International Progress Report

IPR-09-18

Äspö Hard Rock Laboratory

Status Report
May – August 2009

Svensk Kärnbränslehantering AB

November 2009

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Äspö Hard Rock
Laboratory

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of the client.

Overview

The Äspö Hard Rock Laboratory (HRL) constitutes an important part of SKB's work to design and construct a geological repository for spent nuclear fuel and to develop and test methods for characterisation of a suitable site. The plans for SKB's research and development of technique during the period 2008–2013 are presented in SKB's RD&D-Programme 2007 /SKB 2007/. The information given in the RD&D-Programme related to Äspö HRL is annually detailed in the Äspö HRL Planning Report /SKB 2009/.

This Äspö HRL Status Report is a collection of the main achievements obtained during the period May to August 2009.

Geoscience

Geoscientific research is a natural part of the activities at Äspö HRL and is conducted in the fields of Geology, Hydrogeology, Geochemistry and Rock Mechanics. The major aims are to establish and maintain geoscientific models of the Äspö HRL rock mass and to establish and develop the understanding of the Äspö HRL rock mass properties as well as the knowledge of applicable measurement methods.

Natural barriers

Many experiments in Äspö HRL are related to the rock, its properties and in situ environmental conditions. The goals are to increase the scientific knowledge of the safety margins of a final repository and to provide data for performance and safety assessment. The ongoing projects and experiments are: Tracer Retention Understanding Experiments, Long Term Sorption Diffusion Experiment, Colloid Transport Project, Microbe Projects, Matrix Fluid Chemistry Continuation, Radionuclide Retention Experiments, Padamot, Fe-oxides in Fractures, Swiw-tests with Synthetic Groundwater and Äspö Model for Radionuclide Sorption. Tests of models for groundwater flow, radionuclide migration and chemical/biological processes are addressed in the Task Force on Modelling of Groundwater Flow and Transport of Solutes.

Engineered barriers

Another goal for Äspö HRL is to demonstrate technology for and function of important parts of the repository system. This implies translation of current scientific knowledge and state-of-the-art technology into engineering practice applicable in a real repository. The ongoing projects and experiments are: Prototype Repository, Long Term Test of Buffer Material, Alternative Buffer Materials, Backfill and Plug Test, Canister Retrieval Test, Temperature Buffer Test, KBS-3 Method with Horizontal Emplacement, Large Scale Gas Injection Test, Sealing of Tunnel at Great Depth, In Situ Corrosion Testing of Miniature Canisters and Cleaning and Sealing of Investigation Boreholes. THM processes and gas migration in buffer material are addressed in the Task Force on Engineered Barrier Systems and in a parallel Task Force geochemical processes in engineered barriers are studied.

Äspö facility

The Äspö facility consists of the Hard Rock Laboratory and the Bentonite Laboratory which where taken into operation in 1995 and 2007 respectively. Important parts of the activities at the Äspö facility are the administration, operation and maintenance of instruments as well as the development of investigation methods. The Public Relations and Visitor Services group is responsible for presenting information about SKB and its facilities. They arrange visits to the facilities all year around as well as special events.

Environmental research

Äspö Environmental Research Foundation was founded 1996 on the initiative of local and regional interested parties. The aim was to make the underground laboratory at Äspö and its resources available for national and international environmental research. During 2003-2008 the activities were concentrated to the Äspö Research School. According to plan the activities in the school were concluded in 2008 and the remaining and new research activities were transferred within the frame of a new co-operation, Nova Research and Development (Nova FoU).

International co-operation

The Äspö HRL has during the years attracted considerable international interest. Eight organisations from seven countries participate in the co-operation or in Äspö HRL related activities, apart from SKB, during 2009.

Contents

1 General

The Äspö Hard Rock Laboratory (HRL), located in the Simpevarp area in the municipality of Oskarshamn, constitutes an important part of SKB's work with design and construction of a deep geological repository for final disposal of spent nuclear fuel. One of the fundamental reasons behind SKB's decision to construct an underground laboratory was to create an opportunity for research, development and demonstration in a realistic and undisturbed rock environment down to repository depth. In the Bentonite Laboratory, taken into operation in 2007, studies on buffer and backfill materials are performed to complement the studies performed in Äspö HRL.

The underground part of the laboratory consists of a tunnel from the Simpevarp peninsula to the southern part of Äspö where the tunnel continues in a spiral down to a depth of 460 m. The rock volume and the available underground excavations are divided between numerous experiments performed at the Äspö HRL. In Figure 1-1, the allocation of the main experimental sites in Äspö HRL is shown.

SKB's overall plans for research, development and demonstration during the period 2008–2013 are presented in SKB's RD&D-Programme 2007 /SKB 2007/. The planned activities related to Äspö HRL are detailed on a yearly basis in the Äspö HRL Planning Report /SKB 2009/. This Status Report presents main achievements during the period May to August 2009. In the Annual Report more detailed information is given of new findings and results obtained during the whole year.

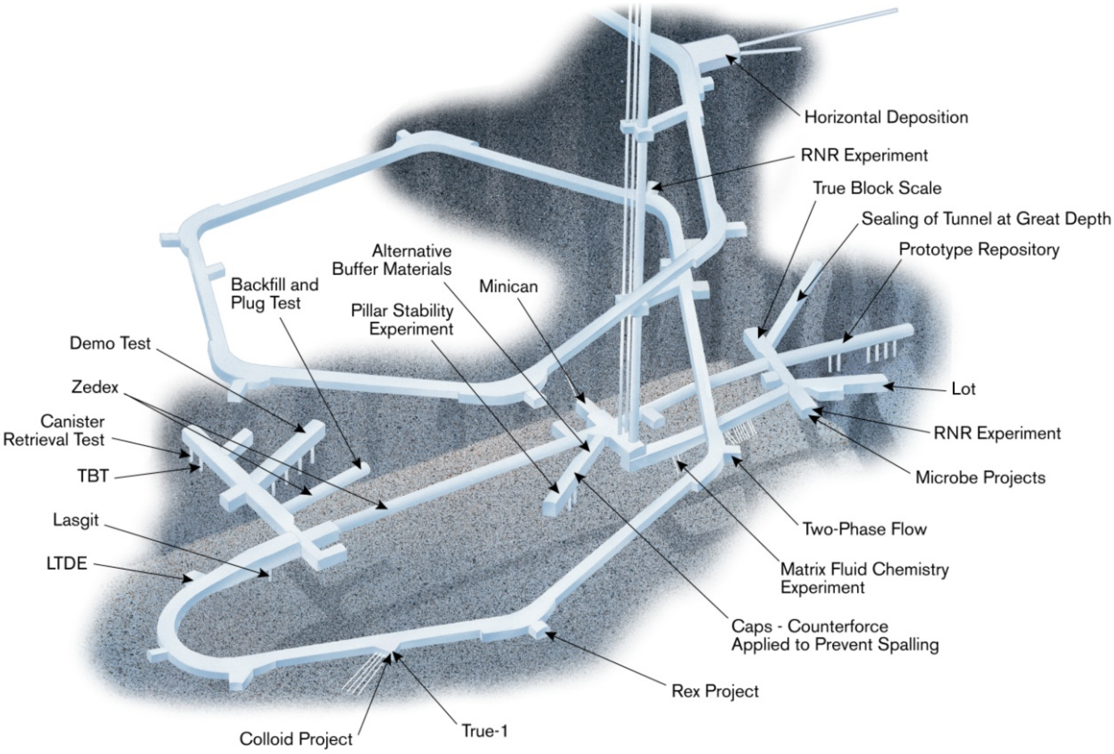


Figure 1-1. *Overview of the Äspö HRL and the allocation of the experimental sites from -220 m to -450 m level.*

2 Geoscience

2.1 General

Geoscientific research is a natural part of the activities at Äspö HRL and is conducted in the fields of geology, hydrogeology, geochemistry and rock mechanics. The studies include laboratory and field experiments, as well as modelling work. The overall aims are to:

- Establish and develop geoscientific models of the Äspö HRL rock mass.
- Establish and develop the understanding of the Äspö HRL rock mass material properties as well as the knowledge of applicable measurement methods.

One main task within the geoscientific field is the development of an Äspö Site Descriptive Model (SDM) integrating the information from the fields of geology, hydrogeology and geochemistry, see Figure 2-1. The SDM will facilitate the understanding of the geological, hydrogeological and geochemical conditions at the site and the evolution of the conditions during operation of Äspö HRL.

The SDM provides basic geoscientific data to support predictions and planning of experiments performed in Äspö HRL. The aim is also to ensure high quality experiments and measurements related to geosciences.

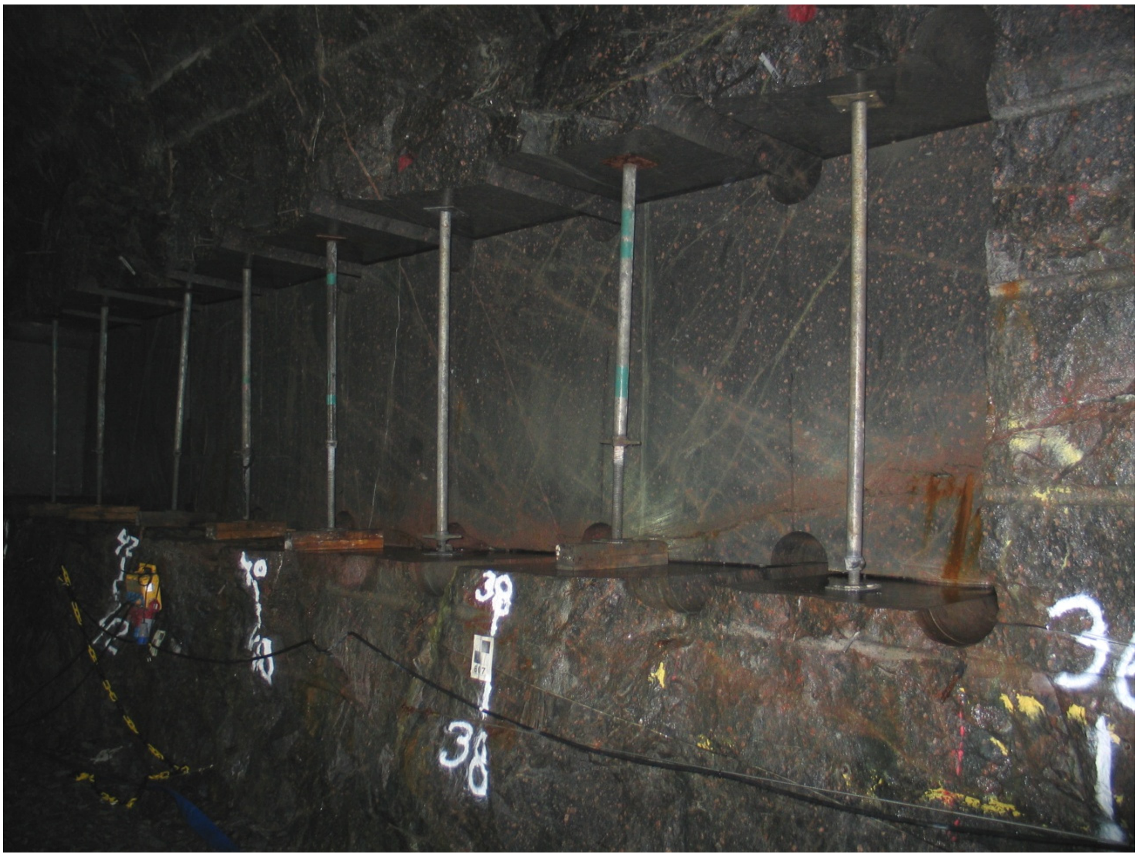


Figure 2-1. *TASS-tunnel, section 36-42 m (approximately). The Excavation Disturbed Zone (EDZ)-slot on the right wall which was mapped in detail during the previous four-month period of 2009.*

2.2 Geology

Geological work at Äspö HRL is focused on several main fields. Major responsibilities are mapping of tunnels, deposition holes and drill cores, as well as continuous updating of the geological three-dimensional model of the Äspö rock volume. In addition, the development of new methods in the field of geology is a major responsibility.

2.2.1 Geological Mapping and Modelling

Tass-tunnel, section 80.7 m (end section). Tunnel front with measuring weir in front.

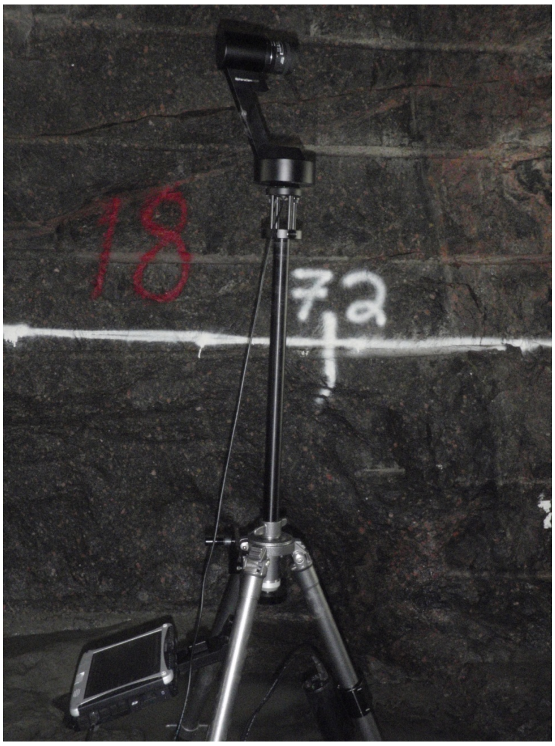
All rock surfaces and drill cores at Äspö are mapped. This is done in order to increase the understanding of geometries and properties of rock types and structures, which is subsequently used as input in the 3D-modelling of the rock volume together with other input data.

Achievements

The main activities or achievements during May to August 2009 have been:

- The report based on pre-investigations from boreholes KI0010B01, KI0014B01 and KI0016B01 concerning the Tass-tunnel has been adjusted after being on review and is now published /Hardenby et al. 2008/.
- The report regarding a study of possible differences in the mapping procedure and achieved results from geological mapping of a drilled and blasted tunnel and a TBM bored tunnel has been printed /Hultgren 2008/.
- As a part of the ongoing work with the site descriptive model of Äspö (Äspö SDM) discussions concerning the rock type nomenclature used by the site investigation team of Oskarshamn and that used by the geologist at the Äspö HRL are ongoing.
- A great number of the photos taken during the mapping of the tunnels of Äspö HRL since early nineties have earlier been digitalised. All these digital photos are now being organised and labelled.
- Work has started to transfer the geological data from the TMS-system (Tunnel Mapping System) to the SKB database Sicada.
- The modelling work that commenced in 2005 concerning water bearing fractures at the -450 m level is finished. Adjustments in the report after being returned from the review are still ongoing.

2.2.2 Rocs – Method Development of a New Technique for Underground Surveying



Creative Tools AB demonstrates their photogrammetric system by using a SpheronCam digital camera mounted on a tripod in the Tass-tunnel.

A feasibility study concerning geological mapping techniques has been completed /Magnor et al. 2007/. Based on the knowledge from the feasibility study SKB has commenced a new phase of the Rocs project.

The purpose is to investigate if a new system for rock characterisation has to be adopted when constructing a final repository. The major reasons for the project are aspects on objectivity of the data collected, traceability of the mappings performed, saving of time required for mapping and data treatment and precision in mapping. These aspects all represent areas where the present mapping technique may not be adequate.

The project will concentrate on finding or constructing a new geological underground mapping system. Laser scanning in combination with digital photography will, at least at the time being, be a part of that system. The resulting mapping system shall operate in a colour 3D environment where the xyz-coordinates are known.

Achievements

The scan data from the Tass-tunnel have been used to create 3D-models of the tunnel. The problems in fitting together the data from the various scanning events have now been solved. The work continues concerning tests of software to handle the laser data.

A complementary demonstration of the SpheronCam digital camera was performed in the Tass-tunnel by the company Creative Tools AB, see photo above. In addition, the company ATS AB has demonstrated a new version of the Faro laser scanner combined with a digital camera in the same tunnel.

At the time being evaluation of the various tests, methods and equipment is ongoing in order to present a recommendation for rock characterisation to SKB.

2.3 Hydrogeology

The objectives of the hydrogeological work are to:

- Establish and develop applicable methods for measurement, testing and analysis for the understanding of the hydrogeological properties of the Äspö HRL rock mass.
- Ensure that experiments and measurements in the field of hydrogeology are performed with high quality.

The main tasks are firstly to continue work for further development of quality control and quality assurance procedures in the field of hydrogeology and secondly to upgrade the Äspö Site Descriptive Model. The main features are the inclusion of additional data collected from various experiments and the adoption of modelling procedures developed during the site investigations. The intention is to develop the model into a dynamic working tool suitable for predictions in support of the experiments in the laboratory as well as to test hydrogeological hypotheses. Another part of the work with the site description is the continued development of a more detailed model of hydraulic structures at the main experimental sites.

Achievements - Äspö Site Descriptive Model

A number of quality issues with the basic datasets were identified and work is progressing in addressing those issues. No further achievements until the quality issues are resolved.

2.3.1 Hydro Monitoring Programme

The hydro monitoring programme is an important part of the hydrogeological research and a support to the experiments undertaken in Äspö HRL. The monitoring of water level in surface boreholes started in 1987 while the computerised Hydro Monitoring System (HMS) was introduced in 1992.

The HMS collects data on-line of pressure, levels, flow and electrical conductivity of the groundwater. The data are recorded by numerous transducers installed in boreholes. The number of boreholes included in the monitoring programme has gradually increased, and comprise boreholes in the tunnel in the Äspö HRL as well as surface boreholes on the islands of Äspö, Ävrö, Mjälen, Bockholmen and some boreholes on the mainland at Laxemar. To date the monitoring programme comprises a total of about 140 boreholes (about 40 surface boreholes and 100 tunnel boreholes). Many boreholes are equipped with inflatable packers, dividing the borehole into sections. Water seeping into the tunnel is diverted to trenches and further to 25 weirs where the flow is measured.

