

**International
Progress Report**

IPR-09-15

Äspö Hard Rock Laboratory

Status Report January – April 2009

Svensk Kärnbränslehantering AB

September 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 January to April 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 on-going 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

One of the goals 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 on-going 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 that was taken in operation in 1995 and 2007 respectively. An important part of the activities at the Äspö facility is 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 e.g. the Äspö HRL. 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. 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).

International co-operation

The Äspö HRL has so far 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.

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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 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 have to be divided between all the experiments performed at the Äspö HRL. In Figure 1-1, the allocation of the 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 January to April 2009. In the Annual Report more detailed information is given of new findings and results obtained during the whole year.

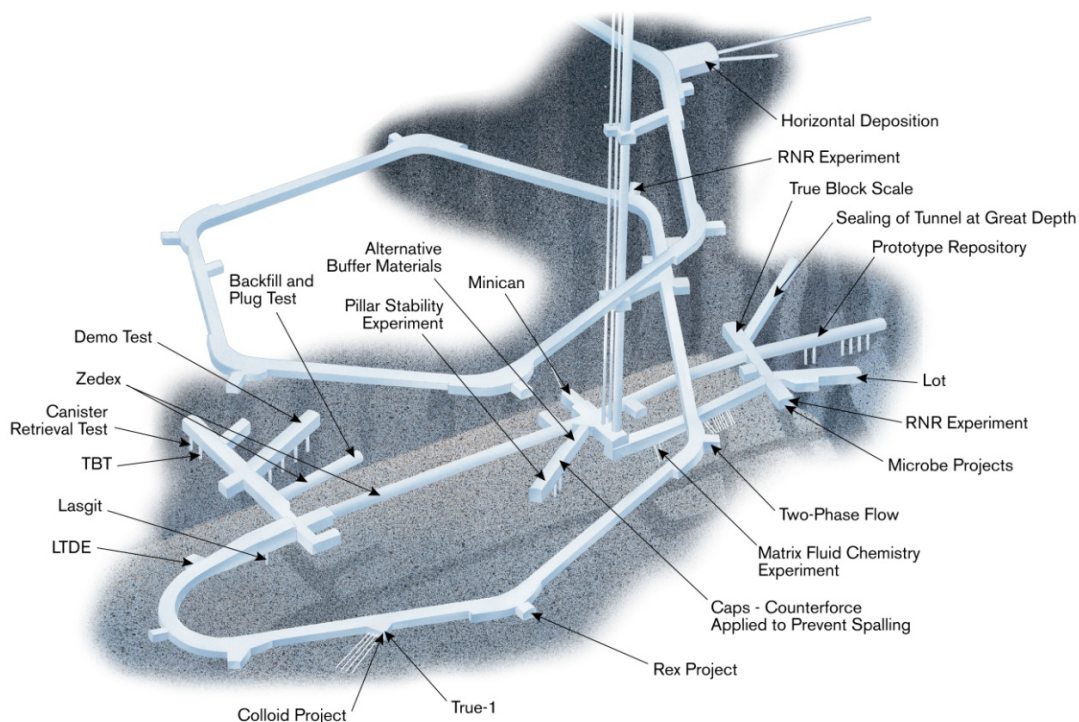


Figure 1-1. Overview of the Äspö HRL and the allocation of the experimental sites from -220 m to -450 m level.

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 of experiments and measurements related to geosciences.

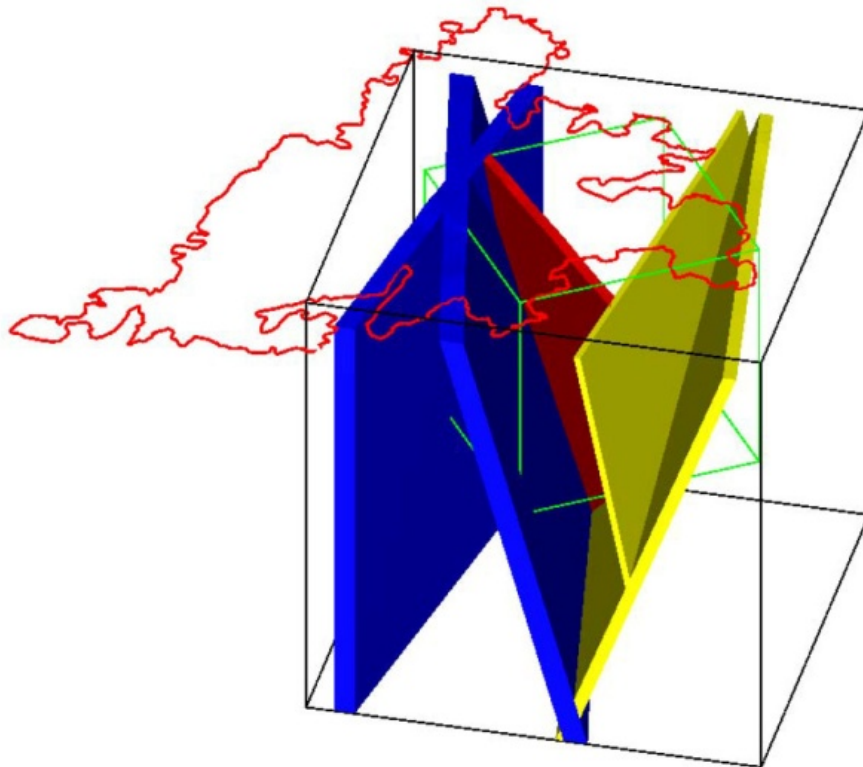


Figure 2-1. Schematic view of the Äspö Site Descriptive Model.

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



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.

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

Achievements

The main activities or achievements during the period January to April 2009 have been:

- The excavation of the Tass-tunnel (the tunnel for sealing fractures at great depth) is completed. Geological mapping of the tunnel (fronts, walls, roof and floor, including the EDZ-slot) has been completed, up to the end section 80.7 m. All data and drawings have been fed into the TMS (Tunnel Mapping System) and have together with photos been delivered to the Sicada archive.
- Laser scanning combined with digital photography has been performed in the entire Tass-tunnel (section 0 - 80.7 m), including the EDZ-slot. The laser data have partly been analysed and used for modelling work (see the Rocs project).
- The pre-investigation report concerning the Tass-tunnel has been returned to the authors after review and adjustments are on-going.
- 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 on-going.

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



Demonstration of the JointMetrix-3D photogrammetric system by using an ordinary digital camera mounted on a tripod.

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 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 new project plan is now approved. The documents concerning specification of requirements for various parts of the project have been sent for review; for example specification of requirements for the geological mapping and how to handle laser scan or photogrammetric data.

Four laser scanning events combined with digital photography in the Tass-tunnel have been completed and the data delivered. Scanning and digital photography has now been performed to the end of the tunnel (80.7 m). At the last event, scanning of the EDZ-slot also took place. The scan data has been used to create 3D-models of the Tass-tunnel. There have been some problems, however, in fitting the data from the various scanning events together. The work continues concerning tests of software to handle the laser data.

The company 3G Software & Measurement has demonstrated their photogrammetric system “JointMetrix-3D” in the Tass-tunnel, see figure above. The test gave promising and interesting results.

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 works 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.

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, Mjälén, 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 on-going. The monitoring points have been maintained and performed well, particularly the equipment installed in tunnel. A review of potential supporting and corrective measures for the surface borehole was performed and work for replacing the monitoring equipment from two surface drilled boreholes, KAS03 and KAS09 was initiated, see Figure 2-2. The extracted equipment in KAS09 was installed in April 1990 and part of it proved corroded and difficult to retrieve.



Figure 2-2. Mobilising for retrieval of monitoring equipment from borehole KAS09.

Due to the large number of experiments and activities in the tunnel, it is a delicate task to plan new activities so they do not adversely affect the on-going experiments. The HMS along with the Site Descriptive Model, are the tools that provide the basis for judgement in terms of likelihood on “what-if” scenarios. For example, this was provided for when assessing the impact of extraction of holes in the Alternative Buffer Material project (see section 4.4) and also for finding suitable boreholes for testing a newly developed pipe string system.

The monitoring is reported every four months in quality control documents and on an annual basis, describing the measurement system and basic results. The monitoring report covering year 2008 has been published /Wass and Nyberg 2009/.

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.

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 on-going experiments have the possibility to request sampling of interest for their projects.

Achievements

The yearly monitoring campaign for groundwater chemistry was conducted as planned during September and October 2008. Data are now quality assured and reported. Several boreholes in the upper bedrock (-50 to -100 m) were thus disregarded due to low groundwater pressures or failing packed-off sections.

