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In this issue:

ODP Leg 204 Investigates Gas Hydrates Beneath Southern Hydrate Ridge, Northeast Pacific Ocean

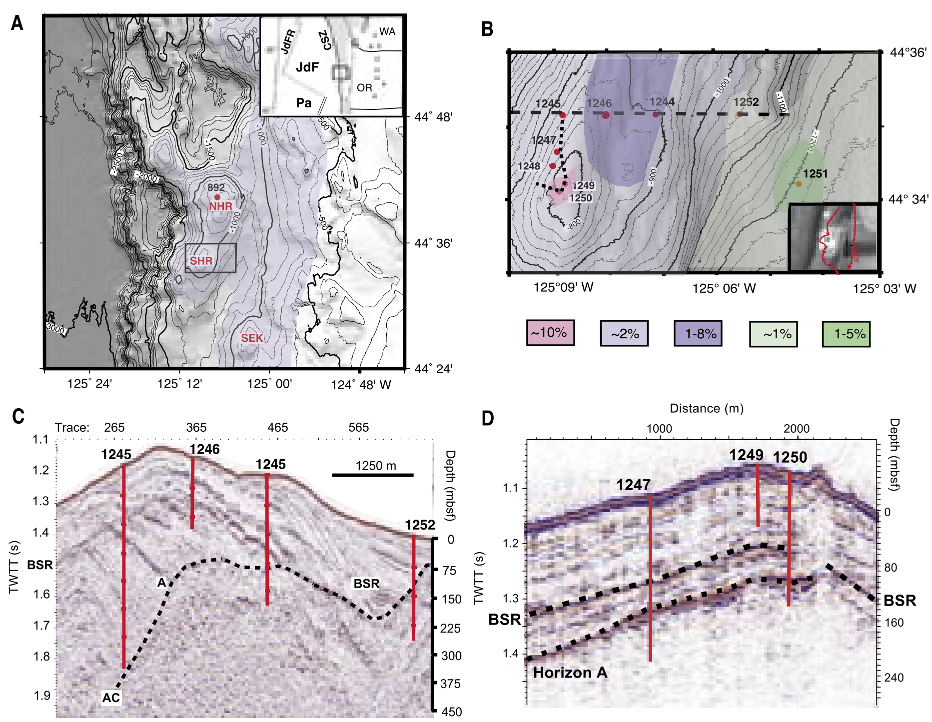

Figure 1 (top)

Captions are on Page 1 and the article starts on Page 5

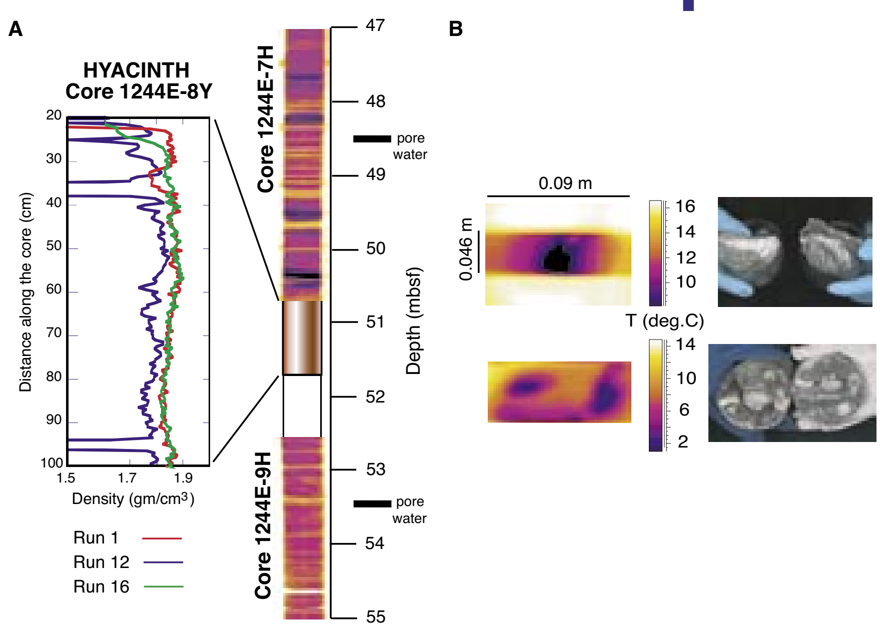

Figure 3 (right)

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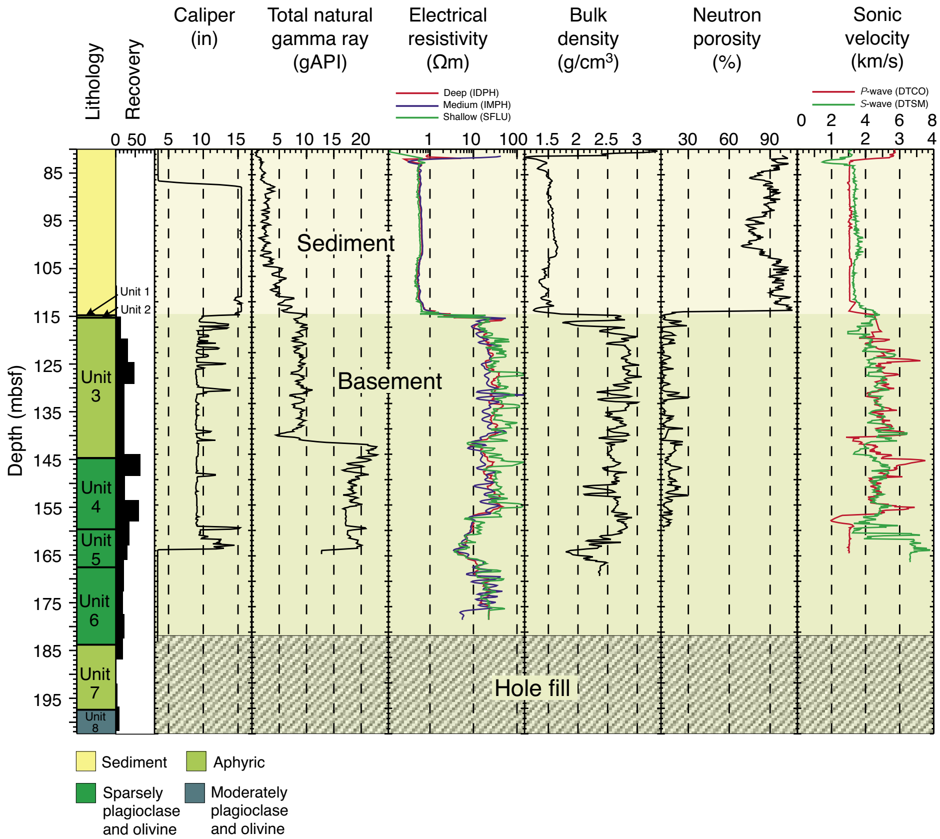

Figure 2. *Composite plot of downhole measurements in the sediment and basement section of Hole 1243B. Note that log depths are based on wireline measurements, whereas core depths are based on drill pipe measurements. The core lithology has been shifted down 6.3 m to match the logging-derived depths. GAPI= American Petroleum Institute gamma ray units ((Orcutt, Schultz, Davies et al.,* 2003).

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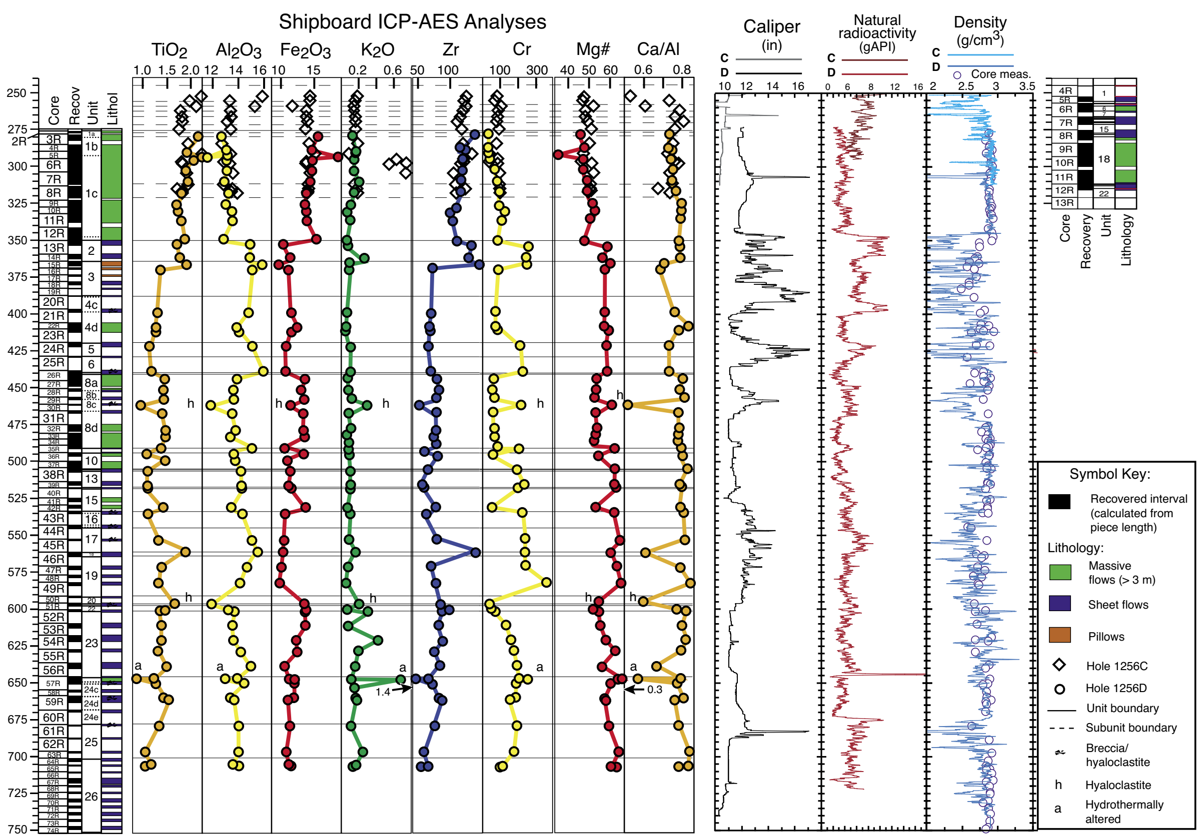

Figure 3. *Core recovery, lithologies, and selected chemical and logging results for basement in Leg 206 Holes 1256C and 1256D.*

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Figure 3. A. *An infrared (IR) camera scan of 6 m of core adjacent to a HYACINTH pressure core sample. Dark bands are "cold spots" interpreted to result from dissociation of lenses and nodules of gas hydrate. Strongly heterogeneous distribution of gas hydrate with depth on the cm scale is apparent. A dramatic decrease in density of layers at ~36 cm and 95 cm along the core during run 6 is interpreted to indicate the presence of free gas resulting from dissociation of gas hydrate. A smaller decrease in density throughout the core probably represents gas exsolution as the pressure decreased. Leg 204 represents the first successful use of the HYACINTH pressure core sampler and shipboard logging systems.* **B.** *Two examples of IR anomalies and the gas hydrate found when the corresponding sections of core were split. High-resolution (2 cm spacing) measurements of the chloride concentration in the pore water in such a sample were used to calibrate estimates of the hydrate content of the sediments derived from the IR temperature anomaly data (Tréhu et al., in review).*

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ODP Leg 203: An Equatorial Pacific ION Site

John A. Orcutt [1], Adam Schultz [2], Thomas A. Davies [3] and the Leg 203 Scientific Party

INTRODUCTION AND OBJECTIVES

Leg 203 was devoted to operations at Site 1243 in the eastern equatorial Pacific (Fig. 1). Site 1243 is in a particularly interesting location for understanding the interplay between ocean chemistry, productivity, climate, and plate tectonics in a fast-spreading environment.

The climatic implications of the region were studied in detail with core samples recovered from a series of 11 boreholes drilled during Leg 138. The Leg 203 scientific party returned to the immediate vicinity of Site 852 of Leg 138 and developed a legacy hole to support a long-term multidisciplinary observatory to be used for studies ranging from the seismic structure of the mantle to air-sea interaction. The Leg 203 program thus represented the partnership of the ODP with two programs: the DEOS (Dynamics of Earth and Ocean Systems) multidisciplinary ocean observatory planning effort in the USA and UK, and the multinational IASPEI/ION Consortium (International Association of Seismology and the Physics of the Earth's Interior/International Ocean Network).

