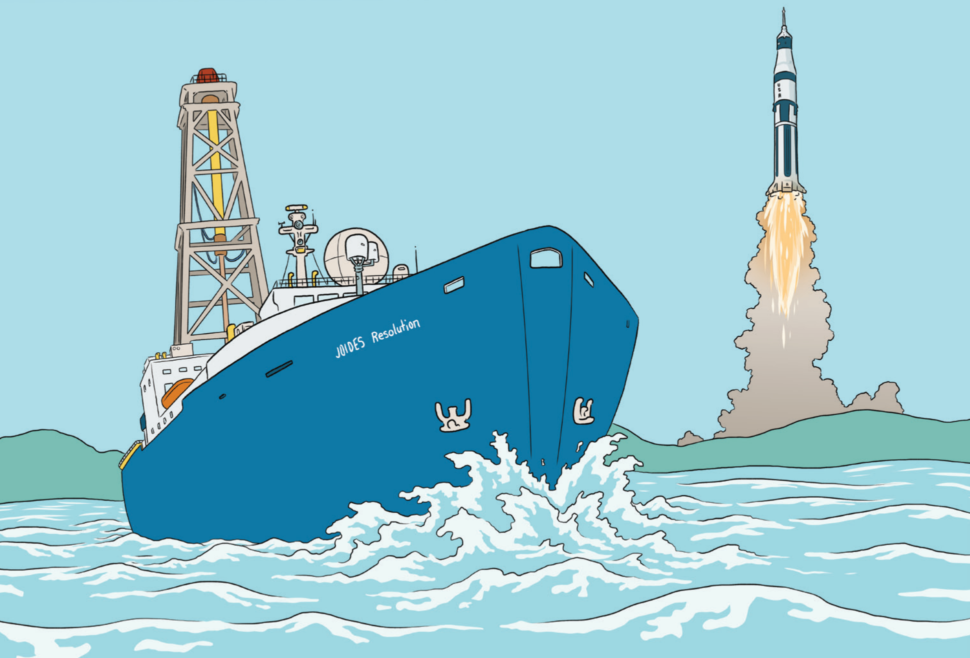
MYSTERIES *of the* DEEP

A PROGRAM TO RIVAL THE SPACE RACE...

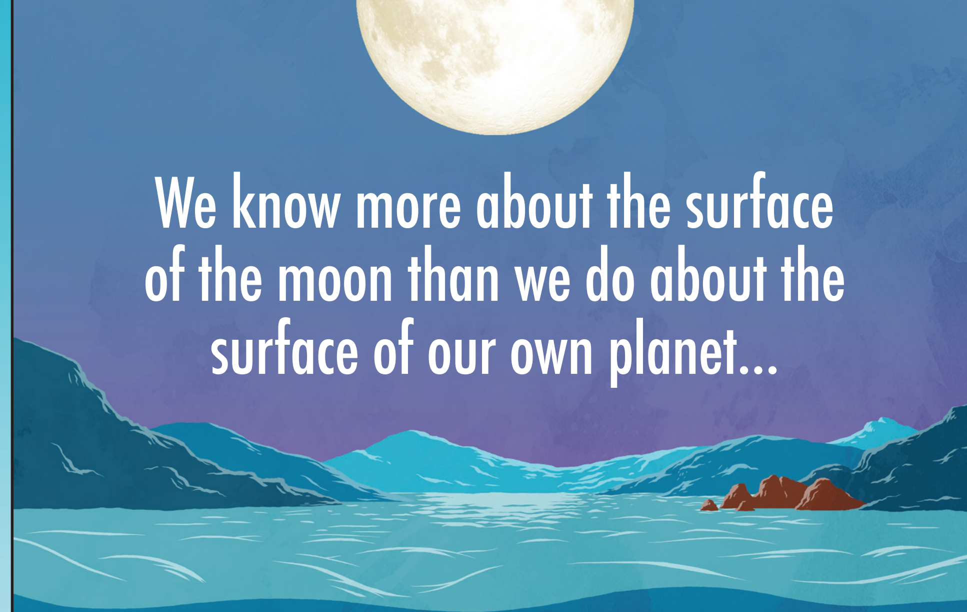


*Over the past fifty years the secrets of the **oceans** have been revealed through an amazing international collaboration - scientific ocean drilling.*

A program rivalling the scale and ambition of the space race, it spanned the divisions of the Cold War to bring together countries across the globe in scientific collaboration.