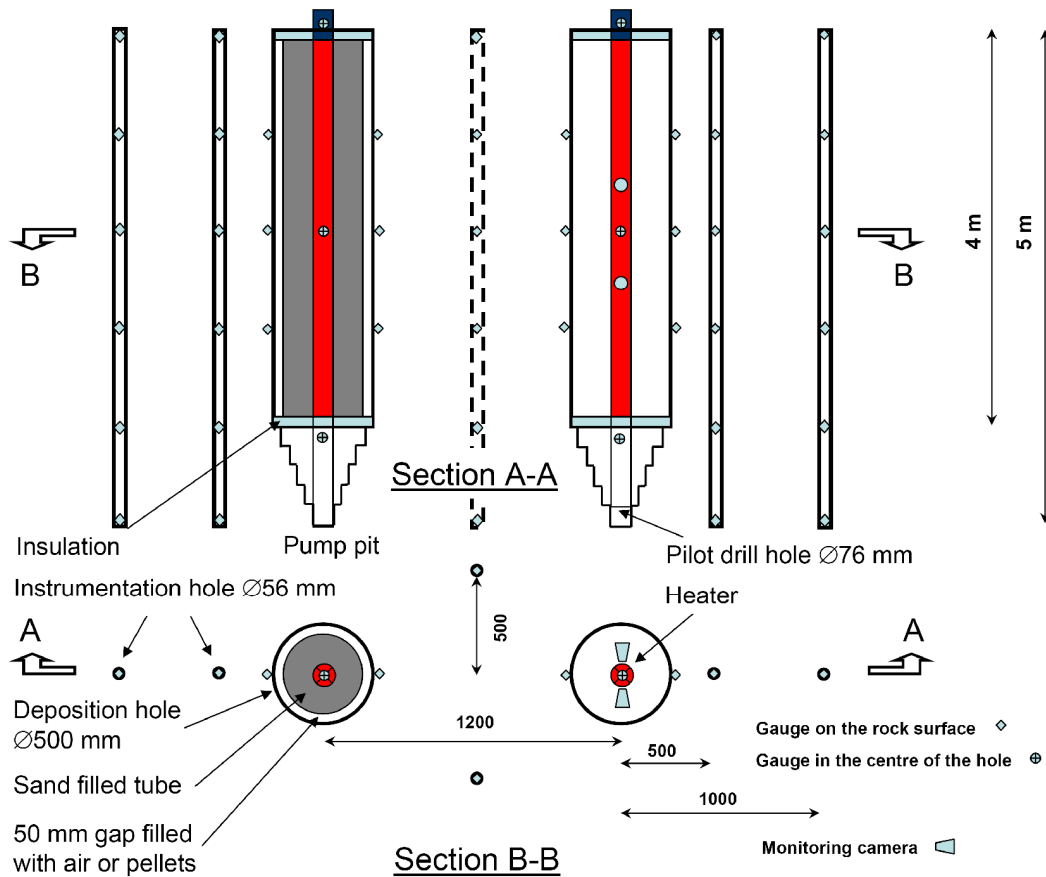
2.5 Rock Mechanics

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.

In addition, a project called Caps (Counterforce Applied to Prevent Spalling) comprising field test in Äspö HRL and numerical modelling is on-going.

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 tests, that include four pairs of heated half-scale KBS-3 holes, will be carried out as a series of demonstration experiments 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

The results from the third test, with a slot filled with Leca, indicated that dry pellets cannot prevent the borehole wall from cracking, whereas it might keep the rock slabs in place and by this preserving the geometry of the holes. The results have implied a focus on the hydraulic conductivity of the damaged zone and the intention is to determine a value of this parameter in the holes of the final heating test.

The final heating test was initiated in the mid of February 2009 and the heating continued during two months. Compared to previous test, the change of heating power was performed in a stepwise manner in this test to reduce the temperature gradient in the surrounding rock. The maximum temperature was reached in the end of March and the temperature had not reverted to ambient temperature in the end of April.

After revert to the ambient temperature the hydraulic conductivity of the damaged zone will be determined by injection tests in a number of core drill holes that intersects the damaged zone. The preparation for the injection tests has already started and the preliminary results from these tests are expected to be available in the beginning of June. In addition to the planned hydraulic tests, the evaluation of the results from the previous heating tests continues as well as the reporting of the field test.

3 Natural barriers

3.1 General

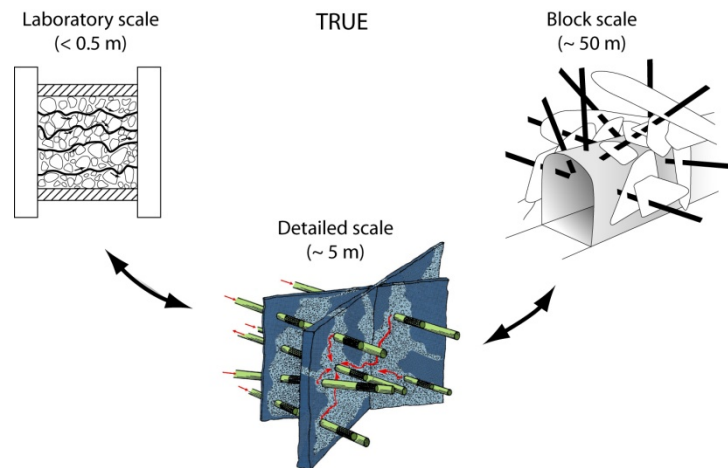
Experiments at the Äspö HRL, are performed at conditions that are expected to prevail at repository depth. The experiments are related to the rock, its properties and in situ environmental conditions (Figure 3-1). The goals are to increase the scientific knowledge of the safety margins of the repository 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

During the four-month period all three BS3 articles mentioned above have been formally submitted to Water Resources Research (WRR). Furthermore, a first incomplete draft of the article directed to Science has been completed, to be subject to internal review during the summer.

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 four months of 2009, with the exception of work performed within TRUE-1 Completion (see 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 on-going 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

In January a reference group meeting was held with the purpose to discuss the analysis plan of the cores from KXTT3 and KXTT4 in relation to the project budget. In order to agree with the project means it was decided that the analyses should focus on the target structure Feature A in KXTT4 and the amount of analyses for Feature A' in KXTT4 and Feature A in KXTT3 should be reduced. Furthermore, some suggested analyses were decided to be an option in the analysis plan. These options may be carried out later if earlier activities are less costly than estimated or if additional means may be assigned to the project.

The activity plan for the analyses of the cores from KXTT3 and KXTT4 was reviewed and approved after an update according to the decisions at the reference group meeting. The actual work according to the activity plan was initiated in March and will continue until December 2009. However concrete results from the analyses are not yet available.

3.3 Long Term Sorption Diffusion Experiment



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.

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

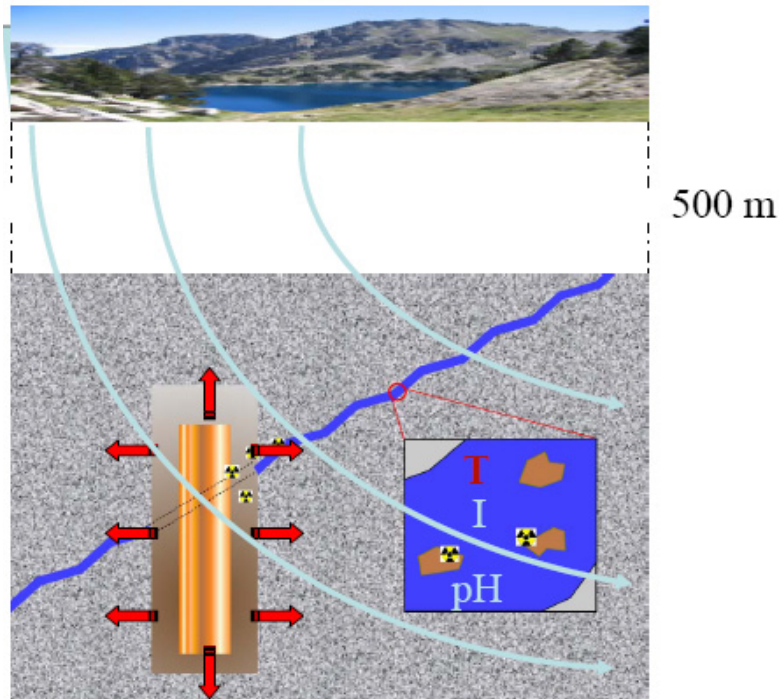
Achievements

A method for separation of Ni in rock core samples has been developed. The method has been adopted on crushed and dissolved rock slices from five sample cores extracted from the fracture surface on the core stub and four sample cores extracted from the matrix rock. Preliminary results from the subsequent analysis of Ni-63, using liquid scintillation (LSC) indicates a strong surface sorption and penetration depth within a few millimetres.

All crushed and intact rock slices selected for subsequent leaching, and LSC analysis of Cl-36 and S-35, have been analysed for γ -emitting tracers (Na-22, Co-57, Se-75, Sr-85, Zr-95, Ag-110m, Cd-109, Sn-113, Ba-133, Cs-137, Gd-153, Hf-175, (Ra-226) and Pa-233) using a HPGe γ -detector. Analyses of the other samples are on-going, however twelve hours detector time needed for each sample, and problems with the automatic sample feeder, resulted in slow progress.

Laboratory experiments with specimen from the core of the small diameter extension borehole, the replica core stub and the pilot borehole core have been going on at Chalmers University of Technology in Gothenburg according to the experimental plan. Same tracer cocktail as for the in situ experiment, with HTO added, is used. Measurements performed are batch sorption tests on crushed material (three particle size fractions) and sorption/diffusion tests on intact drill core samples. The batch sorption tests have been finalised. The sorption/diffusion tests were, after prolongation, stopped in late April. Some completing sampling and tracer analysis is planned for in May.

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 with the Pollux Beamline at Swiss Light Source (SLS) in Switzerland. Results show that the structures of montmorillonite colloids in solution are not planar but spherical or ellipsoidal with an internal structure. Na-montmorillonite colloids are less dense than Ca-montmorillonite and contain more gel.

Modelling of bentonite colloid transport in the “Quarried Block” shows that the retention in the system can be coupled to physical filtration (mass loss) and attachment or detachment (delay). Larger colloids experience more physical filtration and smaller more attachment or detachment with the rationale that the smaller travel closer to the fracture walls in the flow field. The results were presented at Material Research Society 2008 and are published in the proceedings herein.

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.

Different tasks of the Colloid Transport Project have been reported in a number of articles /García-García 2009ab, Holmboe 2009, Cheng and Cvetkovic 2009/.

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 cm² 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

No work has been performed within *Micored* during the first four months of 2009.

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.

