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INTERNAL DOCUMENT 203

A Proposal to the JOIDES Ocean Drilling Programme for Drillsites relevant to the Great Meteor East HLRW Study Area

Robert B. Kidd & Philip P.E. Weaver

IOS Internal Document No. 203

NATURAL ENVIRONMENT RESEARCH COUNCIL
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Work carried out under contract to the Department of the Environment

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Forward

Investigations to date on the Seabed Working Group HLRW study areas have frequently shown the need for information and samples from the sediment sequences that are beyond the penetration capability of conventional piston coring (approx. 20 metres sub-bottom). The only system presently capable of providing high quality continuous sediment sections from such depths is the hydraulic piston coring equipment developed by the Deep Sea Drilling Project and deployed until recently from the D.V. Glomar Challenger. The JOIDES organisation is traditionally averse to use of its technology on a hire basis for applied research. On the other hand, it often looks favourably on drillsite proposals that are aimed at testing fundamental scientific ideas and which are based on well-documented surveys conducted for applied research objectives. Previous site proposals from SWG investigators have been successful and holes have been drilled in HLRW study areas established to characterise pelagic clay and pelagic carbonate environments. DSDP Site 576 was drilled in the PAC-1 area primarily to examine the long term geochemical history of a pelagic clay sequence while DSDP Site DSDP Site 608 was drilled at the KTF area with a prime objective to investigate the tectonic history of the King's Trough complex. Both allowed SWG investigators access to deep samples for geochemical and geotechnical studies, as well as calibrating the regional seismic stratigraphy for analysis of the continuity of the sediment sequences.

Here we present a proposal for drilling on the Madeira Abyssal Plain and Saharan Continental Rise based partly upon DOE-funded survey data. Its scientific rationale is founded firstly upon the collaborative work of Weaver at IOS and Kuijpers of the Dutch Geological Survey, which showed a link between GME piston core stratigraphy and glacial-interglacial sea-level changes on the adjacent continental margin. Secondly, it is based upon the continental rise studies of Kidd & Simm at IOS aimed at understanding processes of sediment transport to the region of GME.

The proposal is in competition with a number of others for drilling on the Northwest African continental margin during the first two-year phase of the JOIDES Ocean Drilling Programme that is scheduled to begin with a new drillship at the end of 1984. If we are successful and our proposed sites are accepted in the drilling programme, a number of important SWG objectives will be met in the MAP-1 site:-

(1) It will allow detailed calibration of our seismic reflection profiling data from which to establish the continuity of the sediment barrier in the GME distal turbidite environment.

(2) Samples will become available for geochemical and geotechnical investigations to depths of a few hundred metres. In particular this will allow more precise studies to be made of pore water mobility.

(3) The geotechnical properties of the pre-turbidite sequences can be studied in order to investigate further the origin of faulting and the possible post depositional instability of deeper horizons in the area.

(4) Detailed stratigraphic analysis of the deeper sedimentary sections will establish whether or not the absence of erosion in the shallower horizons continues at greater depths.

<u>ODP ATLANTIC DRILLING</u> <u>MARCH 1984</u>

CONTINENTAL MARGIN SEDIMENT INSTABILITY INVESTIGATED BY DRILLING ADJACENT TURBIDITE SEQUENCES

A proposal for drillsites on the Madeira Abyssal Plain and Saharan Continental Rise

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Introduction

The two years of Atlantic drilling scheduled to represent the initial phase of the ODP programme is, at present, largely based upon previously proposed areas of drilling. Nevertheless, it also provides the opportunity to insert sites to tackle some new and exciting ideas and objectives. Here we promote an idea for drillsites off Northwest Africa (Figure 1) that we hope can be inserted in this early phase of drilling to tackle some topical sedimentological objectives.

Three recent short papers provide the background for this outline proposal:-

(a) Weaver & Kuijpers (1983) have investigated the frequency of distal turbidites deposited on the Madeira Abyssal Plain in the late Quaternary. They have demonstrated that turbidites occur between lithological alternations that reflect glacial climate changes, and consequently eustatic sea-level changes. They observe that turbidite activity has frequently been linked to eustatic changes but only to low stands of sea level (Sarnthein, 1978). They record, on the other hand, turbidite input during the regressions and transgressions, rather than during the low stand quiet period between.

(b) Klein (1984) examined the frequency distribution of turbidite cycles in three drillsites from the Coral Sea and Sea of Japan. He interpreted the frequency trends of the depositional events as correlating with trends of increasing and decreasing continental tectonic uplift. The frequency of individual preserved turbidite units in the sedimentary basins were taken as a measure of tectonic uplift in the adjacent source terrains. However, where a high turbidite frequency at one site correlated with a high sea level stand, according to Vail et al. (1977), this he took as an indication that the controlling factor was not sea-level fluctuation but a tectonic uplift.

(c) Simm & Kidd (in press) have mapped, using long range sidescan sonar, the distribution of a turbidity current channel system on the Saharan continental rise, adjacent to the Madeira abyssal plain. They have shown that debris flows from upslope sediment slide activity are plastered over parts of the channel system and its overbank turbidite deposits. Some of the debris flows reach the edge of the abyssal plain and are over 1000 km from the slide scar of the Saharan Sediment Slide (Embley & Jacobi, 1979) which is their source. Airgun profiles across the lower rise show stratified sequences in which energy loss occurs in patches elongated horizontally. These may feasibly represent earlier 'long distance' debris flows.

Scientific Objectives

We propose that a modification of Klein's (1984) approach be applied to two new drillsites. Note that we hope the thematic panels will also consider this idea in a more general sense following Weaver & Kuiper's demonstration of the availabiity of a complete stratigaphic section in distal turbidite sequences. Both active and passive margins could be investigated in this way using HPC and XCB coring.

The record of turbidite cycles in the Madeira basin offers a detailed record of instability on the Northwest African continental margin.

Our primary objectives here are:-

(1) that an extended reference section should be established in the non-erosive distal abyssal plain setting, which would allow a detailed stratigraphy to be built from the pelagic intervals between the turbidites, as in Weaver & Kuijpers piston cores.

(2) that, with HPC and XCB coring at this distal site, we should establish a continuous record of the 'glacial' turbidite cycles observed by Weaver & Kuipers but should also look for tectonic control by examining the pre-glacial record.

(3) that we should drill a second continental rise site to investigate the controls the frequency of turbidite events and debris flows in this setting and to establish the influence of sediment slides on the turbidite deposition on the abyssal plain.

(4) that the prime distal site should be drilled well beyond the turbidite sequence to basement in order to provide information on the early history of the Cape Verde

Basin where drilling data is presently lacking. Included as deeper objectives are: the dating of basement, the eolian dust chronology, tephra chronology and CCD fluctuations.

