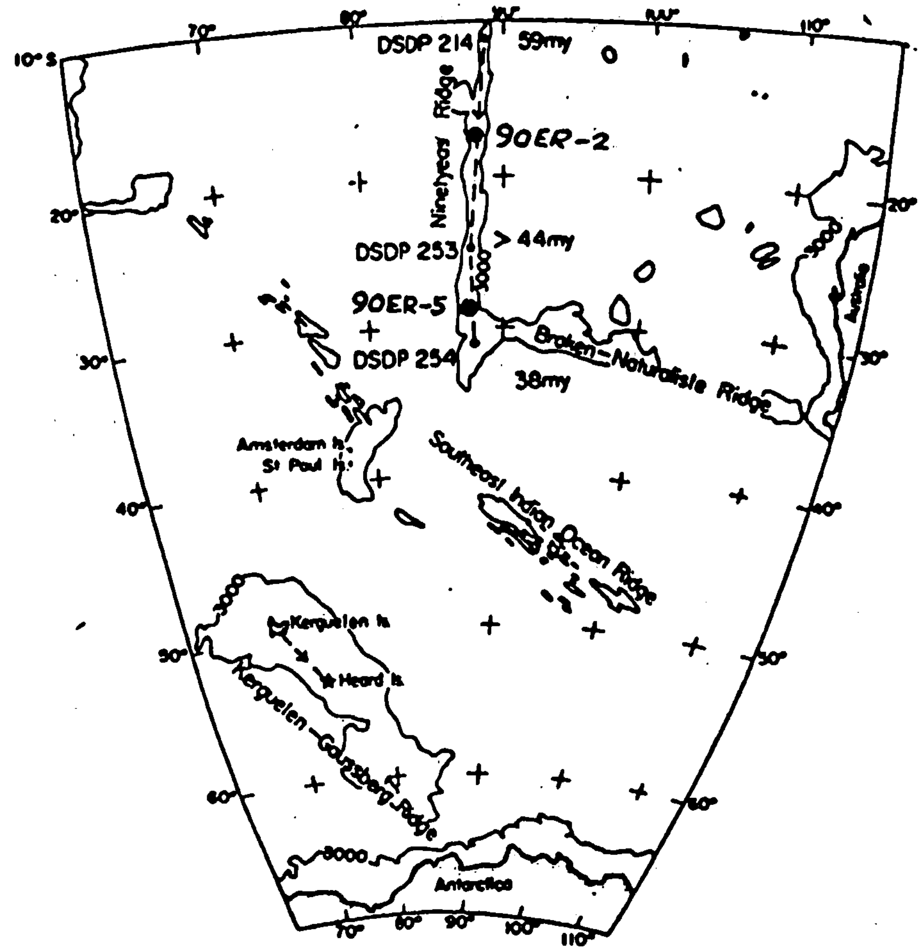


RAJMAHAL TRAPS
105 my
~90 my
DSDP 217
>73-80 my
90ER-1
DSDP 216
65-81 my
DSDP 215
61 my
DSDP 214
59 my

DSDP 214
59my
Ninetyeast Ridge
90ER-2
DSDP 253
> 44my
90ER-5
DSDP 254
Broken-Naturalisle Ridge
38my
Amsterdam Is.
St Paul Is.
Southeast Indian Ocean Ridge
Kerguelen Is
Heard Is
Kerguelen-Gaussberg Ridge
Antarctica
Australia

# SUMMARY OF EXMOUTH PLATEAU DRILLING PROGRAM

The Exmouth Plateau off NW Australia is a submerged marginal plateau representing a very wide, sediment-starved stretched passive margin with transform boundaries and a well-defined Callovian (in the N) or Neocomian (in the S) breakup unconformity. It is an ideal area to study the Triassic to Late Jurassic (or Noecomian) pre- and post-breakup development of sediment facies, paleobathymetry and subsidence of a continental margin and to test the global sealevel curve. In the Exmouth Plateau region continental margin sediments corresponding to the pre-rift, rift and early-post rift phases are easily accessible to ODP-type drilling.

## DRILLING OBJECTIVES

The major topics and objectives include :

1) Test the Late Jurassic to Neogene global sealevel curve in an almost hiatus-free continental margin section (mainly EP-5 or 7).

2) Study differential subsidence and paleobathymetric development in a paleodepth transect between the plateau and the adjacent marginal parts and Argo Abyssal Plain (all sites).

3) Study early-rift history and test subsidence and stretching models for continental margin and marginal plateau evolution near the continent-ocean boundary (EP-2, 8,10,11).

4) Study Triassic to Late Jurassic sediment facies paleoclimate and paleoenvironment (EP-2,8,10,11; shallow-water carbonates of this age range belonging to the SE realm of the Tethys ocean, have been dredged along the North Exmouth Plateau margins).

