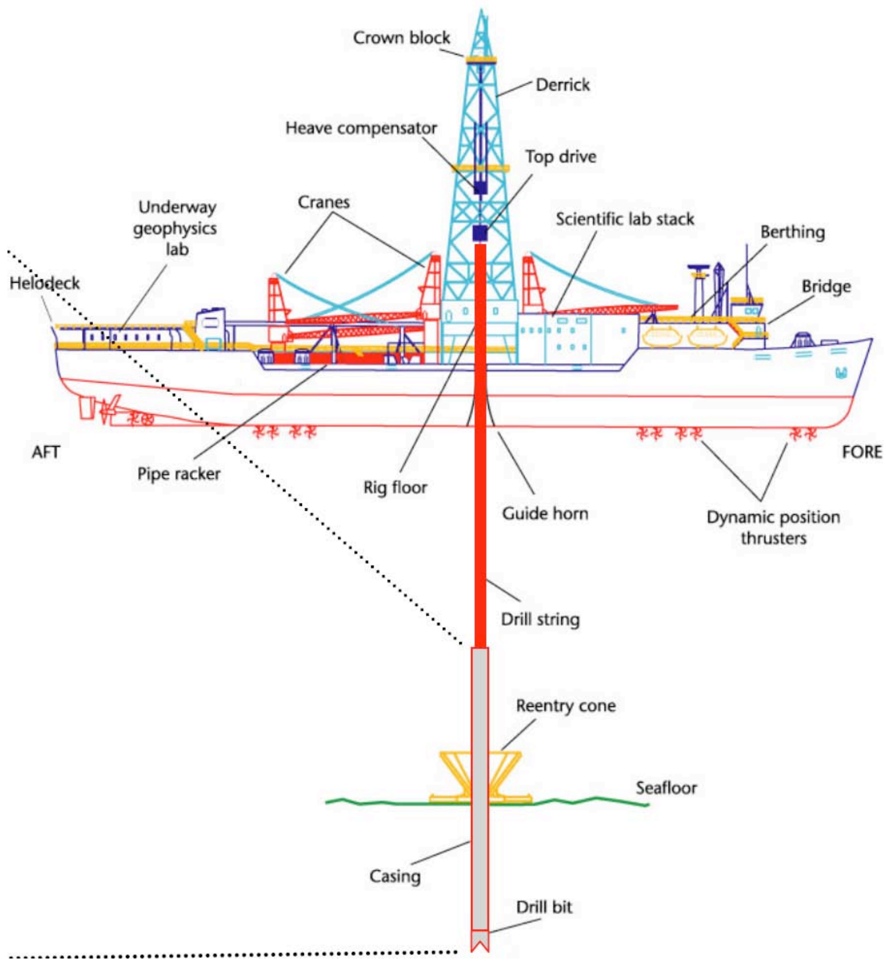
Well Logging Principles and Applications
G9947 - Seminar in Marine Geophysics
Spring 2008



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)**
- **Ocean Drilling Program (1985 - 2003)**
- **Integrated Ocean Drilling Program (2003 -)**

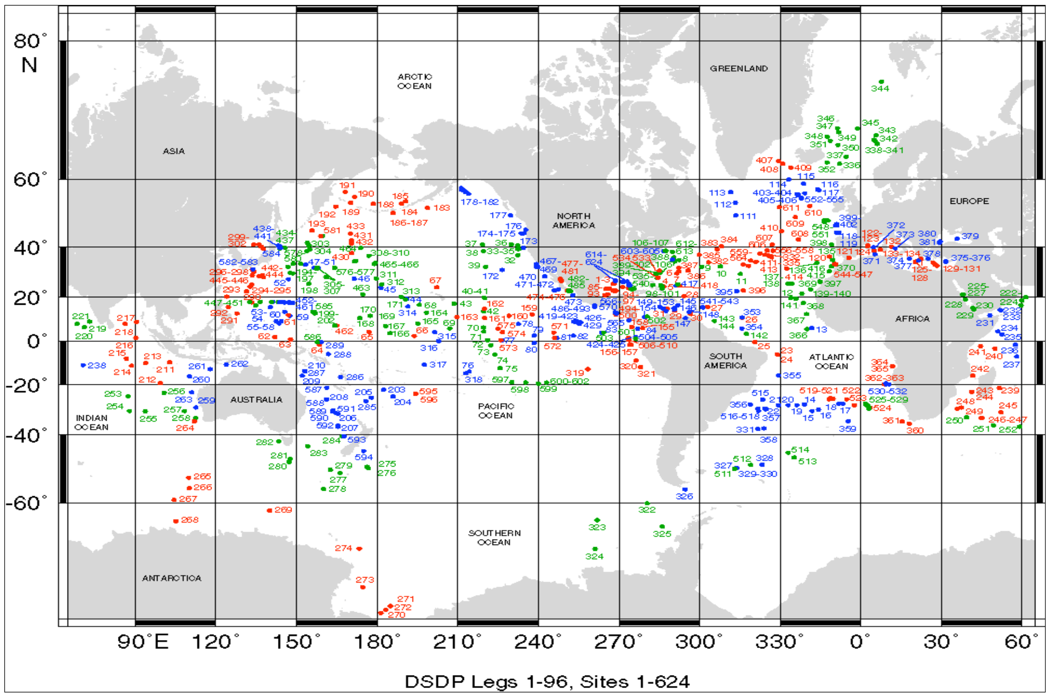
Project Mohole

•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

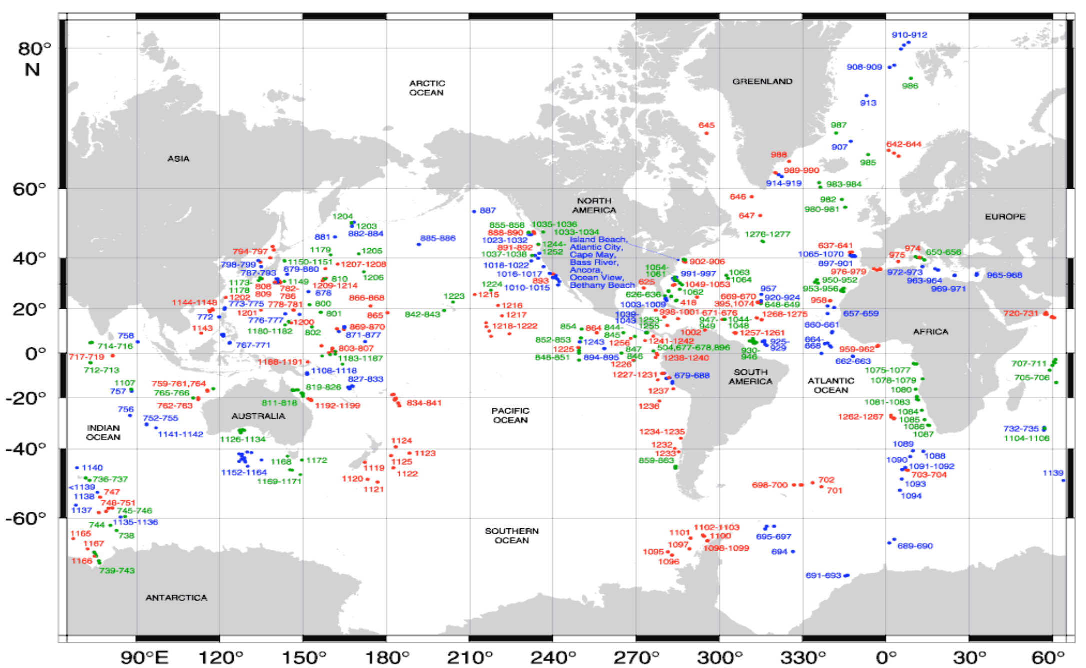


During worldwide operations, the *Glomar Challenger* sailed 96 Legs and drilled 624 sites.

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.

