International Progress Report

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Äspö Hard Rock Laboratory

Status Report
October – December 2007

Svensk Kärnbränslehantering AB

March 2008

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Äspö Hard Rock Laboratory

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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 2005–2010 are presented in SKB's RD&D-Programme 2004 /SKB 2004/. The RD&D-Programme for the period 2008–2013 was published in fall 2007 /SKB 2007a/. The information given in the RD&D-Programme related to Äspö HRL is annually detailed in the Äspö HRL Planning Report /SKB 2007b/.

This Äspö HRL Status Report is a collection of the main achievements obtained during the fourth quarter of 2007.

Geoscience

Geoscientific research is a natural part of the activities at Äspö HRL and is conducted in the fields of Geology, Hydrogeology, Geochemistry (with emphasis on groundwater chemistry) 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 experiments performed at conditions expected to prevail at repository depth are: Tracer Retention Understanding Experiments, Long Term Sorption Diffusion Experiment, Colloid Dipole Project, Microbe Projects, Matrix Fluid Chemistry Continuation, Radionuclide Retention Experiments and Swiw-tests with Synthetic Groundwater.

Tests of models for groundwater flow, radionuclide migration and chemical/biological processes are one main purpose of the Äspö HRL. The major project is the Äspö 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. A number of large-scale field experiments are therefore conducted or planned at Äspö HRL: 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, In Situ Corrosion Testing of Miniature Canisters, Cleaning and Sealing of Investigation Boreholes, Rock Shear Experiment and Earth Potentials.

THM processes and gas migration in buffer material are addressed in the Task Force on Engineered Barrier Systems.

Äspö facility

The Äspö facility comprises of the Hard Rock Laboratory that was taken in operation in 1995 and the Bentonite Laboratory which was constructed during 2006 and its inauguration took place in March 2007. 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

On the initiative of the Äspö Environmental Research Foundation, the University of Kalmar has set up the Äspö Research School. The research school has a special interest in the transport of pollutants and their distribution in rock, groundwater and biosphere. The research school is co-financed by the municipality of Oskarshamn, SKB and the University of Kalmar.

International co-operation

The Äspö HRL has so far attracted considerable international interest. Nine organisations from eight countries participate in the co-operation or in Äspö HRL related activities, apart from SKB, during 2007.

Contents

1 General

The Äspö Hard Rock Laboratory (HRL), 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. 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.

The Äspö HRL and the associated research, development and demonstration tasks have so far attracted considerable international interest. During 2007, nine organisations from eight countries participate in the co-operation or in related activities at Äspö HRL. SKB's overall plans for research, development and demonstration during the period 2005–2010 are presented in SKB's RD&D-Programme 2004 /SKB 2004/. The RD&D-Programme for the period 2008–2013 was published during fall 2007 /SKB 2007a/. The planned activities related to Äspö HRL are detailed on a yearly basis in the Äspö HRL Planning Report. The role of the Planning Report is also to present the background and objectives of each experiment and activity. This Status Report concentrates on the work in progress and refers to the Planning Report /SKB 2007b/ for more background information. The Annual Report presents and summarise new findings and results obtained during the present year.

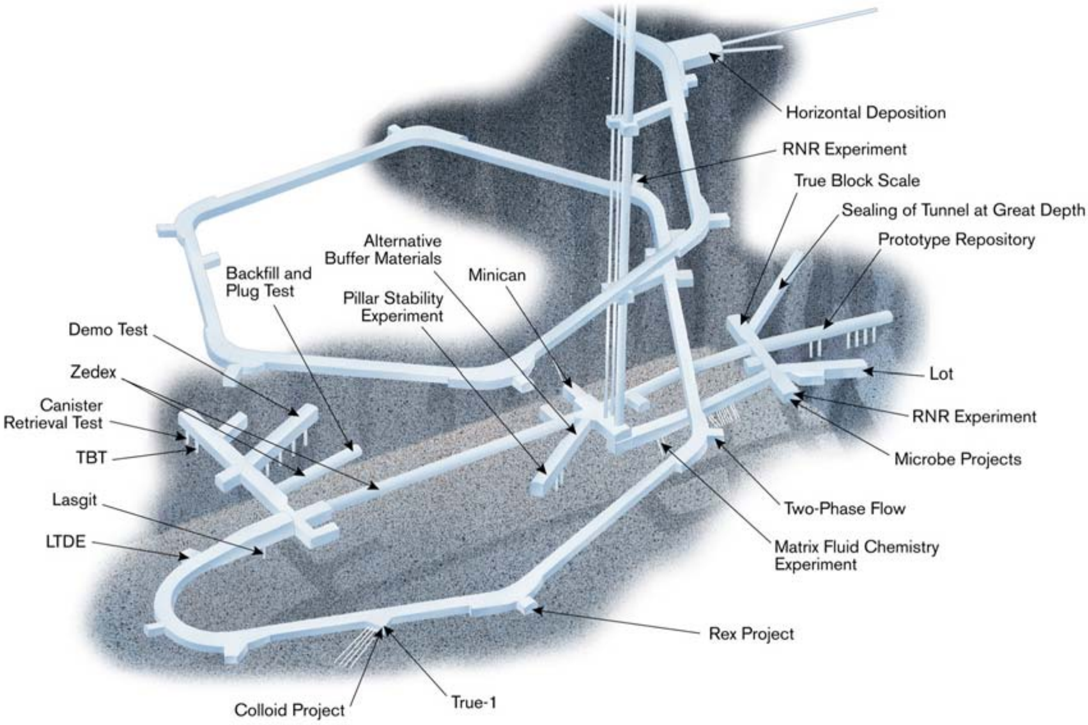


Figure 1-1. *Allocation of experimental sites in Äspö HRL from -220 m to -450 m level.*

2 Geoscience

Geoscientific research is a natural part of the activities at Äspö HRL and is conducted in the fields of geology, hydrogeology, geochemistry (with emphasis on groundwater chemistry) and rock mechanics. Studies are performed in laboratory and field experiments as well as by modelling work. The overall aims can be summarised as:

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

The main task within the geoscientific field is the development of the Äspö Site Descriptive Model (SDM) integrating the information from the fields of geology, hydrogeology, geochemistry and rock mechanics. The activities further aim to provide basic geoscientific data to the experiments and to ensure high quality of experiments and measurements related to geosciences.

2.1 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 and contribution with input knowledge in projects and experiments conducted at Äspö HRL. In addition, development of new methods in the field of geology is a major responsibility. As a part of the latter, the Rock Characterisation System (RoCS) feasibility study is being conducted.

2.1.1 Geological Mapping and Modelling

TASS-tunnel, geological mapping of the tunnel front, section 8.7 m (photo Carljohan Hardenby)

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 together with other input data.

Modelling tasks are performed both in the general geological 3D-model of the Äspö rock volume (the former GeoMod-project) and in more detailed scale on smaller rock volumes.

Achievements

The main activities during the fourth quarter of 2007 have been:

- The excavation of the new tunnel TASS ("The injection test tunnel - sealing fractures at great depth") at the -450 m level, where testing of injection methods and materials will take place, has commenced. Geological mapping of two tunnel fronts has taken place.
- The geological mapping of the floor in TASQ-tunnel was finished during July and the documentation of the geological mapping data into the TMS (Tunnel Mapping System) is now completed. Quality control of data is only partly performed.
- The modelling work that commenced in 2005 concerning water bearing fractures at the -450 m level is finished and the report is almost completed.
- Some old mapping of tunnels and deposition holes still needs to be entered into the TMS.

2.1.2 RoCS – Method Development of a New Technique for Underground Surveying

TASQ-tunnel, mounting of the Faro laser scanner used by ATS (photo Björn Magnor)

A feasibility study concerning geological mapping techniques is performed besides the regular mapping and modelling tasks. The project Rock Characterisation System (RoCS) is conducted as an SKB-Posiva joint-project.

The purpose is to investigate if a new system for rock characterisation has to be adopted when constructing a final repository. The major reasons for the RoCS 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.

In this initial feasibility study-stage, the major objective is to establish a knowledge base concerning existing and possible future methods and techniques to be used for a mapping system suitable for SKB's and also Posiva's requirements.

Achievements

The first part of the feasibility study, establishing of the technical state-of-the-art, is completed and the results have been published /Magnor 2007/. During 2007, the results from the laser scanning of the TASQ tunnel, performed during 2006, have been delivered and a report will be printed during the first half of 2008.

After 2007, the RoCS-project will no longer be treated as separated project but will continue as a part of the ordinary tasks within the discipline at Äspö HRL. The aim will in the future be concentrated on geological matters.

2.2 Hydrogeology

The major aims of the hydrogeological activities are to:

- Establish and develop the understanding of the hydrogeological properties of the Äspö HRL rock mass.
- Maintain and develop the knowledge of applicable measurement methods.
- Ensure that experiments and measurements in the hydrogeological field are performed with high quality.
- Provide hydrogeological support to active and planned experiments at Äspö HRL.

The main task is the development of the integrated Äspö Site Descriptive Model. An important part of the site description is the numerical groundwater model which is to be continuously developed and calibrated. The intention is to develop the model to a tool that can be used for predictions, to support the experiments and to test hydrogeological hypotheses. Another part of the work with the site description is the continued development of a more detailed model of the hydraulic structures at the main experimental levels below -400 m. The reporting of the work with the model at the -450 m level is now almost completed.

2.2.1 Hydro Monitoring Programme

The hydro monitoring programme is an important part of the hydrogeological research and a support to the experiments undertaken in the HRL. The programme had also had legal grounds. It was conditioned by the water rights court, when granting the permission to execute the construction works for the tunnel, that a monitoring programme should be put in place and that the groundwater head conditions should continue to be monitored until the year 2004.

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 and in the tunnel. The number of boreholes included in the monitoring programme has gradually increased, and comprise boreholes in the tunnel in the Äspö HRL as well as surface boreholes on the islands of Äspö, Ävrö, Mjälen, Bockholmen and some boreholes on the mainland at Laxemar. The tunnel construction started in October 1990 and the first pressure measurements from tunnel drilled boreholes were included in the HMS in March 1992. The tunnel excavation began to affect the groundwater level in many surface boreholes during the spring 1991.

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

Achievements

The main activities in the Hydro Monitoring Programme during the fourth quarter have been:

- Quality check and calibration of data from the tunnel in December.
- Preparations in Sicada for automatic transfer of data from Hydro Monitoring System (HMS).
- Completion of a study about renovation of cored surface boreholes.

The monitoring system has been performing well and the monitoring points have been maintained. However, maintenance and improvements are continuously made on the system to increase the performance. Instrumentation, measurement methods and the monitoring during 2006 is described in a report /Nyberg et al. 2007/.

2.3 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.

One of the overall main tasks within the geoscientific programme is to develop an integrated site description of the Äspö HRL. The use of the achieved knowledge will facilitate the understanding of the geochemical conditions and the development of underground facilities in 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. In general, hydrogeochemical support is provided to active and planned experiments at Äspö HRL.

2.3.1 Monitoring of Groundwater Chemistry

During the Äspö HRL construction phase, different types of water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. 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 hydrogeochemical conditions with respect to time and space within the Äspö HRL. This programme is designed to provide information to determine where, within the rock mass, the hydrogeochemical changes are taking place and at what time stationary conditions are established. In addition, all ongoing experiments have the possibility to request additional sampling of interest for their projects.

Achievements

The yearly monitoring programme was conducted as planned during September and October. Examples of additional parameters that were sampled and analysed are ATP (adenosine triphosphate) and isotopes. Full reporting is expected during the second quarter of 2008.

2.3.2 Gas migration

New activities within the geochemistry field have been identified regarding the migration of gases. The plan is to analyse isotopes both in the gas and liquid phase and evaluate their possible implication for sulphate reduction or biomineralisation in general.

Achievements

Initial tests of existing gas sampling equipment have been performed and samples are sent for analysis of new parameters. Results are expected in the beginning of 2008. Preliminary data suggests methane to be present in the gas phase. Further sampling and analysis are needed to get more reliable data of concentrations and for being able to decide whether this is enough for further analysis of the isotopic composition (in the gas phase).

2.4 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 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.

2.4.1 Stress Measurements - Core Disking

The objective of this study is to determine the stress levels at which core disking (solid cores) and ring disking (hollow cores) develop. This is achieved by overcoring, supplemented with core drilling, in an area where stress conditions are reasonably well known, i.e. in this case the TASQ-tunnel at Äspö HRL. In addition to the field work, geological modelling and numerical stress analysis are conducted to aid in explaining field observations.

Achievements

The conducted field work comprised drilling of four vertical boreholes in the tunnel floor in the vicinity of deposition hole DQ0063G01 in the TASQ-tunnel. Detailed core logging was performed, followed by geological modelling and creating an RVS-model of the test site, see Figure 2-1. The numerical modelling was conducted using the three-dimensional distinct element code 3Dec /Itasca, 2003/.