Weekly quality checks of preliminary groundwater head data are performed. Absolute calibration of data registered with HMS is performed three to four times annually. This work involves comparison with groundwater levels checked manually in boreholes.

The data collected in HMS is transferred to SKB's site characterisation database, Sicada.

Achievements

The hydrogeological monitoring has been ongoing, monitoring points were maintained and performing well, particularly the tunnel installed equipment. It was however during the work with the Äspö site descriptive model discovered that there are a couple of quality issues with the Hydro Monitoring database (HMS). Firstly, it was found to be incomplete and secondly it was not harmonised with the information in the site characterisation database Sicada. Corrective measures to address these issues were initiated and are still ongoing.

A review of potential supporting and corrective measures for the surface borehole was performed and work for replacing the monitoring equipment has been initiated. The monitoring equipment from two surface drilled boreholes, KAS03 and KAS09, have been removed and awaits installation of new equipment after water sampling and some borehole logging measurements have been undertaken.

The monitoring is reported every four-month period through quality control documents and on an annual basis. In the annual report the measurement system and basic results are given. /Wass and Nyberg /2009/ is the latest annual report documenting the 2008 monitoring year. An example of results from the hydro monitoring system taken from the mainland at Laxemar is given in Figure 2-2.

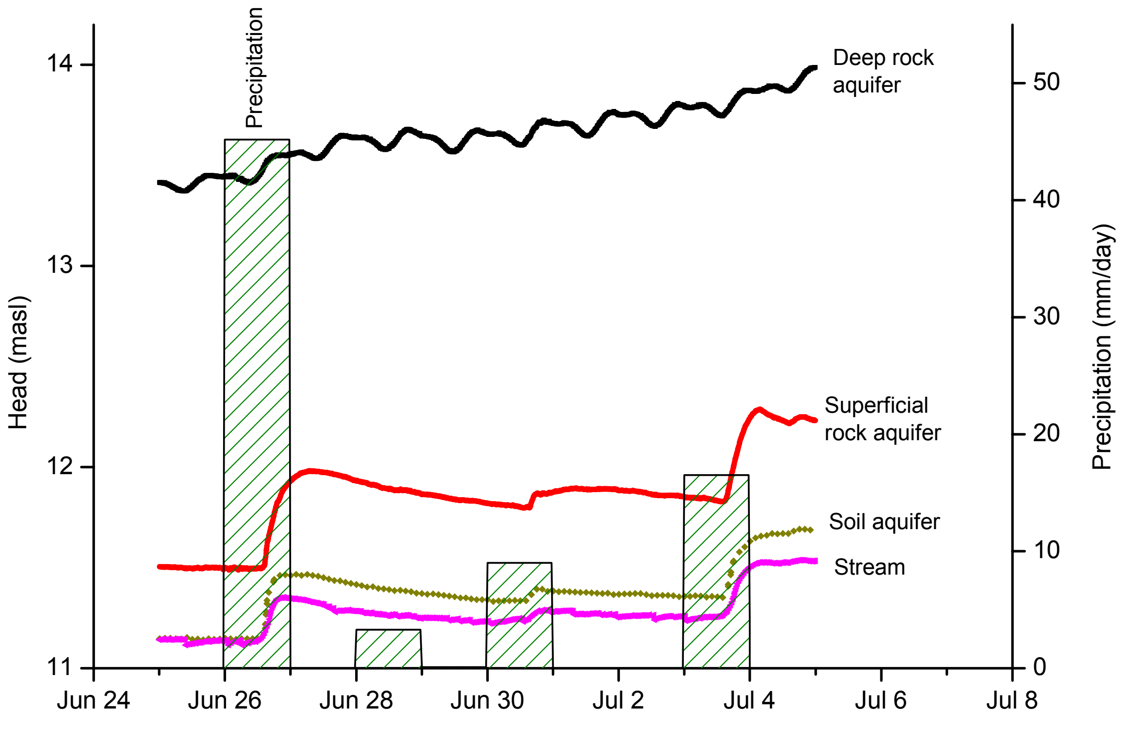


Figure 2-2. *Example of results from the Hydro Monitoring System (HMS) taken from the mainland at Laxemar. The graph shows the time series from one location of water head at different depths and precipitation events where it may be concluded that precipitation events above a certain amount are required to trigger groundwater recharge in the superficially situated aquifers.*

2.4 Geochemistry

The major aims within geochemistry are to:

- Establish and develop the understanding of the hydrogeochemical properties of the Äspö HRL rock volume.
- Maintain and develop the knowledge of applicable measuring and analytical methods.
- Ensure that experimental sampling programmes are performed with high quality and meet overall goals within the field area.
- Provide hydrogeochemical support to active and planned experiments at Äspö HRL.

An important part is the compilation of geochemical data for the Äspö Site Descriptive Model. The use of the information generated will facilitate the understanding of the geochemical conditions at the site and the way in which they change during operation. The intention is to develop the model as to be used for predictions, to support and plan experiments, and to test hydrogeochemical hypotheses. This is important in terms of distinguishing undisturbed and disturbed conditions.

Achievements - Äspö Site Descriptive Model

Quality assurance of data for the Äspö site modelling has continued. Additional information with respect to activities with the potential to disturb the surrounding groundwater will complement the delivered dataset. The sampling in the Tass-tunnel was finalised during the summer and the compilation of the hydrochemistry and colloidal data is initiated. A PM will be written summarising the findings coupled to the different issues regarding nitrogen content of the process water in the tunnel and the sealings (Silicasols) different resistivity for different salinity distributions.

2.4.1 Monitoring of Groundwater Chemistry

Water sampling in a tunnel at Äspö HRL.

During the Äspö HRL construction phase, water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. The samples were collected from boreholes drilled from the ground surface and from the tunnel. At the beginning of the Äspö HRL operational phase, sampling was replaced by a groundwater chemistry monitoring programme, with the aim to sufficiently cover the evolution of hydrochemical conditions with respect to time and space within the Äspö HRL.

The monitoring programme is designed to provide information to determine where, within the rock mass, the hydrogeochemical changes are taking place and at what time stationary conditions are established. In addition, all ongoing experiments have the possibility to request sampling of interest for their projects.

Achievements

Final results from previous years' analysis are now accomplished and a final report is accepted for internal publication. During the second four-month period the main focus has been to plan the upcoming monitoring campaign and sample programme to be performed mainly during this autumn.

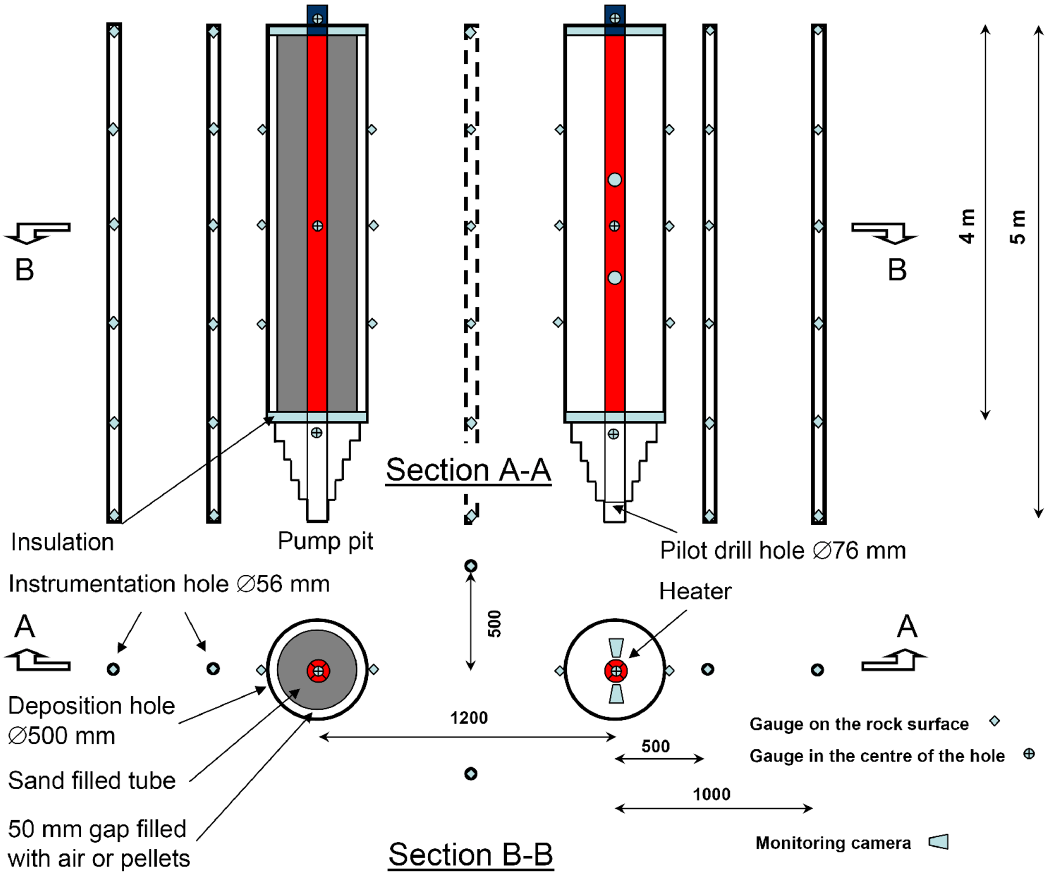
2.5 Rock Mechanics

Rock mechanic studies are performed with the aims to increase the understanding of the mechanical properties of the rock but also to recommend methods for measurements and analyses. This is mainly done by laboratory experiments and modelling at different scales and comprises:

- Natural conditions and dynamic processes in natural rock.
- Influences of mechanical, thermal and hydraulic processes in the near-field rock including effects of the backfill.

A project called Caps (Counterforce Applied to Prevent Spalling) comprising field tests in Äspö HRL and numerical modelling is ongoing and is described in the section below.

2.5.1 Counterforce Applied to Prevent Spalling



Configuration of the test holes and the positioning of instruments in the experiments in the Tasq-tunnel as original design with one open and one pellet filled hole. In reality the tests have been performed in two pairs of open holes and two pairs of pellet filled holes.

The field experiment within Counterforce Applied to Prevent Spalling (Caps) has been initiated as a demonstration experiment to determine if the application of dry bentonite pellets is sufficient to suppress thermally-induced spalling in KBS-3 deposition holes. The experience gained from the Äspö Pillar Stability Experiment, conducted between 2002 and 2006, indicated that spalling could be controlled by the application of a small confining pressure in the deposition holes.

The field experiment includes four pairs of heated half-scale KBS-3 holes and is carried out as a series of demonstration tests in the Tasq-tunnel at Äspö HRL.

Each test consists of two heating holes of 0.5 m diameter and 4 m depth separated by a 0.7 m pillar, which are surrounded by a number of boreholes for installation of temperature gauges.

The first step in the testing sequence includes heating of one pair of open holes to ensure that spalling will occur and can be observed in the test holes. The next step includes heating and observation of spalling in separate pair of holes. A 50 mm gap created between a large inner tube and the borehole wall is filled with a loosely placed pellets substitute. The final step is a complementary test that is carried out to address questions that arise during the previous tests.

Achievements

Post characterisation of the spalled damaged zone of the heating holes constituted the main activity during the second four-month period of 2009. In one of the heating holes in the final test (KQ0046G03) the hydraulic transmissivity of the spalled zone was examined through water injection tests. In the other heating holes, the spalling results have been documented by a number of monitoring methods, i.e. laser scanning, ultra sonic measurements, photographing with thin lighted slot and video recording of the holes. The post characterisation of the spalled zone is expected to be finished in the mid of September.

After the temperature in the final test had reverted to the ambient temperature the hydraulic transmissivity of the damaged zone was determined by injection tests in a number of core drill holes that intersected heating hole KQ0046G03. The results from these tests are summarised in Figure 2-3. The stationary transmissivity evaluated for the borehole sections indicated in the figure are marked in connection to the water injection holes. Except for one borehole (KQ0045G02) most likely penetrating a section with faulty sealing of the leca filled slot, the evaluated hydraulic transmissivity of the damaged zone corresponded to the measurement limit of the used equipment (1 ml/min). Moreover, no interference was detected between the water injection holes penetrating heating hole KQ0046G03. Thus, the results from the hydraulic tests are promising and indicate that the thermal spalling that occur in a deposition hole supported by dry pellets will not induce any continuous hydraulic zone along the hole.

The evaluation of the test results, as well as the reporting of the field test has been in progress during the period. The results will be reported in a memo in September and a draft of the final report is scheduled to the end of October 2009.

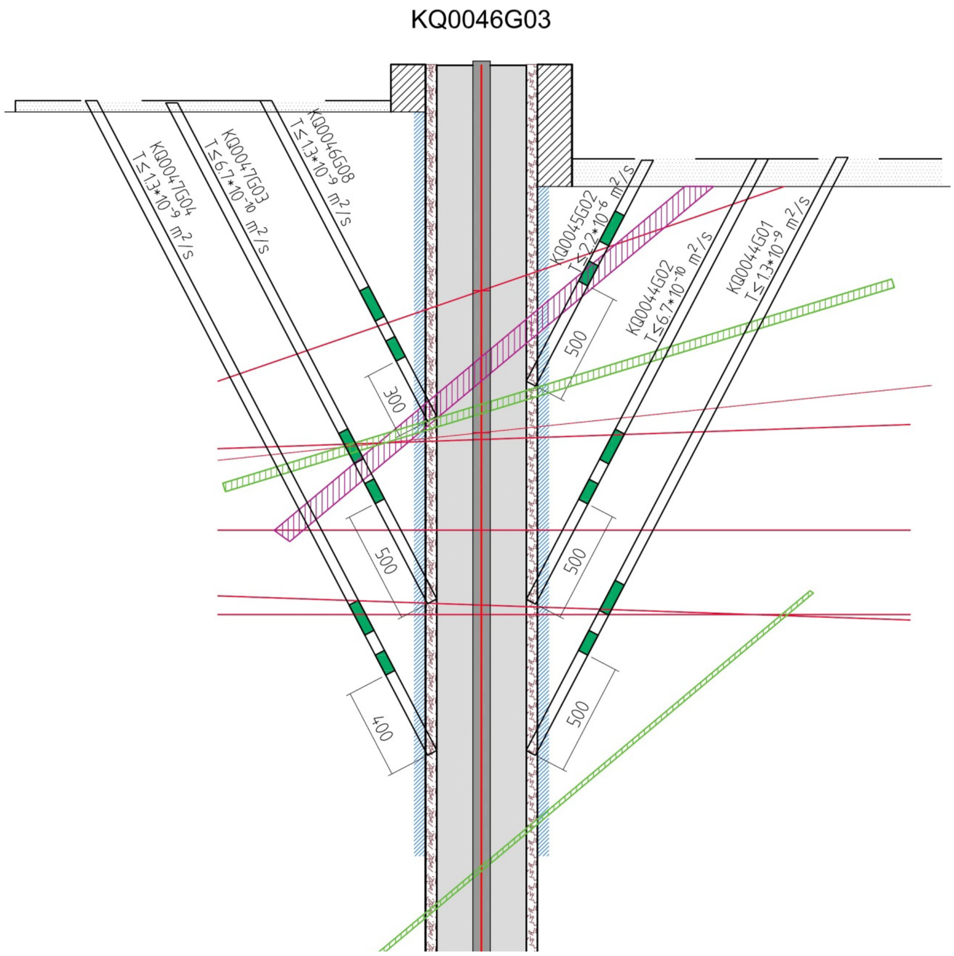


Figure 2-3. *Stationary transmissivity evaluated from water injection tests in boreholes penetrating the spalled damaged zone in heating hole KQ0046G03. The values presented in the figure are based on injection of water in the section marked below the installed double packer.*

3 Natural barriers

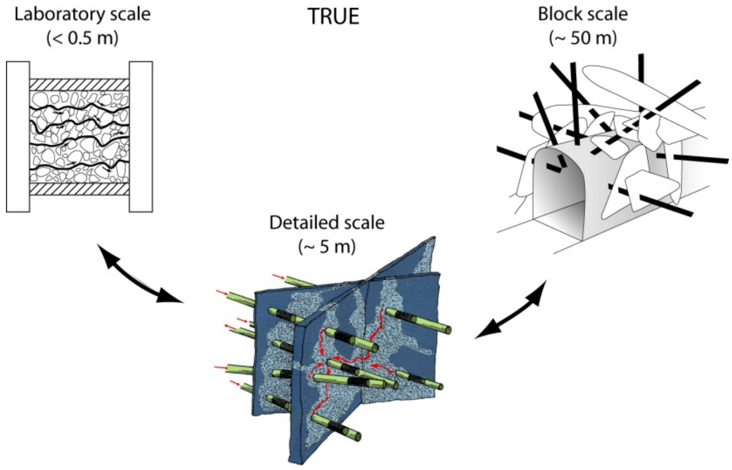
3.1 General

Experiments at the Äspö HRL are performed at conditions that are expected to prevail at repository depth. The experiments are related to the rock, its properties and in situ environmental conditions (Figure 3-1). The goals are to increase the scientific knowledge of the safety margins of the repository and to provide data for performance and safety assessment and thereby clearly present the role of the geosphere for the barrier functions: isolation, retardation and dilution.

Tests of models for groundwater flow, radionuclide migration and chemical/biological processes are one of the main purposes of the Äspö HRL. The programme includes projects with the aim to evaluate the usefulness and reliability of different models and to develop and test methods for determination of parameters required as input to the models.

Figure 3-1. *Fracture surface with thin coating of mainly chlorite, calcite, clay minerals and epidote. The length of the base of the photograph is 46 mm.*

3.2 Tracer Retention Understanding Experiments



Tracer tests with non-sorbing and sorbing tracers are carried out in the TRUE family of projects. These are conducted at different scales; laboratory scale (< 0.5 m), detailed scale (<10 m) and block scale (up to 100 m) with the aim to improve understanding of transport and retention in fractured rock. The work includes building of hydrostructural models and conceptual microstructure models. Numerical models are used to assess the relative contribution of flow-field related effects and acting processes (diffusion and sorption) on in situ retention.

