International Progress Report

IPR-06-03

Äspö Hard Rock Laboratory

Status Report
October – December 2005

Svensk Kärnbränslehantering AB

February 2006

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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 deep 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 information given in the RD&D-Programme related to Äspö HRL is annually detailed in the Äspö HRL Planning Report /SKB 2005/.

This Äspö HRL Status Report is a collection of the main achievements obtained during the fourth quarter 2005.

Technology

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 at Äspö HRL: Canister Retrieval Test, Prototype Repository, Backfill and Plug Test, Long Term Test of Buffer Material, Cleaning and sealing of investigation boreholes, KBS-3 method with horizontal emplacement, Large Scale Gas Injection Test, and Temperature Buffer Test. THM processes and gas migration in buffer material are addressed in the Task Force on Engineered Barrier Systems.

Geo-science

Geo-scientific research is a natural part of the activities at Äspö HRL. Studies with the major aims to increase the understanding of the rock mass properties and to increase the knowledge of measurements that can be used in site investigations are important activities: Geological mapping and modelling, Heat transport, Inflow predictions, Seismic influence on the groundwater system, Rock mechanic studies, and Äspö Pillar Stability Experiment.

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 the deep 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 (True Block Scale Continuation and True-1 Continuation), Long Term Diffusion Experiment, Radionuclide Retention Experiments, Colloid Project, Microbe Project, and Matrix Fluid Chemistry.

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.

Äspö facility

An important part of the work at the Äspö facility is the administration, operation, and maintenance of instruments as well as development of investigation methods. Other issues are to keep the stationary hydro monitoring system (HMS) continuously available and to carry out the programme for monitoring of groundwater head and flow and the programme for monitoring of groundwater chemistry.

The information and public relations group at Äspö HRL is responsible for presenting information about SKB and its facilities. They arrange visits to the facilities all year around as well as special events.

International co-operation

The Äspö HRL has so far attracted considerable international interest. Nine organisations from eight countries participated in the co-operation at Äspö HRL, apart from SKB, during 2005.

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.

Contents

1 General

The Äspö Hard Rock Laboratory (HRL) constitutes an important part of SKB's work to design and construct a deep geological repository for spent nuclear fuel and to develop and test methods for characterisation of a suitable site.

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, managed by the Repository Technology Department within SKB, have so far attracted considerable international interest. 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 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 2005/ for more background information. The Annual Report will in detail present and summarise new findings and results obtained during the present year.

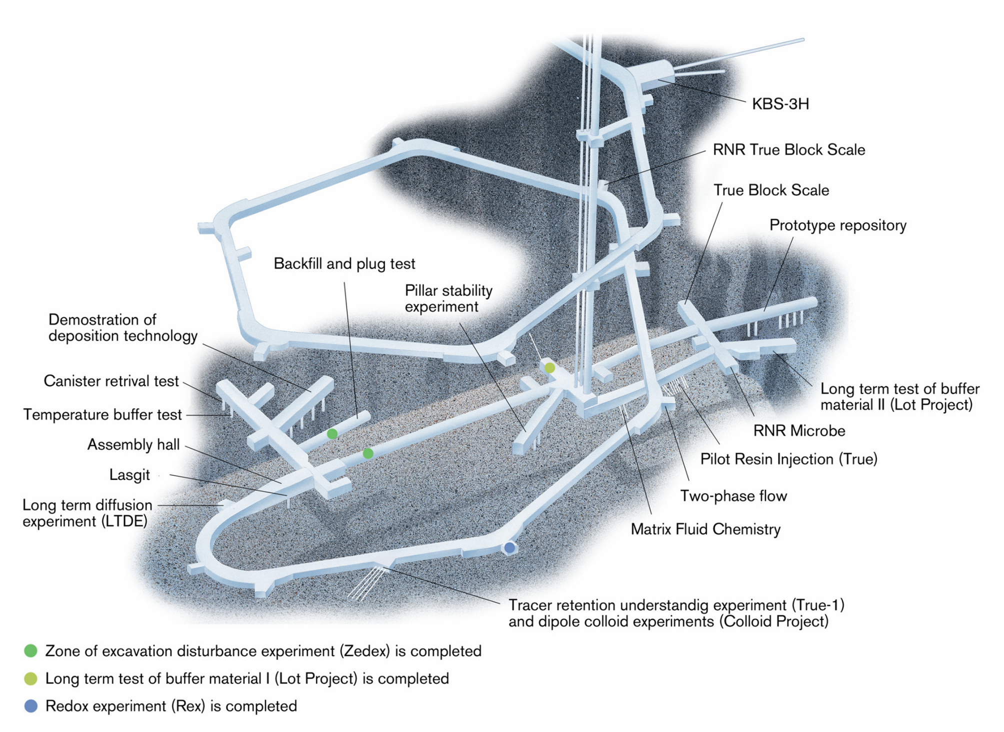


Figure 1-1 *Allocation of experimental sites in Äspö HRL from -220 m to -450 m level.*

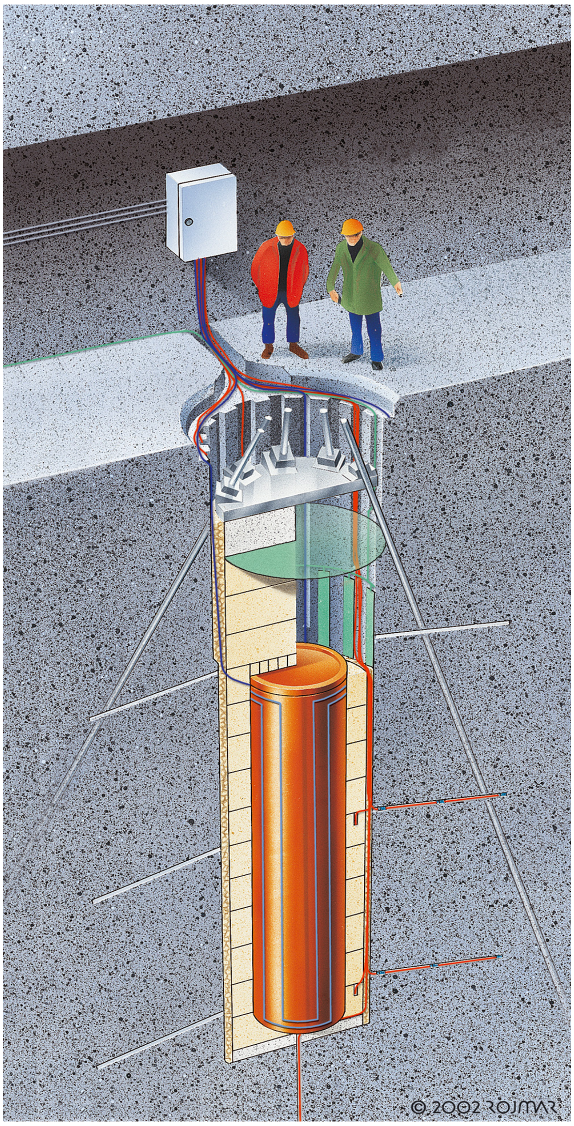
2 Technology

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 2-1. The experiments focus on different aspects of engineering technology and performance testing, and will together form a major experimental programme.

Figure 2-1 *Control measurements of horizontal deposition hole (KBS-3H).*

2.1 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.