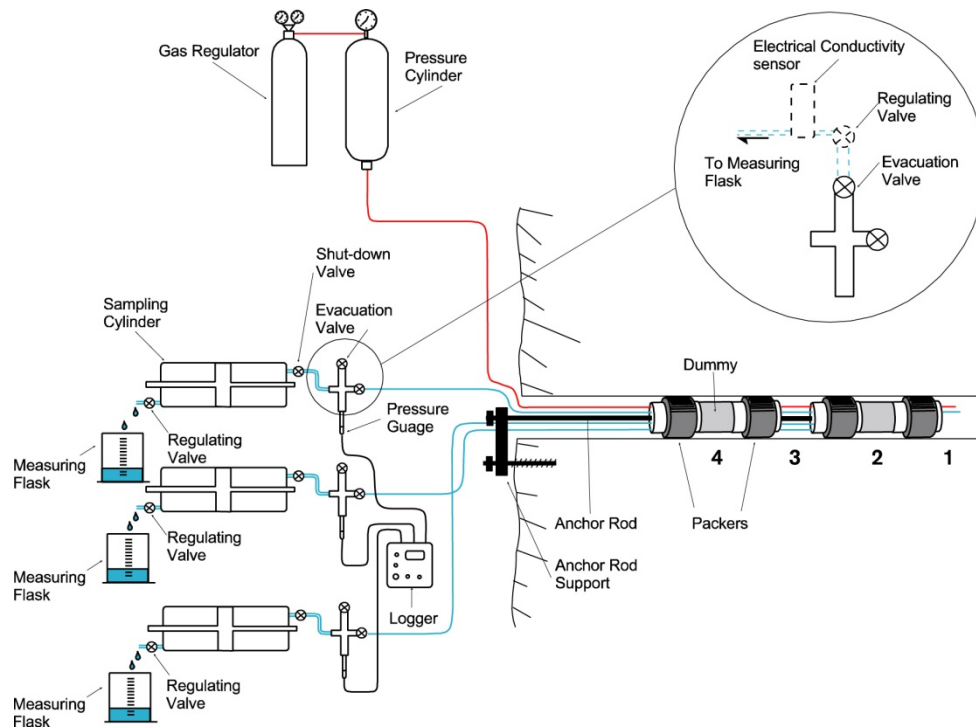
The work within Micomig will:

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

Achievements

No work has been performed within Micomig during the first four months of 2009.

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 period. Final reporting of the matrix borehole hydraulic studies is presently on-going.

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.

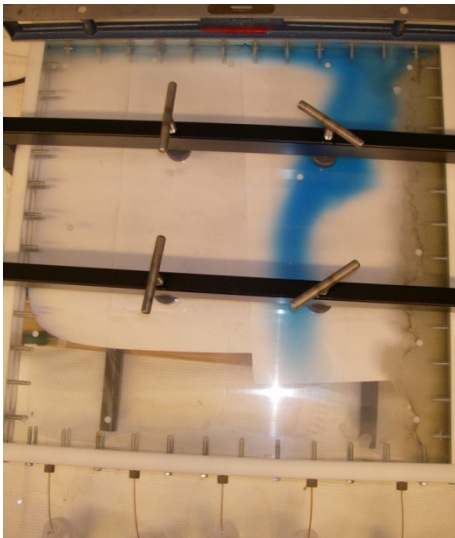
Experiments in Chemlab 1:

- 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.

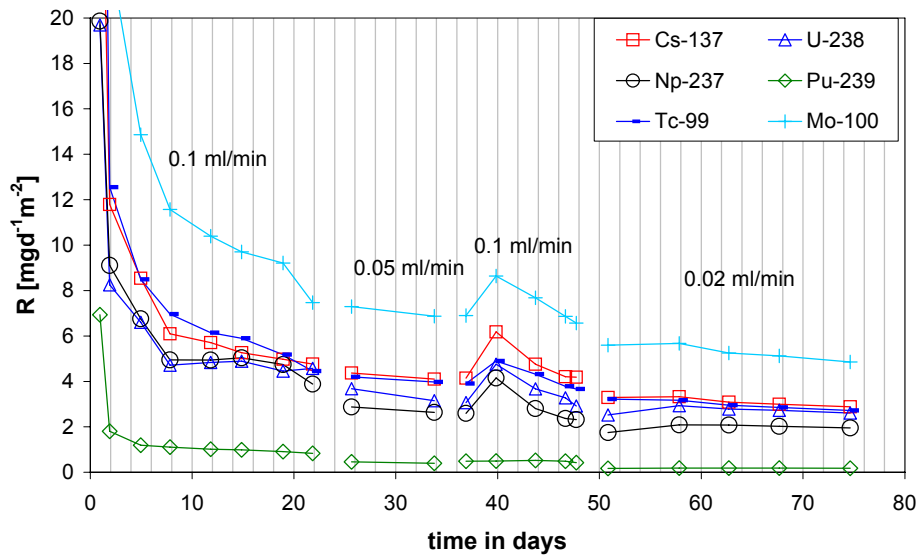
The transport resistance is concentrated to the interface between the bentonite buffer and the rock fracture. The mass transfer resistance due to diffusion resistance in the buffer is estimated to only 6% and the diffusion resistance in the small cross section area of the fracture in the rock to 94% /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 four 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.

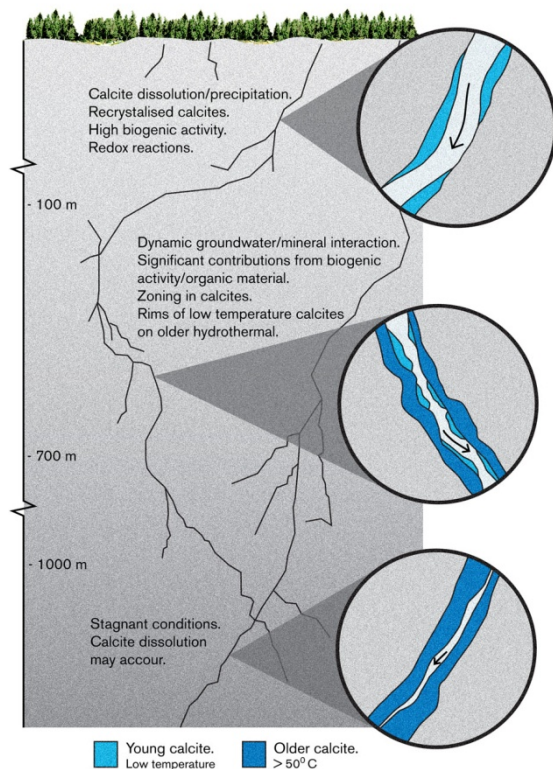
The in situ experiments will be preceded by laboratory experiments where the scope is both to examine parameters that may influence the leaching as well as testing the equipment to be used in the field experiments.

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 four 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:

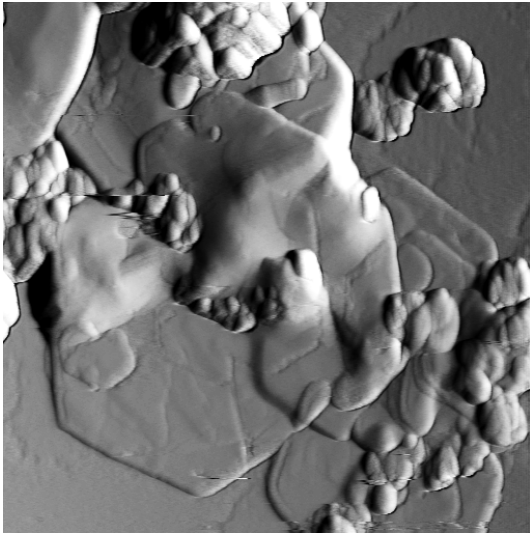
- Further developments of analytical techniques for uranium series analyses applied on fracture mineral samples and inter laboratory comparisons.
- The use of these analyses for determination of the redox conditions during glacial and postglacial time.
- A summary of the experiences from the palaeohydrogeological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

Uranium series analyses have been applied by the two different laboratories taking part in the project (Helsinki University and SUERC in Glasgow) on split samples from two structures in drillcore KAS17. The results show over all good correspondence, but points also to sample inhomogeneities which are along the line of the conceptual understanding of the water conducting structures, e.g. the importance of channelling. Moreover, the leaching analyses make it possible to identify the recently mobile fraction of the total uranium inventory in each sample. This is an important step for the understanding of the uranium leaching/deposition pattern in the present groundwater system. Further evaluation will be discussed during the project meeting in Glasgow the 1st – 3rd of September 2009. The project will be reported this autumn.

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 project during the first four 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

The only activity within the project during the period was writing of the project decision and project plan. The decision and plan are currently on review. Therefore, a final project decision has not yet been taken.

3.11 Äspö Model for Radionuclide Sorption



Instrument for making surface area determinations



A piece of the mineral chlorite

Today, geochemical retention of radionuclides in the granitic environment is commonly assessed using K_d -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.