Regional Sedimentation

The Institute of Oceanographic Sciences has over the past few years been studying Late Quaternary sediment distribution and processes of the West African continental rise and the adjacent abyssal plain (Figure 1). Work has been concentrated on the Madeira Abyssal Plain and Saharan continental rise employing a novel integrated approach that uses long range sidescan sonar and seismic profiling data to provide information on regional sediment facies distributions. Near-bottom camera and profiler surveys and sediment coring at selected locations then provide information on the detailed distribution of sediments at the present day and through Late Quaternary time.

The Neogene sequences of the continental slope and rise off the Spanish Sahara have been examined previously, mainly using airgun and 3.5 kHz high resolution seismic profiling. Embley (1976) described a major Late Quaternary submarine sediment slide that originated on the upper continental slope near the Canary Islands and resulted in 'tongues' of debris flows that reach downslope to the continental rise. To the north, Embley (1976) and later Jacobi (in preparation) mapped turbidity current channel systems that appear to originate on the upper continental slopes off the mainland and also on those of major islands such as Madeira. The long range sidescan sonar (GLORIA) surveys by IOS on the abyssal plain and rise have shown that the Saharan slide debris flow 'lobes' extend right to the edge of the abyssal plain and show a complex relationship with a system of turbidity current channels which extends southwest of Madeira (Simm & Kidd, in press). Despite losing material through overbank deposition on the rise, most of the sediment carried through the channel system is deposited as turbidite units several metres in thickness on the Madeira Abyssal Plain. The GLORIA and seismic profiling results show the turbidity current flow pathways and the eventual ponding of the turbidites around the abyssal hill topography.

The Madeira Abyssal Plain has been an ideal location for the study of distal turbidites (Figures 2 and 3) and it has proven possible to unravel the history of turbidite and non-turbidite deposition in its upper 20 metres of sediment. Studies based on over 50 piston cores show a strong correlation between turbidite deposition and glacial onsets and terminations on the Madeira Abyssal Plain (Weaver and Kuijpers, 1983). The correlation is almost certainly the result of turbidites being initiated by rising and falling sea level above the upper continental slope or shelf along the NW African margin. The abyssal plain is particularly suitable for such investigations because the turbidites are so distal that they can be shown to be virtually non-erosive. Individual turbidites of up to 5 metres thickness are found, spearated by thin (but complete) pelagic sequences. It has been possible using bio- and lithostratigraphic analyses to subdivide the pelagic units into oxygen istope stages, thus providing the high resolution stratigraphy required to derive a detailed history of the area. The studies have been concluded only on the upper 20 metres of sediment, representing the last 200,000 years.

The Madeira Abyssal Plain Site (MAP-1)

We propose to drill the sequence of turbidites on the distal abyssal plain (Lat: 31 deg 09.5′N; Long: 25 deg 36.2′W; water depth 5370m) to ascertain the relationship of turbidite input to sea level change prior to 200,000 years BP. We would plan to continue this hole (Figure 4) well beyond the initiation of turbidite sedimentation in order to examine the development of the abyssal plain during its pelagic sedimentation history and to date basement in an area which is poorly known from magnetic anomaly analysis or from previous drilling.

From studies of piston cores in the turbidite province an average sedimentation rate of about 10 cm/1000 years can be calculated for the upper 20 metres, although this figure might be less in the older parts of the cores. Estimates of the thickness of the turbidite sequence on this abyssal plain vary. Dutch studies based on water gun records, provide an average thickness for their stratigraphic unit 'A' of 125 metres while IOS estimates, based on airgun records, suggest thicknesses of the upper stratified unit in excess of 200 metres. Either estimate places the onset of turbidite sedimentation near the base of the Quaternary, or slightly earlier at around the 2.4 million years established by DSDP Leg 94 as the onset of N. Atlantic glaciation (Kidd et al., 1983).

The sparse magnetic anomaly information on the area (Perry et al., 1981) suggests basement ages ranging from 106 to 84 my BP. Sediment thicknesses vary considerably (Figure 5). Comparisons between subsidence curves (after Parsons & Sclater, 1977) and CCD fluctuations through the post Jurassic period (Van Andel, 1975) suggest that the turbidites invaded a pelagic clay area. The area dropped below the CCD somewhere prior to 80 my BP. We estimate by extrapolation of sedimentation rates, that about 160m of Late Cretaceous carbonate sediment should drape a basement of possible Turonian age. Most seismic records in the western part of the abyssal plain do indeed show a draped acoustic unit on basement of about this thickness.

We propose to double HPC at this site to refusal and extend one hole with the XCB through the base of the turbidite unit and on to basement at around 600 metres sub-bottom. Previous experience on DSDP leg 94 suggest that this strategy would involve approximately four and a half days of operations; or five days allowing for logging the hole. Site survey data is extensive enough that we could easily offer alternate sites if required.

The Saharan Continental Rise Site (SR-1)

We propose a second site in the rise province (Lat: 30 deg 32.07N; Long: 22 deg 25.3'W; water depth 5060m) to obtain a record of overbank deposition from the channel systems that feed the abyssal plain and to look for evidence of pre-Saharan Slide, mass sediment movements on this margin.

The site proposed is at the base of the continental rise where today we have mapped both channel systems and debris flows (Figure 6). Drilling at the chosen site should pass through a Saharan Slide debris flow near surface and then reveal sequences of overbank turbidites interbedded with more pelagic material (Figures 7 and 8) as in the abyssal plain. Inconsistencies in the airgun records suggest that earlier debris flows may be present deeper in the section. The airgun profile (Figure 7) shows patches of energy loss which are the suspected debris flows. The Saharan Slide debris flow unit is present in a crossing 3.5 kHz profile above the uppermost overbank turbidite deposits (Figure 8). Turbidite grain sizes will be considerably coarser than those of the plain and they may be associated with significant erosion. We hope, nevertheless, to correlate turbidites (and possibly debris flow) events from this site with the MAP-1 reference section and make an investigation of any link between glacial/sea level cycles and different types of sediment instability on the continental margin. The experiment should add considerably to our knowledge of mass sediment transport processes and establish any relationship of the debris flows to the turbidites.

We propose to double HPC and XCB at this site to refusal which, because of the expected incidence of sands, will certainly occur well before basement is reached, probably above 150 metres sub-bottom. The estimated time for operations at this site is about one and a half days. Steaming time from MAP-1 to SR-1 is about three-quarters of a day.

Site Survey Data

This part of the Cape Verde Basin is probably at present the most extensively surveyed portion of abyssal plain and adjacent rise in the world ocean. The proposed MAP-1 site lies within a study area of the Seabed Working Group whose studies are aimed at examining a number of deep ocean environments where the sediment sequences might provide suitable media for subseabed HLRW disposal. A dense network of airgun and water-gun 3.5 kHz profiling tracks has been built up by the Dutch Geological Survey and IOS (Figure 2) and in some parts of the area tracks have already been run at spacings of less than 2 nautical miles. Near-bottom profiler, survey camera and coring data is also available from the general area of the MAP-1 site. Density of coring on this part of the abyssal plain as a whole is approximately one per 10 nautical miles (Figure 3). Both sites are in areas of GLORIA coverage.