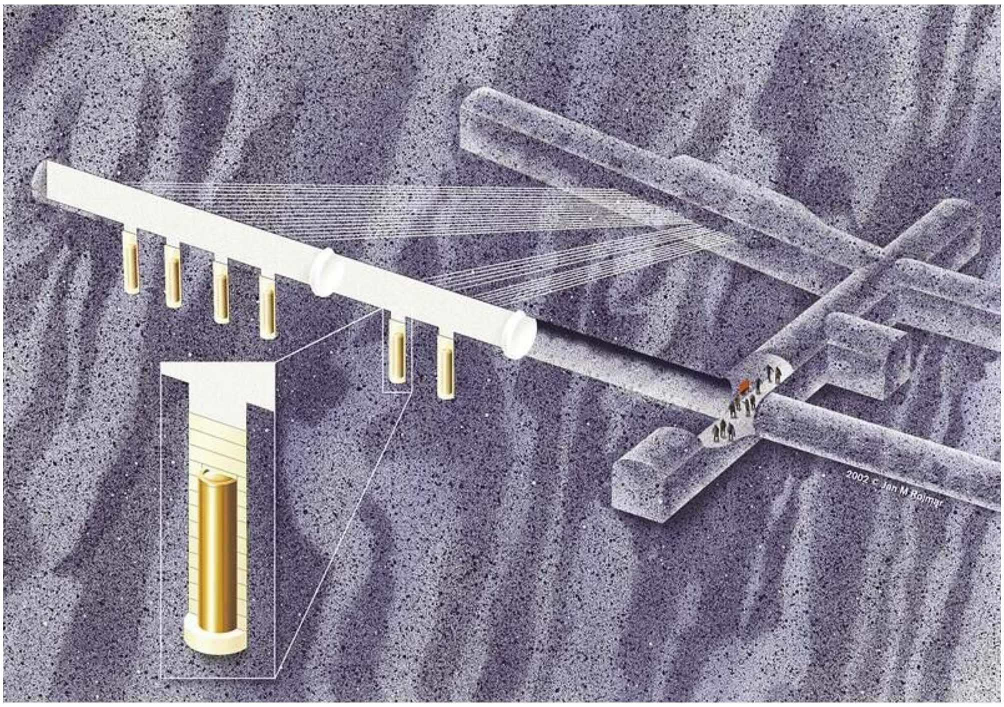
The test has been running for more than five years with continuous measurements of the wetting process, temperature, stresses, and strains.

Achievements

The measurements with a large number of transducers in order to study the THM-processes and to provide a basis for e.g. modelling purposes have continued. The data report covering the period up to 1st of May 2005 /Goudarzi *et al.* 2005a/ is available and the report covering the period up to 1st of November 2005 has been processed during this quarter. Modelling of pressure, water content etc. in the buffer during the saturation process is in progress although delayed.

The water pressure applied in the mats was reduced to atmospheric pressure in March and the remaining power of 1,200 W was shut down on October 10. The filter mats were emptied in mid December as a preparation for the planned excavation during spring 2006.

2.2 Prototype Repository



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

The Prototype Repository should, to the extent possible, simulate the real deep 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.

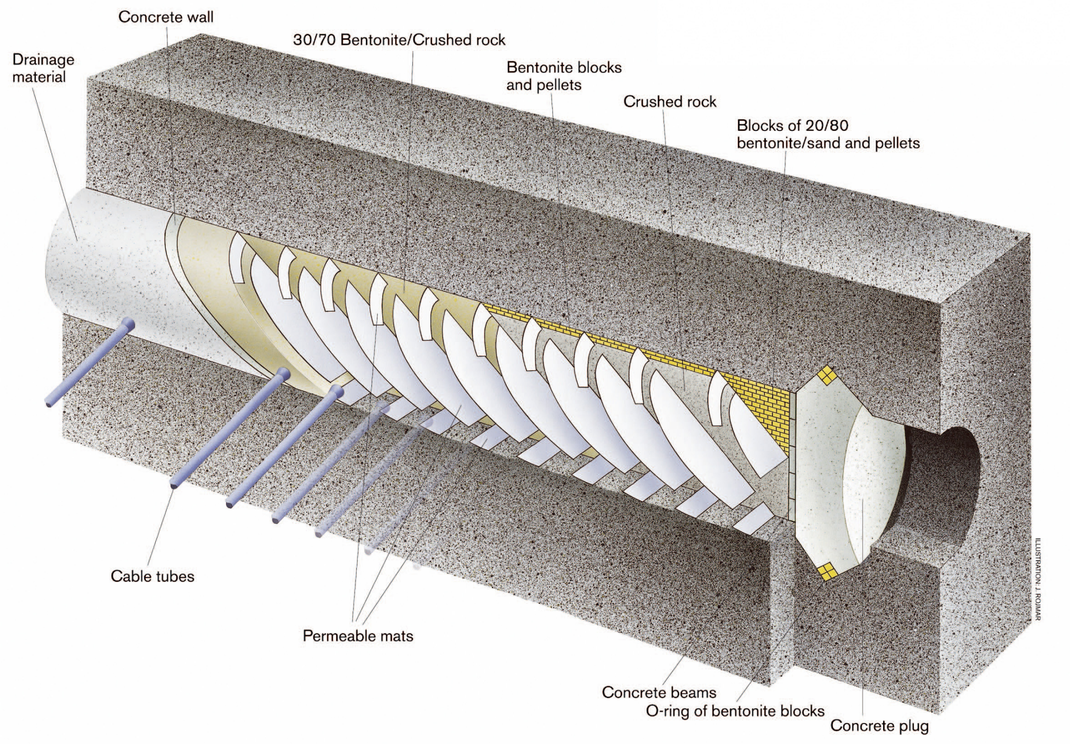
The inner tunnel (Section I) was installed and the plug cast in 2001 and the heaters were turned on one by one. The outer tunnel (Section II) was backfilled in June 2003 and the tunnel plug with two lead-throughs was casted in September the same year.

Achievements

The data collection system comprises temperature, total pressure, pore water pressure, relative humidity and resistivity measurements in buffer and backfill, as well as temperature and water pressure measurements in boreholes in the rock around the tunnel. The collection of data is in progress and data report No: 13 covering the period up to June 2005 is finished and printed /Goudarzi and Johannesson 2005/. Overhauling of the data acquisition system is in progress and hydraulic tests of the rock mass have been done. Other activities performed during the fourth quarter are:

- A report covering the acoustic emission and ultrasonic monitoring around deposition hole DA3545G01 between April 2005 and September 2005 has been finalised.
- A program for sampling and analyses of gases and microorganisms in the backfill and buffer has started.
- A thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been developed.

2.3 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 the 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.

Achievements

Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured and registered. The sensors data report No: 11 covering the period up to 1st of July 2005 /Goudarzi *et al*. 2005b/ is available.

Flow testing of the backfill materials has been finalised in both directions. Additional flow testing in individual points has started and so far the results support the results from the flow tests between the mats.

In addition to the field testing, laboratory experiments and modelling with the aim to evaluate the hydraulic conductivity of the backfill materials are in progress but delayed.

2.4 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.

The test parcels containing heater, central tube, clay buffer, instruments, and parameter controlling equipment are 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 repository.