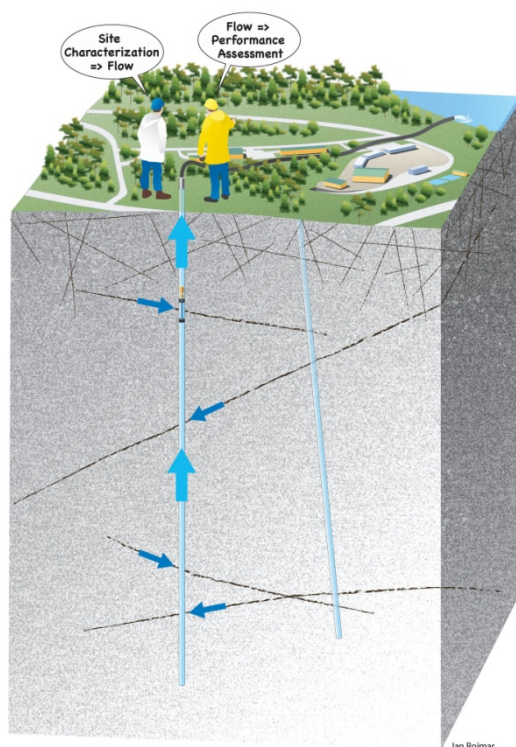
For adoption of this approach to granitic material, the particle size/surface area dependence of radionuclide sorption and effects of grain boundaries need to be resolved. Furthermore, it is desirable to verify sorption of radionuclides to specific minerals within the rock.

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 first four months of 2009 a new gas adsorption instrument for determining specific surface area and porosity has been taken into operation. A method to determine the specific surface area of centimetre sized pieces of geological material has been adopted, tested and modified. Specific surface areas as low as $0.001 \text{ m}^2/\text{g}$ have been measured with good precision, using krypton gas adsorption through the BET-method. Furthermore, a number of pure mineral samples have been acquired for the experimental work in this project. A previously started compilation and review of literature sorption data of selected radionuclides to some important minerals in granitic material has also been continued and deepened.

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 first four months 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. Task 8 – Interface between engineered and natural barriers, is still in the planning phase.

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. The 24th international Task Force meeting was held at Äspö in September 2008. The presentations were mainly addressing modelling results on sub-task 7B. The discussions on the continuation of Task 7 and also the start up of Task 8 were constructive. 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. The proceedings of this venue have been distributed to the Task Force.

A workshop on Task 7 and 8 was held in Lund, January 2009, and the minutes have been distributed. Planning for the 25th international Task Force meeting is on-going.

Table 3-1. Task 7 - descriptions and status (end of April 2009).

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. (Updated results presented at a workshop in Lund on Task 7 and 8).
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. (In planning)

4 Engineered barriers

4.1 General

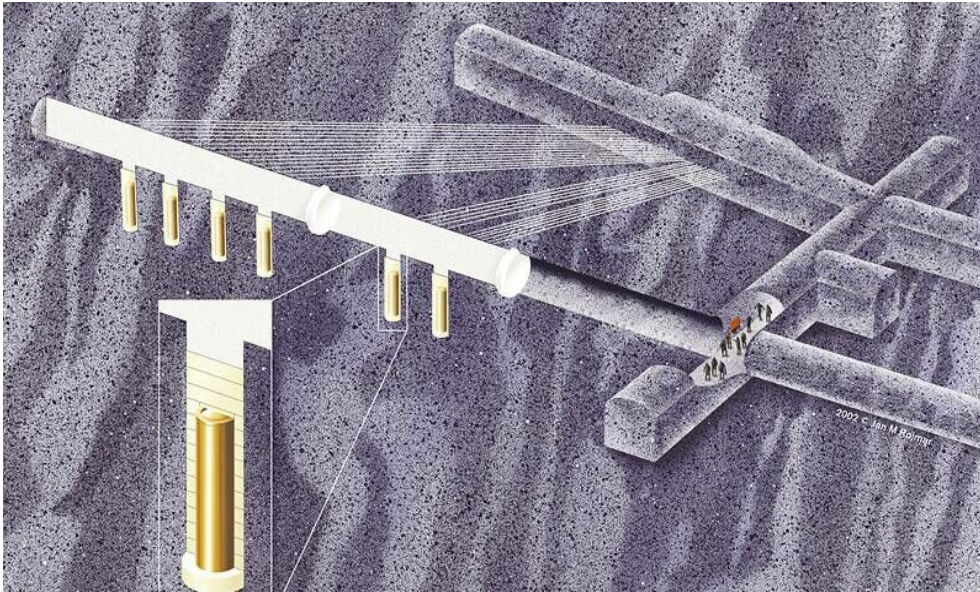
One of the goals for Äspö HRL is to demonstrate technology for and function of important parts of the repository system. This implies translation of current scientific knowledge and state-of-the-art technology into engineering practice applicable in a real repository.

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 (Figure 4-1). The experiments focus on different aspects of engineering technology and performance testing and will 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-throughs 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, porewater 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/. 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 October 2007 to March 2008 and April 2008 to September 2008 respectively 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 and 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.

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 first four months of 2009, all the equipment has been working well and data from the three on-going test parcels have been collected and controlled, see Table 4-1. Detailed geochemical analyses have been performed on the heated material in the A2 parcel. The review work of the report concerning the A2 test is on-going.

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	On-going
S	1	90	T	1	Reported
S	2	90	T	>5	On-going
S	3	90	T	>>5	On-going

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

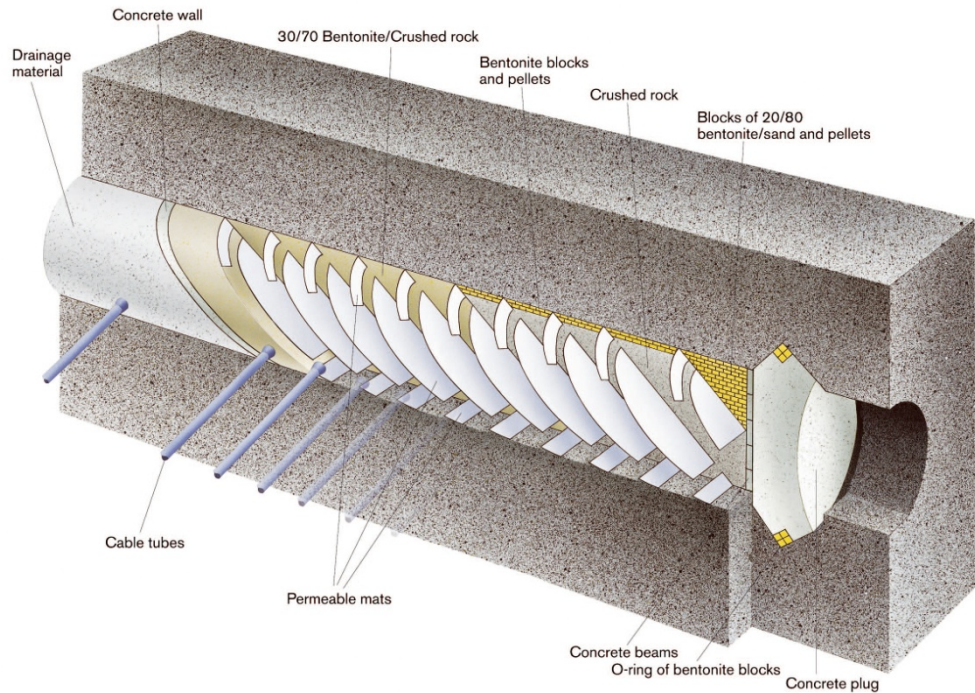
The retrieval of test package 1 has been prepared during the period and two activity plans have been written. The temperature was decreased during April and the drilling is planned to start the 4th of May. The heating of test package 2 was started in August 2008 when the temperature was increased in a first step to about 50°C (the heating of this package should start after saturation of the buffer) but since some cracks were formed on the upper concrete plug together with movements it was decided that additional increase of the temperature should wait until the concrete plug has been repaired and reinforced. This work has now been finished and the temperature has been increased to the target temperature i.e. 130°C. Parallel to the increase of temperature also the water pressure in this test package was increased to 4 bars.

The reinforcement work also included the concrete plug in test package 3 in order to prevent problems in the future. Test package 3 has now been running at the target temperature, 130°C, for more than 500 days.

A meeting was held at Äspö on the 3rd of February. The aim with the meeting was to discuss and decide how material from test package 1 should be treated and kept after retrieval.

The work with analyses of the reference materials has continued during this 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.

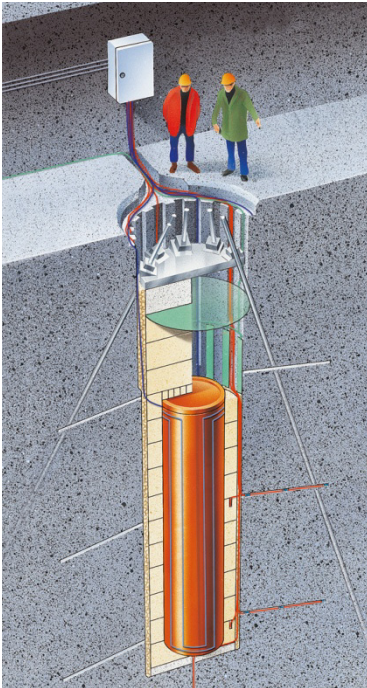
The monitoring comprise continuous measurements and registrations of water pressure and total pressure in the backfill and water pressure in the surrounding rock as well as leakage of water through the plug.

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. 2008a/.

Measurement of local hydraulic conductivity in the zone with crushed rock through installed equipments (CT-tubes) is on-going 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 samples retrieved from the upper part of the buffer in the Canister Retrieval Test (CRT) have been analysed. The performed analyses concerns: chemistry/mineralogy, swelling pressure/hydraulic conductivity and investigations of the mechanical characteristics. Below, some of the findings from the analyses are given. The results given below should, however, be considered as preliminary since they have not been published yet.

- No significant differences have been found in chemistry/mineralogy in buffer samples close to the canister and above the canister. The lubricant used when manufacturing the bentonite blocks complicated the analyses somewhat. Additional analyses of the penetration of the lubricant have been performed. These results have not been evaluated yet.
- The buffer samples show insignificant differences in both hydraulic conductivity and swelling pressure when compared with referential material. This can be seen in Figure 4-2 and Figure 4-3, where hydraulic conductivity and swelling pressure are given as a function of dry density for ring 4 and ring 7.
- An increased brittle character in the mechanical behaviour has been found in the buffer samples close to the canister. To obtain higher statistical significance in the studies, yet 10 samples are to be tested.

