GFZ
Helmholtz-Zentrum
Potsdam

Scientific Drilling – telescopes into the Earth's interior

→ Key messages:

- **Climate research**
  Research drilling enables us to better understand the dynamics of planet Earth and the physical and chemical processes that have shaped and continue to shape our world. Through drilling, scientists gain insights into the diverse environmental and climatic conditions and their changes throughout Earth's history. From this, robust predictions for the climate of the future are derived.

- **Securing energy needs**
  Research drilling can be used to investigate geothermal reservoirs and thus contribute to the exploration and provision of a sustainable and base-load energy source. Scientific drilling is also essential for exploring the possibility of storing gases such as carbon dioxide and hydrogen in the underground.

- **Exploration of mineral georesources**
  Scientific drilling is used to explore the fundamental processes involved in the formation of deposits of mineral georesources, such as ores and rare earths. The sustainable extraction of such geo resources is a necessary condition for the technological development of our society in the 21st century.

- **Dealing with natural hazards**
  With the help of scientific drilling, the dynamic forces and processes in the Earth's interior can be explored. Triggers of potential natural hazards such as earthquakes and volcanism directly affect the living space of many people. Insights into underground processes help to better understand natural hazards and to take adequate precautionary measures.

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The Earth's interior is inaccessible to us humans. With drilling, direct access to this geological subsurface is established. The aim of scientific drilling is to generate a comprehensive understanding of the processes in the subsurface. Drilling is the only method that provides both data and samples from the depths. This method is used in various scientific disciplines. The scientific objectives of such drilling are often linked to issues of high societal relevance.

How is drilling carried out?

In principle, scientific drilling is carried out using the same drilling methods and procedures as applied in commercial drilling. With a borehole, a hole with a diameter in the range of centimeters to a few decimeters is drilled hundreds of meters to several kilometers deep into the Earth's crust. For this purpose, a hollow drill pipe is screwed to a drilling tool within a drill rig and lowered into the ground. The drilling progress is achieved by rotating the drilling tool. No pressure is exerted on the drilling tool from the Earth's surface. Drilling fluid is pumped through the drill pipe to cool the drilling tool and to transport the drilled material, the so-called cuttings, out of the borehole. Drill cores, i.e. rock cylinders on which a variety of scientific investigations are carried out are procured using different drilling tools. In the past, this drilling method was used to penetrate down to 12 kilometers deep into the subsurface (e.g. the Kola borehole, which has now been abandoned).

Depending on the stability of the borehole and the possibility of deep water or other fluids entering into the borehole, it is cased in sections, i.e. a steel cylinder is lowered into the borehole to seal it off from the formations being drilled through. This so-called casing is cemented into place to ensure a firm connection with the borehole wall. Before the casing is inserted, many boreholes use geophysical probes to measure the rocks that have been drilled through. These instruments are lowered into the borehole on special cables and scan the hole with sensors that register a continuous profile of physical, chemical and mechanical properties. For long-term monitoring, instruments can be anchored within boreholes over longer periods, for example to monitor deformations and thus earthquake hazards. Nowadays, fibre optic cables can even be used to measure temperature or stress throughout the entire borehole, which is essential for earthquake research or geothermal use.

Risks in drilling

After more than 150 years of experience in deep drilling technology, the risks of drilling are known today and can be controlled if appropriate measures are taken. On the one hand, there are dangers associated with the uncontrolled entry of pressurized fluids into the borehole, which in the worst case can lead to a blowout of the fluids from the borehole. On the other hand, contamination of different layers in the subsurface can occur due to the exchange of fluids along the borehole. Fluid and gas influxes are controlled during drilling by the circulating drilling fluid. If necessary, the density of the drilling fluid is increased so that a blowout is prevented. As a further safety measure in the event of a possible blowout, a so-called blowout preventer is used to close off the borehole at the surface. Contamination of formations through exchange of fluids along the borehole is prevented by the above-mentioned casing. After use, boreholes are filled with cement so that a permanent sealing is guaranteed.

In Germany, mining authorities approve and monitor boreholes deeper than 100 meters. They determine the measures to minimize risks so that hazards can be prevented as far as possible. Research drilling is also only undertaken where extensive preliminary investigations have ruled out potential risks, such as pressurized gas.

The International Continental Scientific Drilling Program ICDP

The International Continental Scientific Drilling Program (ICDP) supports teams of scientists both financially and operationally with technical and scientific assistance. ICDP-funded drilling has produced groundbreaking new discoveries. In total, 64 drilling projects have been funded by ICDP in 27 years. The GFZ coordinates this program and actively participates in various ICDP projects.

More about the ICDP-Program: https://www.icdp-online.org/projects/

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Scientific drilling in Germany

Continental Deep Drilling Program of the Federal Republic of Germany (KTB)

The mother of all scientific drillings in Germany is the Continental Deep Drilling Program of the Federal Republic of Germany (KTB), which drilled two holes of 4 and 9.1 km depth (today the deepest existing borehole on Earth!) in Windischeschenbach/Upper Palatinate between 1989 and 1995. The KTB fundamentally expanded our understanding of the composition of the Earth's upper crust, heat and fluid flow, pressure conditions and many other aspects. Even though drilling activities ceased in 1994, the boreholes at the KTB are still accessible to the scientific community and to the general public through the Geocenter at the KTB site. Since mid-2023, hydraulic experiments have been conducted there to test the possibility of generating an artificial heat exchanger between the two boreholes approx. 200 m apart at a depth of approx. 4 km by injecting water.

Swarm quakes at the Egergraben

At the Egergraben, a border region between the Czech Republic and Germany, the occurrence of so-called swarm earthquakes is being investigated by means of several scientific boreholes within the framework of the ICDP-funded project EGER-RIFT of the GFZ. An important research objective in this context is whether and how the movement of CO_2 in the subsurface, which partly rises to the Earth's surface, contributes to swarm quakes. Simple life forms that settle in these CO_2-rich zones underground are also being studied.

Climate history in Tannwald near Winterstettenstadt

Part of the ICDP project "DOVE - Drilling Overdeepened Alpine Valleys" is a research drilling in Tannwald near Winterstettenstadt in Germany on the border to Switzerland, which should provide information about the climate history of the past 450,000 years in the region. Of particular interest here are the changes in climate conditions in the Alpine region during various ice ages and the influence of glacial movements.

Heat and cold storage Adlershof, Berlin

A research drilling in Adlershof/Berlin, carried out by the GFZ 2021 to 2022 and funded by the Federal Ministry for Economic Affairs and Energy, aimed to determine the potential of deep aquifers for seasonal heat and cold storage. In particular, the risk of finding such aquifers in the Berlin urban area was to be reduced through drilling and innovative exploration methods. At the same time, this provided a planning basis for efficient system integration with reliable and safe operation of Berlin's district heating supply.

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