RESULTS

The eastern equatorial Pacific location of Site 1243 satisfies two of the ODP's scientific objectives for crustal drilling. It is located in oceanic crust created by fast seafloor spreading, one of the high-priority regions for the OSN and DEOS, and provides a rare opportunity to examine crustal genesis, evolution, and crust/mantle interaction for a seafloor-spreading end-member responsible

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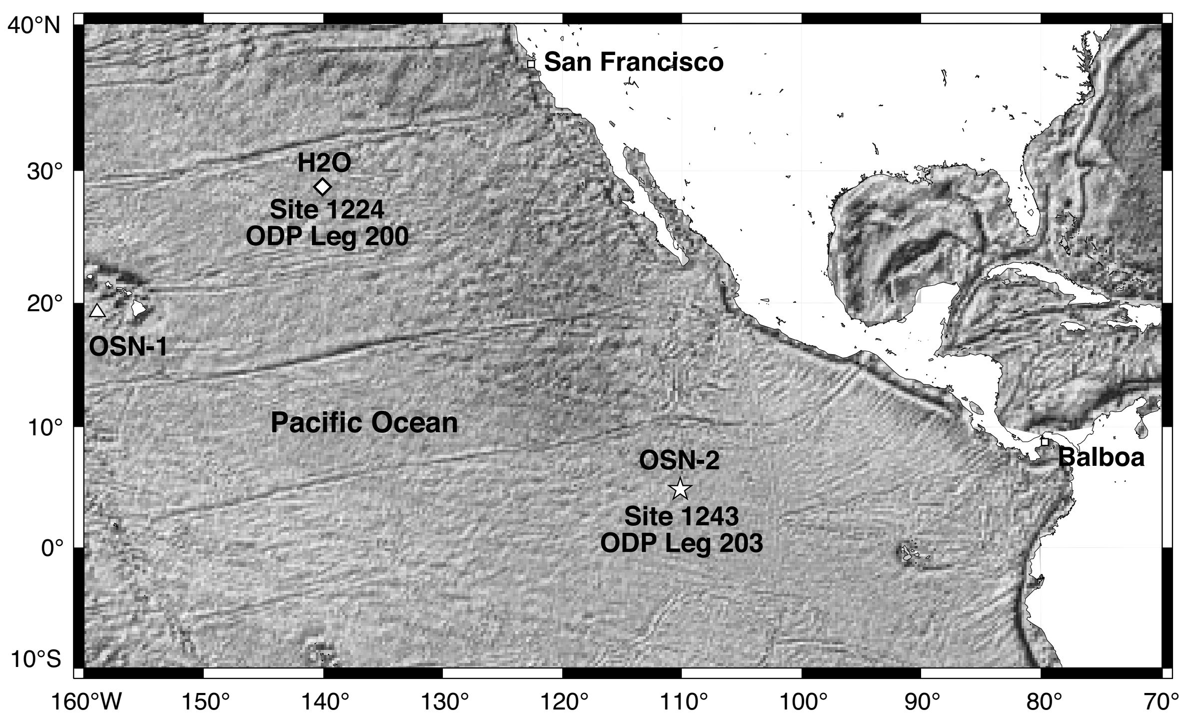

Figure 1. *Location of Leg 203 Site 1243 (OSN-2, star) superimposed on a free air gravity anomaly map derived from Geosat and ERS-1 data (courtesy of D. Sandwell and W. Smith). Other sites shown are the Hawaii-2 Observatory (H2O) and the OSN-1 Observatory (Orcutt, Schultz, Davies et al., 2003).*

for generating the majority of the oceanic lithosphere.

Hole 1243A: Future Location of a DEOS Multidisciplinary Observatory

ODP Hole 1243A, a cased reentry hole and the location of a future DEOS multidisciplinary observatory, is located at 5˚18.0660'N, 110˚4.5798'W in the eastern equatorial Pacific (Fig. 1). The hole, in 10 Ma to12 Ma lithosphere at a water depth of 3882 m, was drilled to a total depth of 224 m, and penetrated 121 m of sediment and 103 m of basement. Failure to successfully seat the 16 in casing in the 18-1/2 in borehole led to the completion of Hole 1243A by drilling with an 18-1/2-in rotary bit without coring. 10-3/4 in casing was then cemented in place to minimize risk to the integrity of the hole. This was the largest cementing job yet attempted by ODP into a formation that is porous and fractured near the bottom of the hole. The casing extends to 212 mbsf, with the top of the cement at a depth of 199 mbsf. Subsequent logging showed the casing to be well bonded to basement in the lower 40 m of the borehole; deviation of the hole from vertical never exceeds 1º.

Hole 1243A will be used subsequently to install an observatory quality broadband (0.001 to 5 Hz), three-component seismometer as well as a high frequency (1 to 20 Hz), three-component seismometer to ensure high fidelity recording over the range of frequencies normally recorded by the terrestrial Global Seismic Network (GSN). The seismic system, as well as other instrumentation associated with the observatory, will be connected to a DEOS mooring for both power and high-speed data telemetry to a land station and the global Internet.

Hole 1243B: Coring and Logging of Fast-Spreading Oceanic Crust

Since casing complications obviated coring and scientific logging in Hole 1243A, a second, uncased hole was drilled 600 m to the East to satisfy the secondary objective. Hole 1243B (5˚18.0543'N, 110˚4.2544'W) penetrated 110 m of sediment, had a total depth of 195 m, and was fitted with a reentry funnel. The drill bit was jetted in to just above the sediment-basement interface in an attempt to sample the interface before RCB coring penetrated through 85 m of basement. A recovery rate of 24.9% was achieved in 10 Ma to 12 Ma, mildly altered pillow basalt. Logging with the Triple Combo tool and FMS (Formation MicroScanner)/Sonic tool was followed by a WST (Well Seismic Tool) run in a VSP (Vertical Seismic Profile) configuration. Data were collected successfully on all runs, and multiple trips to authenticate measurements were made for the first two logs (Fig. 2, inside front cover).

The rocks recovered from Hole 1243B are largely pillow basalts and comprise both aphyric and sparsely phyric plagioclase and olivine basalts (Fig. 2, inside front cover). Eight units were identified; seven are igneous, and one, Lithologic Unit 2, is represented by a single piece of limestone. There was no evidence of thicker, massive lava flows in the material recovered nor in the log analyses. All units are tholeiitic with the exception of Lithologic Unit 4 that consists of alkali basalt. The compressional seismic velocities measured in the shipboard samples were high, with a mean of 5.26 km/s. While the sonic log and VSP velocities were lower, they were consistent with increasing integration of cracks and joints in the increasing wavelengths of the techniques applied. Paleomagnetic measurements indicate that the basaltic cores recovered from Hole 1243B, after the removal of the drilling-induced remagnetization, record a stable component of magnetization with both normal and possibly reversed inclinations.

IMPLICATIONS

ODP Leg 203 accomplished its stated goals despite the shortening of an already modest operational component of the leg by the decision to reroute the ship to Victoria, British Columbia, Canada rather than San Francisco, and despite the significant technical challenges of handling long casing strings. The deep ocean research community now has a complete, cased, cemented legacy hole penetrating nearly 100 m of basement for the future installation of seafloor observatory-based broadband seismometers. This legacy hole exists in an area of considerable interest to researchers in other disciplines of the Earth and ocean sciences, and provides the infrastructure for a future DEOS multidisciplinary moored observatory. In addition, the Leg 203 Shipboard Party was able to recover basalts from the upper oceanic crust in fast-spreading, young lithosphere in the Pacific in excess of the depth drilled on most previous legs.

For more information on shipboard science during this cruise, visit the Leg 203 Initial Reports volume, available online at http://www-odp.tamu.edu/publications/203_IR/203ir.htm.

LEG 203 SCIENTIFIC PARTY

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REFERENCES

Orcutt, J.A., Schultz, A., Davies, T.A. et al., 2003. *Proc. ODP, Init. Repts.,* 203, 1-30 [CD-ROM]. Available from Ocean Drilling Program, Texas A&M University, College Station TX 77845-9547 USA.

ODP Leg 204: Gas Hydrate Distribution and Dynamics Beneath Southern Hydrate Ridge

A.M. Tréhu [1], G. Bohrmann [2], F.R. Rack [3], M.E. Torres [1], and the Leg 204 Scientific Party

INTRODUCTION

Gas hydrates are ice-like compounds that form at low temperature and high pressure conditions common in shallow marine sediments, at water depths greater than 300 to 500 m, when concentrations of methane and other hydrocarbon gases exceed saturation. Estimates of the total mass of methane carbon that resides in this reservoir vary widely (Kvenvolden and Lorenson, 2001; Milkov et al., 2003). While marine geologists generally agree that gas hydrates are a factor in the global near-surface carbon budget (Dickens, 2003), accurate estimates of the amount of gas hydrate present in nature are difficult to obtain. Gas hydrates dissociate as samples are recovered, and much of the gas is lost. This leads to controversy over whether gas hydrates could be a major source of fossil fuel in the future, and whether periods of global climate change in the past can be attributed to destabilization of this reservoir.

ODP Leg 204 was designed to address these questions by determining (1) the distribution, amount, and rate of formation of gas hydrate within an accretionary ridge and adjacent basin; (2) the sources of gas for forming hydrate; (3) identification of geologic proxies for past gas hydrate occurrence; and (4) calibration of remote sensing techniques to quantify the *in situ* amount of gas hydrate that can be used to improve estimates where no boreholes exist. Several new techniques tested during Leg 204 included the first geophysical logs of cores at *in situ* pressure, the first comprehensive infrared camera scans of all cores from within the gas hydrate stability zone (GHSZ), and the first use by ODP of logging-while-drilling as a roadmap to guide subsequent coring.

GEOLOGIC SETTING

Nine sites were drilled and cored during Leg 204 on southern Hydrate Ridge, a topographic high in the Cascadia subduction zone accretionary complex, located approximately 80 km west of Newport, OR (Fig. 1A, front cover). Previous studies documented the presence of seafloor gas vents, outcrops of massive gas hydrate, and a 50-m tall "pinnacle" of authigenic carbonate near the summit (Suess et al., 2001; Torres et al., 2002). Deep-towed sidescan data (Fig. 1B, front cover) show an approximately 300 m x 500 m area of relatively high acoustic backscatter that indicates the extent of seafloor venting (Johnson et al., 2003). The seafloor elsewhere is covered with low reflectivity sediment. The presence of a regional bottom-simulating seismic reflection (BSR) suggests gas hydrates are widespread (Tréhu et al., 1999).

Leg 204 boreholes can be grouped into three end-member environments based on stratigraphic and structural interpretations of 3-D seismic reflection data acquired along the southern Hydrate Ridge (Figs. 1C, 1D; front cover). Sites 1244 through 1247 characterize the southern Hydrate Ridge flanks, Sites 1248 through 1250 are located along the active seafloor venting at the summit, and Sites 1251 and 1252 characterize the slope basin east of Hydrate Ridge, where rapid sedimentation contrasts with the erosional environment of Hydrate Ridge.

LITHOLOGIC GROUNDTRUTHING

Leg 204 confirmed that highly deformed, underthrust sediments of the accretionary complex underlie the boundary labeled AC (Figs. 1C, 1D. front cover). This facies is

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overlain by dipping Pleistocene and Holocene, silty and sandy turbidites interlayered with fine-grained hemipelagic sediments that represent uplifted and deformed trench and slope basin deposits on the western and eastern flanks, respectively.

Three anomalously strong reflections, A, B and B', result from coarse-grained and/or volcanic ash-rich horizons. Reflection A is continuous for ~1 km from the flank of Hydrate Ridge to the summit (Figs. 1C, 1D; front cover) and has unusual sedimentological, chemical and physical properties (Fig. 2). These data suggest that this stratigraphic horizon provides a path along which methane and higher order hydrocarbon gases migrate from the accretionary complex to the summit (Milkov et al., in review). In contrast, reflections B, B' and adjacent horizons are characterized by numerous, small-offset normal faults that may facilitate upward fluid flow over a broad region (Fig. 1C. front cover).

IN SITU GAS HYDRATE AMOUNT, DISTRIBUTION, AND SOURCES

The *in situ* amount of gas hydrate was estimated using (1) HYACINTH pressure core samplers (PCS), the only means of recovering all the gas present *in situ*; (2) dilution of the chloride concentration in pore water that provides robust estimates of *in situ* gas hydrate content provided that the hydrate formation rate is slow enough that salts excluded during gas hydrate formation are removed by advection or diffusion; (3) detection of temperature anomalies in the cores with infrared (IR) cameras to locate cold spots resulting from gas hydrate dissociation (Ford et al., 2003) within or near the GHSZ; (4) geophysical logs of borehole resistivity, density and sonic velocity for continuous estimates of hydrate distribution in the boreholes; and (5) seismic profiles that allow regional extrapolation of borehole results (Fig, 3, front cover). The first two techniques provide well-constrained but incomplete estimates of the gas hydrate content of the subsurface because they sample only a few percent of the GHSZ. Approaches 3 through 5 provide good spatial coverage, but algorithms for quantifying gas hydrate from the observations must be calibrated and verified by other techniques.

