BGR Fact Sheet

Clay and Claystone Research

A nuclear repository for radioactive waste in claystone?

BGR carrying out geophysical measurements in the Mont Terri rock laboratory in Switzerland

The Federal Institute for Geosciences and Natural Resources (BGR) has researched since the 1990s the suitability of claystone as a geological barrier to host a deep underground nuclear repository for high-level radioactive waste. In addition to claystone as a host rock, BGR is also investigating the long-term behaviour of geotechnical clay barriers (bentonite) used to enclose the radioactive waste. For that purpose, BGR participates in international research projects in underground laboratories in France, Sweden and Switzerland.

Triaxial testing machine with heating facilities in BGR's geomechanical laboratory

Why are claystones potential host rocks for nuclear repositories?

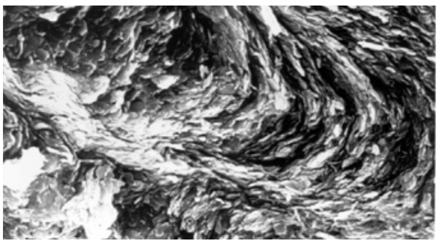
Fossils are witnesses of the past. If they are optimally enclosed in clay, then fossils such as this ammonite even retain their organic material, and thus the shimmering mother-of-pearl on the shells

The Federal Government in Germany is responsible for establishing a nuclear repository for radioactive waste pursuant to the Atomic Energy Act. The Federal Institute for Geosciences and Natural Resources (BGR) works on the geoscientific and geotechnical issues involved in the Federal Government's nuclear repository measures.

Many claystones were originally deposited as mud on the floor of ancient oceans. This initially soft mud was increasingly covered by other sediments, buried deeper and deeper underground, and became consolidated as a result. Claystones mainly consist of tiny platelets of clay minerals with a grain diameter of up to 0.002 millimetres.

Clays and claystones have good sealing properties. For instance, tree stumps were found in a clay pit in Dunarobba (Italy) whose wood had been conserved for over 2 million years. This example demonstrates the capacity of clay to insulate objects against water and gas over a long time.

Humans use the special properties of clay when they make pottery



Claystone under a scanning electron microscope. The specific surface of one gram of clay can total 800 square metres. The width of the photo of approx. 0.08 millimetres corresponds to the thickness of a sheet of paper

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Which properties of claystone are important for a nuclear repository?

Stabilisation (shotcrete and lining) in a mining gallery in claystone

Temperature resistance

The maximum temperature caused by the waste heat in nuclear repositories hosted by claystones must not exceed 100 °C (unlike rock salt, where up to 200 °C are permissible). Higher temperatures lead to mineral alterations which affect the geomechanical properties of the clay minerals and therefore their barrier effectiveness.

Permeability

The very low permeability in particular is a very favourable property of claystones for a nuclear repository. The long-term effectivity of claystone formations as geological barriers is for instance evidenced by the sealing layers capping natural oil and gas deposits.

Sorption behaviour

Claystone is interesting as a host rock because it has very good containment properties, and can bind radionuclides. This binding – called sorption by experts – is attributable to the electrically charged surfaces of clay minerals.

Anisotropy

Many claystones are bedded. Because of this layering, they show very anisotropic behaviour, i.e. their mechanical and hydraulic properties vary in different spatial directions.

Deformation behaviour

Some clay minerals can swell up. Influx of water causes the volume of these clay minerals to increase. If this occurs at a fracture surface, this can lead to the self-sealing of fractures and fissures.

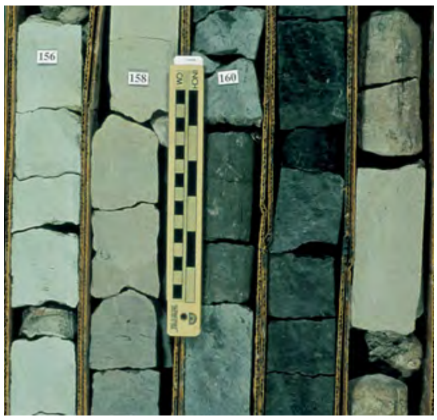
Cavity stability

Constructing a nuclear repository in deep underground formations generally requires that the rock has adequate strength to ensure that underground workings can be constructed and remain open. The stability of cavities constructed in claystones can only be maintained by the use of additional stabilisation measures such as shotcrete, anchoring, and even lining in some cases. These stabilisation measures are particularly complex and expensive in the case of unconsolidated clays.