High resolution 3.5 kHz profiling data is equally as densely spaced in the area of the proposed SR-1 drillsite (Figure 6) but IOS coring and other stations were selected from the GLORIA interpretation and consequently are less frequent. Airgun profiles close to the IOS reference profile are few and generally are not in a suitable west to east orientation. (A further airgun profile could be run by RRS Discovery in October 1984).

Safety and Jurisdiction

Possible piercement structures (mud diapirs) (Embley & Jacobi, 1977) are presently being investigated in this basin but both sites selected are well away from any of these structures, which seem to correlate with the thickest abyssal plain sediment sections.

Both sites are in international waters.

Secondary Objectives

Apart from primary litho- and stratigraphical objectives of these sites there are a number of others that warrant consideration:

(1) Sedimentary Processes. Much has been made of the downslope continuum of near-bottom sedimentary processes in the deep marine environment (Hampton, 1972) suggesting a field relationship that would suppose each of the Saharan Rise debris flow lobes might have a turbidite unit associated with it in the abyssal plain sequences. This relationship is not at all clear in the Late Quaternary sequences that we have sampled to date despite our unique knowledge of surface and near-surface sediment distributions in the area. Our two-drillsite experiment could provide an insight into the relative importance of the turbidite channel and mass sediment movement processes in building the abyssal plain sequences.

(2) Atlantic CCD Fluctuation and Basin Analysis. Our predictions for the lithologies expected in the lower part of the sediment sequence are based entirely upon concepts of plate-stratigraphy (Berggren & Winterer, 1974; Kidd & Davies, 1978), whereas both basement ages and CCD levels through time are very imperfectly known in this area. Dating of the carbonate-pelagic clay boundary and investigation of the sharpness of this transition will aid regional seismic interpretation considerably.

Knowledge of CCD changes will provide further information on the history of bottom water circulation in the eastern Atlantic basins.

(3) Seismic Stratigraphy. We presently have studies underway linking sonic velocity logs of piston cores from the abyssal plain to seismic profiles and near-bottom profiler surveys. An investment in downhole and core logging aboard ship would pay dividends in analysis of seismic records from these and similar abyssal plain sequences.

(4) History of Saharan Dust Contribution to the Deep Ocean and Tephra Chronology. A prime objective of many of the other sites proposed off West Africa (see: Sarnthein et al. proposal) is the history of the eolian sediment contribution to the deep ocean. This could be investigated in the lower parts of the drilled abyssal plain and rise sections as well as in the pelagic interbeds of the turbidite/debris flow sequences, where following Weaver & Kuijpers' work we can expect a complete stratigraphic section. The sites would provide a useful link between open ocean pelagic sites and the new drilling on the margin itself.

Dutch seismic studies suggest that tephras may cause regional reflectors in this area and the MAP-1 site could address this problem by providing a regional tephra chronology.

(5) Physical Properties and Geochemical Objectives. Seabed Working Group interest in this area is presently concentrated upon rates of pore water movement, permeability

and sediment shear strength. Any HPC coring beyond the 26 metres maximum penetration achieved here with conventional piston coring will be of interest to these and other investigators interested in the physical and geochemical properties of abyssal plain sequences and the geotechnical characteristics of debris flows and turbidites.

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Figure Captions

Figure 1. Location of the proposed Madeira Abyssal Plain (MAP-1) and Saharan Continental Rise (SR-1) drillsites off Northwest Africa. Boxes show study areas shown in figures 2, 3, 5 and 6. Bathymetric contours are in metres; dark stipple shows Saharan Slide debris flows as mapped by Embley (1976), using 3.5 kHz profiling; light stipple is the area of the slide scar.

Figure 2. Profiling tracks in the Great Meteor East/Madeira Abyssal Plain study area. The MAP-1 location is starred. IOS tracks with single-channel airgun dashed. Dutch airgun and watergun tracks: thin continuous line; IOS echo-sounder and 3.5 kHz profiles: thickened continuous line.

Figure 3. Stations in the Great Meteor East/Madeira Abyssal Plain study area. The MAP-1 location is arrowed. See key for station types.

Figure 4. Single-channel airgun profile over proposed site MAP-1.

Figure 5. Isopach map of total sediment thickness on the Great Meteor East/Madeira Abyssal Plain study area. The MAP-1 location is starred. See key for further explanation.

Figure 6. Seismic profiling tracks and station positions in the Saharan continental rise study area. The

SR-1 location is arrowed. Lines with widely-spaced ticks (day changes) are single-channel airgun tracks: Farnella-7, Vema 23, Aegis 76 and Aegis 75. Lines with closely spaced ticks (hour changes) are 3.5 kHz high resolution tracks only: Shackleton 126 and Discovery 126. Stippling represents area outside GLORIA coverage made by Farnella-7. Key for Shackleton and Discovery stations as in Figure 2.

Figure 7. Single-channel arigun profile over proposed SR-1 drillsite. Note patches of energy loss elongated horizontally within the stratified sequence.

Figure 8. 3.5 kHz high resolution seismic reflection profile showing the distribution of (transparent) debris flow material in the vicinity of the SR-1 site.