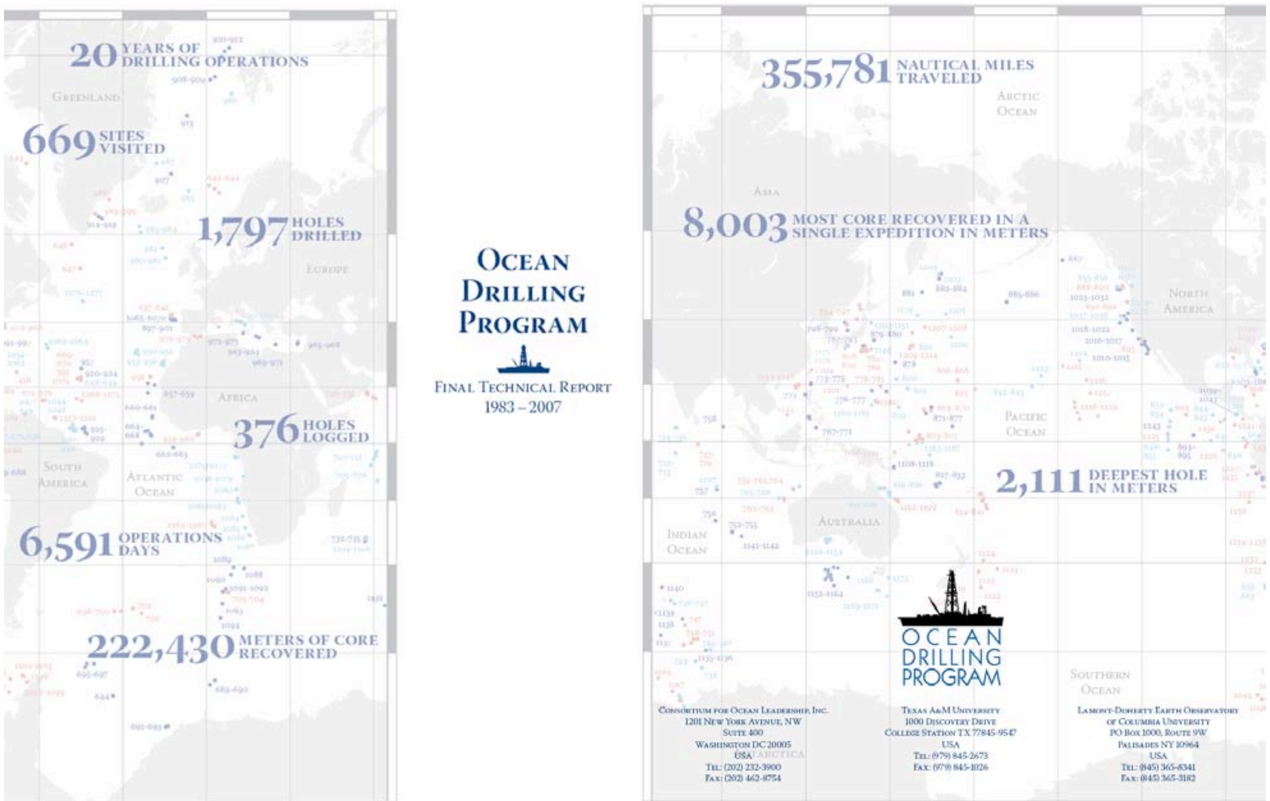
Ocean Drilling Program 1985-2003



ODP Legs 100–210, Sites 625–1277

- **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

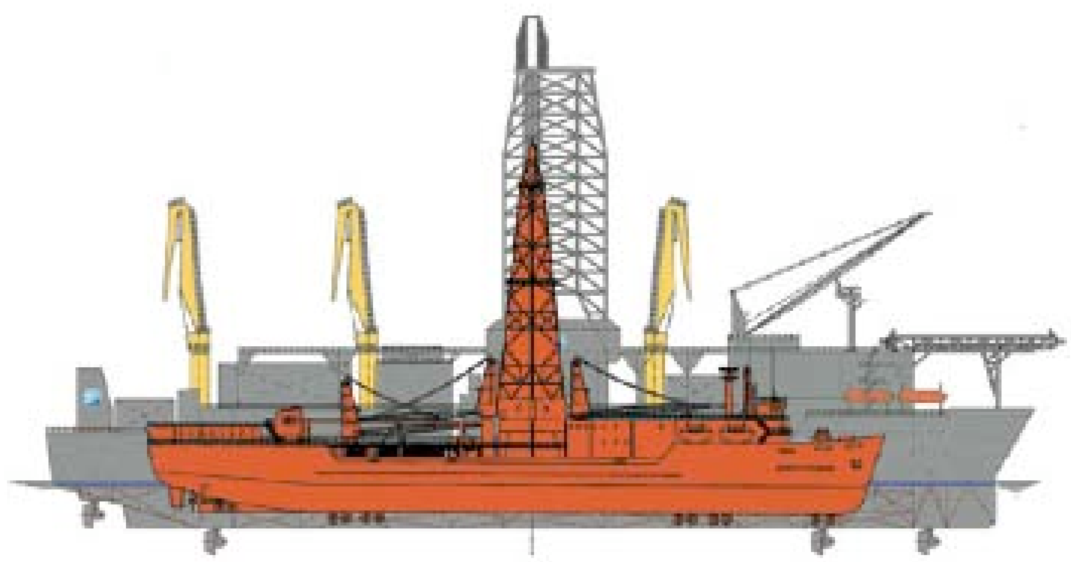
Non-riser Platform

Mission-Specific

Chikyu
Riser Platform

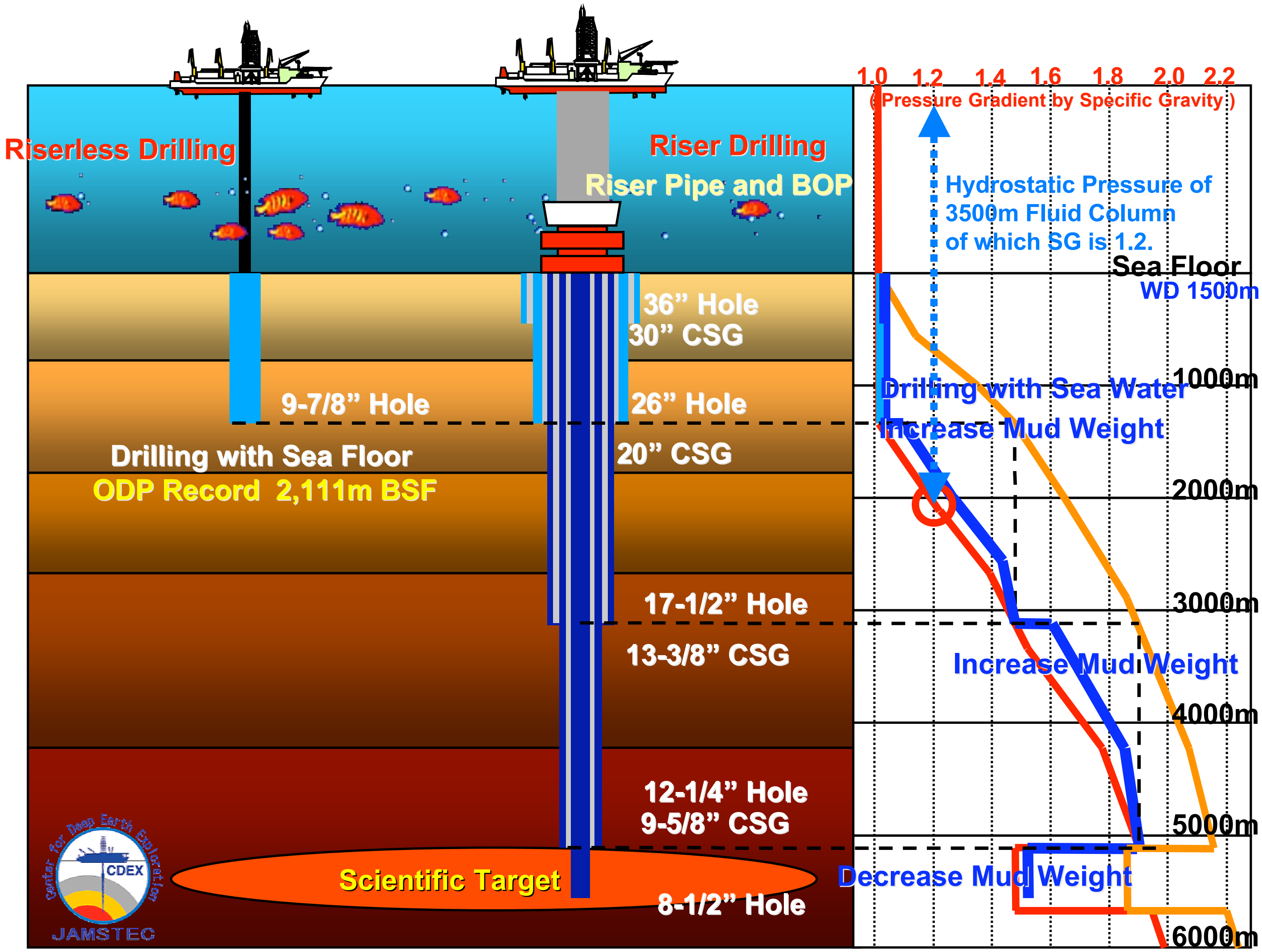
- Operated by Japan's JAMSTEC Center for Deep Earth Exploration (CDEX)
- Scheduled to begin IODP operations in 2007
- 12,000 m drillstring with 2500 m riser capability

IODP - Multiple Drilling Platforms



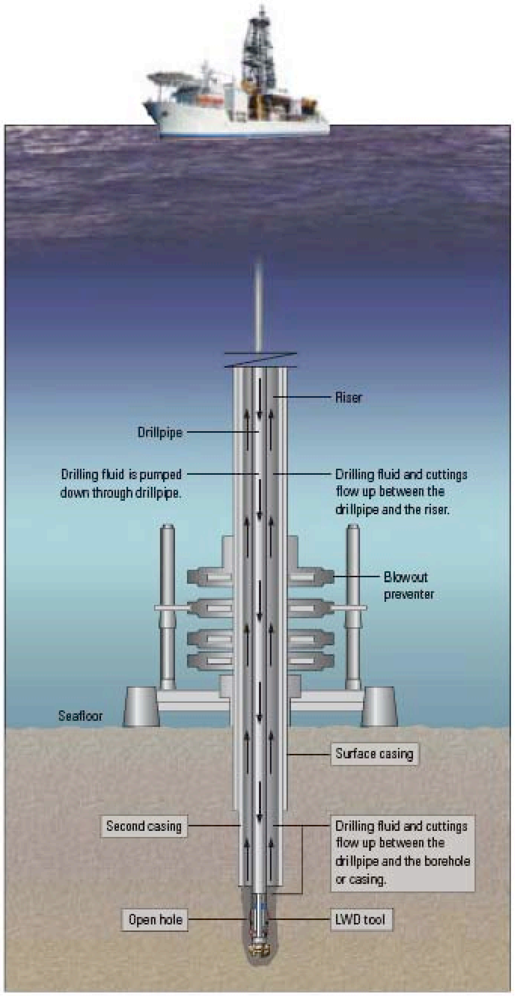
- Riserless drilling vessel
- Riser-equipped drilling vessel
- Mission specific platforms

Riser versus Non-Riser: What's the difference?

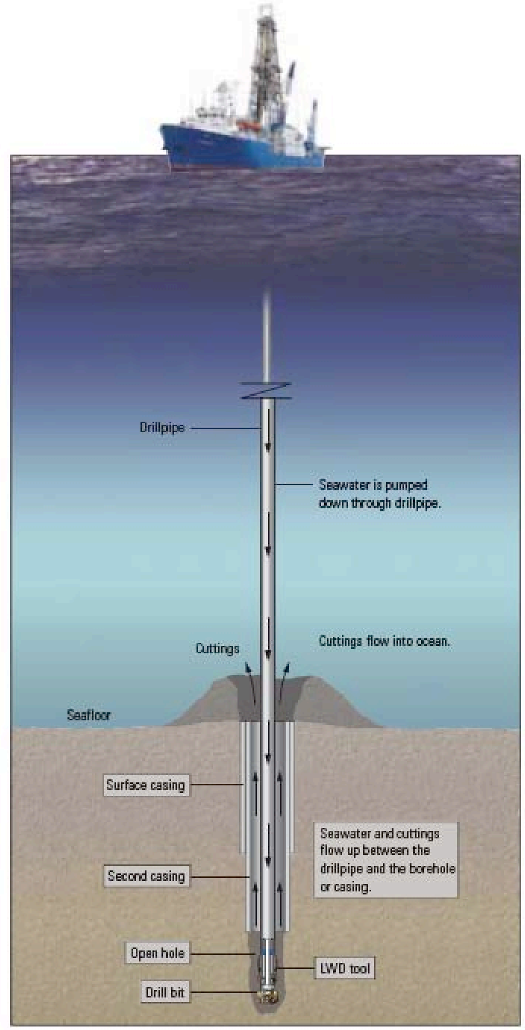


LEGEND

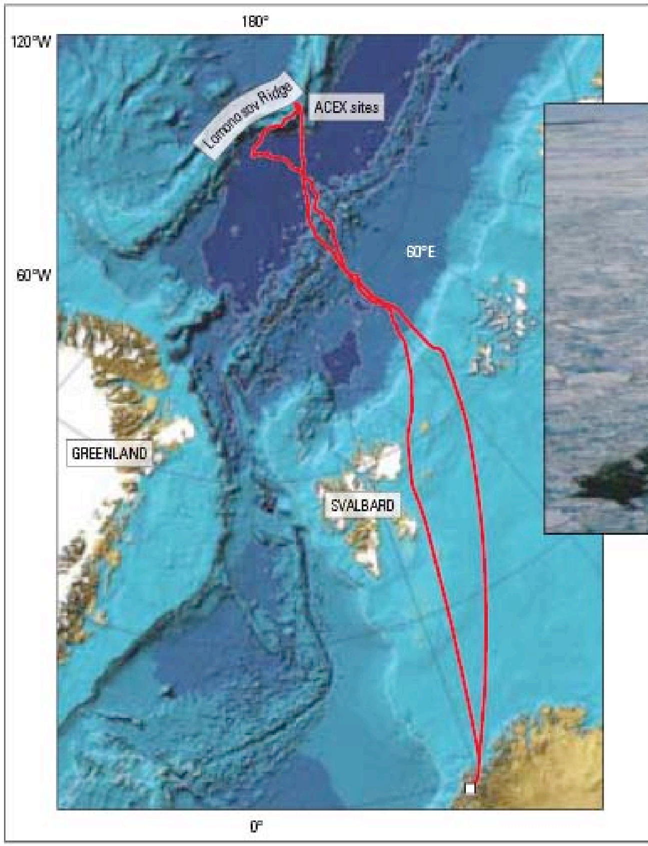
- Formation Pore Pressure Gradient
- Formation Fracture Pressure Gradient
- Mud (Drilling Fluid) Weight



^ 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 attached to the drillship, while its bottom is secured at the seafloor. A blowout preventer (BOP) placed at the seafloor between the wellhead and the riser provides protection against overpressured formations and sudden release of gas. The riser pipe diameter of up to 21 in. [53.3 cm] is large enough to allow the drillpipe, logging tools and multiple casing strings to pass through.