5) Late Jurassic to Cenozoic post-breakup develpment of sedimentation and paleoenvironment form a juvenile to mature ocean stage (all sites).

6) Correlation of unconformity-bound sequences (from very dense seismic grid) with sedimentation, tectonics, and global sea level fluctuations (EP-5,7, also EP-2 and EP-8).

## PROPOSED SITES

We propose four non-reentry sites with an alternative site for each of them to make a complete depth transect from the Central Exmouth Plateau (EP-7, alternate site EP-5A with reentry) at about 1300 m water depth, via the northern plateau margin (EP-9B, 3320 m w.d. and EP-10A, 2050 m w.d. ; alternate sites EP-8A and EP-11B) to the ocean-continent boundary (EP-2A, 4050 m w.d. ; alternate site EP-2B).

Site EP-7 (Central Exmouth Plateau) :
The Central Exmouth Plateau is an ideal area to test parts of the global sea level curve and to study the Cretaceous to Cenozoic paleooceanography and sedimentation history, as well as the differential subsidence between the plateau and adjacent parts of the stretched sediment-starved continental margin (see SOHP "deep stratigraphic test proposal"). The major appeal of EP-7 is its ability to provide a relatively complete section from Late Jurassic to Present in a synclinal, non-faulted situation. Central Exmouth Plateau has an excellent data base consisting of a closely spaced, high-quality seismic reflection grid and industry exploration wells. The seismic data at EP-7 and correlations to surrounding areas demonstrate a detailed history of marine and coastal onlap, offlap and erosional truncation throughout Cretaceous and Tertiary times. Close calibration available from spore/pollen and foraminiferal biostratigraphy provides a unique opportunity to establish the relatioships between sediment supply, relative sea level and tectonic activity, as well as an experiment to test the validity of available explanations of such relationships (e.g. the VAIL model based on unpublished, confidential data). Surrounding wells provide a useful regional framwork for this study. The nearby wells are no duplication of the proposed ODP site, since their objective was to test structural traps in Jurassic fault blocks and only very few sidewall core samples were obtained from the Cretaceous and Cenozoic sequence. Other objectives of ODP drilling on Central Exmouth Plateau include an opportunity to drill a complete sequence from rift to mature ocean stage in a passive margin setting due to the thin sediment cover and a possibility of encountering a continuous sequence through the Cretaceous-Tertiary boundary.

Site EP-5A (Central Exmouth Plateau) is located on GSI-line 76-20 near SP 2000 (near the shallowest part of Central Exmouth Plateau) and has been proposed as an alternate site to EP-7 by SOHP in October 1987. The objectives are identical to EP-7 and the suggested penetration would be 1800 m down to the Upper Jurassic DingoClaystone. Although this site has the advantage of higher sedimentation rates in the Lower to Middle Cretaceous deltaic section and thus better stratigraphic resolution to test the VAIL curve, IOP favours EP-7 for two reasons :

- although EP-7 has a more condensed section than EP-5, a detailed study of all available GSI lines calibrated to the commercial wells on the Central Exmouth Plateau, suggested that EP-7 has a more complete section between the Albian-Cenomanian Gearle Siltstone and Neogene.

- Site EP-7 is located in a synclinal setting without closure and away from Cretaceous deltaic lobes and pre-rift Triassic fault blocks. No hydrocarbons have been encountered in post-Jurassic sediments on Exmouth Plateau, except in arched domes associated with delta lobes. The Cretaceous sequence proposed for drilling is unfaulted and composed of prodelta shales, away from any potential delta front sandstone reservoirs. The site is considered to conform to safety standards and is the most suitable site available on Central Exmouth Plateau. Site EP-5, on the other hand, has not been approved by a preliminary safety preview (letter by G. Claypool of February 26, 1986), because it is located close to a broad regional high and close the gas-prone delta-front of the Barrow Delta. Site EP-5A might similarly be questioned by the safety panel.

EP-9B and EP-10A (Northern Exmouth Plateau Margin) :
We propose two sites in the area of the Northern Exmouth Plateau Margin to obtain a more or less complete Triassic to Neogene record and to address objectives 2-5 : site EP-9B in the Montebello Trough (Neogene to mid-Cretaceous) and EP-10A on the Southeastern Wombat Plateau. Sites 8A and 11B have identical objectives as EP-10A and serve as alternate sites. The major objective of these sites is to decipher the early to middle Mesozoic pre-rift history and early post-breakup evolution which is documented by marginal to shallow-marine Tethys-type sediments and to compare it with the Mesozoic evolution in the nearby Argo Abyssal Plain Site AAP-1B and central plateau Site EP-7.

