JOIDES Journal

Volume 23 Number 2

Complete Sediment Subduction and Implications of Fluid Flow in the Middle America Trench off Costa Rica

by Eli Silver and the Leg 170 Scientific Party

Understanding of mass and chemical balance and fluid flow processes is a major focus of modern studies of convergent margins. Leg 170 off Costa Rica was designed to address these topics in a setting where trench turbidites are not in evidence, thus eliminating a major source of uncertainty in the input parameters. In addition, a sedimentary apron covers most of the Costa Rica slope, thus eliminating another uncertainty - that of erosional removal of accreted material.

During predrilling studies of this region it was discovered that evidence for fluid venting indicators at the trench axis or lowermost trench slope was lacking (Kahn et al., 1996; McAdoo et al., 1996), in spite of abundant evidence of stratal thinning within the underthrust section near the trench axis. The thinning was interpreted as sediment dewatering due to the load of the overlying plate. These observations suggest that either dewatering is highly dispersed through the lower part of the slope, or dewatering is not accompanied by chemosynthetic vent communities that have been found ubiquitously elsewhere, including higher on this margin. A second problem discovered prior to drilling was extremely low heat flow on the incoming plate and higher but still very low heat flow on the upper plate (Langseth and Silver, 1996). These conclusions were based on averaging a large number of measurements, rather than relying on a few isolated values. A tentative hypothesis to explain these observations included massive fluid flow distributions within the lower plate and upper plate as well.

Five sites were drilled on Leg 170, and each of these problems has been highly illuminated, if not fully answered (Silver, Kimura, Blum et al., 1997). Comparison of the lower plate reference Site 1039 with two sites on the lowermost slope (1040 and 1043) and one on the mid slope (1041) shows that little if any of the incoming sediment is accreted frontally to the upper plate (Fig. 1). Drilling was not sufficiently deep into the mid slope Site 1041 to rule out underplating farther arcward from the toe region, and indeed the seismic data allows such underplating. Our discovery of essentially no frontal accretion was surprising, because some of the seismic reflection data had indicated truncations of uppermost incoming strata, suggesting up to 40 m of frontal accretion. Given a subduction rate of 80 km / My the frontal deformed wedge of sediment could have been accreted in 2 My or less. Evidence for no frontal accretion included bio- and magneto-stratigraphy, physical stratigraphy, geochemistry and logging while drilling (LWD).

The stratigraphy indicated that virtually the entire incoming section cored at Site 1039 was present in the underthrust section at Sites 1040 and 1043, with the exception of 4-5 m of turbidites. However, a 3.5 kHz profile run between these sites showed clearly that the upper 5 m at Site 1039 pinches out before reaching the base of the slope, probably due to the action of bottom currents. In addition, the youngest bio- and magnetostratigraphic picks at Site 1039 are present in the underthrust strata of Sites 1040 and 1043. A more detailed physical stratigraphic comparison can be made between the sites using the resistivity and LWD results. These data are available in the underthrust section only for Site 1043, but comparison with Site 1039 suggests a possible difference of 9 m between these sites. Because the upper 5 m of strata at Site 1039 are turbidites, the LWD data suggests up to 4 m of sediment scraped off near the toe in Site 1043. A similar inference can be made from the observations of pore water geochemistry.

The almost complete lack of frontal accretion at the toe of the slope off Costa Rica is consistent with the physical stratigraphy seen

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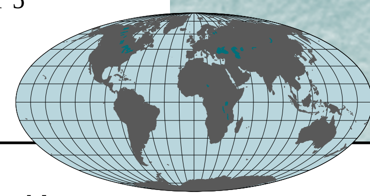

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at each of the drill sites as well. If the deformed sedimentary wedge at Sites 1040 and 1043 were composed of materials scraped off the incoming Cocos Plate, then the composition of the sediments should be similar to those drilled at Site 1039. In fact, the composition of sediments in the deformed wedge at Sites 1040 and 1043 is not representative of that from Site 1039. The latter has an upper layer rich in diatoms and a lower carbonate layer. The deformed wedge, in contrast, has no carbonate and is very poor in diatoms. It is largely a hemipelagic silty clay. The closest unit in the underthrust section to that of the deformed wedge is unit U2A, which is a sparsely fossiliferous hemipelagic silty clay. However, unit U2A has abundant volcanic ash layers compared with few ash layers in the deformed wedge. In contrast to the underthrust section, the sedimentary apron at Site 1041 has significant commonality with the deformed wedge. It is likely that the deformed wedge represents material of the sedimentary apron that has flowed downslope to the toe of the slope (Baltuck et al., 1982) and has been deformed by rapid and long term subduction beneath it.

A further question concerns long term sediment accretion vs non-accretion on the Costa Rica margin. This question was tackled by drilling first at Site 1041 then at Site 1042 in order to penetrate into the high amplitude reflection surface (Shipley et al., 1992) beneath the sedimentary apron, material of which has recently been shown to have relatively high velocity (Ye et al., 1996). Site 1041 did not penetrate to this surface (550 mbsf) because of sticky (possibly due to high pressures) muds, so Site 1042 was drilled at a site where the surface lies at 325 mbsf. At Site 1042 we recovered a carbonate cemented sandstone breccia, whose seismic velocity satisfied that observed with seismic refraction studies. Beneath this sandstone breccia was a second breccia containing clasts of red chert and mafic rocks, similar to those found in the Nicoya complex

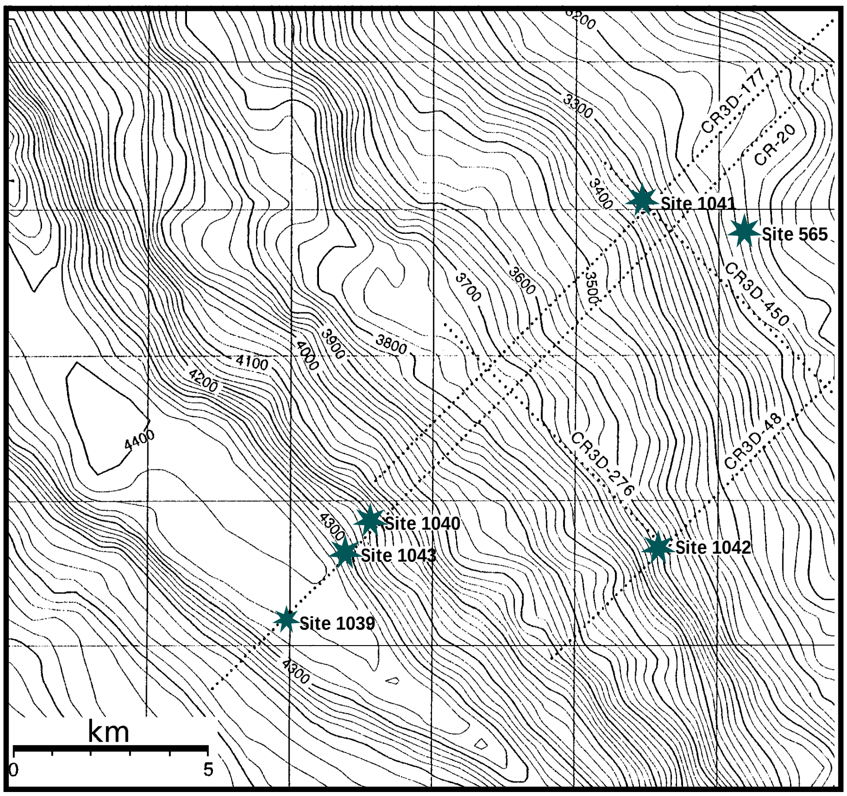
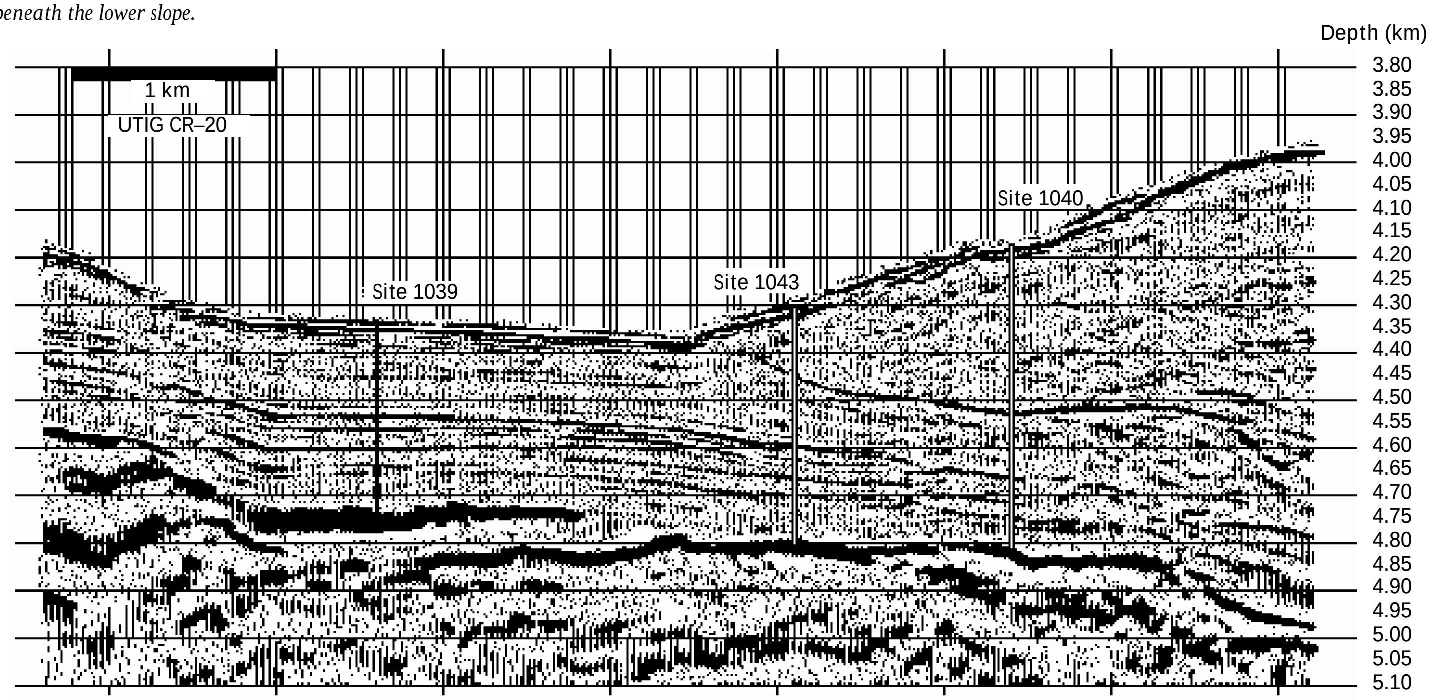


Figure 1. (Upper) Location of ODP Sites 1039-1043 off the Pacific margin of Costa Rica. (Lower) Seismic reflection profile across the toe of the slope and the Middle America Trench, showing locations of ODP Sites 1039, 1043, and 1040. Note thinning of subducted strata beneath the lower slope.



onshore. The sequence of breccias was middle Miocene in age, present as fault slices overlying upper Miocene hemipelagic silty clays. The Miocene breccia sequence drilled at Site 1042 is similar to that reported from outcrops near the Osa Peninsula onshore (M. Protti, oral communication, 1996). It is very likely that the material underlying the slope apron represents rocks with onshore affinities. The rocks we recovered do not have affinities to the reference section drilled at Site 1039.

The role of fluids is critical to understanding the processes acting off Costa Rica. LWD records define the nature of the decollement as well as faults within the upper plate section. In Site 1043, the decollement is defined as the lower of three zones of low density material at a depth of 147 mbsf (Fig. 2). The other two are at 138 and 124 mbsf, and each has a thickness of about 1-2 m. Another zone of low density, probably within a fault zone, is recorded at 73 mbsf. Each of these low density zones is accompanied by zones of low resistivity and low gamma ray values. These regions of low density are also accompanied by geochemical anomalies, but because of the low spatial resolution (10 m sample interval) the geochemistry does not resolve the kind of detail that is seen with LWD. Anomalous lows are seen between 130 and 150 mbsf at Site 1043 in chlorinity and salinity, K and Si. These species also define lows in the 60-80 mbsf range as well. Similar chemical results are found for Site 1040, with the decollement defined at 371 mbsf. The fact that sharp chemical and physical boundaries occur at the decollement and at a limited number of defined faults within the section argues against a broad zone of dewatering through the deformed wedge.

Regional low heat flow on the incoming Cocos Plate averages 12 mW / m^2 from surface heat flow (Langseth and Silver, 1996) and downhole temperature measurements at Site 1039 show values of 8 mW / m^2. These values increase slowly upslope to surface values of about 30 mW / m^2 and downhole values at Site 1041 of 17 mW / m^2. A reasonable explanation for such low values is sea water cooling of the uppermost crustal rocks, probably through downward seepage in lower plate normal faults. Direct evidence of sea water cooling of the crust is seen in the geochemistry results at Sites 1039 and 1040. At both Sites 1039 and 1040, values of Si increase downsection to within a few tens of meters of basement, then rapidly decrease toward seawater values in the lowermost part of the section (Fig. 3). At Site 1039 we also see the same pattern for Ca. These observations are explained by a source of seawater chemistry at the base of the sedimentary section at these sites, and are consistent with the hypothesis of seawater percolation into basement, providing a cooling mechanism for the uppermost crustal rocks.

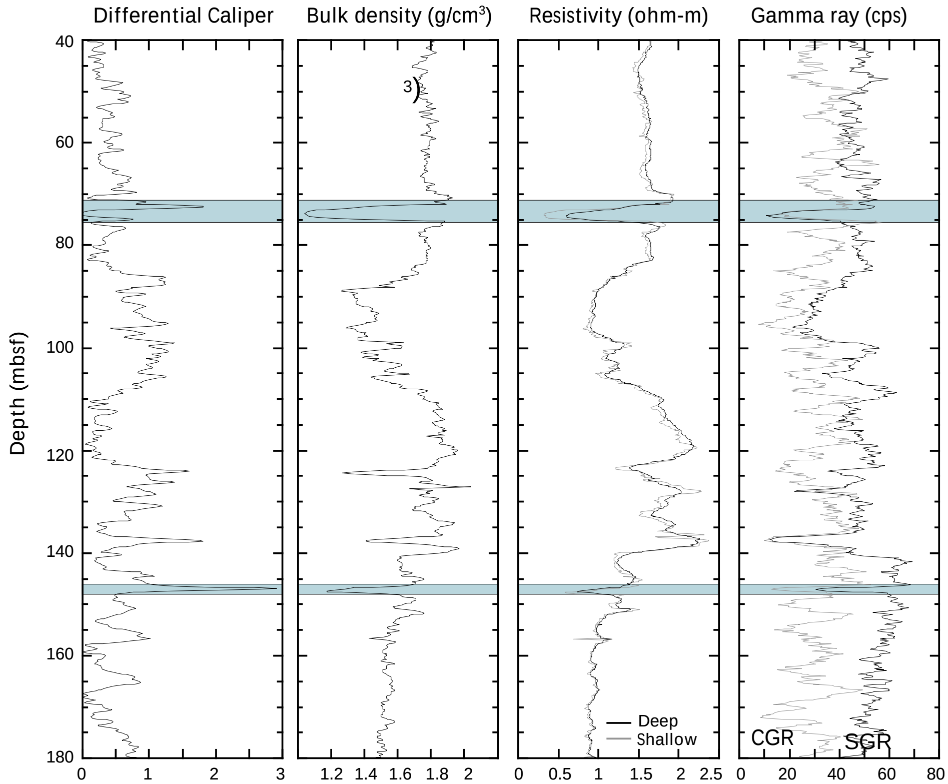


Figure 2. Logging-while-drilling results for Site 1043, showing bulk density, gamma ray and resistivity logs. Deep vs. shallow resistivity refers to depth horizontally into the formation. Note sharp alignment of logs with décollement (approximately 147 mbsf) and intrawedge thrust (73 mbsf).

Leg 170 Scientific Party

Gaku Kimura, Co-Chief Scientist, Osaka Prefecture University, Japan; Eli Silver, Co-Chief Scientist, University of California, Santa Cruz; Peter Blum, Staff Scientist, Ocean Drilling Program; Gerard Blanc, Alistair Bolton, Michael (Ben) Clennell, John Griffin, Bernard Housen,Masako Ibaraki, Peter Ireland, Toshiya Kanamatsu, Miriam Kastner, Nancy Lindsley-Griffin, Andreas Lückge, Kirk McIntosh, Martin Meschede Julie Morris, Jay Muza, Greg Myers, Marino Protti, Ola Saether, Saneatsu Saito, David Scholl, George Spence, Harold Tobin, Paola Vannucchi, Lisa White.

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Initiation and Evolution of Fault Zones: Insights from Barbados Accretionary Prism Logging While Drilling ODP Leg 171A

by J. Casey Moore, Adam Klaus and the Leg 171A Scientific Party

In less than 12 days of operations during Leg 171A, Logging While Drilling (LWD) acquired over 2959 m of density, resistivity, gamma ray, photoelectric effect, and neutron porosity logs at five sites (Fig. 1, 2). The high quality data bear on many aspects of the geology and geophysics of the northern Barbados Ridge because the data was acquired in an area with 3D seismic control and numerous previous DSDP / ODP sites. Here we report on the initiation and evolution of faults and the seismic imaging of this process; for an overview of Leg 171A see the preliminary cruise report at: “http: / / www-odp.tamu.edu / publications / prelim / 171A_prel / 171Atoc.html”.