Achievements

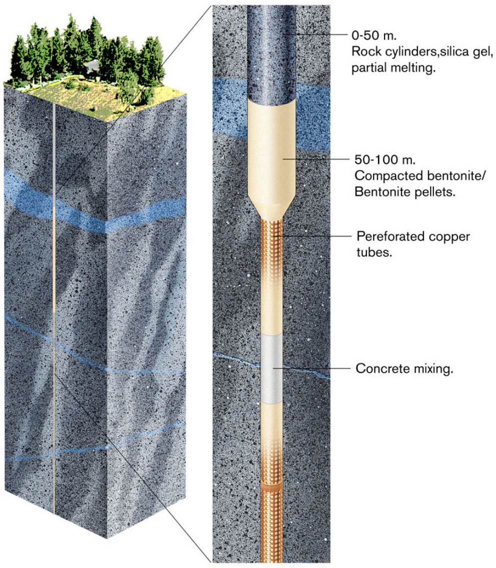
The main activity during this period has been the planning for the uptake of parcel A2. An activity plan has been produced, reviewed and approved. The preparation work for the uptake in January 2006 has been initiated and the power to the parcel has been turned off and the water supply has been shut down.

Table 2-1 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	Terminated (uptake 2006)
A	3	120-150	T	5	On-going
S	1	90	T	1	Reported
S	2	90	T	5	On-going
S	3	90	T	>>5	On-going

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

2.5 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 comprised initially two phases. Phase 1 was mainly an inventory of available techniques, and the aim with Phase 2 was to develop a complete cleaning and sealing concept and to demonstrate it. In Phase 3 large-scale testing in boreholes will be performed.

A laboratory test program on candidate sealing materials is part of the project. Short and long boreholes from the surface and from tunnels underground, will be used to demonstrate the plugging concept.

The project is run in co-operation between SKB and Posiva.

Achievements

The third phase of the project has been initiated and the status of the on-going project is given below:

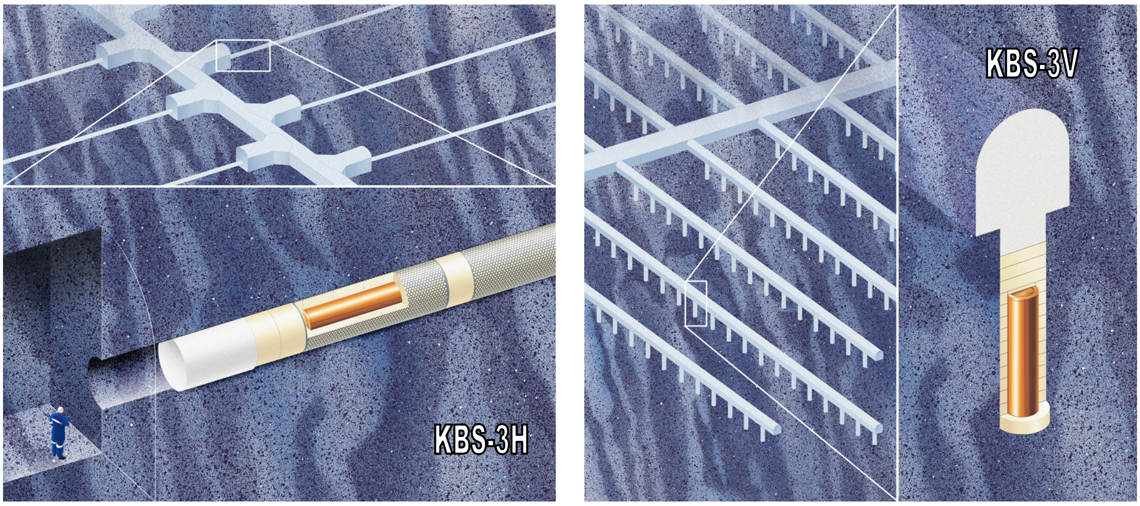
Sub-project 1. A report "Theoretical study of water saturation and homogenisation of borehole plugs" has been completed by Clay Technology. It has been taken as a basis for selecting the geometry of the perforation of the copper tubes to be used in the various plugging tests. Laboratory tests on clay erosion rates, and manufacturing and testing of density and water content on clay columns for the various plugging tests have been performed. In addition, equipment for installation of bentonite without supporting tubes has been tested.

Sub-project 2. Testing of the sealing concept will be made in short boreholes drilled in Äspö HRL at the -450 m level. Preliminary structural modelling of the 5 m holes has been made for selecting suitable holes for plugging and pressuring. Hydraulic characterisation has partly been made (inflow tests) and the remaining packer tests will start during the first quarter next year.

Sub-project 3. Most of the performed work concerns the plugging of a deep borehole OLKR24 in Onkalo in Finland. The work has mainly comprised: borehole and core inspection for identifying sections that needs to be stabilized, preparation of perforated copper tubes for 76 mm holes by reducing the dimensions of standard 76.1 mm tubes to Ø 72mm, testing of the joints between copper tubes, development and manufacturing of techniques and tools for emplacing clay and cement/quarts plugs in deep holes, and installation of two cement/quartz plugs and one 10 m long clay plugs at 520 m depth in the borehole.

Sub-project 4. Preparations are ongoing for plug testing of the upper part of boreholes (Ø 200 mm) in Äspö HRL. Preliminary plans have been worked out and the design of equipments to mill slots in 200 mm holes has been initiated.

2.6 KBS-3 method with horizontal emplacement



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

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

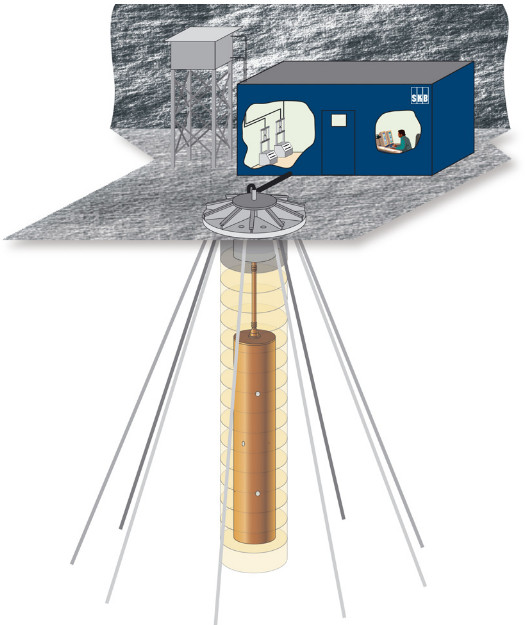
Achievements

The site for the demonstration of the method is located at 220 m depth in Äspö HRL. A niche with a height of about 8 m and a bottom area of 25 x 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 holes were excavated by blind horizontal raise boring.

Preparations are finished in the short hole for the testing of a low-pH shotcrete plug. The company Aitemin has installed the data sensors in the hole and the casting of the plug was made in the beginning of November. The pressure testing of the plug will be performed in February next year.

In the long hole the deposition equipment will be tested. The mounting of docking- and gating flange for the Super-container on the wall in the KBS-3 niche was made before Christmas. The rebuilding of the storage area at the entrance tunnel, for mounting of the Super-container, is done. Component parts of the Super-container as copper canister, buffer rings and perforated steel cylinder were delivered in November and the assembly of two Super-containers were performed in mid December. The French manufacturer of the deposition machine, CNIM, follows the time schedule and the first machinery parts will be delivered early 2006 and the testing of the deposition machine will take place during spring 2006.

2.7 Large Scale Gas Injection Test



A full-scale canister (without heaters) and a bentonite buffer are installed in an available bored deposition hole in Äspö HRL. Water is, since January 2005, artificially supplied to the buffer at isothermal conditions.

When the buffer is fully saturated gas injection will start, first with small gas volumes and finally with volumes corresponding to gas formation from a defect full-size canister.