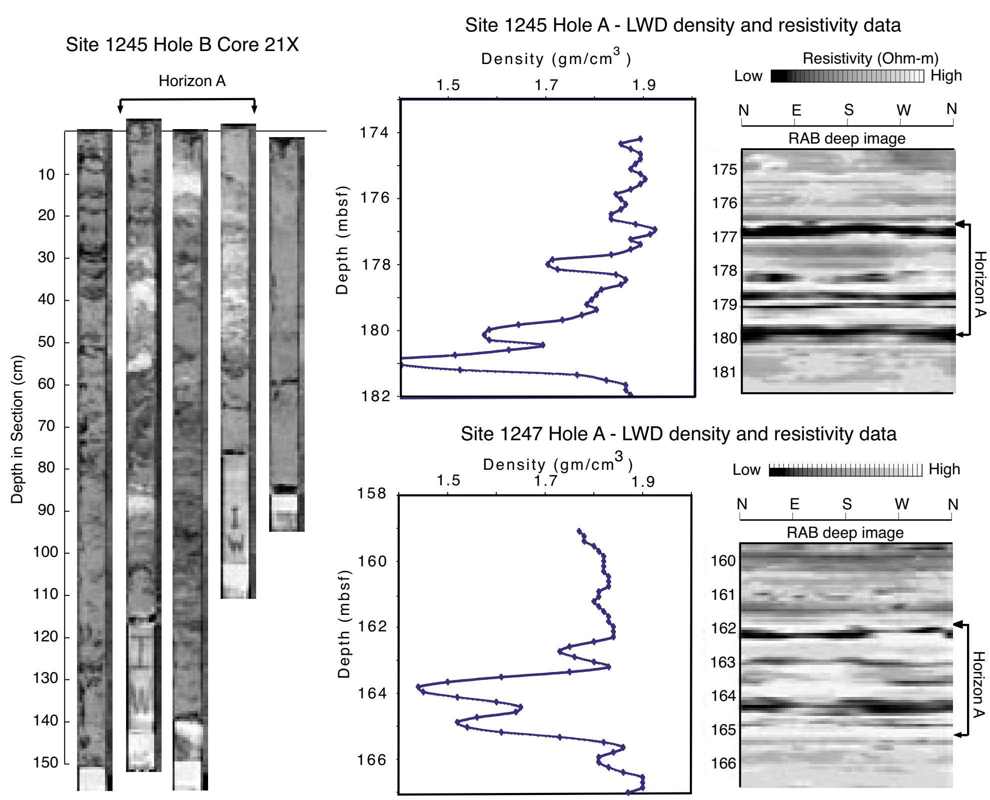

Figure 2. *Logging-while-drilling (LWD) data revealed that Horizon A is associated with very low* in situ *density and a distinctive pattern of high resistivity layers. The signature of this horizon is remarkably similar in Site 1245, 1247 and 1250 boreholes. Coring revealed the presence of multiple coarse-grained layers containing a high fraction of volcanic glass. The core from Site 1245, Hole B, is shown here. Low density and high resistivity log intervals indicate the presence of free gas* in situ*; this interpretation is supported by seismic data.*

Tréhu et al. (in review) discuss calibration of the infrared camera data using porewater chloride concentrations and present estimates of the spatial variability and average gas hydrate content in each of the end-member settings. Most of the gas hydrate is present as clustered layers, veins or nodules of sub-mm to cm scale (Fig. 3, front cover); limited evidence exists for gas hydrate disseminated in the pore space, especially near the base of the gas hydrate stability zone at Site 1251. Gas hydrate is present in the upper 40 to 50 mbsf only at the summit. Although the gas hydrate content of the sediments can locally be quite high when averaged over a few 10s of m, it is low when averaged over the GHSZ (Fig. 1B, front cover).

At the southern summit (Sites 1248 through 1250), Leg 204 data indicate that the upper ~25 m of sediment contain as much as 25% gas hydrate by volume. The deposit's subtle but distinctive seismic signature (Fig. 4) can be used to estimate the total amount of methane trapped within this deposit and to identify similar gas hydrate deposits elsewhere.

Distinctive patterns in the methane/ethane observed methane ratio were noted during shipboard analyses. Post-cruise integration of the Leg 204 biogeochemical data with the 3-D seismic data-derived structural and stratigraphic frameworks will explore the sources of the gases that form the gas hydrate.

GAS HYDRATE DYNAMICS AT THE SUMMIT

Observations of gas bubbles streaming from the seafloor (Torres et al., 2002; Heeschen et al., 2003) and very high pore water chloride concentrations from the upper ~25 mbsf at Sites 1248 through 1250 indicate non-equilibrium conditions and rapid gas hydrate formation at the summit. Efforts are underway to incorporate these observations into a comprehensive dynamic model for gas hydrate formation in this environment. Other post-cruise efforts include chemical and physical mechanisms whereby methane migrates from Horizon A into and through the gas hydrate stability zone, the conditions under which gas hydrate and free gas can coexist within the GHSZ, and the rate of gas hydrate formation.

IMPLICATIONS

Leg 204 drilling has led to the first high-resolution estimate of the 3-D distribution of gas hydrate within an accretionary ridge system. Comparisons of drilling results with stratigraphic and structural patterns imaged in the seismic data have elicited new ideas on the spatial variability in gas hydrate distribution and the dynamic processes that create these deposits. Results from this cruise provide a foundation for a new generation of models for the response of marine gas hydrates to tectonic and environmental change.

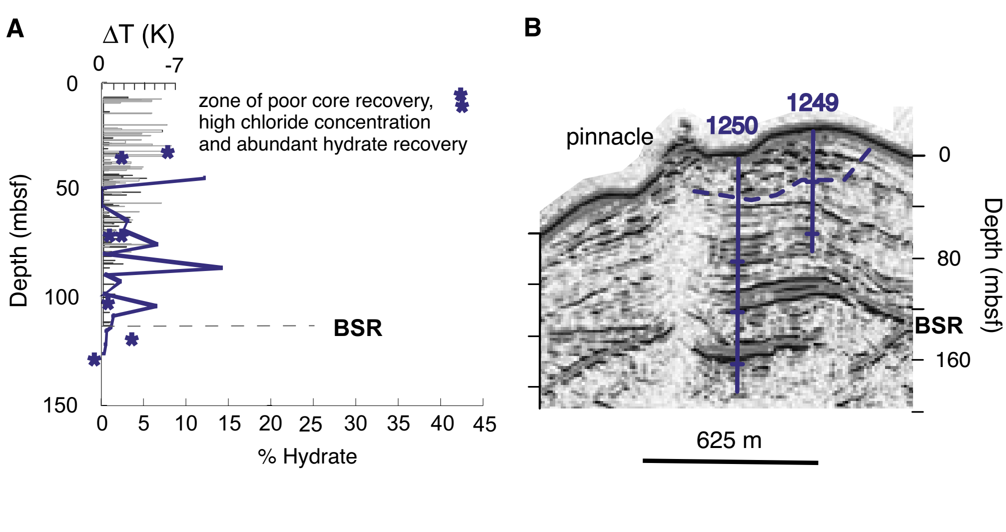

Figure 4. A. *Indicators of abundant gas hydrate in Site 1249 and 1250 boreholes in the upper 20 to 40 mbsf beneath the southern summit of Hydrate Ridge. Pressure core samples shown by blue stars, large IR temperature anomalies by gray bars, and high chloride concentration in pore waters by blue line.* **B.** *Summit region image (extracted from 3-D seismic reflection data) shows characteristic seismic signature of the shallow hydrate deposit above the dashed blue line (adapted from Tréhu et al., in review).*

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The low average concentration of gas hydrate supports conservative estimates of the global volume of methane stored in gas hydrate, leading to questions about whether the role of gas hydrates in driving global change is as important as has been hypothesized. Concentrated deposits just below the seafloor, however, may respond rapidly to warming of the ocean or changes in sea level and are susceptible to disruption by earthquakes, anthropogenic activities, and other events. High concentrations in thin, patchy zones just above the BSR may be destabilized by tectonic uplift, producing inversions in sediment strength and fluid/gas pressure that may drive venting and slope instability.

The results provide a challenge for models of gas hydrate formation in nature. Time-dependent models that include multiphase fluid flow in a heterogeneous medium are needed.

To read the Leg 204 Initial Reports volume online, visit http://www-odp.tamu.edu/publications/204_IR/204ir.htm. Post-cruise results will be presented in session OS09 at the Fall 2003 AGU meeting.

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REFERENCES

Dickens, G.R., 2003. Rethinking the global carbon cycle with a large, dynamic and microbially mediated gas hydrate capacitor. *Earth Plan. Sci. Let.* 6724**,** 1-14.

Ford, K.H., Naehr, T.H., and Skilbeck, C.G., 2003. The use of infrared thermal imaging to identify gas hydrate in sediment cores. *In* D'Hondt, S.L., Jørgensen, B.B., Miller, D.J. et al., *Proc. ODP, Init. Repts.*, 201, College Station, TX (Ocean Drilling Program), 1-20.

Heeschen, K.U., Tréhu, A.M., Collier, R.W., Suess, E., and Rehder, G., 2003. Distribution and height of methane bubble plumes on the Cascadia margin characterized by acoustic imaging, *Geophys. Res. Lett.*, 30:1643-1646.

Johnson, J.E., Goldfinger, C., and Suess, E., 2003. Geophysical constraints on the surface distribution of authigenic carbonates across the Hydrate Ridge region, *Marine Geol.*

Kvenvolden, K.A., and Lorenson, T.D., 2001. The global occurrence of natural gas hydrate. *In* Paull, C. K. and Dillon, W.P. (Eds.), Natural Gas Hydrates: Occurrence, distribution and detection, *Geophys. Monogr. Am. Geophys. Union*, 124:3-18.

Milkov, A.V., Claypool, G.E., Lee, Y.-J., Dickens, G.R., Xu, W., Borowski,, W.S., and the ODP Leg 204 Scientific Party, 2003. *In situ* methane concentrations at Hydrate Ridge offshore Oregon: New constraints on the global gas hydrate inventory from an active margin. *Geology*, 30:833-836.

Milkov, A.V. and the Leg 204 Shipboard Scientifc Party, in review. Co-existence of gas hydrate, free gas, and brine within the gas hydrate stability zone at the southern summit of Hydrate Ridge (Oregon margin): Evidence from prolonged degassing of a pressurized core. *Earth Planet. Sci. Lett.*

Suess, E., *et al.,* 2001. Seafloor methane hydrates at Hydrate Ridge, Cascadia margin, *In* Paull, C. K. and Dillon, W.P. (Eds.), Natural Gas Hydrates: Occurrence, distribution and detection, *Geophys. Monogr. Am. Geophys. Union*, 124:87-98.

Torres, M.E., McManus, J., Hammond, D.E., de Angelis, M.A., Heeschen, K.U., Colbert, S.L., Tryon, M.D., Brown, K.M., and Suess, E., 2002. Fluid and chemical fluxes in and out of sediments hosting methane hydrate deposits on Hydrate Ridge, OR, Part 1: Hydrologic provinces. *Earth Planet Sci. Lett.*, 201:525-540.

Tréhu, A.M., Torres, M.E., Suess, E., Bohrmann, G., and Moore, G., 1999. Temporal and spatial evolution of a gas-hydrate-bearing ridge on the Oregon continental margin. *Geology*, 27: 939-942.

ODP Leg 205: Fluid Flow and Subduction Fluxes Across the Costa Rica Convergent Margin

Julie D. Morris [1], Heinrich W. Villinger [2], Adam Klaus [3], and the Leg 205 Scientific Party

INTRODUCTION

A transect of boreholes was drilled across the Middle America Trench off Costa Rica during Leg 205 (Fig. 1, inside back cover) near the location of Leg 170 drilling (Kimura et al., 1996). Leg 205 investigated active fluid flow in the subducting plate and within the décollement zone, characterized the upper igneous section of the incoming plate, and installed long-term seafloor observatories (CORK-IIs) to monitor pressures and temperatures and sample fluid flow. The scientific objectives addressed both the controls on hazardous interplate seismicity in the seismogenic zone and subduction recycling at convergent margins (the subduction factory).

The fates of incoming sediments, altered ocean crust, and associated volatiles as they pass through the shallow levels of a subduction zone (0 to 50 km depth) profoundly affect the behavior of the seismogenic zone that produces most of the world's destructive earthquakes and tsunamis. Fluid pressure and sediment porosity influence fault localization, deformation style, and strength, and may control the updip limit of the seismogenic zone. Fluids affect early structural development and transport chemical species. The mineralogy and chemistry of subducted sediments, and their dehydration reactions during subduction, may affect the physical properties of the deeper subduction interface and, hence, downdip as well as updip limits of the seismogenic zone.

The escape of fluids to the surface from the downgoing plate at depth supports a deep biosphere, contributes hydrocarbons for gas hydrate formation, affects seawater chemistry, and is intimately linked to deformation, faulting, and the evolution of the décollement. Shallow subduction zone processes also affect the way the residual slab contributes to continent-building magmatism, explosive volcanism, ore formation and, ultimately, the evolution of the mantle through time.