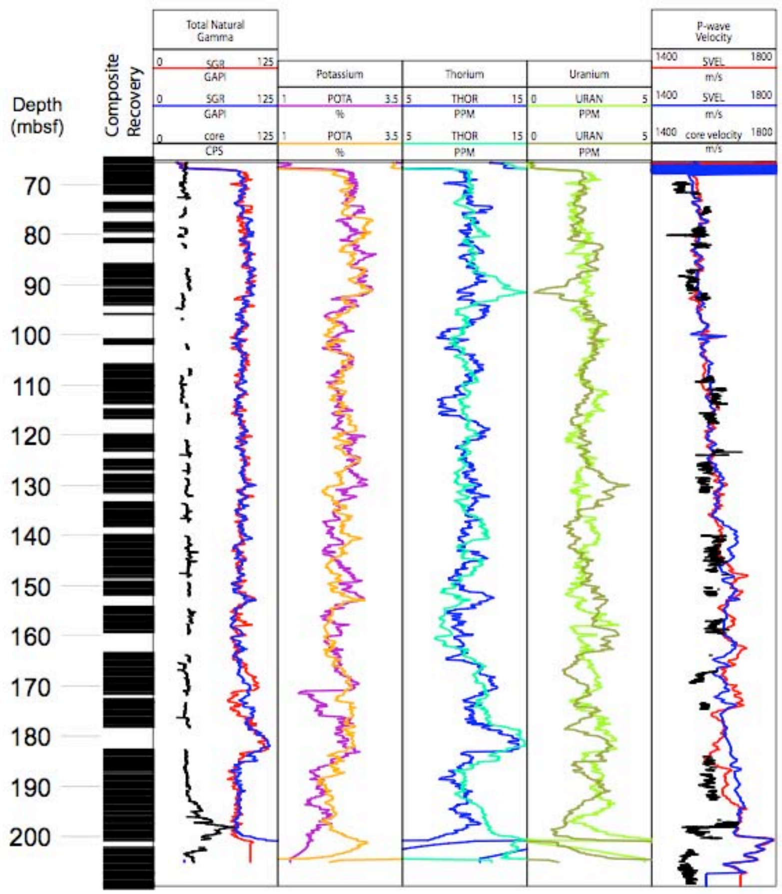


^ Riserless drilling. Seawater is pumped down through the drillpipe to clean and cool the bit. The drilling fluid and the cuttings flow up between the drillpipe and the borehole or casing, where they spill onto the seafloor and do not return to the surface.

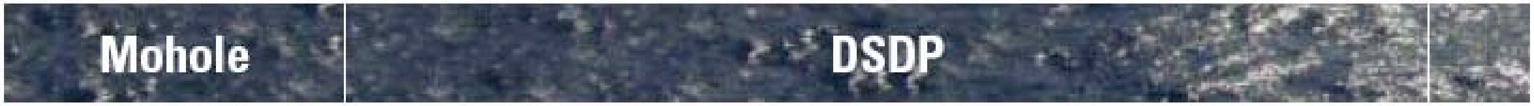


< An example of an MSP operation (Expedition 302) in the Arctic. The first Arctic coring expedition (ACEX) was conducted from August to September 2004, at the crest of the Lomonosov Ridge in the central Arctic Ocean (*left*). The *Vidar Viking* drillship (*right*) was protected by two icebreakers *Oden* and *Sovetskiy Soyuz*. *Vidar Viking* drilled five boreholes at four sites, and a 339-m [892-ft] long sedimentary sequence was recovered in the cores. (Photograph courtesy of M. Jakobsson, IODP.)

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)



1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983

1961
Positioning drillship in 3,570 m [11,713 ft] of water and testing drillpipe integrity with internal magnetic sondes

Mohole test hole confirms ability to sample pelagic sediment and basement rock in deep waters

1968
DSDP Leg 1: discovery of salt domes in the Gulf of Mexico in 1,067 m [3,500 ft] of water depth

DSDP Leg 3: conclusive evidence of seafloor spreading and continental drift

1970
Sonar-guided borehole reentry

DSDP Leg 13: first solid evidence of Mediterranean sea-drying events

1973
Trials of heave compensation system

1974
DSDP Leg 39: causal link between Earth's 23,000-year processional cycle and large-scale climate change

1975
Use of reentry cone to reenter borehole in 5,519 m [18,108 ft] of water depth

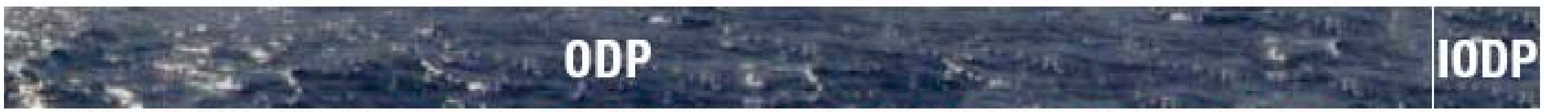
1976
Releasable bit to allow larger ID wireline sondes to log open hole in riserless environment

1978
DSDP Leg 60 in Mariana Trench in 7,034 m [23,079 ft] of water depth

1979
Trials of hydraulic piston corer to recover undisturbed sediment cores

1981
Cores from DSDP Leg 62 (1981) and ODP Leg 148 (1993) giving evidence for microbes in oceanic basalt

1982
DSDP Leg 84: recovery of 1-m long massive gas hydrate core offshore Costa Rica



1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004

1985
Reentry of an 8-year-old borehole in 5,511 m [18,080 ft] of water depth

1989
Openhole logging in 5,980 m [19,620 ft] of water depth

Leg 124E: use of diamond coring bits to drill through hard ocean crust

ODP Leg 125: discovery of serpentine mud volcanoes emanating from the mantle

ODP Legs 158 and 193: revealing the size and structure of active massive sulfide deposits, like those that form the basis of world-class mining sites

1991
CORK borehole seals deployed for true in-situ borehole monitoring

1992
ODP Leg 146: highest resolution record of oceanic environmental and biotic changes over the last 160,000 years; evidence of climate change cycles with periods as low as 50 years

1995
Pressure core sampler recovery of core at high in-situ pressures

ODP Legs 164 (1995) and 204 (2002) revolutionize understanding of natural gas hydrate deposits

1996
LWD in 5,056 m [19,214 ft] of water depth

1997
ODP Leg 171B: recovery of pristine soft-sediment cores of the Cretaceous/Tertiary extinction boundary

1999
ODP Leg 186: two seismic/crustal deformation observatories installed in 2,000 m [6,562 ft] of water at 1,000 m [3,280 ft] below seafloor. Only 50 km [31 miles] apart, one area ends up being seismically active, the other not

2000
ODP Leg 189: 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

2001
Real-time LWD in 4,791 m [15,718 ft] of water depth

2002
Successful test of RAB Resistivity-at-the-Bit logging-while-coring system

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**

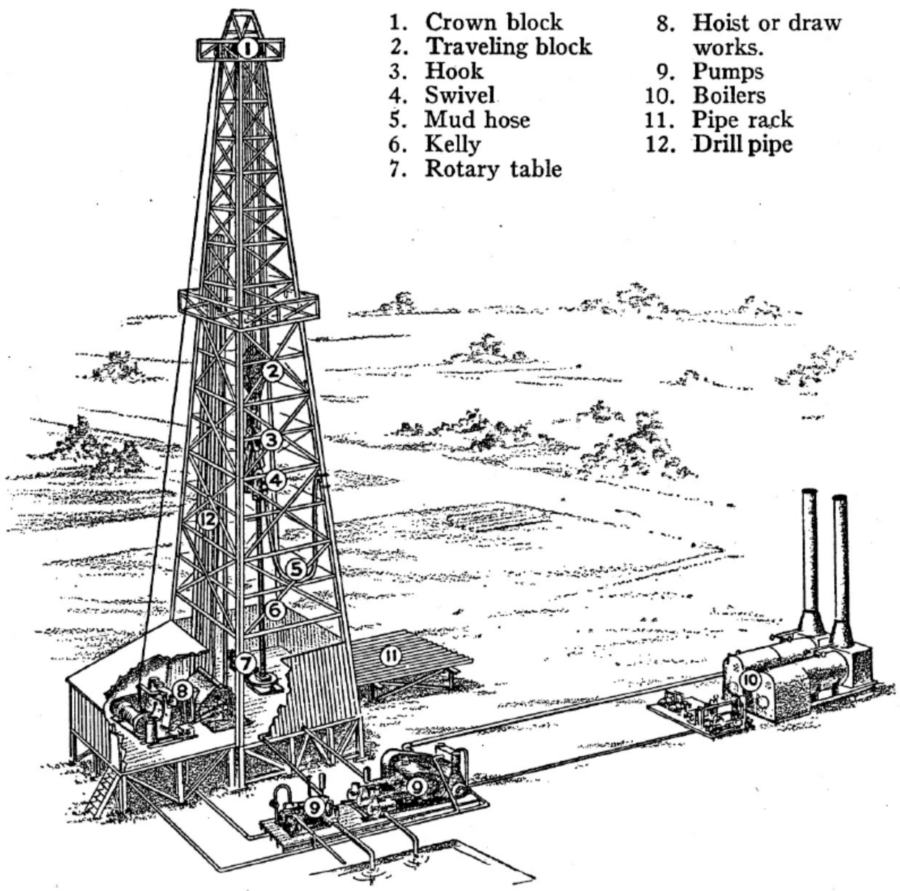
•**IODP Phase 1: *JOIDES Resolution* (2003 - 2005)**
•
•**IODP Phase 2: JR conversion (IODP operations start August 2007)**

