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## ABSTRACT

The primary accomplishments during the first quarter were to mobilize materials and supplies to meet the deployment schedule for equipment and activities, as proposed under the DOE/NETL cooperative agreement with JOI, with initial testing and use of specialized tools and equipment on Ocean Drilling Program (ODP) Leg 201.

As a requirement of the award, two copies of a technical feasibility report entitled "Preliminary Evaluation of Existing Pressure/Temperature Coring Systems" were delivered to DOE/NETL on October 22, 2001. The report was written to provide a discussion of the availability and compatibility of the four existing pressure coring devices in existence. Most of these systems are available for use by JOI/ODP aboard the D/V JOIDES Resolution, via purchase, lease, modification, etc. and the proposed capabilities to upgrade existing devices or systems for use on other platforms. In addition, the report provided a discussion of the compatability of each existing coring device in conjunction with the use of the other coring devices, such as the advanced piston coring (APC) system used by ODP. Based on an evaluation of the JOI report, the DOE/NETL Program Manager William Gwilliam provided a "Go" decision to JOI for the further development of the ODP Pressure Coring System (PCS) and PCS Gas Manifold.

During the reporting period negotiations were conducted with various potential subcontractors and vendors to establish the specific cost-sharing arrangements and work breakdown necessary to definitize the terms of the DOE/NETL cooperative agreement with JOI. The discussions were communicated with the DOE/NETL Program Manager, William Gwilliam, to keep NETL closely informed about events as this project evolved.

A series of meetings were also held with ODP engineers, technical staff, and to plan for the implementation of the various tasks outlined in the JOI proposal to DOE for deployment during ODP Legs 201 and 204. These meetings helped to answer numerous unresolved questions and establish a firm timetable of remaining activities that needed to be accomplished by January 28, 2002, when ODP Leg 201 will begin.

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## INTRODUCTION

The primary accomplishments of the first quarter are described in this report. Among these accomplishments, JOI was successful in getting this project underway under severe time pressure to mobilize materials and activities to meet the deployment schedule for equipment and procedures for initial testing and use on Ocean Drilling Program (ODP) Leg 201, under the DOE/NETL cooperative agreement with JOI.

The "Preliminary Evaluation of Existing Pressure/Temperature Coring Systems" report was successfully completed and delivered to DOE/NETL on October 22, 2001 to fulfill the obligations under Task 1.1 of the Cooperative Agreement (Rack, 2001).

This report provides a prelimary evaluation of four existing coring devices, namely, the Ocean Drilling Program (ODP) Pressure Core Sampler (PCS), the HYACE Rotary Corer (HRC), the FUGRO Pressure Corer (FPC), and the Japanese Pressure Temperature Core Sampler (PTCS). Each of these four systems are wireline retrievable and are designed to recover sediment, fluids, and gas at near in-situ pressures in the sub-seafloor.

## EXECUTIVE SUMMARY

During the reporting period of this report, the primary accomplishment was to get the project underway, under severe time pressure to mobilize materials and activities to meet the deployment schedule for equipment and procedures, as proposed under the DOE/NETL cooperative agreement with JOI, for initial testing and use on Ocean Drilling Program Leg 201.

Two copies of a technical feasibility report, entitled "Preliminary Evaluation of Existing Pressure/Temperature Coring Systems" , was delivered to DOE/NETL on October 22, 2001. The DOE/NETL Program Manager William Gwilliam provided a "Go" decision to JOI for the development of the PCS and PCS Gas Manifold.

Dr. Frank Rack (JOI), Derryl Schroeder (ODP/TAMU), and Dr. Dan Weill (JOI) attended the HYACINTH "kick-off" meeting in Leamington Spa, UK, on October 8-10, 2001, to negotiate conditions for the establishment of a cooperative agreement between JOI/ODP and the HYACINTH partners to test two HYACINTH pressure coring tools on the D/V JOIDES Resolution during ODP Legs 201 and 204. The HYACINTH project is a European Union (EU) funded effort to develop tools to characterize methane hydrate and measure physical properties under in-situ conditions. The field-testing of these tools provides a corollary benefit to DOE/NETL at no cost to this project.