Today the project involves more than 20 countries working together in an effort to understand the oceans from the Arctic to Antarctic.

Thousands of scientists, crew and support staff have spent many months or even years of their lives at sea for this program. Together they have discovered the story of our blue planet.



We know more about the surface of the moon than we do about the surface of our own planet...

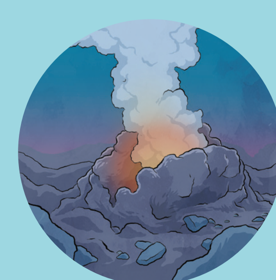
... because 70% of our planet's surface is covered by oceans.

The coasts, where waves and tides meet the land, are familiar places of great beauty but are a tiny fraction of the ocean. The oceans are vast, and extend to enormous depths below the surface we see.

What Lies Beneath?

Teeming life, from the smallest virus to the largest animals on Earth.

Furious undersea volcanoes that never stop erupting.



Vast chasms and great mountain ranges taller than Everest.

The oceans impact all our lives.

The patterns of warm and cold currents control the climates we live in. Hot oceans provide the energy for hurricanes and the moisture for the monsoon rains. Waters teem with life and keep many human communities alive. Shifting movements in the deep can devastate the coasts with giant tsunamis. Understanding this complexity is a challenge on a global scale.

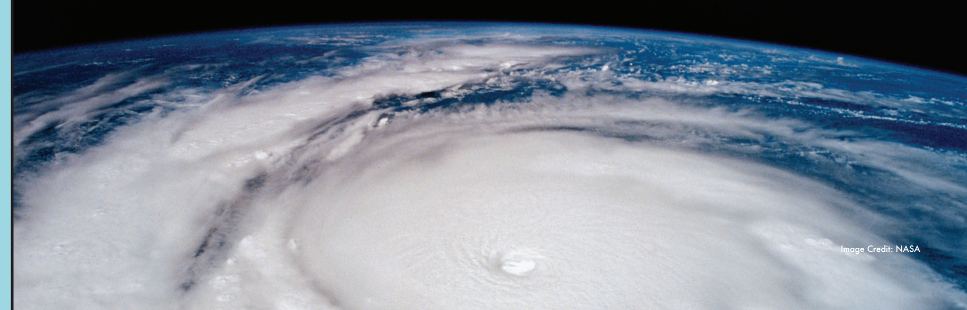
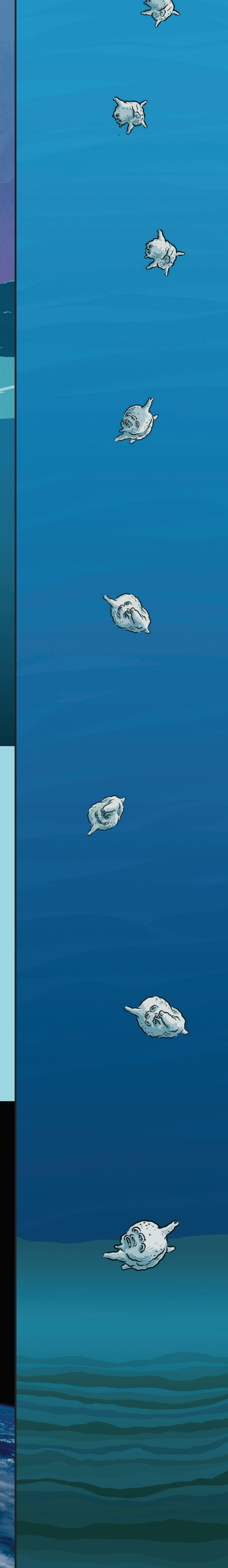


Image Credit: NASA



A RECORD OF EARTH'S HISTORY

How do we know about ice ages? Mass extinctions? Ancient climates?
The secrets to all these are hidden below the seafloor...

The shells of tiny plankton, mud from rivers, and even dust blown from far away land, all end up on the ocean floor. Over time, new grains fall on older grains, burying a record of Earth's history in the mud of the ocean floor.

THE TINIEST FOSSILS THE BIGGEST CLUES

The fossil remains of tiny single-celled life forms, called foraminifera ("forams"), are key to this story. Many forams grow a hard shell and the chemistry of these shells reflects the environment they grew in.

