

Äspö Hard Rock Laboratory

A unique place for experiments and research





The rock in Äspö Hard Rock Laboratory is a fairly common granitic rock with both water-tight and water-conductive parts. We have extensive knowledge of rock properties and variations, which means that we can find suitable sites for many different types of experiments.

Äspö Hard Rock Laboratory – a unique place for experiments and research

In SKB's underground hard rock laboratory on the Island of Äspö, north of Oskarshamn, a large part of the research and technology development needed for final disposal of spent nuclear fuel takes place. Here we test different technical solutions at full scale under realistic conditions.

Äspö Hard Rock Laboratory is a unique research facility that extends down to a depth of 460 metres in the Swedish bedrock. For more than 30 years, this has been a central site for development of the method for final disposal of spent nuclear fuel. Here, SKB has built up a large part of the knowledge that is now being used in preparation for the construction of the Spent Fuel Repository in Forsmark, as well as knowledge that will be used in the construction and future operation of the repository.

In many ways, Äspö Hard Rock Laboratory is similar to the future final repository. There are copper canisters that will contain the spent nuclear fuel, clay buffer that protect the canisters, machines for handling canisters as well as tunnels and boreholes where canisters are deposited. But one thing is different: Äspö Hard Rock

Laboratory is, and will remain, a facility for research and technology development – there is no spent nuclear fuel or other radioactive waste here.

Understanding the rock from the surface

The first development efforts on Äspö were made even before the laboratory was built. Before and during construction, different methods for studying bedrock from the surface were tested. This is what we call site investigations. The investigation methods were developed, as well as the models used to describe bedrock properties. We wanted, above all, to make sure that the boreholes drilled from the surface provided enough information about the conditions below. Later we were able to study the rock in detail from the tunnels and shafts in the laboratory, and compare the results from

the site investigations with reality. The investigation methods were then used for the site investigations in Forsmark and Oskarshamn, before the choice of a site for the Spent Fuel Repository.

The construction of Äspö Hard Rock Laboratory also gave important technical experience and knowledge of the design and construction of underground facilities. For example, we have used drill and blast technique and tunnel boring to excavate tunnels in Äspö Hard Rock Laboratory. This gave us the opportunity to study how the rock around a tunnel is affected by the different methods and how ground-water flow paths may be affected.

Research in depth

A large part of the activities at Äspö Hard Rock Laboratory has focused on research and development of the method to be used for final disposal of spent nuclear fuel. Under realistic conditions, we have studied how the repository barriers – copper, bentonite clay and rock – interact. Several experiments have been conducted to study the properties of the rock and especially the significance of these properties for long-term safety, after the repository is closed. This can, for instance, concern how the rock slows down the movement of radioactive substances or how microbes affect conditions at depth.

Some of the most important experiments at Äspö Hard Rock Laboratory are our full-scale tests. They allow us to try out the method in full scale under real conditions. One of the major full-scale experiments is the Prototype Repository, which can be described simply as a copy of a final repository, but without nuclear fuel. There, we study how the different parts of a final repository work together during the first years after closure.

Technology in practice

As several research issues have been resolved, the experiments at Äspö Hard Rock Laboratory have increasingly focused on technical implementation. It is now a question of adapting the technology to the industrial process that will be used in the operation of the Spent Fuel Repository. We test and demonstrate the technical solutions in practice: how copper canisters are deposited, how the clay buffer is put in place and how the deposition tunnels are backfilled with clay and closed off with concrete plugs. We develop and test the machines and equipment required. We have prototypes of several of the machines that will be used in the Spent Fuel Repository in Forsmark, for example a machine that deposits copper canisters and a robot that backfills tunnels after deposition.



Magne is a prototype of the deposition machine that will be used in the Spent Fuel Repository to deposit copper canisters in the bedrock. It has been developed and tested at Äspö Hard Rock Laboratory. More than a thousand depositions has been conducted with the machine.



One of the most important full-scale experiments is the Prototype Repository, where six full-scale canisters have been deposited.

