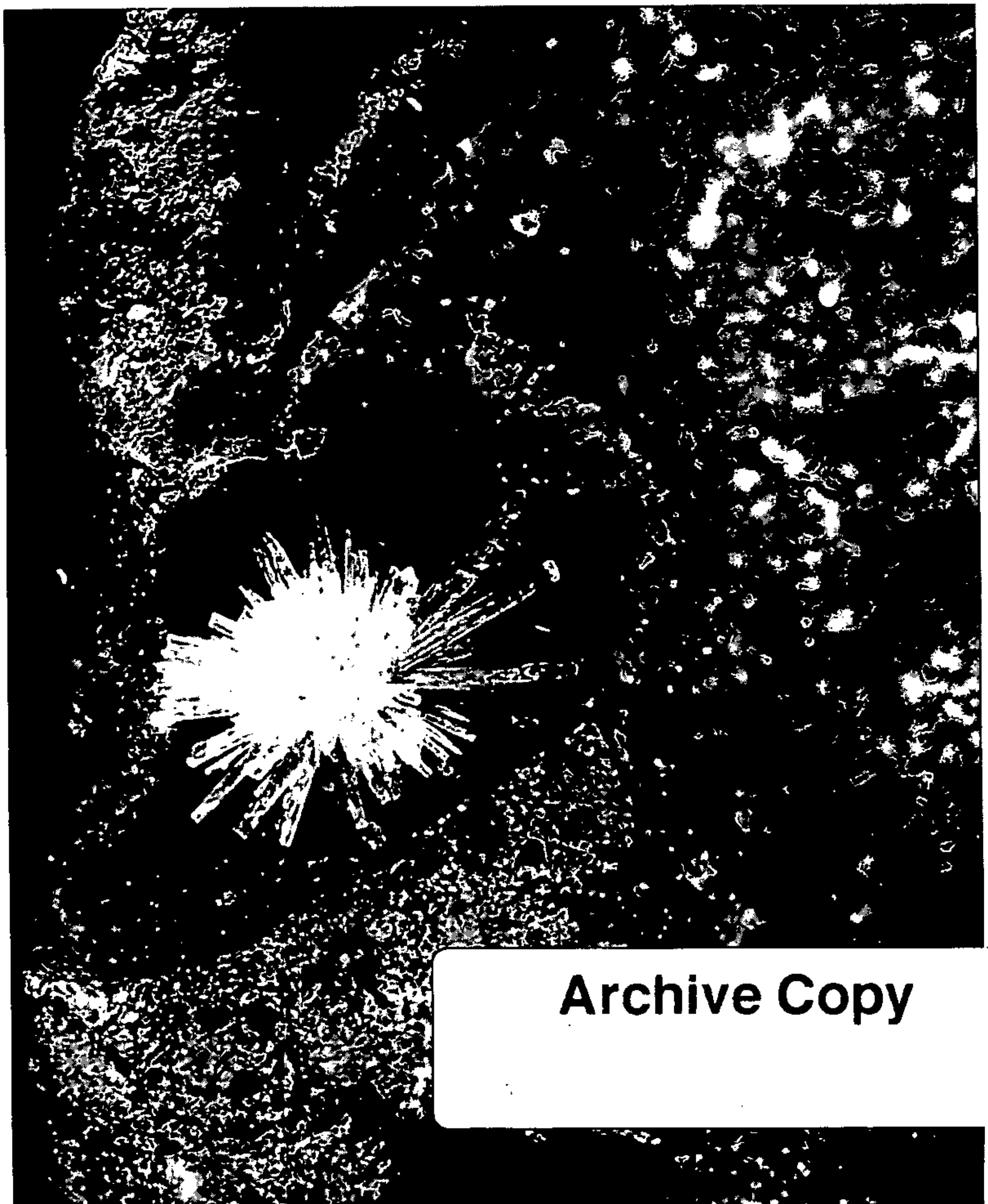
JOIDES Journal

VOL. XV, No. 3, October, 1989



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FOCUS

This newsletter gives me the opportunity to summarize for you the status of long-range planning in the JOIDES organization. For the longer term, the Executive Committee has accepted from the Planning Committee the Long Range Planning Document that Nick Pisias and his associates prepared. EXCOM passed it on to JOI, Inc., where it will be augmented and edited to become the basic scientific document for use in program renewal before the mid-1990's. JOIDES member countries will be able to use the Long Range Plan (LPR), or any parts of it,with whatever additional documents are needed to support their own particular renewal activities.

In passing the LPR to JOI, EXCOM asked that such additions as examples of benefits to education and industry be included. EXCOM also asked PCOM to reexamine the overall balance of the LPR, especially with regard to hard-rock coring versus sediment coring. At its August meeting PCOM did so. Because the Long Range Planning Document is a general assessment of the research areas in which scientific advancement is achievable by drilling, and not a specific drilling plan, PCOM concluded that the balance of drilling opportunities given in it does not require revision now. The balance of actual drilling will be determined by the proposals received and the thematic priorities that evolve as science and technology advance.

As the previous FOCUS newsletter stated, PCOM in spring 1990 will determine the general direction of the vessel over the following four years. The proponents of drilling are responding, and the JOIDES structure is gearing up for the task. New proposals and revisions of earlier ones are arriving at a rapid rate, and are being sent to the thematic panels for their review. Whereas we last reported that for several months proposals had been running about 4 to 1 in favor of the Pacific, for the past three months the ratio has been 3 to 1 in favor of the Atlantic. We have new or recently revised proposals for every ocean and the larger seas as well.

PCOM has adopted procedures designed to reduce possible misinterpretations of panel decisions about priorities and rankings. At the spring meeting each year, PCOM will determine the general track for the next four years in order to carry out a set of drilling programs which one or more of the thematic panels have ranked highly. Programs come from actual proposals addressing, in a specific locality, a scientific theme that has been published in a planning document, such as a COSOD report or a panel white paper. Programs must have a good chance of success with regard to present and anticipated site surveys, engineering developments, drilling platforms, and political and safety clearances. Programs may require less than one, one, or more than one leg of drilling; some programs may require back-to-back mega-legs, or perhaps a return to an area periodically. Each year PCOM will update its general 4-year plan, certainly by adding to the general track at the distal end and perhaps by modifying the intermediate part, depending on any revised rankings of its panels, and the state of such developments as site surveys and instrumentation.

In advance of every spring meeting, each thematic panel will prepare a single rankings list of the priority of the programs it wants drilled, regardless of region. The lists will be accompanied by a brief paragraph about each ranked program, to reduce the chance that PCOM will misunderstand the aim or importance of the program. Each year, as some proposals mature and as technical developments evolve, panels will update their lists for PCOM.

By the time you read this, the thematic panels will have completed their fall 1989 deliberations, but they will meet again in the late winter or early spring of 1990 to complete their evaluations and rankings. We wish them good luck.

Ralph Moberly
Planning Committee Chairman

JOIDES RESOLUTION OPERATIONS SCHEDULE

LEGS 128 - 135

		DEPARTURE		ARRIVAL			
LEG	AREA	LOCATION	DATE	LOCATION	DATE	IN PORT	DAYS AT SEA*
128	Japan Sea II	Pusan, Korea	08/26/89	Pusan, Korea	10/16/89	10/16 - 10/17	51
-----	Transit	Pusan, Korea	10/18/89	Singapore	10/27/89	10/27 - 11/11	9
-----	Transit	Singapore	11/12/89	Guam	11/22/89	11/22 - 11/23	10
129	Old Pacific	Guam	11/24/89	Guam	01/19/90	01/19 - 01/23	56
130	Ontong Java	Guam	01/24/90	Guam	03/25/90	03/25 - 03/29	60
131	Nankai	Guam	03/30/90	Pusan, Korea	05/31/90	05/31 - 06/04	62
132	Engineering II	Pusan, Korea	06/05/90	Guam	07/30/90	07/30 - 08/02	55
-----	Transit	Guam	08/03/90	Port Moresby, Papua New Guinea	08/10/90	08/10 - 08/11	7
133	N.E. Australia	Port Moresby, Papua New Guinea	08/12/90	Brisbane, Australia	10/07/90	10/07 - 10/11	56?
134	Vanuatu	Brisbane, Australia	10/12/90	Suva, Fiji	12/07/90	12/07 - 12/11	56?
135	Lau Basin	Suva, Fiji	12/12/90	?	02/06/91	?	56?

Revised 07/19/89

*Schedule subject to change pending detailed planning for Legs 130 through 135

LEGS 125 AND 126: BONMAR PRELIMINARY REPORT

INTRODUCTION

Leg 125 sailed from Guam on 20 February 1989 and arrived at Tokyo, Japan on 17 April, 1989. Leg 126 departed Tokyo, Japan on 22 April 1989 and returned to Tokyo on 19 June 1989. Leg 125 Co-Chiefs were Drs. Patricia Fryer (HIG) and Julian Pearce (U. Newcastle-Upon-Tyne). Drs. Brian Taylor (HIG) and Kantaro Fujioka (ORI) were Co-Chief Scientists for Leg 126. Drs. Laura Stokking and Tom Janecek were ODP Staff Scientists for Legs 125 and 126, respectively. Comprehensive reports on the preliminary scientific and operational results are available from the Ocean Drilling Program Publications Distribution Specialist, Texas A&M University Research Park, 1000 Discovery Drive, College Station, TX 77840.

The Bonin-Mariana region (Fig. 1) is made up of a complex series of arcs and basins formed since the start of westward subduction of Pacific lithosphere during the Eocene. Subduction of Pacific oceanic lithosphere is currently taking place at absolute velocities between 8-10 cm/yr to the northwest; the subduction angle is about 20° at shallow depths, steepening in some places to nearly vertical below about 100 km.

The evolution of these arc and basin systems is thought to have begun in the early-middle Eocene, when westward subduction of Pacific lithosphere began beneath the West Philippine plate (Ben-Avraham and Uyeda, 1983; Karig, 1975; Ogawa and Naka, 1984). Development of the system continued through the early Oligocene, forming an intraoceanic volcanic arc. Rifting in the middle Oligocene split the entire arc system, and the southern part of the arc split again in the late Miocene.

The Mariana and Izu-Bonin forearcs differ in both their tectonic evolution and plate-convergence characteristics. The northern half of the Izu-Bonin forearc has experienced little deformation since subduction began (Honza and Tamaki, 1985) and is made up of a broad foearc basin filled with volcaniclastic and hemipelagic sediments that developed behind an outer-arc high. The structure of the Mariana forearc is similar, but the forearc has undergone extensive vertical uplift and subsidence resulting from seamount collision, and from tensional and rotational fracturing associated with adjustments to plate subduction and to changes in configuration of the arc. There is a broad zone of serpentinite seamounts along the trench-slope break (outer-arc high) of the Mariana system. These seamounts are suggested to have formed by diapirism (Bloomer, 1983; Fryer *et al.*, 1985b; Fryer and Fryer, 1987). In the Izu-Bonin forearc, choritized mafic and serpentinized ultramafic rocks have also been dredged from a chain of local highs located less than 50 km from the trench axis along a lower-slope terrace (Ishii, 1985).

The modern 150-220-km-wide Izu-Bonin and Mariana forearcs may have formed by volcanism during arc development in the Eocene and early Oligocene. The origin and evolution of the forearc basement may have progressed in accordance with one of the following scenarios, each of which implies a different crustal structure:

1. The frontal arc and outer-arc high could have been continuous originally, and subsequently separated by forearc spreading.

2. The frontal arc and outer-arc high could have been built separately but nearly synchronously on former West Philippine plate crust.

3. The terrane could form part of a continuous Eocene arc volcanic province, possibly with overprints of later forearc volcanism.

The forearc stratigraphy should also record a history of the variations in intensity and chemistry of arc volcanism, and allow the correlation of these variations with such parameters as subduction rate and backarc spreading. Studies of the tephrachronology, the frequency and geochemistry of ash and

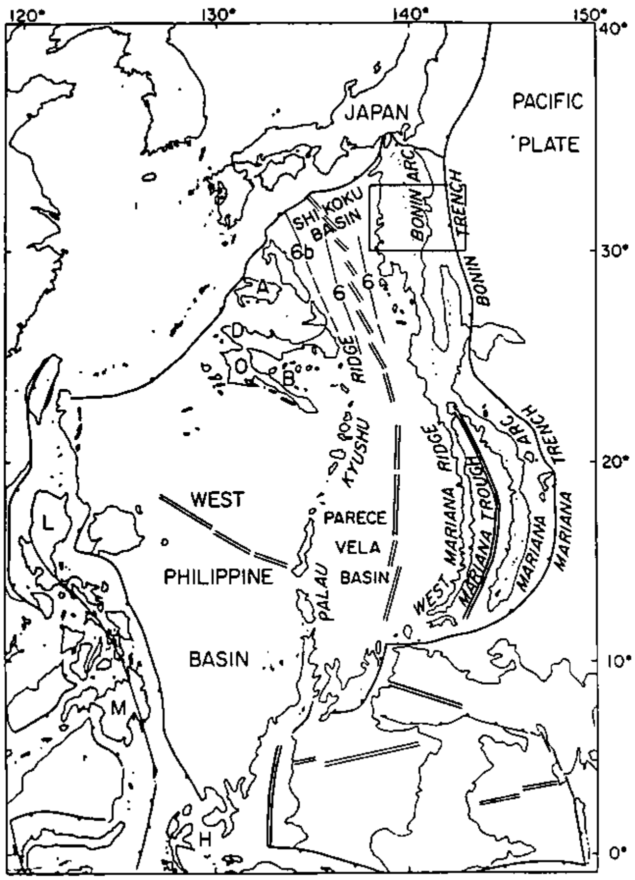

Figure 1. Active plate boundaries and relict spreading centers in the Philippine Sea region. Barbed lines locate subduction zones, medium double lines locate active spreading centers, and thin double lines locate relict spreading centers. Basins and ridges are outlined by the 4-km bathymetric contour, except for the Izu-Bonin, West Mariana and Mariana arcs which are outlined by the 3-km contour. Magnetic anomalies 6 and 6B are shown by thin lines in the Shikoku Basin. A=Amami Plateau; B=Daito Basin; D=Daito Ridge; H=Halmahera; L=Luzon; M=Mindanao; O=Oki Daito Ridge. The box shows the location of Figure 2.

pyroclastic flow deposits in the forearc basin drill cores, will enable the various models of arc volcanism to be evaluated.

LEG 125 HIGHLIGHTS

Leg 125 drilled nine sites four in the Mariana forearc (Sites 778 through 781) and five in the Bonin forearc (Sites 782-786). The primary objective of all nine sites was the study of two important, yet poorly understood aspects of the Izu-Bonin-Mariana forearc terranes:

•The origin and evolution of the forearc terranes, investigated by drilling a series of holes through the sediments and into the basement of the Mariana and Izu-Bonin forearc basins (Sites 782, 785 and 786) and into serpentinite seamounts from the Mariana mid-forearc region (Sites 778-781) and Izu-Bonin lower-slope terrace (Sites 783-784).

•Dewatering of the subducted lithosphere, investigated indirectly from the composition of forearc basin crust and directly from analysis of fluids, chemical precipitates and metamorphic rocks from the serpentinite seamounts.

Mariana Izu-Bonin Forearc

The principal results from drilling in the Mariana and Izu-Bonin forearcs include:

•A Pliocene or younger basalt flow or sill, penetrated at Site 781, is the first evidence for such recent magmatic activity in any extant intra-oceanic forearc terrane.

•The uppermost basement recovered at Site 782 consists of Eocene intermediate-acid submarine volcanic rocks of island-arc tholeiite to calc-alkaline affinities.

•The deep penetration of Eocene volcanic crust at Site 786 provided a record of the construction and structure of the forearc volcanic basement as well as a basis for the understanding of early arc magmatism, in general, and boninite petrogenesis, in particular.

•The identification of numerous ash layers within the forearc basin sediments indicates peaks of volcanic activity during the Eocene-Oligocene and from the late Miocene to the Holocene.

•The volcanic basement at Site 786 shows extensive evidence of hydraulic fracturing and precipitation of sulfide and other minerals from hydrothermal fluids.

Mariana-Izu-Bonin Serpentinite Seamounts

Initial results of Leg 125 show that:

•The serpentinite seamount, Conical Seamount (Sites 778-781), may be constructed from protrusions (flow emplacement) of serpentinite mantle materials and/or flows of unconsolidated serpentinite mud and entrained ultramafic and rare mafic clasts emanating from a central conduit.

•Low- to medium-grade metamorphism characterizes the source region of the serpentinite that formed both seamounts.

•Dehydration of the subducted lithosphere may have played an important role in the serpentinization of the source region of the serpentinite seamounts.

•Hydrocarbons are a significant component of the fluids associated with Conical Seamount.

•The Izu-Bonin seamount (Sites 783, 784) is at least Miocene in age, hence older than Conical Seamount and currently inactive in terms of flow generation.

•Serpentinization is still occurring in the Izu-Bonin seamount, but without the low-chlorinity component identified at Conical Seamount.

LEG 126 SITE REPORTS

The Izu-Bonin and Mariana regions are type examples to which other, less well studied arc-trench systems are compared. Yet fundamental questions about their evolution existed with regard to (1) arc rifting, (2) arc/forearc magmatism and structure, and (3) arc/forearc stratigraphy and vertical tectonics. To address these questions, Leg 126 had the following objectives:

In the arc/backarc (Sites 788-791):

(1) The differential uplift/subsidence history of the rift basin and adjacent arc margin; (2) The nature of volcanism and sedimentation in the rift and on the arc; (3) The duration of rifting and the nature of the rift basement; and (4) The chemistry of fluids circulating in the rift basin.

In the forearc (Sites 787, 792, and 793):

(1) The uplift/subsidence history across the forearc to provide information on forearc flexure and basin development as well as the extent of tectonic erosion; (2) The stratigraphy of the forearc with its record of (a) sedimentation, depositional environment and paleoceanohgraphy; and (b) the variations in intensity and chemistry of arc volcanism over time; (3) The nature of igneous basement forming the frontal arc, outer-arc high and beneath the intervening basin, to answer questions concerning the initial stages of subduction-related volcanism, the origin of boninites, and the formation of the 200-km-wide arc-type forearc crust; and (4) The microstructural deformation and the large-scale rotation and translation of the forearc.

Site 787

Site 787 (proposed site BON-5C; 32°22.51'N, 140°44.64'E, 3259.0 m water depth) is located on the eastern edge of the Izu-Bonin forearc sedimentary basin (Fig. 2). It is located in the axis of Aoga Shima Canyon; the canyon has removed up to 1 km of the sedimentary section. The principal objectives were to determine: (1) The stratigraphy of the forearc basin and hence both the temporal variations in sedimentation, depositional environment, and paleoceanography and the history of the intensity and chemistry of arc volcanism; (2) The uplift and subsidence history across the forearc to provide information on forearc flexure and basin development as well as on the extent of any vertical tectonic activity which may have taken place since the formation of the forearc terrane; and (3) The microstructural deformation

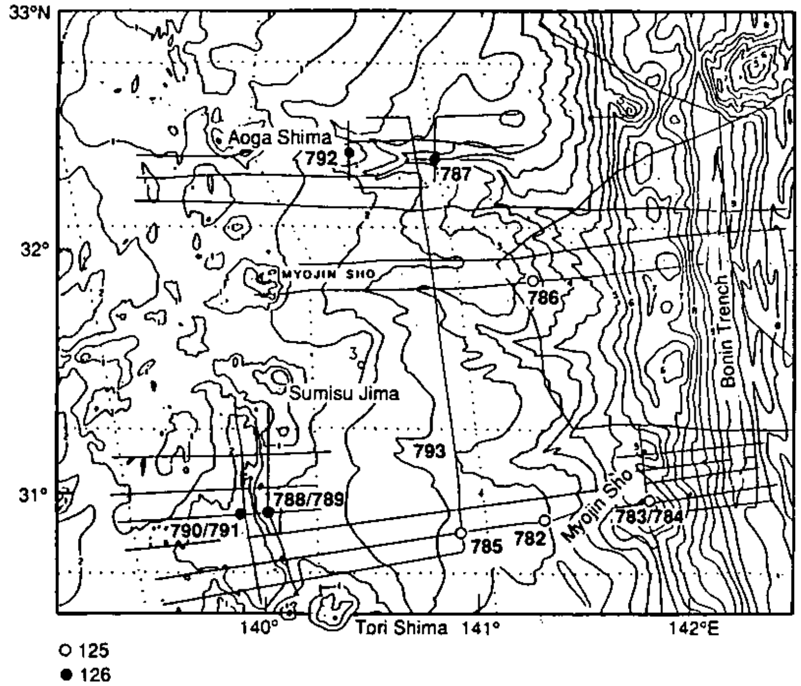

Figure 2. Location map showing multichannel seismic (MCS) survey lines and precise setting of Leg 126 sites (filled circles) and Leg 125 sites (open circles).

and the large-scale rotation and translation of the forearc terrane since the Eocene.

The principal results of this site are:
(1) Characterization of hemipelagic and turbidite deposition in this deep-water forearc basin in the late Oligocene;
(2) Documentation of continuous arc volcanism during the previously purported Bonin-Mariana volcanic minimum in the late Oligocene,
(3) Recognition of moderate to high sedimentation rates in the late Oligocene and extrapolation of average rates greater than 100 m/my back to the presumed middle Eocene basement;
(4) Paleomagnetic evidence that there has been Neogene translation of this site about 8° to the north; (5) Microstructural evidence of extensional deformation;
(6) Constraints on the time of major submarine canyon formation in this area to the (probably late) Miocene-Pliocene; and (7) Pore-water indications of a possible seawater aquifer within the basin.

Four lithostratigraphic units were defined at Site 787:

➡Unit I (0-21.4 mbsf) is lower Pleistocene sandy gravel, gravelly sand, gravel, and silty sand, all scoriaceous and pumiceous.

➡Unit II (21.4-40.3 mbsf) is Pliocene and upper miocene lithic-vitric-rich nannofossil ooze and nannofossil-bearing volcanolithic silty clay.

➡Unit III (40.3-118.9 mbsf) is upper Oligocene vitric-rich claystone, nannofossil chalk and pumiceous and scoriaceous sandy claystone, with a lower 2.6-m-thick welded crystal-lithic lapilli tuff.

➡Subunit IVA (118.9-281.7 mbsf) is upper Oligocene interbedded graded vitric silty sandstone, bioturbated silty claystone, and nannofossil silty claystone, with volcanic ash distributed throughout.

➡Subunit IVB (281.7-320.1 mbsf) is upper Oligocene gravel-rich and pebbly coarse sandstone and nannofossil silty claystone.

Units I and II are unconsolidated, whereas III and IV are lithified. All sediments were deposited in water depths below 2000 m and above the CCD. The volcaniclastic sands and gravels of Unit I represent early Pleistocene canyon fill. Unit II is bounded both above and below, and is separated internally, by unconformities and records of intermittent hemipelagic deposition during canyon erosion. The lithification of the Oligocene erosion requires significant former overburden. The clastic component in Unit III results from distal turbidite deposition and volcanic ash fall as well as one andesitic submarine pyroclastic flow. Subunit IVA represents basin-plain volcaniclastic turbidite deposits interbedded with fine-grained hemipelagic sediments. Subunit IVB is probably a channel deposit, although the seismics suggest that this higher velocity coarse material is regionally distributed. The upper Oligocene section is strongly burrowed. Extensional microfaults, conjugate fracture sets, low-angle shear planes, clastic injections, and dewatering veinlets all evidence post-depositional extensional deformation.

Sites 788 and 789

Sites 788 (proposed site BON-2; 30°55.4'N, 140°00.2'E; 1113.0 m water depth) and 789 (30°55.2'N, 139°59.8'E; 1129 m water depth) are located on the eastern margin of the Sumisu Rift between the Izu-Bonin arc volcanoes Sumisu Jima and Tori Shima (Fig. 2). The sites are just over 0.5 km apart and are situated on the summit of the rift-flank footwall uplift, which is cut by high-angle normal faults dipping away on both sides from Site 788. The principal objectives at these sites were to determine: (1) The vertical motion history of the rift margin; (2) The time of intitial rifting; and (3) The nature and history of volcanism and sedimentation between the major arc volcanoes.

The principal results of these sites are: (1) The arc margin footwall of Sumisu Rift has been uplifted 200-1700 m; (2) The footwall uplift, and therefore the initiation of rifting occurred since 2.35-33.56 Ma; (3) Present-day and pre-rift volcanism and sesdimentation along the volcanic front is dominated by rhyolitic pumice eruptions; and (4) unlike other arcs such as Japan and the Cascades, there is no evidence of igneous vents or lava flows between large frontal-arc volcanoes during the last 5 my.

Two lithostratigraphic units were defined at Site 788:

➡Subunit IA (0-230.0 mbsf) is upper Pleistocene and Pliocene sandy, granule- and pebble-sized puniceous gravel locally interbedded with vitric sands and rare vitric silts.

➡Subunit IB (230.0-249.0 mbsf) is a Pliocene transition unit comprised of the same material as Subunit IA, but which has been lithified to conglomerate.

➡Subunit IIA (249.0-278.6 mbsf) is lower Pleistocene interbedded nannofossil-rich claystone and vitric sandstone, silty claystone, and siltstone, moderately burrowed.

➡Subunit IIB (278.6-374.0 mbsf) is lower Pliocene interbedded pumiceous conglomerate and vitric sandstone, siltstone, and silty claystone.

Site 789 recovered 0.1 m of Pleistocene pumice from the surficial core.

The sediments are dominantly arc-derived volcaniclastics; no igneous rocks were recovered. The silt/clay component and all biogenic materials are virtually absent from the coarse clastics, probably as a result of winnowing. Carbonate-rich sections (Unit II) reflect slower deposition during volcanic minima lasting up to 300 ky. Upward-coarsening intervals in Unit I repsresent four large eruptions or four periods during which volcanism climaxed, three in the Pliocene and one in late Pleistocene. The degree of compaction of Unit II suggests that formerly the overburden was greater than at present.

Sites 790 and 791

Site 790 (proposed site BON-1A; 30°54.96'N, 139°50.66'E; 2223 m water depth) and Site 791 (30°54.97'N, 139°52.50'E; 2268 m water depth) are located near the center of Sumisu Rift, a backarc graben west of Izu-Bonin island arc volcanoes Sumisu Jima and Tori Shima (Fig. 2). The sites are 2.4 km apart and are situated on the western side of the eastern inner-rift half graben.

The syn-rift sediments dip to the east with regional basal dips of 15° and are cut by 45-60° dominantly west-dipping normal faults.
The principal objectives of this site were to determine: (1) The vertical motion history of the rift basin; (2) The nature of volcanism and sedimentation in the rift; (3) the duration of rifting and the nature of the rift basement; and (4) The chemistry of fluids circulating in the rift basin.

The principal results of this site are: (1) Rifting began, and rift basement depths exceeded 2 km prior to 1.1 Ma; (2) Basement was formed by early-rift basaltic lavas and intrusives, as well as by arc pyroclastics metamorphosed to zeolite or lower greenschist facies; (3) A large volume, deep submarine eruption of water-rich basalt produced basaltic Mousse, a highly expanded basaltic glass with vessicular "clasts" in an even more vessivular glassy matrix of the same composition; (4) Extremely rapid, differential and accelerating subsidence and sedimentation occurred in the inner-rift half-graben in the last 1.1 my; (5) Intra-rift basaltic eruptions and rhyolitic arc eruptions were common, but explosive arc volcanic activity dramatically increased 250 Ka; (6) A large proportion of the pyroclastic and pelagic materials were (re)deposited by submarine mass flows; (7) Fluids other than seawater are not circulating locally through the sediments; and (8) The decrease of dipole intensity and the reversal in inclination associated with the Brunhes/Matuyama polarity transition is limited to about 600 yr and occurred in perhaps as little as 100 yr.

Three lithostratigraphic units were defined at Sites 790 and 791:

➡Unit I, deposited in the last 0.25 my, is vitric silt and sand, pumiceous gravel and virtic silty clay at Site 790 (0-165.0 mbsf) and is pumiceous gravel and sand, vitric silt, pumiceous pebbly sand and vitric clay at Site 791 (0-473.0 mbsf).

➡Unit II, deposited 0.25-1.1 Ma, is burrowed nannofossil-rich clay, silty clay and clayey silt at Site 790 (165.0-271.0 mbsf) and is nannofossil-rich, burrowed claystone and sandy mudstone and vitric silt at Site 791 (473.0-834.0 mbsf).

➡Unit III, is scoriaceous basalt at Site 790 (271.0-387.0 mbsf), and is, in order of first occurrence downsection, basalt breccia, basalt, disbase, basaltic "mousse," and mafic to felsic tuff and lapilli tuff at Site 791 (834.0-1145.0 mbsf) A vitric siltstone occurs at 329 mbsf at Site 790 and a coarse sandy silt occurs at 975 mbsf at Site 791; both layers are Pleistocene.

Bimodal mafic-felsic volcanism is recorded throughout the sedimentary history of the basin, though the relative proportions of each component change. Explosive arc volcanism, probably from Sumisu and/or South Sumisu calderas, provided large thicknesses of felsic sand and gravel five times during the deposition of Unit I at approximately 60-ky intervals.

Differential subsidence between the two sites is matched by both the clastic and biogenic sedimentation, with rates for Unit II at Site 791 being nearly four times those at 790. This, and the lack of coeval material on at least the eastern rift flank, requires that a large proportion of the pyroclastic and pelagic materials were redeposited by submarine mass flows.

Site 792

Site 792 (proposed site BON-4; 32°23.96'N, 140°22.80'E, 1787 m water depth) is located on the western half of the Izu-Bonin forearc sedimentary basin (Fig. 2). The principal objectives of this site were to determine: (1) The stratigraphy of the forearc basin and hence both the temporal variations in sedimentation, depositional environment and paleoceanography, and the history off the intensity and chemistry of the arc volcanism; (2) The uplift and subsidence history across the forearc; (3) The nature of the igneous basement and the formation of the 200-km-wide arc-type forearc crust; and (4) the microstructural deformation and the large-scale rotation and translation of the forearc terrane since the Eocene.