How faults initiate and develop is fundamental both academically and practically. Convergent plate boundaries move undeformed sedimentary sections into the subduction zone where they are separated by the plate boundary thrust or décollement zone into an offscraped section and an underthrust section. Legs 156 (Shipley, Ogawa, Blum, et al., 1995) and 171A acquired logs from six sites penetrating the proto-décollement and décollement zone at distances from six km east to four km west of the deformation front (Fig. 2). With these logging data, drill cores, and the 3D seismic survey we can address 1) how the décollement initiates, 2) how its physical properties evolve with underthrusting and accretion, and 3) how these changes in physical properties affect the seismic images. Our ultimate goal is to calibrate the seismic reflection techniques as a remote sensing tool to investigate active fault zones and develop an approach for extending these combined seismic reflection and drilling studies into the seismogenic zone.

In the Leg 171A area, previous DSDP Leg 78A, ODP Legs 110 and 156 focused on the northern Barbados accretionary prism because the décollement zone develops at a shallow depth in drillable muddy sediments with good biostratigraphic resolution. Here the sediments incoming to the subduction zone are about 700 m thick and lie on an oceanic crustal high, the Tiburon Rise. Approximately the upper 200 m of this section are offscraped with the remainder being underthrust to the west at about 2 cm / yr. Despite the success of previous cruises in drilling 10 cored holes, and emplacing two CORKS, logging had been unsuccessful until the application of LWD technology.

Because the logging tools are integrated into the drillstring just above the bit, LWD measures physical properties *in situ* within minutes after the borehole has been cut, before the borehole has significantly degraded. LWD is superior to wireline logging under difficult hole conditions that are typically encountered at convergent margins. Physical property information acquired by LWD is more useful than that from cores because LWD measurements are high resolution (> 1 per 15 cm

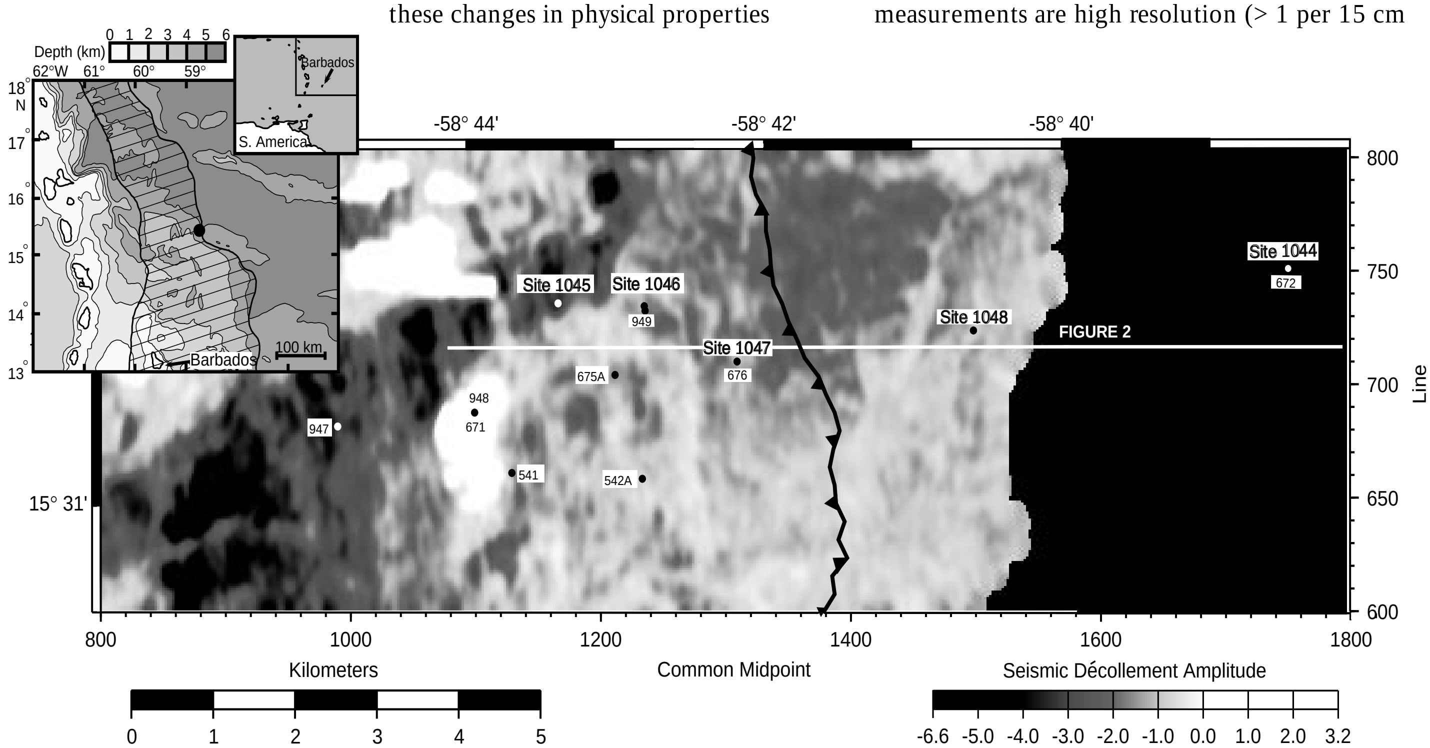

Figure 1. Location of ODP Leg 171A area, Barbados accretionary prism. Sites are shown over a map of peak seismic reflection amplitude of décollement zone and part of proto-décollement zone (after Shipley et al., 1994 and Moore et al., 1995). Line shows location of cross section shown in Figure 2.

depth), are not selectively sampled, and not subject to elastic rebound nor loss of data from unrecoverd sections. LWD opens new realms for study of *in situ* physical properties in sedimentary sections previously unattainable by wireline logging or studies of cores.

Initiation of the Décollement Zone: Paleoceanographic Controls on Tectonics

During Leg 171A, Sites 1044 and 1048 penetrated the seaward extension of the décollement zone or the proto-décollement zone. Cores at Site 672 (co-located with Site 1044) indicate the position of the proto-décollement zone; the proto-décollement zone can be traced to Site 1048, using the seismic data. The proto-décollement zone at both sites is characterized by an interval of anomalously low density (Fig. 2). Core lithologies from Site 672 indicate that a lower Miocene radiolarian mudstone comprises this low density interval. Landward or west of the deformation front, every cored penetration of the décollement zone lies in lower Miocene radiolarian mudstone indicating that this lithology is the preferential surface of failure beneath the toe of the accretionary prism. Hence the low density, high porosity and, by inference, low strength allow for preferential failure in the radiolarian mudstone relative to the surrounding clays. Low density, high porosity sediments are inherently weak (Hoshino et al. 1972); also anomalously low density, high porosity sediments have a large potential for consolidation and can become preferentially overpressured and fail as they are tectonically loaded.

The lower Miocene radiolarian mudstone accumulated at a slow rate (1.4 m / my) after a waning of terrigenous input and before the onset of an influx of volcaniclastic detritus (Shipboard Scientific Party, 1988a). Thus, paleoceanographic conditions and the former tectonic setting control the initiation of the décollement zone at the base of the Barbados accretionary prism.

Evolution of the Décollement Zone: Heterogeneous Consolidation During Underthrusting

The numerous penetrations of the proto-décollement and décollement provide an indication of initial and current degree of consolidation across the toe of the accretionary prism. Site 1044 and co-located Site 672 provide density and lithologic data that are the baseline to evaluate changes at other sites to the west. The depth shifting necessary to make the comparisons between sites is controlled by matching the character of the logs in the underthrust sequence below the décollement or proto-décollement zones (Fig. 2).

Overall, the consolidation of the décollement zone is heterogenous but increases to the east. The similar density variation at both Sites 1044 and 1048 demonstrates a consistent initial condition of the low density proto-décollement before underthrusting (Fig. 2). The density is lower in the proto-décollement zone at Sites 1044 and 1048 than in the décollement at sites 948, 1045, 1046, and 1047. The density curve through the proto-décollement zone at Sites 1044 and 1048 is a lower-bound reference for the décollement zone at all sites beneath the accretionary prism. Located 0.8 km east of the deformation front, Site 1047 shows modest consolidation of the décollement zone and little change in the underthrust and

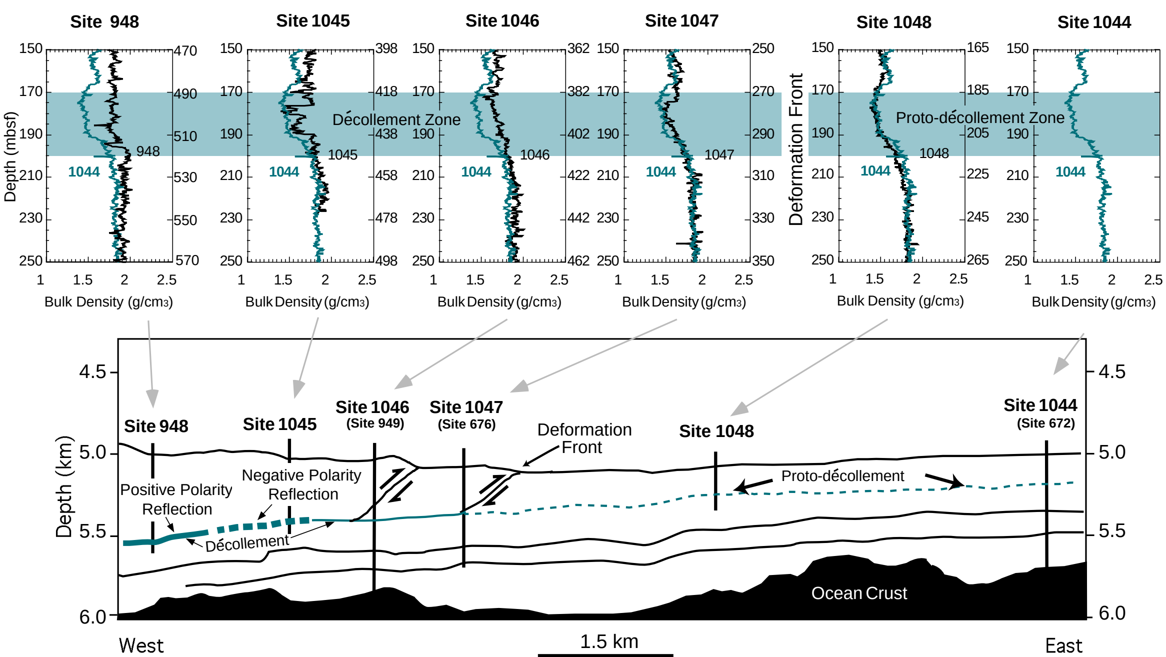

Figure 2. Generalized cross section showing LWD density distribution through proto-décollement zone or décollement zone at all sites. Depth scale on left sides of density plots refers to depth of Site 1044 data; depth scale on right side of density plots refers to depth scale for the site indicated by the arrow. Horizontal bar shows approximate depth of proto-décollement and décollement zones across all sites. Site 1044 LWD data are used to represent the baseline undeformed reference density pattern.

overthrust sedimentary sequences, relative to Site 1044. This pattern of consolidation continues with increasing magnitude through Sites 1046 and 948, respectively 1.7 and 4.4 km west of the deformation front. At Site 948, the low density signature of the décollement zone is lost except for several thin negative spikes. Previously these negative spikes were interpreted as hydro-fractures (Moore et al., 1995). However, comparison to Site 1044 suggests a simpler interpretation as zones of residual underconsolidation. The décollement zone at Site 1045 includes a ~10 m thick section of anomalously low density.

Seismic Reflection Data as a Proxy for Fluid Content of the Décollement Zone

The oil industry has pioneered the use of seismic reflection data to interpret the fluid content of hydrocarbon reservoirs. The northern Barbados ridge seismic reflection and drilling results allow application of this methodology to faults. Patches of clearly-defined positive and negative polarities occur along the décollement reflector about 2–4 km east of the deformation front (Fig. 1). LWD Sites 948 and 1045 respectively penetrate strong positive and strong negative reflection localities; Sites 1046 and 1047 penetrate in a décollement zone of transitional character to the east. The negative polarity reflections were initially interpreted as fluid rich, dilatant zones, whereas the positive polarity reflections were considered as lower porosity intervals (Shipley et al., 1994). The logs from Sites 1045 and 948 bear out and calibrate these suppositions, except for the requirement of dilation. The density distribution at Site 1045 is a partially consolidated basinal density curve as seen at Sites 1044 and 1048. The sharp density changes adjacent to the 10m-thick low density zone at Site 1045 cause reflections of opposite polarity that interfere to produce the observed strong negative polarity reflection (Bangs et al., 1996). Thus, here the negative polarity reflections are most simply explained as a thick interval of residual underconsolidation, not dilation; the positive reflections at Site 948 apparently represent areas where the preferentially low porosity of the decollement zone has collapsed.

Questions and Some Answers

What is the origin of the locally low density of the proto-décollement? Lithologic variation explains the anomalously low density of the radiolarian-rich proto-décollement zone. Comparison of radiolarians (and siliceous sediments in general) to clayey sediments indicates that the former maintain lower densities and higher porosities over 100's of meters of burial, presumably because of the open structure of the radiolarians and their resistance to collapse (Hamilton, 1976). The very slow accumulation of the lower Miocene radiolarian mudstone of the proto-décollement zone (1.4 m / my) was succeeded by less than 200 m of sediment deposited at slow to moderate rate (5-13 m / my; Shipboard Scientific Party, 1988a). Accordingly, overpressuring due to rapid sedimentation is unlikely. There is no strong evidence for fluid flow from the accretionary prism into the proto-décollement zone at Site 672, which argues against a tectonically maintained overpressure.

What causes the preferential density increase in the décollement? The décollement zone increases in density due to shear-induced collapse of the sediment fabric, including collapse of the radiolarian tests. The décollement zone increases in density more rapidly than overlying or underlying sediments. Radiolarian-rich sediments buried in basinal conditions do not show significant increases in density at depths comparable to the greatest depths of burial of décollement at any of the logged sites (Hamilton, 1976). Therefore, the excessive density increase is not due to only uniaxial consolidation or vertical loading, but must be related to the additional influence of tectonic processes active in the décollement zone. Available scanning electron microscope images of the décollement zone indicate that the hollow radiolarian tests fracture and implode during underthrusting, increasing the sediment density and expelling water (Moore et al., 1986). Apparently, the lateral stresses imposed by the compressional environment and the shearing along the fault surface accelerate the densification of the décollement zone.

What controls the patchy consolidation of the décollement zone? If décollement consolidation is controlled by overburden, it should increase with underthrusting to the west. However, Site 1045 is less consolidated than Site 1046 to its east. Figure 1 illustrates the heterogeneity of consolidation, assuming that the peak amplitude of the seismic data is a proxy for consolidation (Site 1045 less consolidated high amplitude negative polarity; Site 948 most consolidated high amplitude positive polarity). Perhaps the areas of low consolidation (Site 1045 and band of negative polarity reflections to southwest) are maintained by fluid flow from depth.

Are there hydrofractures or dilation features along the décollement zone? The LWD data do not require hydrofractures or dilation to explain the low density signature of the décollement zone, nor do the data exclude them. Mud- and mineral-filled veins in the décollement zone indicate the presence of small scale hydrofractures in the décollement zone (Shipboard Scientific Party, 1995). As previously noted, interpretations of LWD density results from Site 948 as indicating hydrofractures (Moore et al., 1995) are not supported by our more complete data set. Because the density measurements occur 30- 50 minutes after the hole is cut, any open hydrofractures could have expelled their fluid to the open borehole. Negative polarity reflections can be produced, at least at Site 1045, from the underconsolidated interval and do not require hydrofracturing to lower the sediment density. However, the deeply sourced focused fluid flow along the décollement zone (Vrolijk, et al., 1992) may retard consolidation such as observed at Site 1045, and locally support hydrofracture. Although we have argued for production of the décollement zone density distributions by consolidation, the simplest explanation, the low density intervals could also be produced by consolidation plus subsequent dilation.

Conclusions

- The décollement zone initiates in a low density radiolarian interval about 30 m thick. The low density of the proto-décollement zone is controlled by lithology and not overpressure. The localization of the décollement zone at the toe of the accretionary prism is ultimately due to unique depositional conditions and is a case of sedimentary inheritance.
- During underthrusting, the LWD data indicate the décollement zone consolidates, albeit in a heterogeneous manner. The physical collapse of the porous radiolarian tests apparently hastens consolidation, and probably releases porewater and locally increases the pore pressure.
- The peak amplitude of the seismic reflection from the décollement zone indicates significant thicknesses of underconsolidated sediments with strong negative polarity reflections and areas of substantial consolidation with positive polarity reflections. Thus, the seismic data are an effective proxy for fluid content of the décollement zone.

Leg 171A Scientific Party

J. Casey Moore, Chief Scientist, University of California, Santa Cruz, Santa Cruz; Adam Klaus, Staff Scientist, Ocean Drilling Program; Nathan L. Bangs, Barbara Bekins, Warner Brückmann, Christian J. Bücker, Stephanie N. Erickson, Olav Hansen, Candace Olson Major, Gregory F. Moore, Sheila Peacock, Saneatsu Saito, Elizabeth J. Screaton, John W. Shimeld, Philip Henry Stauffer, Tuncay Taymaz, Philip A. Teas, Tomochika Tokunaga, Thomas Horton, Peter Ireland.