The first in situ experiment (TRUE-1) /Winberg et al. 2000/ performed in the detailed scale and the TRUE Block Scale series of experiments /Winberg et al. 2003/ have come to their respective conclusion.

Complementary field work and modelling have been performed as part of two separate, but closely coordinated, continuation projects. The TRUE Block Scale Continuation (BS2) project, which was a continuation of TRUE Block Scale (BS1), aimed at obtaining additional understanding of the TRUE Block Scale site /Andersson et al. 2007/.

A further extension of the TRUE Block Scale Continuation (BS3) involves production of peer-reviewed scientific papers accounting for the overall TRUE findings, and in particular those of BS1 and BS2.

In the TRUE-1 Continuation and Completion projects the objectives are to obtain insight in the internal structure of the investigated feature and to study fixation of sorbing radioactive tracers. Prior to the resin injection in Feature A, complementary hydraulic and tracer tests are performed to better understand Feature A and its relation to the surrounding fracture network. In addition, a dress rehearsal of in situ resin injection is realised through a characterisation project focused on fault rock zones.

Additional work includes complementary laboratory sorption investigations on fracture rim and fault gouge materials, plus a series of three scientific articles on the TRUE-1 experiment.

3.2.1 TRUE Block Scale Continuation

In the aftermath to the BS2 project, a second step of the continuation of the TRUE Block Scale (BS3) was set up. This step has no specific experimental components and emphasise consolidation and integrated evaluation of all relevant TRUE data and findings collected thus far. This integration is not necessarily restricted to TRUE Block Scale, but may include incorporation of relevant TRUE-1 and TRUE-1 Continuation results.

The planned series of articles covering the TRUE Block Scale experiments have been transformed into one two-part series of papers entitled *Transport and retention from single to multiple fractures in crystalline rock at Äspö (Sweden):*

I. *Evaluation of tracer test results and sensitivity analysis*

II. *Fracture network flow simulations and global retention properties*

This series is flanked by a standalone paper entitled - *The role of enhanced porosity adjacent to fractures for tracer transport in crystalline rock*.

A second step in the scientific reporting of the TRUE experiments is a more high-profiled paper directed to the general scientific public. The title of this paper, aimed at the journal Science is entitled *Field-scale retention of radioactive isotopes in crystalline rock.*

Achievements

Review comments for all three manuscripts submitted to Water Resources Research (one more general on the effect of the rim zone as observed in the TRUE tests and two related to TRUE Block Scale/Block Scale Continuation tests) have been received. The overall assessment is positive with suggested revisions. Revisions of all three manuscripts have been completed during the summer/early fall and are currently with the editor/reviewers for their consideration.

A first draft of a more high-profiled paper directed towards Science was prepared and circulated during the summer. Based on received comments, the paper will be subdivided in two parts. One paper will be directed towards Geophyscial Research Letters (GRL) retaining the more technical content of the paper, whereas the paper directed towards Science will focus on comparison with literature and will feature physical demonstration of retention in crystalline rock as given by the results of TRUE-1 Completion. An overruling objective is to convey the notion that field-scale retention is controlled by diffusion and sorption, and furthermore, that robust model predictions are feasible and extrapolation of results to other scales is possible.

3.2.2 TRUE-1 Continuation

The TRUE-1 Continuation project is a continuation of the TRUE-1 experiments and the experimental focus is primarily on the TRUE-1 site. The continuation included performance of the injection of epoxy resin in Feature A at the TRUE-1 site and subsequent overcoring and analysis (TRUE-1 Completion). In addition, this project includes production of a series of scientific articles based on the TRUE-1 project and the Fault Rock Characterisation project.

Achievements

No work has been performed within TRUE-1 Continuation during the first eight months of 2009, with the exception of work performed within TRUE-1 Completion, see section below.

3.2.3 TRUE-1 Completion

TRUE-1 Completion is a sub-project of the TRUE-1 Continuation project and is a complement to already performed and ongoing projects. The main activity within TRUE-1 Completion was the injection of epoxy with subsequent overcoring of the fracture and following analyses of pore structure and, if possible, identification of sorption sites. Furthermore, several complementary in situ experiments were performed prior to the epoxy injection. These tests were aimed to secure important information from Feature A and the TRUE-1 site before the destruction of the site.

Achievements

The major activity within the project during the last four month period was the ongoing analyses of cores from boreholes KXTT3 and KXTT4. Generally, the analyses have been carried out according to plan and the chosen methods have been working well. The analyses will continue until December 2009. Hence, only preliminary results are available from the analyses at this point. The most important preliminary results from the last four-month period are:

- Epoxy from the previous injection was found in the fractures that had been classified as open in previous characterisations of the 56 mm boreholes but also in some other fractures. This indicates a more complex system of open fractures within the borehole intervals than previous interpretations indicate.
- Epoxy covers a major part of the main fracture of Feature A.
- The character of the main fracture of Feature A is varying.
- Radioactive Cs is heterogeneously distributed in Feature A in KXTT4.

3.3 Long Term Sorption Diffusion Experiment

Drilling of sample cores from matrix rock surrounding the test section in the small diameter extension borehole.

This experiment is performed to investigate diffusion and sorption of solutes in the vicinity of a natural fracture into the matrix rock and directly from a borehole into the matrix rock.

The aims are to improve the understanding of diffusion and sorption processes and to obtain diffusion and sorption data at in situ conditions.

A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole and a small-diameter borehole is drilled through the core stub and beyond into the intact unaltered bedrock.

Tracers were circulated over a period of 6 ½ months after which the borehole was over cored. This activity is followed by analyses of tracer content.

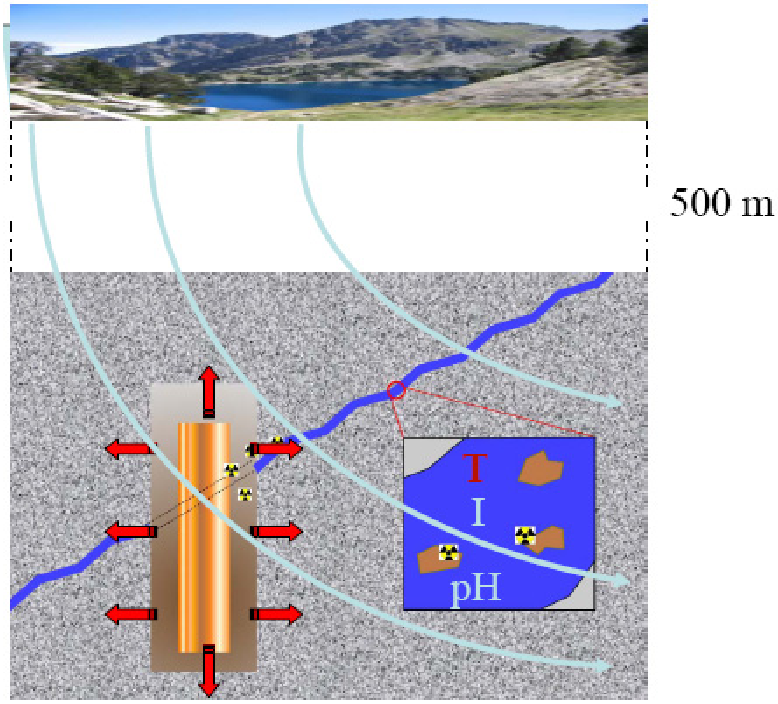
Small diameter (24 mm) sample cores have been extracted from the 1.1 m long and 278 mm diameter large core retrieved from the over coring. 34 sample cores have been extracted both from the fracture surface on the core stub and from the matrix rock surrounding the test section in the small diameter (36 mm) extension borehole.

Achievements

All crushed and intact rock slices selected for subsequent leaching, and LSC analysis of ^{36}Cl and ^{35}S, have been analysed for γ-emitting tracers and analyses of the other samples are ongoing. Leaching and subsequent analysis of ^{36}Cl in crushed and intact rock slices have been initialised.

Laboratory experiments with specimen from the core of the small diameter extension borehole have been going on at Chalmers University of Technology in Gothenburg. The batch sorption tests and sorption/diffusion tests with intact rock pieces from the core of the small diameter extension borehole, the replica core stub and the pilot borehole core were finalised in late April. Some completing sampling and tracer analyses have been done and are ongoing, as well as evaluation of the resulting data.

3.4 Colloid Transport Project



The Colloid Transport Project is a continuation of the Colloid Dipole Project, which was ended in the beginning of 2008. The overall goal for the Colloid Transport Project is to answer the questions when colloid transport has to be taken into account in the safety assessment, and how the colloid transport can be modelled.

In the beginning of the lifetime of a deep repository, in bedrock with groundwater of high ionic strength, bentonite and natural colloids are not stable, and colloid transport can be neglected. Of special concern is bentonite erosion, since that could give loss of material leading to a decrease of the barrier function of the bentonite buffer.

In the scenario of intrusion of dilute glacial water the conditions for colloids stability drastically changes and the transport of colloids might be the limiting factor.

In the case of a leaching canister, the bentonite colloids can possibly facilitate the transport of sorbed radionuclide towards the biosphere. In the project, also the transport of organic colloids and other natural colloids are studied and their effect on especially actinide mobility.

The ambition is further to include studies on the transport of colloids which are formed in the spent nuclear fuel.

Achievements

To determine geometry and structure of Ca- and Na-bentonite colloids in solution X-ray microspectroscopy analysis have been performed at the Pollux Beamline at SLS in Switzerland. Results show that the structures of montmorillonite colloids in solution are not planar but spherical or elliptoidical with an internal structure. The results are published in Applied Geochemistry /Degueldre et al. 2009/ and another manuscript is under preparation.

Mockup tests of erosion and generation of Na- and Ca-montmorillonite show that the gel propagation is significantly affected by the groundwater composition. The difference between gel propagation rate in a dilute water and Grimsel groundwater, with 0.001 M Na and 0.0001 M Ca is large. Ca-bentonite acts as expected very differently from Na-bentonite. The montmorillonite colloid concentrations outside a bentonite barrier will be at least one magnitude lower in the contact with Grimsel groundwater compared to deionised water. A manuscript with the results is under preparation.

Bentonite erosion experiments have been performed in the Quarried Block with MX-80 in contact with Grimsel groundwater. The results from the experiments are under evaluation.

Sorption experiments of colloids on fracture filling materials such as quartz and biotite have been performed in 0.001 M ionic strength and in the pH range 4-10 to study sorption of colloids in favourable and less favourable conditions. In addition, transport experiments with latex- and montmorillonite colloids have been performed to study retention mechanisms such as sorption and filtration of colloids. The results are under evaluation and two manuscripts in preparation.

3.5 Microbe Projects

Microorganisms interact with their surroundings and in some cases they greatly modify the characteristics of their environment. Several such interactions may have a significant influence on the function of a repository for spent fuel /Pedersen 2002/. There are presently four specific microbial process areas identified that are of importance for proper repository functions. They are: bio-mobilisation of radionuclides, bio-immobilisation of radionuclides, microbial effects on the chemical stability of deep groundwater environments and microbial corrosion of copper.

The study of microbial processes in the laboratory gives valuable contributions to our knowledge about microbial processes in repository environments. However, the results obtained by laboratory studies must be tested in a repository like environment. The reasons are several. Firstly, at repository depth, the hydrostatic pressure reaches close to 50 bars, a setting that is very difficult to reproduce in the laboratory. The high pressure will influence chemical equilibrium and the content of dissolved gases. Secondly, the geochemical environment of deep groundwater, on which microbial life depends and influence, is complex. Dissolved salts and trace elements, and particularly the redox chemistry and the carbonate system are characteristics that are very difficult to mimic in a university laboratory. Thirdly, natural ecosystems, such as those in deep groundwater, are composed of a large number of different species in various mixes /Pedersen 2001/. The laboratory is best suited for pure cultures and therefore the effect from consortia of many participating species in natural ecosystems cannot easily be investigated there. The limitations of investigations arrayed above in a laboratory situated on ground have resulted in the construction and set-up of an underground laboratory in the Äspö HRL tunnel. The site is denoted the Microbe Laboratory and is situated at the -450 m level, see below.

Three new circulation systems in the Microbe Laboratory were installed during 2008.

The Microbe Laboratory has been installed in the Äspö HRL for studies of microbial processes in groundwater under in situ conditions.

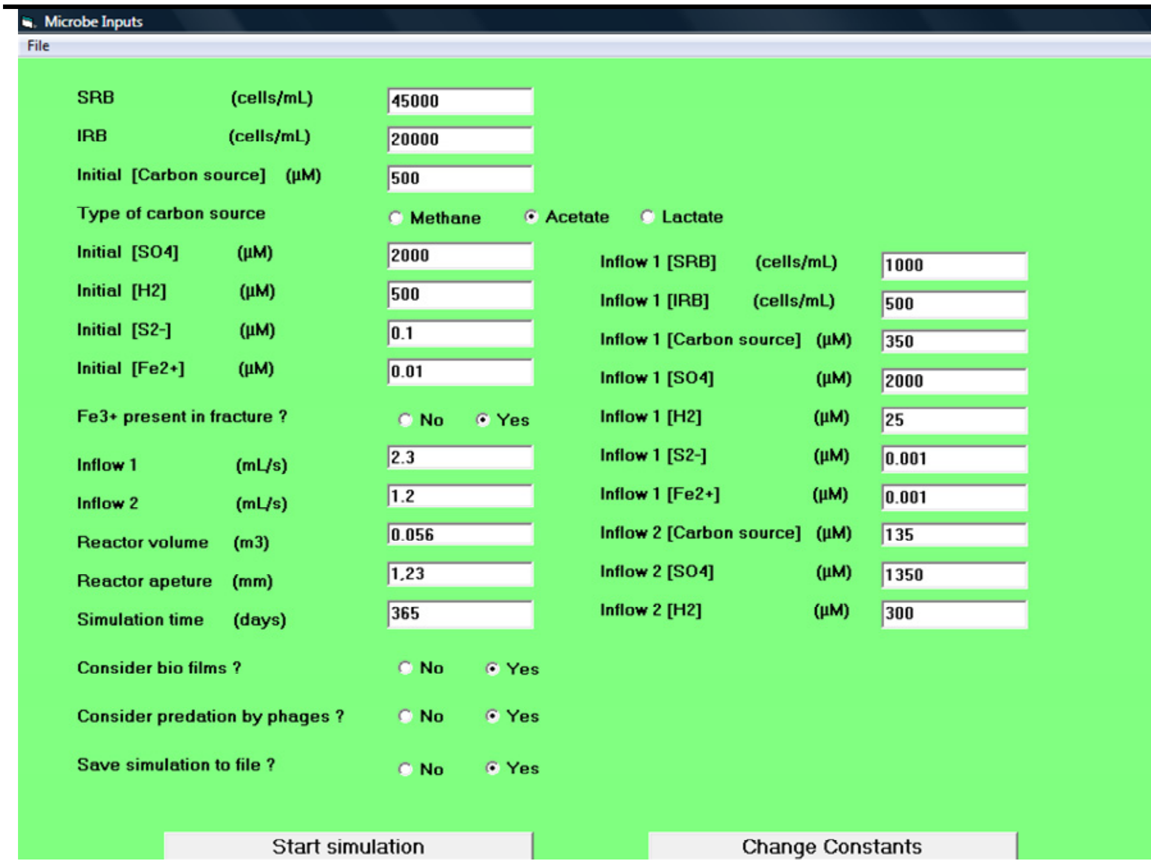
The Microbe site is on the -450 m level where a laboratory container with benches and an advanced climate control system is located.

Three boreholes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures are connected to the Microbe Laboratory via tubing. The laboratory is equipped with six circulation systems offering 2,112 cm^2 of test surface (three systems are shown in the image to the left).

The major objectives are to:

- Offer proper circumstances for research on the effect of microbial activity on the long-term chemical stability of the repository environment.
- Provide in situ conditions for the study of bio-mobilisation of radionuclides.
- Present a range of conditions relevant for the study of bio-immobilisation of radionuclides.
- Enable investigations of bio-corrosion of copper under conditions relevant for a high level radioactive waste repository.
- Constitute a reference site for testing and development of methods used in the site investigations.

3.5.1 Micored



The input panel of the simulation program Microbe39. The program calculates in situ growth and activity of microorganisms in groundwater. The background data for program functions and constants have been generated at the Microbe site and in the laboratory with microorganisms isolated from Äspö HRL. SRB=sulphate reducing bacteria; IRB=iron reducing bacteria.

Microorganisms can have an important influence on the chemical situation in groundwater. Especially, they may execute reactions that stabilise the redox potential in groundwater at a low and, therefore, beneficial level for the repository.

It is hypothesised that hydrogen and possibly also methane from deep geological processes contributes to the redox stability of deep groundwater via microbial turnover of this gas. These metabolisms will generate secondary metabolites such as ferrous iron, sulphide, acetate and complex organic carbon compounds.

The work within the Micored project will:

- Clarify the contribution from microorganisms to stable and low redox potentials in groundwater.
- Demonstrate and quantify the ability of microorganisms to consume oxygen in the near-and far-field areas.
- Explore the relation between content and distribution of gas and microorganisms in deep groundwater.
- Create clear connections between investigations of microorganisms in the site investigations for a future repository and research on microbial processes at Äspö HRL.

Achievements

Work is ongoing with preparation of a paper for publication in a scientific, peer-review journal. This paper will deal with numbers, diversity and distribution of sulphate reducing bacteria in Äspö groundwater sampled from boreholes along the tunnel.

3.5.2 Micomig

Sampling a new-drilled fracture surface for microbial presence and activity using DNA/RNA analysis methods.

Microbes can mobilise trace elements. Firstly, unattached microbes may act as large colloids, transporting radionuclides on their cell surfaces with the groundwater flow. Secondly, microbes are known to produce ligands that can mobilise soluble trace elements and that can inhibit trace element sorption to solid phases.

A large group of microbes catalyse the formation of iron oxides from dissolved ferrous iron in groundwater that reaches an oxidising environment with oxygen. Such biological iron oxide systems (Bios) will have a retardation effect on many radionuclides.