During October and November 2001, numerous phone and email discussions were conducted with various potential subcontractors and vendors to establish the specific cost-sharing arrangements and work breakdown necessary to definitize the terms of the DOE/NETL cooperative agreement with JOI. The discussions were communicated with the DOE/NETL Program Manager, William Gwilliam, to keep NETL closely informed about events as this project evolved.

On December 3, 2001, Dr. Frank Rack met in Houston, TX with Gary Humphrey and Joseph Castleberry of FUGRO to discuss the proposed Task 6.0 activities related to the modification and field-testing of the FUGRO Piezoprobe and Hydraulic Fracture Tool onboard the D/V JOIDES Resolution during ODP Leg 204. Technical and logistical issues, and operational potential challenges, were flagged for further discussion as the project evolved in consultation with ODP engineers.

On December 4, 2001, Dr. Frank Rack (JOI) met with Dr. Gerald Dickens, ODP engineers, and ODP technical staff in College Station, TX to discuss the status of the PCS Gas Manifold design activity for ODP Leg 201. This project was determined to be on schedule for deployment in late-January, 2002, and a parts list of components to be purchased was drawn up during the meeting.

On December 5-7, 2001, the Pre-cruise meeting for ODP Leg 204 was held in College Station, TX. The two Co-Chief Scientists (Dr. Anne Trehu, Oregon State University, U.S.; and Dr. Gerhard Bohrmann, GEOMAR, Germany), the ODP Staff Scientist (Dr. Carl Richter), Dr. Frank Rack (JOI), Dr. Jack Baldauf (ODP/TAMU), Derryl Schroeder (ODP/TAMU), Mike Storms (ODP/TAMU), and other ODP/TAMU engineers and technical staff met to discuss planning and preparations for science and engineering activities related to this expedition.

Emrys Jones (Chevron/Texaco) was invited to attend the meeting as a guest in order to exchange information about ODP planning for Leg 204, and to exchange information about possible future collaborative activities with JOI/ODP related to the Gulf of Mexico.

On December 11-12, 2001, Dr. Frank Rack met with William Gwilliam (DOE/NETL) at the American Geophysical Meeting in San Francisco, CA, to discuss various aspects of the cooperative agreement between JOI and DOE/NETL and exchange information about the status of the various tasks in the JOI project.

On December 18, 2000, Dr. Frank Rack met with ODP engineers, ODP Technical Staff, and others at the portcall of the D/V JOIDES Resolution to hold discussion and plan for the implementation of the various tasks in the JOI project during ODP Legs 201 and 204. These meetings helped to answer numerous unresolved questions and establish a firm timetable of remaining activities that needed to be accomplished by January 28, 2002, when the portcall for ODP Leg 201 will begin.

## EXPERIMENTAL

Two days of drilling stand testing of the Pressure Coring System (PCS) with three new cutting shoes were conducted using Texas Cream Limestone drilling samples, at the facilities of Mauer Engineering in Houston, TX during mid-November, 2001. These tests were successful and provided information about RPM, flow rate, and weight-on-bit (WOB) for each cutting shoe tested.

Design for PCS Gas Manifold will be finalized so that parts can be procured for assembly prior to Leg 201. Dr. Gerald Dickens (Rice University) will work with JOI to define the necessary components of this manifold. The PCS tool and manifold will be shipped to San Diego and placed onboard the JOIDES Resolution during portcall in late January, 2002. These activities are included in Task 2.0 of the DOE/NETL Cooperative Agreement with JOI.

The Davis-Villinger Temperature Probe (DVTP), Davis-Villinger Temperature Probe with Pressure (DVTP-P) and other ODP memory tools will be shipped to San Diego and placed onboard vessel during portcall for use on ODP Leg 201 (Task 3.0).

Selection and purchase of Infra-Red Thermal Imaging System (IR-TIS) is underway for delivery in mid-January, 2002 (Task 4.0). JOI will designate the appropriate staff members to be trained in mid-January, 2002 to operate the IR-TIS during ODP Leg 201.

Discussions are ongoing between ODP engineers and LDEO logging staff scientists related to the specifics of LWD and VSP experiments planned for ODP Leg 204 (Task 5.0). Preliminary technical discussions have been ongoing since early December 2001 to define the scope of this activity. (Tom Pettigrew, Mike Storms, ODP/TAMU engineers; Greg Myers, LDEO contact). Some tool modifications may be required to integrate ODP sample chambers with the Resistivity-at-bit (RAB) LWD tool.