EP-2A (Western Exmouth Plateau Margin) :
This site is located at the western margin of Exmouth Plateau near the ocean-continent boundary and is designed to test subsidence and stretching models for rift and subsequent continental margin evolution, leading to marginal plateau formation. Site EP-2 is the deepest sites of the Exmouth Plateau transect. It should be possible to integrate stratigraphic and paleontological data from open file commercial exploration wells on the summit of the Plateau and adjacent shelf, to establish a comprehensive picture of paleo-water depths and environments. This should allow construction of a definitive subsidence curve and to test various models of passive margin and plateau evolution. It is anticipated that four units would be encountered in site EP-2A, which would adequately define pre-breakup margin subsidence seaward of the lower plateau slope. The seismic stratigraphic interpretation and correlations with Vinck n°1 and Eendracht n°1 suggest that Triassic non-marine sediments should be encountered at 630 m subbottom. The overlying 530 m of pre-breakup, rift-phase sediments might be expected to show progressive upward marine influence. However, most of the 4000 m of submarine subsidence probably occured post-breakup (120 m.y. ago).

The alternate site EP-2B would reach the continental or "transitional" basement already at 500 m subbottom.

Details of these sites are given in the table following.

Exmouth Plateau Drilling Program

| Site - Location | Water Depth (m) | Penetration (m) Total | Bsm't | Operations | Time on site (day) Total | Logging |
|---|---|---|---|---|---|---|
| EP-7 Central Exmouth Pl. 20°36'S - 112°07'E | 1365 | 990 | - | Rotary core HPC | 9 | |
| EP-5A Central Exmouth Pl. 20°15'S - 113°12'E | 900 | 1800 | - | Rotary core HPC Re-entry | 16 | |
| EP-9B Northern Exmouth Pl. 17°12'S - 115°39'E | 3320 | 600 | - | Rotary core | 9 | |
| EP-10A Northern Exmouth Pl. 16°56.6'S - 115°33.1'E | 2050 | 980 | - | Rotary core | 10 | |
| EP-8A Northern Exmouth Pl. 17°10'S - 115°09'E | 2250 | 700 | - | Rotary core | 9 | |
| EP-11B Northern Exmouth Pl. 16°49.1'S - 117°29.0'E | 3360 | 990 | - | Rotary core | 11 | |
| EP-2A Western Exmouth Pl. 19°56'S - 110°27'E | 4050 | 800 | - | Rotary core | 13 | |
| EP-2B Western Exmouth Pl. 19°55.5'S - 110°25.5'E | 4030 | 550 | - | Rotary core | 12 | |

The program (drilling and logging) including all prioritized sites EP-7, EP-9B, EP-10A, and EP-2A, amounts to 41 days. Sites EP-5A, EP-8A, EP-11B, and EP-2B are alternates.

STATUS OF SITE SURVEY

All sites surveys for sites EP-2, EP-8, and EP-11 have been carried out by BMR in April/May 1986. For EP-7 and EP-5 there exists a very dense grid of commercial MCS lines tied to commercial exploration wells which are all on open file. Processing of BMR's Rig Seismic Cruise 55 and 56 lines will be finished by mid-1987.