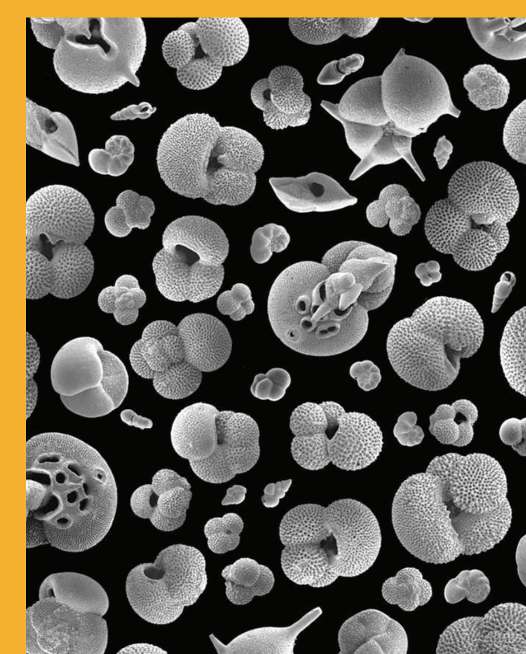


Image © Professor Paul Pearson

By analysing these ancient foram shells, we can tell many things about past oceans and climates: temperatures, carbon dioxide levels in the atmosphere, and even the size of polar ice sheets.

GREENHOUSE WORLDS

How does our planet respond to high levels of carbon dioxide? Geologists can look back at ancient climates to answer these questions. In the Eocene Epoch atmospheric carbon dioxide concentrations were about three times modern levels. The Eocene world was so warm that palm trees grew on Antarctica and the Arctic Ocean was an ice-free freshwater lake.

EXTINCTION

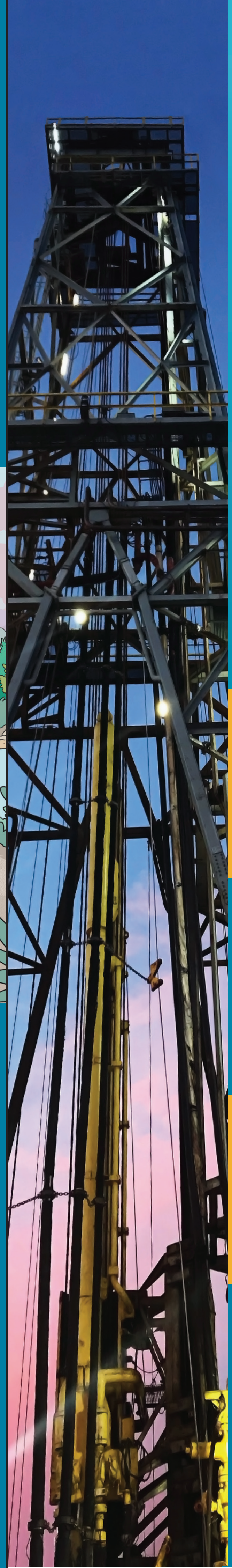
The greatest story ever told by fossils is of an Earth once ruled by dinosaurs. But why, after 160 million years, did this massively successful group suddenly disappear? In 1980, father and son team Walter and Luis Alvarez suggested a giant asteroid might have been to blame.

It was an extraordinary claim, but scientific ocean drilling provided the proof. Cores showed a layer of far-flung dust and vaporised rock seen across the globe, all from the same time as a mass extinction of marine life.

PLATE TECTONICS

In the 1960s geologists proposed a radically new idea about our planet – that the continents had drifted together and apart throughout Earth's history, and that the ocean floor was made in some places and destroyed in others.

But how could this theory of plate tectonics be tested? Drilling deep into the oceans' crust revealed that the volcanic rocks of the ocean floor are youngest near the mid-ocean ridges where they are formed.



CORING THE DEPTHS

Scientific ocean drilling programs have sent ships all over the world to bring back sediment cores from the ocean floor. Looking at these cores we can see different layers of sediment, built up over time. Each layer offers a snapshot of a certain moment in Earth's history. The deeper we go, the further back in time we travel!

How Do We Pull up a Core Sample?

The first job is to reach the seafloor with the drill pipe. This can be up to 5 kilometers below the ship - as deep as Mont Blanc is tall! The drill pipe is screwed together and then sent down through a hole in the bottom of the ship until it touches the seafloor.

