



# IODP

INTERNATIONAL OCEAN  
DISCOVERY PROGRAM

## Japan's Contributions and Next Targets

### ■ What is the International Ocean Discovery Program (IODP)?

IODP is an organization of more than 20 countries with a mission to unravel mysteries of the Earth by drilling boreholes deep into the ocean floor. We use ships with the most modern technology including, Japan's CHIKYU, which is the world's largest research vessel for deep water drilling, USA's JOIDES Resolution which has sailed for decades all the oceans of the world, and Europe's unique set of platforms for shallow water drilling.

### ■ What have we learned from drilling the ocean floor?

From 2003 IODP has drilled boreholes in every ocean from the Arctic to Antarctica. The scientific results have provided valuable data that answer key questions about Climate and Ocean Change, the Beginning and Limits of Life, the Dynamics and Structure of the Earth, and Disastrous Earthquakes that threaten our populations.



Japan Drilling Earth Science Consortium  
(J-DESC)



**JAMSTEC** 国立研究開発法人  
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Japan Agency for Marine-Earth Science and Technology

## Reading the Past, Informing the Future

### Investigating the Asian Monsoon

Over half of the world's population is concentrated in Asia. To help sustain the large numbers of people, we need to better understand the changing climate conditions which are largely controlled by the Asian monsoon. IODP is carrying out scientific drilling in all the oceans of surrounding Asia and data

from these cores record the climate changes during the last several million years. Many factors including ocean temperatures and particle material such as the 'eolian dust (Kosa)' from the Asian continent affect the climate changes in the past and help us understand what to expect in the future.

