JOIDES Journal

Joint Oceanographic Institutions for Deep Earth Sampling
volume 21, number 1, February 1995

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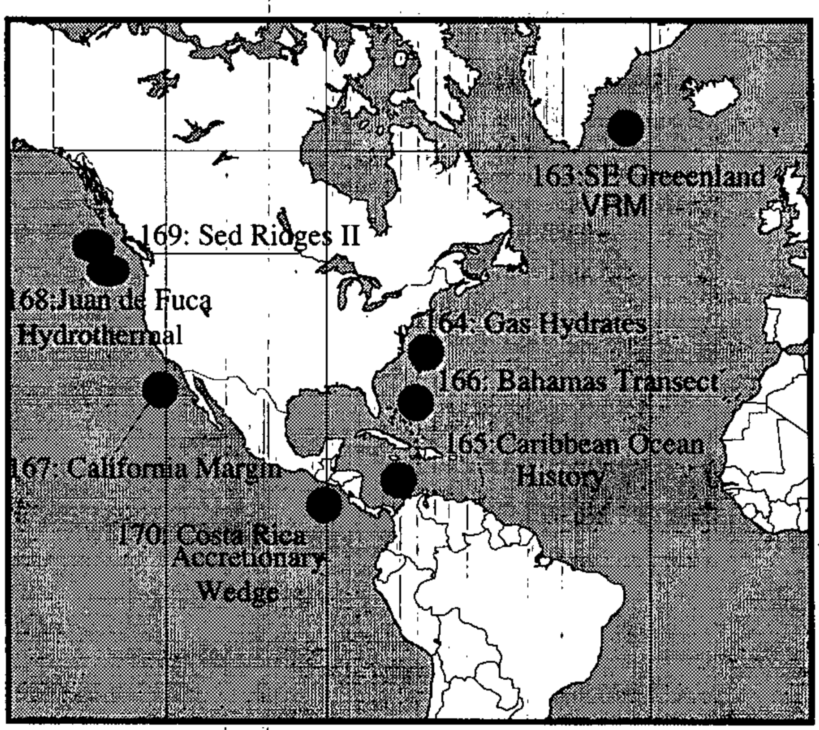
Archive Copy

FY 1996 Science Plan



See inside cover for details of FY 1996 Legs

COVER : Schematic showing the areas of operation of the *JOIDES Resolution* for the period September 1995 to December 1996. Note that the previously scheduled Gas Hydrates leg (now Leg 164) has been moved from the FY95 to the FY96 schedule to provide an operationally better weather window for the S E Greenland leg, now Leg 163. A full *JOIDES Resolution* schedule can be found on the back cover of this volume.

The *JOIDES Journal* is edited by Colin Jacobs, Kathy Ellins is the ODP Proposal News, International News and Liaison Group News Reporter, Julie Harris produces the *JOIDES/ODP Directory*. Any comments, suggestions and contributions should be directed to :

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JOIDES FY96 Science Plan
Drilling Objectives

LEG 163 SE GREENLAND VRM

The main objectives of the SE Greenland Volcanic Rifted Margin (VRM) drilling program are to understand: 1) The origin, state and emplacement of hot asthenospheric material below the margin during breakup; 2) deformation of the lithosphere in response to rifting; and 3) the concomitant interaction between asthensosphere and lithosphere during rifting. The results of the ODP offshore drilling will be analysed in combination with planned continental geology and geophysical studies to provide an unprecedented picture of the development of a LIP related to mantle plume activity and continental breakup.

LEG 165 CARIBBEAN OCEAN HISTORY

The Caribbean drilling program will investigate the nature of the Cretaceous/Tertiary boundary, Caribbean palaeoceanography related to plate tectonic evolution and the opening and closing of Atlantic-to-Pacific seaways, and the evaluation of the Caribbean crust as a large igneous province (LIP). Drilling in the Cariaco Basin will provide an important late Quaternary record of tropical climate change on interannual to millennial time scales and document relationships between environmental change and sedimentary and geochemical properties in a large anoxic basin.

LEG 166 BAHAMAS TRANSECT

The Bahamas Transect drilling will evaluate the rate and amplitude of eustatic versus relative sea level changes, and examine facies variations so as to document the sedimentary response of the carbonate environment to sea level oscillations. One deep hole will be drilled to assess the cause of the Bahama platform demise in the mid-Cretaceous, to potentially sample the K/T boundary, to acquire a low-latitude record of the Paleogene and Neogene, and to determine the onset of the Florida Current.

LEG 167 CALIFORNIA MARGIN

The California Margin drilling program will examine the evolution of the California Current and associated coastal upwelling systems, evolution of deep and intermediate water properties of the northeast Pacific Ocean to understand the oceanographic and atmospheric processes that led to the build-up of the Pleistocene ice sheets, and will also provide key information about the carbon cycle and the dynamics of terrestrial and marine organic carbon burial in continental margin environments. The program will also explore the tectonic evolution of the Pacific margin of North America looking at a high-resolution record of palaeosecular variations in Earth's magnetic field.

LEG 168 SEDIMENTED RIDGES II

The Sedimented Ridges II drilling program will investigate mechanisms of massive sulphide deposition occurring near the Juan de Fuca and Gorda Ridges. These sulphide deposits are the best analogues to the economically viable massive sulphide deposits in ancient rock sequences, which are the principal source of the world's zinc, lead, silver, and copper, and are important sources of gold and rare metals. The genesis and evolution of these deposits is of profound interest to the mining industry and the scientific community that seeks to understand controls on the transfer of energy and matter from the earth's interior to the hydrosphere.

LEG 169 EAST JUAN DE FUCA HYDROTHERMAL

The drilling program will focus on the physics and fluid chemistry of ridge-flank fluid circulation on the eastern flank of the Juan de Fuca Ridge where three hydrothermal flow regimes have been identified. These sub-seafloor hydrologic regimes represent situations that occur in all ocean basins and are well suited to quantitative studies. This drilling will contribute to understanding the nature of fluid flow through the crust and seafloor, the magnitudes of chemical exchange of elements between the crust and water column, and the factors that influence rock-water interaction, fluid chemistry, and the chemical and physical alteration.

LEG 170 COSTA RICA ACCRETIONARY WEDGE

The Middle America Trench (MAT) is the surface trace of the convergent boundary between the Caribbean Plate and the subducting Cocos Plate. The trench slope is underlain by a sedimentary apron, below which is the Costa Rica accretionary complex. The goal of the drilling program is to determine mass and fluid flow paths through the Costa Rica accretionary wedge in order to obtain mass balance estimates and thus gain a better understanding of the structural, mechanical, and geochemical processes at convergent margins.

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JOIDES Journal

Joint Oceanographic Institutions for Deep Earth Sampling

University of California, Scripps Institution of Oceanography

Australia - Canada Consortium for Ocean Drilling

Columbia University, Lamont-Doherty Earth Observatory

European Science Foundation: Belgium, Denmark, Finland, Greece, Iceland, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland, Turkey

France: Institut Francais de Recherche pour l'Exploitation de la Mer

Germany: Bundesanstalt für Geowissenschaften und Rohstoffe

University of Hawaii, School of Ocean and Earth Science and Technology

Japan: Ocean Research Institute, University of Tokyo

University of Miami, Rosenstiel School of Marine and Atmospheric Science

Oregon State University, College of Oceanic and Atmospheric Sciences

University of Rhode Island, Graduate School of Oceanography

Texas A&M University, College of Geosciences and Maritime Studies

University of Texas at Austin, Institute for Geophysics

United Kingdom: Natural Environment Research Council

University of Washington, College of Ocean and Fisheries Sciences

Woods Hole Oceanographic Institution

Introduction

Welcome to the first **JOIDES JOURNAL** to be assembled and edited from the Cardiff JOIDES Office. Its format is a continuation of previous Journals, most recently assembled by Brian Lewis, Karen Schmitt, and Bill Collins at the Seattle JOIDES Office; later in this editorial we consider major format changes that may soon be necessary in the interests of making budget savings and taking increasing advantage of the Internet.

At **CARDIFF** we continue to tackle the challenges of proposal handling, meeting coordination and communications with the JOIDES community. We began on 1 October 1994 with, in addition to myself: Colin Jacobs and Kathy Ellins as executive assistants and Julie Harris as our Office coordinator. Colin is seconded from the UK's Institute of Oceanographic Sciences while Kathy came from the University of Florida and is our US liason from JOI. Julie formerly worked part-time with me during my period as Site Survey Panel Chair. All of us gained enormously from the help provided by the Seattle group during the transfer of the Office to this its first non-US location. One of our first tasks was to coordinate the 5 day PCOM Annual Meeting in Texas (straight in at the deep end!). This set the FY96 *JOIDES Resolution* schedule and received and acted upon input from each Panel Chair. **MEETING REPORTS** leading to the Texas PCOM are in the next section.

Following the January 1 round of new drilling proposals, we are currently collating minutes of the Spring panel meetings, including global science rankings, and preparing for the April PCOM meeting in Tokyo. Having decided upon a 1996 schedule that takes the drillship through the Caribbean and along the western margin of North America, PCOM must now consider general areas of operations to be targeted over the next 4 years. This is of immediate concern in relation to the Revised ODP Long Range Plan (LRP), which has been in preparation for the past 10 months, because post-1998 is seen as a new Phase leading to operations with more than one platform. We live in exciting times for Ocean Drilling!!

LEG REPORTS in this issue document recent major successes for the Program:

- at Barbados (Leg 156) ODP has emplaced CORKs and for the first-time instrumented holes in an active earthquake zone for continued monitoring. Leg results confirm the importance of fluid flow in subduction zones and logging-while-drilling (LWD) as a major new tool for investigation of actively deforming areas.

- off the Canary Islands (Leg 157) ODP established the frequency of volcanic events and island collapse and sea-level changes that influence the timing of massive submarine slides. In the turbidite fill of the Madeira Abyssal Plain we obtained a unique record of these potential large-scale geohazards.

Next issue will report on further advances in ore body studies at TAG and deep drilling into the Eastern Equatorial Transform. *JOIDES Resolution* has just embarked on the first of two scheduled legs to study collisional processes in the Mediterranean. Together the Mediterranean legs will also establish an east-west transect of sites to investigate oceanographic changes in these enclosed small ocean basins that lead to organic-rich sapropel formation.

Revising the ODP Long Range Plan

The latest draft of the **ODP REVISED LONG RANGE PLAN (LRP)** will be discussed and its science objectives finalised at the April PCOM. A first draft prepared for the Annual Meeting by PCOM's LRP Subcommittee was the subject of much debate with respect to both its format and the balance of future ODP science themes. Discussions between the Subcommittee and Panel members and JOIDES national and international groups continued through to its presentation by Subcommittee Chair, Brian Lewis, at EXCOM in Hawaii at the end of January. EXCOM recommended that highest priority should be given to the science component of the document leaving further input on implementation and funding projections to a subcommittee of EXCOM.

A full meeting of the LRP-Subcom, which I now chair, was held in Cardiff earlier this month where we received new input from ODP Panels and made substantial progress in all of the areas of previous concern. Two broad science themes are now proposed set under the umbrella title, **"UNDERSTANDING OUR DYNAMIC EARTH"**. The two thematic categories are **DYNAMICS of EARTH'S ENVIRONMENT** and **DYNAMICS of EARTH'S INTERIOR.**

Scientific goals expressed under **DYNAMICS of EARTH'S ENVIRONMENT** include 1) Earth's Changing Climate, 2) Causes and Effects of Sea level Change, 3) Fluids, Sediments and Bacteria, and 4) Biological Evolution. Scientific objectives included under **DYNAMICS of EARTH'S INTERIOR** are 1) Transfer of heat and material to and from Earth's interior, 2) Deformation of the Earth and Earthquake Processes and 3) Chemical exchanges between the Solid Earth and Seawater. New text continues to be written and diagrams changed to convey the science themes in a straightforward, understandable and stimulating manner. Pending PCOM's approval of this draft, our goal is to produce a version stripped of most of its technical jargon before presentation at EXCOM in July. We believe that one of the successes of the meeting was the drafting of an impressive set of science accomplishments of the ODP era polished to be understandable for the lay reader; these we plan to highlight by placing them at the front of the final text.

A major item considered at the PCOM Annual Meeting was confirmation of a **PROJECTED LEVEL ODP BUDGET** to the end of the current phase through 1998. This requires budget trimming of the order of $1 million in each of the next 3 financial years, unless a new full JOIDES member joins in the meantime.

At the BCOM meeting in Washington at the end of February all of the operators were required to sustain cuts across the board. An area targeted by PCOM was publications and a PCOM subcommittee report has been prepared for the April meeting. Although the JOIDES Journal was not included in this review, BCOM is seeking a reduction of $10K each year in JOI's $43K per year printing and distribution costs. This could be achieved by targeting size reduction in the hard copy version of Journal and by making a full length version available electronically on the World-Wide Web. Some have argued that they only require the updated directory and information such as schedules, proposals, databases and repository news as hard copy.

COULD YOU SWITCH TO RECEIVING JOIDES JOURNAL ELECTRONICALLY?? Ideas that we have at Cardiff for shortening the format of the Journal are compatible with this budgetary development. We think that we can begin to change before the 1996 budget changes have an impact. You will find a **QUESTIONNAIRE** inserted in this issue and available at the JOIDES Office FTP site (see page 61). Please return the card promptly to the JOIDES Office or reply by e-mail. Make sure that you send us your views!!

ROB KIDD, Robert B. Kidd
CHAIR, JOIDES PLANNING COMMITTEE

JOIDES Committee Reports

Planning Committee (PCOM)

College Station, Texas, November 30 - December 3, 1994

PCOM met for their annual meeting at ODP-TAMU in College Station Texas. The meeting was preceded as last year by a one-day meeting of the Drilling Options Committee (DRILLOPTS) who look at each prospectus proposal in terms of operational feasibility, and the annual Panel Chairs' (PANCH) meeting. At this meeting PCOM had some crucial questions to address in terms of the ODP Long Range Plan and Budget prioritisation, as well as defining the FY96 Science Plan. A summary of the important decision and actions arising from that meeting are given below.

Science Plan - Ship Schedule

Based on Panel rankings and discussions at this meeting, PCOM decided that for the FY96 schedule, there should be only one Caribbean Leg scheduled as opposed to two, and that to enhance the respective weather windows, a Leg of further SE Greenland drilling could be inserted into the FY95 schedule to now come before the already scheduled Gas Hydrates Leg. With these two prerequisites, PCOM adopted the following schedule for Legs 163 to 170:

- Leg 163 East Greenland VRM
- Leg 164 Gas Hydrates
- Leg 165 Caribbean Ocean History
- Leg 166 Bahamas Transect
- Leg 167 California Margin
- Leg 168 Juan de Fuca Hydrothermal
- Leg 169 Sedimented Ridges II
- Leg 170 Costa Rica Accretionary Wedge

NOTE : With PCOM assent, ODP-TAMU changed the Caribbean and Bahamas, and the Juan de Fuca and Sed. Ridges II for operational reasons.

The schedule now ends with investigations on the Costa Rica accretionary wedge, this end point will allow PCOM to consider in late 1995 the merits of a return to the Atlantic or of a move on to further Pacific drilling. It also places the ship strategically for a late engineering leg with DCS on the East Pacific Rise or in the mid-Atlantic.

Budget

The projected budget is flat for the period 1996-98, which actually requires a reduction of approx. $1M per year ($3M over 3 years), but this cannot be taken from fixed cost items such as ship operations and the Schlumberger contract. The impact is that we need to look for continuing savings and all panels were asked to discuss this matter and each bring a prioritisation to the Annual Meeting. PCOM also received reports that refer to 'large-budget items' including JOI Inc.'s Data Base Management Steering Committee, the TAMU response to the EDRC and the JimNatland (for PCOM) report, ODP-TAMU and TEDCOM reports on the history and projected future development of DCS. A consensus resulted reaffirming continued support for the replacement of the computer-based data management system and continued development of the DCS, if still judged feasible after its current Phase II.

PCOM offered the following prioritisation list to BCOM with respect to budget cuts required by flat funding of $44.9M for FY96, 97 and 98 as identified by NSF.

1. Publications;
2. Technical Support: Reduce the technical staff on the ship by one per leg (2 FTE) or equivalent shore-based technical support;
3. Engineering Development;
4. To the extent possible, support certain experiments and certain special logs with non-commingled funds;
5. Reduce funds set aside for "Special Operating Expenses" from 4% to 3% of the annual budget.

In addition, new approaches to "project management" should be considered to identify special operating expenditures in advance and thus provide tighter control on costs.

PCOM also set up a Publications Sub-Committee charged with finding ways to reduce this particular annual budget item by one third by FY98 whilst taking advantage of advances in technology and opportunities to improve the impact of drilling results. This report is set for presentation at the March BCOM meeting.

Sub-Committee / Working Group Activity

As well as the new Publications sub-committee PCOM agreed to recommendations to form new working groups on Data Base Integration and a Structural Data User Working Group. On receiving the report of the Data Base Management Steering Committee PCOM recommended that JOI Inc. review its mandate and membership, and its working relationship with TAMU.

Long Range Plan

This is being revised at a critical time, the ODP is undergoing an NSF required Performance Evaluation review and at the same time both France and the UK are having their own internal reviews of their ODP participation. In Reykjavik PCOM reviewed both the new Thematic Panel White Papers and an outline of the proposed revised LRP. PCOM charged its LRP sub-committee to prepare a draft based on these inputs for the Annual meeting. The draft tabled at College Station resulted in vigorous debate largely around the balance of thematic objectives proposed, ensuring that the goals of non-US global community programmes are sufficiently represented and its suggestions for changes to the Panel structure. The sub-committee was charged with refining the document for the next PCOM.

PCOM Liaison Groups

PCOM set in place a mechanism of formal liaisons with a number of international geoscience research programs including, InterRidge, Margins, DOLCUM, ION, MESH, IMAGES, Antostrat and Nansen Arctic Drilling (NAD). There was a recent NAD meeting in Russia, where they were encouraged to submit a proposal to drill in the Bering Sea and they also want to drill in the central Arctic Basin. PCOM looked forward to when Russia would rejoin the ODP and passed the following recommendation to EXCOM; "In view of Russia's unique capabilities and interest in the Arctic, PCOM recommends to EXCOM that high priority be given to identifying a process that will lead to Russia being re-associated with the ODP".

Panel Recommendations

PCOM accepted in principle most of the panel recommendations presented at the annual meeting (see over), however, they added the caveat that budgetary pressures may mean that not all can be implemented.

Pre-PCOM Panel Meetings and Recommendations (where practical, now implemented)

Panel Chairs Meeting (PANCH 94)

College Station, Texas, November 29, 1994

Data Base Management System

PANCH believes that a successful upgrade will require communication between the user community and the contractor. To facilitate this communication PANCH recommends to PCOM that they approve:

- the establishment of a LISTSERVER to serve as a forum for the posting of information on the progress of the computer upgrade including bulletins and items of interest to thematic and service panels as well as concerns and suggestions from the wider earth science community. The chairs of IHP, SMP, and PANCH will explore the requirements for such a LISTSERVER.
- the establishment of formal liaisons from the thematic panels and DMP to both IHP and SMP, at least for the duration of the upgrade. These liaisons, with the panel chairs, will serve as the primary conduit of information between IHP (and hence the SC) and the thematic panels.
- that the user groups established by ODP-TAMU to test prototype data modules also participate in the initial formulation of the methodology and goals for each of those modules. The work done by the CLICOM group should serve as a model for how such user groups can provide advice and guidance in software development.
- that the thematic panels be given the list of data modules and data types as soon as possible and that they be directed to prepare an outline of their suggestions for the data modules of interest to them.

Thematic Panel Meetings

PANCH recommends to PCOM that they advise the JOIDES Office not to approve any Spring thematic panel meetings (for 1995) proposed to be held later than March 7, except in extraordinary circumstances. This scheduling will provide adequate time for SSP to assemble the data packages for highly ranked proposals and to schedule their Spring meeting early enough before the April PCOM meeting.

Budget Prioritisation

In an effort to provide some help to PCOM in grappling with the projected budget shortfalls in the 1996-98 fiscal years, PANCH offered its thoughts about what the program is about and what it needs, at a minimum, to complete its mission in the short-term.

Lithosphere Panel (LITHP)

Rouyn-Noranda, Canada, October 3 - 5, 1994

This panel believes that diamond coring at sea represents the most innovative engineering that the program has undertaken and that it holds potentially tremendous rewards for the entire scientific drilling community. There are very few rocks (as opposed to sediments) in which RCB coring produces anything near 50% recovery, DCS has the potential to achieve up to 90%. This Panel believes that there is no more innovative development we can undertake than the construction of an ocean-going diamond coring system. In the light of this, we recommend to PCOM that they review the development of DCS so far, and make a commitment to its development, in light of the recommended changes in engineering development and operations at ODP-TAMU, as a tool to be deployed in phases, with clearly stated specific short-term and long-term operational goals. This development would be a stepping-stone to the development, post-2003, of a DCS which could be routinely deployed for more standard coring operations in various locations and lithologies.

The Panel reviewed the results from the principal offset-section drilling legs to date (735B, Hess Deep, and MARK) and again concluded that the scientific return for these legs had been tremendous. The Panel recommends to PCOM that they seriously consider the request from ODP-TAMU for an engineering leg to test a variety of tools and techniques that may improve our drilling results in tectonized and faulted terrains. At present it is unclear how to proceed with our offset section strategy until we can identify the key variables which are influencing drilling conditions and recovery in different environments. An offset-section meeting at ODP-TAMU identified two strategies for improving our results in these tectonic windows; first, learn how to find easier places to drill, requiring a better understanding of the important variables in determining drilling conditions and better site surveys, and secondly, learn to drill in hard places.

The LITHP was disappointed by the removal of Return to 735B from the FY95 schedule, Return to 735B will continue to be one of our high priority sites and we hope that a serious effort will be made to drill this globally important site at the first opportunity.

The Panel recommends to PCOM that they explore options to occasionally accommodate mini-legs for transit to reach high priority sites. We fear otherwise that the ship will become mired in limited areas of the ocean because of the strictures of long transits and 56-day legs.

Correspondence has been exchanged between Hartley Hoskins (Woods Hole Oceanographic Institution) and engineers at ODP-TAMU concerning the development of a tool which would collect chips created during the drilling process. This modification would allow the collection of chips in addition to the collection of core and it might alleviate some drilling problems by collecting chips which would otherwise have to be washed out of the hole as it was advanced. The Panel recommends that PCOM facilitate (through whatever action they deem most appropriate) the development and testing of a chip-catching tool.

FY96 Prospectus Rankings:

Rank	Number	Proposal Title	Score
1	411-Rev	Caribbean Basalt Province	7.21
2	SR-Rev3	Sedimented Ridges II	6.62
3	440-Add	Eastern Juan de Fuca	5.79
4	460	SE Greenland Volcanic Margin	5.31
5	400 Rev2	Costa Rica mass balance	5.00
6	415-Rev2	Caribbean Basin multi-obj.	2.86
7	386-Add3	California Margin	2.14
8	461	Rift-to-drift processes off Iberia	1.79

Ocean History Panel (OHP)

Townsville, Australia, September 27 - 29, 1994

Budget Prioritisation

In response to PCOM's charge to prioritise our needs regarding program services and facilities and identify areas where programmatic costs can be reduced, we arrived at the following consensus's. First, we identified our priorities for efforts which must be maintained. These are (1) those things which cannot be done later, (2) those things which are necessary for stratigraphy and chronology and thus allow the definition of the completeness and continuity of recovered sedimentary sections, therefore potentially influencing drilling strategy in real-time, and (3) those things which communicate the objectives and results of the program to the community. Categories (1) and (2) assign high-priority to shipboard efforts. For example, Category (1) includes such things as MST scanning of cores, physical properties measurements, logging, and interstitial water chemistry. Category (2) includes biostratigraphy, core-to-core and core-to-log integration, database upgrades, MST scanning of cores, logging, color sensing, magnetostratigraphy, etc. Category (3) includes the Initial Reports, with core photos, the Scientific Results volumes, and other means of communication.

Second, we note that the complete and continuous recovery of sediments of all lithologies is of highest scientific priority to OHP. However, if asked what to eliminate, OHP does not support further expenditure on the current diamond coring system (DCS). We still wholeheartedly support the drilling capabilities the DCS is intended to supply and the resulting scientific objectives which could be addressed, but note this lack of further support as a programmatic decision when asked what should be eliminated to address budget problems.

FY96 Prospectus Rankings

Rank	Number	Proposal Title	Score
1	415-Rev 2	Caribbean Ocean History	0.89
2	386-Add3 / 422-Rev	California Margin	0.83
3	404	W N Atlantic Sediment Drifts	0.51
4	404-Add	Blake Plateau and Blake Nose	0.38
5	412-Add3	Bahamas Transect	0.23
6	411-Rev	Caribbean Basalt Province	0.16

Sedimentary and Geochemical Processes Panel (SGPP)

Fukuoka, Japan, October, 12 - 14, 1994

Site Surveying on New Jersey Margin
SGPP strongly supports the effort to obtain the additional funding required to complete and evaluate site survey data necessary to allow safe drilling in shallow water depths > 40m toward the inshore end of the New Jersey transect. The survey will be run in summer 1995, so that a drilling leg could be placed in the prospectus for 1997.

Pressure Core Sampler
SGPP requests that PCOM press for testing of the modified PCS on a Leg well prior to 163, the test is essential to ensure that there is a working PCS on the Gas Hydrate Leg.

Budget Prioritisation
In engineering development, the item of greatest importance to SGPP is the PCS. SGPP are also interested in "CORKs," but the CORKing program should be examined to determine its fiscal impact and cost/benefit ratio for science information gained. It is perceived that a major part of the budget concerns the maintenance and validation of 3rd party tools, and costs in this area should be justified.

Reviews of Letters of Intent (LOIs)
Letters of Intent were rated only for thematic relevance. SGPP strongly urges that all LOIs rated A1 be developed into full proposals. SGPP would be interested in seeing proposals developed from LOIs rated A3 if they are also of interest to another thematic panel.

FY96 Prospectus Rankings

Rank	Number	Proposal Title	Score
1	412	Bahamas Transect	47
2	400	Costa Rica mass balance	42
3	SR-Rev3	Sedimented Ridges II	41
4	440-Add	Eastern Juan de Fuca	36
5	386-Add3	California Margin	24
6	415-Rev 2	Caribbean Ocean History	22

Tectonics Panel (TECP)

Nicosia, Cyprus, October 20 - 22, 1994

TECP is generally supportive of fluid sampling devices (WSTP and PCS) but places a high priority on the WSTP or some modified version of this tool as a means to constrain pore fluid pressures. TECP also has an interest in using CORKs as a platform for stress and strain monitoring and spatial and temporal fluid pressure and temperature variations. TECP has been led to believe that radar technology and NMR require relatively little development to be deployed in ODP boreholes (i.e., primarily repackaging existing sensors to fit the specifications of ODP operations).

TECP would like long term tool development to focus on cross-borehole or sea floor to borehole experiment technology. They believe that these techniques have a potential to relate borehole measurements and core analysis to regional three-dimensional structural and lithological frameworks and therefore endorses a long term plan to investigate the feasibility of and develop cross-borehole experiments and non explosive sea-floor sources.

TECP strongly recommends that structural data be summarised by addition of a column to the existing published Core Barrel Summary Sheets. TECP strongly recommends that a Structural Data Table be completed; i) Routinely (i.e. mandatory) during legs that have been highly ranked in the top 6 by TECP; ii) Whenever structural data are noted in cores by shipboard scientists during other legs. It is not intended that the structural table be routinely filled out on all legs where there are no structural data.

FY96 Prospectus Rankings
Note: TECP voted in favour of also ranking 376-Rev3 Vema Fracture Zone

Rank	Number	Proposal Title	Score
1	400-Add3	Costa Rica	8.00
2	460——	SE Greenland Margin	7.73
3	461——	Return to Iberia	6.67
4	376-Rev3	Vema Fracture Zone	5.10
5	411-Rev	Caribbean Basalt Province	4.03
6=	SR-Rev3	Sedimented Ridges II	3.90
6=	386-Rev2	California Margin	3.90
8	440-Add	East Juan de Fuca	2.90
9	415-Rev2	Caribbean Ocean History	2.77

Site Survey Panel (SSP)

Lamont-Doherty Earth Observatory, November 14 - 16, 1994

Site Designations and Procedures
SSP recommends that PCOM direct the JOIDES Office to develop, promulgate, and insist upon the use of, a consistent system of designating proposed drill sites, such that each location on the seafloor proposed for drilling is identified by a unique and unchanging site designator. This was accepted by PCOM, see Drilling Site Designations in the Proposal News Section on Pages 27-28.

SSP Recommendation to PCOM concerning new sites for scheduled legs: SSP recommends that PCOM direct the JOIDES Office to develop and enforce the use of a formal procedure for the addition of new sites to the program for scheduled legs.

After a leg has been scheduled for drilling, it occasionally becomes necessary or desirable to add new sites to the plan for the leg. Sometimes, the co-chiefs send some data and accompanying verbiage to SSP in support of their new sites; sometimes they bring these materials direct to PPSP. There seems to be no standard procedure, late-added sites do not always benefit from thematic or SSP review, and data in support of such sites is not always deposited in the ODP Data Bank for use by the community. Therefore we recommend that all changes or additions of sites to scheduled legs should be submitted as an addendum through the JOIDES Office, including new site summary forms and statement of scientific objectives. Such additions should be accepted throughout the year, independent of the January 1 and July 1 proposal deadlines. The JOIDES Office should distribute the addendum immediately to the appropriate thematic and service panels (always SSP and PPSP, occasionally DMP or SMP) and to ODP-TAMU for comment. SSP and PPSP should only review sites which have come from the JOIDES Office, not sites that have come directly from proponents or co-chiefs.

Site Survey Implications of Recently Drilled Legs
Site 954 was located within half a mile of the position of an underwater communication cable, discovered by the Captain of the *JOIDES Resolution* during the leg on Admiralty Chart 1869. We feel that information about man-made seafloor hazards should enter the system much earlier, well before the ship goes to sea. Thus SSP recommended to PCOM that they request JOI to direct ODP-TAMU to investigate the occurrence of man-made seafloor hazards in the vicinity of proposed drillsites as part of their preparation for the DRILLOPTS meeting.

Feedback to Proponents
SSP Chair distributed a set of guidelines to SSP members on what to include as feedback when preparing watchdog letters to proponents, in essence each panel member is to send a watchdog letter to the lead proponent of each watchdogged proposal for a potential future drilling leg, reporting the sense of the SSP discussion and enclosing the appropriate section of the minutes. SSDB representative is to send a watchdog letter to the co-chiefs of each scheduled leg. Copies of all watchdog letters to be sent to the Data Bank, and the Data Bank will forward a copy of the complete packet of watchdog letters to the JOIDES Office.

SSP Guidelines on Re-entry sites
A core has long been a required data type at all re-entry sites, the rationale is that the core is needed for the operations people for planning the casing and re-entry cone emplacement. As yet the suite of physical properties measurements required has not been defined, therefore the SSP to ODP-TAMU liaison will be discussing with ODP operations superintendents the circumstances under which re-entry cone emplacement has been difficult or unsuccessful. If a pattern emerges from this investigation, SSP may consider asking for a limited suite of physical properties measurements from surficial sediments at proposed re-entry sites, under specific circumstances where there is reason to fear difficult re-entry operations.

Shipboard Measurements Panel (SMP)

Las Palmas, Gran Canaria, Spain, September 25 - 27, 1994

Equipment procured or planned for procurement through available funds can be summarised as follows:

1. Improvement in the underway geophysics laboratory;
2. Equipment for real-time navigation;
3. New thermal conductivity heater box;
4. New palaeontology microscope;
5. Sun Sparc-5 work station dedicated to data integration;
6. Funds for the upgrade of the MST device.

In addition the following equipment was submitted for consideration by SMP:

1. Rig Instrumentation Project;
2. GC/MS with autosampler for Organic Geochemistry;
3. Upgrade of LASENTEC particle size analyser;
4. New data integration work stations;
5. XRF pellet fluxer.

Multiple Sensor Track (MST)
SMP recommends that ODP/TAMU be encouraged to go ahead as soon as possible with the envisaged upgrade of the MST. Funds have been allocated for this purpose and SMP recommends strongly that special attention be given to a more centralised work station capable of replacing the manifold of computers presently associated with the MST.

Cookbooks
SMP notes from visits to the ship's laboratories that "cook books" of laboratory procedures are important items that are often missing in the various laboratories. SMP recommends that such "cook books" be developed through co-operation between laboratory users of the appropriate expertise and designated ODP technical staff. SMP suggests that future staffing by ODP may bear this aim in mind, so that procedure cook books can be developed in the near future.

XRF and XRD Laboratory
SMP wishes to stress that the X-Ray Fluorescence apparatus on board ship should be utilised to its fullest extent to include a full set of major and trace element determinations. The SMP strongly endorses the proper use of the XRF by the technical staff, with the aim of continuing the collection of high quality major and minor element data, comparable with most competent shore-based laboratories. If experienced XRF scientists sail, then these scientists should assume responsibility for the operation of the XRF, get thoroughly involved in the analyses, and provide guidance and training for the technicians.

SMP also discussed the X-Ray Diffraction (XRD) aspects of this laboratory and suggests that there should be pre-cruise communication about the use of the XRD instrumentation and that experienced XRD scientists should have access to this equipment in collaboration with the ODP technical staff person assigned to the XRD laboratory.

Software Development - Etch-a-Sketch
SMP urges that the further development of Etch-a-Sketch and similar programs be put on hold. SMP considers it of importance that for the capture of data on VCD, Etch-a-Sketch, Rocky, or Structure Data, the capability be explored by TAMU of commercially available CAD programs.

Software Development - FossiList
SMP recommends that the development of this software continues in the near future. SMP urges that, in order for FossiList to become operational, due attention be given to inclusion of the prime data fields as defined by IHP/SMP. IHP urges that ODP give first priority to the continued development of FossiList, so that the impetus will not be lost and the program will become fully functional in the near future.

Data Integration
The Core-Log Integration Committee (CLICOM) met at Oregon State University (August 15-16, 1994). The principal objective of this meeting was to advise PCOM on the status of CLIP (Core-Log Integration Platform) developed by Terri Hagelberg and Peter deMenocal. A separate report to PCOM has been issued on this subject.