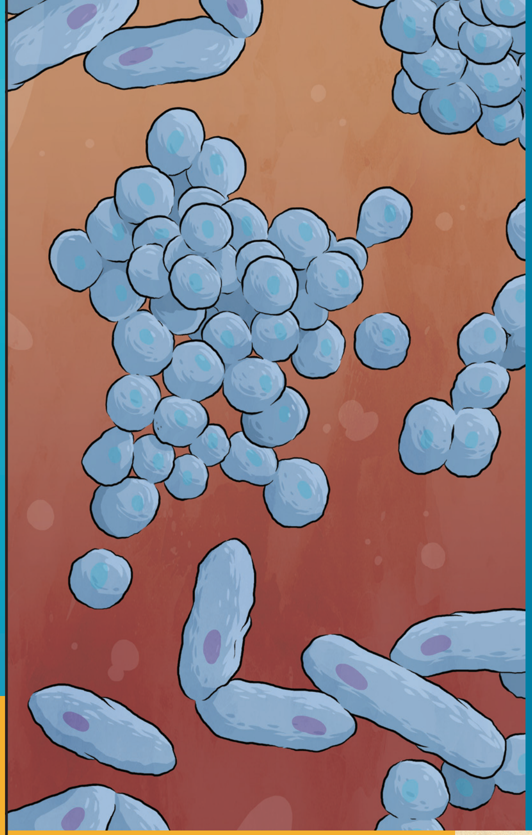
To grab a core sample we send a 9 meter core barrel down to the bottom of the drill pipe. Then the drillers crank up the pressure behind it until it fires down into the sediments with enormous force, like a supercharged submarine apple corer! When the rocks are harder, we spin the whole drill pipe to cut down into the the rocks below.

When the core barrel is full, it is winched back up to the ship. On the rig floor the core barrel is emptied. Out comes a long plastic liner which contains densely packed sediment, ready to be handed over to the science team.

Technicians from the science team lug the long, heavy core along to the catwalk where it is laid out and cut into more manageable sections. This is hard outside work, especially in the freezing winds of Antarctica or the hot sun of the equator.

The team take these sections to the lab, where they are scanned, described, sampled and analysed.

It is at this point that the Earth's secrets can be revealed!



HIDDEN LIFE

Life can survive in many surprising places - from boiling hot springs to frozen glaciers. Exploration deep below the ocean floor has now found life in perhaps the most extreme conditions yet. Without energy from the sun, and under immense pressure, microbes have been found in sediment cores from hundreds of meters below the sea bed. This whole new realm of hidden life lives on tiny scraps of ancient organic matter and the chemicals coming from the rocks themselves. They may even hold clues for how life might survive on other planets.

EARTHQUAKES & TSUNAMIS

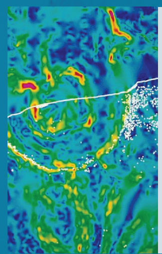
Tsunamis have been the most devastating natural hazard of this century. Major faults within the seabed can suddenly fracture, causing the seafloor to lurch up or down. This moves the whole ocean above it, creating devastating waves that travel thousands of miles. Recent expeditions have drilled right down into these fracture zones to find out what they are made of and even install early warning instruments hundreds of meters below the seafloor.

MELTING ICE & SEA LEVELS

Modern global warming is melting the massive ice sheets of the Antarctic and Greenland. This releases water into the ocean causing sea levels to rise. The future of many coastal communities depends on how large and fast this sea level rise will be. Predicting how these ice sheets melt is very hard. By studying past times of ice melting and sea level rise, ocean drilling has started to provide some answers.

DISCOVERIES FROM THE DEEP

Across the globe, scientific ocean drilling has explored the ocean depths to uncover the mysteries of our planet. These are just some of the highlights of this journey of discovery.



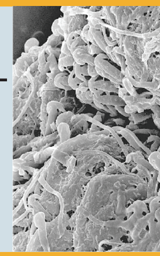
IODP Expedition 364: Extinction

Location: Chicxulub Impact Crater, Gulf of Mexico.

Evidence: Rocks melted at high temperatures, followed by sediments formed as water rushed in to fill the crater.

Conclusion: Cores show the devastating effects of a massive impact 66 million years ago; a perfect fit with the extinction of the dinosaurs.

IODP Expedition 302: Greenhouse Worlds



Location: Lomonosov Ridge, central Arctic Ocean.

Evidence: 50-million-year-old Eocene sediments containing fossils of the freshwater fern *Azolla*.

Conclusion: During the Eocene the Arctic Ocean must have been free of sea ice with a warm summer growing season. Estimates of Eocene Arctic temperatures from these sediments go up to 20°C!