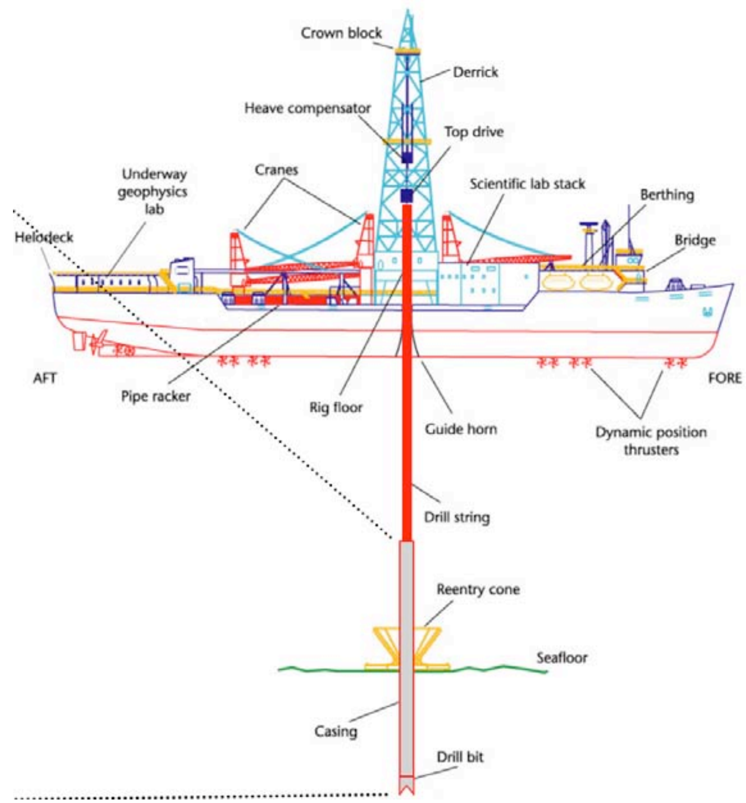
DRILLING

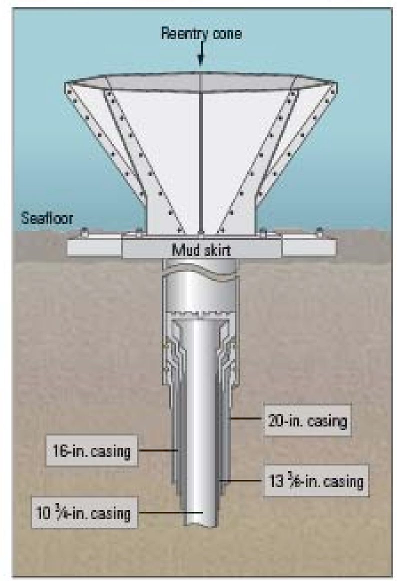

JOIDES Resolution

A Rotary Rig

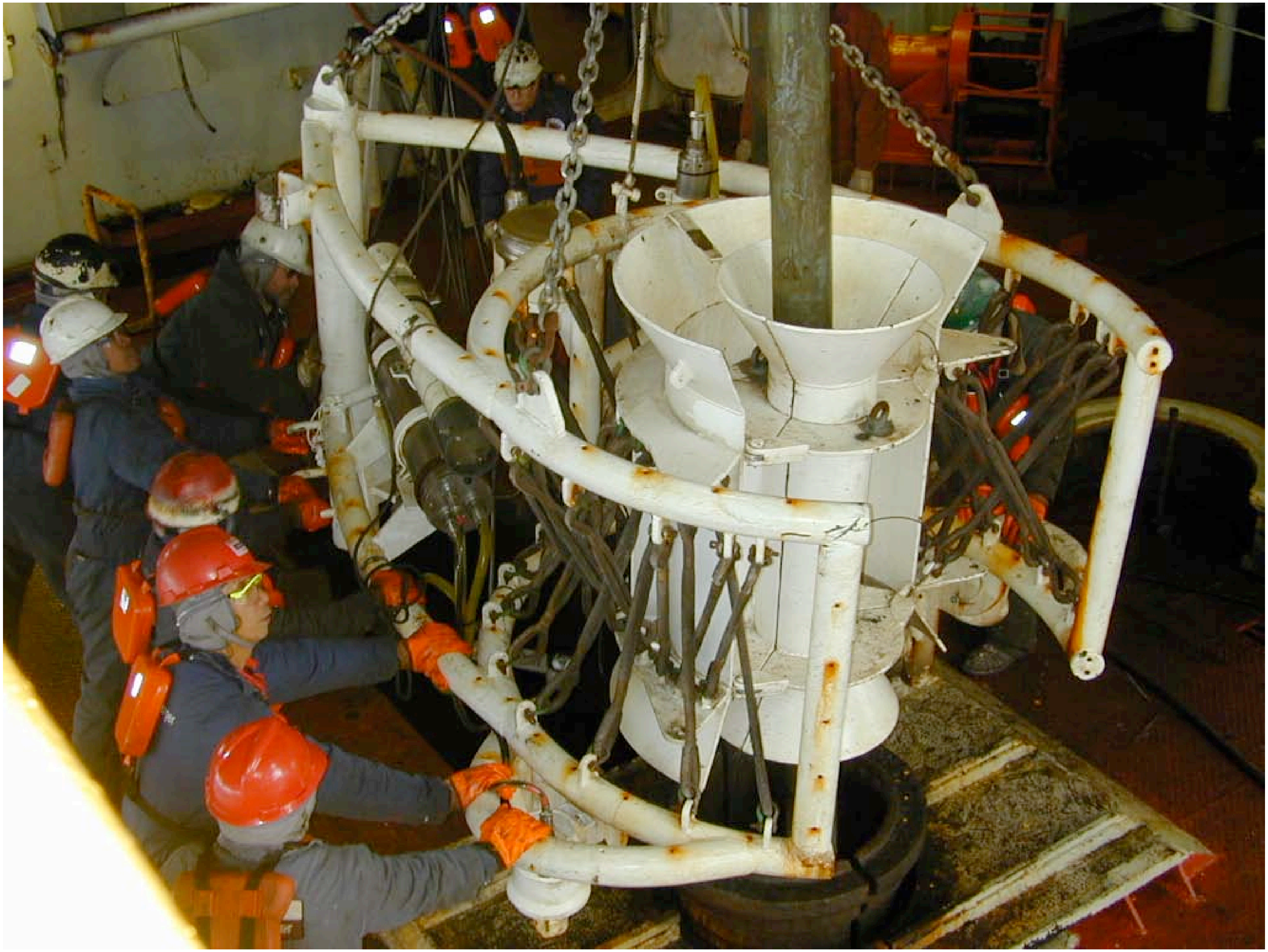
1. Crown block
2. Traveling block
3. Hook
4. Swivel
5. Mud hose
6. Kelly
7. Rotary table
8. Hoist or draw works.
9. Pumps
10. Boilers
11. Pipe rack
12. Drill pipe





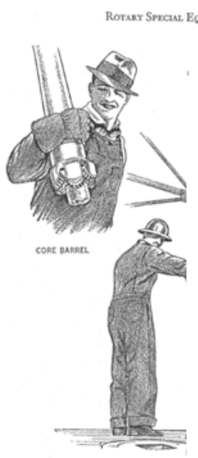


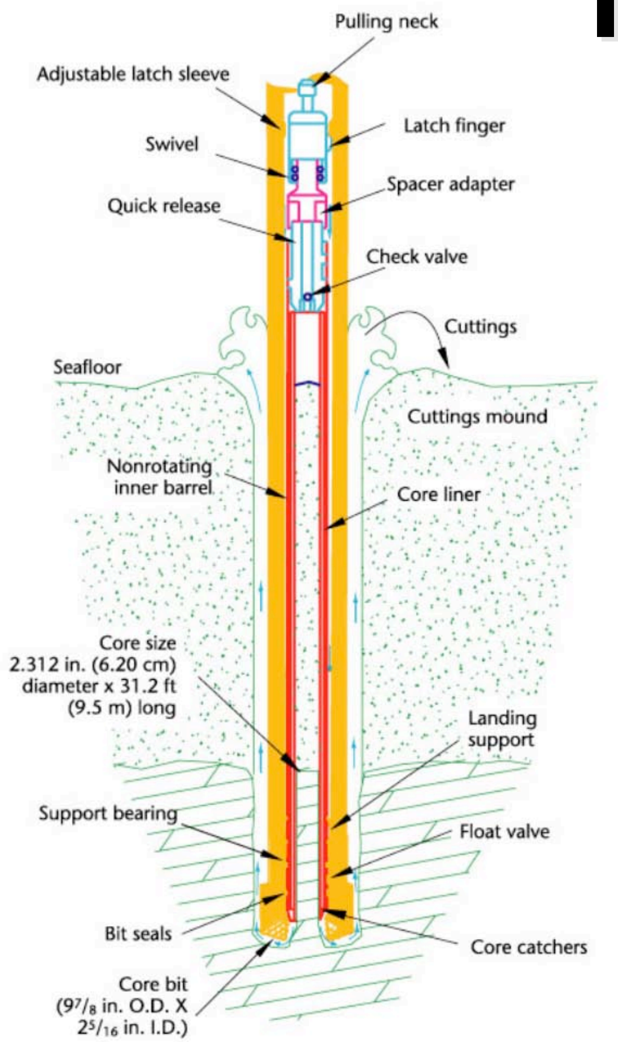
^ The reentry cone. A large 3.7-m [12-ft] diameter, funnel-shaped installation on the seafloor serves as a conduit for relocating a previously drilled hole and for landing and supporting the surface casing string. The reentry cone is released through the moon pool (*top*). (Photograph courtesy of Texas A&M University.)