Data Integration Summary and Recommendations
1. The CLIP program, developed by Peter deMenocal in collaboration with Terri Hagelberg, after extension of this program in the future, will be an important feature of data integration efforts. CLICOM realises that the CLIP program is still in a development stage and can be made available to shipboard scientists, especially for core-core data integration However, CLICOM is satisfied about the future prospects of the CLIP platform and, therefore, CLICOM recommends that CLIP be recognised as an important component of the future data base update and that the future contractor remain in full contact with BRG-LDEO with regards the future implementation of this program;

2. CLICOM agrees and recommends that a very careful record be kept of depth changes achieved during the manipulations necessary to reach the common depth scale of cores and logs and that each Initial Report of ODP contain a separate chapter on core-log integration or any other Shipboard Data Integration (SDI) effort;

3. CLICOM recommends the maintenance on board ship of three work stations available for dedicated data integration, especially during drilling legs in which core-log integration plays a major role:

1. In the core laboratory;
2. In the co-chief scientist's office;

3. In the library;
4. With the Multiple Sensor Track (MST) being one of the most important component of SDI CLICOM recommends that attention be given to:
a) Dedicated technical support through a well trained ODP MST specialist;
b) Dedicated future support for continued further software and hardware development (MST track improvements).

5. Though staffing of a cruise, during which core-log integration is envisaged to be of importance, is usually done in collaboration with the co-chief scientists of that cruise, CLICOM recommends special attention to the following aspects of this staffing: Shipboard data integration requires the co-ordination by a dedicated Shipboard Data Integration Specialist, who will have the sole responsibility to carry out the shipboard program of data integration, in collaboration with scientists operating the MST, the physical property experts, as well as shipboard biostratigraphers, paleomagnetists, chemists, and, of course, the logging specialists. The Shipboard Data Integration Specialist will end up defining the depth scales - working together with all other shipboard scientists to confirm / validate and even constrain depth scales.

CLICOM realises that this report is mainly directed towards consideration of the state of development of the CLIP platform, and does not fully conform with the directives of the PCOM Chair. However, this report should also serve as a potential basis for future more extensive discussion on data integration. This should be discussed in greater detail by the SMP and IHP panels.

Major SMP related concerns are:
1. The recommendation of CLICOM that, especially on legs in which data integration is expected to play a major role, a careful selection of staff is made, including the appointment of a scientific staff member responsible only for data integration, in close collaboration with other specialists working in this area (MST, PP, color scanner, palaeontology);

2. Dissemination of information with regards the importance of core-core/core-log or, simply, data integration in other legs with sediment and/or hard rock recoveries.

Data integration is presently most feasible and constitutes a major advance in a subject long advocated, but presently achievable. SMP strongly endorses the further development of the Data Integration Platform (formerly CLIP).

Downhole Measurements Panel (DMP)

Lamont-Doherty Earth Observatory, September 21 - 23, 1994

Budget Prioritisation
The results of extended DMP deliberations resulted in the following Recommendation to PCOM: The DMP recommends that the BRG develop a budget scenario detailing the programmatic impact of level funding, i.e. a yearly 3-5% inflationary decrease in real dollars. This trial scenario should include at least: (1) details of actual expenditures over the past three years, (2) an estimate of expenditures for the next three years, (3) an estimate of the cost reduction realised by eliminating either the Geochemical Tool or the Formation Microscanner from the standard logging suite (which ever the BRG deems the most expensive to operate) and (4) an estimate of the cost per leg of running the chosen tool as a specialty item. The requested information is to be presented to the DMP at its Spring meeting.

There has been some initial difficulty with log analysis in logs processed at subcontractor locations. Consequently the BRG has instituted a Quality Assurance and Control procedure.

Results of Logging Operations at Barbados
The logging operations at Barbados saw the first deployment of Logging-While-Drilling (LWD) technology in the ODP, it enabled for the first time the upper 70-90 meters of an open hole to be logged, and it enabled the first a complete suite of logs in an accretionary prism. Core-log correlations from hole to hole are very encouraging.

Add-on Experiments
Add-on experiments originating outside of the JOIDES structure may have undergone superficial reviews in regard to feasibility and cost, that insufficient concern may not have been applied to the unique requirements of ODP research, and that panels are asked to comment on experiments without being given sufficient time to digest pertinent information. Thus, the DMP makes the following Recommendation to PCOM: That add-on experiments be subjected to a uniform scientific and feasibility review by appropriate JOIDES Panels, and that a minimum of six months time be allocated for this task. More time will be required if the experiment is unique, difficult, or if information given to the panels is inadequate.

DMP Requirements for land tests of third-party tools
1. Pressure Housing Test. The DMP requires a test in a well or autoclave to replicate the pressure and temperature environment expected in ODP operations.

2. Electronics Test. The DMP requires that the uphole and downhole electronics be demonstrated to function properly under anticipated operating conditions. This means that components subjected to high temperatures be tested at temperature, perhaps in an oven, and that the duration of such tests be consistent with the expected duration of ODP operations.

3. Vibration Test. The DMP requires that tools and surface equipment be subjected to vibration tests commensurate with use, both in shipping and downhole. Standards for these tests are to be the same as applied to commercial tools, and tests may be done best at commercial facilities.

4. Wireline Test. The DMP requires that tools using active wirelines to transmit data and receive power demonstrate successful operation on wirelines used in the ODP.

5. Systems Test. The DMP requires that a logging system demonstrate an ability to produce meaningful data. This means that a systems test that exercises simultaneously all components (downhole tools, uphole controllers, data processing algorithms, interfaces to shipboard and BRG data computers, etc.) be passed. Ideally, the systems test would be performed in an appropriate well. If the cost of such a test is prohibitive, other scenarios will be considered by the DMP.

DMP will appoint a watchdog assigned to each tool progressing through the third-party system. This watchdog will aid in the interpretation of the Third-Party Tool Guidelines and the above requirements (e.g., well tests versus autoclave/oven tests), and report on progress periodically to the DMP, without assuming the responsibilities assigned to the Principal Investigator, to the BRG, or to the ODP-TAMU as are stated in the Third-Party Tool Guidelines.

DMP Requirements for Third-Party Tool Calibration
A DMP watchdog will become familiar with calibration issues for each third-party tool, and aid the Principal Investigators, the BRG, and ODP-TAMU in presenting them to the DMP. The DMP will then issue a recommendation concerning calibration needs.

Technical Innovation
DMP prioritised the list of topics that deserved support, the leading candidate is Logging While Coring; High-Temperature Systems was a close second. In view of the Panel discussions, the following Recommendation is made to PCOM: That a feasibility, practicality, and cost study be conducted to advance the concept of Logging While

Coring in the ODP. The study would be conducted in FY96, and it would be a joint effort between the BRG, ODP-TAMU, and a logging service company, with the DMP and TEDCOM acting in an advisory role. Appropriate funds, not to exceed $30K, are sought under the BCOM mandate that 4% of a contractor's budget be spend on innovation. Significant additional funds may be sought in FY97 pending the results of the requested study.

INFORMATION HANDLING PANEL (IHP)

Bremen, Germany, August 24 - 27, 1994

Report on the Micropalaeontological Reference Centres (MRC)
1) Nannofossil and diatom collections from the Lamont MRC are being transferred to the University of Nebraska. That institution will prepare eight sets of nannofossil and four sets of lithologic smear slides.
2) The transfer of the Texas A&M MRC to ODP was accomplished smoothly, and that collection is already being used actively.
3) The Smithsonian needs a letter authorising accession of its MRC collection, in order to be eligible for resources needed to maintain it. In view of the special status of the Smithsonian as a Federal institution, IHP voted unanimously to approve accession of the Smithsonian MRC collection to Smithsonian Institution.
4) IHP voted unanimously to permit California Academy of Science to become a semi-permanent loan institution for the diatom collection.
5) The IHP unanimously endorses the concept of publishing an announcement of opportunity for receipt of portions of MRC Collections that are currently under-utilised as part of its continuing effort to get the collections where they will be better used.

Lithologic Database
IHP discussed the existing problems of the Lithologic data base and recommends that ODP make information on its data structures available via the Internet and geosciences meetings - both existing structures and the new structures as they come on-line. IHP suggests that ODP become plugged in to existing databases and that a meeting be held to help convergence of database structures between ODP and industry.

Report on FossiList software
IHP is very grateful for the rapid development since the last meeting. The program was sent to the ship and various IHP panel members for review. IHP urges ODP to give high priority to continued development of FossiList so that the impetus will not be lost.

Stratigraphic Database Centre
The IHP recommends that PCOM endorse the concept of specialised data centres associated with core repositories and readily accessible micropalaeontological reference centres. Such an endorsement would be useful for prospective Database Centre organisers in their efforts to secure funding. The IHP further recommends that north German institutions be encouraged to spearhead an international effort to develop an ODP Stratigraphic Database Centre associated with the core repository at Bremen University, in co-operation with other European laboratories participating in ODP activities.

Publication of the ETH Neogene Chronologic Database
Based on the review of the ETH Neogene Chronologic Database by Bill Riedel, John Saunders and Brian Huber, IHP recommends publication of the Lazarus et al. database as a Technical Report.

Publications
Visibility of DSDP/ODP volumes: ISI Citation search - 88% of the visibility of the program comes from the SR volumes. The citations since 1988 have continued to grow and show no sign of slowing down. This kind of data will help to dispel the impression on the part of the scientific community that the SR volumes constitute grey literature.

1) Cited in high visibility journals (e.g., JGR, Palaeo3, Mar. Geology, J. Sed. Petrology (JGR = highest no. of cites))
3) DSDP still highly cited
4) Citations by countries: highest in U.S., ESF, France, lowest in Japan
5) IR/SR citations
  a) IR: Leg 111 had many citations, though only 45 m of core recovered
  b) SR: very different set of numbers; Leg 113 highest
6) R Merrill et al. plan to publish summary of this in an ODP publication, Geotimes or EOS

TECHNOLOGY AND ENGINEERING DEVELOPMENT COMMITTEE (TEDCOM)

College Station, Texas, November 7 - 8, 1994

DCS Review
A new development plan was prepared in accordance with the recommendations of the Engineering Development Review Committee (EDRC) report, to prove the feasibility of continued DCS development. The work will be divided into phases. Initially Stress Engineering Services (SES) will modify and improve the DCS simulation model after which four phases are planned as follows:

- Phase I Create a design/development plan
- Phase II Develop controller concepts and test on the computer model and the mechanical simulator
- Phase III Implement the controllers in software and install on DCS hardware
- Phase IV Land tests

Phase II is scheduled to be completed by June 1995 for an estimated cost of $240,000. TEDCOM recommends that the above DCS development plan be accepted and implemented for an estimated cost of $240,000 for Phases I and II. If DCS feasibility is demonstrated by Phases I and II then TEDCOM recommends that Phase III be implemented for a further $80,000 (estimated) and that land tests be planned for late 1995 or early 1996. PCOM should assume that the above testing program will be successful (including land tests) and provisionally plan now for a DCS Sea Test late 1996. TEDCOM wishes to emphasise that it is important to maintain momentum on the DCS development. If DCS feasibility is not demonstrated by Phases I and II of the above plan, TEDCOM will assess the situation and make a recommendation to PCOM.

Main Compensator Seal Test Program
Friction in the seals of the main compensator were a major source of inefficiency. Redesigned seals with reduced friction would benefit normal coring operations as well as DCS. This program is well advanced and testing is due to be completed late 1994. The TEDCOM recommends to PCOM that the present seals on the main heave compensator of the JOIDES Resolution be replaced by low friction seals as soon as possible. This should be treated as a high priority item since such seals could lead to improved performance of several tools (not just DCS).

DCS Bit Tests
Two types of bit have been tested namely a V-grooved flat face, series 2 impregnated style bit, and a M-profile surface set carbonado style bit. In a first phase the bits were tested in limestone similar to that expected at the Vema site. The bits were not destroyed and excellent core recovery (98%) was obtained even for the cases where the bits came off bottom. Colombia River Basalt was chosen for the second phase. The Carbonado bit survived the tests with much less wear than the impregnated bit. Core recovery was not affected by the bit coming off bottom.

Diamond Retractable Bits (DRB). Tests were carried out with a Russian SRK-76 retractable diamond bit which could be redesigned to

be compatible with the DCS. A total of about 40 m penetration was obtained in limestone and 10 m in basalt with excellent core recovery in both cases.
Tricone Retractable Bit (TRB). Tests were carried out in Moscow of a TRB designed for use with the DCS DI-BHA. The tests were very successful (see Appendix I). Eighteen holes were drilled in granite in 7 days of testing, 20.18 m were drilled in 36.38 hours. The hardware is considered to be operational and ready to be deployed.

TEDCOM Conclusions on DCS
The TEDCOM endorses diamond drilling for core recovery in fractured basalt. It should be noted that penetration is not limited to 500m. The TEDCOM recommends that diamond drilling be provisionally included in the Long Range Plan from 1998.

Riser Drilling
TEDCOM recommends that PCOM redefine their objectives with respect to deep drilling and core recovery and specify which limitations need to be extended. Following such clarification a workshop should be organised between TEDCOM/TAMU/PCOM/scientists to define the best ways of addressing the objectives.

Potential of Logging While Coring (LWC)
The LWC concept consisted of integrating into the core barrel an instrument that could record bottom hole data. This would be more accurate and less expensive than sending the information by mud pulsed telemetry, and would also enable information to be obtained more rapidly and regularly than with LWD, which only gave information each time the bit was pulled. TEDCOM considers LWC to be feasible. If the tool development can be justified by DMP needs, then TEDCOM would recommend integrating WOB and torque measurement into the tool. However, the latter information is of insufficient interest to justify the tool development on its own.

An Upgrade of the ODP Data Management System (Project JANUS)
A Status Report by Rakesh Mithal

Ocean Drilling Program, 1000 Discovery Drive, College Station, Texas 77845-9547, U.S.A.

The Ocean Drilling Program is in the middle of a major improvement of its Data Management System. The work began in Oct. '94, and is being performed by Tracor Applied Sciences Inc. based in Austin, Texas. Tracor was selected after a careful evaluation of 11 proposals received in response to a widely circulated request for the proposals. The scientific input to the design of the new system is being provided by a JOI Database Steering Committee. The project is being managed by the Science Operator of ODP at Texas A&M University (TAMU).

The Statement of Work for this project is available on MOSAIC (http://www-odp.tamu.edu/janus). There are more than 30 data types and they have been divided in 8 data groups. The Group 1 contains the basic corelog and sample information needed by all other data types, and obviously will be done first. The priorities within the other 7 data groups were developed by interactions with IHP and SMP. The JOI Inc. Steering Committee approved it and later added wireline logging data, which was under question at the time that IHP/SMP did the prioritization. The current priority list is included in the SOW, and is attached here also. It should be noted that these priorities are subject to change by the JOI Steering Committee based on input from the wider scientific community, Tracor, and/or TAMU.

To provide scientific input to JANUS, the JOI Steering Committee is forming User Groups from the international scientific community corresponding to each of the data groups. The current list of people in the User Groups is available on MOSAIC (http://www-odp.tamu.edu/janus). Any comments or concerns about the current priorities of data types and/or User Groups may be addressed to Brian Lewis (blewis@ocean.washington.edu) or Terri Hagelberg (terrih@gsosun1.gso.uri.edu).

To analyze the current ODP data management environment Tracor is using a well established technique known as "Structured Analysis", and have selected the commercial software "System Architect" for this purpose. They have completed study of the available literature, done interviews with people at TAMU, and sailed on *JOIDES Resolution* on the Falmouth-Dakar transit. Now they are producing a report of their analysis from which they will develop an estimate of the work that needs to be done for each data type. The JOI Steering Committee will re-evaluate the priority list based on this input from Tracor. Soon Tracor will start development of the Group 1 data acquisition application. The new Data Management System will be built using ORACLE Database Management System, Unix server(s), and will be accessible from PCs, Macs and Unix workstations.

Priority List of Data Types for the JANUS Project agreed upon by IHP/SMP, Oct. 1994. (* added by Steering Committee, Jan. '95)

Group 1.	Group 2a.	Group 2b.	Group 3.
Corelog data, Leg/Site/Hole	Grape	Paleontology	Adara (cont. work on 2b)
Sample Data, Chemical Samples	P-Wave	ageprofile	WSTP
	Magnetic susceptibility	smearslide	thermal conductivity
	natural gamma		sonic velocity
	color reflectance		shear strength
	paleomagnetics		index properties
	geochem and quad-combo logs *		

Group 4a.	Group 4b.	Group 5.	Group 6.
Rock eval/Geofina	sediment description	Hard rock description (cont. work	tensor/sonic core monitor
carbon/carbonate	structural description	thin section description on 4b)	underway geophysics
gas chromatography			seismic
interstitial water			core photos
XRF/XRD			FMS logs *

Barbados Ridge Accretionary Prism

Science Operator Report Leg 156

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ABSTRACT

Leg 156 investigated temporal and spatial scales of fluid flow, the role of faults in fluid transport, and the relationship between mechanical state and seismicity in the northern Barbados Ridge accretionary prism. The strategy was to drill into areas of strikingly different polarity and amplitude of the décollement reflection, revealed by recently acquired, three-dimensional seismic data and interpreted as areas of varying fluid content and/or fluid migration paths within the décollement.

Eight holes were drilled at Sites 947, 948, and 949, located 6 km, 4 km, and 2 km west of the thrust front, respectively. Site 948 is located in an area of positive polarity, inferred to have normal porosity, decreasing with depth, from the seismic data. Sites 947 and 949 investigated portions of the décollement zone that have negative-polarity seismic reflections thought to represent high-porosity zones of high fluid pressure. Our scientific objectives required an ambitious operational program including cased-hole installations, downhole measurements, and emplacement of long-term borehole observatories in a region known for its drilling and downhole logging difficulties due to unstable hole conditions.

Logging-while-drilling (LWD) at Sites 947 and 948 at the beginning of the leg recorded the most complete resistivity, natural gamma-ray, density, and neutron porosity logs ever obtained from the notoriously unstable accretionary-prism environment. At Hole 948A, logging data show that the positive-polarity reflection results from an increase in velocity and bulk density at a lithologic change within the décollement at about 515 m. However, the LWD data also reveal two thin zones of high (66% and 60%) porosity at 505 and 514 m; these two thin zones are below the limits of seismic resolution. At Hole 947A, just above the décollement from 520 to 535 m and in the zone where the drill string became stuck, the porosity is also anomalously high (about 70%). Synthetic seismogram modeling using the logging data creates a negative-polarity seismic reflection at this level, which is also present on the seismic data. The zone is interpreted as a listric thrust rising off the décollement. The logging results at Sites 947 and 948 suggest that high fluid pressure of differing magnitude may exist all along the décollement zone.

The décollement zone was well defined by coring at Site 948. It includes lower to middle Miocene claystone, underlain by lower Miocene and upper Oligocene variegated claystones, with muddy turbidites and redeposited chalk. The 31-m-thick fault zone exhibits scaly fabric, fracture networks, and stratal disruptions interleaved with intact intervals of sediment. Coring at Site 949 recovered insufficient core to define the extent of the décollement. The accretionary-prism sections cored at Sites 948 and 949 are permeated at distinct levels by fluids having a salinity lower than that of seawater. The most distinct low-Cl fluid interval (about 18% less than seawater) was intercepted at Site 948 at the top of the décollement. Although less intensive, three low-Cl intervals intercepted at Site 949 correlate with postulated thrust faults. Thus, the geochemical-depth profiles are consistent with active focused fluid flow along conduits from greater depth.

In Holes 948D and 949C, casing was set from the seafloor through the décollement. Casing within the décollement zones was perforated and screened to allow hydrologic communication between the cased hole and the décollement. This allowed successful packer measurements of fluid pressure and permeability in the décollement zone. Initial analysis of packer results from Site 948 suggests that pressure may have increased to 90% of lithostatic during the period the screened section was isolated, providing tantalizing indications of high in situ fluid pressure. Confirmation however can only follow shore-based work.

Vertical seismic profiles were collected in the cased holes to calibrate the seismic reflection models. An offset VSP at Site 949 used 18 bottom-shot explosions to determine shear-wave polarization to study stress orientation and structural fabrics. Holes 948D and 949C were finally instrumented with a French-designed and a U.S.-Canadian-designed temperature and pressure sensor string, respectively, and at Site 949 with a U.S.-designed continuous fluid sampler. Prior to instrument deployment, Hole 948D had to be "killed" with heavy mud to stop sediment infill and outflow of sediment-laden water from the reentry cone, whereas sediment infill in Hole 949C was stopped by means of a mechanical plug at the bottom of the casing. The instruments deployed in these holes are designed to collect data over the next few years to assess the episodicity of fluid behavior. A submersible expedition in 1995 will collect pressure and temperature data from the sensors and conduct hydrologic testing in the sealed holes.

INTRODUCTION

The importance of fluids in accretionary-prism tectonics was a special topic at a NATO-sponsored workshop in 1989 and spurred innovative experiments and new techniques (Langseth and Moore, 1990). Fluids critically affect the structural development and architecture of accretionary prisms and their potential evolution into mountain belts (e.g. Hubbert and Rubey, 1959). Structural and geochemical studies of recovered samples from Barbados and elsewhere attest to multiple fluid-flow events and for the importance of both intergranular and fracture permeability (e.g. Moore and Vrolijk, 1992; Knipe et al., 1991; Moore et al., 1982). Yet we have not been able to tie these observations to even the most fundamental temporal and spatial scales to validate dynamic flow models (e.g. Screaton et al., 1990; Shi and Wang, 1988). On Leg 156, our objective was to combine both in situ measurements of permeability and fluid pressures, long-term monitoring of temperature and pressure, and fluid chemistry and structural fabric studies in an integrated program. This experiment is an important and necessary step in evaluating the role of faults in fluid transport, episodicity of fluid flow, and the relationship to seismicity. Understanding the fate of subducted and accreted fluids will also contribute to geochemical cycle definition (Kastner et al., 1991). This program is a logical step in advancing the technological and drilling techniques needed in this environment.

Site 947

Site 947 (proposed Site NBR-3) was positioned, in part, to explore the high-amplitude negative-polarity fault reflection for comparison to the seismic character at Site 948, where the décollement exhibits positive polarity (Figures 1, 2, and 3). For the first time in the history of ODP, we deployed a logging-while-drilling (LWD) system. This logging system was necessary because hole instability had prevented wireline logging on both Leg 78A and Leg 110. The LWD program at Hole 947A obtained logs from the seafloor to 574 mbsf. Drilling conditions stopped the LWD about 60 m above the seismically identified décollement in a fault splay.

The principal results at this site are from interpretation of the logging data. The primary logs include dual resistivity with natural gamma-ray spectroscopy and compensated density-neutron. Because of the high rates of penetration the total gamma-ray counts are of good quality, but the spectral data are not. Neutron porosity logs are noisy and show significantly higher values than calculated from the density log. Without cores, the logging data interpretations use "electrofacies" (boundaries in log character, internal curve shape). Seven identified log "units" define subtle depositional variations and commonly have sharp boundaries related to compaction trend offsets. Four primary intervals having a downhole decrease in density relate to two different processes. Two intervals may represent discrete thrust packages bringing higher density sections over lower density ones, given the sharp nature of the boundaries. Two other intervals are more diffuse at their boundaries and could result from natural lithologic variations or faulting; whether due to faulting or lithologic variations, the density trend reversals indicate elevated pore pressures necessary to arrest compaction.

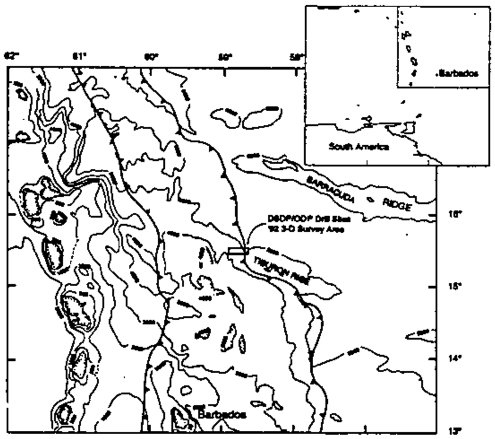

Figure 1. Index chart of the Lesser Antilles. Stippled zone is the extent of the northern Barbados Ridge accretionary prism. The Tiburon Rise dams along-axis trench transport, partly explaining the reduction in width of the prism to the north. A box illustrates the location of the DSDP/ODP transects. The box is approximately the size of the 3-D seismic survey that identified the drilling locations on Leg 156 (figure modified from N. Bangs, personal communication). Bathymetry shown in meters.

Near the base of the hole the density falls to low values which, when using Site 671 grain densities, yields a porosity of 70%, essentially the same value found at the surface and at the incipient décollement at Site 672. The high porosity at this depth must be supported by high fluid pressures.

We planned to return to Site 947 after completing Site 948 to core, obtain wireline logs, and carry out VSP, packer and CORK experiments. Unfortunately, after completion of Site 948 there was insufficient time to return and complete a full operational and experimental program. In its place Site 949 examines a similar objective at a shallower sub-bottom depth. Site 947 for now consists of logs and no cores, an unusual event in scientific ocean drilling.

Site 948

Site 948 (proposed Site NBR-2) calibrates the positive-polarity seismic signature of the décollement (Figure 3). It is also as close as we could navigate to Hole 671B, which penetrated the 40-m-thick décollement and 151 m into the underthrust section on ODP Leg 110 (Figure 2). Hole 948A was dedicated to logging. Hole 948B was a jet-in test site. Hole 948C was dedicated to interval coring and logging. Hole 948D, 200 m south of Holes 948A and 948C, was cased to 535.3 mbsf for special experiments.

At Hole 948A we collected logs using logging-while-drilling (LWD) technology, which is a more effective technique than wireline logging in unstable formations such as accretionary prisms. The logging provided compensated dual resistivity, natural gamma-ray (CDR tool), compensated density neutron, neutron porosity, and gamma-ray (CDN tool) measurements from 0 to 582 mbsf. Drilling conditions remained very good to about 515 mbsf, when circulation pressures increased. The section logged included the décollement zone, which was observed in Hole 671B at about 500 to 540 mbsf and in Hole 948C at 498 to 529 mbsf.

The resistivity, gamma-ray, and bulk-density logs correlate with the physical properties measured on Site 671 cores. An abrupt decrease in density below a fault at 132 mbsf marks the overthrusting of tectonic packages recorded at Site 671. This same trend is observed in the resistivity log. An increase in total gamma-ray count from 315 to 380 mbsf is related to a distinct break in the relative abundances of carbonate and clay minerals, where carbonate is absent and the clay-mineral content (which contains a larger portion of radioactive elements) increases.

The LWD logs show pronounced changes across the décollement. Resistivity drops, and bulk density increases. Gamma-ray and re-

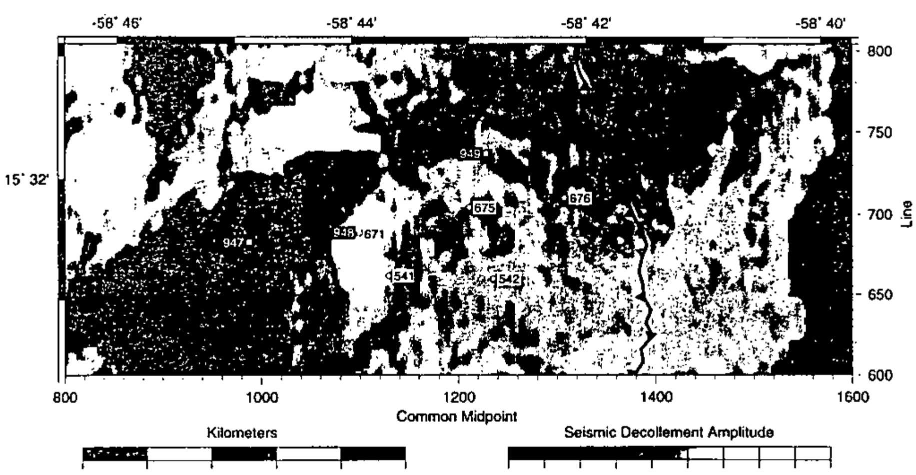

Figure 2. Map of décollement showing the Leg 156 drill sites superposed on a seismic amplitude map. The amplitude map is based on digitized 3-D seismic data. The frontal thrust, DSDP, and other ODP drill sites are shown.

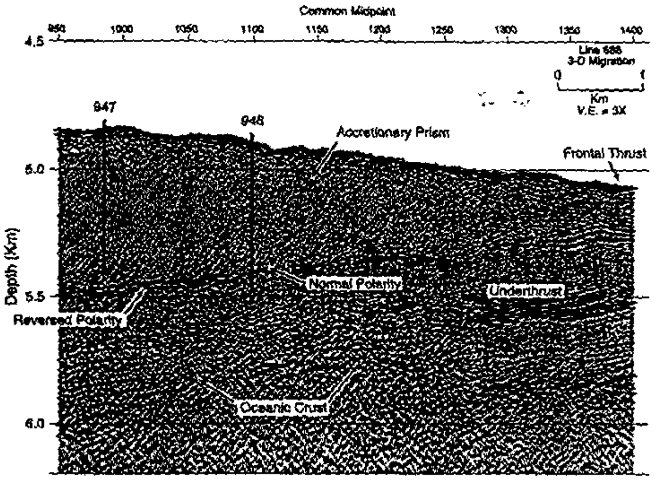

Figure 3. Seismic section illustrates reflection characteristics of the décollement at Sites 947 and 948. Section is in depth using velocity function derived from Site 671 (Shipley et al., 1994). Site 948 prism velocity = 1740 m/s; underthrust section velocity = 1779 m/s; Site 947 prism velocity =1777 m/s; underthrust section velocity = 1811 m/s. Section gain was equalized with a 500-ms symmetric moving window.

sistivity changes occur over a 10-m interval corresponding to the middle of the structurally defined décollement. These differences primarily reflect the change in lithology and clay mineralogy at about 514 mbsf. The increase in gamma ray in the underthrust section must in part be due to an increase in illite (potassium-rich) observed at Sites 671 and 948.

Within the structurally defined décollement there are two low-density spikes at 505 and 514 mbsf. Assuming these are not related to grain-density changes, they reflect porosities of 66% and 60%, in contrast to surrounding sections with 55% to 47% porosity. The second spike is coincident with the lithologic boundary and spans a 3-m interval. Overall, such changes could reflect fault-zone dilation across thin zones that are below the resolution of the 3-D seismic data.

A substantial decrease in density from about 2.0 Mg/m3 at 395 mbsf to 1.8 Mg/m3 at 500 mbsf, just above the décollement, is similar to density trends in the interval from 100 to 200 mbsf. Given the fairly uniform lithologies, this zone must be related to significant undercompaction and high fluid pressures. This zone coincides with the lowest pore-water chlorinity.

LWD is unique in logging the upper hundred meters of the hole; this section cannot be studied by wireline logs because of the necessity to leave some pipe in the hole. The shallow LWD logs will specify the physical property evolution related to both compaction and the unique tectono- hydrologic conditions of this environment.

Hole 948C began with a mud-line core that recovered 10.1 m of Pleistocene brown clay with nannofossils. The section includes abundant ash layers. The hole was drilled without coring from 9.5 to 420.8 mbsf. Temperature measurements at 65, 103, 200, 248, 327, and 422 mbsf, when added to Site 671 data, yielded gradients from 92°C to 97°C/km in the upper part of the hole, to about 66°C/km in the lower part of the section. Coring at Hole 948C resumed with Cores 156-948C-2X to -19X (420.8 to 592.0 mbsf), with 95% recovery. Based on the seismic reflection geometry and seafloor depths, the depth to the décollement from the seafloor is 6.5 m deeper in the A and C holes than in the D hole.

Above the décollement the anisotropy of magnetic susceptibility (AMS) results indicate horizontal, east-west shortening in the prism. Just above the décollement the AMS orientation gradually changes to a geometry consistent with a vertical compaction fabric. Below the décollement the amount of vertical compaction indicated by AMS is more pronounced.

Physical property data provide correlation and calibration of the LWD data and a comprehensive downhole profile through the fault zone. An offset in most downhole profiles occurs within the décollement zone. This is the result of a major lithologic change. Below 508 mbsf a sharp offset to higher densities is observed. Compressional-wave velocities decrease somewhat, but the overall impedance change is a positive contrast, similar to the seismic data. Shear-wave velocities measured in discrete samples are low, probably indicative of the low strength of these sediments.

Hole 948D was drilled for the long-term borehole observatory (CORK) and other downhole experiments. A triple-string casing program was designed to ensure hole stability for the experiments and placement of a screened section across the fault. Cement was pumped down to the bottom of the second casing shoe at 476 mbsf to assure hydrologic isolation of the formations above the décollement for subsequent packer and CORK monitoring. After the second casing placement, a cement bond log (CBL) and a vertical seismic profile (VSP) were run. There was good bonding in the lowermost 25 to 30 m of the logged hole, plus another 10 m estimated below the lowest log depth hydrologically isolating the lower part of the hole from the upper part. The VSP extends from about 470 up to about 96 mbsf within the cased hole using magnetically clamped geophones. The data confirm the results from the cement-bond log, showing the best records near the base of the hole, less than 50 m above the décollement. Uphole the records are more noisy, but shipboard processing shows that the data are of good quality throughout the logged interval. The velocity estimated from the VSP is generally higher than the laboratory measurements or the sonic logging data.

Screened casing was set through the fault zone from 480.7 to 522.6 mbsf. A series of packer tests was run with a drill-string packer set in the casing above the screened interval. First, a series of "negative" pulse and flow tests exposed the isolated formation to hydrostatic pressure and monitored its recovery. A positive pulse test showed a rapid pressure rise, then a small initial decay, and then remained elevated and constant for the next 55 min. Three more positive pulse tests were run, and then three positive, constant flow tests at three different pumping rates, each including shut-in and measurement of recovery at the end. The packer recorded pressure increases to near lithostatic values during the time the well was shut in. However, these data require substantial analysis and evaluation, given the significant formation disturbance during the setting of casing.

Lastly, we deployed the temperature and pressure sensor string with the data logger and the borehole seal (CORK) assembly. Our efforts were hampered by sediment filling the casing from below and flow out the reentry cone at the sealoor. Cleaning attempts could not keep up with the sediment filling the casing. We stopped the sediment inflow by filling the hole with a column of 1.66 Mg/m3 mixed barite and bentonite mud from 538 to about 65 mbsf. We do not know if the screen was damaged (allowing inflow through the perforations in the casing) or if sediment was flowing up from the bottom of the open casing. We then deployed the IFREMER data logger with 20 temperature sensors and 3 pressure sensors. Pressure sensors are at 8, 479, and 509 mbsf.