SKB has during several years performed a number of experiments with gas injection on MX-80 bentonite. Today, there is a relatively good understanding of the processes determining the gas transport. One remaining question is, however, the importance of the scale. All bentonite experiments so far have been performed in the centimetre scale and the extrapolation of the results from these experiments to repository scale is unclear. Therefore, the Large Scale Gas Injection Test (Lasgit) has been initiated.

The major aims of the project are to:

- Perform and evaluate full-scale gas injection tests based on the KBS-3 concept.
- Answer questions related to up-scaling.
- Get additional information on gas-transport processes.
- Obtain high quality data for testing and validation of models.
- Demonstrate that gas formation in a canister do not have obvious negative consequences for the repository barriers.

Achievements

The artificial wetting of the bentonite started in January, 2005 and the test is now in the operation phase. All measuring systems are functioning in the field laboratory, and BGS are delivering the measured data to the SKB database Sicada. Data is also to some extent available on the Lasgit homepage for the participants in the projects. BGS is quarterly summarising the status of the experiment and the reporting is available for project members on the Lasgit homepage.

After the start of the artificial hydration the canister moves downwards away from the lid indicating hydration is preferentially occurring above the canister. The artificial hydration of the buffer and the monitoring will continue. The gas testing can start when the buffer is water saturated. Before gas testing, the baseline hydraulic properties have to be defined, which is scheduled to take place in the end of 2006.

2.8 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. They 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 the outer 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. The collection of data is continuing and data report No: 6 covering the period up to 1st of July 2005 is available /Goudarzi *et al*. 2005c/. Data acquisition is continuously ongoing and data is reported on a monthly basis. The data link from Äspö to Andra's head office in Paris has been functioning well. A report presenting a number of scooping calculations performed prior to finalising the test design is available /Hökmark *et al*. 2005/.

The artificial watering and evaluations are in progress and the bentonite around the upper heater appears to be close to saturation, whereas the innermost parts of the blocks around the lower heater still are unsaturated. A predictive modelling task was recently completed. This concentrated on a mock-up test, conducted by CEA, designed to mimic the conditions at the interior of the buffer around the lower heater. The modelling results, additional mock-up tests to be performed by CEA, and the future operation of the field test were discussed at the modelling meeting held in Barcelona in October 2005.

2.9 In situ corrosion testing of miniature canisters

The evolution inside a copper canister with a cast iron insert after failure is of great importance for the release of radionuclides from the canister. After failure of the outer copper shell, the course of the subsequent corrosion in the gap between the copper shell and the cast iron insert will determine the possible scenarios for radionuclide release from the canister. This has been studied experimentally and been modelled. The corrosion will take place under reducing, oxygen free conditions and such conditions are very difficult to create and maintain for longer periods of time in the laboratory. *In situ* experiments at Äspö HRL would be invaluable for understanding the development inside the canister after initial penetration of the outer copper shell.

The objective of the project is to obtain a better understanding of the corrosion processes inside a failed canister. The results of the experiment will be used to support process descriptions and safety analyses. Miniature copper canisters, with a diameter of 15 cm, will be emplaced in boreholes, with a diameter of 30 cm. The canisters will be exposed to natural reducing groundwater during several years and the experiment will be monitored.

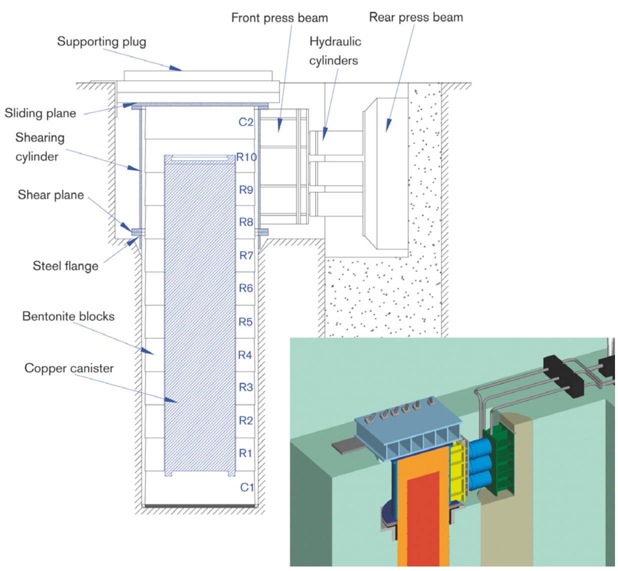
Achievements

The location for the boreholes has been agreed and five boreholes have been drilled. Some problems have been experienced with excess water emerging from the rock faces around the boreholes and various options have been explored for sealing the rock faces. It is anticipated that the rock faces will be sealed by January. The design of the miniature canisters has been completed and the components of five canisters have been manufactured, see Figure 2-2.

Figure 2-2 *Photographs of first miniature canister.*

Defects (Ø 1 mm) will be drilled into the canisters near the welds. The next stage is to clean the copper and iron surfaces and send the canisters to The Welding Institute (TWI) for electron beam welding. TWI has carried out successful trials with electron beam wielding of trial pieces with the same geometry as the miniature-canister lids. The support cages to hold the canisters have been designed and the CAD drawings are being finalised. Three of the experiments will use bentonite clay loosely packed into the support cage, to condition groundwater entering the support cage. The fourth test will contain compacted bentonite and the last will contain no bentonite, but will be exposed directly to incoming groundwater. A number of different types of test electrode (electrochemical reference electrodes, Eh probes) are being tested in groundwater taken from the underground laboratory to determine whether they will be able to withstand the *in situ* conditions. These tests will include pressurisation to 40 bar with nitrogen in an autoclave. When these trials are complete a final decision will be taken about which electrodes to use in the experiments. Trials have been carried out on electrochemical monitoring equipment from various manufacturers and a decision has been taken on which system will be used. The equipment will enable corrosion measurements of corrosion coupons to be made using a range of techniques, including AC impedance, linear polarisation resistance and electrochemical noise. Potential monitoring equipment has been purchased to monitor the corrosion potential of corrosion coupons, together with the potential of Eh probes and inert metal electrodes (gold and platinum). The same equipment will be used to monitor strain gauges on two of the canisters. The detailed designs of the arrangements for connecting to the test electrodes are nearing completion. Successful trials have been carried out to test the possibilities for remote control of the electrochemical monitoring equipment; the next stage is to carry out trials on equipment in the underground laboratory and to set up remote control from the Serco laboratories in UK.

2.10 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.

The *in situ* test set-up is planned to be installed 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 will be used for the buffer and canister, while the other deposition hole is used for the shearing equipment.

Achievements

The first phase, a pre-study of design and feasibility is completed. A draft report has been delivered and the finalisation of the report is in progress. Scoping calculations indicating the forces and shearing speed needed have provided the basis for the design of the test set-up. The conclusion from the study is that the test is feasible. A meeting for discussion and decision on how to continue was held 13th of May. The plans include possible international co-operation. At the meeting it was decided to continue with planning and preparations for the test. Supporting laboratory tests could be started in 2007, with the aim of performing the actual shear simulations around 2010. No additional work has been done during this quarter.

2.11 Learning from experiences

Several large-scale experiments have during the years been installed in Äspö HRL and methods and machines used have provided experiences for refinement and evaluation of limits of the methods applied. Emplacement of buffer and canisters, and backfilling of tunnels have been experienced in Canister Retrieval Test, Prototype Repository and Backfill and Plug Test.