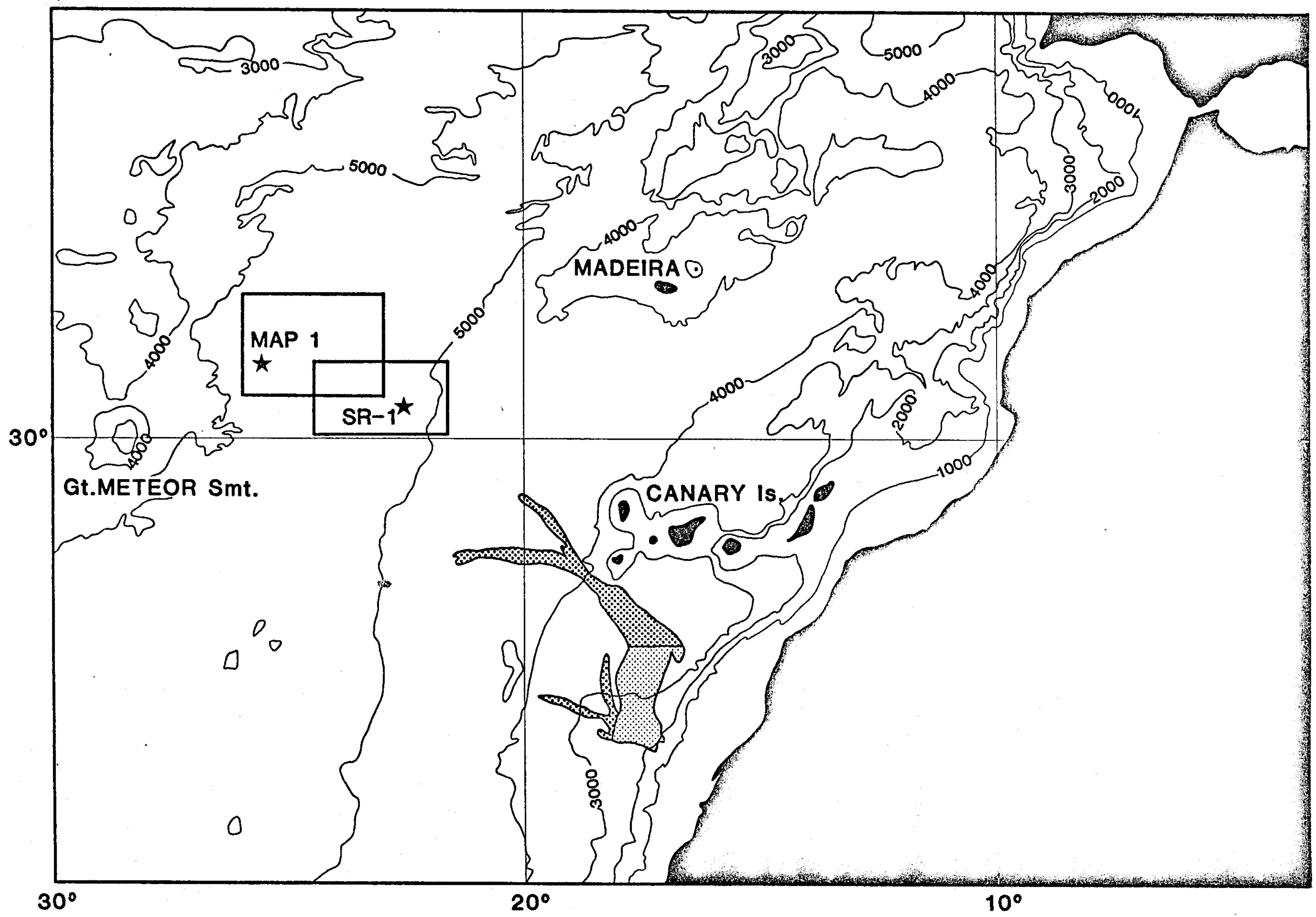

3000
5000
4000
1000
2000
MADEIRA
MAP 1
SR-1
30°
Gt.METEOR Smt.
CANARY Is.
20°
10°

FIGURE 1

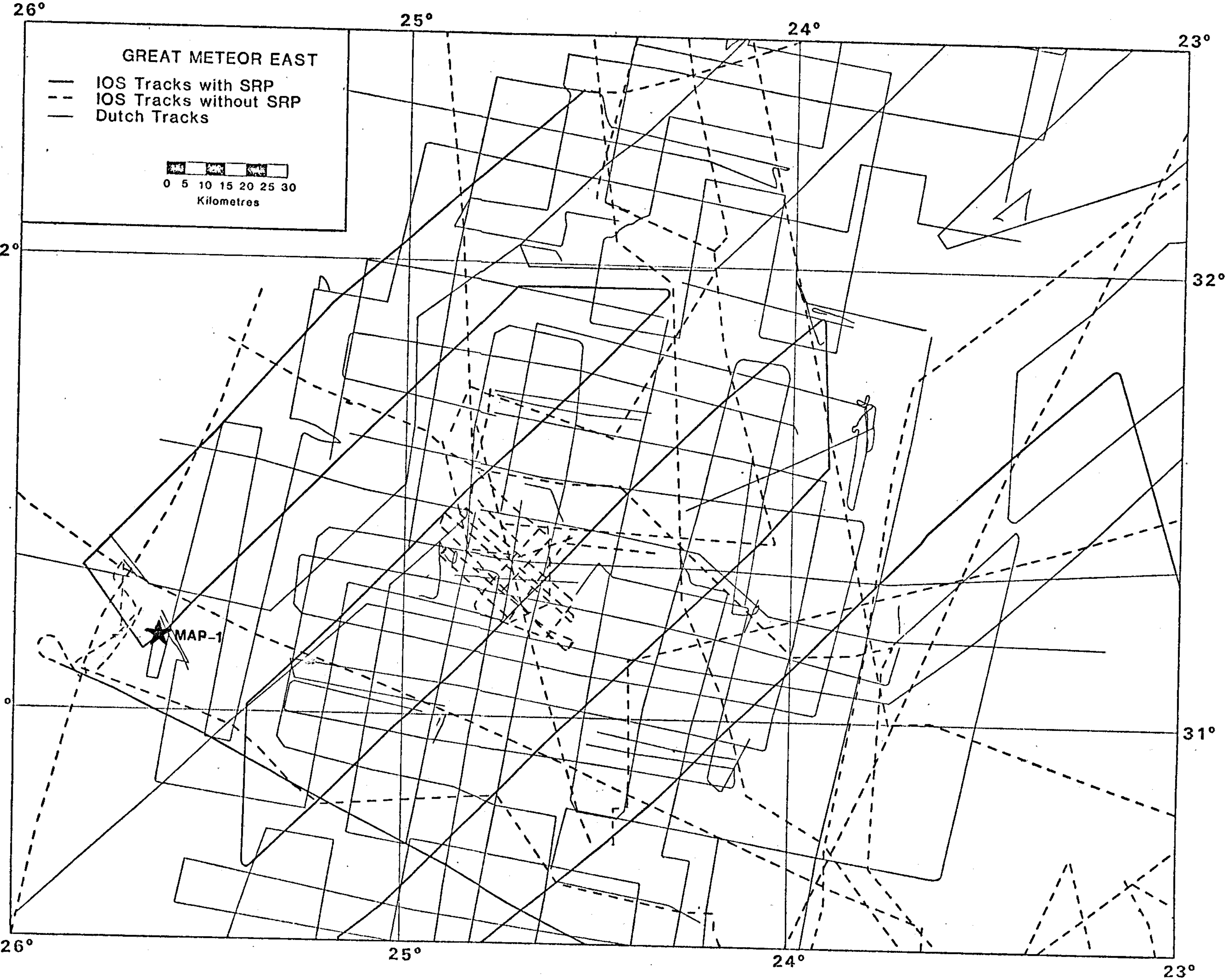
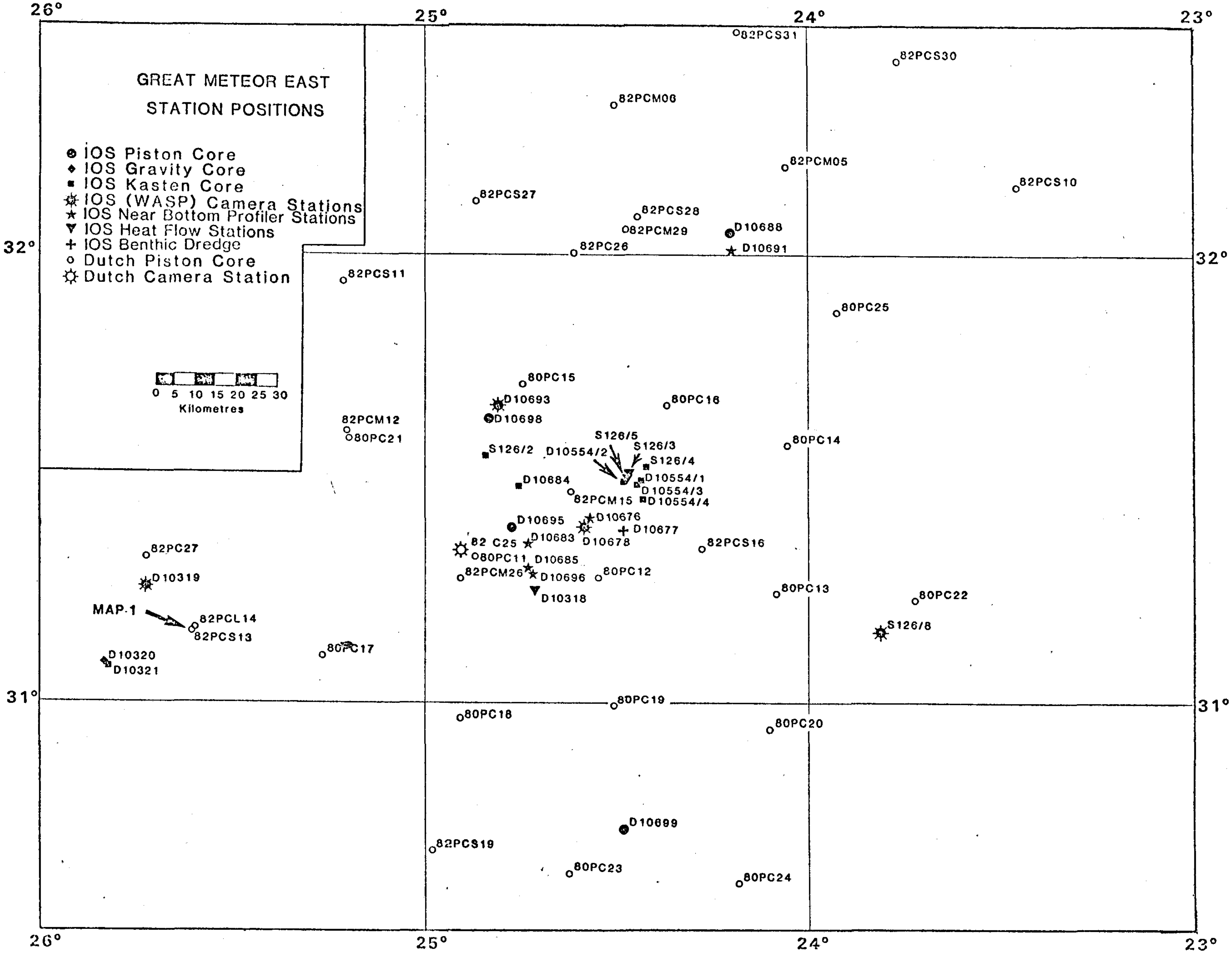

