Well Logging Principles and Applications
G9947 - Seminar in Marine Geophysics
Spring 2008
A Brief History of Scientific Ocean Drilling

Project Mohole

Deep Sea Drilling Project

Ocean Drilling Program
Drilling for Science

Scientists have been using drilling technology to understand Earth’s history since 1958.

- Project Mohole (1958 -1966)
- Deep Sea Drilling Project (1968 -1983)
- Integrated Ocean Drilling Program (2003 - )
Project Mohole

• Project Mohole attempted to drill through the Earth’s crust to the Mohorovicic Discontinuity and retrieve a sample of the mantle.

• Recovered the first sample of oceanic crust.

• Although the mantle was never reached, Project Mohole showed that deep ocean drilling was a viable means of obtaining geological samples.
Deep Sea Drilling Project
1968-1983

During worldwide operations, the Glomar Challenger sailed 96 Legs and drilled 624 sites.
DSDP Scientific Highlights

- Verified the theory of plate tectonics;
- Discovered that Antarctica has been ice-covered for 20 million years;
- Showed that the Mediterranean Sea completely dried up between 5 and 12 Ma.
Ocean Drilling Program
1985-2003

• During ODP, the JOIDES Resolution sailed 110 Legs and drilled 650 sites
ODP Scientific Highlights

• Defining the longest record of Earth’s natural climate variability;

• Collecting the first marine record of the K/T boundary;

• Sampling gas hydrates
How is IODP different?
Multiple Drilling Platforms

Riser Platform
Non-riser Platform
Mission-Specific
Chikyu Riser Platform

- Operated by Japan’s JAMSTEC Center for Deep Earth Exploration (CDEX)
- Scheduled to begin IODP operations in 2007
- 12,000 m drillstring with 2500 m riser capability
IODP - Multiple Drilling Platforms

- Riserless drilling vessel
- Riser-equipped drilling vessel
- Mission specific platforms
Riser versus Non-Riser: What’s the difference?

- **Riserless Drilling**
- **Riser Drilling**
- **Riser Pipe and BOP**

**Formation Pore Pressure Gradient**

**Formation Fracture Pressure Gradient**

**Mud (Drilling Fluid) Weight**

- **Scientific Target**
- **ODP Record 2,111m BSF**

- **9-7/8” Hole 30” CSG**
- **26” Hole 20” CSG**
- **17-1/2” Hole 13-3/8” CSG**
- **12-1/4” Hole 9-5/8” CSG**

- **Increase Mud Weight**
- **Decrease Mud Weight**

- **Hydrostatic Pressure of 3500m Fluid Column of which SG is 1.2.**

- **Pressure Gradient by Specific Gravity**

- **WD 1500m**

- **Sea Floor**

- **1.0 1.2 1.4 1.6 1.8 2.0 2.2**
**Riser drilling.** The riser is a pipe that extends from the drilling platform down to the seafloor. Drilling mud and cuttings from the borehole are returned to the surface through the riser. The top of the riser is sealed to the drillship, while its bottom is secured at the seafloor. A blowout preventer (BOP) placed at the seafloor between the mudline and the riser provides protection against overpressures formations and suction release of gas. The riser pipe diameter of up to 21 in. (533 mm) is large enough to allow the drillpipe, logging tools and multiple casing strings to pass through.

**Riserless drilling.** Steamer is pumped down through the drillpipe to clean and cool the bit. The drilling fluid and the cuttings flow up between the drillpipe and the borehole casing, where they spill onto the seafloor and do not return to the surface.
An example of an MSP operation (Expedition 292) in the Arctic. The first Arctic coring expedition (ACDK) was conducted from August to September 2004, at the crest of the Lomonosov Ridge in the central Arctic Ocean (left). The Víctor Viking drillship (right) was protected by two drillers' ships and seven supply ships. Víctor Viking drilled two boreholes at four sites, and a 339-m (232-ft) long sedimentary sequence was recovered in the cores. (Photograph courtesy of M. Jakobsson, JOIDES)
Expedition 302: Logging Highlights

• First set of downhole log data ever obtained in the Central Arctic Ocean.