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Northwest Atlantic Sediment Drifts

by ODP Leg 172 Shipboard Scientific Party

ODP Leg 172 was designed to obtain a detailed history of late Neogene paleoceanography and paleoclimate in the westernmost North Atlantic. This location, between the northward-flowing surface waters of the Gulf Stream and the net southerly flow of intermediate and deep waters, is presently an important region for exchange of heat, salt, and water with other ocean basins, and for accumulation of sediment drifts related to deep- and intermediate-ocean circulation. Sediment drifts are characterized by high accumulation rates, and can therefore provide important records of North Atlantic past climate variability on orbital to centennial time scales. In addition, the sediments at some sites have provided records of Earth's magnetic field at a previously unseen resolution.

The main focus of Leg 172 was to recover a sequence of sediment cores along a depth transect to document rapid changes in climate and ocean circulation during middle Pliocene to Pleistocene time. Eleven sites were drilled on the Carolina Slope, along the Blake-Bahama Outer Ridge (BBOR), on the Bermuda Rise, and on the Sohm Abyssal Plain. At most sites (Figure 1), sedimentation has been continuous and at a high deposition rate (10-50 cm/k.y.) through the Pleistocene, and important features such as the evolution of the "100 k.y. world" from the "40 k.y. world" are evident. Being preliminary, most of the shipboard work has concentrated on the evidence for orbital-scale climate changes, but millennial- and perhaps centennial -scale changes are preserved and resolvable at some sites.

Current control on sedimentation is observed at all locations. Indeed, the influence of thermohaline circulation is so pervasive in the western North Atlantic that it accounts for much of the uniformity observed among coring locations spanning a depth range in excess of 4 km. In fact, nearly identical sedimentary units are present from the shallowest site on the Carolina slope (Site 1054, 1291 m) to the deepest site on the Blake-Bahama Outer Ridge (BBOR; Site 1062, 4775 m), indicating that

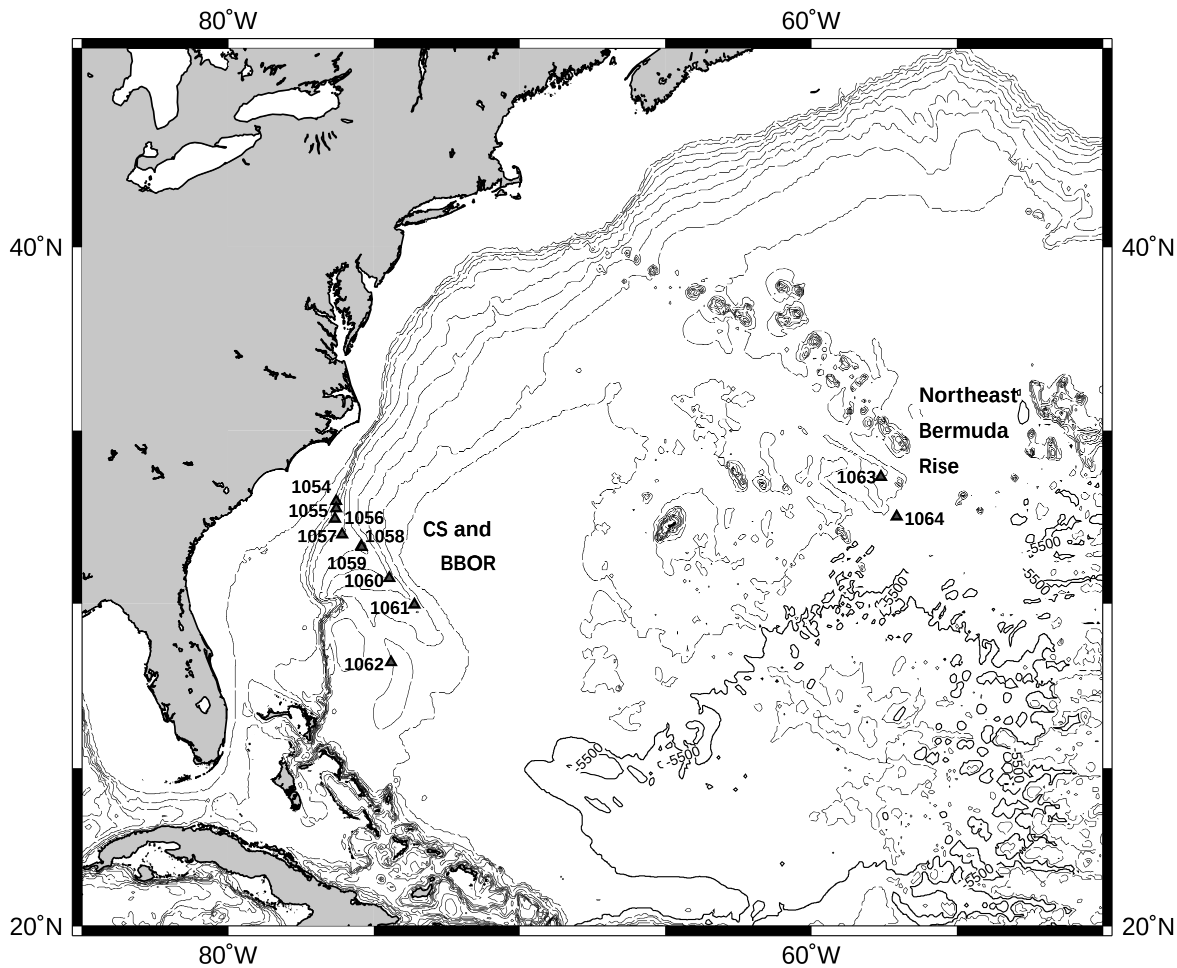


Figure 1. ODP Leg 172 site locations.

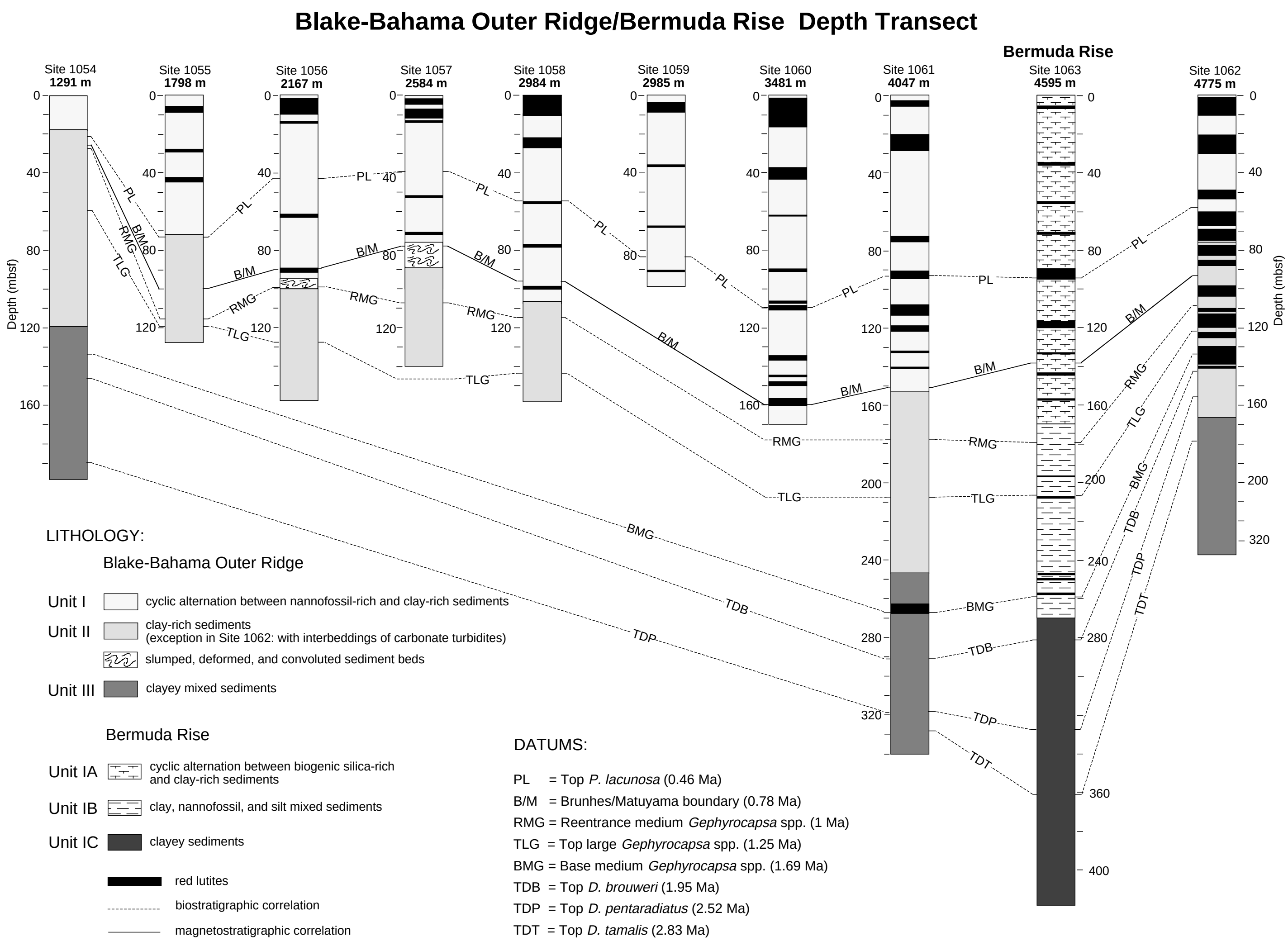
patterns of sedimentation are basin wide (Figure 2). Every location has an upper unit marked by cyclic alternation between nannofossil-rich and clay-rich sediments, whose base is close to or a little older than the Brunhes / Matuyama boundary, roughly 800 ka. That this lithological change is close in age to the mid-Pleistocene origin of 100-k.y. orbital forcing of climate (~900 k.y) attests to the strong influence of climate on sedimentation and ocean circulation.

Stratigraphic coherence among Leg 172 sites is evident also on much shorter time and depth scales. A preliminary shipboard chronology has been established for the past 900 k.y. using magnetic susceptibility, which provides a proxy for oxygen isotopes or percent carbonate, with increased values during glacial stages because of increased terrigenous flux to the ocean. The observed robust trend of greater deposition during the past 60 k.y. is consistent from site to site and could signify increased continental erosion during the latest glacial-interglacial cycle, possibly coupled with more energetic deep ocean circulation.

Most Leg 172 cores were drilled deep enough to recover the top of large *Gephyrocapsa* spp. (dated to 1.25 Ma; Figure 2) so that the "40 k.y" world of the early Pleistocene is adequately represented for detailed study. The transition at about 900 ka from climate records dominated by a 40 k.y. period to those dominated by the familiar late Pleistocene glaciations at ~100 k.y. period is a subject of intense debate and active research. The sediments recovered during Leg 172 throughout the western North Atlantic region provide important evidence for such a climatic transition, which may be found in the change in lithology (discussed above) and in proxy records such as carbonate accumulations.

Striking evidence of this change is found on the Bermuda Rise, and expressed by changes in seismic patterns, GRAPE data and logging results. At Site 1063, an abrupt transition occurs at a depth of 162 mbsf (~0.86 Ma). Reflectors above this depth are characterized by higher amplitudes and a lower frequency (widely spaced, 100 k.y cycles), whereas the deeper reflectors are character-

Figure 2. Summary of litho-, bio- and magneto-stratigraphy for Leg 172 sites (excepting Sohm Abyssal Plain Site 1064). Sites 1054 through 1063 all contain similar lithologic units of similar ages, attesting to the strong and coherent control of western North Atlantic circulation patterns on sedimentation. Especially noteworthy is the occurrence of red lutites, which seem to be more prevalent in the late Pleistocene at deeper sites, and the curious occurrence of late Pleistocene biogenic silica-rich sediments on the Bermuda Rise.



ized by slightly lower amplitudes and a higher frequency (closely spaced, 40 k.y. cycles). This transition and these cycles can also be seen in the bulk density measurements provided by the GRAPE data at Site 1063. The properties of sediments younger that 0.86 Ma vary with conspicuously lower wavelengths than those of older sediments.

This "mid-Pleistocene transition" is particularly well documented by logging results at Sites 1061 and 1063. Figure 3 compares the older "100 k.y." cycles of SPECMAP (A), the HCGR log from Site 1063 (B) and the resistivity logs from Sites 1061 and 1063. The logs are characterized by long wave-lengths cycles which contrast with shorter cycles of lesser amplitude below 162 mbsf; clearly the logs are tracking the older 40 k.y. and the younger 100 k.y. cycles in climate. The resistivity and natural gamma ray radiation logs follow the known glacial-interglacial stages of the $\delta^{18}O$ record. Peaks in natural gamma radiation are a measure of clay content (because the K and Th that emit the gamma rays are contained mostly in the clays) and the glacial sediment has a higher clay content than the interglacial sediment.

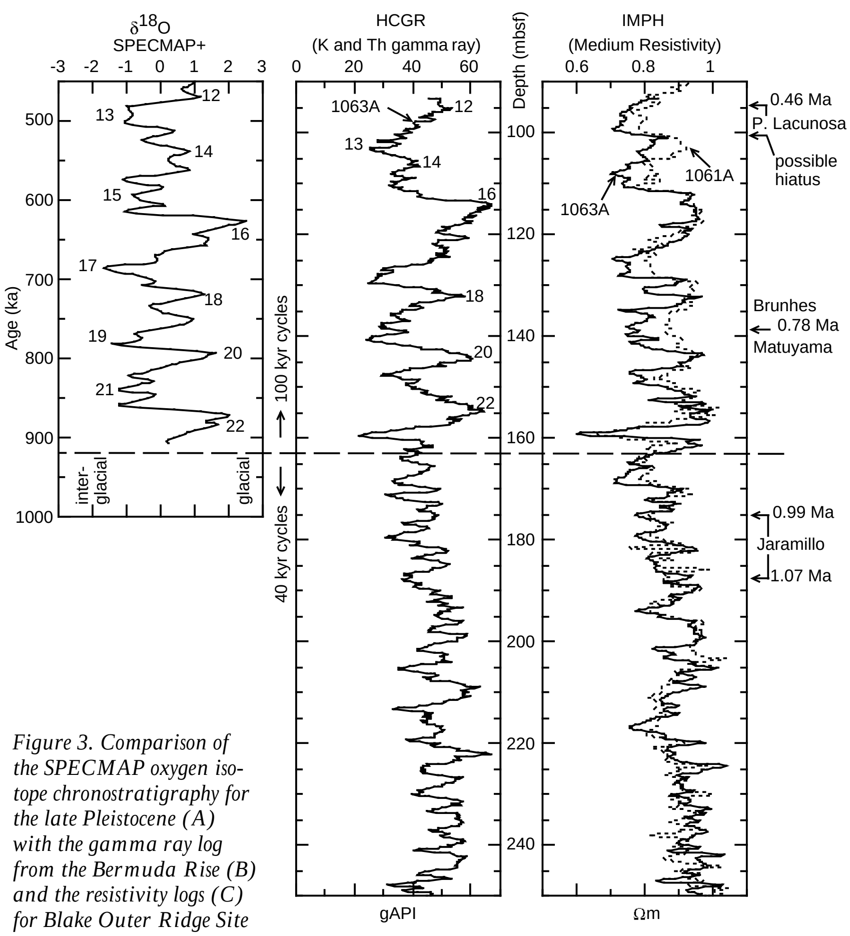


Figure 3. Comparison of the SPECMAP oxygen isotope chronostratigraphy for the late Pleistocene (A) with the gamma ray log from the Bermuda Rise (B) and the resistivity logs (C) for Blake Outer Ridge Site 1061 and Bermuda Rise Site 1063 (with the former scaled to the latter). The match of the log data to the stable isotope stack supports the chronology and the observation that physical and chemical properties of Leg 172 sediments are closely linked to orbitally-driven climate change. Especially striking is the switch at about 0.9 Ma from 40 k.y. cycles to 100 k.y. cycles recorded at ~162 mbsf on the Bermuda Rise.

Sediments collected during Leg 172 contain the most detailed and complete record of the Earth's magnetic field variability for the last 1.2 Ma that has ever been recovered by Earth scientists. Interspersed within the secular variation are at least 14 Brunhes-aged excursions and at least four Matuyama-aged excursions. In addition, magnetic field transition records were recovered for the Brunhes / Matuyama, Jaramillo onset / termination, and Cobb Mountain onset / termination boundaries. These records of magnetic field behavior all occur in sediments with accumulation rates between 10-25 cm / kyr providing perhaps the best chance of resolving details of magnetic field variability that has ever been recovered from ODP sediment sequences.

On-board paleomagnetic measurements indicate that magnetic field excursions tend to occur in "bundles" of two or three close together with intervening intervals of distinctive magnetic field secular variation. Altogether, the bundles tend to last 20-50,000 years. It is possible that these bundles of closely spaced excursions indicate a continuous "excursional state" or pattern in the core dynamo process which spans the duration of the bundles. The number and ages of the recovered Brunhes excursions also suggest that excursions can no longer be viewed as simply or even primarily regional anomalies of the geomagnetic field. If confirmed by further shore-based studies, the observations made during Leg 172 suggest that excursions are not rare, random perturbations of the stable geomagnetic field, but rather an important systematic and distinct component of the Earth's magnetic field variability between field reversals.