The next step in the buffer investigation is to analyse the obtained data and to continue with reporting of the findings.

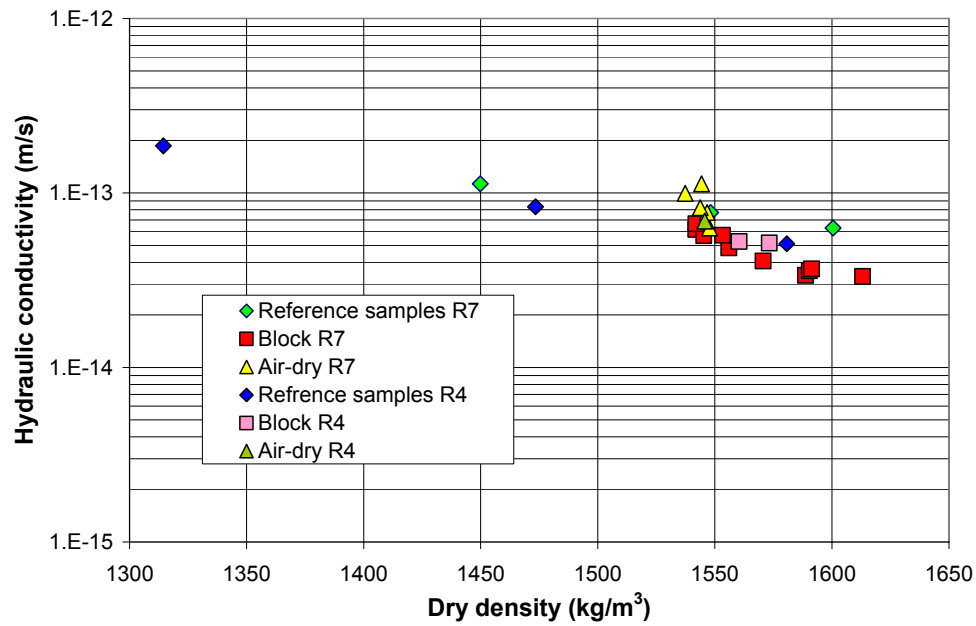


Figure 4-2. Hydraulic conductivity given as a function of dry density for CRT samples and reference material for ring 4 and ring 7.

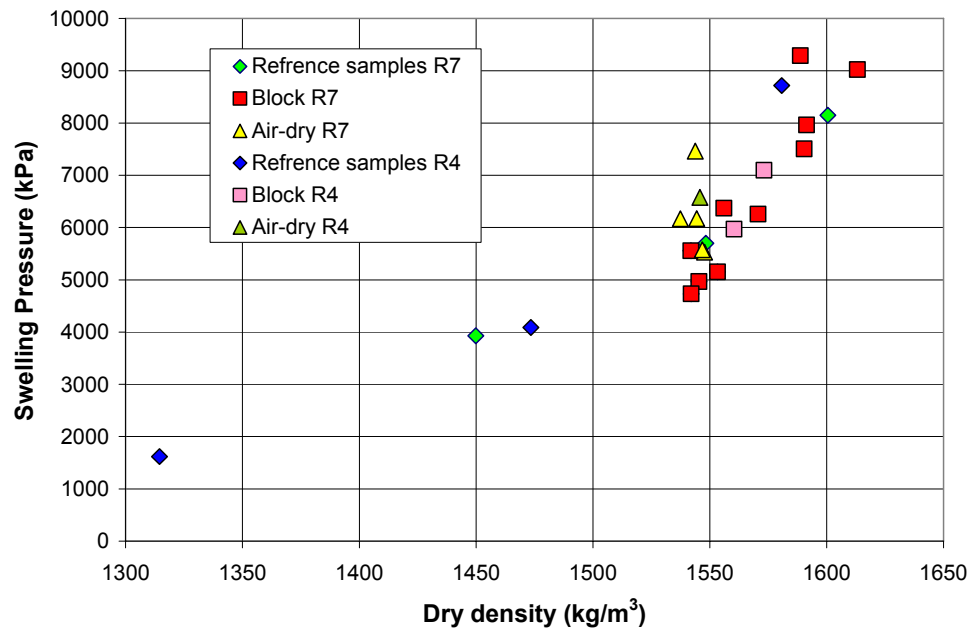


Figure 4-3. Swelling pressure given as a function of dry density for CRT samples and reference material for ring 4 and ring 7.

Numerical modelling

In the Task Force on Engineered Barrier Systems (see section 4.13) the Canister Retrieval Test was selected to be one of the full scale assignments. During the present period the modelling by the EBS Task Force teams has progressed and results were presented at the meeting held at 12th -13th of November 2008. One of the results presented in the assignment is the dry density profile after homogenisation. The dry density profiles obtained from measurements and the model developed by the SKB Team 1 are shown in Figure 4-4.

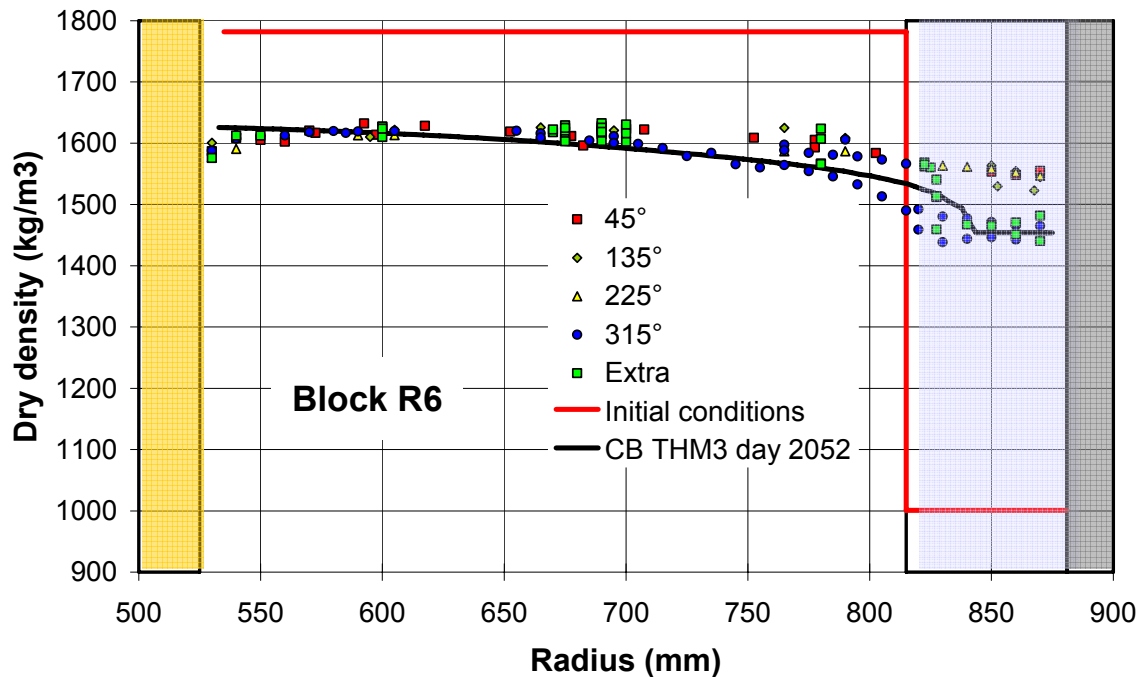


Figure 4-4. Dry density profiles obtained from measurements and the SKB Team 1 model at day 2052 (At the end of the test).

The EBS Task Force teams will continue with the modelling of the CRT experiment and present their new results at the next meeting (25th - 26th of May 2009).

Simulations of the thermal, hydraulic and mechanical processes in CRT will also be 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 for the Swedish KBS-3 repository. The modelling that will be part of the safety assessment is in progress. New simulations of the CRT may also be 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.

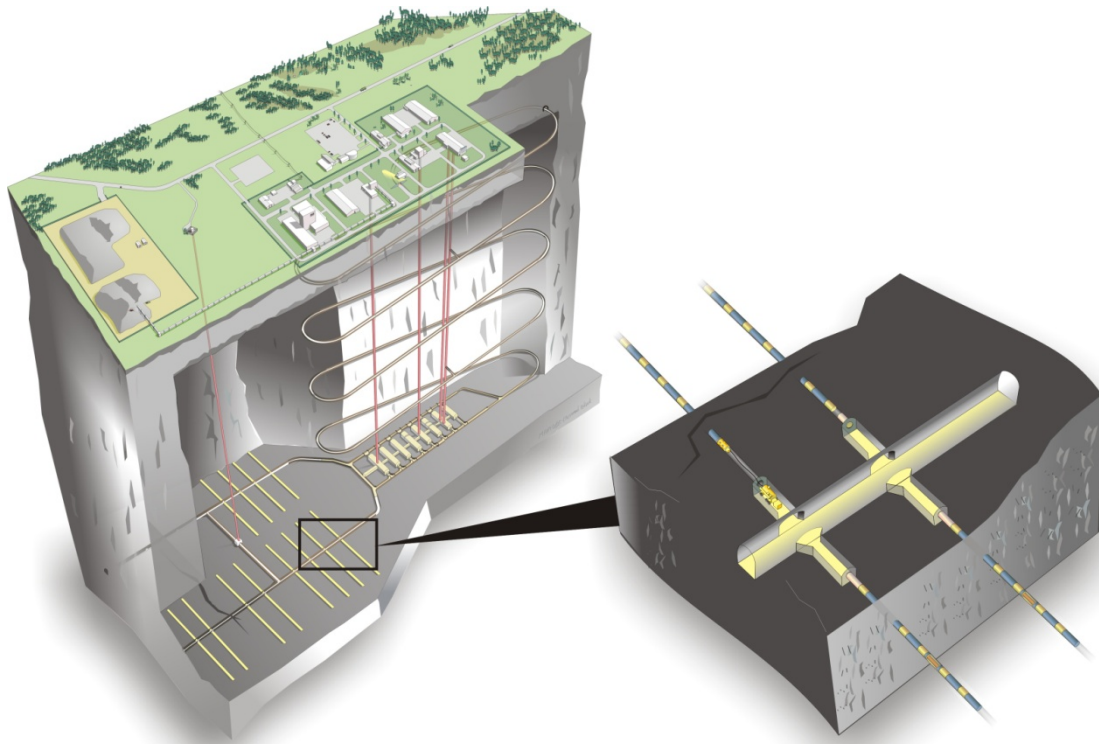
Data acquisition is continuously on-going and data is transferred by a link from Äspö to Andra's head office in Paris.