The Central American region has been studied extensively by international scientists in relationship to the Seismogenic Zone and Subduction Factory initiatives. As one of the few modern arcs subducting a carbonate-rich sediment section, Central America permits study of CO_2 recycling through a subduction zone. Differences in earthquake magnitude and recurrence interval and arc magmatism along the length of the margin appear to correlate with changes in the balance between sediment accretion, erosion and subduction (sediment dynamics) along strike. Differences in earthquake magnitude and recurrence interval, in the extent of coupling between the upper and downgoing plates, and in the updip limit of seismicity, are observed between Nicaragua and Costa Rica (Newman et al., 2002).

A major offset in the volcanic chain occurs just north of the northernmost Nicoya peninsula (Fig. 1, inside back cover). Nicaraguan volcanoes are smaller than those of Costa Rica,. The chemistry of the arc volcanics also differs, with a stronger sediment signature in Nicaragua dominated by a contribution from the uppermost hemipelagic sediments of the incoming plate. These differences seem to correlate with changes in the balance between sediment accretion, erosion, and subduction along strike.

ACTIVE FLUID FLOW ACROSS THE COSTA RICA MARGIN

Incoming Oceanic Plate

In the vicinity of reference Site 1253, both heat flow data and the chemistry of pore

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fluids sampled from deep sediments suggest extensive flow of cool fluids in the basement of the incoming oceanic crust, created at the East Pacific Rise at ~24 Ma. Heat flow in the vicinity of Leg 205 operations is only about 1/3 of that expected from lithospheric cooling (Langseth and Silver, 1996; TICOFLUX I and II, METEOR Cruise 54-2, Stein and Stein, 1992). Similarly aged crust to the south of the Fracture Zone Trace (Fig. 1. inside back cover) has normal values. Shipboard pore fluid chemical profiles also suggest extensive fluid flow at depth beneath reference Site 1253 on the incoming plate. Variations in Ca, Sr, Li, H_4SiO_4 and SO_4 concentrations in pore fluids sampled from calcareous sediments at depth were observed in Hole 1253A (Fig. 2). In all cases, concentrations in basal sediments change towards values typical of modern seawater. Similar patterns also were observed in Leg 170 samples (Silver et al., 2000).

Coring at Hole 1253A recovered 230 m of sediment and igneous rock; ~170 m of penetration was within two igneous units. The upper unit is a 30 m thick sill with sediments above and below. Logging to 150 mbsf was conducted primarily in the lower igneous section. The lower igneous unit may be an exceptionally thick sill composed of multiple intrusions, or a series of often thick and slowly cooled lava flows of oceanic crust created at the East Pacific Rise. Core descriptions showed that the section is more extensively altered and fractured below about 510 to 513 mbsf. Logging results confirmed more fracturing imaged in the borehole walls.

Prism Landward of Deformation Front

Coring into the prism at Hole 1254A penetrated through a thrust fault zone at ~197 to 219 mbsf and through the décollement zone at 338 to 365 mbsf. Deformation, particularly brecciation and brittle shearing, was observed despite drilling disturbance to generally increase downward in both zones, but with concentration of shear along specific horizons (Fig. 3, inside back cover). Anomalously high concentrations of thermogenic hydrocarbons, including ethane, pentane and hexane, in the gases and sediments, and unique pore water chemistry of elevated Li and Ca with decreased K, were seen within both fault zones, indicating advection of exotic fluids, possibly along sandy horizons showing brittle fracture within

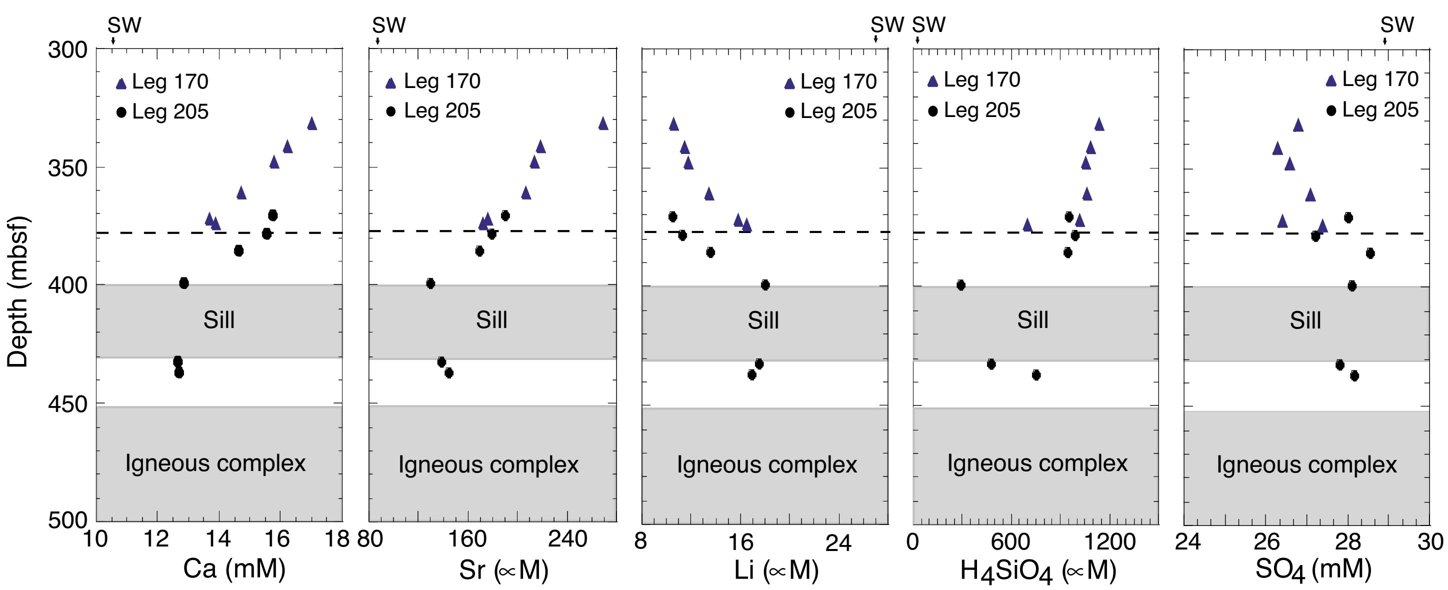

Figure 2. *Composite diagram showing chemical variation in pore fluid samples (blue triangles) collected from calcareous sediments immediately above the igneous section of the incoming plate at reference site Hole 1253A (Unit 4A, gabbro sill), showing changes towards values typical of modern seawater compositions. Data from Leg 170 pore fluid samples (black dots) nearby are shown for comparison (Silver et al., 2000).*

the fault zones. The pore fluid geochemistry suggests that some fraction of the fluids derived from regions with temperatures >90ºC to 100ºC, or possibly higher. The base of the décollement lies within the uppermost part of the underthrust section at Site 1254, as opposed to between the prism and underthrust sediment as at Leg 170 Site 1040, 50 m away.

The JOIDES *Resolution* moved to prism Site 1255, ~0.4 km inboard of the deformation front, where very limited coring was conducted to identify the décollement zone prior to a CORK-II installation. The base of the décollement is at 144 mbsf and corresponds to the lithologic boundary between prism and underthrust sediments. The chemical signature of deeply sourced fluids also was observed just above the base of the décollement zone; the signature was weaker than at Site 1254.

CORK-II INSTALLATIONS

A CORK II long-term seafloor observatory was installed at reference Hole 1253A, with temperature probes and osmotic fluid and gas samplers within the oceanic crustal section from 497 to 504 mbsf and 512 to 519 mbsf (Jannasch et al., in press). Pressure monitoring devices similar to those described for Leg 196 Nankai Trough ACORKS (Mikada et al., 2002) are located above the packer at ~453 mbsf and within the upper OsmoSampler zone (Fig. 4). The osmotic samplers consist of Teflon tubing for fluid analysis and copper tubing for gas analysis, and use osmotic membrane pumps to recover borehole fluids that are pushed progressively further along the sampling coils with time.

Two attempts were made during Hole 1254A operations to install a CORK-II into the décollement zone, and once into the shallower thrust fault. All failed due to a combination of operational difficulties and hole conditions.

At prism Hole 1255A, the CORK-II was installed successfully into the plate boundary fault, with the packer centered at 129 mbsf, the OsmoSampler for fluids and gases centered at 140 mbsf within the décollement zone, and a temperature logger and pressure monitoring screen at depth. The deployment also included an OsmoFlowmeter located below the OsmoSamplers (Jannasch et al., in press). The central injection port injects iodate, Rb and Cs at a constant rate into the incoming fluids, and is surrounded by four osmotic sampling ports that subsequently sample the incoming fluids.

FUTURE USE OF BOREHOLE INSTALLATIONS

Both Leg 205 CORK-II installations were visited by DSV *Alvin* in November 2002, and are fully operational (K. Becker, pers. comm., 2002). DSV *Alvin* will again visit both installations in March 2004, and pressure data will be downloaded. The lower interior assembly, which includes the OsmoSamplers and temperature probes, will be removed and replaced with similar units designed to operate for four years. The OsmoSampler seats for the CORK-IIs were designed to allow

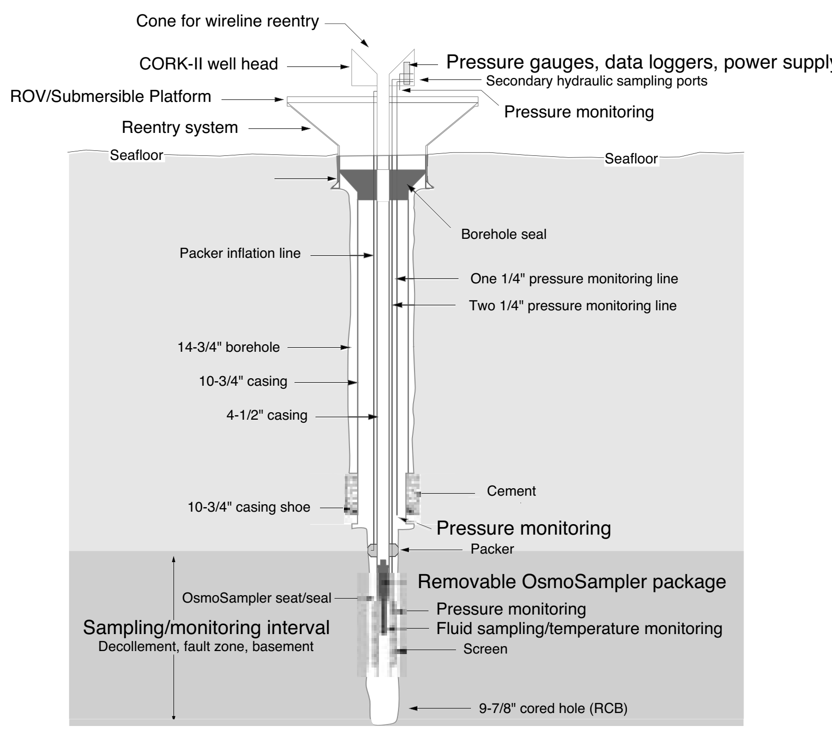

Figure 4. *Schematic CORK-II installation. In the reference site Hole 1253A, the packer is centered at 472.9 mbsf. The upper OsmoSampler is interior to the pressure monitoring centered at 500.4 mbsf, and the lower OsmoSampler dangles within the open borehole, centered at 515.8 mbsf; both are within the igneous section. In the prism Hole 1255A, the packer is centered at 129.3 mbsf and the OsmoSampler and OsmoFlowmeters are interior to the pressure monitoring screen centered at 140.2 mbsf.*

replacement without disruption of the pressure conditions established since installation and the 2004 visit. Data from the temperature probes, located in the upper and lower parts of the OsmoSamplers, will be downloaded for modeling. Fluid and gas samples from the OsmoSampler coils will be transferred to clean Teflon vials and glass ampoules, respectively, with care taken to maintain the time series preserved in the OsmoSampler coils. The diluted concentrations of the injected tracers in the fluids at Hole 1255A can be used to constrain flow rate; this can be used with fluid compositions to determine fluxes of elements such as Si, B, Li, U, K, Ca out of the downgoing plate. Ideally, post-cruise analysis of pressure and temperature data and fluid and gas chemistry will show that the boreholes have recovered from drilling disturbances and are monitoring and sampling flow of formation fluids. The combined data sets would then be used to model the hydrology of the convergent margin.

LEG 205 SCIENTIFIC PARTY

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REFERENCES

Barckhousen, U., Roeser, H.A., and von Heune, R., 1998. Magnetic signature of upper plate structures and subducting seamounts at the convergent margin off Costa Rica. *J. Geophys. Res.*, 103:7079-7093.

De Mets, C., Gordon, R.G., Argus, D.F., and Stein, S., 1990. Current plate motions. *Geophys. J. Internat.*, 101:425-478.