The CORK was then seated but would not latch, leaving the weight of the CORK (and its associated pipe) to hold the seal in weight is equivalent to the piston force that will be acting on the CORK if the fluid pressure below it reaches about 1 MPa (142 psi). The radical use of heavy mud to prevent the formation from flowing into the casing will undoubtedly further modify the hydrologic system. The failure of the CORK to latch will also potentially be a problem, which may at least in part be accommodated by the heavy mud and multiple pressure sensors. The deepest pressure sensor, within the screened zone, should come to equilibrium with the formation fluid pressure, provided that it does not become hydraulically isolated from the surrounding formation.

Using the preliminary estimates of fluid density and of the mud volume, the column of mud will exert a force of probably not more than 2.8 MPa (400 psi) at the depth of the center of the screen. Combined with the CORK weight, the total CORK and mud system might balance 3.8 MPa. The calculated lithostatic load, which should be the maximum possible overpressure, is estimated from the LWD density log to be 4.0 MPa (575 psi) at the screen. (These numbers are rough, tentative estimates.) If the CORK should vent during the next year, we may be able to latch it during planned submersible work.

Site 949

Site 949 (proposed Site NBR-7) was chosen to investigate fault properties associated with the reversed-polarity seismic signature of the décollement. Site 949 is located where the overlying accretionary prism is thinner, and the amplitude of the negative-polarity reflection is not as high as at Site 947 (Figures 2 and 4). Seismic data define a shallow dipping series of splay faults at about 150 to 225 mbsf, cutting off near-horizontal reflections at about 275 mbsf and deeper, and the main décollement at 375 mbsf, marked by a reversed-polarity reflection. At 425 mbsf is another reversed-polarity reflection, thought to be either an incipient fault or a stratigraphic boundary.

Hole 949A (line 738, CDP 1227) consists of a mud-line core taken to determine water depth and was followed by a jetting test to determine the first casing point. The core contained lower Pleistocene gray clay with nannofossils. We then offset 125 m south and 30 m east to drill Hole 949B (line 733, CDP 1229), which was the prime coring site. Coring started at 244.1 m in upper Miocene gray claystone with nannofossils but recovered only 40%. Hole 949C (line 737, CDP 1228) was dedicated to the casing, downhole experiments, and emplacement of a sensor string and the CORK. We again cored the interval below the second casing point, from 401.0 to 463.8 m, with the RCB system to obtain more samples from the critical interval of the fault, but recovered only 4% of the cored interval.

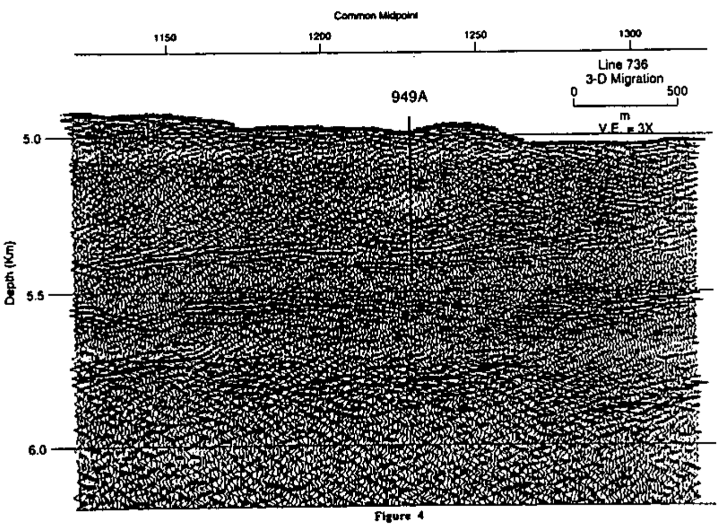

Figure 4. Seismic section illustrates reflection characteristics of the décollement at Site 949. Section is in depth using velocity function derived from Site 671 (Shipley et al., 1994). Specifically at Site 949 the prism velocity used was 1699 m/s, and the underthrust section velocity was 1743 m/s. Section gain was equalized with a 500-ms symmetric moving window.

The sedimentology deduced from the limited recovery is similar to that of Site 948. The poor recovery precludes any detailed comparison with other sites cored in this area on Leg 78A or Leg 110. Even so, the basic stratigraphy can be reconstructed using Site 948 for reference. A stratigraphic inversion indicates that a thrust fault displaces the upper part of the cored section by a significant amount. Early Miocene radiolarians in a pale yellowish brown claystone occur at about 400 m, in the same core as some scaly fabric, and similar to the décollement association at other sites. Examples of the underthrust brownish gray to greenish gray claystone, with interbeds of siltstone turbidites and remobilized nannofossil chalks, occur in the lower part of the cored interval.

Physical properties data for Holes 949B and C are sparse, and thus downhole profiles are incomplete. Specific relationships between observed reflections and their possible physical cause remain uncertain. The increase in velocity and density across the lithologic boundary, for example, does not explain the negative-polarity reflection observed here and correlated seaward into the basin. The physical property data will serve as a background for the evaluation of thermal and chemical information gained from the long-term measurements in the CORK hole. The data will also add to the general data sets collected on Leg 156 and on Legs 78A and 110.

The second string of casing was placed from near the seafloor to just above the décollement, and the section was cemented to provide hydrologic isolation between the overlying section and the décollement. A cement-bond log indicated that the lowermost 40 m of the second casing string is well bonded, providing a hydrologic seal from the formations above.

A shear-wave vertical seismic profiling (VSP) experiment used explosive charges on the seafloor around Hole 949C. Eighteen shots were recorded at two intervals to observe shear-wave velocities and polarizations that relate to deformation fabric alignment. A conventional air-gun VSP followed, and the resulting velocity estimates and images confirmed our depth estimates within the borehole relative to the seismic reflection data. As at Site 948, velocities are about 2% higher than values used in the original three-dimensional seismic migration and depth conversion, and the velocities decrease just above the décollement.

The final casing string comprised a 54-m-long perforated and screened section above a 14-m unperforated section. Prior to reentering to set this casing, turbid water was observed filling the reentry cone, a situation similar to that encountered at Site 948, and suggested some flow out of the borehole. During two attempts to set the third casing string, sediment fill was found inside the second casing string. This fill was circulated out of the hole, and the third casing string was latched. Next, we tried to use a plug to close the bottom of the casing but could not advance past a spot about 54 m up from the bottom. The casing plug was modified to improve circulation and was redeployed and set about 3 m above the bottom of the casing.

Next, the packer was used to perform a series of formation pulse and flow tests to measure hydrologic characteristics at the décollement. Preliminary analysis suggests modest overpressures, less than the pressures recorded at Site 948. This result is consistent with the more subdued evidence for flow and casing filling at this site. A second VSP run in the third casing string followed the packer experiment.

Finally, a string of 10 thermistors and 2 pressure transducers, associated data logger, and a mechanical continuous fluid sampler (MCFS), attached to the sensor string and driven by an osmotic pump, was deployed in Hole 949C. The hole was then sealed with the CORK. Pressure and temperature will be monitored and fluid samples collected for 2 years.

The décollement zone depth is not well defined but is between 380 to 433 mbsf. The detailed lithostratigraphy and structural geology are not precisely known because of poor core recovery. Deformation structures are similar to those at Site 948 but are weaker in intensity, as aregeochemical indications of fluid flow. The less well-defined décollement and evidence of less intense strain are probably related to the location of the sites only about 2 km from the thrust front. We did not have time to log this site, but the VSP provides direct correlation of the seismic data tothe hole. Detailed velocity data also show a decrease in the 40-m interval above the décollement,suggesting density trends similar to those observed at the other sites. As at Site 948, we observed fluid flow out of the reentry cone and sediment infilling of the casing, which made operations challenging. The packer data are suggestive of overpressure within the décollement, but lower than at Site 948. Further analysis is necessary to confirm these values and to make estimates of bulk permeability. The CORK measurements will provide other estimates of in situ conditions and monitor for a longer period changes in fluid properties.

SUMMARY AND CONCLUSIONS

ODP Leg 156 logged, cored, cased, and instrumented the major plate-boundary fault (décollement) beneath the northern Barbados Ridge accretionary prism. Site 948 drilling penetrated an area characterized by positive polarity seismic amplitudes on a map derived from three-dimensional seismic data, whereas operations at Sites 947 and 948 investigated portions of the décollement zone that have negative-polarity seismic reflections.

Leg 156 operations, geared to achieve ambitious scientific goals, represented a new era of scientific ocean drilling.This included an impressive set of techniques either rarely used before, not used to this extent before, or used for the first time

1. Logging-while-drilling (LWD), employed for the first time in the ODP, recorded complete logs from the accretionary prism at Sites 947 and 948. At Site 948, the logs represent the first of their kind across a major plate boundary.
2. Casing strings up to more than 500 m long, from the seafloor through the décollement, were set at Sites 948 and 949. Perforated casing within the décollement zone allowed hydrologic experiments within the main fault.
3. Packer experiments were run successfully to measure fluid pressure and permeability in the décollement zone from within the cased holes.
4. Vertical seismic profiles (VSPs) were collected inside the cased holes to calibrate the seismic reflection models. An offset VSP at Site 949 used 18 bottom-shot explosions to determine shear-wave polarization to study crack alignment and hence stress orientation and structural fabrics.
5. Holes at Sites 948 and 949 were instrumented with temperature and pressure sensors, and at Site 949 a continuous fluid sampler, that are designed to collect data over long periods, to assess the episodicity of fluid behavior.

Cores from the fault zone include lower to middle Miocene claystone, underlain by lower Miocene and upper Oligocene variegated claystones, with muddy turbidites and redeposited chalk. The fault is a 31-m-thick zone of scaly fabric, fracture networks, and stratal disruptions interleaved with intact intervals of sediment. Variations in interstitial-water chemistry exhibit both diffusive and advective characteristics. Geochemistry-depth profiles characterized by low-Cl fluid intervals are consistent with active focused fluid flow along conduits from greater depth.

The anomalously high porosities in the vicinity of the décollement zone from the Site 947 and Site 948 LWD data suggest high fluid pressures. It seems likely that the high porosities are maintained by fluid influx, as dilatant (hydrofractured) zones.The more localized occurrence in the two narrow zones at Site 948 suggests that high-pressured zones may occur throughout the décollement, and that they are not apparent everywhere from seismic data owing to limitations in seismic resolution.

High pore pressures and related formation instability caused operational difficulty at all sites. At Site 947 the drill string became stuck in the 15-m-thick high-porosity section just above the décollement. Constant infilling of the casing by sediment and outflow of sediment-laden water from the reentry cone at Site 948 continued until flow was stopped with a heavy mixed barite and bentonite mud. Sediment also rapidly filled the casing at Site 949 prior to installation of a mechanical plug at the bottom to stop the flow.

Initial analysis of packer results from Site 948 suggests that pressure may have increased to 90% of lithostatic during the period in which the screened section was isolated, providing tantalizing indications of high in situ fluid pressure. Confirmation, however, can only follow shore-based work.

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Science Operator Report Leg 157

The Clastic Apron of Gran Canaria and the Madeira Abyssal Plain

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ABSTRACT

ODP Leg 157 drilled seven sites (Sites 950 through 956) in the Madeira Abyssal Plain and the volcaniclastic apron around Gran Canaria, recovering over 3 km of core, which ranges in age from middle Eocene to Quaternary. Sites 950, 951, and 952, situated in the southwestern, northern, and southeastern parts of the Madeira Abyssal Plain, respectively, reveal a detailed history of organic, calcareous, and volcaniclastic turbidite deposition that began between 11.3 and 15 Ma. The highest rate of turbidite deposition (all types) occurred between 0 and 3 Ma. The input of volcaniclastic turbidites was minimal before 6.5 Ma. Integrated biostratigraphic, lithologic, and logging data show that many individual turbidites can be correlated across the entire plain. A change in the carbonate compensation depth (CCD) is reflected by an increase in calcium carbonate from very low values before about 3 Ma to oscillating high and low values from 0-3 Ma. Pore-water chemistry data reveal the great importance of bacterially mediated oxidation of organic matter, located principally in organic-rich turbidites, in controlling diagenetic environments. Active sulfate reduction and methanogenesis are documented for the first time in this area. Resulting changes in pore-water chemistry modified carbonate equilibria, causing the precipitation of calcite and dolomite, while the dissolution of biogenic silica and volcanic glasses led to the appearance of new silicate minerals, principally smectites and zeolites.

Four sites (Sites 953 through 956) drilled north and south of Gran Canaria demonstrated that the compositional evolution, growth, and mass wasting of an ocean island is reflected in the sediments of the adjacent volcaniclastic apron. All major volcanic and nonvolcanic phases of Gran Canaria have been recognized in the ages and compositions of sediments, physical properties, and geophysical logs. Sites 953 and 954 were drilled in the basin north of Gran Canaria, whereas Sites 955 and 956 were drilled to the southeast and southwest of the island, respectively. The shield stage is represented at Sites 953, 954, and 956 by a sequence of massive hyaloclastite tuffs and debris flows, breccias and lapillistones, and fine volcanic turbidites. Middle Miocene felsic volcanics overlying the shield stage were recognized at Sites 953, 955, and 956, including the submarine facies of ignimbrite P1, which marks the beginning of explosive volcanism on Gran Canaria at 14.1 Ma. Pliocene Roque Nublo volcanism is represented by a layer of basaltic lapillistone at Sites 953 and 954. Pleistocene volcanic ashes and pumice layers occur in both the northern and southern sites and presumably come from Tenerife. The two southern sites contain both organic-rich sediments and quartz, reflecting a source from the African margin. In contrast, the two northern sites have little or no organic muds and quartz, indicating that they were mostly protected from African sediment sources by the barrier of the eastern Canary Islands. Major slump deposits in the southern sites also likely come from the African margin. Pore-water chemistry data show remarkable correlations to sediment composition; Site 953 is dominated by fluid-rock interaction between pore waters, volcanic glasses, and minerals; Site 954 displays large geochemical anomalies associated with levels of carbonated pore waters, possibly related to Holocene volcanic activity on northern Gran Canaria; at Site 955, organic matter, located principally in slumped sediments derived from the Northwest African margin, is driving intense sulfate reduction and methanogenesis at shallow depths, while the deeper sediments contain saline brines, possibly originating from the leaching of African shelf evaporites.

INTRODUCTION

MAP

The Madeira Abyssal Plain (MAP) project was aimed at testing the hypothesis that ocean-basin sedimentation is controlled by sea-level changes that affect the stability of sediments on continental margins, including those on the flanks of volcanic islands. The products of mass-wasting events accumulate on the continental slope and on the abyssal plains, but the abyssal plain is the only place where a complete record can be obtained at one drill site. Seismic evidence suggests that the abyssal plain is a young feature, with the whole 350m-thick turbidite sequence (20,000 km^3) having been deposited in just a few million years. The drilling on the Madeira Abyssal Plain will also allow mass-balance calculations of sediment transported from the continental margins to the deep sea, including mass balances for volcanogenic sediments derived from Madeira and the Canary Islands. The history of volcanogenic turbidites will be closely tied to the history of the volcanic islands and should provide information on the initiation of hot-spot activity, on phases of increased volcanic activity, and major island-flank collapse events.

The study of early diagenesis in sediments accumulating under non-steady-state conditions will also be advanced by study of these sediment sequences. The concept of a "progressive oxidation front" was first proposed following studies of the MAP turbidites (Wilson et al., 1985, 1986; Thomson et al., 1987). When the turbidite top is in diffusive contact with bottom waters following deposition, several elements redistribute themselves around the oxic/postoxic (or suboxic) boundary at the front. This results in layers of metal concentrations, with some metals persisting long after conditions have become reducing, and some metals disappearing quickly. We need to know more about the long-term persistence of these signatures to aid in interpreting paleo-redox conditions. The presence of multiple fronts will allow successively older signatures to be examined. The diagenesis and maturation of organic matter can also be examined in the turbidites, as well as in the clastic apron sites, by techniques such as Rock-Eval pyrolysis.

VICAP

The aim of VICAP (Volcanic Island Clastic Apron Project) was to study the physical and chemical evolution of the confined system "asthenosphere-lithosphere-seamount-volcanic island-peripheral sedimentary basin" by drilling into the proximal, medial, and distal facies of the volcaniclastic apron around Gran Canaria, one of the best studied volcanic islands. The volcaniclastic apron consists of the seismically "chaotic" flank facies with velocities around 3.4-4 km/s, and the basin facies characterized by widespread reflectors that represent volcaniclastic sediments interfingering with biogenic and continent-derived clastic material. The basin facies contains large amounts of material representing the evolution of the entire complex island volcano; most importantly, it includes material from the inaccessible submarine stage, representing >90%, by volume, of the volcanic edifice.

Gran Canaria is unusually well exposed and well studied. The island has been volcanically active intermittently throughout the past 15 m.y. Igneous rocks, both mafic and evolved, show a large spectrum in chemical and mineralogical composition. Gran Canaria has experienced several stages of extreme magma differentiation, unique among volcanic islands, generating both frequent explosive rhyolitic, trachytic, and phonolitic fallout ashes and many ash-flow deposits. The distinct composition of individual ash flows, as well as other volcanic rocks, throughout the island's evolution will greatly facilitate stratigraphic subdivision of the cores. The evolved rocks contain significant amounts of K-rich mineral phases (feldspar and mica), a prerequisite for high-resolution age studies. A major element of the program will be high-precision, single-crystal 40Ar/39Ar age dating with the aim of monitoring the island and basin evolution in time slices as short as 100,000 years.

The combined VICAP-MAP project focuses on the development of the Canary Basin in terms of the history of volcanic activity in the Canary hot spot, the detailed evolution of large volcanic oceanic islands, the growth of peripheral sedimentary basins (volcanic aprons), and the filling of the distal Madeira Abyssal Plain.

RESULTS

Site 950

Site 950 is located in the western part of the Madeira Abyssal Plain at 31°9.01'N, 25°36.00'W, at a water depth of 5437.8 m in the Cruiser Fracture Zone Valley (Figure 1). Seismic profiles for the area show two major units: an upper unit showing relatively high-amplitude parallel reflectors that onlap onto basement highs, and a lower unit that partly onlaps and partly drapes the basement highs. The upper unit can be subdivided into three subunits by relatively strong reflectors at 180 ms and 240 ms. Reflectors within the lower two subunits are weaker than in the upper subunit. This seismic pattern is typical for the whole abyssal plain and is interpreted as pelagic drape over basement, with the deeper draped sequences being later infilled by rapidly accumulated turbidites.

A single hole was cored at Site 950, and a total of 17 APC cores (0-154.4 mbsf) and 24 XCB cores (154.4-381.3 mbsf) were retrieved with average recovery rates of 100.5% and 81.1%, respectively. The hole was logged with the seismic stratigraphy, lithoporosity, geochemical, and formation microscanner (FMS) tools.

The sedimentary sequence at Site 950 comprises four lithologic units (Figure 2).

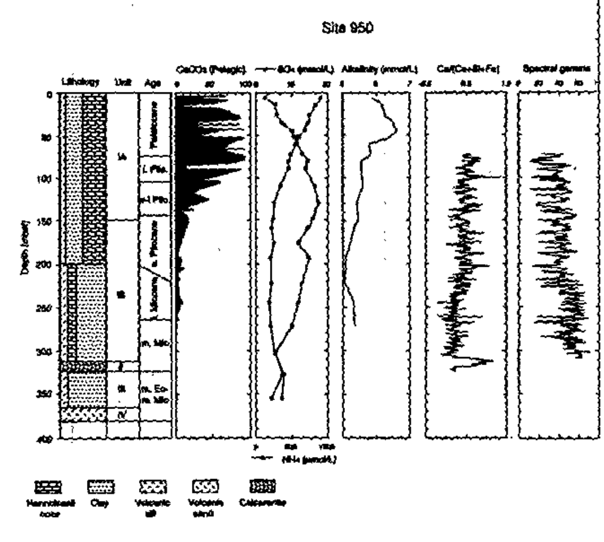

Figure 2. Summary diagram of Site 950, showing lithology, lithologic units, age, pelagic calcium carbonate content, pore-water chemistry (SO_4, NH_4, alkalinity), and logging data (Ca/[Ca+Si+Fe] ratio and spectral gamma).

Unit I (0-314 mbsf) consists of Pleistocene to middle Miocene (0-13.6 Ma), thick, clayey, nannofossil mixed sediment and nannofossil clay turbidites, interbedded with pelagic nannofossil oozes, mixed sediments, and clays. Below 150 mbsf, the pelagic interbeds are all clays. There are three primary types of turbidites: volcaniclastic from the volcanic islands within the basin, organic-rich from the Northwest African margin, and calcareous from seamounts to the west of the plain. Only rarely do two turbidites lie adjacent to each other.

Unit II (314-332 mbsf) consists of massive calcarenite of middle Miocene age (13.6-15 Ma). Core recovery in this interval was poor,

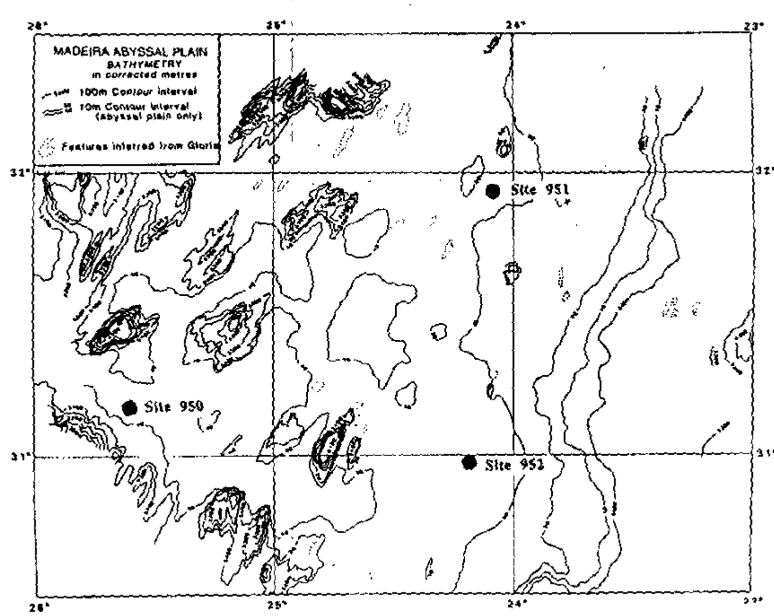

Figure 1. Bathymetric map of the Madeira Abyssal Plain, showing the location of Sites 950, 951, and 952. Bathymetry in meters.

but the logging data clearly show three calcarenite units with turbidites between each unit. The composition of this unit strongly suggests that it was derived from local sources such as the Cruiser/Hyeres/Great Meteor seamount complex to the west.

Unit III (332-370 mbsf) consists of dominantly red pelagic clays with thin interbeds of clayey, nannofossil mixed sediment and zeolitized volcanic-ash bands. Nannofossils within the turbidites suggest that this unit ranges in age from middle Miocene to middle Eocene (15 to 47 Ma).

Unit IV (370-381 mbsf) consists of two depositional units of dark volcaniclastic siltstone and sandstone separated by clay. The volcanic-ash bands and volcaniclastic flows are all interpreted to have been derived from the Cruiser/Hyeres/Great Meteor seamount complex.

Paleomagnetic stratigraphy gave usable datum levels from C1n to C2An.2, based on measurements in the pelagic interbeds between turbidites. Planktonic foraminifers also provided useful biostratigraphic data from the pelagic interbeds in the upper part of the hole (0-140 mbsf). Nannofossils, however, were found consistently in pelagic interbeds from 0 to 200 mbsf (0-5.8 Ma) and intermittently to 273 mbsf (11.5 Ma). Below this, stratigraphy is based on first-occurrence data from turbidites and also deduced from extrapolation of the accumulation rates of the pelagic units.

The major change in the accumulation rate of the pelagic interbeds from 1.5 m/m.y. to 5.6 m/m.y. occurs at 2.6 Ma, coinciding with the change from clays to alternating clays, marls, and oozes. This is also coincident with the onset of major Northern Hemisphere glaciation and associated deepening of the CCD, which placed this site above the CCD. The overall sediment-accumulation rate for Unit I averages 42 m/m.y. from 0-3 Ma, 28 m/m.y. from 3-6.5 Ma, and 21 m/m.y. between 11 and 13.6 Ma. The interval from 6.5 to 11 Ma appears to have a lower accumulation rate of 9 m/m.y. The lower part of the hole, dominated by red clay deposition (Unit III), has a very low accumulation rate of 1 m/my.

Pore-water geochemical results demonstrate that sulfate reduction is occurring principally in the deeper parts of the sequence, below 130 mbsf. Calcium and magnesium results suggest that precipitation of carbonate is occurring above, and within, the sulfate-reducing zone. Silica, potassium, and other pore-water data demonstrate that biogenic silica is being dissolved in the upper parts of the sequence, while diagenesis in the deeper section is related to clay-mineral and zeolite formation.

A total of four Schlumberger tool strings were run at Hole 950A: the seismic stratigraphy, lithoporosity, geochemical, and FMS tool combinations. The thick sequence of interbedded turbidites is well defined by the geochemical logs, which respond to the varying clay and carbonate composition. The transition, lower down in the hole, to a more clay-rich, carbonate-poor sequence is well characterized by the chemical logs and correlates to biostratigraphic data, which indicates a decrease in the rate of sediment deposition. Beneath this unit, in an area of poor recovery, the physical and chemical logs clearly delineate the presence of three calcarenite units, the thickest of which is 10.5 m, of which only 1.1 m in total was recovered in the cores.

A combination of the downhole sonic-log data with the MST velocities measured on the APC cores (0-150 m) provided a complete velocity profile down to 340 mbsf. The base of seismic unit A correlates with the surface of the red clay sequence at about 330 mbsf. In unit B, the upper, parallel reflectors seem to represent the red clay, and the chaotic interval below seems to image the turbidites encountered in the cores below 366 mbsf.

Preliminary results show that major turbidite deposition from the Northwest African margin and Canary Islands began at about 15 Ma, with an increase in the volume of eroded sediment at about 3Ma. The Cr uiser/ Hyeres/Great Meteor seamount chain appears to have been volcanically active from at least 47 to 15 Ma.

Site 951

Site 951 is located in the northeastern part of the Madeira Abyssal Plain at 32°1.89'N, 24°52.23'W, at a water depth of 5449.4 m in the Charis Fracture Zone Valley. Seismic profiles for the area show the same major units as at Site 950.

In combination with the other two abyssal plain sites, the primary objective of this site was to determine the nature of the turbidite fill, and to distinguish discrete sources for the various compositional groups of sediment flows. Our objective is to correlate individual turbidite units between the three sites and tie them to the downhole-log data and, thereby, to the extensive seismic-profile network on the abyssal plain. This will enable mapping of individual flows or groups of flows, calculations of their volumes, and, in combination with the stratigraphic data, estimates of the amount of sediment contributed from each source since the inception of the plain. A secondary objective at all three sites involves determination of the long-term effects of sediment burial and diagenesis in a sequence of mixed volcanic, organic-rich, and organic-poor sediments.

Hole 951A was cored to 255.6 mbsf, and a total of 13 APC cores (0-118.8 mbsf) and 15 XCB cores (118.8-255.6 mbsf) were retrieved, with average recovery rates of 98.6% and 97.5%, respectively. The hole was prematurely aborted when the XCB barrel became jammed inside the drill pipe. Hole 951B was washed to 255 mbsf, and coring continued with the XCB barrel to 351.6 mbsf, recovering 10 cores with 87.6% average recovery rate.

The sedimentary sequence at Site 951 comprises only one lithologic unit, which is comparable to Unit I at Site 950. Sediment-accumulation rates for the pelagic interbeds average 4.4 m/m.y. from 0 to 2.6 Ma and 2.0 m/m.y. between 2.6 and 6.5 Ma. This change at 2.6 Ma is again caused by a deepening of the CCD at this time

As at Site 950, carbonate, organic carbon, and sulfur data from both pelagic sediments and turbidites display major stratigraphic variation that facilitates the subdivision of the sequence.The upper 250 m at Sites 950 and 951 may be correlated with a high degree of confidence. At both sites, organic-rich turbidites contain up to 2% Corg, but display less carbonate and higher sulfur below 220 mbsf.

Site 952

Site 952 is located in the southeastern part of the Madeira Abyssal Plain at 30°47.45'N, 24°30.57'W, at a water depth of 5431.8 m in the Cruiser Fracture Zone Valley. Once again seismic profiles for the area show the same major units as at Sites 950 and 951: an upper unit (0-450 ms) showing relatively high-amplitude parallel reflectors, and a lower unit that drapes the basement highs. The upper unit can be subdivided into three subunits by relatively strong reflectors at 160 and 245 ms. Reflectors within the lower two subunits are weaker than in the upper subunit.

Hole 952 was cored to 425.9 mbsf, and a total of 15 APC cores (0-142.8 mbsf) and 30 XCB cores (142.8-425.9 mbsf) were retrieved with average recovery rates of 100.6% and 95.9%, respectively. The hole was logged with the quad-combo tool between 76-295 mbsf.

The sedimentary sequence at Site 952 comprises only one lithologic unit, which is comparable to Unit I at Sites 950 and 951, consisting of Pleistocene to middle Miocene (0-ca. 13 Ma), thick, clayey, nannofossil mixed sediment and nannofossil clay turbidites, interbedded with pelagic nannofossil oozes, mixed sediments, and clays. The unit has been subdivided into two subunits (IA and IB), based on the proportion of calcium carbonate in the pelagic interbeds. Below 100 mbsf (Subunit IB), the pelagic interbeds are all clays. The three primary types of turbidites seen at Sites 950 and 951 are again present. Above 243 mbsf, all three turbidite types are well represented but, below this depth, the turbidites become much thinner with less common volcaniclastic and calcareous units. The organic-rich turbidites below about 225 mbsf contain siliceous microfossils (diatoms and sponge spicules), and are sometimes separated by very thin pelagic layers, suggesting frequent input of flows. Several thick-bedded sands occur between 380 and 405.5 mbsf, grading up into thick turbidite muds. These contain a mixed assemblage of volcanic and continental minerals, suggesting an origin from the east. The thick and sandy turbidites between 373.7 and 389 mbsf appear to correlate with the base of seismic unit A.

Sediment-accumulation rates for the pelagic interbeds average 4.3 m/m.y. from 0 to 2.6 Ma and 1.3 m/m.y. from 2.6 to 5.04 Ma. The total sediment sequence has an accumulation rate of 31.1 m/m.y. from 0 to 5.56 Ma and probably a similar rate beyond 5.56 Ma, although, in this interval, the estimate is poorly constrained.

Site 952 is the only one of the Madeira Abyssal Plain sites to yield significant quantities of headspace methane, with over 30,000 ppm being recorded below 400 mbsf, together with significant ethane and increasing C1/C2 ratios. These data provide evidence of diagenetic methanogenesis below the cored interval, probably within a continuation of the thinly bedded, organic-rich turbidites, which occur at the base of Hole 952A. The anomalously high rates (for a deep-water, open-ocean site) of bacterially mediated diagenesis occurring in MAP sediments are a consequence of the high organic-matter content (typically about 2% Corg) of the buried turbidite sequence.

The age of the widespread reflector at the base of the main turbidite sequence, again, approximates 13 Ma and is represented at Site 952 by the series of thick sands and breccia beds. Below this, however, the fracture zone valley appears to be filled with thin, green, organic-rich turbidites. The reflector may, therefore, indicate a change from input of small turbidity flows to larger flows that rapidly filled the deeps in the seafloor and spread to form the broad abyssal plain we see today. Numerous turbidite units can be correlated between all three sites (Figure 3), and, using the seismic network, will be mappable across the whole abyssal plain. This will enable estimates of their volumes and, ultimately, calculations of volumes of sediment added to the plain from each of the main sources through the last 15 m.y.

Site 953

Site 953, the first of four sites to be drilled into a volcanic apron, is located 45 km northeast of Gran Canaria, 100 km west of Fuerteventura, and 100 km east of Tenerife, at a water depth of 3577.8 m (Figure 4).

Drilling at Site 953 penetrated a practically complete Quaternary to lower Miocene 1159-m-thick section, based on calcareous nannofossil and planktonic foraminifer biostratigraphies. These nonvolcanic and volcaniclastic sediments were divided into seven major units and three subunits, corresponding closely to the lithostratigraphic subdivision of the volcanic rocks on Gran Canaria.

Unit I (0-197 mbsf) is Holocene to late Pliocene (0-3 Ma), and consists dominantly of pelagic clayey, nannofossil ooze and graded nannofossil clay-silt, with lesser amounts of foraminifer

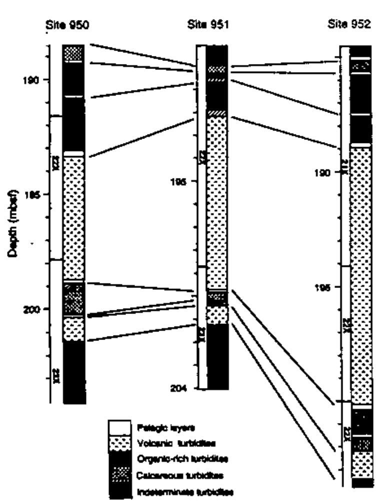

Figure 3. Example of turbidite correlation between all three MAP sites.

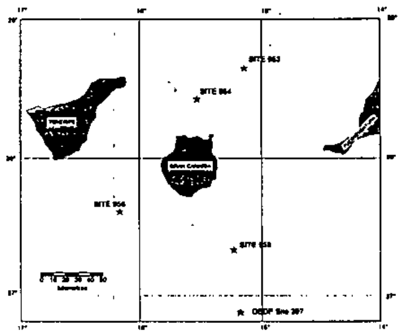

Figure 4. Map showing locations of Sites 953 through 956, in relation to the islands of Gran Canaria, Tenerife, and Fuerteventura.

sands, lithic crystal sands, and silts. The remarkable coarse beach sands, rich in neritic biogenic material, recovered in the upper 100 m are interpreted as turbidites possibly related to glacially controlled changes in sea level. The minor, thin fallout tephra layers at this site were probably erupted in Tenerife and may represent the outer part of larger fallout fans.

Unit II (197-264 mbsf) is late to early Pliocene (3-4.3 Ma), and consists of clayey nannofossil ooze with foraminifers and graded nannofossil clay-silt, foraminifer lithic silts and sands, and basaltic lapillistones. This unit coincides closely in time and mineralogical composition with sands of the Roque Nublo volcanic phase on Gran Canaria. It is also a period of high sedimentation rates.

