

Ocean DRILLING

Scientific certainties and uncertainties

Living on land as we do, it is easy to forget that oceans cover more than 70% of the Earth's surface. Some say planet Earth should be called planet Ocean.

The oceans hold vital information about our planet's past and present and therefore its future. Over the past 40 years, scientists have drilled over 2,000 holes into sediments and rocks under the oceans to learn what makes up the Earth. That may seem like a lot of holes, but when you consider that the British Geological Survey's borehole database contains records for over 800,000 drill holes just for the UK, you get an idea of how much of the ocean floor remains unexplored. Trying to understand the deep ocean floors from those 2,000 holes is a bit like inferring the geology of the British Isles by looking at an area smaller than your back garden.

Drilling into the seafloor to recover rocks and sediments, and to set up seafloor observatories, allows scientists to explore and better understand these uncharted subterranean environments. Buried in seafloor sediments and the underlying crust is a rich history of the waxing and waning of glaciers, the creation and ageing of oceanic lithosphere (the hard rock crust), the evolution and extinction of micro-organisms, and the building and erosion of continents.

The study of the deep oceans has revealed much about the Earth's dynamic nature, but we are only just beginning to recognise that plate tectonic processes and the accompanying changes in ocean circulation and climate have influenced the evolution of life and the cycling of many elements and minerals. The deep oceans are an integral yet poorly understood part of the Earth system. Here we spell out what we see as the key issues in the study of the deep oceans, what we know with a reasonable level of certainty, and what we need to find out.

The information presented here draws heavily on work funded by the UK Natural Environment Research Council, as well as a wide range of published sources. Because of the oceans' size, complexity and dynamic nature, mostly beyond national boundaries, marine science requires interdisciplinary and international efforts. Co-operation is needed both in research and in seeking solutions to ocean problems. If science is to find solutions to ocean problems, there needs to be interdisciplinary and international co-operation.



How deep are the oceans?

The oceans are deeper than anything on land is high. Before the 19th century, people could only speculate about the depths of the open oceans, and most people thought that the ocean floor was relatively flat and featureless. However, as early as the 16th century, a few intrepid navigators, who took soundings with hand lines, found that the open ocean can differ considerably in depth. The deepest part is the Challenger Deep in the Pacific Ocean. It got its name from the British Survey Ship Challenger II, which pinpointed the deep water off the Marianas Islands in 1951. It is 10,915m deep. If you went down to the bottom there would be nearly 7 miles/11km of water over your head. If you cut Mount Everest off at sea level and put it on the bottom of the Challenger Deep, there would still be over a mile of water covering it.

Why is the Challenger Deep so deep? Well, the Earth's crust isn't one solid piece of rock; it's really thin, like eggshell. It's made up of huge plates that float on the molten rock of the Earth's mantle. While floating around on the mantle the edges of these plates slide past each other, bump into each other, and sometimes even crash. The oceanic crust (under the oceans) is much heavier than the continental crust (under the land). When the plates crash into each other, the oceanic plate plunges downward toward the molten mantle. This is what's happening at the bottom of the Pacific Ocean off the Marianas Islands. The deepest part of the ocean, in the bottom of the trench, is created by the downward moving ocean crust.



Why study the deep oceans?

Vast areas under the Earth's oceans and within its interior have never been investigated; there are better maps of the moon than of many of our deep oceans.

Ocean sediments contain a continuous record of the Earth's climate for the last 180 million years. We can use these sediments to detect changes in climate from season to season, as well as changes over millions of years.

Scientists use data from the deep oceans to better understand plate tectonics, volcanoes, earthquakes, sea-level fluctuations, and the evolution of life forms.

Vast populations of microbes live deep within the oceans sediments and crust. These microbes don't need sunlight, carbon dioxide or oxygen, but subsist by eating the very rocks they call home. Researchers believe that these microbes could provide us with new medicines, materials and technologies.

Issues

In many ways, the ocean's relationship with climate remains a mystery. Changes in today's climate may cause major alterations to ocean currents. The Atlantic thermohaline circulation (the Gulf Stream), which gives the UK and Northwest Europe its mild climate, could be disrupted. This could lead to a drop in winter temperatures by 3-4°C.

Increases in ocean temperature or changes in sea level caused by global climate change could affect methane hydrates (ice-like solids of gas and water) beneath the seafloor. If they 'melt', the gas (including methane) released could lead to an increase in submarine landslides and tsunamis (large water waves). Methane is also a greenhouse gas; large quantities released into the atmosphere could accelerate climate change.

People living close to subduction zones (where the oceanic crust is recycled back into the mantle) are at risk from earthquakes and tsunamis. In 1995, the Kobe earthquake in Japan killed 5100 people. In 1998, a tsunami killed 2200 people in Papua New Guinea.

Climate records only go back 100 years, which is not long enough to work out if today's climate change is a natural phenomenon or is caused by human activities.

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What we know

Research into the deep ocean has added immeasurably to our knowledge of the way the deep ocean and the seafloor operates. From over 40 years of research we now know about:

- The intricacies of seafloor formation;
- The way deepwater in the ocean circulates and controls the world's weather and climate;
- The location of vital energy reserves;
- Where to find new forms of life - and new medicines;
- Extensive microbial populations beneath the deep seafloor.

We also know:

- Huge deposits of gas hydrates (ice-like solids of methane and water) exist in ocean sediments. Twice as much carbon is stored in gas hydrates as in all known deposits of fossil fuels. These hydrates also hold as much as eight times the amount of fresh water in the world's rivers;
- Changes in climate can be linked to changes in the Earth's orbit, ocean circulation and plate tectonics;
- Ocean circulation changes on decadal to millennial time scales;

- There is a link between biological evolution and major impact events, such as when a huge meteorite hit Earth 65 million years ago;
- Plate tectonic theory works;
- Ice sheets have not always been present at both poles. The current ice age began over 50 million years ago;
- At certain times in history an increase in biological activity over large areas of the oceans' surface waters resulted in the deposition of black, laminated, carbon-rich shales.