Bentonite – the geotechnical barrier

Bentonite is a claystone formed by the mineralogical alteration mostly of volcanic ashes. This mixture of various clay minerals, quartz, mica and feldspar, which can swell under moist conditions, is intended as a so-called “geotechnical barrier” to seal off the radioactive waste in a nuclear repository in a claystone or granite host rock. BGR carries out investigations to characterise the properties of bentonite. Various aspects including reactions between bentonite and cement pore water, and the corrosion of steel, which could potentially be used for waste containers embedded in bentonite, are studied in experiments.

Bedded claystone reveals its sedimentary origins in a marine environment



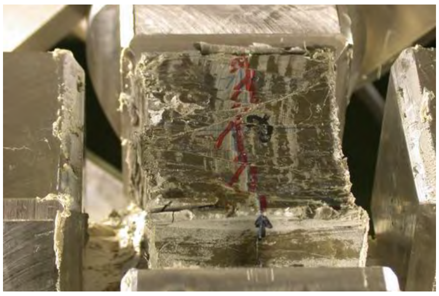
Claystone drilling cores of varied appearance

How does BGR investigate claystones?

Switzerland has already chosen claystone to be the host rock for high-level radioactive waste. The Mont Terri international rock laboratory was therefore set up in the 180 million-year-old Opalinus Clay of Jurassic age to carry out the necessary research. BGR has carried out research work here since 1996. BGR's experiments here benefit from its expertise on research on rock salt.

BGR investigates the geomechanical properties of claystones underground using geophysical and geotechnical measurements. BGR also carries out experiments in its geomechanical testing laboratory, where the thermal, mechanical and hydraulic properties of claystones on rock specimens taken from cores are examined. The physico-chemical properties are analysed in the clay mineralogy laboratory. The dispersal of radionuclides in clay is studied in further experiments.

The emplacement of a dummy container for high-level radioactive waste in claystone was tested in the Mont Terri rock laboratory at a scale of 1 : 1 over a period of 10 years within the framework of an EU project. Changes in the host rock after emplacement, as well as after opening and removing the backfill material (bentonite) were investigated using geophysical measurements. In addition, any changes to the bentonite around the container were monitored. BGR cooperated in this project with the organisations ANDRA from France, ENRESA from Spain, and NAGRA from Switzerland.



Opalinus Clay sample after being stressed in a true triaxial laboratory test rig

BGR investigates in its geomechanical laboratory how claystone reacts to pressure, temperature and changes in chemistry. Combined with model calculations, this helps to evaluate the stability of the underground workings, and to predict the long-term behaviour of claystones.

In situ geophysical measurements conducted from a tunnel wall

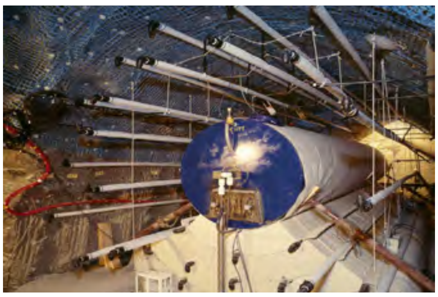
BGR investigates the stress state of the rock mass. The results are used in large scale model calculations for the construction of a nuclear repository in claystone. The models can be used to forecast the mechanical long-term behaviour of clay as a host rock.

Stress measurements in rock with BGR's overcoring probe

Using seismic surveys and geoelectric borehole logs, as well as ultrasonic techniques, BGR determines numerous parameters in underground measurements to characterise the rock and its long-term behaviour in the proximity of underground workings.

Permeability measurements characterise the disturbed zone

Disturbed zones around underground workings are an unavoidable consequence of opening tunnels or galleries. Because they can form potential migration paths for hazardous substances, and influence the stability of underground workings, their study is very important.