Unit III (264-398 mbsf) is early Pliocene to late Miocene (4.3-8.3 Ma), and coincides with the major hiatus in volcanic activity on Gran Canaria. The recovered sediments are dominantly gray to brownish-gray, clayey nannofossil ooze; coarse volcaniclastic material is almost absent.

Unit IV (398-850 mbsf) is late to middle Miocene (8.3-14 Ma), and was subdivided into three subunits, based on the number and composition of volcaniclastic mass-flow deposits. Subunit IVA (398-504 mbsf) consists of interbedded, nannofossil mixed sedimentary rock, nannofossil chalk, slump deposits, graded green nannofossil clay-siltstones, foraminifer sandstones, and green lithic-crystal sandstones and siltstones. Subunit IVB (504-754 mbsf), coinciding with the middle and early Fataga phases, shows a marked increase in abundance and thickness of volcaniclastic sandstones and some pumiceous units. Subunit IVC (754-850 m) consists of nannofossil mixed sedimentary rock, crystal vitric siltstones and sandstones, vitric tuffs and lapillistones, and slump deposits. An influx of volcaniclastic material in this unit is correlated to the Mogan phase on Gran Canaria (13.4-14.0 Ma), which was dominated by major ash-flow eruptions. A notable discovery at this site was the marine facies of cooling unit P1, a 14-Ma ignimbrite that forms the most important stratigraphic marker on the island and separates the basaltic shield from the overlying felsic volcanics.

A major goal of Site 953 was to drill through the feather edge of the shield volcano, which is now believed, based on both drilling and more detailed interpretation of the seismic reflectors, to be represented by Unit VI. The sediments representing the subaerial part of the shield are believed to begin with Unit V.

Unit V (850-889 mbsf) is middle Miocene (10.4-ca. 13 Ma), and consists of nannofossil mixed sedimentary rock, nannofossil claystone, claystone, lithic crystal siltstones and sandstones, and basaltic lapillistone. Hundreds of small turbidite units of volcanic sand and silt, many only a few centimeters thick. These apparently record the growth of the subaerial shield prior to flooding and sealing of the shield volcano by the Mogan ash flows.

Unit VI (889-969 mbsf) is middle Miocene. Volcaniclastic rocks are more complex and variable, they consist largely of basaltic sandstone, lapillistone, and breccia, interbedded with minor calcareous claystone and nannofossil mixed sediments and recovery in this interval was extremely low.

Unit VII (969-1158.7 mbsf) is early Miocene, and consists almost entirely of green hyaloclastite tuffs, lapillistones, and breccias, which are interpreted as debris-flow deposits, from 10 to 50 m thick. They consist of moderately to highly vesiculated shards and contain 30%-70% (by volume) of basaltic fragments, including oxidized scoria. Most basalt clasts have quench textures, which probably represent true submarine basalts. Clinopyroxene, commonly in clots, dominates throughout, and some units are almost picritic, with strongly altered and rarely fresh olivine. Fresh olivine occurs in some basalt clasts. A 0.5-cm-thick, nannofossil-bearing chalk occurs in the lowermost core and indicates an age of 15.8 to 17.4 Ma. Unit VII may be older than Gran Canaria because it is separated from Unit VI, both seismically and by the only thick nonvolcanic sediment bed in the lower 300 m of the hole, and because they differ lithologically.

Major and trace element abundances distinguish between mafic and evolved rocks, and between the Miocene and Pliocene rock suites, with the more subtle differences between Mogan peralkaline trachytes and low-silica rhyolites and the early and late Fataga clearly recognizable. Major changes in sediment (phenocryst) mineralogy throughout the hole reflect known, and dated, changes on land.

A reliable magnetostratigraphy was determined to a depth of 800 m (approximately 14 Ma) but not in the thick underlying hyaloclastites.

An accumulation rate, based on an integrated bio- and magnetostratigraphy sedimentation-rate curve, reflects the major contrast between volcanically active phases (shield, Mogan, Fataga, Roque Nublo, and post-Roque Nublo) and nonvolcanic periods, chiefly the time between approximately 8 and 5 Ma. Accumulation rates are as high as 112 m/m.y. during Mogan and early Fataga time, possibly 182 m/m.y. during accumulation of the basal hyaloclastite debris flows, and only 18 m/m.y. during the central part of the volcanic hiatus between 6.2 and 8.2 Ma (360- 390 mbsf).

The pore-water chemistry at Site 953 displays some of the most marked changes documented in the deep ocean and can be correlated with major chemical changes in the source rocks. Calcium and strontium are being liberated to pore waters in the upper few hundred meters; High sulfate concentrations at about 500 mbsf are attributed to the dissolution of sulfur-rich volcanic glasses; High salinities, chlorinities, and alkali metal concentrations between 400 and 850 mbsf, combined with the precipitation of phillipsite, smectites, and analcime indicate intense alteration of pyroclastic material. Alteration processes in the thick basaltic hyaloclastites below 890 mbsf act as a major source of pore-water Ca, Sr, and possibly K, and provide a sink for most other pore-water constituents. Natrolite and other zeolites are being precipitated in vesicles, vugs, and veins in this interval. Variation in pore-water geochemistry is controlled principally by dissolution of volcanic glasses and the precipitation of smectites and zeolites.

Despite poor hole conditions, the quad-combo tool string (sonic velocity, bulk density, resistivity, neutron porosity, and natural gamma ray) was successfully deployed open-hole from 980 to 375 mbsf. The increase of K, U, and Th downhole (~400 mbsf) relates to the increase in supply of volcaniclastics from the Fataga phase, relative to the volcanic hiatus above. The preceding Mogan volcanic phase (~750-840 mbsf) is well distinguished by high U and Th values, relating to highly evolved rhyolitic pumice flows within this unit. Beneath this, the transition to the basaltic Gran Canaria shield phase (~840 mbsf) is delineated by a dramatic decrease in the Th log from the natural gamma-ray tool. The transition downward into the shield phase (~840 mbsf) is characterized by a sharp increase in density, sonic velocity, and resistivity.

Based on the sonic data, a new twt/depth relation has been constructed, and a good correlation was found with the lithostratigraphic and volcanic-event interpretations of the cored section.

All available data indicate that most volcaniclastic material was supplied to Site 953 from Gran Canaria. Notable exceptions include Pleistocene tephra layers, presumably from Tenerife and the lower part of the basal hyaloclastites (Unit VII), which may have been supplied from islands to the east.

In summary, the marine record at Site 953 shows an excellent first-order correlation to the geological history of Gran Canaria. All major volcanic and nonvolcanic phases on this island are reflected in the ages, types, and compositions of sediments, physical properties, and downhole logs. The lithostratigraphy has been controlled almost entirely by the mid-Miocene to recent subaerial and submarine volcanism of the island. The changes from submarine through emergent and subaerial shield and subsequent ash-flow eruptions are especially well reflected in the sediments. Fundamental changes in composition of the dominant magma types, in the type of volcanic activity, and in the duration and volume of volcanic/magmatic phases as they evolved on land, could be inferred from the marine record.

Site 954

Site 954, the second of four sites to be drilled into a volcanic apron, is located 45 km northeast of Gran Canaria, 100 km west of Fuerteventura, and 100 km east of Tenerife at a water depth of 3485 mbsl (Figure 4).

An investigation of Admiralty Chart 1869 revealed the presence of an underwater cable within a half mile of the proposed location. A short seismic survey repositioned the site approximately 1.3 nmi east of the original prospectus site. The pre-site-survey profiles show a sequence, about 0.4 s in thickness, with an almost parallel layering, overlying an acoustic reflector dipping to the north.

Drilling at Site 954 recovered a 446-m-thick succession of middle Miocene to Holocene sediments, consisting dominantly of fine-grained sediments interbedded with coarser bioclastic and volcaniclastic material (Figure 5). The sequence is interrupted by at least four, possibly slump- related, hiatuses; at about 80 mbsf in the lower Pleistocene to upper Pliocene at about 1 to 1.9 Ma; at about 235 mbsf in the lower Pliocene from roughly 4.4 to 5.3 Ma; at 373 mbsf in the upper Miocene from roughly 8.8 to 9.4 Ma; and between the lowermost sediments and the top of the basal basalt breccia unit. A preliminary, but not continuous, magnetostratigraphy consistent with the biostratigraphy was determined to a depth of ca. 400 mbsf (approximately 11 Ma), but not in the underlying basalt breccia.

The sediments were divided into four major units.

Unit I (0-177 mbsf) is Holocene to late Pliocene (0-3 Ma), and consists of dominantly clayey nannofossil ooze with foraminifers, graded clayey nannofossil mixed sediment, and calcareous sand with lithics. Minor interbeds of crystal lithic sand, pumice sand, and vitric ash layers occur throughout the upper part of Unit I. Beach sands, rich in neritic biogenic material and coarse volcanic clasts, recovered in the upper 100 m, are even more coarse grained than similar sands recovered at Site 953. The minor, thin fallout tephra layers at this site, which probably erupted in Tenerife, are also coarser grained than at Site 953, and pumice is more abundant.

Unit II (177-179 mbsf) is a 2-m-thick, upper Pliocene dark greenish-gray lapillistone containing abundant mafic volcanic clasts. The lapillistone unit is overlain by a dolomitized siltstone, and dolomitization occurs sporadically throughout the lower part of the underlying unit. The lapillistone is similar to lapillistones of roughly similar age in Unit II of Site 953, and closely coincides, in time and mineralogical and chemical composition, with the Roque Nublo volcanic phase on Gran Canaria.

Unit III (179-408 mbsf) is early Pliocene to late Miocene (4.3-11 Ma), and consists dominantly of gray to brownish- gray, thick nannofossil chalk and clayey nannofossil mixed sedimentary rock with minor crystal lithic sandstone, and siltstone interbeds. Coarse volcaniclastic

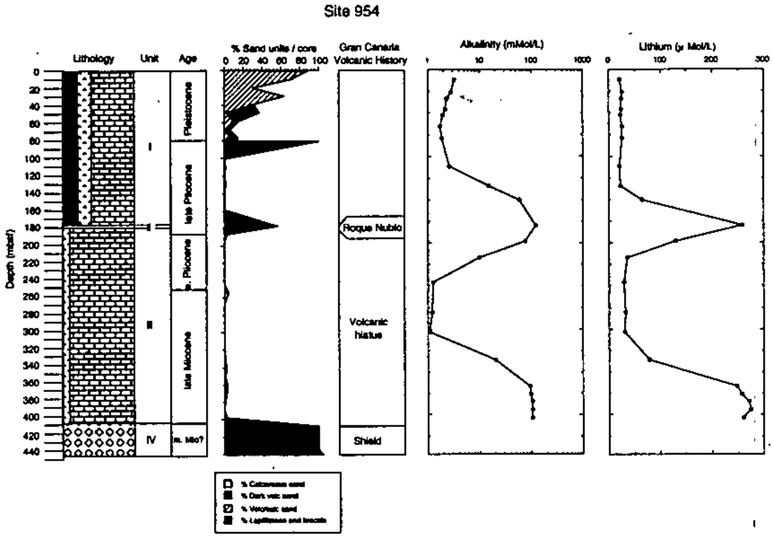

Figure 5. Summary of Site 954, showing lithology, units, age, percentage of sand units/core, relationship to Gran Canaria volcanic history, and pore-water chemistry (alkalinity and lithium).

material is almost absent in this interval, which approximately coincides with the major hiatus in volcanism on Gran Canaria. The base of the sediments in Unit III is assigned to calcareous nannofossil Zone CN6/7, and is dated at approximately 9.4-10.8 Ma.

Unit IV (408-446 mbsf) represents acoustic basement, which consists of a thick breccia with basalt clasts, minor green hyaloclastite tuffs, lapillistones, and a matrix of calcareous sediments and clay. The breccia is dated at approximately 15-14 Ma, based on thin-section examination, which identified Orbulina universa (age no older than Zone M7). Basalt clasts, which represent both subaerial and shallow submarine eruptions, are interpreted to represent the emergent stage of the shield volcano. The mineralogical and chemical composition of basalt clasts and volcaniclastic rocks distinguishes the shield and the younger phases and is consistent with the chemical composition of the subaerial shield basalts from Gran Canaria (Schmincke, 1982).

Volcaniclastic rocks representing most of the Fataga and Mogan phases of dominantly explosive volcanism on Gran Canaria (10-14.0 Ma) are completely missing.

Extreme pore-water compositions occur immediately above and below the lapillistone of Unit II at 180 mbsf, and below 400 mbsf, in the boundary interval between nannofossil chalk of Unit III and the underlying basaltic breccia of Unit IV. Large increases in alkalinity, salinity, sodium, lithium, silica, magnesium and calcium, and low chlorinity are associated with CO_2-charged effervescent pore waters. The proximity of the site to an area of young volcanism is also reflected in the high geothermal gradient (52.7°C/km) and the heat flow (52.7 mW/m^2) at average conductivities of 1.0 W/m.K.

Seismic and lithostratigraphic correlation between Sites 953 and 954 is good to excellent, despite poor recovery from holes at Site 954. Significant volcaniclastic material, supplied to the site from other islands, appears to be restricted to late Pliocene and Pleistocene fallout tephra layers, presumably from Tenerife.

An accumulation rate, based on an integrated bio- and magnetostratigraphy sedimentation-rate curve, which is reasonably constrained above ca. 370 mbsf, reflects the major contrast between volcanically active phases (Roque Nublo and post-Roque Nublo) and nonvolcanic periods, chiefly the time between approximately 8 and 5 Ma. Accumulation rates are as high as 75 m/m.y. from 0 to 80 mbsf, possibly a combination of high pelagic background sedimentation, coupled with periodic influx of thick, coarse-grained "beach sands," and relatively high ash and pumice input from Tenerife. Rates fall to ca. 59 m/m.y. from 80 to 235 mbsf, which includes the phase of Roque Nublo volcanism, and are only 40 m/m.y. during the central part of the volcanic hiatus between 5 and 9 Ma (235-370 mbsf). Accumulation rates were probably much higher during accumulation of the basal breccia flows.

In summary, the geologic evolution of Gran Canaria is well reflected in the sediments cored at Site 954 despite poor recovery between 80 and 270 mbsf and the ca.-4-m.y. hiatus between the lowermost, marly sediments and the basement basalt breccia. The chemical and mineralogical composition of basaltic clasts indicates that the breccia represents the shield and most likely forms a cover above the true submarine seamount stage of the island.

Site 955

Site 955 is located in the southern Canary Channel, 55 km southeast of Gran Canaria, 110 km southwest of Fuerteventura, and 125 km west of the African continental margin on the southeastern volcanic apron of Gran Canaria (Figure 4). The site is separated from Site 953, in the northern basin, by the submarine ridge separating Fuerteventura and Gran Canaria; this ridge has a maximum water depth of ca. 1550 m. The drill site is in a fairly flat area at a water depth of ca. 2860 m.

Site 955 was drilled in the southern volcanic apron of Gran Canaria, which is open to sediment influx from the African continental margin. Because post-Miocene volcanic activity has been absent in the south of the island, the influx of volcaniclastics in the upper part of the sediment column (younger than ca. 10 Ma) is probably small. The major events include large explosive eruptions, which resulted in widespread ash flows and ash falls during Mogan and Fataga volcanism, roughly between 14 and 10 Ma.

The sedimentary succession at Site 955 was drilled with excellent recovery of ca. 85%. the succession is 599 m thick, and consists dominantly of fine-grained, hemipelagic sediments interbedded in the lower part with coarse-grained volcaniclastic and siliciclastic material, ranging in age from latest Quaternary to late early Miocene-early middle Miocene (Figure 6). The sequence at Site 955 differs from that found at Sites 953 and 954 in that the lithostratigraphy has been influenced significantly by the Northwest African continental margin, resulting in the larger amount of (1) siliciclastic material, (2) clay, as reflected also in the generally lower $CaCO_3$ concentrations of the sediment, (3) organic material, and (4) the greater abundance of slumps. Volcaniclastic material, chiefly Miocene fallout and ignimbrites from the Canary Islands, is abundant in the lower part of the sequence.

Unit I (0-207 mbsf) is composed dominantly of clayey nannofossil mixed sediment interbedded with quartz-rich silt and sand, and minor ash layers, and has been strongly affected by slumping. Several discrete packages of, presumably, slumped sediment were identified in the interval from 102 to 240 mbsf.

Units II (207-273 mbsf) and III (273-374 mbsf), the middle part of the sequence, are composed of clayey nannofossil mixed sediment and nannofossil clay with minor interbedded silt and sand. Sediment-accumulation rates (18 m/m.y.) are reasonably well constrained for the interval below 240 mbsf to about 285 mbsf (4.63-6.8 Ma) in Unit II. For Unit III (6.8-8.8 Ma), the accumulation rate is about 42 m/m.y. A hiatus appears to be present at about 370 mbsf, spanning about 0.6 m.y. between 8.8 and 9.4 Ma. A hiatus occurs in the same interval at Site 954, suggesting the possibility of a regional event.

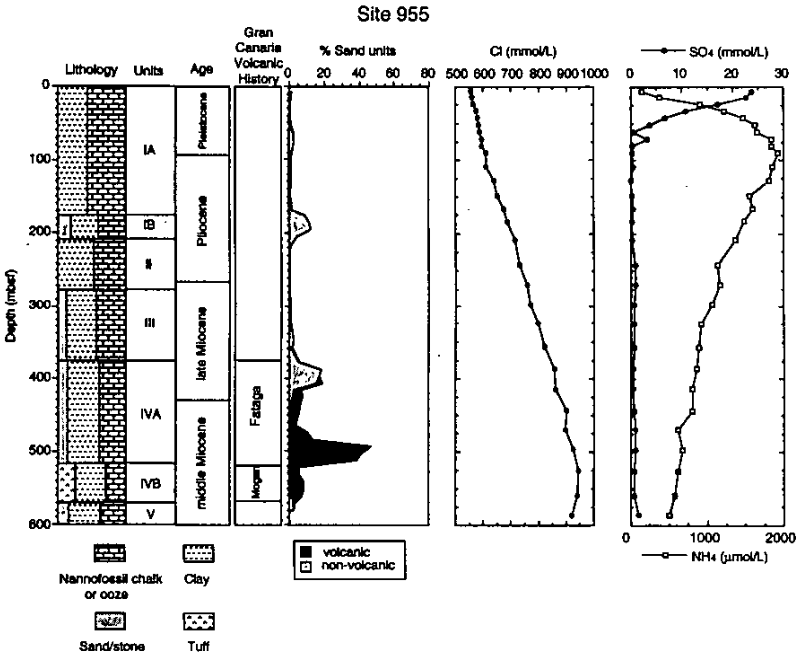

Figure 6. Summary of Site 955, showing lithology, units, age, relationship to Gran Canaria volcanic history, percentage of sand units/core, and pore-water chemistry (Cl, SO_4, NH_4).

There is generally good agreement between the stratigraphic and lithologic interpretations of the cores and the depositional architecture as derived from the seismic profile. Two major sequences can be discerned in the seismic profile, an upper one comprising units A-C, and a lower comprising units D and E. The upper sequence, characterized by basinward-thickening units and pronounced lateral change in seismic facies, corresponds to the Plio-Pleistocene deposits in lithostratigraphic Units I and II. The lower sequence, which thins basinward, corresponds to middle-late Miocene lithologic Units III and IV. The transition from seismic unit D to E seems to mark the middle-late Miocene boundary. The acoustic basement, i.e., the base of unit E at 515 mbsf, corresponds to the top of the lower volcanic sands (lithologic Subunit IVB), tentatively correlated to the Mogan Formation on the island.

Four ADARA temperature measurements, taken between 27 and 113 mbsf, gave a geothermal gradient of 39.99°C/km. Thermal conductivity downhole had an average value of approximately 1.15 W/m.K, resulting in a heat flow value of 45.99 mW/m2. These values most likely reflect the Canary Islands hot spot.

Unit IV, the bottom part of the sequence, has numerous interbedded volcaniclastic deposits that can be correlated with Miocene Fataga and Mogan group volcanism on Gran Canaria. Several compositionally distinct and dated individual ignimbrites studied on land have been recognized in the volcaniclastic-rich lower part of the hole (374-567 mbsf), (Schmincke 1993).

Unit V (567-599 mbsf) marks a return to hemipelagic sedimentation with thin, interbedded siliciclastic sediments and minor basaltic clasts that were probably derived from subaerial erosion of the shield of Gran Canaria.

Two hiatuses interrupt the sequence: one from the lower Pleistocene to upper Pliocene between 102.81 and 103.1 mbsf (representing at least 1.6 to 2.37 Ma), and one in the upper Miocene between 364.0 and 373.6 mbsf (representing about 8.8 to 9.4 Ma). Hiatuses of similar age occurred at Site 954 on the north flank of Gran Canaria.

A complete suite of three logging strings was successfully run at Hole 955A. The quad combo, geochemical, and FMS logs recorded data from the base of hole (599 mbsf) to the end of pipe (72 mbsf). The quality of the recorded logs appears to be good, enabling detailed characterization of this Miocene to Holocene sequence of pelagic, turbidite, and volcaniclastic material. The geochemical logs are diagnostic indicators for the amount and affinity of volcaniclastic material. An increase in the Th log (~500 mbsf) delineates the more geochemically evolved volcaniclastics correlated to the Gran Canaria Mogan stage of volcanism. The downward transition into the shield phase of volcanism (~570 mbsf) is marked by a significant decrease in Th, indicating the more mafic nature of the sediments. Geochemical logs indicate significant concentrations of carbonate above 217 mbsf, which may delineate thick, contiguous slump blocks from the African margin to the east. The FMS shows current bedding in sand units and delineate ash layers as thin as 1 cm.

Together with velocity data from the MST, a complete velocity function from seafloor to 575 mbsf was obtained from the sonic logs, allowing a precise transformation of two-way traveltime to depths.

Site 956

Site 956 is located in the southern Canary Channel, 60 km southwest of Gran Canaria, 65 km southeast of southern Tenerife, and ca. 200 km west of the African continental margin (Figure 4). Unlike the two northern sites, this location is not shielded from sediment influx from the African continental margin. Site 956 is the second of two sites drilled in the southern volcanic apron of Gran Canaria.

The sedimentary succession drilled at Site 956 is 704 m thick and consists dominantly of fine- grained, hemipelagic sediments with interbeds, in the uppermost and lower part, of coarse-grained volcaniclastic and, in the middle part, of siliciclastic material (Figure 7). Ages range from latest Quaternary to middle Miocene. The supply of volcaniclastic material, by sediment gravity flows and fallout from both Gran Canaria and Tenerife, has played a fundamental role in determining the lithostratigraphy of Site 956. The sedimentary succession has therefore been subdivided into five lithostratigraphic units based chiefly on the abundance and composition of volcaniclastic deposits, which correspond broadly in time and composition to the magmatic phases of Gran Canaria and Pleistocene Tenerife.

Unit I (0-158 mbsf) consists mostly of nannofossil mixed sediment with foraminifers, and thick, interbedded coarse debris flows, typically rich in pumice, which were most likely derived from Tenerife, and may be related to sea-level changes caused by Pleistocene glacial-interglacial cycles.

Unit II (158-195 mbsf) had poor recovery, but the angular clasts are petrographically identical to Miocene shield basalts and to trachyphonolitic ignimbrites from Gran Canaria. Much of the unit may represent slump debris from the collapsed flank of Gran Canaria.

Unit III (195-370 mbsf) is 175 m thick, early Pliocene to late Miocene in age, and consists dominantly of nannofossil mixed sediment and clayey nannofossil ooze. The unit is distinguished from Unit II by the lack of coarse-grained material, with only minor interbeds of quartzose and calcareous sand deposits. Slumping is pervasive.

Unit IV (370-564 mbsf) has numerous, interbedded, volcaniclastic deposits, which can be correlated with Miocene Fataga and Mogan group volcanism on Gran Canaria. The compositionally distinct ignimbrite, P1 (14 Ma), previously recognized at 845 mbsf at Site

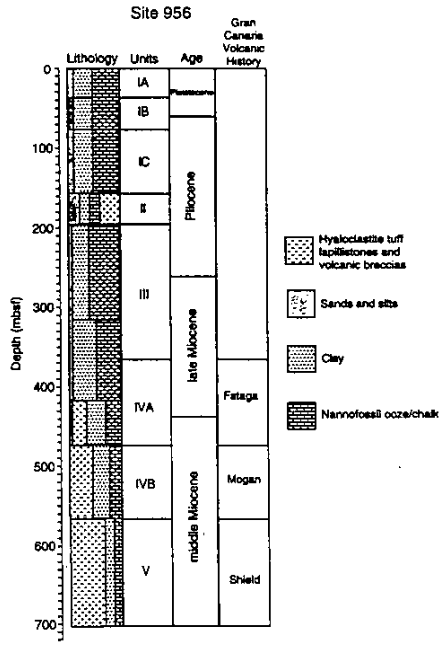

Figure 7. Summary of Site 956, showing lithology, units, age, and relationship to Gran Canaria volcanic history.

953, ca. 170 km to the north of Site 956, and at 560 mbsf at Site 955, 70 km to the east, also occurs at Site 956 at 564 mbsf. Some of the vitric material was reworked and deposited by turbidity currents, whereas at least some may have been associated with the entrance of pyroclastic flows into the sea, with subsequent transformation to water-rich sediment gravity flows.

Unit V (564-704 mbsf), 140 m thick and middle Miocene in age, consists of moderately sorted and graded, massive basaltic breccia and hyaloclastite tuff units, interpreted as debris flows. The breccias contain abundant subrounded to rounded clasts of nonvesicular basalt and red, oxidized, scoriaceous fragments, indicating derivation from subaerial volcanism. Smaller amounts of altered, vesicular hyaloclastite grains also occur, suggesting that hydroclastic eruptions were taking place at this time. The products of both submarine and subaerial volcanism were mixed prior to deposition. A huge debris flow, at least 85 m thick, is present in the basal part of the hole.

Sediment-accumulation rates are difficult to calculate because the upper 370 m within Units I, II, and III contain abundant, chaotically disturbed sediments.

A complete suite of three logging strings was successfully run at Site 956. The quad-combo, geochemical, and FMS logs recorded data from the base of hole (650 mbsf) to the end of pipe (300 mbsf). The transition from the shield to the volcaniclastic sediments, which are correlative to the Mogan Formation, is characterized by sharp increases in density, sonic velocity, and resistivity, as well as an abrupt increase in K, Th, and U. Similarly, the abrupt decrease of K, U, and Th and, to a lesser degree, resistivity, reflects the pronounced decrease in supply of volcaniclastics in the volcanic hiatus above. Even the geochemically similar Mogan and Fataga formations can be distinguished from each other by the patterns of the natural gamma-ray log.

There is generally good agreement between the stratigraphic and lithologic interpretations of the cores and the depositional architecture, as derived from the seismic profile. Two major sequences can be discerned in the seismic profile: an upper one comprising seismic units A-C, and a lower comprising seismic units D and E. The upper sequence, characterized by basinward-thickening units and pronounced lateral change in seismic facies, corresponds to the Plio-Pleistocene deposits in lithostratigraphic Units I and II. The lower sequence, which thins basinward, corresponds to middle-late Miocene lithologic Units III and IV. The transition from seismic unit D to E seems to mark the middle-late Miocene boundary. The acoustic basement, i.e., the base of seismic unit E at 515 mbsf, corresponds to the top of the lower volcanic sands, tentatively correlated to the Mogan Formation on the island.

Four ADARA temperature measurements, taken between 44.1 and 101.1 mbsf, gave a geothermal gradient of 33.51°C/km. Thermal conductivity, downhole, had an average value of approximately 1.11 W/m.K, resulting in a heat-flow value of 37.20 mW/m^2. These values reflect the Canary Islands hot spot.

In summary, the basaltic shield stage of Gran Canaria was penetrated by 140 m and found to consist basically of three debris flows. These do not represent the true submarine stage below the volatile fragmentation depth, but must have formed while the island was already emerged. Seismic data, acquired during the approach to the site, imply that volcaniclastic sediments related to the shield stage extend to much greater depth.

CONCLUSIONS

Leg 157 of the Ocean Drilling Program had two distinct goals: to study the evolution of an oceanic island from sediments in the volcanic apron and to study the history of sediment mass wasting in a deep-sea basin by drilling abyssal-plain turbidites.

Madeira Abyssal Plain

The early infilling of the abyssal plain took place in the deeper parts of the fracture zone valleys (Sites 951 and 952) by relatively small flows derived from the Northwest African margin. The widespread flooding of turbidites, and hence increased erosion within the Canary Basin, began between 11.3 and 15 Ma with a series of large turbidites with thick sandy bases, again from the Northwest African margin. The input of volcaniclastic turbidites from the Canaries or Madeira increased dramatically at 6.5 Ma and has remained high since this time.

Turbidite deposition continued from the inception of the abyssal plain to the present day with major flows involving tens to hundreds of cubic kilometers of sediment occurring every few tens of thousands of years. The pelagic interbeds between turbidites record dramatic changes in the position of the CCD through the last 3 m.y., related to Northern Hemisphere glaciations and associated changes in ocean circulation.

Gran Canaria Volcanic Apron

All major volcanic and nonvolcanic phases of Gran Canaria have been recognized in the ages and compositions of sediments, physical properties, and geophysical logs in the sites drilled.

The highest rate of volcaniclastic deposition corresponds to the mid-Miocene basaltic shield stage of Gran Canaria. Initial phases included deposition of thick, graded hyaloclastite tuffs and debris flows, some containing large clasts of subaerial basalts (the thickest single depositional unit exceeding 80 m), which are possibly associated with large slump events. These are overlain by 40 m of breccias and lapillistones, which record the transition from shallow submarine to subaerial conditions. Establishment of the subaerial shield is reflected in numerous thin fine-grained turbidites (40 m thick at Site 953).

At three sites, up to 170 km apart, we recognized the marine facies of cooling unit P1, a 14.1-Ma ignimbrite that forms an important stratigraphic marker on Gran Canaria, separating the basaltic shield from the felsic volcanics.

An important volcanic hiatus on Gran Canaria between 4.5 and 9.5 Ma corresponds to a period of very low volcaniclastic input to surrounding basins. Erosion of the island, apart from episodic flank collapses, does not appear to contribute large volumes of coarse material to the apron during this hiatus. A significant flux of coarse volcaniclastic sediment to the deep sea occurs only during, and immediately after, periods of active volcanism.

Unusually high alkalinity in the absence of significant organic-matter diagenesis, combined with high magnesium and lithium contents, was observed at Site 954. These CO_2-charged, effervescent pore waters are presumably due to the proximity of Holocene volcanism in northern Gran Canaria, which is also reflected in the highest geothermal gradient (52.7°C/km) measured at any of the sites.

In summary, the evolution of the volcanic apron of Gran Canaria and its detailed correlation with the land record can serve as a model that will improve assessment of the significance of volcaniclastic facies in ancient rock successions, their relationship to the tempo of volcanic activity, and the past volcanic, petrologic, and plate-tectonic environments of sedimentary basins adjacent to volcanic source regions. Drilling, in combination with the high-resolution seismic data and the land record, will allow more realistic calculations of magma-production rates and thus mantle dynamics in hot- spot regions. The great thickness of hyaloclastites and debris flows at the base of the two deepest holes supports the conclusion, based on dating the shield basalts, that the eruptive rate was very high.

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Science Operator Prospectus Leg 160

Mediterranean Sea Leg I

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ABSTRACT

Leg 160 represents the first in a two-leg program to investigate the tectonic and paleoceanographic history of the Mediterranean Sea. Its first focus is upon accretionary and collisional processes associated with the convergent boundary between the African and Eurasian plates. Its second focus is upon the origin and paleoceanographic significance of sapropels, organic-rich layers intercalated in the Plio-Quaternary sediments of the Mediterranean Basin.

The African/Eurasia plate boundary in the Eastern Mediterranean region reflects tectonic settings ranging from effectively steady-state subduction to incipient collision and more advanced collision in different areas. The Eastern Mediterranean is thus an ideal area to investigate the transition from subduction to collision, processes that may be recorded on land in orogenic belts, but which are presently poorly understood. Tectonic-oriented drilling on Leg 160 (Figure 1) will focus on relatively shallow objectives (mainly <500 m). The first objective is to study the collision of the Eratosthenes Seamount with the Cyprus margin in the easternmost Mediterranean, by drilling a North-South transect of four sites, ESM1A-4A (Figure 2). The second objective is to study the origin of mud volcanism, now recognized as creating the widespread "cobblestone topography" over large areas of the Mediterranean Ridge, by drilling at both crestal and flank locations (Figure 3). The third objective is to study subduction and accretion in an area where subduction is still taking place, by drilling sites both on the abyssal plain and on the inner deformation front of the accretionary wedge. The information obtained by drilling will be combined with other data (e.g. land studies) to synthesize the Neogene-Recent subduction/accretion history of the Eastern Mediterranean.

Sapropels are sedimentary expressions of rhythmic changes in the physical circulation system and in biogeochemical cycling of the Mediterranean Sea during the Neogene. They are thin (<0.5 m) organic-rich (up to 15% organic carbon [OC]) layers intercalated in hemipelagic, organic-lean muds and oozes. The timing of sapropel deposition appears to be unrelated to glacial-interglacial cycles, but instead is closely linked to precession-induced fluctuations of monsoonal circulation. One hypothesis for the origin of sapropels postulates that the deeper water column was anoxic during their formation, enhancing preservation of organic carbon at the seafloor. A second hypothesis favors increased primary productivity at the sea surface and increased rates of carbon flux to the seafloor as the reason for sapropel formation. Both hypotheses require a set of testable boundary conditions in the physical, chemical, and biological environment. Drilling a transect of sites across the entire Mediterranean Sea, Legs 160 and 161 will establish both the nature of the environmental change, and the temporal and spatial patterns of environmental conditions leading to sapropel deposition during the Plio-Quaternary.

