IODP USIO

Present technological capabilities, limitations and discussion

Mantle Frontier Workshop

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Washington D.C., USA

Greg Myers

Consortium for Ocean Leadership

IODP

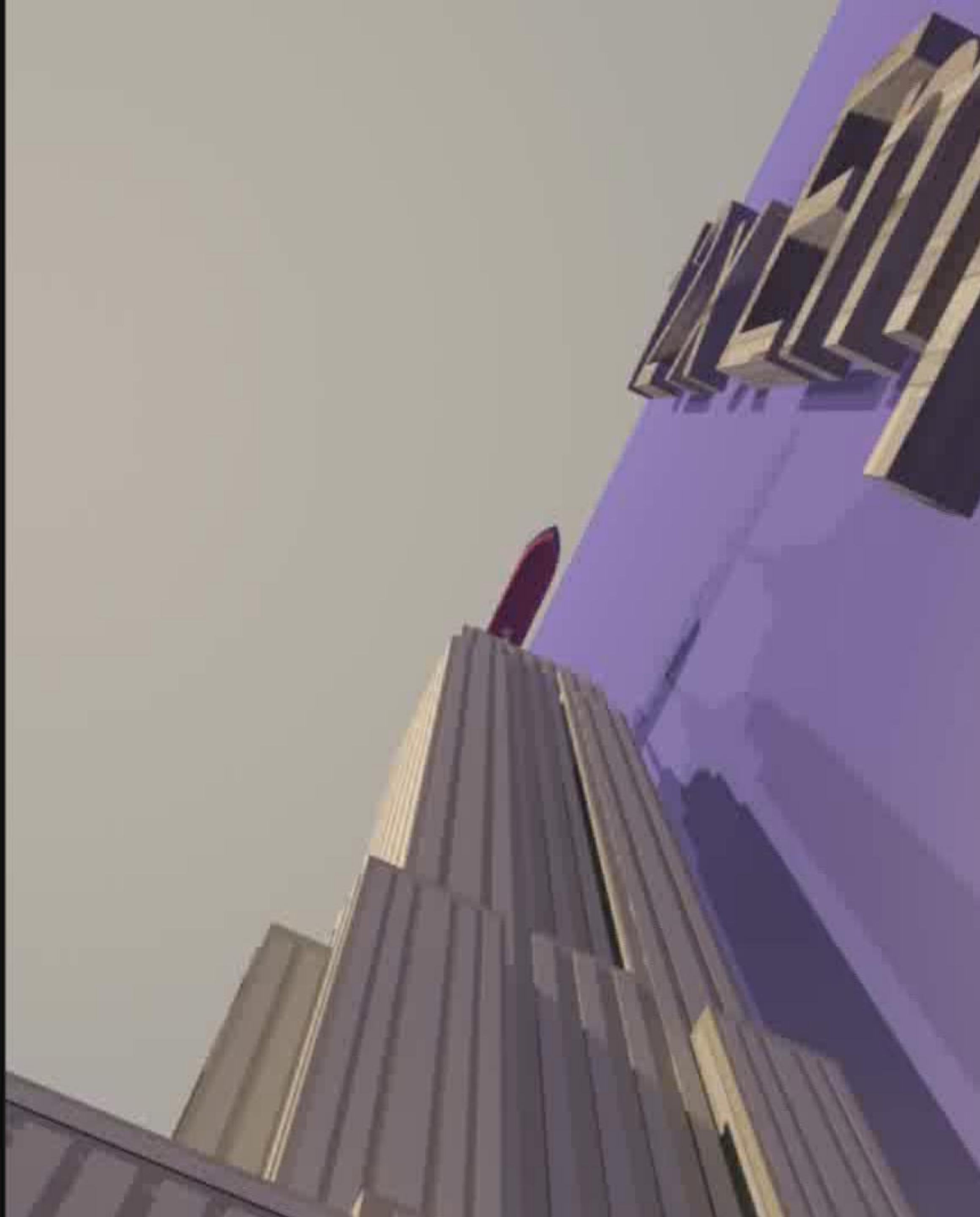
Integrated Ocean Drilling Program

United States Implementing Organization

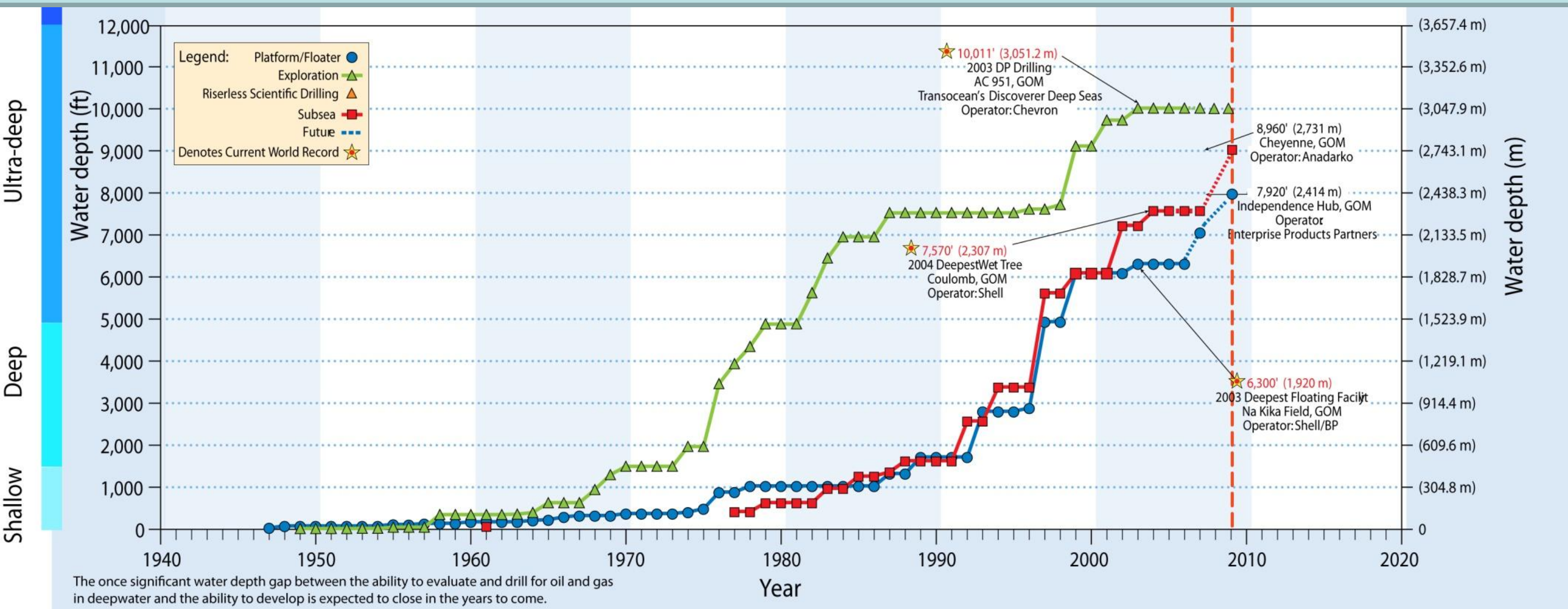
So you want to drill to the Moho

- Consider the following…
  - Water depth over 4km
  - Hole depth over 6km - 7km
    - 10 Empire state buildings of water (4.5km)
    - 14 Empire State Buildings into the seafloor (6km)

Drilling deeply is really not the problem…industry has drilled more deeply. What is unique is the water depth / hole depth combination and the rocks to be drilled



Oil and Gas Industry water depth statistics



The once significant water depth gap between the ability to evaluate and drill for oil and gas in deepwater and the ability to develop is expected to close in the years to come.

SOURCES: "RACE ON FOR DEEPW ATER ACREAGE, 3,500-METER DEPTH CAP ABILITY ," OFFSHORE MAGAZINE OCTOBER 1998, P AGE 40-41, 152, 156. UPSTREAM MAGAZINE , INTERNET SEARCHES, COMP ANY LITERA TURE, AND OFFSHORE MAGAZINE (UPDA TED THROUGH MARCH, 2006); DRILLING WD RECORDS SOURCE: TRANSOCEAN .