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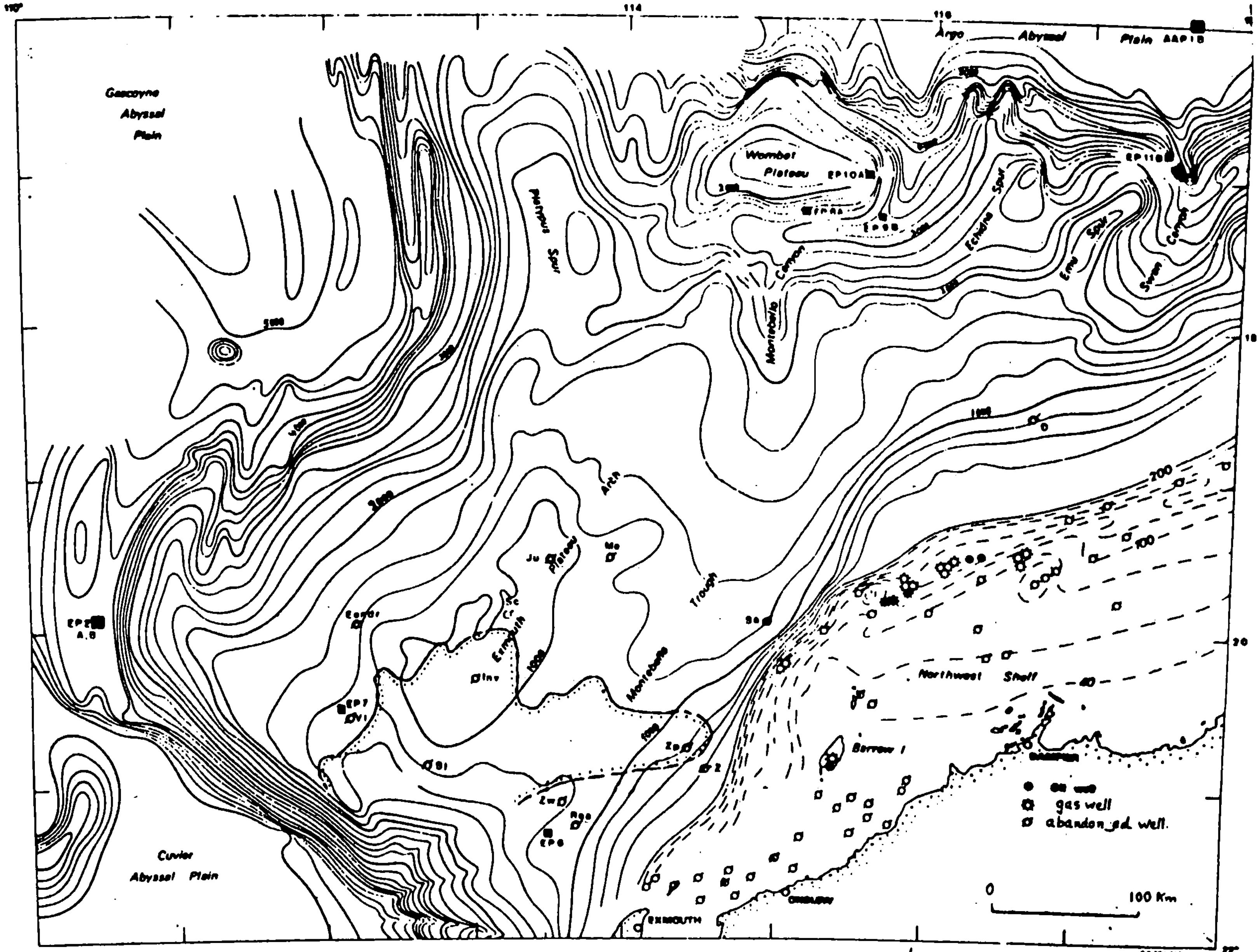
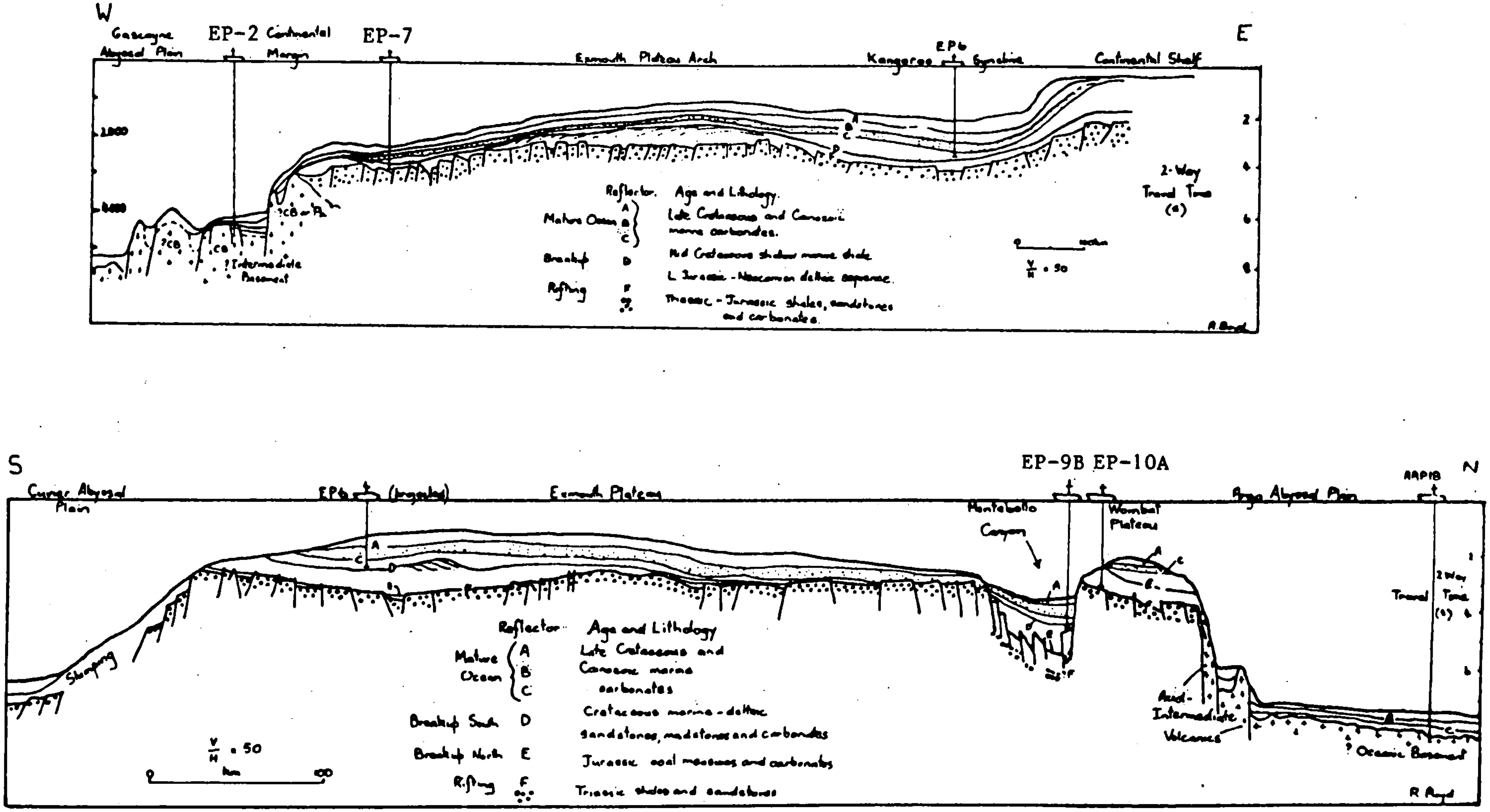
Further details is available from the following proposals : PCOM n°121/B (Von Rad, Exon), n°121/B revised (Von Rad, Exon, Williamson, Boyd), and australian yellow book 1985 (Packham, Keene).