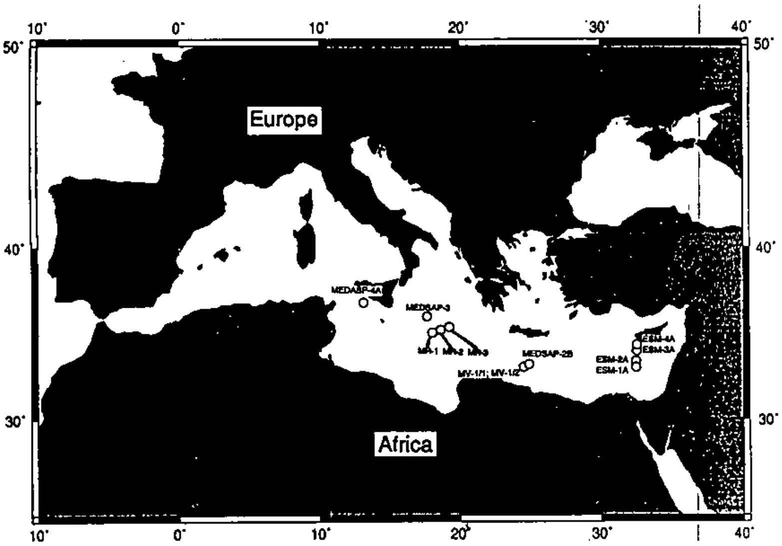

Figure 1. Locations of the proposed drill sites in the Eastern Mediterranean.

SCIENTIFIC OBJECTIVES AND METHODOLOGY

The objectives and methology may be summarized as follows:
1) To estimate deformation processes in relation to incipient continental collision (Eratosthenes transect).
2) To investigate mud diapirism at the Mediterranean accretionary complex, including the influence of salt in sediment deformation and interstitial fluids (Napoli mud diapir).
3) To study accretionary processes at the Mediterranean Ridge related to the incorporation of sediment from an incoming abyssal plain in an area of nearly orthogonal plate convergence (Ionian transect).
4) To investigate the history of sapropel formation in relation to global and regional variations in atmospheric circulation and water-mass variability in the Mediterranean since the Pliocene.
5) To establish variations in environmental conditions at each site as recorded in geochemical, paleontological, and isotopic proxy indicators for water-column stratification, paleo-redox conditions and paleo-productivity levels.
6) To examine the spatial gradients in environmental conditions for coeval sapropels along an East-West transect of drill sites.

DRILLING PLAN/SCIENCE STRATEGY

Drilling in the Napoli mud volcano area is designed to allow sampling of fluids from the crestal area of the Napoli Dome and to investigate its anatomy and construction history by drilling on the flanks.

To determine the influence of the various factors on sapropel formation, we must obtain multi-proxy records along an east-west transect across the entire Mediterranean. The transect permits synoptic mapping of hydrographic and climatic conditions throughout the Mediterranean. It is important not only to investigate the sites of sapropel formation in the eastern basin but also sedimentary records from sites in the western basin where no sapropels formed. Only basinwide analysis of paleoenvironmental conditions will distinguish the driving force behind sapropel formation at different times, and how the Mediterranean's physical circulation and chemical cycling preconditioned the eastern basin toward sapropel formation: The paleoceanography of the entire Mediterranean must be understood if we are to unravel the origin of sapropel formation in its eastern basin.

To achieve these scientific goals, the drill sites for paleoenvironmental reconstructions of Neogene sedimentation have been selected to fulfill three essential requirements:

1) Stratigraphic continuity. Sedimentary sections at targeted sites have to be complete, undisturbed, hemipelagic and pelagic, and shielded from the occasionally drastic effects of submarine karstification, mud volcanism and tectonics of the Mediterranean.

2) High stratigraphic resolution. Sedimentation rates must be high enough to allow for a detailed documentation of the transition into and out of the various sapropels as well as possible internal variability within individual sapropels. High-resolution records are also important for accurate cross-correlation of the multi-proxy records along the drilling transect.

3) Optimum areal coverage. The drill sites must cover the entire Mediterranean Basin to permit evaluation of paleoceanographic, paleochemical, and paleontological zonality and teleconnections throughout the basin. Key locations are close to the Nile Cone (but far enough away from it to avoid its turbidites) as a freshwater source, the Strait of Sicily as the seaway determining water-mass exchange between the eastern and western basins, an Alboran Sea site as the watchdog for Atlantic-Mediterranean water exchange, and central western and eastern basin sites to document pelagic environments between these hydrographic end members.

In order to ensure highest quality information on the depositional environment during sapropel formation, sampling density in the sapropel layers, as well as in the "normal" sediments immediately below and above the sapropels, must be on scales of centimeters to millimeters. Such high sampling resolution is essential for determining the factors that have led to the formation of the sapropels and that have helped in maintaining an environment favorable for the formation of sapropels. At typical rates of sedimentation around 2 cm/k.y., our goal is to distinguish processes operating on time scales of <1000 to 10,000 years. Multiple APC coring (at least quad-

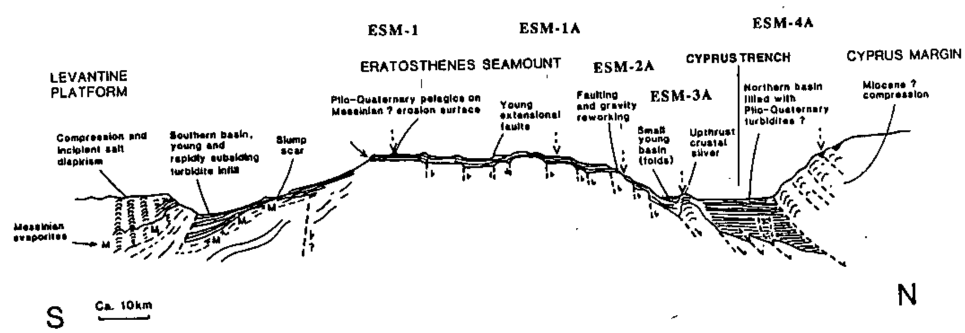

Figure 2. Tectonic setting of the Eratosthenes Seamount as based on the TREDMAR 1993 cruise. The approximate locations of the proposed drill sites are added.

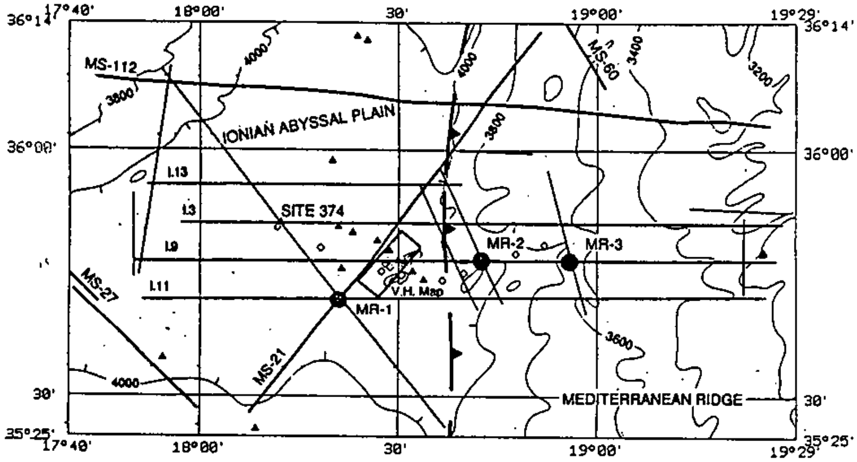

Figure 3. Available site-survey data and proposed drill sites (solid circles) at the Ionian Deformation Front. Triangles = heat flow stations; diamonds = cores; open circles = DSDP Sites.

ruple) will provide sufficient material to allow detailed sampling at the sites specifically designed for the study of sapropels (Medsap 1, 2, 3, and 4). To ensure meeting scientific objectives sampling strategy at these sites may require modification of routine sampling constraints based on the limitations in sediment, but will ensure that crucial parameters can be successfully measured. Economic usage of the limited sediment in sapropel intervals will be possible through on-board construction of composite depth sections from multiple penetration of each sedimentary section.

At sites not specifically designated as sapropel targets, we expect to recover sapropels as well. Here, normal sampling constraints as to the extent and density of shipboard sampling will apply. A site survey is necessary for all sites in the program, because many of the targets are situated in areas of diverse seafloor morphology and highly variable sub-bottom structures. For sites with express sapropel-related objectives, we aim to drill four APC/XCB holes to recover complete sections (a composite section will be constructed while drilling proceeds) and to recover enough material for high-resolution sampling. Should our schedule permit, we hope to log some of the sites (priorities: Medsap 2B, MR-1, MR-2, MR-3) with standard tool combinations and the formation microscanner tool.

SITE SUMMARIES

Site: ESM-1A/MEDSAP-1D
Objectives: To provide a complete record of Plio-Quaternary (or even older) Eastern Mediterranean sapropels; tephra layers could chart the volcanic history of the region; the wind-blown clastic component will shed light on Plio- Quaternary climatic variation; to determine the subsidence history related to the collapse of the Seamount; the nature of the prominent reflector at the base of the inferred Plio-Quaternary succession; a paleomagnetic determinination whether the Seamount has undergone collision-related tectonic rotation; determination of the relation of Messinian features to the Messinian salinity crisis and the bathymetric position of Eratosthenes; and the nature and age of the crust below the inferred unconformity surface.

Site: ESM-2A
Objectives: To penetrate the Eratosthenes basement in an area of minimal sediment cover for comparison this with basement drilled at ESM 1A (or ESM 1) and ESM 3A; to carry out strain and paleomagnetic analysis of the units below the Plio- Quaternary.

Site: ESM-3A
Objectives: To examine the hypothesis that a sliver of Eratosthenes is in the process of being detached and accreted by drilling through the inferred décollement plane; to analyze kinematically the strain related to detachment and accretion of any Eratosthenes crustal sliver; if possible to collect and analyze fluids within the décollement zone; to determine the crustal nature of the inferred accreted crustal sliver; to infer the timing and processes of uplift of the footwall above the décollement; to provide successions of deep-sea sediments (including mud turbidites) for comparison with the condensed succession on the crest of the Seamount.

Site: ESM-4A
Objectives: To sample the sedimentary succession of the Cyprus slope to the north of the sediment-filled trough, and to compare the history of vertical motion with that of the Eratosthenes sites; also to allow detailed comparison with the onshore geology of southern Cyprus.

Site: MR-1
Objectives: First of three shallow holes as part of a transect across the deformation front of the Mediterranean Ridge. It is intended to sample the sediment that is being incorporated into the Mediterranean accretionary wedge.

Site: MR-2
Objectives: To shed light on the age and structure of uplifted sediment directly behind the deformation front; to calculate the rates of uplift; to determine from the composition of interstitial fluids if any evaporites have been involved in the décollement at depth and have found their way upward as fluids to high levels along the décollement to the tip of the deformation front prior to or during uplift.

Site: MR-3
Objectives: To shed light on the age and structure of uplifted sediment directly behind the deformation front; to calculate the rates of uplift; to determine from the composition of interstitial fluids etc. as at MR-2.

Site: MEDSAP-2B
Objectives: To retrieve a complete Quaternary succession on a structural high extending back at least through the Quaternary and hopefully through at least part of the Pliocene. This site represents the central tie-point of the paleoenvironmental transect.

Site: MEDSAP-3
Objectives: This site is at the Calabrian Ridge on the Pisano Plateau between Beato Angelico Trough and Raffaello Basin and is a crucial site for establishing land-sea correlations (exposures in Calabria). Deep coring has recovered at least 15 sapropel intervals and 3 magnetic reversals in the topmost 32 m.

Site: MEDSAP-4A
Objectives: To be used as the watchdog for water-mass exchange between the eastern and western Mediterranean basins. The site is also crucial for land-sea correlation (early Pliocene exposures of Capo Rosello on Sicily) and establishment of current regimes across the Strait of Sicily during sapropel deposition.

Site: MV-1/1, MV-1/2
Objectives: Site MV-1 will be located on the Eastern flank of the Napoli Mud Volcano (Olimpi mud diapir field). Drilling 200 m of sediment section will permit:

1) Sample extensively and date mud sills propagating radially away from the central mud breccia conduit.
2) Obtain a detailed section of the physical properties of the mud breccia.
3) Obtain information on the chemical com
position of the interstitial fluids of the mud breccia in order to evaluate depth of origin, migration paths, and diagenetic alterations.

Site MV-1 is conceived as a multiple-hole site (MV-1/1, MV-1/2), composed of a transect of three holes spaced 50-100 m across the flank. This strategy will permit sampling, including possible "mud sills" that could be produced by the interfingering of host hemipelagic sediments and the diapiric mud.

Mediterranean Sea Leg II

Science Operator Prospectus Leg 161

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ABSTRACT

Leg 161 represents the second in a two-leg program to investigate the tectonic history of the Mediterranean Sea and the origin of sapropels, laminated organic-rich layers deposited in the Eastern Mediterranean Basin. Leg 161 will focus upon the tectonic evolution of the Alboran Sea, a typical "Mediterranean backarc basin," and the paleoceanography of the Western Mediterranean. There are five primary sites for drilling during this leg Alb 2/3/4 and MedSap 5/6 (Figure 1).

The cause of the extension in basins such as the Alboran Sea Basin, and the rapid evolution of a collisional zone into superimposed regions of extension and adjacent contraction, has not yet been adequately explained, and the Alboran basin presents an ideal situation to investigate competing hypotheses. The Neogene extensional basin beneath the Alboran Sea developed behind an arc-shaped mountain belt and is located on the site of a late Cretaceous/Paleogene orogen generated from collisional stacking. The region straddles the boundary between the European and African plates which converged during the Neogene; the basin thus formed in an overall environment of plate convergence. During the Miocene, the migration of the arcuate mountain front may have been nearly coeval with extension in the inner part of the arc that resulted in crustal attenuation and basinal spreading on the Alboran Domain. The basin formed from early Miocene onward, whereas, outside the arc, the thrusting processes continued.

Three proposed sites (Alb-2, Alb-3A, and Alb-4A) have been chosen to determine the origin and tectonic evolution of the basin (Figure 2). Petro-structural and petrological studies, of the predicted-metamorphic basement rocks on a structural high in the Western Alboran Basin (site Alb-2) will help to determine the history of convergent tectonism, and to which particular crustal domain, or units within those domains, the basement belongs. Combining drill results regarding the timing of later tilting and uplift of the basement high in the Western Alboran Basin (site Alb-2), and the syn-rift and post-rift subsidence in the Eastern Alboran Basin (site Alb-4A), with seismic and commercial well data will allow us to determine the magnitude of the extension and the relative proportions of syn-rift to post- rift subsidence in the basin. The nature of the postulated late Miocene to Holocene contractional reorganization that produced folding, strike-slip faulting, block rotation, and pull-apart-type structures in the basin will be tested by drilling in the Eastern and Southern Alboran Sea (sites Alb-3A and Alb-4A).

The transect of Leg 160 and Leg 161 sites across the entire Mediterranean will be drilled to determine the history of water- mass circulation and the influence of monsoon-driven atmospheric forcing on Mediterranean climate. This drilling program is needed to establish a database that will allow synoptical mapping of hydrographic and climatic conditions throughout the Mediterranean. This will concentrate on sampling the westernmost occurrence of sapropels and areas in the western part of the basin, where no sapropels formed. The primary paleoceanographic goal of Leg 161 is to document the history of water-mass circulation and hydrographic variability in the Western Mediterranean as a function of climate change and atmospheric forcing back to Pliocene/Miocene times. High-resolution geochemical and sedimentological profiles are needed at the different drill sites to determine hydrographic and geochemical gradients between the Eastern and Western Mediterranean, from which potential flow patterns and geochemical balances between the eastern and western basins will be inferred. This will eventually enable us to decipher the Mediterranean-wide hydrographic changes, which must have occurred during times of sapropel formation in the east.

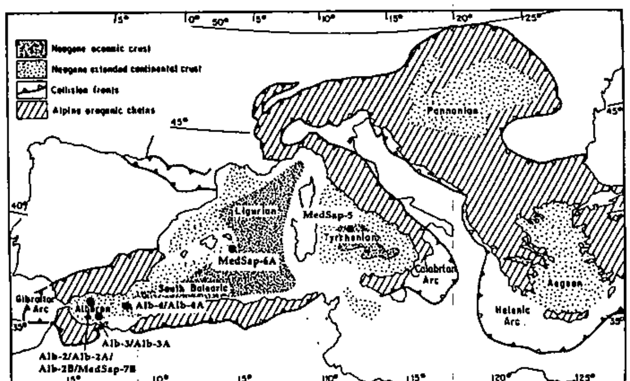

Figure 1. Tectonic map of the Mediterranean basins and mountain belts. Leg 161 proposed sites are shown.

SCIENTIFIC OBJECTIVES AND METHODOLOGY

Summary of Objectives

1. To better understand the dynamics, kinematics, and deformation of the continental lithosphere, particularly in regard to (a) the development of extensional basins on collisional orogens, (b) the dynamics of the collapse of collisional ridges resulting in extensional basins surrounded by arc-shaped orogenic belts, and (c) collisional processes.

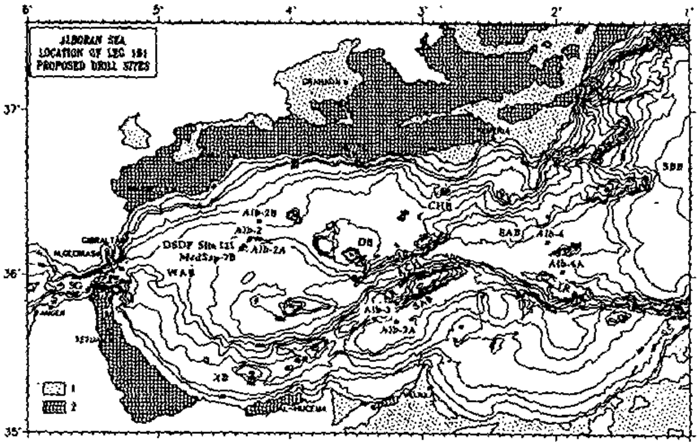

Figure 2. Bathymetric map of the Alboran Sea showing Lege 161 sites. Contours in meters. ACH = Alboran Channel, AR = Alboran Ridge, CHB = Chella Bank, DB = Djibuti Bank, EAB = Eastern Alboran Basin.

2. To investigate the nature of the crust, to develop a lithospheric model for the observed rifting system, and to establish (a) models for Miocene rifting, particularly to constrain the nature of the basement and the geometry of rifting, (b) the magnitude and timing of extensional faulting, (c) the nature of syn-rift vs. post-rift subsidence and the pattern of total tectonic subsidence, and (d) the timing and role of volcanism during extension.

3. To investigate post-rift deformation, in particular (a) late Miocene to Holocene contractive reorganization, (b) the transition to recent strike-slip tectonics, (c) the role of volcanism, and (d) recent basin collapse.

4. To determine the sedimentary sequence and document the amplification of the global isotopic signal, to determine the late Miocene desiccation of the Mediterranean basins, and to calibrate the sea-level signal.

5. To determine the paleoceanographic evolution of the Western Mediterranean from the Pliocene to Holocene. This will provide the database to determine inter-basin hydrographic and biogeochemical gradients between the Western and Eastern Mediterranean.

High-resolution sampling of complete sequences (triple APC coring) will be necessary to address objectives 4 and 5 at all sites. Where possible, we will triple APC core to obtain complete sequences for high-resolution sampling of laminated intervals and take whole rounds for organic analyses. However, these samples may be taken from sites with only one hole.

PROPOSED DRILL SITES AND DRILLING PLAN/ STRATEGY

Site: MedSap-5

MedSap-5 reoccupies ODP Leg 107, Site 652, in the Tyrrhenian Sea on the lower Sardinian margin. It is located on a small tilted block between the Central Fault and de Marchi Seamount overlain with pre-rift, syn-rift, and post-rift sedimentary units. Site 652 penetrated 684 m of Messinian through Pleistocene sediments and recovered 8 sapropels The sedimentary units will consist of calcareous muds and marly nannofossil oozes with scattered mudstone intervals and volcanic ash layers. This is the westernmost location where sapropels have been recovered. Discontinuous recovery and rotary (RCB) drilling at Site 652 requires that we reoccupy this site to use APC/XCB technology to obtain continuous and undisturbed cores for the sapropel program and other paleoceanographic studies. At this site, the upper 200 m of sediments will be cored to provide a complete Pliocene-Pleistocene section. Triple APC holes will be cored to refusal, from where the rest of the sequence will be cored with double XCB tools down to 200 m. The standard three logging suites will be carried out, including formation microscanner (FMS), geochemical tool string, and quad combo. We also propose to run magnetic susceptibility logs, should the tool be available.

Site: MedSap-6A

MedSap-6A is on the Menorca Rise at 2369 m water depth. This site was chosen to monitor "mean hydrographies" of the Western Mediterranean. Different water masses originating from the Alboran and Balearen seas blend in this region before flowing into the Eastern Mediterranean. SCS profiles at this site reach the M Reflector (also called Y Reflector), representing the top of Miocene sediments. Triple APC holes will be cored to refusal, from where the rest of the sequence will be cored with double XCB tools down to 350 m. The standard three logging suites will be run, including FMS, geochemical tool string, and quad combo. We also propose to run magnetic susceptibility logs, should the tool be available.

Site: Alb-2

Alb-2 will address the paleoceanographic objectives of the sapropel program as well as Alboran Basin tectonic objectives. It is located in the Western Alboran Basin, on a structural basement high, which corresponds to the same high that was drilled at DSDP Site 121 (Figure 3). The high is believed to be a middle Miocene horst of the continental basement of the basin and has an irregular west-facing, fault-controlled escarpment that is roughly parallel to the axis of the main early to middle Miocene graben in the Western Alboran Sea. The drilling plan at proposed site Alb-2 is to penetrate through the sediment column for sapropel and paleoceanographic objectives and to sample the uppermost 200 m of metamorphic basement for tectonic objectives. The sediment sequence will be recovered by triple APC coring to refusal, from where the rest of the sequence will be double XCB cored down to the top of the basement at 640 mbsf. One XCB hole will be logged using the standard three logging suites (FMS, geochemical tool string, and quad combo). We also pro-

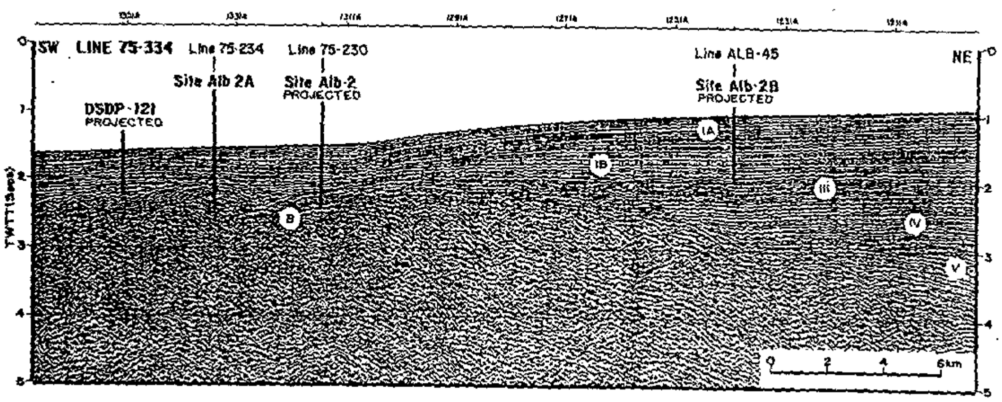

Figure 3. Proposed sites Alb-2, Alb-2A and Alb-2B and DSDP site 121 on MCS. Numbers represent seismostratigraphic units, B = basement.

pose to run magnetic susceptibility logs and use the borehole televiewer (BHTV), should these tools be available. Should the sediment and/or basement objective not be met at proposed site Alb-2, alternate site Alb-2A will be drilled.

Metamorphic complexes, affected by Miocene extension, are thought to underlie the Alboran Sea, and their nature is well known. Petrostructural and petrological studies (metamorphic fabrics, PTT path, and radiometric ages) of metamorphic basement samples will establish their affinity to a particular crustal domain, or units within those domains. Prevailing hypotheses suggest that the basement of the Alboran Basin is formed by the Alboran Domain, a polyphase thrust stack that includes three nappe complexes. Sampling the basement will determine if these basement rocks belong to the hanging wall of the detachment systems cropping out on land or to the exhumed footwall. Ties to on-land structural data will help to discriminate between models for lithospheric rifting.

At sites Alb-2 or Alb-2A, we will not penetrate the lower Miocene sedimentary units they have already been penetrated in commercial wells along the Spanish and Moroccan margins. The sedimentary sequence to be drilled corresponds to about 640 m of Pliocene-Pleistocene sediments upon the Messinian M unconformity. An interval of conglomerate or breccias is expected to be encountered at the sediment/basement boundary.

Site: Alb-4A
Alb-4A is located in the Eastern Alboran Basin (Figure. 2). They are situated on small graben structures to the north of the Yusuf Ridge and Basin in the East Alboran Sea, and to the east of a northeast-southwest- trending strike-slip fault system. The drilling plan is to single APC/XCB core to refusal, then to log this hole using the standard three logging suites plus magnetic susceptibility tools (if available). Then we will RCB core to penetrate and sample the sedimentary sequence to total depth and log this interval.

The Eastern Alboran Basin does not seem to have the same structural pattern as the Western Alboran Basin. This region is underlain by northwest-southeast- or east-west-trending basement ridges and basins, with thinner and probably younger sedimentary fill and a relative lack of extensional structures.

The tectonic objective at site Alb-4A, is to sample the "syn- rift "and "post-rift " sediments to understand the subsidence history of the Eastern Alboran Basin as compared to that of the Western Alboran Basin. Comparing the subsidence history from both regions will have strong implications on constraining the tectonic model and structural evolution for the whole Alboran Sea Basin. Additionally, it is important to calibrate the sediment-fill stratigraphy and seismic units in this region where there has been no prior drilling.

These sites were selected because they show a lower sequence of tilted, hummocky reflectors with several internal unconformities, and may represent the earliest sediments that infilled the graben and therefore be "syn-rift" sediments. The tilted sequence is overlain by "passive" Pliocene-Quaternary sediments. Our main objective is to penetrate and sample the unconformity, which lies at about 650 mbsf and separates syn- and post-rift sequences, and continue to total depth to sample "syn-rift" sediments to obtain data about the age and nature of the internal unconformities and on the relative proportions of syn-rift to post-rift subsidence and total subsidence.

Site: Alb-3A
Alb-3A is located in the Southern Alboran Basin and are situated on the southern flank of the Alboran Ridge. Existing MCS and SCS reflection profile data indicate a zone of deformation during, and following, deposition of the sediments. The deformation is expressed as a series of folds near the base of the ridge. On the southern ridge flank, there is evidence that the deformed zone (5 km wide) extends laterally for up to 50 km. Both deformation and tilting appear to be relatively recent.

The drilling plan is to single APC/XCB core to refusal, then to log using the standard three logging suites plus magnetic susceptibility tools and the BHTV (if available). After that, we will RCB core to penetrate and sample the sedimentary sequence to total depth.

Alb-3A is planned to penetrate the main intra-Pliocene unconformity at this site, lying at about 600 mbsf (0.65 sec twt). The objectives are to calibrate the recent stratigraphy of the southern part of the Alboran Basin, and to time the later tilting and uplift of the Alboran Ridge and the associated folds and strike-slip faulting. Comparison between recent folding and strike-slip faulting on land (elevated onshore parts) and the offshore deformation, which occurred contemporaneously with the Pliocene to Holocene subsidence, will allow us to constrain the later stage of contractional reorganization of the basin.

ODP Proposal News

This year we received 22 new and revised full proposals at the JOIDES Office for the January 1st deadline and 12 Letters of Intent (see page 29 for details).

The way to get your ideas into JOIDES/ODP system is by submitting either a Letter of Intent or a full drilling proposal. A Letter of Intent is a three to four page outline of your idea(s) for scientific ocean drilling. It may be submitted as an alternative to a full proposal and will be forwarded to the panels for comment. Based on panel response, the preparation of a formal proposal may be recommended.

A full drilling proposal must include an outline of thematic objectives and how drilling strategies will be integrated with other investigations in the proposed area, information on site survey data, and strategies for drilling, sampling, and downhole measurements. The scientific objectives of drilling proposals should be linked to COSOD, ODP Long Range Plan (LRP), or thematic panel White Paper themes (these documents are available from the JOIDES Office).

Ten hard copies of the entire proposal must be sent to the JOIDES Office. The JOIDES Office would also appreciate receiving a copy of the proposal via electronic mail or on floppy disk. Proposals received by the JOIDES Office are forwarded to the four thematic panels for review.

Remember: Proposals must be updated every three years to remain on the active list (see pages 29-31).

JOIDES PROPOSAL REVIEW DEADLINES

While drilling proposals can be submitted at any time of year to the JOIDES Office, Thematic Panels review proposals twice a year, in Spring and Fall, following the JANUARY 1 and JULY 1 deadlines for submission. The JOIDES Office returns comments, recommendations, and data package requirements to proponents in April and October. Proposals submitted directly to thematic panels are not reviewed.

PROPOSAL PREPARATION AND FORMAT GUIDELINES

TARGET LENGTH: The main body of text of an ODP drilling proposal should be about 25 pages in length.

An ODP drilling proposal must contain an ABSTRACT (400 words or less).

All relevant FIGURES should be in the main body of the proposal or placed after the references. Proponents may submit additional foldouts, large maps, and full seismic sections with a master copy of a proposal to be retained on file in the JOIDES Office. Proponents should not expect these to be reduced by the JOIDES Office or Panel Chairs, and therefore they may not be distributed with proposals to the thematic panels for review (the panels conduct science reviews, not technical evaluations). Foldouts, large maps, and full seismic sections should be sent to the Site Survey Data Bank at LDEO as part of the Site Survey Data Package at such time as proponents are instructed by the JOIDES Office.

COLOUR FIGURES should be avoided as they often jam copy machines. They look nice but are not essential unless conveying the most complex information.

Do not attach REPRINTS to proposals. Proponents may submit these with the proposal to be kept on file in the JOIDES Office, but they will not be sent out with proposals to the panels for review.

All pages should be NUMBERED sequentially....just in case an unstapled proposal is acidentally dropped, which, of course, would lead to great wailing and gnashing of teeth!

Use <u>only</u> staples for BINDING, please. Proposals just get ripped apart to facilitate copying.

MARGINS should be at least one inch all the way around regardless of paper size.

Completed ODP Site Summary Forms containing information on DRILLING SITES that are tied to the stated scientific objectives and justified by appropriate site survey data are required. Blank site summary forms are available from the JOIDES Office on disk or hard copy or can be downloaded from the anonymous ftp server (see page 61).

DRILLING SITE DESIGNATIONS

A uniform system of designating proposed sites has been adopted by the JOIDES Office as directed by PCOM in December 1994. In accordance with this format each point on the seafloor considered for drilling will be known by one and only one name, and that name will never to be used for any other point on the seafloor. The new convention is:

AAAAAA- nnX

where

- AAAAAA is up to 6 alphanumeric characters indicating the area of the proposed drill site.
- nn is two numerals indicating the number of the site within that area
- X is one letter indicating variants (alternates or revisions) of that site.

The site designator should not attempt to encode information about the priority of the site (i.e. no "alt." designators). Because site priorities often change as the proposal passes through the advisory system, a site name that encodes priority may became obsolete or misleading by the time the site is drilled. The first time a site is proposed, X=A. If alternative sites are proposed in close geographic proximity and sharing scientific objectives, they will have X=A, X=B, X=C, etc.

What if a drill site is moved?

As a proposal moves through the advisory system, it occasionally becomes necessary or advisable to shift the position of a site in response to new data, new hypotheses, safety concerns, international clearance issues, or man-made seafloor hazards. Every time a site is moved, a new value of X will be used to identify the relocated site.

Why a new format?

The common practice of retaining the site designator when the position of a proposed site (as defined by latitude and longitude or shotpoint along a seismic line) is moved, causes great confusion for the JOIDES Office, SSP, PPSP, the Data Bank, and proposal reviewers. The new format is intended to alleviate such confusion and represents a uniform system of designating proposed sites, in which each point on the seafloor that has ever been considered for drilling is known by one and only one name.

SITE SURVEY DATA PACKAGE

Proponents of proposals that have been highly ranked will be asked by the JOIDES Office to submit a site survey data package to the ODP Data Bank at LDEO by a July or November deadline for review by the Site Survey Panel (SSP). The SSP review is based on identification of drilling target categories and site survey techniques that can provide the optimal data set for each target. The guidelines for submission of site survey data are available from the JOIDES Office at any time.

For more information, please contact:

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Fax: +44 1222 874943
Internet: joides@cardiff.ac.uk

**P.S. Don't Forget....
The next Proposal Deadline
is 1st July 1995**

Acknowledgement: We thank Dr. Sherman Bloomer, Chair of LITHP, for his input to the development of Guidelines for Proposal Preparation and Format.

New and Revised Proposals in the ODP /JOIDES review system received for the January 1995 deadline

Proposal #	Abbreviated Title	Contact
300-Rev-Add	Return to ODP Hole 735B.	Natland, J.H.
355-Rev5	Peruvian Margin/Gas Hydrates.	Von Huene, R.
367-Rev2	Cenozoic carbonates of the Great Australian Bight.	Feary, D.A.
404-Rev	Late Neogene paleoceanography.	Keigwin, L.D.
431-Add2	Western Pacific Seismic Network.	Suyehiro, K.
441-Add1	Southwest Pacific Gateway.	Carter, L
442-Rev	Rift Initiation in Back-Arc Basin - N. Mariana Trough.	Stern, R.
445-Rev	Deformation & fluid flow in the Nankai Trough Prism.	Moore, G.F.
448-Add	Origins, age & post-emplacement history of the Ontong Java Plateau.	Kroenke, L.W.
451-Rev2	Ocean drilling in the Tonga Forearc.	Tappin, D.R.
452-Rev	Antarctic Glacial History and Sea-level Change.	Barker, P.F.
457-Rev	Drilling on the Kerguelen Plateau and Broken Ridge.	Frey, F.A.
461-Add	OCT-Iberia.	Whitmarsh, R.B.
462——	Blake Plateau and Blake Nose.	Norris, R.D.
463——	Testing the Plume-Impact Hypothesis at Shatsky Rise.	Sager, W.W.
464——	Southern Ocean Paleoceanography (Transo).	Gersonde, R.
465——	SE Pacific Paleoceanography.	Mix, A.C.
466——	GAB/Continental Margin.	Willcox, J.B.
467——	Sea-level changes in the Western Mediterranean.	Droz, L.
468——	Carbonate platforms at the Romanche Fracture Zone.	Bonatti, E.
469——	Argo Abyssal Plain.	Symonds, P.A.
470——	Red Sea/Atlantis II Deep.	Sichler, B.