The principal results of this site are: (1) Characterization of varying volcanogenic input to the forearc, from extremely rapid prior to 27 Ma to minimal between 27 and 13 Ma to moderate and increasing between 13 Ma and present; (2) Documentation of ongoing explosive volcanism since the late Pliocene; (3) Correlation *via* VSP and logging of the core and seismic stratigraphy, indicating filling of the basin between the frontal arc and outer-arc highs in the mid-Oligocene; (4) The first recovery of the igneous basement beneath such an intra-oceanic forearc basin and initial description of its unusual trace element chemistry, characterized by weakly enriched low field strength elements and depleted high field strength elements, the latter indicating derivation from a refractory mantle source; (5) Benthic foraminiferal evidence for 1-2 km of basement uplift since 29 Ma; (6) Microstructural evidence of extensional deformation; (7) Pore-water indications of low-temperature alteration of the volcanogenic sediments, producing fluids extremely enriched in Ca and depleted in Mg, silica, and sulfate; (8) Paleomagnetic evidence that the Brunhes/Matuyama reversal involved a double polarity transition during a period of decreased field intensity lasting 3000 yr or less; and (9) measurement of heat flow at 56 mW/m^2.

Six lithostratigraphic units were defined at Site 792:

➡Unit I (0-183.7 mbsf) is upper Pliocene to Holocene nannofossil-rich, vitric silty clay and clayey silt, interbedded with vitric silts and sands and minor pumiceous and scoriaceous gravels.

➡Unit II (183.7-357.4 mbsf) is middle and upper Miocene sandy mudstone, muddy sandstone, and silty claystone (all with nannofossil-rich intervals), vitric sandstone and vitric siltstone.

➡Unit III (357.4-429.3 mbsf) is upper Oligocene to middle Miocene intensely bioturbated, nannofossil-rich claystone and nannofossil chalk, and rare crystal vitric siltstone and sandstone.

➡Unit IV (429.3-783.4 mbsf) is upper Oligocene vitric sandstone and volcanic sandy conglomerate containing claystone intraclasts, with minor silty claystone and claystone that have some nannofossil-rich intervals.

➡Unit V (783.4-804.0 mbsf) is altered volcanic sandstone with claystone intraclasts.

➡Unit VI (804.0-885.9 mbsf) is porphyritic andesite with minor basaltic andesite and dacite.

Site 793

Site 793 (31°06.33'N, 140° 53.27'E; 2964 m water depth) is located in the center of the Izu-Bonin forearc sedimentary basin, about 70 km east of the volcanic front between the islands of Sumisu Jima and Tori Shima (Fig. 2). The principal objectives of this site were the same as for Site 792.

The principal results of this site, which made the deepest penetration reaching basement in the history of DSDP/ODP, are: (1) Documentation of the absence of pre-middle Oligocene sediments in the forearc basin depocenter; (2) Benthic foraminiferal evidence that depositional water depths shallowed from 4-5 km in the middle Oligocene to 2-4 km at present; (3) Interpretation that the forearc basin formed by mid-Oligocene rifting separating the formerly contiguous Eocene forearc and outer-arc highs; (4) Recovery of the igneous basement beneath the center of the forearc basin; (5) Confirmation of varying volcanogenic input to the forearc, including volcanic quiescence during the early Miocene and a dramatic increase in volcanic activity in late Quaternary; (6) Documentation of a Neogene intrusion 70 km in front of the "volcanic front;" (7) Microstructural evidence of an extensional regime throughout the forearc basin history; (8) Paleomagnetic evidence that the forearc has been translated about 15° north since 30 Ma; (9) Pore-water indications of low-temperature alteration of the volcanogenic sediments, producing CaCl-type waters; and (10) Establishment of a deep, open reentry site for future investigators.

Seven lithostratigraphic units were defined at Site 793. They are:

➡Subunit IA (0-32.5 mbsf) is Pleistocene pumiceous gravel, sandy gravel, nannofossil clay, nannofossil clayey silt, nannofossil-rich clay and nannofossil-rich clayey silt with rare vitric sand, vitric silt and vitric sandy silt.

➨Subunit IB (32.5-99.7 mbsf) is Pleistocene pumiceous and vitric sand, nannofossil-rich clay and nannofossil-rich clayey silt, nannofossil clay and nannofossil silty clay, vitric silt and pumiceous gravel.

➨Unit II (586.5-591.0 mbsf) is an olivine-clinopyroxene-orthopyroxene diabase.

➨Unit III (591.0-735.7 mbsf) is lower to middle Miocene nannofossil-rich silty claystone, nannofossil-rich and nannofossil claystone, vitric siltstone and sandstone, clayey siltstone, and nannofossil-rich clayey siltstone.

➨Unit IV (735.7-759.0 mbsf) is lower Miocene claystone, nannofossil and nannofossil-rich claystone, and vitric siltstone.

➨Unit V (759.0-1373.1 mbsf) is upper lower and upper Oligocene vitric sandstone, pumiceous sandstone, granule- to fine-pebble conglomerate, siltstone, clayey siltstone and silty claystone.

➨Unit VI (1373.1-1403.9 mbsf) is upper lower Oligocene very poorly sorted volcanic breccia with sandy matrix, and mixer fresh to altered clasts of mainly plagioclase-rich andesite.

➨Unit VII (1403.9-1682.0 mbsf) is upper lower Oligocene breccias and massive to pillowed flows of porphyritic clinopyroxene-orthopyroxene, and aphyric, basaltic andesites and andesites.

Volcanism without epiclastic sedimentation accompanied the initial mid-Oligocene forearc basin subsidence; as the formerly contiguous Eocene outer-arc and frontal-arc highs were separated. This separation probably resulted from rifting rather than spreading at a well-defined axis, given the scale of the basin (40-70 km wide) and because the multichannel seismic data suggest the presence of half-graben and low-angle detachments in the basement. Most of the Site 793 basement lavas and breccias belong to a high-Mg series of basaltic andesites, with boninitic affinities. The aphyric lavas and clasts belong to a low-Mg series with tholeiitic affinities. Their high field strength element ratios indicate a depleted mantle source.

Summary and Conclusions

Initial results of Leg 126 show that:

•The forearc basin formed between 31 and 34 Ma by separation of formerly contiguous frontal- and outer-arc highs. Igneous basement beneath the center of the forearc basin includes high-Mg series basaltic andesites, andesites with boninitic affinities, and low-Mg series lavas with tholeiitic affinties. The forearc has been translated about 15°N and uplifted 1-2 km since 30 Ma.

•The present rifting of the arc at 31°N began 1.1-3.56 Ma. The basement of the rift is composed of early rift basaltic lavas and intrusives as well as arc pyroclastics metamorphosed to zeolite or lower greenschist facies. The pyroclastic eruption of highly vesicular basalt (mousse) in the rift occurred in relatively deep water (>1.5-2.0 km). The footwall of the Sumisu Rift has been uplifted 200-1700 m.

•Following a minimum in volcanic output between 24 and 13 Ma, there has been a steady increase in explosive volcanic activity, with a dramatic increase at 250 Ka in the Sumisu Jima region.

•High-resolution paleomagnetic records of the Brunhes/Matuyama reversal event document a sequence of two rapid reverse-to-normal changes in inclination and declination, with transitions occurring on a scale of hundreds of years.

•The most extensively altered pore-water fluids ever documented by DSDP/ODP occur in Oligocene volcanogenic sediments in the forearc basin. Low-temperature alteration of the sediments has produced fluids enriched in Ca and depleted in Mg, silica and sulfate, relative to seawater.

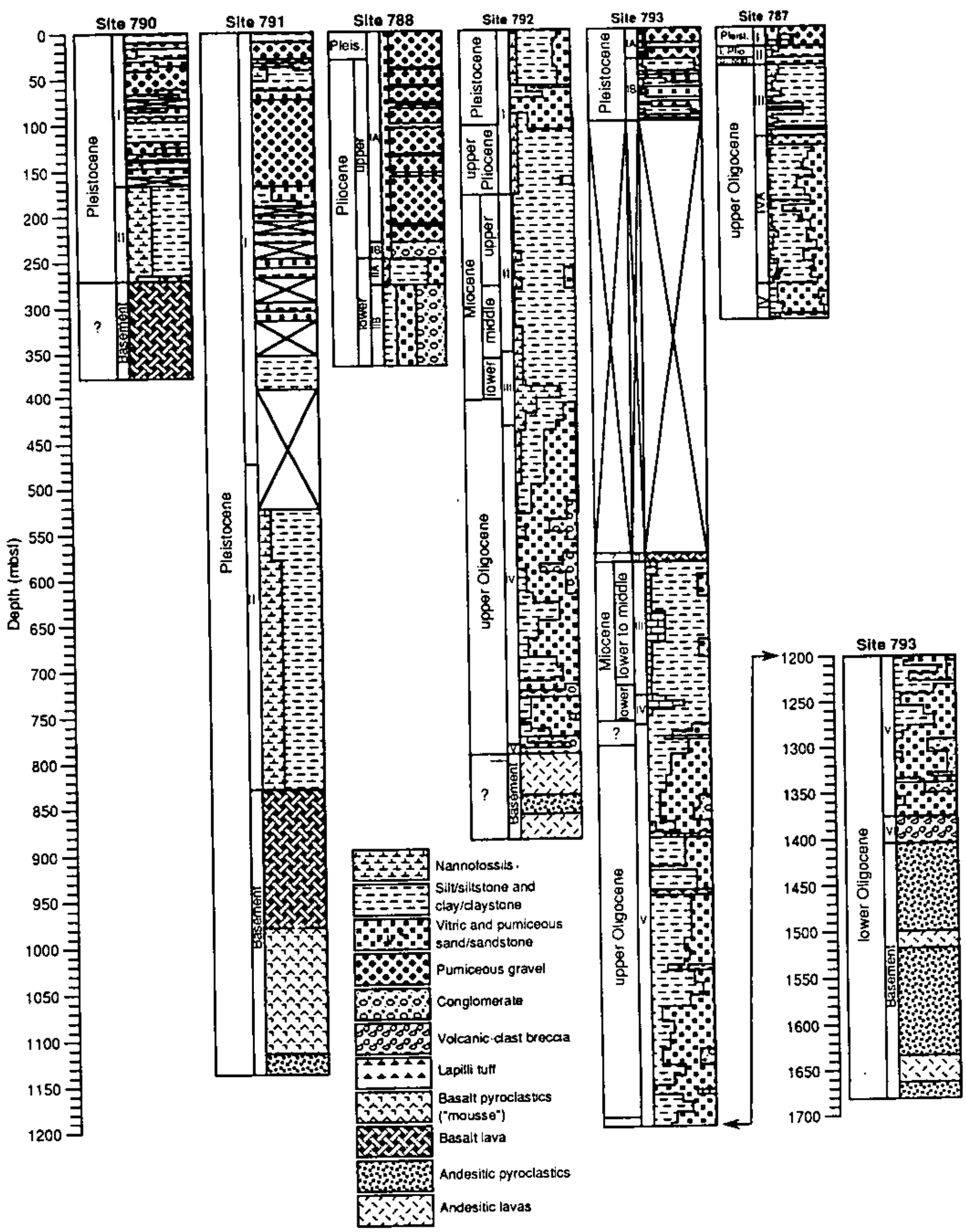

Figure 3. Summary lithostratigraphy for Leg 126 sites.

Table 1. Summary Site Information, Legs 125 and 126

Hole	Latitude (°N)	Longitude (°E)	Water Depth Meters*	Number of Cores	Meters Cored	Meters Recov'd	Percent Recov'd	Meters Total Penet.
787A	32°22.51'	140°44.64'	3259	1	34.5	6.0	17.4	34.5
787B	32°22.51'	140°44.64'	3259	34	320.1	159.9	50.0	320.1
788A	30°55.35'	140°00.23'	1111	5	45.3	1.2	2.7	45.3
788B	30°55.38'	140°00.17'	1113	4	35.6	0	0	35.6
788C	30°55.36'	140°00.21'	1113	28	258.5	146.2	56.5	262.5
788D	30°55.37'	140°00.22'	1113	16	154.4	12.3	8.0	374.0
789A	30°55.24'	139°59.84'	1129	6	54.1	0.1	0.2	54.1
790A	30°54.95'	139°50.66'	2222	4	37.4	35.71	95.5	37.4
790B	30°54.96'	139°50.66'	2223	15	138.9	88.7	63.9	138.9
790C	30°54.95'	139°50.69'	2223	33	302.1	127.3	42.1	387.1
791A	30°54.96'	139°52.20'	2268	49	457.0	179.9	39.4	457.0
791B	30°54.98'	139°52.19'	2268	79	738.0	114.3	15.5	1145.0
792A	32°23.97'	140°22.81'	1787	10	95.0	72.1	75.9	95.0
792B	32°23.96'	140°22.81'	1787	11	100.7	43.6	43.3	146.4
792C	32°23.94'	140°22.78'	1787	1	9.6	0.6	6.2	146.4
793D	32°23.93'	140°22.80'	1787	1	9.6	0.8	8.8	146.4
792E	32°23.96'	140°22.79'	1787	78	750.3	361.9	48.2	885.9
793A	31°06.35'	140°52.26'	2964	11	99.7	79.0	79.2	99.7
793B	31°06.33'	140°52.27'	2964	114	1095.5	697.9	63.7	1682.0

* Depths are drill-pipe measurements corrected to sea level.

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LEG 127: JAPAN SEA SITE REPORTS

INTRODUCTION

Leg 127 began on 19 June with a port call in Tokyo, Japan, and ended on 21 August in Pusan, South Korea, after 58 operational days. The following site summaries were prepared by *JOIDES Resolution* Co-Chiefs Drs. Kenneth Pisciotto and Kensaku Tamaki (ORI). Dr. James F. Allan was the ODP/TAMU Staff Scientist for Leg 127. The unifying objective for drilling in the Japan Sea was to assess the style and dynamics of rifting and marginal sea formation in a continental arc setting.

Site Summary, Site 794

Hole 794A
Latitude: 40° 11.41' N
Longitude: 138° 13.86' E
Water Depth: 2811 m

Hole 794B
Latitude: 40° 11.40'N
Longitude: 138° 13.87'E
Water Depth: 2811 m

Hole 794C
Latitude: 40° 11.41'N
Longitude: 138° 13.86'E
Water Depth: 2809 m

The specific objectives at Site 794 (proposed site J1B-1), located in the northern Yamato Basin, were (1) to determine the nature and age of the basement, (2) to measure the direction of the present stress field, and (3) to characterize the sedimentation, subsidence and oceanographic evolution of the area.

The principal results at Site 794 are as follows:

(1) A dolerite sill complex was encountered in the deepest penetration. The age of the claystone above the uppermost sill gives a minimum age of basin initiation at this site of 14.5-16.5 Ma. The exact age and nature of basement, however, is still uncertain because (a) the tuff and claystone beneath the 110-m-thick interval of dolerite sills could not be dated and, (b) the acoustically opaque seismic interval, which underlies the highly reflective dolerite sill complex, and which may represent true basement, has not yet been penetrated. The *in-situ* stress field is not yet known because logging and packer tools used to make the measurements could not be run past stuck pipe in Hole 794C.

(2) The sedimentary and paleontologic sequences indicate that this area of northern Yamato Basin evolved in three stages: (a) A middle Miocene period characterized by bioturbated, hemipelagic claystones, gravity-flow tuffs, and minor glauconite and phosphorite, deposited at upper bathyal depths (~500 m) in suboxic marine waters on a slope or borderland ridge; followed by, (b) subsidence to lower bathyal depths (~>1500 m) during late middle Miocene and deposition of hemipelagic diatomaceous sediments and increasing amounts of volcanic ash through the early Pliocene in cool, well-oxygenated waters; and finally (c) a late Pliocene-to-Holocene period in which diatomaceous sedimentation shut down, volcanic ash production increased, and oscillating climate and tectonic activity conspired to produce interbedded massive and laminated hemipelagic sediments. Except for parts of the Quaternary, preservation of primary biogenic carbonate is poor, suggesting a consistently shallow CCD or dissolution during early diagenesis. Dissolution of siliceous microfossils is also widespread. Silica diagenetic transitions of opal-A/CT and opal-CT/quartz were well identified by lithology, geochemistry of sediments and interstitial water, physical property measurements and logging data. The opal-A/CT transition shows up clearly as a widespread bottom simulating reflector that can be traced extensively.

The sedimentary section cored in Holes 794A and B consists mainly of fine-grained hemipelagic sediments of Quaternary to early middle-late early Miocene age. Tuffs and tuffaceous sediments were recovered from Hole 794C between dolerite sills. The division of units is as follows:

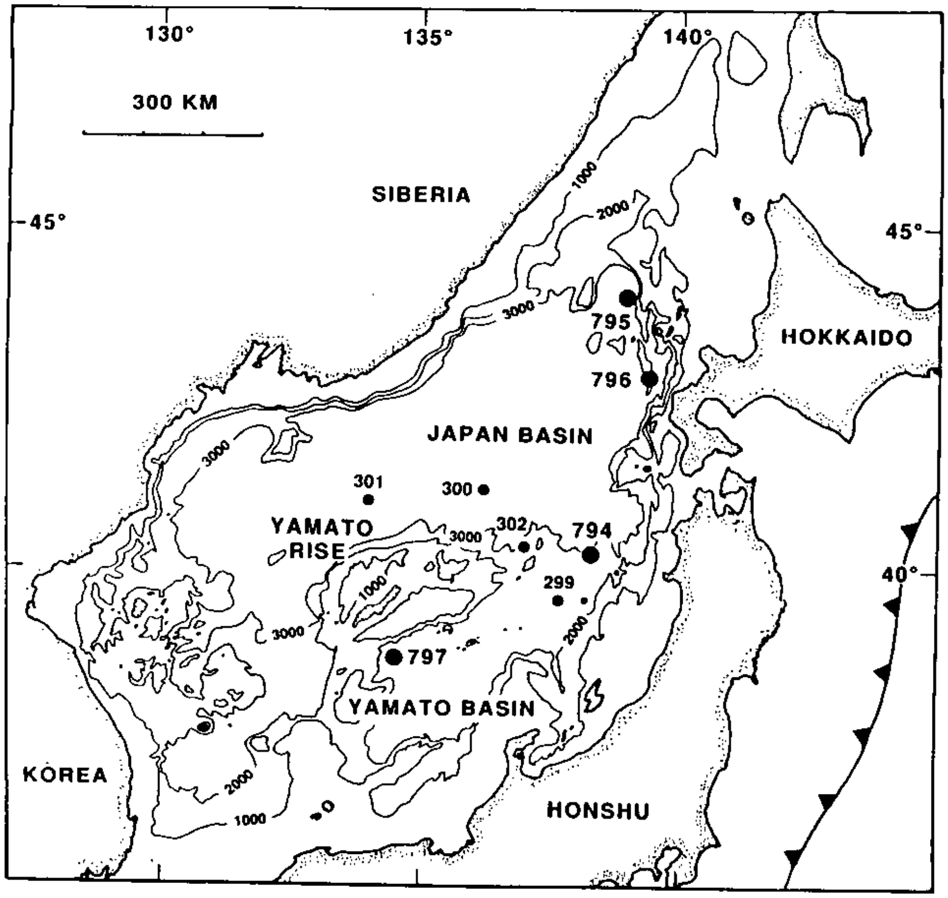

Figure 1. Location map of the Japan Sea showing Sites 794 through 797 drilled during Leg 127. DSDP Sites 299 through 302 are also shown.

➡Unit I (0 - 92.3 mbsf, 0-3.0 Ma): Clay and silty clay. The upper 63.8 m is alternating light bioturbated zones and dark laminated zones with common thin ash layers. The lower 28.5 m is similar, but with fewer dark zones.

➡Unit II (92.3 - 293.5 mbsf, 3.0-8.1 Ma): Diatomaceous ooze and clay. The upper 124.7 m consists of bioturbated ooze and clayey ooze with sparse ash layers. Diatomaceous clay comprises the lower 76.6 m. Diatoms decrease and opal-CT cement increases within this unit.

➡Unit III (293.5 - 491.7 mbsf, 8.1-~14.6 Ma): Clay and claystone. The upper 57.8 m is bioturbated clay and claystone with minor ash, pyrite and micritic carbonate. The lower 140.3 m is bioturbated claystone with rare laminated intervals. Porcellanites occur at several levels and dolomitic, sideritic, siliceous cements and phosphatic lenses are common.

➡Unit IV (491.7 - 520.6 mbsf, ~14.6-15.8 Ma): Interbedded tuff, lapilli tuff and claystone. Tuffs are variously thin- to thick-bedded, normal to inversely graded with sharp basal contacts. Some beds contain planar, convolute and cross laminations. Others contain burrowed intervals and are massive and poorly sorted with claystone fragments. Interbedded claystones are moderately bioturbated.

➡Unit V: (520.6 - 543.0 mbsf; ~15.8 - 16.5 Ma) Interbedded claystones of various compositions with minor tuffs. From top to bottom, silty claystone, phosphatic claystone and black claystone are the dominant lithologies with minor thin intervals and lenses of glauconitic claystone, pelletal phosphorite and pyrite. Sparse, thin tuff layers display cross laminations and flame structures.

➡Unit VI: (644.1 - 645.6 mbsf, age unknown): Bioturbated claystone and massive to laminated, fine-grained tuff. The tuff also shows colvolute laminations, small slump folds, normal size grading and bioturbated tops. This unit is separated from Unit V by about 100 m of dolerite.

Sedimentation rates are 30 m/m.y. for the Pleistocene-Pliocene (0-4.8 Ma), 45 m/m.y. for most of the late Miocene (4.8-9.4 Ma), and 30 m/m.y. for the early late Miocene-early middle to late early Miocene (9.4-16 Ma). These rates are computed using present-day compacted sediment thicknesses.

Sediments from Holes 794A and 794B are characterized by low organic carbon contents (TOC: range 0.1-3.0%; avg 0.7%) and by increases in diagenetic silica, dolomite, and phosphate with depth, particularly below 300 mbsf. Diatoms (opal-A) and volcanic glass decrease markedly below this level. Biogenic carbonate is sparse throughout much of the sediment column. Interstitial water profiles also show pronounced gradient changes below 300 mbsf. Sulfate is present throughout, indicating that the entire section is within the zone of sulfate reduction. Virtually no hydrocarbon gases were detected.

Penetration below the first contact between the dolerite and sediments is 6 m in Hole 794B and 109.4 m in Hole 794C. A total of 34.5 m was recovered below this contact (including sedimentary Unit VI). The igneous rocks are divided into the following six units:

➡Unit 1 (543-549 mbsf; the interval from 549 to 560 mbsf was not cored): Moderately plagioclase-phyric dolerite. A horizontal contact is observed at the top of this unit, with a thin zone of baked clay sediment above and a chilled margin of moderately plagioclase-phyric basalt below.

➡Unit 2 (560-601 mbsf): Moderately to highly plagioclase-phyric dolerite, massive and dense, with some highly fractured intervals.

➡Unit 3 (601-623 mbsf): Aphyric dolerite, moderately vesicular, massive and highly fractured.

➡Unit 4 (623-634 mbsf): Aphyric dolerite, massive, vesicular, medium- to fine-grained. The upper half of the unit is highly fractured.

➡Unit 5 (634-644 mbsf): Aphyric dolerite, highly vesicular. The lower boundary of the unit is sharply defined by a baked contact with tuffaceous sediments.

➡Unit 6 (645-646 mbsf): Aphyric basalt; the top of this unit is a chilled, intrusive margin against baked and welded tuff in the sedimentary Unit VI.

Temperature runs at 10 horizons down to 351 mbsf in Hole 794A measured a temperature gradient of 125°/km. The calculated heat flow is 103 mW/m^2, close to the average heat flow value of the Yamato Basin (97±12 mW/m^2).

Three logging runs were completed in Hole 794B (combination sonic-lithodensity/temperature/DIT, geochemical, and formation microscanner). The combination of the tools lengths and shallow basement penetration (5m) did not permit logging beyond 1 m above the basement-sediment contact. The boundary between Units II and III at 293 mbsf is clear on all three logs. The opal-A/CT transition, the opal-CT/quartz transition are clearly defined. Unit IV, the interval of tuff and claystone, shows up clearly between 490 and 520 mbsf as a zone of low density, velocity and resistivity. Each of these parameters increases again below this in the dolerite interval.

Site Summary, Site 795

Hole 795A
Latitude: 43° 59.2'N
Longitude: 138° 58.0'E
Water Depth: 3299.0 m

Hole 795B
Latitude: 43° 59.2'N
Longitude: 138° 57.9'E
Water Depth: 3298 m

Site 795 was located in a bathymetric embayment in the northernmost Japan Basin, just south of proposed site J1d-2. The specific objectives of Site 795 were to determine the age and nature of basement, to measure the direction of the present stress field, and to characterize the sedimentation, subsidence and oceanographic evolution of the area.

Principal results at this site are:

(1) Basalts, basaltic andesites, and basaltic breccias constitute acoustic basement at this locality. Textures, mineralogy, and chemistry indicate that these rocks contain calc-alkaline and volcanic arc affinities, quite different from rocks associated with seafloor spreading. They could be associated with either arc volcanism or with initial arc rifting. Sediment overlying these rocks give a minimum age of basin initiation of 15.5 Ma.

(2) The *in-situ* stress field could not be determined because a blockage in the hole at 230 mbsf precluded downhole logging and packer/hydrofracture experiments.

(3) The sedimentary and palentologic sequences indicate a three-stage evolution of this part of the northern Japan Basin that is broadly similar to that at Site 794: (a) A middle Miocene period beginning with explosive volcanism resulting in ash falls and submarine gravity-flow tuffs, coincident with and followed by marine claystone deposition on a well-oxygenated to mildly anoxic slope or basin that subsided from upper and mid-bathyal (~500-1000 m) to lower bathyal (~1500 m) depths; then, (b) A gradual increase in hemipelagic diatomaceous sedimentation in cool, well oxygenated waters, beginning in the late Miocene and culminating in the early Pliocene; finally, (c) A late Pliocene to Holocene stage during which diatomaceous sedimentation pulsed, volcanic ash production increased, climate cycled from arctic to subarctic conditions, and local tectonism produced complex interbedding of hemipelagic and terrigenous sediments that were deposited at nearly twice the rates found at Site 794.

The sedimentary section consists of mostly fine-grained hemipelagic diatomaceous, and terrigenous sediments of middle Miocene to Quaternary age. The division of units is as follows:

➧Unit I (0-123.0 mbsf, 0-2.1 Ma): Silty clay and clay. The upper 85 m is color-banded, light and dark silty clay, clay, diatomaceous clay and minor ash. Subtle color grading occurs in the silty clays and ashes. The lower 38 m is similar but with increasing diatom content and bioturbation.

➧Unit II (123.0-239.0 mbsf, 2.1-4.0 Ma): Diatom ooze, diatom silty clay and diatom mixed sediment. Minor ash layers are present and the unit is moderately to extensively bioturbated.

➧Unit III (239.0-325.0 mbsf, 4.0-5.4 Ma): Silty diatom claystone and diatom-clay-silt mixed sediment. The lower 50 m of this unit contains slightly less clay than the upper part. Minor calcareous and dolomitic nodules are present and bioturbation is common.

➧Unit IV (325.0-665.0 mbsf, 5.4-14.5 Ma): Siliceous claystone and silty siliceous claystone. The upper 146 m of this unit is opal-CT siliceous silty claystone with minor porcellanite, dolomite, and some chert. The lower 194 m consists of burrowed claystone with minor tuff and micrite layers, and pyritic and calcareous nodules. A cyclicity in style of bioturbation increases with depth as does the abundance of small faults and calcite- and clay-filled fractures. The tuff layers are normally graded with internal laminations and burrowed tops.

➧Unit V (665.0-683.5 mbsf, 14.5-15.5 Ma): Claystone and tuff. This unit overlies basalt and basaltic breccia and consists of interbedded claystone and altered, fine- to coarse-grained tuff that are commonly graded, laminated and burrowed in the style of the overlying sediments. Small faults and clay-filled fractures are common in the claystone. Calcite-filled fractures occur in the tuff.

Summarizing all the age data, uncompacted sedimentation rates are 60 m/m.y. for the Pleistocene through latest Miocene (0-6.4 Ma), 39 m/m.y. for most of the late Miocene (46.4-10.7), and 29 m/m.y. (10.7-15.5 Ma).

Sediments from Holes 795A and 795B are characterized by variable organic carbon contents particularly in the color-banded Pliocene-Pleist- Organiterrestrial with minor marine algal sources. Methane occurred in low amounts from the seafloor to 80 mbsf; below this level methane increased sharply and ethane appear but quantities were still relatively low. Sporadic traces of propane occur below ~325 mbsf. The base of the sulfate-reduction zone occurs at 80 mbsf. Ca and Mg profiles are typical to about 325 mbsf, where the Ca gradient increases sharply to the base of the sediment column.

Basalts, andesites and basaltic breccias comprise acoustic basement at this site. All rocks are moderately to highly altered and vesicular (5-30%). These are subdivided into three units on the basis of texture and mineralogy.

➡Unit 1 (683.5-703.3 mbsf): Brecciated sparsely plagioclase pyroxene phyric basaltic andesite.

➡Unit 2 (703.3-704.0 mbsf): Silicified brecciated moderately plagioclase phyric basalt.

➡Unit 3 (704.0-762.2 mbsf): Sparsely pyroxene plagioclase phyric basalt. This unit is further divided into two subunits. Unit 3A (704.0-733.7 mbsf) is mostly massive basalt; and Unit 3B (733.7-762.2 mbsf) is predominantly brecciated basalt and basaltic andesite.

The mineralogy and chemistry of the igneous rocks indicate that they have calc-alkaline and volcanic arc affinities, yet contain little or no evidence of involvement of continental crust in their genesis. The Site 795 igneous rocks were erupted subaqueously. Constraints imposed by the overlying sediments imply eruption below wavebase (100-200 mbsl), yet the high vesicularity implies a shallow water depth (probably above 1000 mbsl). The lavas could be associated with the initial rifting of either an oceanic or continental volcanic arc.

