DOE/NETL Project Review Meeting
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In-Situ Sampling and Characterization of Naturally-Occurring Marine Methane Hydrate: ODP Leg 204, Hydrate Ridge

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D/V JOIDES *Resolution*

The JOIDES *Resolution* is a uniquely outfitted dynamically-positioned drill ship, that has a seven-story laboratory complex onboard. This vessel has been contracted for the Ocean Drilling Program (ODP) since 1985 to conduct worldwide scientific coring operations.

JOI/ODP Proposal to U.S. DOE/NETL "Methane Hydrates" Solicitation

NETL awarded $ 1,438,202 (including cost-share) in Phase 1 of this cooperative agreement, entitled: "In-Situ Sampling and Characterization of Naturally Occurring Marine Methane Hydrate Using the D/V JOIDES Resolution".

Tasks 1-7: Upgrade the ODP Pressure Core Sampler (PCS), PCS gas manifold, and ODP memory tools (DVTP, DVTP-P, APC-methane, APC-T tools) for use on Legs 201 and 204.

Acquire equipment to characterize methane hydrates (e.g., G/GI Seismic Gun, Infrared Thermal Imaging System); modify the FUGRO piezoprobe tool for use with the ODP bottom hole assembly (BHA). Geriatrics Study on Leg 204.

JOI Cooperative Agreement with DOE/National Energy Technology Lab

Deliverable: Task 1.1 - Preliminary Evaluation of Existing Pressure/Temperature Coring Systems (October 2002).

Report available online at DOE/NETL website.
http://NETL.CERTREC.COM
Login: NETL
Password: ARCHIVE
Go to Bottom of List (52.4 MB file)
HYD_00037_2001.PDF

739 page summary of information available about four existing pressure coring systems synthesized from Technical Notes, JOIDES meeting minutes, Web Pages, and other information sources.

Pressure Coring of Methane Hydrates

ODP Pressure Core Sampler (PCS): wireline-retrievable, top-drive rotary/push; standard tool; 10,000 psi (690 bar) max. pressure. Gas manifold system mates to tool for measuring gas volume and composition of gas.

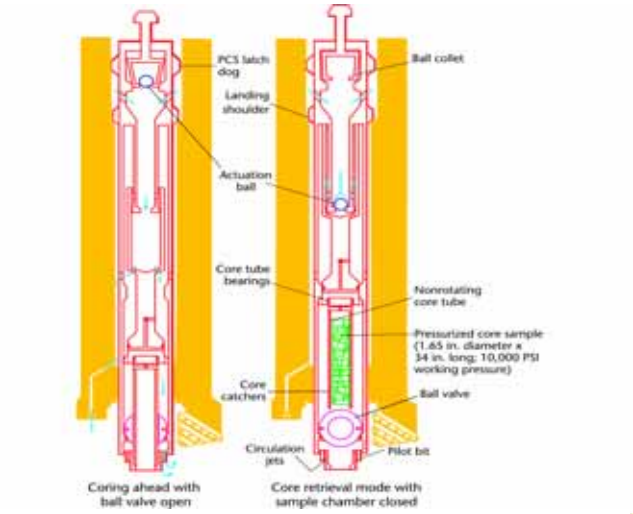
FUGRO Pressure Corer (FPC): wireline-retrievable, percussion/push; prototype tool; 3625 psi (250 bar) max. pressure.

HYACE Rotary Corer (HRC): wireline-retrievable, downhole mud motor rotary/push; prototype tool; 3625 psi (250 bar) max. pressure.

JNOC Pressure Temperature Core Sampler (PTCS): wireline-retrievable, top-drive rotary/push; 3,500 psi (241 bar) max. pressure.

Only the ODP PCS Tool testing was part of the DOE/NETL cooperative agreement with JOI. However, JOI negotiated a collaborative agreement with the HYACINTH consortium for testing and use of their two pressure coring tools during ODP Legs 201 and 204 at no cost to the DOE project.

ODP Pressure Coring System (PCS) - Task 2



ODP Leg 164 (Nov-Dec 1995)
Blake Ridge and Carolina Rise

Operating Parameters for PCS Rotary Coring:

- **RPM: 40 – 60 rpm**
- **Flow Rate: 200 gpm**
- **WOB: 15 – 20 klbs**
- **Core Barrel Spaced-out where the cutting shoe was positioned at either 0.15 m or 0.46 m ahead of the bit.**

ODP Leg 164 PCS Results:

- **Total deployments: 46**
- **Successful (i.e., core under pressure): 24**
- **Average core recovery: 31%**
- **Average pressure retention: 77%**
- **Average push core recovery 48%**
- **Average rotary core recovery 14%**