Biofilms in aquifers will influence the retention processes of radionuclides in groundwater. Previous research at Äspö HRL indicated that biofilms may enhance or retard sorption, depending on the radionuclide in question.

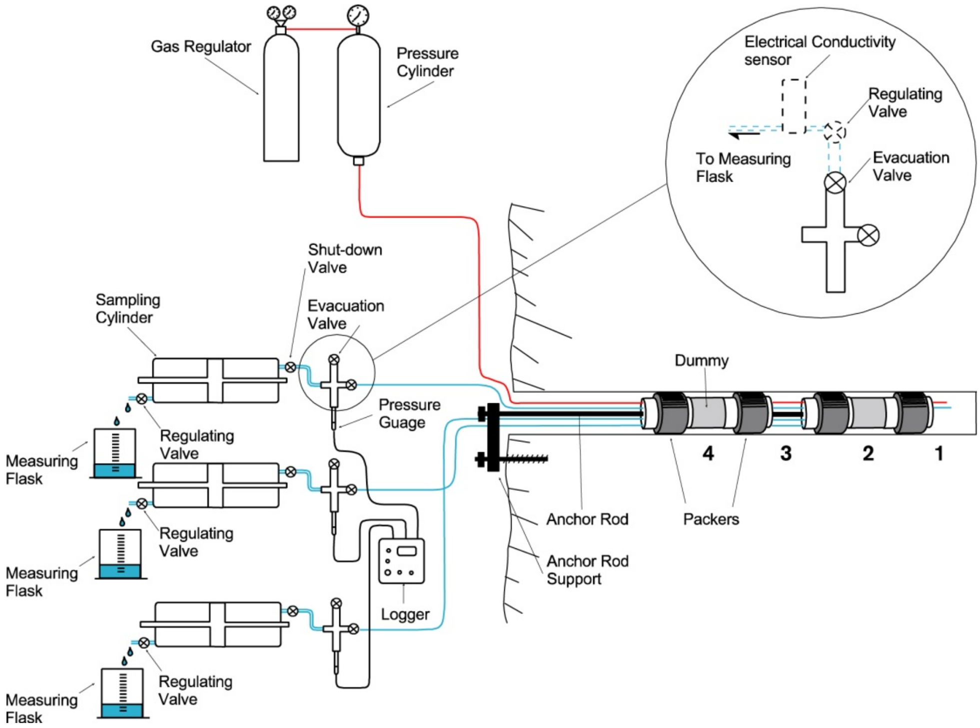
The work within Micomig will:

- Evaluate the influence from microbial complexing agents on radionuclide migration.
- Explore the influence of microbial biofilms on radionuclide sorption and matrix diffusion.

Achievements

Work is ongoing with preparation of a paper for publication in a scientific, peer-review journal. This paper will deal with numbers, diversity and distribution of microorganisms in biofilms from the circulation systems on the -450 m level in Äspö HRL and from drill cores collected at 1,362 m depth.

3.6 Matrix Fluid Chemistry Continuation



The main objectives of the Matrix Fluid Chemistry experiment are to understand the origin and age of fluids/groundwater in the rock matrix pore space and in micro-fractures, and their possible influence on the chemistry of the groundwater from the more highly permeable bedrock.

Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied to determine their contribution, if any, to the composition of the matrix fluids/groundwater.

A first phase of the project is finalised and reported /Smellie et al. 2003/. The major conclusion is that porewater can successfully be sampled from the rock matrix and there is no major difference in chemistry compared to groundwater from more highly conductive fracture zones in the near-vicinity.

A continuation phase of the project started 2004 with the aim to focus on areas of uncertainty which remain to be addressed:

- The nature and extent of connected porewaters in the Äspö bedrock.
- The nature and extent of the microfracture groundwaters which penetrate the rock matrix and the influence of these groundwaters on the chemistry of the porewaters.
- The confirmation of rock porosity values previously measured in the earlier studies.

Achievements

There have been no major achievements in the project during the first eight months of 2009. Final reporting of the matrix borehole hydraulic studies is ongoing.

3.7 Radionuclide Retention Experiments

Radionuclide Retention Experiments are carried out with the aim to confirm results of laboratory studies in situ, where natural conditions prevail concerning e.g. redox conditions, contents of colloids, organic matter and bacteria in the groundwater. The experiments are carried out in special borehole laboratories, Chemlab 1 and Chemlab 2, designed for different kinds of in situ experiments. The laboratories are installed in boreholes and experiments can be carried out on for instance bentonite samples and on tiny rock fractures in drill cores.

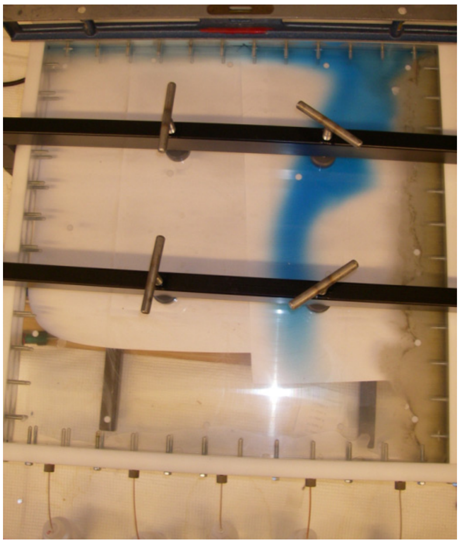
Experiments in Chemlab 1:

- Investigations of the influence of radiolysis products on the migration of the redox-sensitive element technetium in bentonite (finalised).
- Investigations of the transport resistance at the interface between buffer and rock (planned, see section 3.7.1).

Experiments in Chemlab 2:

- Migration experiments with actinides in a rock fracture (almost finalised).
- Study of spent fuel leaching at repository conditions (planned, see section 3.7.2).

3.7.1 Transport Resistance at the Buffer Rock Interface



The equipment intended for the laboratory experiments. The equipment is currently used in another SKB project, Bentonite Erosion.

If a canister fails and radionuclides are released, they will diffuse through the bentonite buffer. If there is a fracture intersecting the deposition hole, the water flowing in the fracture will pick up radionuclides from the bentonite buffer.

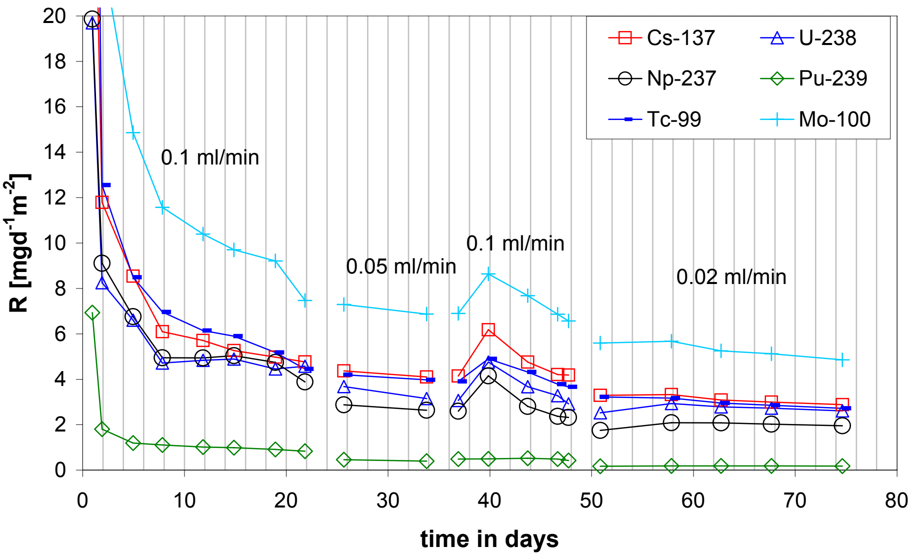
The transport resistance is concentrated to the interface between the bentonite buffer and the rock fracture. The mass transfer resistance due to diffusion resistance in the buffer is estimated to only 6% and the diffusion resistance in the small cross section area of the fracture in the rock to 94% /Neretnieks 1982/. The aim of the Transport Resistance at Buffer-Rock Interface project is to perform studies to verify the magnitude of this resistance.

The experiment will be performed in the laboratory, where a fracture is simulated as a 1 mm space between two Plexiglas plates. The equipment includes a water pump for very low flow rates. The design of field experiments depends on the outcome of the laboratory experiments.

Achievements

No work has been performed within project during the first eight months of 2009.

3.7.2 Spent Fuel Leaching



Dissolution rates based on different monitors. The spent fuel was leached with 10 mM $NaHCO_3$ under oxidising conditions. Constant dissolution rates could be achieved after some days.

In the Spent Fuel Leaching experiments, to be performed within the framework of the programme for in situ studies of repository processes, the dissolution of spent fuel in groundwater relevant for repository conditions will be studied. The objectives of the experiments are to:

- Investigate the leaching of spent fuel in laboratory batch experiments and under in situ conditions.
- Demonstrate that the laboratory data are reliable and correct for the conditions prevailing in the rock.

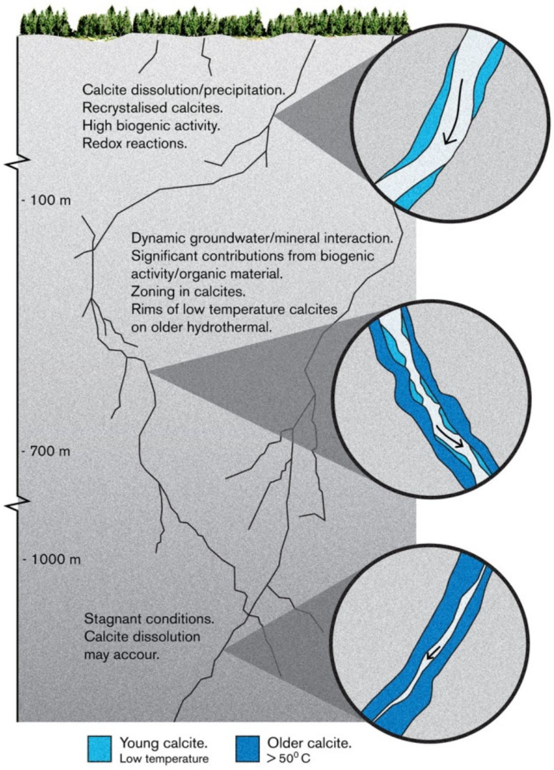
The in situ experiments will be preceded by laboratory experiments where the scope is both to examine parameters that may influence the leaching as well as testing the equipment to be used in the field experiments.

In the field experiments spent fuel leaching will be examined with the presence of H_2 (in a glove box situated in the gallery) as well as without the presence of H_2 (in Chemlab 2).

Achievements

No work has been performed within project during the first eight months of 2009.

3.8 Padamot



Potential calcite-groundwater interaction at various depths at Äspö.

Padamot (Palaeohydrogeological Data Analysis and Model Testing) investigates changes in groundwater conditions as a result of changing climate. Because the long term safety of an underground repository depends on the stability of the repository environment, demonstration that climatic impacts attenuate with depth is important. Currently, scenarios for groundwater evolution relating to climate changes are poorly constrained by data and process understanding.

The EC-part of the project was finalised and reported in 2005. The Padamot continuation project comprises:

- Further developments of analytical techniques for uranium series analyses applied on fracture mineral samples and inter laboratory comparisons.
- The use of these analyses for determination of the redox conditions during glacial and postglacial time.
- A summary of the experiences from the palaeohydrogeological studies carried out at Äspö.

The analyses are carried out on split samples of fracture material from a surface borehole drilled at Äspö (KAS17). This borehole penetrates the large E-W fracture zone called the Mederhult zone.

Achievements

The inter laboratory studies have shown a good correspondence between different laboratories and different methods. The content of uranium and thorium analysed by alfa-spectrometry and ICP-MS gives the same picture of variation versus depth, see Figure 3-2). The use of bulk analyses and sequential extraction has been successful and the use of both these methods is recommended for studies of the mobile uranium fraction in fracture and wall rock samples. The inter laboratory study together with repeated analyses at the same laboratory have shown that the fracture material in the upper part of the bedrock (close to the redox transition zone) show relatively small variation in their uranium and thorium content but larger variation in uranium isotope ratio. The results support the present understanding of the fracture system (i.e. channeling and changes in flow due to climatic changes but also annual variations).

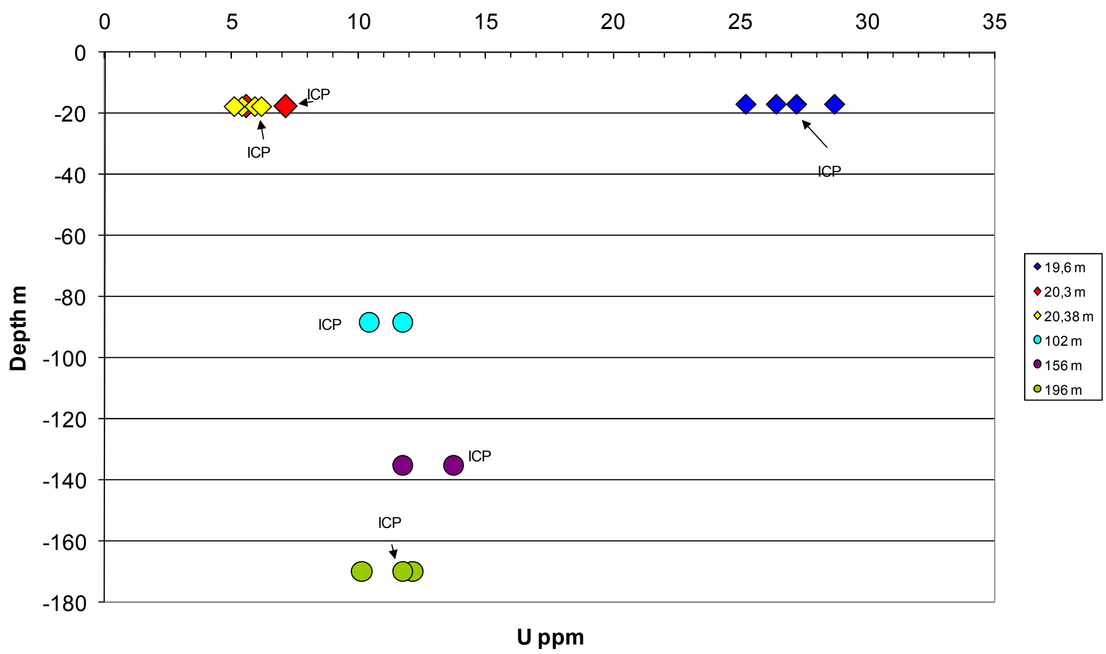
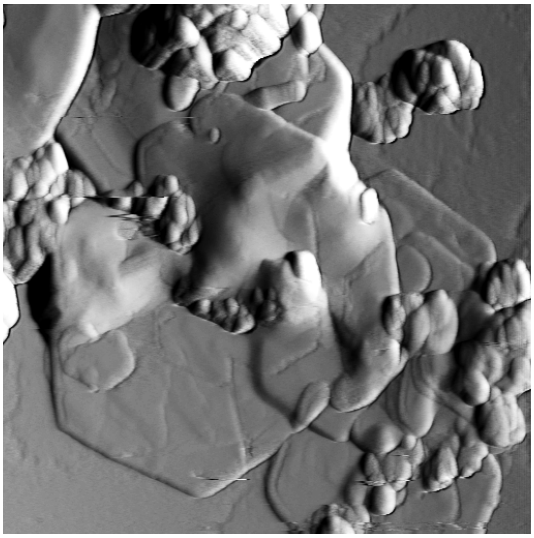


__Figure 3-2.__ Uranium content in fracture coatings versus depth in samples from borehole KAS17. Samples analysed by ICP-MS are marked in the plot.

3.9 Fe-oxides in Fractures



Atomic Force Microscopy image of green rust sulphate. Image is 2.5 x 2.5 microns

Proof of reducing conditions at repository depth is fundamental for the safety assessment of radioactive waste disposals. Fe(II) – minerals are common in the bedrock and along fracture pathways and constitute a considerable reducing capacity together with organic processes. Another area of interest is the radionuclide retention capacity provided by Fe-oxides and –oxyhydroxides in terms of sorption capacity and immobilisation.

The basic idea of the project is to examine Fe-oxide fracture linings, in order to explore for suitable palaeo-indicators for their formation conditions, while at the same time learning about the behaviour of trace component uptake in general, both from the natural material as well as through testing of behaviour in controlled parametric studies in the laboratory.

Following the original project, a continuation phase of the project was started. The aim with this phase is to establish the penetration depth of oxidising water below ground level. Oxidising waters may represent present-day recharge, or reflect penetration of glacial melt waters during the last glaciation.

Achievements

No work has been performed within the project during the first eight months of 2009.

3.10 Swiw-tests with Synthetic Groundwater

Injection of tracer in fracture

The Single Well Injection Withdrawal (Swiw) tests with synthetic groundwater constitute a complement to performed tests and studies on the processes governing retention, e.g. the TRUE experiments as well as Swiw tests performed within the SKB site investigation programme.

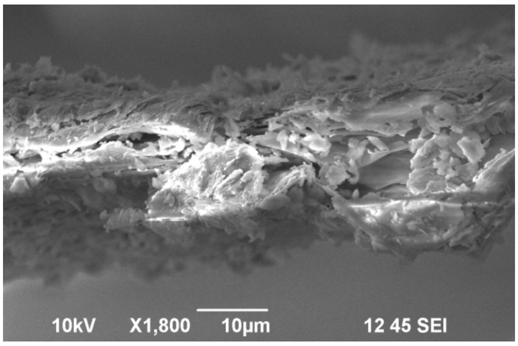
The general objective of the Swiw test with synthetic groundwater is to increase the understanding of the dominating retention processes and to obtain new information on fracture aperture and diffusion. The basic idea is to perform Swiw tests with synthetic groundwater with a somewhat altered composition, e.g. replacement of chloride, sodium and calcium with nitrate, lithium and magnesium, compared to the natural groundwater at the site.