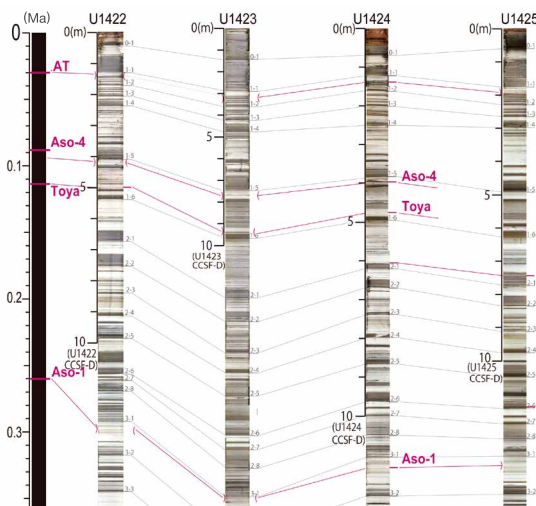


Figure 1. Correlation of the upper sections of cores excavated in the Japan Sea

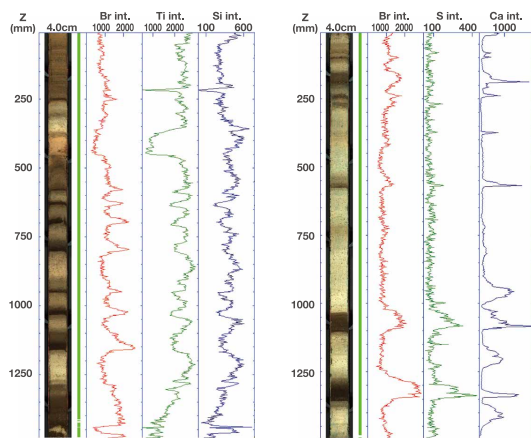


Figure 2. Change in element concentrations in the light and dark layers

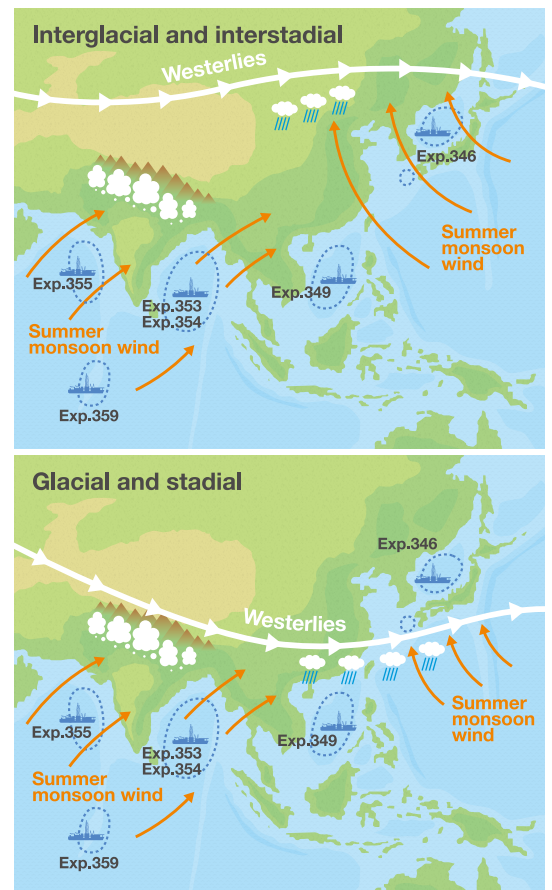


Figure 3. Schematic diagram of the Asian monsoon oscillation

# Biosphere Frontiers

## Deep Life, Biodiversity, and Environmental Forcing of Ecosystems

### Discovery of the world's deepest biosphere

We are starting to learn that the seafloor environment, which was previously believed to be devoid of life and contain only fossils, actually has vast numbers of microorganisms and viruses.

Recently, three important IODP expeditions in the Okinawa Trough, coal beds off the Shimokita Peninsula and the Nankai Trough off of Cape Muroto, have greatly advanced our understanding of the biosphere beneath the ocean floor. The deepest (2466 meters below the seafloor) and highest temperature ecosystems in the world were discovered from the deep cores retrieved in these expeditions. The results of these studies have significantly expanded our knowledge of the role of the seafloor biosphere in carbon and energy cycles, as well as extending the depth limits of life in the known biosphere.

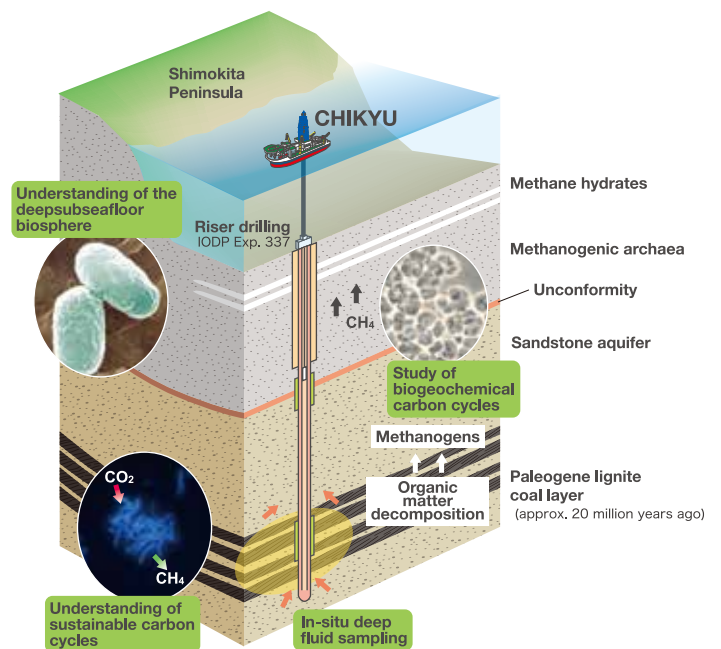


Figure 1. Shimokita Hachinone region that was drilled in 2012.

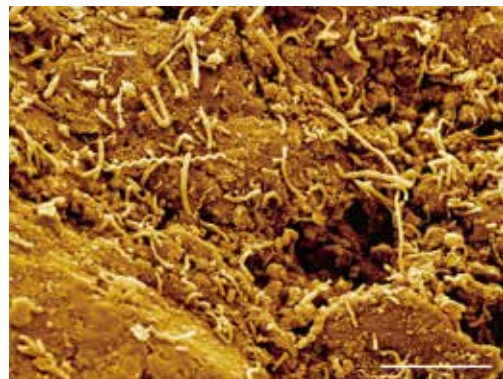


Figure 2. Photographs of microorganisms cultured from samples of the world's deepest biosphere collected from deep coal beds 2 km below the seafloor.

# Deep Processes and Their Impact on Earth's Surface Environment

## Closing in on the origins of the Izu-Bonin-Mariana Arc

IODP Expeditions to the Izu-Bonin-Mariana Arc focused on fundamental questions of the formation of island arc volcanic chains. These are important geologic structures of the Earth where most of the major earthquakes and volcanoes of the world occur.