PCS Tool Modifications Prior to ODP Leg 201

- **New Cutting Shoe Designs**
- **Extended Cutting Shoe - Meter Ahead of Bit**
- **Improved Flow to Cutting Shoe**
- **Increased Inner Barrel ID (inside clearance ratio from 5% to 8%)**
- **Eliminated Core Catchers**

PCS Cutting Shoe Test at Maurer Facility November-December 2002

- **Test Rock: Texas Cream limestone, compressive strength of 2600 psi.**
- **Test Matrix using Flow Rate, Rotation Speed and Weight on Bit as variables.**
- **Conclusions:**
  - **RPM > 150 rpm**
  - **Flow > 200 gpm**
  - **WOB = 3 - 5 klbs**

ODP PCS Tool Specifications

	Leg 164	Leg 201/204
Core Diameter	1.65 in/42 mm	1.70 in/43.2 mm
Core Length	34 in/0.86 m	39.4in/ 1.00 m
Core Volume	1190 cc	1465 cc
Cutter O.D.	3.75 in/95.3 mm	3.75 in/95.3 mm

ODP Leg 201 (Feb-Mar 2002)
Offshore Peru Continental Margin

Operating Parameters for PCS Rotary Coring:

- **RPM: 100 – 120 rpm**
- **Flow Rate: 100 – 200 gpm**
- **WOB: 7 klbs**

ODP Leg 201 PCS Results:

- **Total Deployments: 17**
- **Successful (core under pressure): 13**
- **Average Core Recovery: 76%**
- **Average Pressure Retention: 67%**
- **Methane Found in Gas Samples: 11 Runs**
- **Methane Gas Recovered: 16 Liters**

PCS Tool Modifications Prior to ODP Leg 204

- **Installed APC Methane Tool at Top of Core Barrel Assembly for Continuous Temperature and Pressure Recording (required removing accumulator).**
- **Increased Strength of Bit Sub Connection**
- **Changed Core Barrel Material to Stainless Steel**
- **Increased Link Pin Diameter for Strength**

ODP Leg 204 (Jul-Sept 2002)
Hydrate Ridge, Offshore Oregon

Operating Parameters for PCS Rotary Coring:

- **RPM: 80 – 100 rpm at depths greater than 100 mbsf, 50 rpm at shallower depths**
- **Flow Rate: 100 gpm**
- **WOB: 5 klbs**

ODP Leg 204 PCS Results:

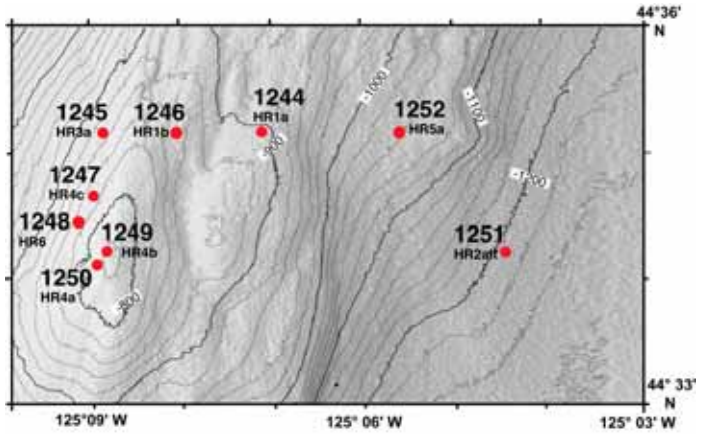
- **Total Deployments: 39**
- **Successful (core under pressure): 30**
- **Average Core Recovery: 95%**
- **Average Pressure Retention: 64%**
- **Methane Found in Gas Samples: 30 Runs**
- **Methane Gas Recovered: 183 Liters**

Factors for PCS Tool Success on
ODP Legs 201 and 204

- **Active Heave Compensator Allowed Weight on Bit Control +/-2000 lbs**
- **High RPM (Nominal 100 rpm)**
- **Low WOB (Nominal 5 - 7 klbs)**
- **Cutter Extended 1/2m Ahead of Bit**
- **Increased I.D. of Core Barrel**
- **Cutting Shoe Design**
- **Additional Funding Available for Technology Development and Engineering Testing (DOE/NETL Award)**

Pressure Coring System (PCS)
Gas Manifold System (Task 2 cont.)