Achievements

The TBT-test is in the operation and data acquisition phase since March 2003. Data acquisition is continuously on-going and the data link from Äspö to Andra's head office in Paris has been functioning well. Monthly data reports have been distributed during the period. A sensors data report /Goudarzi et al. 2008b/ and a paper evaluating the TBT_3 mock-up test /Åkesson et al. 2009/ have been published.

The current plan is to perform a retrieval test of the upper heater, and to dismantle and sample the test during the period from November 2009 to February 2010. A number of techniques for sampling and removal of different components during dismantling will be tested in the near future.

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.

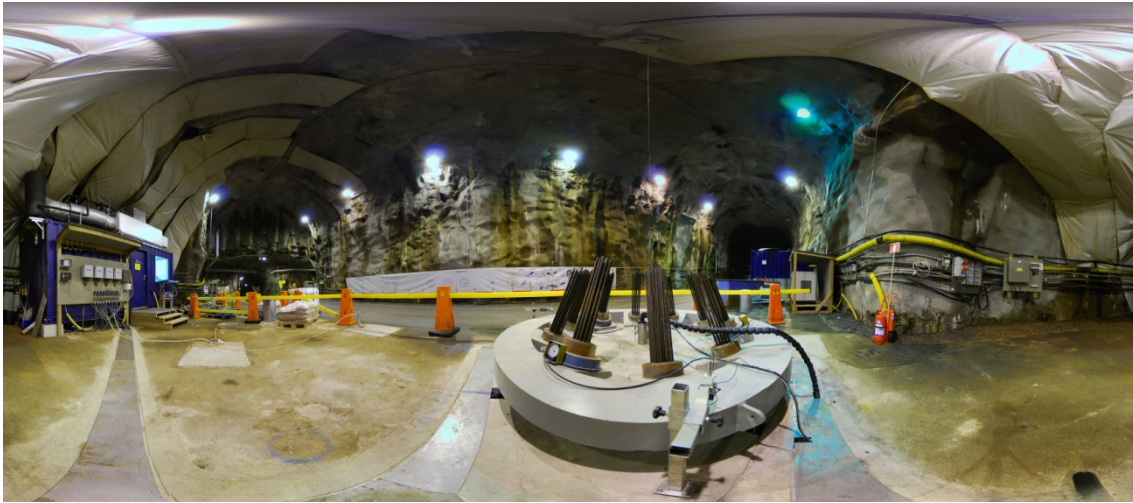
Achievements

Installation of the compartment plug was continued during the period. Casting of the fastening ring was successfully conducted in the first half of January. After the casting the collar and cap were installed. The installation was carried out quickly and in accordance with the plans. Supporting systems, such as water pressure system and monitor system, were also installed.

The first pressurising test, with only water behind the compartment plug, was initiated in the end of March. The test was terminated within two weeks due to high leakages through the plug. Leakage has been observed all the way around the circumference of the compartment plug. The visible leakage is at the boundary concrete/fastening ring. It is likely that the welding of the collar and fastening ring has induced fractures/leakage paths along the fastening ring. The tests will continue during the spring and summer.

Regarding demonstration of deposition machine some maintenance work has been performed and the machine has been tested further, but more limited.

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 first four months period 2009 began with a full calibration of Lasgit instrumentation in readiness for the second stage of gas testing. At this time, the interface vessel used in gas testing was reconnected and pressurised with around 1 litre of helium in order to leak test the system. This was left at pressure which verified that the vessel was indeed gas tight.

Soon after calibration was complete (day 1,472; February 11th) the hydraulic test was initiated. In the previous testing stage all artificial hydration filters were allowed to decay, including FL903 – the filter selected for gas testing. This time FL903 was raised to the high pressure stage at the start of the hydraulic head test on day 1,472 in order to reduce the total duration of the hydraulic head test. The pressure in FL903 was raised to 4,250 kPa and the flux into the buffer was monitored. Figure 4-5 shows the filter pressures for quarter 1 of 2009 and the pressure decay of all filters. Permeability and

storage can be calculated from these results. As seen, FL903 was raised to a pressure of 4,250 kPa on day 1,472 and reduced to 1,000 kPa on day 1,507. The magnitude of the lower pressure step was estimated from the pressures in the other filters of the lower plane filter array.

The flow data achieved (Figure 4-6) by the hydraulic head test indicates that the permeability of the clay around FL903 has reduced since the previous hydraulic tests. This will be confirmed during the next four-month period through numerical modelling.

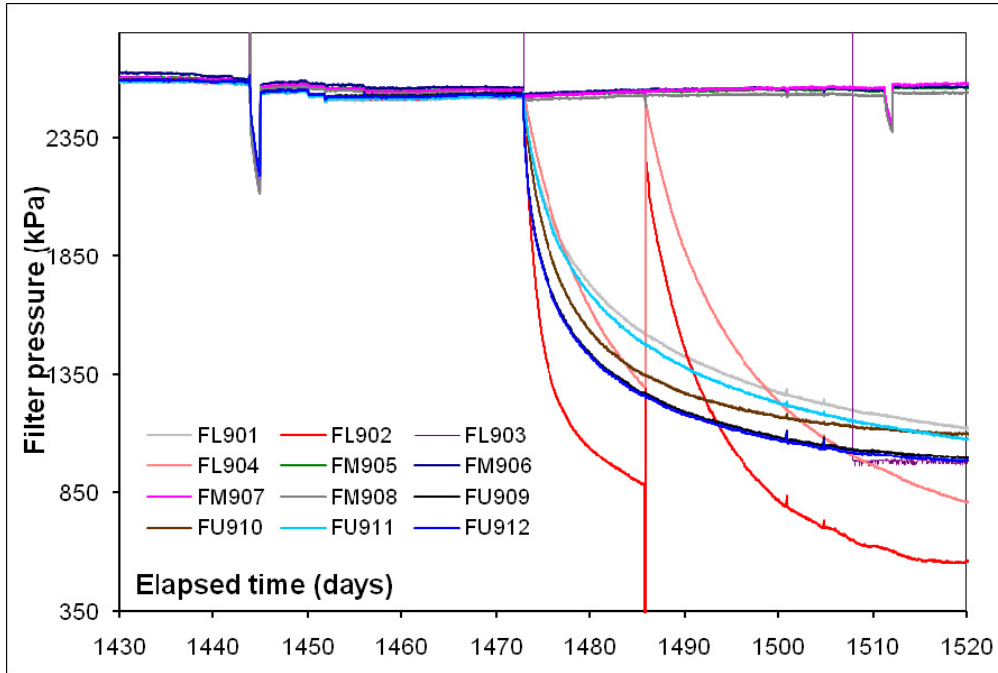


Figure 4-5. Pressure decay in the artificial hydration filters.

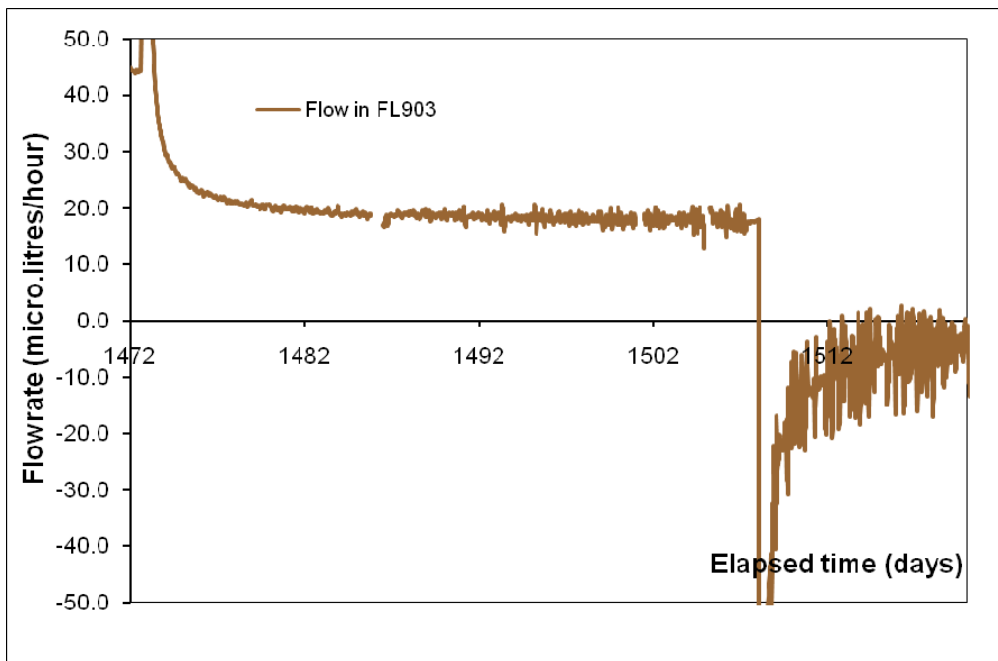


Figure 4-6. Results from the hydraulic head test in filter FL903.