The results from this work showed that it was not possible to fulfil the primary objective, to determine stress levels at which core disking occurs. The reasons for this were: (i) the lack of systematic core disking in the boreholes (only a few, separate, instance of disking observed), and (ii) the practical difficulties in drilling and overcoring, thus achieving only four core holes, and only one successful stress measurement. However, both this single measurement, and the observed isolated instances of core disking and borehole breakouts indicated low stresses in the test volume. The final report titled "Core disking study in the TASQ-tunnel" is now completed and will soon be published.

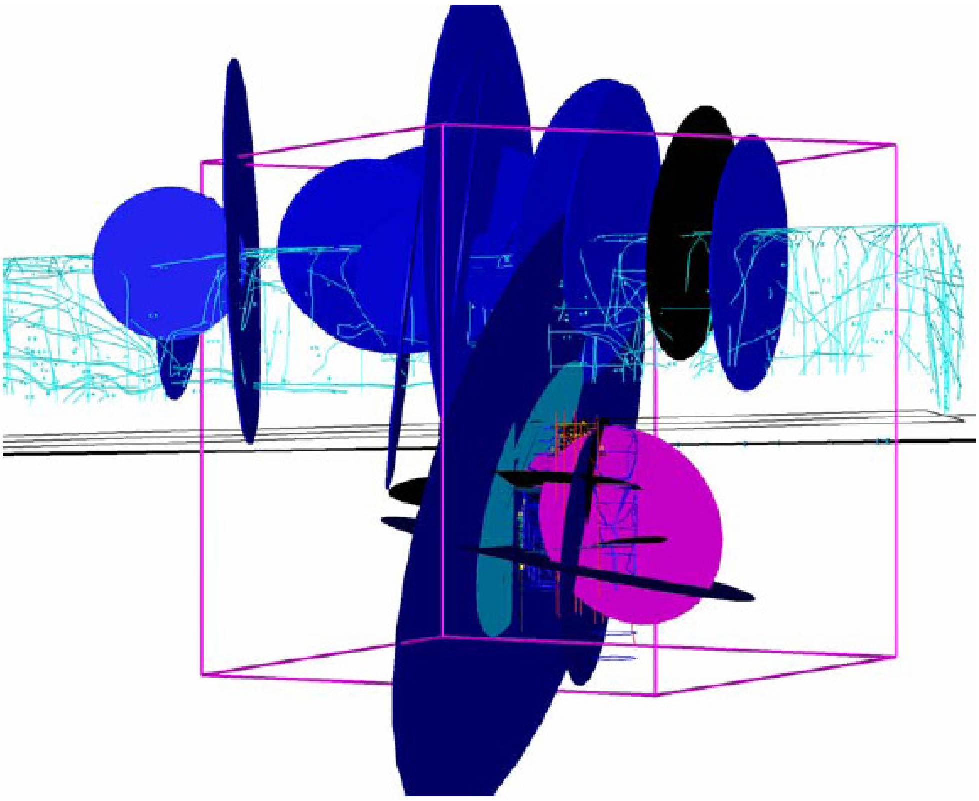


Figure 2-1. *The RVS model of the investigated area shown together with the mapped fractures in the TASQ-tunnel (light blue lines). Data from the characterisation of the Apse experiment volume /Andersson 2007/ and from this study has been used to develop the 3D fracture model. Notice especially the steeply dipping large fractures in a large angle to the tunnel, trending NW –SE. The high frequency of this fracture set in the investigated volume of rock was the major cause for the problems encountered.*

3 Natural barriers

At the Äspö HRL, experiments 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. 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. As an example, the processes that influence migration of species along a natural rock fracture are shown in Figure 3-1.

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.

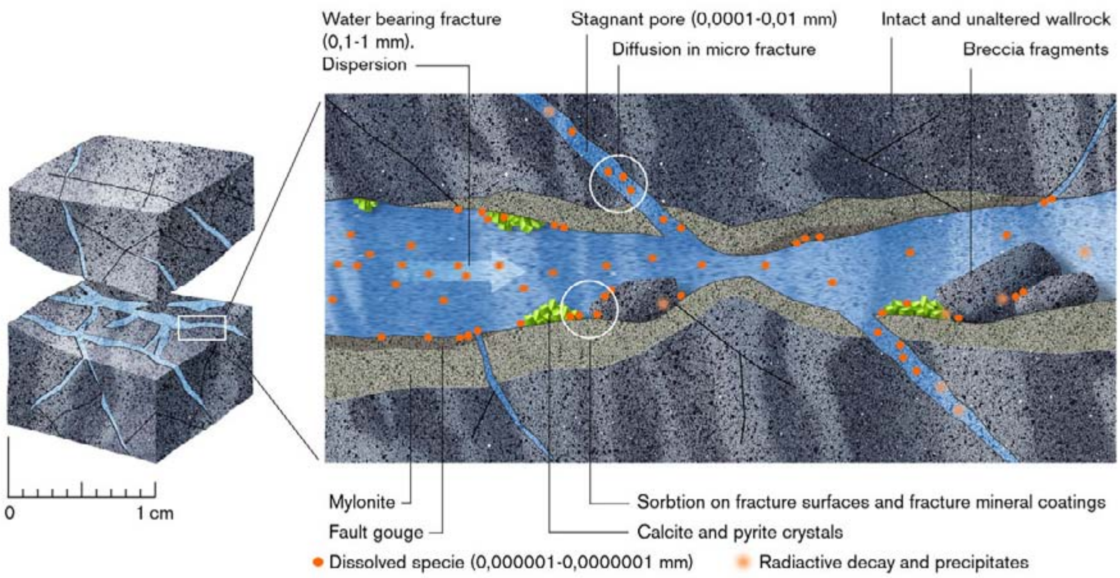
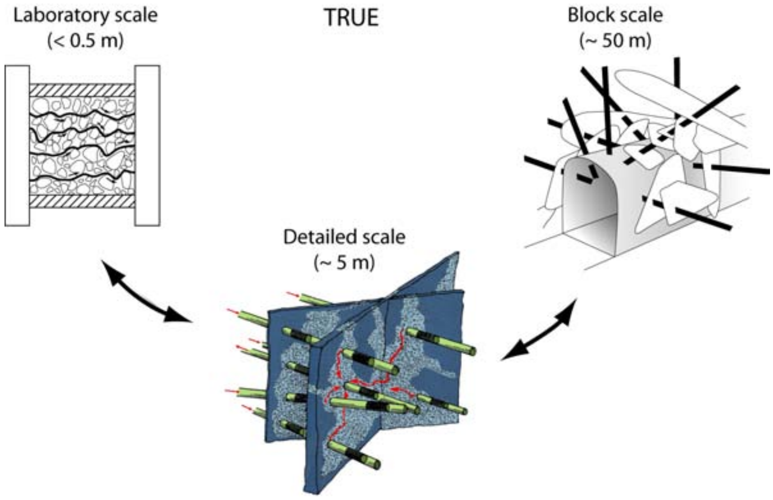


Figure 3-1. *Processes that influence migration of species along a natural rock fracture.*

3.1 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) performed in the detailed scale and the True Block Scale series of experiments have come to their respective conclusion. Complementary field work and modelling are performed as part of two separate but closely coordinated continuation projects.

The True Block Scale Continuation project aims at obtaining additional understanding of the True Block Scale site. The project is now completed and the final report is published /Andersson et al. 2007/.

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.

3.1.1 True Block Scale Continuation

The True Block Scale Continuation (BS2) project had its main focus on the existing True Block Scale site. Work performed included complementary modelling work in support of planned in situ tests (BS2a) and in situ tracer tests with sorbing tracers and subsequent assessment of the relative retention in flow paths made up of fault rock zones and background fractures, respectively (BS2b). Results verified lower retention material properties in the background fractures flow path but also showed a higher overall retention in this flow path owing to the much lower flow rate therein /Andersson et al. 2007/. In the aftermath to the BS2 project, a second step of the continuation of the True Block Scale (BS3) has been 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.

Achievements

During the fourth quarter work was devoted to finalise manuscripts reporting results of the True Block Scale/Block Scale Continuation experiments. The two part series of scientific papers are devoted to "Transport and retention from single to multiple fractures in crystalline rock at Äspö (Sweden)". Both articles are planned to be submitted to peer-reviewed scientific literature during 2008.

In the first paper, the main goal is to test several hypotheses as a basis for predicting transport and retention in the performed tests. A preliminary incomplete draft manuscript has been completed and will be circulated for comments. In preparing the final draft, however, a new set of discrete fracture network (DFN) simulations with ConnectFlow is required (made as part of an ongoing PhD thesis work) which will constitute an important new contribution during 2008.

The goal of the second paper is first to evaluate in situ retention parameters similar to what was done for the True-1 tests in the second part of the True-1 series scientific articles /Cvetkovic et al. 2007/ thereby completing a consistent suite of in situ retention parameters evaluated for all True tests. Furthermore, the hydrodynamic control of retention, and the impact of longitudinal variability and depth-wise trends in matrix porosity of the rim zone will be discussed. Finally, the entire set of measured (in situ) and evaluated (ex situ) retention properties from True tests will be discussed, attempting to establish a consistent general picture for the retention properties of the Äspö site.

3.1.2 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 includes performance of the planned 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, furthermore, performance of the Fault Rock Characterisation project, the latter in parts a dress rehearsal for True-1 Completion.

Achievements

Two articles on True-1 have been published in Water Resources Research (WRR) in 2007. The third of the planned papers, dealing with effects of micro-scale heterogeneity, was submitted to WRR in December. For achievements in the sub-project True-1 Completion see the following section.

3.1.3 True-1 Completion

True-1 Completion is a sub-project of the True-1 Continuation project and is a complement to already performed and ongoing projects. The main activity within True-1 Completion is 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 will be performed prior to the epoxy injection. These tests are aimed to secure important information from Feature A and the True-1 site before the destruction of the site, the latter which is the utter consequence of True-1 Completion.

Achievements

The major activity during the period was the reconstruction and characterisation of the cores from the boreholes KXTT3 and KXTT4 with focus on the target structures as visible in Figure 3-2. As presented in earlier reports, the cores from the target sections included more pieces than intended due to breakage of the cores during the drilling, whereas the reconstruction was rather complicated. However, the cores from the target sections are still considered to provide valuable information in coming analysis. Since the original plan was based on intact cores, the up-coming activities, such as preparation and analysis of core material, had to be revised during the period.

Figure 3-2. *Feature A in KXTT3 (to the left) and in KXTT4 (to the right). The green material is uranine tagged epoxy.*

3.2 Long Term Sorption Diffusion Experiment

Sample core drilled from the fracture surface on the core stub

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.

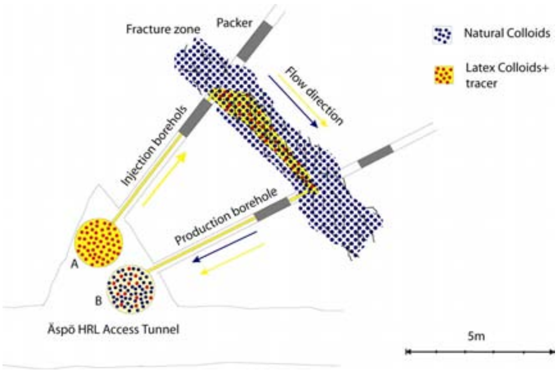
The aims are to improve the understanding of diffusion and sorption processes and to obtain diffusion and sorption data at in situ conditions.

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 will be followed by analyses of tracer content.

Achievements

The small diameter sample cores (24 mm) extracted 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 are underway to be cut into thin slices and scanned with autoradiography. So far 8 sample cores of totally 34 have been sliced and scanned. Scanning of the first slices showed that radionuclide tracers had been transported by the drill bit along the envelope surface on the sample cores during drilling of the cores. To remove this contamination the following sample cores were sawed into square profile pillars before slicing. Preliminary results from analysis of saw fluid (alcohol) and saw debris from slicing shows penetration depth up to about 30 mm for ^{22}Na and ^{85}Sr.

3.3 Colloid Dipole Project



The Colloid Dipole Project is a continuation of the Colloid Project which was ended in 2006. The Colloid dipole experiment comprises studies of the potential of colloids to enhance radionuclide transport and the potential of bentonite clay as a source for colloid generation. The concentration, stability and mobility of colloids in the Äspö environment are studied and in situ experiments where the colloidal effect on actinide transport in a water bearing fracture will be studied.

The ended Colloid Project included laboratory experiments, background colloid measurements and borehole specific measurements.