In this project these experiences are documented and analysed with respect to possible improvements as well as acceptable water inflows. The prime objective is to answer questions and provide information to the work on the SKB's applications for an Encapsulation Plant in 2006 and a Deep Repository in 2008. The aims are to:

- Compile results from more than ten years of performed engineering experiments in Äspö HRL.
- Compile and evaluate experiences from methods for emplacement of buffer and canisters, backfilling of tunnels, and estimate acceptable water inflows for the applied methods.

Achievements

A draft list of questions to be answered as a basis for the applications, has been compiled and a number of practical issues have been investigated, primarily:

- Water inflow in tunnels and deposition holes in the phase of placing buffer and backfill; this work continues.
- Performance of instruments in buffer and backfill.
- Accuracy of recordings of temperature, wetting rate and build-up of swelling pressure compared to predictions.
- Identification and assessment of major chemical processes in buffer and backfill in the wetting phase and a few years thereafter.

The first priority issue, the impact of water inflow to tunnels on the backfilling method, material composition and quality of result is ongoing. Due to limited available manpower this and other major issues on the list has proceeded slower than planned.

2.12 Task Force on Engineered Barrier Systems

Task Force on Engineered Barrier Systems (EBS) was in 2000 decided to focus on the water saturation process in buffer, backfill and rock. Since the water saturation process also was a part of the modelling work in the Prototype Repository project, the work was transferred to the Prototype Repository project, and the Task Force was put on a stand-by position. As the European Commission funding of the Prototype Repository project ceased in February 2004 it was judged most convenient to activate the Task Force on EBS and continue the modelling work in the Prototype Repository project within this frame, where also modelling work on all other experiments can be conducted.

The Äspö HRL International Joint Committee decided, on May 19th 2004, 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).

Achievements

Two benchmark tests for Task 1 (THM-processes) were delivered in spring 2005 and the modelling teams were requested to simulate these laboratory tests:

- Benchmark 1.1 - THM mock-up experiments on compacted MX-80 bentonite, with two different initial water contents. The experiments have been performed by CEA.
- Benchmark 1.2 - Large-cell experiments are currently being performed by Ciemat in their laboratory in Madrid. One of the tests is kept under isothermal conditions and the other test is performed under a thermal gradient.

The modelling results for Task 1 were reported at the Task Force meeting that was held in October. In addition, the benchmark tests for Task 2 (gas migration) were presented at the meeting.

An EC application dealing with THMC-modelling (Theresa) with the Task Force on EBS as a part is submitted. The application has been selected by the first evaluation and there is a good chance that the project will be financed.

3 Geo-science

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), rock mechanics, and buffer materials. Studies are performed in laboratory and field experiments as well as by modelling work. The activities further aim to provide geoscientific base data and to ensure high quality of experiments and measurements related to geosciences. The major aims are to:

- Establish and maintain 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.

3.1 Geological mapping and modelling

All rock surfaces and drill cores are mapped at Äspö. This is done in order to increase the understanding of geometries and properties of rocks 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.

Besides the regular geological tasks at Äspö HRL, a feasibility study with the acronym RoCS (Rock Characterisation System) is being performed, see Section 3.1.1.

Achievements

At present no exposed rock surface or drill core from Äspö rock volume is unmapped. There are, however, earlier mappings that have not been digitized or entered into Sicada database. Possibilities to catch up have however increased, as one more TMS (Tunnel Mapping System) station is in operation since summer 2005 and Sicada operators are engaged to assist in data entering and quality control.

The geological 3D model of Äspö rock volume had a major revision in 2002, reported in the GeoMod report (2003). Minor revisions are performed successively as new data are achieved. A detailed 3D structural geological and hydrogeological model of the -450 m level has been initiated. The model will be based on all available data from earlier investigations.

A project with the purpose to establish true width of deformation zones by using magnetic anisotropy (AMS) has been initiated. The major part of the sampling is completed.

3.1.1 RoCS – Method development of a new technique for underground surveying

A feasibility study concerning geological mapping techniques is performed beside the regular mapping and modelling tasks. The project 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 future deep 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, 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 requirements.

Achievements

In December 2005 the first part of the feasibility study was planned to be completed and reported, the establishing of the technical state-of-the-art. A slight delay is, however, present at the time being. Test of data collection methods has been performed using both digital photogrammetry and laser scanning. In Onkalo both methods have been tested whereas at Äspö HRL only laser scanning has been tested. Also, several complementary techniques, such as geophysical survey methods, have been investigated, as well as software applications.

3.2 Heat transport

The aim of the heat transport project is to develop a strategy for site descriptive thermal modelling to decrease the uncertainties in the estimates of the temperature field in a repository. Less uncertain estimates of the temperature field make it possible to optimise the distance between canisters in the repository layout. The work includes measurements of thermal properties of the rock, examinations of the thermal conductivity distributions, analyses of thermal properties at different scales, and inverse modelling of thermal properties from the measured temperature changes in the rock mass at the prototype repository. In order to determine the significant scale for the variation of thermal properties in a repository, a large number of numerical simulations are included in the work.

Achievements

Inverse modelling of thermal properties from the measured temperature in the rock mass has been conducted at the Prototype Repository. A prognosis model of the thermal properties has been established based on earlier measured data. The prognosis model is evaluated against values calculated through inverse modelling. The inverse modelling is based on an iterative process where a fitting of measured and calculated temperatures is performed with a numerical model.

The inverse modelling, uncertainties and scale dependencies in data have been evaluated during the summer of 2005 and the reporting is in progress /Sundberg *et al.* 2005/.

3.3 Inflow predictions

SKB has conducted a number of large field tests where predictions of inflow into tunnels or depositions holes have been a component: Site characterisation and validation tests in Stripa, Prototype Repository, and Groundwater degassing and two-phase flow experiments in Äspö HRL. The results from these tests show that when going from a borehole to a larger diameter hole, the inflow into the larger hole is often less than predicted, and the explanation for this is not yet well understood.

The ability to predict inflow is of importance from several aspects:

- Evaluation of experimental results from Äspö HRL. A good understanding of the mechanisms controlling inflow would improve the possibilities for good experimental set-ups and accurate result interpretation.
- Evaluation and comparisons between potential repository sites. It is desirable to be able to predict the inflow conditions into the excavations, already before the construction work starts, based on hydraulic measurements made in small diameter boreholes.
- Evaluation of the expected bentonite buffer behaviour. The amount of inflow into deposition holes will influence the time needed for saturation and also the expected performance of the buffer.
- Design and optimisation of the repository layout. Poor prediction of inflow could lead to less optimal design alternatives.

Achievements

A report has been written about the hydro-mechanical data acquisition project at the Äspö Pillar Stability (Apse) site /Mas Ivars 2005/. In this project a large field experiment was conducted with the aim of acquiring hydro-mechanical data during the drilling of the de-stressing slot at the site, see Section 3.6.

To better understand the data acquired in the previously mentioned HM data acquisition project, a three dimensional mechanical modelling study of the de-stressing of the Apse pillar has been carried out using 3DEC. The results from this modelling exercise show the stress redistribution in the Apse tunnel during the drilling of the de-stressing slot. The reporting is in progress and it will be ready before spring 2006.

For the next step, two 30mm diameter boreholes have been drilled. These two boreholes intersected a very conductive fracture where flow and displacements were monitored during the de-stressing of the Apse pillar. Coupled stress-flow laboratory tests will be conducted on large fracture samples from the mentioned boreholes.

