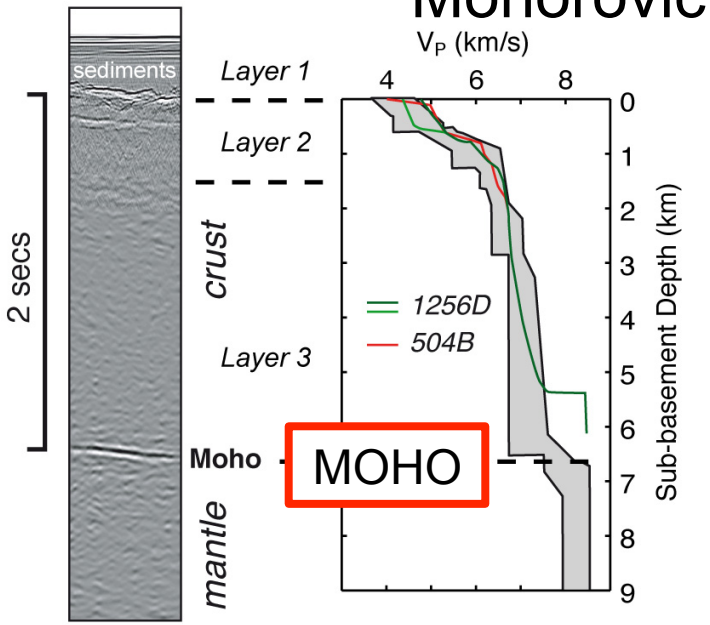
The MoHole
Journey to the Earth's Mantle

K. Michibayashi (Shizuoka University) &
Japanese Scientist Group for the MoHole project

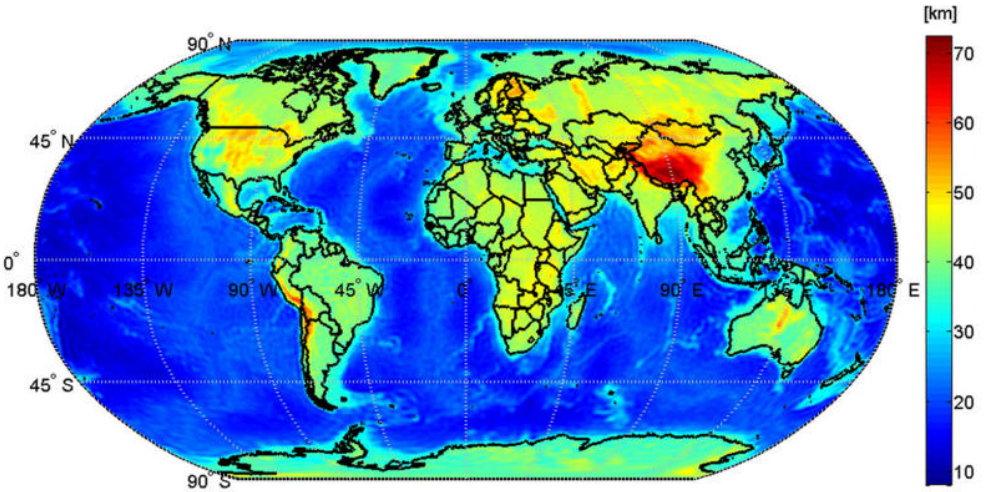
Special thanks to B. Ildefonse
for some nice slides

Geological significance of geophysical interfaces

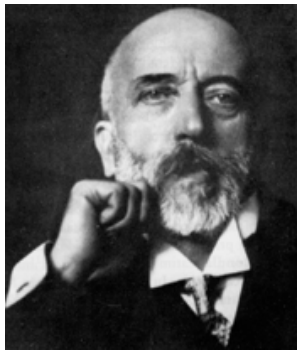
"Mohorovičić discontinuity" - MOHO



Seismic imaging of Pacific lithosphere



Global map of Moho depth (from GOCE data, 2012)



Andrija Mohorovičić

- *Is the Moho the interface between :*
  - *magmatic crust & residual mantle ?*
  - *magmatic rocks of different compositions ?*
  - *serpentinized mantle & fresh mantle ?*
  - *mantle + magmatic intrusions & mantle ?*

No sample

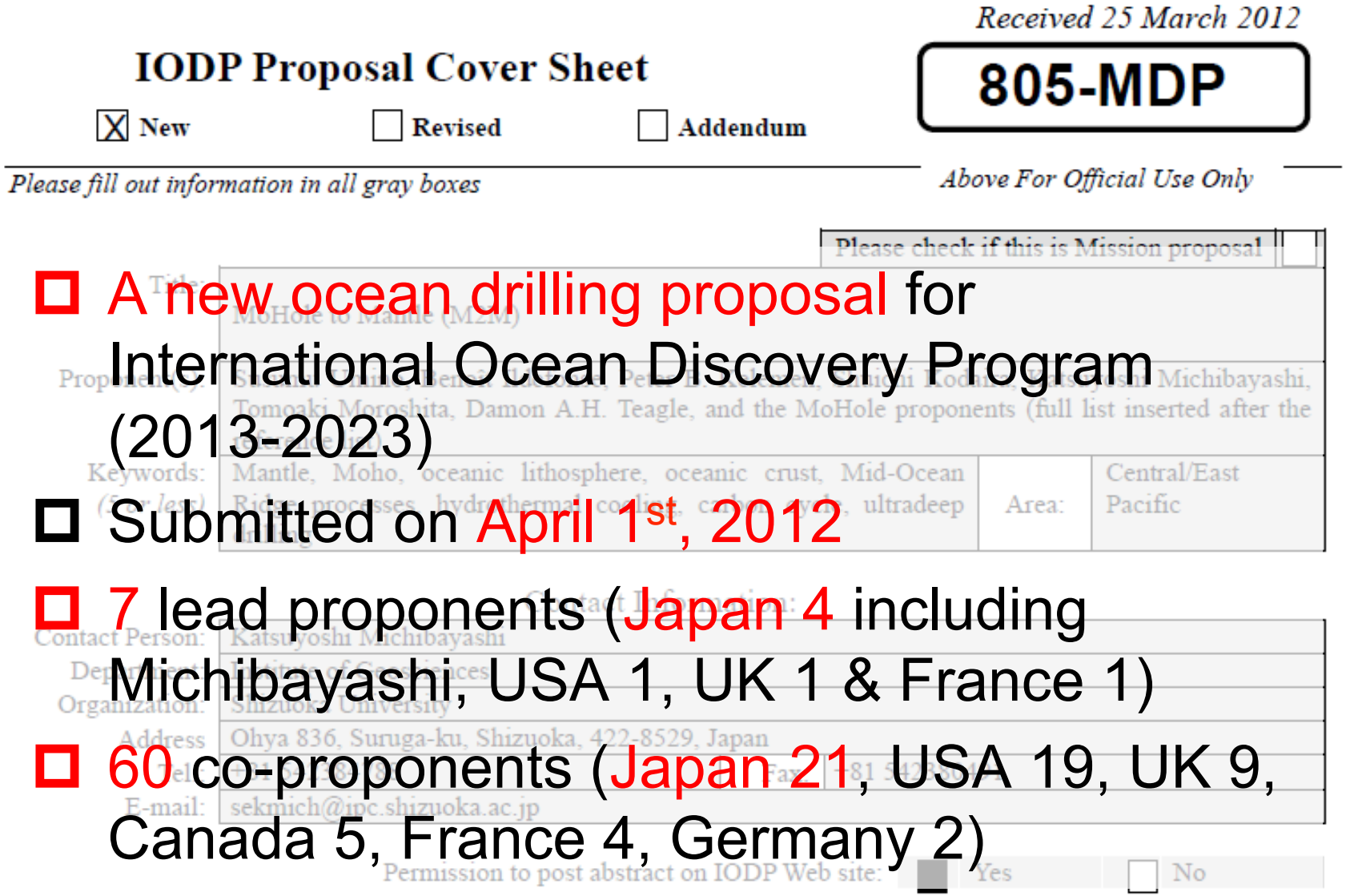
Michibayashi et al. MIS04-1

The MoHole: The Journey to the Earth's mantle

The MoHole is the project to drill the oceanic lithosphere

MoHo + Hole = “MoHole”

In 2012, The project has been updated to be **MoHole to Mantle (M2M)**



Received 25 March 2012

IODP Proposal Cover Sheet

805-MDP

☒ New ☐ Revised ☐ Addendum

Please fill out information in all gray boxes

Above For Official Use Only

Please check if this is Mission proposal ☐

Title: MoHole to Mantle (M2M)

Proponent(s): Katsuyoshi Michibayashi, Tomoaki Moroshita, Damon A.H. Teagle, and the MoHole proponents (full list inserted after the

Keywords: Mantle, Moho, oceanic lithosphere, oceanic crust, Mid-Ocean Ridge processes, hydrothermal cooling, ultradeep drilling

Area: Central/East Pacific

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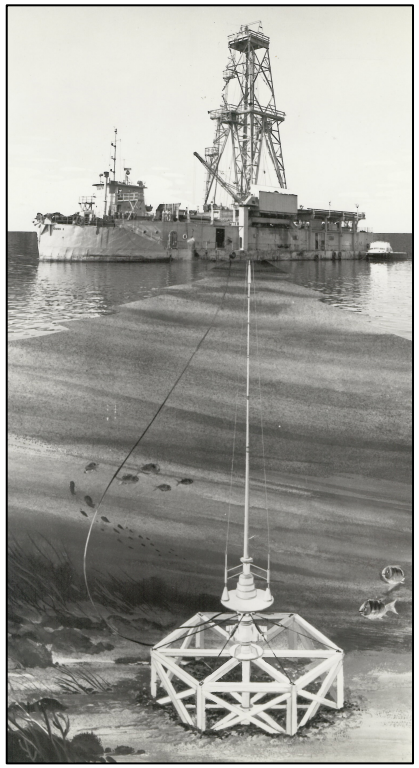
E-mail: sekmich@ipc.shizuoka.ac.jp

Permission to post abstract on IODP Web site: ■ Yes ☐ No

- A new ocean drilling proposal for International Ocean Discovery Program (2013-2023)
- Submitted on April 1st, 2012
- 7 lead proponents (Japan 4 including Michibayashi, USA 1, UK 1 & France 1)
- 60 co-proponents (Japan 21, USA 19, UK 9, Canada 5, France 4, Germany 2)

A brief History of the MoHole project

While we haven't yet found what we are looking for,
the history is becoming longer and deeper!



Project MoHole – 1957-1966

M2M – 2012, …

Phase I of Project Mohole

1957-1966

Project Mohole Meeting around a table aboard the vessel CUSS I off Guadalupe Island in the Pacific Ocean, 1961.

Walter H. Munk proposed to drill toward the Mantle.

"What good will it do to get a single sample of the mantle?"