Temperature measurements at five horizons down to 162.4 mbsf in Hole 795A measured a temperature gradient of 133°C/km; the calculated heat flow value is 113 mW/m^2. This is slightly higher than the average value for this part of the Japan Basin (99 mw/m^2). Logging was not successful at this site due to swelling clays at about 230 mbsf.

<u>Site Summary, Site 796</u>

Hole 796A
Latitude: 42° 50.93' N
Longitude: 139° 24.67' E
Water Depth: 2582 m

Hole 796B
Latitude: 42° 50.92'N
Longitude: 139° 24.85'E
Water Depth: 2634 m

Site 796 is located on the eastward-dipping slope of Okushiri Ridge in the eastern margin of the Japan Sea. The slope is thought to have been formed by a westward-dipping thrust fault. Hole 796B was shifted 250 m downslope from Hole 796A to avoid coarse sand beds (51.7-146.2) that caused hole problems, with the hope that these beds in 796A represented only local channel fill.

The objectives of Site 796 were to:

(1) determine the age and history of uplift of the ridge; (2) measure the direction of the present stress field; (3) determine the age and nature of basement; and (4) characterize the sedimentation and oceanographic evolution of the area. Unfortunately penetration into basement was not attained because of unstable hole conditions. As a result, objectives (2) and (3) were not achieved.

The principal results at Site 796 are:

(1) The age of initiation of uplift of Okushiri Ridge was determined by the shallowest appearance of a sand bed as originally anticipated. Based on diatom biostratigraphy, the Okushiri Ridge (water depth 2300 m) uplifted 1300 m above the Japan Basin floor (water depth 3600 m) 1.8 Ma and at a rate of 0.7 mm/yr. Since the uplift is caused by thrust activity along the eastern margin of the Japan Sea (a possible new Eurasia-North America plate boundary), these results provide the first exact age data on the initiation of convergence and are critical to study of the tectonics of this new plate boundary.

(2) The lithology at Site 796 below the uppermost Pliocene is different from that of Sites 794 and 796, and its characteristics are suggestive of marginal facies of a basin. Paleocean-ographic conditions inferred from

sedimentary sequences and paleontological data, however, are approximately similar to those inferred at Sites 794 and 795. Calcium carbonate abundance in the sediments and microfossil preservation show that the site was above the CCD during the middle (?) Miocene and below it through the late Miocene to the Quaternary. Ubiquitous bioturbation observed throughout the sedimentary column shows that the sediments at Site 796 accumulated under oxic conditions. Interstitial water geochemistry shows elemental depth variation but these variations are well explained when correlated to lithology, *e.g.* ash and sand beds. No vertical fluid transport was suggested by the interstitial water geochemistry data, whereas physical property data may suggest occurrence of some vertical fluid flux.

(3)The highest heat flow ever obtained in the Japan Sea, 156 mW/m^2, was measured in Hole 796B. The associated high temperature gradient (178° C/km) is consistent with the shallow, obscured opal-A/CT transition zone (215 mbsf, 40°C). Frictional heating along thrust faults is one potential source of excess heat, but frictional heat alone cannot account for this high heat flow. A mechanism to concentrate the heat flow, such as fluid flow along faults, is required to match the magnitude of the anomaly.

The division of units is as follows:

➨Subunit IA (0-51.7 mbsf; 0-1.8 Ma): Clay and silty clay without sand. The unit is moderately to highly bioturbated, and associated with soft sediment deformation by slumping and microfaults.

➨Subunit IB (51.7-146.2 mbsf; 1.8-4.1 Ma): Clay and silty clay with frequent sand beds occurring as scattered thin beds that have sharp basal contacts. The sands are dominated by volcanic lithic fragments and pumice of fine to medium grain size.

➨Unit II (146.2-223.5 mbsf; 4.1-5.9 Ma): Clayey diatom ooze and diatom claystone. Detrital input increases toward the base of the unit with sandstone and pebbly claystone. Sandstone beds occur as thin graded units with sharp basal contacts and are composed dominantly of volcanic lithic fragments and glass or pumice.

➨Unit III (223.5-301.0 mbsf; late Miocene): Siliceous claystone, claystone and sandstone. Claystone units are moderately to highly bioturbated. Sandstone and siltstone interbeds are abundant mid-unit. Sandstones are graded and medium- to coarse-grained with volcanic lithic detritus and glass. Scattered glauconite is observed.

➨Unit IV (301.0-416.5 mbsf; late Miocene?): Siliceous claystone, pebbly claystone, tuffaceous sandstone and tuff. Siliceous claystone is interbedded with coarse-grained pyroclastic deposits that consist of sandstone and pebbly claystone with abundant volcanic detritus and discrete tuff beds. The opal-CT/quartz diagenetic boundary is observed at 301-330 mbsf. The claystone is well bioturbated. Pebbly claystone is common through this unit and is matrix-supported, coarse sand- to pebble-size volcanic detritus, including pumice and tuff. Laminated tuffaceous sandstone is present as thin beds throughout, and laminated, graded tuff beds also occur.

➨Unit V (416.5-464.9 mbsf; late-middle (?) Miocene): Siliceous claystone and silty claystone. The unit is distinguished from overlying strata by the paucity of coarse clastic/pyroclastic deposits and by an increase in dolomite and Mg-calcite. Siliceous claystones are generally bioturbated.

Summarizing age data, uncompacted sedimentation rates are 46 m/m.y. for the late Pleistocene, 11 m/m.y. for the early Pleistocene, 39 m/m.y. for most of the Pliocene, and 62 m/m.y. for the late Miocene.

High methane concentrations were observed at 10-140 mbsf; C_1/C_2 ratios in this interval were constantly above 1000, suggesting a biogenic source for this gas. Gas hydrate sampled about 90 mbsf shows that the porewater chemistry at this site is influenced by the presence of methane-clathrates and that clathrates are probably present throughout the upper 120 m. Below 200 mbsf the methane concentration decreases, only to increase again below 340 mbsf, suggesting a minor influx of thermogenic methane. The base of the sulfate reduction zone occurs at 14 mbsf, much shallower than at Site 795 (80 mbsf). The sulfate content increases again below 62 mbsf. Abundant ash layers in the upper 150 m controlled the behavior of alkaline earth elements (in particular the extreme depletion of Mg in this horizon) at this site.

Temperature measurements were made at five horizons down to 127.1 mbsf in Hole 796A and at three horizons down to 79.8 mbsf in Hole 796B. The measurements in Hole 796A yielded spurious data because of an encounter with coarse sediments at several horizons. The measurements in Hole 796B obtained a temperature gradient of 178°/km and a heat flow value of 156 mW/m^2, the highest heat flow ever measured in the Japan Sea.

Four logging runs were completed between 100 and 340 mbsf in Hole 796B. The opal-A/CT transition is recognized at 215 mbsf on logs and is different from the depth determined by XRD analyses. FMS data display frequent, mostly horizontal layers with thicknesses of 5-30 cm. A BHTV run was executed in the sedimentary section observed small-scale fractures but no prominent breakouts. Most of the physical properties show variations correlated to lithologic variations. Some parts of the water content data may be correlated to fluid circulation along faults.

Site Summary, Site 797

Hole 797A
Latitude: 38° 36.94'N
Longitude: 134° 32.16'E
Water Depth: 2862.2 m

Hole 797B
Latitude: 38° 36.94'N
Longitude: 134° 32.16'E
Water Depth: 2862.2 m

Hole 797C
Latitude: 38° 36.93'N
Longitude: 134° 32.18'E
Water Depth: 2864.5 m

The objectives of Site 797 were to: (1) determine the age and nature of acoustic basement; (2) measure the direction and magnitude of the present stress field; and (3) to characterize the sedimentation, subsidence, and oceanographic evolution of the area. Site 797 is located in the southwestern Yamato Basin at the base of the slope leading to the Yamato Rise and Kita-Oki Bank and slightly northwest of site J1E-1.

The principal results at Site 797 are:

(1) Acoustic basement at this site comprises basalts and dolerites with interlayered volcaniclastic sandstones, siltstones and silty claystones. The age of the sediments overlying the shallowest basalt layer is 19 Ma. Based on paleo-depth estimates using microfossils within these sediments and on sedimentary structures within the underlying volcani-clastic sediments, this part of the Yamato Basin probably subsided rapidly during the early Miocene. The uppermost basalts most likely represent submarine lava flows, whereas the bulk of the underlying igneous units are sills and dikes. These are high-Al basaltic rocks, consistent with generation during the initial stages of rifting. Several of the lowermost dikes and sills are alkali-basalts and hawaiites, and are unrelated to the overlying basalts and probably derived from a different mantle source.

(2) The *in-situ* stress field could not be determined because poor hole conditions precluded packer/hydro-fracture tests.

(3) The sedimentary and paleontological sequences indicate at least four principal stages in the evolution of this part of the Yamato Basin: (a) an early Miocene period of submarine basaltic volcanism and concomitant deposition of gravity flow and current-reworked volcaniclastic sandstones and siltstones on a shelf or slope, probably outboard of a delta; (b) a late early to early middle Miocene phase of diminishing submarine volcanic activity, warm surface waters, and deposition of calcareous and phosphatic hemipelagic claystones at lower bathyal depths (1500-2000 m) in a poorly oxygenated basin; (c) a late Miocene to late Pliocene cooling period characterized by slow sedimentation and

dominant but variable diatomaceous sedimentation at lower bathyal depths; and (d) a latest Pliocene to Holocene stage during which diatomaceous sedimentation ceased, volcanic ash production increased, subsidence continued, and climate oscillated to produce a sequence of interlayered light- and dark-colored silty clays having variable organic carbon contents. The site was at or near the CCD throughout much of its sedimentary history. Dissolution of silica is pronounced at this site.

The division of units is as follows:

➡Unit I (0-119.9 mbsf; 0-2.3 Ma): Silty clay and clay. The upper 82 m is color-banded, light and dark silty clay and clay with minor diatom ooze and scattered thin ash layers. Dark layers are moderately well laminated, decrease with depth, and have common pyrite, diatoms and organic matter. Light ash layers are bioturbated or faintly laminated. Diatom content and bioturbation increase in the lower 38 m.

➡Unit II (119.9-224.0 mbsf; 2.3-4.9 Ma): Diatom clay and clayey diatom ooze, minor dolomitic zones and nodules and ash, all extensively bioturbated.

➡Unit III (224.0-301.5 mbsf; 4.9-6.4 Ma): This unit is mostly bioturbated to indistinctly mottled diatom clay and silty claystone with scattered thin layers of bioclastic sand, minor ash and carbonate layers and nodules. Faint to distinct light and dark color banding is common. Sands contain foraminifers, sponge spicules, quartz and feldspar. The opal-A/CT transition occurs at 290 mbsf.

➡Unit IV (301.5-426.6 mbsf; 6.4-13.7 Ma): Claystone and siliceous claystone. The upper 48.5 m consists of indistinctly color-banded layers. Dark layers are faintly laminated to slightly bioturbated; light layers are moderately to extensively bioturbated and characterized by compacted, horizontal burrows. Secondary carbonate layers are common with rare chert. The lower 76.6 m is interbedded claystone, siliceous claystone, porcellanite and chert, which are moderately to extensively bioturbated. Chert is common.

➡Unit V (426.6-627.3 mbsf; 13.7-19.0+ Ma): Faintly laminated claystone with numerous horizontal, compacted burrows. The claystone is slightly siliceous near the top of the unit, but becomes hard and carbonate-cemented at the base. Small, vertically anastomosing, clay-filled fractures are common in the claystone. Stringers and small nodules of secondary carbonate, pyrite and thin glauconite layers are also present. Altered tuff layers, and rare layers of tuffaceous sandstone occur throughout. The lower 73 m contains basalts interbedded with claystones, similar to those above, and thin conglomerates entirely composed of porcellanite pebbles in a siliceous claystone matrix.

➡Unit VI (646.9-900.1 mbsf; >19.0 Ma): Interbedded volcaniclastic and carbonaceous siltstone, sandstone, and minor silty claystone. These rocks occur in intervals 1-10 m thick, interbedded with basalts. Planar and cross laminations, normal size grading, scoured surfaces, load structures, fluid escape features, and extensive grain alteration to clay are common features throughout the sandstones. Siltstones are planar laminated and commonly contain flattened, bedding-parallel lenses of darker siltstone which may variously represent burrows and rip-up clasts.

Using all of the age data, sedimentation rates show three distinct trends: (1) 49 m/m.y. for the Quaternary through uppermost Miocene (0-7.0 Ma) clay and silty clay and diatomaceous sediments; (2) 5 m/m.y. for the upper Miocene to upper middle Miocene (7.0-11.6 Ma) siliceous claystones, cherts and porcellanites; and (3) 30 m/m.y. for the middle and lower Miocene (11.6-19.0 Ma) claystone, siliceous claystone and minor tuffs overlying the basalts. Owing to lack of microfossil control, the sedimentation rate for the underlying volcani-clastic sandstones, siltstones and silty claystones interbedded with the basalts is unknown.

Sediments are characterized by an increase in diagenetic silica below ~300 mbsf and by moderate but variable amounts of organic carbon and carbonate. Diatoms and dissolved silica contents of interstitial waters decrease markedly below ~300 mbsf. This diagenetic boundary restricts fluid communication and divides the sedimentary section into upper and lower diffusive regimes. Carbonate values are generally less than 5% below ~300 mbsf. The organic carbon content fluctuates between high and low values coincident with dark and light layering in the Quaternary and uppermost Pliocene sediments. Organic carbon values are also high in the uppermost Miocene diatomaceous sediments (290-330 mbsf). Sulfate shows two peaks, one near the seafloor and a smaller peak at 350 mbsf. Small amounts of methane (13-200 ppm) occurred, with traces of ethane and propane.

The igneous rocks interlayered with sediments describe two broad and overlapping groups containing 21 units, defined by contact relations, intervening sedimentary rocks, composition and texture. The two groups are:

Group 1: Units 1, 2 and 4 (553.3-609.4 mbsf). These rocks consist of aphyric and sparsely plagioclase olivine phyric basalts interbedded with conglomerate and tuffaceous claystone of sedimentary Unit V. Their brecciated nature, relatively fine grain size and their lack of chilled margins indicate that they may represent submarine lava flows.

Group 2: Units 3 and 5-21 (555.4-900.1 mbsf). The igneous rocks of this group consist of typically highly altered aphyric and sparsely plagioclase phyric basalt and dolertie interlayered with laminated sandstones, siltstones and claystones of sedimentary Unit VI, and tuffaceous claystones of Unit V. Some of the basalts are only slightly to moderately altered. Their massive nature, reltatively coarse grain size, and chilled borders, the latter often associated with baked or altered margins affecting both the basalts and sediments, indicate that they represent sills or dikes.

Most of the igneous rocks of Hole 797C are high-alumina basalts with low amounts of the large ion lithophile elements Rb, Ba, and K, and low amounts of Nb and Ce. Some are quite primitive, with MgO, Cr and Ni values exceeding 10%, 150 ppm, and 350 ppm, respectively. They are rich in Al_2O_3, showing no decrease in Al_2O_3 with lowering MgO, and lack an iron enrichment trend. These two features imply that the samples have relatively high water contents which caused suppression of plagioclase. The extremely low Nb contents are consistent with an arc-related origin, but the low incompatible element contents (with the exception of Sr) indicate that the magmas interacted very little with continental crust. In contrast, some of the lowermost sills and dikes are alkali basalts and hawaiites, containing large amounts of high field strength elements, high amounts of alkalis, and high Ce. These two igneous rock types are genetically unrelated, with the alkaline rocks lacking typical arc signatures. The geologic setting of this site and the igneous compositions suggest that these intrusive and extrusive rocks were emplaced and erupted during the rifting apart of a volcanic arc. The relative timing of emplacement of the different compositional suites is unknown.

Temperature measurements at six horizons down to 185.5 mbsf in Hole 797B measured a gradient of 123°C/km. The calculated heat flow is 101 mW/m^2. This value is identical to a nearby seafloor measurement and similar to the average heat flow for the entire Yamato Basin (97±12 mW/m^2).

Logging runs were completed between 80 and 516 mbsf in Hole 797C. The combination sonic/lithodensity/temperature/induction and the FMS log were run in open hole over this interval. Below 516 mbsf logging was restricted by unstable hole conditions caused by rapidly swelling clays. The geochemical log was run inside pipe from the mudline to 633 mbsf and partial runs were made with the FMS and BHTV using the side-entry sub. General profiles of physical properties at Site 797 mimic Site 794, suggesting similar basin-wide processes controlling the sediments and their diagenesis.

LEG 129 PROSPECTUS: OLD PACIFIC CRUST

INTRODUCTION

The correlation of Mesozoic magnetic anomaly sequences in the Pacific Ocean by Larson and Chase (1972) indicates that the world's oldest ocean crust lies centered in the far western Pacific and that isochrons become concentrically younger in approximately radial fashion (Fig. 1). Recent magnetic anomaly mapping by Handschumacher and Gettrust (1985), Tamaki *et al.* (l987), and Handschumacher *et al.* (1988) has revealed the oldest portion of this tectonic pattern and has extended the Mesozoic magnetic reversal time scale from M29 of Cande *et al.* (1978) to M37. The oldest M-lineations may have recorded the magnetic reversal/seafloor spreading history of the early Late Jurassic (~165 Ma), which was preceded by a magnetic quiet zone ranging back to the Middle Jurassic (~175 Ma).

The inference that the M17 and later isochrons coincide with Jurassic sediments and basement rocks is based entirely on conclusions drawn from geophysical data such as those just cited (Fig. 1). No Jurassic material has ever been recovered from this region, whose size is approximately that of the contiguous United States or western Europe. Past attempts to drill and recover Jurassic sediments and basement rocks in this area have been frustrated by ubiquitous chert layers of generally Late Cretaceous age and by widespread but probably not totally ubiquitous volcanic material of late Early and middle and Late Cretaceous age that blanketed much of the older strata in the area. These geologic units and the lack of multichannel seismic data to define their depths in section, thicknesses, and lateral boundaries have led to previous "blind drilling" on Jurassic basement locations (Fig. 1) that have all terminated in Cretaceous material of various types.

The recent magnetic anomaly mapping cited above, along with joint multichannel seismic expeditions by French and American investigators (Abrams *et al.*, 1988), have led to a much better understanding of the tectonic and geologic history of the area. These investigations have also provided seismic imaging of drill sites in the Pigafetta and East Mariana basins (Fig. 3), where Jurassic sediments and Jurassic oceanic crust may be drilled and recovered with the advanced drilling technology aboard JOIDES Resolution.

OBJECTIVES OF THE PROPOSED DRILL SITES

Age Calibration of Jurassic Magnetic Reversals: The available magnetic and seismic data suggest that the Pigafetta and East Mariana basins are underlain by oceanic crust of Late Jurassic to probable Middle Jurassic age (Fig. 2). The younger parts of the basins toward the northwest may be Kimmeridgian to Oxfordian (anomalies M22 to M25; Late Jurassic), whereas the middle parts may be Oxfordian to Callovian (anomalies M29 to M37), that is, ~160-165 Ma. Toward the southeast, within the Jurassic magnetic quiet zones, the age of the crust may be as old as Bathonian to Bajocian (Middle Jurassic, ~165-175 Ma), found to be a time of extremely frequent magnetic reversals by Steiner *et al.* (1987).

The oldest magnetic anomalies dated in the world oceans are M23 to M26 (Fig. 2), which have been sampled at two sites in the North Atlantic (DSDP Sites 100 and 105). Several sites on M-anomalies have yielded a reasonable calibration for the post- M25 anomaly sequence. Drilling in the area of older M-series anomalies offers an exceptional opportunity to extend the time scale further back into the Jurassic, and possibly to calibrate the series of reversals described from land sections by Steiner and Ogg (1988). Within the Jurassic quiet zone of Pigafetta Basin, Handschumacher **et al**. (1988) have observed an important change in the character of the magnetic signature. Small-amplitude anomalies were observed on all aeromagnetic tracks that extend southeast of M37 but could not be correlated. Farther southeast of this

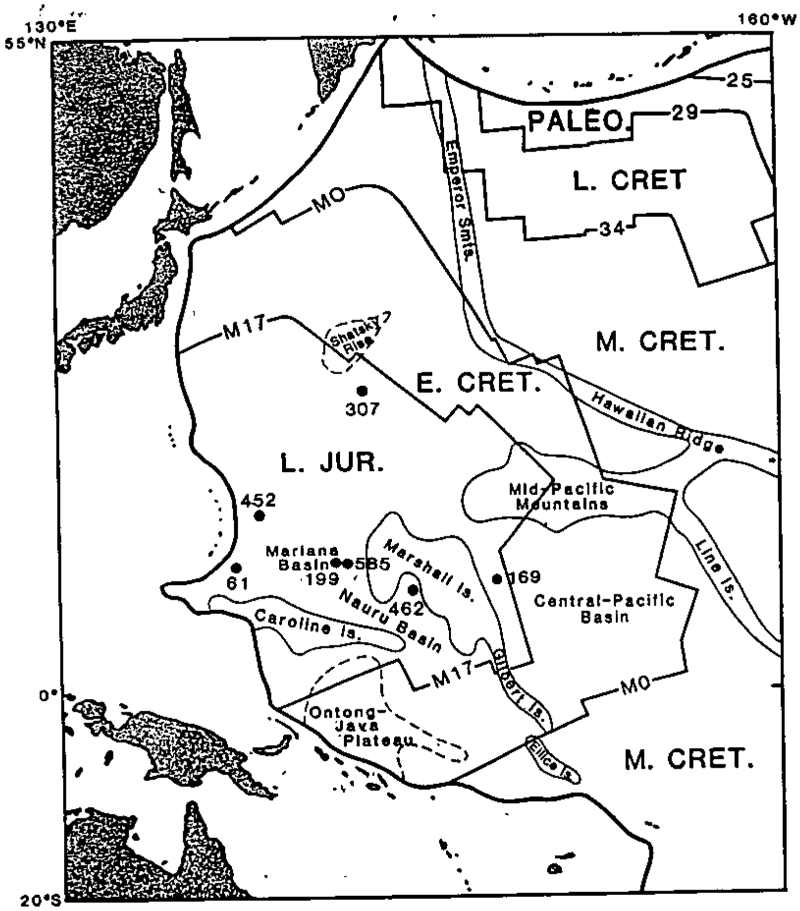

Figure 1. Bedrock isochrons determined from magnetic anomaly lineation mapping on the Pacific plate (from Larson et al., 1985) superimposed on groups of islands, atolls and guyots in the Western Pacific. Solid circles locate DSDP Sites 61, 169, 199, 307, 452, 462, and 585.

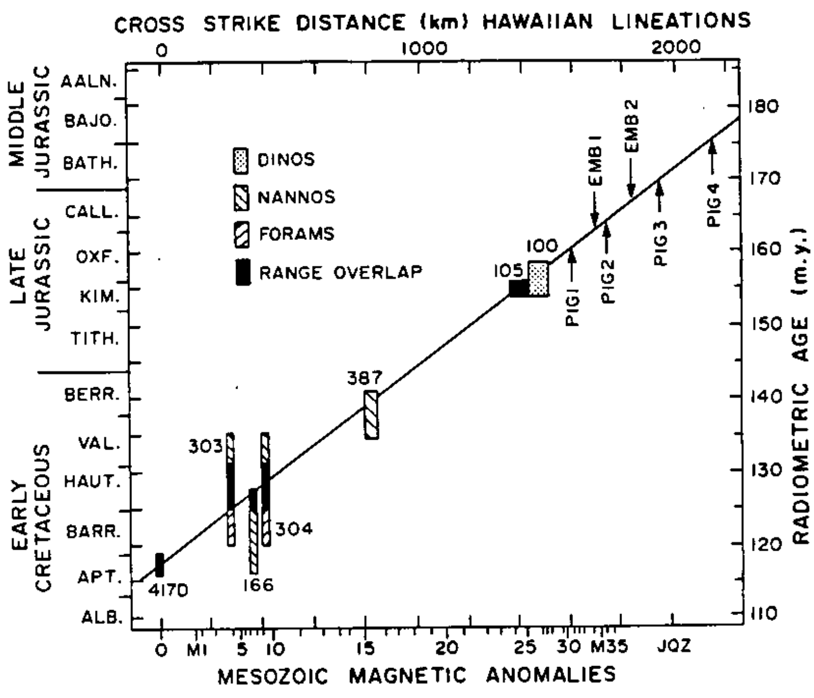

Figure 2. Time calibration plot of the Mesozoic magnetic anomalies M0 to M37 and the preceding magnetic quiet zone. Magnetic anomalies plotted as cross-strike distance across the Hawaiian lineations for M0 to M25. M25 to M37 are normalized to that parameter after Handschumacher et al. (1988). Geologic time scale and radiometric ages are from Harland et al. (1982) as modified by Kent and Gradstein (1985) at the Tithonian/Kimmeridgian boundary. Oldest paleontologic ages in various DSDP holes shown as rectangles. Vertical lengths of rectangles show age ranges from *DSDP Initial Reports* except for 100 (Zotto et al., 1987) and 105 (Gradstein and Sheridan, 1983). Horizontal lengths show magnetic ranges from Larson and Hilde (1975) for DSDP Sites 303, 304, 166, 100, and 105, and DSDP Initial Reports for Sites 387 and 471D. Predicted ages of proposed drill sites (PIGs and EMBs) are shown.

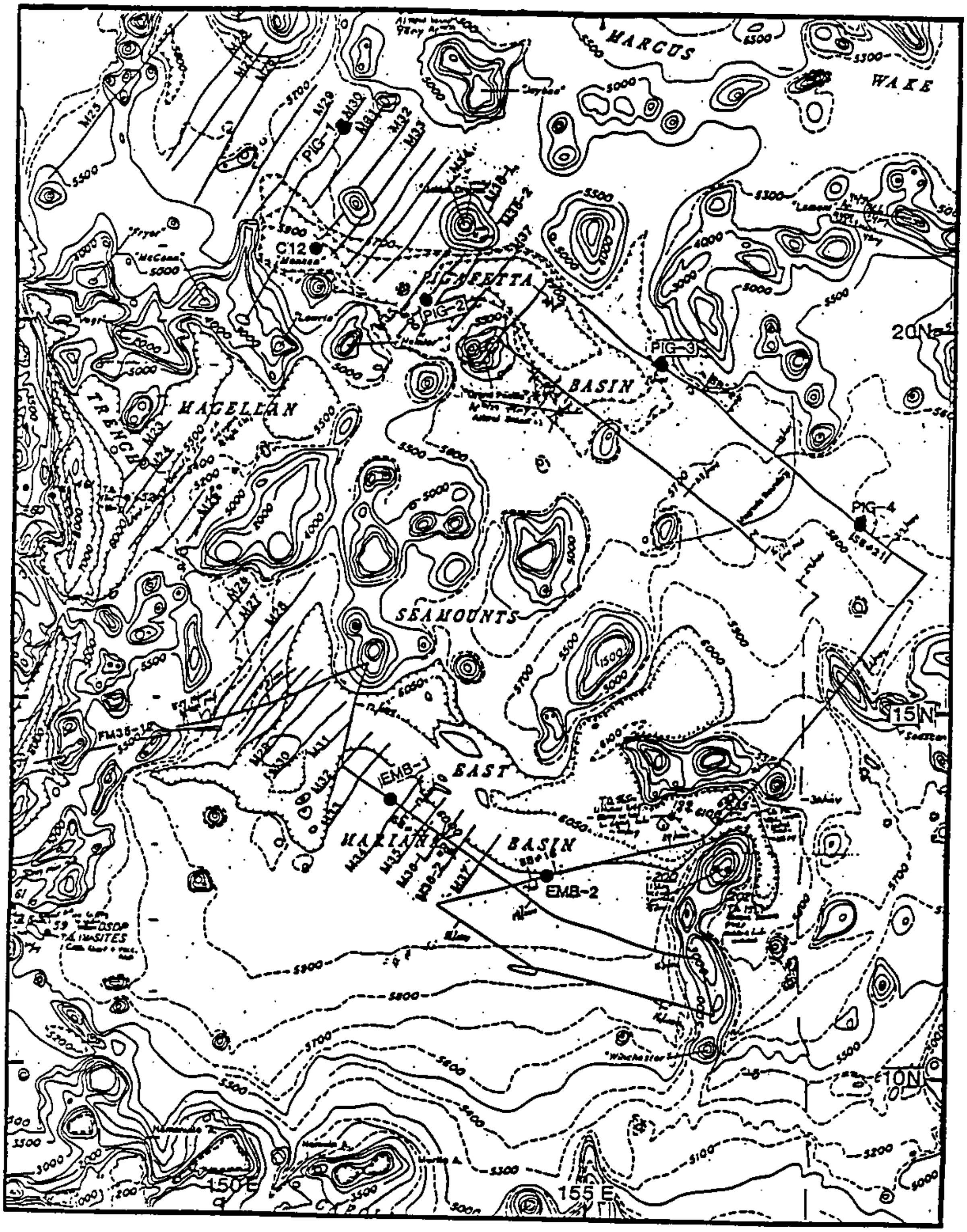

Figure 3. Proposed drill sites (PIGs and EMBs) superimposed on Jurassic magnetic lineations and regional bathymetry of the East Mariana and Pigafetta Basins. Solid line shows multichannel seismic coverage of *R/V Fred Moore* 35-12. C12 (CONRAD 1205) marks location of a single channel seismic record characteristic of NW Pigafetta Basin.

magnetic quiet zone an abrupt change in amplitudes and regional field intensity occurs that has been interpreted as a possible structural boundary roughly parallel to the isochrons. This area may represent the location of the original microplate from which the present-day Pacific plate evolved (Handschumacher *et al.*, 1988), or it could mark the edge of the middle Cretaceous volcanic complex that extends farther south.

Drilling at the Pigafetta and East Mariana basin sites will allow determination of the age of the older M-anomalies, determination of the age of the crust within the Jurassic quiet zone, and investigation of the nature of the crust in the magnetic high amplitude-low regional field area. The predicted ages of these sites (Fig. 2) range from Oxfordian to Bajocian (160-175 Ma).