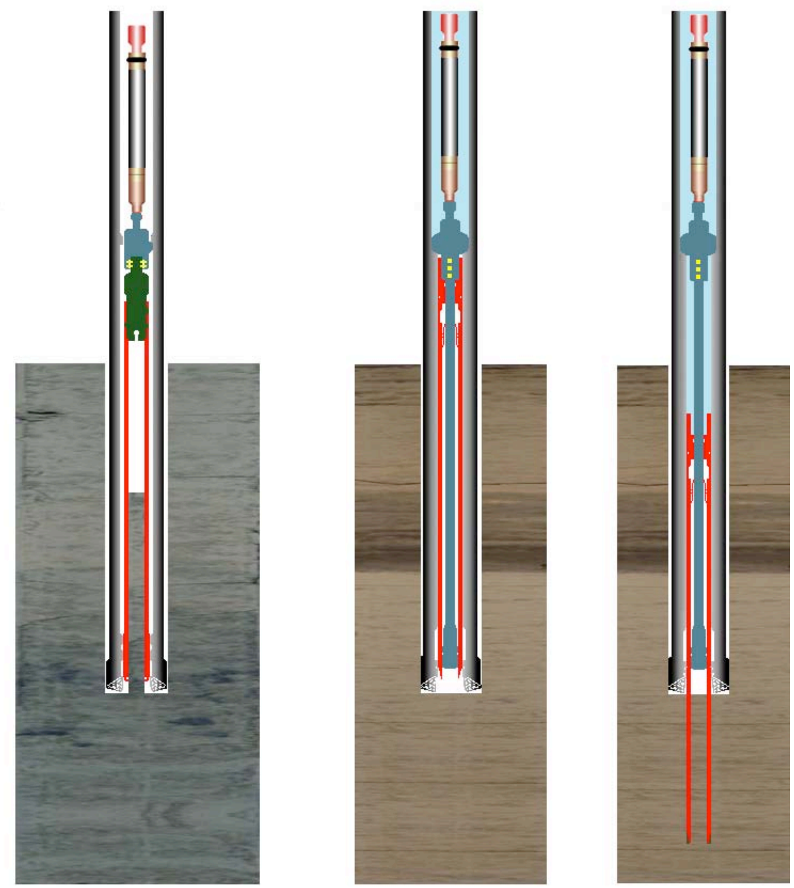


CORING

IODP coring tools



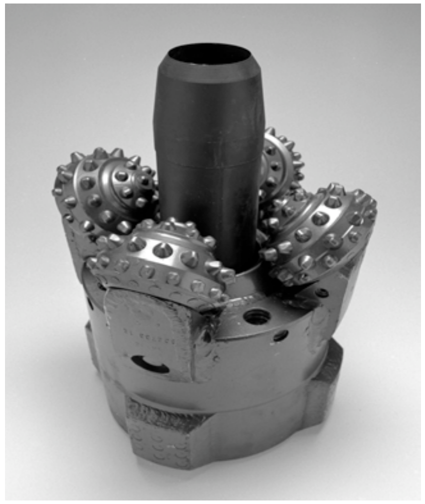




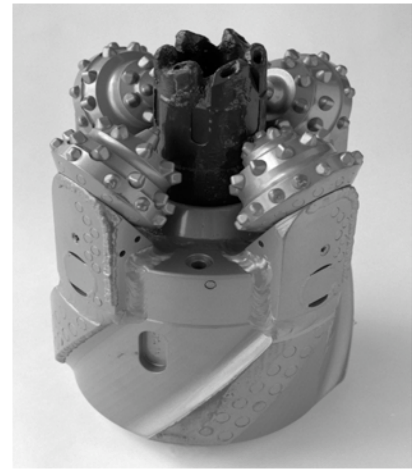
Rotary **Piston**

ODP Standard Coring Bits and Cutting Shoes

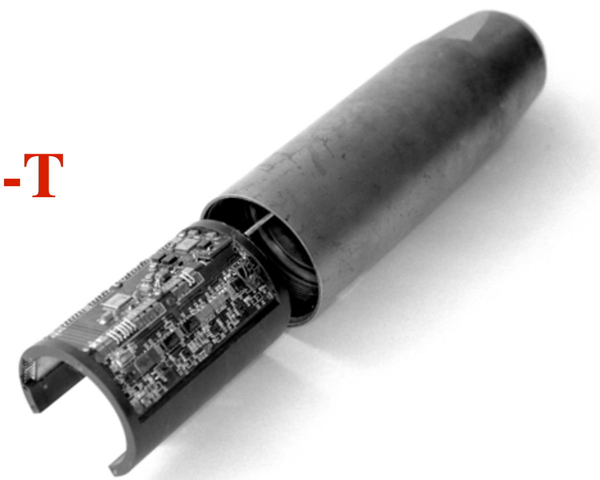
APC



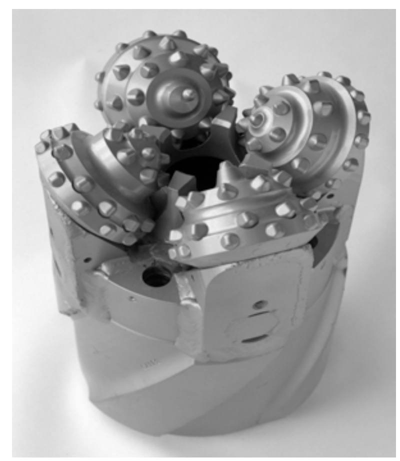
XCB



APC-T



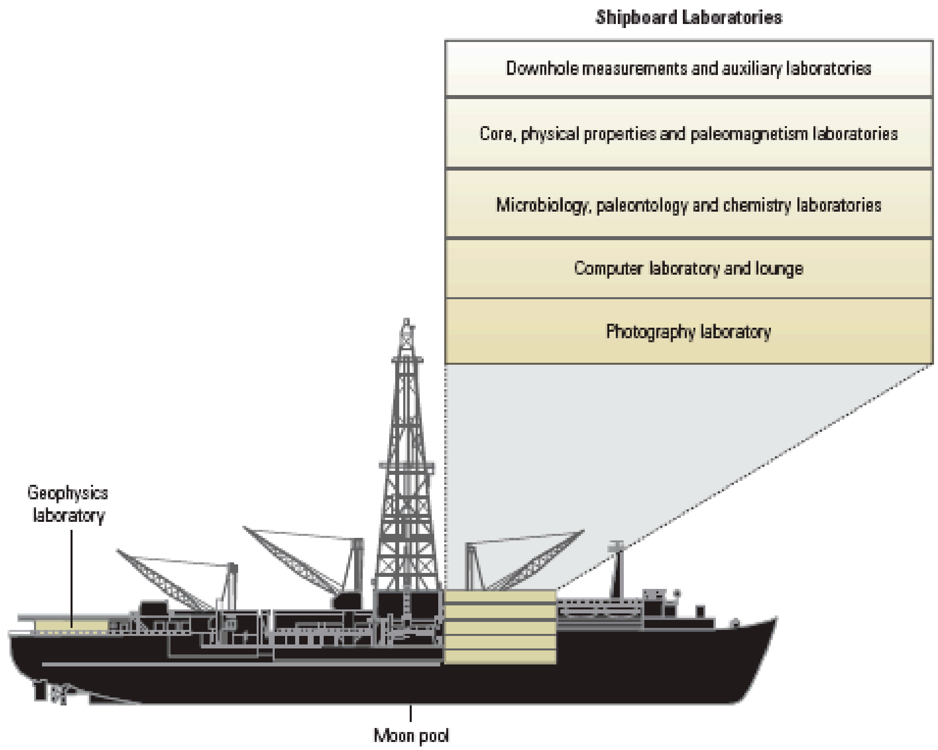
RCB



H2S Safety Protocols during Core Handling

Pressure Release to Minimize Risk of Core Liner Failure

Catwalk Handling of Sediment Cores after Recovery

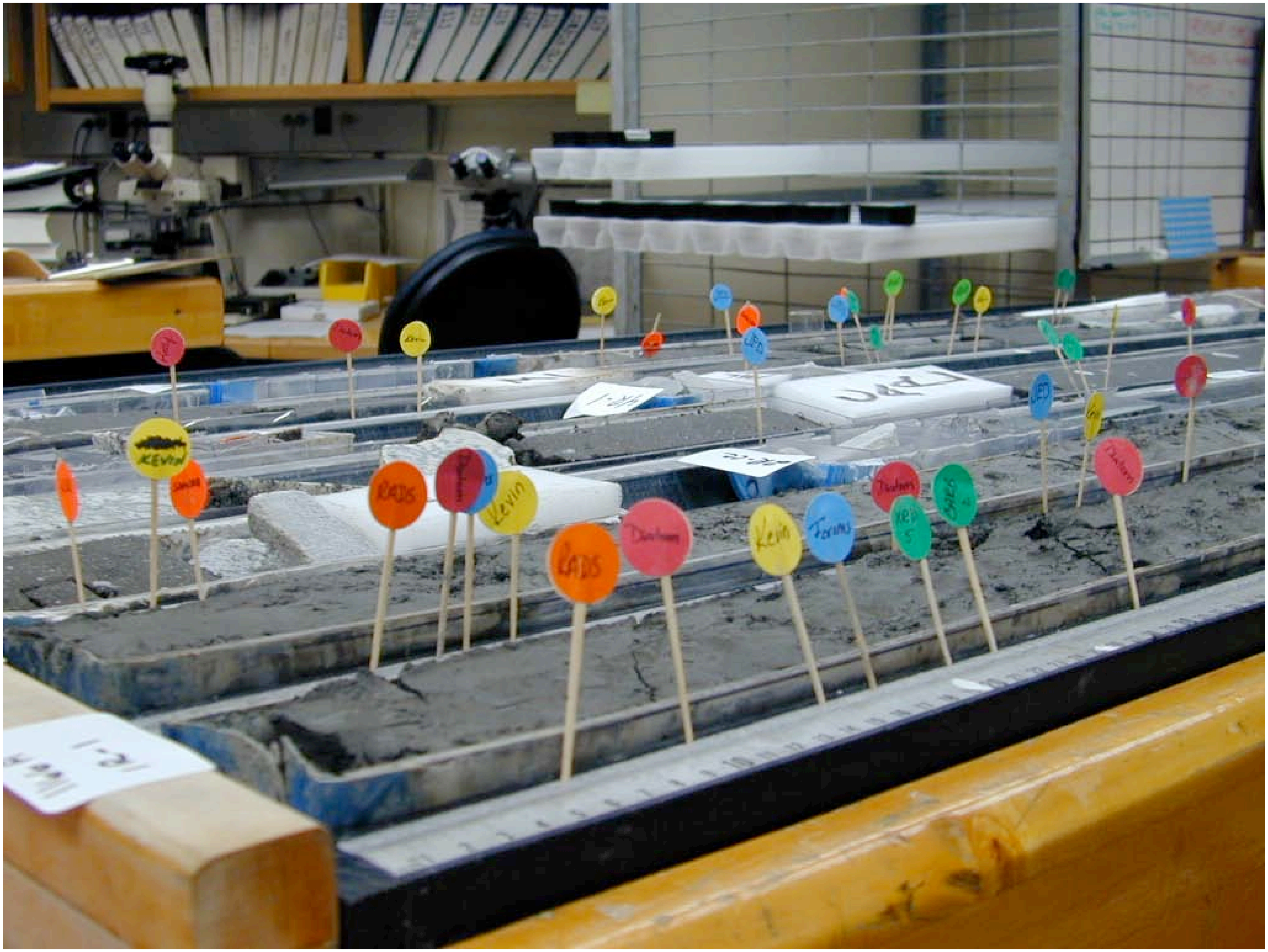


< Drillship *JOIDES Resolution* with seven floors of on-board laboratories. The 143-m [466-ft] drillship features a seven-story laboratory complex to analyze the wide variety of cores and logs collected worldwide. The ship is positioned over the drillsite by 12 computer-controlled thrusters that support the main propulsion system. Near the center of the ship is the moon pool, a 7-m [23-ft] opening in the bottom of the ship, through which the drillstring 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.