Project "Mohole" 1957-1966

Pretty good, but was terminated…


AUTHOR STEINBECK AND PHOTOGRAPHER GORO ON DECK OF THE CUSS I

High Drama of Bold Thrust through Ocean Floor

EARTH'S SECOND LAYER IS TAPPED IN PRELUDE TO MOHOLE

Last week Project Mohole (LIFE, April 7) made scientific history when its drilling barge, CUSS I (whose name is made up of the initials of oil companies who developed it: Continental, Union, Shell and Superior), pierced 601 feet into the sea floor to get core samples of the earth's never-before-penetrated second layer. On board to describe the extraordinary operation for LIFE was Novelist John Steinbeck, who is also an amateur oceanographer.

by JOHN STEINBECK

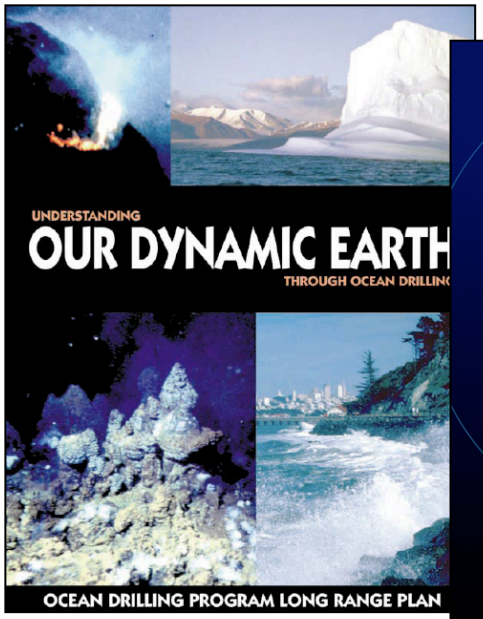
Life, 14 April 1961

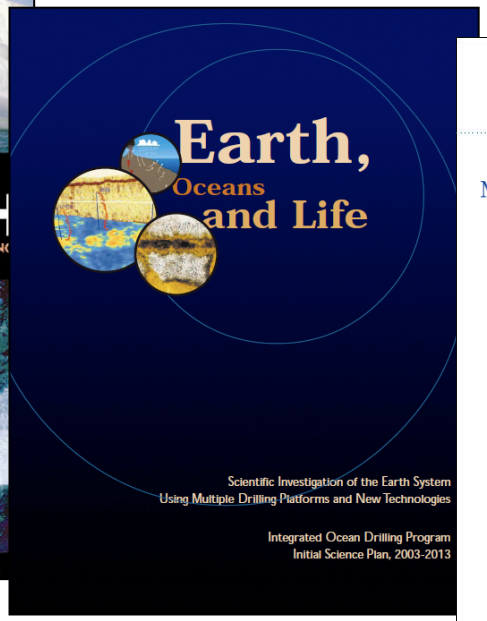
Eastern Pacific
March-April 1961

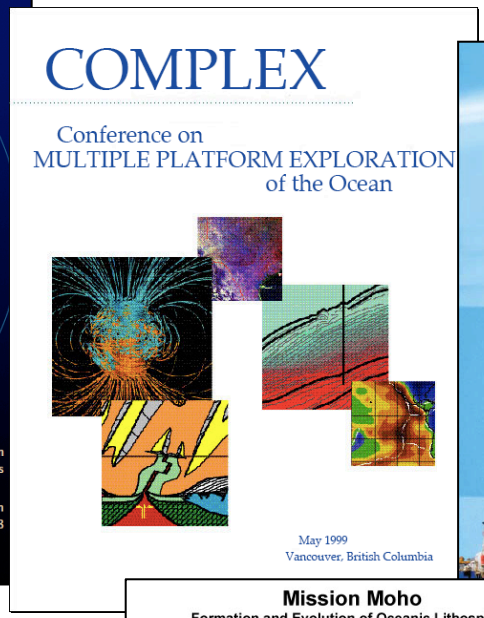
Dynamic positioning
~ 3500 m water depth
5 holes

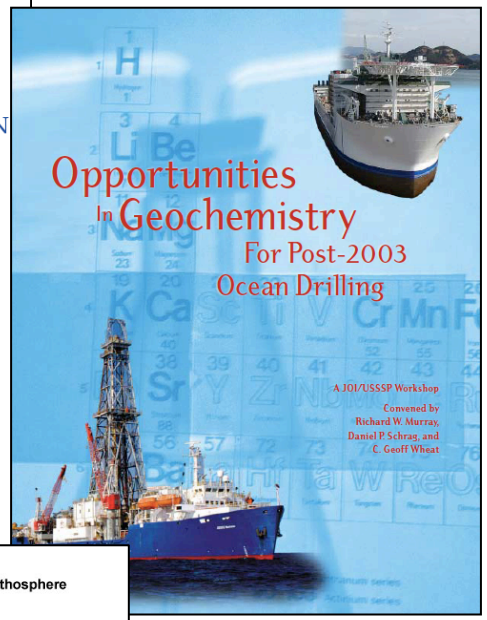
Maximum penetration: 183 m, Miocene sediments, ***~ 14 m of basalt***

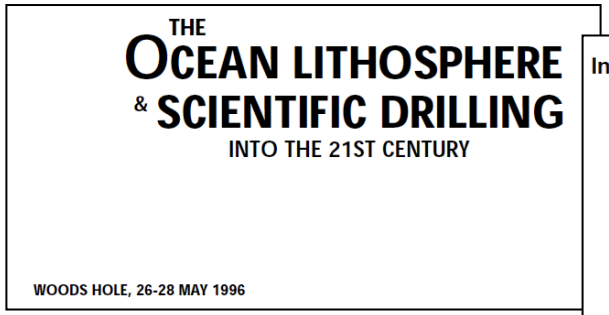
40 years of planning on deep drilling of the ocean lithosphere