Leg 172 Scientific Party

Lloyd Keigwin, Co-Chief Scientist, Woods Hole Oceanographic Institution; Domenico Rio, Co-Chief Scientist, University Of Padova, Italy; Gary Acton, Staff Scientist, Ocean Drilling Program; Giancarlo Bianchi, Walter Borowski, Namik Cagatay, William Chaisson, Bradford Clement, Elsa Cortijo, Gavin Dunbar, Roger Flood, Sven-Oliver Franz, Liviu Giosan, Jens Grützner, Sveinung Hagen, Brian Haskell, Michael Horowitz, Edward Laine, Steven Lund, Makoto Okada, Maria-Serena Poli, Isabella Raffi , Matthew Reuer, Yann Ternois, Trevor Williams, Diane Winter, Miwa Ezaki Yokokawa.◆

Leg 173 Completes Transect of West Iberia Margin from Continental to Oceanic Crust

by Bob Whitmarsh, Marie-Odile Beslier, Paul Wallace and the ODP Leg 173 Shipboard Scientific Party

The rifting of continents and their eventual break-up, which leads to the onset of seafloor spreading, is one of the major recurring geological events on Earth. Yet the evolution of the tectonic and magmatic processes that are involved, which tend to occur deep below the surface, are hard to decipher on many margins. Leg 173 recently tackled this difficult problem by completing a sequence of holes across the ocean-continent transition (OCT) of the west Iberia margin beneath the Iberia Abyssal Plain (Figure 1).

The west Iberia margin has attracted earth scientists for almost two decades as an excellent example of a non-volcanic rifted margin. There have now been numerous geological sampling and geophysical cruises to the area as well as four DSDP or ODP legs (Legs 47B, 103, 149 and 173). Many seismic reflection profiles across the margin provide images of tilted fault blocks and onshore, and apparently offshore, there are scant signs of synrift magmatism. The northern part of the margin is also relatively thinly covered by sediments. Thus, not only are the basement rocks of the margin relatively accessible to the drill, but the lack of magmatism means that it is possible to image seismically, and even sample, the basement rocks that have been tectonically rearranged by extensive low-angle and normal faulting at the time of rifting.

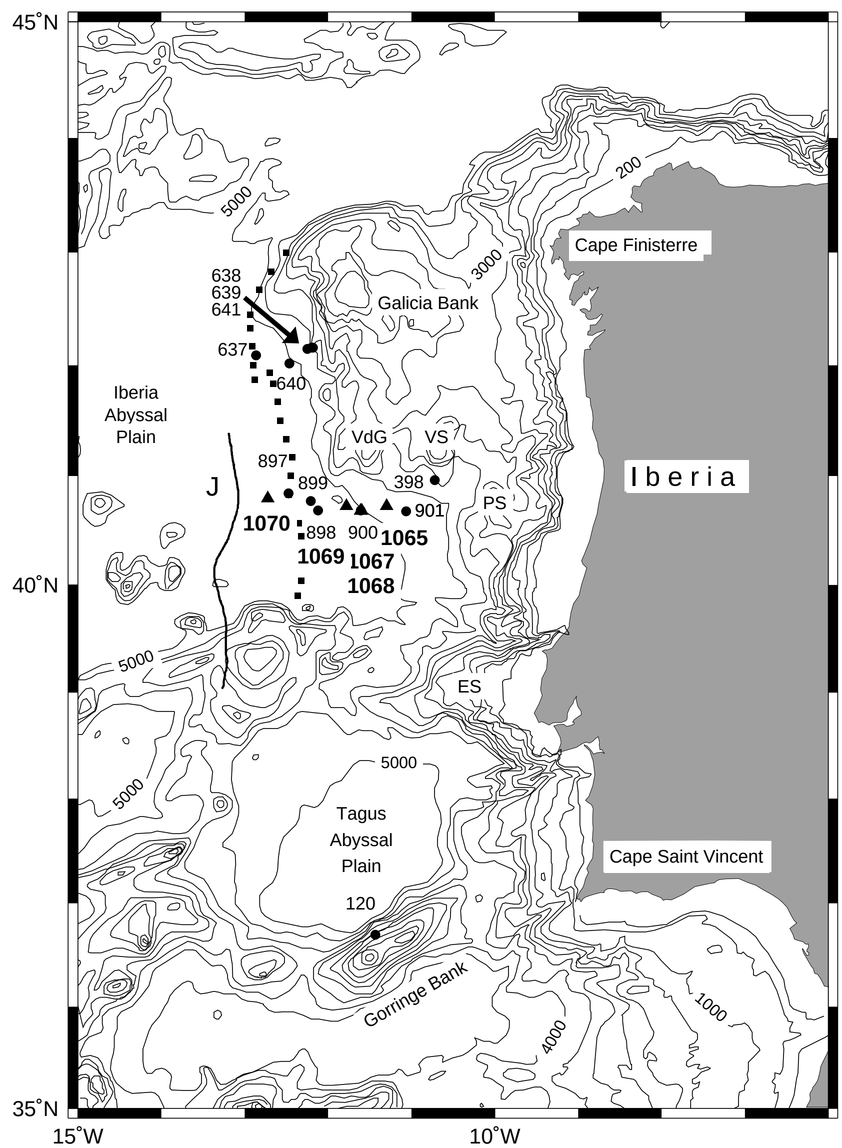
Leg 173 was planned as a sequel to Leg 149 which took place in 1993 (Sawyer et al., 1994; Whitmarsh et al., 1996b). Leg 149 started an east-west transect of holes, located on highs in the acoustic basement, across the OCT in the southern Iberia Abyssal Plain. At Site 897, Leg 149 confirmed the existence of a narrow peridotite ridge that has been traced for over 350 km parallel to the margin (Beslier et al., 1993) and which may mark the landward boundary of the oceanic crust (Whitmarsh et al., 1996a). In between these two sites the only unequivocal *in situ* basement cores were 56 m of metagabbro from Site 900. Even though $^{40}Ar/^{39}Ar$ dating performed on plagioclases from the gabbro indicates an age of 136 Ma (just older than the expected onset of seafloor spreading) and neodymium isotopes suggest the rocks have MORB affinities, the evidence was not absolutely conclusive that these gabbros are synrift melt products.

The main objective of Leg 173 was to investigate the mechanisms of thinning and break-up of the continental lithosphere and the early stages of oceanic crust formation. Subsidiary objectives were to better characterize the OCT, constrain the tectono-metamorphic evolution of the continental and oceanic basement, determine the extent of synrift magmatism, examine the nature of the oldest oceanic crust, and investigate the early sedimentary history of the rifted margin.

Drilling Results

It is clear that continental crust involved in the formation of non-volcanic margins, and possibly volcanic margins as well, suffers extension and

Figure 1. Bathymetric chart of the west Iberia margin showing the Leg 173 (triangles), and earlier (dots), drill sites. The small squares and the bold line mark the peridotite ridge and the J-anomaly, respectively.



thinning through the action of normal and low-angle faults. On the west Iberia margin some intrabasement reflectors, that have been interpreted as low-angle detachment surfaces, extend laterally over at least 20 km. One such reflector called H, which had been suggested to be a relict of lithospheric simple shear (Krawczyk et al., 1996) appears to outcrop in the vicinity of Site 900 on a basement high named Hobby High by the Leg 173 shipboard party (after a pair of hobbies that sought refuge on the ship after being blown out to sea). Because the kinematics of deformation and tectono-metamorphic evolution of deep lithospheric levels during a rifting episode are practically unknown, we attempted to drill through H at Site 1067 where it lay apparently 400 m below the top of acoustic basement (Figure 2).

The basement at Site 1067 consists of a 92 m thick sequence of mafic rocks that is largely strongly to weakly foliated amphibolite. The amphibolites include elongate pods of meta-anorthosite and deformed augen and microaugen or veins of tonalite gneiss. These mafic rocks have enriched- to normal-MORB tholeiitic affinities, and could represent differentiated products of syn-rift mantle melting or possibly former gabbro retrometamorphosed under amphibolite facies conditions. Ductile deformation is evident and decreases from the top toward the bottom of the cored section, suggesting that a ductile shear zone developed in the amphibolite at a level which is now at the top of the basement. The hole was lost while attempting re-entry with a new bit when the bottom hole assembly broke off in the hole. A reassessment of the logistical situation at this point suggested that the objective of reaching the H reflector could not be achieved without compromising the other planned sites. Therefore an offset drilling strategy was adopted whereby, by moving 1400 m to the west flank of Hobby High, it would be possible at Site 1068 to sample the rocks beneath the H reflector, albeit without penetrating the reflector itself (Figure 2).

Beneath the sediment section, Site 1068 encountered 42 m of matrix-supported breccias, clast-supported breccias and clasts showing jigsaw brecciation set in a cataclastite matrix. The latter sedimentary breccias were probably deposited as talus deposits or rock falls at the foot of a fault scarp. The breccias consist of angular fragments of weakly to strongly foliated amphibolites, meta-anorthosites, and meta-gabbros in a calcite-rich matrix. These clasts record a retrograde metamorphic evolution and an intense deformation under upper amphibolite to greenschist facies conditions, broadly comparable to those of the Site 1067 amphibolites and the Site 900 metagabbros. There is strong circumstantial evidence to suggest the hole penetrated a seaward-dipping normal fault at this depth. Next, the hole encountered pervasively serpentinized peridotite. The serpentinization has left only relicts of spinels rimmed by chlorite probably derived from plagioclase, and locally from clinopyroxene, suggesting that these rocks are

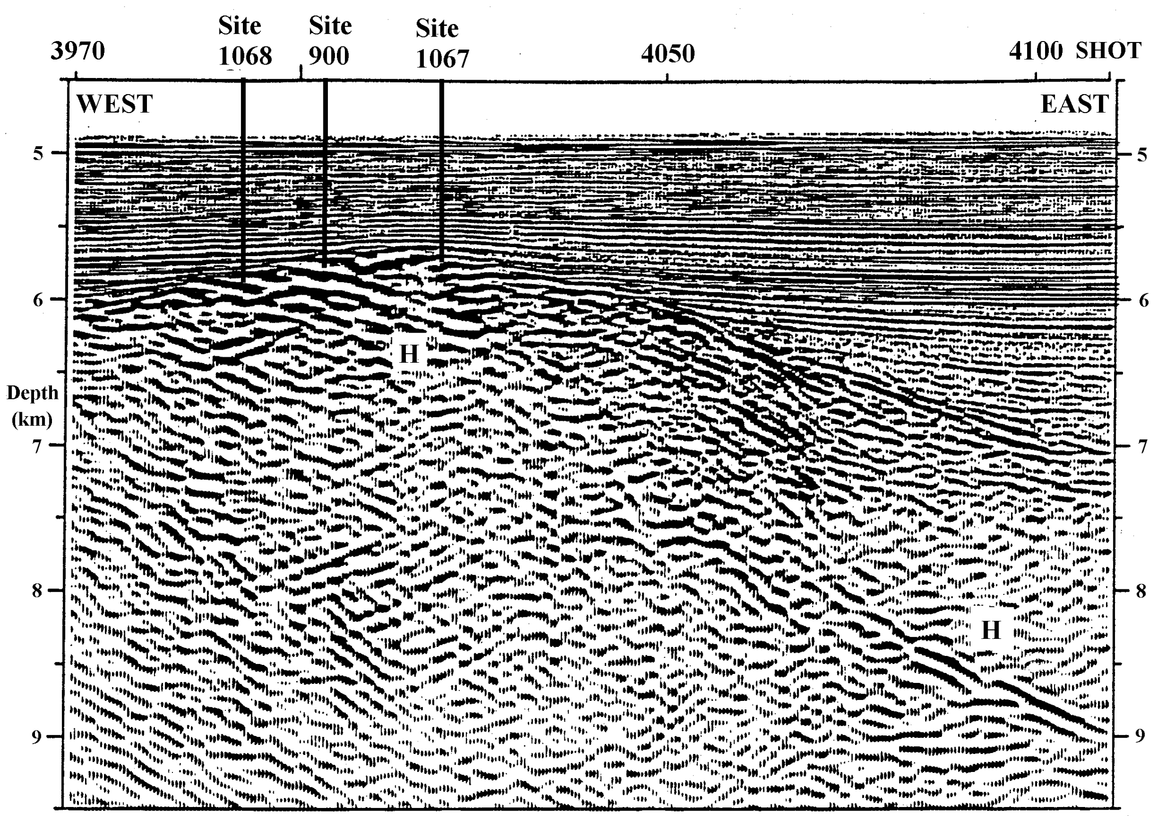


Figure 2. Part of multi-channel seismic reflection profile Lusigal-12 that has been pre-stack depth migrated by Krawczyk et al. (1996) (no vertical exaggeration). The figure shows the relative locations of Sites 1067, 1068 and 900 over Hobby High. H marks two possibly unconnected, but strong, intrabasement reflectors (see text).

derived from plagioclase-bearing lherzolites comparable to those cored at Site 897. Headspace gas samples of as much as 6,000 ppm methane and 1.2 ppm ethane may be the result of serpentinization.

Part of the solution to the problem of understanding the evolution of continental break-up from rifting to seafloor spreading is knowing the nature of the earliest seafloor spreading crust. Seismic velocity models have already suggested that the earliest formed oceanic crust off western Iberia, even though characterized by seafloor spreading magnetic anomalies, is abnormally thin (only about 5 km compared with the North Atlantic average of 7 km). Therefore Site 1070 was located 20 km west of the peridotite ridge but 15 km east of the enigmatic J anomaly often equated with the M0 isochron (Figure 1).

The main objective at this site was to sample oceanic basement in order to characterize the chemistry and melting of the early formed oceanic crust. The basement consists of matrix-supported serpentinized peridotite breccias, pegmatitic gabbro and serpentinized peridotite. The breccia clasts consist mainly of serpentinized peridotite and the matrix of several generations of calcite. Abundant jigsaw clasts and a transition downwards into an incohesive fault gouge suggest a tectonic origin for these breccias. The underlying pegmatitic gabbro shows a clear intrusive contact with the serpentinized peridotite that it overlies. The serpentinized peridotite itself is intruded at several locations by 1- to 4-cm-thick, strongly altered, coarse-grained gabbroic dikes. The presence of gabbroic veins demonstrates that the gabbro was intruded while the ultramafic rocks were in a brittle regime. The peridotite displays variable amounts of pyroxene, from pyroxenitic layers (up to 80% pyroxene) to a more dunitic layer (less than 10% pyroxene). In general, the peridotites are strongly serpentinized; relict clinopyroxene and spinel are common and small, but abundant relicts of olivine are present in the deeper part of the cored section. Thin-section observations suggest that the peridotites were only weakly deformed at high temperatures.

In the past, some doubt has been thrown on the interpretation that tilted fault blocks on seismic sections across rifted margins represent blocks of continental crust; it has been suggested that since such blocks exist in regions of slow-spreading oceanic crust, their occurrence in the OCT also indicates seafloor spreading (Srivastava and Keen, 1995; Sawyer in Whitmarsh and Sawyer, 1996). Site 1065 was intended to confirm predictions of the existence of continental crust on one such tilted fault block and then to determine the approximate crustal level from which the rocks originated and their petro-structural evolution. Concurrently, it would also be possible to set an unequivocal landward limit to the OCT. The sedimentary section consists of two lithostratigraphic units: slumped early Miocene nannofossil chalks (>58 m thick) overlying Middle(?) to Upper Jurassic clays, claystones and dolomitic claystones (>322 m). The thinly bedded and laminated Miocene nannofossil chalks and claystones were largely deposited from suspension as pelagites and hemipelagites. Pebbles of continental basement lithologies (slate and meta-arenite) and shallow water limestones (very similar to Tithonian rocks recovered during Leg 103) occur, and probably originated from the seamounts some 30 km to the north. The Jurassic sequence is subdivided into soft clay (192.7 m) (remarkably plastic and very slow to drill) and claystone (>129.9 m), some of which is dolomitic. While the shallow water lithologies encountered in the prerift / synrift (Middle(?)-Late Jurassic) sediments strongly indicate the presence of underlying continental crust, igneous or metamorphic basement was not reached. The acoustic basement reflection appears to be caused by lithification of Jurassic clays under which no clear seismic reflection from the top of the crystalline crust could be discerned.

Site 1069 was also located over an apparent tilted fault block and afforded an opportunity to test a number of different models of the formation of the OCT (Brun and Beslier, 1996; Krawczyk et al., 1996; Whitmarsh and Miles, 1995; Whitmarsh and Sawyer, 1996), as well as filling a 75-km-wide gap between Hobby High and the peridotite ridge. Biostratigraphic data indicate that this site was at shelf depths in the earliest Cretaceous, then subsided, and had reached abyssal depths by the late Campanian. This evidence, together with very low grade metasediments (probably occurring as clasts in a conglomerate, but recovery was exceptionally poor) encountered in the top of acoustic basement at the bottom of the hole, leads to the tentative conclusion that the site was drilled on a continental fault block. There is no sign of the mafic or ultramafic rocks that were encountered at Sites 897, 899, 900, 1067 or 1068. If this conclusion is correct, it indicates that Site 1069 overlies a continental fault block flanked by serpentinized peridotite basement to the west and by possibly synrift mafic rocks on Hobby High to the east.