Sorbing as well as non-sorbing tracers may be added during the injection phase of the tests. In the withdrawal phase of the tests the contents of the "natural" tracers (chloride sodium and calcium) as well as the added tracers in the pumping water is monitored. The combination of tracers, both added and natural, may then provide desired information on diffusion, for example if the diffusion in the rock matrix or in the stagnant zones dominates.

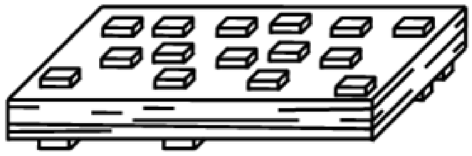
Achievements

During the last four-month period the project decision and project plan were finalised and approved. Three of the activities in the project plan were also initiated during the period; Activity 4 - Site selection, Activity 5 - Scoping calculation of radon and Activity 6 - Activity plan for field experiments. These activities will make a basis for decision about the progress of the project and will be finalised during the coming four-month period.

3.11 Äspö model for radionuclide sorption



A SEM image of a chlorite particle /Zazzi et al. 2009/



A sketch of a rough and partly disintegrated chlorite particle /Zazzi et al. 2009/.

Today, geochemical retention of radionuclides in the granitic environment is commonly assessed using Kd-modelling. However, this approach relies on fully empirical observations and thus to a limited degree contribute to the evaluation of the conceptual understanding of reactive transport in complex rock environments.

In the literature, the process based Component Additivity (CA) approach, which relies on a linear combination of sorption properties of different minerals in a geological material, has been suggested for estimation of sorption properties.

For adoption of this approach to granitic material, the particle size/surface area dependence of radionuclide sorption and effects of grain boundaries need to be resolved. Furthermore, it is desirable to verify sorption of radionuclides to specific minerals within the rock.

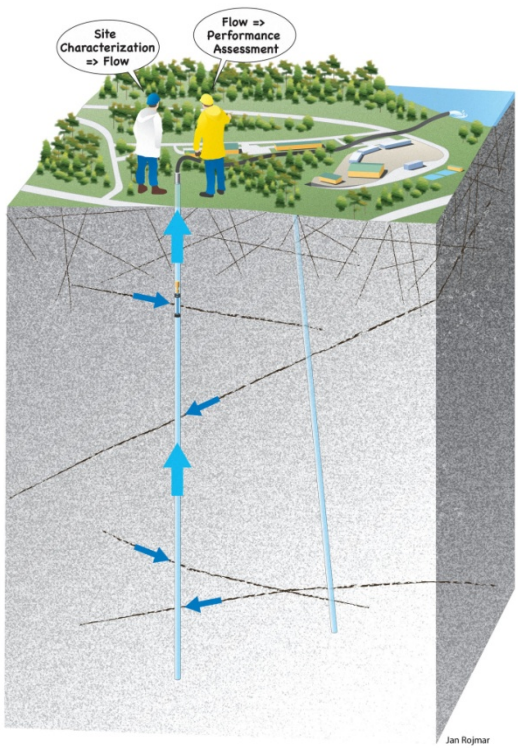
The overall objective of this project is to formulate and test process quantifying models for geochemical retention of radionuclides, in granitic environments, using a combined laboratory and modelling approach.

Achievements

During the period May-August 2009 preparation and characterisation of acquired pure mineral samples have begun. The characterisation aims at confirming the identity of the minerals and determining their chemical composition and purity. The early preparation of mineral samples particularly includes preparation of up to centimetre pieces for specific surface area and porosity determinations. Later mineral preparations will include crushing and sieving the minerals into size fractions. Both the large pieces and the crushed material will be used in subsequent laboratory sorption experiments.

A co-operation with researchers at Nuclear Chemistry and Inorganic Chemistry at KTH, Stockholm, Sweden, on the model interpretation of the specific surface area and radionuclide sorption properties of the mineral chlorite has been initiated. As part of this co-operation, a surface complexation model for Ni^{2+} sorption onto chlorite as function of pH in small scale laboratory experiments was tested for two different chlorite samples. It was found that despite an order of magnitude difference in the specific surface area between the two chlorites, the sorption could be modelled with the same model, due to similar sorption strengths of the two samples. It was proposed that this similarity in sorption reactivity is due to similar reactive surface areas between the samples, despite difference in the total specific surface area as determined by N_2 sorption through the BET-method /Zazzi et al. 2009/. From theory it was shown that this situation may occur, for example, if the basal plane of the chlorite is rough or the particle partly disintegrated, as had been observed by SEM (Scanning Electron Microscopy) for one of the chlorite samples used. Preliminary results of the modelling work were presented at the 12th Goldschmidt conference in Davos in June 2009 /Dubois et al. 2009/.

3.12 Task Force on Modelling of Groundwater Flow and Transport of Solutes



Task 7 - Reduction of Performance Assessment uncertainty through modelling of hydraulic tests at Olkiluoto, Finland

The Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes is a forum for the organisations supporting the Äspö HRL to interact in the area of conceptual and numerical modelling of groundwater flow and transport of solutes in fractured rock.

The Task Force shall propose, review, evaluate and contribute to the modelling work in the project. In addition, the Task Force shall interact with the principal investigators responsible for carrying out experimental and modelling works for Äspö HRL.

The work within the Task Force constitutes an important part of the international co-operation within the Äspö HRL.

Achievements

During the second four-month period of 2009, work has mainly been performed in Task 7 - Reduction of Performance Assessment uncertainty through modelling of hydraulic tests at Olkiluoto, Finland. The status of the specific modelling tasks within Task 7 is given within brackets in Table 3-1. In addition, papers on Task 6 have been published in Hydrogeology Journal. Task 6 tries to bridge the gap between Performance Assessment (PA) and Site Characterisation (SC) models by applying both approaches for the same tracer experiment. A printed theme issue on Task 6 was distributed from the Hydrogeology Journal in July. Thereby, Task 6 is finalised. Task 8 – Interface between engineered and natural barriers, is in the start-up phase. Task 8 will be a joint effort with the Task Force on Engineered Barriers, and will be addressing the processes at the interface between the rock and the bentonite in deposition holes.

Task 7 is focusing on methods to quantify uncertainties in PA-type approaches based on SC-type information; along with being an opportunity to increase the understanding of the role of fracture zones as boundary conditions for the fracture network and how compartmentalisation influence the groundwater system. The possibilities to extract more information from interference tests will also be addressed. A workshop on Task 7 and Task 8 was held in Lund, January 2009, and the minutes have been distributed. The 25th Task Force meeting was planned for June, but was postponed to October tentatively.

Table 3-1. Task descriptions and status (within brackets) of the specific modelling sub-tasks.

7	**Reduction of Performance Assessment uncertainty through modelling of hydraulic tests at Olkiluoto, Finland.**
7A	Long-term pumping experiment. (Final results of sub-task 7A1 and 7A2 are reported as ITDs).
7A1	Hydrostructural model implementation.
7A2	Pathway simulation within fracture zones.
7A3	Conceptual modelling of PA relevant parameters from open hole pumping.
7A4	Quantification of compartmentalisation from open hole pumping tests and flow logging.
7A5	Quantification of transport resistance distributions along pathways.
7B	Sub-task 7B is addressing the same as sub-task 7A but in a smaller scale, i.e. rock block scale. Sub-task 7B is using sub-task 7A as boundary condition. (Preliminary results presented at the 24th Task Force meeting).
7C	Here focus is on deposition hole scale issues, resolving geomechanics, buffers, and hydraulic views of fractures. (In planning).
7D	Tentatively sub-task 7D concerns integration on all scales.

4 Engineered barriers

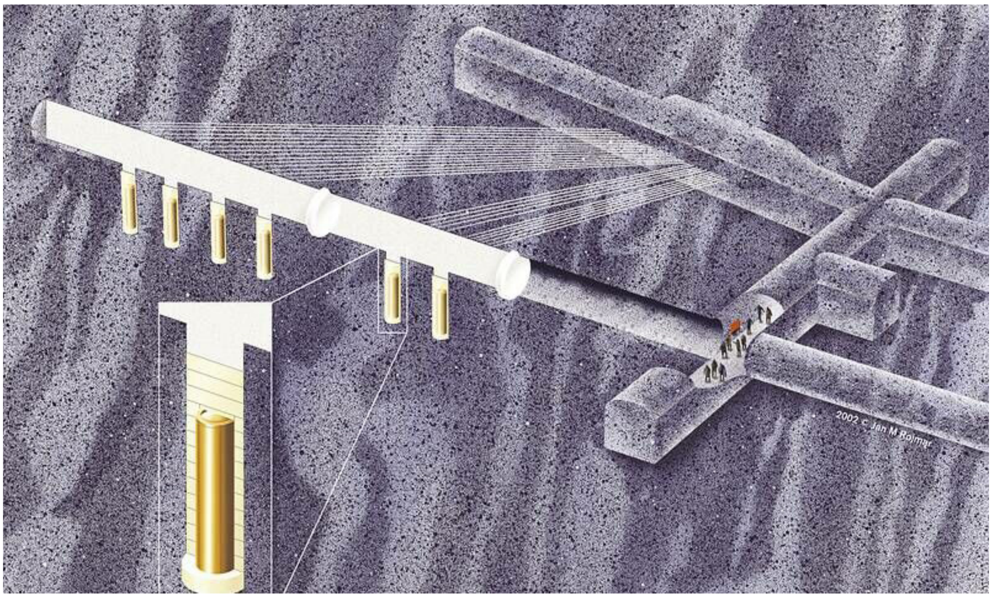
4.1 General

Another goal for Äspö HRL is to demonstrate technology for and function of important parts of the repository system. This implies translation of current scientific knowledge and state-of-the-art technology into engineering practice applicable in a real repository.

It is important that development, testing and demonstration of methods and procedures, as well as testing and demonstration of repository system performance, are conducted under realistic conditions and at appropriate scale. A number of large-scale field experiments and supporting activities are therefore conducted at Äspö HRL, see Figure 4-1. The experiments focus on different aspects of engineering technology and performance testing and together form a major experimental programme.

Figure 4-1. *Water filled measuring weir in the project Sealing of Tunnel at Great Depth.*

4.2 Prototype Repository



The Prototype Repository is located in the TBM-tunnel at the -450 m level and includes six full scale deposition holes. The aims of the Prototype Repository are to demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions.

The Prototype Repository should, to the extent possible, simulate the real repository system regarding geometry, materials and rock environment.

The inner tunnel (Section I, canisters #1 - #4) was installed and the plug cast in 2001 and the heaters in the canisters were turned on one by one. The outer tunnel (Section II, canisters #5 - #6) was backfilled in June 2003 and the tunnel plug with two lead-troughs was cast in September the same year.

Installed instrumentation is used to monitor processes and properties in the canister, buffer material, backfill and the near-field rock. The evolution will be followed for a long time.

Achievements

The data collection system comprises temperature, total pressure, pore water pressure, relative humidity and resistivity measurements in buffer and backfill, as well as temperature and water pressure measurements in boreholes in the rock around the tunnel. The collection of data is in progress and the data report No. 20 covering the period up to December 2008 has been published /Goudarzi and Johannesson 2009/. A new data report covering the period December 2008 to June 2009 will be finalised. Overhauling of the data acquisition system is in progress.

Acoustic Emission and Ultrasonic monitoring from the rock around deposition hole 5 and 6 is continuing. Two new reports covering the measuring periods April 2008 to September 2008 and October 2008 to March 2009 have been finalised and will soon be published.

Studies using the thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been reported /Kristensson and Hökmark 2007/. A report concerning 1D THM modelling of the buffer in deposition hole 1 and 3 will soon be published. A report concerning a 3D TM model of the entire experiment is in progress. In this report the possibility of spalling is investigated and also the stress state on a thought fracture plan is studied. The THM modelling of the Prototype Repository according to the initial planning has been delayed.

Samples of gas and water from the buffer and backfill have been taken and some analyses have been made. The analyses of the samples will continue.

4.3 Long Term Test of Buffer Material

The project Long Term Test of Buffer Material (Lot) aims to validate models and hypotheses concerning mineralogy and physical properties in a bentonite buffer.

Seven test parcels containing heater, central tube, clay buffer, instruments and parameter controlling equipment have been placed in boreholes with a diameter of 300 mm and a depth of around 4 m.

The test concerns realistic repository conditions except for the scale and the controlled adverse conditions in four parcels.

Temperature, total pressure, water pressure and water content, are measured during the heating period. At termination of the tests, the parcels are extracted by overlapping core-drilling outside the original borehole. The water distribution in the clay is determined and subsequent well-defined mineralogical analyses and physical testing of the buffer material are made.

The test parcels are also used to study other processes in bentonite such as cation diffusion, microbiology, copper corrosion and gas transport under conditions similar to those expected in a deep repository.

Achievements

During the second four-month period 2009, all the equipment has been working well and data from the three ongoing test parcels have been collected and controlled, see Table 4-1. Detailed mineralogical analyses have been performed on the A2 parcel material. Further analyses are planned and the reporting of these will be made separately from the main report concerning the A2 test. Reporting and reviewing of the reports concerning the A2 and A0 tests have been ongoing during the period and will be finalised during the next period.

Table 4-1. Buffer material test series.

Type	No.	max T (°C)	Controlled parameter	Time (years)	Remark
A	1	130	T, [K^+], pH, am	1	Reported
A	0	120-150	T, [K^+], pH, am	1	Reported
A	2	120-150	T, [K^+], pH, am	5	Report on review
A	3	120-150	T	>>5	Ongoing
S	1	90	T	1	Reported
S	2	90	T	>5	Ongoing
S	3	90	T	>>5	Ongoing

A = adverse conditions, S = standard conditions, T = temperature, [K^+] = potassium concentration, pH = high pH from cement, am = accessory minerals added

4.4 Alternative Buffer Materials

Installation of one of the three parcels illustrating the mixing of the different compacted buffer discs.

In the Alternative Buffer Materials project different conceivable buffer materials are tested. The aim is to further investigate the properties of the alternatives to the SKB reference bentonite (MX-80).

The objectives are to:

- Verify results from laboratory studies during more realistic conditions with respect to temperature, scale and geochemical circumstances.
- Discover possible problems with manufacturing and storage of bentonite blocks.
- Give further data for verification of thermo-hydro-mechanical (THM) and geochemical models.

Eleven different clays were chosen to examine effects of smectite content, interlayer cations and overall iron content. Also bentonite pellets with and without additional quartz are being tested.

The field test started during 2006 and is carried out in the same way and scale as the Long Term Test of Buffer Material (Lot). Three parcels containing heater, central tube, pre-compacted clay, buffer, instruments and parameter controlling equipment have been emplaced in vertical boreholes with a diameter of 300 mm and a depth of 3 m.

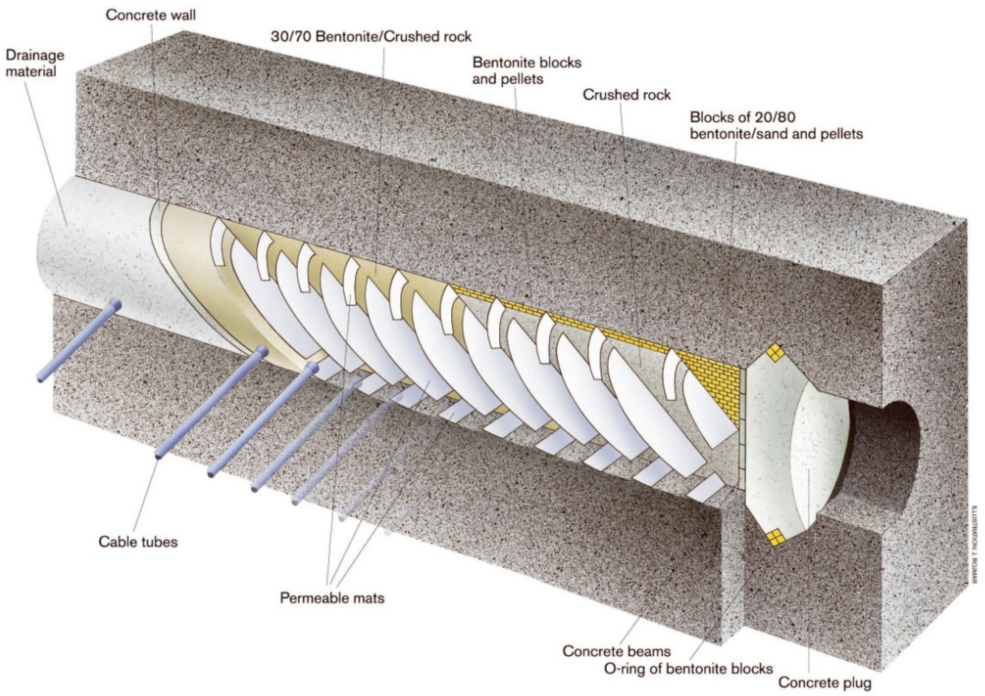
Achievements

Test package 1 was retrieved in May 2009 after about eighteen months test duration at the intended test temperature, 130°C. The technique used for retrieval was to drill bore holes in the rock around the bentonite blocks to a depth of 3.2 m (length of test package was 3.0 m). This seam drilling was then completed with two core drilled holes (diameter 300 mm) which were used for installation of a wire sawing equipment. It was possible to saw the bottom of the rock column with this equipment. The rock column including the bentonite blocks could then be lifted up on the ground. Immediately after retrieval, the work with division of the bentonite specimens started. Samples of the different bentonite materials have been sent out to all participating organisations (Nagra, Andra, BGR, JAEA, Posiva, RAWRA and AECL) that are going to contribute with analyses of the test materials. Preliminary results from the laboratory analyse shows that the clay from test package 1 is close to full saturation.

A report, describing the results from the work with characterisation of the reference materials, is under preparation.

Data from the two ongoing test packages have been collected and controlled during the period.

4.5 Backfill and Plug Test



The Backfill and Plug Test includes tests of backfill materials, emplacement methods and a full-scale plug. The inner part of the tunnel is filled with a mixture of bentonite and crushed rock (30/70) and the outer part is filled with crushed rock and bentonite blocks and pellets at the roof.