ODP Leg 204 Site Locations



Summary of ODP Leg 204 - Hydrate Ridge

- **Leg 204 began and ended in Victoria, B.C., Canada. The leg was planned as a 59.4 day leg - actually was 57.1 days long.**
- **50.4 days (88.3%) was spent operating; 6.7 days (11.7%) were spent in port and/or in transit to/from Hydrate Ridge.**
- **Overall, 9 Sites were drilled/cored, with a total of 45 Holes.**
- **Water depths of sites ranged from 788.5 mbrf to 1228.0 mbrf.**
- **Penetration depths varied from 9.5 mbsf to 540.3 mbsf.**
- **8 of 9 sites were drilled using LWD (resistivity-at-bit, NMR, density/neutron) technology.**
- **Eleven (11) holes were drilled using a tricone bit for LWD or wireline logging. Thirty-three (33) holes were cored using APC and/or XCB coring systems; 1 hole was cored with RCB.**

Summary of ODP Leg 204 Coring Activities

- **Over 3674.5 meters of sediment were cored and 3068.3 meters of sediment was recovered (83.5% core recovery).**
- **Nine rendezvous with the D/V *JOIDES Resolution* took place during Leg 204; including 7 helicopters and 2 supply boats.**
- **42 personnel were exchanged on/off the ship.**
- **A series of holes were dedicated to the rapid recovery and preservation of hydrate-bearing sediment cores for a "Geriatric Study" of hydrates [DOE/NETL Task 7] which was cooperatively-funded by DOE-NETL and NSF/ODP.**
- **50 meters of hydrate-bearing core was recovered and stored in steel pressure vessels at 4°C and 600 psi using methane gas. Steel pressure vessels are 3" I.D. and are rated to 3000 psi; Core is 2.66" O.D. (goal was to minimize head space of gas).**
- **35 meters of hydrate-bearing core was recovered and stored in 8 liquid nitrogen cryo-freezers (160 liter capacity each) at the ODP Gulf Coast Repository.**

Summary of Pressure Coring Activities on Leg 204

- **30 out of 39 runs with the ODP Pressure Core Sampler (PCS) were successful (core under pressure recovered). One PCS core contained 95 liters of methane from a ~1 meter-long core [DOE/NETL Task 2].**
- **2 out of 10 runs with the (HYACINTH) Fugro Pressure Corer (FPC) were successful.**
- **4 out of 8 runs with the (HYACINTH) HYACE Rotary Corer (HRC) were successful. One HRC core contained 105 liters of methane from a ~1 meter-long core.**
- **Cores were recovered with the ODP Advanced Piston Corer, transferred to the ODP-Logging Chamber (ODP-LC), repressurized and logged.**
- **Cores were recovered with the HYACINTH FPC and HRC under pressure, were transferred under pressure to a logging chamber, and were logged using the GEOTEK vertical-multi-sensor core logger (V-MSCL).**

Summary of Leg 204 Specialty Tool Deployments

• 81 out of 81 successful runs with the APC-Temperature Tool (memory tool that fits into APC coring shoe) [DOE/NETL Task 3].

• 8 out of 8 successful runs with the Davis-Villinger Temperature Probe (DVTP) [DOE/NETL Task 3].

• 16 out of 16 successful runs with the Davis-Villinger Temperature Probe with Pressure (DVTP-P) [DOE/NETL Task 3].

• 1 out of 2 successful runs with the Fugro Piezoprobe tool [DOE/NETL Task 6], which measures pore pressure dissipation *in situ*. This tool is run on the Schlumberger logging cable (real-time data) as opposed to the wireline deployment of the DVTP-P (data in memory).

• 107 out of 110 successful runs with the APC-methane Tool [DOE/NETL Task 3], which includes Temperature, Pressure, and Conductivity sensors in the APC piston head (time series measurements).

Summary of Leg 204 Specialty Tool Deployments

- Cores were collected during LWD activities at Site 1249 using a prototype RAB-C system, which was an integration of the Schulumberger/Anadrill resistivity-at-the-bit (RAB) LWD tool and the ODP motor-driven core barrel (MDCB) core tube [DOE/NETL Task 5]. The MDCB core tube fits inside the annulus of the RAB tool.

- 28 runs with the LDEO DrillString Acceleration (DSA) tool; 17+ runs were fully/partially successful. Low temperatures affected tool performance on this leg.

- Vertical seismic profiling (VSP) experiments were conducted at several sites using a range of techniques (e.g., VSP, offset-VSP, walkaway VSP) [DOE/NETL Task 5]

- Impact of the APC into hard hydrate layers at Site 1249 was used as an energy source to record acoustic data using ocean bottom seismometers deployed nearby.

- Physical (whirlpak bags filled with 10 micron-sized fluorescent beads) and chemical (perfluorocarbon - PFT) tracers were used on 88 cores to provide QA/QC for microbiological sampling and contamination studies.