Conclusions

The three sites (900, 1067 and 1068) on Hobby High present a bewildering heterogeneity of mafic, possible synrift rocks within the OCT. The most important features of these rocks however may prove to be the evidence they can provide in terms of the regional P-T-t history and absolute geochronology, which are largely independent of their specific mineralogy and petrology. We must also now question whether the upper part of the H reflector under Hobby High is, in fact, a tectonic contact. Is there continuity between the upper and lower H reflectors in Figure 2 and, if not, could the upper H reflection represent the crust / mantle interface? Ultramafic rocks have now been encountered over a 90-km-broad region at Sites 897, 899 and 1068 within the OCT and at Site 1070 in probable oceanic crust. Whereas the serpentinized peridotite may well represent upper mantle within the OCT, at Site 1070 we are probably seeing the result of a poor magma supply having led to a thin initial oceanic crust with a thin or absent Layer 2 (basalt flows and sheeted dikes), as is sometimes found at the Mid-Atlantic Ridge. In fact, the almost complete absence of synrift basalt on the west Iberia margin leads to the important conclusion that the asthenosphere may have been relatively cool at the time of break-up. Sampling igneous / metamorphic continental crust has proved to be frustratingly difficult, yet the circumstantial evidence that it underlies Sites 1065 and 1069 (as well as Site 901) is fairly compelling.

Recent geophysical studies are beginning to suggest that significant along-margin changes in the structure of the OCT may exist in the vicinity of the drilling transect. Pickup et al. (1996) suggest a wide expanse of serpentinized peridotite only 30-40 kilometers to the south, whereas it is clear from geological sampling of Galicia Bank and associated seamounts (Boillot et al., 1995 and earlier work), that beginning only 15 km north of Site 1069 there is a wide expanse of continental crust over the same range of longitude.

The unexpected discovery of a possibly isolated continental fault block under Site 1069, as well as the likelihood that the Site 1065 continental basement ridge can be traced northwards under the Iberia Abyssal Plain directly into Vasco da Gama seamount, support the suspicion that the drilling transect lies close to what might be described as a major transfer zone along the west Iberia margin.

Leg 173 Scientific Party

Robert B. Whitmarsh, Co-Chief Scientist, Southampton Oceanography Centre, United Kingdom; Marie-Odile Beslier, Co-Chief Scientist, Géosciences Azur, Observatoire Océanologique, France; Paul J. Wallace, Staff Scientist, Ocean Drilling Program; Natsue Abe, Christophe Basile, James S. Beard, Véronique Gardien, Nikolaus Froitzheim, Réjean Hébert, Laurence J. Hopkinson, Kristen E. Kudless, Véronique Louvel, Gianreto Manatschal, Adrian C. Newton, Michael J. Rubenach, Alasdair D.L. Skelton, Susan E. Smith, Hideo Takayama, Michael J. Tompkins, Brent D. Turrin, Elspeth Urquhart, Hans-Joachim Wallrabe-Adams, Roy H. Wilkens, Richard C.L. Wilson, Sherwood W. Wise, Xixi Zhao.

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Platforms for Shallow Water Drilling

by Gregory Mountain and Neal Driscoll

Gregory Mountain is a Senior Research Staff and Program Leader at Lamont-Doherty Earth Observatory. Neal Driscoll is an Assistant Scientist in the Geology & Geophysics Department at the Woods Hole Oeanographic Institution.

Additional platforms for shallow water drilling that complement the strengths and capabilities of the *JOIDES Resolution* are required to address fundamental questions about continental margin development and evolution. One of the major objectives of margin studies is to assess the morphologic and stratigraphic response of the continental margins and sedimentary basins to a number of environmental forcing functions over a variety of scales. More complete core recovery and downhole logging across the entire continental margin from shallow to deep is required for understanding the links between fundamental physical processes and the formation of the preserved stratigraphic record.

Rapid advances in technology have greatly improved the accuracy and precision with which we can navigate and seismically image the sea floor and sub-bottom horizons (i.e., scales of meters to kilometers). However, coring technology available to the research community has not kept pace with these geophysical advances, especially in shallow-water environments. Hole stability in, and core recovery of, unconsolidated sediments remains poor, which greatly limits our groundtruthing / correlating capability. In fact, hole stability problems caused by the thick unconsolidated sands encountered on the New Jersey continental shelf during ODP Leg 174A highlights the need for additional platforms to operate in shallow water environments (< 75 m) that can penetrate, sample, and log deeper into the sedimentary succession. This need was echoed at the COMPOST meetings (COMmittee on POST 98 Drilling) that concluded that the scientific community needs access to the technology necessary to increase the penetration capability and core recovery of ODP's drilling platform(s). New coring and downhole logging technology developed for industry offers exciting prospects for continuously coring and logging unconsolidated sediments in diverse environments (e.g., continental shelf and slope).

In addition, climatic studies will benefit from additional shallow-water drilling platforms because most open ocean sediment cores cannot be used to resolve short period climate change, and records from most corals and varved sediment sequences are not long enough to resolve millennial-scale changes. However, every ocean basin is rimmed by continental margins with exceptionally high rates of sediment accumulation (10 -100's cm / 1000 yrs). At these locations, high resolution paleoclimate studies complement the records of corals, bivalves, and varved sediments. Continental margins as a whole have been grossly underrepresented in studies of paleoclimate, because the high terrigenous flux has been viewed as a liability rather than an asset. With shallow-water drilling platforms and chemical analysis using sensitive instruments, it is possible to recover high resolution series of paleoclimate proxy data. In particular, shallow-water drilling will prove essential to correlate marine and terrestrial results.

MarineCAM, a shallow-water drilling workshop held at Lamont-Doherty Earth Observatory on May 1 and 2, 1997, was convened by Gregory Mountain (LDEO). The workshop was funded by the JOI / USSAC and Office of Naval Research (ONR). The main objective of the meeting was to examine state-of-the-art industry drilling and logging technology for shallow-water environments (<500m) in order to determine if these tools could accommodate the needs of the scientific community. A total of 28 scientists and 6 representatives from 4 offshore engineering companies attended (Alpine Geophysical, Fugro-McClelland Marine Geosciences, Inc., Rosscore, and Warren George, Inc.). Three general approaches were presented for shallow-water sediment sampling and logging: (1) vibra-coring, (2) push / percussive / rotary coring, and (3) *in situ geotechnical monitoring* without coring (Table 1). In this article, we provide a brief summary of these three sampling and logging approaches and outline the associated costs with the different technolgies.

Vibracoring is accomplished by using a cable to lower a corepipe to the seabed and vibrating it into the sediment with a submerged motor. The pipe and motor assembly is vertically stabilized in one of several ways, and must be deployed and retrieved for each core. Vibracores can be acquired in virtually any near shore setting except where high energy surf precludes safe operation. The deep-water limit is determined by ship stability and by the type of vibrating motor: pneumatic and hydraulic systems are practical to about 75 m water depth, while electric systems can continue to 750 and perhaps to 1500 m. Depth of penetration and degree of core disturbance are controlled in part by the frequency and amplitude of the applied vibrations. Vibracore penetration and quality can be severely limited by thick sand and more importantly, stiff silts and clays. Nevertheless, penetration of difficult horizons can be accomplished by offset vibracoring and washing down or "jetting" without sampling through the horizon with continued core recovery beneath it. The practical penetration for all types of existing vibracores are in the range of 10-20 m subbottom.

Push / percussive / rotary coring spans a large range of operating settings and costs. The basic approach applies a constant load or percussive impulse from above the sea surface that drives a core pipe into the sediment. With increasing induration of the sedimentary succession, operations switch to a top-drive motor that rotates a drill bit and cuts into the formation. As water depth and desired depth of penetration increase, progressively more robust systems can be used to reach 1000's of meters below seafloor (mbsf) in 100's m of water. The low end of push / percussive / rotary coring begins with a lightweight system typically operated from an anchored platform, which is limited to water depths of less than 30 m because of its weather sensitivity. Depending on the substrate, samples can be recovered to 30 m subseafloor. A modular, portable barge system can be assembled on-site; its operating depth is limited by weather sensitivity, and the size / buoyancy of the barge governs the depth of seafloor penetration. Typical estimates for the modular barge system are up to 30 m water depth and 100 m subbottom penetration. Increased sea worthiness and mobility make ships more versatile platforms than floating barges. Mid-sized, anchored vessels with coring through a center well can recover samples to 650 mbsf in water depths up to 300 m. A dynamically positioned ship increases the operating water depths to 700 m, again with penetration to 650 mbsf. A jack-up platform can be used instead of a ship to lower legs to the seafloor, raise the platform out of the water, and isolate the drill rig from wave motion. These platforms begin with small, towed barges that are recommended for 6-20 m water depths; they can hang enough pipe to core to 500-1000 mbsf. Larger, self-propelled jack-up barges can work to 100 m water depth and core to 1000 mbsf. Oil field jack-ups complete this group of platforms, operating in water depths up to 100 m with penetration capabilities of well over 1000 m.

The Terrabore system is a variation of the above coring technique currently under development by a consortium of Norwegian companies. It is adapted from mining technology and is under review by Antostrat for possible use in over consolidated glacial tills along the Antarctic continental margin. It uses rotary coring only, is planned for deployment from mid-sized ships of opportunity either over the side or through a center well, and is intended for operating in 500 m of water with penetration of 50-100 mbsf. Thus far, however, and in contrast to the available technologies described previously, Terrabore has limited heave compensation, a function that is vitally important to maximizing core recovery / quality. In further contrast to existing systems, Terrabore at present has no capacity to acquire *in situ* measurements via wireline logs.

The third approach collects a suite of *in situ* measurements of sediment properties but fails to recover any samples. These tools record any of several geotechnical engineering properties typically used to determine bearing load capacity before placing structures directly on the seafloor. Because of the cm-scale resolution, high reliability, and downhole continuity of these data, workshop participants agreed this information could be a valuable asset to push / percussive / rotary coring. The tools discussed were cone penetrometers, vane shear devices, pressuremeters, and packers. Mea-

Table 1: MarineCAM options

Downhole Device	Typical Platform	WD, m	mbsf	~costs[4,5]
pneumatic vibracorer	mid-size ship of opportunity	0–75	10[1,2]	4 – 8
electric vibracorer	mid-size ship of opportunity	0-1500	10[1]	4 – 8
lt-wt electric vibracorer	small ship of opportunity	0–5000	10[1]	2 – 6
lt-wt push/percuss/rot corer	small portable barge	5–30	301	4 – 6
push/percuss/rotary corer	portable barge[3]	6–30	100	15 / 250 / 500[a]
"	self-elevating barge	6–100	1000+	30 / 1,200 / 2,000[b]
"	oil field jack-up	20–100	1000+	>> ?1,000 total
"	anchored mid-sized ship w/pool[3]	6–300	650	30 / 500 / 1,000[b]
"	Dynamic Positioning–DP ship[3]	100+	650	75 / 1,000 / NA[b,c]
geotech measurements	anchored mid-sized ship w/pool[3]	6–100	701	30 / 500 / 1,000[b]
"	DP ship w/ pool[3]	100+	701	75 / 1,000 / NA[b,c]

[1] limited by stiff clays + thick sands
[2] "could be increased to 50 mbsf or more" – K. Moran
[3] need seafloor reaction mass
[4] $K/day vibra-coring includes mob/demob, ~3–6 cores/day
[5] wireline coring based on 100 mbsf, 30 days on site (~9 – 100 m cores):
[a] $K/day not incl mob from east coast US / $K east coast US ops[6] / $K west coast USD ops[6]
[b] $K/ day not incl mob from Gulf of Mexico / $K east coast US ops[6] / $K west coast US ops[6]
[c] west coast US ops only if ship available from SE Asia or China
[6] mob/demob costs only

surements can be performed in undisturbed sediment 3 m or less ahead of the bottom hole assembly while either continuously pushing the device into the seabed, or in a "measure - advance - measure" mode. Data are stored downhole and downloaded to a top-side computer when the tool is retrieved. Typical properties extracted from these measurements include pore pressure, permeability, shear strength, present stress field, and proxies for sediment density and composition. These devices can be used to 3000 m water depths or more. Their sub-bottom window of applicability is determined by sediment induration; typical applications to 70 mbsf were described. Each can be deployed from the same platform that acquires push / percussive / rotary cores, i.e., a floating barge, ship, or jack-up. Whatever the platform, however, a seafloor "reaction mass" is needed to stabilize the bottom assembly and as much as possible isolate it from platform motion at sea level.

The relatively affordable costs and the large variety of appropriate platforms ensure that vibracoring is within reach of expected scientific budgets. Furthermore, pre-site characterization needed for 10-20 m penetrations is far more modest than for deeper sampling operations.

The jump in cost and operational complexity between vibracoring and push coring poses a significant challenge to meeting a variety of scientific goals. The only route to >20 mbsf samples discussed at the workshop is to hire specialized companies. Daily costs begin at $15K and continue upward to more than $100K (Table 1). Contractors estimated that mobilization costs for these platforms deployed to either the east or west coast of the US would range from $250K to $2M. Obviously, every effort will be needed to reduce these costs by either sharing mobilization with other interests, waiting for a 'platform of opportunity' that is transiting through a given study area, or defining scientific programs that are in areas close to where these platforms are already deployed.

ODP could provide managerial benefit to coring at margins. For example, the recently formed Scientific Drilling in Shallow Water Systems Program Planning Group could help to: a) formulate precise scientific objectives; b) maintain a schedule of platforms of opportunity; c) recommend site surveys for pre-coring site evaluation; and, d) ensure proper sample distribution and archiving at one of the ODP core repositories. Participants left the workshop with renewed confidence that the time had come for coordinated coring at margins. The potential rewards in this virtually untapped geologic archive are very large, but so are the costs for reaching those goals.◆

For more information on the drilling technology, see the JOIDES web page.

Costa Rica – Recent Leg Reports – Continued from page 3

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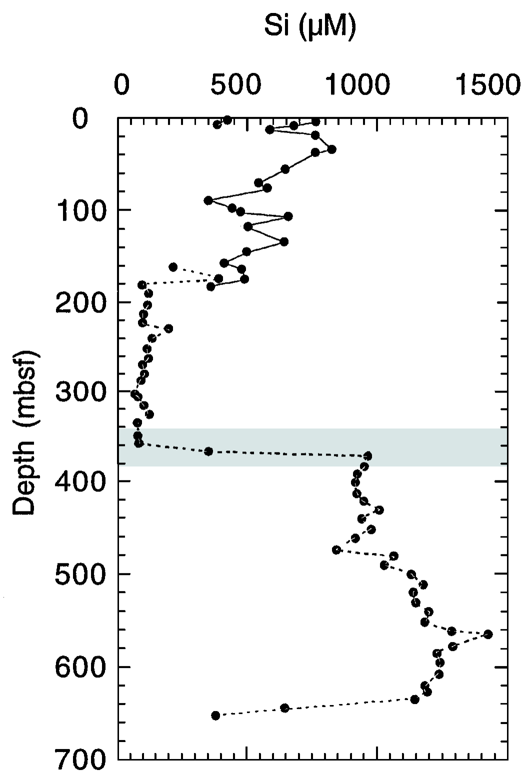

Figure 3. Distribution of silica vs. depth in interstitial waters at Site 1040. Note sharp change in concentration at the décollement (371 mbsf) and sharp decrease in silica concentration at the base of the section, tending toward seawater values.

Borehole Observatories – Global Networking and 4–D Monitoring

by Kiyoshi Suyehiro

Kiyoshi Suyehiro is at the Ocean Research Institute at the University of Tokyo.

In recognition of the fact that borehole observatories will become a more and more critical and irreplaceable element in advancing our understanding of the Earth's dynamics, a new initiative involving *"In Situ Monitoring of Geological Processes"* was identified in the 1996 ODP Long Range Plan. At its last meeting in December 1996, the JOIDES Planning Committee (PCOM) established a Program Planning Group (PPG) for Long-Term Observatories. The PPG, co-chaired by Keir Becker (Univ. of Miami) and myself, met for the first time in Monterey, California in July, 1997 with the immediate goal of planning for the establishment of borehole observatories during ODP Phase III to address key scientific questions.

Brief History

Since the DSDP era, boreholes have been used for seismic, pressure and temperature measurements. These experiments were important seeds to today's increasing successes in making long-term borehole observations. In 1988, JOI / USSAC held a workshop in Woods Hole to discuss the establishment of long-term broadband downhole seismometers (Dziewonski and Purdy, 1988). At the time of that meeting, the introduction of digital broadband sensors had greatly improved the deep internal image of the Earth. The first broadband seismographic observations in boreholes were successfully made in the Japan Sea (Hole 794D) in 1989 (Suyehiro et al., 1992), and then later in the Atlantic Ocean (Hole 396B) in 1992 (Montagner et al., 1994) (Figure 1).

Almost a decade after the Woods Hole meeting, seismic tomographers are trying to image the undulation of the core-mantle boundary, the deep roots of the ridge systems and hot spots, and the fate of the subducting plates. In recognition of the importance of these scientific goals, ODP drilled a hole in 1991 specifically for the U.S. Ocean Seismic Network (OSN-1 at Hole 843B) off Oahu to test the value of borehole observations as compared with seafloor observation. In addition, ODP will drill a second hole for installation of a broadband seismometer in 1998 (Leg 179) on the Ninety East Ridge, which will fill an important gap in coverage in the Indian Ocean (Figure 1).

In order to share information and discuss scientific and technical goals of borehole installations, and to coordinate the efforts of the international scientific community, the ION (International Ocean Network) committee was formed in 1993, when an international ocean bottom engineering workshop was held in Hawaii. This committee is now affiliated with IASPEI of IUGG.