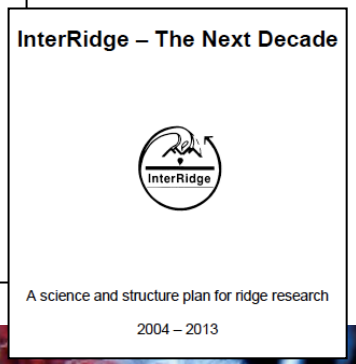


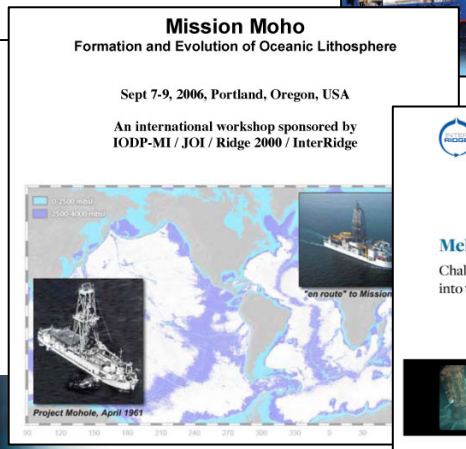


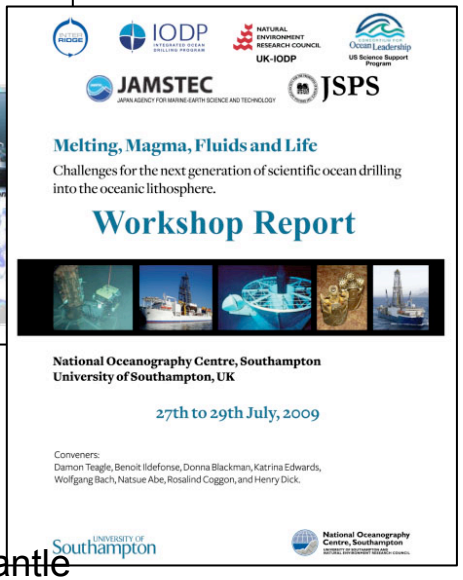




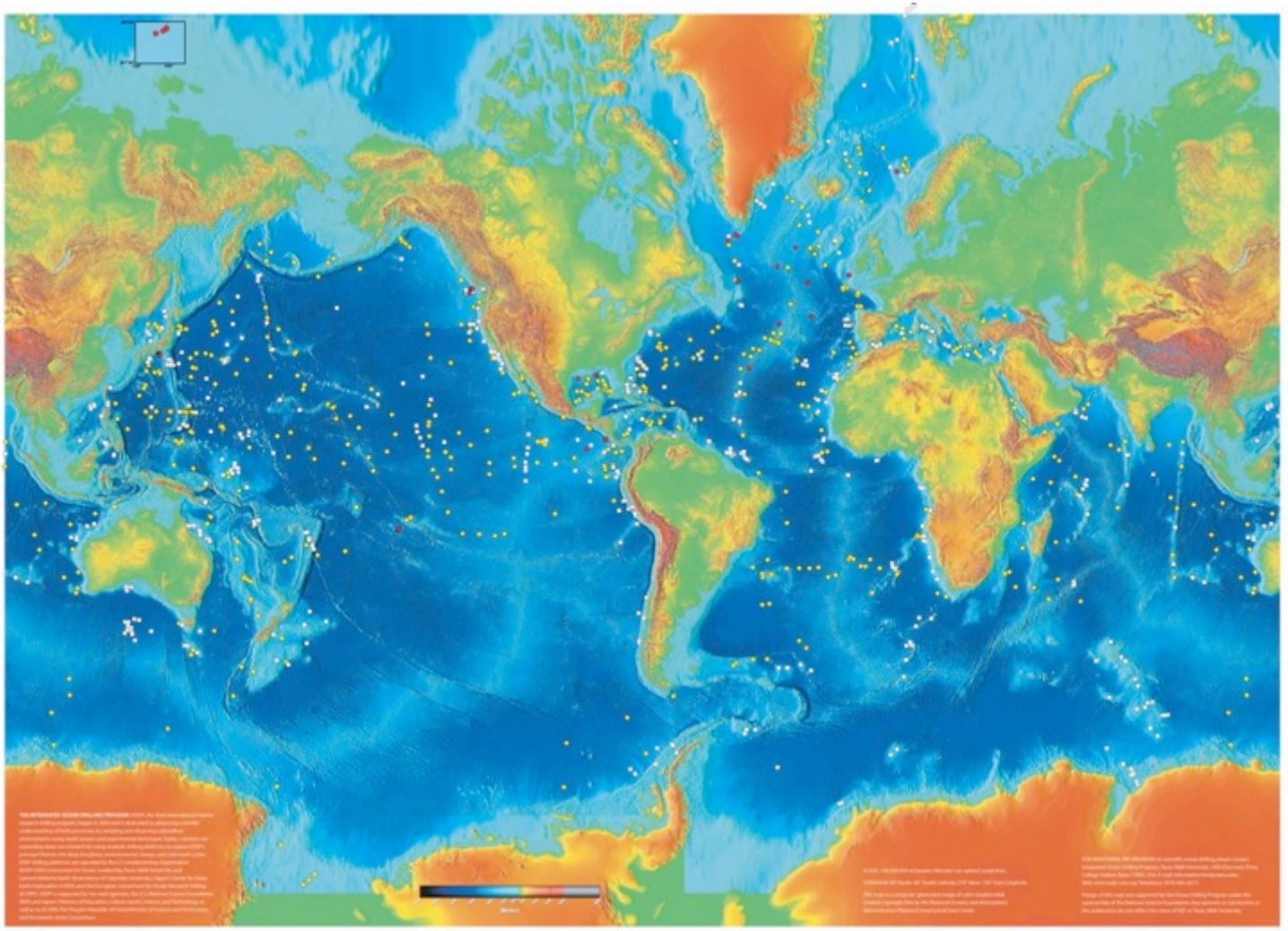








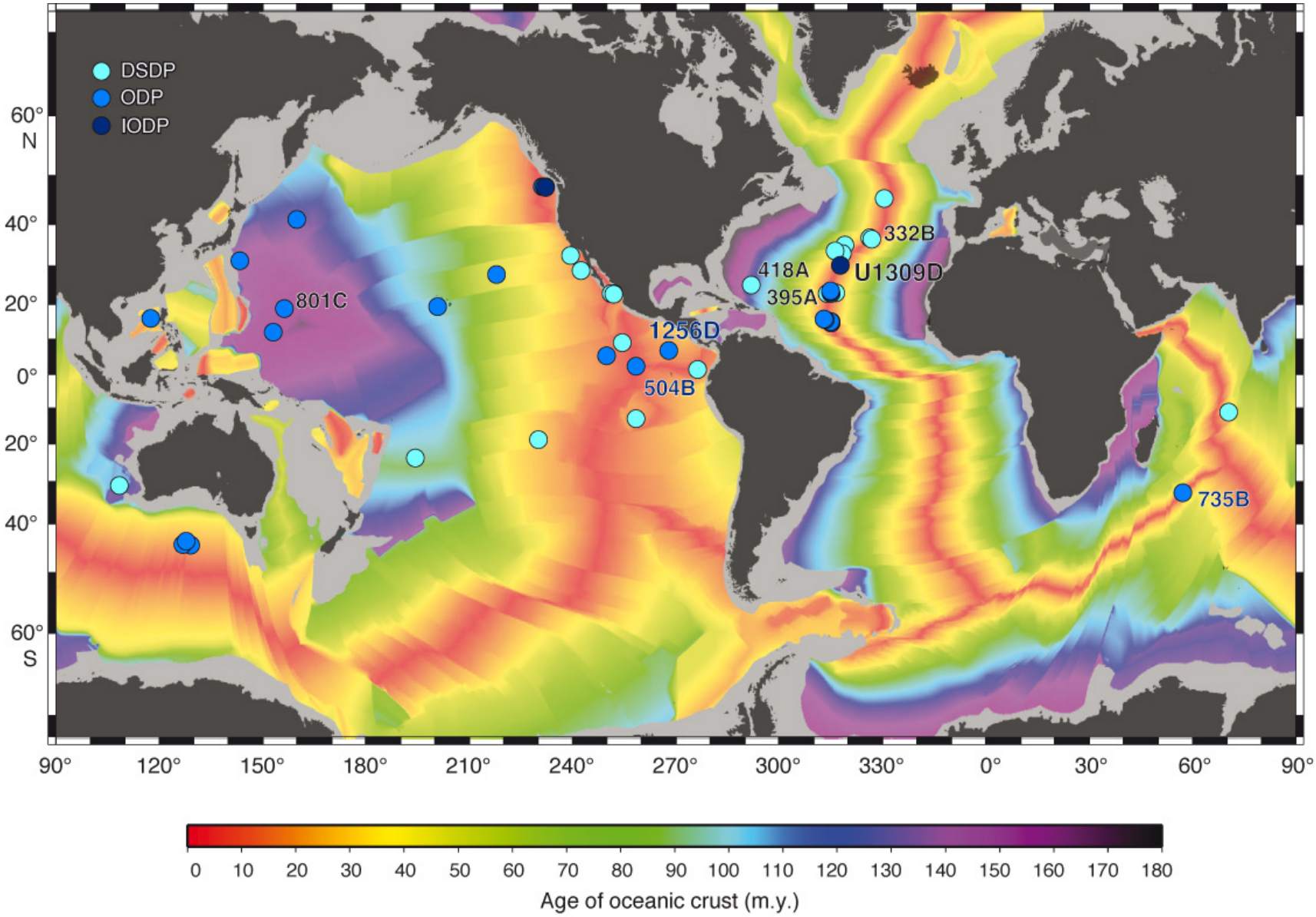
DSDP/ODP/IODP holes in ocean floor



◆ Deep Sea Drilling Project ▫ Ocean Drilling Program • Integrated Ocean Drilling Program

Hundreds of holes have been drilled to the ocean floor since the Phase 1 MoHole project.

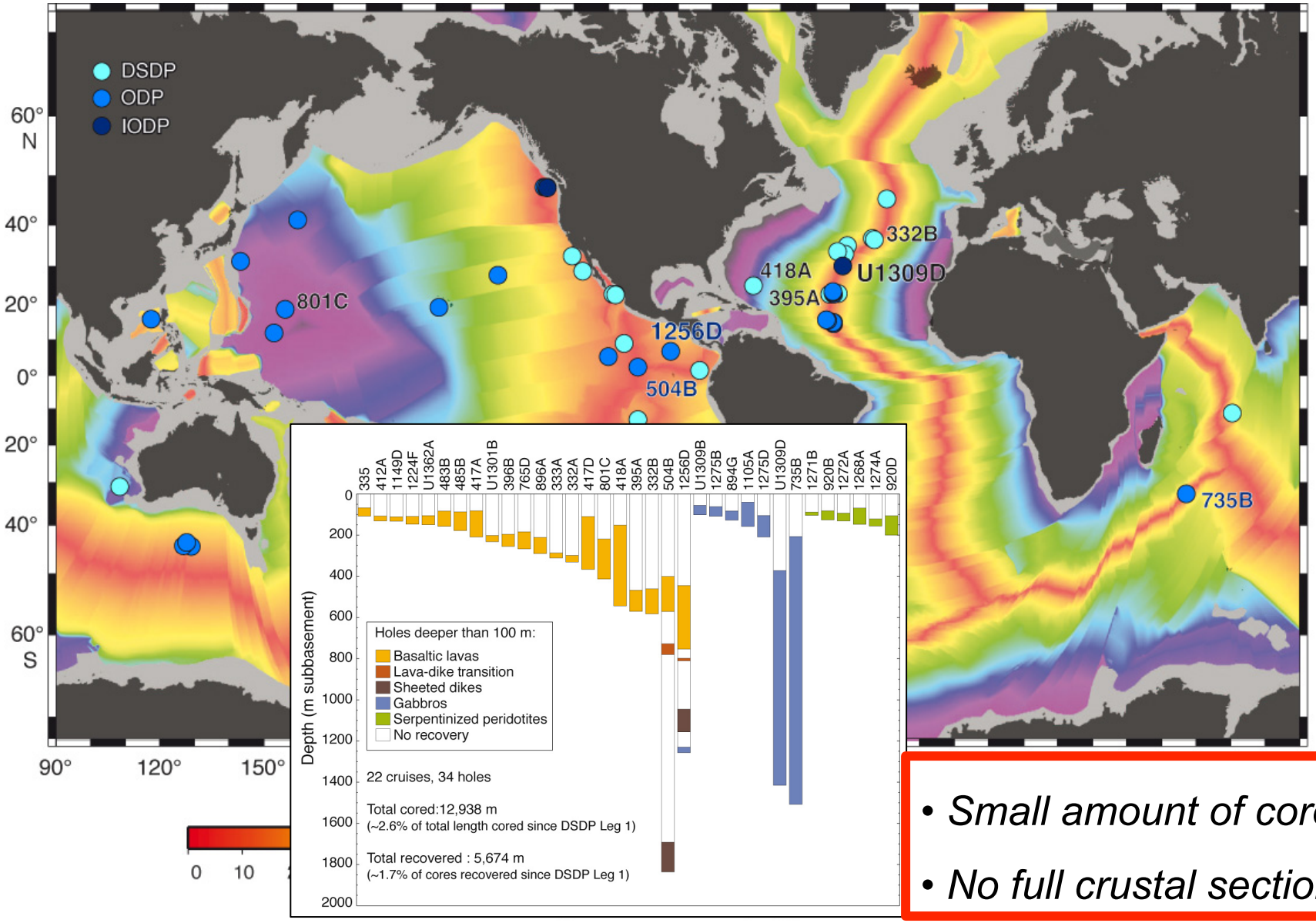
DSDP/ODP/IODP holes in oceanic crust (>100m, 1974-2011)



DSDP/ODP/IODP holes in oceanic crust

(>100m, 1974-2011)

Not included: oceanic plateaus, arc basement, hydrothermal mounds, and passive margins



- *Small amount of cores*
- *No full crustal section*

Deep Sea Drilling Vessel CHIKYU,
which will make it happen!

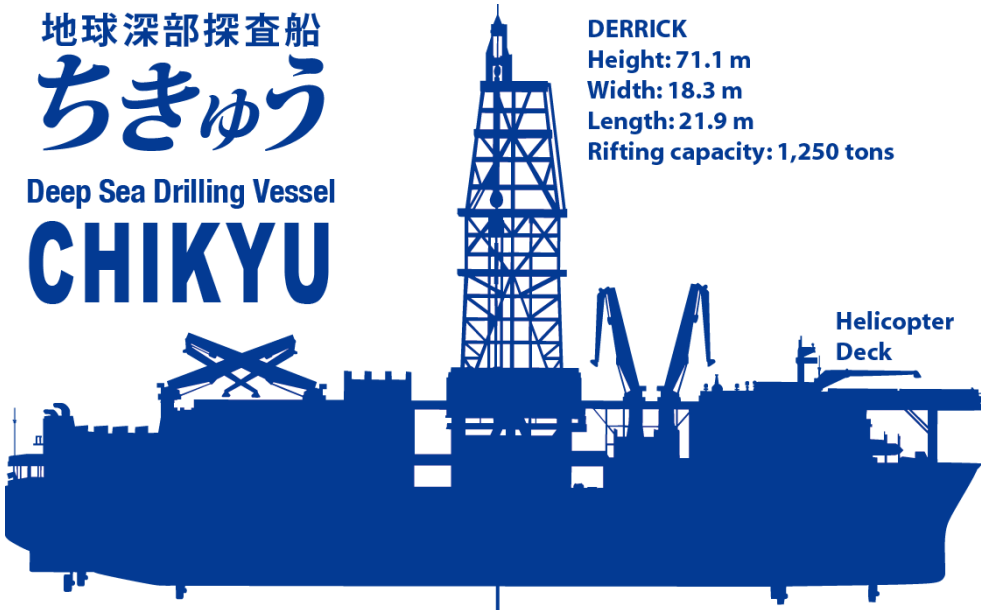
Michibayashi et al. MIS04-1

1st April, 2012 when we submitted M2M!

CHIKYU has been constructed by JAPAN in 2005.

CHIKYU means the Earth in Japanese.

地球深部探査船
ちきゅう
Deep Sea Drilling Vessel
CHIKYU



OPERATING SEA CONDITION
Wind Speed: 23 m/sec
Wave Height: 4.5m
Surface Current: 3-4 knots
Direction of External Force: ±30°

DRILLING CAPACITY
Riser drilling system
Riser-less drilling system
Max. Water Depth: 2,500m
(Riser drilling)
Drill String Length: 10,000m

Blowout Preventer (BOP)
Weight: 380 tons
Height: 14.5 m
Pressure: 103 MPa

Riser pipe
Length: 9.5 m
Diameter: approx. 50 cm

Drill pipe
Length: 9.5 m
Diameter: 13-14 cm

PRINCIPLE PARTICULARS
Class: NK (Nippon Kaiji Kyokai)
Navigation area: Worldwide
Length Overall: 210 m
Breadth: 38.0 m
Height : 130 m from ship bottom
Depth:16.2 m
Draft: 9.2 m
Gross Tonnage: 56,752 tons
Range: ca.14,800 nautical miles
(Full load condition, 10 knots)
Complement: 200 people
Max.Ship Speed: 12 knots