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Ultra-deep Drilling Statistics

Site	Water Depth (m)	Borehole Depth (m)	Total Depth (m)	Comments
Proposal 698Full-2	1,798	8,000	9,798	1 year? <250°C
KTB	0	9,101	9,101	4+ years; $338 million; 265°C
Kola SG-3	0	12,262	12,262	24 years; 190°C
Bertha Rogers 1-27	0	9,583 (31,441ft)	9,583	1974 gas well
Nankai NT3-01	~2,000	6,000	8,000	450 days allocated; ~175°C
1256D	3,635	1,507	5,142	~5 months; ~70 °C
JR			**10,290 (SODV)**	Total string length
Deepest hole	3,463	**2,111**	5,574	190°C, Site 504B
Deepest water	**5,980**	560	6,540	
Chikyu (riser)	2,500 (max)	7,000 (max)	**9,500**	<250°C borehole
Deepest hole	500	**3,700**	4,200	Off Australia, non-IODP
Deepest water	**2,200**	2,700	4,900	
Chikyu (non-riser)		7,000 (max)	**10,000**	
Deepest hole	1,936	**1,401.5**	3,337.5	C2 Leg 314
Deepest water	**4,081**	494	4,575	

Table created by Bill Ussler - MBARI

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Drilling to MOHO is straight forward...all you have to do is…

- Stabilize the vessel to drill/core/log in water depths ~12,000 feet (3,600 meters) and greater
- Cut rocks with a bit, connected to a drillstring
- Clean the borehole
- Keep the borehole vertical
- Manage pressure within the borehole
- Manage temperature within the borehole
- Manage stress issues within the borehole
- Collect samples, return all equipment
- Avoid unfavorable met-ocean conditions
- Find the funding and stay within time and financial constraints

Integrated Effort

- Will this be an integrated effort? We have a chance for true integration and to take advantage of vessel strengths
- One possible concept could be:
  - 1 MSPs (Mission Specific Platform) for site characterization and shallow drilling. Could use seafloor drilling systems for geotechnical characterization
  - 2. JOIDES Resolution could drill upper section of borehole
  - 3. CHIKYU could drill to total depth

Additionally, this saves costs by using the right vessel for the right phase of the project

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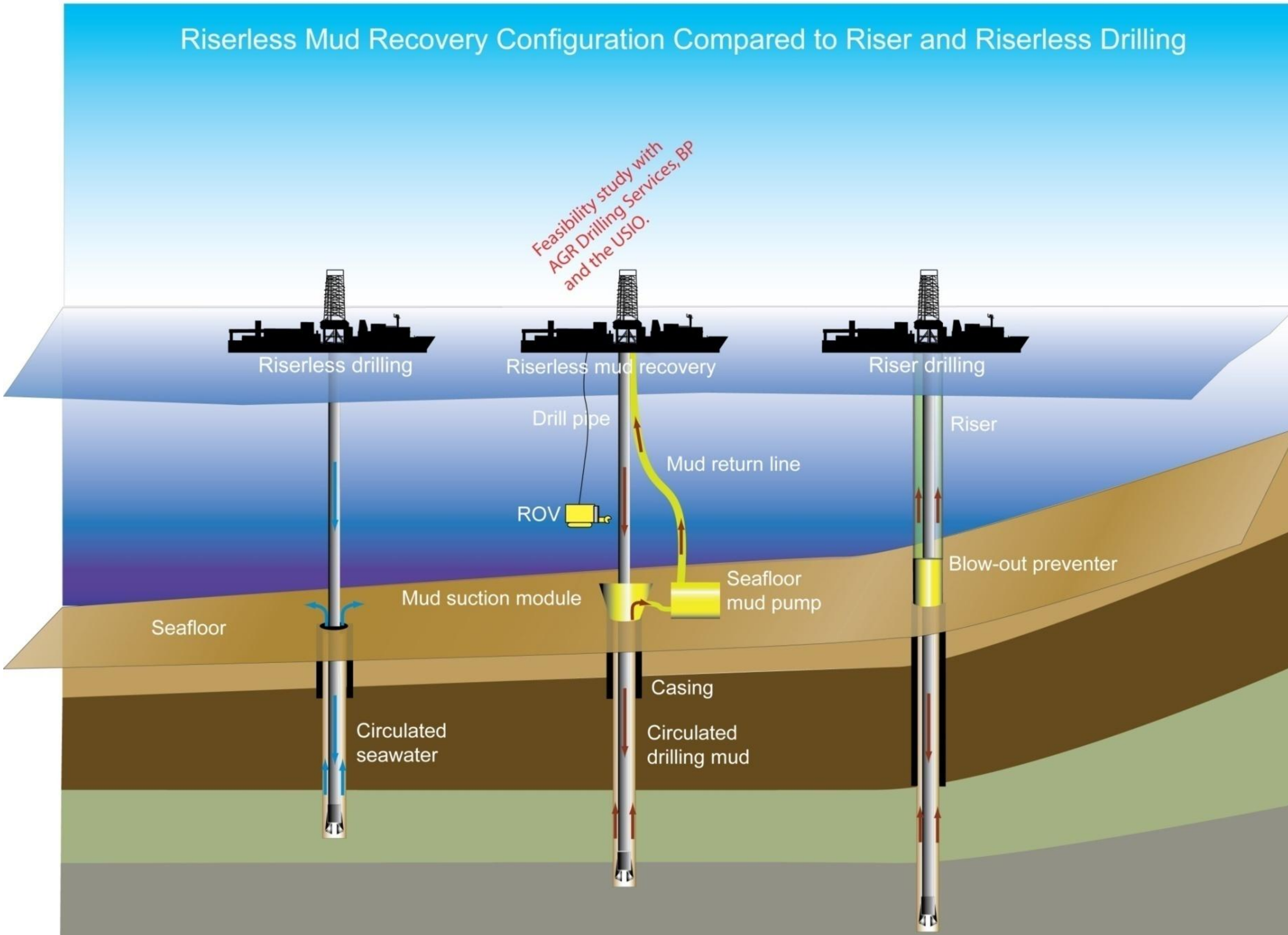
Primary Approaches to Drilling



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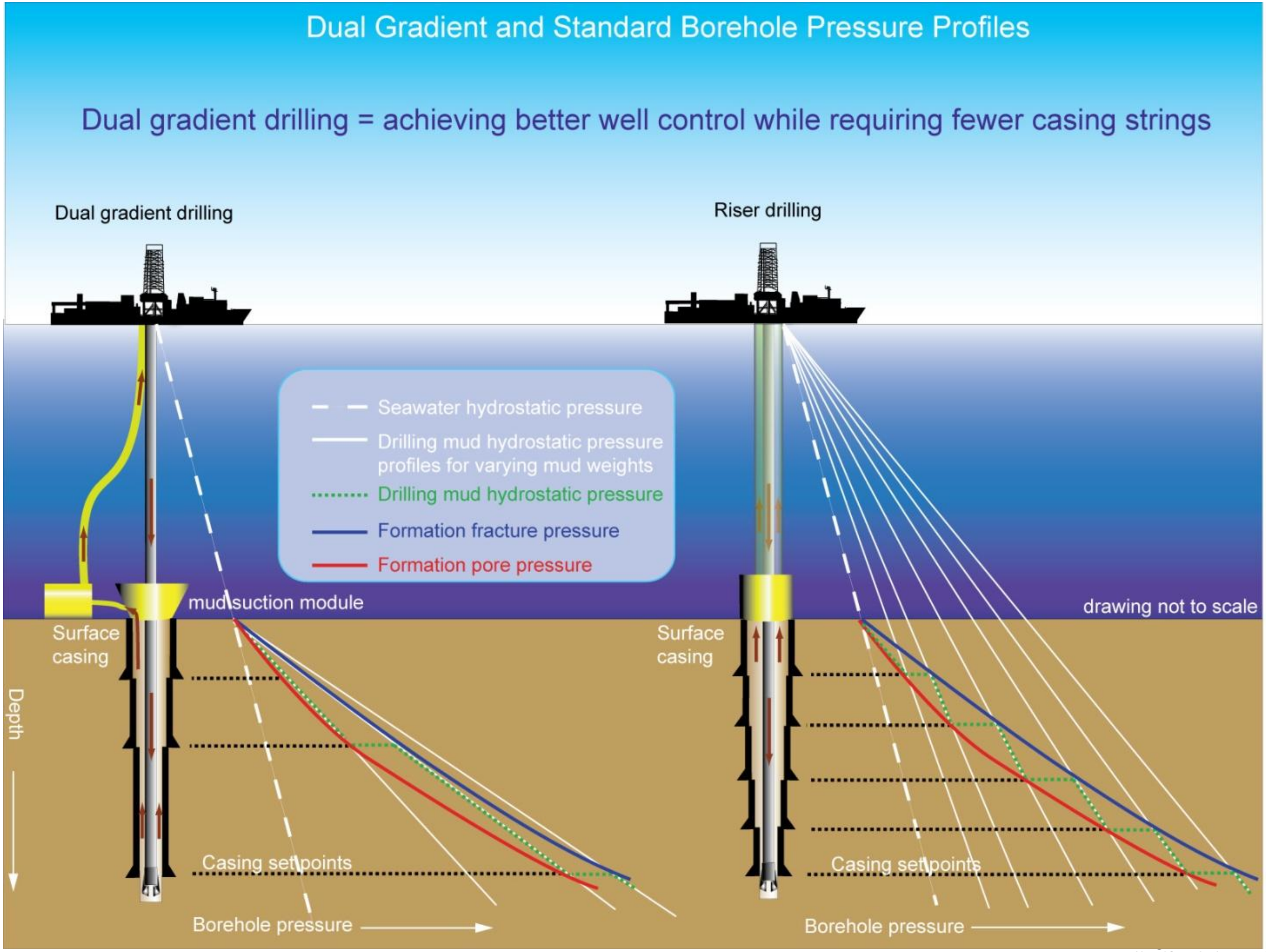
Borehole Management