Volcanic and plutonic rocks from 52 millions of years ago form the foundation of the crust. Over geologic time, the chemical composition of erupting magma changes because parts of the crust plunge downward into the mantle (subduction zones), and then mantle rises up and then its convection starts above the down-going crust. These complicated processes can be untangled by studying the IODP cores. Also the migration of the locations of active volcanoes throughout the region can be seen from analyses of the collected core data.

The studies in Izu-Bonin-Mariana Arc have significantly changed the ideas and models about the formation of subduction zones and arc volcanisms and shed light on the active tectonic processes of our Earth.

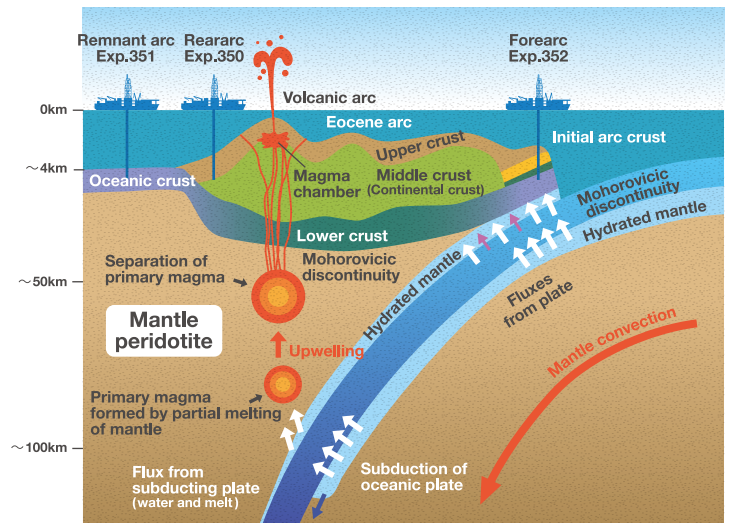


Figure 1. Sites drilled during the three expeditions (Exps. 350, 351, 352) to the Izu-Bonin-Mariana Arc. The positions of the drilling sites relative to the island arc are shown in the schematic cross-section of the subduction zone and island arc.

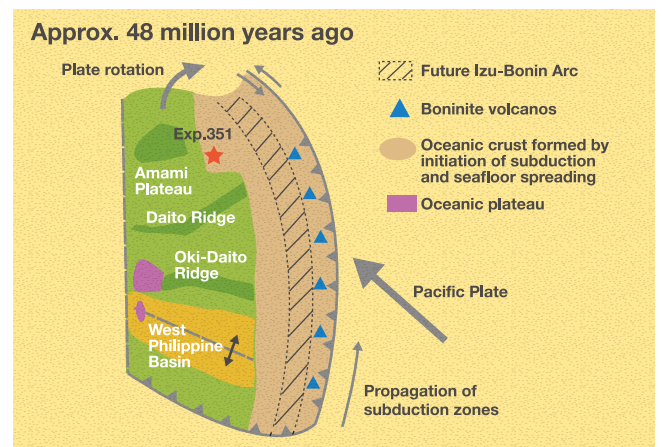


Figure 2. Tectonic reconstruction of Izu-Bonin-Mariana Arc after the initiation of plate subduction (approximately 48 million years ago) based on data from Expedition 351.

# Earth Connections

## Processes and Hazards on Human Time Scales

### ■ Rapid investigations of the 2011 Tohoku-oki earthquake (M9.0)

Soon after the earthquake, core samples were collected from the plate boundary fault of the Japan Trench off the coast of Miyagi Prefecture. This fault had the largest displacement ever observed for an earthquake (over 50 meters). Analyses of the cores, laboratory experiments on the fault material and temperature measurements in the borehole, all showed important discoveries about frictional and physical properties of the fault during the earthquake. From these results, we learned that the fault experienced extremely low friction at the time of the earthquake, allowing it to slip massively and causing the devastating tsunami. Similar results about the frictional level during earthquakes are seen in IODP data from the Nankai Trough in southwest Japan. These observations contribute to our evaluations of the soon expected Nankai earthquakes and tsunamis.