Jannasch, H., Davis, E., Kastner, M., Morris, J., Pettigrew, T., Plant, J., Solomon, E., Villinger, H., Wheat, C., in press. CORK II: Long-Term Monitoring of Fluid Chemistry and Hydrology in Instrumented Boreholes at the Costa Rica Subduction Zone. *In* Morris, J., Villinger, H., Klaus, A. et al., *Proc. ODP, Init. Repts.*, 205. College Station, TX (Ocean Drilling Program).

Kimura, G., Silver, E., Blum, P., et al., 1997. *Proc. ODP, Init. Repts.,* 170: College Station, TX (Ocean Drilling Program).

Langseth, M.G., and Silver, E.A., 1996. The Nicoya convergent margin: a region of exceptionally low heat flow. *Geophys. Res. Lett.,* 23:891-894.

Mikada, H., Becker, K., Moore, J.C., Klaus, A. et al., 2002. *Proc. ODP, Init. Repts.,* 196 [Online]. Available from World Wide Web: http://www-odp.tamu.edu/publications/196_IR/196ir.htm.

Newman, A.V., Schwartz, S.Y., Gonzalez, V., DeShon, H.R., Protti, J.M., Dorman, L.M., 2002. Along-strike variability in the seismogenic zone below Nicoya Peninsula, Costa Rica. *Geophys. Res. Lett.*, 10.10292002GL015409.

Shipley, T.H., McIntosh, K.D., Silver, E.A., and Stoffa, P.L., 1992. Three-dimensional seismic imaging of the Costa Rica accretionary prism: structural diversity in a large volume of the low slope. *J. Geophys. Res.*, 97:4439-4459.

Silver, E.A., Kastner, M., Fisher, A.T., Morris, J.D., McIntosh, K.D., and Saffer, D.M., 2000. Fluid flow paths in the Middle America Trench and Costa Rica margin. *Geology,* 28:679-682.

Stein, C.A., and Stein, S., 1992. A model for the global variation in oceanic depth and heat flow with lithospheric age. *Nature*, 359:123–129.

SCIENCE
Leg Reports

ODP

ODP Leg 206: Upper Oceanic Crust Formed at a Superfast Spreading Rate

Damon A.H. Teagle [1], Douglas S. Wilson [2], Gary D. Acton [3] and the Leg 206 Shipboard Scientific Party

INTRODUCTION

Sampling a complete section of oceanic crust has been an objective of scientific ocean drilling since its inception. Recovery of *in situ* ocean crust is imperative to understanding igneous accretion and the complex interplay between magmatic, hydrothermal, and tectonic processes, as well as a means for calibrating remote geophysical observations, especially seismic and magnetic data. Only by drilling a complete section of upper crust formed in a simple tectonic setting can the processes operating at normal mid-ocean ridges be understood. Leg 206 completed the initial phase of a planned multi-leg project to drill a complete *in situ* section of the upper ocean crust that will eventually extend through the extrusive layer and sheeted dikes and into gabbros. Operations were conducted at Site 1256 into 15-Ma oceanic lithosphere of the Cocos plate that was created by superfast seafloor spreading (~220 mm/yr).

SCIENTIFIC OBJECTIVES AND SITE SELECTION

The rationale for drilling crust formed at a superfast spreading rate follows the observation that an inverse relationship exists between spreading rate and the depth to axial low-velocity zones imaged by multichannel seismic experiments at mid-ocean ridges (Fig. 1). Although the exact geological nature of these zones remains unknown, they are hypothesized to be axial melt lenses or magma chambers positioned near to the dike-gabbro boundary. Recent interpretation of magnetic anomalies formed at the southern end of the Pacific/Cocos plate boundary identified crust that was formed at full spreading rates of ~200 to 220 mm/yr from ~20 to 11 Ma (Wilson, 1996; Fig. 2). This interpretation led to the selection of Site 1256 based on its high spreading rate, rapid initial sedimentation rate, heat flow predicted at only 2/3 of that at Hole 504B, and logistically favorable location in calm seas close to Central American ports. Site 1256 lies at 6°44'N, 91°56'W in 3635 m of water, ~1150 km east of the present crest of the East Pacific Rise. Four boreholes were drilled during Leg 206.

THE SEDIMENTARY OVERBURDEN

Nearly complete sedimentary sections were recovered in Holes 1256A, 1256B and 1256C.

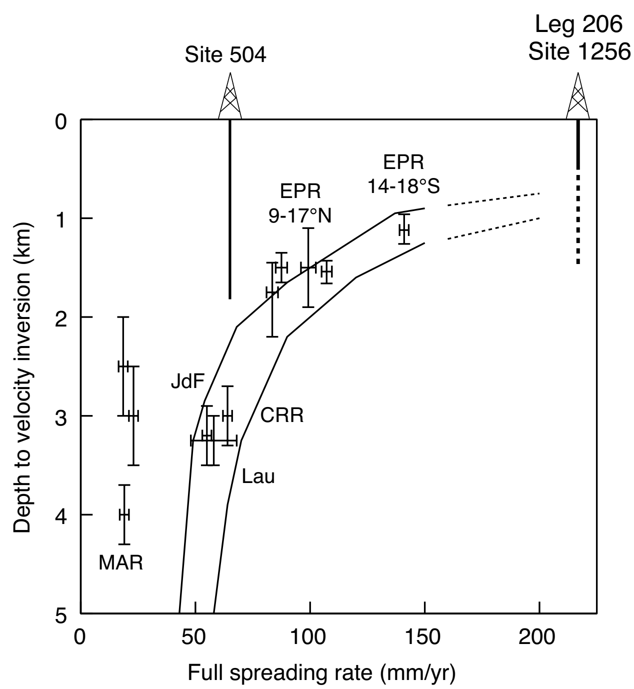

Figure 1. *Depth to axial low-velocity zone plotted against spreading rate modified from Purdy et al. (1992) and Carbotte et al. (1997). Depth vs. rate predictions from two models of Phipps Morgan and Chen (1993) are shown, extrapolated subjectively to 200 mm/yr. Penetration to date in Holes 504B and 1256D is shown by solid vertical lines. MAR=Mid-Atlantic Ridge; EPR=East Pacific Rise, JdF=Juan de Fuca Ridge; Lau=Valu Fa Ridge in Lau Basin; CRR=Costa Rica Rift.*

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The sedimentary overburden is divided into two units: Unit I (0-40.6 mbsf) is clay rich, with a few carbonate rich layers and Unit II (40.6-250.7 mbsf) is predominantly biogenic carbonate. The interval from 111 to 15 mbsf is rich in biogenic silica that forms a distinct diatom mat deposited at ~10.8 Ma. The primary control on the interstitial water chemistry at Site 1256 is diffusion between seawater and basement fluids, with a continuous chert bed at 158 mbsf providing a low-diffusivity barrier. The calcareous microfossil biostratigraphy is in good agreement with the magnetostratigraphy. Calculated sedimentation rates vary from ~ 6 to 36 m/my; these rates generally decreased with time as the site moved away from the high productivity zone near the paleo-equator. An abrupt drop in sedimentation rate after the deposition of the diatom mat may be due to a 'carbonate crash' that affected the east Pacific and the Caribbean Sea (Farrell et al., 1995). Heat flow of 113 mW/m^2 is close to the prediction for conductive cooling of oceanic lithosphere.

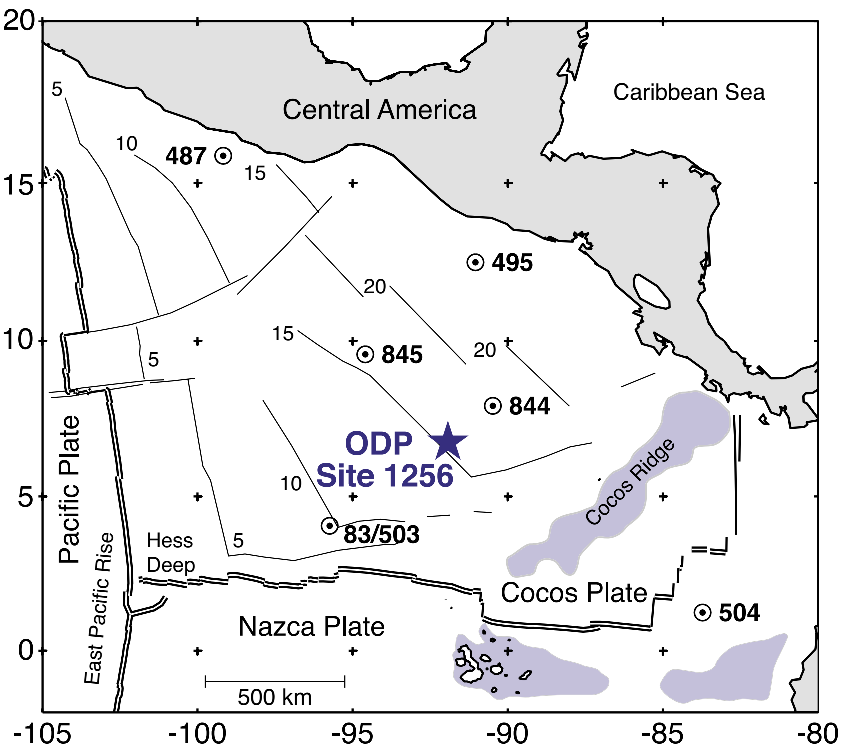

Figure 2. *Age map of the Cocos plate, with isochrons at 5-m.y. intervals based on magnetic anomaly identifications. Selected DSDP and ODP sites where boreholes reached basement are indicated by circles. Location of ODP Site 1256 visited during Leg 206 is shown by the blue star. The wide spacing of 10-my to 20-my isochrons to the south reflects the extremely fast (200 to 220 mm/yr) full spreading rate.*

OCEAN CRUST FORMED AT SUPERFAST SPREADING RATE

Pilot Hole 1256C penetrated 88.5 m into the basement with a core recovery of 61.3%. The total depth of penetration at Hole 1256D, located ~30 m due south of Hole 1256C, was 752 mbsf including 502 meters drilled into basement; recovery was 47.8%. Hole 1256 D was fitted with a large reentry cone supported by 95 m of 20-in casing and 269.5 m of 16-in casing cemented into the uppermost basement.

Igneous Stratigraphy and Geochemistry

A summary of the igneous stratigraphy is presented in Fig. 3 (inside front cover). The igneous basement is dominated by thin (10s of cm to ~3 m) basaltic sheet flows separated by chilled margins that make up ~60% of the cored interval in both holes. Massive flows (>3 m thick) are the second most common rock type in both holes and include the thick ponded flow near the top of each hole. Minor intervals of pillow lavas (~20 m thick) and hyaloclastite (a few m thick), and a single dike, were recovered in Hole 1256D. Igneous units 1256C-18 (32 m thick) and 1256D-1 (75 m thick) were interpreted to be the same ponded flow, probably deposited at least 5 km off axis in the presence of significant faulted topography. For all of the Hole 1256C flows, chemical similarity and anomalous, steep paleomagnetic inclination (where not obscured by drilling overprint) suggest rapid accumulation over, at most, a few centuries.

Shipboard measurements of petrographically fresh samples by shipboard Inductively Coupled Plasma Optical Emission Spectrometry (ICP-AES) revealed general downhole variations. Compatible elements Mg, Ca, Al, Cr, and Ni, as well as Mg# and Ca/Al ratios, broadly increase with depth, and incompatible elements Ti, Fe, Zr, Y, Nb, V, and Sr generally decrease with depth, albeit with smaller scale variations superimposed on these general trends (Fig. 3, inside front cover). All lavas from Site 1256 plot in the normal Mid-Ocean Ridge Basalt (N-MORB) field on a Zr-Y-Nb ternary diagram. Indicators of magmatic evolution such as Mg# are bimodally distributed, with an evolved population (modal Mg#=53, Cr=70 ppm) dominated by Hole 1256C lavas and the massive flows from Hole 1256D, and the primitive population (modal Mg#=61, Cr=220 ppm) dominated by thin sheet flows from Hole 1256D. Because massive flows become less common with depth, this bimodal distribution leads to overall correlations between fractionation and depth.

Two anomalous groups of samples depart notably from a general trend controlled largely by varying degrees of fractionation from similar parental magmas: one subset of samples from the massive ponded flow (Unit 1256C-18) that have very high K_2O, and one group of five samples from three igneous units with anomalously high Zr for a given TiO_2 value. Samples from 294 to 306 mbsf in Hole 1256C (approximately the middle to lower third of Unit 1256C-18) have exceptionally high K_2O (0.53 to 0.74 wt%; compared with 0.05 to 0.20 wt% elsewhere) and high natural gamma radiation (NGR), although neither the chemical nor the NGR anomaly are apparent in Hole 1256D. This large increase in K_2O is not matched by variations in Mg# or other measures of fractionation. Another explanation must be invoked, such as geochemical zonation in source composition, local assimilation of an unknown high-K sediment or altered lava, or hydrothermal alteration that had little effect on the primary crystals.