- Managing the borehole means:
  - Remove cuttings
  - Provide lithostatic and pore pressure compensation
  - Develop mud cake on borehole wall to provide additional stability
  - Mitigate fluid inflows and outflows
  - Limiting excess pumping rates
- Historically, seawater with occasional mud sweeps has been utilized, thus the deepest IODP hole is 2,111m deep
- Engineered mud must be circulated continuously as part of a comprehensive plan to drill and core effectively

Riser and Riserless Options



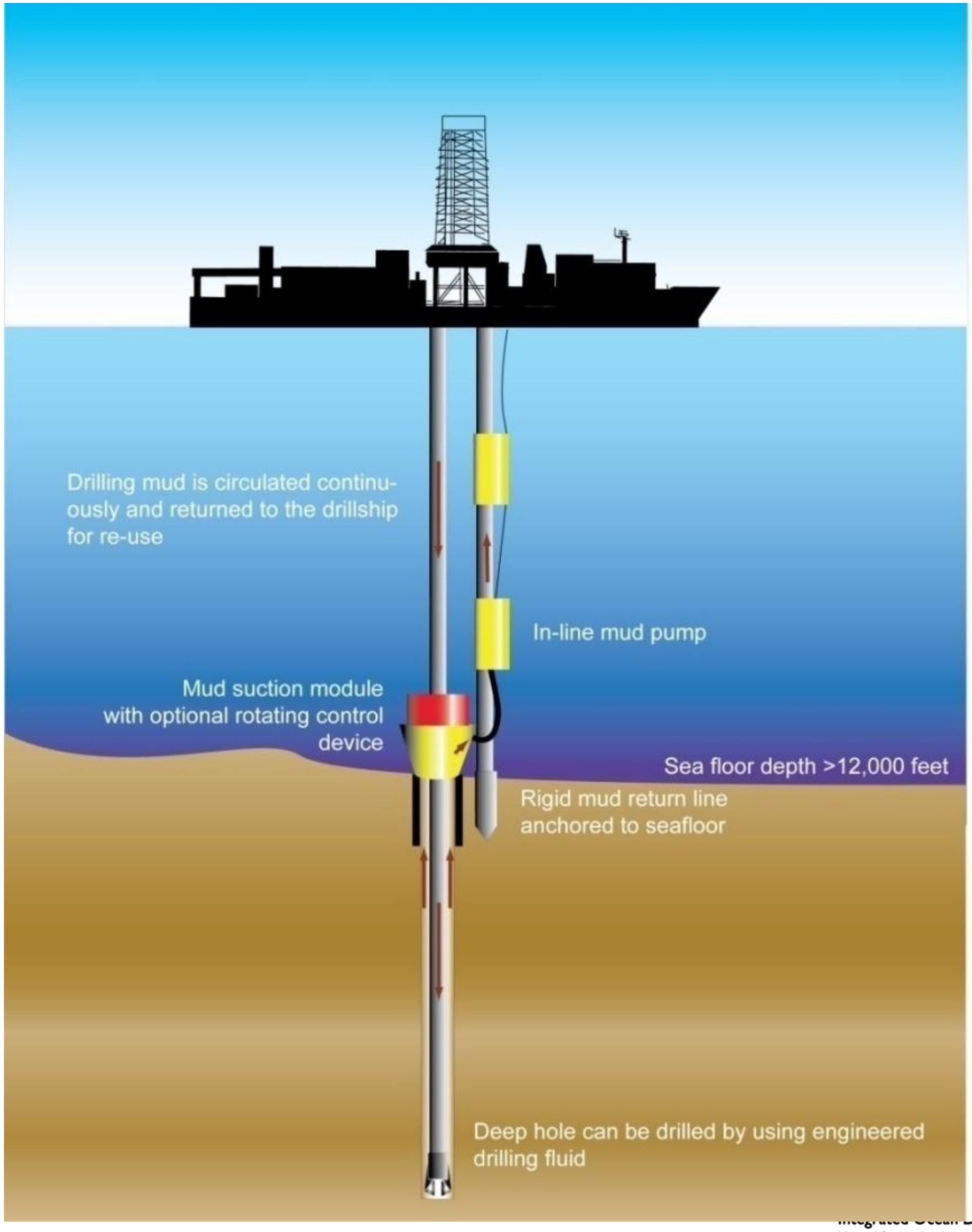
Low Cost Dual Gradient Drilling Project

The industry funded project to identify the requirements for deploying AGR Drilling Services' Riserless Mud Recovery system on a drillship such as the *JOIDES Resolution*.

This enabling technology benefits the IODP science community by providing environmentally friendly drilling access to areas previously not drillable by IODP, this includes deep crustal and overpressure sites.

This technology is directly applicable to Chikyu, *JOIDES Resolution* and MSPs.

Funds provided by the DeepStar Consortium



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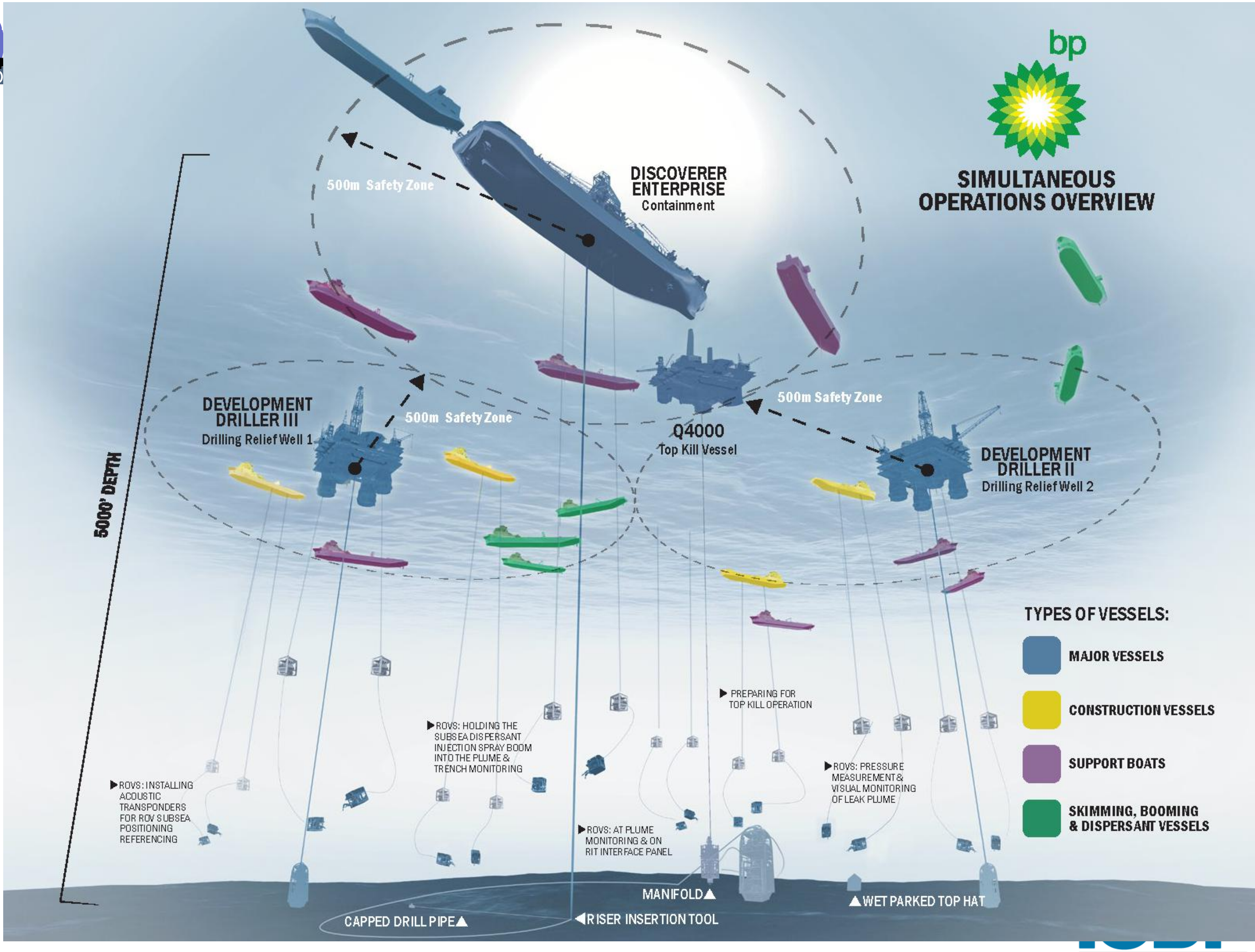