Global Networks and Active Processes

In January 1995, ION organized the Marseilles International Workshop on Multidisciplinary Observatories on the Deep Seafloor, in which about 70 scientists from around the globe (Montagner and Lancelot, 1995) participated. It was recognized that the number of projects underway to establish seafloor and borehole observatories for geodesy, geophysics, geochemistry, and physical oceanography, as well as the number of scientists interested in pursuing these projects, was growing quickly. It was agreed that the use of observatories would serve two main purposes. The first would be to constitute nodes of a global network, in particular the digital broadband seismological network as noted above. This is a natural extension of the existing land network and is necessary to attain homogeneous, worldwide distribution with at least the 2000 km node spacing

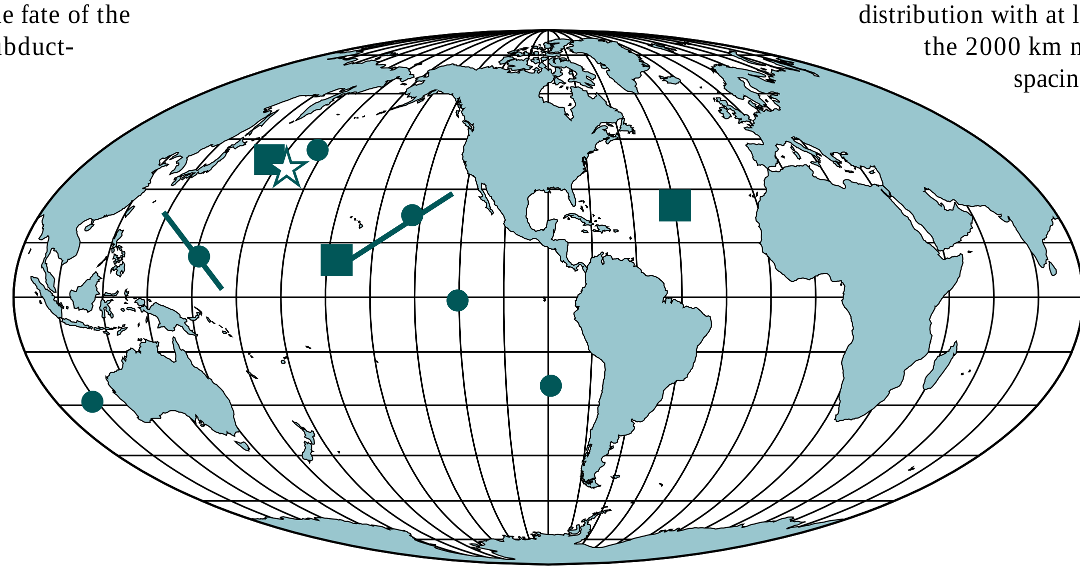

Figure 1. Square symbols are locations where pilot experiments have been (or will be) carried out in drillholes (see text). Circles are prototype station sites for global/ regional objectives. The star shows the Japan Trench site for active processes objectives. Two sites can make use of retired undersea telecommunication cables (solid lines).

(Figure 1) required for investigating global mantle dynamics. Such a global coverage of observatories would also be beneficial for geomagnetic and geodetic measurements. Despite the difficult environment, state-of-the-art sensors would be installed in boreholes drilled by ODP. Although some sensors are likely to be placed on the seafloor rather than in deep boreholes, many of the ocean floor nodes are expected to be co-located to share power supply and data storage systems, and for economical maintenance.

The second purpose of seafloor and borehole observatories is to observe active processes *in situ*, with sensors on the seafloor and in boreholes constituting a 4-D network to monitor fluid flow, faulting, or magma motions at an unprecedented resolution. Key questions to be addressed include how the volcanic and tectonic processes at diverging plate boundaries create oceanic crust, and how the plates interact at subduction zones to cause large earthquakes. The first step in such experimentation has already begun with the recent successful long-term CORK hydrogeological and geochemical experiments being carried out in sedimented mid-ocean ridge ridge and subduction regimes (Carson et al., 1996).

Maintaining Observatories

The two major technical issues that must be faced during maintenance of seafloor and borehole observatories are power supply and data recovery. In 1989, when we deployed a digital seismometer on Leg 128, we were able to put only a 60 Mbyte cartridge tape and a number of lead acid batteries on the seafloor, and these provided data storage and a power supply for a month. Today, an observatory consuming 10 W may be sustainable over a year (about 90 kWh). Data storage has become practically a non-problem with rapid advances in digital storage systems. However, retrieval of data from the seafloor is not easy without human intervention, which means cost. An ROV or submersible may visit the site every year or so to retrieve data, and exchange or recharge batteries. A surface ship may communicate with the seafloor observatory through acoustic telemetry, which requires an additional power source on the seafloor. This data transfer occurs at a very slow pace compared with data transfer rates over telephone lines. However, efforts are being made to make this acoustic telemetry practical. Another option, which may be realized earlier, is to send “messengers” from the seafloor to the surface. A “messenger” would store months of data, and then would either surface on command to be picked up by a vessel, or would transmit data via satellite.

A permanent cable connection to land would be ideal for real-time data recovery and would allow constant monitoring of the instrument functions. Co-axial cables for telecommunications are rapidly becoming obsolete as they are superceded by fiber optic cables, and hence would provided ideal connections for seafloor or borehole observatories. However, if one compares the cable layout with where global seismic network gaps lie, few locations overlap (Figure 1). Nevertheless, these cables could become a great asset for geoelectromagnetics or physical oceanography. In addition, a number of new fiber optic cables are already being laid out around Japan and Hawaii, where real-time observation is essential and important for hazard mitigation and can justify the expense can be justified.

Crustal Deformation Monitoring

Another important set of parameters that need to be measured relate to the need to quantify crustal deformation, particularly along plate boundaries, many of which are beneath the ocean. Seismic tomographic red-to-blue images attracted broad interest from the earth science community, as do the maps showing crustal motions, monitored by GPS array stations, that are becoming available at geologically active places such as the San Andreas, Japanese islands, or Anatolia.

To this end, a seafloor adaptation of the Sacks-Evertson volumetric borehole strainmeter is currently under development and prototype testing. It can measure 1/100 of a nanostrain (1 micron change over 1 km). This instrument needs to be cemented in an open borehole. It is installed on the end of the drill string, and is hollow so that grout can be pumped through. After grouting, the drill string is detached and withdrawn above the re-entry cone, leaving the instrument hanging on line-pipe supported by a collar in the re-entry cone. Temperature, pressure, tilt and seismic measurements can be made in the same hole. Planning is already underway for installation of one of these instruments in a hole in a subduction zone.

We now know that the plates are moving at a relatively constant rate from geological to human time scales. Yet large thrust earthquakes recur tens to hundreds of years apart depending on subduction zones. In one extreme, the interacting plates are 100% coupled and only move with large earthquakes. The other extreme is totally aseismic motion. Real cases seem to be between these end members, but more has to be learned about the factors controlling the seismicity. For example, in the northern Japan (Tohoku) region, only a fraction (1/4) of the plate motion is accommodated by normal earthquakes, whereas in the area

Continued on page 23

A Message from the Chair —

The JOIDES Office has now been in Woods Hole for a year — and what a year it has been! Setting up the new Advisory Structure has been a major task, particularly because of the need to compress the normal annual schedule of decision-making into eight months to allow a drilling schedule to be determined in August instead of December. I am pleased to report that, as of late August, the Panels and Committee of the new JOIDES Advisory Structure are now all in place, and have each met once. With their membership being determined by each ODP partner's national committees, we have tried to bring some new blood into the system while retaining some corporate memory. For most Panels and Committees, this has resulted in a 50-50 split between members who have served before, and members who are new to the Advisory Structure. See the new ODP Directory for a complete listing. The flexible component of the Structure, and where we can bring different segments of the community and other global geoscience initiatives into the planning process, is composed of the Program Planning Groups (PPGs) and Detailed Planning Groups (DPGs). Based on a careful look at proposal pressure and Program priorities, new groups are currently being formed. This is discussed on page 22.

New submission and evaluation procedures have been designed and are now in effect. The two-step system of proposal submission commences with ideas for scientific ocean drilling first being submitted as Preliminary Proposals. These will be evaluated by the Science Steering and Evaluation Panels (SSEPs) who will provide an early assessment of a project's potential and interest to the Program before considerable effort is expended by the proponents on its development. The SSEPs will nurture those proposals of interest through the development of detailed scientific objectives and drilling strategies until such time as they recommend the submission of a Full Proposal. Full Proposals will be sent out for external comment so as to involve the wider geoscience community in assessing the importance of the proposed drilling to the advancement of scientific knowledge — this process is described on page 21.

This summer saw the first time that the new process envisioned for determining a drilling schedule was tested. With the creation of an Operations Committee (OPCOM), SCICOM was freed up from consideration of logistical, site survey, and budgetary considerations to spend time discussing the science of each proposal considered of high priority by the SSEPs. These deliberations went on for a day and a half, and culminated in a global scientific ranking of proposals. OPCOM then produced a drilling schedule for FY'99 (and slightly beyond) on the basis of logistical, site survey, and budgetary considerations. Their proposed schedule has now received approval from SCICOM and is shown on page 31. Those on the list sent to OPCOM that did not make it on to the schedule will not have to go back through the entire system, but will be re-ranked again next year by SCICOM. My personal feeling about how this new system worked was very positive, particularly with the extensive discussion of the science that SCICOM was able to have. I see this as a step in the right direction for planning within ODP.

I am hopeful that all these sweeping changes will not only streamline the decision-making within ODP, but will also provide a fresh approach to accomplishing the scientific objectives of ODP. However, we all need to be aware of the serious challenge facing the Program in terms of accomplishing many of its ambitious scientific goals in a time of ever increasing fiscal constraints. Most funding and ODP membership scenarios paint a picture of decreasing (in real terms) funding over the next five years. A key factor for ODP will be to maintain scientific excellence and a strong component of technological innovation while making the difficult decisions that will constitute budgetary reality in the near future. The letter from Bob Detrick, Chair of the Executive Committee (EXCOM) discusses the ODP budget in more detail (page 24), and encourages each of you get behind an effort to find additional resources. Let's do it!

Susan E. Humphris

The External Comment Process

by Kathy Ellins

As part of the recent reorganization of the JOIDES Advisory Structure, an external evaluation process was established to solicit and incorporate comments on ODP proposals from the broad international marine geoscience community. External evaluation is intended to ensure that proposals focus on high priority problems that promise exciting results and fundamental contributions to our understanding of Earth science.

The external comment process was introduced in early 1997. In late January of 1997, an interim Science Steering and Evaluation Panel (SSEP) met in Woods Hole to consider all the active drilling proposals in the JOIDES system. This interim SSEP was convened to jump-start the transition from the old to the new JOIDES Science Advisory Structure. Proposals (Table 1) were selected for external evaluation from among the active proposals on the basis of criteria developed by the JOIDES Office, in consultation with JOI and NSF. The JOIDES Office provided JOI, which managed the external evaluation process in order to protect the anonymity of the external evaluators, with the list of proposals selected by the interim SSEP, together with the recommendations from both the Panel and the proponents of potential evaluators. Each proposal selected was sent to four external evaluators who were asked to comment on the following aspects of the drilling proposal:

- the importance of the scientific problem addressed by the proposed drilling effort;
- the fundamental advances in understanding Earth's history and / or Earth's processes that will be made by the proposed drilling;
- the appropriateness of the location selected for drilling to address the stated scientific problem;
- the likelihood that the sections drilled will contribute significantly to the solution of the stated scientific problem.

For 38% of the proposals, all four evaluators returned comments; for 33% of the proposals, three evaluators returned comments; and for 29% of the proposals only two evaluators returned comments. External comments were returned to the proponents, who were encouraged to respond briefly to them in a short, two-page letter.

At their first meeting in early June, the two new Science Steering and Evaluation Panels (SSEPs) considered the anonymous external comments, together with the proponents' responses, in assessing scientific merit and the priority of each proposal in the context of the overall achievement of the ODP Long Range Plan. Site survey readiness, provided by two liaisons from the Site Survey Panel (SSP) to the SSEPs, was also taken into consideration. At its August Meeting, SCICOM took the SSEPs' assessment of each proposal, the external comments, and the proponents' responses into account when ranking proposals on the basis of their scientific merit and importance for ODP's LRP.◆

Number	Brief Proposal Title (Contact Proponent)	Evaluations Returned
355	Peruvian Margin Gas Hydrates *(N. Kukowski)*	4
426	Australia-Antarctica Discordance *(D. Christie)*	4
431	Western Pacific Seismic Network *(K. Suyehiro)*	2
442	Rift Initiation in Back-Arc Basisn *(R. Stern)*	2
448	Origin and Post-Emplacement History of the Ontong Java Plateau *(L. Kroenke)*	2
445	Nankai Trough Accretionary Prism *(G. Moore)*	4
450	Taiwan Arc-Continent Collision *(N. Lundberg)*	3
451	Ocean Drilling in the Tonga Forearc *(D. Tappin)*	4
455	Laurentide Ice Sheets *(D. Piper)*	4
463	Plume-Impact at Shatsky Rise *(W. Sager)*	3
465	SE Pacific Paleoceanography *(A. Mix)*	3
472	Mariana-Izu Mass Balance *(T. Plank)*	3
485	East Asian Monsoon History *(P. Wang)*	2
485	Southern Gateway – Australia & Antarctica *(N. Exon)*	2
486	Paleogene Equatorial Pacific APC Transect *(M. Lyle)*	3
489	Ross Sea Shelf: Glacial History *(F. Davey)*	4
490	Prydz Bay Glacial History *(P. O'Brien)*	2
496	VRMS and Oceanic Plateaus *(T. Plank)*	3
499	ION Equatorial Pacific Site *(J. Orcutt)*	4
503	East Antarctic Ise Shield – Weddell Basin *(W. Jokat)*	3
511	Sea Level Models – Canterbury Basin *(C. Fulthorpe)*	4

Table 1: Proposals sent out for External Comment (Spring 1997).

An Update on Current PPGs

by Maria Mutti

Program Planning Groups (PPGs) have an important function within the new JOIDES Advisory Structure. They are small focused planning groups formed by SCICOM when there is the need to develop drilling programs or technological strategies to achieve the goals of the Long Range Plan. These groups can exist for up to three years and form a flexible component of the JOIDES Advisory Structure. To date, seven PPGs have been established. The justification for these groups was based on an analysis by SCICOM of the existing proposal pressure in relation to the themes of the Long Range Plan (LRP).

Understanding Earth's Changing Climate is a major objective of the LRP theme Dynamics of the Earth's Environment. Up to now, ODP has mainly focused on Neogene or younger time intervals, and there is the need to extend our knowledge further back in time. Therefore, **the Extreme Climate and Environments of the Paleogene and Cretaceous PPG** was established to develop goals and drilling plans to investigate past warm climate intervals of the middle Cretaceous to Paleogene and the biotic response to these unusual climates. More specifically, these goals include the determination of the frequency, amplitude, and forcing of global climate change, latitudinal thermal gradients, sources of deep water and vertical ocean structure, and changes in global sedimentary fluxes. Additional goals include the investigation of major aberrations in the global carbon budget (e.g., mid-Cretaceous black shale), the development of a firm astronomical time scale for the Paleogene and a preliminary one for the Cretaceous, and integration of this chronology with the magnetobiostratigraphy.

Causes and Effects of Sea-Level Change is another major topic of the ODP LRP. Continuous cores from either carbonate or siliciclastic shallow environments are needed, but progress has been limited due to recovery problems and the need to drill in shallower water than those in which the *JOIDES Resolution* can operate. In order to achieve sea-level goals as well as climate records on decadal / millenial and longer time scales, new drilling technology and supplementary platforms in addition to the *JOIDES Resolution* are needed. The **Scientific Drilling of Shallow-water Systems PPG** is intended to develop a coordinated drilling plan, and identify drilling / technological requirements needed for scientific drilling of shallow-water systems. This is critical for understanding the causes and effects of Pleistocene and Recent sea level change (e.g., associated with orbital forcing and abrupt climatic change), and for providing the geographic network of low-latitude cores needed to understand the dynamics of annual to Milankovitch-scale climatic change (e.g., ENSO, monsoon and tropical N. Atlantic variability).

A third, and major goal under of the LRP theme Dynamics of the Earth's Environment includes investigating the role that sediments, fluids, and bacteria play as agents of change. Investigating the subsurface biosphere is a new challenge and direction for ODP, and will bring in a community of scientists new to ocean drilling. Hence, a PPG was established to coordinate this new aspect of research. The main goal of the **Earth's Deep Biosphere Pilot Project PPG**, chaired by John Parkes (UK), is to develop a plan of drilling and downhole sampling to investigate the nature, ecology, distribution, depth extent, and genetic range of the sub-seafloor biosphere living in rocks and sediments, and to assess its contribution to global biogeochemical budgets. Additional mandates include the development of a plan for the integration of microbiological sampling and analysis into drill sites with other objectives, where appropriate, as well as definitions of specifications for a shipboard microbiological facility, development of sampling procedures, analytical techniques, and curation of samples.

Under this theme, another high priority topic is the study of marine gas hydrates. Gas hydrates are estimated to represent a significant fraction of the total mass of hydrocarbons. ODP has contributed largely to this discovery with the exciting results from ODP Leg 164 on the Blake Ridge, as well as a number of other successful gas hydrate drilling achievements. However, very little is known about the dynamics of how these large reservoirs are formed in the marine environment. At its meeting in August, SCICOM established a **Gas Hydrates PPG**, in order to determine the future scientific goals, technologic needs and directions for continued gas hydrate investigations.