GREAT METEOR EAST
IOS Tracks with SRP
IOS Tracks without SRP
Dutch Tracks
0 5 10 15 20 25 30
Kilometres
26°
25°
24°
23°
32°
31°
MAP-1

FIGURE 2


GREAT METEOR EAST
STATION POSITIONS
IOS Piston Core
IOS Gravity Core
IOS Kasten Core
IOS (WASP) Camera Stations
IOS Near Bottom Profiler Stations
IOS Heat Flow Stations
IOS Benthic Dredge
Dutch Piston Core
Dutch Camera Station
0 5 10 15 20 25 30
Kilometres
26°
25°
24°
23°
32°
31°
82PCS31
82PCS30
82PCM06
82PCM05
82PCS10
82PCS27
82PCS28
82PCM29
D10688
D10691
82PC26
82PCS11
80PC25
80PC15
D10693
D10698
80PC16
82PCM12
80PC21
80PC14
S126/5
S126/3
S126/4
S126/2
D10554/2
D10554/1
D10554/3
D10554/4
D10684
82PCM15
D10695
D10676
D10677
D10683
D10678
82PCS16
82PC27
80PC11
D10685
82PCM26
D10696
80PC12
D10319
D10318
80PC13
80PC22
MAP 1
82PCL14
82PCS13
S126/8
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D10321
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80PC20
D10699
82PCS19
80PC23
80PC24