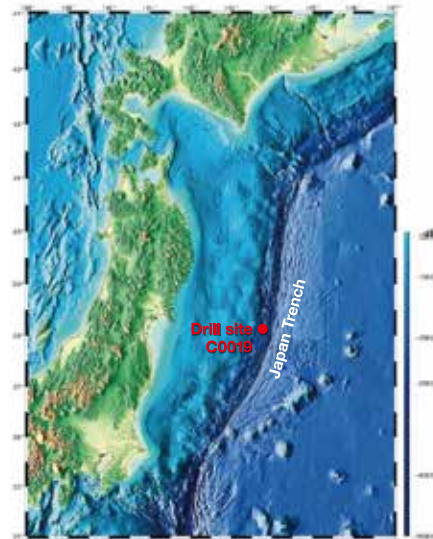


Figure 1. Drill sites in the Japan Trench off the coast of Miyagi Prefecture

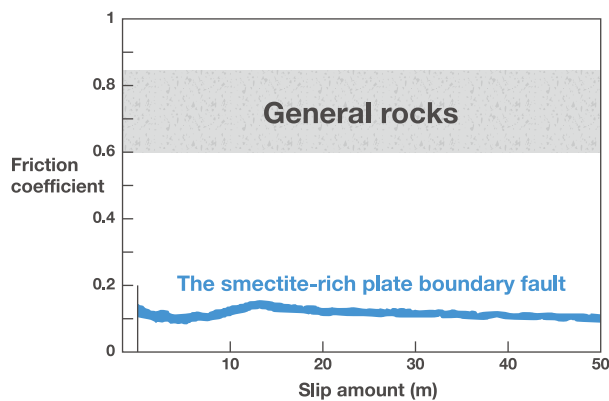
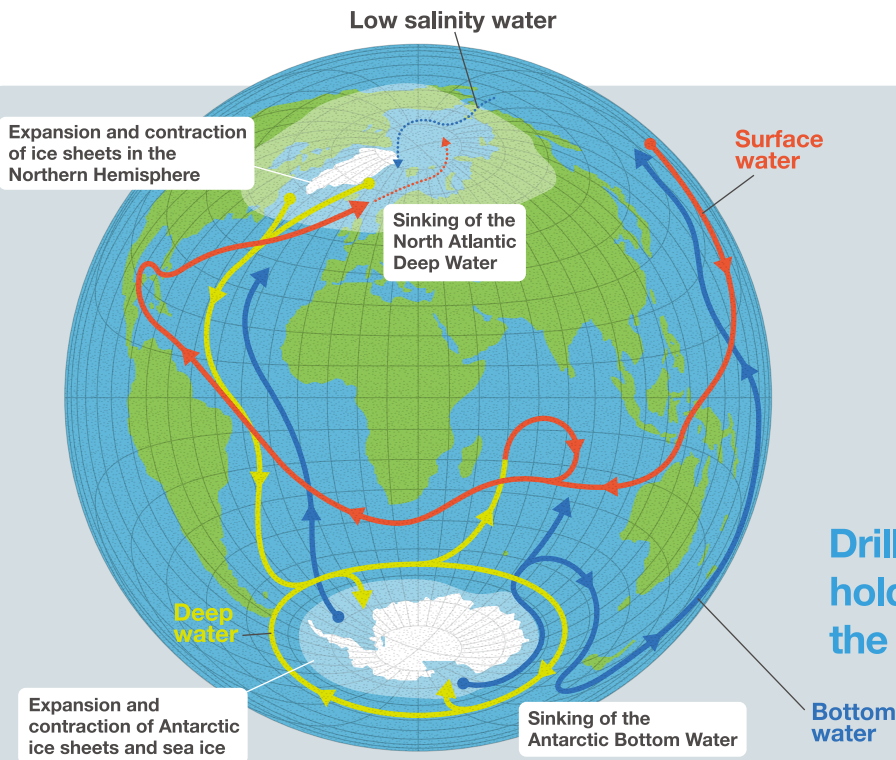


Figure 3. Results of a laboratory experiment using samples from the plate boundary fault



Figure 2. Core sample extracted from the plate boundary fault



# The future of de what are our next targets?



Drilling in the polar regions holds keys for understanding the global climate system.