Jurassic Sediments and Early History of the Ocean: The main interest in Jurassic sediments from the Pacific is that they chronicle the paleoenvironment of the Jurassic superocean, which covered two-thirds of the Earth at that time, but for which we have no direct record. The only samples of pelagic "deep sea" Jurassic sediments come from Tethyan fold belts and DSDP sites in the proto-Atlantic, both of which correspond to relatively restricted marine conditions. Previous attempts to recover Jurassic sediments in the Pacific have failed. The most recent attempts were at locations where thick lava flows and sills of middle to Late Cretaceous age proved impossible to penetrate (DSDP Site 461, Nauru Basin), or where thick accumulations of volcaniclastic material had expanded the sedimentary section beyond the capabilities of the drill ship (DSDP Site 585, East Mariana Basin).

The sedimentary section on seismic profiles through Pigafetta Basin resembles that of the Ptolemy Basin located north of the Marcus-Wake swell, where DSDP Site 307 was drilled to basement of Berriasian (earliest Cretaceous) age beneath 300 m of sediment on anomaly M21. The average sediment thickness in the East Mariana Basin is about 300-500 m, and there is a very good chance of obtaining sediments of Jurassic age. The main difference between the sites proposed here and those drilled previously, apart from the older age of the basal sediments, is the age of the chert layers. The chert is expected to be younger in the Pigafetta Basin and younger still in the East Mariana Basin because of the differences in time of equatorial crossing for the three areas (Lancelot and Larson, 1975). Sediment thicknesses and acoustic signatures appear compatible with this interpretation. We intend to sample Jurassic sediments in the area of the M-anomalies and within the Jurassic quiet zone, where no age determination can be made otherwise.

Geochemical Reference Sections: The proposed drilling locations may also fulfill, in part, objectives commonly referred to as "geochemical reference sections." These objectives include determining the composition of sediments and igneous ocean crust adjacent to a subduction zone for comparison with the geochemical characteristics of the neighboring arc volcanism. In the western Pacific the main variable on the "input" side of the geochemical reference equation may be the presence or absence of large volumes of middle Cretaceous volcanic material in the deep basins now being subducted. The petrology, igneous or sedimentary nature, and depth in section of this material would greatly affect the geochemical "output" signature at western Pacific island arcs. It probably would have much greater variability than the original Jurassic ocean crust and is much more accessible to the drill in the western Pacific. Also, drilling into basement in this region offers a unique opportunity to assess the *in-situ* physical properties of old oceanic crust created at a fast spreading center, because present tectonic models assume that the Pigafetta and East Mariana basins were both created at 6-8 cm/yr spreading half-rate.

While none of the sites proposed for Leg 129 drilling in the Pigafetta or East Mariana basins are directly adjacent to their associated subduction zones, seismic profiles throughout both of these basins suggest that the proposed sites have acoustic sections typical of each basin in question. It is unlikely that any significant diagenesis or other alteration will occur at these sites between now and their eventual subduction. Furthermore, all sites occur in fracture zone-bounded "compartments" that extend to the western Pacific subduction zones. Thus the nature of the sedimentary and crustal sections can be related to those specific subduction zones and their associated backarc volcanism.

Cretaceous Volcanic Complex: It is quite possible that one of the East Mariana Basin sites (EMB-1) and the south-easternmost Pigafetta Basin site (PIG-4) will encounter material generated by the middle Cretaceous volcanic event, either as volcaniclastics or as solid sills and flows. However, seismic data and recent magnetic anomaly mapping allow location of sites typical of large parts of the regional geology of those basins. Drilling through the middle Cretaceous volcanic complex will provide additional understanding on the timing, dimensions, and petrology of this major igneous province, in addition to correlations with the seismic stratigraphy.

Crustal Magnetization and Paleolatitudes: A number of secondary objectives can be met with these drill sites. Crust magnetization objectives also are within the scope of Leg 129 drilling. Paleolatitudes measured on basement rocks and logging measurements that may recover the complete remanent magnetization vector will allow reconstruction of the latitudinal motion and rotation of the Pacific plate during the Jurassic. This latter point is especially important for modeling the overlying sedimentary stratigraphy that is very sensitive to crossings of the Equatorial high-productivity zone.

GEOPHYSICAL SURVEYS

Magnetic lineations indicate that the imaged basement is Middle to Late Jurassic in age and is presumably overlain by deep-sea pelagic sediments representing the paleoenvironment of the "superocean" of that age. Reflection/refraction data analyses provide answers to two first-order questions that have been raised concerning the drilling of oceanic crust in these oldest Pacific basins: (1) Can depth to oceanic crust be determined in these basins? (2) If basement is identified with refraction/reflection data, can it be shown that this basement does not include thick (>500 m) sequences of Cretaceous volcanic deposits overlying Jurassic oceanic crust (as occurs in the Nauru Basin, DSDP 462A, and the East Mariana Basin, DSDP 585), thus making the crust impossible to reach? Rough, unconformable horizons have been imaged and interpreted to be the top of oceanic crust in both the East Mariana and Pigafetta basins, usually occurring beneath a high-amplitude, low-relief, and quite continuous horizon occurring 0.2-0.4 s below the seafloor. Sonobuoy velocity solutions consistently indicate that crustal velocities begin at or just below this dominant horizon. Depth to basement is well established in the East Mariana and Pigafetta basins at an average of 300-500 m (Abrams *et al.*, 1988).

SITE DESCRIPTIONS

Proposed Sites PIG-1 and PIG-2: These two sites are located in the northwest part of Pigafetta Basin, where the magnetic anomalies are well defined and the total sediment thickness is estimated to be ~300-400 m, based on single-channel seismic data from this and adjacent basins. Exact locations for these sites will be determined from the MCS data acquired on board the *N/O Suroit* in August and September 1989. We will be drilling near well defined anomalies M30 and M36, hoping to compare Middle to Upper Jurassic (?Callovian) sediments from the Pacific with those recovered in the central Atlantic at DSDP Sites 105 and 534. The single-channel seismic data in this area, and the MCS data to the southeast, suggest that subsequent middle Cretaceous volcanic sediments and/or hard rocks are not present here. DSDP Site 307 to the north and DSDP Site 452 to the south both suggest that middle to Upper Cretaceous chert will be present in the first 100 m of the section, owing to very slow "brown-clay" sedimentation in the past 80-100 m.y. Both PIG-1 and

PIG-2 would serve to satisfy magnetic-anomaly calibration, paleoenvironmental, and geochemical reference goals.

Proposed Site PIG-3: This site is located within the Jurassic magnetic quiet zone in central Pigafetta Basin, approximately 150 nmi southeast of the last well-defined magnetic anomaly (M37), in an area where an MCS profile shows basement at ~0.6 s below the seafloor. As at PIG-1 and PIG-2 middle to Upper Cretaceous cherts may occur within the first 100 m of the section, overlain by post-Campanian brown clay. There may be minor thickening of the mid-Cretaceous section by volcaniclastic input, but there is no indication in the seismic records that flat-lying sills and flows are present here as they were at DSDP Site 462 in Nauru Basin.

Jurassic basement in this area is correlated with the undulating, hyperbolic reflectors in MCS profiles. At PIG-3 this reflector occurs at 8.0 s two-way reflection time underlying 0.58 s of sediment. Sediment velocities increase from 1.87 km/s to 2.57 km/s with an average sediment velocity of 2.4 km/s and a total sediment thickness of 701 m. These velocities determined from normal moveout times are similar to those of a section of slightly younger age and similar environment recovered at DSDP Site 307.

Long-range sonobuoy 22 was recorded 50 nmi southeast of PIG-3, where the acoustic basement reflector is flatter and the overlying sediment section thinner than at PIG-3. This suggests the possibility of middle Cretaceous volcanics at the location of sonobuoy 22 that are not present at PIG-3, or that the flat-lying reflection simply develops more relief (becomes tectonized?) in the area of PIG-3. In either case we believe that the onset of velocities characteristic of "normal" oceanic crust recorded by sonobuoy 22 correlates to the basement reflector at PIG-3.

Objectives of drilling at proposed site PIG-3 include dating of the Jurassic quiet zone and investigating the nature of low-amplitude magnetic anomalies, as well as the previously mentioned paleoceanographic and geochemical reference goals.

Proposed Site PIG-4: This site at the southeastern end of Pigafetta Basin is the most enigmatic, and therefore the most interesting, of the four proposed sites in this basin. It lies beyond the Jurassic magnetic quiet zone of Handschumacher *et al.* (1988) in an area of high-amplitude, nonlineated magnetic anomalies associated with an anomalously low regional magnetic field. The seismic reflection character of this area is considerably different from the hyperbolic basement reflections seen at PIG-3 in the Jurassic quiet zone. It shows a uniformly flat-lying, very reflective surface about 0.25 s below the sea floor. In some areas, notably at PIG-4, an unconformable reflector of relatively low relief occurs below it that is correlated with basement at PIG-4. These flat-lying reflectors terminate very close to Handschumacher *et al.*'s magnetic boundary and are replaced by more undulating, hyperbolic basement reflectors in the Jurassic magnetic quiet zone. Correlation of these two types of seismic reflection and magnetic signatures is not perfect, as there are some areas in the Jurassic magnetic quiet zone where flat-lying reflectors occur, such as the sonobuoy 22 location referred to in the PIG-3 description above.

At least two hypotheses can be advanced for the origin of this "seismic smooth/ magnetic rough" zone. On the basis of the magnetics alone, Handschumacher *et al.* (1988) postulated it as the original Pacific microplate of Hilde *et al.* (1976). In this hypothesis it would be the original nucleus and oldest surviving piece of Pacific plate and would also be the oldest ocean crust left on the planet. Our extrapolation of the M-lineations time calibration predicts it to be late Bajocian, about 175 Ma (Fig. 2). Its geographic-tectonic location argues strongly for this possibility. However, modern-day microplates on the East Pacific Rise (e.g., the Easter and Juan Fernandez microplates) are characterized by correlatable, although nonparallel, magnetic lineations and very rough volcanic basement, both owing to very close poles of relative motion. We propose that the "seismic smooth/ magnetic rough" zone is a product of the middle Cretaceous volcanic event. It is probably the northwesternmost location of pervasive middle Cretaceous volcanism in the deep sea although evidence of such volcanism is sporadically present in the Jurassic magnetic quiet zone to the northwest and in seamounts bounding M-lineations of Pigafetta Basin.

As at the other sites proposed in Pigafetta Basin, chert will probably be encountered in the first 100 m of the section underlying 80-100 m.y. of "brown-clay" deposition. An analysis of the sediment section at PIG-4 from the seafloor down to a flat reflector at 0.30 s indicates an average sediment velocity of 2.0 km/s for a total thickness of 300 m of section. The interval between this reflector and apparent basement is 0.10 s with an upper bounded interval velocity of 2.3 km/s (interval thickness of 121 m) for a total thickness from the seafloor to basement of 421 m.

Sonobuoy 21 was deployed approximately 60 km southeast of the PIG-4 location. Velocity solutions indicate that crustal velocities begin at 0.33 s below the seafloor, which correlates to a low-amplitude reflection below the dominant flat reflector discussed above. At the PIG-4 site location this weak reflection is also observed 0.1 s below the flat reflector and is identified as high-velocity basement. In addition to those listed with younger Pigafetta Basin sites, major objectives at PIG-4 include characterization of basement in this "seismic-smooth/magnetic rough" region.

Proposed Site EMB-1: This site lies on magnetic lineation M34 and is typical of the seismic stratigraphy found in the East Mariana Basin. DSDP Site 199 to the east of EMB-1 encountered Tertiary turbidites in the first 300 m of the section overlying Upper Cretaceous-lowermost Tertiary cherts, and it is probable that the flat-lying, coherent reflectors in the upper 0.18-0.2 s of the section at EMB-1 correspond to those same turbidites and cherts. About 0.37 s of sediment lies below the seafloor on top of a low relief, very reflective, and continuous horizon. Velocity analysis yields an average interval velocity of 1.8 km/s, corresponding to 329 m of section down to this horizon. It may be that this very widespread, prominent horizon is Upper Jurassic chert, or a manifestation of the middle Cretaceous volcanic complex either as volcaniclastics or solid flows and sills. It is unlikely to be true Jurassic basement because it is underlain by unconformable weak reflections. At EMB-1 the interval between the reflective horizon and apparent basement is 0.14 s with a velocity of 1.8-3.0 km/s corresponding to a 171 m interval, or a total thickness of 500 m of section. Sonobuoy 7 was recorded 25 nmi southeast of EMB-1 and has similar acoustic stratigraphy. Crustal velocities begin at 0.49 s below the seafloor, where a 4.725 km/s arrival was recorded.
The prime objectives at this site are to provide a stratigraphic date on magnetic anomaly M34, a "ground truth" calibration of the seismic stratigraphy of the East Mariana Basin, and a geochemical reference for the Mariana Trench.

Proposed Site EMB-2: This site lies within the Jurassic magnetic quiet zone of the East Mariana Basin and is located in an area where the reflective horizon displays an unusual amount of relief but is otherwise similar to EMB-1 stratigraphically. The upper 0.23 s of flat-lying coherent reflections is believed to represent the Tertiary turbidites overlying Late Cretaceous-early Tertiary cherts recovered at DSDP Site 199. Velocity analysis at EMB-2 reveals 0.37 s of 1.8 km/s material (thickness = 329 m) overlying the reflective horizon. The interval between this layer and the weaker, discontinuous and unconformable reflector that may be basement consists of 0.11 s of 1.8-3.0 km/s material (thickness = 133 m), resulting in a total sedimentary thickness of 462 m.

Sonobuoy 18 was deployed just southwest of site EMB-2 in an area where the reflective horizon is flat-lying.

Velocity solutions indicate the onset of crustal velocities at 0.3-0.35 s below the seafloor at or just below the prominent reflective horizon. Both this reflector and the lower amplitude, discontinuous basement reflectors appear to deepen in the immediate vicinity of EMB-2, but the crustal velocites recorded by sonobuoy 18 probably correspond to the reflection identified as basement. Objectives for proposed site EMB-2 are essentially the same as those for PIG-1, with additional interest in drilling the two East Mariana Basin sites to make interbasinal correlations with results of drilling in the Pigafetta Basin.

OPERATIONS PLAN

Leg 129 is scheduled to depart from Guam on 24 November 1989 after a 5-day port call and return to Guam on 19 January 1990 after 56 operational days at sea (Table 1). The operations plan must remain somewhat flexible so that operations can be adjusted to either difficult or surprisingly successful drilling. The plan will be focused to optimize drilling, downhole experiments, and recovery of Lower Cretaceous to Jurassic sedimentary material and Jurassic basement at all sites. The main problem to overcome in obtaining these objectives is associated with Upper Cretaceous chert/porcellanite beds that occur high in the sedimentary sequence. These beds cause drill-string torquing and hole-collapse problems. High-pressure pumping required to keep the hole clean of chert chips tends to "firehose" away soft sedimentary material in the underlying formations, making a reconstruction of the age and physical stratigraphy at the site difficult in the older sedimentary material.

Our primary drilling strategy is to rely on rotary coring. We also hope to improve the situation at the first site drilled by setting a reentry cone and casing off the unstable chert formation. If most of the chert/porcellanite occurs in the upper 200 m of the drill hole, then it should be possible to isolate this portion of the section and drill with reduced pump pressure in the older sedimentary units to enhance core recovery. A reentry cone and casing will be set at PIG-1, PIG-2, or PIG-3, depending on the thickness of the

Table 1. Summary Site Information, Leg 129[1]

Site	Lat./Long.	Water Depth (m)	Penetration (m) Sed.	Bsmt.	Drilling	Logging (days)	Total
Leg 129 departs Guam on 24 November 1989							
PIG-1	22°30'N 151°30'E	5885	345	100	17.9	4.0[2]	21.9
PIG-3	19°30'N 155°56'E	5580	701	50	12.6	2.0[3]	14.6
PIG-4	17°29'N 158°44'E	5680	421	50	9.0	2.0[3]	11.0
Alternate Sites:							
(Alternate for PIG-1)							
PIG-2	20°18'N 152°35'E	5885	345	100	17.9	4.0[2]	21.9
(Alternates for PIG-3 and PIG-4)							
EMB-1	13°39'N 152°19'E	5920	500	50	9.8	2.0[3]	11.8
EMB-2	12°43'N 154°27'E	5950	462	50	9.2	2.0[3]	11.2

[1] Locations tentative; site survey to be completed in early September 1989.

[2] Includes standard logs plus BHTV, mag/susc, and packer in basement.

[3] Includes standard logs plus mag/susc in basement.

soft sediment section above the first chert occurrence (Table 1). The topmost soft sediment section must be a minimum of ~60 m to wash in a reentry cone and conductor casing. The hole will then be drilled down to 200-250 mbsf, and smaller diameter casing set to isolate the chert sequence. Standard rotary (RCB) drilling will then proceed, if possible with reduced pump pressure in the older sediments, below the casing shoe to a maximum depth of 100 m into basement. If hole stability and recovery prove to be less of a problem, owing to the enhanced stability of JOIDES Resolution's positioning and drilling systems, then it may be possible to reduce the downhole hardware commitment at subsequent sites. Subsequent holes may be drilled with less casing, using only enough conductor casing to stabilize the reentry cone, a mini-cone, or as a single-bit hole with no reentry capabilities. The optimum program of sites is PIG-1 or PIG-2 drilled first, the second site at PIG-3, the third site at PIG-4, and the fourth site at EMB-1 or EMB-2.

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WIRELINE SERVICES CONTRACTOR REPORT

LEG 124

Objectives and Logging Operations

The prime objective of ODP Leg 124 was to determine the ages and tectonic histories of the Celebes and Sulu seas. The crust of these marginal basins could have formed either by entrapment of normal oceanic crust or by back-arc spreading. The sedimentary sequences overlying the basement in the two basins provide a record of the tectonic and volcanic histories of both the basins and their neighboring regions. In addition, measurement of the current stress direction could provide evidence of forces now acting on the basins. Downhole measurements on Leg 124 focused on providing the stress measurements and, in conjuction with the coring, continuous records of both crustal properties and downhole changes in sediment composition. Of the five sites drilled on Leg 124, the three deep sites (767, 768 and 770) were logged; two shallow sites (769 and 771) were not logged. Sticky clays provided a challenge, but in each case nearly the entire hole was successfully logged by using the technique of logging while pulling pipe. At Hole 767B, the seismic stratigraphic and geochemical tool strings were run from the sea floor to 646 and 662 mbsf, respectively; loss of the bottomhole assembly prevented logging the deeper C hole. At Hole 768C the seismic stratigraphic and lithoporosity tool strings were run from the seafloor to 1260 and 1258 mbsf, respectively; the borehole televiewer was run over the intervals 810-870 and 949-1250 mbsf. At Hole 770C four tool strings were run: seismic stratigraphic (0-528 mbsf), geochemical (0-516 mbsf), lithoporosity (0-515 mbsf), and borehole televiewer (405-524 mbsf).

Crustal Geophysical Properties

Basement penetrations at Sites 768 and 770 far exceeded expectations. The 222 m basaltic penetration at Site 768 is the deepest ever into crust of back-arc origin, and the only significant amount of back-arc crust ever logged. The 100 m of logged crust at Site 770 surpasses all but a handful of DSDP and ODP sites. The log measurements of *in situ* velocity, density, resistivity, porosity and magnetics will provide a detailed ground truth to remote geophysical measurements of oceanic crustal properties. The logs have already provided detailed flow delineation, and processing of the borehole televiewer records is expected to reveal fracturing and porosity variations. Core analyses at Site 770 show that the geophysical properties are not normal: Velocities are much higher (3.6-5.4 km/s) and porosities are much lower than usual. In contrast, the back-arc crust of Site 768 has normal geophysical properties in pillow basalts, and also has two massive sills. The combination of geophysical and geochemical basement logs at the site suggests several episodes of volcanism, probably spanning a longer time interval than is typical for crustal accretion at mid-ocean ridges.

Stratigraphic Record of Changes in Source Regions and Volcanism

Source regions for the sediments of Sites 767 and 770 (Celebes Sea) varied through time. For Site 767, both x-ray diffraction and fluorescence (XRF) measurements at 10-m intervals demonstrated broad changes in "continentality": Initial open-ocean clay deposition changed to deposition of sediments first of dominantly continental, then of dominantly island-arc provenance. Geochemical logs show the same broad trends as the XRF data; although more inaccurate than XRF measurements, the logs provide a detailed and continuous record. Because Site 770 was only spot-cored, the geochemical logs provide the primary record of its changing continentality.

At Site 768 (Sulu Sea), a thin basal clay is overlain by 250 m of vitric tuffs and lapillistone. Geochemical logs provide a continuous record of the fluctuations between the rhyolitic and andesitic compositions of these tuffs. Above the tuffs, turbiditic/hemipelagic alternations are indentified on the logs. As in the Celebes Sea region, changes in arc volcanism left a pronounced signature on the potassium log.

Stress Pattern

Measurements of *in situ* stress direction and magnitude were planned for Leg 124, in order to determine the relative importance of subduction vs collision as a source of intraplate stress within the basins. An effort to measure stress magnitude at Site 770 was unsuccessful, because hole collapse precluded reentry of the hole with a packer. Stress directions determined at Sites 770 and 768 are based on borehole ellipticity and rare breakouts identified by the borehole televiewer (BHTV). Both sites show similar northeast orientations of maximum horizontal stress, suggesting that collision of the basins and their flanking ridges with the Philippine mobile belt is now the dominant source of intraplate stress.

LEG 124E

Leg 124E was dedicated to engineering tests of new ODP technologies. Downhole measurements objectives were: (1) Test the consolidation of standard logging from three strings to two longer strings; (2) Test and improve the performance of the wireline heave compensator; (3) Evaluate the ability to cool hot holes by circulation while using the side-entry sub, in order to permit running of standard logging tools in holes that are otherwise above the maximum temperature certification; (4) Compare the quality of through-pipe geochemical logs to conventional openhole geochemical logs.

One site was planned for achievement of these objectives, with five days scheduled for drilling plus logging. To assure that lithologies penetrated would be suitable for the objectives and to avoid spending much of the available time coring, Site 776 was located close to DSDP Site 453. Hole conditions were bad; the bottom assembly became stuck and had to be severed. Thus, no logging was possible.

Two different ways of running two-string tool combinations were tested in pipe at Site 776 and confirmed to be viable. The final aspect of this test, assuring that no tool interference will occur during actual logging of boreholes, had to be deferred to Leg 125 (where it was successfully demonstrated).

During Leg 124E the wireline heave compensator was extensively tested and tuned, resulting in a substantial improvement in its performance. A particular concern was that its performance should be good enough to permit full utilization of the very high resolution obtainable with the formation microscanner (FMS). As the Leg 126 Preliminary Report (this issue) indicates, the effort was successful.

The major impact of losing Site 776 was that no tests of hole cooling and no comparisons of through-pipe and openhole logs were possible.

LEG 125

Downhole logging was attempted at four of the nine sites drilled in the Marianas and Izu-Bonin forearcs of ODP Leg 125. The sites on the serpentinite diapir in the Marianas forearc encountered very poor drilling conditions, with chronic hole collapse problems rendering most holes unsuitable for logging. Logging was attempted in Hole 780C, on the summit of the diapir, since the scientific reward of even limited logging results were deemed to justify the risks. Logging was terminated by hole collapse just below the 60 m depth. Only the Lamont Temperature Logging Tool produced useful data, with temperatures of 13.5°C at only 60 mbsf! The drillhole obviously acted as a vent to allow the highly unusual porewaters to escape, transporting heat from below.

Logging in the Izu-Bonin forearc was more successful. Good logs were obtained at Sites 782 and 786, while the attempt at Site 784 failed due to pipe problems.

Site 782

Site 782 is on the eastern margin of the Izu-Bonin forearc basin about halfway between the volcanic arc and the trench. Hole 782B was logged in two runs. The

first run used the "quad" combo for the first time at a standard scientific site, with the dual induction tool (DIT), dual lithodensity tool (HLDT), sonic digital tool (SDT), natural gamma-ray spectrometry tool (NGT), and the temperature logging tool (TLT). The second run used the induced gamma-ray spectroscopy tool (GST), general purpose inclination tool (GPIT), aluminum clay tool (ACT), compensated neutron porosity tool (CNT), and the NGT and TLT.
The logs define three units: The boundary between the upper (0-~300 mbsf) and middle (300-370 mbsf) units is marked by a sudden increase in density and resistivity downhole, and may correspond to an increase in sediment compaction or to a change in sedimentation regimes at the Oligocene/Miocene unconformity. The boundary between the middle and lower (370-420 mbsf) units is marked by an increase (and increased variability) in compressional-wave velocity and in density, along with higher silica and potassium contents. This boundary may correspond to the Eocene/Oligocene unconformity.

Site 786

Site 786 is also located near the eastern margin of the Izu-Bonin forearc basin. Hole 786B penetrated deeply into an Eocene volcanic complex with highly varied structure and geochemistry. The logging of Hole 786B was done with five strings. The upper part of the hole (0-387 mbsf) was logged first with the DIT-SDT-NGT-TLT tool string, then with the HLDT-CNT-NGT-TLT string. The hole was then cleaned, and the end of the pipe was set deeper. The DIT-HLDT-CNT-SDT-TLT string was run from 464-820 mbsf. The geochemical string with the GST-ACT-NGT-TLT tool combination was run from 0-820 mbsf. A final logging string consisting of only the BHTV was run and obtained both high-frequency and low-frequency images in the interval 470-580 mbsf. The logging results cannot be briefly summarized other than to say that they also show the very complex sequence of flow units, intrusives, and alteration that was found in the core samples. Preliminary analyses of the BHTV images shows breakouts in the N10°E-S10°W direction.

PROPOSALS RECEIVED BY THE JOIDES OFFICE

23 May 1989 through 30 August, 1989

Ref. No.	Theme/Area	Author(s)	Country	Date Rcvd
327/A	Argentine continental rise	K. Hinz & al.	G/ARG	5/89
203/E Rev.	Cretaceous guyots in NW Pacific	E.L. Winterer & al.	US	5/89
328/A	Continental margin of E. Greenland	K. Hinz & al.	G	6/89
329/A Rev.	Paleocommun. between N & S Atlantic	J.P. Herbin & al.	FR	7/89
330/A	Mediterranean ridge, accretionary prism	M.B. Cita & al.	I/G	7/89
331/A	"Zero-age" drilling: Aegir Ridge	R.B. Whitmarsh & al.	UK/G/FR	7/89
332/A	Florida escarpment drilling transect	C.K. Paull & al.	US	7/89
333/A	Tectonic and magmatic evolution: Carribean Sea	B. Mercier de Lepinay & al.	FR/US	7/89
334/A	The Galicia margin new challenge	G. Boillot & al.	FR/SP	7/89
335/E Rev.	Drowned atolls of the Marshall Islands	S.O. Schlanger & al.	US	7/89
336/A	Arctic to N Atlantic gateways	J. Thiede	G	7/89
337/D	Test of sedim. architect. Exxon sea-level curve	R.M. Carter & al.	A/NZ/US	7/89
338/D	Neogene sea-level fluctuations: NE Australia	C.J. Pigram	A	8/89
339/A	Drilling transects of the Benguela current	L. Diester-Haass & al.	G/US	8/89
340/D	Evolution of foreland basins: N. Australia	M. Apthorpe & al.	A	8/89
341/A	Global climate change-Holocene	J.P.M. Syvitski	CAN	8/89
342/A	The Barbados accretionary prism	R.C. Speed & al.	US/UK/FR	8/89
343/A	Drill in window Cret. volc. form. Carribean	A. Mauffret & al.	FR	8/89
344/A	Western N Atlantic Jurassic magnetic quiet zone	R.E. Sheridan	US	8/89
345/A	Sea level and paleoclim. West Florida margin	J.E. Joyce & al.	US	8/89
346/A Rev.	The Equatorial Atlantic transform margin	J. Mascle & al.	FR	8/89
347/A	Late Cenozoic paleocean., S.Equat. Atlantic	G. Wefer & al.	G/US	8/89
348/A	Upper Paleoc. to Neog. seq.: mid-Atl. margin	K.G. Miller & al.	US	8/89
349/A	Clastic apron of Gran Canaria	H.-U. Schmincke & al.	G/US/UK	8/89

EXECUTIVE COMMITTEE REPORT

FY90 PROGRAM PLANNING

The Executive Committee met at LDGO during 31 May-2 June 1989. At that meeting several EXCOM members reported concerns expressed by colleagues about the substitution of the Old Pacific program for the Geochemical Reference program at the Oslo PCOM meeting; in particular, LITHP was not represented at the meeting and had no direct input. In terms of thematic ranking, Geochemical Reference did not make the list of high priority legs for SOHP, TECP or LITHP. At the December 1988 PCOM meeting Old Pacific did not have complete surveys and the attainment of its objectives was questionable. By May 1989, however, Old Pacific was highly ranked and surveys had shown that old crust could be reached. Because of letters received about the removal, PCOM will reconsider FY90 planning at its August meeting. EXCOM adopted the FY90 Program Plan and its budget.

LONG-RANGE PLANNING DOCUMENT

Whereas the emphasis of the long-range planning (LRP) has apparently shifted to deep crustal drilling targets in accordance with the thematic panel priorities, there was some concern that the future of the program as a whole may reside in the success of technological developments. The author of the LRP, N. Pisias, explained that the thrust is not for deep basement *per se*, but that the engineering development required for deep targets is needed to carry the program beyond its present capabilities. Since deep crustal hard-rock drilling is very time-consuming, it may appear to predominate over paleoceanography programs; however, scientific effort cannot be equated to drilling efforts alone. Further discussion included: (1) The need for a slim-line riser for drilling continental-margin deep holes; (2) the need for more emphasis on the detailed understanding of the Earth's magnetic field over the last 200 my, which can only come from drilling; (3) minor modifications to the text of the document. EXCOM voted to adopt the Long-Range Plan pending modifications.

ENGINEERING DEVELOPMENT

EXCOM directed PCOM to proceed with near-term (FY89-93) Diamond Coring System (DCS) engineering design that will allow deployment of modern logging tools in future ODP drillholes. Discussion centered on the apparent incompatibility between the 4-inch diameter DCS drillhole and modern logging instruments.