• Figure depicts total natural gamma (core and log), spectral gamma (log), and p-wave velocity (core and log)
<table>
<thead>
<tr>
<th><strong>Mohole</strong></th>
<th><strong>DSDP</strong></th>
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<tr>
<td>1961</td>
<td>1973</td>
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<tr>
<td>Positioning drillship in 3,570 m (11,713 ft) of water and testing drillpipe integrity with internal magnetic sones</td>
<td>Trials of heave compensation system</td>
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<td>Mohole test hole confirms ability to sample pelagic sediment and basement rock in deep waters</td>
<td>Reusable bit to allow larger ID wireline sondes to log open hole in riserless environment</td>
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<td><strong>1968</strong></td>
<td><strong>1974</strong></td>
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<td>DSDP Leg 1: discovery of salt domes in the Gulf of Mexico in 1,067 m (3,500 ft) of water depth</td>
<td>DSDP Leg 39: causal link between Earth’s 23,000-year precessional cycle and large-scale climate change</td>
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<td>DSDP Leg 3: first solid evidence of Mediterranean sea-drying events</td>
<td>DSDP Leg 60 in Mariana Trench in 7,004 m (23,079 ft) of water depth</td>
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<td><strong>1970</strong></td>
<td><strong>1975</strong></td>
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<td>Solar-guided borehole reentry</td>
<td>Use of reentry cone to reenter borehole in 5,519 m (18,108 ft) of water depth</td>
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<td>DSDP Leg 12: first solid evidence of Mediterranean sea-drying events</td>
<td><strong>1976</strong></td>
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<tr>
<td><strong>1979</strong></td>
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<tr>
<td>Trials of hydraulic piston corer to recover undisturbed sediment cores</td>
<td>DSDP Leg 61 in Mariana Trench in 7,004 m (23,079 ft) of water depth</td>
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<td>Cores from DSDP Leg 62 (1981) and ODP Leg 148 (1990) giving evidence for microbes in oceanic basalt</td>
<td><strong>1978</strong></td>
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<td><strong>ODP</strong></td>
<td><strong>IODP</strong></td>
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<td>1984</td>
<td>2000</td>
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<td>Reentry of an 8-year-old borehole in 5,511 m (18,080 ft) of water depth</td>
<td>ODP Leg 18B: confirmed findings from DSDP Leg 29 (1973) that the separation of Australia from Antarctica produced massive ocean current and climate change— including the development of the Antarctic ice sheet</td>
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<td><strong>1989</strong></td>
<td><strong>1999</strong></td>
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<td>Openhole logging in 5,980 m (19,620 ft) of water depth</td>
<td>ODP Leg 18B: two seismic/crustal deformation observatories installed in 2,000 m (6,562 ft) of water at 1,000 m (3,200 ft) below seafloor. Only 50 km [31 miles] apart, one area ends up being seismically active, the other not</td>
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<td>Leg 124E: use of diamond coring bits to drill through hard ocean crust</td>
<td><strong>1995</strong></td>
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<td>DSDP Leg 125: discovery of serpentinite mud volcanoes emanating from the mantle</td>
<td>ODP Legs 164 (1995) and 204 (2002) revolutionize understanding of natural gas hydrate deposits</td>
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<td>DSDP Legs 158 and 190: revealing the size and structure of active massive sulfide deposits, like those that form the basis of world-class mining sites</td>
<td><strong>1996</strong></td>
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<td>CORK borehole seals deployed for true in-situ borehole monitoring</td>
<td>LWD in 5,056 m (19,141 ft) of water depth</td>
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<td>Pressure core sampler recovery of core at high in-situ pressures</td>
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<td>LWD in 5,056 m (19,141 ft) of water depth</td>
<td>Real-time LWD in 4,791 m (15,718 ft) of water depth</td>
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<td><strong>2002</strong></td>
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<td>ODP Leg 171B: recovery of pristine soft-sediment cores of the Cretaceous/Tertiary extinction boundary</td>
<td>Successful test of RAB Resistivity-at-the-Bit logging-while-coring system</td>
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Scientific Ocean Drilling Vessel
Non-riser platform

• Operated by the U.S. Implementing Organization:
  • Joint Oceanographic Institutions
  • Texas A&M University
  • Lamont Doherty Earth Observatory

• IODP Phase 1: JOIDES Resolution (2003 - 2005)
• IODP Phase 2: JR conversion (IODP operations start August 2007)
DRILLING
A ROTARY RIG

1. Crown block
2. Traveling block
3. Hook
4. Swivel
5. Mud hose
6. Kelly
7. Rotary table
8. Hoist or draw works
9. Pumps
10. Rollers
11. Pipe rack
12. Drill pipe
The reentry cone is a large 37 in (9.4 m) diameter funnel-shaped installation on the seafloor that serves as a conduit for recirculating a previously drilled hole and for landing and supporting the surface casing string. The reentry cone is released through the moonpool (top).

(Photograph courtesy of Texas A&M University.)
IODP coring tools

 Rotary  

 Piston
ODP Standard Coring Bits and Cutting Shoes

APC

XCB

APC-T

RCB
H2S Safety Protocols during Core Handling
Pressure Release to Minimize Risk of Core Liner Failure
Catwalk Handling of Sediment Cores after Recovery
Drillship *JOIDES Resolution* with seven floors of on-board laboratories. The 143-m (468-ft) drillship features a seven-story laboratory complex to analyze the wide variety of cores and logs collected worldwide. The ship is positioned over the drill site by 12 computer-controlled thrusters that support the main propulsion system. Near the center of the ship is the moon pool, a 7-m (22-ft) opening in the bottom of the ship, through which the drill string is lowered. The drillship is a virtual university that can house 50 scientists and technicians and 65 crew members, with a stack of laboratories on seven floors. The bottom two floors (not shown) have core-storage facilities. At the fantail of the ship, on the left, is a geophysics laboratory, which contains equipment that gathers ship position, water depth and magnetic information used in studying the seafloor topography.
Preparation of Core Samples for Pore Water Extraction
Hydrocarbon Monitoring using Gas Chromatograph
Storage of ODP Cores in D-tubes for Transport
Refrigerated Core Storage Facilities
ODP Gulf Coast Repository, College Station, TX
LOGGING
Conventional Wireline Logging

Wireline Logging

Schlumberger MCM Unit, Winch

Downhole Measurements Lab

- Resistivity
- Litho-Density
- Porosity
- Natural Gamma
- Sonic velocity
- Resistivity Image (FMS)
- Magnetic Field, Susceptibility
Logging While Drilling (LWD)
Schlumberger Data Acquisition System
VSP - GI AirGun Deployment
VSP - GI Airgun Deployment
VSP - GI Air gun firing
HEAVE COMPENSATION
Exp 304/305: Logging Highlights
DATA
Scientific deep-ocean drill sites from 1961 to 2003. The Mohole project (green) initiated in 1958 used a converted naval barge *Casseius* to drill at two sites near La Jolla, California, USA, and Guadeloupe, Mexico, from 1961 to 1966. The Deep Sea Drilling Project (black) used the drillship *Glomar Challenger* to drill at 924 sites, from 1968 to 1983. During the Ocean Drilling Program (red) between 1984 and 2003, the drillship *JOIDES Resolution* sailed as far north as 80° and as far south as 71° latitude, and drilled the next 953 sites.