Image Credit: Margaret Collinson, Judith Barke, Johan van der Burgh, Johanna van Konijnenburg-van Cittert

IODP Expedition 343: Earthquakes & Tsunamis

Location: Honshu, Japan.

Evidence: Rock samples and pressure data from the earthquake zone that caused the 2011 Tohoku earthquake and tsunami.

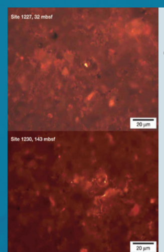
Conclusion: The type of rocks present in this area allow pressure to build close to the seafloor. When the rocks crack they release the pressure in a devastating earthquake, often causing a tsunami. Ongoing data collected from the area will help predict future hazards.

IODP Expedition 310: Melting Ice & Sea Levels

Location: Tahiti, South Pacific Ocean.

Evidence: Cores showing widespread drowning of coral reefs 14,000 years ago.

Conclusion: At the end of the last ice age the melting of large ice sheets was so quick that sea levels rose by 15 meters in 400 years. Coral reefs couldn't grow fast enough to stay in the sunlit zone and 'drowned'.



ODP Leg 201: Hidden Life

Location: East Pacific Ocean.

Evidence: Huge numbers of live microbes in ancient sediments hundreds of meters below the seafloor. Changes in chemistry of waters within sediment pores.

Conclusion: Microbes survive and reproduce deep beneath the ocean floor. These communities have been separated from the surface for millions of years and constitute a newly-discovered realm of life – the 'deep biosphere'.

Image Credit: Axel Shippers and Springer Nature

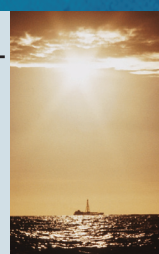
IODP Expedition 374: Melting Ice & Sea Levels

Location: Ross Sea, Antarctica.

Evidence: Cores showing alternating layers of sediments. Some layers were formed in open ocean environments and some at the edge of a major ice sheet.

Conclusion: The West Antarctic ice sheet has grown and melted many times in the past. Sometimes these events happen very quickly, within a few thousand years. These results will improve models of ice sheets to predict future melting.

DSDP Leg 3: Plate Tectonics



Location: South Atlantic Ocean.

Evidence: The closer you get to the mid-Atlantic ridge, the newer the volcanic rocks that make up the ocean crust.

Conclusion: The surface of the Earth is always changing. As the tectonic plates move apart from each other, the gap is filled by undersea volcanic eruptions that make new crust.

IODP Expedition 318: Greenhouse Worlds

Location: Wilkes Land, East Antarctica.

Evidence: Palm tree pollen in Eocene sediments off the shore of Antarctica.

Conclusion: Temperatures on the coast of Antarctica must have been sub-tropical in the Eocene for palm trees to grow.

Image Credit: Joerg Pross

VOYAGES WITH:

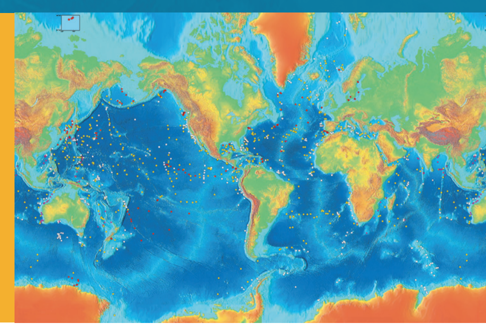
JOIDES Resolution

Glomar Challenger

Mission Specific Platforms

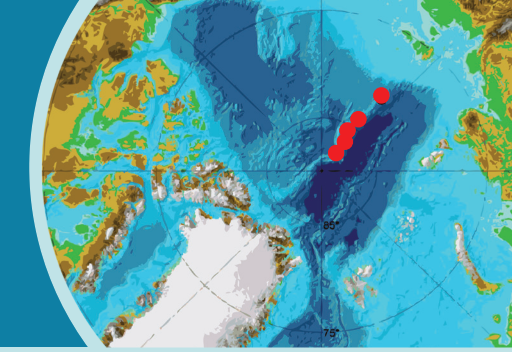
Chikyū

Drilling thousands of sites across the oceans:



ARCTIC CORING - IODP EXPEDITION 302

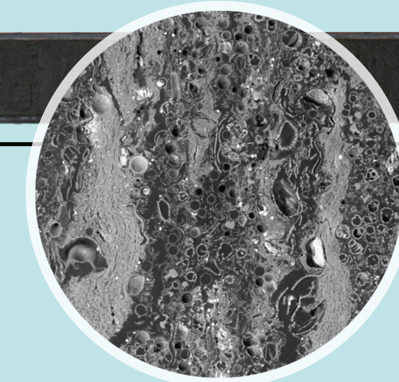
The first ever scientific ocean drilling within the central Arctic Ocean, reaching within 250 km of the North Pole.