POLITICAL CONSTRAINTS ON DRILLING

In order to dispel the perception of the European science community that the drillship will remain in the Pacific, EXCOM formally reaffirmed that ODP is a global program of ocean drilling, exploring all oceans and driven by the quality of the scientific proposals within approved thematic priorities.

PUBLICATION POLICY

The new Publications Policy (published in the June 1989 issue) was adopted with the deletion of paragraph C, since the Science Operator would be quicker at handling problems with copyright and lead times than IHP.

RADIOISOTOPES ABOARD THE JOIDES RESOLUTION

Because of the large amounts of C^{14} used by biological experiments (up to 10^9 times higher than naturally occuring levels), there is a very real danger of shipboard contamination. With the advent of tandem accelerator mass spectrometry, it is even more critical that contamination of the *Resolution* be prevented. EXCOM called on PCOM to resolve the question of radioisotope-handling policy as a matter of urgency.

Lastly, EXCOM unanimously approved both the mandate changes proposed by PCOM for OHP, SMP and TEDCOM and the establishment of liaisons with other global geoscience initiatives.

DOWNHOLE MEASUREMENTS PANEL MEETING SUMMARY

The Downhole Measurements Panel met at Scripps during 23-24 May to develop a logging program for CEPAC. The minutes are abstracted herein.

Recommendations for Leg 129, Old Pacific, were as follows: Sites PIG 1-3 require a standard logging suite (excluding FMS) plus magnetometer/susceptibility. Site PIG-4 (or EMB-2) requires a standard logging suite (including FMS), plus packer/wireline packer, BHTV, magnetometer/susceptibility, dual laterolog and the Barnes/Uyeda tool (WSTP) in sediments. It was stressed that PIG-4, a geochemical reference site, should not be the last hole drilled, as doing so would jeopardize the downhole measurements program.

The panel offered the following recommendations for Leg 130, Ontong Java Plateau, superceding DMP Recommendation 89/5: Sites OJ-7, OJ-12, and OJ-14 require a standard logging suite (including FMS); in addition to this, BHTV and testing of the Geoprops Probe should be undertaken at the re-entry site. Pore-fluid samples would contribute to the objectives of Leg 130.

Logging surveys were identified and proposed for the following CEPAC programs which have not yet been formalized into legs: Cascadia accretionary prism, Chile triple junction, Neogene paleoceanography in the eastern equatorial Pacific, lower crustal penetration of layer 3 at 504B, East Pacific Rise barerock drilling, and hydrothermal processes at sedimented ridge crests. The panel noted that stress-direction measurements appear to have been overlooked in the Chile triple junction program and alerted CEPDPG to the apparent omission.The panel concurred that long-term sealing should be effected after further drilling at 504B, with subsequent in-hole experimentation directed at temperature and fluid flow. Since the CEPAC program contains several hostile-environment sites, DMP recommended that "hostile environment drilling programs should be staggered to allow time for lessons learnt to be incorporated into subsequent legs." The revised WPAC schedule has Nankai as Leg 131. Substantial changes to the drilling and logging programs have emerged from the pre-cruise meeting. It was noted that these changes have impacted on the original thrust to obtain *in situ* properties. More generally, the vast amount of time spent by DMP in discussing Nankai had been rendered irrelevant. DMP recommended that because of the importance of the Navidrill to the deployment of the Geoprops Probe during Leg 131, the Navidrill should be modified to overcome operational problems prior to Leg 130, when it should be tested at sea.

Recognizing that high temperature (slimhole) logging is the most important technical issue facing DMP, the following recommendation was formulated: "In view of the technical complexity and cost of high-temperature logging operations, an experienced engineering scientist (should) be dedicated full time to evaluating the status of off-the-shelf high-temperature logging technology for possible future development in ODP. Because of time limitations this activity needs to be completed within a six-month period commencing as soon as possible. The deliverable would be technical advice to ODP on what is achievable with current technology at different temperatures and for different hole diameters. DMP considers this strategy to be the most cost effective in the short term, and one which would optimize the chances of success."

The recommendations formulated by the DMP subcommittee on shipboard physical properties measurements, which met in August, 1987, have not been input to the new Shipboard Measurements Panel (SMP). SMP also seems unaware of the DMP policy on VSP, *i.e.* that VSP should not be carried out routinely. DMP attendance at the next SMP meeting and the possibility of a joint DMP/SMP meeting in 1990 should be explored.

WORKING GROUP REPORT: DRILLING TO UNDERSTAND THE FLUID REGIMES OF ACCRETIONARY WEDGES

Sediments entering subduction zones are typically composed of 50% water, whereas rocks preserved in subaerially exposed accretionary wedges have, on average, less than 5% porosity. The fluid expelled by this volume reduction, plus that produced by thermally activated mineral dehydration processes, must flow through the accretionary wedge, developing in it an active hydrogeological system. Fluids affect virtually all aspects of the geologic evolution of accretionary wedges. Understanding of the fluid component of accretionary wedges is critical in analysis of their tectonics, and, by implication, the tectonics of mountain belts, of which accretionary wedges are an important component or submarine analogue. Indeed, investigation of the role of fluids in tectonic processes in present-day accretionary wedges will be of great value in understanding the processes that were once active in old mountain belts. Furthermore, the escape of fluids from the upper part of the subduction zone exerts a control upon the budget of water and soluble ions that will be taken into the Earth's mantle and be available to be involved in the generation of subduction zone magmatism.

The evolution of fluids in accretionary wedges can be investigated through studies of surface venting phenomena from which the geochemistry of the fluids provides an integrated signal. Similarly, investigation of subaerially exposed accretionary complexes can provide information on the long-term interaction of fluids and structural processes. However, ocean drilling would form the principal component of an integrated study of this active geological system. Drilling not only allows documentation of the effects of fluids through lithologic sampling, but also provides real-time physicochemical measurements of the processes associated with fluid flow. Intensive programs comprising a minimum of three drilling legs, separated by sufficient intervals of time to assess results and improve techniques, are advocated for a small number of very well studied accretionary wedges that represent the spectrum of development. The choice of wedge would reflect the need to determine the effects of naturally varying quantities such as sediment thickness, sediment type, rate of accretion, age of subducting lithosphere, and to keep other parameters as simple as possible, such as convergence direction being normal rather than oblique. Drill sites should be chosen to sample adequately the vertical and horizontal changes in structure and physical properties in the wedge.

Deep holes through the toe of an accretionary wedge, ideally as deep as the oceanic igneous crust, are required to characterize flow through this region, which may be from sources much farther landward beneath the décollement or laterally along the sequence beneath the wedge. The toe region also shows the greatest rate of change in physical properties.

Shallow holes farther landward would investigate the fluid regime of structures that are developed there, such as major our-of-sequence thrusts, and pervasive flow out of the surface of the wedge, following appropriate surveys. These holes would also investigate the progressive deformation of the wedge in relation to fluid content and chemistry, and would study fluids from sources deep within or beneath the wedge released by such processes as dehydration reactions. The evidence for flow into the wedge and forearc basins from adjacent continental crust would also be an objective of more landward sites.

For each site the following are essential for adequate description and understanding of the effects of fluids: As complete a definition of structure as possible, using all methods pertinent to the situation investigated by the drill site: pore fluid pressure*; permeab[illegible] temperature* gas chemistry beyond the standard prescribed measurements; lithology; and diagenetic history. For the starred quantitites a significant advance on what has been done in the past is necessary.

Measurements of *in situ* stresses and mechanical properties have high priority. Also of high priority is the calibration from in hole of measurements of properties of the wedge such as seismic velocity and electrical resistivity made with surveying techniques.

It may appear that the technological requirements for drilling with the objective of understanding the fluid regime of accretionary wedges are so great in comparison to what has been used in the past that it is surprising that any worthwhile information has been obtained concerning fluids in accretionary wedges. In fact, discoveries of great importance have been made with relatively unsophisticated sampling in earlier legs. The questions raised by these discoveries, however, emphasize the need for the comprehensive approach advocated in this report. While it would be unduly restrictive to wait until all the proposed techniques were available as routine before commencing upon a program of drilling, a significant improvement in the effectiveness of the techniques used to determine the important parameters is necessary to justify a heavy investment in drilling time.

Surveys Prior to Drilling

The surveys prior to drilling require greater detail than is usual in ODP studies. Therefore a two-stage strategy is recommended. The first stage surveys require 100% swath bathymetry to delineate the surface morphology; because of their complexity, mud diapirs, thrust faults and folds should be imaged with digital multichannel seismic techniques and processed to resolve them clearly. The broad distribution of water outflow from the wedge may be obtained from heatflow stations, the geochemistry of pore water in piston cores or direct measurement of pressure gradient and permeability with a penetrating probe. The second stage is designed to provide the high resolution data required to site the individual drill holes. Drill sites targeting conduits for fluid venting and circulation almost certainly require investigation by submersibles. Survey data should be located using acoustic navigation from an array of seafloor transponders. Effective placement of drill sites may require high resolution sidescan sonar, reflection, and underwater photography. Detailed heatflow and sampling near prospective sites are needed to evaluate the data obtained from drilling fully in relation to the processes active in the areas of the sites.

Requirements for Logging and Sampling

In general, high absolute accuracy of measurement of the parameters is required, not high spatial resolution of stratigraphy, thus, long-spacing tools (such as velocity) are most important. Neutron porosity, gamma density, electric and velocity logs are critical to calibration of surface geophysical measurements, as are long-spacing velocity logs and uphole and oblique seismic experiments. Various resistivity and induction logs are important for calibration of surface electrical mesurements. Temperature measurements *via* downhole sediment probe or APC temperature shoe are critical to modelling of deformation; high resolution logging HRT repeated at several time intervals to allow extrapolation to equilibrium and detect water flows needs more attention. Stress and strain indicators are vital for definition of deformation processes and geometry; these include televiewer and microlog dipmeter for hole ellipticity and structure (fault zone dip), packer hydrofracture in consolidated sections at depths for stress magnitude and orientation and anelastic strain measurements on consolidated core. There is great need for improving the sensitivity of the Salinity Index Ratio (SIR) and testing its limits for measuring reliably small salinity changes of around 1 per mil; changes of such magnitude are ubiquitous in pore fluids of accreted margins and carry major information on the nature, source and history of advected fluids.

Sampling policy and methodology at

accretionary wedge sites - where principal objectives involve the physico-chemical characters of the sediments and fluids as well as the mechanical state of sediments, and where paleoclimatologic or historical objectives are generally of minor concern - should be flexible to accomodate the objectives and characteristics of individual sites. Blanket procedures on sampling should be avoided, except to form a ceiling on the total percentage of material sampled. Maximizing the spatial resolution at downhole intervals should be the objective during sampling of pore fluids. The optimal spacing required to resolve gradients cannot be predicted, but has to be determined in real-time as drilling proceeds. With the existing procedures for fluid sampling by squeezing, this requires extreme flexibility in sampling policy and more frequent whole-round samples at the discretion of the co-chiefs. To permit this flexibility, drilling of B and C holes at certain sites should be considered.

It is imperative that a pressure core barrel system be employed which allows not only sampling of sediment-fluid-gas under *in situ* conditions, but also ensures detection and measurement of the gas content onboard. Accurate total gas contents must be unaffected by losses due to evolution and escape. This procedure should also address the problem of stripping of trace gases during degassing of methane and carbon dioxide, because the trace gases, noble gases, and thermogenic hydrocarbons contain important information on the source depth of migrating fluids.

Requirements for Downhole Measurements & Experiments

At present a number of tools to measure pore pressure, permeability, temperature and stress *in situ* are under development. It is clearly desirable to increase the frequency of deployment of the *in situ* pore water samplers per drill hole coupled with temperature sensors. The deterioration of drill hole conditions during *in situ* sampling and probing is a problem that needs to be overcome.

Packer deployment for sampling of fluids is very promising in certain structural settings such as venting conduits, décollement zones, faults and unconformities, whereas side-wall sampling for fluids seems an approach that is not very promising, as contamination by drilling fluid and caking of mud is highest adjacent to the drill-hole wall. In addition to tools that obtain *in situ* measurements directly, several tools measure correlative properties, such as seismic velocity and electrical resistivity. High-quality seismic experiments and large-scale resistivity experiments are very informative when used in conjuction with other geophysical measurements.

Requirements for Laboratory Measurements & Experiments

Laboratory experiments and measurements beyond the normal shipboard suite are necessary to obtain additional characteristics and to correlate or calibrate logging and other measurements. Of the laboratory experiments pertinent to studies of accretionary wedges, intergranular permeability tests, anelastic strain recovery (ASR) measurements, fracture analysis, sediment mechanical tests, and seismic velocity measurements under *in situ* conditions were perceived as most important. Both ASR tests and structural analyses will require some method to orient the core. Although there is no way at present to orient cores of consolidated material at depths beyond APC penetration, a number of indirect methods should suffice. These include correlation of *in situ* and core dips using the formation microscanner tool and paleomagnetic measurements on the cores. Thermal conductivity measurements in consolidated sediments are difficult and time consuming using the needle probe. The development of a 'thermal pad' to measure conductivity on the face of split core is to be encouraged. Attention should be paid to the extra demands placed on onboard equipment by the need to make measurements under preserved *in situ* conditions from a pressure core barrel system, and to the storage and transport of these samples.

Finally, techniques with which the physical properties of gas hydrates can be determined should be developed.

Post Drilling Experiments

Long-term measurements of strain, fluid pressure, temperature and perhaps fluid chemistry in boreholes should be considered as a means of placing the drill site data within a temporal context. It is important that the borehole be sealed to prevent fluid flow along it. Borehole measurements should be made in association with seabed monitoring of strain, temperature and fluid pressure gradient, and seismicity.

TEDCOM MEETING SUMMARY

The Technology and Engineering Development Committee met at College Station, Texas, during 27-28 April, 1989. The two-day meeting had two primary objectives: (1) Assess results of the first engineering leg (124E), in particular the performance of the Diamond Coring System (DCS); and (2) formulate the TEDCOM response to the ODP Long Range Plan.

The DCS system is a top-driven system using high-speed, narrow-kerf, diamond-impregnated bits. A secondary heave compensator limits the weight on the bit (WOB) to 2500 ± 500 lbs. The DCS testing demonstrated that the system can be deployed in severe weather conditions and that the mining system top drive can be used effectively in 1600 m of water, although it was not used at top speed. The secondary heave compensator was effective in limiting WOB, as required. Results were generally perceived as positive even though hole stability problems were severe and tests were*not* performed in basement. During discussion of the Navidrill tests, it was suggested that ways of dissociating the weight on the bit from the rotational speed be studied, possibly by using a sand line to reduce the WOB.

The TEDCOM mandate was reworded in accord with TEDCOM's function and submitted to PCOM for approval. The following four recommendations regarding future engineering tests were made: (1) The DCS should be retested as soon as possible in optimum conditions with a cased hole, at a properly surveyed site with basement at an acceptable depth. Water depth should not be greater than 1500 m unless demanded by site considerations; (2) A TEDCOM subcommittee, consisting of W. Svendsen, K. Millheim, F. Schuh, J. Coombs and P. Wickland, should be created to advise TAMU on mining drilling; (3) A. Skinner of B.G.S., knowledgable in the field of DCS systems, should participate in the aforementioned subcommittee. His travel expenses should be paid by JOI; and (4) TAMU should study ways of modifying the DCS to immobilize the lower end of the API string during all phases of DCS operation.

Hard-rock core orientation was discussed at the request of R. Moberly. TEDCOM concurred with TAMU that no acceptable system was currently available today. (An ARCO system that suppressed the natural magnetism of the cores was considered unsuitable.)

TEDCOM considers that TAMU is spreading its research effort too wide. In particular high-temperature drilling research efforts, already being undertaken by Los Alamos and Sandia, should not be duplicated.

TEDCOM members were alarmed at the frequency with which bottom hole assemblies have been explosively released in recent months. SMP will look at ways of acquiring data from cores to give indications on swelling that could lead to stuck pipe. TEDCOM recommended that ODP acquire an unconfined compression tester for hard rock, which would yield immediate knowledge of compressive strengths, to improve drilling and coring operations.

TEDCOM concurred with TAMU that the cleaning of hole 504B should not be combined with an engineering leg.

SEDIMENTARY AND GEOCHEMICAL PROCESSES (INTERIM) MEETING SUMMARY

The Sedimentary and Geochemical Processes Panel met at Lamont-Doherty Geological Observatory, Palisades, NY, during 19-20 July, 1989. The major goal of this meeting was the production of a new white paper, necessitated by the formation of the new SGPP and OHP Panels. The current working draft of the paper will be revised and finalized at the next scheduled meeting. Five major themes will be highlighted in the document: Changes in sea level, fluid circulation and geochemical balances, metallogenesis, paleocean chemistry and depositional architecture and sedimentary processes.

Geochemical reference holes, as a concept, continue to rank among the highest priorities for SGPP. The panel expressed concern about the process through which the Geochemical Reference Hole was removed from the 1990 schedule, apparently without scheduled debate. Top-ranked thematic priorities for 1991 are the proposed drilling of:
(1) Sedimented Ridge Crests; (2) Cascadia Accretionary Prism; (3) East Pacific Rise Bare Rock; (4) Eastern Equatorial Pacific Neogene Transect; (5) Lower Crust at Site 504B and (6) Chile Triple Junction. The panel wishes to make it clear that the first two priorities far outrank the remaining four.

Significant new scientific developments have taken place since first establishing the present sampling procedure, hence, pore-water and gas sampling procedures on board the *JOIDES Resolution* are in need of a major overhaul. A major discussion of this issue was deferred pending the ODP Geochemistry Workshop in January of 1990. Interim SGPP recommendations are that: (1) Titanium squeezers should be constructed to allow pore-water studies involving metallic elements; and (2) Routine squeezing of half-round (50 cc) samples for interstitial water be discontinued. A move on this latter procedure was requested by the ODP Science Operator/TAMU. Other issues, such as centrifuging, using inert atmospheres during extraction, and teflon squeezers will be dealt with during the overhaul of the entire pore-water procedure.

The importance of successfully drilling and recovering adequate core material in sandy sediments was stressed repeatedly during the meeting. The success of the Cascadia Accretionary Prism and Sedimented Ridge programs demands improvements within this area of technology. The time penalty of one round trip per core in order to recover sand may be tolerable under certain circumstances.

ODP SITE SURVEY DATA BANK REPORT

The ODP Data Bank received the following data between 1 April 1989 and 31 May 1989. For additional information, please contact Dr. Carl Brenner at ODP Data Bank, LDGO, Palisades, NY 10964.

- From E. Winterer,SIO: Digital tape of navigation merged with underway geophysics for *R/V Washington* cruises ROUNDABOUT 10 and 11 (Central Pacific Guyots and Ontong Java Plateau regions, respectively), along with microfilms of seismic reflection profiles and seabeam contour swaths.
- From J. Phillips, UT: Vertical seismic profile records collected aboard *JOIDES Resolution* during Leg 111 drilling of Site 504B.
- From K. Tamaki and K. Suyehiro, ORI, Japan: Lines KT-87-6-MC1, KH-86-2-5, KH-86-2-6, KT-88-9 107, KT-88-9 108, KT-88-9 109, KT-88-9 110 and DELP 85-E, as additional documentation for Japan Sea drilling.
- From P. Davies, BMR, Australia: Multichannel seismic lines 27-30, 37, 39, 41, 43, 45, 46, 57 and 59 from RIG SEISMIC cruise 75, ODP site survey of the Northeast Australian Margin.
- From B. Bornhold, PGC, Canada: Magnetic tape of bathymetry and magnetics merged with navigation for PARIZEAU cruise 87, ODP survey of the Patton-Murray Seamount Chain, along with piston core listings for the area.
- From P.J. Fox, URI: Six magmetic tapes of gridded Seabeam and SeaMARC data from the JOI/USSAC synthesis of the East Pacific Rise area.

DRAFT, TECTONICS PANEL WHITE PAPER
(EDITED FOR INCLUSION IN THIS ISSUE)

INTRODUCTION

This article summarizes the contribution of the Tectonics Panel (TECP) to the JOIDES/ODP long-term planning process. The prioritized tectonic themes embrace the deep structure of the planet as well as the crust, the driving forces of the plates as well as their relative motions, interactions, and responses to both compressional and extensional forces. Although many of the tectonic processes of interest to earth scientists, including the most fundamental ones, are beyond the reach of the drill, the philosophy of the TECP is that the ODP should contribute to the understanding of these processes wherever practical. Deep seated processes can be addressed by indirect methods such as seismology and stress determination, shallow ones by examination of cores and *in situ* measurement of physical and chemical properties. Both types of approach need to be undertaken with complementary geological, geophysical and geochemical studies. The prime criteria for identifying a tectonic project suitable for the ODP are scientific quality and absolute need for deep sea drilling.

The paper presents five themes, outlines the specific tectonic significance of each, summarizing the state of knowledge, and pointing out the contribution that can be made by ocean drilling. The background data and technical development necessary for a successful drilling program are outlined, and drilling strategies are suggested. Specific drilling targets are mentioned as examples only. It is the task of the science community to develop these ideas and propose specific drilling experiments.

TECP believes ODP must move into a mode of drilling for tectonic objectives that is characterized by technical development and increased use of physical and chemical measurements. Proposals to study any of TECP's main themes are likely to involve multiple, related sites, including sites distributed over single plates, across conjugate rifted margins, along the lengths of hot spot chains and across convergent margins. Consideration could also be given to carefully designed drilling programs in single oceanic regions or small ocean basins that involve interplay of key tectonic processes. The transect of holes drilled in the Tyrrhenian Sea, for example, demonstrates the related roles of rifting, passive margin development and convergence in a young, small ocean basin that has considerable potential for ultimate preservation in the geologic record. Comparable tectonic laboratories for integrated study include the Caribbean Sea, Atlantic Ocean, Japan Sea, Scotia Sea, and elsewhere in the Mediterranean basin. The Mediterranean basin has obvious potential to unlock outstanding secrets of Alpine mountain buiding. The Japan Sea, Caribbean and Scotia basins have similar potential for Cordilleran orogenesis. The Atlantic Ocean basin is the obvious laboratory for studying supercontinental break-up and the long-term development of both volcanic and non-volcanic rifted continental margins. Ocean drilling for tectonic goals should thus interface with other types of geoscience investigation, on land as well as at sea, and involve a broad cross section of earth scientists, as envisaged by the COSOD II participants.

MAJOR THEMES FOR FUTURE TECTONIC DRILLING

Deformation Processes at Convergent Plate Boundaries

• *Tectonic significance*

Convergent plate boundaries are first order tectonic features. Tectonic processes operating at these boundaries need to be investigated using simple examples with well established kinematic histories and settings. Here, the lithospheric surface area added at divergent boundaries is consumed. In the process, material is scraped off the downgoing plate to generate an accretionary wedge, or in other cases eroded from the overriding plate to contribute to an underplating process (subcretion). The magmatism at longlived convergent plate boundaries is second only to the generation of oceanic lithosphere at spreading ridges and a major factor in the generation of continental lithosphere. Deformation of the overriding plate can, even without significant collisional events, generate major mountain ranges, *e.g.* the Andes. Generation and destruction of marginal ocean basins at convergent plate boundaries is a vital link, as yet poorly understood, between deep-seated processes and orogenesis.

• *State of knowledge*

In the past few years sediment accretion has been demonstrated at many margins, but non-accretion and/or tectonic erosion has been inferred at other margins. Increasingly sophisticated models have been developed to explain the geometry, kinematics and mechanics of accretion. Effluents of accretionary complexes are known both from direct observation and by inference from reduction in the porosity of the constituent sedimentary rocks.

Mass transfer and balance are important underlying themes in convergent margin studies. Information is needed with regard to how much sediment is added to accretionary wedges and how this sediment is deformed, how much sediment is subducted into the mantle, whether accreted sediment and crystalline basement can be lost by tectonic erosion, whether there are episodes of growth and loss, and the extent to which sediment drawn down into the mantle has been dewatered by shallower tectonic, diagenetic and metamorphic processes.

Although rapid advances have been made in our understanding of convergent margin processes, many questions still remain. Models of stress systems in accretionary wedges require high pore-fluid pressures at the basal décollement to reduce shear stress, but reliable measurements of elevated fluid pressures directly in the vicinity of the décollement are nonexistent, and the distribution of fluid pressure within the wedge or the flow regime within the wedge is unknown. The distribution of stresses in the forearc is also poorly understood. Deeper processes within the wedge have only been inferred from seismic images and vertical movements of the wedge. While seismic images and drilling have revealed various styles of deformation in parts of accretionary wedges, more information about modes of deformation is needed. Although topographic features, such as seamounts, ridges and oceanic plateaus, are carried into subduction zones, the response of accretionary wedges to such collisions is poorly documented.

• *Potential ODP Contribution*

Mechanics of deformation: Most accretionary complexes are wedge-shaped in cross section. As sediment is added to the leading edge, or toe, of the wedge, the wedge thickens in response to the increased horizontal stress resulting from the increase in its length. The processes by which wedges thicken include vertical extension associated with horizontal shortening, motion along and rotation of the thrusts by which sediment is accreted to the toe, the formation of new out-of-sequence thrusts, and subcretion of sediment to the base of the wedge. Drilling and other data suggest that some wedges are undergoing tectonic erosion along their bases. The process of accretion at the toe of the wedge has been well studied, but little is known of other processes that add or remove material from the wedge and how they are influenced by the stress regime and strength of the wedge.

Accretionary wedges constitute a natural laboratory for studying the response of porous sediments to deformation and consolidation under differential stress. Environmental conditions (stress, temperature), physical properties (strength, porosity, permeability) and mechanical state (cohesion, internal friction, compressibility) in the deforming sediments must be quantified.

It is important to determine the gradients in density and porosity of accreted sediments accurately as a function of both depth within the wedge and distance from the toe of the slope. An understanding of the strength and state of failure in deforming sediments can only be achieved with extensive experimentation and *in situ* measurements, including logging, geotechnical probes, and vertical and offset seismic experiments. Most models explicitly or implicitly invoke high pore-fluid pressures to reduce the stresses acting on the base of the wedge. Variation in pore pressure within an accretionary wedge causes variation in strength, hence, in shape and the kinds of structures that form within it. *In situ* measurements of pore water pressure within the wedge and in the décollement region will constrain the other variables in the models and probably eliminate some proposed models. Similarly, sampling and laboratory testing for stress-strain behavior will constrain the rheology appropriate for models of accretionary wedges, and when tied to microstructural studies of core material will produce information on the mechanisms that control rheologies during different stages of development of the wedge. A much neglected, but important aspect of the deformation of wedges is the time dependency and episodic nature of deformation and the extent to which it can be related to seismicity in the subduction zone. Long-term sea-bed monitoring of strain, fluid pressure, and seismicity is required.

The movement history on major out-of-sequence thrusts, which provide one mechanism of preserving wedge taper, can be obtained by drilling where slope sediments are overridden. The processes that add and remove material from the wedge can also be examined indirectly by their effects upon the overlying accretionary wedge and slope drape sediments. Opportunities for direct sampling exist where the wedge is thin and subcretion occurs near the toe of the wedge. The study of forearc basins will be of great value in understanding the dynamics of accretionary wedges. The nature of the basement of most of these basins is unknown and needs to be determined with deeper (~2 km) holes. In the so-called residual forearc basins that overlie what is believed to be igneous or metamorphic crust of the overriding plate, the pattern of sedimentation associated with subsidence and uplift reflects the growth of the wedge and the deformation of the sediment records the landward motion and propagation of the wedge. Slope basins, situated on an accretionary wedge, record the absolute and relative variations of uplift associated with its growth or subsidence associated with tectonic erosion. It would be valuable to determine how the episodic development of many forearc regions is related to changes in plate motion and sediment input. Many of these changes are recorded in the interaction between slope sedimentation and tectonic activity. The question of mass balance, particularly partitioning of materials that are being offscraped, subcreted, eroded or subducted, will only be resolved by a better understanding of how wedges "work." Until then, reliable estimates of the subduction zone contribution to the global geochemical cycle will be difficult to quantify.

<u>Hydrogeology:</u> The pressure of pore fluids reduces the effective confining pressure acting on a rock mass, and can influence deformation strongly, especially if pore fluid pressures vary to produce local zones of very low shear strength. Some models suggest that fluid pressures in excess of 90% of the lithostatic pressure make possible low-angle faults with large displacements.

The production of high fluid pressures and expulsion of fluids are associated with compaction and diagenesis within both the sediments of the wedge and underlying terrain. The fluids transport heat, and the chemistry of the fluids reflects both the conditions in the source region and water-rock interactions along fluid migration pathways. Geochemistry of the fluids is important to fluid motion and pathways within the prism, particularly in the deeper parts not accessible to direct sampling. Hydrogeochemical studies may provide specific information on fluid flow rates and permeabilities in otherwise inaccessible parts of the wedge, critical to assessing the state of stress. Fluids are a vital component controlling the strength of rocks and deformation styles, yet the nature of the basic fluid budget is poorly known at present. A comprehensive fluid-budget and migration pathways program can be developed using combined geophysical and geochemical techniques. For example, long-term geochemical monitoring of selected sites should provide a sensitive means of evaluating temporal and episodic development within a wedge.