Background and Vein-Related Alteration

Rocks from Holes 1256C and 1256D exhibit a dark gray background alteration, where the rocks are slightly to moderately altered and olivine is replaced and pore spaces are filled by saponite and minor pyrite. This background alteration is reflected in the distribution of dark gray rocks and of pyrite and saponite, and is the result of low-temperature seawater interaction at low cumulative seawater/rock ratios.

Vein-related alteration is manifested as different-colored alteration halos along veins. The black halos contain celadonite and are interpreted to result from the presence of upwelling distal low-temperature hydrothermal fluids enriched in iron, silica, and alkalis (Edmond et al., 1979; Alt, 1999). The iron oxyhydroxide-rich mixed halos are later features formed by circulation of oxidizing seawater. The brown halos have a similar origin and formed along fractures that were not bordered by previously formed black halos. This vein-related alteration occurs irregularly throughout Hole 1256D below the massive ponded flow but is concentrated in two zones at 350 to 450 mbsf and 635 to 750 mbsf. These zones are likely regions of greater permeability and, consequently, increased fluid flow. The appearance of albite and saponite partially replacing plagioclase below 625 mbsf indicates a change in alteration conditions possibly due to slightly higher temperatures at depth or more evolved fluid compositions (e.g., decreased K/Na and elevated silica).

Overall, the basalts recovered from Site 1256 do not exhibit a general decrease in seawater interaction with depth, and there is no simple reduction in the amount of alteration halos or iron oxyhydroxide with depth. When the alteration of the basement section at Site 1256 is compared with other sites (Fig. 4), Holes 1256C and 1256D contain a much smaller amount of brown, mixed, and black alteration halos. The abundance of carbonate veins at Site 1256 is also lower than in many other holes. The alteration is, however, quite similar to that observed in Site 801 crustal samples also generated at a fast spreading ridge. One important feature is the lack of any oxidation gradient with depth in Site 1256, in contrast to the stepwise disappearance of iron oxyhydroxide and celadonite in Hole 504B and the general downward decrease in seawater effects at Sites 417 and 418.

Downhole Logging

Although logging of the sediment-basement interface in Hole 1256C was only partially successful due to poor hole conditions. A full suite of logging tools was run successfully in Hole 1256D, with the exception of the Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) gyromagnetometer. The

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tools utilized were the triple combo tool string, the Formation MicroScanner (FMS)/sonic, the BGR gyromagnetometer, the Ultrasonic Borehole Imager (UBI), and the Well Seismic Tool (WST). This is the first time the UBI has been used in a hard rock hole. The downhole measurements and images show a large amount of variation across the massive units, lava flows, pillow lavas, and hyaloclastites recovered in Hole 1256D. Excellent images from both the FMS and UBI, coupled with other measured parameters, will allow the stratigraphy of different rock types and flow thicknesses to be determined and structural features to be measured onshore. Post-cruise core-log integration will be greatly enhanced due to the scanning of the outside surface of all pieces of orientable core recovered using the Deutsche Montan Technologie (DMT) Digital Color CoreScan system. This will allow the determination of the true depth of the recovered pieces and the direct calibration of downhole parameters with rock type.

A second cruise to Hole 1256D dedicated to deep drilling is estimated to be able reach a depth in excess of 1400 m sub-basement, using rates of penetration of ~1.4 m/hr recorded during Leg 206 and during Hole 504B drilling. Successful drilling would reach depths at which gabbros are predicted to occur, and allow the first sampling of a complete section of *in situ* upper ocean crust.

LEG 206 SCIENTIFIC PARTY

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REFERENCES

Alt, J.C., 1999. Very low grade hydrothermal metamorphism of basic igneous rocks. *In* Frey, M., and Robinson, D. (Eds.), *Very Low Grade Metamorphism*, Cambridge, UK (Blackwell Scientific), 169–201.

Alt, J.C., in press. Alteration of the Upper Oceanic Crust: Mineralogy, Chemistry, and Processes. *In* Davis, E. and Elderfield, H. (Eds.), *Hydrogeology of the Oceanic Lithosphere*, Cambridge, UK (Cambridge University Press).

Carbotte, S., Mutter, C., Mutter, J., and Ponce-Correa, G., 1997. Influence of magma supply and spreading rate on crustal magma bodies and emplacement of the extrusive layer: insights

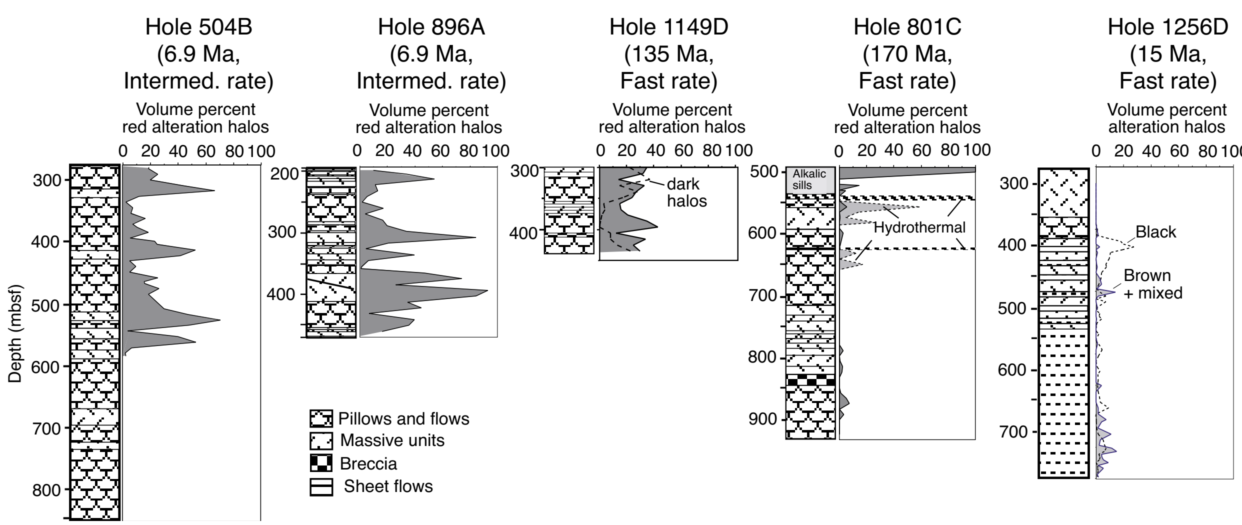

Figure 4. *Distribution of alteration zones with depth in selected ODP basement sections (Alt, in press). Hole 1256D is shown for comparison.*

from the East Pacific Rise at lat 16°N. *Geology,* 26:455-458.

Edmond, J.M., Measures, C., Magnum, B., Grant, B., Sclater, F.R., Collier, R., Hudson, A., Gordon, L.I., and Corliss, J.B., 1979. On the formation of metal-rich deposits at ridge crests. *Earth Planet. Sci. Lett.,* 46:19-130.

Farrell, J.W., Raffi, I., Janecek, T.R., Murray, D.W., Levitan, M., Dadey, K.A., Emeis, K.-C., Lyle, M., Flores, J.-A., and Hovan, S., 1995. Late Neogene sedimentation patterns in the eastern equatorial Pacific. *In* Pisias, N.G., Mayer, L.A., Janecek, T.R., Palmer-Julson, A., and van Andel, T.H. (Eds.), *Proc. ODP, Sci. Results,* 138: College Station, TX (Ocean Drilling Program), 717–756.

Phipps Morgan, J., and Chen, Y.J., 1993. The genesis of oceanic crust: magma injection, hydrothermal circulation, and crustal flow. *J. Geophys. Res.,* 98:6283-6297.

Purdy, G.M., Kong, L.S.L., Christeson, G.L., and Solomon, S.C., 1992. Relationship between spreading rate and the seismic structure of mid-ocean ridges. *Nature,* 355:815–872.

Wilson, D.S., 1996. Fastest known spreading on the Miocene Cocos-Pacific plate boundary. *Geophys. Res. Lett.,* 23:3003-3006.

ITALIA 2004

32ND INTERNATIONAL GEOLOGICAL CONGRESS

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Topical Symposium T26.02

PROGRESS FROM INVESTIGATIONS OF ACTIVE ANALOGUES OF ANCIENT MINERALIZATION

Conveners:
Damon A.H. Teagle* and Maria Boni

There has been significant recent progress in understanding ancient ore deposits through investigations of active mineralization processes both in the oceans and in continental settings. Although we would like to highlight the discoveries made through the direct sampling by the Ocean Drilling Program of active seafloor hydrothermal systems on bare-rock and sedimented mid-ocean ridges and arcs, we wish to include other research into active analogues for ore-forming systems. These include shear-zone hosted metamorphogenic gold, epithermal, Cu-porphyry, placer/paleoplacer, weathering/paleoweathering and many other styles of mineralization. In this Symposium we aim to bring together researchers of both ancient and active ore-forming systems to highlight the progress made, and discuss whether the active systems investigated truly represent the processes that formed the Earth's major mineral deposits.

*Please contact Damon Teagle (dat@soc.soton.ac.uk) to contribute to this session.

Abstract deadline: 10th January, 2004

The 32nd IGC will be held in the beautiful setting of the Fortezza da Basso, Florence.
Additional information about the Scientific Program can be found on the 32nd IGC website:
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PLANNING Panel Reports

ODP IODP

Final Report Excerpts: Hard Rock Working Group of the JOIDES Scientific Measurements Panel (SCIMP)

James Allan (Chair and SCIMP Co-Chair) [1], Jeff Alt [2], Shoji Arai [3], Sherman Bloomer (SCICOM member) [4], Georges Ceuleneer [5], Henry Dick [6], Jay Miller [7], James Natland [8], Paul Robinson [9], Peter Herzig (SCICOM Member) [10], and Chris Macleod (SCICOM Member) [11]

INTRODUCTION

The Hard Rock Working Group arose from discussions within the June 2001 JOIDES Scientific Measurements Panel (SCIMP) regarding the need to create new means of more effectively describing hard rock core. The acquisition of the GEOTEK line scan camera onboard the JOIDES *Resolution* offered unparalleled opportunities to modernize and streamline how hard rocks are described. ODP hard rock descriptive methods use an antiquated system that requires the core to be hand drawn; descriptions are based on artificial coring and curation intervals and not linked to visual core representations. SCIMP recognized at the June 2001 meeting that it did not have the internal expertise required for making effective recommendations for overhauling hard rock core description. With the following motion, SCIMP requested permission from the JOIDES Science Committee (SCICOM) to convene a workshop with additional expertise and experience as needed for making effective suggestions for core descriptive program and database design:

> **SCIMP Motion 01-1:** SCIMP recommends to SCICOM that a workshop be convened to define the characteristics and requirements of a hard rock core description methodology. The implementation of the GEOTEK line scan camera provides a digital image that may serve as the foundation of a core's description. The workshop should look forward to the [Integrated Ocean Drilling Program,] IODP.

During discussion of this motion in August 2001, SCICOM believed that a more effective tack would be for SCIMP to initially seek advice from experienced members of the hard rock drilling community by forming a short-lived Hard Rock Working Group, allowing the effective expertise of the SCIMP to be expanded greatly. In essence, this group would represent the community in examining critical issues of hard rock description in IODP, and make recommendations to SCIMP regarding developmental needs required to take full advantage of digital image acquisition. The following consensus statement was made:

> **SCICOM Consensus 01-02-04:** In response to SCIMP Recommendation 01-1-4, SCICOM approves a small SCIMP working group to define the characteristics and requirements of a hard rock description methodology. This working group should have approximately six members representing volcanic, magmatic, metamorphic, and structural expertise, should be organized no later than the next SCIMP meeting, and should meet once at ODP-TAMU. The SCIMP co-chairs should be prepared to report on the working group findings at the next SCICOM meeting.

In subsequent discussions with the SCICOM Chair, a slightly larger working group was approved to ensure expertise depth regarding the descriptive needs of complex igneous, metamorphic, and sulfide core, all with potential structural overprints. Additionally, the group was asked to take advantage of work done during JANUS [database] planning, namely "picking up where JANUS left off."

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[2] University of Michigan, USA
[3] Kanezawa University, Japan
[4] Oregon State University, USA
[5] Centre National de la Recherche Scientifique, France
[6] Woods Hole Oceanographic Institution, USA
[7] Texas A&M University, USA
[8] University of Miami, USA
[9] Dalhousie University, Canada
[10] University of Freiberg, Germany
[11] University of Wales, UK

The Report of the Hard Rock Working Group, if accepted by SCIMP and SCICOM, would be forwarded to the IODP planning structure for further endorsement. It was further understood that endorsement by the interim Scientific Measurements Panel (iSCIMP) and the interim Planning Committee (iPC) could lead to attempts to raise funds for a larger community workshop, if deemed necessary.