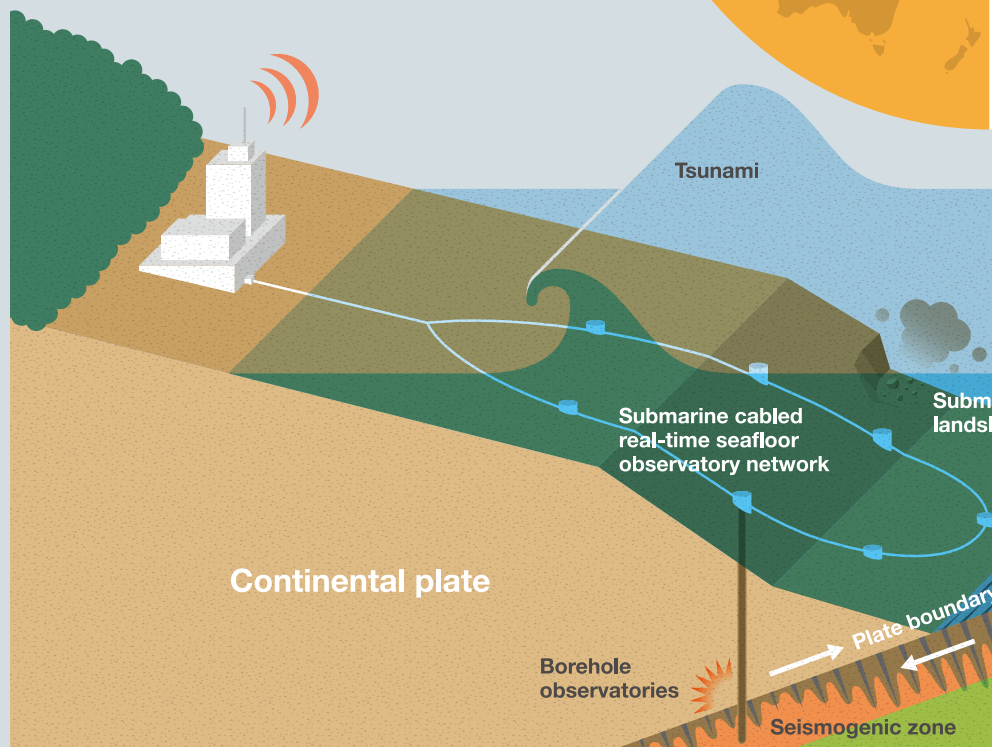
Throughout geologic history, repeated changes in the polar ice sheets have affected sea levels, changed ocean circulation and caused abrupt climate changes. Geologic studies of the warm periods during the Eocene when there were no polar icecaps, to the ice ages of the

Pleistocene, provide valuable scientific data for understanding our present changes of climate. IODP leads many expeditions in the polar and other oceanic regions to study climate change. Also preparations are underway for a Japanese Antarctic drilling initiative.

## Climate and Ocean Change

## Preparing for earthquakes with realtime monitoring

IODP boreholes will be used for intense monitoring of ocean faults that cause the most disastrous earthquakes on Earth. Installed in boreholes, instruments can be located close the faults providing precise measurements of small changes of strain, temperature, water pressure and tiny earthquakes that may precede and accompany the huge earthquakes. Monitoring of tsunamis and underwater landslides, along with providing realtime information for Earthquake Early Warning, provide some of the most direct societal benefits of the IODP program.



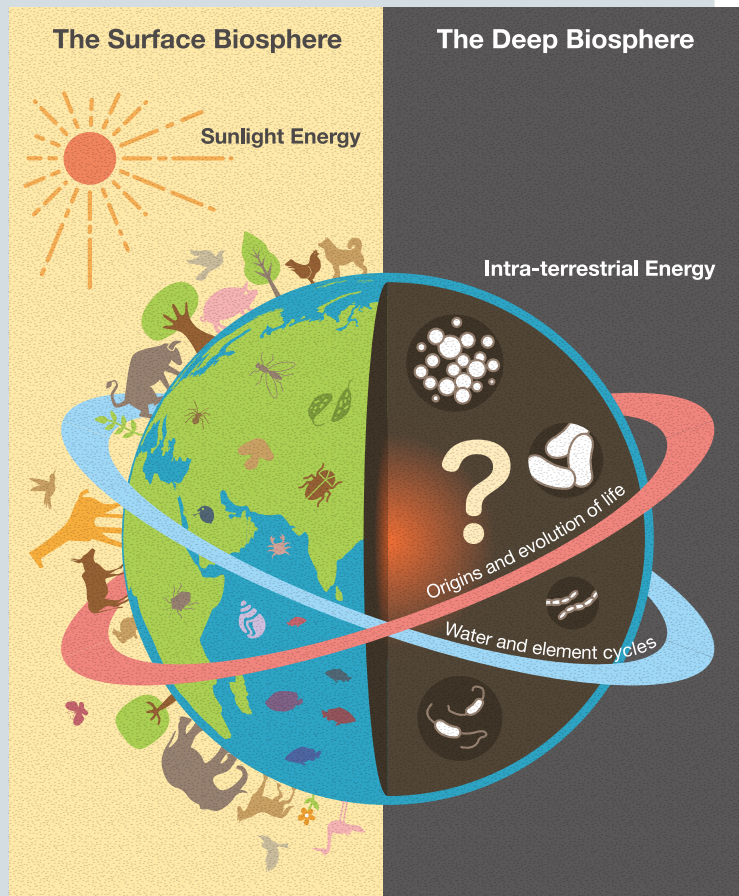
# Deep-ocean drilling :