Summary of Leg 204 Core Measurements

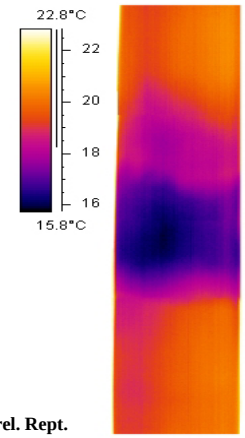
- Rigfloor handling of core barrels was optimized to reduce time between recovery of cores and delivery to the catwalk. Hydrate safety handling protocols were used from rigfloor to catwalk. Hydrogen Sulfide safety protocols were used routinely.

- Core liners were immediately scanned on the catwalk using one or more FLIR ThermaCam SC2000 infrared thermal imaging systems (automated track-mounted, and hand-held IR cameras) to observe thermal (cold) anomalies, which correlate with gas hydrates in the core [DOE/NETL Task 4].

- Gas hydrate samples found in cores were immediately stored in liquid nitrogen or in pressure vessels [DOE/NETL Task 7], or were dissociated and analyzed by injection into gas chromatographs (GC's) onboard. GC's were used for routine hydrocarbon monitoring according to ODP drilling/coring safety procedures.

- Whole-round core samples were collected, trimmed, and squeezed in the onboard chemistry laboratory to obtain interstitial (pore) waters to measure geochemical properties (e.g., chlorinity) and produce downhole profiles.

FLIR ThermaCam SC2000 IR-TIS - ODP Leg 201
First Thermal Image of Hydrate Sample - Site 1230



D'Hondt, Jorgensen, Miller, et al., 2002. ODP Leg 201 Prel. Rept.

Automated and Manual Catwalk Infrared Thermal Imaging of Sediment Cores During ODP Leg 204

Summary of Leg 204 Core Measurements

- Most cores were imaged using a whole-core X-ray linear scanner developed by Lawrence Berkeley National Laboratory by Barry Freifeld and others with funding from DOE/NETL [JOI cooperative project with DOE/NETL and LBNL].
- All cores were passed through the ODP multi-sensor core logging system, which provides closely-spaced measurements of gamma density, inductive conductivity (resistivity), magnetic susceptibility, compressional (P-wave) velocity.
- All cores were visually described by shipboard sedimentologists to identify sedimentary structures, fabrics, composition, grain size, etc.
- All cores were visually imaged using a digital line-scan imaging system and photographed using color and black & white film.
- At each site, age control was provided by diatom and nannofossil biostratigraphy.
- Extensive physical properties measurements, and geochemical and microbiological sampling was conducted on all cores recovered.

JOI/ODP Cooperative Geriatrics Study with DOE/NETL

Dr. Frank Rack proposed a geriatric (long-term) sample preservation effort to DOE/NETL while onboard the *JOIDES Resolution* during ODP Leg 204.

Funding was received to coordinate sample recovery and preservation using (a) Steel Pressure Vessels and (b) Liquid Nitrogen Cryofreezers. Samples were returned from Victoria, B.C., Canada to the ODP Gulf Coast Repository for post-cruise analyses and storage in a HAZMAT Container.

Experiment design, equipment and supplies procurement, planning for logistics and shipping, hazardous transport clearances (USDOT, Canadian DOT), and other activities were accomplished within 5 week time frame, start to finish.

~50 meters of hydrate-bearing core samples from ODP Site 1249 were preserved using methane as the carrier gas in pressure vessels at 600 psi; ~35 meters of hydrate-bearing core samples were preserved in liquid nitrogen and stored in cryofreezers at the ODP Gulf Coast Repository.

Pressure Vessels and Cryofreezers in Refrigerated Van Used for "Geriatrics Study" Initiated on ODP Leg 204

What was the Estimated Cost of ODP Leg 204?

NSF/ODP	$5.3 Million U.S. Dollars	Shipboard Operations
DOE/NETL	$1.5 Million U.S. Dollars*	JOI Cooperative Agreement
NSF (Ewing)	*$0.5 Million U.S. Dollars (est.)*	Offset/Walkaway VSPs
EC-HYACINTH	*$1.0 Million U.S. Dollars (est.)*	Pressure Coring Tests
Subtotal	$8.3 Million U.S. Dollars	Direct Operational Costs
NSF/JOI-USSSP	$0.8 Million U.S. Dollars	U.S. Science Support
USGS/DOE	*$1.0 Million U.S. Dollars (est.)*	Interagency Science Support
International	*$1.0 Million U.S. Dollars (est.)*	International Science Support
Subtotal	$2.8 Million U.S. Dollars	Science Support Costs
Total Cost (est.)	$11.1 Million U.S. Dollars	Shipboard & Postcruise

* Including cost sharing as part of JOI cooperative agreement with DOE/NETL

Joint Oceanographic Institutions, Inc. / Ocean Drilling Program