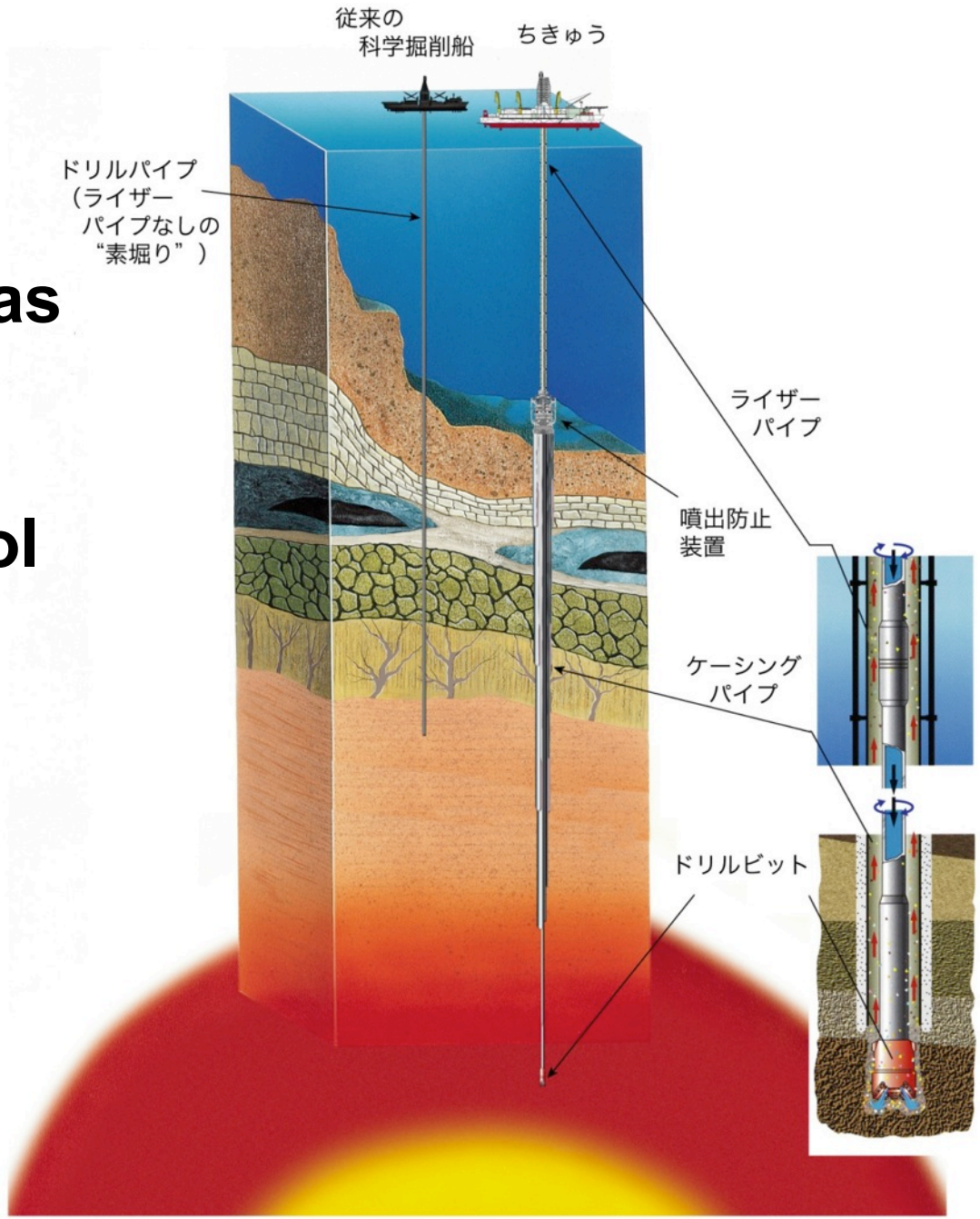
Azimuth Thruster: 4,100kW
x 3 (the bow)
x 3 (the stern)
Diameter of propeller: 3.8 m
Side Thruster: 2,550kW
x 1 (the bow)
Main Generator: 5,000kW x 6
Aux. Generator: 2,500kW x 2

MOON POOL: 12 m x 22 m

Michibayashi et al. MIS04-1

CHIKYU can drill the ocean floor as deep as 6000 meters!

So, we got a right tool to drill to the Mantle after nearly a half century since the 1st MoHole project.



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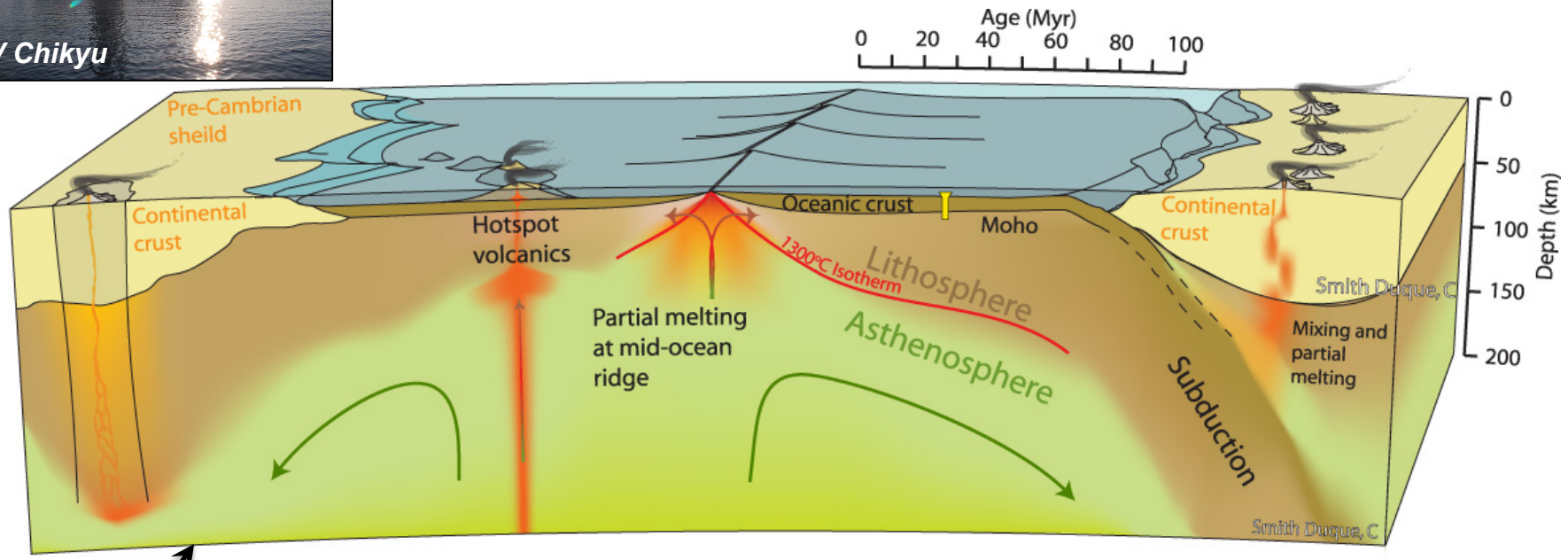
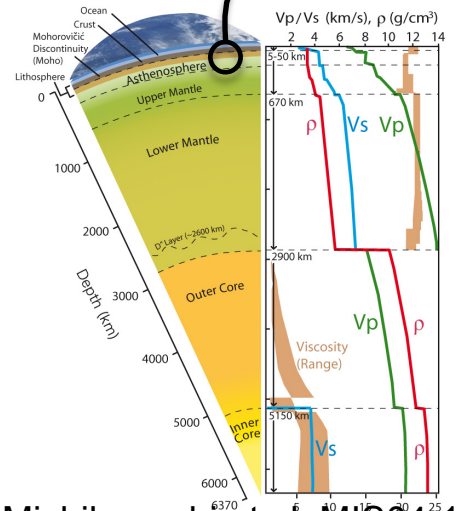
Topics on the MoHole project

What haven’t we yet found what we are looking for?

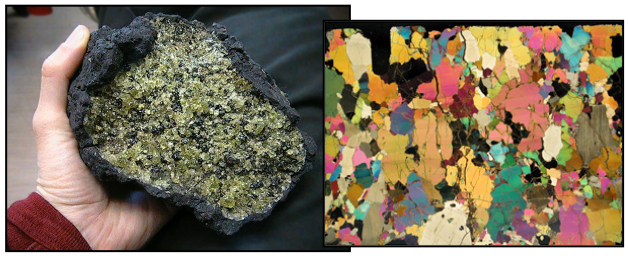
We are planning to drill to the mantle from somewhere between ridge and trench, where is a typical oceanic lithosphere.

MoHole To the Mantle (M2M)



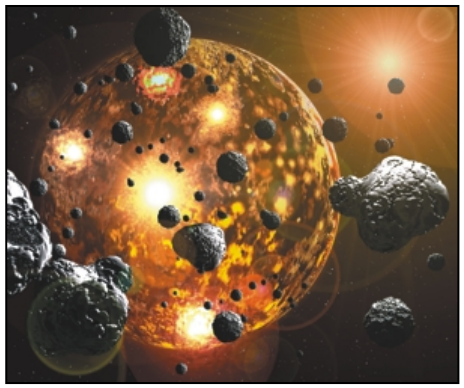


- *Series of workshops and meetings since 2006*
- *Primary motivation: sample **in-situ mantle***



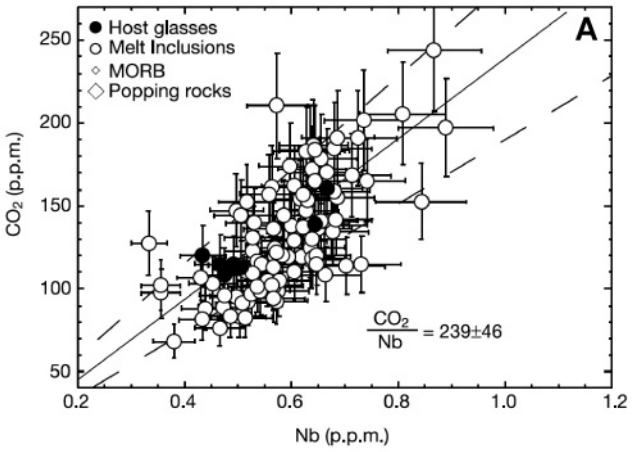
Obtain the first in-situ samples of Earth's mantle

- *Compositional and isotopic heterogeneity*
- *Volatiles contents (CO_2, H, …)*
- *Contribution to global carbon budget*
- *Melt migration processes*
- *Physical properties (rheology, seismic anisotropy, …)*
- *…*