During this period, discussions were initiated with FUGRO (Task 6.0) to negotiate a sub-recipient Statement of Work for modifying their Piezoprobe tool for testing onboard the JOIDES Resolution during ODP Leg 204. Technical and operational issues related to the use of this tool are being explored. A Go-no-Go decision for this project will be made by JOI in early-March, 2003, once time and operational schedules for ODP Leg 204 are better defined.

## RESULTS AND DISCUSSION

The "Preliminary Evaluation of Existing Pressure/Temperature Coring Systems" report was successfully completed and delivered to DOE/NETL on October 22, 2001 to fulfill the obligations under Task 1.1 of the Cooperative Agreement (Rack, 2001). DOE/NETL Program Manager William Gwilliam provided "go" decision for development of improvements to the ODP Pressure Coring System (PCS) and PCS Gas Manifold.

This report provides a prelimary evaluation of four existing coring devices, namely, the Ocean Drilling Program (ODP) Pressure Core Sampler (PCS), the HYACE Rotary Corer (HRC), the FUGRO Pressure Corer (FPC), and the Japanese Pressure Temperature Core Sampler (PTCS). Each of these four systems are wireline retrievable and are designed to recover sediment, fluids, and gas at near in-situ pressures in the sub-seafloor.

There are two existing PCS tools at present and one prototype tool for each of the HYACE systems (i.e., HRC and FPC), plus four existing PTCS tools, to the best of this author's knowledge. These four coring devices share a common early development history in the Pressure Core Barrel (PCB) development of the Deep Sea Drilling Project (DSDP) and the subsequent development of the PCS by ODP since 1986.

International engineers representing the future HYACE and the Japanese PTCS development teams, who participated in ODP Leg 164 onboard the D/V JOIDES *Resolution,* gained valuable experience and operational insights from the intensive scientific deployments of the ODP Pressure Core Sampler prior to the start of these other projects.

The PCS is a wireline retrievable rotary pressure corer, which is driven by the rotation provided by the top drive mounted in the derrick of the D/V JOIDES *Resolution*. This system can also be used as a push corer without rotation.

The PCS has been used on ODP legs in a wide range of deepwater. Moderate modifications to the PCS were made prior to the deployments on ODP Leg 164 which resulted in extensive use of the PCS and gas manifold modifications. Discussions about the PCS design and potential modifications to improve its use have continued.

During ODP Leg 164 on Blake Ridge and Carolina Rise the PCS was successfully deployed on 46 runs to recover core samples at near in-situ pressures up to 5205 psi/355 bars. The PCS was instrumental in providing estimates of in situ gas concentrations and compositional analyses that resulted in revised estimates for the volume of gas contained in gas hydrate reservoirs in the subsurface of Blake Ridge (Dickens, et. al., 2000).

The PCS has not been used extensively since Leg 164, but minor upgrades and testing are planned for ODP Leg 201 (Peru Margin; January 28 through April 1, 2002), folllowed by

operational use of the tool on ODP Leg 204 (Oregon Margin, Hydrate Ridge; July 8 through September 6, 2002). The PCS is considered an operational tool by ODP. The primary issues to be addressed in time for ODP Leg 201 are modifications to the PCS bit design, better weight-on-bit (WOB) control, reduced maintenance and turn around time, and improved quality of fluid sampling.

The HYACE Rotary Corer (HRC) and FUGRO Pressure Corer (FPC) tools have been developed through a European Union (EU) research project known as HYACE, or "HYdrate Autoclave Coring Equipment", which existed from late 1997 until March 2001. The HRC, has been designed to be a wireline retrievable, rotary coring tool driven by a downhole inverse moineau motor. The FPC is designed to be a wireline retrievable push and percussion corer driven by a hydraulic hammer that evolved originally from a Russian design. Both of these tools are prototype systems, meaning that there is only one of each available for testing. The other parts of the "complete" HYACE system are (1) the Laboratory Transfer Chamber (LTC) and (2) the GEOTEK vertical LTC Logger. These two systems are planned to be available for testing during ODP Leg 204.