Achievements

The main activities during the fourth quarter of 2007 have been:

- A licentiate-thesis dealing with the impact of groundwater chemistry on the stability of bentonite colloids was presented on the 5th of October /Garcia Garcia, 2007/. Results from experiments on the individual and combined effects of pH, ionic strength and temperature on bentonite colloid stability are summarised in the thesis.
- A Colloid Workshop was given in Stockholm, 15th -16th of November. Experimental and modelling activities performed in the project during 2007 were presented. Both project members and people outside the project participated in the workshop. The first day of the workshop was devoted to presentations while planning of activities for Phase II was performed during the second day. Special emphasis was given to planning and discussion of activities of both experimentalists and modellers.
- The transport experiments in the quarried block at the AECL laboratory are finished. The following issues have been studied: (i) colloid migration in saline waters, (ii) effects of particle sizes, in monodisperse and polydisperse suspensions, on colloid migration and (iii) colloid migration in low to high flow between separated boreholes.
- Modelling of transport data.
- Experimental studies on colloid stability and radionuclide colloid interaction under Äspö groundwater conditions are concluded and evaluated.

3.4 Microbe Projects

3.4.1 The Microbe laboratory and the Bios site

Scientists working with Prototype microbiology analysis

The Microbe laboratory and the Bios site have been installed in the Äspö HRL for studies of microbial processes in groundwater under in situ conditions.
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.

The Microbe site is on the -450 m level where a laboratory container with benches, an anaerobic gas box 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. Each borehole has been equipped with a circulation system offering 2,112 cm^2 of test surface.

Retention of naturally occurring trace elements in the groundwater by Biological Iron Oxides (Bios) is investigated at tunnel length 2,200 m. There is a vault with a borehole that delivers groundwater rich in ferrous iron and iron oxidising bacteria. The borehole is connected to two 200 × 30 × 20 cm artificial channels that mimic ditches in the tunnel. The channels have rock and artificial plastic support that stimulate Bios formation.

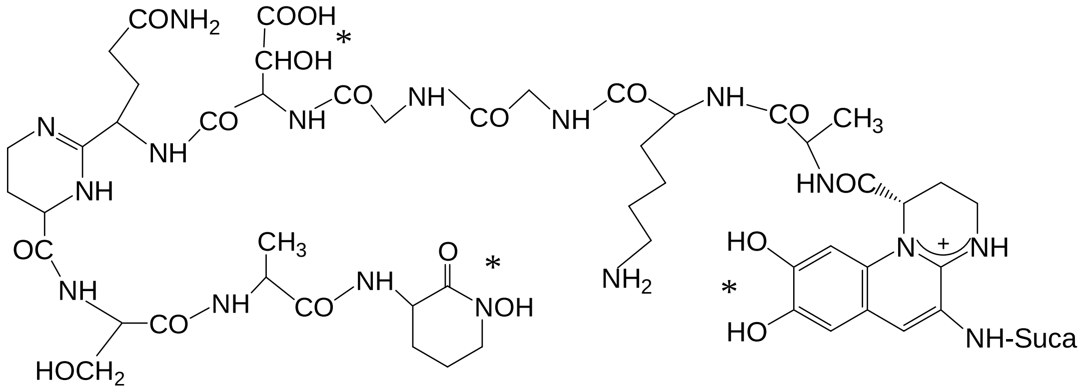
Achievements

The Microbe site has been used as a base for investigations of the Prototype Repository (see Section 4.1) that offers a unique opportunity to explore microbe-gas-chemistry interactions in bentonite buffer and backfill. Over all, the observations strongly supported the present hypothesis that oxygen will be consumed by bacteria within a short time span (i.e. weeks to years), as opposed to the time span predicted by abiotic processes (many years). The gas data generally showed that oxygen is disappearing and that methane oxidising bacteria (MOB) were responsible for at least some of the oxygen decrease. The microbes also affected the chemistry in the Prototype Repository, both indirectly by being active and changing redox and pH and possibly directly with compound-specific ligands.

Analysis of the gases hydrogen, helium, nitrogen, oxygen, carbon monoxide, carbon dioxide, methane, ethane and ethene was performed on samples from 16 hydrochemical sampling points within the Prototype Repository. The sampling points in the Prototype that delivered porewater were analysed for total number of cells (TNC), the amount of ATP (i.e. the biovolume), cultivable heterotrophic aerobic bacteria (CHAB), sulphate-reducing bacteria (SRB), MOB and autotrophic acetogens (AA). The collected porewater from the Prototype Repository was sent for chemical analysis. The sampling and analysis protocols worked properly and were improved during 2007, when pressure vessels in stainless steel were introduced to extract pore water. By this, it was possible to extract water from nine of the 16 sampling points, compared to the previous six. During the years of examination of the gas composition, microbial composition and chemistry in the Prototype Repository, it has been revealed that many of the hydro chemical sampling points differs quite remarkably from each other. The 16 sampling points have therefore been divided into seven sampling groups with similar properties. One sampling group (KBU10002+8) resembles the groundwater while others (KBU10004+6, KBU10005, KFA01-04) are different in e.g. microbial composition and salinity, sulphate content, concentration of Ca, K, Mg, Na, pH and many dissolved metals, actinides and lanthanides. One sampling group contains sampling points that seems to have contact with tunnel air (KBU10003+7). One sampling group contains sampling points near the canisters in the buffer (KB513, 514, 613 and 614) where most of the porewater likely evaporates leaving very little porewater with very high pH and salt content. One sampling point in the backfill has not yet been reached by the groundwater (KBU10001).

The gas composition in the sampling groups was uniform in the aspect that the nitrogen content was increasing and the oxygen content was decreasing. In most sampling groups, the oxygen content in the gas phase was around 3-7% (May 2007), which can be compared to the oxygen content in 2005 of 10-18%. Hydrogen, methane, helium and carbon dioxide concentrations varied, especially in the sampling groups with extractable porewater. The variation of these gases could be due to microbial activity. High numbers of MOB correlated with high oxygen content. High numbers of CHAB correlated with high carbon dioxide content and high numbers of AA correlated with high hydrogen content and low carbon dioxide content. Hydrogen seemed to stimulate SRB. ATP analyses showed that the biomass in the Prototype Repository is increasing. The microbiological results showed that aerobic bacteria such as MOB and CHAB bacteria thrived in the aerobic Prototype environment, where 120-2,300 times more microbes of the respective kind were found in comparison to the surrounding groundwater. Anaerobic SRB were increasing in abundance and occasionally exceed the number of SRB outside 12 times. AA was found in numbers 200 times over the surrounding groundwater. The chemistry data showed differences between the sampling groups. The pH and concentrations of Na and K were higher in the porewater than in the groundwater outside. Ca and sometimes Mg were lower than in the groundwater. Obviously, cation exchange in the montmorillonite interlayers had occurred. Occasionally, high concentrations of Al, Ni, Zn and Cu were observed in the Prototype repository porewater. Corrosion of the heavy instrumentation can be a possible explanation. However, in sampling points with active microbes Rb, Cs, V and U are enriched from two to over 400 times compared to the groundwater. It is possible that microbes were responsible of the dissolution by excretion of compound-specific ligands (confer Micomig).

3.4.2 Micomig



Structure of the pyoverdin from P. fluorescens (CCUG 32456) with a succinamide (Suca) side chain (Suca-Chr-Ala-Lys-Gly-Gly-OHAsp-(Gln-Dab)-Ser-Ala-cOHOrn). Asterisks indicate the complexation sites. The amino acids Ala, Lys, and Gln (underlined) are D-configured.

It is well known that 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. Recent work indicates that these surfaces adsorb up to 50% of these radionuclides in natural conditions with retention factors (Ka) approaching 10^5 and 10^6 (m) for Co and Pm respectively.

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

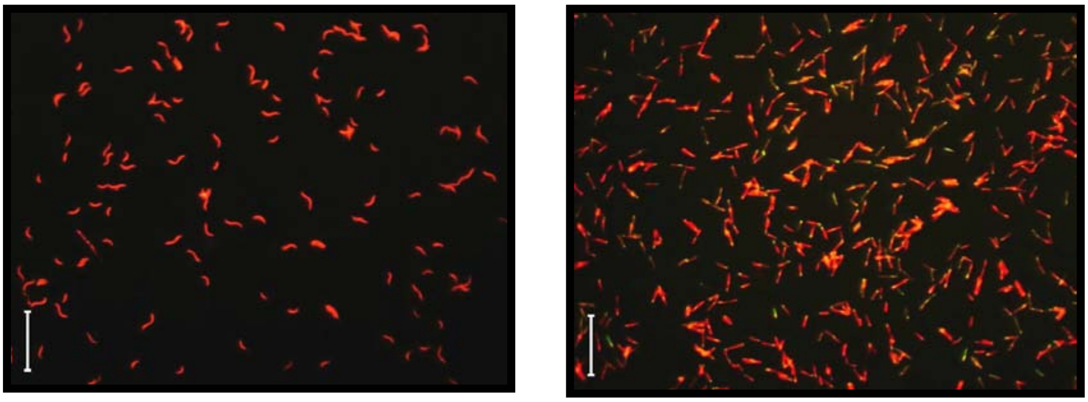
Several *Pseudomonas* species synthesize siderophores called pyoverdins under iron-deficient conditions. Pyoverdins produced by different species display many structural similarities: they are yellow–green, water-soluble and due to the presence of a chromophore, fluorescent pigments that are very effective in complexing and transporting iron(III).

Structurally, they can be divided into three different parts: (1) a peptide chain composed of 6 to 12 mainly hydrophilic amino acids bound via their N-termini to the carboxyl group of the chromophore, (2) the chromophore (1S)-5-amino-2,3-dihydro-8,9-dihydroxy-1H-pyrimido[1,2-a]quinoline-1-carboxylic acid and (3) an acyl chain attached to the NH2 group of the chromophore consisting of dicarboxylic acid residues, for example, succinate or its amide form depending on the growth conditions. The composition of the peptide chain displays great diversity depending on the producing strain. To date, more than 50 different pyoverdins have been reported in the literature. So far only one pyoverdin produced by a *P. fluorescens* strain has been structurally determined using X-ray analysis.

Pyoverdin-type siderophores have a high potential to dissolve, bind, and thus transport uranium in the environment. The formation of complexes of UO_2^{2+} with pyoverdins released by the groundwater bacterium *Pseudomonas fluorescens* (CCUG 32456) isolated at a depth of 70 m in the Äspö HRL, was studied. Mass spectrometry indicated that the cells produce a pyoverdin mixture with four main components: (1) pyoverdin with a succinamide side chain, (2) pyoverdin with a succinic acid side chain, (3) ferribactin with a succinamide side chain and (4) ferribactin with a glutamic acid side chain. Three pK values could be determined from the pH-dependent changes in the absorption spectra of the pyoverdin mixture: log $ß_{012} = 22.67 \pm 0.15$ ($pK_1 = 4.40$), log $ß_{013} = 29.15 \pm 0.05$ ($pK_2 = 6.48$) and log $ß_{014} = 33.55 \pm 0.05$ ($pK_3 = 10.47$). The fluorescence properties of the pyoverdin mixture were pH dependent. The emission maximum changed from 448 nm at pH = 2.1 to 466 nm in the pH 3.8–8.9 range. At pH > 4 a monoexponential fluorescence decay dominates with a decay time of 5,865 ± 640 ps. A drastic change in the intrinsic fluorescence properties, e.g., static fluorescence quenching, occurred due to the complex formation with UO_2^{2+}. Species containing UO_2^{2+} of the type $M_pL_qH_r$ were identified from the dependencies observed in the ultraviolet visible and time-resolved laser-induced fluorescence spectroscopy spectra at pyoverdin concentrations below 0.1 mM. The following average formation constants were determined: log $\beta_{112} = 30.00 \pm 0.64$ and log $\beta_{111} = 26.00 \pm 0.85$ at ionic strength I = 0.1 M ($NaClO_4$). The determined stability constants can be used directly in safety calculations of the mobilising effect of released pyoverdins on uranium, in uranium-contaminated environments such as mine and radioactive waste disposal sites.

Three papers have been completed within Micomig during 2007 /Essén et al. 2007, Moll et al. 2007a, b/.

3.4.3 Micored



Fluorescent microscopy of the vibrioid D. aespoeensis strain Da22 (to the left) and the rod shaped D. aespoeensis strain Da3 (to the right) stained with acridine orange. The bars represent 10 µm.

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 from deep geological processes contributes to the redox stability of deep groundwater via microbial turnover of this gas. Hydrogen, and possibly also carbon monoxide and methane energy metabolisms will generate secondary metabolites such as ferrous iron, sulphide, acetate and complex organic carbon compounds. These species buffer towards a low redox potential and will help to reduce possibly introduced oxygen.

