Jochen Erbacher

Secrets of the Deep

The International Ocean Discovery Program, the world's largest research collaboration in the geosciences, is celebrating its 50th anniversary. With significant scientific and financial participation from Germany, the IODP expeditions and their core samples are providing fundamental insights into the Earth's structure and climate history.

Scientists use research vessels to drill deep into the ocean floor. In heavy seas and with a lot of drift, this can be very challenging work. Shown here is the JOIDES Resolution, which has made a name for itself in deep-sea research. The first part of the name stands for Joint Oceanographic Institutions for Deep Earth Sampling.

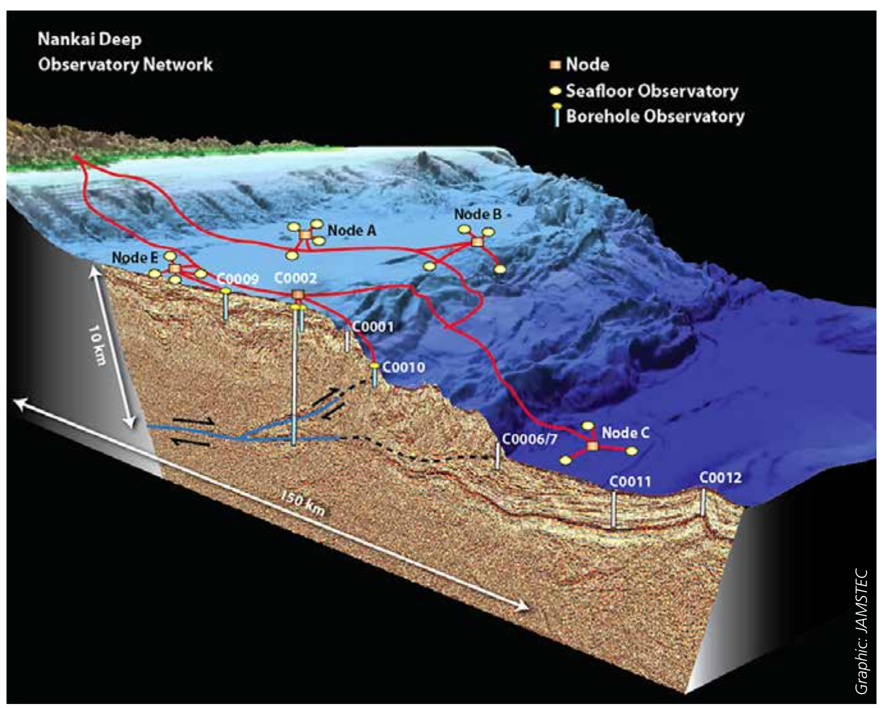
Illustration: IODP/William Crawford

50 years ago, a new era in the scientific study of our planet began. It was the start of an international scientific collaboration in which researchers use challenging deep-sea drilling projects to reconstruct the formation and structure of the Earth and the associated climate history in a new way. The roots of the endeavour go back even further, to March 1961, when a prominent group of geologists, drilling engineers and crew – including the nature-loving US author John Steinbeck (The Grapes of Wrath) – set sail on board CUSS 1. Their visionary objective was to retrieve core samples from between the Earth's crust and the mantle. This boundary deep within the Earth lay a whole 8,000 metres beneath the ship's deck. By the end of the expedition, the team would have drilled through 183 metres of rock in 3,500 metres of water. It was a sensational achievement. Steinbeck, who would later win the Nobel Prize in Literature, was so inspired by the expedition into the unknown that he pocketed a piece of basalt from the drilled core.

It wasn't until nine years after CUSS 1 that a second research drilling vessel left port in Galveston, Texas. The first expedition of the Glomar Challenger signalled the start of the active phase of the Deep Sea Drilling Project (DSDP). In 1969, the first German scientist took part in a DSDP expedition: micropalaeontologist Erlend Martini from Frankfurt's Goethe University. Germany joined DSDP in 1975, and the same year saw the first expedition under German leadership: one of the two expedition leaders was marine geologist and later DFG President Eugen Seibold (1918–2013).

In 1976, the DFG approved a Priority Programme to fund research within the framework of DSDP, and since then it has funded a major proportion of the German contribution. Since the first DSDP expedition with the Glomar Challenger, the expeditions have been consecutively numbered. The third expedition, Leg 3, in the Atlantic confirmed the hypothesis that new oceanic crust was being formed along the mid-ocean ridge and that the continents were moving. Subsequent expeditions allowed scientists to demonstrate that the age of the oceanic crust increased with distance from the mid-ocean ridge. It was exciting proof of Alfred Wegner's theory of plate tectonics.