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Other variations

- Sea floor drilling systems
  - Can presently drill holes approximately 150m deep
- Deviated wells or offset wells can be considered…time and resource heavy
- Horizontal well (continuous coring likely not possible)
- Coiled tubing drilling (continuous coring presently not possible)
- Other emerging technologies such as REELWELL system

- Continuous coring
  - What recovery % is expected.
- Spot coring
  - Drill quickly and use targeted coring

Needed downhole equipment

<u>Drilling and Coring</u>

- Instrumented drill collars
- Microbio core barrels
- Transition zone corers
- High temperature mud and equipment (>175C)
- Hyper-deepwater mud circulation

<u>Logging</u>

- Drill collar fluid sampling and seismic measurements
- Latest generation wireline tools deployable from all platforms
- Fluid samplers, sidewall corers, geochemistry, magnetic resonance etc

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GEA Technology Showcase

Perma Works LLC

"An energy company engineering new technologies for Enhanced Geothermal power production"

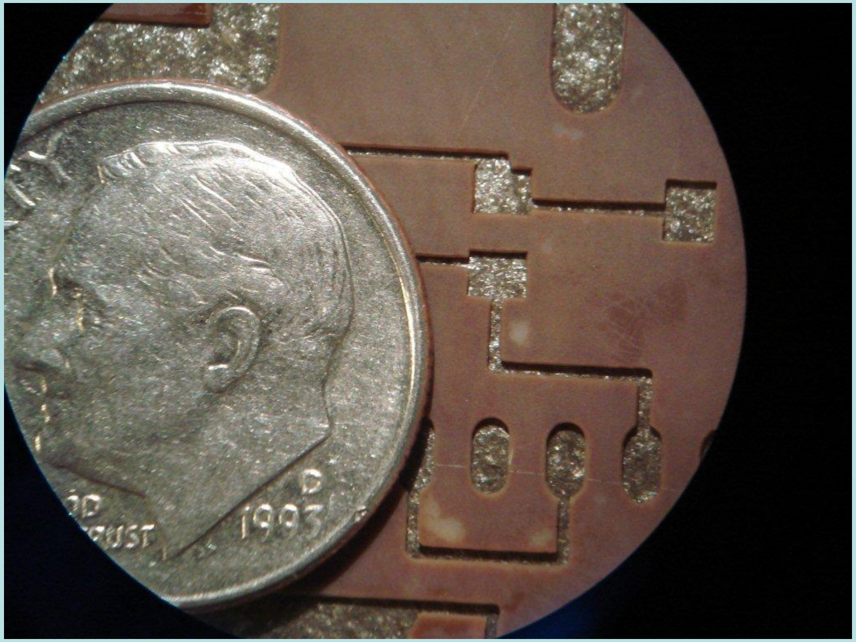
Randy Normann, CTO

randy@permaworks.com

Perma Works Stays In The Well

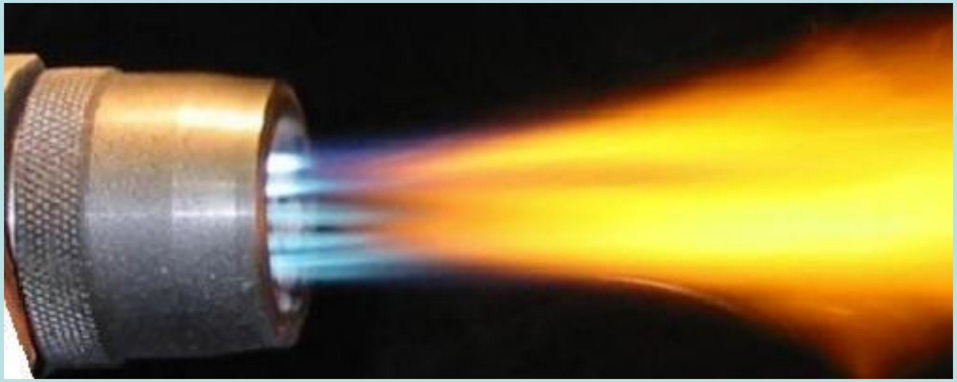
- While others log the geothermal well using electronics in a thermos bottle, we take the heat continuously
  - Licensed the Sandia National Laboratory HT chip set
  - Perma Works is building a complete set of electronics needed to build geothermal well control systems

New Extreme Temperature Circuit Boards

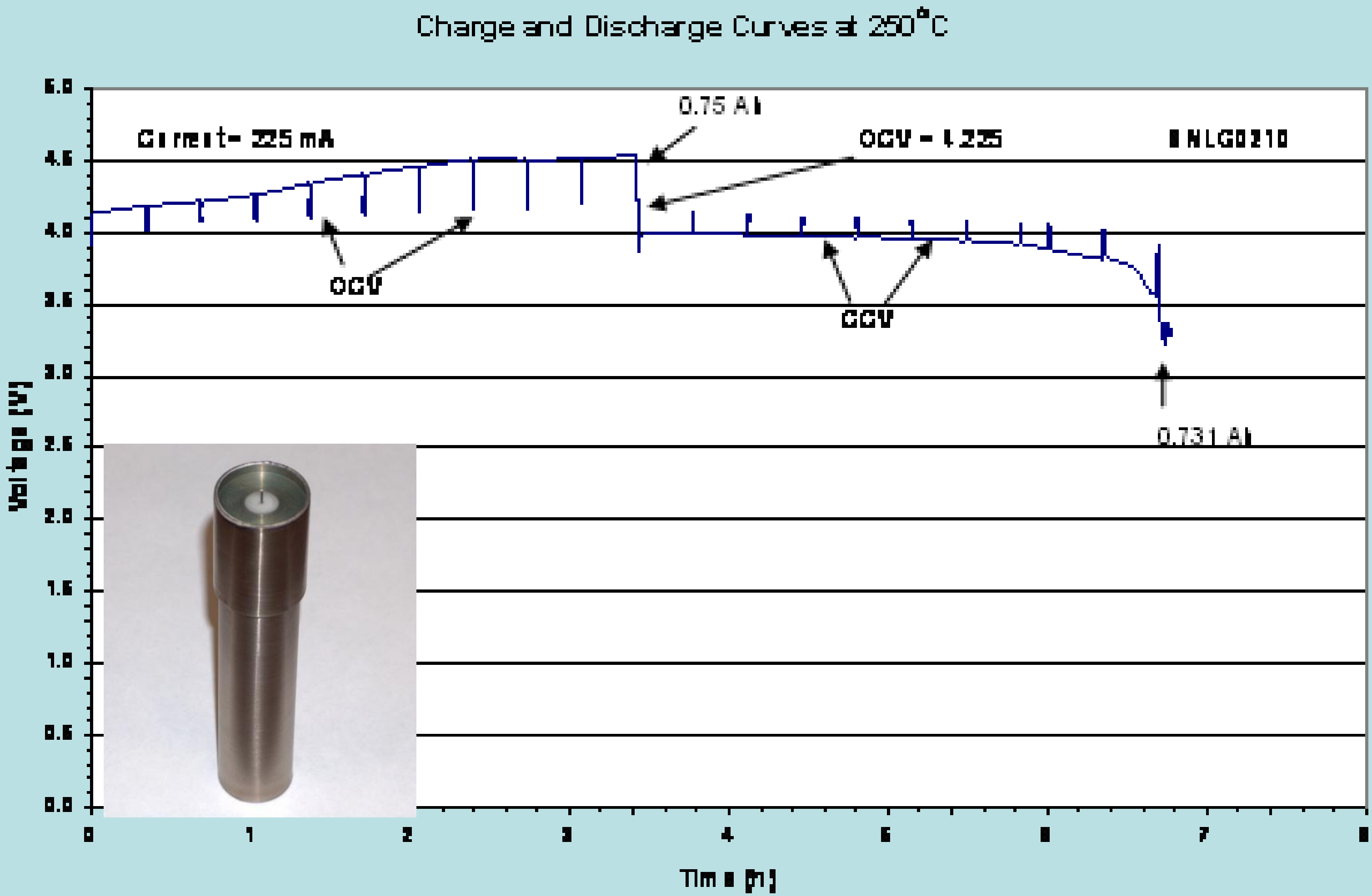


- Lab tested to 400C!
- Absolutely no organic materials!
- Traces are etched ceramic!
- Flame blasted metal conductors