## How is the Earth's mantle related to the evolution of life?

Important clues to unraveling the mystery of the origins and evolution of life lie hidden in the unexplored biosphere below the ocean floor. We need to study the unusual connections between life and the geology /chemistry of the mantle of the Earth. The evolutionary processes we observe may be very different from the Darwinian changes seen on the surface. IODP drilling is used for multi-faceted analysis of deep core samples and experiments to reproduce the primeval Earth environment. These observations from deep under the ocean floor can lead to discoveries of new principles regarding the evolution and origins of life.

Biosphere Frontiers

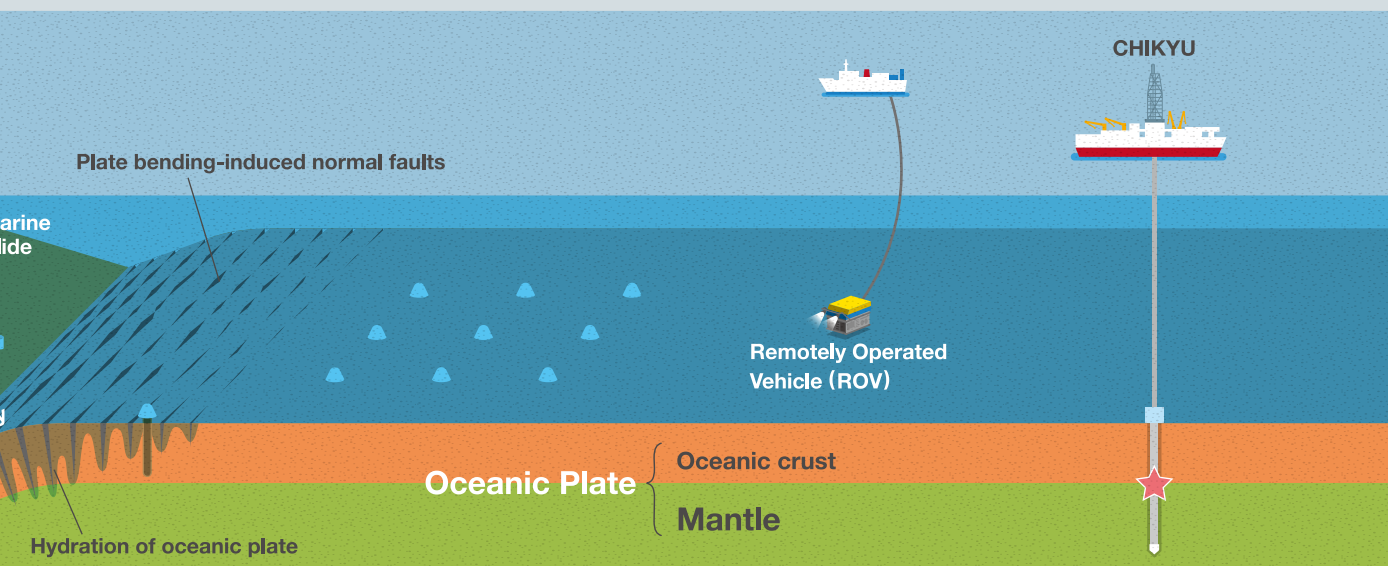
Earth Connections



## Now is the time for deep drilling to the Earth's mantle!

Very deep drilling into the Earth will reach new frontiers that have never been directly observed before. Key questions can be answered with samples from the hot mantle. What is the driving force behind plate tectonics? What kind of life exists in the inhospitable environment? What is the

global circulation of water and carbon? This project is technically very challenging, so we will need the collaboration of scientists, engineers and contributors from many fields to reach this goal which has never been achieved before.