On expeditions with the research vessel Chikyu*, geologists drilled measuring points (shown in yellow) along the Nankai Trough off the south coast of Japan.*



Graphic: JAMSTEC

Since then, more than 350 expeditions have taken place as part of DSDP and three successor programmes. Thousands of researchers from more than 30 countries have worked on board or on shore in the laboratory, analysing the collected material and data. Researchers from Germany have been involved in the expeditions on more than 400 occasions. For many of them, taking part in a deep-sea drilling expedition has been an important part of their scientific careers. The research topics covered by the International Ocean Discovery Program (IODP) are as diverse as the range of disciplines relating to the solid Earth.

Alongside ice cores from the polar regions, the layered sediments of the ocean floor are the most important climate archive on the planet. For this reason, palaeo-environment research on the sediment cores, which may be up to 175 million years old, has been an important scientific focus of the programme for decades. In 2004, the first deep-sea drilling expedition ventured into the Arctic Ocean. Funded by the European consortium in the IODP, the European Consortium for Ocean Research Drilling (ECORD), and working just 250 kilometres from the North Pole, the expedition produced some extremely informative cores. They enabled scientists to reconstruct the climate history of the Arctic over the last 56 million years.

To cope with the sea ice, the drilling vessel was accompanied by two other icebreakers, including a Russian nuclear-powered icebreaker. The oldest drilled strata bore witness to something incredible: 55 million years ago, temperatures in the Arctic Ocean were as high as summer temperatures in the modern Mediterranean – the result of greenhouse-like global climate conditions. The next drilling campaign in the Arctic Ocean is scheduled for 2021, and is intended to provide more data on the palaeo-oceanography of the Arctic Ocean and its role in climate development.

Some of the most fascinating findings from the last 20 years in basic geosciences research include understanding the role and importance of microbe communities in geochemical processes and detailed insights into microbial life in the oceanic crust. Microbes are known to feed on the organic material found in deep-sea sediments, for example metabolising the metals in volcanic rock. This is just one example of the groundbreaking findings achieved in connection with drilling programmes.

Geomicrobiology is, in fact, an integral aspect of the IODP expeditions. One of the burning questions in this field relates to the physical

Sea water repeatedly sprays out as the drill pipe beneath the drilling tower is pulled back to the JOIDES Resolution.

Illustration: IODP/Tim Fulton

limits of life. Last year, IODP Expedition 370 focused on finding the upper temperature limit for microbial life in the oceanic crust. Off the coast of Japan, the Philippine Sea plate is sliding beneath the Eurasian plate. Immediately in front of this subduction zone, temperatures in the oceanic plate are high even at shallow depths. It's an ideal location to access "hot" strata by drilling.

The Japanese drilling vessel *Chikyu* has drilled into regions 7,000 metres beneath the vessel with a temperature of 130 degrees Celsius. Research being carried out by the working group of Bremen-based expedition leader Verena Heuer is expected to soon provide answers to the question of whether microorganisms live there, or at what temperatures above the total drilling depth life ceases to exist. However, it is a difficult task, as the number of specialised, heat-loving single-celled organisms in the sediments is extremely small. The detection limit must therefore be extremely low. For the cores drilled by Expedition 370, it was just four cells per cubic centimetre. By comparison, Germany's forest floors are home to around 1 billion cells per cubic centimetre.

On the active continental margin off Japan, a few hundred kilometres east of Expedition 370, the longest and probably most innovative IODP drilling campaign has been taking place for over ten years. Over this period, during the eleven expeditions with *Chikyu*, multiple holes were drilled along the Nankai Trough as well as a transect – a straight line of measuring and observation points. The purpose of this campaign is to carry out 4D monitoring of seismic activity off Japan's Kii peninsula. Because it is situated in the area where multiple plates converge, the region has some of the highest seismic risks in the world.

The main borehole is already 3,000 metres deep and is to be deepened further as of the end of 2018. In spring 2019, the drill is expected to break through the crust-mantle boundary at a depth of 5,200 metres. The boreholes are already equipped with an array of measuring instruments connected to deep-sea cables, which continuously register pressure and temperature fluctuations and can monitor seismic activity. This means that the observation and interpretation of activity within this active continental margin in four dimensions will become a reality in the near future.