An extension to the HYACE project was granted by the EU program managers (i.e., from September 2000) to allow the field testing on ODP Leg 194 to take place in early 2001.

The HRC and FPC were each deployed four times in test runs during ODP Leg 194. Progress was made in learning about the handling requirements for these tools onboard the D/V JOIDES *Resolution* and in providing experience with the operation of these prototype tools. A total of 72 hours was allocated to the testing of these HYACE tools. During Leg 194, two holes (i.e., Hole 1192A = 242 mbsf (meters below sea floor) Total Depth (TD); Hole 1192B = 240 mbsf TD) were drilled in 385 m and 374 m of water depth, respectively.

The FPC was used three times in Hole 1192 A, at 28.5 mbsf (push mode), 86.5 mbsf (percussion mode), and 192 mbsf (percussion mode) and in Hole 1192B at 179.9 mbsf. The HRC was used twice in Hole 1192A, at 231 mbsf and 241.4 mbsf, and twice in Hole 1192B, at 180.9 mbsf and 335.2 mbsf. The autoclave (pressure chamber) on the FPC was only able to hold pressure (42 bar; 617 psi) during one of the four tool deployments.

The HRC recovered one 35 cm-long core out of the four runs and had a variety of operational problems. Concern was expressed by the ODP engineers about the difficulty in handling and assembling the tools on the rig floor, as well as the potential weakness of the flapper valve used in the HYACE tool design. FUGRO and HYACE engineering teams plan to provide a more robust flapper hinge in future versions of these tools and to address other perceived design flaws. Bending stresses on both of the tools were reduced by the fabrication of supports onboard the drillship by the core techs and drilling engineers; the HRC had difficulty latching into the extended core barrel (XCB) bottom hole assembly (BHA). Other modifications to the handling and operational plan were crafted in real time during testing operations on ODP Leg 194.

The general feeling of the ODP operations staff was that the level of precruise communication and information exchange between ODP and the HYACE teams prior to the cruise was inadequate (this observation was disputed by the FUGRO engineers). Part of these communications problems may have resulted from multiple points of contact operating independently in each of the several groups involved in the Leg 194 testing (e.g., TU-Berlin, TU-Clausthal, FUGRO, ODP/TAMU).

The HYACE tool developments will continue as the EU-sponsored HYACINTH project, which will be initiated in late October or early November of 2001 and continue for three years. In order to foster improved communication with the HYACINTH project partners, Dan Weill (JOI Director), Frank Rack (JOI Asst. Director), and Derryl Schroeder (ODP/TAMU Engineer) attended the "kick-off" meeting of the HYACINTH group in October, 2001.

Discussions among the HYACINTH partners and ODP suggested that FUGRO assume the role of "caretaker" or "steward" of the HYACINTH prototype systems (e.g., FPC, HRC, and LTC) so that an addendum agreement with ODP would only require the signature of FUGRO and GEOTEK partners (e.g., the commercial partners). This arrangement was acceptable to the HYACINTH academic partners. Access to future developments under the HYACINTH project would be subject to additional addendum agreements, as deemed appropriate by ODP. Additional addendum agreements to the main cooperative agreement could be initated by any outside party.

At this "kick-off" meeting, both the FUGRO and HYACE engineers (e.g., TU-Berlin and TU-Clausthal) stated that they felt confident that they either are, or will be addressing the lessons-learned from the Leg 194 testing. They are enthusiastic about the possibility of further testing on ODP Leg 201 (FPC only) and Leg 204 (i.e., complete HYACE system: FPC, HPC, LTC, and LTC logger).

Preparation of the other parts of the HYACE/HYACINTH system are being planned (e.g., additional specialized transfer chambers; modularization of the FPC and HRC tools) in this phase of the project. These components will not be available in the coming year and may take considerable time and design/experimental effort to develop.

The details of the PTCS design are provided in U.S. patents 6,216,804 and 6.230,825 issued to James Aumann and Craig Hyland. Operational information and preliminary test results for this tool are provided in Rack (2001), for deployments at the Mallik 2L-38 well in the Mackenzie Delta of Arctic Canada and for wells drilled offshore Japan in Nankai Trough.