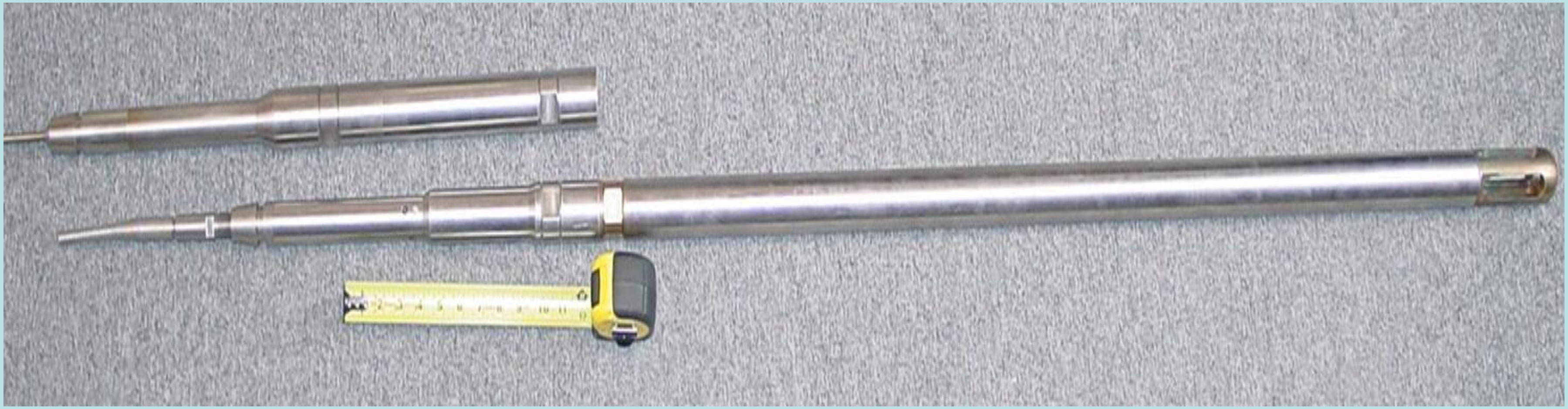
- Aircraft circuit boards are not good enough for geothermal. PW had to make improvements now benefiting aerospace



New 250C Batteries For Drilling Tools



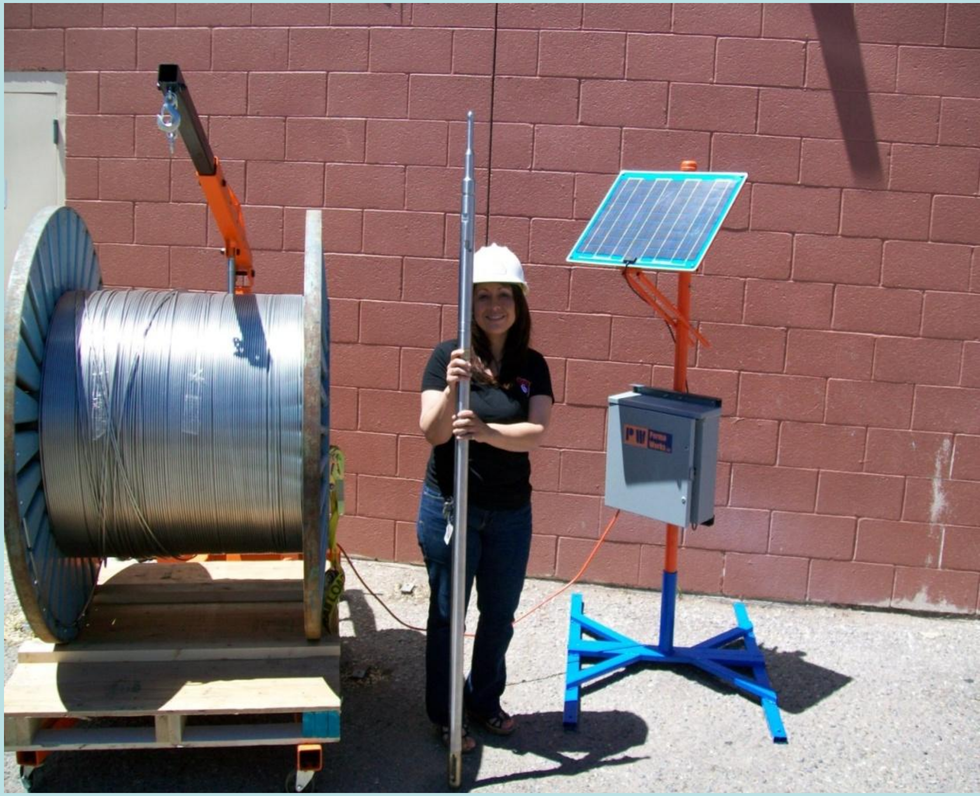
PW Complete Digital Solution at 250C



Perma Works is currently offering a 300C analog tool for monitoring pressure, temperature and flow inside geothermal wells.

Perma Works has a complete digital solution for 250C with plans to increase the operating temperature to 275C