Final disposal of nuclear waste

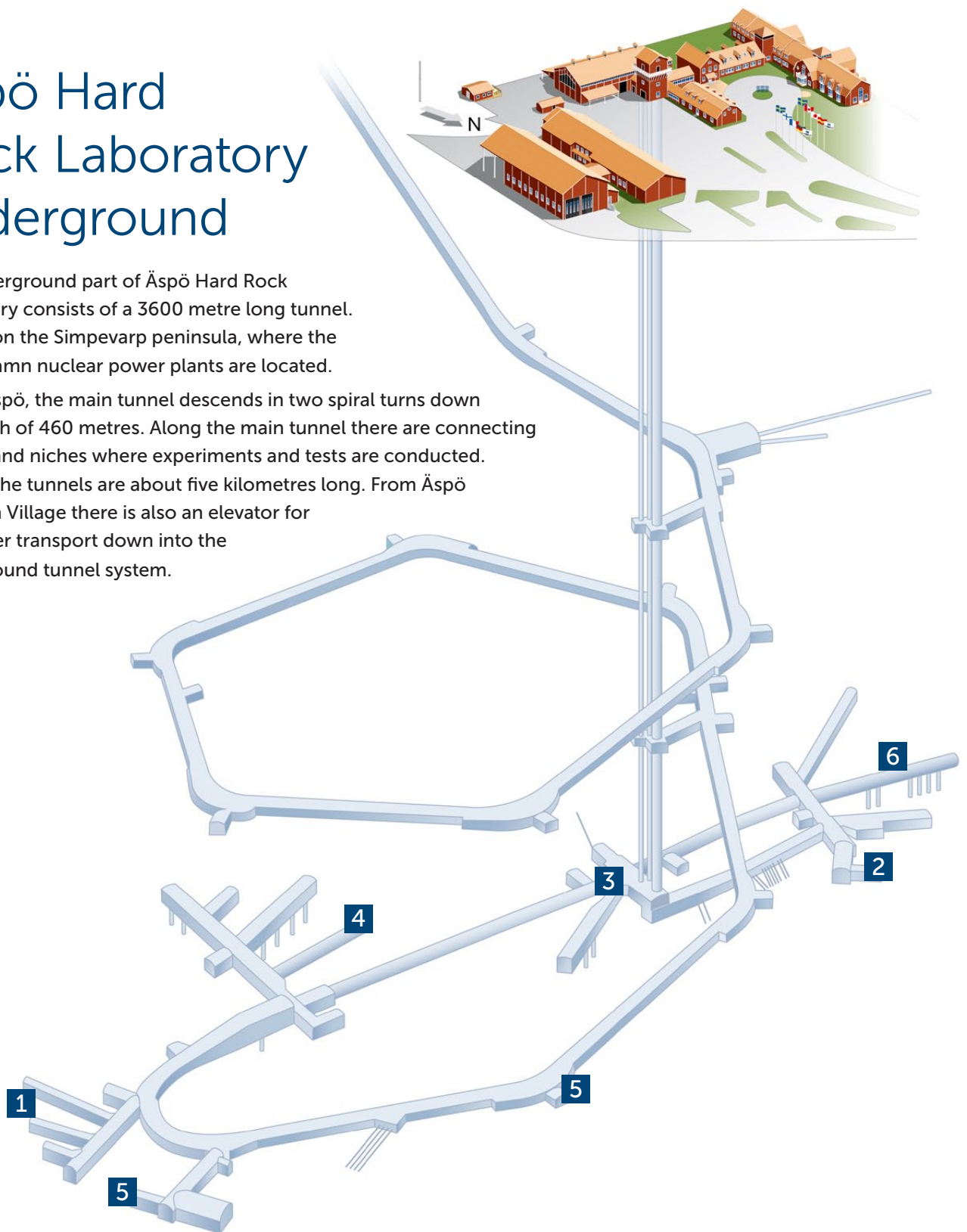
Currently all spent nuclear fuel in Sweden is interim-stored at Clab in Oskarshamn. The fuel will be radioactive for a very long time. To prevent it from causing damage – today or in the future – the waste must be isolated from human beings and the environment for long periods of time. SKB therefore plans to build a final repository for spent nuclear fuel at Forsmark in the municipality of Östhammar, known as the Spent Fuel Repository.