The work within the Micored project will:

- Clarify the contribution from microorganisms to stable and low redox potentials in near-and far-field 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

Four strains of *Desulfovibrio aespoeensis* (Da2, 3, 5, 22) and five of *Acetobacterium carbinolicum* (Ac1-4, 6) were isolated from groundwater at 450 m depth in the Äspö tunnel and identified with the 16S rRNA and adenosine 5´-phosphosulphate A (apsA) gene sequences. In addition, the type strain of *D. aespoeensis* previously isolated from Äspö was investigated. The newly isolated *D. aespoeensis* strains had identical 16S rRNA and apsA gene sequences but differed in 8 and 30 positions, respectively, compared to the type strain of *D. aespoeensis*. The five strains of *A. carbinolicum* had identical 16S rRNA gene sequences. This sequence was identical to the sequence of *A. carbinolicum* X96956.

Recently, we discovered that the isolated *D. aespoeensis* (Da) strains had different morphologies. Therefore, we examined the genotypic and phenotypic diversity of the *D. aespoeensis* strains and also of the *A. carbinolicum* (Ac) strains further. The whole genome was investigated using Enterobacterial Repetitive Intergenomic Consensus PCR (ERIC-PCR). To evaluate if the differences in genotypes were reflected in the phenotypes, the strains were incubated at several temperatures, salt concentrations and with different carbon sources.

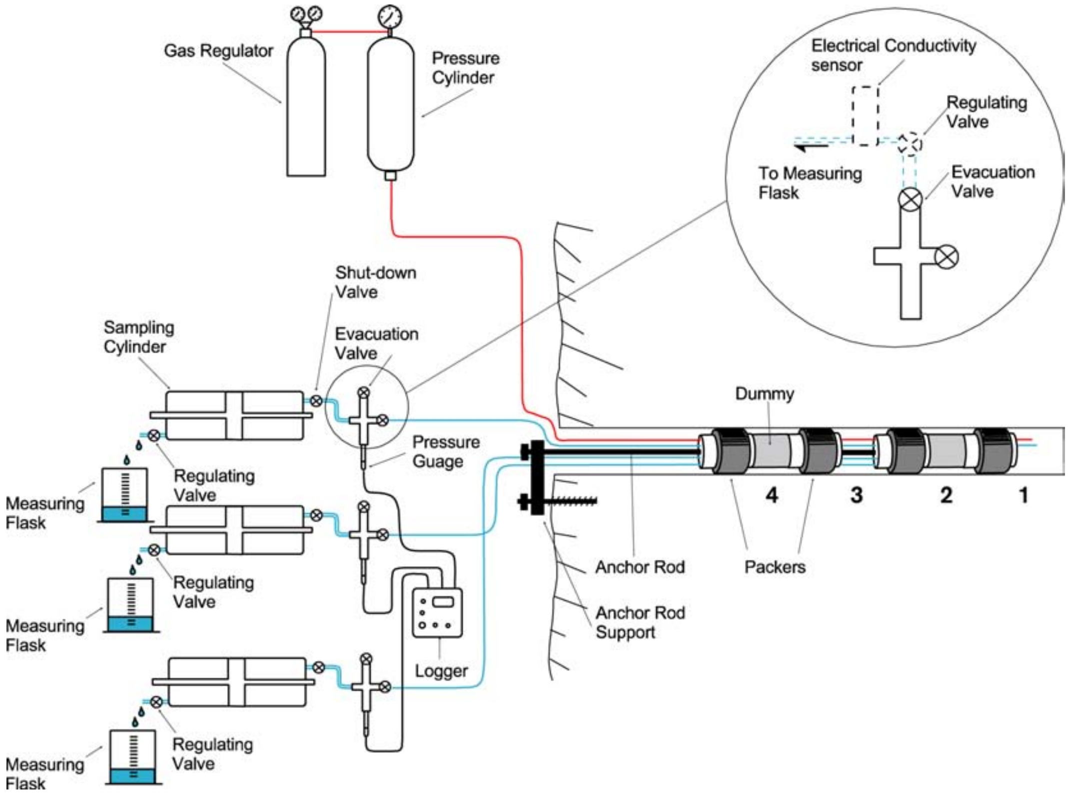
The ERIC-PCR revealed a clear genetic diversity of the analysed strains. All Da strains had substantially different ERIC-PCR patterns compared to the type strain of *D. aespoeensis.* The Da strains, especially strain Da3, differed between themselves in ERIC-PCR profiles despite identical 16S rRNA and apsA sequences. Strain Ac1 and Ac2 had almost identical ERIC-PCR profiles. Ac6 had a similar profile compared to these but nevertheless lacked the 1,400 bp long band, which existed in Ac1 and Ac2. Ac3 and Ac4 were similar to each other and lacked bands longer than 500 bp.

The genotypic diversity of the 10 strains, revealed by ERIC-PCR, was clearly reflected in the phenotype. The cells of the Da strains were slightly longer than the type strain of *D. aespoeensis.* This strain also differed from the other Da strains in its optimal, lower, growth temperature and inability to grow on lactate without addition of yeast extract. The phenotypic diversity was reflected in Da3 being a straight rod compared to the vibrioid shape of Da2, 5 and 22. Furthermore, Da3 was able to grow autotrophically on H_2 without addition of yeast extract. All the Da strains grew best at 37°C and with 0.7% NaCl. However, strain Da5 and Da22 (having identical ERIC-PCR profiles) grew only slightly faster at 37 °C compared to 16°C – 22°C, while Da2 grew considerably faster at 37 °C compared to 16°C – 22°C. Strain Ac1 and Ac2 had similar ERIC-PCR profiles and grew in the temperature interval 22˚C – 37˚C. Strain Ac3 and Ac4 had similar ERIC-PCR profiles and grew in the temperature interval 16˚C – 22˚C. Strain Ac6, with unique ERIC-PCR profiles, differed from the other Ac strains in the ability to grow on lactate without addition of yeast extract and to grow in a wide NaCl interval (0.7% – 4%).

In conclusion, the genotypic ERIC-PCR profiles and the phenotypic characters of the studied *D. aespoeensis* and *A. carbinolicum* strains were investigated independently of each other and were found to correlate. ERIC-PCR and phenotypic characterisation revealed a strain diversity that was absent in the 16S rRNA gene sequence information. Differences in the phenotype as well as the genotype were evident for the *D. aespoeensis* and *A. carbinolicum* strains, despite identical 16S rRNA gene sequences. Micro-diversity is clearly present among microbes isolated from the deep Äspö HRL biosphere.

Three papers have been completed within Micored during 2007 /Eydal and Pedersen 2007, Hallbeck and Pedersen 2008, Kyle et al. 2008/.

3.5 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.

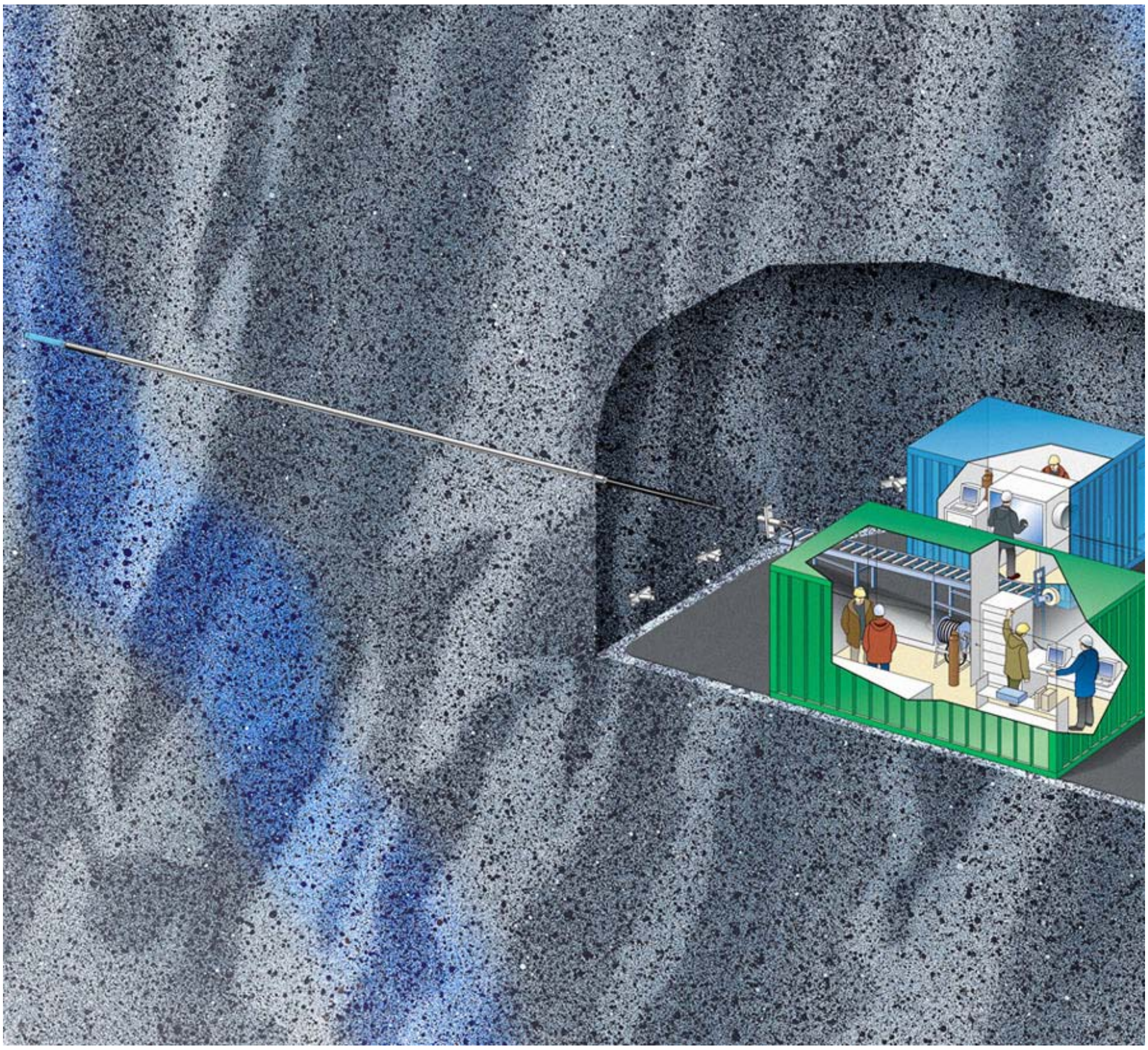
Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied to determine their contribution, if any, to the composition of the matrix fluids/groundwater.

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.

Achievements

Final reporting of matrix fluid chemistry and matrix borehole hydraulic testing are underway and scheduled to be finalised at the end of May, 2008.

3.6 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 bentonite samples and on tiny rock fractures in drill cores.

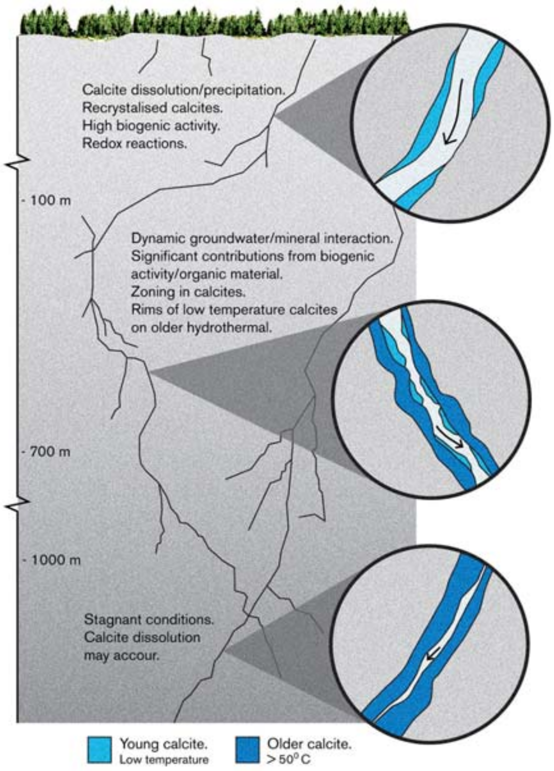
Chemlab 1:
- Investigations of the influence of radiolysis products on the migration of the redox-sensitive element technetium in bentonite (finalised).
- Investigations of the transport resistance at the buffer/rock interface (planned).

Chemlab 2:
- Migration experiments with actinides in a rock fracture (almost finalised).
- Study leaching of spent fuel at repository conditions (planned).

Achievements

All resources from the Radionuclide Retention Experiments have been allocated by other projects with higher priority and therefore there have been no experimental activities since 2005.

3.7 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 objectives of Padamot are to:

- Improve understanding and prioritise palaeo-hydrogeological information for use in safety assessments.
- Collect chemical/isotopic data using advanced analytical methods.
- Construct a database of relevant information and develop numerical models to test hypotheses.
- Integrate and synthesise results to constrain scenarios used in performance assessments.
- Disseminate the results to the scientific community.