The PTCS was used from 1175 m to 1254 m sub-seafloor in Nankai Pilot Hole No. 2. It took 4-5 hours to cut a 3 m core, retrieve it and reset an empty barrel by wireline operation. It took 5 days to finish 27 PTCS runs of this 79 m zone, with a recovery of

37% (29 m). Additional runs of the PTCS were conducted in a second additional survey hole, with 16.9 m of core recovered (47% recovery) in 2.5 days. An evaluation of the operation of the PTCS is difficult, since the reported drilling results are qualitative, e.g., "A few barrels were empty, while a few were full. Most barrels kept downhole temperatures, but some had a malfunction of temperature read out. Some barrels kept downhole pressures, but some failed".

A summary of the system capabilities for each of the four pressure coring tools discussed in the preliminary evaluation report submitted to DOE/NETL is provided in Table 1 of Rack (2001), which is reproduced below.

Table 1. Preliminary Evaluation of Four Pressure Coring Systems.

| **System Capability** | **ODP PCS** | **HRC** | **FPC** | **PTCS** |
|---|---|---|---|---|
| Type of System (rotary, percussion, push, etc.) | rotary, push | rotary | push, percussion | rotary, push |
| Number of Existing Units | 2 complete PCS tools | Single prototype tool | Single prototype tool | four complete tools. |
| Wireline Retrievable? | YES | YES | YES | YES |
| From what vessels/platforms have the tools been deployed offshore? | PCS tools have been deployed numerous times from D/V JOIDES Resolution by the ODP. | HRC tool has been deployed from D/V JOIDES Resolution by ODP, with 2 HYACE engineers. | FPC tool has been deployed from D/V JOIDES Resolution by ODP, with 2 FUGRO engineers. | Tool was deployed in the Mackenzie Delta of Arctic Canda. Tool was also deployed in Nankai Trough by the semi-submersible "M.G. Hulme, Jr.". |
| What lithologies were encountered? | Various; wide range of lithologies from soft to hard and fine-grained to coarse-grained. | soft to sticky, and hard clays; fine-grained and cemented sediments were cored during land tests. | soft to sticky, and hard clays; fine-grained and cemented sediments were cored during land tests. | sandy horizons with varying amounts of hydrate. |
| Tool can be deployed with which kind of bottom hole assemblies (BHA)? | The PCS is compatable with the ODP APC/XCB BHA. | Designed to be compatable with ODP APC/XCB BHA. Some problems during ODP Leg 194. | Designed to be compatable with ODP APC/XCB BHA. Some problems during ODP Leg 194. | Large diameter tool which is incompatable with existing ODP bottom hole assemblies. |
| Maximum Length and Diameter of Sample | PCS recovers a core that is 42 mm in diameter and up to a maximum length of 86 cm. | HRC recovers a core that is 50 mm in diameter and up to 1.0 m in length. | FPC recovers a core that is 58 mm in diameter and up to 1.0 m in length. | PTCS recovers a core that is 67 mm in diameter and up to 3.0 m in length. |

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|---|---|---|---|---|
| Instrumentation Capability of Tool | PCS is not presently internally instrumented; however, a pressure transducer allows external pressure monitoring, and external sampling ports can be mated to a gas manifold to conduct degassing experiments. | Pressure and temperature monitoring is under consideration for future versions of this tool, beyond the 2002 phase of ODP testing. | Pressure and temperature monitoring is under consideration for future versions of this tool, beyond the 2002 phase of ODP testing. | Temperature and pressure sensors are built into the design of this tool. The existence of sampling ports is unknown. |
| Capability to maintain pressure of sample in chamber? | YES | Unknown at this time. | Unknown at this time. | Unknown at this time. |
| Design limitations for pressure? | The PCS pressure limit is 10,000 psi (690 bar), with a 4:1 factor of safety. | The HRC pressure limit is 3,625 psi (250 bar). | The FPC pressure limit is 3,625 psi (250 bar). | The pressure limit for the PTCS is 3,500 psi (241 bar), with a 4:1 factor of safety. |
| Capability to maintain temperature of sample in chamber? | PCS sample chambers can be placed into a water bath during degassing experiments. Additional capabilities are possible, depending on timetable and availability of external funding. | Unknown at this time. | Unknown at this time. | Unknown if this capability is functional in this tool. A thermo-electric cooling system was included in the design specifications. |
| Capability to Transfer Sample at In-Situ Pressure | Not available; Plans for this capability have been on hold since 1992; pending recommendations by scientific community. | Not available at this time; the development of one or more lab transfer chambers for use with the HRC is a planned outcome of the HYACINTH Project. | Not available at this time; the development of one or more lab transfer chambers for use with the FPC is a planned outcome of the HYACINTH Project. | Unknown if this capibility is available at this time. Plans to add this capability in the future are also unknown. |
| Status of Tool | Operational Tool; Modifications are being made to improve operations in some lithologies. | Prototype Tool; Future ODP testing is planned. | Prototype Tool; Future ODP testing is planned. | Operational tool?; Second phase of testing and development? Status unknown. |