# Coordination with continental drilling

Japan's International Continental Scientific Drilling Program initiative



## ■ What is the International Continental Scientific Drilling Program (ICDP)?

ICDP is the terrestrial counterpart to the IODP and includes 23 countries that cooperate on research using land based drilling. Data collected from boreholes are used to study important societal issues, such as Climate and Ecosystems, Natural Hazards, and Sustainable Georesources. IODP and the ICDP coordinate their research so that data from both the continents and the oceans can be used to unravel geological and biological mysteries of the Earth.

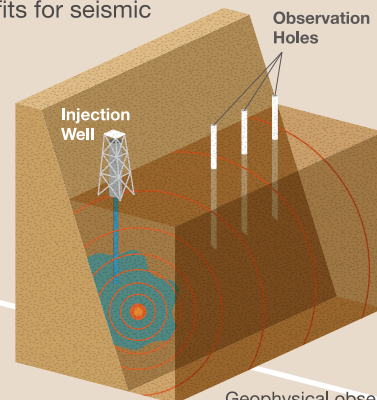
## Drilling Lake Biwa for a 450,000 year climate record

Sediments in lakes provide valuable records of the past climate. For example, a >250m thick clay deposits in Lake Biwa can produce one of the best detailed records of climate for the past 450,000 years. The fossil pollen record with precise age control by numerous volcanic ash layers shows temperature and precipitation oscillations regulated by different astronomical rhythms. A project is underway to further explore the sediments of Lake Biwa so we can establish the definitive history of climate change and understand the mechanism of the monsoons for this region.

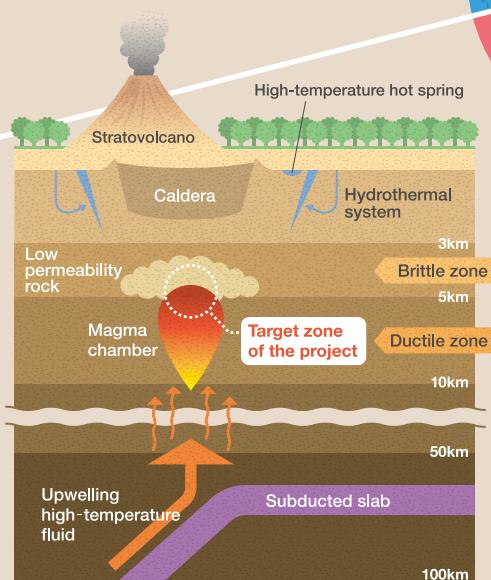
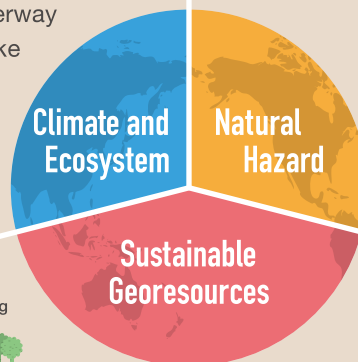


## Earthquakes triggered by People

There have been many recent examples of seismic events caused by human activities, such as underground fluid pumping, filling of water reservoirs, and geothermal power production. To understand the mechanisms of these events, as well as learn about natural earthquakes, we are planning unique experiments to trigger small and moderate earthquakes by injecting water into active faults. Studying the stress and fluid conditions, as well as the safety factors, for these events has important societal benefits for seismic hazards.



Geophysical observations to monitor seismic activity for an experiment of water injection into an active fault.



Conceptual diagram of the supercritical geothermal power generation system targeted by JBBP

## Future Geothermal Power through the Japan Beyond-Brittle Project

Current geothermal power generation relies on naturally occurring heat reservoirs (underground areas near hot magma where water is heated). An innovative technique to improve the efficiency and sustainability of future geothermal power is being developed by the Japan Beyond-Brittle Project (JBBP). This project targets the deep and high temperature zone where brittle rock changes to ductile material. Little is known about this transition, so in addition to the energy applications, important results are expected for volcanology, seismology, and geochemistry.



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