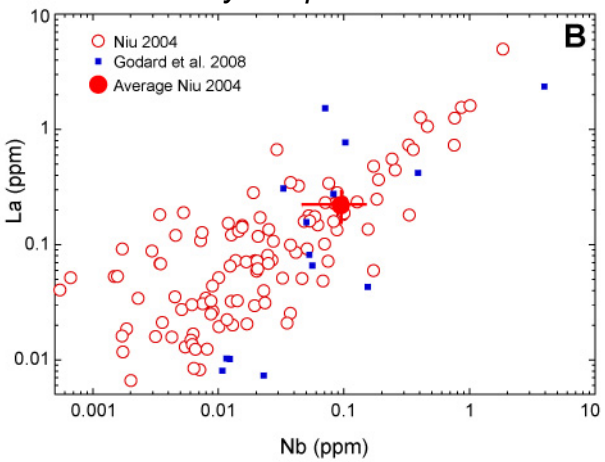


Late veneer

Mid-ocean ridge basalts



Abyssal peridotites



CO_2-Nb-La correlation

Refertilization of Oceanic lithosphere

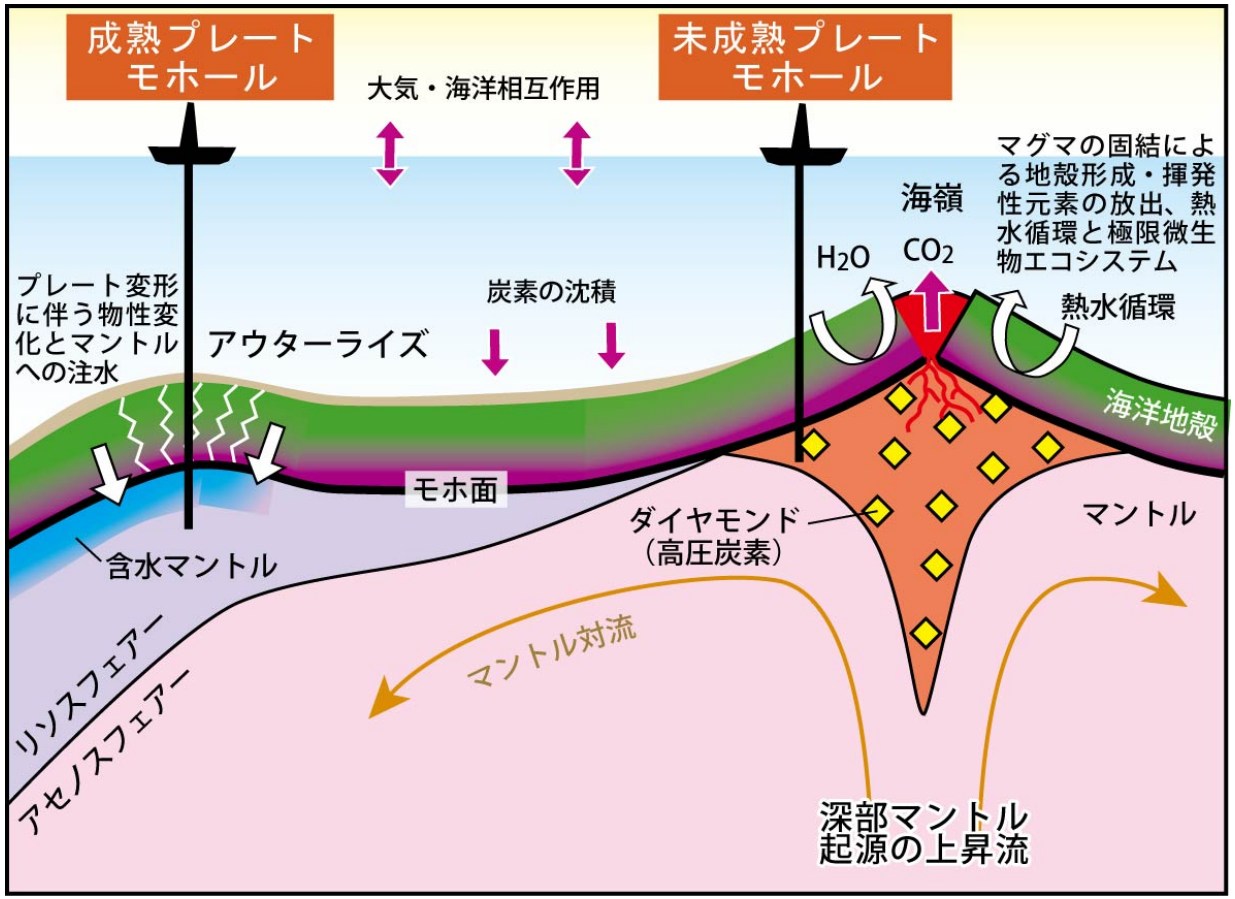
How much CO_2 in the lithospheric oceanic mantle ? (10 ppm > ~10^{20} tons for 10km)

No samples

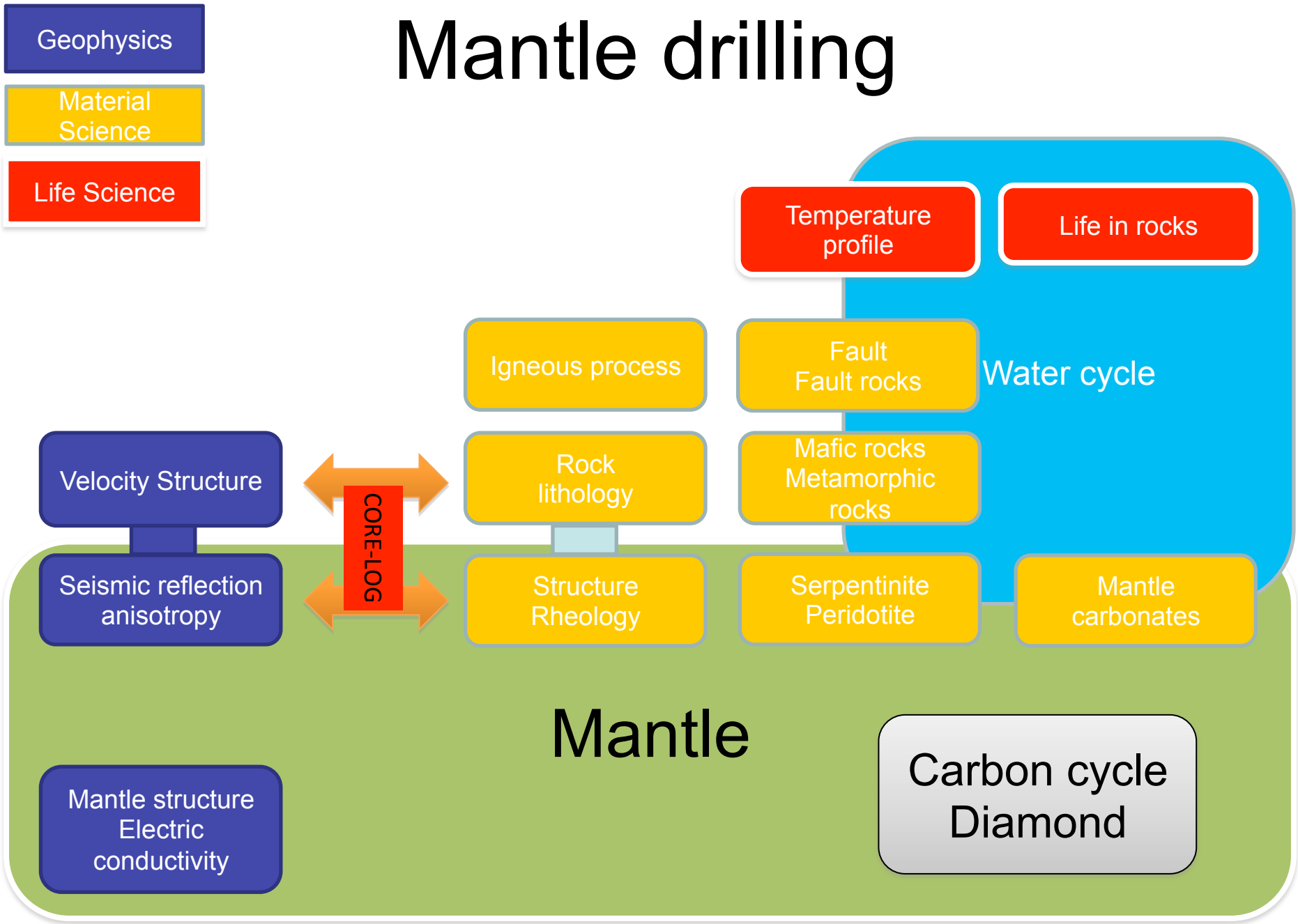
Michibayashi et al. MIS04-1

M2M (MoHole to Mantle) Project

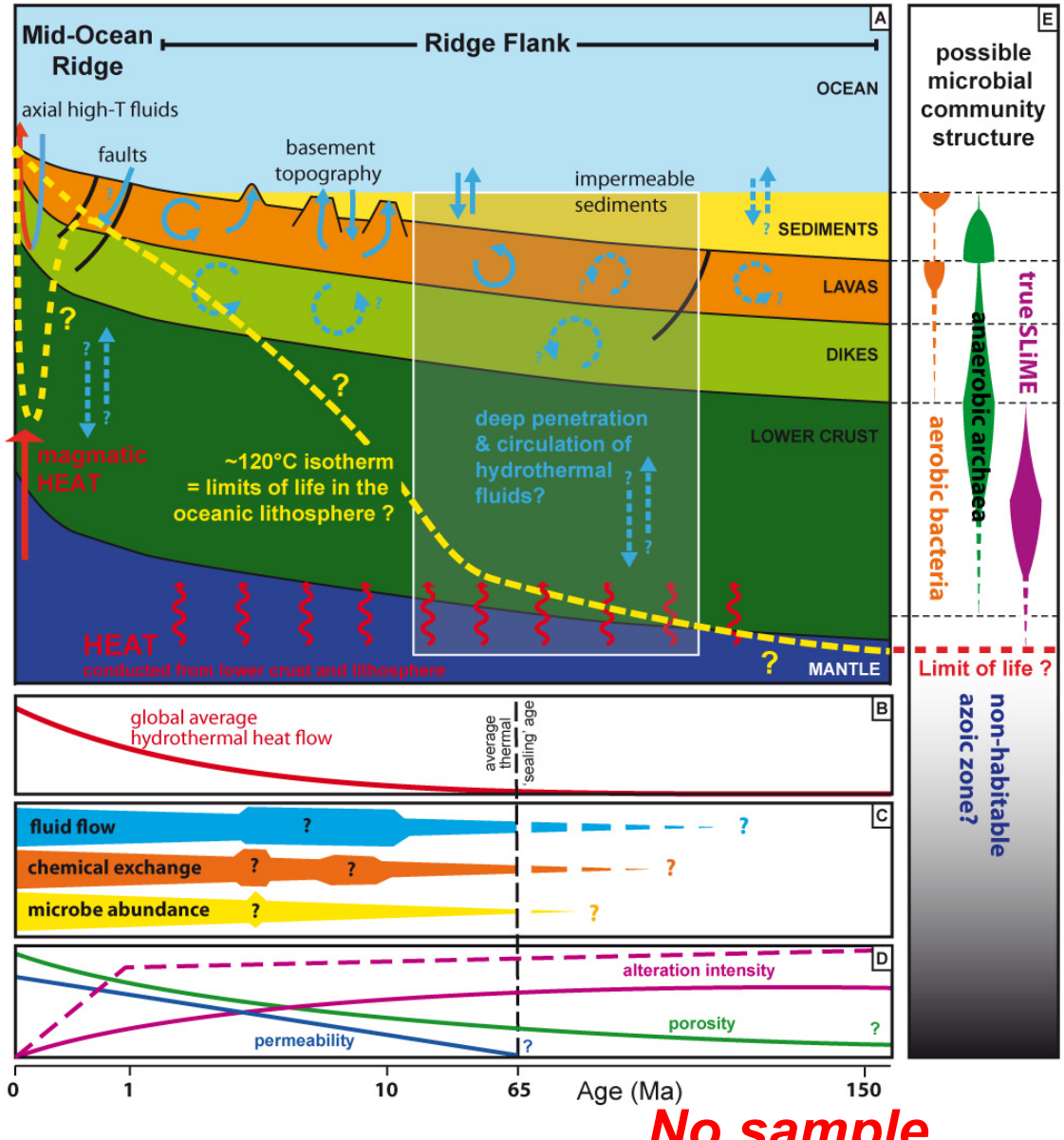
Search for carbon cycle and its reaction with water in the Earth's interior and near surface