FIGURE 3

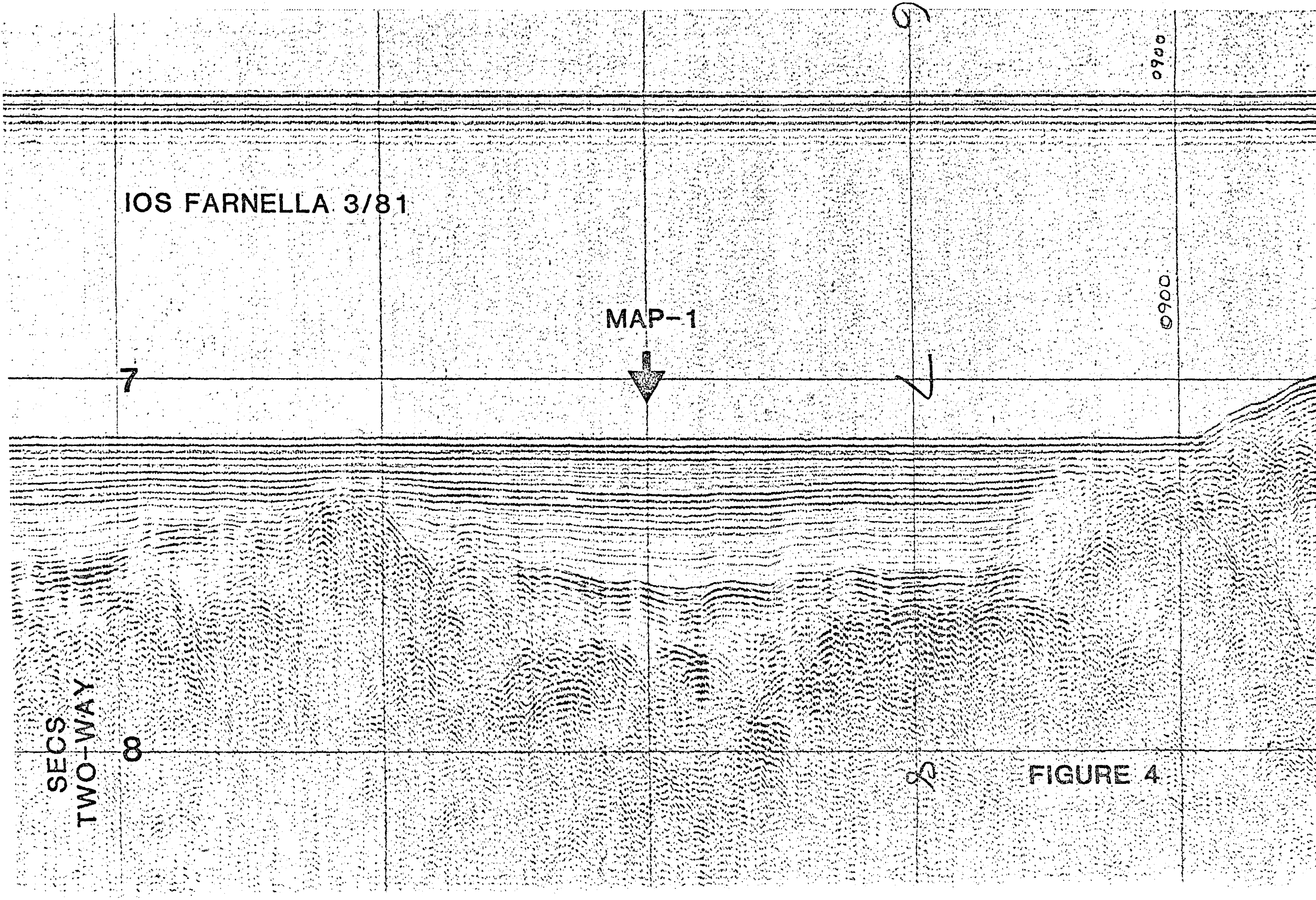


FIGURE 4

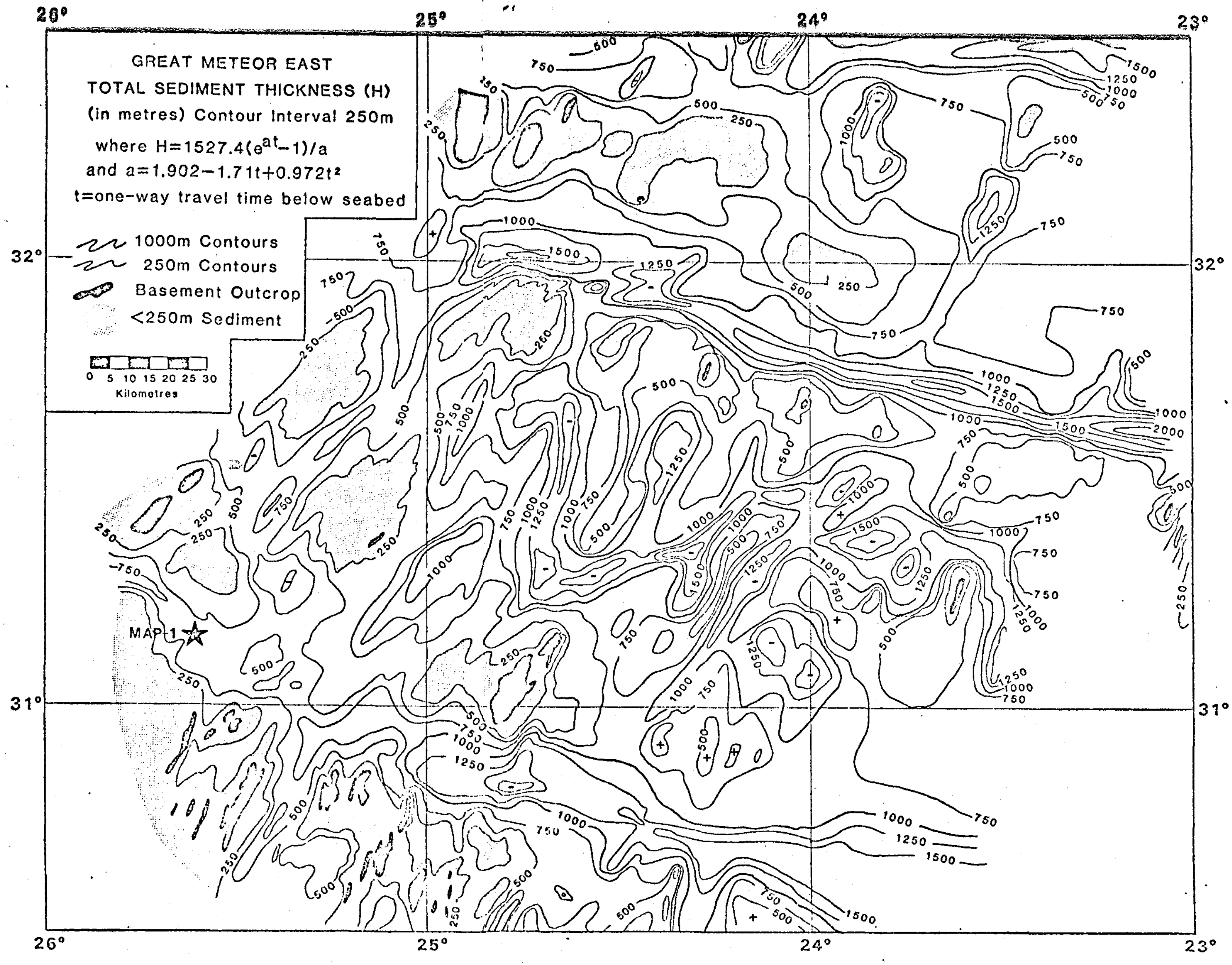

GREAT METEOR EAST
TOTAL SEDIMENT THICKNESS (H)
(in metres) Contour Interval 250m
where H=1527.4(e^at-1)/a
and a=1.902-1.71t+0.972t²
t=one-way travel time below seabed
1000m Contours
250m Contours
Basement Outcrop
<250m Sediment
0 5 10 15 20 25 30
Kilometres
26°
25°
24°
23°
32°
31°
MAP-1