New Technology '09 & '10
From PermaWorks Suppliers

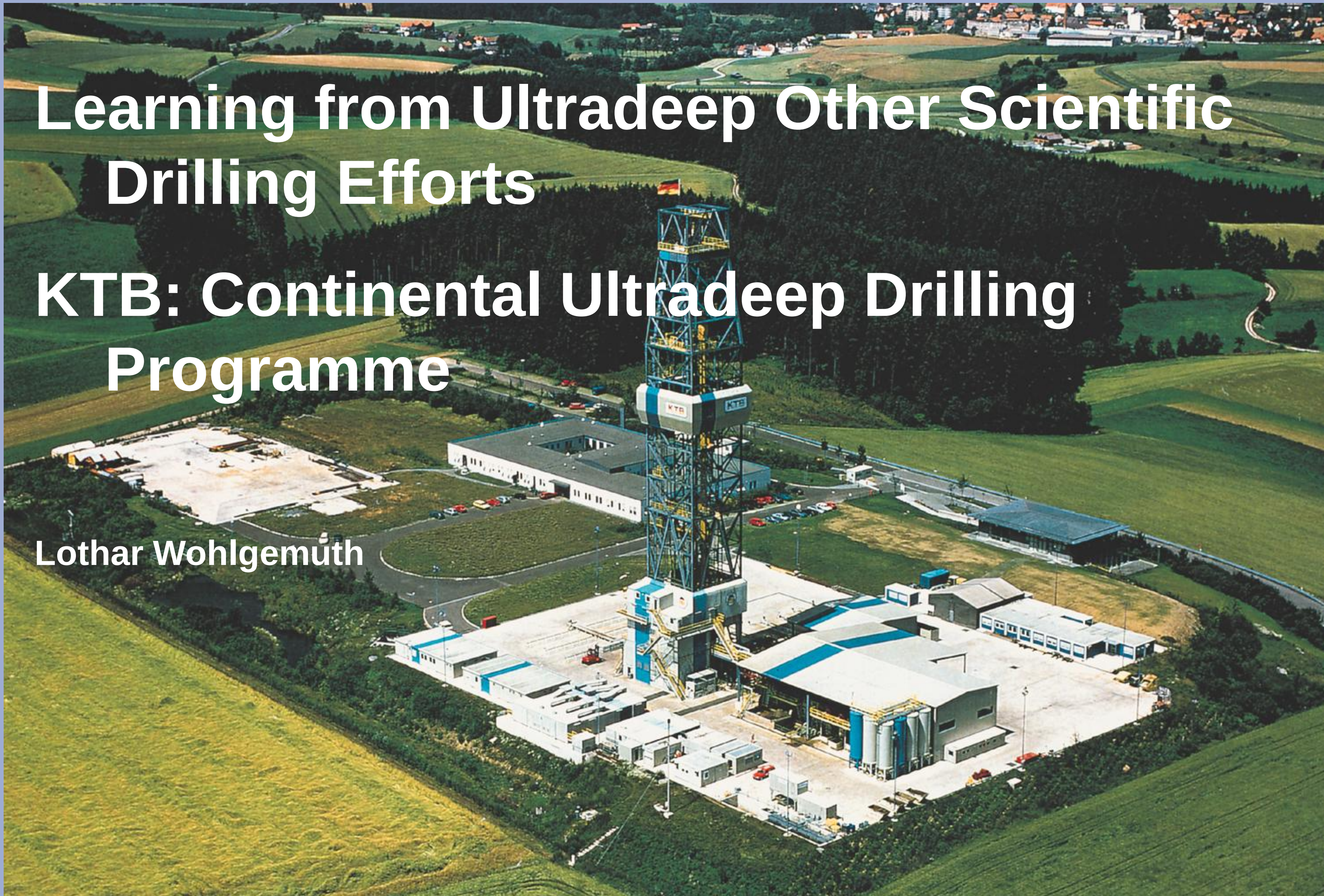


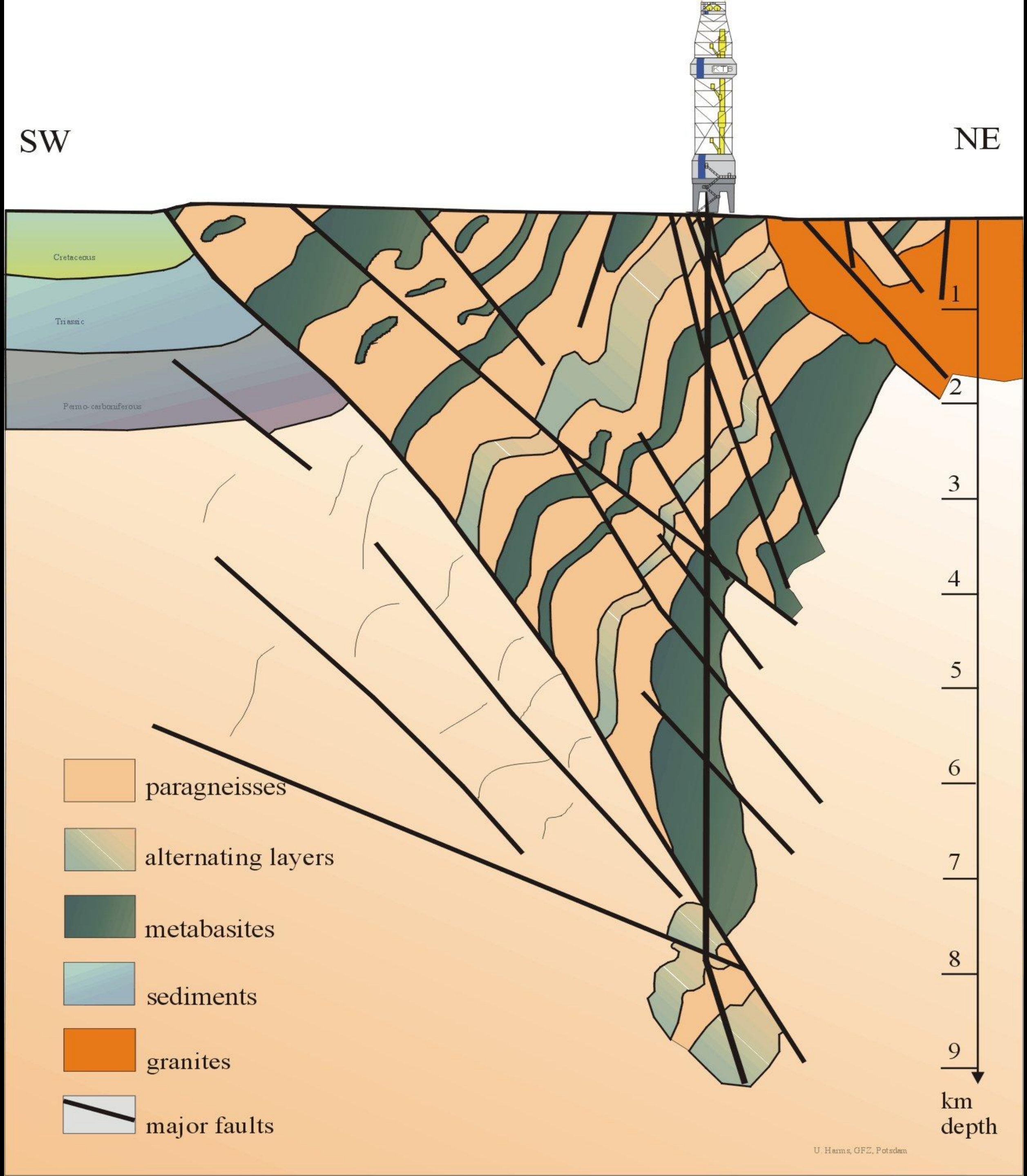
- **Draka Cableteq, Tx**
  - 350°C cable
- **Eclipse NanoMed, Nv**
  - 300°C Capacitors
- **NASCENTechnology, SD**
  - 300°C Inductors
- **Honeywell SSEC, Mn**
  - 300°C IC Memory
- **Electrochemical Systems, TN**
  - HT Battery
- **Frequency Management, Ca**
  - 300°C Digital Clock

Learning from Ultradeep Other Scientific Drilling Efforts

KTB: Continental Ultradeep Drilling Programme

Lothar Wohlgemuth




SW
NE
Cretaceous
Triassic
Permo-carboniferous
paragneisses
alternating layers
metabasites
sediments
granites
major faults
1
2
3
4
5
6
7
8
9
km
depth
U. Harms, GFZ, Potsdam

KTB - Kontinentales Tiefbohrprogramm der Bundesrepublik Deutschland

Preparatory Phase	**Location Survey**	**1984 - 1086**
Pilot Phase	**4 km Pilot Drill Hole**	**1987 - 1989**
	Test Programme	**1989 - 1990**
Main Phase	**9.1 km Main Hole**	**1990 - 1994**
	Key Experiments	**1994**
Final Phase	**Deep Crustal Lab -**	**since 1996**

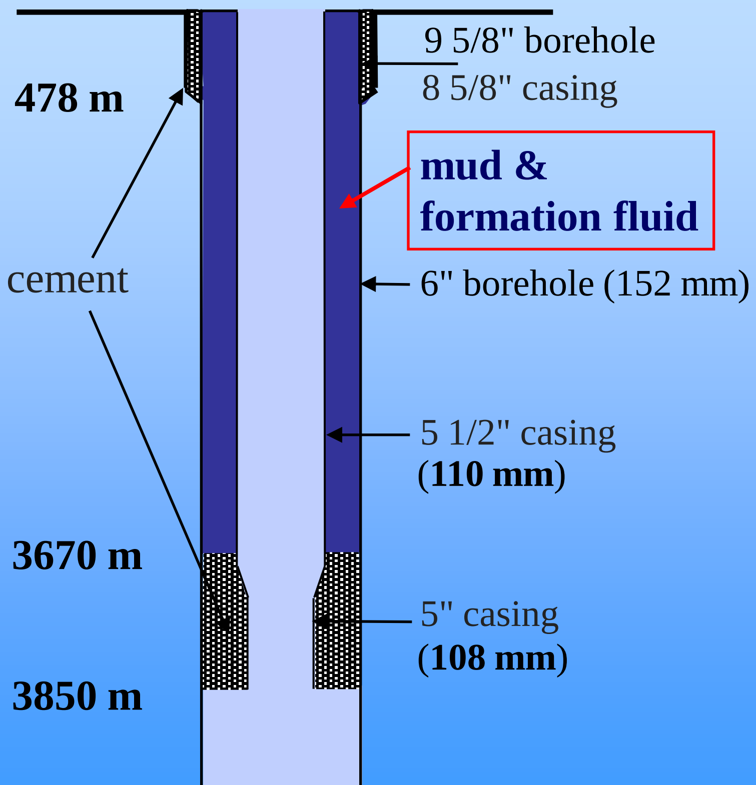
Currently: Long-term scientific experiments (seismic; fluids; temp)