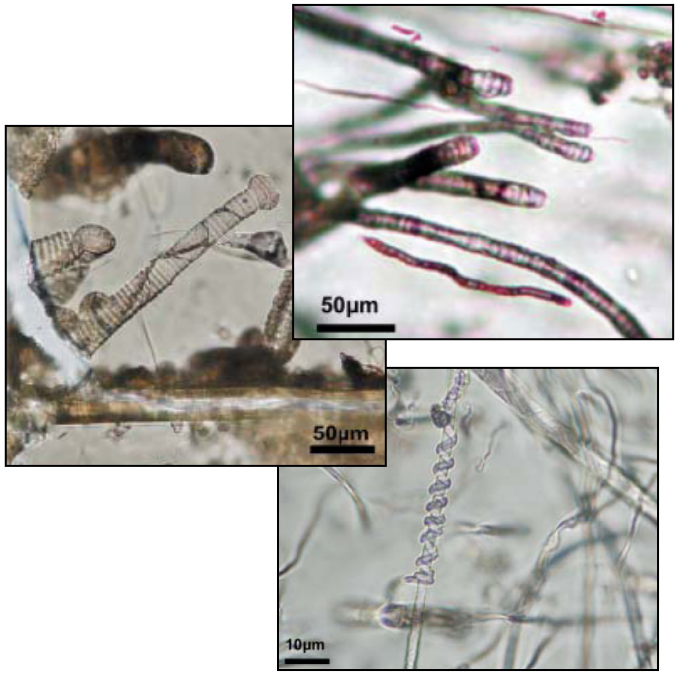


Mantle drilling



Hydrological-Geochemical-Microbiological Feedbacks



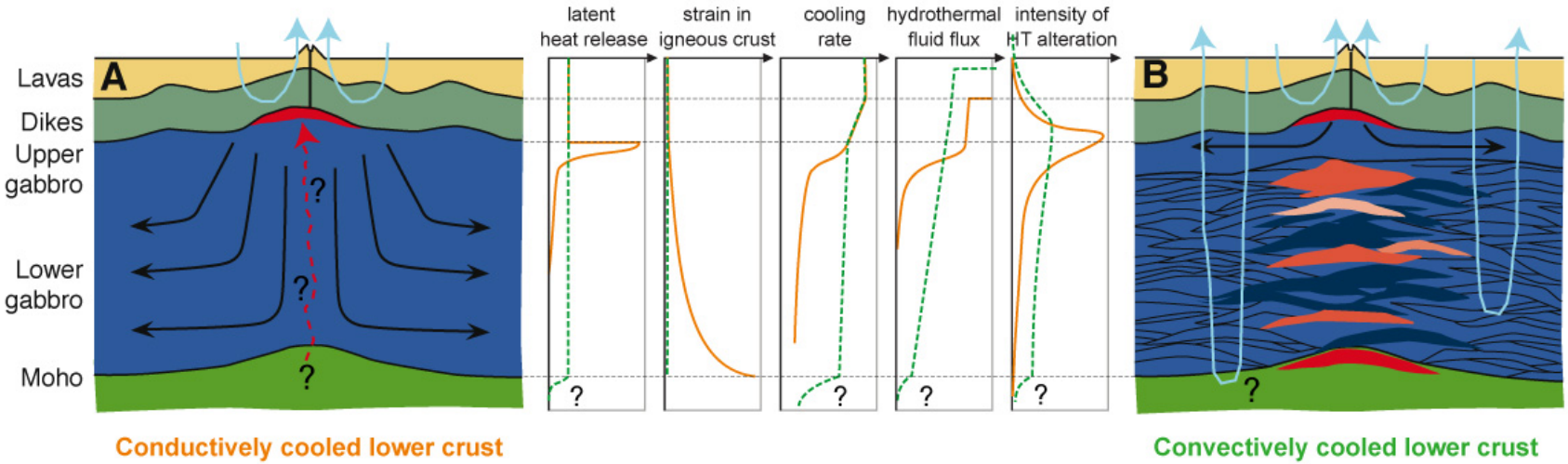


McLoughlin et al., 2008

- *What processes control exchanges ?*
- *Impact on global bio-geochemical cycles ?*
- *Limits (and controlling factors) of deep biosphere ?*

No sample

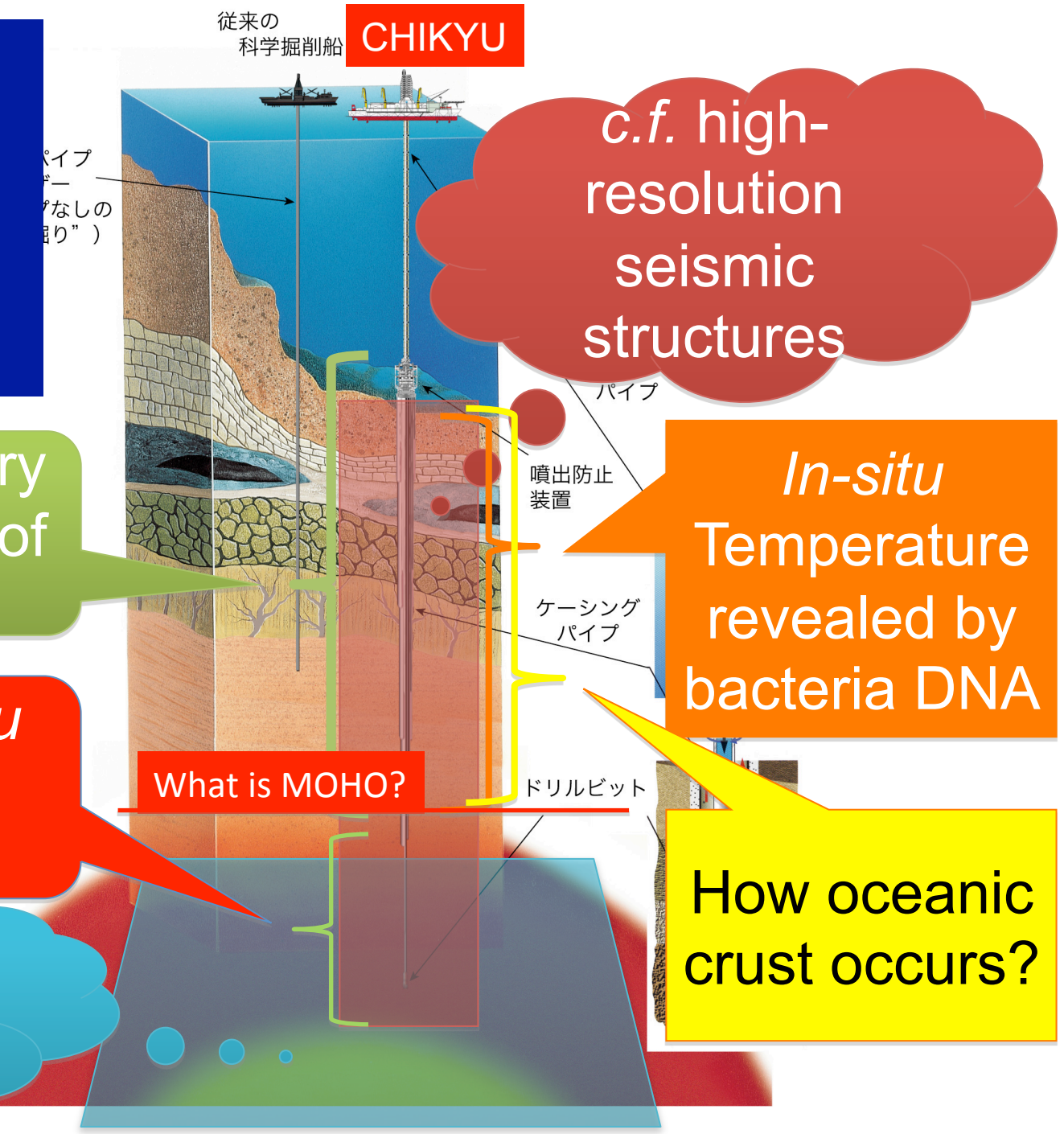
Formation and cooling of the lower crust



- *Accretion mode(s) of the lower crust ?*
- *Vigor of hydrothermal cooling ?*

No sample

Topics on Ultra deep drilling by Chikyu



c.f. high-resolution seismic structures

Bio-geochemistry
Water and limit of life

In-situ Temperature revealed by bacteria DNA

What is *in-situ* mantle peridotite?

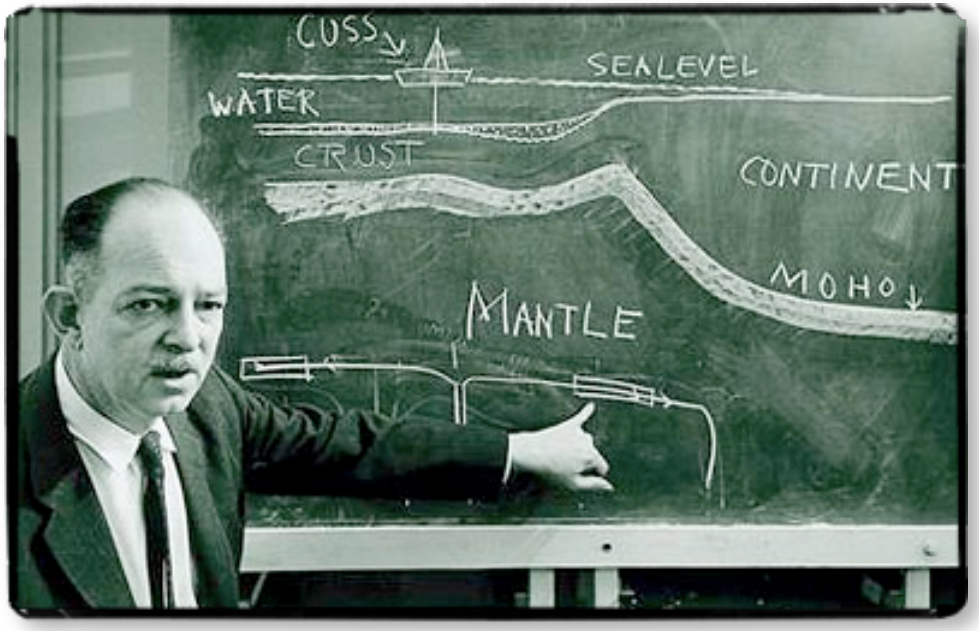
How oceanic crust occurs?

Mantle structures revealed by geophysical monitoring

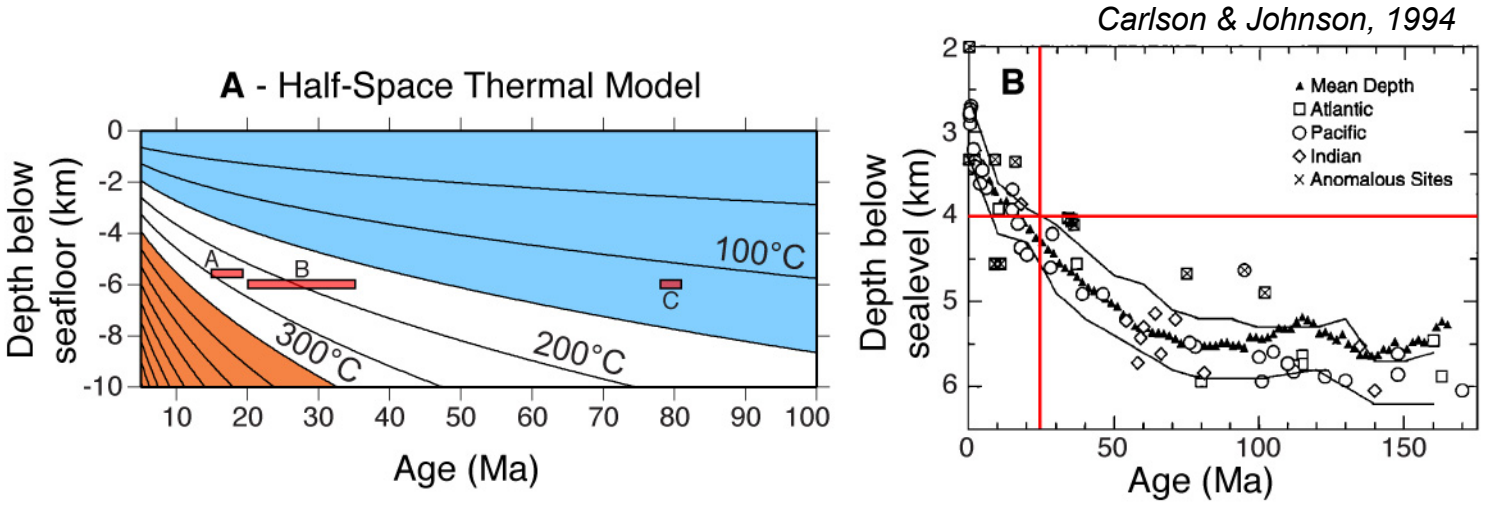
Where should we lock on the mantle?