Niche with dummy container on a bentonite bed with instrumentation

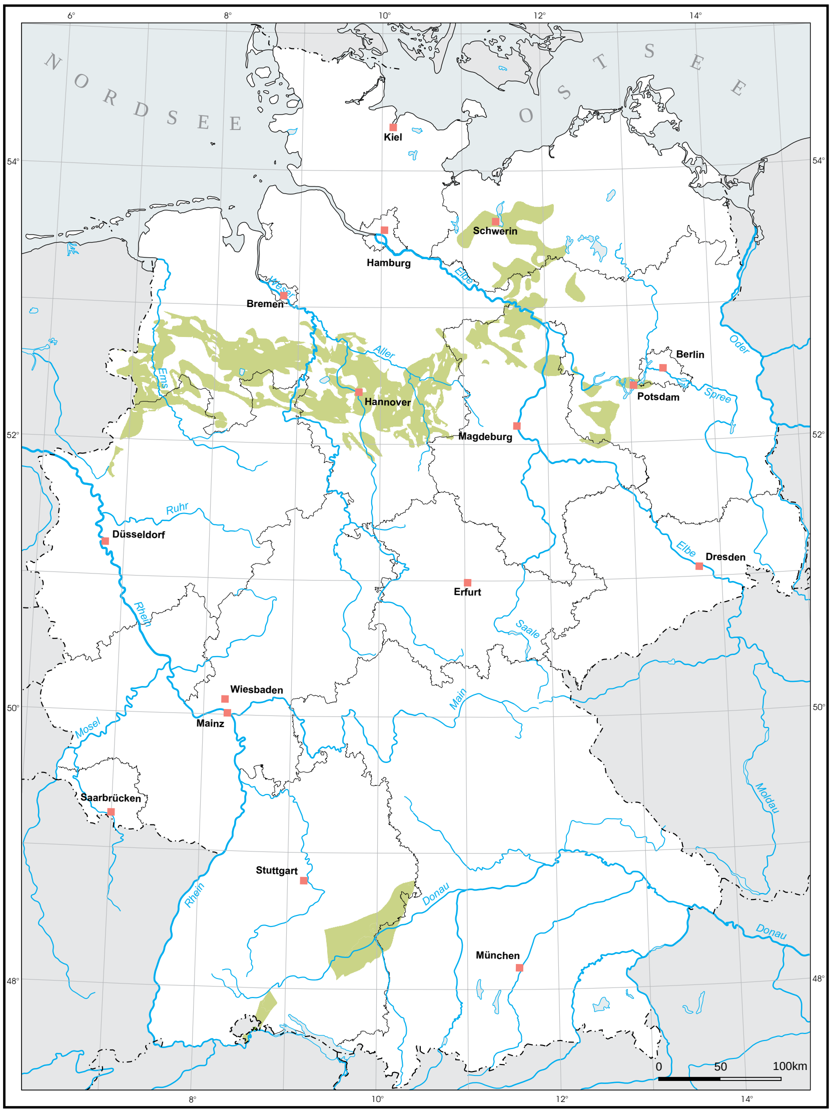
The niche shown on the left was permanently monitored for 10 years after backfilling

Which claystone formations are worthy of investigation in Germany?

BGR was tasked by the Federal Ministry for Economic Affairs and Technology (BMWi) in 2003 with undertaking a study on the distribution of claystones in Germany as potential host rocks for a nuclear repository for high-level radioactive waste. The “Clay Study” was published in 2007 and supplements the previously published BGR studies on two other potential host rocks: rock salt and crystalline rocks.

The study was based on the host-rock-independent exclusion criteria and minimum requirements established in 2002 by the Committee on a Selection Procedure for Repository Sites (AkEnd). In addition, the selection of potential host regions also took into consideration the evaluation criteria considered relevant by BGR from a geoscientific point of view.

The results of the study are shown in a map of the claystone deposits considered worthy of further investigation. These are of Lower Cretaceous and Jurassic age in Northern Germany, and of Jurassic age in Southern Germany.



Claystone formations in Germany worthy of further investigation

Why is research on clay and claystone important?

Research on clay and claystone undertaken by BGR focuses on characterising the host rock, the use of clay (bentonite) as a geotechnical barrier, as well as the long-term safety of a nuclear repository in claystone. Claystones vary – depending on how they were formed – from plastic clays to transitional types all the way to highly consolidated and fractured claystone.

There are also correspondingly large differences in mineral composition, deformation behaviour, temperature sensitivity and rock stability. Understanding these processes and their interactions is only possible on the basis of comprehensive research work.

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