## CONCLUSION

The PCS, FPC, and HRC can be operated with the standard bottom hole assembly of the ODP APC/XCB systems (with some minor modification of the HYACE/HYACINTH tools). The Japanese PTCS requirement for larger pipe diameter make its use by ODP at present unlikely; however, this system may find a role in the future Integrated Ocean Drilling Program (IODP) after October 1, 2003.

At the present time, to this author's knowledge, there is no existing compatible system, deployable aboard research vessels or drill-ships for the transfer and examination of hydrate cores at near in-situ conditions from a pressure core sampler. German researchers have been attempting to develop a pressure maintenance system for use with shallow piston cores; this system has been tested on the R/V Sonne. It is unknown if this system can be perfected for use with pressure core samplers at higher pressures, such as are discussed in this report. The EU-sponsored HYACINTH project is planning to investigate this possibility.

JOI/ODP management are committed to exploring the full range of pressure coring systems and have had an ongoing dialogue and collaborative relationship with the HYACE and HYACINTH projects. These tools will likely be available for use through the HYACINTH commercial partners (e.g., FUGRO and GEOTEK) at whichever time that they are deemed operational. JOI/ODP is laying the foundation for access to these tools during ODP and also for future use in IODP. The terms of the HYACINTH cooperative agreement make it possible for commercial use of these tools as well, through addendum agreements to be negotiated with interested commercial entities.

JOI/ODP management are also discussing the status of the PTCS and are trying to determine the Japanese plans for this tool. These discussions are at a very preliminary stage, but will continue over the course of this project. The desired outcome is that these tools will be available for use by IODP and other interested parties, as appropriate, in the near future. The pressure coring workshop proposed by JOI/ODP in this proposal to DOE/NETL is viewed as an important step in exchanging information about all of these tools and preparing for future development paths.

There are no additional significant results to discuss at this point in the project. The activities undertaken during this quarter were primarily to procure materials and modify equipment for deployment at sea on ODP Leg 201, as outlined in the previous section.

## REFERENCES

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| APC | Advanced Piston Corer |
| BHA | Bottom Hole Assembly |
| DOE | Department of Energy |
| DSDP | Deep Sea Drilling Program |
| DVTP | Davis Villinger Temperature Probe |
| DVTPP | Davis Villinger Temperature Probe with Pressure |
| EU | European Union |
| FPC | Fugro Pressure Corer |
| HRC | HYACE Rotary Corer |
| HYACE | Hydrate Autoclave Coring Equipment |
| HYACINTH | Deployment of HYACE tools In New Tests on Hydrates |
| IODP | Integrated Ocean Drilling Program |
| IR-TIS | Infrared Thermal Imaging System |
| JOI | Joint Oceanographic Institutions |
| JOIDES | Joint Oceanographic Institutions for Deep Earth Sampling |
| LDEO | Lamont Doherty Earth Observatory (Columbia University) |
| LTC | Laboratory Transfer Chamber |
| LWD | Logging While Drilling |
| MBSF | Meters Below Sea Floor |
| NETL | National Energy Technology Laboratory |
| NSF | National Science Foundation |
| ODP | Ocean Drilling Program |
| PCS | Pressure Coring System |
| PSI | Pounds per Square Inch |
| PTCS | Pressure Temperature Coring System |
| RAB | Resistivity at the Bit |
| R/V | Research Vessel |
| TAMU | Texas A&M University |
| TU | Technical University |
| VSP | Vertical Seismic Profiling |
| WOB | Weight on Bit |
| XCB | Extended Core Barrel |