Collisional Processes: One of the most challenging objectives for the next decade will be to relate, more directly that is currently possible, collisional processes at convergent margins to continental orogenesis. After oceanic lithosphere is consumed, continent-continent collision ensues, forming Alpine-type and Himalayan-type mountain ranges. Short of this extreme, topographic highs, *i.e.* seamounts or aseismic ridges, may be swept into convergent margins with variable, and as yet poorly understood, consequences. Land studies (*e.g.* in the Tethys and Iapetus) suggest that the early stages of continental collision show many features similar to oceanic convergent zones, although the nature of the sediments accreted and the structures may differ. Contemporary collision zones vary considerably and it is not yet known how the thick sediment cover of continental margins interacts with the forearc, or how collision affects the distribution of deformation across the entire zone of convergence. Drilling incipient collision zones may shed light on the nature and timing of vertical and horizontal displacements, synchronous sedimentation, crustal flexure and deformation style. The precise targets require careful consideration.
During collision large slices of oceanic crust may be emplaced onto continental margins. Land studies suggest that major ophiolite slices form part of the 'orearc that converges on a subducting ontinental margin, but the deep ructure and composition of oceanic cearcs remain very poorly understood. nll exposed ancient ophiolites mument the end product of deformation foremplacement, not the collisional conanism. Young ophiolites, like those

ıic margin sediments. Critical relati^he between the emplacing oceanic ɛ the parent oceanic crust are not ·ins. exposed. Key questions still to be ɪal answered include the petrology, ·rc- geochemistry, structure and tectonic n setting of incipient ophiolites and the. process of detachment, uplift and emplacement onto continental margin

Extensional collapse of high collisiona ridges may result in the formation of arc shaped orogenic belts. A phenomenon common to these structures is that they develop in convergent settings, yet they are underlain by thinned crust on the inner sides of the arc. Research into the dynamics of this process is critical for the understanding of mountain building. The study of the structure, subsidence history and basement of such inner-arc basins may be most rewarding in areas of restricted post-orogenic sedimentation (*i.e.*, where the basement is readily accessible).

Dynamics of Convergent Plate Margins: One of the most intriguing areas in which to conduct submarine stress measurements is in the overriding plate. Despite the assumptions that go into theoretical modeling of convergent margins, relatively little is known about their stress fields. The stress measurements that exist are largely on or adjacent to islands, which are, by nature, anomalies. The transition from compressional to extensional strain fields upslope from the trench and toward the back arc is commonly interpreted to mimic a transition in the stress field. Indirect geological indicators have been used to infer the orientations of stress axes, but there is little in the way of direct data bearing on such critical questions, for example, as the origin and inversion of marginal basins (*i.e.*, the transition from Marianas-type to Chile-type margins).

The magnitudes of different stresses beneath the landward trench slope can be uncertain by an order of magnitude or more. In many cases, much can be learned from measurements of stress orientations over a wide range of upon relative strengths of two different forces (*e.g.* slope-related gravitational stresses and friction along a fault) that can be predicted theoretically to contribute differently to total stress. A sequence of measurements in the accretionary prism on the outer-arc high, and in the forearc basin, arc, and back-arc basin would shed light on basic issues related to how stress is transmitted and modified near a plate margin.

Additional measurements could resolve the forces acting on the Nazca plate and the overriding South American plate, where tectonic erosion is believed to be an active process. Comparison of the stresses on the South American plate above "flat-slab" subduction and "normal" subduction segments, and north and south of the Chile Rise triple junction, could also provide important constraints for orogenic processes.

• *Background Data*

All of the above themes relevant to ODP drilling on convergent margins require a clear understanding of the geometry of the structures. It is also essential that a comprehensive recent history of plate interactions and kinematics for the margin be available. This should include plate ages, convergence directions and rates. For present day motions, seismicity, fault plane solutions and other stress/strain indicators should be as fully investigated as possible. "Site Survey" is no longer merely a matter of identifying a satisfactory and safe place to drill. Detailed seismic surveys are required. It is necessary to image: The top of the undeformed lower plate and subducted sediments; the internal geometry of the wedges including folds, thrusts, normal faults, duplexes and mud diapirs; the lateral changes in the structures (3D) including thrust faults and ramps.

Accurate depth-corrected images must be provided. This requires improved geophysical estimates of the velocity structure.

Specific proposals to study the role of fluids would be greatly improved by initial reconnaissance of the hydrothermal vents, including heat flow measurements and direct diving observations.

• *Technical Developments*

The principal technological development required to drill deeper and maintain hole stability in undercompacted sediments or clastic materials is a riser. Drilling into the deepest parts (25-30 km) of convergent margins is impracticable, but drilling 2-4 km into inferred zones of incipient subcretion is feasible. It is a prime requirement to obtain an undisturbed, oriented core.

Development of packers for *in situ* pressure measurements is of the highest priority. The clear understanding of the role of fluids will require a knowledge of pore pressures, flow rates and the fluids themselves. Long-term instrumentation should be planned for specific holes, in order to measure the thermal regime, fluid circulation and seismicity over long periods of time.

Instrumentation needs to be improved for *in situ* stress and strain measurements. Besides existing dip meters, new tools for orientation of the cores are still needed. Logging time should be increased to allow time for the downhole measurement and sampling required. Vertical or offset seismic profiles will be required in most holes to provide accurate ties to geophysical data and to estimate the physical state of the rocks away from the drill holes. The full value of drill holes will not be realized until there is a well established pathway of information from microstructural studies of core materials and experimental work on its dynamic and physical properties, through borehole logging of *in situ* properties, to the mapping of structural and physical properties away from the drill sites by geophysical and other means.

• *Drilling Strategy*

Investigation of accretionary wedges should continue by focusing a broad suite of investigative strategies on a few selected regions and treating these regions as natural laboratories that would ultimately be permanently monitored to investigate dynamic processes that have both temporal and spatial variability. Processes that should be investigated include hydraulic circulation and related dewatering processes, the development of stress fields and related strains, and mass transfer processes that occur throughout the forearc region. A thorough investigation by geophysical means including seismic reflection and side-scan sonar techniques, will lead to an image of structures which are related to these processes. Then holes can be drilled into these structures both to investigate the structures at scales smaller than the resolution of geoacoustic techniques and to measure physical and chemical parameters related to dynamic processes. The future drilling will vary in two fundamental ways from previous drilling efforts: improved drilling techniques will permit much deeper penetration and better core recovery; and improved instrumentation will permit a broader range of observation over a longer time span.

• *Locations*

In nearly all cases the choice of location for drilling programs to understand tectonic processes at convergent margins should be influenced by substantial benefits to be gained from integration with geological and geophysical work on land. Drilling should take place in at least one clastic-dominated margin (*e.g.* Nankai, Cascadia, southern Barbados), one pelagic-dominated margin (*e.g.* northern Barbados, Costa Rica) and one non-accretionary/erosional margin (*e.g.* Japan, Peru Trench).

An appropriate drilling strategy is needed to document the role of collisions, large and small, in orogenesis. Collision of an active mid-ocean ridge is best exemplified by the Chile Rise-Chile Trench triple junction, but has been a dominant feature of the history of other margins such as the western Antarctic Peninsula. The process of collision between an island arc and continental margin involving thrusting of the island arc over continental crust as exemplified by the Sunda arc-Australian continent collision, also deserves to be better understood.

Back-arc basins formed during convergence may later be inverted, leading to arc-continent collision and subsequent mountain building, as hypothesized on land in the West Pacific region (S. China/Taiwan/Japan), southern Andes, the Alps and the Appalachians. The initial stages of back-arc underthrusting appear to be taking place in the West Pacific region (Banda Sea, S. China Sea).

Collisional processes are diachronous in space and time. The Mediterranean, for example, offers a rich tectonic laboratory to study comparative collisional processes, ranging from steady-state consumption of oceanic lithosphere under the Hellenic arc, to possibly initial stages of collision in the Eolian arc in the western Mediterranean, and potentially more advanced collision along the Cyprean arc in the eastern Mediterranean.

Deformational Processes at Divergent Plate Boundaries

• *Tectonic Significance*

The rifting of a continent is commonly the first event in the formation of an ocean basin. Such breakup typically involves normal faulting, igneous activity, uplift and subsidence, erosion and sediment deposition, and encompasses the time interval between initial extension and normal sea-floor spreading. Breakup varies in duration from a few million years to 50 million years or more, and forms the basis for all important aspects of subsequent margin evolution. Patterns of continental breakup are one of the primary indicators of the structure and rheology of the continental lithosphere. Preexisting continental structures and tectonic fabric play a key role in controlling rift location and style. The age of the continental lithosphere, *i.e.* the time since the last major heating or tectonic event, controls the geotherm, the most important factor in determining its strength. Anomalous heating from mantle sources may produce weaknesses in continental lithosphere that are exploited by rifting. These and other factors control the lateral distribution of continental extension and its surface manifestation. The heat budget of the margin is also established by extension. The distribution and amount of extension determine the tectonic subsidence and uplift during the post-rift phase. The change in sedimentary evironment in response to tectonic activity is complex and depends on the amount of sediment supplied.

The major problems to be investigated at rifted margins are: (1) What is the distribution of strain in the crust and mantle across the margin and its conjugate; (2) What is the distribution of volcanics and intrusives on a margin; and (3) What is the distribution of flexural strength across a margin and how does it vary with time? Naturally, the causes for these distributions are of interest, but first the distributions are on different margins must be established. Only then can patterns be discerned in the data.

Rifted continental margins differ in width, distribution of crustal extension, amount, nature, and timing of igneous activity and symmetry. Hotly contested end-member models for various tectonic aspects of continental breakup exist; end-member models of rifting by pure or simple shear reflect a debate about whether extension is distributed evenly through the continental lithosphere or localized at one or a few very large shear zones. Variations in volcanism during rifting have spawned both debate and numerous models to explain the observed differences. Transform rifts are predicted to behave quite differently from normal pull-apart rifts. Rift diversity is undoubtedly a result of the interplay of all these phenomena.

Rifting in oceans is also of great interest, and it would appear that oceans should be an excellent place to study the rifting process because of the comparatively simple structure of the oceanic crust. The tectonics of mid-ocean ridges with propagating rifts, overlapping spreading centers and changing rift profiles offers much that is new and exciting in the study of tectonics, especially in relation to magmatism. Equally interesting are questions of how intraoceanic rifting is initiated, how it ceases, and how ridge topography is preserved for periods of several tens of millions of years. Understanding of the nature and evolution of faulting, distributed strain and block rotation at ridges is an important tectonic theme that can be pursued in parallel with other studies of the oceanic lithosphere (e.g. petrology and geochemistry).

•*State of Knowledge*

Until recently, rifting was viewed as a symmetric tectonic process. Many geological and geophysical observations now emphasize the importance of asymmetric structures in the crust. For example, regionally extensive low-angle normal faults have been traced from the surface to mid-crustal depths in the Basin and Range of the western United States using seismic reflection techniques. A related class of asymmetric crustal structures is represented by certain metamorphic core complexes, where mid-crustal rocks have been tectonically denuded by normal detachment faults that are now nearly flat-lying. Strong topographic and volcanic asymmetries also exist across some conjugate rifted margins. Asymmetric deformation is commonly characterized as being a result of simple shear. This has led to the suggestion that the entire lithosphere may deform through simple shear.

Rifting must extend the crust and mantle portions of the lithosphere by the same overall amount, but the question remains concerning how that extension is distributed spatially and temporally. The problem of the spatial distribution of extension is often cast in terms of end-member models of pure- versus simple-shear deformation. The key difference between these models of extension is whether lateral offset of crustal extension relative to mantle extension occurs. For the simple-shear model, there is spatial separation between crustal thinning and lithospheric thinning, while for pure-shear rifting, the crust and lithosphere in any vertical crustal column extend by the same amount. Lithospheric deformation is surely more complex than these idealized models, but it is useful to try to evaluate data in terms of the amount of offset of crustal and mantle extension. One example of a hybrid of these models has no offset between the center of crustal extension and mantle extension, but the mantle extension is spread over a wider area than the crustal extension. This leads to initial uplift of the area flanking the crustal extension.

Some rifted margins require a component of simple-shear extension. For example, the Newark Series basins in the United States east coast contain synrift sediments, but no postrift section, and they do not exhibit thermal subsidence. However, these basins were eventually abandoned, and it appears that pure-shear deformation, centered east of the Newark basins, led to extreme crustal thinning and eventual formation of the North Atlantic Ocean basin.

Data suggest that pure-shear deformation has been the dominant mechanism of extension at some rifted margins. For example, heat flow data for the northern Red Sea require that most of the approximately 100 km of extension that has occurred there in the last 20 My has not involved lateral offset of lithosphere and crustal thinning.

Modeling lithospheric deformation will eventually lead to quantification of the process by which lithospheric extension transforms from simple shear to pure shear. Nonetheless, very limited data on the timing of progressive changes in the mode and width of extension exist, and only drilling can supply such information.

In addition to determining the distribution of deformation, the role of volcanism in extension must be quantified. Some margins seem to have little or no volcanic rocks overlying extended continental crust. In other regions, seismic data reveal that volcanics cover broad areas, and their thickness may be greater than that of adjacent oceanic crust. Models are presently being developed for extensive volcanism on rifted margins. In one, partial melting is related to anomalously high temperatures in the mantle caused by mantle plumes. In another, extra melting is due to vigorous asthenospheric convection driven by lateral temperature gradients. These models are not mutually exclusive, but they predict testable differences in the average degree of partial melting and chemistry of the magmas produced. Again, the rocks essential for testing the models can only be sampled by drilling.

Over the past four years, ODP has made substantial strides towards understanding the geological evolution and kinematics of both volcanic and nonvolcanic rifted margins. Site 642 penetrated a seaward-dipping reflector sequence on the Voring Plateau, suggesting strongly that these edifices, which are known to characterize some rifted margins from Norway to the Antarctic, are rapidly emplaced volcanic piles deposited at or near sea level. Off Galicia, Leg 103 addressed the geologic evolution of perhaps the best known example of a sediment-starved, nonvolcanic margin. The drilling of the Tyrrhenian Sea on Leg 103 allowed a determination of the timing and magnitude of subsidence across the rifted basin, which is critical for constraining models of extension. A transect of shallow holes not only refined prerift, synrift and postrift sedimentary history, but raised provocative new questions regarding the nature of reflector S, a prominent, continuous seismic horizon which may be a low-angle detachment. Leg 121 showed that Broken Ridge formed by a rapid uplift event, documenting the importance of flexure during extension.

• *Potential ODP Contribution*

In the decade to come, the main goal of ocean drilling on rifted margins will be to continue to test and discriminate among existing (and undoubtedly new) end-member models of margin evolution. It is of fundamental importance that ODP develop process-oriented investigations aimed at resolving fundamental rifting mechanism(s) controlling extensional deformation. In order to do this, drilling must sample continuously thick, postrift, synrift and prerift volcaniclastic sections *en route* to deep crustal structures elucidated both from remote sensing and other types of regional geologic studies. As an example, Leg 103 results have recently led some investigators to propose a simple-shear origin for the

Galicia margin and its conjugate off the southeastern Grand Banks. This hypothesis has been supported by new, deep geophysical data and a great deal of petroleum industry-derived well-control offshore eastern Canada. The model may be testable with the drill off Galicia, where one or more deep holes to reflector S could confirm its postulated identity as a through-going, low-angle detachment characteristic of a lower plate margin. The nature of continental crust thinned under extreme conditions of ductile shearing could also be determined in places like the Alboran Sea in the western Mediterranean.

As another example, geochemical studies of ODP samples of seaward-dipping reflector sequences (SDRS) from various rifted margins should offer a continuing and outstanding opportunity to understand one of the more obvious roles that volcanism plays during lithospheric extension. While Leg 104 found that the Voring Plateau SDRS is a basaltic edifice, drilling did not confirm its oceanic affinity because of rocks of continental affinity encountered near the base of the hole. Samples recovered from future SDRS drilling should improve our knowledge concerning the degrees of partial melting and the nature of the underlying mantle source(s) which produce SDRSs. An added complication is that SDRSs on other margins, *e.g.* off southwest Africa, are known to be at least partially silicic, suggesting the probability of the complex involvement of continental fragments in the transition from continent to ocean basin. Detailed geochemistry may be able to constrain degrees of nonoceanic interactions during emplacement, thereby allowing more definitive assessments of the "oceanic" vs. "continental" character of SDRSs to be made. Integration with land-based petrologic and geochemical studies in the Thulean and Gondwanaland igneous provinces will provide a complete picture of the igneous activity associated with supercontinental breakup. Furthermore, as ODP continues to sample rift basins in the marine environment, other, less seismically obvious, forms of volcanic involvement in rifting processes will undoubtedly be documented.

Other tectonic problems at mid-ocean ridges that can be investigated with the drill are: Are the inclined seismic reflectors in the oceanic lower crust faults, or are they related to magma emplacement; is the crustal fabric close to fracture zones and overlapping spreading centers different from "normal" oceanic crust?

•*Background Data*

The primary objective of rifted-margin studies is to recognize and characterize the transition between oceanic and continental lithosphere and to understand the geologic processes that control that evolution.Though at a scale of thousands of kilometers the tectonic evolution of oceanic regions and initial plate configurations is now well understood, significant deviation exists at scales of hundreds of kilometers and less. Consequently, the success of any drilling operation depends heavily on the collection and anaylsis of all possible geological and geophysical information from the region in which the drilling is to be carried out. To distinguish the wide variety of processes which may have taken place prior to the separation of large lithospheric plates, a precise understanding of the kinematic history of the adjacent oceanic basin is required. Therefore geophysical data on *both* conjugate margins must be synthesized prior to drilling.

In particular, pre-drilling geophysical data must be able to discriminate pre-rift structures and syn-rift versus post-rift sedimentary successions within rift basins to ensure precise site selection. Acquisition methodologies should provide data allowing direct comparison between conjugate margins in terms of age and volcanic and tectonic history. Much of the focus should be on the deep crust and upper mantle, because the interpretation of detachment faults, the inferred role of pure- versus simple-shear extensional mechanisms, and the importance of magmatism during extension depend heavily upon establishing the nature of the lower crust and the manner in which it deformed.

Furthermore, the formation of sedimentary basins landward of many rifted margins is fundamental because of the hydrocarbon resources that these basins contain and their almost continuous geologic record of rifting processes. Information obtained through the search for hydrocarbons must be integrated with ODP drilling results to fully elucidate the rifting process.

• *Technical Developments*

Deep drilling on rifted margins will require significant advances in technology to improve hole stability and ensure adequate recovery while maintaining the requisite level of safety, even on young margins. Holes penetrating to depths of 2-3 km and more will probably require at least a slimline riser capability. The COSOD II participants recommend even deeper holes on rifted margins. Engineering development for such sites should definitely be initiated, but implementation is probably several years away, after the highest priority riserless sites have been drilled.

• *Drilling Strategy*

Future studies of continental rifting, including ocean drilling, should examine a margin and its conjugate whenever possible. This should manifest itself both in the acquisition of data and in their interpretation. For ocean drilling, this does not necessarily require that holes be drilled on both sides, but it does require that in doing site surveys or other regional work, the conjugate margin be considered part of the site region. A common, though overly simplistic, way to distinguish between currently debated pure- and simple-shear models of rifting is the degree of symmetry of lithosphere extension. The key difference between simple-shear and pure-shear margins, which can be shown by drilling, is the ratio in thickness between synrift sediments and postrift sediments. These ratios are indicative of the differences in vertical motions produced by the mechanisms. An extreme simple-shear model would result in no postrift sediments over the location of the maximum synrift section. Generally, the horizontal distribution in this ratio is needed to determine the contribution of each mode of deformation. The flexural strength of the lithosphere also affects the distribution of subsidence sedimentation. Subsidence is spread over a broad area if the lithosphere rigidity is high. To evaluate this requires looking at conjugate margins and determining their configuration late in the rifting process. Conjugate margin basins also share common basement and sedimentary systems during rifting, and such similarities may be exploited by drilling one part of the system on one margin and the other on its conjugate.

A significant problem with using ocean drilling to solve tectonic problems on passive margins is the thickness of sediment deposited during and following rifting. While some useful information about subsidence history may be extracted from continuously deposited sediments, they can constitute a technological challenge to reaching rocks directly affected by rifting. However, this problem is less pronounced either when rifting has been recent or there has been slow drift sedimentation. Therefore, ocean drilling should continue to focus on young and/or sediment-starved rifted margins. Types of targets that we feel are most valuable are: Basement rocks; prerift and earliest synrift sediments; and prominent seismic reflectors of unknown geologic origin.

The drilling of oceanic ridges to determine the composition of the crust is a top priority of the Lithosphere Panel. Sites should be selected where tectonic problems (*e.g.* faulting and block rotation) can be addressed along with studies of composition.

• *Locations*

ODP should concentrate initially on drilling young conjugate passive continental margin pairs, where the sediments are thin, the thermal signature of rifting is more pronounced, and there is greater potential to discriminate between rifting models. These opportunities exist, for example, in the Red Sea and Bransfield Strait (late Tertiary rifting), Gulf of Valencia/Gulf of Lyon (mid-Tertiary rifting), and SE

Greenland/Norway (early Tertiary rifting). Sediment-starved conjugate margins, such as the Flemish Cap/Goban Spur margin of Late Cretaceous age, should be considered, also. Significant tectonic problems can be addressed in each of these areas using current or only slightly augmented drilling capability to drill holes to 1-2 km depth. Immediate, significant effort should be made to develop extensive geological and geophysical data bases to support drilling on these margins. The importance of obtaining adequate geophysical data both before and after drilling cannot be overestimated. As most tectonic problems are two- or three-dimensional, drilling must be used in concert with geophysical data that can provide three-dimensional regional control.

Intraplate Deformation

• *Tectonic Significance*

Plate interiors, away from the complexities of plate boundaries, are ideal locations for study of the behavior of the lithosphere under deviatoric stress. A vast area of the interiors of the major plates are water-covered, so the deformation resulting from loading can best be studied by the drill. By comparing the displacements, subsidence/uplift history or other expressions of the deformation to model predictions, it is possible to learn much about the rheology of the crust and upper mantle.

• *State of Knowledge*

Surface Loading: Much of our current knowledge of the long-term strength of oceanic lithosphere has come from studies of how it responds to loads such as those imposed by volcanoes and sediments, and studies of the response to various loads at island arc-trench systems. These loads are all of sufficient size that they strain the lithosphere almost to the limits of its strength. The largest load on the Earth's surface is at the Hawaiian Islands in the interior of the Pacific plate. The weight of the volcanoes has caused the oceanic lithosphere to flex by up to 4-5 km over distances of about 250 km. The geometry and timing of such large deformations place constraints on the long-term mechanical properties of the lithosphere. Drilling offers the opportunity to determine precisely the magnitude of the displacement and the state of stress at a point in the deformed lithosphere. Moreover, by determining the displacement history as recorded by the material infilling the moats that flank large loads it may be possible to constrain the form of the recovery as the lithosphere "relaxes" from its short-term thickness to its long-term elastic thickness.

Side-driven Loading: One result of flexure studies has been to demonstrate that on a geologic time scale, oceanic lithosphere behaves much like a thin elastic plate overlying a fluid substrate. The plates should act as stress guides, at least with regard to the forces that originate at plate boundaries, such as ridge-push and trench-pull. Deformations resulting from plate-driving forces may be observed in the plate interiors, and the driving forces themselves may be assessed. One such area is the interior of the Indo-Australia plate just south of Sri Lanka. Gravity and geoid data suggest the oceanic lithosphere in this region is thrown into a series of gentle folds with amplitudes of up to a few hundred meters and wavelengths of up to several hundred kilometers. Composite focal mechanism solutions suggest that the area is in a state of compression and that, in a sense, it is behaving as an incipient plate boundary. Preliminary results from Leg 115 have shown that drilling provides a unique opportunity to date the timing of deformation and to determine if it can be correlated with collisional events at the plate boundaries.

Loading from Below: Another type of deformation arises from loads acting from within or below the lithosphere due to thermal convection, thermal reheating around hot spots or other processes. Numerical modeling studies have shown that density-driven thermal convection can lead to significant displacements of the upper boundary layer. The amount of the displacement depends on the rigidity of the lithosphere and the relative proportion of buoyancy to viscous forces in the convecting material. Gravity anomaly and geoid studies suggest that surface displacements of 1-2 km with wavelengths of about 2000 km could occur as a result of convection. A related type of load results from buoyancy forces associated with reheating of the lithosphere around hot spots. These loads could cause displacements with amplitude and wavelength similar to those resulting from thermal convection. The areal extent of the displacements associated with such deep processes in the Earth is probably best mapped by constructing residual depth anomaly maps. The detailed record of the form of the displacements and the question of whether the subsidence/uplift patterns have persisted through time can, however, only be addressed by drilling.

• *Potential ODP Contribution*

The ODP contribution will come from determining the geometry and timing of deformation in the plate interiors. Stress determinations will also play a role in understanding both the deformations themselves and the driving forces on the plates.

• *Background Data*

In order to conduct drilling that has a good chance of making a contribution to understanding of the rheologic behavior of the lithosphere based on intraplate deformation it is necessary to have extensive regional geophysical surveys of the deformed fabric(s) to be studied.

• *Technical Developments*

This type of study probably does not require any special technologic development beyond those mentioned elsewhere in this document for the assessment of the tectonic environment.

• *Drilling Strategy*

Well designed experiments are required in areas where the chronologic resolution is sufficient to discriminate between different models of lithospheric rheology. Holes drilled to basement (or at least to lithified sediments) are required for stress determinations.

• *Possible Locations*

Locations for drilling to address the rheologic behavior of the lithospheric plates by studying the effects of intraplate loading include: The Hawaiian Islands, the Cape Verde Islands, the Marquesas Islands, the central Indian plate, and the east-central Pacific plate.

Plate Kinematics

• *Tectonic Significance*

Ocean basins contain the majority of information used to reconstruct former positions of the world's plates. Fracture zones and magnetic anomalies provide the only direct measurement of the long-term divergence histories of the plates, while paleomagnetic data and hot-spot tracks are used to relate these displacement histories to various global reference frames. Global plate reconstructions, in turn, offer the critical linkages necessary to study spatial and temporal relationships within nearly all branches of earth science. This synthesis of the geologic histories of oceans and continents demands well determined oceanic basement ages for constraints on spreading history and magnetic-time scales, an understanding of magnetic quiet zones, widespread data on hot-spot tracks, and a large volume of high-quality paleomagnetic data.

• *State of Knowledge*

Global plate-displacement histories are fairly well determined for the past few tens of millions of years, but poorly known prior to about 65 Ma. For instance, major uncertainties exist for plate kinematics within the Cretaceous Normal Superchron interval from 120-180 Ma. Evidence exists that unresolved magnetic anomalies may be present within this tectonically and paleoenvironmentally critical time interval. Basement ages are also badly needed for dating of the M-sequence magnetic anomalies from 170 to 120 Ma. These two time intervals account for 90 million years of Earth history. Plate motions within this interval will remain highly uncertain until more data are obtained.

Hot-spot traces are widely used as a viable frame of reference for relating motions between oceanic and continental plates in areas where subduction has erased much of the record. However, valid applications of hot-spot hypotheses to earlier times are possible only after the demonstration that they show consistency in Cenozoic times. Hot-spot traces such as the Hawaiian-Emperor chain have shown a remarkable age progression along their small-circle trends, but few equivalent studies on other traces have been carried out. Critical comparisons of age progressions and relative positions of traces within each plate and between ocean basins are needed to further establish the validity of this valuable reference frame. Of equal importance is the extension of these types of data sets into the Mesozoic. Because of problems encountered with global circuits, the hot-spot framework may be the only hope for establishing pre-80 Ma plate motions.

Paleomagnetic data from ocean basins have proven valuable in the determination of paleolatitudinal displacements, apparent polar-wander paths and true polar wander. Episodes of relative motion between the spin-axis (paleomagnetic) and hot-spot (mantle) reference frames have been proposed and could provide important insights into Earth's internal processes. Other types of paleomagnetic investigation contribute to the understanding of polarity transition, secular variation, geomagnetic excursions, and rock magnetic properties, all of which enhance our ability to successfully interpret marine anomalies and paleomagnetic data sets.

• *Potential ODP Contribution*

Although many of the advances in the understanding of plate tectonics have come through marine geophysical techniques, the verification and calibration of ocean-floor ages and magnetic time scales is, perhaps, the greatest achievement of DSDP. Drilling still remains the only available technique for widespread sampling of the ocean floor for age dating and paleomagnetic measurements. Continuing refinement of plate reconstructions and the understanding of plate motions is, in many instances, totally dependent upon an ongoing program of drilling.

The major areas in which ODP can contribute are: Hot-spot reference frames; seafloor age; Mesozoic plate motions; paleomagnetism.

Hot-spot Reference Frames: The hot-spot reference frame has been remarkably successful in establishing, confirming and underpinning global plate motions. Nevertheless, a number of specific and general uncertainties remain, such as: Do hot spots move, how fast, and in what direction? Manifested as seamounts, large portions of global hot-spot chains do not appear above sea level. Although magnetic-anomaly modeling and dredging can give some information, only drilling can reach and sample the basal igneous rocks of these structures. Among the specific goals of an ongoing program of ocean drilling should be: (1) The age progression of hot-spot chains, providing information about plate velocities, particularly in places with no currently calibrated hot-spot traces and on pre-Tertiary chains; (2) Geochemical evolution and discrimination, providing information about the nature of hot-spot volcanism itself and providing signatures for distinguishing superimposed, merged or cross-cutting hot-spot traces; (3) Relative motions, through paleomagnetism, establishing paleolatitudes and motions relative to the paleomagnetic framework and addressing fundamental problems of true polar wander and hot-spot motion.

Seafloor Age: The magnetic reversal time scale is the fundamental tool for ocean-floor age determination. Nevertheless, in many cases where magnetic anomalies are disturbed, subdued, destroyed by hydrothermal processes, or fragmented, the method cannot be applied. Large portions of sea floor such as the Bering Sea basin, the Canada basin, and the South Pacific Ocean basin are undated. Plate reconstructions for major areas of the globe (*e.g.* Alaska and West Antarctica-New Zealand) remain uncertain until the age and provenance of these pieces of ocean floor can be fitted into a satisfactory framework.

Mesozoic Plate Motions: The Mesozoic motions of oceanic plates are not well known because of the limited occurrence of Mesozoic oceanic lithosphere and increased uncertainties in the magnetic reversal chronology (particularly in the Cretaceous and Jurassic Quiet Zones). In consequence, global plate reconstructions become progressively less accurate in the Mesozoic. With a coherent drilling program, ODP can aim at reducing uncertainties to a minimum through:
(1) Identification of Mesozoic ocean crust and crustal remnants (*e.g.* Mozambique Basin, W. Pacific); (2) Establishing the spreading geometry, history, evolution and "absolute" motion of this crust; (3) Improved calibration of the Cretaceous-Jurassic reversal time scale (M-sequence).