One theme of interest to both the Earth's Environment and Interior groups is the interaction between climate and tectonics. This topic is truly interdisciplinary and has important implications for different fields in Earth sciences. Hence it requires bringing together scientists from a number of different disciplines. The overall goal of the **Climate-Tectonics Links PPG** is to develop drilling plans to investigate the interaction between climate and tectonics; specifically, the influence of first-order displacements of the earth's crust on regional to global-scale climate change. The intent is to integrate, on a multidisciplinary scale, tectonic and climate elements of the problem through the use of multiple proxies, including sedimentological, sediment provenance, faunal and geochemical measurements to be made on OPD core material. Crustal displacements of interest may include orogenic events, first order epeirogenic motions of continental interiors, including continental rift systems, and surface deformations which may lead to changes in ocean circulation patterns. Aspects of the climate system of interest may include changes in deep ocean, ocean surface circulation and temperatures, regional to planetary-scale changes in atmospheric circulation and water vapor transport (e.g. monsoon circulation, jet stream patterns), and onset of glaciation.

Under Dynamics of Earth's Interior, a new initiative is focused on monitoring *in situ* geological processes, to provide a clearer view of Earth's structure and a means to monitor in real time processes and hazards such as earthquakes. The overall goal of the **Long-Term Observatories PPG**, co-chaired by Keir Becker (USA) and Kiyoshi Suyehiro (Japan), is to develop a plan for the integration of long-term instrumentation in boreholes with seafloor observatories planned by other global geoscience programs, with the goal of investigating the structure and dynamics of the Earth's interior, and quantifying the flux of heat and materials to and from the Earth's interior. Specific mandates of this group include definition of experiments that incorporate the use of ODP boreholes for long-term measurements at seafloor observatories and the recommendation of mechanisms for the implementation, emplacement, and oversight of borehole-related instrumentation in the context of seafloor observatories. (See the article by Kiyoshi Suyehiro in this issue under technological developments, page 18).

An additional topic requiring particular attention under Dynamics of Earth's Interior is the architecture of oceanic crust. SCICOM identified this as a topic that needs to develop scientific objectives focusing on deep drilling. The overall goal of the **Architecture of the Oceanic Lithosphere PPG** is to develop a plan to study ridge-crest processes and the architecture of the oceanic lithosphere. The plan might include, but not be limited to, a complete penetration of oceanic crust, and maybe also be linked to the establishment of long-term seafloor observatories at ridge axes and in older crust off axis. Specific mandates of this group are to develop a long-term strategy to investigate the architecture of the oceanic lithosphere formed at different spreading rates, to define the technological requirements necessary to achieve these objectives, and to ensure that long-term seafloor observatories are integrated into the long-term strategy by effective communication with the Long-Term Observatories PPG.

These PPGs will report to the Science Steering and Evaluation Panels (SSEPs) and will be disbanded once their mandates are accomplished. This flexible component within the JOIDES Advisory Structure has the potential of involving a larger, and more diverse, segment of the geoscience community in basic scientific planning within ODP, as well as providing a mechanism for active collaboration with other international initiatives.◆

Borehole Observatories– Continued from page 19

where the Philippine Sea plate subducts beneath southwest Japan, essentially all of it seems to be. Therefore, in the Took region, or in other regions where earthquake slips are significantly less than expected from plate motion, most of the stress redistribution and concentration must occur as episodic slow earthquakes, or continuously. Such discrimination is difficult from land data alone. Also, we cannot test whether any precursory process takes place immediately before a large thrust earthquake without a nearby high-resolution instrument.

Increasing Needs

The development of borehole observatories is still in its infancy, and there is a lot to learn. During Phase III, ODP expects to play an important role in monitoring geological processes, although a high level of patience will be necessary as we try to obtain time series of data that record Earth in action — something that will easily take years. In the next century, when deep riser drilling becomes a reality, we will face a new challenge of drilling directly into the "source" of active processes.

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Letter from EXCOM Chair on the ODP Budget

Dear Colleague,

ODP is the largest, most successful international research program in the geosciences. Perhaps because of its great success, and the long history of scientific ocean drilling over the past 30 years, we have grown to take ODP for granted. Two recent events have brought home to many members of the JOIDES community that we can no longer do this. In June the JOIDES Executive Committee made the controversial decision that ODP simply cannot afford, within its present budget, to continue to produce, print and distribute the traditional IR and SR volumes. In July bids for an iceboat came in some $600K overbudget. ODP was immediately faced with the prospect of canceling Leg 178, or cutting/delaying other high priority projects such as the installation of a dynamic heave compensation system on the *JOIDES Resolution*, or the migration of historical data into the JANUS database. Leg 178 will go ahead as scheduled. But will the money be there the next time an iceboat is needed for a high latitude drilling leg, or when a leg needing an expensive logging program and CORKS is scheduled? With the potential for significant increases in the drillship day-rate next year, the continuing inflation of costs, and the prospect of flat funding for Phase III of the program, the day may come very soon when the answer will be no.

How did ODP get into this situation? It didn't happen overnight. ODP has been flat funded for the past five years, which means, in real dollars, the ODP budget is now about 14% less than it was in 1994. Almost all of the international partners in ODP have stated that Phase III renewal is contingent upon a fixed membership fee, i.e. no inflation correction. This means that any increase in funding for ODP over the period 1999-2003 will be dependent on the addition of new members to the Program (an uncertain prospect at best). If current trends continue, by the year 2000 ODP could be operating on a budget that is 20% less in inflation-adjusted dollars than in 1994.

OK, you say, but the ODP budget is still $44 M/yr. Surely this is enough money to publish the IR and SR volumes, charter an iceboat, and undertake many of new initiatives outlined in the ODP Long Range Plan. Unfortunately, this is not the case. ODP is a program with very high fixed costs, both for equipment and personnel. Excluding the SEDCO contract for the drillship, ODP (including TAMU, L-DEO and JOI/JOIDES) operates on an annual budget of ~$21 million. Within this figure ODP has a very small "discretionary" budget. In FY98 this so-called Special Operating Expense (SOE), or X-based budget, will be about $3.7M. It is this budget that supports most new engineering development (e.g. development of DCS or the active heave compensation system), CORKS and hard rock guidebases, specialized logging tools (e.g. LWD), iceboats or alternative drilling platforms - i.e. all the costs beyond that of a "standard" drilling leg. Budget projections for FY99 and beyond indicate this SOE or X-based budget will drop to about $2M/yr. And this assumes the current drillship day-rate; if that cost increases significantly then there will be even less money available for technical innovation and new initiatives within the program. Measured against this, the cost of publishing IR books, or hiring an iceboat, are very significant numbers indeed. ODP's two main subcontractors, TAMU and L-DEO, have already been subjected to stringent cost-cutting (with staff reductions and reorganizations), and there is general agreement that any further cost savings will be small, unless existing program services are cut back or eliminated. At the same time, it is clear that continued funding of ODP is dependent on the program pursuing the new initiatives and technical innovation outlined in the ODP Long Range Plan. Unless ODP continues to address problems at the cutting edge of the field, using the most advanced technology, the prospects for a continuation of scientific ocean drilling beyond 2003 will be bleak.

What can we do? First, as Roger Larson noted in a recent USSAC editorial, we can't let the difficult decisions we have to make – like the one over publications – divide us and undermine basic support for the program. We need to pull together and fight for our common goal of preserving this extraordinary scientific program. Second, we need to send a very strong message to the funding agencies in our respective countries that flat funding of ODP is slowly strangling the program, and that without additional resources ODP will not be able to accomplish many of the goals set out its current Long Range Plan. The members of ODP Council consistently tell EXCOM that there are no additional resources that can be found to go to ODP. You need to tell them that ODP is so important to you, and to your research, that additional resources must be found. The future of scientific ocean drilling is at stake – make your voice heard.

Sincerely,

Bob Detrick,
EXCOM Chair

Electronic Publishing at the Ocean Drilling Program

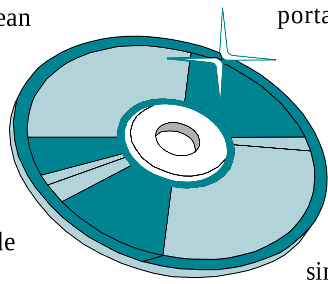
Jennifer Pattison Rumford

Jennifer Rumford is at ODP-TAMU in College Station, Texas.

For anyone with a need to research the history, geography, or ethnicity of the Pacific Ocean and its people, the journals generated between 1768 and 1779 by Captain James Cook and his crew tell the story of the original voyages of discovery. Original copies of these volumes, and reprints, exist in every library.

The Ocean Drilling Program, sailing in Captain Cook's wake, generates its own set of volumes, the Proceedings of the Ocean Drilling Program. These volumes stand as the culmination of years of cutting-edge science, and they will continue to be the legacy of the Ocean Drilling Program for generations.

At this time, the volumes can be found in libraries around the world both in printed format and as CD-ROMs. A new frontier is being crossed this year, as ODP takes on the challenge of World Wide Web (WWW) publishing.



Dawn of the Electronic Publishing Era at ODP

The electronic publishing effort began in 1992 with the Initial Reports (IR) Volume 138, which used a CD-ROM to deliver large datasets, including tables, core data, site data, and examples of source code from the leg.

The use of CD-ROMs has enabled other technological advances to be incorporated into the Proceedings. An animation was published in Scientific Results (SR) Volume 130 that demonstrated a reconstruction of Southwest Pacific paleogeography developed by C.Y. Yan and L.W. Kroenke. The Initial Reports (IR) Volume 169 will include the first QuickTime movie for ODP, which is accessed from, and runs as part of, the Acrobat version of the volume. The movie is a 14-second black-and-white video footage from the ODP vibration-isolated drill string television camera. It shows active venting of hot hydrothermal fluid issuing from the throat of a reentry funnel.

The first electronic index was prepared by Ian Gibson, and was published in SR Volume 130. Each CD-ROM now includes an electronic index for that volume, thereby allowing an electronic search engine to be used. The search engine used on ODP CD-ROMs goes beyond a simple search/find. It allows Boolean searches, and can also search based on word proximity, word stem, word sound-alike, and a thesaurus choice. It can also be case-sensitive, and will review all documents in the specified directory structure, including figures.

Each CD-ROM also contains a compiled version of all individual indexes from the SR volumes. Other indexes are currently under development. Possibilities include a keyword index, from the list of keywords supplied by the authors, an author index, for each volume or cumulatively, and a title index.

In order to best serve the diverse community of scientists that participate in ODP, it was necessary to find a format that is multiplatform; i.e., that runs on UNIX, Macintosh and Windows systems. Hence, starting with the IR Volume 151, test volumes have been produced using Acrobat, which is Adobe's portable document format (PDF).

The two most recent innovations expand the electronic publishing efforts to include test versions of WWW products. The IR Supplement Volume 150X was released in two versions on the WWW, with files in HTML format for quick retrieval and access, and a single Acrobat PDF file, which is easily printed and has high-resolution graphics.

Publishing ODP Volumes on the Web (WWW)

The Initial Reports for Leg 166 is the first volume to be published entirely on the WWW, although it was also released in print and as a CD-ROM. This volume, which can be accessed at http://www-odp.tamu.edu/publications/166IR/INTRO.HTM, offers the chance to explore some of the options made possible by electronic publishing. The table of contents at this WWW sites is an HTML file that leads to files of various types (e.g., Adobe Acrobat PDF files, ASCII files), depending on the material being presented, and contains links to other sites.

Users will find a map of all ODP sites that is updated with each leg, available in both PDF format and as an Encapsulated Postscript file (EPS). It is accompanied by a listing (both as an Excel spreadsheet and an ASCII text data file) of leg and site numbers, locations, and coring information. The chapters of the Volume are presented as Acrobat PDF files that can be viewed on the WWW by configuring a browser such as Netscape to access the Adobe Acrobat Reader software, or can be copied to an individual computer system.

Some of the highlights of IR Volume 166 are color graphics when available, tables presented as ASCII files for accessibility, and a complete presentation of the leg core data from the ODP database (including GRAPE, index property, magnetic susceptibility, natural gamma data, P-wave, and reflectance data). Color images of the core photographs are linked to the visual core description page within the volume, and are available individually.

The way in which a user will want to access the files depends on the specific purpose. One of the primary differences between an Acrobat volume on the WWW is the ease of printing the material. With HTML format, each file of either text, a table, or a figure can be printed separately. In Acrobat format, the text, tables and figures are integrated as one file, hence requiring a single print command.

Although all images are prepared for high-resolution printing, HTML figure files are usually limited to 72 or 150 dpi and print poorly. Hence, Acrobat files may be preferable as, for the most part, the resolution of the print is limited by the quality of the printer.

Images of color core photographs are included at 300 dpi. In an Acrobat PDF file, any figure that is prepared as an Encapsulated PostScript (EPS) file originally, or can be transferred into an Illustrator EPS format, can be enlarged to reveal tiny details (up to 800% enlargement). Details that cannot be seen with the human eye on a printed page, can be included for on-screen viewing. (Note: scanned images tend to pixelate at much lower levels than EPS files.)

The JOIDES Executive Committee (EXCOM) has recommended that electronic publishing using both CD-ROMs and the WWW be phased in for all ODP Proceedings Volumes. Starting with Leg 176, the IR Volumes will be published as CD-ROMs and not in the traditional hard copy format. In producing CD-ROMs for earlier volumes, ODP has been refining its techniques and product to best address the needs of the community.

Electronic documents will allow the development of a new archive form for ODP materials. Instead of releasing a single ODP volume pertaining to an individual leg, the papers and data would reside in a collection, or digital library. Conceptually, the digital library is a box. Each side of the box contains a window that could be named for ODP cruises, subjects, authors, geographic locations, or geologic terminology. A reader can reach into the box using any window, or any combination of windows.

ODP serves a scientific and engineering community that is very comfortable with preparing material electronically. Consequently, ODP is in the enviable position among publishers of having ready access to electronic files for almost everything that is published in a Proceedings volume. This makes it both possible and realistic for ODP-TAMU Publications Services to continue to explore the realms of electronic publishing, and to develop a product that is useful to the current generation of users, and the future generations of users.

For on-going developments in CD-ROM and WWW electronic publishing, please refer to recent ODP volumes which include CD-ROMs, or to the ODP-TAMU WWW site: http://www-odp.tamu.edu/ ◆

STOP PRESS!

ODP Responds to Community Concerns

Over the last few months, JOI and the JOIDES Office have received many letters expressing concern over the recent changes in ODP's publications policy that will result in the phasing out of a printed *Initial Results* volume. In response to this, JOI has investigated the options that may exist for continuing to provide access to some form of a printed version of the *Initial Reports* volumes beyond October 1996 within the budgetary constraints imposed by the Executive Committee (EXCOM).

These options were presented and considered at the recent August Science Committee (SCICOM) meeting. SCICOM has recommended that two options be pursued. The first is that the CD-ROM be accompanied by a "companion volume" of 50-150 pages that provides a summary of the results of the drilling leg, thereby enabling the user to more effectively access the information on the CD-ROM. Final details of what material and/or data will be included in the "companion volume" will be determined by the JOI Publications Steering Committee. The second option is that, during a transition period, JOI investigate subcontracting printing of a full paper copy on user-demand and at cost to the user. SCICOM envisages that individuals would be able to request, at their expense, a printed copy of an *Initial Results* volume directly from a subcontractor.

SCICOM continues to support the move towards electronic publication, both as CD-ROMs and on the World Wide Web, and firmly believes that it will result in greater access of ODP data and results to the global scientific community and other interested parties. The continued provision of access to a printed version for the immediate future will hopefully address the concerns expressed by the community, and will smooth the transition to electronic publication of ODP volumes.

Recommendations from the CONference on Cooperative Ocean Riser Drilling (CONCORD)

Planning for the future of scientific ocean drilling post-2003 took a major step forward in July when about 150 scientists and deep-sea drilling engineers from 17 different countries convened in Tokyo for the Conference on Cooperative Ocean Riser Drilling (CONCORD). A vessel with the capabilities to control borehole conditions (i.e. riser drilling), thereby allowing drilling to greater depths and in difficult or overpressured environments, has been the aspiration of the scientific drilling community for more than a decade. Since 1990, the Japan Marine Science and Technology Center (JAMSTEC) and the Japanese Science and Technology Agency (STA) have been actively pursuing the possibility of building a new riser-equipped drillship for scientific drilling in deep water that would be part of a new international drilling program. In January 1997, the National Science Foundation, STA/JAMSTEC and the Ministry of Education, Science, Sports and Culture (MONBUSHO) agreed on a framework for planning a new post-2003 program, temporarily referred to as the Integrated Ocean Drilling Program.