22 November, 1986




**PROPOSED NORTHWEST AUSTRALIAN ODP LINES RELATED TO BATHYMETRY**

Barrow delta > 1000m thick




Schematic cross sections (N-S and E-W) across the Exmouth Plateau

# SUMMARY OF THE ARGO ABYSSAL PLAIN DRILLING PROGRAM

The Argo Abyssal Plain is a sediment starved remnant of the Tethys located north of the Exmouth Plateau off NW Australia and underlain by the oldest (M25, Oxfordian or older) crust of the Indian Ocean. It is the only area in the Indian Ocean where we can easily study the Jurassic oceanic crust and the Late Jurassic to Early Cretaceous paleoenvironment, paleoclimate and paleoecology.

## DRILLING OBJECTIVES

Drilling in the Argo Abyssal Plain will address the following objectives :

1) Composition and alteration style of the oldest Indian Ocean crust (M25 or older). Reference site in connection with the Sunda Arc transect to study the composition of igneous rocks being subducted in the Java Trench.

2) High resolution, multiple bio-magnetostratigraphy for the precisely interpolated but inaccurate standard Jurassic time scale, including matching of marine magnetochronology (basement age) and sedimentary bio-magnetostratigraphy for dating of anomaly M25.

3) Three-dimensional, quantitative distribution model of microfossils which is needed in paleoenvironment reconstructions, paleogeography and stratigraphy.

4) Vertical seismic experiments to improve understanding of the nature of seismic horizons, particularly in relation to Exmouth Plateau.

5) Testing the fossil patchiness in deep water sediments and response of benthic microfossil communities to "warm" ($\sim 10°C$?) abyssal ocean bottom water.

6) Quantitative evaluation of the survival rate at the species and genus level of microfossils from Jurassic into Cretaceous.

7) Reconstruction of Jurassic surface and deep circulation and paleo-biogeography in a critical part of the equatorially (east-west) oriented Mesozoic world ocean system, between (proto) Atlantic and (super) Pacific.

## PROPOSED SITES

The program calls for drilling of a transect of two stratigraphically staggered sites, both to approximately 1000 m deep in the Argo Abyssal Plain on Jurassic oceanic crust.

<u>Site AAP 1B</u> : This site will be drilled in the oldest southeasternmost part of the Argo Abyssal Plain in water depth of 5 740 m with a total penetration of about 1 000 m, including Quaternary to Upper Jurassic (Callovian ?) sediments and 50 to 100 m of pre M25 oceanic crust. The main objectives are : Late Jurassic to Early Cretaceous Eastern Tethys paleocirculation and paleoecology, subsidence history, and age of the oldest Indian Ocean crust.

<u>Site AAP 2</u> : This site, also in the southeastern part of the Argo Abyssal Plain, is slightly northwest of site AAP 1B on magnetic anomaly M25. Drilling at this site will provide an overlapping section for high resolution stratigraphy and will date M25 oceanic crust.

Details of these two sites are given in the table below.

| Site - Location | Water Depth (m) | Penetration(m) Total | Bsm't | Operations | Time on site(day) Total | Logging |
|---|---|---|---|---|---|---|
| AAP 1B - Argo Basin 15°58.5'S-117°33.9'E | 5740 | 950 | 50 | Re-entry | 20 | 2 |
| AAP 2 - Argo Basin 15°40'S -117°30'E | 5800 | 1100 | 50 | Re-entry | 15 | 3 |

Site AAP 2 will be cored only from Neocomian to basement. The program (drilling and logging) requires 35 days on site. This estimate does not include the time allocated to the northern 90°E Ridge site (9 to 10 days) which may be added to this program for logistical reasons.