Paleomagnetism: The number of fully oriented paleomagnetic samples from the ocean basins is remarkably small. This has resulted in a highly land-biased data set from which characteristics of the paleomagnetic field throughout the Earth's history have been modeled. Currently it is not possible to obtain a good definition of possible nondipole components of the Earth's field prior to the Neogene. Clearly, because the paleomagnetic field remains one of the most critical reference fields against which motions are measured, refinement of these models is essential for more reliable calibrations in many fields of geoscience. ODP should aim to provide much more comprehensive paleomagnetic sampling in both age and geographic distribution for contributions toward these goals. High-resolution paleomagnetic studies should be undertaken at nearly all future ODP sites to enhance our knowledge of the following: (1) Long-term behavior of the Earth's magnetic field through global correlations of magnetostratigraphic sections; (2) Short-term magnetic field behavior through investigations of polarity transitions, geomagnetic excursions, and secular variation; (3) Characterization of rock magnetic signatures to explore the age-dependent nature of oceanic crustal magnetization with particular emphasis on marine magnetic anomaly parameters.

• *Background Data*

The establishment of specific drilling sites for oceanic crust and seamounts requires the standard spectrum of marine geophysical techniques. In terms of oceanic crust, apart from bathymetric and seismic data to establish basement depths, the single most important parameter remains the magnetic anomaly field. Through a systematic magnetic survey grid (*e.g.* $\leq$ 10 km spacing) the grain and structure of the crust needs to be securely established. This is essential to ensure that a basement age sample comes from normal, lineated crust (undisturbed by transforms, propagators, ridge jumps or seamounts) from which the direction and polarity of spreading can be determined. Experience in areas over which detailed magnetic surveys have been carried out suggest that a line spacing of twice the ocean depth over an area of at least 50 x 50 km is not unreasonable.

In terms of seamounts, it is clear that detailed bathymetric (Seabeam) and swathmapping (SeaMARC, GLORIA) are also essential to locate flows, slumps, incised canyons and other features that should be either avoided or targeted in a drilling strategy. A preliminary dredging program should have been carried out both to provide supplementary information for drilling results and perhaps to eliminate the need for certain holes. Ideally, drilling will be sited within such a context that it will be clear whether samples are likely to represent the last eruptive phase, early flows or typical edifice geology. The age of the surrounding ocean floor established through regional interpretation of magnetic lineations is also an essential constraint.

• *Technical Developments*

The major technical goal underlying the achievement of useful measurements for kinematic purposes is a method of acquiring fully oriented samples (of both sediments and igneous rocks) for paleomagnetic and magnetic property measurements. Although methods have been developed commercially and are currently available, they suffer from a number of drawbacks and are not applicable in all modes of drilling. For instance, methods of downhole orientation of cores which depend on internal magnetic compass measurements are likely to be many degrees in error in basaltic sequences. It is clear that a significant initiative needs to be taken to develop new tools and orientation methods (perhaps considering the feasibility of a logging tool for measuring total magnetization direction *in situ*) before some of the objectives outlined above can be efficiently and economically achieved.

Shipboard improvements in achieving a magnetically clean environment, core barrel demagnetization and preservation of core orientation during handling should also be addressed.

• *Drilling Strategy*

Hot-spot Reference Frames: Clearly, for the achievement of goals of determining plate motions and relative hot-spot motions, it will be important to choose hot-spot chains which, through length and position, satifactorily define poles and rates of motion for individual plates. Ideally, two separated hot-spot chains for each plate would satisfy the kinematic requirements. In practice, achievement of one fully callibrated hot-spot chain on each major plate would be a significant advance of our present knowledge. For the determination of relative hot-spot motions, a broad global distribution of hot-spot traces is necessary.

Seafloor Age: Major gaps in seafloor dating are currently evident. The paucity of drilling results in the southern oceans may be partially compensated by magnetic coverage, but lack of knowledge of areas such as the Arctic Ocean and Bering Sea severely limits northern hemisphere plate reconstructions. Drill sites should be proposed within the context of a thoroughly modeled plate reconstruction scheme so that results will have an immediate consequence in terms of prediction and can lead directly to the formulation of new, testable hypotheses. Attention should be paid to calibration of gaps in the paleomagnetic reversal time scale.

Mesozoic Plate Motions: Drilling should be designed to calibrate M-series magnetic anomalies and, where possible, address any resolution of absolute motions for this period.

Paleomagnetism: The principal successes in oceanic paleomagnetic measurements conducted to date have been in basalts and limestones. Although pelagic and/or clastic sediments may provide more continuous sequences, sedimentary and diagenetic processes may produce systematic biases in paleomagnetic directions. Achievement of a broad spread of samples in both space and time is likely to come from a coherent plan of "add-on" measurements to drilling sites initiated for other reasons. Recognition that this plan has priority, even though drilling may be primarily sited for other purposes, needs to be part of the approval process.

•*Possible Locations*

Hot-spot Framework: Louisville-Gilbert-Marshall-Marcus-Geisha; Emperor (Detroit and 50-55 Ma); Gulf of Alaska; New England; South Atlantic hotspots; oceanic plateaus.

Sea-floor Age: Bering Sea; Canada Basin; polar oceans; Kula fragments; Weddell Sea.

Mesozoic Ocean Floor: Atlantic margins; Mozambique-Somali; North Australia basin; West Pacific (Mariana-Nauru basins).

Paleomagnetism: All areas.

Plate Dynamics

The Ocean Drilling Program is now in a position to make unique contributions to understanding of the most fundamental tectonic processes through stress determinations and deployment of ocean-floor geophysical observatories.

• *Tectonic Significance*

Measurement of stress within plates and at plate boundaries can provide new understanding of fundamental tectonic processes. Data on the stresses within plates can help assess the relative importance of various forces acting on the plates: Ridge-push, trench-pull, plate-drag, etc. Ultimately, this will lead to better understanding of orogenesis and help forge links between oceanic and continental tectonics.

Long-term ocean-floor geophysical observatories working in unison with the land-based seismological stations, can provide data pertinent to several broad subject areas, three of which we consider to be of primary tectonic significance, particularly in the areas of plate dynamics: Global earth structure; oceanic upper mantle dynamics and lithospheric evolution; earthquake source studies. In addition, the existence of a global network involving ocean-floor observatories would impact the following areas: Oceanic crustal structure; tsunami warning and monitoring, and studies of sources of seismic noise.

• *State of Knowledge*

At present, the global stress map has enormous areas virtually devoid of data. Stress indicators consist almost entirely of earthquake focal mechanisms, with only a very small number of direct downhole stress measurements (only three by ODP). Results of preliminary stress-orientation studies conducted for several lithospheric plates (*e.g.* North America, Indo-Australia and Nazca) suggest that measurements in comparatively few additional localities can discriminate between different models of plate driving forces. More detailed studies, particularly those around the San Andreas fault, have emphasized the potential usefulness of reliable stress orientation data in understanding tectonic processes. They have highlighted the difficulty of using focal mechanisms alone to derive stress orientations near plate boundaries. Measurement of both the orientations and magnitudes of the stresses can be of enormous tectonic value.

The land-based digital seismographic data collected since the mid-70's provide novel information on three-dimensional Earth structure, leading to a significant improvement in the quantification of earthquakes. Even though the resolution of current 3-D maps of the Earth's interior is rather low because of the inadequate distribution of the stations, the information content was sufficient to discover the dominant role of very large wave-length lateral heterogeneities in the lower mantle.

Very broad-based techniques of studying source-time functions allow the retrieval of fine details of source radiation and correct determination of the total moment released even for a very complex event. The current density of stations is insufficient to undertake a general analysis of the source radiation in both space and time. Generally, there is a sufficient body of knowledge and the technical means to take full advantage of data provided by a new global network including stations sited in ODP drill holes in oceanic lithosphere.

•*Potential ODP Contribution*

Intraplate Stresses and the Driving Forces: Although considerable progress has been made over the past 10 to 15 years, many aspects of plate-driving forces are still poorly understood. One important way in which this deficiency can be attacked is by adding to the available data base of intraplate stress measurements. At present, stress fields in the oceans are virtually unknown. Most stress orientation data points from the oceans are derived from earthquake focal mechanisms, which are not direct indicators of stress orientation and therefore can yield ambiguous results.

The accumulation of a global stress map might be considered analogous to the process of putting together the geologic time scale: For the most part, it is an iterative, "unglamourous" task, but the information contained in such a data set would be of great importance in understanding a wide range of geologic problems. Intraplate stress measurements can be very useful in differentiating between various possible plate driving-force models, as long as the measurements are from areas in which the predictions of different models diverge. For this reason, measurements from areas near corners and bends in plate geometry are likely to be particularly useful. Gradients in stresses across large plates may yield constraints on distributed (not boundary) driving forces and on the nature of areas of active midplate seismicity.

Plate Boundary Stresses and Deformation: Measurements of strike-slip faults can yield important insights into the mechanics of crustal rocks, even if only principal stress orientations can be obtained. Recent results from the San Andreas region demonstrate clearly that the San Andreas represents a weak zone within otherwise strong crustal rocks. This conclusion is based upon the observation that the San Andreas is inclined at an angle of only a few degrees to the least horizontal stress axis. Because it is so close to one of the principal stress axes, the shear traction along the San Andreas is far smaller than the regional differential stress in magnitude. This result explains the well known lack of an observed geothermal anomaly across the San Andreas. Potentially important candidates for such studies exist in many other geologic settings, including oceanic transform faults and the strike-slip faults found in many convergent margins.

The stress field required to drive strike-slip faulting in arc and back-arc regions is of considerable interest because its activity appears to be related to other attributes of the margin, including the obliquity of convergence and the overall balance between the compressional and extensional tectonics in the overlying plate. It is not well understood whether strike-slip faulting in the overriding plate near subduction zones is controlled by the strength and geometry of coupling along the subduction boundary, whether fault strength is a function of total displacement (as some rock-mechanical studies suggest), or if there are significant differences between the strengths of such faults at different margins.

Active ridge-transform systems present other interesting mechanical questions related to stress fields: How strong are transform faults? Are they sufficiently strong as to be a significant factor in the balance of plate driving forces? Is their strength dependent on age? What is the contribution of thermal contraction and of plate-boundary effects to the stress field of ridge-transform system? What is the stress field around overlapping spreading centers?

Deep Structure: It is expected that full deployment of the ocean bottom components of the global network will be an international undertaking. The most important and irreplacable contribution of ODP would be the drilling of holes for seismographic stations and initial emplacement of sensors and recording equipment. It is assumed that support for seismographic equipment will be available from other sources.

•*Background Data*

No special data are required for stress measurements *per se*. Extensively detailed site surveys need to be undertaken before deployment of a long-term geophysical observatory. Both stress measurements and deployment of a seismologic observatory are envisaged as part of a major tectonic experiment involving seismic, side-scan sonar and submersible work (for example a study of transform-fault dynamics or one of ridge-crest propagation).

•*Technical Developments*

The Borehole Televiewer is a very useful tool for determining orientations of horizontal stress components. This instrument will be able to obtain breakout orientations in well lithified sediments, as well as in basalt. It is anticipated that it will be used in most logged holes. If so, it will offer the opportunity of gathering the sort of routine measurements of stress orientations that is necessary for the gradual building up of the data base. One possible limitation is that penetration of some holes may be shallower than the depths at which breakouts occur.

Packer experiments, like the one to be attempted in the Argo Basin, can also be of significance. There are numerous tectonic problems, particularly those associated with strike-slip and thrust faulting, for which magnitudes of stresses are key data, but unfortunately, are poorly known. Although they can be combined with other valuable measurements such as permeability, measurements with a packer are inevitably time-consuming. Therefore, such measurments must be carried out only where there is a clear objective. However, fundamental issues related to the mechanics of deformation simply cannot be answered without judicious application of the packer. In the future, it may be possible for ODP to obtain information on stress magnitudes with alternative approaches, such as breakout shape used in conjunction with hydraulic fracturing.

and experimentation before specific plans for deployment of permanent geophysical observatories can be made.

(1) Seafloor and subseafloor noise: Although knowledge of deep ocean noise sources and propagation mechanisms has increased substantially in recent years, insufficient understanding exists to guide deployment of permanent observatories.

(2) Islands and seafloor stations: Island seismic stations play an important role in the global seismic network and are at present the only locations where permanent observatories may exist in the oceans. Pilot studies are required to resolve how adequate these stations are (*i.e.* can downhole observatories by fully justified?).

(3) Short-term technical issues: An urgent priority is to adapt a presently available broadband sensor for operation on the ocean floor. One year recordings will be necessary during pilot experiments and, though systems with the data storage capacity and timing accuracy necessary for this are currently under development, they have never been deployed.

(4) Long-term technical issues-telemetry, power, sensors: The major problems here are related to how a permanent global ocean-floor netowrk would be operated. With a data rate of approximately 50 MBytes per day, the problems of both internal recording (with periodic data retrieval) or real-time telemetry are extremely challenging.

•*Drilling Strategy*

There are several alternative approaches that could be taken in planning ODP stress measurements. COSOD II has emphasized the importance of determination of stress in oceanic lithosphere, and pointed out the large gaps in the world stress map. There is a clear need to bring about a gradual filling of the stress map, but the map is now so sparse that a sporadic, target-of-opportunity approach is likely to yield useful measurements for several years into the future. TECP emphasizes that collection of stress orientations is something that should be done as a matter of course in at least one hole in any area where logging to sufficient depths is to be done. A dedicated hole may be justified where a critical gap exists on the stress map. Even if drilling of an entire hole to obtain stress data in a certain area is not justified, it is important to take advantage of cases in which drilling carried out largely for other purposes has reached, or is close to a depth, at which stress measurements are possible.

A second approach is one of carefully planning regional stress measurement programs, especially where existing data provide a framework for constraining models of plate-driving forces and/or the generation of important structures. Such an experiment would have the advantage of being able to resolve stress gradients that can yield important information on the dynamic processes involved in plate motions. It may be some time before enough stress measurements have been collected in the world's oceans to justify plate-scale experiments, but we do not believe that carefully posed experiments need to be of this scale. Even a few measurements could conceivably yield very valuable results, if drilling were done at sufficiently critical locations with respect to plate geometry. It is important to develop a set of models that yield predictions that are sufficiently different for the data to be able to discriminate between them.

Finally, opportunities should be taken in deep holes (including re-entered ones) to measure stress magnitude as a function of depth. Details of a drilling strategy for deploym[illegible]
obser[illegible]

They are dependent on the results of the experiments outlined above.

•*Locations*

Several interesting and potentially valuable examples of stress-measurement programs exist. For example, data from the northwestern corner of the Nazca plate suggest that trench-pull, rather than ridge-push, may be the dominant force there, since compression axes are parallel to the trench along the western margin of South America and not perpendicular to the Nazca-Cocos Ridge. The Indo-Australian plate is another potentially fruitful, if complex, laboratory with a variety of plate-boundary settings and a zone of central intraplate deformation. Small plates (e.g. Juan de Fuca and the Philippine Sea) would make interesting targets because comparatively few measurements would produce stress gradients that could be related to different types of plate boundary and hence to possible driving mechanisms.

It is logical to assume that the greatest benefit for the deployment of ocean bottom seismic stations will be in places far distant from land masses (including islands) and where detailed interdisciplinary studies of phenomena such as plate rifting and accretion, transform motion, and plate convergence can be undertaken.

PHASED IMPLEMENTATION PLAN

TECP has devised a 12-year program that indicates the progress required to achieve the scientific objectives outlined above.

Phase I (1989-92)

This phase comprises a transition from the present strategies and technologies for tectonic drilling to those required for later years of the program.

Convergent Plate Boundaries:

•Complete two case studies of deformation processes and fluid flow in accretionary wedges with appropriate logging and instrumentation; appropriate sites include Nankai, Cascadia/Vancouver, Barbados; 4 legs.

•Undertake thorough study of ridge crest-trench collision processes; Chile Rise/Trench triple junction; 2 legs.

•Conduct study of aseismic ridge/island arc collision zone; Vanuatu; 1 leg.

Divergent Plate Boundaries:

•Conduct studies of the structural development of oceanic lithosphere in conjunction with other mid-ocean ridge drilling.

Intraplate Deformation:

•Undertake a study of deformation associated with top surface intraplate loading; Hawaii?; 1 leg.

Plate Kinematics:

•Refine Mesozoic magnetic anomaly time-scale; Western Pacific; 1 leg.

•Refine hot-spot reference frame in Pacific; North Pacific; 1 leg.

Plate Dynamics:

•Initiate routine intraplate stress measurements on an opportunity basis.

•Deploy and test seismic observatory (off Hawaii?) on an opportunity basis.

Development for Phase 1:

•Tools for quantifying environments of active tectonism.

•Accurate core orientation and paleomagnetic measurements.

•Deep and closed circulation (riser) drilling capabilities.

•Geophysical observatories.

Planning for Phase 2:

•Establish detailed planning groups for deep continental margin drilling and sea-floor geophysical observatories.

•Initiate new generation of detailed site surveys for tectonic objectives including geophysical observatories.

Phase 2 (1993-96)

Convergent Boundaries:

•Advanced case study of deformation and fluid flow in an accretionary wedge including long-term instrumentation; Middle America, Barbados; 2 legs.

Divergent Plate Boundaries:

•Conjugate rifted continental margins

(volcanic and nonvolcanic); North Atlantic, Mediterranean basins, Bransfield rift; 6 legs (3 dedicated).

Intraplate Deformation:

•Deformation associated with lithospheric loading in compression and/or extension; central Indian Ocean, east-central Pacific Ocean; 2 legs (1 dedicated).

Plate Kinematics:

•Plate motions including hot-spot histories using paleomagnetism; 4 legs.

Plate Dynamics:

•Stress determinations for driving forces on a plate; Nazca or Juan de Fuca plates; 2 legs.

•Dynamics of transform faulting; east-central Pacific, Atlantic; 2 legs.

•Establish geophysical observatories; 2 legs.

Development for Phase 3:

•Tools for quantifying environments of active tectonism.

•Deep drilling and riser capabilities.

Planning for Phase 3:

•Complete site surveys for deep drilling sites at convergent and divergent boundaries and for geophysical observatories.

Phase 3 (1997-2000)

Convergent Plate Boundaries:

•Augment earlier case studies with deep drilling; establish long-term observatories; W. Pacific, Middle America, Barbados; 6 legs.

Divergent Plate Boundaries:

•Augment earlier drilling and industrial data with deep drilling and establish geophysical observatories; Atlantic and Mediterranean margins; 6 legs (2 dedicated).

Intraplate Deformation:

•Continue study of intraplate deformation; Indian Ocean, east-central Pacific; 2 legs.

Plate Kinematics:

•Continue study of hot-spot reference frame.

Plate Dynamics:

• Complete deployment of geophysical observatories; 2 legs.

The overall plan calls for 48 legs over 12 years; 2.5 per year in Phase 1, 5 per year in Phase 2, and 4.5 per year in Phase 3. Although this may seem to be a high proportion of the available time, only approximately 50% needs to be dedicated to TECP legs, and we believe that with appropriate planning to combine TECP objectives with those of other thematic panels, this is an ambitious but not unrealistic goal.

INTERFACE WITH OTHER GLOBAL PROGRAMS

The type of study proposed in this plan is going to lead to much greater interaction between the Ocean Drilling Program and other global geoscience programs than in the past. Specific examples are the Global Geoscience Transects Project of the Inter-Union Commission on the Lithosphere, the U.S. EDGE project, global seismic networks, RIDGE, and continental tectonics and petrology/geochemistry studies of orogenesis and magmatism related to supercontinental breakup.

JOIDES/ODP BULLETIN BOARD

JOIDES MEETING SCHEDULE (09/01/89)

Date	Place	Committee/Panel
2-3 October	Palisades, NY	SMP
3-5 October	The Netherlands	EXCOM
16-18 October	Hannover, FRG	SSP
26-28 October	Giessen, FRG	OHP**
16-17 November	Palisades, NY	CEPDPG
26 November	Woods Hole, MA	Panel Chairmen
27-30 November	Woods Hole, MA	PCOM
14-16 January, 1990*	Santa Cruz, CA	SGPP**
16-17 January, 1990*	College Station, TX	DMP
January, 1990*	United Kingdom	TEDCOM
6-7 February, 1990*	US West Coast	PPSP
24-26 April, 1990	France	PCOM
20-22 June, 1990	Washington, DC	EXCOM & ODPC
7-9 August, 1990	Hawaii	PCOM
October, 1990	France	EXCOM
25 November, 1990	Hawaii	Panel Chairmen
26-29 November, 1990	Hawaii	PCOM
April, 1991*	Austin, TX	PCOM
August, 1991*	FRG	PCOM
? Date*	Palisades, NY	ex-IOP & Co-Chiefs

* Tentative meeting; not yet formally requested and/or approved.

** Each of the thematic panels will also meet between about 1 February and 15 March 1990.

ODP/TAMU PANEL LIAISONS

Downhole Measurements Panel - SUZANNE O'CONNELL
Information Handling Panel - RUSS MERRILL
Pollution Prevention & Safety Panel - LOU GARRISON
Site Survey Panel - AUDREY MEYER
Technology & Engineering Development Committee - BARRY HARDING

ODP GEOCHEMISTRY: PROGRESS AND OPPORTUNITIES

January 9-12, 1990

UCLA Conference Center, Lake Arrowhead, CA

A JOI/USSAC sponsored workshop on the importance of geochemistry to the continuing scientific success of the Ocean Drilling Program will be convened by Drs. Miriam Kastner and Garrett Brass. The workshop will bring together geochemists studying a spectrum of geochemical problems that use the resources of the ODP. The central topics to be discussed and evaluated are (1) Sedimentary Geochemical Problems (*e.g.* element recycling, paleoceanography, diagenesis); (2) Basement Geochemical Problems (*e.g.* trace element and isotope abundances, high and low temperature crustal alteration); (3) Organic Geochemistry; (4) Geochemical Logging (*e.g.* core logging, new logging tools, measurements, special sampling/coring programs, fluid sampling).

The workshop will review the results to date and consolidate proposals for new programs in geochemistry and for new tools and techniques. Attendance is open, though only limited travel support for U. S. participants is available through JOI/USSAC. Applications must be received by October 15, 1989. Questions and applications for participation and travel funds should be directed to Dr. Garrett W. Brass, RSMAS-MGG, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149 (Telemail: G.Brass), or to Dr. Miriam Kastner, Scripps Institution of Oceanography, A-012, La Jolla, CA 92093 (Telemail: M.Kastner).

WORKSHOP REPORTS AVAILABLE

The following reports are available. For copies please write to JOI/USSAC Workshop Report, 1755 Massachusetts Ave. NW, Suite 800, Washington, D.C. 20036-2102.

Scientific Seamount Drilling, Tony Watts and Rodey Batiza, conveners.

Vertical Seismic Profiling (VSP) and the Ocean Drilling Program (ODP), John Mutter and Al Balch, conveners.

Dating Young MORB?, Rodey Batiza, Robert Duncan and David Janecky, conveners.

Downhole Seismometers in the Deep Ocean, Mike Purdy and Adam Dziewonski, conveners.

Ocean Drilling and Tectonic Frames of Reference, Richard Carlson, William Sager and Donna Jurdy, conveners.

Science Opportunities Created By Wireline Reentry of Deep-Sea Boreholes, Marcus G. Langseth and Fred N. Speiss, conveners.

Wellbore Sampling, Richard K Traeger and Barry W. Harding, conveners

South Atlantic and Adjacent Southern Ocean Drilling, James A. Austin, convener.

Measurements of Physical Properties and Mechanical State in the Ocean Drilling Program, Daniel K. Karig and Matthew H. Salisbury, conveners.

Paleomagnetic Objectives for the Ocean Drilling Program, Kenneth L. Verosub, Maureen Steiner and Neil Opdyke, conveners.

Cretaceous Black Shales, Michael A. Arthur and Philip A. Meyers, conveners.

ODP THEMATIC PUBLICATIONS OPPORTUNITIES

The ~~JOI-US Science~~ Support Program is seeking ~~US~~ scientists interested in serving as conveners or leading editors for ODP thematic volumes. ~~JOI/USSSP~~ has seed money available to defray out-of-pocket costs such as postage, telephone, copying, travel to consult with colleagues or potential publishers, etc. ~~for US scientists~~. These volumes would be published by outside firms or societies, rather than ODP. For more information, write or call Ellen Kappel at the JOI Office.

JOI/USSAC Ocean Drilling Graduate Fellowship

Joint Oceanographic Institutions, Inc./U. S. Science Advisory Committee is seeking doctoral candidates of unusual promise and ability who are enrolled in U. S. institutions to conduct research compatible with that of the Ocean Drilling Program. The one-year award is $18,000 to be used for stipend, tuition, benefits, research costs and incidental travel, if any. Applications are available from the JOI office and should be submitted according to the following schedule:

ODP Cruise	Application Deadline
Leg 133 Vanuatu	September 1, 1989
Leg 134 Lau Basin	September 1, 1989
Shorebased work	January 1, 1990

Please call or write to the JOI office to receive application materials and further information.

JOI/USSAC

JOI/USSAC Ocean Drilling Fellowship Program
Joint Oceanographic Institutions, Inc.
Suite 800
1755 Massachusetts Avenue, NW
Washington, DC 20036-2102
(202) 232-3900
Telex: 7401433 BAKE UC

SITE SURVEY AUGMENTATION

The JOI/U.S. Science Support Program has a limited amount of funds available for supplementing ODP site survey data sets. Proposals generally fall into the following categories:

- Support to participate in non-U.S. site surveys
- Support to assemble site data
- Support for "site science" on ships of opportunity

By making Site Survey Augmentation funds available, the JOI/U.S. Science Support Program allows U.S. scientists to take advantage of a wide range of drilling-related opportunities. Proposals for SSA support may be submitted at any time. Please contact Ellen Kappel at the JOI office for further information and proposal guidelines.

ATTENTION HACKERS!

There are big changes in the works for the *Resolution's* computer system! During the upcoming drydock in Singapore new equipment will be installed, programs will be revised and the capabilities of the system significantly enhanced.

Nine new Macintosh computers will be installed to satisfy the many requests we've received from shipboard scientists. In addition, three spare systems have been purchased to allow us to guarantee complete reliability. All systems are equipped with hard disks and at least four megabytes of memory. The new Macs will be located strategically around the labstack.

Three Apple Laserwriter printers will also be added to the shipboard system. Two of these printers will be placed in immediate service with the third serving as a spare. These new units will provide quick access to high quality output in the labstack and science library.

The PC compatibles are joining in the fun *via* the addition of Localtalk PC networking boards. These boards allow any garden-variety PC system to send output directly to the laser printers and access the VAX-based fileserver for shipboard data. The laser printers, Macs and PC compatibles will all be connected as parts of a ship-wide local area network. These changes will narrow the gap between the PC and Mac and allow shipboard participants to share data more easily than ever.

Finally, we will be replacing that noisy beast of an air conditioner in the computer user room with a quiet and relatively petite substitute. In the process, we will gain the space vacated by the old A/C unit, enough for a new desk and two chairs.

The drydock period is scheduled to begin in mid-October, followed by a short transit to Guam before the beginning of Leg 129.

COLOR CORE PHOTOS AVAILABLE ON SLIDES OR VIDEO DISK

The entire collection of color core photographs from the Deep Sea Drilling Project (DSDP) and the Ocean Drilling Project (ODP) is now available to the scientific community. The photos show cores recovered from holes drilled at more than 750 sites in the world's oceans. The collection includes over 23,000 photographs and comes in two formats: 35-mm slides or 12-inch video disk. The 35-mm slides are boxed and consecutively numbered. Both the slides and video disk come with an Introduction booklet giving details on their use and an index. To view the video disk, the user must have access to a NTSC standard disk player with random access capabilities and a video monitor. (An example of such a player is the Sony video disk player #20002-2.)

This collection will be particularly useful to those scientists working on samples from either DSDP or ODP. Those considering placing requests for DSDP or ODP samples will find the photographs make it easier to select the particular interval from which they want their samples taken.

The cost of the slide collection is US$4,500. The video disk costs US$50. These prices are in effect until July 1, 1989. Please call thereafter for a new quote.

To place an order, or for additional information, call or write to: Publications Distribution, Ocean Drilling Program, Texas A&M University, 1000 Discovery Drive, College Station, Texas 77840, U.S.A., Tel: (409) 845-2016.

BIBLIOGRAPHY OF THE OCEAN DRILLING PROGRAM

The publications below are available from ODP Subcontractors. Items from ODP/TAMU are available at 1000 Discovery Drive, College Station, TX 77840. Items from LDGO can be obtained from the Borehole Research Group, LGDO, Palisades, NY 10964.