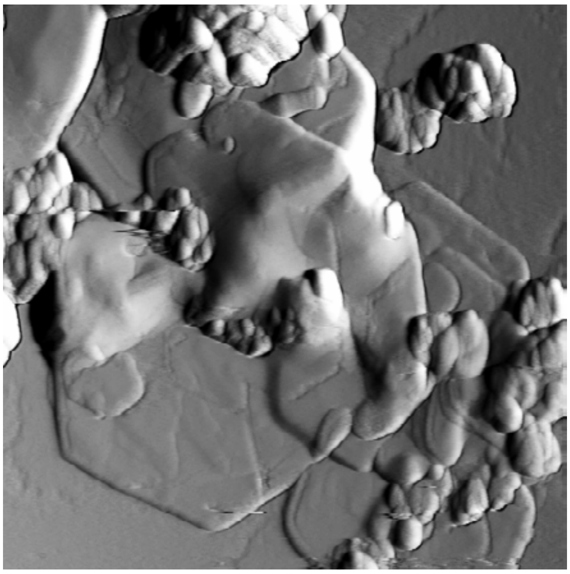
The EC-part of the project was finalised and reported in 2005. The present project comprises analytical and modelling tasks mainly based on uranium series analyses. Material from borehole KAS17 at Äspö is used in this study.

Achievements

The new phase of the project concerns uranium series measurements where different approaches are tested by two different laboratories. 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 and several sections with fractured rocks are intersected by the borehole.

New results using sequential leaching techniques combined with the U-series analyses carried out at Helsinki university show very promising results and add valuable information to the already achieved results from the “whole sample” analyses.

3.8 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 was 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.

The aim of the present continuation programme is to establish the penetration depth of oxidising water below ground.

Achievements

Present status is that the approximately 60 samples collected in September 2006 have been examined with optical microscopy and half have been selected for more detailed study. These samples have been studied with X-ray diffraction, Mössbauer spectroscopy (MS) and scanning electron microscopy (SEM).

Amorphous and very fine-grained Fe-oxides have been identified down to approximately 20 m, and crystalline and fine-grained Fe-oxides down to approximately 50 m. In addition, finer-grained goethite has been identified to depths of approximately 60 m and 90 m respectively, which is interesting because it is not usually found in such environments. Although the study is not complete, these results suggest that iron oxides have formed at low-temperature down to 50 m below surface and possibly even down to a depth of 90 m. Unfortunately the lower boundary for the passage of oxidised water is constrained by only two hydrothermal samples. To resolve this situation, an additional three samples from the longer drill core KLX09A have been made available to look for Fe-oxides at greater depth. Preliminary optical microscopy shows that only two of these samples are likely to contain Fe-oxides. These Fe-oxides will now be subjected to detailed study which will include Fe-isotope analysis and, possibly, dating using U-decay series. For a few selected samples, a small amount of solid material will be saved with the aim of performing analysis of their O isotope content.

These redox front observations from detailed studies of a few strategically selected samples are important in that they confirm much of the general ongoing mineralogical work being carried out within the Laxemar and Forsmark site investigation programmes.

3.9 Swiw-test with Synthetic Groundwater

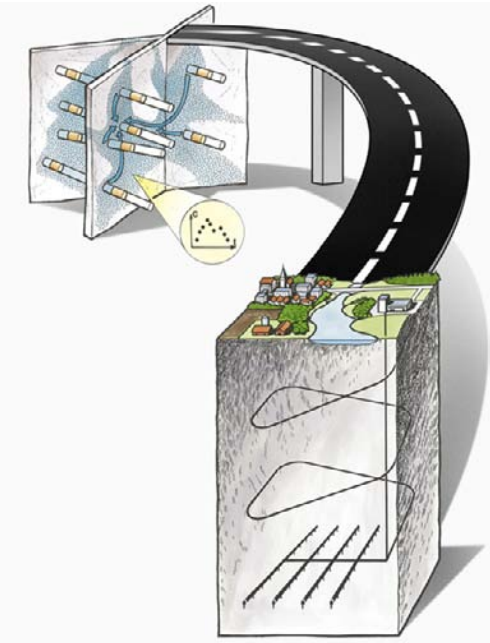
The Single Well Injection Withdrawal (Swiw) tests with synthetic groundwater constitute a complement to performed tests and studies on the processes governing retention, e.g. the True-1 and the True Block Scale experiments. This project aims to deepen the understanding of retention. Swiw-tests with synthetic groundwater facilitate the study of diffusion in stagnant water zones and in the rock matrix. It also facilitates the possibility to test the concept of measuring fracture aperture with the radon concept.

The original location in mind for the tests was the True Block Scale site and the well characterised Structures #19 and #20. The two structures have been object to a large number of tracer tests, possess different characteristics and are located on different distances from the tunnel. The usage of the True Block Scale site gives a unique possibility to ”calibrate” the concept of single hole tracer tests, Swiw, to multiple borehole tracer tests. The results from such a calibration can be applied directly to the Swiw-tests performed within the SKB site investigation programme.

Achievements

The major activity during the period was finalisation of the feasibility study. The report will be reviewed before printing. Results from the study show that a combination of Swiw tests with and without waiting period will be the best way to distinguish between fast and slow diffusion processes. Furthermore, it shows that it is useful to use many tracers with different characteristics to facilitate the interpretation of the tests. As mentioned in earlier status reports, True Block Scale may be used as a test site, however it is not accessible until early 2009 due to the tunnelling in the vicinity. At that point it is a clear risk that the new tunnel has altered the conditions in True Block Scale so that it no longer is suitable for Swiw tests. Hence, it may be necessary to find an alternative test site for Swiw test with synthetic groundwater.

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



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 Äspö Task Force constitutes an important part of the international co-operation within the Äspö Hard Rock Laboratory.

Achievements

In the Task Force, work has been in progress in Task 6 and Task 7 during the fourth quarter. The 23rd Task Force meeting was held in Toronto in the end of October and the minutes have been sent out. The status of the specific modelling tasks is given within brackets in Table 3-1.

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. It is hoped that this will help to identify the relevant conceptualisations (in processes/structures) for long term PA predictions and to identify site characterisation data requirements to support PA calculations. A summary of the outcome of Task 6 has been submitted to a scientific journal. In addition, four modelling groups have submitted papers to the same scientific journal in conjunction with the summary paper.

Task 7 addresses modelling of the OL-KR24 long-term pumping test at Olkiluoto in Finland. The task will focus on methods to quantify uncertainties in PA approaches based on SC information. The task is also an opportunity to increase the understanding of the role of fracture zones as boundary conditions for the fracture network and how compartmentalisation influences the groundwater system. The possibilities to extract more information from interference tests will also be addressed. Task 7 is divided into several sub-tasks. A task description for the sub-task 7A has been sent out to the modellers and preliminary results from the modelling have been presented. Updated Task 7 information and data deliveries have been made.

Table 3-1. Task descriptions and status of the specific modelling sub-tasks.

6	**Performance Assessment (PA) modelling using Site Characterisation (SC) data.**
6A	Model and reproduce selected True-1 tests with a PA model and/or a SC model to provide a common reference. (External review report printed).
6B	Model selected PA cases at the True-1 site with new PA relevant (long term/base case) boundary conditions and temporal scales. This task serves as means to understand the differences between the use of SC-type and PA-type models and the influence of various assumptions made for PA calculations for extrapolation in time. (External review report printed).
6C	Develop semi-synthetic, fractured granite hydrostructural models. Two scales are supported (200 m block scale and 2,000 m site-scale). The models are developed based on data from the Prototype Repository, True Block Scale, True-1 and Fracture Characterisation and Classification project (FCC). (External review report printed).
6D	This sub-task is similar to sub-task 6A and is using the synthetic structural model in addition to a 50 to 100 m scale True-Block Scale tracer experiment. (Most modelling reports printed and final review report available).
6E	This sub-task extends the sub-task 6D transport calculations to a reference set of PA time scales and boundary conditions. (Most modelling reports printed and final review report available).
6F	This sub-task is a sensitivity study, which is proposed to address simple test cases, individual tasks to explore processes and to test model functionality. (Most modelling reports printed and final review report available).
7	**Long-term pumping experiment.**
7A1	Hydrostructural model implementation (Preliminary results were presented at the Task Force Workshop in June).
7A2	Pathway simulation within fracture zones (Preliminary results were presented at the Task Force Workshop in June).
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	This sub-task 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.
7C	Here focus is on deposition hole scale issues, resolving geomechanics, buffers, and hydraulic views of fractures.
7D	Tentatively this sub-task concerns integration on all scales.

4 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.

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

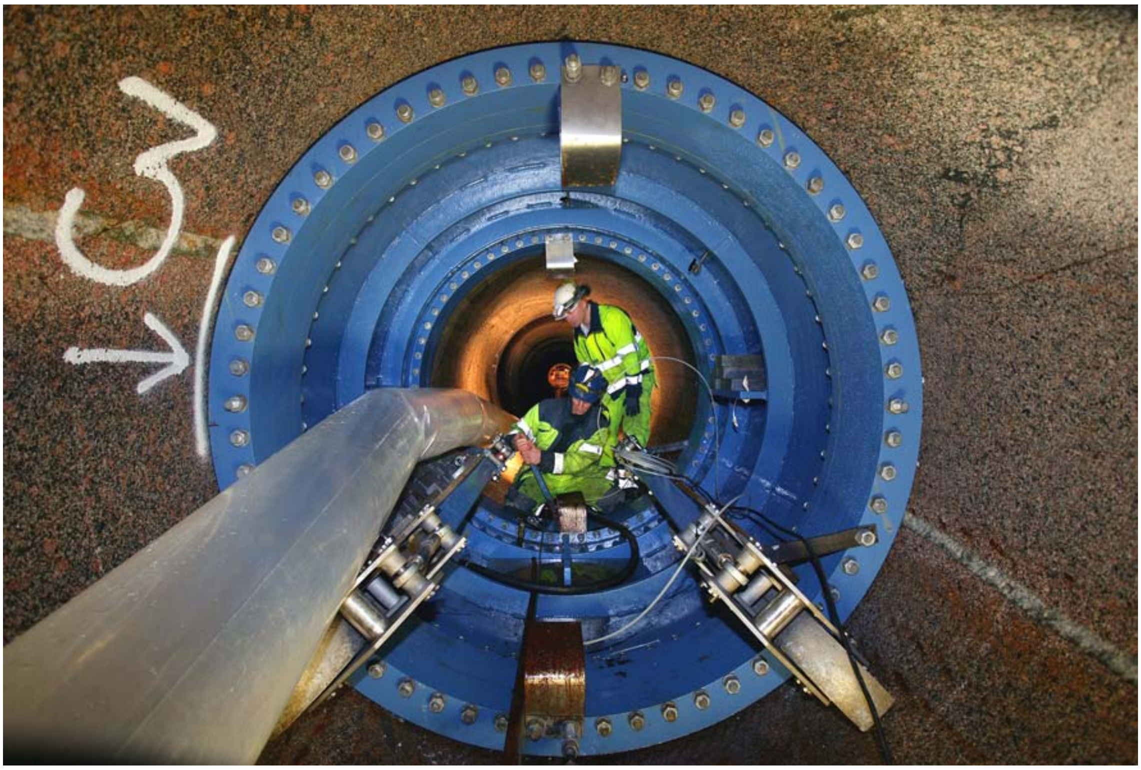
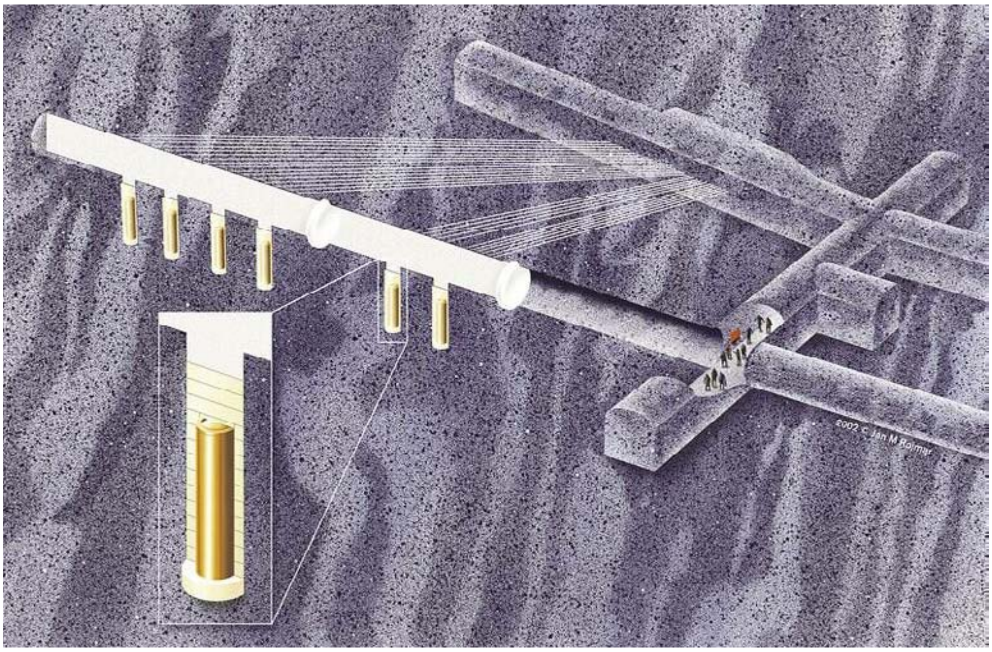


Figure 4-1. *Grouting tests performed in the KBS-3H project with Megapacker in the 95 m long deposition hole located at -220 m level in Äspö HRL.*

4.1 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.