FIGURE 5

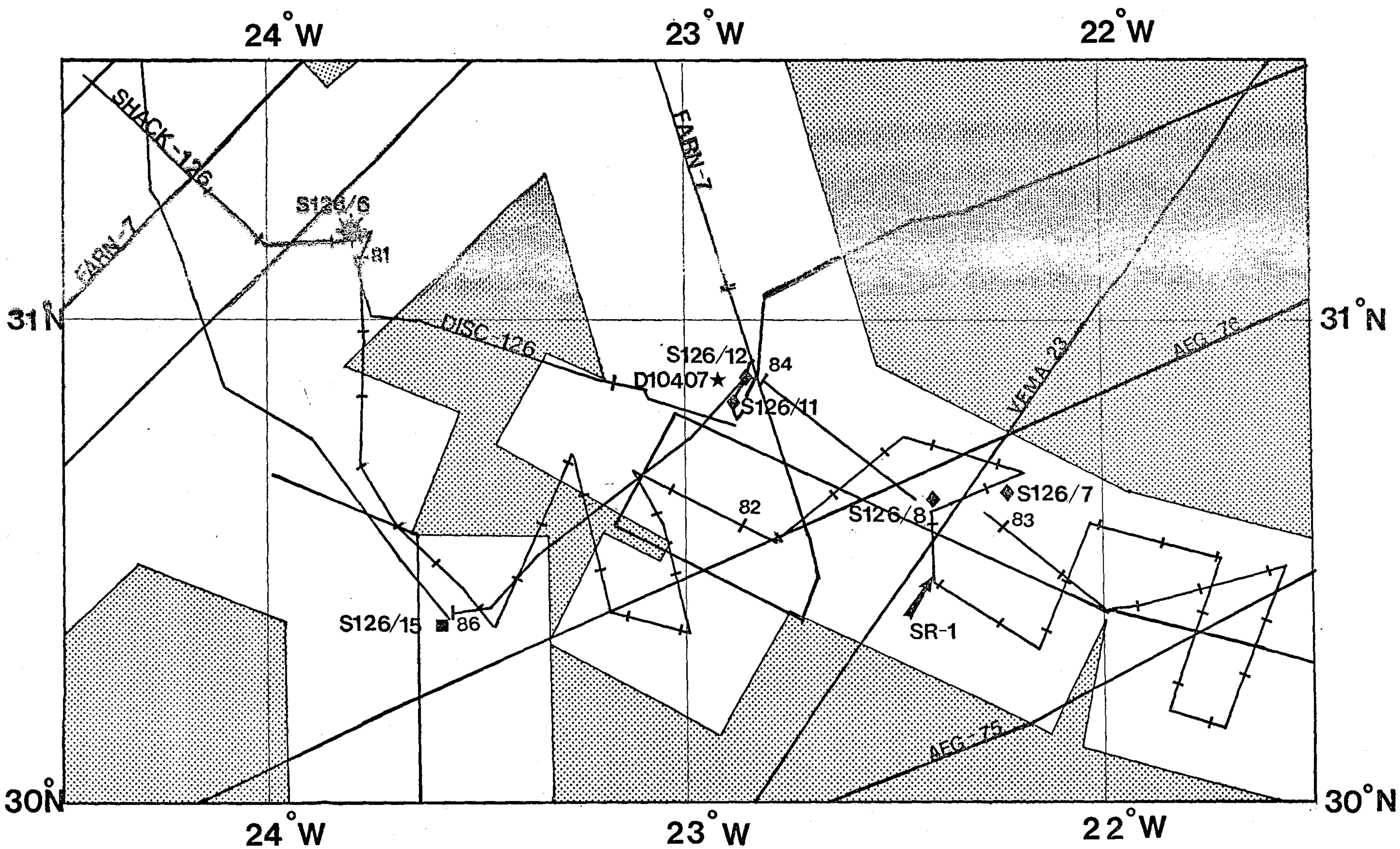

24°W
23°W
22°W
31°N
30°N
SHACK-126
FARN-7
S126/6
81
DISC-126
S126/12
84
D10407★
S126/11
VEMA-23
AEG-76
82
S126/8
S126/7
83
SR-1
S126/15
86
AEG-75

FIGURE 6

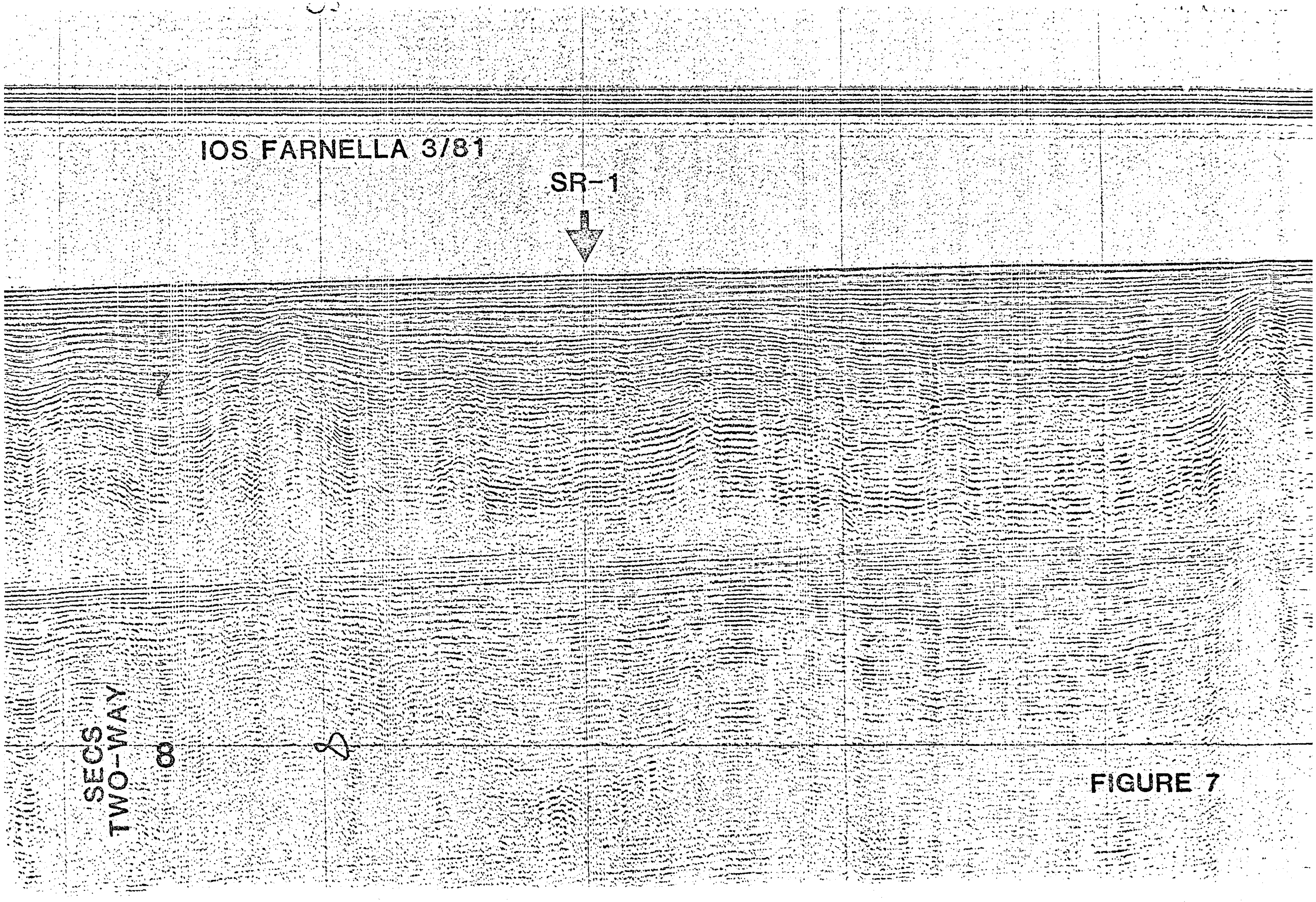
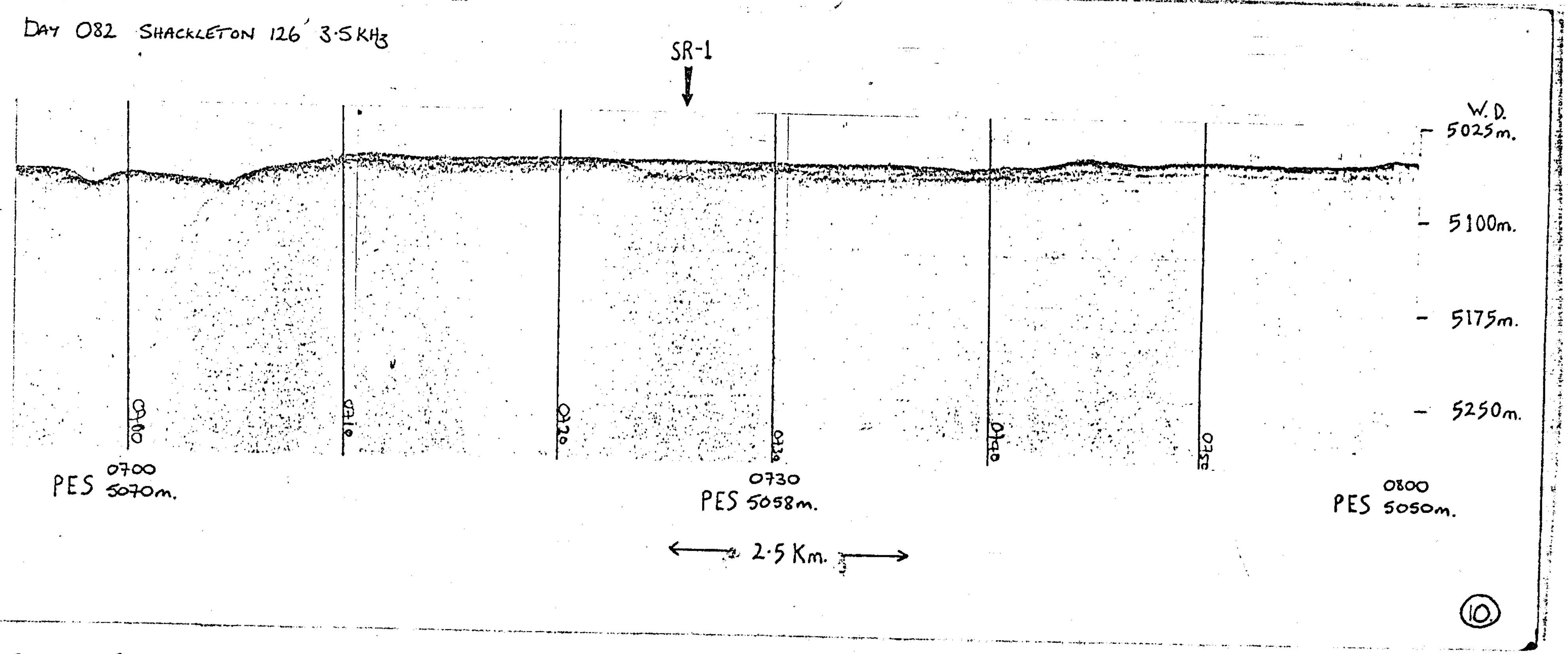