Final geological disposal is based on three barriers that, both separately and together, prevent the radioactive substances in the spent fuel from reaching the surface. The fuel is first placed in copper canisters that resist corrosion and mechanical forces that can occur due to movements in the rock. The canisters are placed in the rock at a depth of about 500 meters and are embedded in bentonite clay. The clay acts as a buffer and protects the canisters from corrosion and minor rock movements. The purpose of the rock is to isolate the waste. It provides a stable chemical environment and protection from events on the surface.

Äspö Hard Rock Laboratory underground

The underground part of Äspö Hard Rock Laboratory consists of a 3600 metre long tunnel. It starts on the Simpevarp peninsula, where the Oskarshamn nuclear power plants are located.

Under Äspö, the main tunnel descends in two spiral turns down to a depth of 460 metres. Along the main tunnel there are connecting tunnels and niches where experiments and tests are conducted. In total, the tunnels are about five kilometres long. From Äspö Research Village there is also an elevator for passenger transport down into the underground tunnel system.



Facts about Äspö Hard Rock Laboratory

Tunnel length: The main tunnel is 3.6 kilometres long. The total tunnel length in the Äspö rock is about 5 kilometres.

Depth: The tunnel reach down to a depth of 460 metres.

Construction year: Preparations for construction of an underground laboratory at Äspö began in 1986. The facility was constructed between 1990 and 1994 and began operation in 1995. Thereafter, experiment tunnels have been excavated gradually.

Construction technology: Down to a depth of 420 metres, tunnels were blasted. The final 400 metre stretch of the main tunnel, down to 460 metres depth, was drilled with a tunnel boring machine.

The rock: The Äspö rock was formed 1.8 billion years ago and consists of several rock types, mainly granite and Äspö diorite.

The water: Every minute, we pump up 1000 litres of water from the tunnel. The water has a salinity of about two percent.



1 Rock excavation

In Äspö Hard Rock Laboratory we are able to develop, test and evaluate different methods for tunnel excavation. The facility has been extended on several occasions. On these occasions, we have also taken the opportunity to test different methods for sealing and inspecting the rock. In the Spent Fuel Repository, walls, ceilings and floors must be smooth enough for the tunnels to be backfilled after the canisters are in place. How the rock cracks during tunnel excavation may also be of importance for how the rock conducts water, and thereby the post-closure safety of the repository. During the extension of new tunnels that took place from 2011 to 2012, cautious blasting was therefore used with a smaller amount of explosive charges closest to the tunnel wall.



2 Dome plug

In the Spent Fuel Repository, the entrance of deposition tunnels will be sealed with concrete plugs. We have tested several plugs at Äspö Hard Rock Laboratory. The latest is the dome plug at a depth of 450 metres. A slot was created in the rock using wire sawing before the plug could be cast in place. The tightness was tested under high pressures, corresponding to those that will prevail in the Spent Fuel Repository.

3 Blasting or drilling tunnels

The tunnels at Äspö Hard Rock Laboratory are excavated using both drill and blast technique and tunnel boring. Tunnel boring gives a rounder and smoother tunnel contour, which can be seen at a depth of 420–460 metres.



4 Backfilling a tunnel

It took 1700 clay blocks and about four days to fill a twelve-metre long tunnel. This was the result when the method for backfilling deposition tunnels was tested at full scale at Äspö Hard Rock Laboratory. SKB's specially equipped stacking robot was used in the experiment, which was an important step towards an industrialised process for the operation of the Spent Fuel Repository.



5 Experiments with concrete

Not only spent nuclear fuel can be disposed of in the bedrock. In Forsmark there is already a final repository for low- and intermediate-level waste. In Äspö Hard Rock Laboratory we study how different materials in the low- and intermediate-level waste degrade in a repository environment and how this can affect the material in the barriers, such as bentonite clay. In about ten holes at two different locations in the rock, packages with concrete, clay and other materials have been placed.

6 Prototype Repository

In the Prototype Repository experiment we study how different parts of the final repository work together. In the early 2000s, six full-scale canisters were placed in the rock. Two of them were retrieved after eight years. Besides detailed studies of the copper canisters, a large number of samples from the material in the tunnel backfill and the clay buffer around the copper canisters were also analysed.