Status and processes of the deep continental crust

K T B - Deep Crustal Lab

K T B – Casing Scheme VB / HB

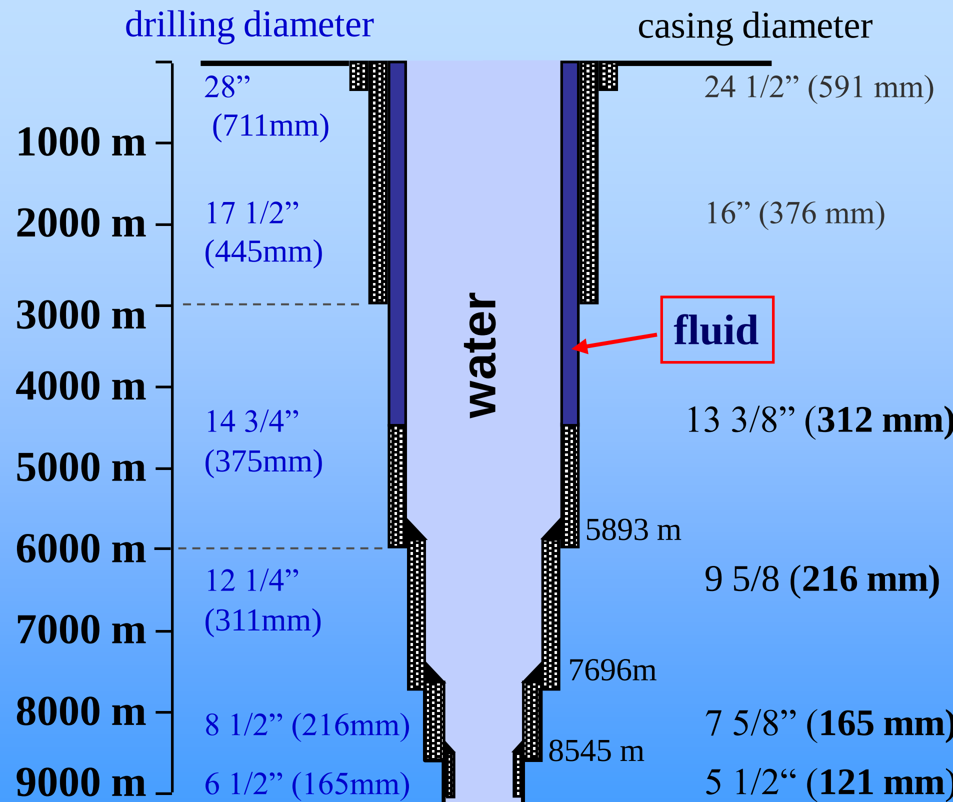
KTB VB



4000 m

open hole: 3850-4000 m

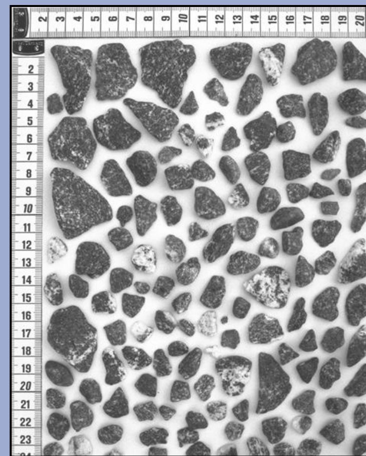
KTB HB



9101m

open hole: 9031-9101m

KTB

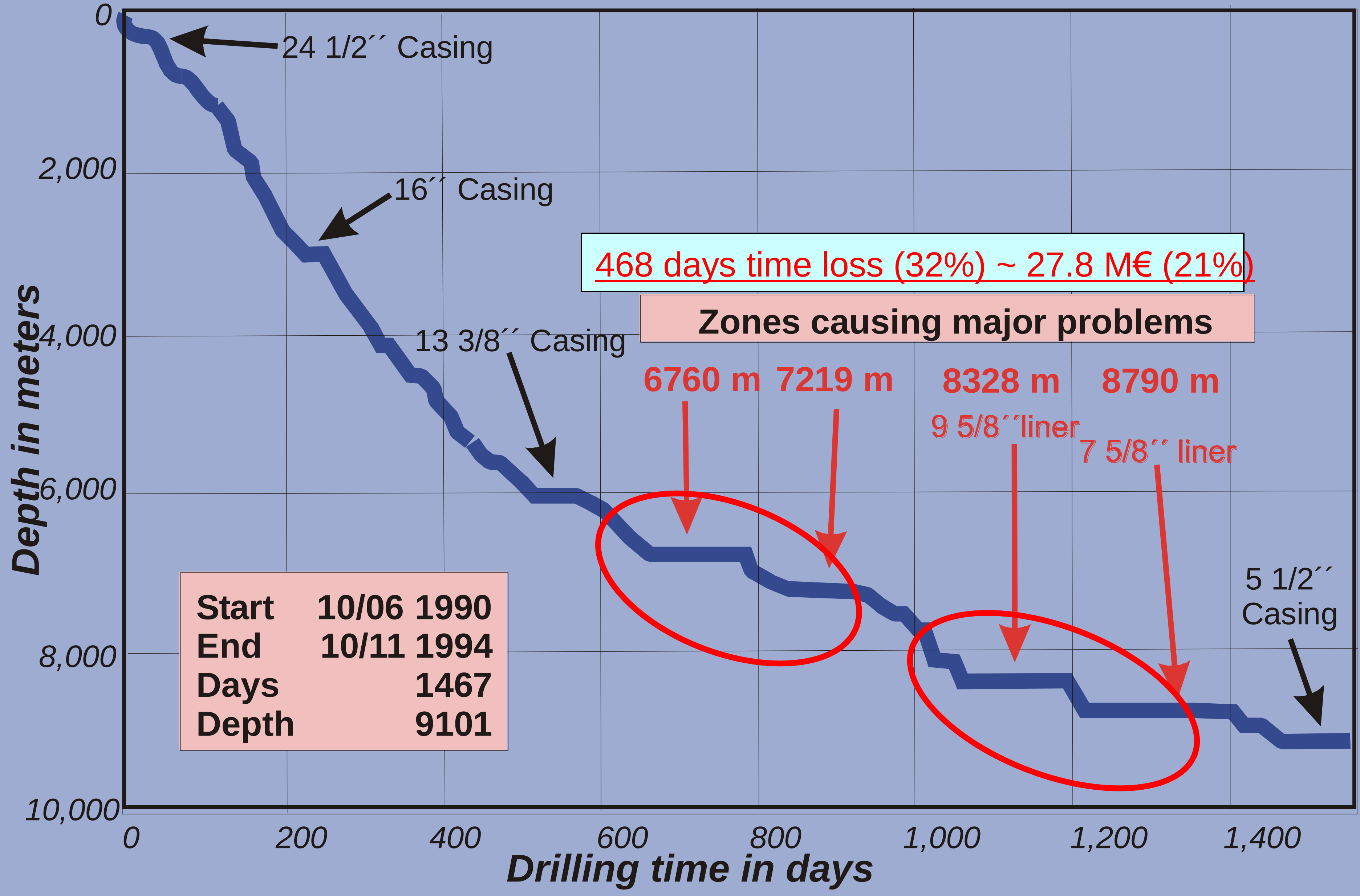


Samples:

- **core, core, core**
- **side-wall cores**
- **cuttings**
- **mud samples**
- **fluids**
- **gases**