4.10 Sealing of Tunnel at Great Depth



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.

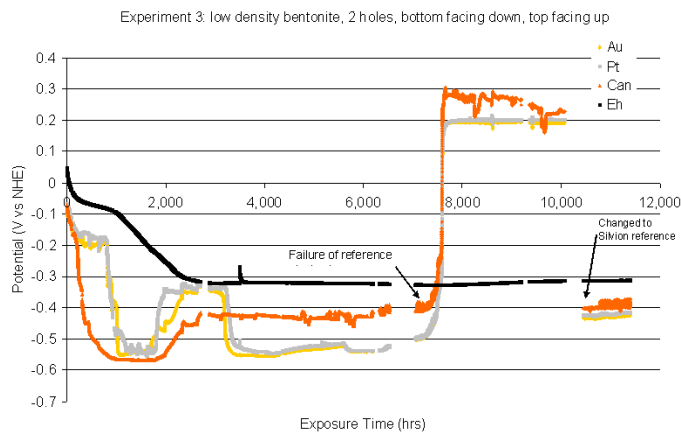
Achievements

The excavation of the Tass-tunnel (80 meters) has been completed. The tunnel includes two grouting fans outside the contour (fans 2 and 3) and three fans (fans 4, 5 and 6) inside the contour. It has earlier been shown that it is possible to reduce the inflow to a value below 1.0 litre/minute and 60 m, using ordinary outside fans. This is now also shown for fans where grouting holes are kept within the contour (fans 5 and 6).

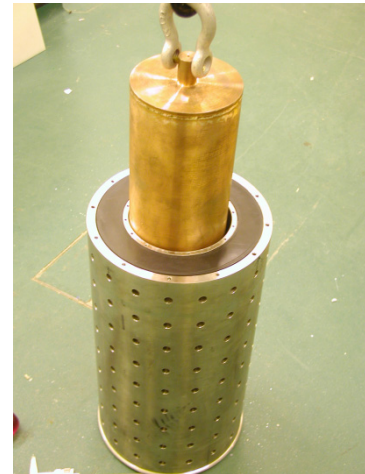
Based on the very low inflows from sounding holes at the tunnelling front it was decided not to advance the tunnel further. It was also concluded that any extra measures to improve the tightness at the tunnel front was not needed.

The pre-grouted rock mass along fan 4 does not fulfil the tightness requirement. At present post-grouting of this section is under way. Post-grouting is generally considered a difficult task. The major challenge is the high hydraulic gradient that forms around a rock opening under the groundwater table. In this case it is extra pronounced, as the natural water pressure is 3.5 MPa.

4.11 In Situ Corrosion Testing of Miniature Canisters



Example of electrochemical potential data obtained from one miniature canister.



Miniature canister with support cage

This 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.

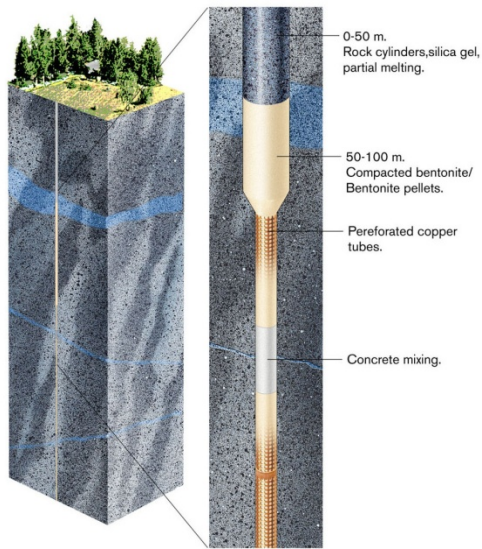
Achievements

During the 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 will be included in a new report which is in preparation. A steering group meeting will be held to plan further analyses and the possible removal of one or more canisters in order to assess the extent of any corrosion processes and to validate the electrochemical measurements obtained to date.

A report on the set up of the experiments and the results obtained up to May 2008 is being finalised and a report containing data obtained up to February 2009 is in preparation.

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.

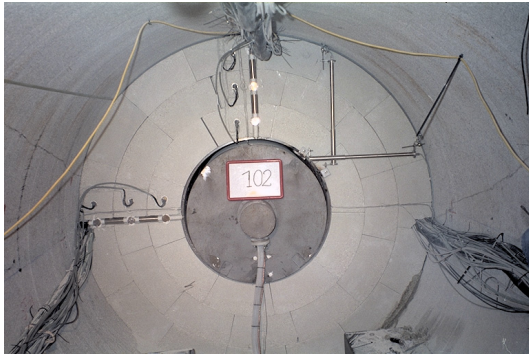
A number of representative boreholes will be considered and those suitable for sealing will be divided into categories for which conceptual designs will be worked out. The project will select boreholes at Äspö, Laxemar, and Forsmark, for detailed design. The holes should represent typical rock conditions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

Achievements

During the first four-month period the follow-up of data from the site characterisation database, Sicada, have continued. The modelling of Forsmark boreholes has been conducted and delivered in a draft version. The delivery of the flow model for Laxemar has been delayed and therefore also the modelling work.

Project meetings have been held with briefing of borehole data and modelling assignments. A suggestion of a new sub-project has been proposed, comprising plugging of 300 mm boreholes in the Äspö tunnel. The sub-project will be conducted during the second four-month period of 2009. Work will also continue with the Laxemar model and quality descriptions and cost estimates for the assignment will be made.

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 at Äspö HRL has continued during this four-month period. Altogether eight modelling teams are modelling this test. The first phase includes modelling of a number of laboratory and field tests as compiled in Table 4-2.

The task to model the Canister Retrieval Test 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. Work with scoping calculations and test design has been done during this period.

Table 4-2. Modelled tests in the first phase of the Task Force on Engineered Barrier System.

Benchmark 1 – Laboratory tests

Task 1 – THM tests

- 1.1.1 Two constant volume tests on MX-80 (CEA)
- 1.1.2 Two constant volume tests on Febex bentonite – one with thermal gradient and one isothermal (Ciemat)
- 1.1.3 Constant external total pressure test with temperature gradient on Febex bentonite (UPC)

Task 2 – Gas migration tests

- 1.2.1 Constant external total pressure (BGS)
- 1.2.2 Constant volume (BGS)

Benchmark 2 – Large scale field tests

- 2.1 URL tests Buffer/Container Experiment and Isothermal Test (AECL)
 - 2.2 Canister Retrieval Test in Äspö HRL (SKB)
-

Task Force Geochemistry

Results from simple 1D laboratory diffusion experiments performed at Clay Technology have been distributed to the participating groups as proposals for benchmark modelling tasks. Experimental results from the Long Term Test of Buffer Materials (A2 parcel) are used for modelling purposes by the Finnish and the Swiss groups.

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 on-going. 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.

5 Äspö Facility

5.1 General

The organisational unit at Äspö Hard Rock Laboratory is responsible for the operation of the Äspö facility and the co-ordination, experimental service and administrative support of the research performed in the facility. Activities related to information and visitor services are also of great importance not only to give prominence to Äspö HRL but also to build confidence for SKB's overall commission. The Äspö HRL unit is organised in four operative groups and a secretariat:

- *Project and Experimental service (TDP)* is responsible for the co-ordination of projects undertaken at the Äspö HRL, for providing services (administration, planning, design, installations, measurements, monitoring systems etc.) to the experiments.
- *Repository Technology and Geoscience (TDS)* is responsible for the development and management of the geo-scientific models of the rock at Äspö and the test and development of repository technology at Äspö HRL to be used in the final repository.
- *Facility Operation (TDD)* is responsible for operation and maintenance of the Äspö HRL offices, workshops and underground facilities and for development, operation and maintenance of supervision systems.
- *Public relations and Visitor Services (TDI)* is responsible for presenting information about SKB and its facilities with main focus on the Äspö HRL. The HRL and SKB's other research facilities are open to visitors throughout the year.

Each major research and development task carried out in Äspö HRL is organised as a project that is led by a Project Manager who reports 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 maintains the database and expertise on results obtained at the Äspö HRL.

In May 2008 it was decided that SKB will be reorganised stepwise in parallel with the on-going site selection process of the final repository for spent nuclear fuel. The common goal within the company is to have all the organisational changes done when the application for the final repository have been completed and sent in to the authorities for their final examination. Some organisational changes have already been implemented, and some other are prepared to be implemented during the next reporting period (May-August 2009). One of the foreseen changes handles the union of the organisational unit *Äspö Hard Rock Laboratory (TD)* and the unit *Repository Technology (TU)*. This change is done to focus the remaining development of the repository technology by doing experiments and test in a realistic repository environment at Äspö HRL. The new and larger unit will inherit the name *Repository Technology*. The residence of the new unit will be at 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

During the first four-month period of 2009, the tests concerning impact of water inflow on buffer and backfill have continued. In the tests, the time for breakthrough, amount of eroded material and inflow of water have been measured. After a settled time, the tests were interrupted and excavated. The results from the tests indicated that erosion is not a controlling factor for the speed of the backfilling process, rather, it is the water inflow which is the controlling factor.

Experiments to study water inflow to the buffer in the deposition hole have continued. The aim of the tests is, amongst other, to control the axial expansion of the buffer. The tests are done with an installation above the buffer simulating the counter pressure from the backfilling. Measurements are made of the amount of inflowing water and the amount of eroded material.