3.4 Seismic influence on the groundwater system

The Hydro Monitoring System (HMS) registers at the moment the piezometric head in about 280 positions underground in the Äspö HRL. An induced change of the head with more than 2 kPa triggers an intensive sampling. All measured data are stored in a database.

The data in the database are assumed to bear witness of different seismic activities in Sweden but also abroad, dependent on the magnitude of the event, as well as the position of the epicentre. By analysing the data on changes in the piezometric head at Äspö connections to specific seismic events are expected to be established.

Achievements

Data measured during the fourth quarter are in the same way as earlier stored in HMS, waiting for future analyses.

3.5 Rock mechanics

Rock Mechanic studies are performed with the aims to increase the understanding of the mechanical properties of the rock but also to recommend methods for measurements and analyses. This is 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.

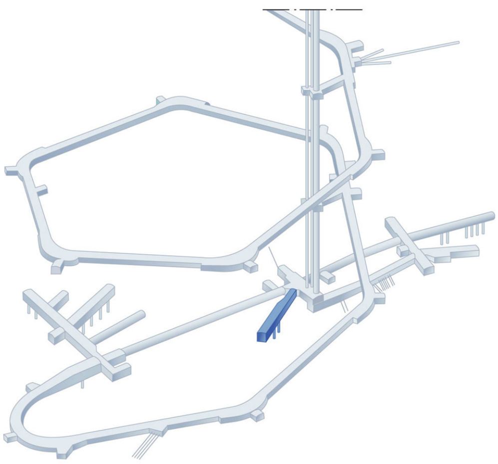
During 2005 work have been performed within the following projects:

- Coupled processes in rock including dynamic processes at natural conditions.
- Stress measurements and stress interpretation methods.
- Understanding of variability of rock under different load conditions. Methods to calculate stability of underground openings and large scale failures (dynamic effects of earthquakes).
- Mechanical processes in the interface between rock and backfill.
- Äspö Pillar Stability Experiment.

Achievements

During this quarter the main activities have been within the Äspö Pillar Stability Experiment, see Section 3.6.

3.6 Äspö Pillar Stability Experiment



The major aims with the Pillar Stability Experiment are to demonstrate the capability to predict spalling in fractured rock mass and the effect of backfill on the propagation of micro cracks. The experiment is a complement to an earlier study performed at URL in Canada.

A new tunnel was excavated at Äspö HRL to ensure that the experiment was carried out in a rock mass with a virgin stress field. The site is located at the -450 m level. The pillar was created between two vertical deposition holes drilled in the floor of the tunnel.

The stress in the pillar was further increased by a thermal load to reach a stress state that induced brittle failure/spalling. One of the boreholes was subjected to an internal water pressure via a rubber bladder giving a confining pressure of 0.7 MPa.

The heating phase of the experiment was finished in mid July 2004. Spalling occurred to almost five metres depth in the open borehole and good measuring series were achieved with all the instruments used. Five pillar blocks were sawn and in January 2005 all blocks were lifted up.

Achievements

The reports describing the observations and monitored results from the field part of the experiment have been finalized and printed /Andersson & Eng 2005, Haycox *et al*. 2005/. The report describing the methology and results from the back calculation of the temperature in the pillar during heating is also finished and printed /Fälth *et al*. 2005/. In /Eng & Andersson 2004/ the displacement and thermal monitoring equipment is described in detail.

Integration and interpretation of the different data sets have been performed and are almost finalised. The deepened analysis of the data set has shown that it is of good quality. The data set is judged as very reliable. The integrated data reports will be written during the first half of 2006.

The detailed geological mapping of the pillar blocks is almost finished and a report is scheduled to be printed in early 2006.

4 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 deep 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. Processes that influence migration of species along a natural rock fracture are shown in Figure 4-1.

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.

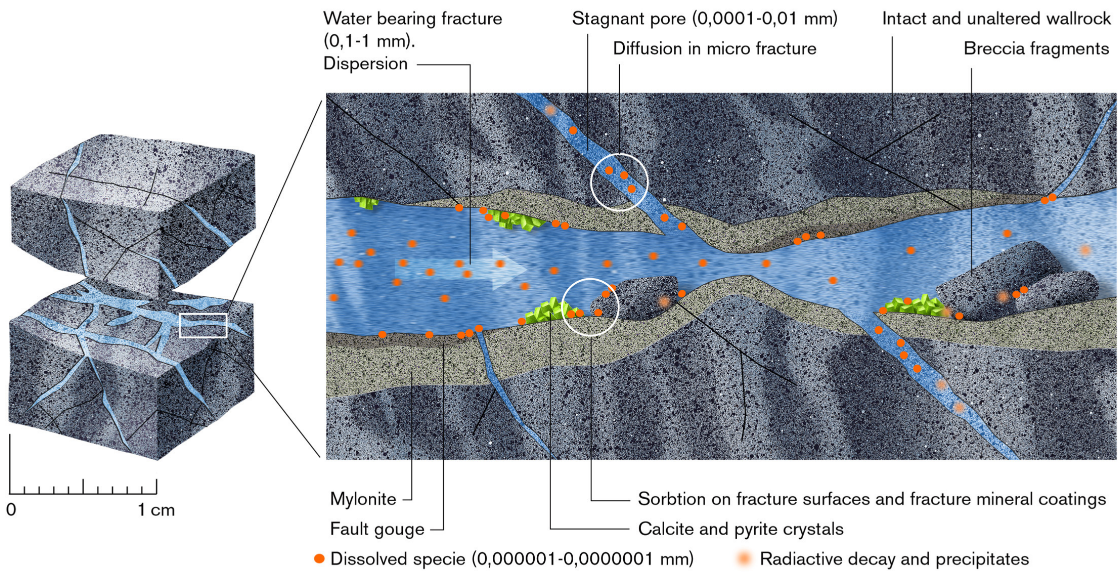
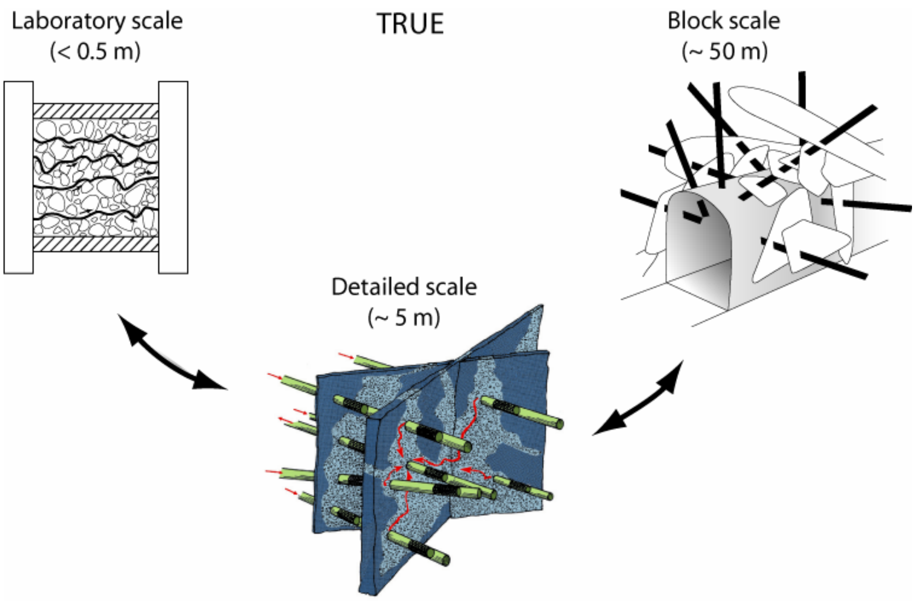


Figure 4-1 *Processes that influence migration of species along a natural rock fracture.*

4.1 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 and the evaluation and final reporting are completed. Complementary field work and modelling are currently 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 True-1 Continuation project is a continuation of the True-1 experiment. According to present plans the True-1 site will be injected with resin and excavated and analysed. 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. Furthermore, attempts are made to assess fracture apertures using radon concentrations in groundwater.