  all sampled systematically in pre-determined depth distances

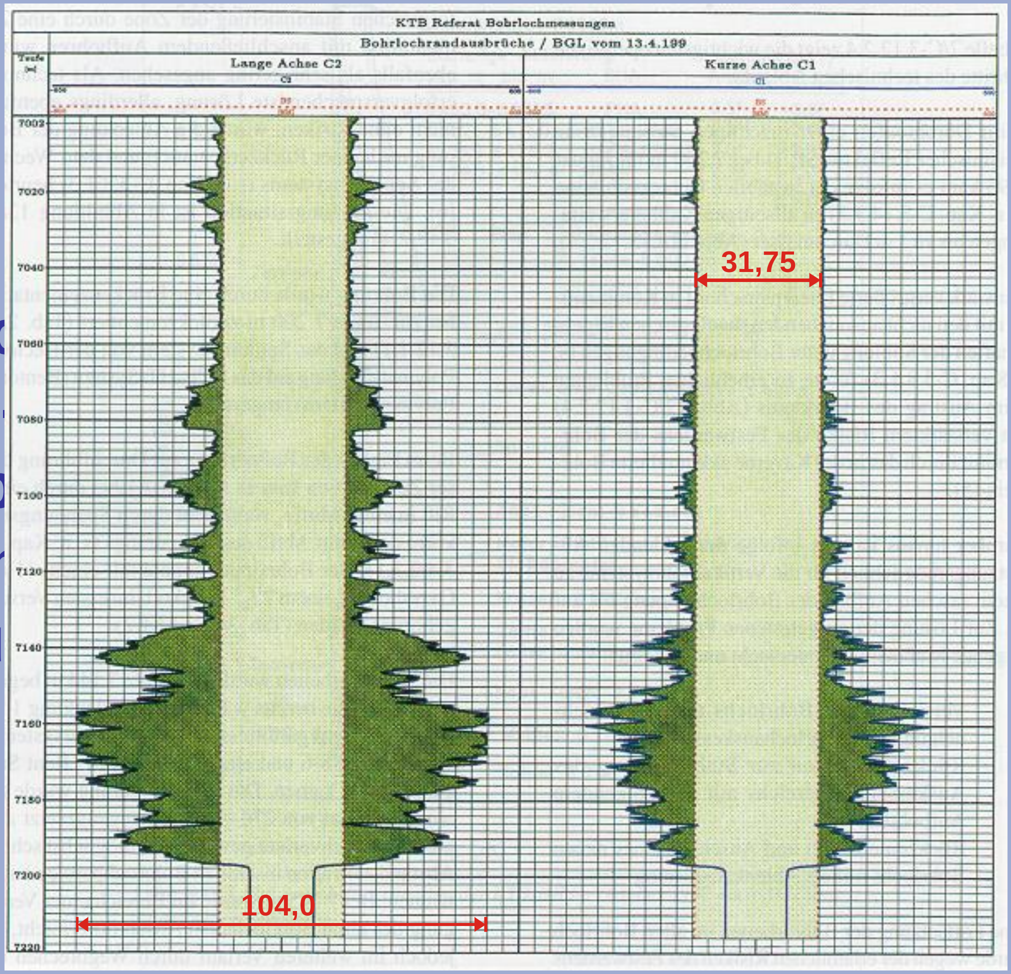
  and according to needs and interests


0
2,000
4,000
6,000
8,000
10,000
Depth in meters
24 1/2´´ Casing
16´´ Casing
13 3/8´´ Casing
468 days time loss (32%) ~ 27.8 M€ (21%)
Zones causing major problems
6760 m
7219 m
8328 m
8790 m
9 5/8´´liner
7 5/8´´ liner
5 1/2´´ Casing
Start 10/06 1990
End 10/11 1994
Days 1467
Depth 9101
0
200
400
600
800
1,000
1,200
1,400
Drilling time in days

Continental Ultradeep Drilling Programme

Big troubles in the KTB-Main Hole → Reasons:

- High rock stress
- Anisotropy of the horizo
- Bore hole instability
- Excessive caliper breako
  sections in the elliptical
- Unfavourable situation b
  and the direction of the h
- Using of waterbased mu
  →bore hole instability)



Continental Ultradeep Drilling Programme

Important conclusions →Learning effect from KTB:

- **Exact pre-drill site selection**
- **Extensive subsurface investigation (3D-/4D-seismic etc.)**
- **Knowledge of the horizontal stress at the detail (maximum value; axis; direction)**
- **Consolidated planning & engineering for the drilling and casing concept**
- **Assessment of the borehole direction against for the direction of the horizontal stress**
- **Using of oilbased mud (No absorption of water →better bore hole stability)**

Borehole stability:

- The key problem for ultra deep drilling
- Top priority in the planning phase of the ultradeep borehole

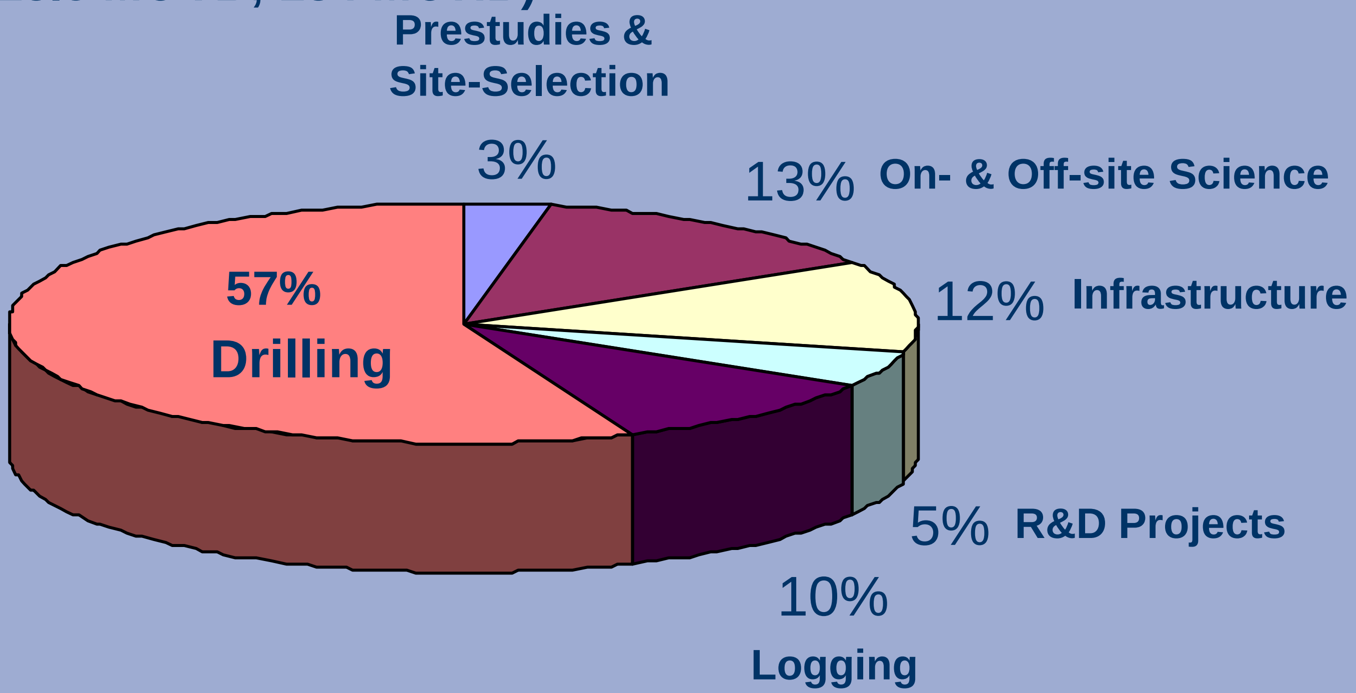
KTB - project costs

KTB total project costs

(1982 - 1995; incl. all pre-drilling studies):

264,000,000 €

(13.5 M€ VB; 134 M€ HB)



Thoughts on a Moho Program

Site Selection Issues

- **Drilling**: Water depth, Moho depth, expected borehole temperatures, lithological variations, pressures, stresses, core size, etc
    - This will affect vessel parameters, pipe specifications, mud composition and volume, casing specs, etc
- **Logistics**: Re-supply, crew rotations, permitting
    - This will affect, vessel parameters, mobilizations/demobilizations and access
- **Weather** (Met ocean): Average sea state, storm frequency, currents, commercial fishing, whale migrations
    - This affects vessel parameters, heave compensation, drive offs, crew preparation, dynamic positioning equipment need

A Few Critical Questions

- Can the MoHole science community deviate from continuous sampling techniques? How about…
  - Subsea drilling systems
    - Presently, uses for shallow hole site characterization
    - Especially useful for upper 100m of young crust
    - Full depth systems under development (Seabed Rig AS)
  - Rapid Installation of borehole
    - Drill, recover cuttings, wireline log, spot core or sidewall core
    - Lower cost, drill deeper
    - Latest generation logging tools needed
- What does the science community define as MoHole Success?
  - Sampling certain amount of crust, vs, upper mantle, coring, fluids, logging, etc
- How many holes must be drilled?
  - Can a multiple site program work?
  - Pilot hole with main hole
  - Multiple holes
  - Holes to be established for observatories?

Concerns

- Moving target for program success
  - Definition for success must be clear and understood by all
  - How far below the Moho to be drilled?
- Lack of continuous funding
  - Starting a phase of drilling and not being able to complete it could compromise the entire project
- Continuous management structure
  - Once a working structure is established, it should remain until project completion

Kanazawa Report Addresses Many of these

- Sites have been narrowed
- Conversation is open regarding the operational reality of continuous vs targeted coring
- Requirements for success
  - What must be sampled
  - In situ measurements

- A next step could be to take the Kanazawa report and begin building on it with a scoping study, executed by an international program office comprised of scientists and engineers (funding needed). The scoping study would distill the science and technical data and provide several options with costs for completing the Moho objectives.

Hot topics

- Site selection primary issues
  - how much water?
  - how deep is the target?
  - how hot will the fluid be?
- How to circulate drilling fluids
  - Marine Drilling riser
  - Riserless Mud Recovery
  - Robotic seafloor drilling system
  - Other emerging technologies
- Pilot hole or not
- Subsea safety devices or not
- Model for project management
  - A project this size will require new paradigm for management

In Summary

- Drilling to MOHO appears to be technologically feasible through several options in shallow and deep water
  - Cost/benefit/risk analysis must be completed
- The scale of the project will be huge and the options for the operation plan with associated technology must be carefully studied
- Project office is important to conduct feasibility, costing and option analysis.
- Formation of the project should consider how all IODP assets can be utilized
- What are we waiting for…consensus?, organization?, funding?

Technology Talks

- Michael Freeman - Drilling Fluids
- John Cohen – Mud circulation systems
- Michael Ojovan - Self Sinking Capsules
- Larry Karl – ROV’s and subsea operations
- John Kotrla – Risers and BOP’s
- John Thorogood –Project Management