The integrated function of the backfill material and the near-field rock in a deposition tunnel excavated by blasting is studied as well as the hydraulic and mechanical functions of the full-scale concrete plug.

The entire test set-up with backfill, instrumentation and casting of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through filter mats started in late 1999.

The backfill was completely water saturated in 2003 and flow testing for measurement of the hydraulic conductivity was running between 2003 and 2006.

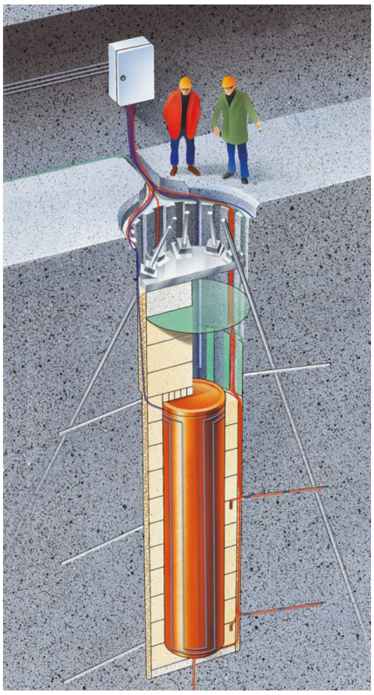
The monitoring comprise continuous measurements and registrations of water pressure and total pressure in the backfill and water pressure in the surrounding rock as well as leakage of water through the plug.

Achievements

The main work has included continuous measurements and registrations of water pressure and total pressure in the backfill and water pressure in the surrounding rock as well as leakage of water through the plug. Data covering the period up to 1st of January 2007 can be found in /Goudarzi et al. 2008/.

Measurement of local hydraulic conductivity in the zone with crushed rock through installed equipments (CT-tubes) is ongoing but delayed.

4.6 Canister Retrieval Test



The Canister Retrieval Test is aiming at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite is fully saturated.

In the Canister Retrieval Test two full-scale deposition holes have been drilled, at the -420 m level, for the purpose of testing technology for retrieval of canisters after the buffer has become saturated.

These holes have been used for studies of the drilling process and the rock mechanical consequences of drilling the holes.

Canister and bentonite blocks were emplaced in one of the holes in 2000 and the hole was sealed with a plug, heater turned on and artificial water supply to saturate the buffer started.

In January 2006 the retrieval phase was initiated and the canister was successfully retrieved in May 2006. The saturation phase had, at that time, been running for more than five years with continuous measurements of the wetting process, temperature, stresses and strains.

Achievements

Buffer analyses

The penetration of the lubricant, used when manufacturing the bentonite blocks, has been analysed. The results are shown in Figure 4-2 and Figure 4-3, where 0 mm is situated at the interface between the canister and the bentonite block.

When studying the profiles of the total fraction of carbon and sulphur, an approximate penetration of 5 mm from the interface can be seen. Thus, the mineralogical/chemical analyses performed on material closer then 5 mm from the interface are influenced by the presence of the lubricant and are consequently of limited value.

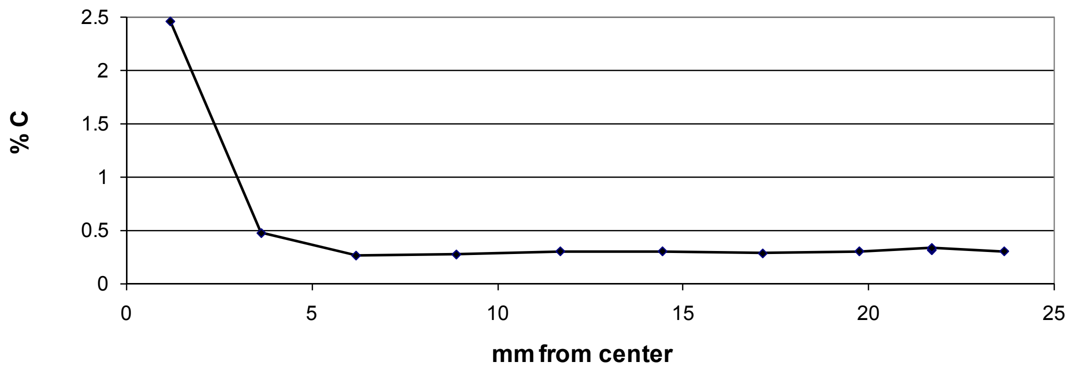


Figure 4-2. *Profiles of the total fraction of carbon.*

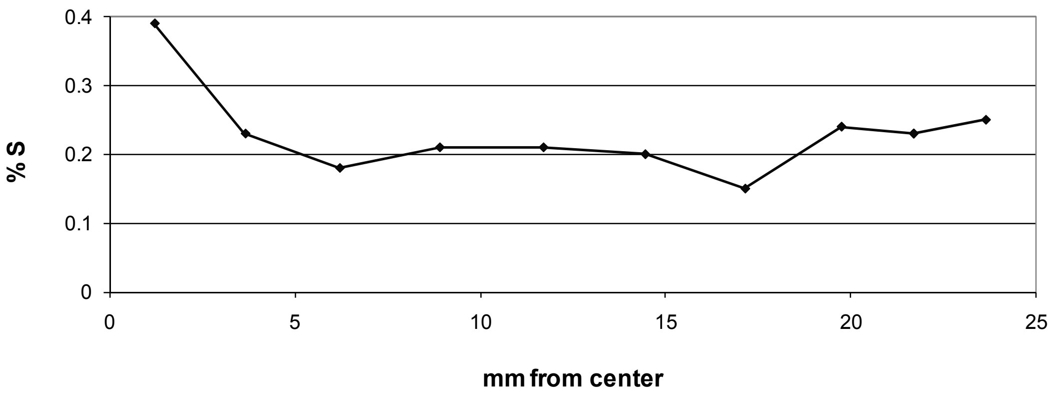


Figure 4-3. *Profiles of the total fraction of sulphur.*

Numerical modelling

In the Task Force on Engineered Barrier Systems the Canister Retrieval Test was selected to be one of the full scale assignments, see Section 4.1.3.

During the second four-month period, the EBS Task-Force teams have continued their modelling of the CRT experiment and presented their new results at the meeting held in Stockholm on the 25^{th}-26^{th} of May 2009.

Simulations of the thermal, hydraulic and mechanical processes in CRT are also a part of the safety assessment analysis (SR-Site). Much of the work presented in the context of EBS Task-Force will be the basis for the material to be reported in the safety assessment analysis concerning natural homogenisation. New simulations of the CRT experiment have also been performed exclusively for the safety assessment.

4.7 Temperature Buffer Test

The French organisation Andra carries out the Temperature Buffer Test (TBT) at Äspö HRL in co-operation with SKB.

The aims of the TBT are to evaluate the benefits of extending the current understanding of the THM behaviour of engineered barriers during the water saturation transient to include high temperatures, above 100°C.

The scientific background to the project relies on results from large-scale field tests on engineered barrier systems, notably Canister Retrieval Test, Prototype Repository and Febex (Grimsel Test Site).

The test is located in the same test area as the Canister Retrieval Test, which is in the main test area at the -420 m level.

The TBT experiment includes two heaters in the axis of the deposition hole, one on top of the other, separated by a compacted bentonite block. The heaters are 3 m long and 610 mm in diameter and are constructed in carbon steel. Each one simulates a different type of confinement system: a bentonite buffer only (bottom section) and a bentonite buffer with inner sand shield (upper section).

An artificial water pressure is applied in a slot between the buffer and rock, which is filled with sand and functions as a filter.

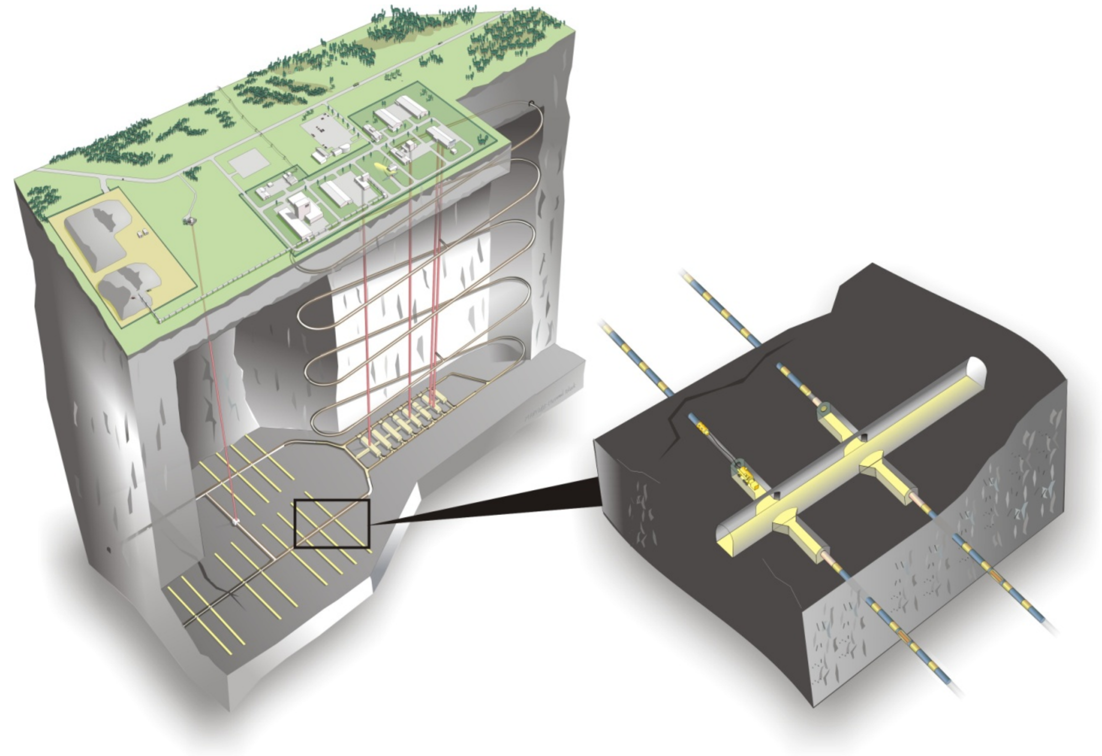
Data acquisition is continuously ongoing and data is transferred by a link from Äspö to Andra's head office in Paris.

Achievements

The TBT-test is in the operation and data acquisition phase since March 2003. Data acquisition is continuously ongoing and the data link from Äspö to Andra's head office in Paris has been functioning well. Data covering the period up to 1st of July 2008 can be found in /Goudarzi et al. 2009/. Four monthly data reports have been distributed during April-August 2009.

A planning meeting for the dismantling of the test was held in Lund on the 18th of June. The current plan is to perform a retrieval test of the upper heater, and to dismantle and sample the test during the period from the second half of October 2009 to February 2010. The first activity of the dismantling operation - "Termination of heating and filter hydration" - was started on schedule on the 17th of August.

4.8 KBS-3 Method with Horizontal Emplacement



The possibility to modify the reference KBS-3 method and make serial deposition of canisters in long horizontal deposition holes (KBS-3H), instead of deposition of single canisters in vertical deposition holes (KBS-3V), is studied in this project.

One reason for proposing the change is that the deposition tunnels in KBS-3V are not needed if the canisters are disposed in long horizontal deposition holes and the excavated rock volume and the amount of backfill can be considerably reduced. This in turn reduces the environmental impact during the construction of the repository and also the construction costs.

The site for the demonstration of the method is located at -220 m level. A niche with a height of about 8 m and a bottom area of 25×15 m forms the work area.

Two horizontal deposition holes have been excavated, one short with a length of about 15 m and one long with a length of about 95 m. The deposition equipment will be tested in the long hole and the short hole will be used for testing of different drift components.

The project is a joint project between SKB and Posiva. Now the next phase of the project "Complementary studies of horizontal emplacement KBS-3H" goes on. The main goal of the complementary studies (2008-2010) is to develop the KBS-3H solution to such a state that the decision on full-scale testing and demonstration can be made.

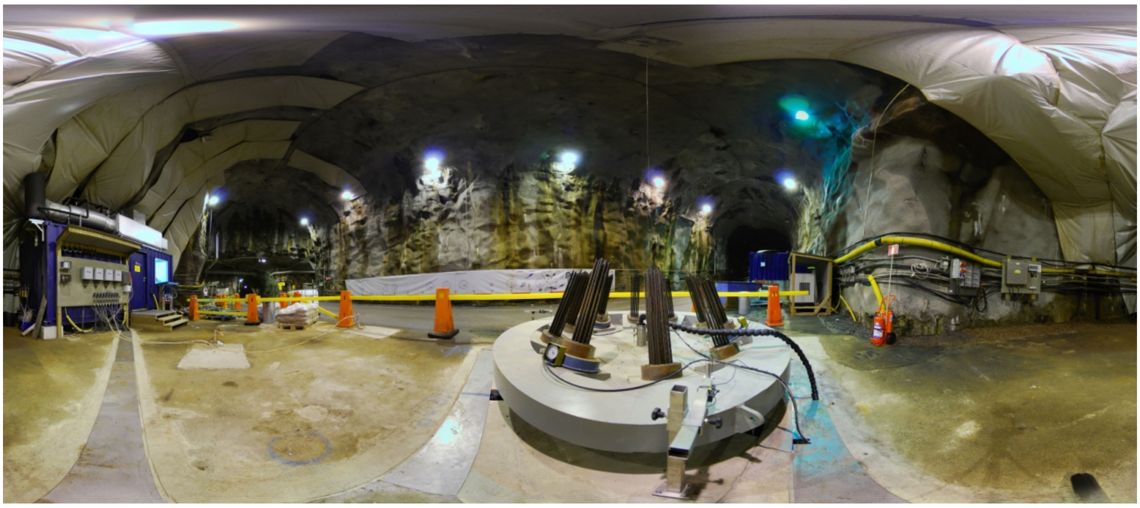
Achievements

The compartment plug was installed in the beginning of 2009 and during the first test of the compartment plug in February, it was quickly established that the leakage was quite high. For that reason, the first test was terminated after less than two weeks. The order of the test sequence was discussed and it was decided to update the test plan and perform test two (grouting) before test three (pellet filling behind the plug).

Silica sol grouting of the casting was conducted successfully in June 2009. During the summer, natural pressure had built up behind the plug and no leakage could be observed. Pressurisation of the compartment plug will show if the grouting is fully functional also at 5MPa.

The work with the full-scale test plan for the next KBS-3H project phase 2011-2014 has begun. The organisation for the work is being built and should be up and running in the fall of 2009.

4.9 Large Scale Gas Injection Test



Panorama of the Large-scale gas injection test (Lasgit) 420 m below ground at Äspö HRL.

Most knowledge pertaining to the movement of gas in a compacted bentonite buffer is based on small-scale laboratory studies. These diagnostic tests are designed to address specific issues relating to gas migration and its long-term effect on the hydro-mechanical performance of the buffer clay.

Laboratory studies have been used to develop process models to assess the likely implications of gas flow in a hard-rock repository system. While significant improvements in our understanding of the gas-buffer system have taken place, a number of important uncertainties remain. Central to these is the issue of scale and its effect on the mechanisms and process governing gas flow in compact bentonite.

The question of scale-dependency in both hydration and gas phases of the test history are key issues in the development and validation of process models aimed at repository performance assessment. To address these issues, a Large Scale Gas Injection Test (Lasgit) has been initiated.

Its objectives are:

- Perform and interpret a large scale gas injection test based on the KBS-3V design concept.
- Examine issues relating to up-scaling and its effect on gas migration and buffer performance.
- Provide information on the process of hydration and gas migration.
- Provide high-quality test data to test/validate modelling approaches.

In February 2005 the deposition hole was closed and the hydration of the buffer initiated.

Thereafter preliminary hydraulic and gas transport tests were performed. These will be repeated as the buffer matures in order to examine the temporal evolution of these properties. Comprehensive series of gas injection tests will be undertaken in the saturated buffer to examine the mechanisms governing gas flow in KBS-3 bentonite.

Achievements

The second four-month period of 2009 began with recalibration of the system in preparation for a stage of gas testing (day 1,577; May 28). A known quantity of neon gas was introduced into the interface vessel and then increased in pressure equal to that observed in the injection filter FL903 (1,300 kPa). This resulted in neon moving into solution within the pore fluid. During this time the gas pressure was held constant (for approximately 4 weeks) until stability was achieved.

Gas testing was initiated on day 1,606 with a 9 day constant flow gas injection stage in order to increase the gas pressure to the target value of 2,550 kPa. Preliminary analysis of the data suggests that gas flow into the clay occurred early in the test history (Figure 4-4), indicating that the gas pressure in FL903 exceeded the entry pressure.