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.

The inner tunnel (Section I) 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) was backfilled in June 2003 and the tunnel plug with two lead-throughs was casted in September the same year.

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. 17 covering the period up to May 2007 has been published /Goudarzi and Johannesson 2007/. Overhauling of the data acquisition system is in progress and hydraulic tests of the rock mass have been performed. Measurements of pH and Eh of water samples taken from boreholes in Section I and II of the Prototype Repository and the G-tunnel is ongoing.

A programme for sampling and analyses of gases and microorganisms in the backfill and buffer has started, see Section 3.4.1. The results from the first and second campaign are reported in a technical document and the third campaign is finalised. The measurements will continue during next year. A report of the analyses performed in the buffer and backfill during 2004-2007 has been written and will be published soon as an International Progress Report.

Acoustic Emission and Ultrasonic monitoring results from deposition hole 5 and 6 have been reported for the period between October 2006 and March 2007 /Zolezzi et al. 2007/ and the measurements are continuing.

A thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been developed and reported /Kristensson and Hökmark 2007/. The 1 D THM modelling of the buffer in deposition hole 1 and 3 has been finished and a report will soon be published. The thermal model of the entire experiment has been extended to incorporate mechanical behaviour in order to evaluate whether occurrence of spalling is possible. This work has been finalised and will be reported at the beginning of 2008. Furthermore, a 2D TH modelling of an entire deposition hole is in progress and will be reported during 2008. Small THM models have been developed in the Mathcad environment in order to calibrate an elasto-plastic material model to be used for the bentonite block and the outer slot filled with bentonite pellets.

4.2 Long Term Test of Buffer Material

The Long Term Test of Buffer Material 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.

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 related processes such as bentonite diffusion properties, microbiology, copper corrosion and gas transport in buffer material under conditions similar to those expected in a deep repository.

Achievements

Mineralogical analyses of the A2 parcel made by laboratories in Finland, France, Germany, Sweden and Switzerland have been finalised and were presented at a workshop in Lund in November 2007. Extended rheological and mineralogical analyses have been performed. Remaining three test parcels (see Table 4-1) are running without malfunction, and only minor maintenance and improvement work have been made. Water pressure, total pressure, temperature and moisture have been continuously measured and stored every hour, and the data have been checked monthly.

Table 4-1. Test series for the Long Term Test of Buffer Material.

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	Analysed
A	2	120–150	T, [K^+], pH, am	5	Analysed
A	3	120–150	T	5	Ongoing
S	1	90	T	1	Reported
S	2	90	T	5	Ongoing
S	3	90	T	>>5	Ongoing

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

4.3 Alternative Buffer Materials

Installation of one of the packages illustrating the mixing of the different compacted buffer discs.

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

The project will be carried out using material that according to laboratory studies are conceivable buffer materials. The experiment will be carried out in the same way and scale as the Long Term Test of Buffer Material.

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.

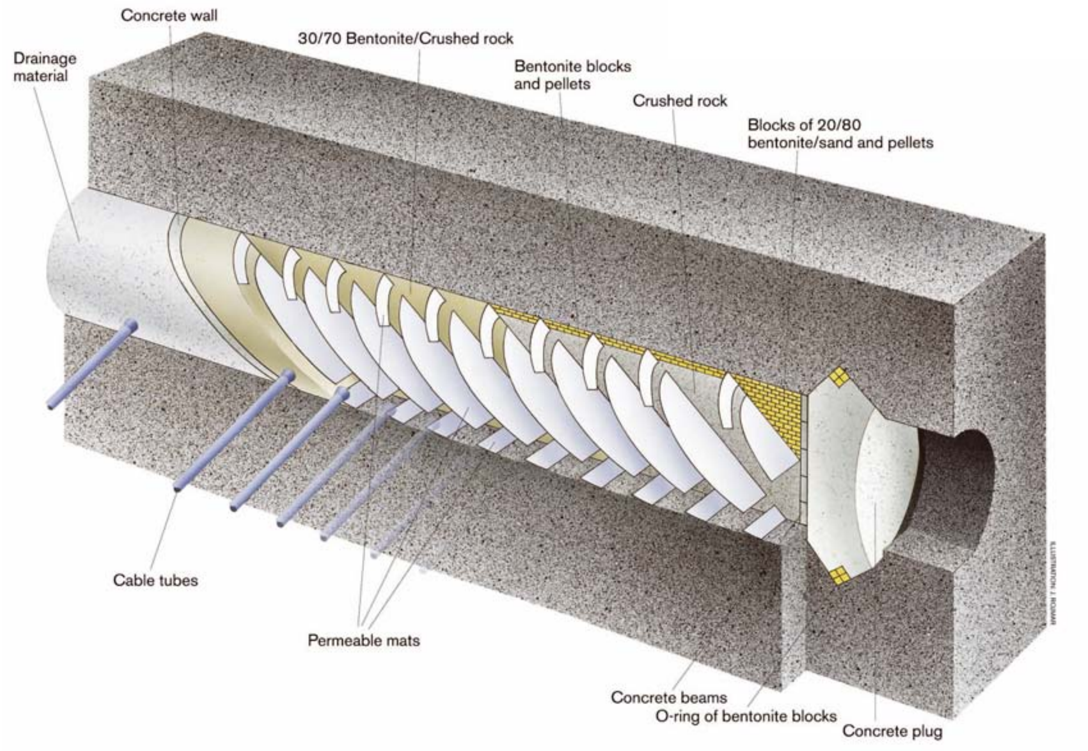
The field tests started during 2006 at Äspö HRL. Eleven different clays have been chosen to examine effects of smectite content, interlayer cations and overall iron content. Also bentonite pellets with and without additional quartz are being tested. The different clays are assembled in three packages.

Achievements

During the last quarter of 2007 the heaters in the packages have been exchanged to more powerful versions. This was done since the available power in the old heaters was not enough to reach the goal temperature of 130°C.

A project meeting was held in Lund in co-operation with the Lot project. The meeting discussed the analyses done on the reference materials as well as the analyses to be performed on the materials to be retrieved. The meeting decided not to retrieve the first package during 2008. The plan is to have a steady state operation at 130°C during one year prior to retrieval and therefore the retrieval will not take place before early 2009.

4.4 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 has been running since late 2003.

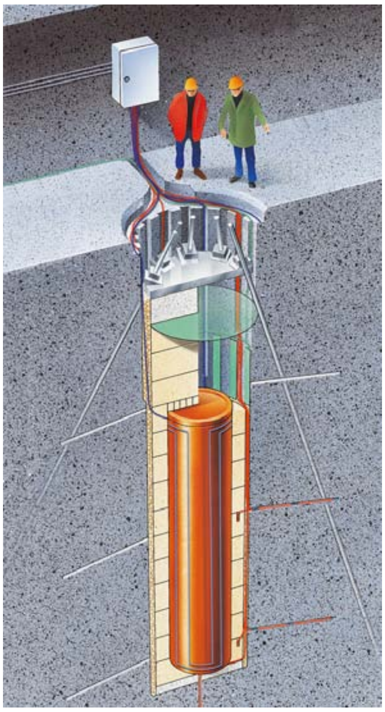
In autumn 2006 activation of the four pressure cylinders mounted on the floor and in the roof started. These will be used for mechanical testing of the compressibility of the backfill.

Achievements

The main work during the fourth quarter 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. The data report covering the period up to 1st July 2006 is available /Goudarzi et al. 2006/ and the report covering the period up to 1st January 2007 has been written but not published.

Preparations have been made during this quarter to be able to use the tubes installed in the section with crushed rock for measurements of local hydraulic conductivity.

4.5 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 on 12th of 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

A draft report on the analyses of the heaters inside the canister was delivered during the fourth quarter. The report states that the main reason for the heater failure was the external cable malfunction. A discussion on the effect on the heaters from the environment inside the canister during operation is also made in the report. The report is also of interest for other projects, with similar heaters such as the Prototype Project.

Further analyses of the buffer have been conducted by Clay Technology and will be reported during the first quarter of 2008. The report from the initial analyses has been reviewed and will be sent for approval in the first quarter of 2008.

The report from the buffer disintegration has been reviewed and will be approved in the first quarter of 2008. The report is so far only available in Swedish, but will be translated to English after approval.

Modelling of the buffer within the Task Force on Engineered Barrier Systems has continued during the period and will do so also during 2008.

4.6 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 EBS, 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 backfill (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.

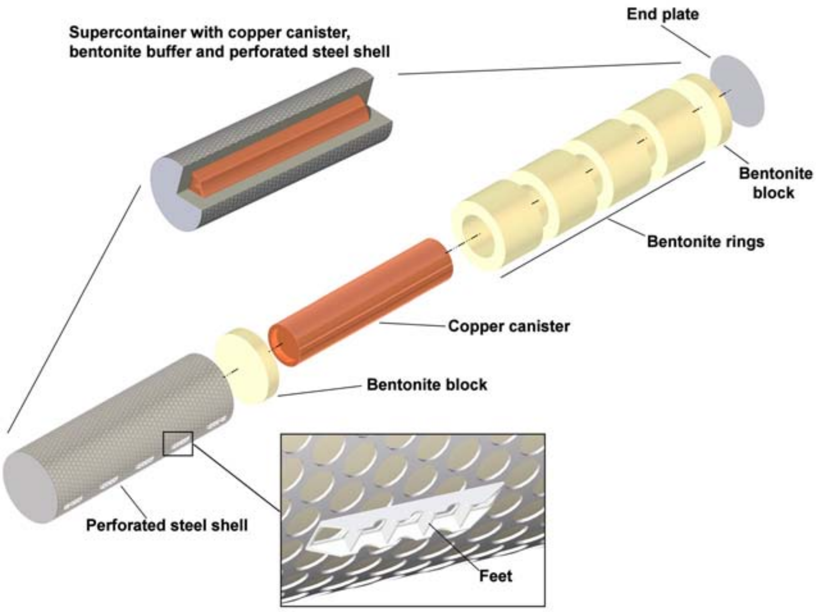
Achievements

The TBT-test is in the operation and data acquisition phase since March 2003. Data acquisition is continuously ongoing and the data link from Äspö to Andra's head office in Paris has been functioning well. Three monthly data reports have been distributed during October-December 2007 and the data report covering the period up to 1st July 2007 is available/Goudarzi et al. 2007/.

The power output from the heaters has been changed during the fourth quarter. The power from the lower heater was increased from 1,600 to 2,000 W, while the output from the upper heater was decreased from 1,600 to 1,000 W. This change in the thermal conditions has also influenced the hydro-mechanical conditions as recorded by the sensors for total pressure and pore pressure. Significant pore pressures around the lower heater now indicate that full saturation has been reached in this part.

The hydration of the sand shield is in progress. The aim of this is to saturate the sand shield around the upper heater with water. At the end of December 2007, approximately half of the available pore volume had been filled with water.

4.7 KBS-3 Method with Horizontal Emplacement



Supercontainer with copper canister, bentonite buffer and perforated steel shell.

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.

The KBS-3H project is a joint project between SKB and Posiva. 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 a low-pH shotcrete plug and of different drift components.

The KBS-3H project is partly financed by the EC-project Esdred – Engineering studies and demonstration of repository designs.

Achievements

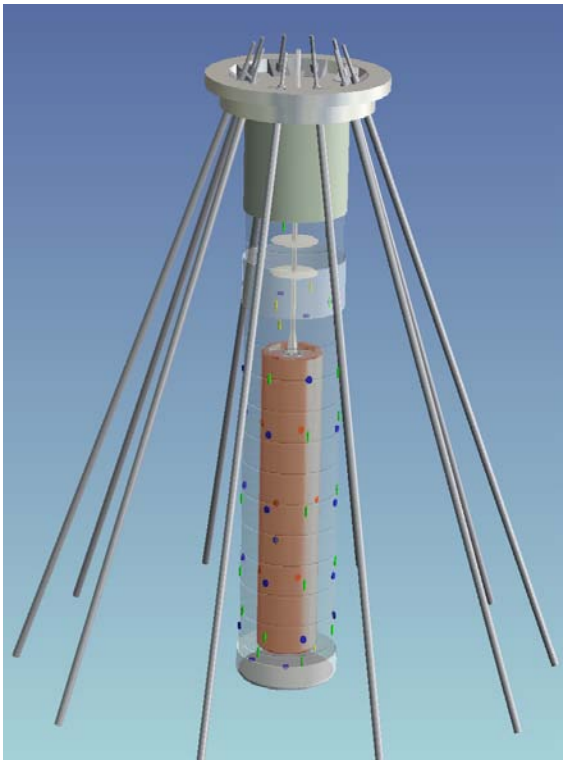
The first phase of the Megapacker test is now completed, see Figure 4-1. Two of totally five identified fracture zones in the 95 m long hole have been grouted with silica sol using the Megapacker. The results are still being analysed but are looking very promising. The leakages in the fracture zones were significantly decreased, from 0.45 to 0.015 L/min in section 3 and from 2.2 to 0.007 L/min in section 1. By grouting two of five fracture zones the total inflow was reduced from 4.4 to 2.77 L/min. Before the next phase of the test, grouting of the remaining three fracture zones, the Megapacker will be somewhat improved. The issues are mostly related to work environment but minor upgrades in functionality will also be implemented.