CONCORD was organized by an international Steering Committee, ably co-chaired by Dr. Hans Christian Larsen and Professor Ikuo Kushiro, on behalf of JAMSTEC, the Ocean Research Institute (ORI) of the University of Tokyo, and ODP/JOIDES, and was co-sponsored by STA and MONBUSHO. The goal of the meeting was to define the scientific problems that can only be addressed through use of a riser-equipped drilling vessel. Through discussions in a series of topical Working Groups, the CONCORD participants identified a series of exciting and fundamental scientific problems, including (in no priority order):

- The Deep Biosphere: Exploring the Lost World;
- A Mesozoic Reference Section: Anchoring the Global Array;
- Tectonics and the Initiation and Evolution of the Monsoon Climate System;
- Sea-Level Rhythms and Responses in the Greenhouse World;
- Ultra Deep Drilling of the Lower Oceanic Crust and Moho (the 21st Century Mohole);
- Water-Rock Reactions and the Evolution of the Oceanic Crust;
- Mantle Dynamics and the Formation of Oceanic Plateaus;
- Mantle Dynamics and the Rupture of Continental Lithosphere;
- Dynamics of Subduction Earthquakes and Faulting;
- Initiation of Subduction, Island Arc Evolution, and the Birth of Continents;
- Understanding Earthquake Cycles by Direct Long-Term Observations of Active Processes in the Seismogenic Zone.

Achieving many of these objectives will require long-term observation of temporal changes in deep subseafloor processes through the installation of borehole and seafloor observatories. These will be particularly important in investigating the various geological, geophysical and geochemical processes that interact in the seismogenic zone during an earthquake cycle, and in understanding the hydrogeology of the oceanic crust.

Given the significant increase in the level of planning and preparation that will be needed for riser drilling programs, the CONCORD participants recognized the need to identify a specific theme that would be the first project for the new vessel. The experiment that was selected is a comprehensive study of an active seismogenic zone within a subduction zone system. This world-class problem was chosen because of its outstanding scientific potential, readiness, societal relevance, and logistical suitability regarding water depths and proximity to the ship's home port, as required for the initial shakedown phase and testing of the drillship. The whole experiment, from planning to execution, is envisaged to be a concerted international effort, and will provide an example of the future mode of international and global operation of the riser-equipped drilling vessel.

A report of the meeting, and a list of the recommendations, is expected to be published by JAMSTEC early in the fall. As the planning process for drilling post-2003 proceeds, another international meeting will be necessary that will integrate these objectives with those of a *JOIDES Resolution*-type vessel to produce a set of focused scientific goals for the program that will succeed ODP. Such a meeting will likely be convened sometime in the next few years, and will take the form of the third Conference on Scientific Ocean Drilling (COSOD III). In the mean time, we wish our Japanese colleagues every success in obtaining approval for the construction of a riser-equipped drilling vessel for future scientific ocean drilling!◆

Reported by Susan Humphris.

In keeping with ODP's commitment to actively seek collaboration and communication with other global geoscience initiatives, each of the next few issues of the JOIDES Journal will highlight one or two of these programs in order to inform the ODP community of their goals and objectives.

Focus on International Geoscience Initiatives

InterRidge — Initiative for International Cooperation in Ridge-Crest Studies

by Cara Wilson

InterRidge is an international, interdisciplinary initiative concerned with all aspects of mid-ocean ridge crest research from biology to geophysics. It is designed to encourage scientific and logistical coordination of research projects, with particular emphasis on problems that cannot be addressed by nations acting alone or in limited partnerships. Its activities range from dissemination of information on existing, single-institution experiments to initiation of fully multinational projects. Besides ODP, the InterRidge program has links with other international research programs, such as the International Lithosphere Project and SCOR (Scientific Committee on Oceanic Research). Currently there are 21 countries associated with InterRidge: 6 Principal Members (France, Germany, Japan, Spain, UK, USA), 2 Associate Members (Norway, Portugal) and 13 Corresponding Members (Australia, Brazil, Canada, Denmark, Iceland, India, Italy, Korea, Mexico, Russia, South Africa, Sweden, Switzerland).

InterRidge Themes and Objectives

InterRidge has identified three principal themes aimed at (i) discovering the interrelationships among the diverse manifestations of the ridge system, and (ii) integrating a growing understanding of ridge dynamics with knowledge about the functioning of the Earth as a whole. These themes are Global Studies, Meso-Scale Studies and Active Processes, and they are designed to:

• Acquire a balanced set of global-scale data on the entire mid-ocean ridge system. Of specific note is that this objective implies a concerted effort of exploration in high latitudes where data are extremely sparse.

• Observe, measure and monitor active processes at individual ridge sites in order to begin to quantify the fluxes of mass and energy involved and their biological consequences.

• Investigate the interplay of mantle processes at temporal and spatial scales that bridge the gap between the Global Studies perspective and fine-scale studies of Active Processes. These "meso-scale" studies focus on magmatic and tectonic patterns as well as on fluxes, and include a specific effort on ridges in marginal (back-arc) basins.

• Understand the evolution, reproduction strategies, and dispersion paths of hydrothermal vent biota, and determine their relevance to, and interaction with, physical, chemical, and geological processes at the ridge-crest.

Pursuit of these scientific themes involves integration of many disciplines, from seismology to bacteriology, and a variety of approaches at many different scales. Consequently, since its inception in 1990, InterRidge has convened a number of thematic workshops that have initiated nine working groups, each of which has been formed to tackle a specific scientific question or need identified as a priority by the international ridge crest research community. These working groups, which organize workshops, special sessions at international conferences, write workshop reports and program plans, and ensure international cooperation on each issue can be grouped under the three major programmatic themes:

Global Studies —
- Global Digital Atlas
- SWIR (Southwest Indian Ridge)
- Arctic Oceans;

Meso-Scale Studies —
- 4-D Architecture of the Oceanic Lithosphere
- Quantification of Fluxes
- Back-Arc Basin Data Base;

Active Processes —
- Event Detection and Response / Observatories
- Biological Studies at the Ridge Crest,
- Undersea Cables.

More information regarding the scientific objectives of each working group, as well as the name of each chairperson, is available on the InterRidge web page.

It is clear from these working groups that InterRidge and ODP have many scientific objectives in common. Of particular relevance in the immediate future are those topics that have thematic overlap with ODP Program Planning

Groups (PPGs) that have recently been set up to develop drilling strategies to address specific scientific problems. Three ODP PPGs that will require close communication with InterRidge in the next few years are the Long-Term Observatories PPG, the Earth's Deep Biosphere PPG, and the Architecture of the Oceanic Lithosphere PPG. It is planned that there will be InterRidge representation within each of these ODP groups.

Some Relevant InterRidge Publications

There are a number of InterRidge publications that are of relevance to the ODP community. A complete listing can be found on the InterRidge web page, and all documents are available on request from the InterRidge Office. The following may be of particular interest:

Fara-InterRidge Mid-Atlantic Ridge Symposium Results from 15°N to 40°N. J. Confer. Abs. 1(2), 1996.

The Oceanic Lithosphere and Scientific Drilling into the 21st Century, Abstract Volume, an ODP-InterRidge-IAVCEI Workshop, 1996.

InterRidge Meso-Scale Workshop Report: 4-D Architecture of the Oceanic Lithosphere, Boston, MA, USA, pp. 15, May 1995.

InterRidge Meso-Scale Project Symposium and Workshops Reports, 1994: Segmentation and Fluxes at Mid-Ocean Ridges: A Symposium and Workshops & Back-Arc Basin Studies: A Workshop, pp. 67, June 1994.

InterRidge Meso-Scale Working Group Meeting Report, Cambridge, UK, pp.6, 1992.

The InterRidge Office is currently based at the Laboratoire de Pétrologie at the Université Pierre et Marie Curie in Paris, France. The Office is Chaired by Mathilde Cannat, and is run by Cara Wilson, the InterRidge Coordinator, and Hélène Horen, the Assistant Coordinator. For more infomation, please contact:

InterRidge Office
Laboratoire de Pétrologie
Tour 26, 3ème étage, couloir 26-25
Université Pierre et Marie Curie
4 place Jussieu
75252 Paris Cédex 05
France

Tel: +33 1 44 27 75 78
Fax: +33 1 44 27 39 11
e-mail: intridge@ext.jussieu.fr
http://www.lgs.jussieu.fr/~intridge

MARK YOUR CALENDAR

Upcoming InterRidge Sponsored Events

First International Symposium on Deep-Sea Hydrothermal Vent Biology
Funchal, Madeira, Portugal, 19-24 October 1997

The objective of this symposium is to bring together the international community of scientists involved in research on deep-sea hydrothermal vents and cold seeps. The schedule includes 73 talks and posters, with 91 people, from 12 different countries, registered for this meeting. The InterRidge Office will be producing an abstract volume for the Symposium, in addition to a citable volume of full length papers.

Special AGU Tectonics session "Magma Focusing and the Segmentation of Mid-Ocean Ridges at all Spreading Rates"
Fall AGU meeting, San Francisco, CA, AGU, 8-12 December 1997

This session is sponsored by the 4-D Architecture of the Oceanic Lithosphere working group, and will be followed by an open discussion/4-D working group meeting to focus on the key areas of uncertainty in ridge architecture and how to address them.

Special AGU Volcanology session "Hydrothermal Activity at Different Spreading Rates"
Fall AGU meeting, San Francisco, CA, AGU, 8-12 December 1997

This session is sponsored by the Quantification of Fluxes working group and will be followed by a panel to discuss unresolved questions about hydrothermal fluxes such as:

1) the partitioning along axis as a function of both spreading rate and also tectonic vs magmatic controls, and;
2) the partitioning between on-axis vs off-axis hydrothermal activity, and between high-T axial flow, diffuse axial flow and off-axis flow.

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1755 Massachusetts Ave., N.W., Suite 800
Washington DC 20036-2102, USA
Tel. (202) 232-3900 or (202) 939-1620
Fax 202 / 232-8203 • joi@brook.edu

JOIDES Office
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Marine Geology & Geophysics Department
Woods Hole Oceanographic Institution, MS #22
Woods Hole, MA 02543, USA
Tel. (508) 289-3481 • Fax. (508) 457-2187
joides@whoi.edu

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Lamont-Doherty Earth Observatory
P.O. Box 1000, Rt. 9W
Palisades, NY 10964, USA
Tel. (914) 365-8542 • Fax (914) 365-8159
odp@ldeo.columbia.edu

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- Science Operations
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Ocean Drilling Program
Texas A&M University
1000 Discovery Drive
College Station, TX 77845-9547, USA
Tel. (409) 845-2673 • Fax (409) 845-4857

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Lamont-Doherty Earth Observatory
P.O. Box 1000, Rt. 9W
Palisades, NY 10964, USA
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borehole@ldeo.columbia.edu

Bremen Core Repository
- Sample Information
- Availability of Residues and Thin Sections (from ODP Leg 151 onward)

Bremen University
Ocean Drilling Program
Bremen Core Repository
Konsul-Smidt Str. 30
Schuppen 3
28217 Bremen, Germany
Tel. 49 (421) 3966336 • Fax 49 (421) 3966684
walter_hale@odp.tamu.edu

Member Country/Consortia Administrative Offices

Australia-Canada-Chinese Taipei-Korea Consortium
Dr. Steve Scott, Director
Canadian ODP Secretariat
Department of Geology
University of Toronto
22 Russell Street
Toronto, Ontario M5S 3B1, Canada.
Tel: (416) 978-6554 • Fax: (416) 978-4820
E-Mail: scottsd@ecf.utoronto.ca

ESF Consortium for Ocean Drilling (ECOD)
Dr. Judith McKenzie, Chair
ESCO Secretariat,
ETH-Zentrum,
Sonneggstrasse 5
CH-8092 Zurich, Switzerland
Tel: 41 (1) 632-5697 • Fax: 41 (1) 632-1080
E-Mail: ESCO@erdw.ethz.ch

France
Dr. John Ludden, Président du Comité Scientifique
ODP-France
CRPG
B.P. 20
54501 Vandoeuvre-les-Nancy
France
Tel: 33 (3) 83 51 22 13 • Fax: 33 (3) 83 51 17 98
E-Mail: ludden@crpg.cnrs-nancy.fr

Germany
Dr. Helmut Beiersdorf, Coordinator
DFG "ODP / DSDP Priority Program"
Bundesanstalt f. Geowiss und Rohstoffe
Stilleweg 2, Postfach 510153
D-30631 Hannover, Germany
Tel: 49 (511) 643-2413 or 2782
Fax: 49 (511) 643-2304
E-Mail: beiersdorf@gate1.bgr.d400.de

Japan
Dr. Tetsuya Hirano, Director
ODP Japan Office
Ocean Research Institute,
University of Tokyo
1-15-1 Minamidai, Nakano-ku,
Tokyo 164, Japan
Tel: 81 (3) 5351-6438 • Fax: 81 (3) 5351-6439
E-Mail: ataira@ori.u.tokyo.ac.jp

United Kingdom
Dr . Roger Padgham, Programme Manager
UK ODP Office,
N.E.R.C.,
Polaris House,
North Star Avenue,
Swindon SN2 1EU, United Kingdom
Tel: 44 (0) 1793 411573 • Fax: 44 (0) 1793 411502
E-Mail: rcpad@wpo.nerc.ac.uk

United States
Dr. Ellen S. Kappel
Program Director / JOI / USSSP
Joint Oceanographic Inst., Inc.
1755 Massachusetts Ave. NW, Suite 800
Washington, DC 20036-2101
Tel: (202) 232-3900 x216 or (202) 939-1624
Fax: (202) 232-8203 • ekappel@brook.edu

JOIDES Resolution Operations Schedule						
Leg	**Destination**	**Cruise dates**	**Port of Origin**	**Total Days**	**Tran-sit**	**On Site**
176	Return to Hole 735B	15 Oct–10 Dec '97	Cape Town, 10–14 Oct	56	16	40
177	S. Ocean Paleoceanography	15 Dec '97–9 Feb '98	Cape Town, 10–14 Dec	56	16	40
178	Antarctic Peninsula	14 Feb– 11 Apr '98	Punta Arenas, 9–13 Feb	58	18	38
179	NERO/Hammer Drilling	16 Apr– 4 Jun '98	Cape Town, 11–15 Apr	49	35	24
180	Woodlark Basin	9 Jun– 4 Aug '98	Darwin, 4–8 Jun	56	8	48
181	SW Pacific Gateways	9 Aug– 4 Oct '98	Townsville, 4–8 Aug	56	15	41
182	Great Australian Bight	9 Oct– 4 Dec '98	Wellington, 4–8 Dec	56	13	43
183	Kerguelen	9 Dec '98–7 Feb '99	Fremantle, 4–8 Dec	60	22	38
184	East Asia Monsoon	12 Feb – 9 April '99	Fremantle, 7–8 Feb	56	14	42
185	Izu–Mariana Mass Flux	14 April – 9 June '99	Hong Kong, 9–13 Apr	56	14	42
186	W. Pacific Seismic Network–Japan Trench	14 June–9 Aug '99	Tokyo, 9–13 Jun	56	TBA	TBA
	Dry-Dock	Aug – Oct	TBA	TBA	TBA	TBA
187	Australia–Antarctic Discordance	Oct – Dec	TBA	TBA	TBA	TBA
188*	Prydz Bay	Dec '99 – Feb '00	TBA	TBA	TBA	TBA

* This leg is contingent upon successful drilling on Leg 178, and identification of funds for an ice support vessel.

Upcoming Meetings

The next annual meeting of the German ODP community will be in **Freiburg (Germany)** on **March 4 – 6, 1998.** The official name of the meeting is **"Kolloquium des DFG-Schwerpunktprogramms ODP/DSDP"** (or Colloquium of the DFG Priority Programme ODP/DSDP). Organization rests with the German ODP Office and the local host Prof. Dr. Jan Behrmann, Universitaet Freiburg, Geologisches Institut, Alberstr. 23B, D-79104 Freiburg (email: behrmann@perm.geologie.uni-freiburg.de). Inquiries should be sent to "odp@bgr.de".

Société Géologique de la France will sponsor a meeting in **Paris** on **January 27 – 28, 1998**, at CNRS, rue Michel Ange, Paris. "Forages oceaniques; nouveaux enjeux" Organizers are Catherine Mevel and John Ludden. For additional information, please contact the Secretariat ODP-France.

The biennial conference of the Geological Society, in conjunction with the UK Geophysical Assembly and supported by the British Geological Survey and the Geologists'Association, will be held at the **University of Keele, Staffordshire** from **April 14-18, 1998**. There will be symposia on subjects including basin modeling in petroleum exploration; natural gas hydrates; active continental tectonics; and rock fracture. Please contact the Geological Society for a First Circular and all full details. Abstract deadline for poster and oral presentations is November 14, 1997. The Geological Society, Burlington House, Piccadilly, London W1VOJU. Fax: 44(9) 171 4940579 or email: (lakinj@geolsoc.org.uk).

The 2nd EUROFORUM ODP Meeting will be held in **Edinburgh, Scotland, UK**, on **September 18 – 22, 1998.** The program is currently being organized and a first announcement will be distributed this fall. A second and final announcement with full details will be available in early 1998. For information, contact Alastair Robertson in Edinburgh, Tel: 0131-650-8546, Fax: 0131-668-3184, Email: Alastair.Robertson@glg.ed.ac.uk.

JOIDES Journal
Woods Hole Oceanographic Institution
Woods Hole MA 02543 USA

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Permit No. 2268
Washington DC U.S.

Published bi-annually by the JOIDES Office at the Woods Hole Oceanographic Institution. For subscription information contact:
Shirley Waskilewicz
JOIDES Office, MS #22
Woods Hole Oceanographic Institution
Woods Hole MA 02543
(508) 289-3481
Fax: (508) 457-2187
joides@whoi.edu

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The JOIDES Journal is published and distributed biannually by Joint Oceanographic Institutions, Inc., Washington, DC for the Ocean Drilling Program under the sponsorship of the National Science Foundation and participating member countries. The material is based upon research supported by the National Science Foundation under prime contract OCE-9308410.