New LOIs in the ODP/JOIDES system, January 1995

LOI#	Abbreviated Title	Contact
40	ODP drilling in the Banda Sea, Indonesia.	E. Silver
41	A stress/strain observatory system: Costa Rica.	K.M. Brown
42	High resolution paleocene drilling, Scott Plateau.	B. Opdyke
43	Drilling of the Rodriguez Triple Junction.	K. Tamaki
44	Japan trench downhole observatory.	T. Kanazawa
45	LWD-APC transects of the E. North American Continental Margin.	C. Pirmez
46	Antarctic Glacial History & Sea Level Change.	Y. Kristoffersen
47	Scientific drilling in the Red Sea.	J. Ludden
48	Physical property variations across convergent margins.	C. Moore
49	Drilling the prograding sequences of the Wilkes Land.	A. Cooper
50	Antarctic glacial history and sea level change.	P.J. Barrett
51	A strategy to drill deep near DSDP/ODP Site 504.	P. Pezard
52	Antarctica Prydz Bay.	P.E. O'Brien

ALL ACTIVE PROPOSALS IN THE JOIDES/ODP SYSTEM as of February 1995

Proposal #	Date Rec'd	Abbreviated Title	Contact
079——	28/08/84	Tethyan stratigraphy and oceanic crust, Indian Ocean.	Coffin, M.F.
079-Rev	31/07/92	Tethys and the birth of the Indian Ocean.	Coffin, M.F.
079-Rev2	28/06/93	Tethys and the birth of the Indian Ocean.	Coffin, M.F.
086——	12/10/84	Red Sea.	Bonatti, E.
086-Rev	25/09/85	Red Sea.	Bonatti, E.
086-Rev2	27/07/92	Drilling in the Red Sea.	Bonatti, E.
253——	28/08/86	Black shales in the ancestral Pacific, Shatsky Rise.	Sliter, W.V.
253-Add	28/12/92	Deposition of organic carbon-rich strata, ancestral Pacific.	Sliter, W.V.
253-Rev	19/06/91	Deposition of organic carbon-rich strata, ancestral Pacific.	Sliter, W.V.
300——	18/02/88	Deep crustal drilling, Site 735B, SW Indian Ridge.	Dick, H.J.B.
300-Rev	01/08/92	Return to Site 735: very slow-spreading lower ocean crust.	Dick, H.J.B.
300-Rev-Add	03/01/95	Return to ODP Hole 735B.	Natland, J.H.
332——		Ghost of 204——.	
332-Rev		Florida Escarpment Drilling transect (Ghost of 204-Rev).	
332-Rev2	25/07/89	Drilling transect, Florida Escarpment.	Paull, C.K.
332-Rev3	04/02/92	Florida Escarpment drilling transect.	Paull, C.K.

333——	27/07/89	Evolution of pull-apart basin, Cayman Trough.	Mann, P.
333-Add	04/02/92	Update to Cayman Trough transect.	Mann, P.
333-Add2	01/07/94	Evolution of pull-apart basin, Cayman Trough.	Mercier de Lépinay, B.
333-Rev	31/12/92	Evolution of pull-apart basin, Cayman Trough.	Mercier de Lepinay, B.
333-Rev2	01/07/93	Evolution of pull-apart basin, Cayman Trough.	Mercier de Lépinay, B.
334——	28/07/89	Detachment faults and crust-mantle boundary, Galicia margin.	Boillot, G.
334-Rev	27/12/90	S reflector and ultramafic basement, Galicia margin.	Boillot, G.
334-Rev2	27/07/92	Galicia margin S reflector.	Boillot, G.
334-Rev3	30/06/93	Galicia margin S′ reflector.	Boillot, G.
337——	31/07/89	Tests of Exxon sea-level curve, New Zealand.	Carter, R.M.
337-Add	21/12/92	Tests of Exxon sea-level curve, New Zealand.	Carter, R.M.
338——	03/08/89	Sea-level fluctuation, Marion carbonate plateau, NE Australia.	Pigram, C.J.
338-Add	13/07/92	Sea-level fluctuation, Marion carbonate plateau, NE Australia.	Pigram, C.J.
339——	07/08/89	Paleoceanographic transects, Benguela Current.	Meyers, P.A.
340——	07/08/89	Tectonic, climatic, oceanographic change, N Australian margin.	Symonds, P.
340-Rev	31/12/92	Tectonic, climatic, oceanographic change, N Australian margin.	Symonds, P.
347——	15/08/89	L. Cenozoic paleoceanography, south-equatorial Atlantic.	Wefer, G.
347-Add	30/07/92	L. Cenozoic paleoceanography, south-equatorial Atlantic.	Wefer, G.
347-Rev	24/12/92	Late Cenozoic Paleoceanography, South-equatorial Atlantic.	Wefer, G.
348-Add3	05/11/94	TIE (Upper Paleogene to neogene US Mid-Atlantic Transect).	Austin, J.
354——	18/09/89	Late Cenozoic upwelling system, Angola/Namibia.	Wefer, G.
354-Add	30/07/92	Benguela Current and Angola/Namibia upwelling.	Wefer, G.
354-Add2	01/07/93	Benguela Current and Angola/Namibia upwelling.	Wefer, G.
354-Add3	01/07/94	Benguela Current and Angola/Namibia upwelling.	Wefer, G.
354-Rev	30/01/92	Benguela Current and Angola/Namibia upwelling.	Wefer, G.
354-Rev2	30/12/93	Benguela Current and Angola/Namibia upwelling.	Wefer, G.
354-Add4	03/01/95	Benguela Current.	Wefer, G.
355——	18/09/89	Formation of a gas hydrate.	Von Huene, R.
355-Rev	04/10/89	Formation of a gas hydrate.	Von Huene, R.
355-Rev2	30/08/90	Formation of a gas hydrate.	Von Huene, R.
355-Rev3	27/12/93	Formation of a gas hydrate.	Von Huene, R.
355-Rev4	30/06/94	Formation of a gas hydrate: Peruvian Margin.	Von Huene, R.
355-Rev5	04/01/95	Peruvian Margin/Gas Hydrates.	Von Huene, R.
367——	07/02/90	Cool water carbonate margin, southern Australia.	James, N.P.
367-Add	05/10/92	Cool water carbonate margin, southern Australia.	James, N.P.
367-Rev	23/12/93	Great Australian Bight cool-water carbonates.	James, N.P.
367-Rev2	04/01/95	Cenozoic carbs. of the Gt. Australian Bight.	Feary, D.A.
372——	26/02/90	Cenozoic circulation and chem. gradients, N Atlantic.	Zahn, R.
372-Add	15/12/92	Cenozoic circulation and chem. gradients, N Atlantic.	Zahn, R.
372-Add2	01/07/93	Cenozoic circulation and chem. gradients, N Atlantic.	Zahn, R.
376——	07/03/90	Layer 2/3 (and crust/mantle) boundary, Vema FZ.	Auzende, J.M.
376-Rev	16/09/91	Layer 2/3 boundary and vertical tectonics, Vema F.Z.	Auzende, J.M.
376-Rev2	27/07/92	Vema F.Z.: Upper mantle, gabbro/dyke, limestone cap.	Bonatti, E.
376-Rev3	27/01/94	Vema F.Z.: Upper mantle, gabbro/dyke, limestone cap.	Bonatti, E.
404——	11/09/91	Neogene paleo. from W North Atlantic sediment drifts.	Keigwin, L.D.
404-Rev	04/01/95	Late Neogene paleoceanography.	Keigwin, L.D.
406——	16/09/91	North Atlantic climatic variability.	Oppo, D.
406-Add	24/05/93	North Atlantic climatic variability.	Oppo, D.
411-Rev	22/6/94	Caribbean Basalt Province	Donnelly, T.W.
413——	03/02/92	Magmatic/tectonic evolution of oceanic crust: Reykjanes Ridge.	Murton, B.J.
416——	11/03/92	Glacial history, Svalbard margin.	Solheim, A.
416-Rev	27/01/94	Glacial history, Svalbard margin.	Solheim, A.
417——	30/06/92	Gas hydrate in vicinity of gas plume, Okhotsk Sea.	Soloviev, V.
418——	27/07/92	Miocene biomagnetostrat. reference section, Menorca Rise.	Cita-Sironi, M.B.
419——	28/07/92	Convergence at Azores-Gibraltar plate boundary.	Zitellini, N.
419-Rev	31/12/92	Convergence at Azores-Gibraltar plate boundary.	Zitellini, N.
420——	30/07/92	The evolution of oceanic crust.	Purdy, G.M.
421——	30/07/92	Alkali-acidic rocks of the Volcano Trench.	Vasiliev, B.I.
421-Rev	28/07/93	Alkali-acidic rocks of the Volcano Trench.	Vasiliev, B.I.
424——	31/07/92	To "CORK" Hole 395A.	Becker, K.
424-Rev	31/12/92	To "CORK" Hole 395A.	Becker, K.
425——	31/07/92	MAR at 15°37′N: crust generation at magma-poor MOR.	Cannat, M.
425-Rev	01/07/93	Mid-Antlantic Ridge Offset Drilling.	Casey, J.F.
426——	20/08/92	Australia-Antarctic discordance.	Christie, D.

427——	31/12/92	South Florida Margin SeaLevel.	Hine, A.C.
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428——	28/12/92	Tyrrhenian Seafloor and Hydrothermal Sulfide Deposits.	Savelli, C.
429——	31/12/92	Atlantic-Mediterranean Gateway.	Nelson, C.H.
430——	31/12/92	Subantarctic Southeast Atlantic Transect.	Hodell, D.A.
431——	31/12/92	Western Pacific Seismic Network.	Suyehiro, K.
431-Add	01/01/94	Western Pacific Seismic Network.	Suyehiro, K.
431-Add2	05/01/95	Western Pacific Seismic Network.	Suyehiro, K.
432——	28/06/93	Galicia deep hole S-reflector.	Reston, T.J.
433——	30/06/93	East Mediterranean Orogeny.	Hsü, K.J.
435——	01/07/93	Nicaragua/Izu-Marianas Mass Balance.	Plank, T.
435-Add	28/06/94	Mass Balance: Nicaragua Margin.	Plank, T.
435-Rev	01/01/94	Mass Balance: Nicaragua Margin.	Plank, T.
435-Rev2	01/01/94	Mass Balance: Mariana-Izu.	Plank, T.
435-Add2	04/01/95	Mariana-Izu Margin.	Plank, T.
436——	20/12/93	Campeche Bank Stratigraphy.	Fulthorpe, C.S.
437——	23/12/93	Lau-Havre-Taupo rift to drift.	Parson, L.M.
438——	01/01/94	Test of reflecting interfaces in oceanic crust.	Mutter, J.
439——	01/01/94	Marquesa Islands, mass budget of Hot Spots.	McNutt, M.K.
441——	27/12/93	Southwest Pacific Gateway I & II.	Carter, R.M.
441-ADD1	05/01/95	Southwest Pacific Gateway.	Carter, L.
442——	27/12/93	Rift initiation in Back-arc Basins: N. Mariana.	Stern, R.J.
442-Rev	05/01/95	Rift Initiation in Back-Arc Basins/N. Mariana Trough.	Stern, R.
443——	29/12/93	Faults, crustal heterogeneity & hydrology at 504B/896A.	Alt, J.C.
444——	01/01/94	Joban margin sea level.	Soh, W.
445-Rev	05/01/95	Deformation & fluid flow in the Nankai Trough Prism.	Moore, G.F.
446——	01/01/94	Ocean drilling in the Tonga forearc (Ghost of 451-Rev2).	Bloomer, S.H.
447——	01/01/94	Continental extension in W. Woodlark Basin.	Taylor, B.
447-Rev	04/01/95	Extension in the W. Woodlark Basin.	Taylor, B.
448——	01/01/94	History of the Ontong Java Plateau.	Kroenke, L.W.
448-Rev	01/07/94	History of the Ontong Java Plateau through basement.	Kroenke, L.W.
448-Add	04/01/95	Origins, age & post-emplacement history of the Ontong Java Plateau.	Kroenke, L.W.
449——	01/01/94	Evolution of the Mesozoic Weddell Basin.	Wise, S.W.
450——	01/01/94	Taiwan arc-continent collision.	Lundberg, N.
450—Rev	05/01/95	Taiwan arc-continent collision.	Lundberg, N.
451——	01/01/94	Tonga Ridge Island Arc Transect.	Tappin, D.
451-Rev	01/07/94	Tonga forearc.	Tappin, D.
451-Rev2	05/01/95	Ocean drilling in the Tonga Forearc.	Tappin, D.R.
452——	27/12/93	Antarctic glacial history & causes of sea level change.	Barker, P.F.
452-Add	17/02/94	Antarctic glacial history & causes of sea level change.	Barker, P.F.
452-Rev	05/01/95	Antarctic Glacial History & Sea-level Change.	Barker, P.F.
453——	01/01/94	Bransfield Strait, Antarctica.	Fisk, M.
454——	14/01/93	East Australian Current.	Jenkins, C.
455——	27/06/94	High resolution record of sediment fluxes: NW Atlantic.	Occhietti, S.
456——	28/06/94	Tjornes FZSB: Paleoceanography & Sedimentation History.	Fridleifsson, G.O.
457——	01/07/94	Large igneous province in Kerguelen Plateau.	Frey, F.A.
457-Rev	05/01/95	Drilling on the Kerguelen Plateau and Broken Ridge.	Frey, F.A.
458——	01/07/94	Southern Ocean Trasect (Ghost of 454).	Gersonde, R.
459——	01/07/94	Norwegian Sea overflow.	Kuijpers, A.
461——	01/07/94	Basement of OCT W of Iberia (former NARM-Add3).	Whitmarsh, R.B.
NARM-Add3	22/12/93	Basement sampling of OCT west of Iberia.	Reston, T.J.
461-Add	03/01/95	OCT-Iberia.	Whitmarsh, R.B.
462——	04/11/94	Blake Plateau and Blake Nose.	Norris, R.D.
463——	04/01/95	Plume-Impact at Shatsky Rise.	Sager, W.W.
464——	04/01/95	Southern Ocean Paleoceanography (Transo).	Gersonde, R.
465——	04/01/95	SE Pacific Paleoceanography.	Mix, A.C.
466——	04/01/95	GAB/Continental Margin.	Willcox, J.B.
467——	04/01/95	Sea-level changes in the Western Mediterranean.	Droz, L.
468——	05/01/95	Carbonate platforms at the Romanche F. Z.	Bonatti, E.
469——	05/01/95	Argo Abyssal Plain.	Symonds, P.A.
470——	05/01/95	Red Sea/Atlantis II Deep.	Sichler, B.
NARM-Add	30/06/93	Newfoundland Basin.	Austin, J.A., Jr.

Tectonics Panel White Paper

Overview

The thematic focus of the JOIDES Tectonics Panel is on the processes and products of Earth deformation. This includes the mechanisms, kinematics and dynamics of deformation, as well as the architecture of the resulting structures, set in a time framework. Understanding the deformation of the Earth in general is important because it shapes the environment in which we live, determines the location and concentration of earth resources, influences the long-term climate, and triggers short-term natural hazards such as earthquakes and landslides. Much of the additional information we need will require continued and indeed expanded drilling in the oceans. Other techniques cannot by themselves provide the necessary data. Tectonic processes operate on all scales from the molecular to the motion of the vast crustal plates. Today, tectonic processes are active in many parts of the world, and through time have moulded the earth as we know it. Understanding the forces that drive the dynamic earth has been an historic goal of earth scientists. The study of the oceans provides unrivalled opportunities for better understanding of fundamental Earth processes.

Tectonically-focused ocean drilling uses two complementary approaches: (i) characterising the history and styles of deformation recorded in the structures and stratigraphy of former plate boundaries; (ii) determining the controlling parameters and mechanisms of active deformation. Global-scale tectonic processes include rifting, spreading, transform faulting, subduction, collision, mantle convection and bolide impacts. An understanding of tectonic processes involves the determination of geometry, kinematics and dynamics and includes inferences concerning displacement, strain, strain rate, pressure, temperature, composition and stress field. Understanding of fundamental tectonic processes, however, cannot be achieved by deep drilling alone. Mechanisms and their effects transgress the boundary between land and marine domains and call for future close interaction between marine- and land-based earth scientists. In the future, TECP also seeks to participate with other global geoscience programs to establish well characterised natural laboratories, preferably in active systems, in which ODP drilling is one component of a much larger set of observations, rather than an isolated one-dimensional sampling of the subsurface. In addition to providing rock samples, TECP requires drilling to be augmented by advanced borehole studies to determine the conditions of pressure, temperature, stress, strain and fluid compositions. Also required is the emplacement of borehole seismometers to monitor active deformation and determine global Earth structure.

Although much can be done with existing technology, the desire to study, for example, active fault zones, often at >2 km depth will require substantial technology development, ultimately including controlled circulation. Drilling in fractured formations would benefit from a Diamond Coring System. Determination of *in situ* conditions will require high temperature, and perhaps slim-hole, logging tools and sampling devices. Logging while drilling will be essential in some unstable environments. Multi-disciplinary borehole experiments and monitoring will become the norm rather than the exception in TECP-supported studies.

1 INTRODUCTION

It has occasionally been suggested that the drill is not an effective tool for addressing tectonic problems, as targets are often deep (>2 km below seafloor) and geologically complicated (e.g. rifted margins). However, in practice this is not a valid criticism, since achievements and progress have been very substantial overall. Undoubtedly, one of the greatest successes of ODP has been the drilling of accretionary prisms, where study has moved on from essentially the description of anatomy, to *in situ* monitoring of active processes, as at the Nankai, Cascadia and Barbados active margins. The Tectonics Panel has consistently supported an increasingly complex set of drilling experiments in the toes of those accretionary prisms in which the deformation fabrics, fluid compositions, and pore pressures can be determined *in situ*. This will be a continuing theme in the future. Drilling into various rifted margins, notably those of continents, arcs, and plateaux has also so far successfully characterised different types of basement. These include tilted fault blocks (e.g. Iberia margin), dipping reflectors (e.g. SW Greenland margin) and peridotite bodies (e.g. Tyrrhenian Sea). Vertical motion histories have been quantified effectively as indicators of tectonic processes, but drilling into rifted margins has not yet reached the stage where measurement and quantification of the tectonic processes is possible. However, this is planned for the future. In addition, only limited progress has yet been made on the study of strike-slip processes, e.g. oceanic fracture zones and translational continental margins, as few such settings have been drilled. Also, collisional processes remain inadequately documented and thus the links with continental tectonic processes and mountain building remain to be fully documented. There is this a strong case for continued exploratory, as well as carefully focused drilling in the future.

2 FUTURE TECP OBJECTIVES

In future the Tectonics Panel intends to focus on the study of large-scale tectonic processes operating in the following kinematic environments: i) *Extensional*; ii) *Contractional*; iii) *Translational*; and iv) *Vertical*. This approach recognises that fundamental tectonic processes operate globally and transcend the conventional division into plate tectonic settings. For example, extensional processes operate to some extent at rifted margins, but also in arc and transform areas. Focus on such fundamental processes in a range of tectonic environments encourages the collection of appropriate data sets that in turn facilitate the development of comprehensive theory.

The Tectonics Panel also believes that the study and quantification of active or recently active systems in general will in the future prove more rewarding than continued study of ancient dead systems that are commonly deeply buried and thus difficult to reach by drilling. However, the Panel recognises that its mandate remains broad and does not wish to exclude any existing aspects from future study. TECP also notes that in addition to focussing on young, active (or recently active) systems, it will still be essential in future to document important tectonic settings that remain little investigated (e.g. strike-slip and collisional).

In **Section 3** below, we discuss in turn the rationale for drilling, unsolved problems, and future drilling strategy for each of the four large scale kinematic environments listed above. Study of these is achieved mostly by study of the downhole products of deformation. Such study utilises a number of approaches, each involving specific methodology, for example investigation of stress/strain evolution (rheology), or fluid flow related to deformation. These aspects are set out in **Section 4**. Obtaining the necessary information requires the development of specific technology, including the means to: improve core recovery in different settings (e.g. development of a Diamond Coring System); document retrieved core (e.g. colour scanning) and obtain data by remote sensing (e.g. wireline logging). The Tectonics Panel also favors development and installation of at least one multidisciplinary seafloor earth observatory, preferably in an active margin setting. This topic is discussed in **Section 5.**

3 SPECIFIC KINEMATIC ENVIRONMENTS

3.1 Extensional Settings

3.1.1 Rationale

Extension is a pervasive tectonic process that occurs in a wide variety of tectonic settings. Rifted (i.e. passive or Atlantic-type) margins are formed by deformation and modification (rifting) of continental lithosphere, and are amongst the most prominent topographic features on Earth. Continental rifting is commonly the first event in the formation of the Earth's great ocean basins. The ocean floor grows by active tectonic extension along mid-ocean ridge plate boundaries. Propagating rift tips produce extension in the oceanic lithosphere, while extensional backarc basins develop behind many subduction zones. Rift propagation through continental lithosphere is currently proving very interesting. For example, what is the critical break point of the continenal lithosphere (e.g. in the North Atlantic and Red Sea). All of the oceanic lithosphere in the present-day plate mosaic, as well as all the oceanic lithosphere created since the initiation of plate tectonics, and ca. 60% of the world's continental margins, have been created by extensional tectonics.

Patterns of continental break-up are primary indicators of the structure and rheology of the continental lithosphere. Pre-existing continental structures and tectonic fabric, and the lithospheric composition and thermal regime play key roles in determining rift location, style and the amount and rate of extension. The structure and stratigraphy of rifted continental margins provide unique records of the foundering of the continental lithosphere, the embryonic stages of ocean lithosphere formation, the vertical movement (uplift and subsidence) of the margin, and changes of relative sea level, climate and oceanography caused by plate dynamics and global climatic change.

At mid-ocean ridges, interplay of the processes of magmatic construction, manifest as the extrusion of lavas, intrusion of dikes and crystallisation of plutonic rock bodies at depth, and mechanical extension, shown by near-surface faulting and deeper-level ductile flow coupled with shear zones linking the extensional faults, creates the diverse structures of fast and slow spreading ridges. A fundamental control appears to be the "magma budget", that is the volume of magma and the amount of heat delivered to the ridge axis per unit of plate separation. These competing effects create the structural fabric of mid-ocean ridge axes, ridge-axis discontinuities (e.g. small offsets, overlapping spreading centres, transform faults etc.), the tectonic segmentation of mid-ocean ridges, and the origin of structural/tectonic asymmetries across spreading centres. Mid-ocean ridges thus provide a natural laboratory for understanding extensional processes.

Extension is associated, not only with the development of passive margins and mid-ocean ridges, but also with the formation of backarc basins, during the initiation of subduction zones, and within the forearcs of subduction zones in the midst of continental collision zones. Backarc basins are a key extensional setting to investigate rift and ridge propagation and the interplay of mantle flow and plate tectonics. There are considerable similarities in the extensional styles observed in these various tectonic settings. In each of these there is an interplay of processes, such that extension runs the gamut from wide to narrow rift zones, symmetric to asymmetric geometries and mechanical rifting to magmatic spreading. The same scientific questions about strain partitioning, rift segmentation, igneous versus mechanical extension, and the processes that control them link all extensional environments.

3.1.2 Accomplishments to date

ODP drilling already has made significant contributions to our understanding of the variation in extensional style by providing direct information on globally recognised features that were previously only imaged on seismic data. This drilling has helped characterise the nature of specific extensional settings and 'ground-truthed' some of their seismically-imaged features. Drilling has also helped to establish the similarity of extension processes in different drilling settings, for instance, mechanically extended regions at mid-oceanic ridges and the seaward-dipping reflector sequences (SDRS) at volcanic rifted margins.

Mechanical extension of the lithosphere, well-known at continental rifts and passive margin, has now been established as a major process also in oceanic settings. Drilling on Broken Ridge during Leg 121 revealed rapid uplift of a fragment of an oceanic platform, and documented the importance of flexure during extension in oceanic settings. Drilling has also shown the similarity of extension in backarc basins (Legs 107, 127,128, and 135) to that of passive margins prior to initiation of sea floor spreading. The propagation of rifting at these backarc basins has also been established. Slow-spreading environments such as the Mid-Atlantic Ridge can be viewed as extensional plate boundaries, where mechanical extension predominates over magmatism. ODP drilling has established that tectonic denudation by amagmatic extension can expose peridotites at passive margins (Legs 103, and 149), backarc basins (Leg 107) and at mid-ocean ridges (MOR) (Legs 106, 109, and 147). These results support models of extension by simple shear within the uppermost crust. Drilling on the southwest Indian rift (Leg 118) revealed evidence of a complex interplay of intrusion, alteration and deformation beneath a slow-spreading ridge. In addition, drilling off the northwestern margin of Australia (Legs 122, 123) documented a complex multistage history of rifting and drifting at this passive margin. All these results confirm the tectonic complexity of extension at "non-volcanic margins" and slow spreading ridges. For example, Legs 122 and 123 documented a complex multi-stage history of rifting, in which successive pieces were rifted from the Australian continental margin.

The results of ODP Leg 104 suggested that SDRS's, which characterise the outermost regions of up to 40% of continental margins, may represent large piles of volcanic material. Further detailed investigation of seaward-dipping reflector sequences was successfully carried out during Leg 152. The lavas were initially erupted subaerially. The recognition of "Volcanic-rifted margins" (VRM) has revolutionised ideas about continental break-up and the role of magmatism. ODP drilling in island arc axial regions (Legs 125, 126) has established that intra-oceanic subduction initiation, involving both boninitic and tholeiitic volcanism, created a broad extensional terrane, up to 400 km wide and thousands of kilometers long, that formed in ~10 m.y. These features may well be counterparts of the class of "Supra-subduction Zone" ophiolites, including the Cyprus, Oman and Greek ophiolites. Backarc basins also reveal an interplay of arc volcanism, and rift volcanism and extension, as well as episodicity and compositional changes in magmatism.

The individual tectonic settings of extension also shed light on the processes controlling extension. Trenchward migration in the Tyrrhenian Sea (Leg 107) of the locus of spreading suggested the concept of "roll back" as an important tectonic process. Leg 141 drilling off Chile also suggested that extensional collapse of the margin took place in the area of ridge-trench collision.

3.1.3 Remaining unsolved problems

The solution of important rifted margin problems requires an integrated, multidisciplinary approach in which ODP drilling is one part. ODP has a central to play in providing direct information on the nature of rocks and structures in extensional belts, on the tectonic processes which produce them, and consequently on the construction and testing of models describing extension in various settings.

Studies that need to be used in conjunction with drilling include seismic reflection and refraction studies of deep structure, potential field data, dredging and submersible observations to characterise surface structure and rocks. Theoretical modelling of subsidence and thermal history of sedimentary basins on a lithospheric scale also are needed to determine the relationships between heat and mass transfer during crustal extension, and the history of syn- and post-rift vertical movement. Isotope and trace element studies of magmas can be used to determine the degree of mass transfer between enriched and depleted mantle, asthenosphere and older continental and oceanic lithosphere, and crust and mantle.

This work and many of the long-term objectives of the Tectonics Panel can be advanced by linkage with other international programmes. A number of such linkages would be dependent on initiatives by ODP as a whole. The most obvious candidates are:

MARGINS: This is a US initiative for integrated process-oriented study of continental margins. Drilling will be a key component of MARGINS.

Continental drilling (ICDP, i.e. International Consortium of Continental Drilling): Oceanic and continental drilling could effectively be combined in some areas. Continental drilling is inherently cheaper than ocean drilling and a larger array of back-up data is more readily available (e.g. geological mapping and cross-sections). Linked oceanic and continental drilling would help bring together the marine and land-based communities and stimulate new tectonic hypotheses applicable to global tectonic problems.

InterRidge (Ridge, Fridge, Bridge etc): These are international and national programs to understand mid-ocean ridge dynamics. Some collaboration has already begun. Effective scenarios would include, first InterRidge type surveying to determine drill locations, followed by drilling and instrumentation, then possible follow up to drilling in the light of data obtained, all within one integrated project.

Link with hydrocarbon industry: Advent of a riser system will permit drilling of prospective hydrocarbon areas and aid study of deep-water stratigraphy. Some ODP and industry interests will then run in parallel. These include the following: testing hydrocarbon potential of deep-water settings (e.g. passive margins); geochemical (e.g. maturation) and geophysical (e.g. VSP, 3 D seismics) studies, and borehole logging (methods, modelling and interpretation). Partnership with industry could also broaden the funding base.

An understanding of extensional processes and the internal structure of the regions created or deformed by extension requires detailed information concerning the geometry and kinematics of faulting and magmatism. Direct sampling of extensional terranes by drilling, as well as imaging via borehole logging and geophysical studies, are capable of revealing structural details from which the major processes of extension may be inferred. Drilling can help constrain the distribution of volcanics and intrusives and their relationship to extensional structures. Borehole data can determine the vertical (uplift and subsidence) motions of the rift and its surroundings. Moreover, boreholes can provide access to subsurface regions of the lithosphere and play a major role in natural laboratories, if established. These results can help to solve the major tectonic problems of extensional regimes as follows.

Role of detachments in extension.
In extension, low-angle normal faults have been identified in geological and geophysical studies of both ridges and passive margins. One of the major paradoxes of tectonics today is the inferred low shear stresses required for slip on such major crustal fault zones. Studies of rock mechanics and deformation history have thus far failed to explain the evolution and significance of detachment faults. Are these faults active at low-angles, or have they been rotated into their present attitude? The general perception is that asymmetry in extension is the norm. If so, is this a fundamental mode of extension? Is it limited to upper and middle crustal levels? Detachments have been imaged at many passive margins. In several settings, they appear to have brought mantle material to the surface. The Mid-Atlantic Ridge also appears to have numerous low-angle faults, many of which are still active. The potential for studying a wide range of stages of development, both active and inactive systems, and faults in different rift settings makes oceanic studies appealing. Drilling of active systems offers the possibility of documenting the stages of development of hanging wall and footwall structures, fault rock characteristics, *in situ* stress, fluid pressures, and seismicity. It should be noted that the palaeomagnetic technique (using oriented core) has an important application here to determine rotations about horizontal as well as vertical axes.

Tectonic and magmatic segmentation of rifts and ridges.
Recent studies confirm that the structural geometry of the most slow-spreading ridges is similar in many respects to that of continental rifts and rifted margins. Tectonically extending lithosphere is composed of discrete rift segments, each a few tens of kilometers in length, either linked end-to-end, or en echelon. Offsets between segments may be large or subtle (in the order of 1-10 km of offset) and may be marked by a change in fault polarity. At ridges, this segmentation is mimicked by geophysical and geochemical anomalies, such as the prominent "bulls eye" gravity lows along the Mid-Atlantic Ridge. In the Red Sea, continental breakup is discontinuous and was initiated at segment centres. At other margins and backarc basins propagation of the rift-drift transition may proceed stepwise from segment to segment. These observations strongly suggest that the lithosphere-asthenosphere system responds to plate separation in a discontinuous, but systematic way. Segmentation thus appears to be a universal response to extension. What controls the location and spacing of rift segmentation? Pre-existing structure may influence rifts, but ridges are also segmented. Are they the result of thermal anomalies in the mantle, mechanical thinning of the crust or some combination of the two? Morphological stratigraphic and geophysical observations alone cannot uniquely constrain the processes operating along these segments; geological observations superimposed on a geophysical base can help in this regard. ODP remains an important means of testing geological models and hypotheses concerning variations in the distribution of mechanical extension and of magmatic rocks as a function of this segmentation.

Stresses that drive plate boundary deformation.
Stresses expected from lithosphere-asthenosphere and inter-plate dynamics are very small compared to the yield strength of rocks determined in laboratory experiments. Yet extension is widely observed in both continental and oceanic realms. Backarc basins reorganise from a rifting configuration, that is strongly coupled to the adjacent trench, to an independent spreading system. This transition may be a key to determining the magnitude and transmittal of stresses in the plates. It may also help resolve the driving mechanism of backarc spreading, variously thought to be due to diapiric rise behind an arc, mantle corner flow at the downgoing slab, or absolute plate motion of the slab. Mid-ocean ridges are sites where these stresses are small relative to other boundaries. Drilling and borehole studies can provide information on the structure developed over time in sections of oceanic crust. Stress measurements are required to evaluate hypotheses regarding both stresses near plate boundaries, and stresses required to induce internal deformation of plates. In these areas it should be possible to relate directly deformation structures mapped on the sea floor to deviatoric stresses, a link that is required to evaluate laboratory deformation experiments under natural conditions and time scales (see Sections 4 & 5). Finally, many mountain chains show evidence of pervasive crustal extension and subsidence soon after the climax of collisional deformation. This fundamental process of "orogenic collapse" can be investigated by drilling where basins have collapsed below sea level.

Decoupling of strain and the rheologic layering of the lithosphere.
Numerous studies of lithospheric deformation have tried to relate the brittle faulting and volcanism observed at shallow crustal levels to deeper level processes such as ductile flow, magmatic intrusion

and metamorphic processes. Although there is no consensus at present, it is clear that in many environments the upper and lower lithosphere are decoupled. The nearly flat Moho discontinuity across areas of very different extensional strains in the Basin and Range Province of the western U.S.A. is a dramatic symptom of this condition. Detachments are another result. While asymmetry in rifting at upper to middle crustal levels is observed, extension and flow in the lower lithosphere may be more symmetric. How does the rheologic layering of the lithosphere control the deformation style and decoupling of upper and lower lithospheric deformation?

Magma budget, extensional style and the continent-ocean transition.
At both rifts and ridges, there is a dramatic difference in tectonic style between magma-rich and magma-poor regions. Magma budget appears to account for the range of expressions of the ridge relief between high-magma budget regions, such as the Reykjanes Ridge, and highly faulted, low-magma budget areas, such as that near the 15°20'N Fracture Zone. At slow-spreading environments mechanical extension predominates over magmatism, unless interrupted by an episode of magmatic activity. In contrast, fast-spreading ridges tend to have high magma budgets and therefore show only very small amounts of tectonic extension. There is a strong similarity between volcanic margins and fast-spreading ridges on the one hand, and non-volcanic margins and slow-spreading ridges on the other hand. However, trade-offs in extension rate and thermal structure, and their interaction, which controls the extensional style are not yet quantified. The transition from continental rifting to sea-floor spreading is associated with a transition from mostly mechanical extension to magmatism (mechanical extension, depending on the rate of spreading) as the zone of extension narrows. Thus the continent-ocean transition zone can play a unique role in understanding these processes. Studying the extensional parameters of spreading segments with different magma budgets at a constant spreading rate could help evaluate the role of crustal underplating by magmatic processes. Backarc basins, with nearby arc volcanic sources may also prove to be an important variant.