The summary recommendations below are excerpted from a report compiled following the Hard Rock Working Group meeting held at the Ocean Drilling Program, Texas A&M University, from May 9-10, 2002. The group present at the meeting represented the experience gained via participation on 57 DSDP and ODP legs. Additional expertise was provided by other members who were not able to attend but participated in the compilation of the meeting report. All recommendations represent consensus points agreed upon by all present before the meeting ended.

Given the emphasis on hard-rock description methods for IODP, the Hard Rock Working Group report was presented at the iPC session of the August 2002 SCICOM and iPC meetings in Ghent, Belgium. The iPC forwarded the report to iSCIMP and the IODP Science Planning Committee for potential implementation in IODP.

HARD ROCK WORKING GROUP RECOMMENDATIONS

Recommendation #1: *Real-time digital line scan images need to be the foundation for core description and sampling in IODP.*
Rationale: As shown by work done by the JANUS core description working groups and by the OD21 database concept, real-time digital images of the core most easily serve as a foundation for the description of igneous and metamorphic rock core that typically contain complex, hard to draw features.

Recommendation #2: *We will continue to need color film to represent the archive image of the core, but color film cannot supplant the digital line scan image for core description and sampling purposes. When the dynamic range of CCD cameras equals that of film, the film may be replaced by the CCD digital image, depending on archival requirements.*
Rationale: Experience with the current GEOTEK line scanner underlines the fact that the relatively limited dynamic range of current line scanner technology does not allow for effective color calibration. The Group acknowledges that this will likely change in the future.

Recommendation #3: *To ensure accurate color rendition of the core, a dedicated core image laboratory should be an integral part of the ship and core flow design.*
Rationale: Color accuracy for archival digital images requires that all components in the imaging chain be continuously calibrated for color balance. Sufficient space is also needed for proper illumination geometry and to provide effective implementation of track-mounted digital line scanners.

Recommendation #4: *A fundamental part of any core description package should be the real-time annotation of the core image for descriptive and sampling documentation purposes. Annotation should be within a multi-layer environment, with an X-Y, GIS-like coordinate system linked to a relational database.*
Rationale: This need for real-time annotation was recognized during JANUS planning as a fundamental need for effective description of complex core. In this manner, areas and features of description and sampling are directly noted and linked spatially to descriptive text in the database. The GIS framework allows for layers of information to be linked to a single geographic point in the core.

Recommendation #5: *Line scan images should be made of both the archive and working halves. These images will serve as the foundation for description of the archive half and sampling of the working half. Annotations of these images, preserved in the database, will directly show what feature was described or what area and volume was directly sampled. Sampling annotation of the working half should continue after the cruise.*
Rationale: Even though every attempt is made

to split key features of the core so that they are represented in both the archive and working halves, in practice this is simply not possible. As a result, a permanent visual record needs to be made of both core halves. The line scan image of the working half would function as an effective template for providing visual record of sampled core areas and features, easily showing what is available for future sampling.

Recommendation #6: *Whole-core digital imaging of the unsplit core should be available for routine use as is needed by Leg science. These images should be available for display and annotation in the core description software.*
Rationale: When shipboard parties decide to split the core so as to split features as best as possible between an archive and a working half, the core splitting is already an interpretive process. Often it is the most stunning, easy to see structures that are split, so other fundamental features may be missed, and the manner in which the core is split influences how it may be described. The Group considered examples of whole-core digital imaging from Leg 176, showing correlation of features and magnetic susceptibility data with the unwrapped whole-round image. Concern was expressed as to whether these images could be efficiently incorporated within the core description software package, although this would be desirable.

Recommendation #7: *There is a fundamental need to accurately place in three-dimensional location all coherent core pieces as the core is being described. Critical towards this requirement is the development of bit, bottom hole assembly (BHA), and rig instrumentation, including measuring resistivity, weight on bit (WOB), and torque on bit (TOB) at the drill bit. We also foresee the need, in particular, of directly monitoring core recovery, and encourage further development and deployment of the Sonic Core Monitor.*
Rationale: These engineering developments are necessary for scientific parties to make rational decisions about where to place core in spatial context where recovery is less than 100%. These measurements would effectively complement core-log integration procedures.

Recommendation #8: *Routine processing of the core should include determining depth-shifted core location and orientation using all available coring, logging, and descriptive data. The core description software package should include the ability to display all related data for this effort.*

Recommendation #9: *Despite the need to accurately render in space all coherent core pieces, all core measurements and descriptions should be fundamentally linked to curated depth rather than to an interpreted, adjusted depth.*

Rationale for Recommendations 8 and 9: Any spatial shifting of core represents an interpretive process. The foundation of the core description database should be made on raw data, which is represented by the curated depth of individual core pieces.

Recommendation #10: *Continuous quantitative and semi-quantitative descriptions of specific core features, as currently collected down core in spreadsheet format, are integral to core description and must be incorporated into the database for core-log integration and analysis.*

Recommendation #11: *Integrated textual descriptions of core should be based on mappable unit boundaries, not on artificial sectional or core boundaries based upon intervals of coring.*

Recommendation #12: *We recommend that common spreadsheet fields be defined that may be incorporated into a relational database. We further recommend that common, basic templates be defined for igneous, metamorphic, structural, volcaniclastic, and sulfide lithology. Any descriptive system should allow addition of other critical fields so as to allow leg or project-specific descriptive logs to be created.*

Rationale for Recommendations 10, 11, and 12: The Group felt that a key aspect of effective core description is to describe quantitatively and semi-quantitatively the variation in rock stratigraphy, properties and composition, rather than focus on distinct descriptions on core sections that are recorded as independent observations. Our discussion resulted in a model most useful for description of igneous and metamorphic rock recovered in a drilling program of one or more legs dedicated to crustal drilling.

Staffing of at least several petrologists with igneous, metamorphic, and structural specialization is implicit in our core description system design, with members of these specialties required for proper documentation of all aspects of the core. An analog might be the dedicated paleoceanography program describing the high-resolution stratigraphy of sediment obtained by advanced hydraulic piston coring. Obviously, during legs with limited objectives in the ocean crust, and only one or two petrologists, the core description protocols will be different, and probably more limited. Our general model thus is to allow scientific parties to develop core descriptions emphasizing those aspects of the rocks having particular relevance to their own general scientific objectives. We do not propose an all encompassing template to be used by everyone, but one with flexible attributes, and components or modules that can be selected and modified as necessary. We thus propose using a basic descriptive template keyed to at least one form of digital image of the core, but with options to use additional images as they are deemed useful, and as core flow and staffing allow. The computer environments that now exist also mean that we can also incorporate digitized shipboard laboratory measurements obtained using the multi-sensor track or other instruments. Both images and these laboratory measurements plotted versus depth thus can be brought up on monitors simultaneously and used as a basis for, or components of, the core descriptions. These should be incorporated to the extent that they are useful and consistent with the physical limitations of the core lab and the personnel available to describe the core.

Effectively, this means that there cannot be a single defined database template to serve the needs of all hard rock legs. Instead, we envision spreadsheet templates containing defined fields common to all legs, with an additional 8 to 10 fields that should be leg-specific and user-definable.

Recommendation #13: *A digital image library of rock features such as textures should be incorporated into the database or descriptive program. An additional descriptive cookbook for hard rock needs to be developed.*
Rationale: Planning for JANUS core description recommended pull-down menus for input of the myriad textural terms used in rock description. While choosing not to follow this exact model, we nonetheless see the wisdom in providing user-friendly visual examples of textures used in hard-rock description. A descriptive cookbook is thought to be a more effective, simpler way of ensuring quality hard rock description rather than complex, pull-down menus for filling in descriptive terms.

Recommendation #14: *Any core description package has to include the full description of thin sections, noting that it represents discontinuous data.*

Recommendation #15: *We endorse the OD21 concept of linking core close-up and photomicrograph images with annotation of the core digital images.*

The JOI Alliance Welcomes the Inauguration of IODP

Steven R. Bohlen, Director of JOI

INTRODUCTION

After a decade of planning and negotiation, US participation in the Integrated Ocean Drilling Program (IODP) officially began on September 30, 2003 when Joint Oceanographic Institutions (JOI) signed a ten-year contract with the National Science Foundation (NSF), and NSF committed funds to the US program. For JOI and its partners, Lamont Doherty Earth Observatory (Lamont) and Texas A&M University (TAMU), as well as the US oceans community, September 30 signaled a new chapter in the most important of geoscience endeavors.

The contract signing preceded the official start of the IODP on October 1, and allows the US to bring a research vessel online by next June. Following the advice of the IODP science planning and operations committees, the first expedition will take place next summer at the Juan de Fuca Ridge in the northeast Pacific Ocean to study fluids in the oceanic crust. Other expeditions approved at the meeting propose to (1) develop a millennial-scale stratigraphic template (North Atlantic, September-November 2004); (2) document the conditions under which oceanic core complexes develop (CORE I, November 2004-January 2005); (3) CORE II (January-March 2005); and (4) install a Circulation Obviation Retrofit Kit (CORK) to study bottom water temperature (North Atlantic with CORK, March-May 2005).

The IODP will use the JOIDES *Resolution*, after minor improvements, for these expeditions and for one to two more years. An enhanced vessel capable of achieving the long-range science and engineering goals of IODP will then be acquired, converted, and operated by the JOI Alliance.

The beginning of the IODP seems very similar to that of the ODP: one vessel, the JOIDES *Resolution*, conducting two month expeditions led by JOI, Lamont and TAMU. What is new? How will JOI and its partners change in response the challenges of the new drilling program? With contracting formalities complete, the JOI Alliance invites the research community to read the technical proposal to NSF for systems integration of the riserless vessel and related activities in IODP (available on the JOI website (http://www.joiscience.org). Program highlights are summarized here, along with ideas about the overall scientific goals of the program and what the future might bring.

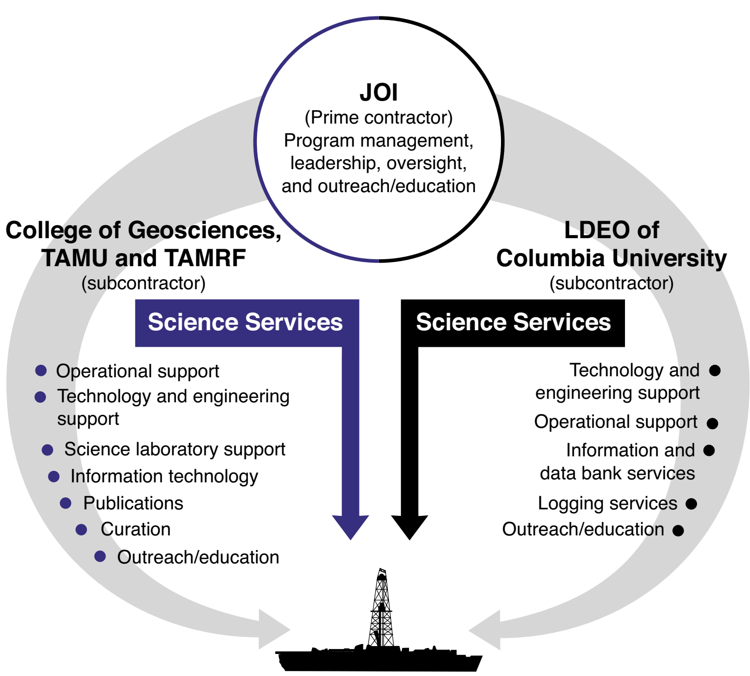


***Figure 1.** Structure of the JOI Alliance for US participation in IODP.*

MANAGEMENT OF THE US RISERLESS DRILLING PROGRAM

To address the new challenges presented by the complexity of a multiplatform program, including the need for coordination and cooperation among the many parties in IODP, JOI and its partners developed a fully integrated alliance that will function synergistically to deliver a wide variety of services to the US and international ocean drilling communities (Fig. 1). The JOI Alliance was developed both in response to the needs of the new program and to implement modifications based on what has, and what has not, worked well in ODP.

For IODP to succeed, four organizations - IMI (IODP Management International), CDEX

(Center for Deep Earth Exploration, the implementing organization within JAMSTEC), the ECORD (European Consortium for Ocean Research Drilling) Science Operator, and the JOI Alliance - must function well together. On the basis of this imperative, leaders at JOI, Lamont, and TAMU concluded that much closer coordination and cooperation, and greater interaction through team approaches to high-level management and operational decision-making, were essential to the success of the US program in IODP. Enhanced science services will be delivered by six teams.

The JOI Alliance Systems Integration Team, led by the President of JOI, the Director of Lamont, and the Dean of the TAMU School of Geosciences, will be responsible for strategic planning and systems integration performance. The JOI Alliance Systems Management Team, led by the Director of Ocean Drilling Programs at JOI, the Director of Science Services at TAMU, and the Director of the Borehole Research Group at Lamont, will be responsible for day-to-day management of the program, setting of priorities, resource allocation, and systems and team integration.