A historic moment: The Glomar Challenger*, launched in 1970, marked the beginning of the active phase of the Deep Sea Drilling Project.*

Illustration: Archive IODP

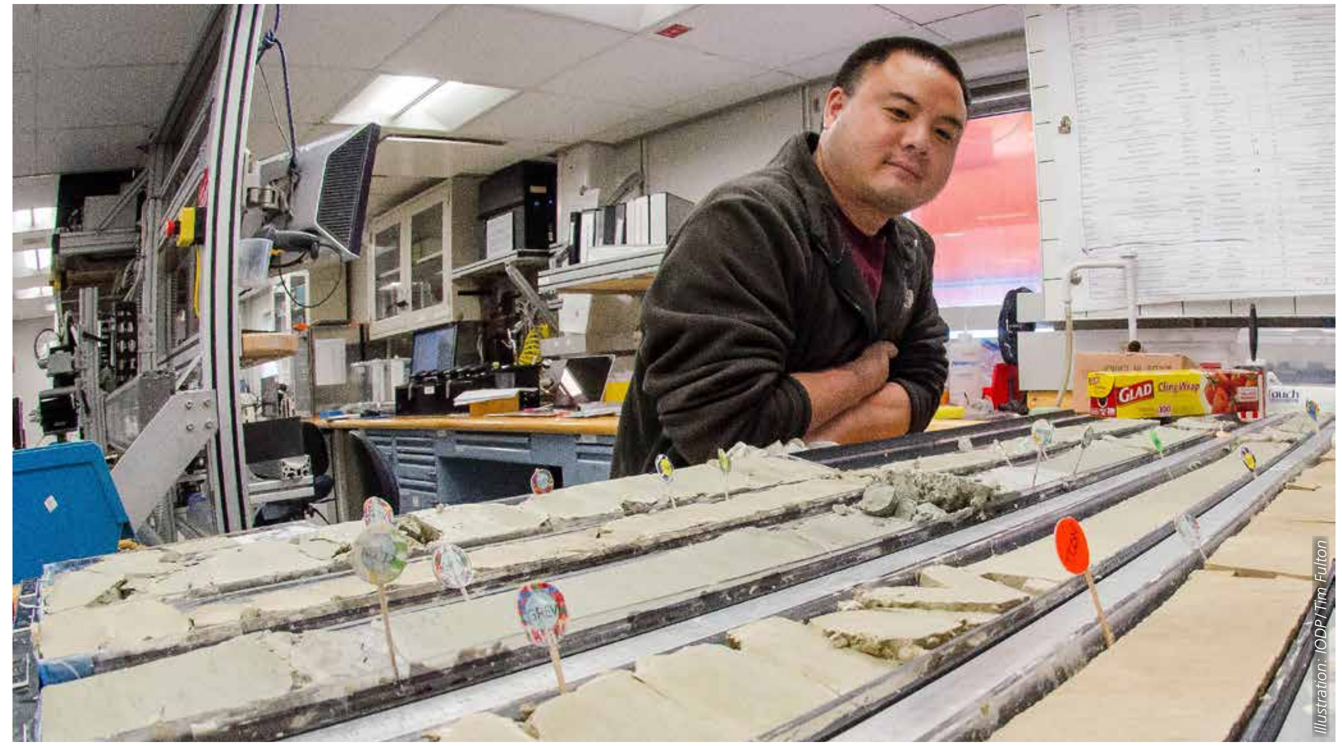


Illustration: IODP/Tim Fulton

Matt Ikari (MARUM, University of Bremen) examines new sediment cores on the sample table during IODP Expedition 375, off north-eastern New Zealand.

Between now and 2023, the IODP scientists will focus on four main topics: Climate, Deep Life, Planetary Dynamics and Geohazards. Planning for the years after 2023 will get underway next year. In April 2019, around 300 researchers from 25 countries will meet in Vienna to start laying the groundwork for a new thematic orientation of international scientific deep-sea drilling. Even after 50 years, there are still vast areas of the sea floor waiting to be explored and key geological processes which are not yet understood. This work can only be carried out with international cooperation and funding. The DFG has been supporting this for the past five decades. The IODP and its three predecessor programmes are the longest and the largest collaborative projects in the geosciences in the world.

We still have not succeeded in reaching the boundary between the Earth's mantle and crust – the aim of *CUSS 1* in 1961. This boundary is defined as a seismic boundary, and in honour of its discoverer, Serbian geophysicist Andrija Mohorovičić, it is known as the Mohorovičić discontinuity or simply "Moho". However, with the help of the US drilling vessel *JOIDES Resolution*, deep-sea drilling expeditions have penetrated to the lower depths of the oceanic crust.

So with a little luck, the original goal of scientific deep-sea drilling will be achievable in the not too distant future. John Steinbeck (1902–1968) did not live to see it, and the strict procedures now in place on board to preserve samples would probably have made it difficult for him to "pilfer" a piece of the boundary material that is so important to our understanding of the Earth's structure. But the expedition scientists will perhaps recall the words Steinbeck wrote in *Life* magazine on the first core brought up by *CUSS 1*: "On this first touching of a new world the way to discovery lies open."

Prof. Dr. Jochen Erbacher,
Federal Institute for Geosciences and Natural Resources, is the coordinator of the DFG Priority Programme "International Ocean Discovery Program".

Contact: Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Koordinationsbüro IODP, Stilleweg 2, 30655 Hannover, Germany

www.bgr.bund.de/IODP