Harry Hess, one of the legends in Earth Sciences

“Perhaps it is true that we won't find out as much about the earth’s interior from one hole as we hope.
To those who raise that objection I say, If there is not a first hole, there cannot be a second or a tenth or a hundredth hole.
We must make a beginning.” (1958)

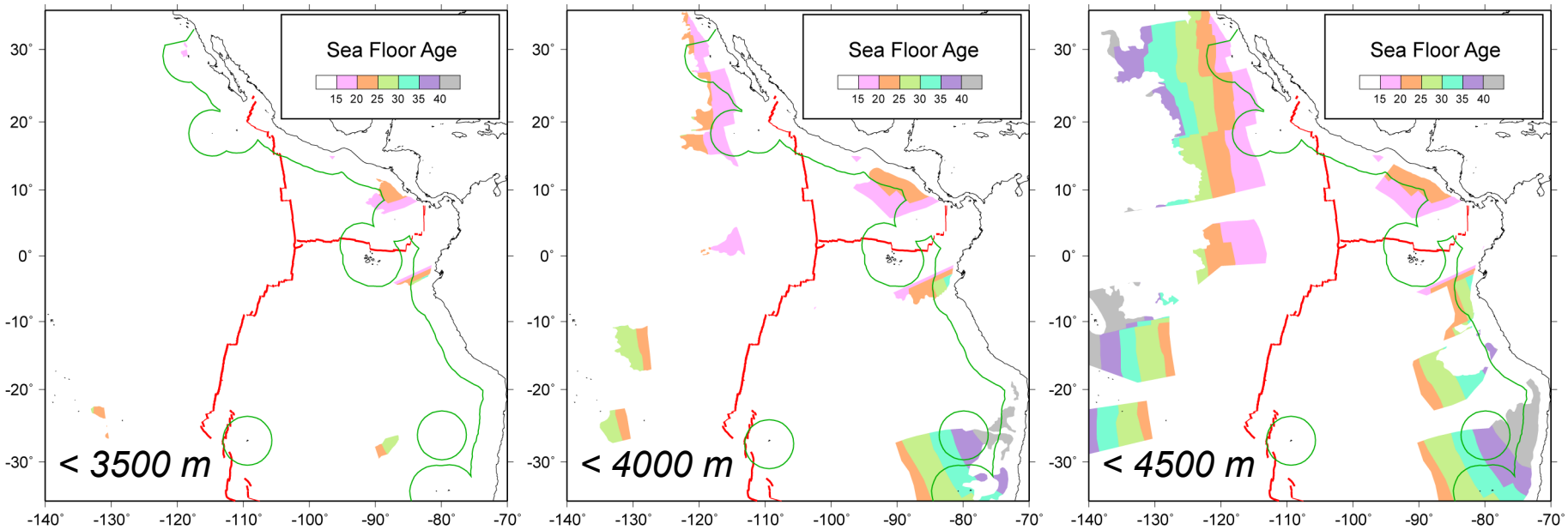


Where? The trade-off between water depth and temperature



Carlson & Johnson, 1994

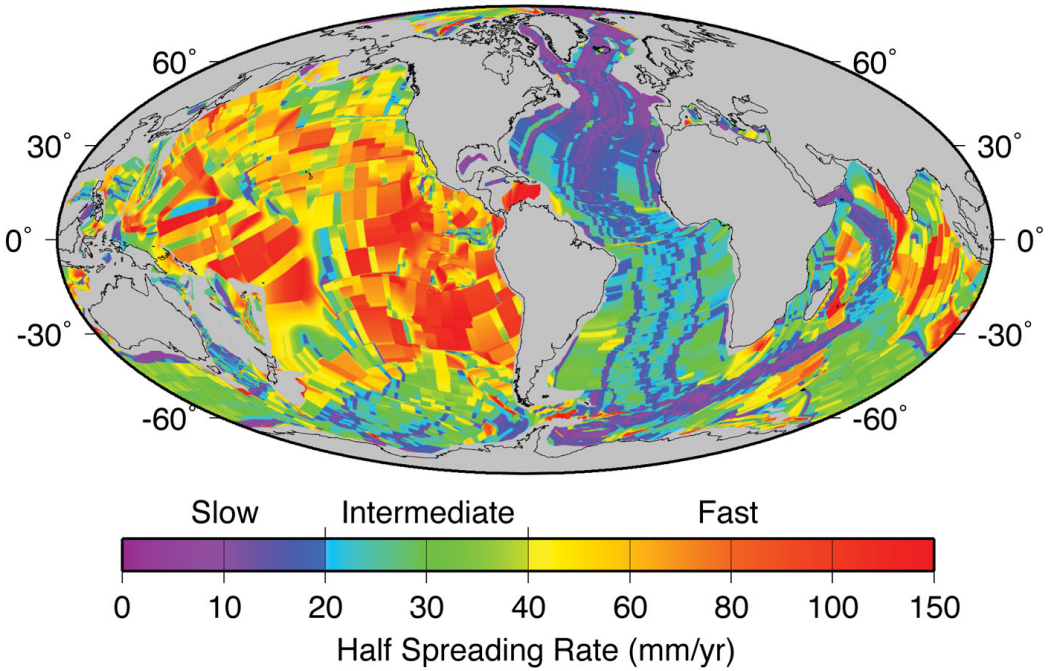
Technological constraints: <~250°C in the mantle & ≤4000-4500 meters of water



Figs: D. Wilson

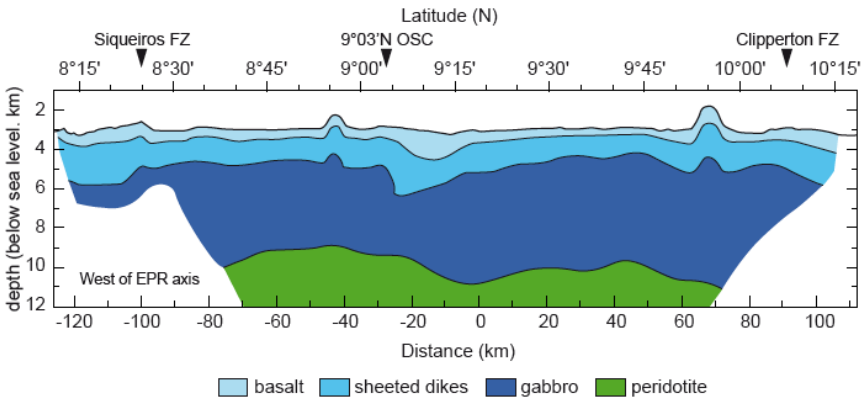
Potential targets in the Eastern Pacific

1st MoHole : fast-spread lithosphere

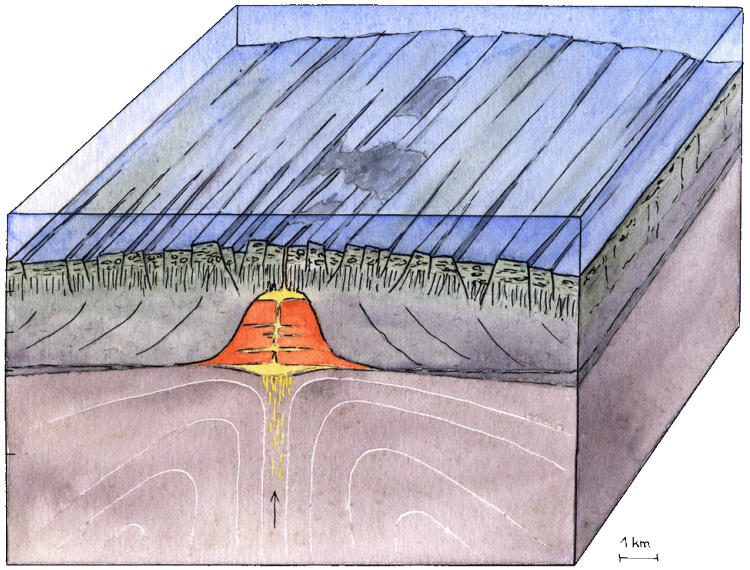


données: Müller et al., 2008

- *Majority of crust recycled into mantle in past 200 Ma*
- *~20% of modern ridges*
  ~50% of oceanic crust
  ~30% of Earth's surface
- *Relatively continuous and uniform*

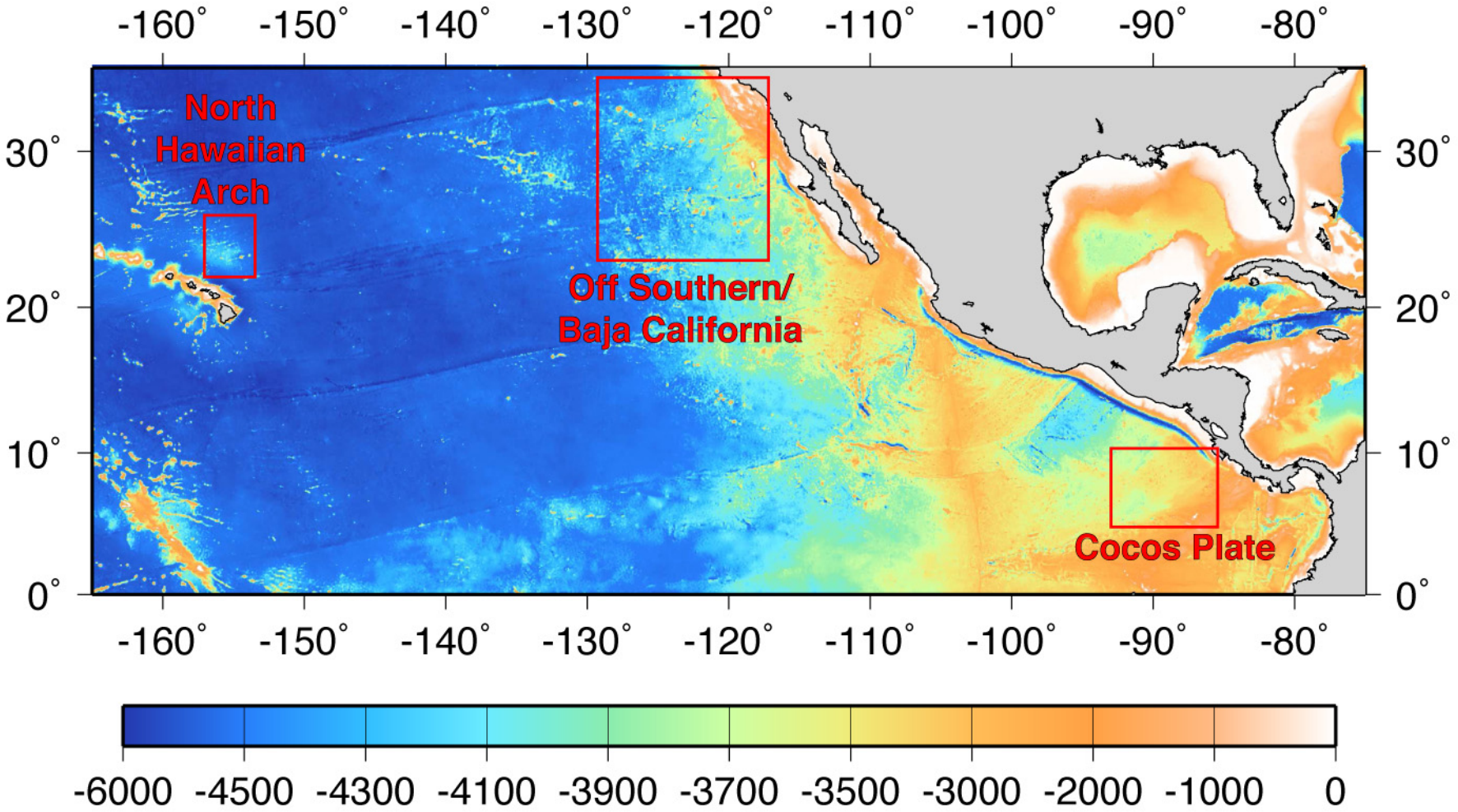


Ildefonse, 2007; after Canales et al., 2003



C. Laverne

Selected regions for M2M



Additional site surveys are required

(partly scheduled or applying/waiting for funding)