4H5
4H7

Preparation of Core Samples for Pore Water Extraction

Hydrocarbon Monitoring using Gas Chromatograph

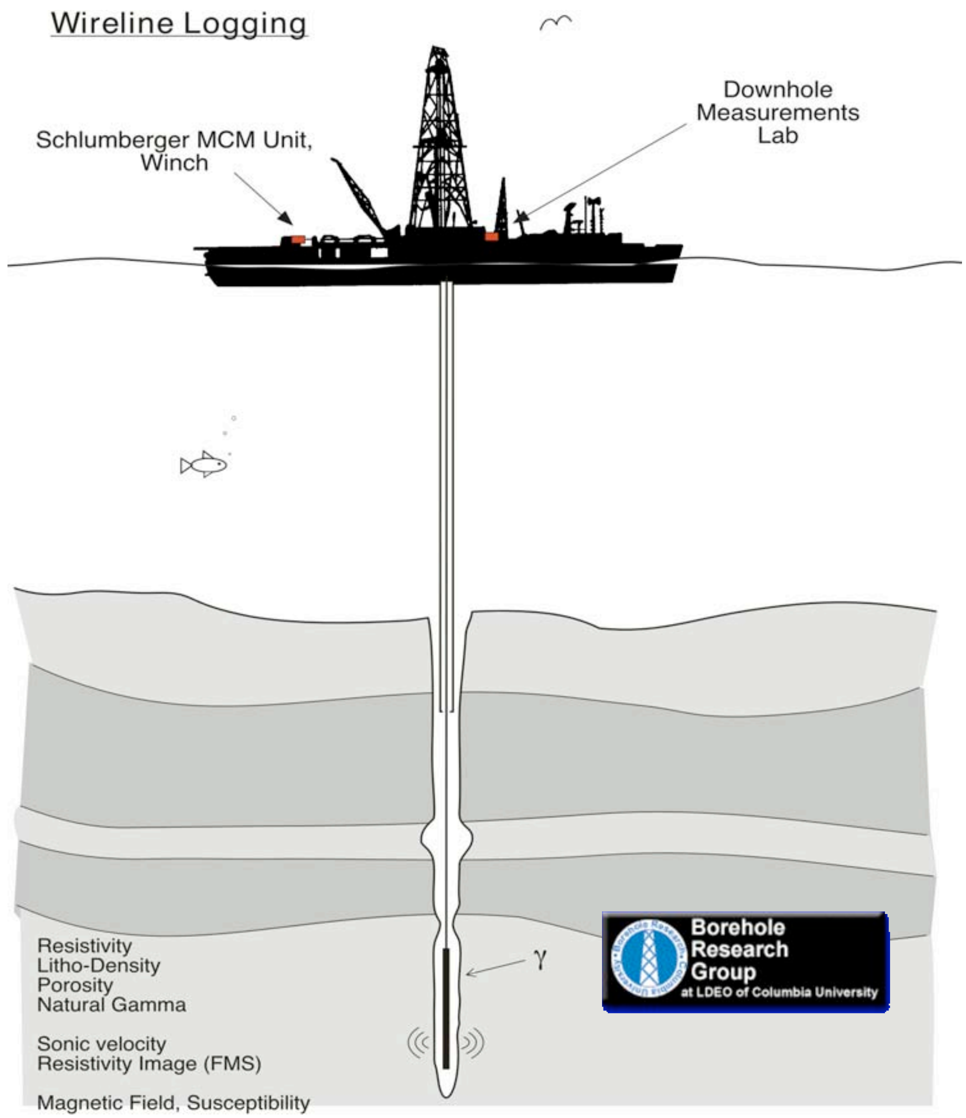

RADS
Kevin

Storage of ODP Cores in D-tubes for Transport

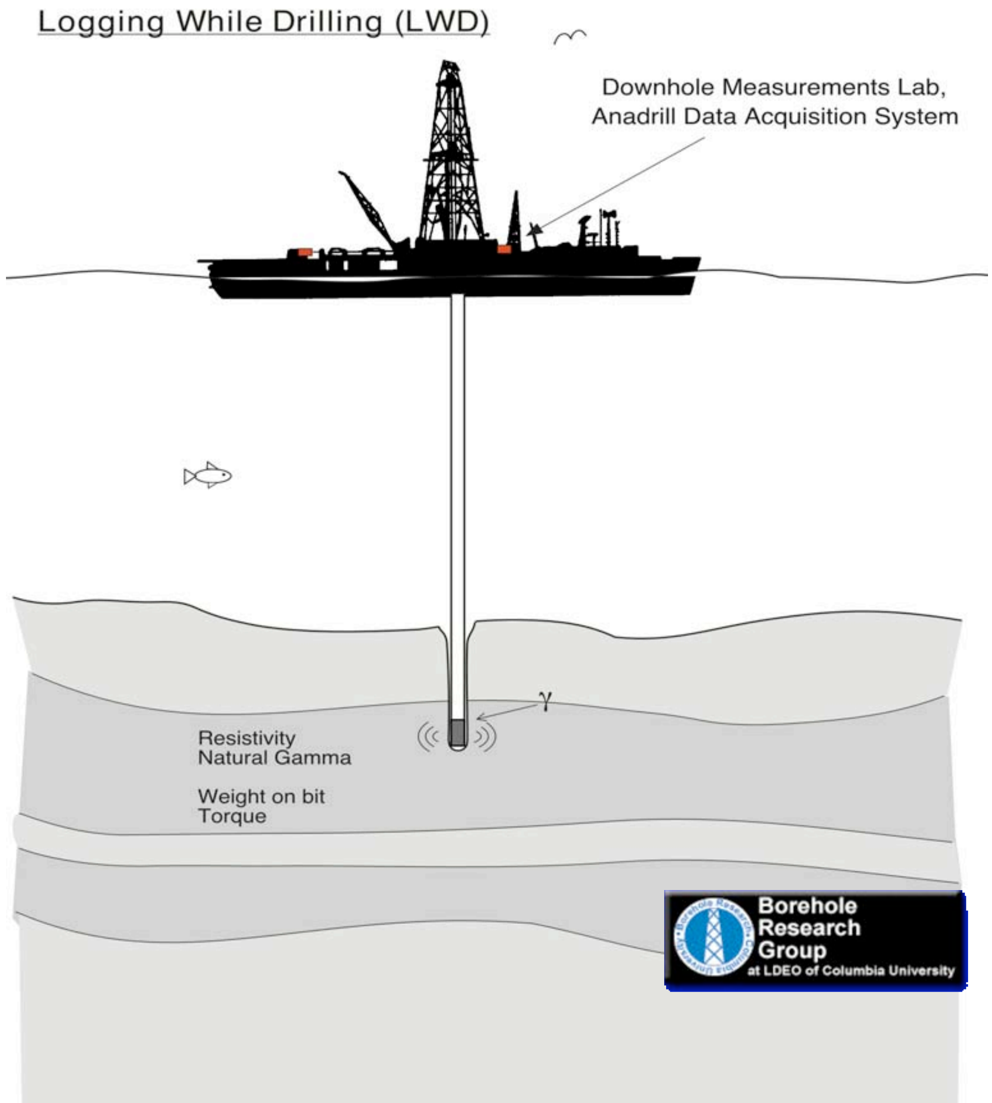
Refrigerated Core Storage Facilities
ODP Gulf Coast Repository, College Station, TX

LOGGING

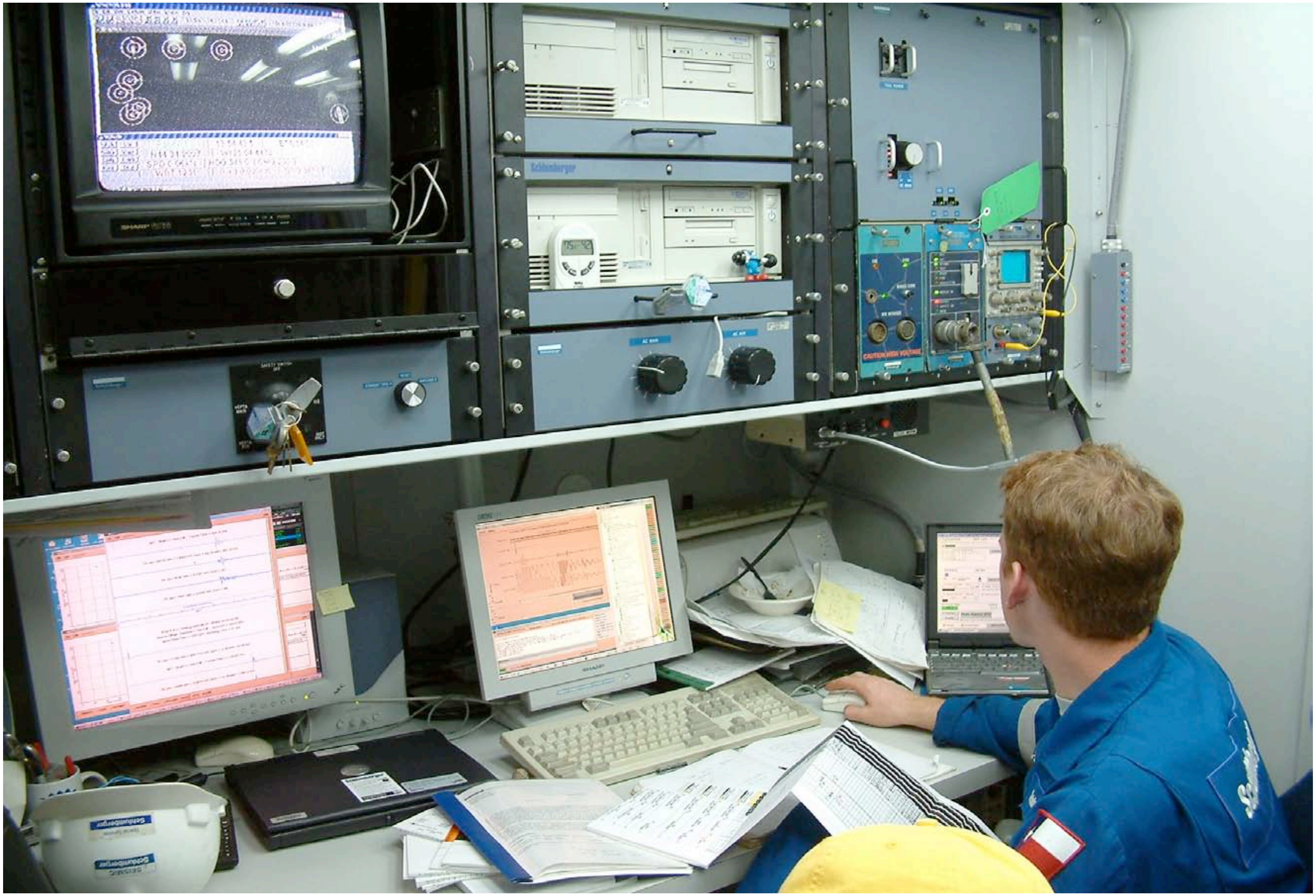
Conventional Wireline Logging



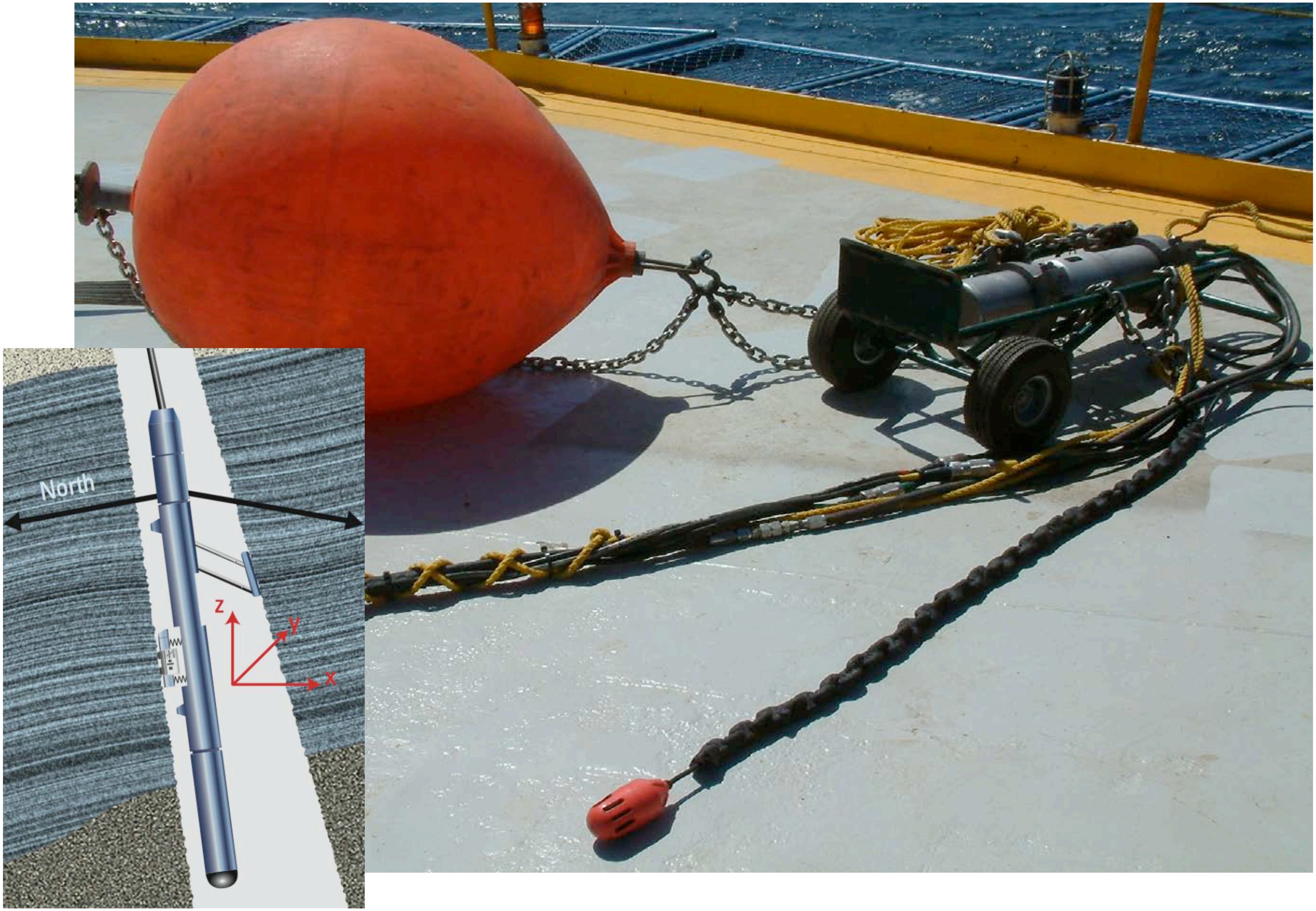
Logging While Drilling (LWD)