FIGURE 7



DAY 082 SHACKLETON 126' 3.5 KHz
SR-1
W.D. 5025m.
5100m.
5175m.
5250m.
0700
0710
0720
0730
0740
0750
0700 PES 5070m.
0730 PES 5058m.
0800 PES 5050m.
2.5 Km.
10

FIGURE 8

ODP SITE PROPOSAL SUMMARY FORM

Proposed Site: Madeira Abyssal Plain
MAP-1

General Objective: History of Sediment Instabili
on the Northwest African Continental Margin

General Area: Cape Verde Basin off N.W. Atlantic
Position: Lat: $31^{0}09.5'$N; Long: $25^{0}36.2'$W
Alternate Site: N/A

Thematic Panel interest: SOHP, OLP
Regional Panel interest: Atlantic

Specific Objectives:

1. Establish stratigraphic record and frequency of distal turbidite cycles to look for glacial/eustatic or tectonic control on turbidity current sedimentation on the abyssal plain.
2. Examine the pre-glacial pelagic sedimentation history of the Cape Verde Basin.
3. Date oceanic basement

Background Information:
Regional Data: IOS Farnella 3/81, 0800 Day 314 and Tyro 1982
Seismic profiles:

Other data: IOS Farnella GLORIA sonographs. Days 314 and 328: Dutch Geological Survey piston core 82PCS 13

Site Survey Data - Conducted by: Institute of Oceanographic Sciences, Wormley, UK
Date: Dutch Geological Survey, Haarlem, Netherlands
Main results:

Operational Considerations

Water Depth: (m) 5370 Sed. Thickness: (m) 580 Total penetration: (m) 630m

HPC ____ Double HPC ✓ Rotary Drill ____ Single Bit ✓ Reentry ____ XCB ✓

Nature of sediments/rock anticipated: Distal turbidites, carbonate oozes and marls, pelagic clays, chalks, oceanic basaltic basement.

Weather conditions/window: None

Territorial jurisdiction: International

Other:

Special requirements (Staffing, instrumentation, etc.) Logging

No special staffing

Proponent: P.P.E. Weaver & R.B. Kidd
Institute of Oceanographic Sciences,
Brook Road,
Wormley,
Nr. Godalming,
Surrey GU8 5UB

Date submitted to JOIDES Office:
15th March, 1984

Rev. 02

ODP SITE PROPOSAL SUMMARY FORM

Proposed Site: Saharan Continental Rise SR-1	General Objective: History of Sediment Instability on the Northwest African Continenta Margin
General Area: Cape Verde Basin off Northeast Africa Position: Lat. 30°32.0'N; Long. 22°25.3'W Alternate Site: N/A	Thematic Panel interest: SOHP, OLP Regional Panel interest: Atlantic

Specific Objectives:

(1) Establish Quaternary record of overbank turbidite deposition from rise channel system
(2) Establish frequency of 'long range' debris flow events.
(3) Investigate relationship of sediment slide and channel turbidite events to turbidite deposition in MAP-1 reference section.

Background Information:

Regional Data:

Seismic profiles: IOS Farnella 3/81, 2200 Day 318

Other data: --{IOS Shackleton 126, 0720 Day 082 (3.5 kHz)
IOS Farnella GLORIA sonographs day 318, IOS gravity core S126/8

Site Survey Data - Conducted by: Institute of Oceanographic Sciences, Wormley, UK

Date:

Main results:

Operational Considerations

Water Depth: (m) 5060 Sed. Thickness: (m) > 600m Total penetration: (m) < 200m

HPC ____ Double HPC ✓ Rotary Drill ____ Single Bit ✓ Reentry ____ XCB ✓

Nature of sediments/rock anticipated: 'proximal' turbidites, marls, debris flows, volcaniclastic sands.

Weather conditions/window: N/A

Territorial jurisdiction: International

Other:

Special requirements (Staffing, instrumentation, etc.) None

Proponent:(s)

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