Flexural strength of extending lithosphere.
While the flexural strength of oceanic lithosphere subject to bending loads as islands and trenches is understood, the flexural strength of lithosphere under extension remains controversial. The flexural rigidity of some rift basins has been estimated to be very low to negligible, yet flexural uplift of rift margins is well documented. There is no effective predictive model of the rigidity of lithosphere either during or following extension. The amount and timing of vertical motions provide critical data on the isostatic response during extension. Subsidence has long been recognised as a key parameter related to the amount of extension, synrift subsidence and sedimentation but is still not fully understood. The importance of rift-flank uplift and the resultant patterns of erosion, sedimentation and hydrothermal fluid circulation have only recently been recognised. Contradictory evidence of both low and high flexural rigidities have been documented. We need to determine the rheological controls on flexural rigidity at rifts and passive margins.

3.1.4 Drilling strategy

To solve tectonic problems discussed above through drilling, TECP recommends that several complementary approaches be utilised:

Transect drilling of geophysically well constrained conjugate margins (e.g. NARM) and backarc (e.g. Tonga) basins that exhibit large variations in rifting and break-up processes, to sample diagnostic and tectonically significant sediment packages and basement lithologies. This approach is needed to understand the deformation pattern of the margins, the distribution of strain, and to investigate the detailed nature of igneous material and the transition from rift to spreading processes.

Transect drilling across young or active features. This approach should be used for rifted margins where conjugate pairs are unambiguously separated by only a narrow zone of 'new' ocean floor (e.g. Red Sea, Gulf of Aden, Cayman Trough), where full back-up and seafloor spreading has not yet commenced (e.g. the western Woodlark Basin), and across oceanic ridges at high and low magma budget end-members (Mid-Atlantic Ridge, East Pacific Rise). This drilling will provide important direct information on well constrained recently formed extensional features, that are exposed or only shallowly buried by sediment.

Drilling of specific features imaged on seismic data that are geophysically well constrained within their extensional settings, and which are considered to be globally significant for rifting processes. Detachments faults are a particular example that can be found in multiple settings including passive margins and mid-ocean ridges. Although the preferred method of studying such features is as part of a drilling transect, these transects may not always be the best and most readily drillable locations for such features, especially where one side or conjugate is inaccessible to the drill. Examples of this approach would be the drilling of the S reflector on the Galicia margin, a well-characterised site which is not located on a drilling transect, or at a slow-spreading ridge near a transform. Further drilling of forearc lithosphere (e.g. Mariana and Tonga) would test whether the large obducted ophiolites (e.g. Oman ophiolite) record mid-ocean ridge or supra-subduction zone lithosphere.

Drilling longitudinal transects along extensional belts. This is particularly important to elucidate backarc rift and spreading processes (e.g. N Mariana, Japan Sea, and Lau-Havre-Taupo areas) where spatial variation along-strike of propagating rifts provide information on the temporal development on the basins; it could also be useful in small rifted oceanic basins (e.g. Red Sea). In addition, the longitudinal variation in the tectonic style of rifts and ridges where the extension rate, proximity to hotspot, or other critical parameter changes rapidly along-strike can provide critical information on the interplay of competing processes.

Experiments to study the *in situ* stress state in and around extensional terranes, and specific rift-related features (see Section 4). The stress field is important to determine the plate-driving forces that produce extension, the local variations of stress near active faults and spreading ridges, and especially at low-angle detachment faults. The rotation and level of stress associate with possible detachments is critical to theories of their development. In backarc basins stress fields associated with the transition from rifting to spreading geometry and the role of trench dynamics (e.g. Lau basin) are important to define.

Phase 1 Recommendations 1996 - 1998
There are a number of remaining objectives in the Atlantic, backed by currently highly ranked proposals. These centre on resolving uncertainties about the crustal structure of the continent-ocean transition in both volcanic ('Greenland margin 2') and non-volcanic settings ('Iberia margin 2'). A major goal is to understand ocean ridge constructional processes in three dimensions (e.g. InterRidge initiatives on studying fast versus slow spreading ridges; MOR versus marginal basin oceanic crust) and to test models for the origin of seismic reflectors in the oceanic crust. The availability of targets will, however, depend on the development of a routinely functioning Diamond Coring System during 1996-98. An additional aim is to study young rift basins that document the transition from rift to oceanic crust under shallow sedimentary covers (e.g. Woodlark basin, northern Gulf of California, Gulf of Aden). The Woodlark basin includes extrusive rocks similar to those in some ophiolites (i.e. high Mg andesites) and is of interest to many land geologists. Much of importance remains to be learnt about forearc (e.g. Tonga), arc (e.g. Tonga Ridge; Lau-Havre-Taupo troughs) and backarc (e.g. Bransfield Straits; N. Mariana) extensional settings. Successful proposals will be those that pose most effectively testable hypotheses capable of shedding light on quantification of fundamental tectonic processes

Phase 2 Objectives for drilling during 1998 - 2003
Drilling of transects across conjugate rifted basins is likely

main a high priority. Younger basins have an advantage as noted above, as less drilling is needed to penetrate key reflectors (e.g. Gulf of California, Red Sea, Gulf of Aden, Woodlark Basin). Conjugate and transect drilling of backarc systems (e.g. Lau-Havre-Taupo; Marianas) will be a high priority. Volcanic rifted margins will also remain possible targets (e.g. Southern South America). Completion of conjugate rifted margins (Iberia-Newfoundland) could be a priority. Studies that involve real-time monitoring of processes via observatories will probably gain momentum (e.g. in marginal basin and MOR). Assuming DCS is by then operational, targets will be legion (e.g. Mid-Atlantic Ridge, Hess Deep, marginal basins, Valu-Fa ridge, Romanche/Vema transforms etc.)

Phase 3 A vision beyond 2003:
Deep drilling. A number of critical tectonics problems can only be resolved in the future by very deep drilling (2-4 km) in deep water, whether or not a riser is available. Drilling as deeply as possible into oceanic lithosphere (e.g. deepening of 504B or equivalent) and study of deeper-level structural processes (e.g. detachment faulting) will remain a priority. At margins as well, pure versus simple shear models will probably still need to be resolved. For example, the Iberia margin S reflector could be drilled as an example of a possible simple shear detachment fault zone. Similar reflectors may be identified in other basins, possibly requiring less deep penetration. In general, the continent-ocean boundary will remain an important but poorly documented setting.

Arc splitting and rift-drift transition in backarc basins (e.g. Sea of Japan; Tyrrhenian Sea; Lau Basin) will require similar investigations.

Much information on extension and early spreading can be obtained by drilling structures (e.g. footwall anticlines; detachment faults) and seismic facies changes (e.g. in deep sea fans) that may happen to be hydrocarbon traps and thus need a riser. Riser drilling will open an entirely new suite of targets for tectonic drilling. Targets include the Atlantic margin (e.g. New Jersey), Sea of Japan, Gulf of California and Red Sea. Also, drilling to basement in other settings may be required, where overlying sediments are potentially hydrocarbon rich (e.g. California borderland).

Relative shallow drilling. Longer term tectonic interest in shallow drilling will focus on study of important settings that remain inadequately documented (e.g. sheared passive margins; small ocean basins; unusual plate boundaries; complex microplate areas). Redrilling of some classic areas to obtain better material, assuming improved recovery (e.g. successions with shallow-water limestones, conglomerates, weakly consolidated sands and cherts) may be necessary. Structurally oriented studies of very young oceanic crust using DCS may also become a priority.

3.2 CONTRACTIONAL SETTINGS

3.2.1. Rationale

Aspects of interest to TECP include the mechanics, kinematics, and mechanisms of deformation within accretionary wedges, mass balances between "input" from the subducting plate and "output" in forearc and arc-axis regions, including thermal evolution and fluid flow; and the modification of these processes by collisions with seamounts, arcs and continental fragments.

Past achievements show that processes operating in accretionary prisms are amongst the most tractable to study by drilling. Accretionary prisms constitute a natural experiment, in which porous sediments are deformed and consolidated under differential stress. These are fundamental processes about which we still have much to learn. Fluids profoundly influence the development of accretionary prisms. The partitioning of accreted, underthrust and subducted sediments, the regional temperature regimes, the nature of diagenetic/metamorphic processes, the distribution of hydrocarbons and even the surface biology depend to some degree on large-scale fluid flow, fluid pressures and permeability, and the episodicity of these phenomena in accretionary prisms.

The process of subduction erosion is an enigma in contractional settings. By its very nature subduction erosion does not leave a positive record; this process can only be inferred from missing terranes, or anomalous subsidence in forearcs. Drilling in active margin settings can provide essential data (e.g. subsidence history) for understanding this process, which may well be of global importance.

Collisional processes at contractional margins lead to many of the world's greatest mountain belts (e.g. Himalayas, Karakoram, Alps), yet active collisional settings at modern convergent boundaries remain virtually unstudied by academic drilling. This topic is much larger in scope than the topic of accretion at subduction zones outlined above, and requires study of a number of key locations potentially providing a wide range of types of information. Close integration with land studies will also be essential.

3.2.2 Accomplishments to date

Drilling has already made great advances in understanding and quantifying tectonic processes, particularly in forearc (accretionary) settings. Holes drilled through accretionary complexes and into subducting sediments have permitted initial characterisation of the decollement zone and underthrust sediments, with enormous implications for the interpretation of other accretionary setting, including those on land in orogenic belts. ODP drilling has allowed an assessment of the effects of fluid expulsion on deformation. Porewater chemistry, temperature anomalies and structural observations from drilling indicate that fluids are moving, primarily through zones controlled by fracture permeability (associated with faults), and secondarily by intergranular permeability along stratigraphic horizons. The accretionary wedge and underthrust sediments comprise two distinct fluid reservoirs, separated by a permeability barrier paralleling the decollement zone. Drilling into serpentine diapirs in the Mariana forearc (Leg 125) documented fluid expulsion from subducting or underplated sediments several tens of km deep. ODP drilling along some convergent margins showed that continental lithosphere extends to within tens of km of the trench axis, indicating that massive tectonic erosion has taken place (Legs 112, 141). Extensive drilling in the frontal portions of accretionary prisms now provides excellent constraints both on the structural geometries and plumbing system development during accretion.

ODP drilling has focused on the relationships between deformation and fluid flow, both in oceanic basement and in accretionary complexes. During deformation, porosity is being continuously modified. This "dynamic" porosity is a key to understanding the hydrodynamics of actively deforming regions. Drilling in the Peru, Nankai, Barbados, and Cascadia accretionary prisms (Legs 112, 131, 156) demonstrated the influence upon fluid flow patterns of deformation fabrics in partially consolidated sediments and in fault zones. Geometrical and cross-cutting relations of deformation and dewatering microstructures and cement phases reflect the temporal variations in fluid flow relative to the deformation history. Drilling in the Nankai accretionary prism provided a unique chance to compare the deformation and hydrogeological regimes above and beneath the basal decollement. Techniques and instrumentation developed include Logging-While-Drilling (LWD) and fitting of boreholes with instrumented borehole seals (see Sections 4 & 5).

Collisional processes pose problems for drilling in view of their obvious complexity and variety. Drilling in the south Chile region (Leg 141) was aimed at testing a model for ridge-trench collision that includes rapid uplift and subsidence of the arc and forearc, high levels of regional metamorphism and elevated thermal gradient, arc magmatic hiatus, anomalous forearc magmatism, and localised subsidence and extensional deformation of the forearc in the collision area. The results have revealed regional uplift just north of the collision (pre-collision margin), extensional deformation in the area of ridge collision, and possible anomalous magmatism and hydrothermal activity within the inner slope of the trench. The subducting Chile Ridge may be causing erosion of the accretionary prism as it sweeps down the margin. Drilling in the Vanuatu forearc (Leg 134) demonstrated the accretion of sediments and volcanic rocks from an incoming oceanic high as discrete thrust sheets that are forming a new tectonostratigraphic terrane.

3.2.3 Remaining unsolved problems

Much still remains to be learned about processes in contractional settings. On an intrinsic level, we need to quantify and relate to each other: strain (finite strain, strain rate, deformation mechanism, fabric); stress (orientation, deviatoric stress, pore pressure); physical properties (porosity, permeability, temperature); and mechanical parameters (strength, cohesion, internal friction, compressibility). In the context of the accretionary prism we must determine: (1) how deformation is distributed throughout the prism; (2) how dewatering is distributed, i.e. what are the mechanics and paths of water flow, what geochemical fluxes are involved, and how is water flow related to stress levels; and (3) what factors control the mechanical partitioning of the incoming sediment cover into that section offscraped by thrusting and folding and that section subducted beneath the prism toe?

It still remains to evaluate the rates, magnitude, and episodicity of fluid flow and to link these hydrogeologic processes to observed geologic features. For example, the volume of fluid flow and ambient fluid chemistry and temperature should be related to the distribution of faults, small-scale features, permeable stratigraphic layers, and to the degree of cementation, veining, and mineralogical alterations. Such observations at drillable depths in accretionary prisms are necessary to provide a basis for interpretations of similar phenomena at crustal depths inaccessible by drilling and also provide the modern analogue to ancient terranes in orogenic belts.

The settings of collision zones vary considerably, from the subduction of seamounts and aseismic ridges, to the impingement of island arc systems and continental margins. It is not yet well known, for example, how topographic irregularities on an oceanic plate or the thick sediment cover of continental margins interact with the forearc, or how collision affects the distribution of deformation across the entire zone of convergence. Drilling actively subducting seamounts as well as propagating collision zones could shed light on critical collisional processes, including the nature and timing of displacements along faults, sources and processes of syndeformational sedimentation, vertical movements of the forearc, crustal flexure and deformational style. Stratigraphic analyses of appropriate sedimentary sections in active collision zones could constrain the initiation and rates of collision processes. We need to determine the timing and magnitude of vertical forearc movements in young collision zones. During collision, large slices of oceanic crust (i.e. ophiolites) may be emplaced onto continental margins. Drilling into active collision zones is needed to establish the critical relations between the emplacing oceanic slab and the parent oceanic crust. Also, the tectonic effects of flexural loading to form foredeeps need investigation by drilling.

Additional drilling at erosive margins is required to more carefully define the magnitude and rate of removal of accreted material. Subsidence studies require detailed benthic paleontology in areas where faunal diversity and sedimentation have been favourable through time. The loci of maximum subsidence and areas of stability or accretion might be quantified in one time slice. Such data would greatly increase knowledge of this tectonic mechanism.

3.2.4 Drilling strategy

It is intended to concentrate drilling on a few "end-member" accretionary prisms (e.g. Barbados, Nankai, Cascadia) that can be treated as natural laboratories to obtain data that will permit better quantification of the behaviour of accretionary prisms. Precise downhole measurements of temperature, stress, fluid pressure, and permeability, as well as *in situ* pore fluid samples must be obtained from ODP boreholes. As noted earlier, an ambitious coring and down-hole measurement program, using innovative Logging-While-Drilling technology, has recently proved successful on the Barbados prism (Leg 156). This is being combined with installation of a borehole seal to be followed by long-term monitoring. This approach can be applied elsewhere (e.g. Nankai) in the future. Examples, of such specific targets include the following:

- characterisation of the permeability and porosity structure of an accretionary prism. It will be necessary to measure *in situ* values of permeability and porosity across thrust faults and basal decollements and to combine these measurements with laboratory measurements on core samples. Use of LWD technology as well as long-term observatories will be important;

- drilling a protothrust zone, where it should be possible to quantify strain and define the stress path better than in more highly deformed parts of the prism. Both the Nankai and Cascadia margins, for example, have well-developed protothrust zones;

- determination of the physical mass balance in the prism. A suitable area (e.g. Costa Rica, Nicaragua) will have thin (or no) trench turbidites, well-defined plate kinematics, with seismically-imaged structures that are shallow enough to reach with the drill, and with no erosion of the accreted sediments. These constraints should allow estimation of the incoming sediment volume, control of the prism geometry, and limit sediment loss only to sediment subduction;

- characterisation of a young collision zone. Propagating collisions are particularly conducive to stratigraphic study since drill sites can be located along a continuum of deformation between the region of subduction and collision. As a collision suture propagates along a continental margin, sediments deposited in flanking basins record collisional events both in their detrital composition and in their subsequent deformation. Drilling a propagating collision would shed light on systematic along-strike variations in structural geometry and tectonic processes as the collision develops. Such movement may reflect displacements along crustal-scale structures imaged independently by geophysical techniques. Several modern collisions exhibit the structural closure of the forearc basin, strata of which may then become incorporated into the rear flank of the accretionary wedge. Some active collision zones also become emergent along strike, such as Taiwan, New Guinea, Indonesia-Timor and Cyprus, allowing detailed onland investigations of deeper crustal levels, unroofed by ongoing collision. Drilling into incipient collision zones may shed light on the nature and timing of vertical and horizontal displacements, synchronous sedimentation, crustal flexure and deformational style.

- study of the effects of seamount subduction. The Costa Rica section of the Middle America Trench is an excellent region for drilling in an area of seamount subduction. A database of 3-D seismic reflection and multibeam bathymetry demonstrates that structures associated with seamount collision extend to shallow levels that could be drilled.

- evaluation of the nature and role of tectonic erosion processes. Future targets for drilling to understand subduction erosion processes include the Peru Trench, where much information already exists from Leg 112 and subsequent marine surveys, the Izu-Bonin/Mariana Trenches, which were drilled on Leg 125/126 (as well as on several DSDP legs), and the Tonga Trench, which has one ODP hole (drilled on Leg 135) and much existing MCS data.

- Forearc-backarc tectonic settings: Much of importance remains to be learnt about forearc (e.g. Tonga), arc (e.g. Tonga

Ridge; Lau Havre Taupo) and backarc (e.g. Bransfield Straits; N Mariana) settings. Successful proposals will be those that pose most effectively testable hypotheses capable of shedding light on quantification of fundamental tectonic processes.

- Greater understanding of accretionary processes will also come from experimental work. Modelling will also become increasingly useful as the constraints imposed by drilling data improve. Many experimental studies require whole-round cores that can only be provided by drilling. These aspects are discussed further in Sections 5 and 6.

Phase 1 Recommendations 1996- 1998
The rationale for selection of future drilling topics is as follows:

- Convergent (subducting) margins: Already well characterised accretionary complexes (e.g. Nankai, Cascadia 2) are ideal settings for more advanced study of *in situ* processes. The recovery of fluids and gases at *in situ* temperatures and pressures is a high priority, as is the determination of *in situ* porosity and permeability. Study of the mass balance of an ideal subduction/accretionary system is also important (e.g. Costa Rica). Geochemically based studies of crustal fluxes through subduction zones to the mantle are anticipated (e.g. Nicaragua).

- Collisional settings. Two legs of partly collision-related drilling are scheduled for 1995. Leg 160 in the Eastern Mediterranean will investigate the collision of the Eratosthenes Seamount with the Cyprus active margin, while Leg 161 will study the subsidence history of the Alboran Sea in the Western Mediterranean as a possible "orogenic collapse" basin. Also the Taiwan arc-continent collision zone has a clear potential to provide a model for the growth of continents through the accretion of exotic oceanic arcs. The Taiwan system is a single, simple propagating collision, progressing from pre-collisional subduction along the intraoceanic Luzon arc to the south; a transition to initial collision over a 150 km-long region south of Taiwan; and relatively well studied mature collision exposed onland in Taiwan. Otherwise, new drilling proposals will be evaluated in relation to the extent to which they shed light on fundamental global, rather than merely local tectonic processes.

Phase 2 Objectives for drilling during 1998-2003
Tectonic objectives during this period are likely to include completion, as far as possible, of the objectives for Phase 1. It is assumed that by this time DCS will be operating routinely and that a sophisticated computerised system of core-log integration will be functional. Major objectives are likely to include the following:

- Convergent (subducting) margin settings: emphasis during this time will probably continue to be placed on *in situ* monitoring of already well studied accretionary wedges (e.g. Barbados, Cascadia, Nankai, Japan trench). Another priority could be drilling of an integrated transect across a trench, forearc, arc-backarc system (S W Pacific), to shed light on overall physical and chemical mass balance (e.g. flux to the mantle). Also, there may be interest in studying the initiation of subduction zones (e.g. Caroline Basin or Zenisu Ridge). Quantification will assume increasing importance. It is also hoped that long-term monitoring of *in situ* observatories will take place.

- Collisional settings: Further progress will depend on drilling deeper into collisional settings (e.g. Mediterranean Ridge Phase) and study of additional areas (e. g. Indonesia/N Australia margin).

A major effort during 1998-2003 will need to be directed at developing techniques (both shipboard and shorebased) that will allow improved extraction of tectonic information from recovered cores (i.e. microstructural studies) and boreholes (i.e. logging). Much depends on the available funding and overall equipment development prioritisation within ODP. Equipment development will particularly be necessary to provide information on the following:

- *in situ* measurements of stress and permeability in relation to values determined in boreholes, especially across key boundaries (e.g. rift decollements; forearc/subduction zone);

- fluid flow, particularly along active faults (e.g. in hydrothermal systems) and effects of deformation on fluid circulation (i.e. dewatering and 'dynamic porosity');

- how chemical and mineralogical reactions (e.g. clay mineral transformations) affect rock failure (e.g. in accretionary wedges);

- strain paths during burial and uplift of oceanic rocks, in the light of land comparisons.

Phase 3 a vision beyond 2003
For contractional process objectives, ideally, it will be necessary to extend the range of deep drilling up to 5 km in >3-4 km of water depth. Drilling possibilities are as follows:

Drilling with a riser. This would not only allow drilling of potentially hazardous hydrocarbon areas, but would also allow greatly improved core recovery at depth within boreholes. However, such drilling could involve a restriction in water depth, at least initially (<2km?), which would greatly limit targets for contractional process drilling.

Deep drilling. A number of critical tectonics problems can only be resolved in the future by very deep drilling (2-4 km) in deep water, whether or not a riser is available. Improved recovery and hole stability are keys to progress (e.g. recovery of weakly consolidated siliciclastic turbidites) and for this a riser system would be very beneficial. Specific tectonic processes for future study would include:

- the relative importance of underplating versus frontal accretion and the effects of oblique, as opposed to orthogonal subduction.
- oblique subduction as a mechanism for possible long-distance lateral transport of "suspect terranes" (e.g. S W Japan or Western U.S.A.);
- anatomy of deeper levels of accretionary wedges, aided by land comparisons(e.g. circum-Pacific);
- active stresses in subduction systems as determined by *in situ* observations (e.g. breakouts), borehole logging, and geophysical experiments (e.g. downhole seismometers, VSPs);
- sampling of fluids and gases at deeper levels of accretionary wedges to test alternative models of chemical and physical interaction and hydrological systems;
- constraining geochemical mass balances of accretionary systems
- formation and unroofing of blueschists.

Relatively shallow drilling. As increasingly high quality site surveys become available, there will almost certainly be continued strong demand for relatively shallow drilling to study contractional processes using a platform similar to the Resolution (especially if DCS is routinely available and core recovery is improved).

3.3 TRANSLATIONAL SETTINGS

3.3.1 Rationale

Translational settings include divergent and convergent continental margins with a substantial oblique component, and oceanic transform faults. Complex three-dimensional tectonic, thermal, and magmatic phenomena in these settings defy traditional cross-sectional geological analysis. The existence of large earthquakes and oil-rich basins along translational margins such as California and the southern and northern Caribbean margins underscore their societal relevance. Despite their obvious scientific importance both in the modern oceans and in orogenic belts (e.g. Alpine-Mediterranean (Tethyan) system), and their obvious importance in understanding of global tectonic processes, these settings have remained virtually undocumented by scientific ocean drilling. Drilling is however essential to help answer fundamental questions concerning the dynamic processes active at the ocean-continent translational boundary, the deformation and the partitioning of motion in oblique settings, the nature of the crust at margins and transform faults, and the effects of translational tectonics on sedimentation and paleoceanography.

3.3.2 Unsolved problems

i) Geodynamical aspects: A key unknown is the detailed thermal history, which largely governs the vertical behaviour of a transform margin. Transform margins appear to show reduced magmatism and subsidence relative to normal rifted passive margins. Vertical motions can be transient and may provide evidence for the level of conductive and/or advective heat dissipation from the rifted lithosphere. The vertical motion history can best be determined by charting subsidence from the sedimentary cover. Localised uplift can also take place by transpression along the transform or by serpentinised diapirs in transtension;

ii) Crustal deformation, partitioning of oblique motion, and mechanical coupling versus decoupling. The partitioning of motion between subduction, crustal shortening, and horizontal translation results in principal stress orientations at a high angle to the trace of faults, block rotation along vertical and horizontal axes, the termination of vertical faults against crustal detachments, and the formation of asthenospheric windows. Translation of crustal fragments along the transform by strike slip, as small "exotic terranes", possibly even out into the ocean basins along fracture zones has been suggested but the mechanism and depth level of translation have not been established. On a smaller scale, is deformation along strike-slip faults pervasive or only local? Is a penetrative cleavage present?

iii) Nature of the crust. Questions arise as to whether the crust near a continent-ocean transform boundary is stretched continental crust, oceanic crust with intrusions (e.g. of serpentinised ultramafic rocks), or a complex mixture of both oceanic and continental crustal types. Is the base of the continental crust at the boundary tectonically eroded by the moving oceanic lithosphere? To what extent is this crust thermally metamorphosed and when in its history does such metamorphism occur? Are basins within a transform margin thin-skinned, or do they represent lithospheric stretching? The nature and composition of basement ridges and median valleys at oceanic transform faults is not well documented;

iv) Tectonic-sedimentary history. Small independent basins controlled by strike-slip and oblique faulting form in many translational settings (e.g the California Borderland, the Gulf of Aqaba). These basins probably are isolated from open oceanic deep-water circulation. Transverse ridges along oceanic transform faults create barriers to both shallow and deep marine circulation. These affect the provenance of the sediments, the nature of timing of development of anoxic versus well-oxygenated fine-grained sedimentation, and the establishment of oceanic "gateways".

3.3.3 Drilling strategy

The only ODP leg devoted to a translational setting so far is the Ivory Coast-Ghana transform margin, which is scheduled for drilling during early 1995. This leg will focus on a longitudinal transect of the outer margin high, including drilling of small ridges close to the continent-ocean boundary. This margin is, however, only one among many translational settings. Two other proposals, currently under consideration, the Vema Fracture Zone and the Cayman Trough, are geared toward different problems in different settings. The Vema Fracture Zone proposal offers to study the timing and kinematics of the development of transverse ridges along transform faults and fracture zones. The Cayman Trough proposal focusses on the interaction of a long transform-short ridge geometry, and on the effects of transpression. Because the Cayman Trough consists of a single rift segment, it is possible to compare sections of the margin not yet affected by the passage of the ridge with those affected by it. Recent transpression along the fault bounding the trough raised the Sierra Maestra Range in southern Cuba, and modified offshore structures, and is posing seismic hazard to the second largest city of Cuba.

Although no other proposals exist at present, proposals should be encouraged in other translational settings. These include the following: The California margin - to document the evolution of the margin, vertical motions on the land, the migration of fault activity, and the influence of the subducted plate in this highly-populated transpressional margin; the Gulf of California and the Gulf of Aden - to document the opening of an ocean basin in a highly oblique setting with varying initial thermal conditions (previous subduction, the presence of a hot spot); the Gulf of Aqaba - to document the initial stages of pull-apart to ocean basin development, the Romanche Fracture Zone - to document the shearing, translation, and deformation of thin continental slivers; the Exmouth Plateau and southern Newfoundland - to compare volcanic and non-volcanic translational margins.

3.3.4 Priorities and phases of drilling

Of greatest importance is to document the three-dimensional complexity of a transform rifted passive margin and an oceanic fracture zone. A return to the Ivory Coast (Equatorial Atlantic) transform could be foreseen if warranted by initial results and/or selection of a young still active transform margin. Of the wide range of oceanic transform faults and fracture zones, the Vema Fracture Zone with its unique limestone cap is an obvious target; a still active transform setting could also be envisaged. It is anticipated that scheduling of drilling to study translational kinematic environments will be integrated with other priorities based on the quality of specific proposals.

3.4 Vertical Tectonic Processes

3.4.1 Rationale

Although vertical tectonic processes specific to particular kinematic environments have been covered above, globally operative processes resulting in vertical motions are also of interest to TECP. For example, the viscoelastic response of the plates to locally applied or removed loads (i.e. ice sheets, denudation along low-angle normal fault systems during rifting), detected in subsidence or uplift of shallow marginal areas, can constrain the rheological stratification of the lithosphere-asthenosphere system. The subsidence history in a region of changing gravitational and thermal load, such as the Hawaiian Arch, can constrain the processes and time constants of plate weakening. Studies of response to loading/unloading at continental margins may further constrain the flexural rigidity and expected elastic response of plates as a function of such variables as age and heat flow. Long-wavelength or plate-wide episodes of epirogenic uplift of subsidence, if detected and differentiated from eustatic sealevel changes, may be related to longer-term dynamic topography and changes in the circulation pattern of mantle convection. The relationship of uplift events to large-volume volcanism (e.g. the Large Igneous Provinces of LIPs) may constrain the dynamic topographic effects of localised mantle upwellings (plume heads) and thus be important to models of plume evolution, thermal budget, and interactions with the mantle convection system and with the lithosphere. Responses of the plates to changes in stress (for example, due to plate reorganisations or orogenesis and plateau development at convergent plate boundaries) may includer local flexurally-induced vertical motions: if these can be arrurately characaterised, they will place useful constraints on stress levels required for deformation of the plates and perhaps on the levels of stress changes resulting from changes in plate geometries.

3.4.2 Drilling strategy

Elucidation of vertical tectonic processes requires determination of uplift and subsidence rates in all global settings, at a variety of time-scales. This is most feasible in settings where relative depth information can be easily obtained (e.g. from biofacies and lithofacies information in shallow water sedimentary rocks) and should be obtained whenever possible as an integral part of all ODP investigations. It is envisaged that progress by drilling will mainly come from specific recognition of the role of vertical tectonic effects and that results will be obtained in conjunction with other drilling objectives.

4 DEFORMATION PROCESSES

4.1 Rationale

The strength of the lithosphere in all tectonic environments is controlled by the physical and chemical conditions during deformation and the inherent properties of deforming lithologies. Changes in environmental parameters such as pressure, differential and deviatoric stress, temperature, pore fluid pressure and chemistry modify the mechanical response of rocks determining, for example, whether failure occurs by seismogenic faulting or steady-state creep. These changes in failure mechanisms cause temporal and spatial variations in strength and the bulk rheological behaviour of the lithosphere. The timing, nature and distribution of deformation is therefore a key aspect for understanding the detailed rheology of crust and upper mantle and the initiation and evolution of plate boundaries.

ODP has made a strong start exploring deformation mechanisms in the crust and mantle in different tectonic settings that complement onshore investigations, rock deformation and theoretical experiments. For example, drilling has provided unique insights to the earliest stages of deformation in partially consolidated sediments in the toes of accretionary prisms, the physical property variations through a continuous 2 km section of *in situ* oceanic crust, and the high temperature plastic and syn-magmatic deformation in the lower oceanic crust. Such targets have significantly expanded our knowledge of the time-dependent deformation processes in different lithologies and present-day deformation environments in diverse tectonic settings.

ODP currently provides the only opportunity to constrain and compare the past and present conditions, distribution and rates of deformation of ocean margins and basins. With this aim, TECP is concerned with two complementary approaches. The first approach concerns direct measurements of active deformation and deformation environments using borehole and seafloor instrumentation. The second approach provides the complementary geological records from core, logging and seafloor data. Combining these approaches is essential to constrain short and long term variations in the location and rate of deformation and structural style.

Strain distribution at gradients.
Records of strain distribution and strain-rate gradients combined with kinematic indicators can be used to demonstrate the response of the lithosphere to evolving tectonic environments. For this purpose TECP endorses proposals which target rheologically significant boundaries at different lithospheric levels and aim to explore lateral variations in strain and strain rate at the same lithospheric levels. Such targets would include the dike-gabbro transition, major shear zones at passive margins and the basal decollements of accretionary prisms. These settings provide key locations to investigate the influence of changing lithology on deformational mechanisms and associated changes in strength and the lateral and vertical variations in kinematic frameworks. Some targets will require deep drilling whereas others demand high resolution studies to determine paleo-stress and strain gradients and the detailed lithological and structural geometries which play a key role in strain localisation. *In situ* monitoring, combined with the fine-scale structures in ODP core and paleomagnetic data, provide valuable semi-quantitative constraints on strain and the kinematics of deformation, including shear sense indicators on faults, local or regional-scale tilting and mantle flow fabric (e.g. Holes 894 and 735B). In conjunction with syn-kinematic mineral assemblages, they also provide a means to trace changes in strain with variations in pressure and temperature that may be associated with magmatic or burial and exhumation histories. For example, studies in Hole 735B, document the shear zone deformation from the late stages of crystallization of a magma over decreasing metamorphic grades with increasing hydrothermal alteration.

Stress magnitude and orientation.
ODP boreholes provide a means to determine the distribution of stress magnitudes and orientations that are essential for understanding how major plate driving forces are expressed at different lithospheric levels in different tectonic settings. Variations in differential stress magnitudes can strongly influence the mechanisms by which lithospheric failure occurs and the distribution and orientation of deformation fabrics are also related to deviatoric stress conditions. The evolution of stress fields can be established from comparisons of paleostress conditions (from core microstructures) with *in situ* stress estimates (e.g. Holes 504B, 735B and Lau Basin). The lateral and vertical variations in *in situ* stress and paleo-stress conditions over a wide range of scales remain a high thematic interest for TECP. These measurements are critical to improving the resolution of a global stress map so that deviations from regionally consistent stress orientations can be related to contrasting plate margin and intraplate settings. On more local scales, it is important to evaluate the heterogeneity of stress fields related to specific structures such as active fault zones or folds and across rheological transitions.

Thermal evolution.
The mechanical evolution of some tectonic settings is strongly influenced by their thermal histories. Temperature is the major control on the transition from brittle to ductile deformation. Fluctuations in thermal gradients can modify physical properties (e.g. thermal cracks) and vary pore fluid conditions (e.g. dehydration reactions and hydrothermal circulation) that also strongly influence the rheological properties of lithospheric materials. Changes in thermal gradients induced by variations in the distribution and extent of magmatism, hydrothermal circulation or major shear zone displacements can cause concomitant changes in deformation mechanisms, modifying strength contours in the lithosphere. ODP boreholes provide a means to evaluate present-day temperature gradients and compare them with past thermal gradients established from metamorphic phases. These provide a means to relate *in situ* stress measurements to seafloor cooling patterns. For example, complex deviatoric stress patterns are predicted as the oceanic lithosphere cools and thickens following its formation off-axis, approaching ridge-transform intersections, or at propagating rift tips. They can also be used to relate strain histories to different pressure and temperature conditions in order to test thermo-mechanical models for the evolution of passive margins.