The main arguments why we propose duplicate coring of the Mesozoic section of the Argo Abyssal Plain are summarized below :

- There is a complete absence of a detailed cored Mesozoic record in the Indian Ocean, which contrasts with the upcoming effort to achieve triplicate or duplicate HPC coring of Neogene and Quaternary sediments.

- The Argo Abyssal Plain allows relatively quick drilling of Jurassic fossiliferous sediments (above CCD).

- Two sites allow high resolution multiple bio-magnetostratigraphy and give insight in the 3-d distribution of microfossils (particularly benthics) as a function of so-called patchiness. "Patchiness" means that we lack reliable distribution models in a statistical sense. The latter is needed for accuracy in time analysis in quantitative correlation using Mesozoic microfossils like foraminifera.

- The tie of seismic abyssal reflector stratigraphy to Jurassic "eustatic" events stratigraphy needs detailed coring without gaps. One site will not give the necessary correlation framework. Since HPC will not work at depth and rotary coring is less continuous, two sites are needed to offset the lack of data and the need for the best resolution. Argo is the only chance in the whole five years of the ODP program for detailed Mesozoic record.

STATUS OF SITE SURVEY

Site survey data are available for site AAP 1B and site AAP 2 (MCS profiles from Rig Seismic : line 56-22 and 56-23, SCS profiles from Atlantis II).

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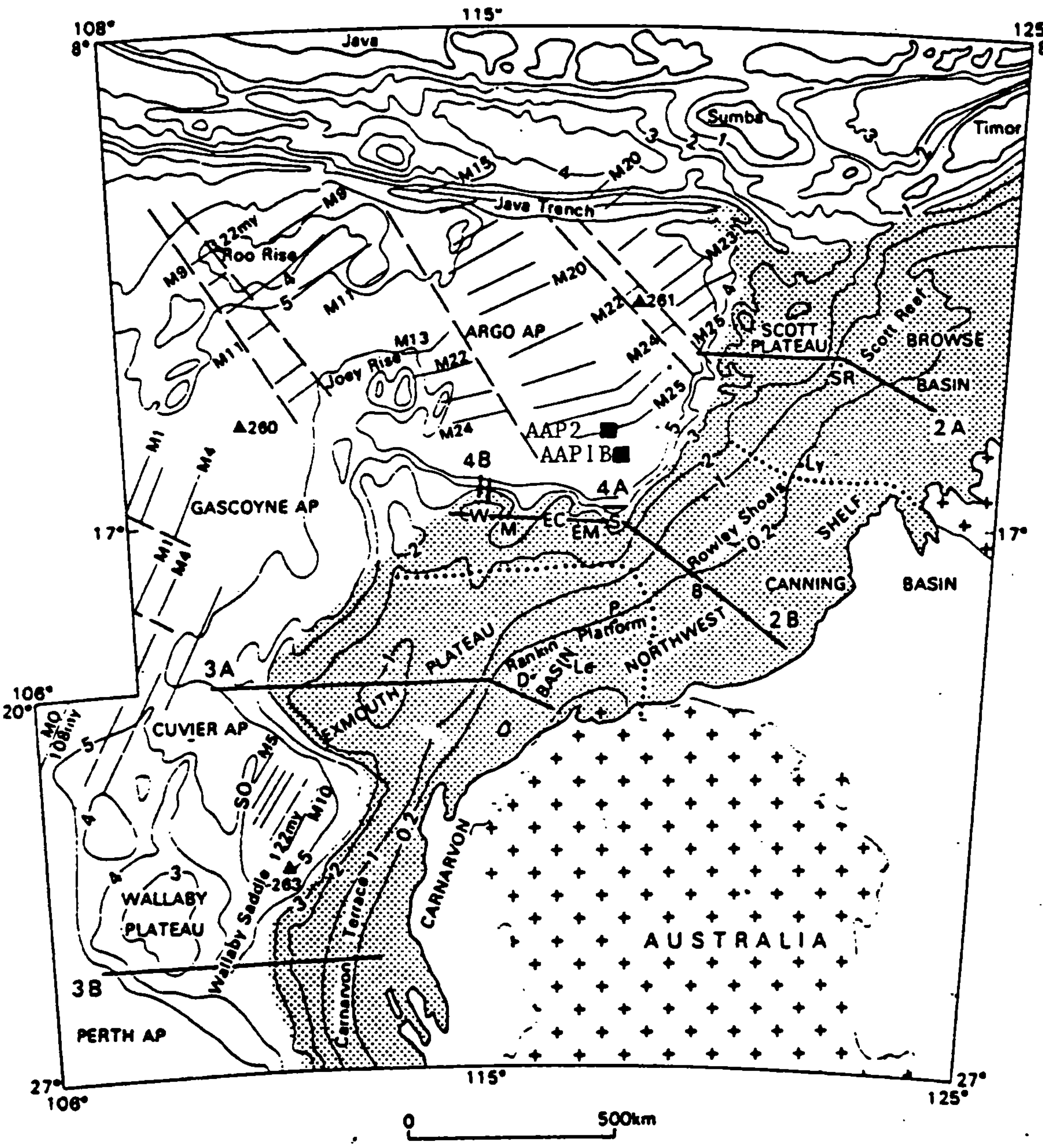
Further detail is available from the following proposals : PCOM n° 121/B revised (Von Rad, Exon, Williamson, and Boyd), n° 240/B (Gradstein).