Schlumberger Data Acquisition System

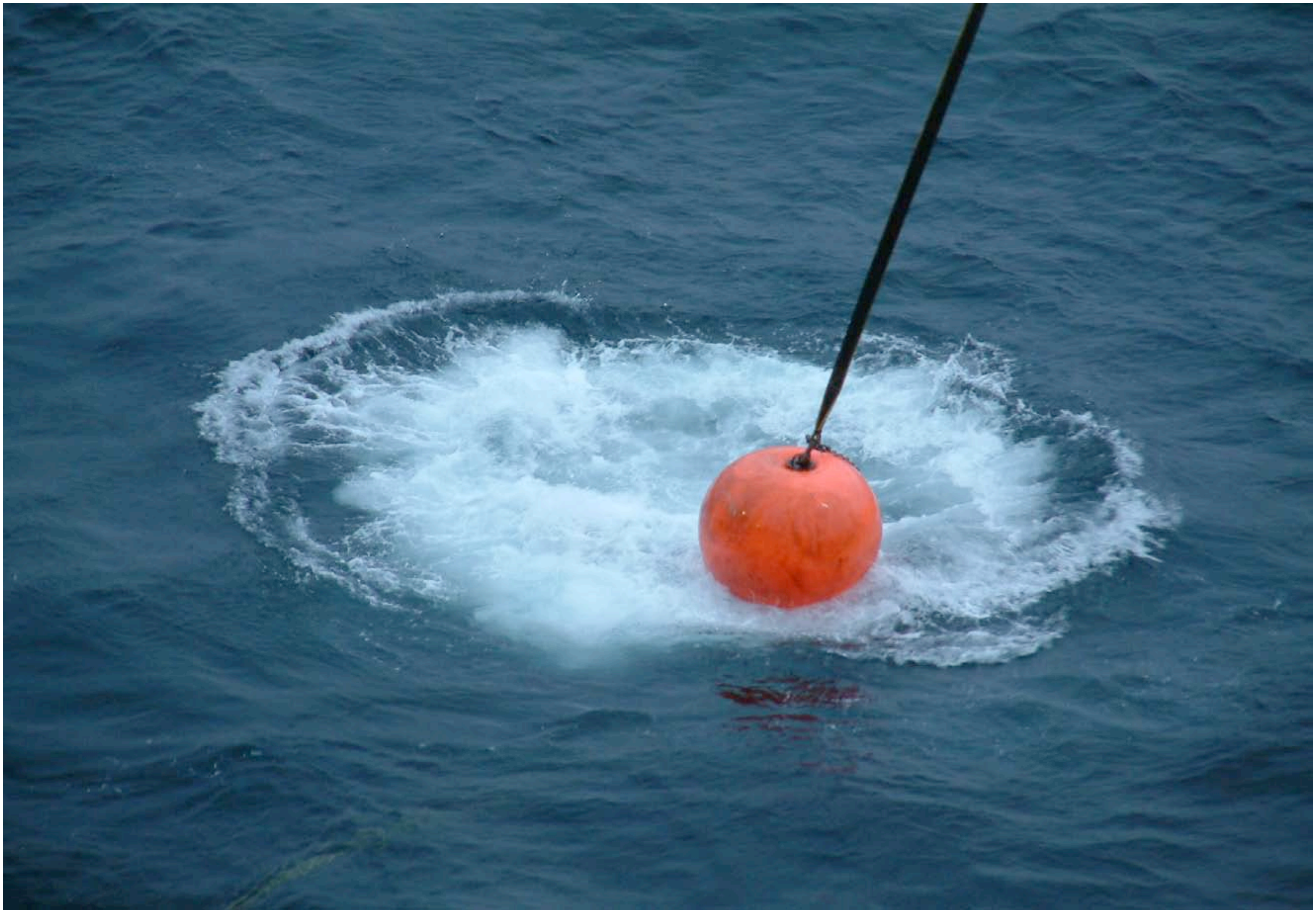


VSP - GI AirGun Deployment

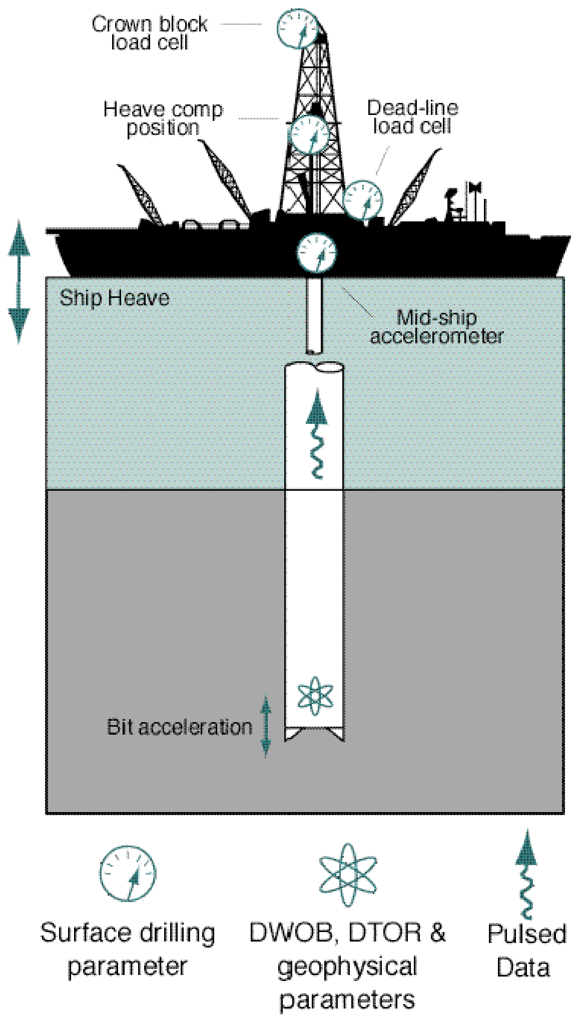


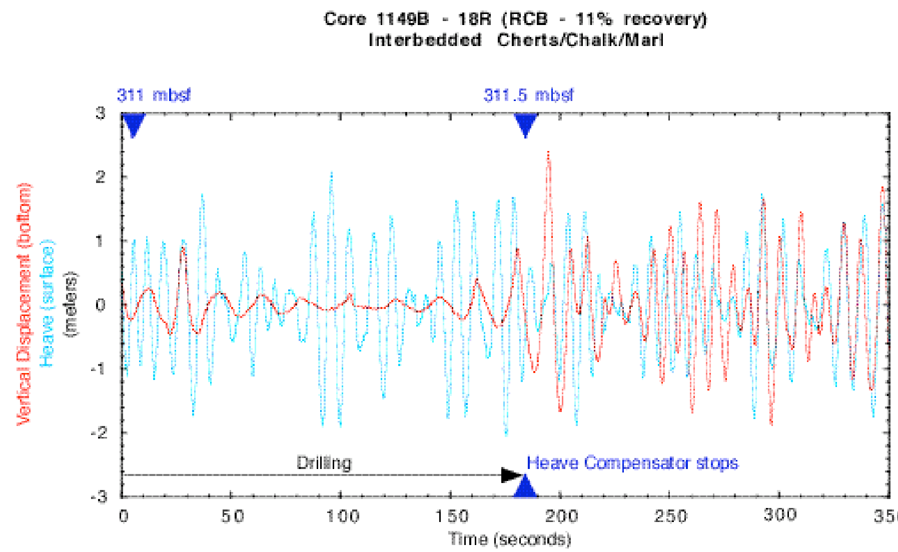
VSP - GI Airgun Deployment

VSP - GI Air gun firing

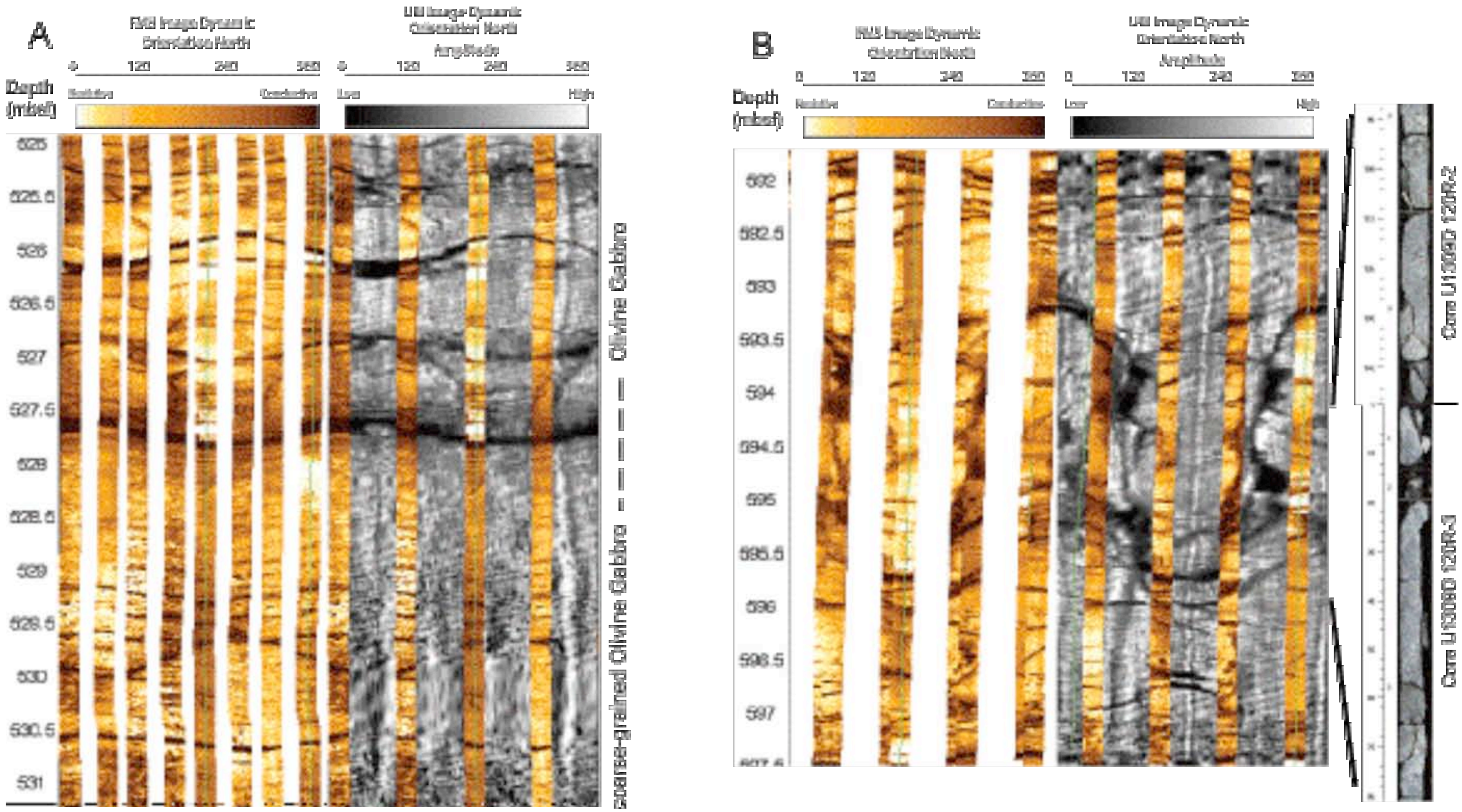


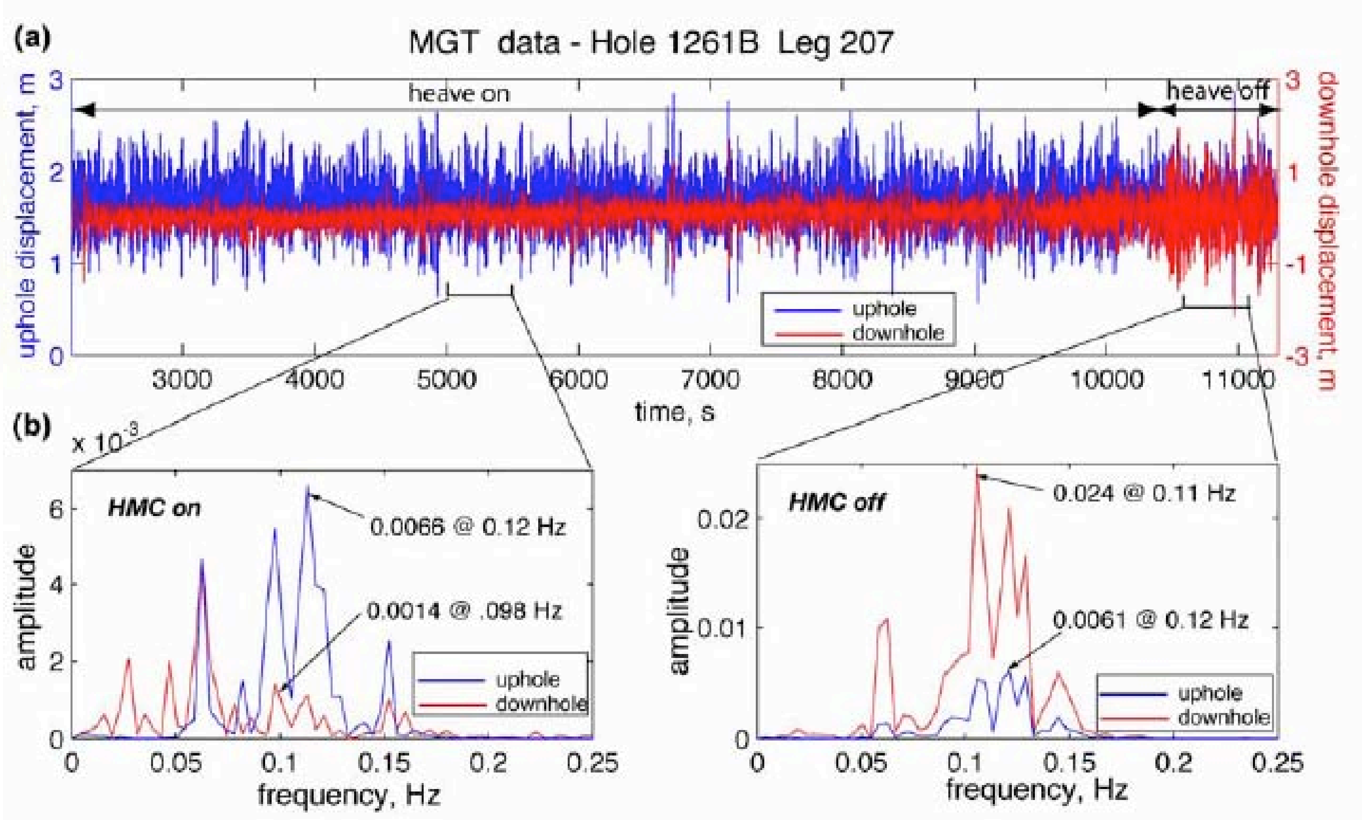
HEAVE COMPENSATION

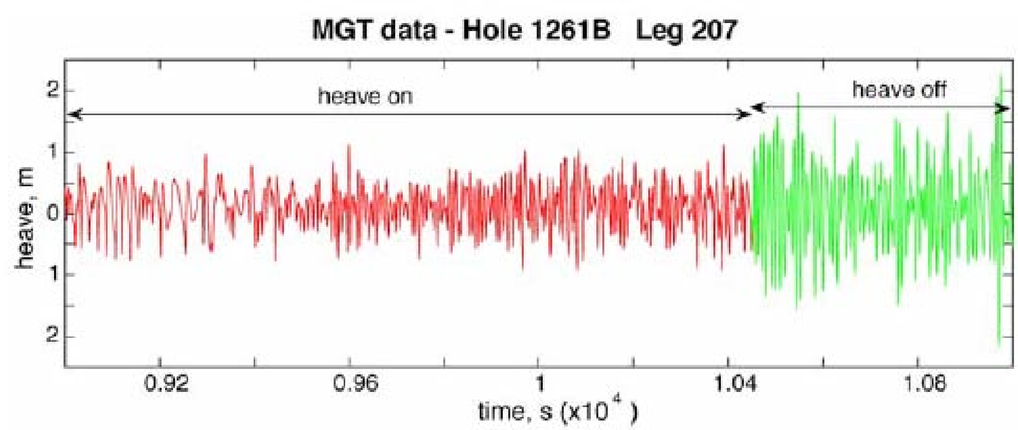

Crown block load cell
Heave comp position
Dead-line load cell
Ship Heave
Mid-ship accelerometer
Bit acceleration
Surface drilling parameter
DWOB, DTOR & geophysical parameters
Pulsed Data


Core 1149B - 18R (RCB - 11% recovery)
Interbedded Cherts/Chalk/Marl
311 mbsf
311.5 mbsf
Vertical Displacement (bottom)
Heave (surface)
(meters)
3
2
1
0
-1