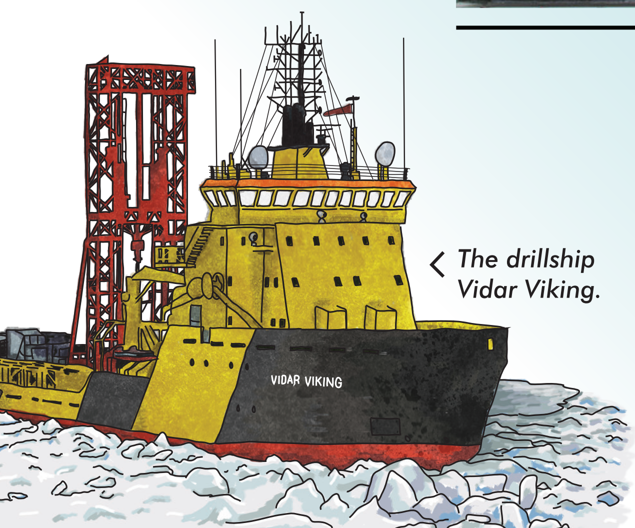
^ Expedition 302 drill sites (red dots) on the Lomonosov Ridge.

Top
300.8 m below the seafloor

Alternating layers of light and dark sediment



< Sediment thin section showing the light and dark layers. (Courtesy of M. Collinson).



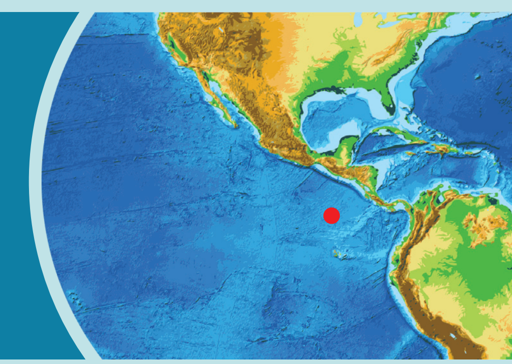
< The drillship Vidar Viking.

The biggest challenge during Expedition 302 was keeping the drillship still enough to operate within moving sea ice 2-4 meters thick.

In the Eocene (~50 million years ago) sediment cores show thin alternating layers of microscopic plankton (dark layers) and the remains of the freshwater fern *Azolla* (light layers). This layering might reflect seasonal changes in the ancient Arctic Ocean.

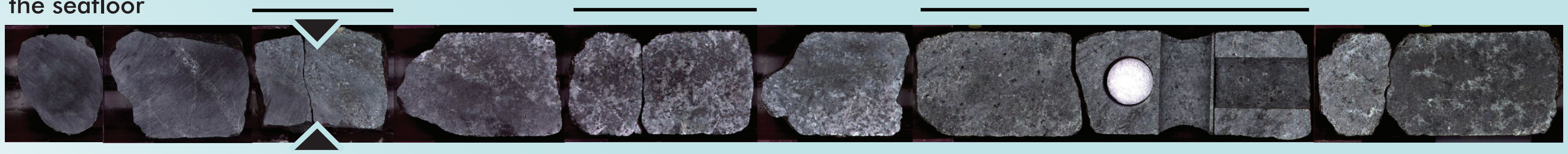
SUPERFAST SPREADING RATE CRUST 3 - IODP EXPEDITION 312

The first to recover an intact series of rocks spanning the boundary between the upper and lower oceanic crust - as shown in this core!



^ Hole 1256D (red dot) was drilled into oceanic crust that formed 15 million years ago at the East Pacific Rise.

Top
1407 m below the seafloor



< The drillship JOIDES Resolution.

New ocean crust is formed from hot magma at mid-ocean ridges. In this core we see parts of an ancient magma chamber from deep within the ocean crust.

Coring is tough going in these very hard rocks. To get this deep the crew needed to replace the drillbit several times.

< Microscope image taken from the core (arrows). This shows a clear contact between two types of magmas. One is a coarse-grained gabbro, representing part of an ancient magma chamber, which is pushing up into finer grained gabbros and basalts in the overlying oceanic crust. (Courtesy of L. France).