22 November, 1986




| | | | | | |
|---|---|---|---|---|---|
| S | Swan Canyon | ·SR | Scott Reef No 1 | — — | *Fracture zone* |
| EM | Emu Spur | ·Ly | Lynher No 1 | MO / 108my | *Magnetic lineation* |
| EC | Echidna Spur | ·B | Bedout No 1 | —5— | *Isobath (km)* |
| M | Montebello Canyon | ·P | Picard No 1 | ........ | *Approximate edge of Phanerozoic basin* |
| W | Wombat Plateau | ·Le | Legendre No 1 | + + | *Precambrian complex* |
| SO | Sonne Ridge | ·D | Dampier No 1 | (stippled) | *Approximate offshore extent of Australian continental crust* |
| | | ▲261 | DSDP hole | 3A | *Line of reference section with figure No* |

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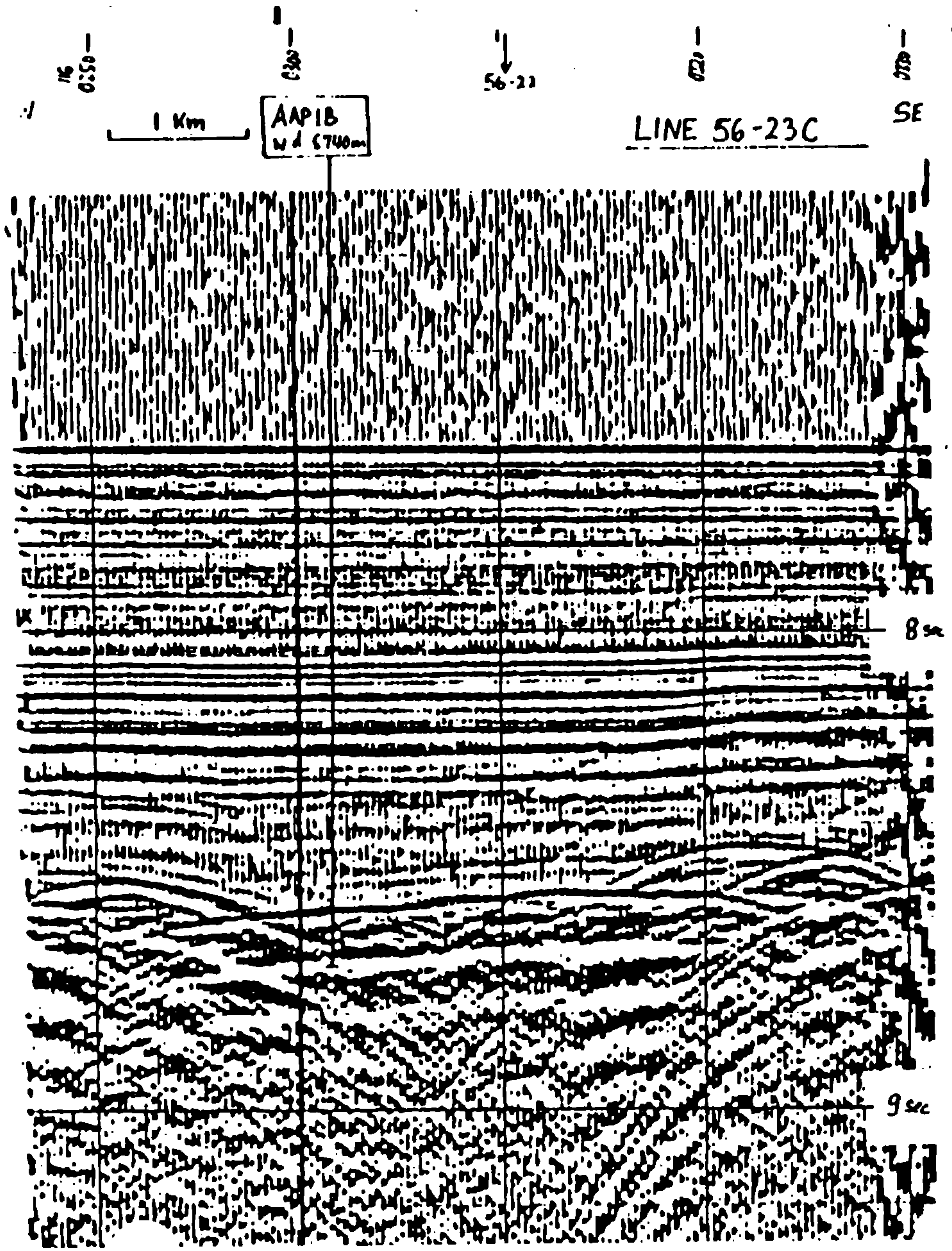
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AAP1B
w.d. 5740m
LINE 56-23C
SE
8 sec
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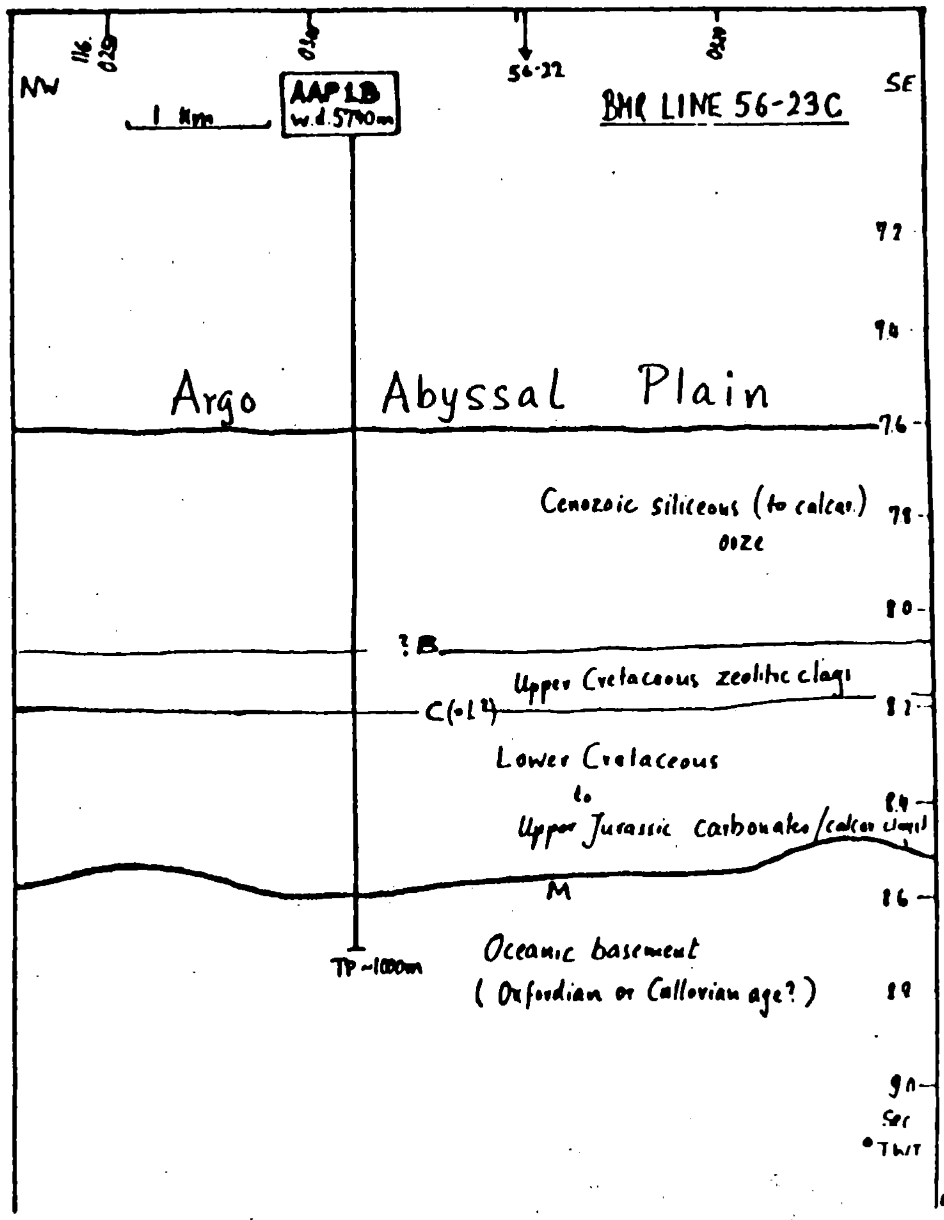
NW
1 Km
AAP1B
w.d. 5740m
56-22
BMR LINE 56-23C
SE
Argo Abyssal Plain
Cenozoic siliceous (to calcar.) ooze
?B
Upper Cretaceous zeolitic clays
C(o1?)
Lower Cretaceous to Upper Jurassic carbonates/calcar. clays
M
TD ~1000m
Oceanic basement (Oxfordian or Callovian age?)
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
8.8
9.0
Sec
TWT