The tests concerning choice of method for backfilling and obtained bearing capacity have continued for the bevel at the deposition hole. The compression of backfilling material in the bevel has to be done so that that backfill blocks can be installed above the bevel without any settlements. Settlements would make the block masonry unstable with possible empty spaces and problems to reach the required density. Preliminary results from the tests show that it is possible to compress granulated material to sufficient density. Work concerning methods and development of techniques for backfilling remain, especially to make the methods more industrialised.

The study of the impact of water inflow has continued, one half scale test and a number of tests in pilot scale have been performed. For the pilot scale tests (see Figure 5-1) the objective is 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 differences in the set up of the half scale compared to earlier tests are that a material from Milos is used in the tests (IBECO-RWC-BF) and the inflow is distributed from inflow spots simulating water-bearing fractures. In the test performed during this period it is obvious that there are a connection between the pellet size and the ability for water take up.

This implicates that tests to study the pellet size and installation of pellet in order to optimise the water take up by the system may be needed. The tests performed during this period will be reported in the end of the year when all the tests in half scale are finished.

The results from a number of earlier tests have been printed during the first four-month period /Dixon et al. 2008, Wimelius and Pusch 2008ab/.

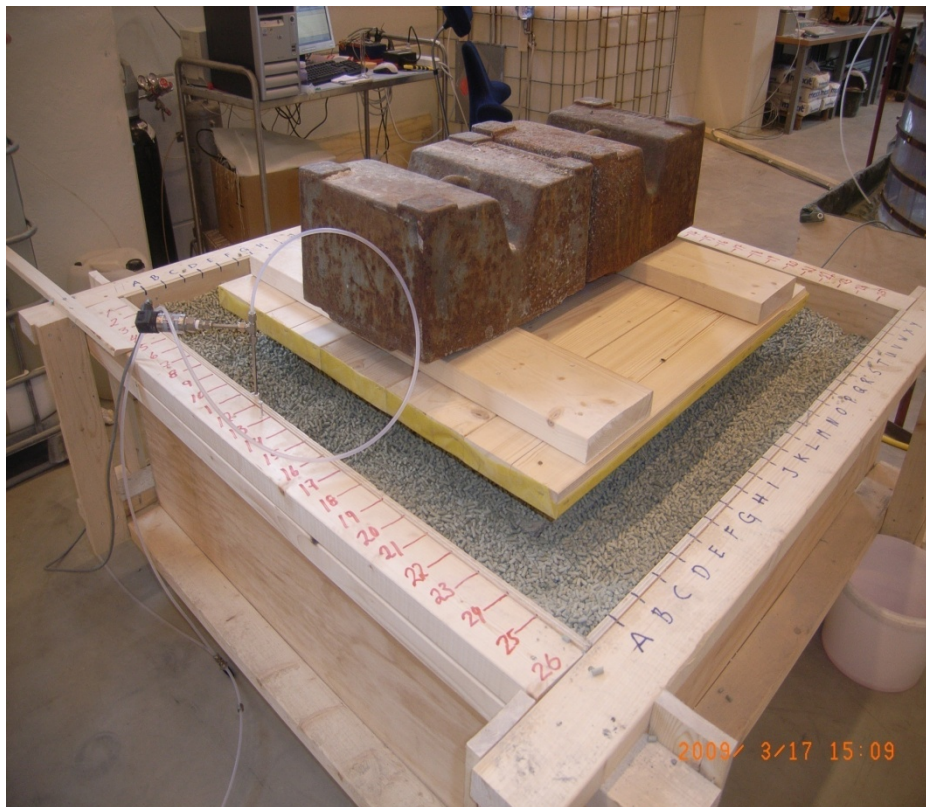
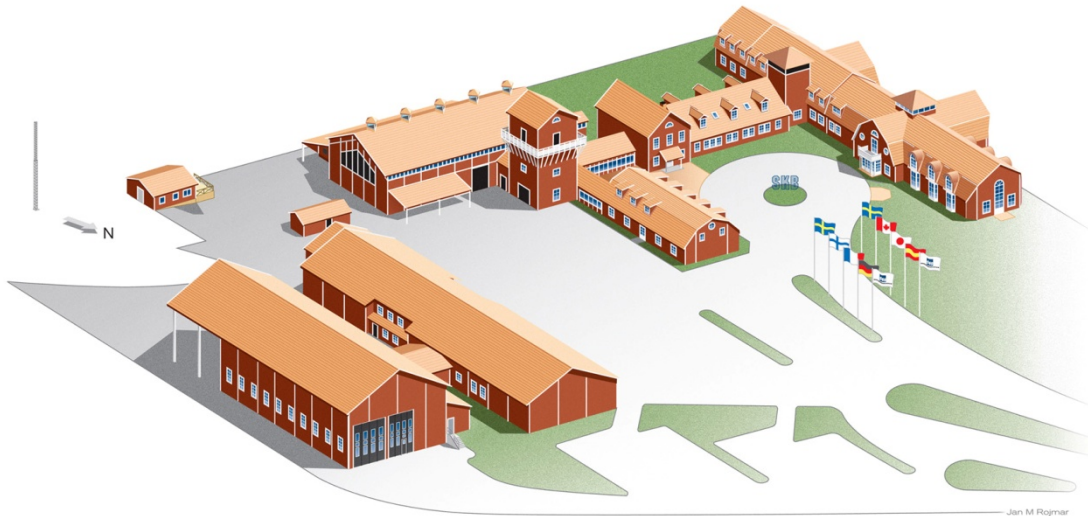


Figure 5-1. Test in pilot scale to investigate the impact of inflow from the rock on the constitution and properties of the pellet backfill in deposition tunnels.

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 first four-month period 2009 has been stable. In January, the operational monitoring system Alfa was upgraded. The system has been on trial for a year. New security and access procedures that meet with the demands of SKB's overall procedures are now in place. In addition, the break-in alarm was updated at the beginning of the year. The operational monitoring system (Alfa) will be coupled with the maintenance system (Idus) in order to keep track of service intervals, spare parts, maintenance manuals and maintenance costs. The aim is that all maintenance actions shall be traceable.

The object monitoring system which SKB developed has finally been implemented. All persons and vehicles in the tunnel are equipped with transponders so that they can be located. The system will, however, be upgraded with new features to facilitate use by the personnel.

Rock maintenance has been carried out as planned, but has been temporarily stopped because a new type of machine is required under the new rules for mobile work platforms. A new platform will be ordered.

In addition, measures to improve the safety of the road to Äspö have been taken and the design of a drinking water reservoir has started. The construction of a catering dining room for personnel and visitors was finished and is now in use.

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 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 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 6,969 persons during the first four months of 2009. The numbers of visitors to SKB's main facilities are listed in Table 5-1.

The booking system has been upgraded to a new platform in order to receive a better technique and to guarantee future need of support. Many important visits from politicians have been carried out during the period, e g the Swedish minister for the Ministry of the Environment, and members of the EU parliament.

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

SKB facility	Number of visitors Jan-April 2009
Central interim storage facility for spent nuclear fuel	967
Canister Laboratory	896
Äspö HRL	2,394
Final repository for radioactive operational waste (SFR)	2,486

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).

Nova FoU is a joint research and development platform at Nova Centre for University Studies, Research & Development in Oskarshamn, Sweden. The platform is supported by SKB and the municipality of Oskarshamn. The platform can use SKB's facilities and competence in Oskarshamn as the base for research and development. The contract was signed at the end of 2007 and runs for five years.

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. The project the "Geochemistry Research Group" has started, see below.

6.2 Geochemistry Research Group



Surface water sampling point at Laxemar catchments area

The Geochemistry Research Group is part of the Nova-FoU platform. This research group is a continuation of the Äspö Research School and is financed mainly by SKB and the University of Kalmar.

The research topic is on chemical elements in soil, water and biota. The aim is to understand how major and trace elements are redistributed and transported in the environment, how they end up in streams and groundwaters, and how they are taken up by plants and animals.

Details on the research activities, the senior researchers and the PhD students are given at <http://www.skb.se/asporesearch>.

Achievements

During this four-month period four scientific publications were published in scientific journals /Lavergren et al. 2009ab, Åström et al. 2009, Fältmarsch et al.2009/.

7 International co-operation

7.1 General

Eight organisations from seven countries will in addition to SKB 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								

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 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. For 2009 there has been a proposal for a joint Task 8 of the two Task Force projects, related to modelling hydraulic interaction of rock and bentonite.

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 January – April 2009, the following reports have been published and distributed.

8.1 Äspö International Progress Reports

Forsmark T, 2008. Prototype Repository. Hydraulic tests and deformation measurements during operation phase. Test campaign 9. SKB IPR-08-22, Svensk Kärnbränslehantering AB.

Äspö Hard Rock Laboratory, 2009. Status Report. July - September 2008. SKB IPR-09-02, Svensk Kärnbränslehantering AB.

Zolezzi F, Haycox J R, Pettitt W S, 2008. Acoustic emission and ultrasonic monitoring results from deposition hole DA3545G01 in the Prototype Repository between April 2007 and September 2007. SKB IPR-09-03, Svensk Kärnbränslehantering AB.

Goudarzi R, Åkesson M, Hökmark H, 2008. Temperature Buffer Test. Sensors data report (Period: 030326-080701) Report No:12. SKB IPR-09-04, Svensk Kärnbränslehantering AB.

Äspö Hard Rock Laboratory. Planning Report for 2009. SKB IPR-09-05, Svensk Kärnbränslehantering AB.

8.2 Technical Documents and International Technical Documents

Seven International Technical Documents have been published during the period January – April 2009.

9 References

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