To verify the ability to remove the saturation pipes in the DAWE (drainage, artificial watering and air evacuation design) tests are made in the Bentonite Laboratory. The first pipe removal test was initiated during this quarter. The equipment has been working properly and the results so far indicate that a rapid removal of the pipes will be necessary since the force applied on the pipes from the buffer increases rapidly. Sampling of the buffer will be conducted during equipment dismantling. Minor changes will also be carried out before the next pipe removal test.

The Supercontainer with poor concrete (to simulate real conditions with compacted bentonite ring and blocks surrounding the canister) has been examined after it has been transported in the 95 m long hole. The examination focused on to find stresses in the steel shell or fractures in the concrete inside the container. No stresses were found but different colours in the concrete can be seen were the feet have been located.

In the overall, work within the KBS-3H project has focused on finalising several reports which summarise work and conclusions achieved in the project phase during 2004-2007.

4.8 Large Scale Gas Injection Test



Layout of the Lasgit experiment conducted in the assembly hall area at the -420 m level.

Current knowledge pertaining to the movement of gas in a compact buffer bentonite 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 subsequent gas phases of the test history are central 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-3 design concept.
- Examine issues relating to up-scaling and its effect on gas movement 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. When the buffer is fully saturated a series of gas injection tests will be undertaken to examine the mechanisms governing gas flow in bentonite.

Achievements

At the request of project stakeholders a preliminary gas injection history was planned for 2007 with a view to verifying the operation and data reduction methodologies outlined in the original concept report and to provide qualitative data on hydraulic and gas transport parameters for a bentonite buffer during the hydration process. With this in mind, activities during the fourth quarter have focused on: (i) the continued hydration of the bentonite buffer, (ii) completion of the initial gas test from the third quarter, (iii) carrying out and preliminary interpretation of a second hydraulic test for the determination of baseline hydraulic properties post gas-testing and (iv) conversion of data for archiving by SKB.

This quarter began with the continuation of the gas injection test that was begun on 7th August in filter FL903. The experiment was halted during August due to concerns of gas escape between the bentonite blocks or along the canister surface, but was restarted on the 11th September. The gas pressure continued to rise with a deflection in the pressure curve observed on 29th September at a gas pressure marginally greater (320 kPa) than the local stress on the rock wall. Pressure continued to rise until a peak pressure of 5,660 kPa was achieved on 1st October, see Figure 4-2. The gas pressure then decayed with a small negative transient, leading to a quasi steady state condition. The post peak gas flux exhibits dynamic behaviour (over and undershooting flux into the system) suggestive of unstable gas flow.

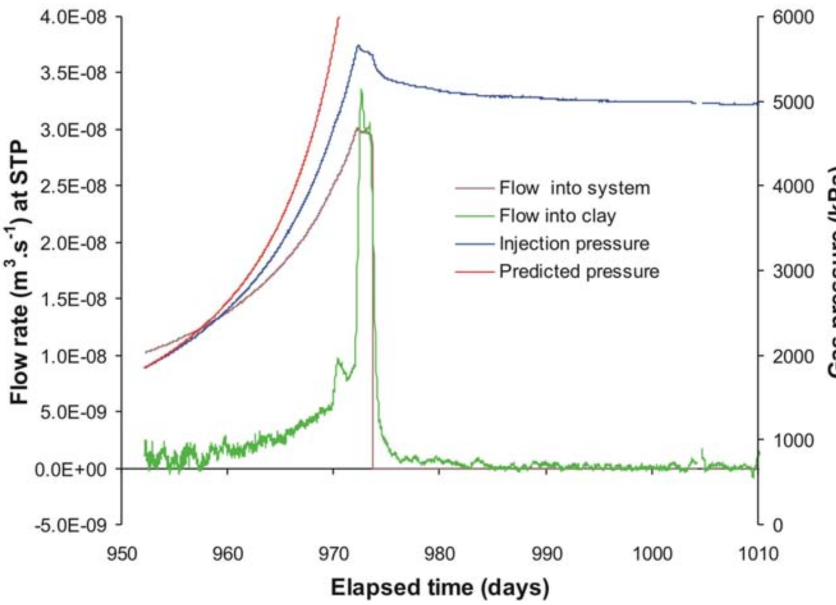


Figure 4-2. *Test results from the gas injection test after the experiment was restarted on 11th September until it was completed on 8th November.*

Following the cessation of gas injection into the system, shows that the pressure initially drops quite rapidly but then decays very slowly towards an asymptotic capillary threshold pressure, which is estimated to be about 4,900 kPa, see Figure 4-2. This value is close to the average radial stress measured on the canister surface. During the pressure decay several events were observed where pressure remained constant for a period of 1 – 5 days, followed by a rapid drop in pressure. However, the over-all observed pressure decay is fairly smooth, with this observed "sticking" of the pressure decay superimposed.

Following peak gas pressure a well pronounced increase in radial stress occurs around the entire base of the deposition hole, with the highest increase noted in the vertical plane below the point of injection. Porewater pressure data from the deposition hole wall exhibit similar behaviour, though initial results suggest that the pulse in porewater pressure dissipates at a faster rate than that of the radial stress. The porewater pressure sensors located within the buffer show no obvious sensitivity to the injection of gas. In contrast, axial stress sensors located beneath and above the canister appear to register the passage of gas providing evidence for the time dependent propagation of gas pathways. Examination of the stress sensors suggests that the gas has moved generally in a downward direction away from the filter. The exact number of the gas pathways and the exact direction is unknown. The general movement direction is logical as there is a stress gradient observed from a high at the top of the deposition hole to lower pressure at the lowest stress sensor. Under most conditions gas would propagate along such a stress vector. However, the general coupling between gas, stress and porewater pressure at the repository scale is extremely important and can readily be explained through concepts of pathway dilatancy.

The gas injection test was followed by a second hydraulic test to examine the effect of gas injection on the hydraulic properties of the buffer. The hydraulic test was started on the 8th November and was conducted in an identical manner as the one prior to gas injection. Filter FL903 was vented to air to expel the gas from the system. Water was then injected in order to help sweep the residual gas from the injection system. Once complete, the hydraulic pressure in the test filter was raised to 4.4 MPa (very close to the original test pressure) and then reduced to 0.5 MPa at around 28 days. Figure 4-3 shows the evolution in flow rate during both hydraulic tests. The data have been adjusted so that the low pressure sections of each test start at the same point in time. While modelling of the post-gas hydraulic data has not been performed, a visual inspection of Figure 4-3 indicates that little if any significant change in permeability of the buffer has occurred due to the injection of gas. The slight offset in the red line during the early section of the test, is indicative of a small change in hydraulic storage. The noise evident in the low pressure section of the post gas injection hydraulic test may be caused by the presence of residual gas.

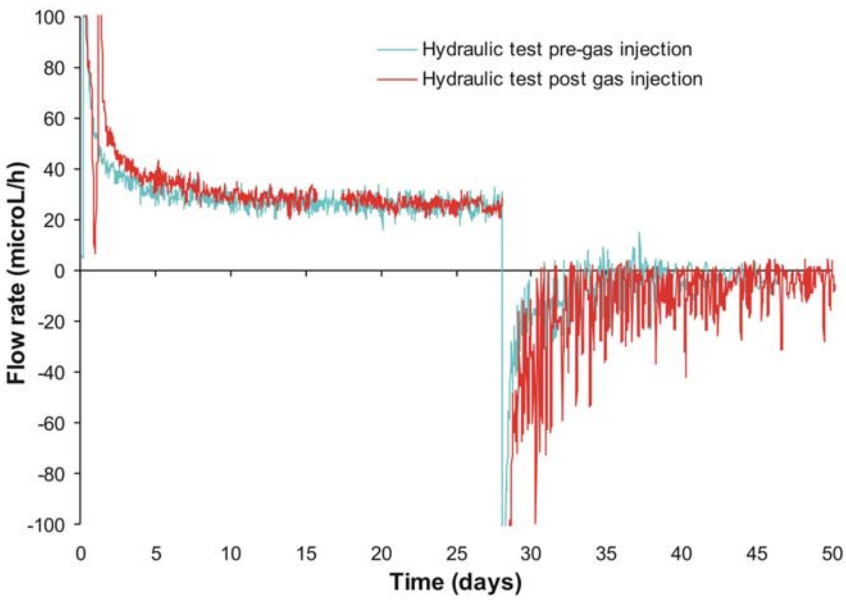
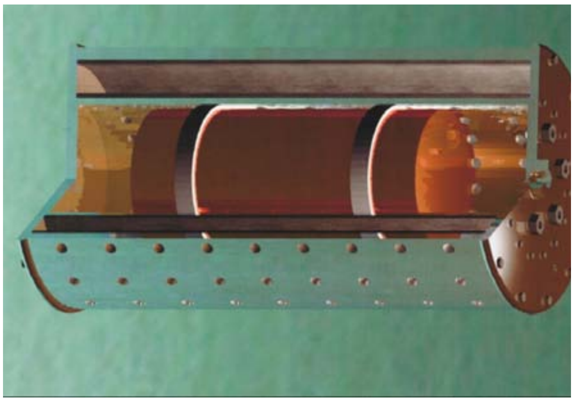


Figure 4-3. *Test results from the hydraulic test pre- and post- gas injection. Similar results are seen suggesting that the gas injection experiment has not significantly altered the hydraulic properties of the bentonite buffer.*

4.9 In Situ Corrosion Testing of Miniature Canisters



Miniature canister with support cage

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

The information obtained from the experiments will be valuable in providing a better understanding of the corrosion processes inside a failed canister. All five miniature canisters were installed in the beginning of 2007.

Installation of first model canister assembly

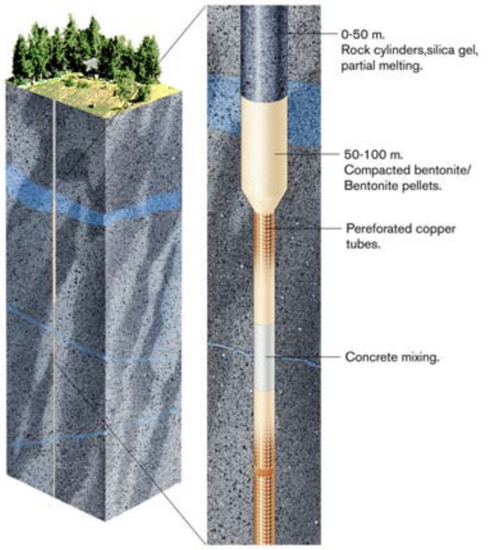
Miniature canisters with a diameter of 14.5 cm and containing 1 mm diameter defects in the outer copper shell have been set up in five boreholes with a diameter of 30 cm and a length of 5 m. The canisters are mounted in support cages, four of which contain bentonite, and are exposed to natural reducing 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 repository conditions that are very difficult to reproduce and maintain for long periods of time in the laboratory.

Achievements

During the last quarter, monitoring of the miniature canister experiments has continued. Data are being collected for corrosion rate of copper and iron electrodes, and electrochemical potentials for a range of electrodes, including Eh, iron and copper. In addition strain gauge data are being collected for two of the canisters. Water analysis, including analysis of microbial content of the water, has been carried out periodically. A report on the set up of the experiments and the first year’s activities and results is in preparation.

4.10 Cleaning and Sealing of Investigation Boreholes



A project, with the aim to identify and demonstrate the best available techniques for cleaning and sealing of investigation boreholes, was initiated in 2002. The project is run in co-operation between SKB and Posiva.

Phase 1 was mainly an inventory of available techniques, and the aim of phase 2 was to develop a complete cleaning and sealing concept.

Phase 3 was divided into four sub-projects, and comprised large-scale testing of the sealing concept in boreholes. The field activities were finished during the first quarter of 2007. All the work from Phase 3 will be summarised in a final report.

Phase 4, the "Joint Work Programme on Borehole Sealing", is ongoing.