ODP/TAMU, Texas A & M University

1. Proceedings of the Ocean Drilling Program, Initial Reports

Volumes 101/102 (combined) Dec 86	Volume 112 published Aug 88
Volume 103 published Apr 87	Volume 113 published Sept 88
Volume 104 published July 87	Volume 114 published Nov 88
Volume 105 published Aug 87	Volume 115 published Nov 88
Volume 107 published Oct 87	Volume 116 published Jan 89
Volume 108 published Jan 88	Volume 117 published June 89
Volumes 106/109/111 (combined) Feb 88	Volume 118 published May 89
Volume 110 published Apr 88	Volume 119 published Sept 89

2. Proceedings of the Ocean Drilling Program, Scientific Results

Volumes 101/102 (combined) Dec 88	Volume 104 published Oct 89
Volume 103 published Dec 88	Volume 105 published Oct 89

3. Technical Notes
   - #1 Preliminary time estimates for coring operations (Revised Dec 86)
   - #3 Shipboard Scientist's Handbook (Revised July 87)
   - #5 Water Chemistry Procedures aboard the *JOIDES RESOLUTION* (Sept 86)
   - #6 Organic Geochemistry aboard *JOIDES RESOLUTION* - An Assay (Sept 86)
   - #7 Shipboard Organic Geochemistry on *JOIDES RESOLUTION* (Sept 86)
   - #8 Handbook for Shipboard Sedimentologists (Aug 88)
   - #9 Deep Sea Drilling Project data file documents (Jan 88)
   - #10 A Guide to ODP Tools for Downhole Measurement (June 88)
   - #11 Introduction to the Ocean Drilling Program (Dec 88)
   - #12 Handbook for Shipboard Paleontologists (June 89)

4. Scientific Prospectuses

#20	(Oct 87)	Leg 120
#21	(Mar 88)	Leg 121
#22/23	(June 88)	Legs 122 & 123
#24	(Aug 88)	Leg 124
#25/26	(Dec 88)	Legs 125 & 126
#27/28	(April 89)	Legs 127 & 128
#29	(Aug 89)	Leg 129
#30	(Oct 89)	Leg 130
#31	(Oct 89)	Leg 131

5. Preliminary Reports

#20	(June 88)	Leg 120
#21	(Aug 88)	Leg 121
#22	(Oct 88)	Leg 122
#23	(Dec 88)	Leg 123
#24	(Feb 89)	Leg 124
#25	(June 89)	Leg 125
#26	(Aug 89)	Leg 126
#27	(Sept 89)	Leg 127

6. Engineering Prospectuses

#1	(Aug 88)	Leg 124E

7. Engineering Preliminary Reports

#1	(Mar 89)	Leg 124E

8. Other Items Available
   - Ocean Drilling Program brochure (English, French, Spanish, German or Japanese)
   - Onboard *JOIDES RESOLUTION* (new edition, 24 pp.)
   - ODP Sample Distribution Policy
   - Micro Paleontology Reference Center brochure

Bibliography of the Ocean Drilling Program, continued

- Instructions for Contributors to ODP Proceedings (Revised Apr 88)
- ODP Engineering and Drilling Operations
- Multilingual brochure with a synopsis of ODP (English, French, Spanish, German and Japanese)
- ODP Poster

LAMONT-DOHERTY GEOLOGICAL OBSERVATORY

- Wireline Logging Manual (3rd Edition, 1988)

DSDP DATA AVAILABLE SOON ON CD-ROM

The National Geophysical Data Center (NGDC) is currently working on a project to produce a 2-volume set of Compact Disks-Read Only Memory (CD-ROMs) of available digital data from the Deep Sea Drilling Project (DSDP). All marine geological data bases including the DSDP Index, Bibliography, and Core Sample Inventory files will be placed on Vol. 1; Vol. 2 will include logging information in the standard LIS format and underway geophysical data in the MGD77 exchange format. The CDs will be in the ISO 9660 format. Minimum system access requirements are: PC/XT/AT-compatible machines running DOS version 2.1 or higher with a minimum of 640K memory, hercules/monochrome or EGA graphics capability with a 10 megabyte hard drive and a CD-ROM reader. Accession software for Macintosh machines will be available in early summer. If you are interested in obtaining a set of CDs, contact: Ellen Kappel at JOI Inc., 1755 Massachusetts Ave., N.W., Suite 800, Washington, D.C., 20036-2102; telemail is e.kappel.

ODP SAMPLE DISTRIBUTION

The materials from ODP Leg 122 are now available for sampling by the general scientific community. The twelve-month moratorium on cruise-related sample distribution is complete for Ocean Drilling Program Legs 101-122. Scientists who request samples from these cruises (after August 1989) are no longer required to contribute to ODP Proceedings volumes, but may publish in the open literature instead.

Preliminary sample record inventories for ODP Legs 101-126 are now in searchable database structures. The Sample Investigations database which contains records of all sample requests, the purpose for which the samples were used and the institute where the samples were sent, has reached a steady state. At present, the most efficient way to access this database is to request a search by contacting the Assistant Curator of ODP.

Request processing (number of weeks to receive samples) during the period January through March, 1989:

Repository	Avg. No. Weeks Processing	Total # Samples
ECR	9	3,681
GCR	3 shorebased, 5 subsequent	3,945
WCR	4	3,155

Investigators requiring information about the distribution of samples and/or desiring samples, or who want information about the sample investigation or sample records database, should address their requests to: The Curator, Ocean Drilling Program, 1000 Discovery Drive, College Station, TX 77840, Tel: (409) 845-4819.

DSDP AND ODP DATA AVAILABLE

ODP Data Available

ODP databases currently available include all DSDP data files (Legs 1-96), geological and geophysical data from ODP Legs 101-123, and all DSDP/ODP core photos (Legs 1-123). More data are available as paper and microfilm copies of original data collected aboard the *JOIDES Resolution*. Underway geophysical data are on 35 mm microfilm; all other data are on 16 mm microfilm.

All DSDP data and most ODP data are contained in a computerized database (contact the ODP Librarian to find out what data are available electronically). Data can be searched on almost any specified criteria. Files can be cross-referenced so a data request can include information from multiple files.

Computerized data are currently available on hard-copy printouts, magnetic tape, or through BITNET.

Photos of ODP/DSDP cores and seismic lines are available. Seismic lines, whole core and close-up core photos are available in black and white 8x10 prints. Whole core color 35-mm slides are available.

The following are also available: (1) ODP Data Announcements containing information on the database; (2) Data File Documents containing information on specific ODP data files; (3) ODP Technical Note #9, "Deep Sea Drilling Project Data File Documents," which includes all DSDP data file documents.

To obtain data or information contact: Kathy Lighty, Data Librarian, ODP/TAMU, 1000 Discovery Dr., College Station, TX 77840, Tel: (409) 845-8495, Tx: 792779/ODP TAMU, BITNET: %DATABASE@TAMODP, Omnet: Ocean.Drilling.TAMU Small requests can be answered quickly, free of charge. If a charge is made, an invoice will be sent and must be paid before the request is processed.

Data Available from National Geophysical Data Center (NGDC)

DSDP data files can be provided on magnetic tape according to user specifications (see table below). NGDC can also provide correlative marine geological and geophysical data from other sources. NGDC will provide a complimentary inventory of data available on request. Inventory searches are tailored to users' needs.

Information from DSDP Site Summary files is fully searchable and distributable on floppy diskette, as computer listings and graphics, and on magnetic tape. NGDC is working to make all DSDP data files fully searchable and available in PC-compatible form. Digital DSDP geophysical data are fully searchable and available on magnetic tape. In addition, NGDC can provide analog geological and geophysical information from DSDP on microfilm. Two summary publications are available: (1) "Sedimentology, Physical Properties, and Geochemistry in the Initial Reports of Deep Sea Drilling Project Vols. 1-44: An Overview," Rept. MGG-1; (2) "Lithologic Data from Pacific Ocean Deep Sea Drilling Project Cores," Rept. MGG-4.

Costs for services are: $90/magnetic tape, $30/floppy diskette, $20/microfilm reel, $12.80/copy of Rept. MGG-1, $10/copy of Rept. MGG-4. Costs for computer listings and custom graphics vary. Prepayment is required by check or money order (drawn of a U.S. bank), or by charge to VISA, Mastercard, or American Express. A $10 surcharge is added to all shipments ($20 for foreign shipments), and a $15 fee is added to all rush orders. Data Announcements describing DSDP data sets are available at no charge. For details, call (303) 497-6339 or write to: Marine Geology and Geophysics Div., Natl. Geophys. Data Center, NOAA E/GC3 Dept. 334, 325 Broadway, Boulder, CO 80303.

AVAILABLE DATA

Data Available	Data Source	Description	Comments
1. LITHOLOGIC and STRATIGRAPHIC DATA			
Visual Core Descriptions			
-Sediment/sedimentary rock	Shipboard data	Information about core solor, sedimentary structures, disturbance,.large minerals and fossils, etc.	
-Igneous/metamorphic rock	Shipboard data	Information about lithology, texture, structure, mineralogy, alteration, etc.	
Smear slide descriptions	Shipboard data	Nature and abundance of sedimentary components.	
Thin section descriptions	Shipboard data	Petrographic descriptions of igneous and metamorphic rock. Includes information on mineralogy, texture, alteration, vesicles, etc.	
Paleontology	*Initial Reports, Proceedings*	Abundance, preservation and location for 26 fossil groups The "dictionary" consists of more than 12,000 fossil names.	
Screen	Processed data	Computer-generated lithologic classifications. Basic composition data, average density, and age of layer.	
2. PHYSICAL PROPERTIES			
G.R.A.P.E. (gamma ray attentuation porosity evaluator)	Shipboard data	Continuous whole-core density measurements.	
Grain Size	Shore laboratory	Sand-silt-clay content of a sample.	Legs 1-79 only
Index properties: bulk and grain density, water content, and porosity	Shipboard data	Gravimetric and volumetric measurements from a known volume of sediment	
Liquid and plastic limits	Shipboard data	Atterberg limits of sediment samples.	
Shear-strength measurements	Shipboard data	Sediment shear-strength measurements using motorized and Torvane instruments.	
Thermal conductivity	Shipboard data	Thermal conductivity measurements of sediments using a thermal probe.	
Velocity measurements	Shipboard data	Compressional and shear-wave velocity measurements.	
Downhole measurements			
-Heatflow	Shipboard data	*In-situ* formation temperature measurements.	
-Pressure	Shipboard data	*In-situ* formation and hydrostatic pressure.	
3. SEDIMENT CHEMICAL ANALYSES			
Carbon-carbonate	Shipboard data, shore laboratory	Percent by weight of the total carbon, organic carbon, and carbonate content of a sample.	Hydrogen percents for Legs 101,103, 104, 106-108; nitrogen percents for Legs 101, 103, 104, 107, 108.
Interstitial water chemistry	Shipboard data, shore laboratory	Quantitative ion, pH, salinity, and alkalinity analyses of interstitial water.	
Gas chromatography	Shipboard data	Hydrocarbon levels in core gases.	
Rock evaluation	Shipboard data	Hydrocarbon content of a sample.	
4. IGNEOUS AND METAMORPHIC CHEMICAL ANALYSES			
Major element analyses	Shipboard data, shore laboratory	Major element chemical analyses of igneous, metamorphic, and some sedimentary rocks composed of volcanic material.	
Minor element analyses	Shipboard data,	Minor element chemical analyses of igneous, metamorphic, and	

AVAILABLE DATA (Continued)

Data Available	Data Source	Description	Comments
4. IGNEOUS AND METAMORPHIC CHEMICAL ANALYSES, CONT'D.			
	shore laboratory	some sedimentary rocks composed of volcanic material.	
5. X-RAY MINERALOGY			
X-ray mineralogy	Shore laboratory	X-ray diffraction	Legs 1-37 only
6. PALEOMAGNETICS			
Paleomagnetics	Shipboard data, shore laboratory	Declination, inclination, and intensity of magnetization for discrete samples and continuous whole core. Includes NRM and alternating field demagnetization.	
Susceptibility	Shipboard data	Discrete sample and continuous whole-core measurements.	
7. UNDERWAY GEOPHYSICS			
Bathymetry	Shipboard data	Analog records of water-depth profile	Available on 35-mm continuous microfilm
Magnetics	Shipboard data	Analog records and digital data.	Available on 35-mm continuous microfilm
Navigation	Shipboard data	Satellite fixes and course and speed changes that have been run through a navigation smoothing program, edited on the basis of reasonable ship and drift velocities, and later merged with the depth and magnetic data.	Available in MGD77 exchange format
Seismics	Shipboard data	Analog records of sub-bottom profiles and unprocessed siganl on magnetic tape	Available on 35-mm continuous microfilm
8. SPECIAL REFERENCE FILES			
Leg, site, hole summaries	Shipboard data initial core descriptions	Information on general leg, site, and hole characteristics (i.e. cruise objectives, location, water depth, sediment nature, drilling statistics).	
DSDP Guide to Core Material	*Initial Reports,* prime data files	Summary data for each core: depth of core, general paleontology, sediment type and structures, carbonate, grain size, x-ray, etc.	Legs 1-85 only
AGEPROFILE	*Initial Reports,* hole summaries	Definition of age layers downhole.	
COREDEPTH	Shipboard summaries	Depth of each core. Allows determination of precise depth (in m) of a particular sample.	
9. AIDS TO RESEARCH			
ODASI		A file of ODP-affiliated scientists and institutions. Can be cross-referenced and is searchable.	
Keyword Index		A computer-searchable bibliography of DSDP- and ODP-related papers and studies in progress.	
Sample Records		Inventory of all shipboard samples taken.	
Site Location Map		DSDP and ODP site positions on a world map of ocean topography.	
Thin Section Inventory		Inventory of all shipboard thin sections taken.	

New ODP Offprint Policy

Current ODP policy calls for 50 offprints of every paper published in the "Scientific Results" volumes of the Proceedings of the Ocean Drilling Program to be made available without charge to the authors of these papers. If a paper has more than one author, the 50 offprints will be sent to the first author unless an alternative distribution is requested.

The practice of charging for offprints was begun almost 2 years ago as the result of a JOIDES policy in response to budget reductions in ODP publications. The financial burden this placed on authors whose institutions could not fund the purchase of offprints has been a major factor in the decision to discontinue charging for them.

It is possible, however, for an author who wants more than 50 offprints of a paper to order these additional copies through the Chief Production Editor at ODP headquarters. Authors must initiate such requests well before the volume is printed and be prepared to pay for the extra offprints ordered, which are provided at cost.

Anyone having questions about this policy should contact Russell B. Merrill, Manager of Science Services, or William D. Rose, Supervisor of Publications.

ODP EDITORIAL REVIEW BOARDS (ERB)

For each ODP cruise, an editorial board is established to handle review of the manuscripts intended for publication in the "Scientific Results" volume of the Proceedings of the Ocean Drilling Program. These boards consist of the Co-Chief Scientists and the ODP Staff Scientist for that cruise, one other scientist selected by the Manager of ODP Science Operations in consultation with the cruise Co-Chief Scientists, and an ODP Editor. These boards are responsible for obtaining adequate reviews and for making decisions concerning the acceptance or rejection of papers. The names of scientists serving on ERBs for Legs 106 through 123 are listed below. Please note that: *indicates Co-Chief Scientist; **indicates Staff Scientist; ***indicates Outside Scientist.

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* indicates Co-Chief Scientist
** indicates Staff Scientist
*** indicates Outside Scientist.

A chairman for each ERB, usually a Co-Chief Scientist, has been elected since Leg 120.

New Publications available on request from the Office of Public Information at ODP-TAMU:

- "ODP Scientific Highlights: Legs 101-123, January 1985-December 1988." The 12-page booklet thematically summarizes the findings of the first four years of drilling.
- "Western Pacific Cruises" summarizes Legs 129-135.

A third publication is available on a limited basis. Reprints of "Four Years of Scientific Deep Ocean Drilling," *Sea Technology*, June 1989, also discusses ODP's achievements in scientific ocean drilling. Authors of the 3-page article are Drs. Rabinowitz, Garrison and Meyer.

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Huchon, Ph.	WPDPG	(33)1-43291225	not available
Humphris, S.*	LITHP	(508)548-1400x2523	951679/OCEANIST WOOH
Hyndman, R.*	WPDPG,FPAPWG	(604)656-8438	0497281/DFO PAT BAY
Ignatius, H.	ODPC	(358)0-469-31	123185/GEOLO SF
Ingersoll, R.	IHP	(213)825-8634	3716012/UCLA LSA
Ito, M.*	SGPP	not available	25607/ ORIUT J
Iwamura, H.	JOIDES	(808)948-7939	7238861/HIGCY HR
James, N.	SGPP	(613) 545-6170	not available
Jansen, E.*	OHP	(47)05-21-3491	8441023/UIBTA N
Jarrard, R.*	LDGO	(914)359-2900X343	7105762653/LAMONTGEO
Jenkyns, H.	PCOM	(44)865-272023	83147 Attn. EARTH
JOIDES Office		(808)948-7939	7407498/JOID UC
Jones, E.	SSP	(44)1-387-7050	28722/UCPHYS G
Jones, M.*	IHP	(44)051-653-8633	628591/OCEANB G
Jung, R.	DMP	(49) 511-643-2857	923730/BGRHA D
Kappel, E.	JOI	(202)232-3900	7401433/BAKE UC
Karig, D.	DMP,FPAPWG	(607)255-3679	6713054/CORNELL ITCA
Kasahara, J.	TEDCOM	(81)3-812-2111X5713	not available
Kastens, K.*	SSP	(914)359-2900X236	7105762653/LAMONTGEO
Kastner, M.*	PCOM	(619)534-2065	9103371271/UCWWD SIO SDG
Kent, D.*	OHP	(914)359-2900X544	7105762653/LAMONTGEO
Kidd, R.	SSP	(44)0792-295149	48358/UCSWAN G
King, J.	SMP	(401)792-6594	257580/KNAU UR
Kinoshita, H.*	DMP	(81)3-472-51-1111	25607/ORIUT J
Kobayashi, K.	EXCOM, PCOM	(81)3-376-1251	25607/ORIUT J
Korsch, R.*	CEPDPG	(61) 62-488178	not available
Kristjansson, L.	ODPC,SRDPG	(354)1-213-40	2307/ISINFO IS
Kroenke, L.*	CEPDPG	(808)948-7845	7238861/HIGCY HR
Kudrass, H.	WPDPG	(49)511-643-2787	0923730/BGR HA D
Ladd, J.	NSF	(202)357-7543	7401424/NSFO UC
Lancelot, Y.	PCOM	(33)1-43-362525x5155	200145/UPMC SIX F
Langseth, M.*	PCOM	(914)359-2900X518	7105762653/LAMONTGEO
Larsen, B.	SSP	(45)2-884022X3210	37529/DTHDIA DK
Larsen, G.	ODPC	(45)6-12-82-33	15652/DK
Larsen, H-C.	TECP	(45)1-118866	19066/GGUTEL DK
Larson, R.*	PCOM	(401)792-6165	7400188/LARS UC
Last, A.	PPSP	(44)1-588-8000	884614/TRIOIL G
Laughton, A.*	EXCOM	(44)42-879-4141	858833/OCEANS G
Le Pichon, X.	FPAPWG	(33)1-14-31-84-88	842202601/ENULM F
Lee, C-S.	IHP	(61)062-499240	AA 62109
Leinen, M.*	PCOM	(401)792-6268	257580/KNAU UR
Levi, S.	PCOM	(503)737-2296	5105960682/OSU COVS
Lewis, B.	EXCOM	(206)543-7419	9104740096/UW UI
Lewis, S.	SSP	(415)856-7096	171449/PCS USGS MNPK
Louden, K.*	SSP	(902)424-3557	01921863/DALUNIVLIB HFX
Loughridge, M.*	IHP	(303)497-6487	258169/WDCA UR
Lyle, M.	SRDPG	(914)359-2900	7105762653/LAMONTGEO
Lysne, P.	DMP	(505)846-6328	169012/SANDIA LABS
Macdonald, K.	SRDPG	(805)961-4005	258976/KMAC UR
MacKenzie, D.	PPSP	(303)794-4750	not available
Magnusson, M.	ODPC	not available	not available
Maldonado, A.	FPAPWG	(34)3-310-64-50	59367/INPB E
Malfait, B.*	NSF	(202)357-9849	7401424/NSFO UC
Malpas, J.*	PCOM	(709)737-4708	0164101/MEMORIAL SNF
Manchester, K.*	TEDCOM	(902)426-3411	01931552/BIO DRT
Maronde, D.	ODPC	(49)228-885-2328	17228312/DFG
Marx, C.	TEDCOM	(49)5323-722239	953813/TU ITE D
Maxwell, A.*	EXCOM	(512)471-4860	9108741380/UTIG AUS
Mayer, L.*	SGPP	(33)1-43-29-61-84	200145/UPMC SIX F
McKenzie, J.	SGPP	(41)1-256-38-28	817379/EHHG CH

McLerran, A.	TEDCOM	(619)481-0482	not available
Merrell, W.*	EXCOM	(409)740-4403	not available
Merrill, R.	ODP/TAMU	(409)845-9324	62760290/ESL UD
Mevel, C.	LITHP,SRDPG	(33)1-43-36-25-25	200145/UPMC SIX F
Meyer, A.	ODP/TAMU	(409)845-9299	62760290/ESL UD
Meyer, H.	SSP	(511)643-3128	0923730/BGR HA D
Michot, J.	ODPC	(32)2-642-22-36	23069/BODPC
Mienert, J.	SGPP	(49) 431-720-0249	not available
Millheim, K.	TEDCOM	(918)660-3381	284255/CDFTU UR
Milton, A.	TEDCOM	(44) 224-574555	739721/BRTOIL G
Mix, A.*	OHP	(503)737-2296	5105960682/OSU COVS
Moberly, R.*	PCOM,EXCOM	(808)948-8765	7238861/HIGCY HR
Moore, G.*	WPDPG	(808)948-6854	7238861/HIGCY HR
Moore, J.C.	FPAPWG	(408)429-2574	not available
Moore, T.C.	IHP	(313)747-2742	not available
Moores, E.	TECP	(916)752-0352	not available
Moran, K.*	SMP	(902)426-8159	1931552/BIO DRT
Morin, R.	DMP	(303)236-5913	not available
Moss, M.*	EXCOM	(619)534-2836	not available
Mottl, M.*	SMP,SRDPG	(808)948-7006	7238861/HIGCY HR
Mutter, J.*	LITHP	(914)359-2900X525	258294/MCSP UR
Natland, J.*	WPDPG	(619)534-5977	9103371271/UCWWD SIO SDG
Nemoto, T.*	EXCOM, ODPC	(81)3-376-1251	25607/ORIUT J
Nobes, P.*	DMP	(519)885-1211X6109	06955259/U OF W WTLO
Normark, W.	SGPP	(415)856-7045	171449/PCS USGS MNPK
Nowak, J.	IHP	(49)511-643-2815	922739/GFIZ D
NSF (ODP)		(202)357-9849	7401424/NSFO UC
Nuti, E.*	FPAPWG	(39)50-41503	502020/IRGCNR I
O'Connell, S.*	ODP/TAMU	(409)845-0507	62760290/ESL UD
ODP/TAMU		(409)845-2673	62760290/ESL UD
ODP Databank	LDGO	(914)359-2900X542	7105762653/LAMONTGEO
Ogawa, Y.*	TECP,SGPP	(81)92641-1101X4320	25607/ORIUT J
Okada, Hakuyu*	CEPDPG	(81)92641-1101X4301	25607/ORIUT J
Okada, Hisakate*	OHP	(81)23631-1421X2585	25607/ORIUT J
Orcutt, J.*	LITHP	(619)534-2887	9103371271/UCWWD SIO SDG
Ottosson, M-O.	EXCOM, ODPC	(46)8-15-15-80	13599/RESCOUN S
Pascal, G.*	DMP	(33)98-46-25-21	940627/OCEAN F
Pautot, G.*	SSP	(33)98-22-40-40	940627/OCEAN F
Paxton, A	TEDCOM	(44)224-574555	739721/BRTOIL G
Pearce, J.	LITHP	(44)91-232-328-511	53654/UNINEW G
Pedersen, T.	OHP	not available	not available
Perfit, M.	LITHP, SRDPG	(904)392-2128	not available
Peters, P.	JOI	(202)232-3900	7401433/BAKE UC
Peveraro, R.	DMP	(44)41-226-5555	777633/BRTOIL G
Phipps-Morgan, J.*	LITHP	(617)253-5951	not available
Powell, T.*	PPSP	(61) 62-499397	not available
Prahl, F.*	SGPP	(503)737-4172	5105960682/OSU COVS
Premoli-Silva, I.	OHP	(39)2-23698248	320484/UNIMI I
Puchelt, H.	LITHP	not available	not available
Pyle, T.*	JOI	(202)232-3900	7401433/BAKE UC
Rabinowitz, P.*	ODP/TAMU	(409)845-8480	62760290/ESL UD
Rea, D.*	CEPDPG	(313)936-0521	not available
Renard, V.	SSP	(33)98-22-42-26	940627/OCEAN F
Reynolds, R.	LDGO	914-359-2900x671	7105762653/LAMONTGEO
Rhodes, J.M.	SMP	(213)545-2841	not available
Richards, A.	SMP	(31) 2977-40012	20000/MCC NL
Riddihough, R.*	TECP	(613)995-4482	0533117/EMAR OTT
Riedel, K.	ODP/TAMU	(409)845-9322	62760290/ESL UD
Riedel, W.*	IHP	(619)534-4386	not available
Rischmüller, H.	TEDCOM	(49)511-654-2669	923730/BGR HA D
Roberts, D.	PPSP	(44)1-920-8474	888811/BPLDNA G G
Robertson, A.	TECP	(44)31-667-1081	727442/UNIVED G
Rosendhal, B *	EXCOM	(305)361-4000	317454/VOFM RSMAS MIA
Rutland, R.	EXCOM,ODPC	(61) 062 499111	not available

Sager, W.*	IHP	(409)845-9828	258781/GRITUR
Saito, T.*	OHP	(81)236-311421X2585	25607/ORIUT J
Sancetta, C.*	CEPDPG	(914)359-2900X412	7105762653/LAMONTGEO
Sartori, R.	SSP	(39)51-22-54-44	511350/ I
Sawyer, D.*	TECP	(713) 285-5106	62013673
Saunders, R.	IHP	(41) 61-295564	not available
Schaaf, A.	IHP	(33)78-898124 x 3810	UCB 330 208
Schilling, J-G.	EXCOM	(401)792-6628	257580/KNAU UR
Schlanger, S.	CEPDPG	(312)491-5097	not available
Schrader, H.	CEPDPG	(47)5-21-35-00	42877/UBBRB N
Schuh, F.	TEDCOM	(214)380-0203	794784/ARCO PLNO
Scott, S.	WPDPG	(416)978-5424	0623887/GEOLOGY TOR
Sengör, A.	CEPDPG, ODPC	(90)1-1433-100	23706/UTU TR
Shackleton, N.*	OHP	(44)223-334871	81240/CAMSPL G
Shipley, T.*	PCOM,FPAPWG	(512)471-6156	9108741380/UTIG AUS
Simoneit, B.	SRDPG	(503)737-2155	5105960682/OSU COVS
Sliter, W.	CEPDPG	(415)329-4988	171449/PCS USGS MNPK
Small, L.	EXCOM	(503)754-4763	5105960682/OSU COVS
Smith, G.*	LITHP	(314)658-3128	550132/STL UNIV STL
Smith, R.	JOI	(202)232-3900	7401433/BAKE UC
Solheim, A.	SMP	(47)-2-123650	74745/POLAR N
Sondergeld, C.	DMP	(918)660-3917	200654/AMOCO UR
Spall, H.*	IHP	(703)648-6078	160443/USGS UT
Sparks, C.	TEDCOM	(33)1-47-52-63-95	203050/IFP A F
Spencer, D.	EXCOM	(508) 548-1400	951679/OCEANIST WOOH
Stanton, P.	TEDCOM	(713)940-3793	9108815579/USEPRTX HOU
Stein, R.	OHP	(49)641-702-8365	482956/GRIWOTY UNIGI D
Stel, J.	EXCOM, ODPC	(31)70-82-42-31	20000/MEMO NL
Stephansson, O.	DMP	(920)91359	not available
Stephen, R.*	DMP, SRDPG	(508)548-1400X2583	951679/OCEANIST WOOH
Storms, M.	ODP/TAMU	(409)845-2101	62760290/ESL UD
Strand, H.	TEDCOM	(47)-4-676066	not available
Stow, D.	SGPP	(619)265-5498	not available
Suess, E.	SGPP,FPAPWG	(49)431-720-020	not available
Sutherland, A.	NSF	(202)357-9849	7401424/NSFO UC
Suyehiro, K.*	SSP	(81)3-376-1251	25607/ORIUT J
Svendsen, W.	TEDCOM	(612)331-1331	210685/LYHQ UR
Symonds, P.*	SSP	(61) 62-499490	not available
Taira, A.*	PCOM	(81)3-376-1251X256	25607/ORIUT J
Tamaki, K.*	IHP,WPDPG, CEPDPG,LITHP,TECP	(81)3-376-1251	25607/ORIUT J
Taylor, B.*	WPDPG	(808)948-6649	7238861/HIGCY HR
Thierstein, H.	PCOM	(41)1-256-3666	53178/ETHBI CH
Thomas, E.*	SMP	(203)347-9411	not available
Tokuyama, H.*	SMP	(81) 3-376-1251	25607/ORIUT J
Tsunemasa, S.*	OHP	(81) 236-311421X2585	25607/ORIUT J
Tucholke, B.*	PCOM	(508)548-1400X2494	951679/OCEANIST WOOH
Valet, J-P.	SMP	(43) 36-25-25X3566	202810
Van Lieshout, R.	ODPC	(31)2159-457-39	not available
van Weering, Tj.	WPDPG	(31)02226-541	not available
Veis, G.	ODPC	(30)1-777-36-13	215032/GEO GR
Villinger, H.*	DMP	(49)471-483-1215	238695/POLAR D
Vincent, E.	OHP	(33)1-43-36-25-25X5162	200145/UPMC SIX F
von der Borch, C.*	SGPP	(61) 8-2752212	not available
Von Herzen, R.*	SSP	(508) 548-1400	951679
'on Huene, R.*	FPAPWG	(49)431-7202271	not available
on Rad, U.	PCOM	(49)511-643-2785	923730/BGR HA D
orren, T.	SGPP	(47)83-44000	64251/N
'ellis, G.	TEDCOM	(30)1-80-69-314	219415/DEP GR
V ggoner, G.	JOIDES	(808)948-7939	7407498/JOID UC
vokins, J.	PCOM	(409)845-8478	not available
vois, T.*	TECP	(914)359-2900X494	7105762653/LAMONTGEO
[illegible]	OHP	(44) 42879-4141	not available

Weigel, W.	SSP	(49)40-4123-2981	214732/UNI HH D
Westbrook, G.	TECP,FPAPWG	(44)21-414-6153	333762/UOBHAM G
Westgaard, L.	ODPC	(47)2-15-70-12	79913/NAVF N
Whitmarsh, R.	SMP	(44) 42-879-4141	858833/OCEANS G
Wilkens, R.*	DMP	(808)944-0404	7238861/HIGCY HR
Winterer, E.*	PCOM	(619)534-2360	9103371271/UCWWD SIO SDG
Wortel, R.	TECP	(31)30-53-50-86	40704/VMLRU NL
Worthington, P.*	DMP	(44)9327-63263	296041/BPSUNA G
Zierenberg, R.	SRDPG	(415)329-5437	171449/PCS USGS MNPK

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Special Issue No. 4: Guide to the Ocean Drilling Program, Supplement 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)