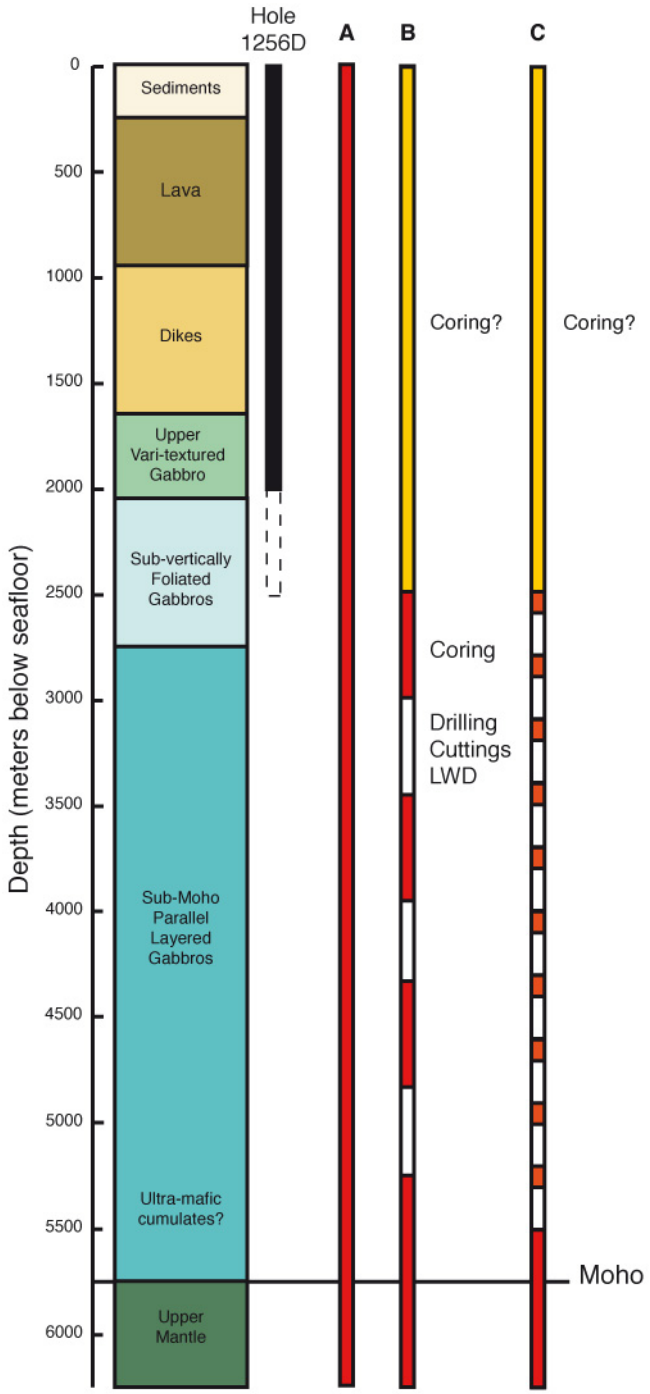
All you need is…

- *Stabilize the vessel to drill/core in water depths ~12000 feet (~3600 m) or more*
- *Clean the borehole hole*
- *Keep the borehole vertical*
- *Manage pressure within the borehole*
- *Manage temperature within the borehole*
- *Manage stress within the borehole*
- *Collect samples, return all equipment*
- *Avoid unfavorable met-ocean conditions*
- *Find funding and stay within time and financial constraints*

Ultra-deep drilling (hole stability, high T, …)

Technology planning and development

Management and scoping



Keys for success

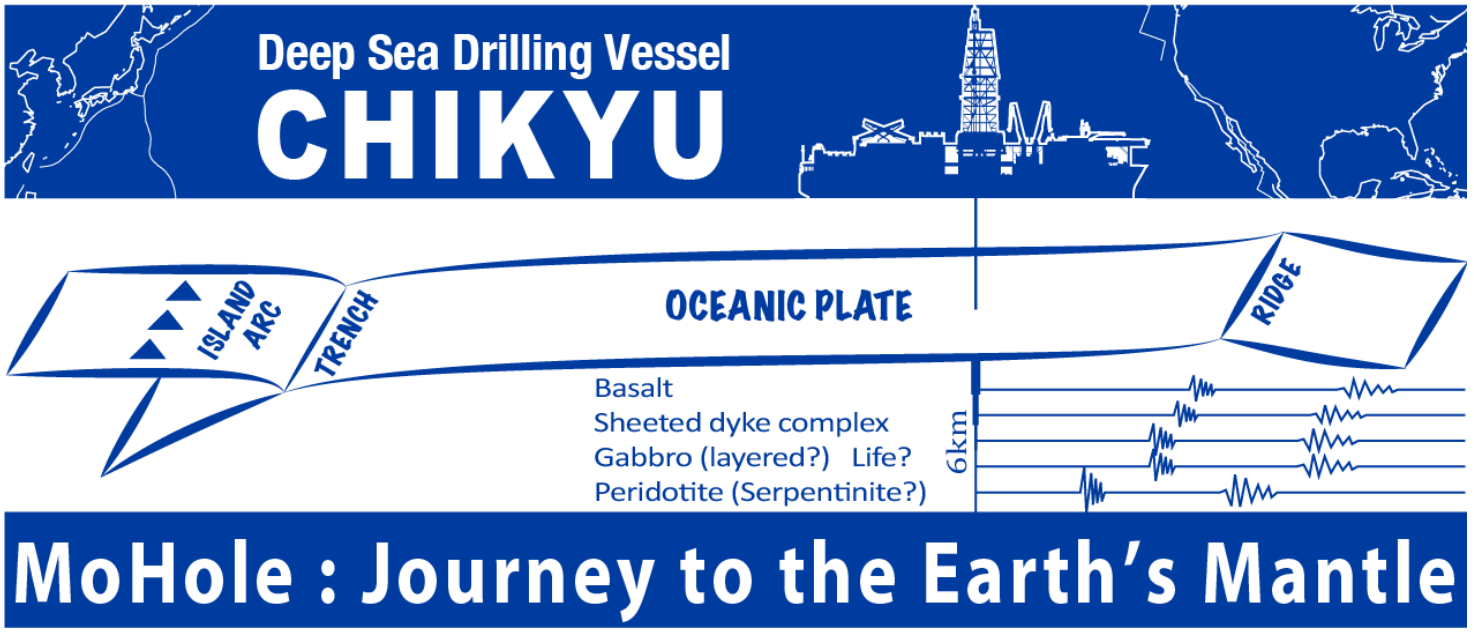
- *Ideally:* ***continuous core samples***
- *Core samples for* ***microbiological studies*** *(avoid and/or control chemical and microbiological contaminations)*
- *Continuous, comprehensive suite of* ***geophysical logs & borehole experiments***
- *Integrate core/log/survey data in a comprehensive* ***synthesis study of the Project Area***
- *Engage of a* ***broad range of scientific communities***
- *Develop required technology and engage industry*
- *Improve* ***public support*** *and understanding of the project*

www.jp.mohole.org
マントル掘削ウェブ

M2M: MoHole to Mantle

The MoHole: The Journey to the Earth's mantle

The MoHole



The plan to drill through the entire oceanic crust is ambitious and exciting, and well worth the expense.

Drilling into the mantle is not expected to be cheap by any means. But in all likelihood, Mission Moho will only cost a fraction of what is currently spent on space exploration…

Peeking into the Earth's interior is closer to home. **The voyage is well worth undertaking**.

Nature Geoscience, Editorial, Nov 2009

Phase I of Project Mohole

LIFE Magazine（http://www.life.com/image/101231681）

Project Mohole Meeting around a table aboard the vessel CUSS I off Guadalupe Island in the Pacific Ocean, 1961.

Walter H. Munk proposed drilling to the Mantle in 1958

“What good will it do to get a single sample of the mantle?”

Nearly 40 years later, Walter H. Munk received The Kyoto Prize in 1999

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Walter may visit to Japan (Univ. Tokyo) in order to support the project in this November.
"Make it happen"

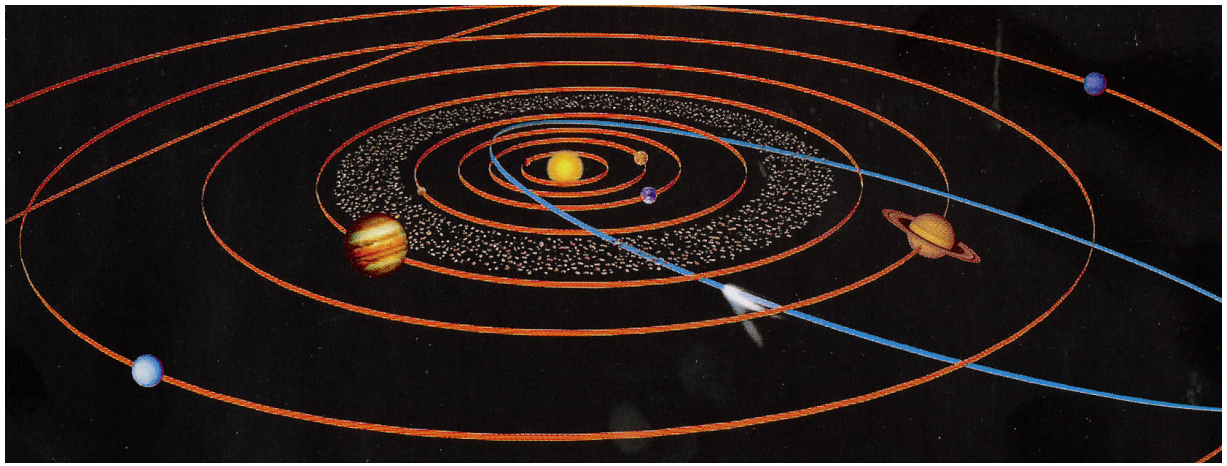
Walter H. Munk

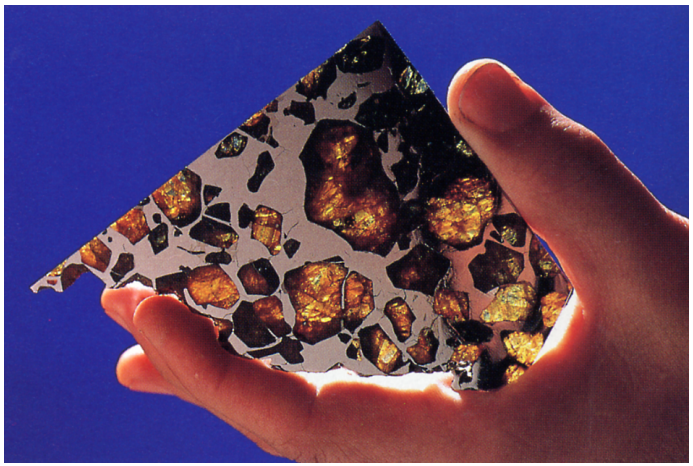
U. S. A. / October 19, 1917

Oceanographer; Professor, Scripps Institution of Oceanography, University of California

During a research career that has spanned more than a half century, Dr. Munk has made fundamental contributions to understanding various ocean waves and tides and the mechanism of oceanic circulation. He was also the first to shed light upon the influence of the atmospheric and oceanic motions on the rotation of the earth, bringing a new development of studies in this field. Through these achievements, he has enormously influenced and promoted the development of earth science, especially oceanography, in the latter half of the 20th century.

At the end, one more stuff





The MoHole Project is not just a project in Earth Sciences. The project will reveal a detailed interior of our planet, where is almost covered by the liquid H_2O and where the miracle of the life happened to be taken place among thousands in our galaxy!

Let's make it happen!