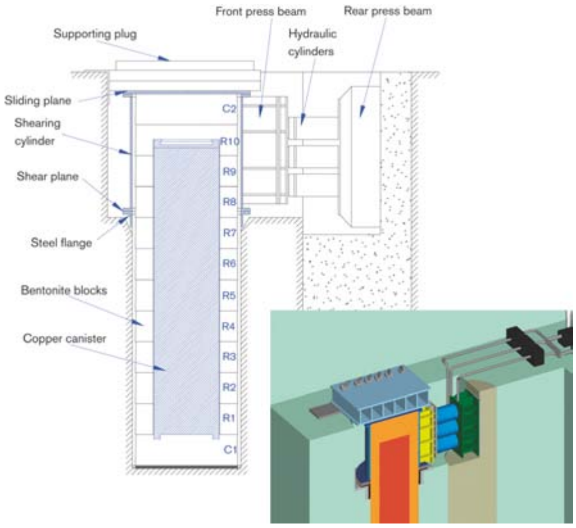
Achievements

Planning for Phase 4 on the "Joint Work Programme on Borehole Sealing" has been initiated. An agreement on the co-operation between Posiva and SKB has been signed of both parties comprising the period 2007-2010.

The preliminary programme consists of the following tasks:

- Developing a conceptual plugging plan for selected boreholes. The boreholes to be sealed and plugged will be divided into categories.
- Principal conceptual designs for each category will be developed.
- For the selected boreholes, detailed designs will be drafted. These comprise among other things estimates on needs and techniques, as well as acceptances criteria.
- The needs for sealing should be connected to overall safety of the geological disposal.

4.11 Rock Shear Experiment



The Rock Shear Experiment (Rose) aims at observing the forces that act on a KBS-3 canister if a displacement of 100 mm would take place in a horizontal fracture that crosses a deposition hole. Such a displacement may be caused by an earthquake and the test set-up need to provide a shearing motion along the fracture that is equal to the worst expected shearing motion in real life.

A possibility is to perform the in situ test at the Äspö Pillar Stability site. Two full scale deposition holes already exist with a rock pillar of one metre in between. One deposition hole can be used for the buffer and canister, while the other deposition hole is used for the shearing equipment.

Achievements

A pre-study of design and feasibility of an in situ test is completed and reported /Börgesson et al. 2006/. The main conclusion is that the test is feasible. A rock shear experiment in full scale in the Äspö HRL is a possibility, however not yet decided on. Presently, the main interest in the area of rock shear effects is laboratory testing.

4.12 Earth Potentials

The main objective of the project is to identify the magnitude of potential fluctuations and stray currents at repository depth and by that estimate the potential problems that could occur. The causes to these effects may be Geomagnetically Induced Currents (GIC) or man-made stray current sources.

Electrical potentials are generated by current flow in conductive media. At shallow depth currents flow parallel to the ground surface because the electrical conductivity of air is very low compared to that of soil and rock. If the conductivity is constant along any plane in the earth the natural current flow is none, while variations in conductivity cause natural currents that can be oriented in different directions.

Achievements

A final report is being compiled and no further work is planned in the project until the report is finished.

4.13 Task Force on Engineered Barrier Systems

The Task Force on Engineered Barrier Systems (EBS) is a natural continuation of the modelling work in the Prototype Repository Project, where also modelling work on other experiments, both field and laboratory tests, are conducted. The Äspö HRL International Joint Committee (IJC) has decided that in the first phase of this Task Force (period 2004-2008), 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 transport 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, BMWi, CRIEPI, Nagra, Posiva, NWMO and RAWRA. 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, THM/Gas and Geochemistry, have common secretariat but separate chairmen.

Achievements

A Task Force meeting was held in Stockholm in November at the meeting the latest modelling results were presented and discussed.

Task Force THM/Gas

For Task 1 the THM modelling has concerned large scale in situ tests (Task 1.2). The modelling of the Buffer/Container Experiment and the Isothermal Test (Task 1.2.1 carried out by AECL) has continued. The other task (Task 1.2.2) that concerns modelling of the Canister retrieval Test at Äspö HRL has been revised and a final task description has been delivered to the participating teams and organisations.

Task Force Geochemistry

Ion diffusion is central in geochemical modelling and in bentonite this is a complex matter due to the montmorillonite structure. The redistribution of calcium minerals in the Lot-experiment at Äspö HRL serves as a benchmark modelling task. Molecular dynamic modelling has been made concerning ion distribution in montmorillonite. Development work concerning diffusion in bentonite has been performed and preliminary geochemical modelling has been made.

5 Äspö facility

The organisational unit 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.

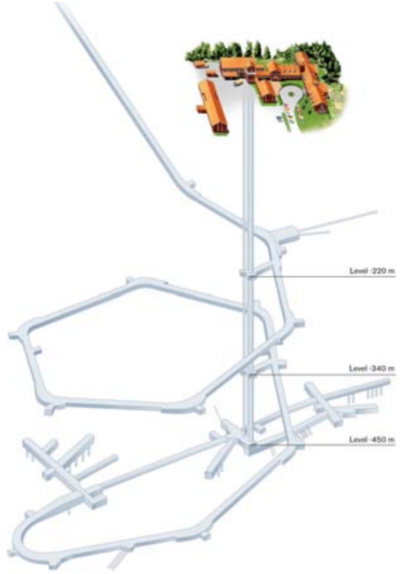
- *Repository Technology and Geoscience (TDS)* is responsible for the development and management of the geo-scientific models of the rock at Äspö and the test and development of repository technology at Äspö HRL to be used in the final repository.

- *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.

5.1 Hard Rock Laboratory



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

This includes preventative and remedy maintenance in order to withhold high availability in all systems as drainage, electrical power, ventilation, alarm and communications.

Achievements

All systems have been close to 100% operational and no interruptions have been reported. Measurements show that the concentration of radon in the air of the tunnel is stable and controlled by the ventilation. A new synthetic diesel fuel, which gives cleaner exhaust and has a higher flashpoint, is being tested in all SKB´s vehicles. Rusting of the elevator cage was discovered on inspection. Repainting has been suggested and the work is planned for summer 2008. Rock maintenance work is being carried out as planned. Old sheets for collection of water drops are being replaced by new fireproof sheets. In all new underground installations which contain wood constructions, the material used must be fireproofed. During the fourth quarter, 165 rock-bolts were installed and injected, a large roof area has been secured with a net at the -450 m level and a drop-sheet has been replaced by a fireproof sheet at the -420 m level.

Documentation of the system for registration of personnel, RFID, has continued during the period and is expected to be finished during the first quarter of 2008. All vehicles and personnel carry their own RFID transponder and can be localised underground. Before the Alfagate (RFID system) is approved, visits to the tunnel are also reported by telephone.

A new unheated storeroom for machines and other equipment has been completed at the tunnel extension and replaces provisional tent storage. Plans for the construction of a new archive and server-room have been delayed by changes in requirements. An existing property is being levelled with rock from ongoing blasting for the project Sealing of Tunnel at Great Depth. The new surface may eventually be used for extension of the office building or as extra parking space. The safety of the road to Äspö HRL has been improved by the installation of road barriers and the clearance of bushes and trees.

Work has begun on the design of a drainage system leading waste water from the facility to OKG’s waste water treatment work. The present system with a sealed tank and tanker transport to the water treatment works is uneconomic and environmentally unsound.

5.2 Bentonite Laboratory

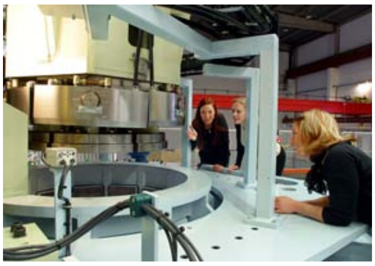
Before building a final repository, where the operating conditions include the deposition of one canister per day, further studies of the behaviour of the buffer and backfill under different installation conditions are required. SKB has built a Bentonite Laboratory at Äspö designed for studies of buffer 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 will also be used for testing of different types of backfill material and the further development of techniques for the backfilling of deposition tunnels.

Achievements

The Bentonite Laboratory is in full operation and different methods and techniques for installation of pellets and blocks in deposition tunnels have been tested. For example tests on block installation have been performed with beddings of different materials and design. It can be concluded from these tests that the properties of the bedding determine the result of the installation.

The tests will continue during 2008 and preparations have been made for the reception and installation of a bentonite mixer which will be delivered to Äspö in the beginning of 2008. In addition, a storage tent has been bought for the storage of bentonite.

5.3 Public Relations and Visitors Service

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

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 HRL, and the SKB siting programme on surface and underground. The team is also responsible for visitor services at Clab and gives support to Canister Laboratory.

In addition to the main goal, the information group takes care of and organises visits for about 1,500 foreign guests every year. The visits from other countries mostly have the nature of technical visits.

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

Achievements

SKB main facilities have been visited by 4,817 persons during the fourth quarter of 2007, and in total by 25,669 persons during the year 2007. The numbers of visitors to SKB's main facilities during the fourth quarter are listed in the Table 5-1.

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

SKB facility	Number of visitors October-December 2007
Central interim storage facility for spent nuclear fuel	321
Canister Laboratory	748
Äspö HRL	1,762
Final repository for radioactive operational waste (SFR)	1,986

A contribution to "Oskarshamn in Light" was held at Äspö on the 1st of December. The event consisted of a light-and-music-show down in the laboratory and was visited by 80 persons.

The Äspö Running Competition took place on the 8th of December and the event celebrated 10 years anniversary. The competition attracted 86 runners, which was a new record seen to the amount of participants.

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. SKB's economic engagement in the foundation was concluded in 2003 and the activities thereafter concentrated to the Äspö Research School. The agreement between SKB and Kalmar University, concerning Äspö Research School, is valid until 30th of September 2008. The future plan for the School is just under discussion. One interesting way to continue the co-operation is to adopt the Äspö Research School in the new research and development platform Nova R&D in Oskarshamn. This new platform is the result of a new co-operation between SKB and Oskarshamn's municipality. Nova R&D is open for a much broader range of sciences in comparison to the current activities within Äspö Research School. Kalmar University have got an invitation to be one of several academic partners in Nova R&D.

6.2 Äspö Research School

Kalmar University's Research School in Environmental Science at Äspö HRL, called Äspö Research School, started in October 2002. This School is the result of an agreement between SKB and Kalmar University. It combines two important regional resources, i.e. Äspö HRL and Kalmar University's Environmental Science Section. The activity within the school will lead to: (a) development of new scientific knowledge, (b) increase of geo- and environmental-scientific competence in the region and (c) utilisation of the Äspö HRL for environmental research. The research activities focus on biogeochemical systems, in particular in the identification and quantification of dispersion and transport mechanisms of contaminants (mainly metals) in and between soils, sediments, water, biota and upper crystalline bedrock. In addition to financial support from SKB and the University of Kalmar, the school receives funding from the city of Oskarshamn.

Achievements

During the fourth quarter a one-weak-long Ph.D. course was held at Äspö HRL. Seven Ph.D. students participated and the course was highly appreciated. The lecturers were held by several professors/researchers with a broad experience of the Äspö HRL and the site investigations. A field trip in Småland was also organised.

On the 2nd of November, Pernilla Rönnback defended her Ph.D. thesis focusing on patterns and controls of major and trace elements mainly of surface waters, but also in overburden and bedrock ground waters, in Forsmark, Oskarshamn and at Äspö /Rönnback 2007/. Further, a paper dealing with uranium in surface and ground waters in boreal Europe have been accepted in Geochemistry: Exploration, Environment, Analysis /Åström et al. 2007/.

7 International co-operation

Nine organisations from eight countries participate in the Äspö HRL co-operation during 2007, 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.

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.

Table 7-1. International participation in the Äspö HRL projects during 2007.

Projects in the Äspö HRL during 2007	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Enresa	Nagra	RAWRA
Natural barriers									
Tracer Retention Understanding Experiments	X			X		X			
Long Term Sorption Diffusion Experiment									
Colloid Dipole Project					X				
Microbe Project		X							
Task Force on Modelling of Groundwater Flow and Transport of Solutes	X		X	X	X	X			
Engineered barriers									
Prototype Repository	X	X		X		X			
Long Term Test of Buffer Material						X			
Alternative Buffer Materials	X	X		X		X		X	X
Temperature Buffer Test	X	X					X		
KBS-3 Method with Horizontal Emplacement						X			
Large Scale Gas Injection Test	X	X			X	X			
Cleaning and Sealing of Investigation Boreholes						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
Empresa Nacional de Residuos Radiactivos, Enresa, Spain
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland
Radioactive Waste Repository Authority, Rawra, Czech Republic

8 Documentation

During the period October – December 2007, the following reports have been published and distributed.

8.1 Äspö International Progress Reports

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8.2 Technical Documents and International Technical Documents

No technical documents have been published during the fourth quarter 2007.

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