4.1.1 True Block Scale Continuation

The True Block Scale Continuation (BS2) project has its main focus on the existing True Block Scale site. The True Block Scale Continuation is divided into two separate phases:

BS2a Complementary modelling work in support of BS2 *in situ* tests. Continuation of the True Block Scale (phase C) pumping and sampling including employment of developed enrichment techniques to lower detection limits.

BS2b Additional *in situ* tracer tests based on the outcome of the BS2a analysis. *In situ* tests are preceded by reassessment of the need to optimise/remediate the piezometer array.

Achievements

During the period individual evaluation reports have been produced by the four modelling teams. Furthermore, a review seminar was held in the Stockholm area in mid September. Using the input received at the review seminar, the final reporting for BS2 will be completed. Contributions to the final report are received and edition work initiated.

The performed joint evaluation emphasise:

- The importance of geological information (hydrostructural and microstructure models) for understanding sorbing tracer transport.
- Immobile zone retention material properties assigned to structure and background fracture flow paths verified by means of back-calculations, those of the structure flow path (Structure #19) being one order of magnitude higher than for the background fracture flow path.
- Overall retention in the background fracture found to be higher while the flow rate is significantly lower than in the structure flow path.

4.1.2 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, see below). In addition, this project includes the production of a series of scientific articles based on the True-1 project. Furthermore, the Fault Rock Characterisation project will be carried out, partly in preparation for True-1 Completion.

Achievements

Fault Rock Characterisation project

A draft report has been produced of the image analyses of the resin-impregnated rock material. Otherwise no work has been performed within the Fault Rock Zones Characterisation sub-project.

True-1 papers

Production of a series of three scientific papers on the True team analysis of the True-1 experiments, now available in draft. Contacts have been taken with the WRR editor and the first two in the series will be submitted early 2006. The papers will cover the following topics under the joint header of "Sorbing tracer experiments in a crystalline rock fracture at Äspö (Sweden)":

Part 1 Experimental results, conceptual model and effective parameter estimation.

Part 2 Micro-scale characterisation of retention parameters.

Part 3 Effect of micro-scale heterogeneity.

True-1 Completion

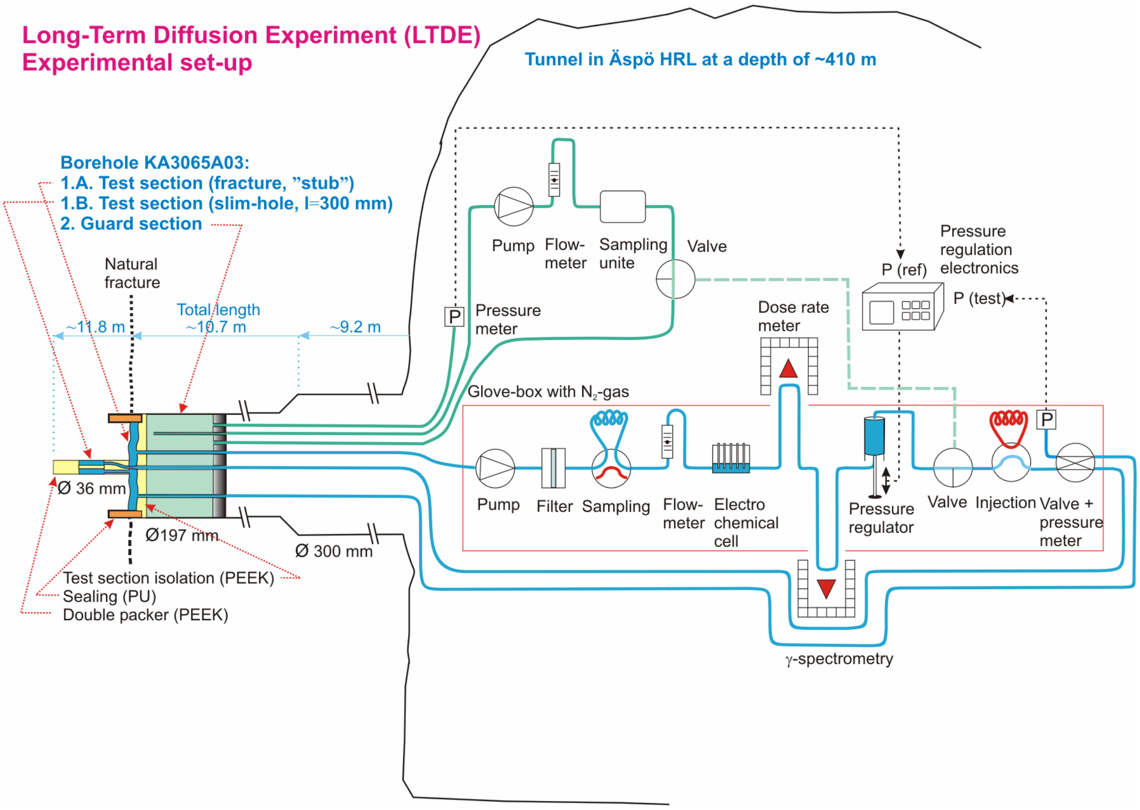
The True-1 Completion project has been initiated, with epoxy injection and subsequent over coring of Feature A at the True-1 site as the main activity. The True-1 Completion project will comprise of complementary tracer tests, e.g. Swiw (Single well injection withdrawal) tests and *in situ* cation exchange tests, which will preced the impregnation. Analyses will be perfomed to provide information about the inner structure of Feature A and of the immobile zones where the main part of the noted retention occurs. The analysis will also update the conceptual micro structural and retention models of Feature A.

Prior to the *in situ* testing a re-instrumentation and establishment of infrastructure at the site is a necessary prerequisite. A complication for the scheduling of future work at the True-1 site lies in the fact that the True-1 and LTDE sites are hydraulically connected hence the re-instrumentation is required to avoid disturbances of LTDE and other projects at Äspö HRL.

Because the advancing LTDE was given priority by SKB all activities at the True-1 site were postponed until after the accomplishment of the LTDE functionality tests. The finalisation of the LTDE functionality tests facilitated the performance of the re-instrumentation at the True-1 site, the disassembly of True Block Scale site and subsequent disengagement of equipment essential to facilitate the complementary tracer tests at the True-1 site.

The complementary tracer tests have been initiated by the performance of a water injection test and a Swiw pre-test. The main aim of the pre-test is to verify if a Swiw test can be performed at the True-1 site without the risk of loosing tracer in the rock. The pre-test will provide vital information for the design of a Swiw test using radioactive tracers and also the possibility to verify the tracer distribution around the injection borehole.

4.2 Long Term Diffusion Experiment



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

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

A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole and a small-diameter borehole is drilled through the core stub and beyond into the intact unaltered bedrock. Tracers will be circulated over a period of two to four years after which the borehole is over-cored and analysed for tracer content.