Bentonite samples are prepared in the materials laboratory.



Chemistry of groundwater is analysed in the chemistry laboratory.

A laboratory with potential

Äspö Hard Rock Laboratory is more than an underground facility. On the surface, above the underground tunnel, lies Äspö Research Village with laboratories for chemical analyses, material investigations and a special bentonite laboratory. Activities are often carried out in cooperation with researchers and stakeholders from other countries and the ambition is to open the facility for a broader range of activities in the future.

In Äspö Research village you find storehouses and office buildings for SKB's staff who are involved in the operation of the Äspö Hard Rock Laboratory, planning and administration of experimental activities and other services and security for staff and contractors working at the facility.

Äspö Research Village also comprises SKB's Visitor Centre which welcomes visitors from all over the world and gives guided tours of the underground facility.

Chemistry and materials are analysed

As support for the underground experiments, there is a chemistry laboratory. The staff conducts analyses and sampling of groundwater in the tunnel and in the surroundings of Äspö, for example in boreholes, streams and in the sea. All analysis results are collected in a database that allows us to monitor changes in the groundwater environment over a longer time perspective. Adjacent to the chemistry laboratory there is also a

materials laboratory. It is used for sampling and analysis of different materials, mainly bentonite clay. Here, research is conducted on issues concerning the safety of the final repository after closure as well as development of methods for quality control of the bentonite clay.

Experiments above ground

In the rock at Äspö Hard Rock Laboratory, technology and equipment are tested under conditions similar to those in the final repository. Often, we also need to conduct tests under more controlled conditions. This is done in the Bentonite Laboratory. Experiments are conducted with bentonite clay in different forms in the 450-square-metre hall. The laboratory contains, for example, equipment for mixing bentonite materials and production of pellets as well as tools for lifting the large buffer rings that will surround the copper canisters.

In the Bentonite Laboratory, there are also models of deposition tunnels at full scale and half scale.



In the Bentonite Laboratory experiments are conducted with bentonite clay in different forms.



Visitors are welcomed from all over the world.

The models are used for testing technology, methods and equipment for backfilling tunnels with bentonite clay in the form of blocks and pellets. To stack the bentonite blocks, there is a specially adapted stacking robot.

In the floor of the Bentonite Laboratory, there are also two holes that represent the deposition holes in the Spent Fuel Repository. There, we test the deposition process and can, for instance, investigate how the bentonite reacts at different water flows.

Cooperation across borders

A large part of the activities at Äspö Hard Rock Laboratory are carried out in cooperation with educational institutions, universities and other organisations. The research conducted here is at the forefront internationally and we therefore cooperate with experts from both Sweden and other countries. There is also extensive cooperation with respect to sharing of technology and experience with SKB's sister organisations worldwide, particularly our Finnish equivalent Posiva. Some of the research is done through the EU Framework Programme for Research and Innovation.

It is also possible for other researchers, companies and organisations outside the nuclear waste business to conduct their own experiments at Äspö Hard Rock

Laboratory. Since 2007, this has been done through the research platform Nova Research and Development, which is a collaboration between SKB and Oskarshamn Municipality.

Future Laboratory

SKB has now reached a point where we can see that our use of the Äspö Hard Rock Laboratory will gradually decrease as the plans for the Spent Fuel Repository are realised. In order for the underground laboratory at Äspö to continue operation in the future, great efforts are being made to find new uses for the facility.

Together with local and regional actors, SKB is working to increase the possibilities for external stakeholders to use the laboratory. One aim is that companies, researchers and other community actors in the future will be able to use the facility in the same way as SKB. This can involve research or technology development in various areas, or testing and demonstrating new technical solutions.

In academic circles, there are advanced plans to create a National Geosphere Laboratory with Äspö Hard Rock Laboratory as a base. It will be designed as an open research infrastructure, where researchers from Sweden and other countries can carry out their own projects.

Sweden has been using electricity generated by nuclear power since the mid-1960s. SKB's task is to manage and dispose of the waste that arises from the production of this electricity. It is we who have had the benefits of nuclear power that should take responsibility for the waste – it should not be left to future generations.

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