How do the oceans control today's climate?

Different parts of the planet receive different amounts of heat from the sun. The poles receive the least heat and equatorial regions receive the most. Currents in the atmosphere and the oceans redistribute this heat. The oceans act as a vast heat reservoir, receiving heat from a warm atmosphere and then supplying heat to a colder one. Prevailing winds drive ocean surface currents, which transport heat. Differences in the density of seawater also set water in motion. The differences in density are caused by differences in temperature and saltiness. Warm water is less dense than cold. Because water is colder at the poles, it is denser and sinks. These cold bottom waters flow towards the equator, moving most quickly at the seafloor.

The Atlantic thermohaline circulation (the Gulf Stream) carries warm water northwards and cold water southwards. Most climate change models predict that as global temperatures rise this current will slow down and eventually stop, which could lead to a drop in winter temperatures of between 3-4°C in the UK.



What we need to know

We need to understand the natural variations in climate and human influences on climate change. To do this we need to acquire more data to improve the accuracy and precision of global change models.

We need to learn to predict the occurrence and severity of earthquakes. To do this we need to directly investigate earthquake mechanisms, by drilling into the seismogenic zone (the zone where earthquakes are generated) and establishing monitors on the seafloor.

We need to know the exact quantity of gas hydrate trapped in oceanic sediments; how it is formed; how stable it is and how it will respond to environmental changes.

Every one million years the entire volume of the oceans moves through the seafloor. Yet we know little about the depth, extent and consequences (physical, chemical and biological) of fluid flow in the oceanic crust and upper mantle. We need to know more.

We need to know what initiates global climate change, how it develops and what circumstances increase or reduce the effects.

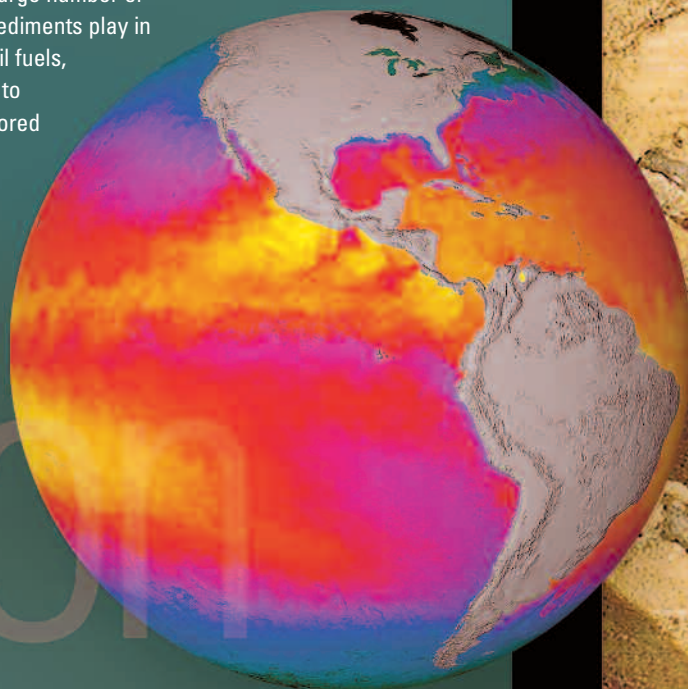
Ocean drilling has barely studied environments covered in ice, like the Arctic, or very shallow environments, such as reefs. What will these environments tell us about our past and future climate? The Arctic in particular is thought to be one of the most sensitive indicators of climate change. With more information about these environments we can produce more sophisticated analyses of the causes, rates, patterns and severity of climate change.

We need to know what part, if any, the large number of microbes recently found within ocean sediments play in such processes as the formation of fossil fuels, mineral and ore deposits. We also need to know what influence this largely unexplored habitat has on our environment.

We need to know what controls the frequency of these events, such as earthquakes and volcanic eruptions, and what effects they have on our global environment.

We need to explore the Earth's interior to sample deep sediment sequences, ocean crust, and, possibly for the first time, unaltered mantle material.

Rocks found beneath the oceans consist of three basic types: sediments, volcanic rocks, and mantle rocks. Cores taken from these materials provide information about the natural resources and history of our dynamic planet, including climate change.



The way forward

The United Kingdom, along with the rest of Europe, has joined the USA and Japan in a new scientific research endeavour called the *Integrated Ocean Drilling Program*. The programme will build upon the early ocean drilling voyages of the Cuss I in 1961, the Deep Sea Drilling Project (1968-1983) and the Ocean Drilling Program (1983-2003). The programme's scientists will investigate and study many of the Earth's regions that were previously inaccessible and processes that are poorly understood.

It will use new resources to support technologically advanced ocean drilling research. To investigate the deep oceans the programme will have three types of drilling platform:

- a traditional drilling vessel;
- a riser-equipped drill ship (a riser is a tube that connects the drill ship with the seafloor so that researchers can drill in unstable areas or drill very deep cores);
- drilling platforms or ships specially designed to work in ice-covered regions or in shallow water.

seafloor
climate

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Integrated Ocean Drilling Program

www.iodp.org

European Consortium for Ocean Drilling

www.ecord.org

JAMSTEC (Japanese Marine Science and Technology Center) Ocean Drilling in the 21st Century (OD21)

www.jamstec.go.jp/jamstec-e/odinfo

USA riserless vessel- Integrated Ocean Drilling Program

www.oceandrilling.org/

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