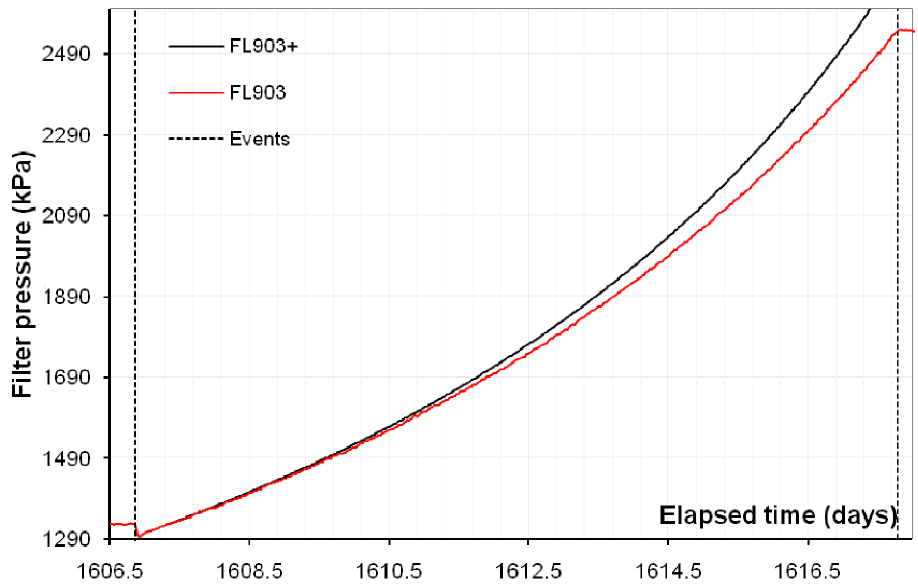


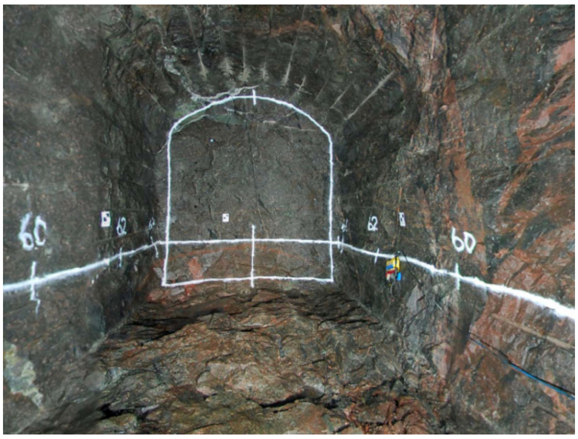
Figure 4-4. *Measured gas pressure in filter (FL903) and predicted (FL903+) indicating that gas entry occurred very early.*

Once the injection was stopped at 2,550 kPa and pressure held constant, flow into the clay greatly reduced. Pressure was held constant for approximately 12 days. This was followed by the second stage of gas testing which begun on day 1,632. As before, this step involved a constant flow stage resulting in the gas pressure rising to 3,800 kPa (after approximately 9 days).

This was followed by a constant pressure stage. As seen previously, flow in to the clay greatly reduced during the change from constant flow to constant pressure. On day 1,659 (August 18) the interface vessel was recharged with neon gas in order to have sufficient gas to complete testing. However, for the remainder of August the pressure in the test system was held constant in order to allow the increased volume of neon gas to stabilise.

By the end of the second four-month period, Lasgit had been in operation for 1,673 days.

4.10 Sealing of Tunnel at Great Depth



The Tass-tunnel in Äspö HRL

Although the repository facility will be located in rock mass of good quality with mostly relatively low fracturing, sealing by means of rock grouting will be necessary. Ordinary grouts based on cement cannot penetrate very fine fractures and due to long term safety reasons a sealing agent that produces a leachate with a pH below 11 is preferred.

Silica sol, which consists of nano-sized particles of silica in water, has shown to be a promising grout, and in the sealing project at Äspö HRL, the use of silica sol is tested at great depth. Low-pH cementitious grouts will also be used and evaluated.

Another issue for the planned repository is the contour and status of the remaining rock after blasting. Drilling and blasting are given special attention and subsequent adjustments aim at successive improvements.

Achievements

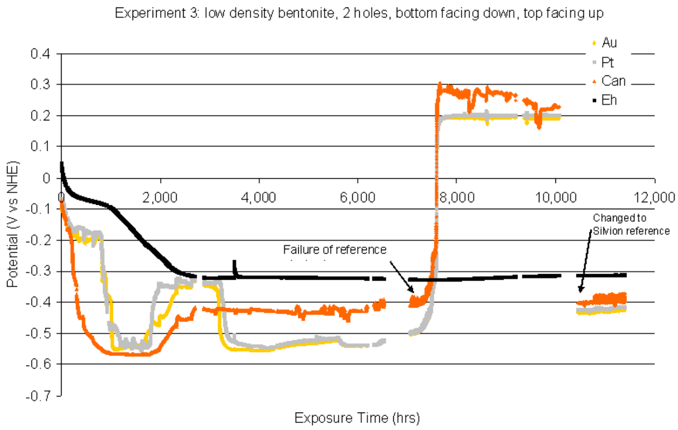
During the period, post-grouting was undertaken along pre-grouting fan number 4. Post-grouting is generally considered a difficult task. In the current case this was extra pronounced due to the big depth with high pressures and steep groundwater gradients. The actual grouting becomes more difficult and the work environment needs extra consideration.

The grouting consisted of systematic roof and bottom fans. The fans were designed to penetrate the fractures judged not yet to be sealed. Four meter packers were used to get the grout further out than the pre-grouting, in order to avoid erosion and backflow of grout. In one grouting hole, an inflow of about 50 litres per minute was registered, which again shows that the rock mass surrounding the Tass-tunnel is at least partially fairly wet. After the systematic grouting, singular holes that were leaking were re-grouted.

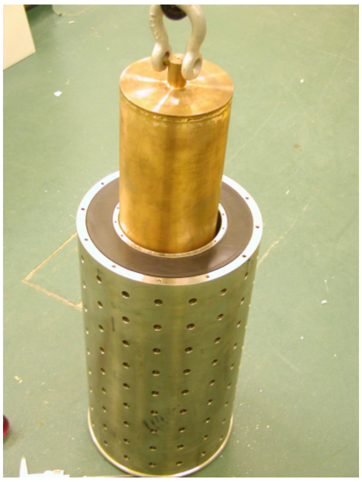
After filling the measuring weir the readings on June 8th implied that the flow was stabilised at 1 litre per minute and 60 meter tunnel, which means that the inflow goal, taking into account the whole tunnel, was reached. However, later measurements have shown an increase of the inflow to the post-grouted tunnel section. Further measurements and observations of the rock walls and floor are needed to evaluate potential reasons for the change and to decide on any further action. Meanwhile, it is observed that the tunnel sections that are not post-grouted, still fulfil the tightness requirements. This also includes the inner section where grouting holes were only drilled within the contour.

A report covering the grouting is now available (in Swedish) /Funehag 2008/ and a report covering the excavation will be available shortly (in Swedish). Final reports are scheduled for 2010.

4.11 In Situ Corrosion Testing of Miniature Canisters



Example of electrochemical potential data obtained from one miniature canister.



Miniature canister with support cage

The MiniCan project is designed to provide information about how the environment inside a copper canister containing a cast iron insert would evolve if failure of the outer copper shell were to occur. The development of the subsequent corrosion in the gap between the copper shell and the cast iron insert would affect the rate of radionuclide release from the canister. The information obtained from the experiments will be valuable in providing a better understanding of the corrosion processes inside a failed canister.

Miniature canisters with a diameter of 14.5 cm and containing 1 mm diameter defects in the outer copper shell have been set up in five boreholes with a diameter of 30 cm and a length of 5 m at Äspö HRL. All five canisters were installed in the beginning of 2007.

The canisters are mounted in support cages, four of which contain bentonite (three low density bentonite, one compact bentonite), and are exposed to natural reducing groundwater. Together with corrosion test coupons which are also in the boreholes, the canisters will be monitored for several years. The corrosion will take place under realistic oxygen-free conditions that are very difficult to reproduce and maintain for long periods of time in the laboratory.

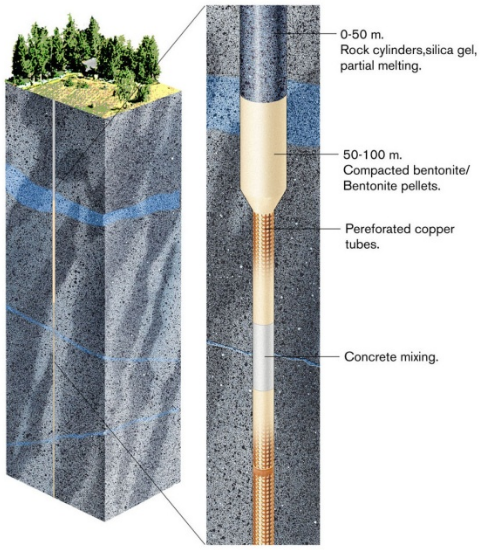
Data are transferred regularly to the UK for analysis through the internet link.

Achievements

During the second four-month period, monitoring of the miniature canister experiments has continued. Data are being collected for the corrosion rate of copper and iron electrodes, and electrochemical potentials are being recorded for a range of electrodes, including Eh, gold, platinum, iron and copper. In addition, strain gauge data are being collected for two of the canisters. Water analyses, including analyses of gases and the microbial content of the water, were carried out regularly up to the autumn of 2007. The experiment was then left to reach equilibrium for approximately one year and a new set of sampling was carried out in October 2008. These data are included in an internal progress report which is soon to be finalised. A steering group meeting has been held to plan further analyses. The steering group decided to remove one of the experiments (canister 3) in order to assess the extent of any corrosion processes and to validate the electrochemical measurements obtained to date.

A technical report on the set up of the experiments and the results obtained up to May 2008 will soon be printed and an internal progress report containing data obtained up to spring 2009 is in preparation. Notes from the steering group meeting are being prepared.

4.12 Cleaning and Sealing of Investigation Boreholes



The project dealing with identifying and demonstrating the best available techniques for cleaning and sealing of investigation boreholes was initiated in 2002 and up to now Phase 1 to 3 have been finalised.

Phase 4 aims to give principles for selecting strategic positions of plugs in boreholes for preventing axial flow by use of clay material and cement-based plugs and focuses on:

- Characterisation and planning of borehole sealing
- Quality assessment and detailed design

The specific goal is to collect available characterisation data of selected reference boreholes for working out generalised rock structure models and for planning sealing of boreholes.

A number of representative boreholes will be considered and those suitable for sealing will be divided into categories for which conceptual designs will be worked out. The project will select boreholes at Äspö, Laxemar and Forsmark for detailed design. The holes should represent typical rock conditions with respect to frequency, size and properties of permeable and unstable fracture zones.

Achievements

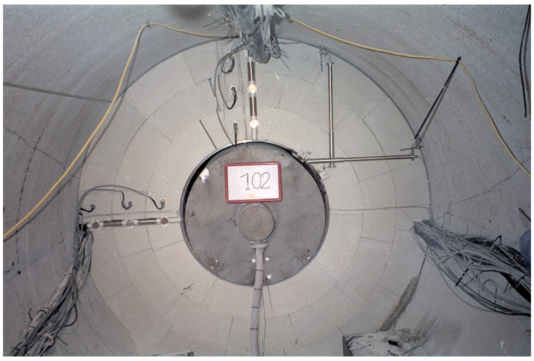
The basis for locating borehole plugs of concrete and clay has been defined and specified for a number of typical bore holes at Laxemar and Forsmark. Seven reference holes have been selected and suitable plug positions in them identified, based on the nature and size of intersected hydraulically important fracture zones.

The importance of the sealing efficiency as a function of time has been investigated by calculating the change in piezometric pressure in a typical borehole left open and sealed by plugs of different quality. This work certified that long-lasting plugs installed in suitable positions is required for avoiding short-circuiting of the rock mass between the repository and the ground surface.

Design of plugs for adequate performance has required careful definition of sufficient length with respect to the hydraulic performance of the near-field as calculated by DFN modelling. This work also included consideration of practical issues, like the required time for installation and documentation of each plugging event. Frequent variation in plug design may cause very high cost and poor plug quality.

Assessment of constructability and long-term performance is currently under way. Pilot tests have been made for simplifying installation of clay plugs by coating them with inorganic paste in order to delay hydration, and using clay mud for stabilising the boreholes and reducing erosion in the installation phase. Investigation of the possibility to eliminate organic fluidizers by using inorganic mineral components has been initiated.

4.13 Task Force on Engineered Barrier Systems



The Task Force on Engineered Barrier Systems (EBS) is a continuation of the modelling work in the Prototype Repository Project, where also modelling work on other experiments concerning both field and laboratory tests is conducted. The Äspö HRL International Joint Committee has decided that in the first phase of this Task Force (initiated 2004) work should concentrate on:

- Task 1 THM modelling of processes during water transfer in buffer, backfill and near-field rock. Only crystalline rock is considered initially, although other rock types could be incorporated later.
- Task 2 Gas migration in saturated buffer.

The objectives of the Tasks are to: (a) verify the capability to model THM and gas migration processes in unsaturated as well as saturated bentonite buffer, (b) refine codes that provide more accurate predictions in relation to the experimental data and (c) develop the codes to 3D standard (long-term objective).

Participating organisations besides SKB are at present Andra (France), BMWi (Germany), CRIEPI (Japan), Nagra (Switzerland), Posiva (Finland), NWMO (Canada) and RAWRA (Czech Republic). All together 12-14 modelling teams are participating in the work.

Since the Task Force does not include geochemistry, a decision has been taken by IJC to also start a parallel Task Force that deals with geochemical processes in engineered barriers. The two Task Forces have a common secretariat, but separate chairmen.

Achievements

Task Force THM/Gas

The work with modelling of the Canister Retrieval Test (CRT) at Äspö HRL has continued during the second four-month period of 2009. Altogether eight modelling teams are modelling this test.

The task to model CRT is divided into two parts where the first part is to model the thermo-hydro-mechanical behaviour of a central section of the test hole with given boundary conditions. The second task is to model the whole test. Most teams have finished the first part and have during this period been modelling the entire test.

The new task common with the Task Force on Modelling of Groundwater Flow and Transport of Solutes that focuses on the hydraulic interaction between the rock and the bentonite has been further developed. The main project goals are the following:

- Scientific understanding of the exchange of water across the bentonite-rock interface.
- Better predictions of the wetting of the bentonite buffer.
- Better characterisation methods of the canister boreholes.

A Task Force meeting was held in Stockholm in May where the results from mainly modelling of CRT were presented.

Task Force Geochemistry

Results from simple 1D laboratory diffusion and ion exchange experiments performed at Clay Technology were presented at the Task Force meeting in Stockholm in May. The results were subsequently distributed to the participating groups as benchmark modelling tasks.

Molecular dynamics (MD) have been used in order to study Donnan equilibrium between hydrated montmorillonite and an external saline solution, and reporting in the form of a scientific article is ongoing. Further, scoping calculations have been performed, and a theoretical base has been worked out for MD simulations of diffusive transport from one interlayer structure to another.

A main purpose with the meeting in Stockholm was to present the ion equilibrium theory for Carl Steefel and to discuss how it could be implemented in the geochemical reactive transport code Crunchflow of which Carl is the principle developer.

5 Äspö Facility

5.1 General

The Äspö facility comprises the Äspö Hard Rock Laboratory and the Bentonite Laboratory, the later taken into operation in 2007. The Bentonite Laboratory complements the underground Hard Rock Laboratory and enables full-scale experiments under controlled conditions making it possible to vary experimental conditions and to simulate different environments.

In May 2009 part of the Äspö operation underwent an organisational change as the units *Äspö Hard Rock Laboratory* (TD) and *Repository Technology* (TU) within the Technology department were united. This change was done to focus the remaining development of the repository technology and performing of experiments and tests in a realistic repository environment at Äspö HRL. The new and larger unit inherited the name *Repository Technology.* Äspö HRL is the residence of Repository Technology but the unit includes employees in both Äspö and Stockholm. The main responsibilities of Repository Technology are to:

- Perform technical development commissioned by SKB's programmes for nuclear fuel and for low- and intermediate level waste
- Develop the KBS-3H concept
- Perform experiments in the Äspö HRL
- Secure a safe and cost effective operation of the Äspö HRL
- Prosecute comprehensive visitor services and information activities in the Oskarshamn area

The Repository Technology unit is organised in five operative groups and an administrative staff function:

- *Geotechnical engineering and rock engineering (TDG),* responsible for the development, testing and demonstration of techniques for installation of buffer, backfill and plugs. The development, testing and demonstration of techniques for backfilling the final repository and plugging of investigation boreholes are also part of the responsibilities within the group.
- *Mechanical- and system engineering (TDM),* responsible for the development, testing and demonstration of equipment, machines and vehicles needed in the final repository.
- *Project and experimental service (TDP),* responsible for the co-ordination of projects undertaken at the Äspö HRL, providing services (administration, design, installations, measurements, monitoring systems etc.) to the experiments.
- Public relations and visitor services (TDI), responsible for presenting information about SKB and its facilities with main focus on the Äspö HRL.

- *Facility operation (TDD),* responsible for the operation and maintenance of the Äspö HRL offices, workshops and underground facilities and for development, operation and maintenance of supervision systems.
- *Administration, quality and planning (TDA*), responsible for planning, reporting, QA, budgeting, environmental co-ordination and administration. The staffing of the Äspö reception and the SKB switchboard are also included in the function.

Each major research and development task carried out in Äspö HRL is organised as a project led by a Project Manager reporting to the client organisation. Each Project Manager is assisted by an on-site co-ordinator with responsibility for co-ordination and execution of project tasks at the Äspö HRL. The staff at the site office provides technical and administrative service to the projects and maintain the database and expertise on results obtained at the Äspö HRL

5.2 Bentonite Laboratory

Lifting of test buffer blocks in full scale

Before building a final repository, where the operating conditions include deposition of one canister per day, further studies of the behaviour of the buffer and backfill under different installation conditions are required.

SKB has built a Bentonite Laboratory at Äspö, designed for studies of buffer and backfill materials. The laboratory, a hall with dimensions 15×30 m, includes two stations where the emplacement of buffer material at full scale can be tested under different conditions. The hall is used for testing of different types of backfill material and the further development of techniques for the backfilling of deposition tunnels.

Achievements

Tests concerning impact of water inflow on backfill have continued during the second four-month period of 2009. In two tests, the time for breakthrough and the amount of inflow of water have been measured. Preparations for a third test have started and the test will be implemented in the autumn. The third test will have a 'dry' section of block and pellet backfill installed in the rear of the chamber (nominally 2 m length). In front of this section a 2 m section of very wet (near saturation) pellets is situated. Two inlet points will be installed in the dry section.

The aim of the test is to investigate the effect on water uptake and pressurisation of gas/water in the dry section. This may be the case for a dry section of a tunnel that is hydraulically isolated by another section where inflow has resulted in saturation of the pellet-filled region. Of greatest concern is the potential for substantial pressurisation of the air in the dry section. This pressurisation leads to a risk of high pressure out gassing if the gas subsequently finds a pathway through the backfill or along the pellet-rock interface.