-2
-3
Drilling
Heave Compensator stops
0
50
100
150
200
250
300
350
Time (seconds)

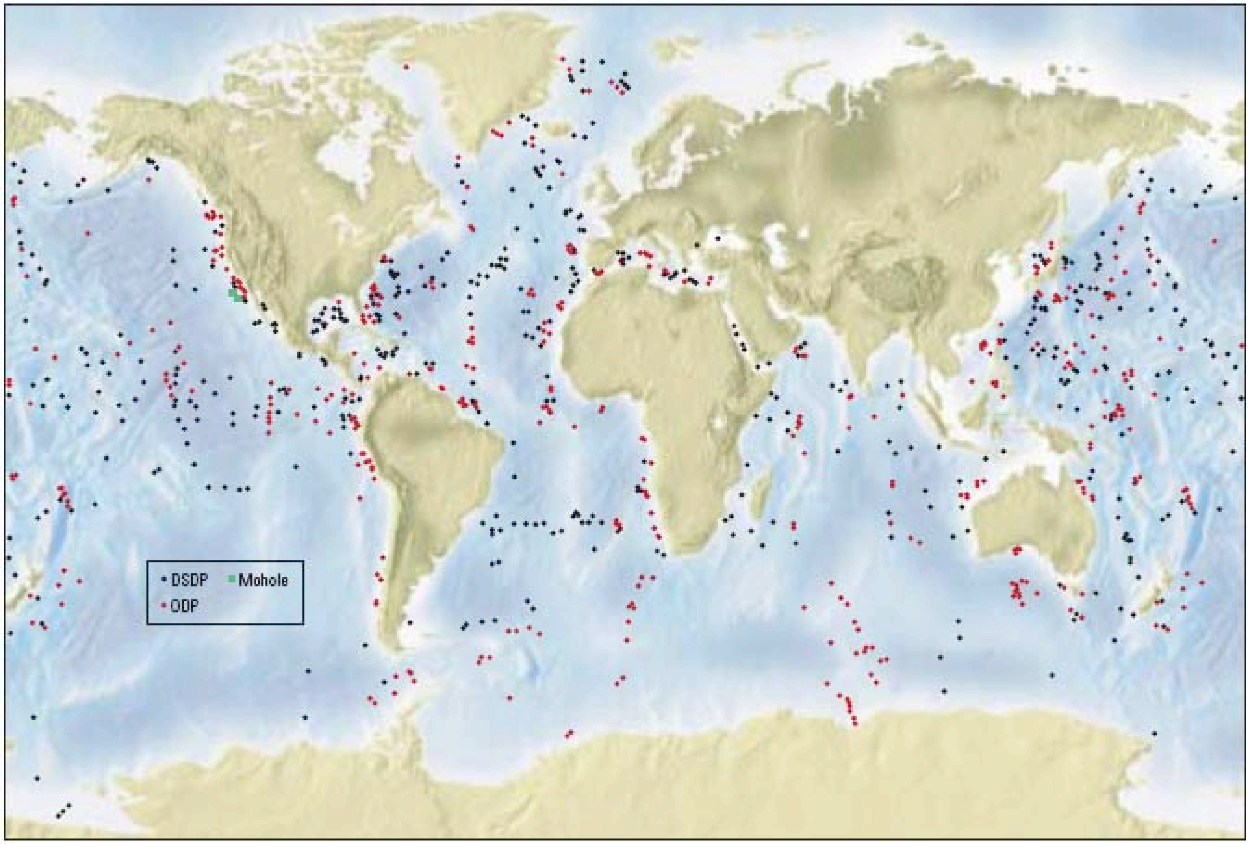
Exp 304/305: Logging Highlights




(a)
MGT data - Hole 1261B Leg 207
heave on
heave off
uphole displacement, m
downhole displacement, m
uphole
downhole
time, s
(b)
HMC on
0.0066 @ 0.12 Hz
0.0014 @ .098 Hz
amplitude
frequency, Hz
HMC off
0.024 @ 0.11 Hz
0.0061 @ 0.12 Hz


MGT data - Hole 1261B Leg 207
heave on
heave off
heave, m
time, s (x10⁴)

DATA



^ Scientific deep-ocean drillsites from 1961 to 2003. The Mohole project (green) initiated in 1958, used a converted naval barge *Cuss I* 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 624 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 653 sites.