Four teams, led by appropriate individuals from each of the Alliance institutions, have responsibility for integration of various systems and facilities in the areas of operations, technical development, information, and publications-education-outreach (see proposal for details). The Joint Operations Team is responsible for cost-effective and operationally efficient delivery of science within budget constraints. The Joint Technical Development Team is responsible for assessing technological advancements for IODP and to develop cutting edge technology beneficial to the science mission of IODP. The Joint Information Team will be responsible for leading the entire spectrum of information technology infrastructure, data management, and software application support, and developing and seamlessly integrating the latest technological enhancements. The goals of the Joint Publications and Education/Outreach Team (now renamed JREPORT) are to manage the delivery of all required publications and reports for the riserless drilling program, and to communicate scientific discoveries arising from shipboard and post cruise research through public relations and education and outreach initiatives.

Mindful that integrated performance is the key to the success of IODP, yet aware of the potential problems of the team approach, the Alliance teams are designed to be small and to focus on priorities and outcomes. The team approach will be supported by clear and well-defined contracting relationships with clear lines of authority and responsibility. The focus of the JOI Alliance is the constellation of stakeholders in IODP (Fig. 2). Integration of activities through joint decision-making and priority setting is essential if the riserless program is to perform well in the framework of the larger and more complicated IODP. Furthermore, the Alliance must be well coordinated to serve effectively the many stakeholders depicted in Figure 2. Ultimately, assessments by these stakeholders, and performance management committees made up of community leaders, will establish external benchmarks for the success of the Alliance approach.

EDUCATIONAL AND RESEARCH INITIATIVES IN SUPPORT OF IODP

The JOI Alliance, via substantial financial commitments by Lamont and TAMU, will

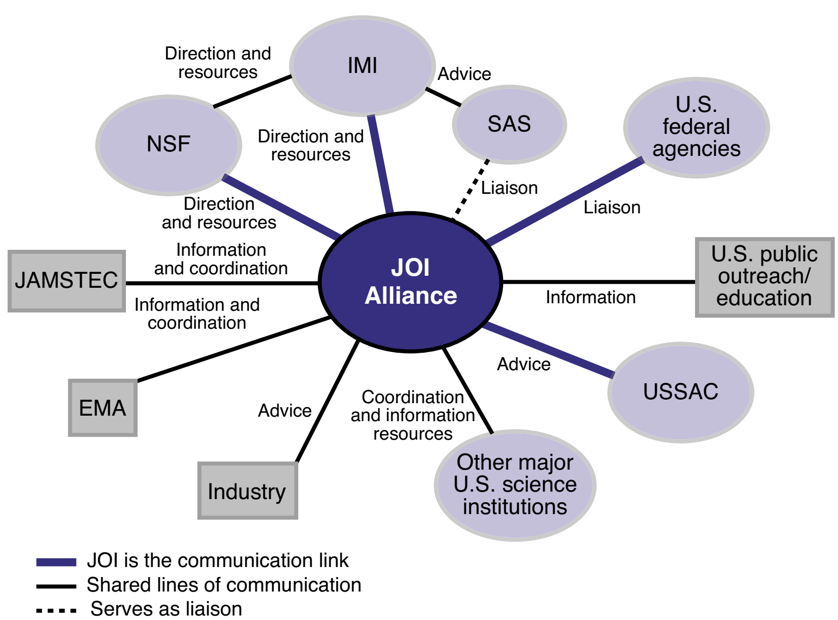


Figure 2. *Stakeholders in IODP served by the JOI Alliance.*

wrap the operational aspects of science delivery for IODP in robust educational and research initiatives. These educational and research efforts, called LODOS (Laboratory for Ocean Drilling, Observation, and Sampling) at Lamont and ODASES (Ocean Drilling and Sustainable Earth Science) at TAMU, are designed to merge strategic mission objectives of these institutions with the science imperatives of IODP (Fig. 3), and to interact with the operational aspects of the program to enhance science delivery for all of IODP. Lamont will fund new postdoc positions and faculty support, educational and outreach efforts, and telecommunications facilities in support of LODOS. TAMU will fund an endowed chair, five new faculty positions in five departments (to be matched with five positions from each of the departments), five new graduate assistant fellowships, education and outreach initiatives, visualization, immersive imaging and telecommunications facilities in support of ODASES. The JOI Alliance Systems Integration Team will be responsible for the synergistic development of these initiatives.

IODP GOALS

Science programs are most productive when their goals are well formulated. Similarly, organizations function best under a well defined mission and a clear set of priorities. The following questions articulate IODP science priorities as expressed in the Initial Science Plan (ISP; http://www.iodp.org) :

1. What is the extent and character of the Earth's deep biosphere, and how has it affected the Earth's geological and environmental evolution?
2. What processes cause environmental change on the Earth, and how are these changes initiated, propagated, amplified or muted?
3. How are solid Earth cycles and geodynamics expressed on the Earth's surface, and how do they influence surficial Earth processes and the environmental history of the Earth?

Less clearly identified in the ISP and supporting documents are the specific goals of IODP beyond the scientific objectives. The following list of goals is offered to guide the activities of IODP management and members of the science community involved in IODP:

1. Create new knowledge and understanding of the Earth's deep biosphere, environmental change, and solid Earth cycles and geodynamics.
2. Develop new avenues of research through partnerships with biologists, physicists, chemists, engineers, and social scientists.
3. Connect ocean drilling with national and international science initiatives.
4. Develop a new generation of leaders in the ocean sciences.
5. Create a society literate in the ocean sciences.

These goals extend beyond IODP and can only be achieved with the support of many national programs (such as the US Science Support Program and its equivalents in other countries) designed to support IODP. The management challenges of IODP are significant and societal expectations of major science programs are broad and high. The JOI Alliance has organized for success in this environment. We look forward to serving the international science community in helping to lead IODP.

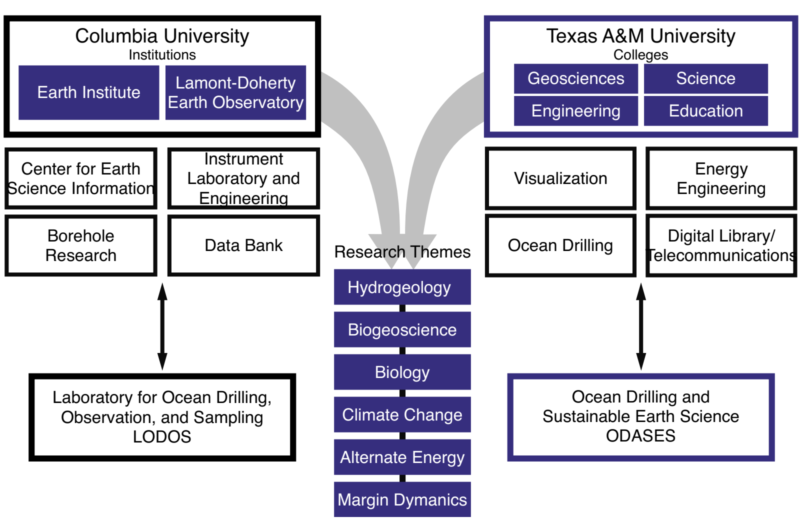
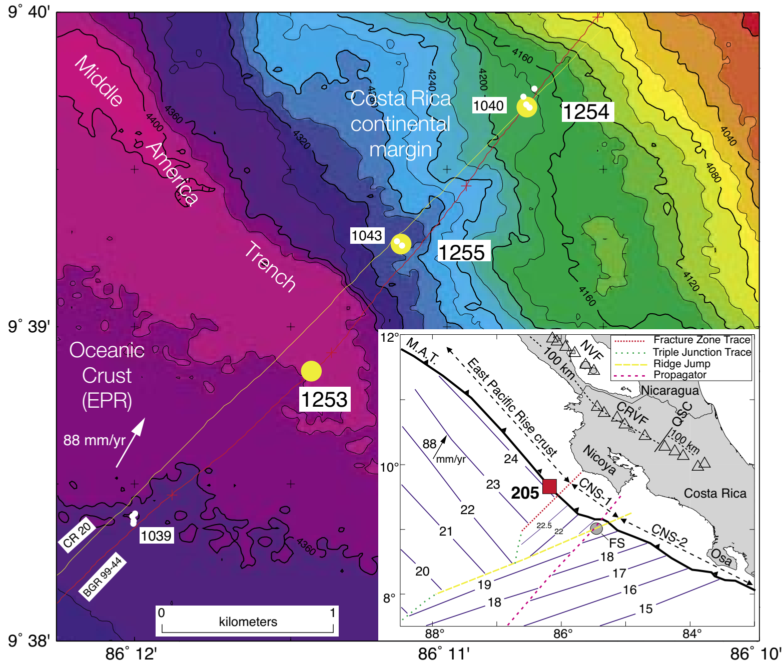


Figure 3. *Educational and research initiatives at Lamont-Doherty Earth Observatory (LODOS) and Texas A&M University (ODASES) established in support of IODP.*

In this issue from pages 10-13:

ODP Leg 205: Fluid Flow and Subduction Fluxes Across the Costa Rica Convergent Margin



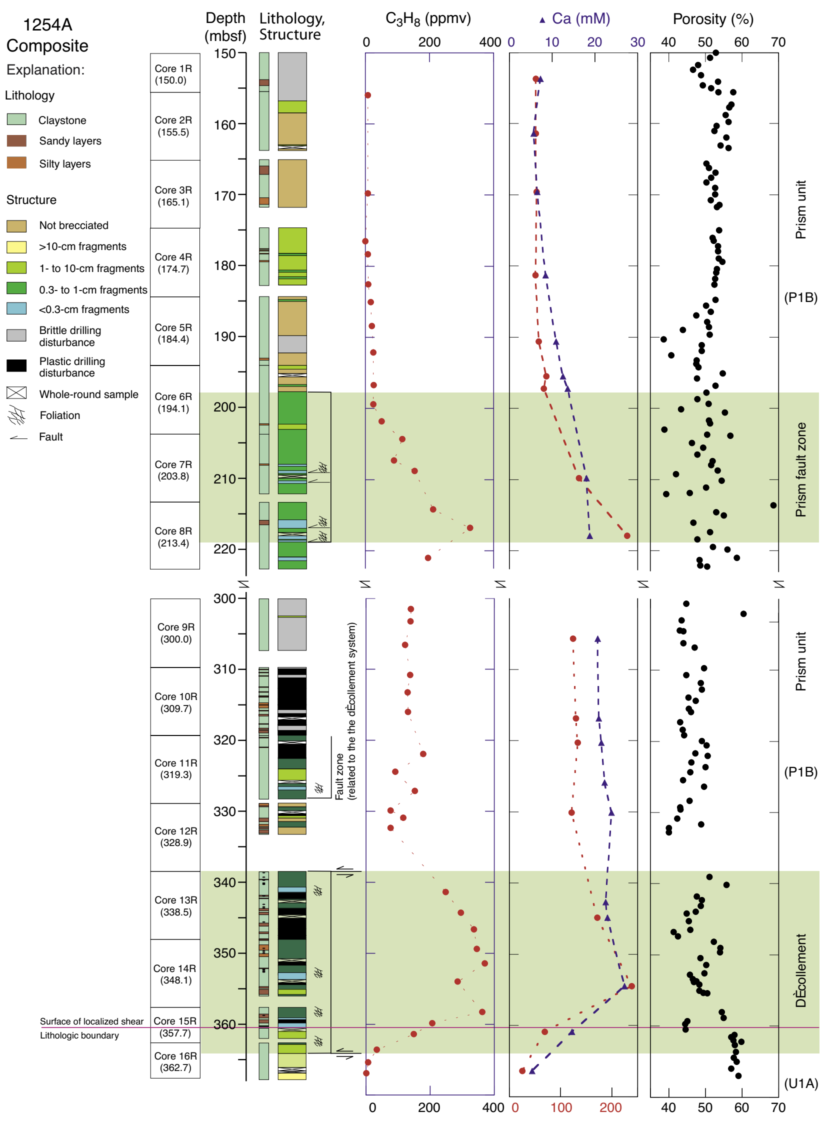


Figure 1 (above). *Bathymetric map offshore Costa Rica with ODP Leg 205 (yellow circles) and Leg 170 (white circles) drill sites; bathymetric contours in m. Seismic profiles shown by red lines (BGR-99-44; C. Reichert and C. Ranero, pers. comm., 2001) and white lines (CR-20; Shipley et al., 1992). Inset shows the Leg 204 drilling area (red box) and isochromes derived from seafloor magnetic anomalies (Barckhousen et al., 1998). Numbers indicate crustal age in Myr. Tectonic boundaries, volcanoes (triangles), convergence direction, and convergence rate (arrow; De Mets et al., 1990) are shown. FS=Fisher Seamount, QSC=Quesada Sharp Contortion.*

Figure 3 (left). *Summary of results at Leg 205 Hole 1254A, showing structural observations within the thrust fault and décollement zone, porosity variations, and elevated pentane, Li and Ca concentrations within the fault zones.*

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