Eight tests on a pilot scale have been performed. The objective with these tests was to study the mechanisms that control the migration and distribution of water entering pellet fills from water-bearing rock fractures in order to get a deeper understanding of the flow of water along the pellet-rock interface.

The tests performed during this period will be reported in the end of the year when all tests are finished.

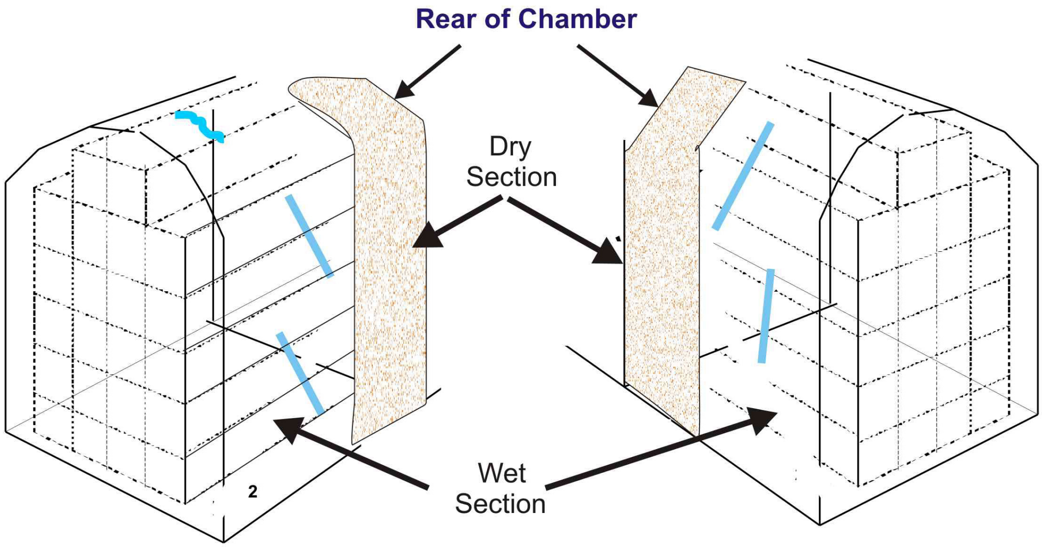
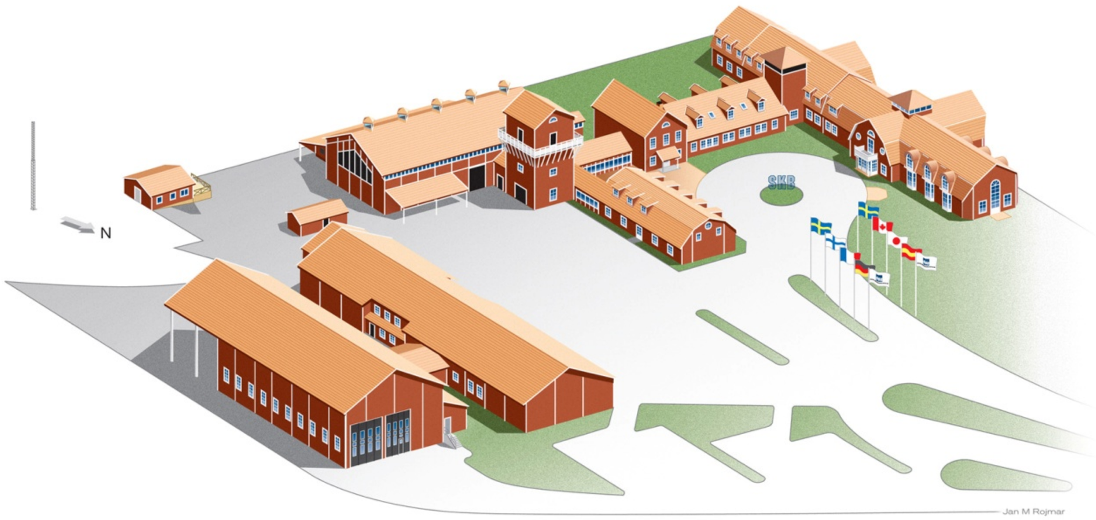


Figure 5-1. *Test set-up in half-scale.*

5.3 Facility Operation



The main goal for the operation is to provide a safe and environmentally sound facility for everybody working or visiting Äspö.

This includes preventative and remedial maintenance in order to ensure that all systems such as drainage, electrical power, ventilation, alarm and communications have a high degree of availability.

Achievements

The operation of the facility during the second four-month period of 2009 has been stable, despite the large workload. The summer's activities and visits to the facility have worked out very well. Alarms were set off a number of times by thunder and lightning and had to be dealt with by emergency personnel. In order to avoid failures, a number of lightning-protectors have been installed at important points in the facility.

The work with facility documentation is ongoing and will continue for the rest of the year. Most of the drawings and instructions need to be updated.

A major rock inspection has been carried out according to the rock maintenance-plan, but the results of the inspection are not yet available.

In addition, a heated storage space for bentonite has been rented in Oskarshamn. A environmental station for the Äspö laboratories and the site-investigation office has been set up by the tunnel entrance ramp. The road to Äspö island has been widened in places and road-barriers have been built.

5.4 Public Relations and Visitor Services

SKB operates three facilities in the Oskarshamn municipality: Äspö facility, Central interim storage facility for spent nuclear fuel (Clab) and the Canister Laboratory. In 2002 site investigations started at Oskarshamn and Östhammar.

The main goal for the Public Relations and Visitor Services group is to create public acceptance for SKB, which is done in co-operation with other departments at SKB. The goal will be achieved by presenting information about SKB, the Äspö facility, and the SKB siting programme on surface and underground. Furthermore the team is responsible for visitor services at Clab and the Canister Laboratory.

In addition to the main goal, the information group takes care of and organises visits for an expanding amount of foreign guests every year. The visits from other countries mostly have the nature of technical visits.

As from autumn 2008 the team also has the responsibility for the production of SKB's exhibitions; stationary, temporary and on tour.

The information group has a special booking team at Äspö which books and administrates all visitors. The booking team also is at OKG's service according to agreement.

Achievements

SKB facilities have been visited by 7,776 persons during May-August 2009 and in total 14,745 persons during the first eight months of 2009. The numbers of visitors to SKB's main facilities are listed in Table 5-1.

The guided summer-tours "Urberg 500" started at the end of June and ended August 21st. During the weeks 27-28, there were no guided tours offered due to maintenance work within the facility. The number of visitors was 2 ,215 persons, which means 122 persons less compared to 2008.

There have been a number of VIP-visits during the period, e.g. the European Atomic attachés meeting, which took place July 13-15. All facilities in Oskarshamn were visited. The meeting was an arrangement within the Swedish Presidency of the European Union.

The information group has been engaged in different PR activities related to the site selection of Forsmark in June and M/S Sigyn, SKB's transport vessel, on tour in June-July.

The planning for coming events has started during the period, e.g. "*Researchers Night 2009*" on September 25th and in November "*The Environmental Day* "in cooperation with Äspö Environmental Research Foundation. A growing interest from foreign visitors has been noticed and arrangements for managing this are to start up during the autumn of 2009.

Table 5-1. Number of visitors to SKB facilities.

SKB facility	Number of visitors May-August 2009
Central interim storage facility for spent nuclear fuel	535
Canister Laboratory	554
Äspö HRL	3,829
Final repository for radioactive operational waste (SFR)	2,636

6 Environmental research

6.1 General

Äspö Environmental Research Foundation was founded 1996 on the initiative of local and regional interested parties. The aim was to make the underground laboratory at Äspö and its resources available for national and international environmental research. The activities have since 2003 been concentrated to the Äspö Research School. When the activities in the school was concluded as planned in 2008, the remaining and new research activities were transferred within the frame of a new co-operation, Nova Research and development (Nova FoU).

6.2 Nova Research and Development (Nova FoU)

SKB wants to broaden the use of knowledge and data gathered within the SKB research programme. Nova FoU (www.novafou.se) is the organisation which implements this policy and facilitates external access for research and development projects to SKB facilities in Oskarshamn. Nova FoU is a joint research and development platform at Nova Centre for University Studies in Oskarshamn.

Nova FoU provides access to the following SKB facilities:

- Äspö Hard Rock Laboratory
- Bentonite Laboratory at Äspö
- Canister Laboratory in Oskarshamn
- Site Investigation Oskarshamn (Laxemar)

Nova FoU can co-finance the projects by valuing the access to the SKB facilities, knowledge and data. The aim with the research and development projects through Nova FoU is to create long term spin-offs and business effects beneficial to the region. Nova FoU supports new and innovative research, for example environmental studies, where the extensive SKB data set from geological, hydrogeological, hydrogeochemical and ecological investigations and modelling can be used (Figure 6-1).

The research and education programme is the most matured activity within Nova FoU and the activities within the Geochemistry Research Group are described in more detail in Section 6.2.1.

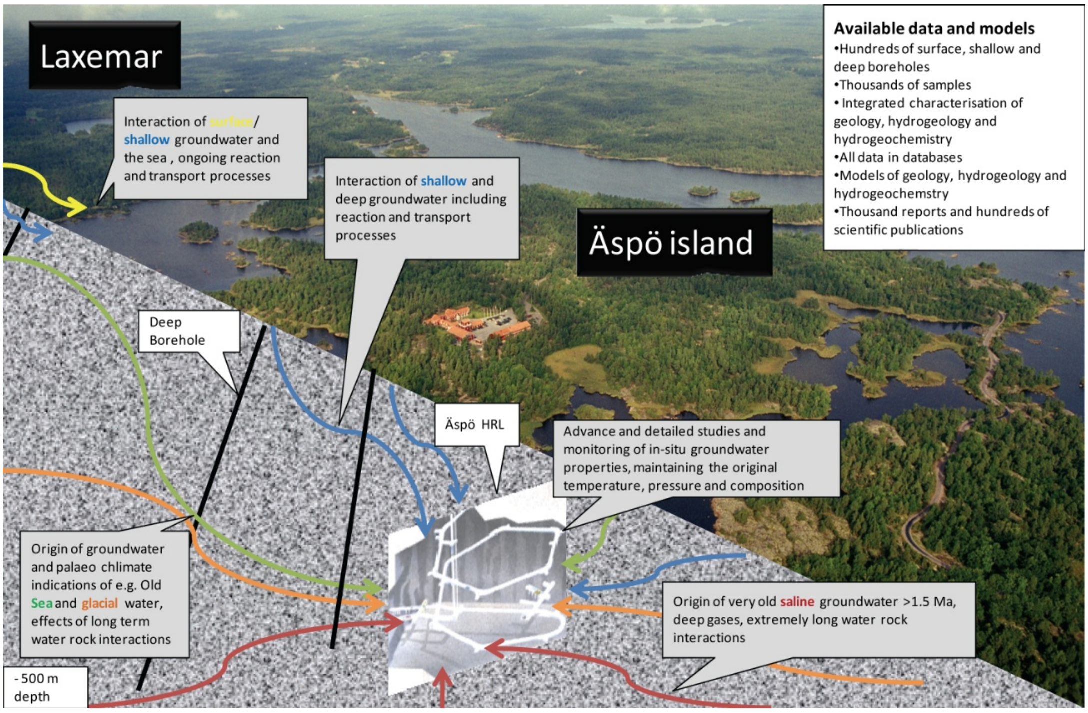


Figure 6-1. *The Äspö and Laxemar areas have been studied in terms of geology, hydrogeology, hydrogeochemistry and ecology. This information can be used for a number of purposes, for example to describe the water cycle and hydrogeochemical processes in 3D.*

The data can be used e.g. for assessing the consequences of natural resource management and pollution risks. The data and models can be used to estimate exposure both at individual and population levels. Development of monitoring and analytical systems can be performed relating to the management of various renewable natural resources in, for instance, agriculture, fisheries, forests and groundwater. Studies which give a better knowledge concerning pollution problems coupled to toxicological and epidemiological issues are possible. Technology, innovations and spin-off effects at pre-market stages are of special interest.

Other possible studies are:

- Groundwater origin, mixtures and evolution
- Interaction between large depths, surface and sea
- Model and technology development
- Tunnel and borehole experiments

Achievements

Ongoing research and development projects, new project activities and marketing activities at Nova FoU are given in Figure 6-2.

Ongoing projects:

- Research and education
- Microbial project
- Coastal modelling
- 3D-identification system (RFID)
- Commercialisation of existing SKB-technique

Marketing activities:

- Marketing meetings with EU, Vinnova, Formas, Mistra, VR
- Marketing activities together with SKB to invite universities
- Identification of research teams

New activities:

- RFID fire protection
- Microbial project (Univ. of Göttingen)
- Formation of an expert group
- Master education for nuclear power and final disposal
- Social research, spatial and time research (Univ. of Göteborg)
- Water management
- Energy efficiency
- Geology and health
- Geosphere institute at Äspö
- EU-project
- VR-project
- Added value discussion
- Monitoring programme for Laxemar

Figure 6-2. *Ongoing projects and activities at Nova FoU.*

6.2.1 Geochemistry Research Group

Surface water sampling point at Laxemar catchments area

The Geochemistry Research Group at Äspö HRL is a project within the research platform Nova FoU. The group consists of a professor, a post doc and three Ph.D. students.

Focus is on research of chemical elements in soil, water, bedrock fractures and biota, and includes detailed studies of how elements are distributed in streams and groundwaters at various depths. The research includes field monitoring, laboratory work and modelling.

Achievements

A major progress during the period was that two new persons were hired to participate in the research group. Dr Henrik Drake was employed as a post doc and Tobias Berger as Ph.D. student. Drake's research will focus on characterisation of young fracture filling minerals, including pyrite and calcite, in bedrock cores drilled in Laxemar and Äspö. Ph.D. student Berger will also work in Laxemar and Äspö and focus on hydrogeochemical studies of groundwaters and surface waters. He will initially work with characterisation of sources and pathways of fluoride, which occurs in exceptionally high concentrations e.g. in Kärrsviksån. After that he will continue to work on lanthanoids in the same area. Both Drake and Berger have had a strong start including detailed planning and successful sampling campaigns.

A seminar for Ph.D. students was arranged at Polstjärnan in Laxemar. Seven Ph.D. students from various universities throughout the country gave a presentation, as follows:

- Daniel Svensson, Lund University: Experiments with swelling clay resolved in time and space by synchrotron x-ray diffraction.
- Frédéric Mathurin, Kalmar University: Drilling water in boreholes: a first interpretation of its impact on the chemical composition of groundwater.
- Isabelle Dubois, Royal Institute of Technology: Model for Radionuclide Sorption: Ni on Chlorite.
- Christoffer Carstens, Royal Institute of Technology: Quantifying groundwater flow partitioning and delivery fractions in coastal catchments with combined quaternary and fractured rock aquifers - an early approach.
- Anna Augustsson, Kalmar University: Trace metals in recharge and discharge ground waters in Forsmark and Simpevarp.
- Fredrik Lidman, Umeå University: Uranium isotopes as a tool to study radionuclide transport across the geosphere-biosphere interface.
- Michael Holmboe, Royal Institute of Technology: Free porosity of compacted saturated MX-80 bentonite and Na-montmorillonite as a function of dry density - a XRD-study.

A total of 18 persons participated in the successful seminar.

7 International co-operation

7.1 General

In addition to SKB, eight organisations from seven countries participate in the co-operation at Äspö HRL during 2009, see Table 7-1. Six of them; Andra, BMWi, CRIEPI, JAEA, NWMO and Posiva together with SKB form the Äspö International Joint Committee (IJC), which is responsible for the co-ordination of the experimental work arising from the international participation.

Table 7-1. International participation in the Äspö HRL projects during 2009.

Projects in the Äspö HRL during 2009	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Nagra	RAWRA
Natural barriers								
Long Term Sorption Diffusion Experiment					X			
Colloid Transport Project (Part of Colloid Formation and Migration CFM)		X			X			
Microbe Project		X						
Task Force on Modelling of Groundwater Flow and Transport of Solutes			X	X	X	X		
Engineered barriers								
Prototype Repository		X				X		
Alternative Buffer Materials	X	X				X	X	X
Long Term Test of Buffer Materials					X	X	X	
Temperature Buffer Test	X							
KBS-3 Method with Horizontal Emplacement						X		
Large Scale Gas Injection Test	X	X			X			
Task Force on Engineered Barrier Systems	X	X	X		X	X	X	X

Participating organisations :
Agence nationale pour la gestion des déchets radioactifs, Andra, France
Bundesministerium für Wirtschaft und Technologie, BMWi, Germany
Central Research Institute of the Electronic Power Industry, CRIEPI, Japan
Japan Atomic Energy Agency, JAEA, Japan
Nuclear Waste Management Organisation, NWMO, Canada
Posiva Oy, Finland
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland
Radioactive Waste Repository Authority, Rawra, Czech Republic

As can be seen in Table 7-1 several of the participating organisations take part in the two Äspö Task Forces on: (a) Modelling of Groundwater Flow and Transport of Solutes, which is a forum for co-operation in the area of conceptual and numerical modelling of groundwater flow (Section 3.12) and solute transport in fractured rock and (b) THMC modelling of Engineered Barrier Systems, which is a forum for code development on THMC processes taking place in a bentonite buffer and gas migration through a buffer (Section 4.13). The proposal of a joint Task 8 of the two Task Force projects, related to modelling hydraulic interaction of rock and bentonite has been further discussed.

SKB also takes part in work within the IAEA framework. Äspö HRL is part of the IAEA Network of Centres of Excellence for training in and demonstration of waste disposal technologies in underground research facilities.

8 Documentation

During the period May – August 2009, the following reports have been published and distributed.

8.1 Äspö International Progress Reports

Hardenby C, Sigurdsson O, Hernqvist L, Bockgård N, 2008. The TASS-tunnel project "Sealing of tunnel at great depth". Geology and hydrogeology - Results from the pre-investigations based on the boreholes Kl0010B01, Kl0014B01, and Kl0016B01. SKB IPR-08-18, Svensk Kärnbränslehantering AB.

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8.2 Technical Documents and International Technical Documents

Two International Technical Documents have been published during the period May – August 2009.

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