Fluid flow.
Stress conditions and strain histories are also strongly influenced by fluid flow in the crust. Variations in fluid pressure modify effective stress levels and fluid temperature and composition influence water-rock interactions and thermal and chemical gradients. Changes in the deformation environment caused by fluid flow can change the mechanical behaviour of the lithosphere. In turn, deformation can change lithological properties modifying fluid flow paths and fluid pressures, thereby generating a feedback mechanism between fluid flow and deformation. For example, dilatancy during brittle failure will enhance porosity and modify permeability, whereas recrystallization at high temperatures or volume loss during pressure solution (enhanced by low effective stresses) would decrease porosity and permeability. Faults and shear zones can act

as, conduits for aqueous fluids or magmas, modifying local fluid circulation patterns and thermal gradients. Fault slip rates and mechanisms are also influenced by the evolving stress states and physical properties resulting from steady or transient fluid flow. To date ODP borehole investigations have yielded valuable qualitative and quantitative constraints on *in situ* pore fluid pressures, physical properties (e.g. direct measurements of porosity and permeability), the relative timing of fluid flow and deformation (e.g. cementation histories) and past and present fluid flow networks in accretionary wedge and oceanic settings. For example, cross-cutting fracture arrays and the fabrics of hydrothermal minerals within them have been used to interpret the spatial variations of kinematic histories in sections of oceanic basement. At Site 504B, localised, intense hydrothermal veining is closely associated with a deformation zone within the pillow-dike transition. The highly successful Logging-While-Drilling (LWD) conducted as part of Leg 156 in the Barbados wedge suggests that the decollement zone of the Barbados wedge is extremely porous, and is probably associated with an open fracture sytem where fluids are migrating along the fault at lithostatic fluid pressures. This is just one of several legs that have made significant steps towards mapping the evolving porosity and permeability in the crust and their relation to deformation processes in actively deforming regions. From this promising start, TECP encourages proposals that address the relationships between deformation and fluid flow, in settings such as active hydrothermal systems at a seafloor spreading centres (Leg 158), the fault-related fluid conduits in an accretionary complexes (i.e. Legs 110, 146, 131, and 156), or even where a hot spreading centre is being subducted beneath an accretionary prism (Leg 141).

Acoustic properties.
Deformation not only influences porosity and permeability but also modifies acoustic properties. Constraining patterns of deformation in different tectonic environments is therefore an important aspect for modelling lithospheric structure based on acoustic signatures. Strong preferred orientations of penetrative foliations or fractures generate seismic anisotropies, while the combined metamorphic and deformation histories will change elastic properties and thereby modify acoustic signatures. The combination of ODP core and logging data provide a powerful method to calibrate the acoustic properties of variably deformed lithologies. Integrated lithological, physical property and microstructural data were used to link regional-scale three-dimensional seismic reflection profiles to the borehole data in the Barbados wedge (Leg 156) to study the heterogeneous three dimensional character of a major active fault zone.

5 TECHNOLOGICAL DEVELOPMENTS/MEASUREMENTS

The main objectives here are to quantify active deformation and non-linear coupled processes.

5.1 *In situ* measurements

Investigations of deformation mechanisms in the crust and upper mantle in active tectonic settings represent an expanding strength of ODP. Combined *in situ* measurements and microstructural and petrological studies can provide qualitative and semi-quantitative estimates of differential stress magnitudes, strain, strain rate, temperature, pore fluid pressure and confining pressure conditions during lithospheric deformation. Such measurements form the essential building blocks of regional interpretations and provide valuable comparisons for kinematic interpretations based on macroscopic structural geometries and relations. Major results to-date have been focused at a few sites but a dramatic improvement in the quality and quantity of structural data has resulted from the introduction of some key technological developments.

Now that structural measurements are routinely acquired during ODP legs there is tremendous potential for correlating downhole measurements with core structures. Increasing awareness of the value of structural measurements is driving technological developments to recover oriented core and establish recovery depths for core material. These developments facilitate the integration of discontinuous core sections with continuous logging data such as FMS or Borehole Televiewer data. This enables a close comparison between physical and chemical property variations in continuous logs or *in situ* point measurements and deformation fabrics in the core. Continued development of computer facilities is required to provide routine, shipboard semi-automated analysis of core structures, such as penetrative fabrics or fractures.

In situ measurements of stress, strain, strain rate and pore fluid pressures are a high priority for TECP. Borehole televiewer images have been successfully used to infer *in situ* stress conditions in Hole 504B. Drilling in the Nankai accretionary prism provided a unique chance to compare the hydrogeological regimes above and beneath the basal decollement. Logging-While-Drilling (LWD) was also used with remarkable success to reveal zones of overpressure within and just above the Barbados accretionary prism decollement. Packer tests in cased holes have determined the permeability and *in situ* fluid pressures in major fault zones in both the Cascadia (Leg 146) and Barbados accretionary wedges (Leg 156). Long-term borehole seals (CORKs) with associated temperature and pressure sensors have also been developed and successfully deployed for long-term monitoring of fluid behaviour in fault zones. These achievements indicate a bright future for the role of ODP in monitoring active tectonic environments, but TECP urges further support be given to technological developments that improve the reliability of existing tools, modify existing technology for ODP boreholes or develop completely new technology.

These developments should include the redevelopment of a water sampler and temperature and pressure tool (WSTP) and the development of the Lateral Stress tool (LAST). Techniques for 'looking-out' from the borehole wall, such as radar images or cross-well seismic experiments should also be developed as a means to filter out drilling-related features and examine the undisturbed deformation record. Existing radar technology and NMR could be modified to be deployed in ODP boreholes (i.e. primarily repackaging existing sensors to fit the specifications of ODP operations). Long-term tool development should focus on cross-borehole or seafloor to borehole experiment technology. These techniques have a potential to relate borehole measurements and core analysis to regional three-dimensional structural and lithological frameworks. TECP therefore endorses a long-term plan to investigate the feasibility of and develop cross-borehole experiments and non explosive seafloor sources. The improved three-dimensional constraints would greatly enhance the value of core structural data. Packer studies should be extended to cross-borehole studies to examine the lateral permeability structure of both deformed and undeformed sections. These would be complemented by studies of water-rock interaction during deformation and the impact of reaction progress on failure mechanisms. TECP has a continuing interest in using CORKs as a platform for stress and strain monitoring and spatial and temporal fluid pressure and temperature variations. Tools that measure tilt, vertical displacement of the CORKs, displacement across faults, and lateral stress variations should all eventually form part of long term monitoring.

In the long term, ODP should also be aiming to provide improved recovery and continuous, deeper sections. An emphasis on sampling fault zones, accompanied by technological developments to enhance the recovery of fractured material is also needed. An increasing demand for deeper holes means that high temperature tool development will also become a high priority. Comparisons of past and present fluid flow regimes and the impact of deformation on fluid circulation also need to be carried out in these deeper settings.

5.2 Observatories

The complex rheology, style of deformation and stress/strain patterns observed in both active and previously active plate boundary environments is a product of complex non-linear coupled interactions. Processes directly involved in deformation (i.e. porosity/permeability reduction, lithification, changing deformation mechanisms, fluid transport and chemical alteration), and environmental factors (i.e. depth, temperature, fluid pressure/stress) interact to continually change the properties of the deforming system. Although some of these parameters and interactions can be quantified by laboratory-based experimental and field-based studies, ODP presents an unparalleled opportunity to study active deformation processes in their natural setting. Continental drilling complements ODP objectives, but many tectonic processes can only be investigated in marine environments.

Past ODP drilling has significantly advanced our largely qualitative understanding of the processes controlling deformation at plate boundaries. In the long term, substantive further progress requires the acquisition of quantitative, *in situ* measurements. These measurements are essential for the development of quantitative models that aim to simulate the complex interactions of tectonically active systems. The quantitative testing of these models should ultimately form part of the driving basis for future ODP proposals. The necessary technological developments outlined above would place ODP at the forefront of studies of active tectonic systems.

A general, but significant result of ODP studies in active tectonic systems is the evidence for changing deformation processes, physical and chemical properties, sometimes even when measured on human time scales. As an example, recent ODP studies of currently active accretionary wedge environments (i.e. ODP Legs 110, 131, 146, 156) have strongly indicated that deformation is dominated by transitory processes with non-steady state fluid flow patterns being indicated by temperature transients and large changes in structural fabrics indicating that faulting events may be associated with substantial overpressuring coupled to transient brecciation events (as in the decollement of the Nankai accretionary wedge, Leg 131). These events probably act over short time frames (time scales that range from hours to less than a few tens of years).

The significance of such instantaneous measurements can only be evaluated when placed in the framework of variations over longer time scales. For example, within a fault zone the strain patterns, stress state, fluid pressure, and strength change with time and do so particularly rapidly around the time at which the fault becomes unstable and moves. The actual strength of the fault during slip is governed by its properties within an unstable period and not the intervening quiescent periods. Long-term observatories will provide more reliable, quantitative constraints on parameters used in steady-state models of active tectonic systems and will also enable us to evaluate the viability of steady-state models.

Initially, the observatory environments should be tectonically simple with high strain rates. Some of the parameters of particular interest to the concerns of the TECP panel would be the variation in stress, fluid pressure, and strain patterns in three dimensions. The necessarily one-dimensional ODP borehole observations should be extended into three dimensions using surface geodetic and stain measurements and it is highly likely that more than one observatory borehole will be necessary to adequately constrain any given system.

The practical use of many different types of strain measurement system requires very good coupling between the instrument package and the seabed. In active sedimented environments the mobile nature of the high porosity near surface sediments can cause problems, with local differential subsidence and fluidisation during earthquake events being potentially significant. Cased ODP holes (with or without emplaced CORKs/ borehole seismometers) supporting and stabilising simple surface platforms to which third party instruments could be securely attached/detached (by submersible or on deployment) would provide a practical answer to this problem. Depending on the local environment and scientific objectives such platforms could be supported by relatively simple (low cost) short (cased) holes a few tens of meters in depth or be part of more substantial observatories that include CORK systems. We have the opportunity to use currently available technology to initiate strain measurement programs that can form an integrated part of observatory systems in active tectonic environments. The following are examples of two types of relatively inexpensive sensors that offer immediate possibilities to ODP and TECP objectives. Highly accurate pressure sensors can be used to measure changes in the observatories depth below the sea surface (i.e. vertical motion in response to faulting) to 10^{-8} accuracy of full scale (i.e. changes of a few mm at full ocean depths). Sonic extensiometers can also be placed on top observatory platforms to measure changes in distance between platforms. Such devices are accurate to a 1-2 cm over distances of 1km between sensors and can be put out in arrays of 16 or more units. Together with tilt meters these types of sensor could form part of the same modular strain measurement package.

Another approach to long-term observations is the long-term objective of developing an oceanic seismic network that is capable of measuring deep earth structure using seismic tomography. In this case seismometres are installed at suitable depths in ideally located oceanic boreholes. To date the only hole for OSN was cored south of the Hawaiian Islands, but mor such holes may be planned in the future.

The authorship of this white paper includes all members of the JOIDES Tectonics Panel (TECP) from 1992 to present, including input from the PCOM liaisons.

International News, Meetings and Announcements

ODP INTERNATIONAL CONSORTIUM NEWS

On September 29, 1994 the Australian Geological Survey Organization (AGSO) and the Geological Survey of Canada (GSC) signed an MOU that will be in effect until September 30, 1998. Australia will now take over the lead role in the Consortium and the Australian Secretariat will be the location of the Consortium Office. A consortium of Universities in Taiwan has applied for funding to join the AUS-CAN Consortium in late 1995 at a 1/6 level of contribution. Numerous discussions with several possible candidates for the remaining 1/6 membership, including P.R. China and South Korea, are currently underway.

The new Australian ODP Secretariat will be at the Department of Geology, James Cook University, Townsville, Queensland. Prof. Bob Carter will serve as Director of the Secretariat and the new consortium lead member on PCOM. Dr. Tom Loutit of AGSO will chair the Australian ODP Council. He will also serve as the AUS-CAN alternate to EXCOM and the OHP Chair. A grant of $936,000 for Australian participation in ODP for 1995 was awarded by the Australian Research Council (ARC).

The Department of Geology at the University of Toronto has been chosen as the location of the new Secretariat of the Canadian ODP. Dr. Steve Scott is the Director of the Secretariat and the PCOM alternate. Dr. Larry Mayer of the Department of Geodesy and Geomatics Engineering at the University of New Brunswick will chair the Canadian ODP Council and serve as the AUS-CAN EXCOM representative.

MEETINGS OF EUROPEAN JOIDES MEMBERS

1. At a meeting in Davos (Switzerland) in September 1994 European JOIDES members met to consider possible European initiatives for engineering development, European ideas on ODP long range planning and to discuss future scenarios for ships in ODP. Specialists from the USA as well as Europe were invited to provide the necessary engineering expertise.

The meeting concluded that the types of engineering development that might be supported through European initiatives such as the Marine Science and Technology (MAST) programs are, in the short term, coring and Logging-While-Drilling systems, and in the long term, bottom landers, drilling from submersibles, riser drilling and borehole instrumentation. At present, only a few of these options are well suited to be the focus of a proposal with clear scientific and technological objectives.

The group felt that a biennial ODP European Meeting would enhance scientific communication and collaboration between the European member countries of JOIDES.

2. Rob Kidd, PCOM Chair, organized a meeting in Cardiff (UK) on February 16, 1995 to gather input to the Long Range Plan (LRP) on European Union earth science programs. European JOIDES Representatives to PCOM and EXCOM met with Dave Falvey (ODP Director), and representatives of EU funding agencies, Jean Boissonnas (Director of the European Union Marine Science and Technology Programs) and David Drewry (NERC). Jean Pierre Henriet (IFREMER) and Alister Skinner (British Geological Survey, Edinburgh) also attended, representing the recently announced "Corsaires" initiative. Dr. Jean Boissonnas presented an overview of the aims and scope of the MAST programs and outlined opportunities for support of some types of engineering development through MAST and other European initiatives. The current status and development of the ODP Long Range Plan, current and future models for the management of ocean drilling, future models for European membership in JOIDES, and the relationship of the European Committee for Ocean and Polar Sciences ECOPS "Corsaires" initiative to JOIDES and ODP were also discussed.

3. The next meeting of European JOIDES representatives will take place during the EUROPEAN UNION OF GEOSCIENCES Meeting in Strasbourg, France at the ESF Offices on Tuesday, April 11, 1995.

FOURTH UK ODP SCIENCE FORUM

The Fourth UK ODP Science Forum was held at the British Geological Survey at Keyworth on February 22, 1995. The program was organized along the following geoscience themes: Magnetism and Tectonic Processes, Sedimentary and Geochemical Processes, Paleoclimatology, and Links with Community Science. The primary purpose of the forum was the annual review of UK science emerging from recent *JOIDES Resolution* cruises, upcoming Legs in 1995/96, proposals for future activities and highlights from the NERC-supported UK Science Programme. Recent and prospective participants in ODP ship Legs and members of the UK ODP Community enthusiastically participated in the day-long meeting.

NEW ODP DIRECTOR

Dr. David A Falvey became the Director of Ocean Drilling Programs at JOI on December 1, 1994. Dr. Falvey was formerly Associate Director of the Australian Geological Survey Organisation, and has represented Australia/Canada on EXCOM for several years. Dave's primary goals are to increase international participation in ODP, and to prepare for the programs' renewal in 1998. He is also pursuing new management initiatives, including the introduction of "project management", "joint ventures" for technology development, and an improved marketing and public relations strategy.

ODP INTERNATIONALISATION EFFORTS

At the invitation of Dr. Luis Gamboa of PETROBRAS (the Brazilian national oil company) Jamie Austin (then Acting Director of ODP) travelled to Brazil on October 25-30, 1994. He gave a talk introducing ODP and its recent scientific achievements to an enthusiastic audience at the 38th Brazilian Geological Congress. Dr. Gamboa has requested ODP's participation in the 39th Brazilian Geological Congress to be held this summer and Dave Falvey is currently making these arrangements.

A group from South Korea contacted the Australian Secretariat concerning possible membership in their consortium and two South Korean observers attended the EXCOM meeting in Hawaii on January 30 - February 1, 1995. Dave Falvey will visit Seoul in May.

Dave Falvey met with Dr. Chao-Shing Lee and Prof. Min-Pen Chen in Taiwan on January 12 and 13 to discuss the participation of the National Taiwan University in ODP. Prof. Min-Pen Chen will attend the April PCOM meeting in Japan as an observer. A positive decision regarding the participation of the National Taiwan University in ODP is hoped for from the Taiwan National Science Council in the spring. If funded, participation will start as soon as the final decision is made, however, funds will not actually be available to ODP until August.

Dave Falvey has also written to to Prof. Zen of Indonesia and Dr.Rao of India encouraging participation in ODP.

ODP Performance Evaluation Committee (PEC-IV) Review

The 4th Performance Evaluation Committee for ODP (PEC-IV) was established in the fall of 1994. The committee, chaired by by John Knauss (URI and SIO), held their first meeting in Washington, D.C. November 2-3. The mandate for PEC-IV is to evaluate the management and performance of JOI and its subcontractors and to recommend action where required. Among the many issues under consideration are the effectiveness of JOIDES short and long-term scientific planning and the integration of scientific ocean drilling with other ongoing international earth science initiatives.

Individual members of PEC-IV have been selected to attend ODP-related meetings during the course of the evaluation. J. Morton attended the LRP meeting at JOI. John Knauss, P. Worthington, and M. Sarnthein attended the PCOM meeting in College Station. J.Knauss and R. Hyndman met with several co-chief scientists fr om recent legs during the fall AGU meeting in San Francisco. The entire PEC-IV Committee visited the Borehole Research Group, the Site Survey Data Bank, and the East Coast Repository at LDEO on January 23-24. J. Delacour and R.Hyndman visited the *JOIDES Resolution* in Marseilles on March 9th and 10th where they met with members of the scientific, technical and drilling crew. They also visited the facilities of Dr. Philippe Pezard at the Institut Mediterraneén de Technologie (IMT).

COMMUNITY SCIENCE PROGRAM NEWS

InterRidge

InterRidge has officially entered Phase 2 of its Program Plan (1995 through 1997). Phase 2 involves in-depth studies in the form of major interdisciplinary field efforts conceived and co-ordinated by InterRidge, and development of a database information catalogue accessible to the international ridge sciences community via the Internet.

Thematic workshops held during Phase 1 (1992-1994) resulted in the design of seven Phase 2 InterRidge Projects in the three thematic areas: Global Studies, Meso-Scale Studies, and Active Processes. It is envisaged that these projects will move forward through concerted international actions at sea and elsewhere, co-ordinated by InterRidge over a period of several years. This action would bring the ships and technology of different nations together in major multi-disciplinary experiments focused on InterRidge thematic goals.

Workshops: The last half of 1994 and early 1995 saw the completion of the Phase 1 round of thematic workshops. In late September, 1994, the Meso-Scale Workshop "4-D Architecture of the Oceanic Lithosphere" was held in Boston, USA and immediately following a DOLCUM/RIDGE ridge segmentation workshop. The draft workshop reports indicate that RIDGE and InterRidge are directly incorporating ODP into their program plans. Specifically, the DOLCUM/RIDGE report identified ODP as an integral component of the intra-segment experiments to directly constrain the structure of lower crust and upper mantle at both slow-and fast-spreading ridges. Drilling strategies discussed during the workshop were considered feasible given the currently demonstrated capabilities of ODP. The workshop emphasised, however, that the least ambiguous means of determining the causes of crustal thickness variations along spreading centers is by drilling deep (full crustal) holes. Thus the continued development of the capability to drill deep holes in young oceanic crust near spreading centers must remain a pressing, high priority goal of ODP.

In November, 1994, the Global Studies Workshop "Arctic Ridges: Results and Planning" was held in Kiel, Germany. Paris, France was the site of the January, 1995 Active Processes Workshop "Event Detection and Response & A Ridge Crest Observatory". Summaries of the results of these workshops are available from InterRidge.

Upcoming Events & News: The InterRidge Biological Studies Ad Hoc Committee will convene a workshop on April 24 & 25, 1995 at Rutgers University, New Brunswick, NJ, USA. Planning is also underway for a workshop which will draw up a science plan and implementation outline for the Meso-Scale Working Group Project "Quantification of Fluxes" as well as for the 1995 InterRidge Steering Committee Meeting which will be held in parallel with a meeting of DeRidge in Kiel, Germany.

WWW. The InterRidge World Wide Web home page is now on line. The home page address is http://www.dur.ac.uk/~dgl0zz1/. The InterRidge home page provides links to the InterRidge Researcher Electronic Directory, information concerning InterRidge program structure and events calendar, workshop announcements and various national and international program home pages.

MESH

Sixty scientists from the USA, Canada, Germany, and Mexico met in Corvallis, Oregon, at a three-day MESH workshop in January, 1995. MESH (Marine Aspects of Earth System History) now exists as a US science program funded by the NSF. It is tied to the international community through IMAGES (part of IGBP/PAGES) and ODP. At the Corvallis workshop, paleoceanographers focussed on plans to improve and develop geologic measures of key oceanic processes: Ocean physical properties such as temperature and salinity; Oceanic measures of atmospheric carbon dioxide levels (and its sources and sinks); Biological productivity of the oceans; Nutrient distributions and budgets; and Ocean-continent interactions.

In the coming year, the MESH Planning Office will work with the MESH Steering Committee and the paleoceanographic community to develop a science implementation plan, to address global change studies ranging from interannual variability to long-term evolution of climates over the past 100 million years. A MESH Program Plan, which outlines thematic objectives, is now published, and is available from the MESH Planning Office. For further information about MESH activities and plans, contact: Dr.Nicklas G. Pisias, MESH Planning Office, College of Oceanic and Atmospheric Sciences, Oceanography Administration Building 104, Oregon State University, Corvallis, OR 97331-5503 USA, pisias@oce.orst.edu, (503)-737-5213.

JOIDES Resolution PORT CALL NEWS

Leith (Edinburgh), Scotland, UK

The *JOIDES Resolution* will be in Leith from the July 4-8, 1995. This port call will coincide with the July EXCOM Meeting. There will be opportunities for geoscientists and members of the public both to visit the ship at Leith docks, and to attend a poster display with a public lecture in the city.

MEETING ANNOUNCEMENT AND CALL FOR PAPERS

5TH INTERNATIONAL CONFERENCE ON PALEOCEANOGRAPHY
Dalhousie University, Halifax, Nova Scotia, Canada - October 10 - 14, 1995

Convenors: Larry Mayer and Frank Rack, University of New Brunswick, and David J. W. Piper, Bedford Institute of Oceanography.
Sponsored by: The Geological Survey of Canada, Scientific Committee on Ocean Research (SCOR), and the Natural Sciences and Engineering Council of Canada (NSERC).

The International Conference on Paleoceanography (ICP) is the premier forum for the presentation and discussion of exciting and timely topics in paleoceanography and paleoclimatology. The theme of the ICP-V will be **LINKAGES - the role of paleoceanographic linkages in the global system.**

SESSION THEMES: Ice Cores, Modelling, New Tools & Proxies, Ocean Fluxes, Tectonic & Climatic Linkages, Land-Ocean Linkages, Time Scales & Stratigraphies, Arctic & Antarctic Records & Linkages, High & Low Latitude Records & Linkages.
FIELD TRIPS: A two day field trip on the glacial history of Nova Scotia, is scheduled for October 7 & 8, 1995. A one day field trip to see the Bay of Fundy Tides is scheduled for October 9 and 15. A two day Coastal Geology Kayak Trip is scheduled for October 5 & 6. On Friday afternoon, October 13th there will be no formal sessions and a number of field trips and special interest excursions have been planned, including: Cape Split Hike, Glacial history of Nova Scotia, Coastal geology and scenery, and historic homes.

ABSTRACT DEADLINE - JUNE 15, 1995

AIR TRAVEL: Special air fares have been arranged through Air Canada, Continental and United Airlines or Fraser & Hoyt Travel Agency. Limited **travel awards** from SCOR and other sources are available for active scientists from developing countries and the former Soviet Union.

FOR ADDITIONAL INFORMATION, PLEASE CONTACT:

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MEETING ANNOUNCEMENT

INTERNATIONAL CONFERENCE "CORING FOR GLOBAL CHANGE"

KIEL, GERMANY

JUNE 28 - 30, 1995

Convenors: Jurgen Mienert, GEOMAR, Kiel, Germany and Gerold Wefer, University of Bremen, Germany.

This international conference is intended to provide a forum for the investigation of short-term global paleoceanographic climate changes on 500K years time scale and to channel geomarine research efforts towards creating new long coring technologies. Participation of scientists and engineers from academia, industry, and administration is encouraged.

Main Topics: Scientific Needs and Requirements, Existing Coring Technologies, New Deep Sea Coring Technologies, Shipboard Requirements.

Expressions of interest and / or contribution abstracts should be sent to Ute Brennwald, GEOMAR, Research Center for Marine Geosciences, Christian Albrechts University, Wischhofstrasse 1-3, 24148 Kiel, Germany. Telephone: 0431-7202-138. FAX: 0431-725391. E-Mail: jmienert@geomar.de.

MEETING ANNOUNCEMENT AND CALL FOR PAPERS

THE GEOLOGICAL EVOLUTION OF OCEAN BASINS RESULTS FROM THE OCEAN DRILLING PROGRAM

BURLINGTON HOUSE
LONDON, ENGLAND, UK

OCTOBER 18 - 19, 1995

Convenors: Drs. Adrian Cramp and Chris MacLeod (Dept. of Earth Sciences, UWCC) and Dr. John Jones (Dept. of Geological Sciences, UCL)

Sponsored by: Marine Studies Group, Geological Society London, Challenger Society

This meeting is designed to bring together a wide range of international geoscientists who have current, recent research interests in the geological evolution of ocean basins and climate fluctuation. The two day meeting will be arranged into thematic sessions each of which will be introduced by keynote speakers.

Expressions of interest and / or contribution abstracts (talk / poster) should be sent to Dr. Adrian Cramp, Marine Geosciences Research Group, Dept. of Earth Sciences, UWCC, P.O. Box 914, Cardiff CF1, UK. Telephone: +44 (0) 1222 874335. FAX: +44 (0) 1222 874326. E-Mail: cramp@cf.ac.uk.

ABSTRACT DEADLINE - JUNE 30, 1995

NOW AVAILABLE

DSDP / ODP RADIOLARIAN COLLECTION

Eight sets of DSDP/ODP strewn slides have been prepared from about 3,000 core samples chosen for radiolaria from important sites drilled during the Deep Sea Drilling Project. These have been made available to the scientific community at eight Micropaleontological Reference Centers (MRCs) geographically selected for world coverage.

To increase the usage of one of these sets, ODP proposes to offer it on loan to an institution that can show an expertise in the field of deep sea radiolaria. The proponent institution must demonstrate a willingness to curate and make available this collection to specialists from the scientific community and should provide space, microscopes, a computer, and a collection of DSDP/ODP volumes for the visitors to use. They should also suggest contributions that they can make towards the general improvement of the MRC collections. Possible contributions include: (1) play an active role in selecting additional samples to improve the coverage of the collections; (2) play an active role in development of image database(s) under the guidance of the JOIDES Information Handling Panel; and (3) contribute toward the preparation of the MRC samples.

Further information can be obtained from :

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NOW AVAILABLE

DSDP / ODP FORAMINIFERAL COLLECTION

Eight sets of DSDP/ODP foraminiferal sieved residues have been prepared from more than 4,000 core samples chosen from important sites drilled since the beginning of the Deep Sea Drilling Project. These have been made available to the scientific community at eight Micropaleontological Reference Centers (MRCs) that have been geographically selected for world coverage.

To increase the usage of one of these sets, ODP proposes to offer it on loan to an institution that can show an expertise in the field of deep sea foraminifera. The proponent institution must demonstrate a willingness to curate and make available this collection to specialists from the scientific community and should provide space, microscopes, a computer, and a collection of DSDP/ODP volumes for the visitors to use. They should also suggest contributions that they can make towards the general improvement of the MRC collections. Possible contributions include: (1) play an active role in selecting additional samples to improve the coverage of the collections; (2) play an active role in development of image database(s) under the guidance of the JOIDES Information Handling Panel; and (3) contribute toward the preparation of the MRC samples.

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JOIDES Resolution PORT CALL NEWS

Marseilles, France

The *JOIDES Resolution* was in Marseilles, France prior to the two Mediterranean legs, March 8-12, 1995. For the occasion, the "Comité Scientifique ODP France" organized a series of tours of the ship for the media, national and local dignitaries, politicians, scientists, and students. As part of the program, Yves Lancelot, Catherine Mével, Philippe Pezard, Mathilde Cannat, Jean Pierre Henriet, and Anne Marie Karpoff gave talks on ODP and their involvement and contributions to the program. A splendid lunch buffet was offered on board the ship for specially invited guests on March 9th and the city of Marseilles hosted a reception for JOIDES in the evening at the Chamber of Commerce and Industry.

The port call was a great success with more than 400 people visiting the ship. Articles about ODP appeared in 8 international, national, and local newspapers, including Le Monde and the International Herald Tribune. Two T.V. stations covered the event. Thanks are due Martine Cheminée, Catherine Mével and Yves Lancelot of ODP France and Aaron Woods of ODP/TAMU for their efforts in organizing the Marseilles port call.

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The JOIDES Office now have data available from an anonymous ftp site on **ftp.cardiff.ac.uk**

The information includes a JOIDES calendar of meetings and a "Resolution" schedule, a directory of the JOIDES community as it will appear in the JOIDES Journal, containing names and addresses, and where known, telephone, fax and e-mail information. The files originated as Word 5.1 for Macintosh, and are stored as Macbinary Word files, RTF text files and unformatted text-only files.

The current usable directory tree is /

/pub/JOIDES/Calendar	Panel/Resolution Schedules
/pub/JOIDES/Directory	JOIDES Journal Directory
/pub/JOIDES/Minutes/DMP, PCOM, OHP, etc.	Panel Minutes
/pub/JOIDES/Proposals	Site Summary Forms etc.
/pub/JOIDES/Reports	

*Note : this system will check the syntax of entered userids

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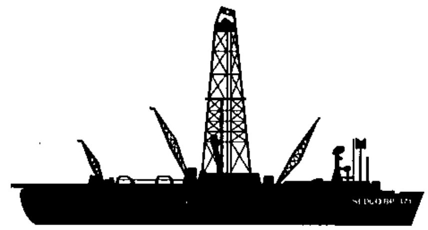

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Special Issue No. 1: Manual on Pollution Prevention and Safety, 1976 (Vol. II)
Special Issue No. 2: Initial Site Prospectus, Supplement One, April 1978 (Vol. III)
Special Issue No. 3: Initial Site Prospectus, Supplement Two, June 1980 (Vol. VI)
Special Issue No. 4: Guide to the Ocean Drilling Program, September 1985 (Vol. XI)
Special Issue No. 4: Guide to the Ocean Drilling Program, Suppl. One, June 1986 (Vol. XII)
Special Issue No. 5: Guidelines for Pollution Prevention and Safety, March 1986 (Vol. XII)
Special Issue No. 6: Guide to the Ocean Drilling Program, December 1988 (Vol. XIV)
Special Issue No. 7: Ocean Drilling Program Guidelines for Pollution Prevention and Safety, Oct., 1992 (Vol. 18)
Special Issue No. 8: Guide to the Ocean Drilling Program, June 1994 (Vol. 20)

Science Planning and Policy
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JOIDES Meeting Schedule

Panel	Dates	Location
TECP	20 - 22 Februaury '95	Pasadena, California
LITHP	22 - 25 Feb '95	College Station, Texas
BCOM	28 Feb - 2 March '95	Washington, DC
SGPP	2 - 4 March '95	Boulder, Colorado
OHP	2 - 4 March '95	Miami, Florida
DMP	8 - 10 March '95	Leicester, United Kingdom
IHP	8 - 10 March '95	College Station, Texas
SMP	8 - 10 March '95	College Station, Texas
PPSP	23 - 24 March '95	College Station, Texas
SSP	5 - 7 April '95	Dartmouth, Nova Scotia
PCOM	25 - 28 April '95	Makuhari, Japan
EXCOM	3 - 6 July '95	Edinburgh, Scotland
PCOM	16 - 19 August '95	Portland, Oregon
SGPP	*26 - 28 September '95	Copenhagen, Denmark
SMP	* Fall '95	Bremen, Germany
OHP	*October '95	Halifax, Nova Scotia

* meeting requested but not yet approved

JOIDES Resolution Operations Schedule

Leg	Destination	Cruise Dates	Port of Origin†		Total Days	Transit	On Site
160	Mediterranean I	12 Mar - 3 May '95	Marseille,	8-11 Mar '95	52	11	41
161	Mediterranean II	8 May - 4 Jul '95	Napoli,	3-7 May '95	57	11	46
162	Atlantic Arctic Gateways II	9 Jul - 3 Sep '95	Leith,	4-8 Jul '95	56	15	41
163	S E Greenland VRM	7 Sep - 26 Oct '95	Reykjavik,	3-6 Sep '95	49	7	42
164	Gas Hydrates	30 Oct - 19 Dec '95	St.John's,	26-29 Oct '95	50	8	42
165	Carib. Ocean History‡	24 Dec '95 - 18 Feb '96	Miami,	19-23 Dec '95	56	11	45
166	Bahamas‡	23 Feb - 19 Apr '96	San Juan,	18-22 Feb '96	56	8	48
167	California Margin	24 Apr - 19 Jun '96	Panama,	19-23 Apr '96	56	17	39
168	Juan de Fuca Hydroth.	24 Jun - 19 Aug'96	San Francisco,	19-23 Jun '96	56	4	52
169	Sedimented Ridges II	24 Aug - 19 Oct '96	Victoria,	19-23 Aug '96	56	6	50
170	Costa Rica Margin	24 Oct - 19 Dec '96	San Diego,	19-23 Oct '96	56	11	45
			Panama,	19-23 Dec '96			

† Although five day port calls are generally scheduled, the ship sails when ready.

‡ These legs may be switched if further study shows that currents in the Santaren Channel are more favourable for the Bahamas project on Leg 165.

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