Achievements

The pre-test programme for evaluation of the hydrological conditions in the vicinity of the experimental borehole, KA3065A03, and possible hydrological interferences from other activities in Äspö HRL are completed. The evaluation and documentation are in progress. A functionality test with short lived radionuclides started in September and was terminated after five weeks.

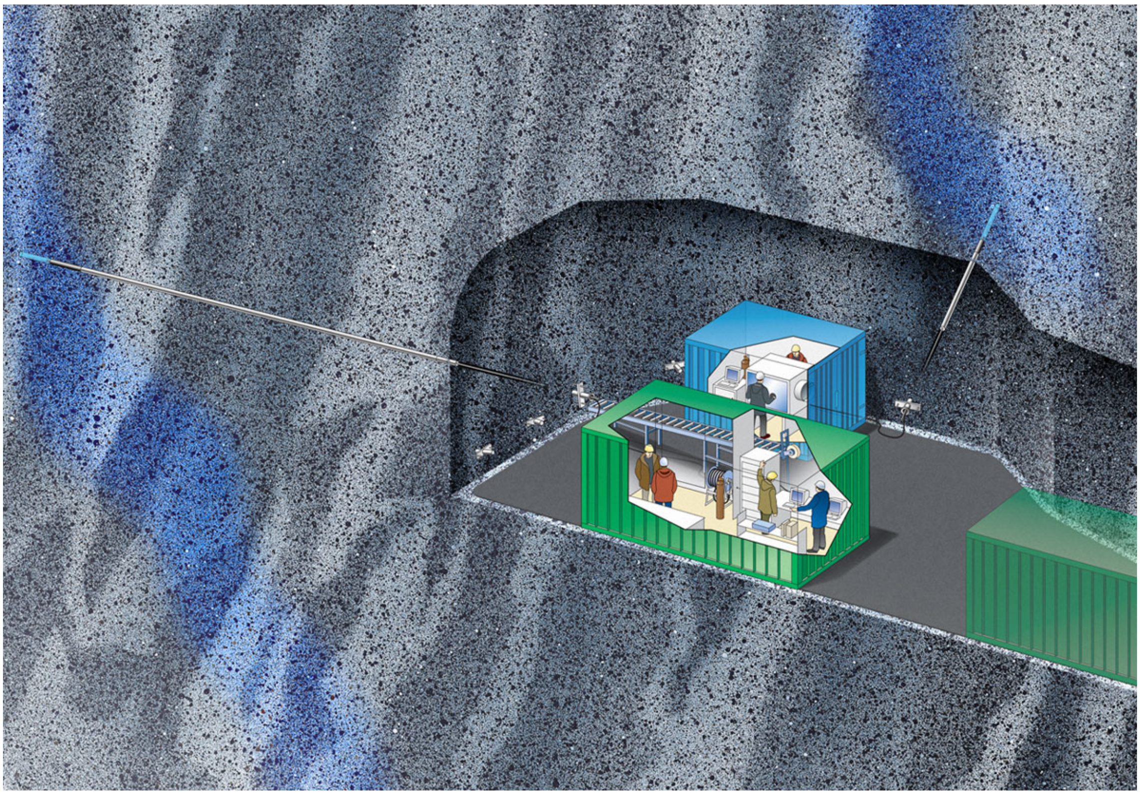
The objectives of the test were to:

- Test the complete experimental set up with respect to functionality and safety.
- Optimise circulation flow rate and injection and sampling procedures.
- Investigate if sorption processes on the stub-surface and on the matrix rock surface in the small-diameter borehole can be monitored with the present experimental set up, i.e. measurement of the decrease of tracer concentration in the test section volume.

The functionality test was followed by a decision to run the experiment based on a slightly up-dated Project plan. The new plan emphasises *in situ* sorption measurements with shorter experimental time frames than the original plan which had more focus on obtaining diffusion data.

Within the framework of collaboration between SKB and OPG's Nuclear Waste Management Division laboratory experiments on core samples from the LTDE borehole KA3065A03 have been performed at AECL in Canada during 2004 and 2005. The experimental programme consists of porosity measurements, diffusion cell experiments, radial diffusion experiments and permeability measurements. So far all measurements on core samples have been accomplished; evaluation and reporting are in progress.

4.3 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)

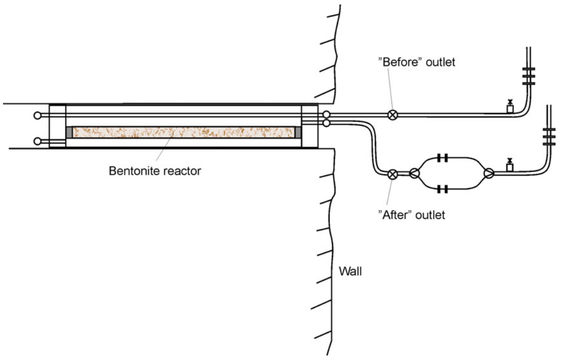
Achievements

The planning of two experiments is in progress; "Investigations of the transport resistance at the buffer/rock interface" and "Study leaching of spent fuel at repository conditions".

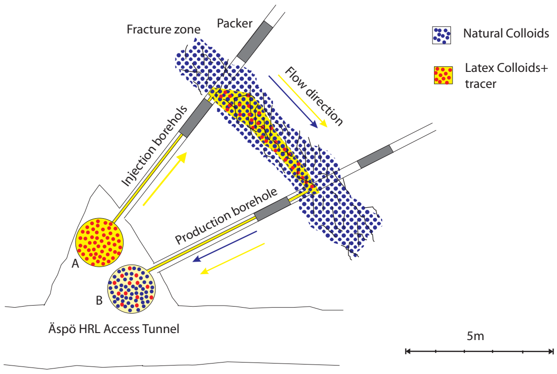
The activity during this quarter concerning the "Interface rock/buffer" experiment has mainly been pre-calculations to design the field equipment and planning and purchasing equipment for supporting laboratory experiments. The "spent fuel leaching" experiment has just been initiated and the planning of laboratory experiments is in progress. The field experiments at Äspö HRL are planned for autumn 2006.

4.4 Colloid Project

Borehole specific measurements



Colloid dipole experiment



In the Colloid Project the concentration, stability, and mobility of colloids in the Äspö environment are studied. The project comprises studies of the potential of colloids to enhance solute transport and the potential of bentonite clay as a source for colloid generation. The Colloid Project includes laboratory experiments, background measurements, borehole specific measurements, and colloid dipole experiments.

Achievements

The preparations for the *Colloid dipole experiment* are carried out in co-operation between SKB, INE, AECL and Posiva. Stability experiments on bentonite colloids and latex colloids are performed in the laboratory where Ca, Na and DOC contents in the water are varied. The experiments will continue with stability experiments on latex-colloids in a cocktail with a colour tracer and latex colloids. Also experiments to determine the critical coagulation concentrations of Ca and Na for bentonite colloids in contact with groundwaters will be performed at the laboratory.

The field experiments are coordinated with the True-1 Continuation experiment and Feature A at the True-1 site is chosen as experimental site. Predictive modelling to define initial conditions for the *in situ* experiments is finished. In addition, laboratory experiments on a granite block are performed by AECL, Pinawa where transport of bentonite colloids in dilute waters in a water bearing fracture is tested.

4.5 Microbe Project

The Microbe Project has been initiated in the Äspö HRL for studies of the microbial activity in groundwater at *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.

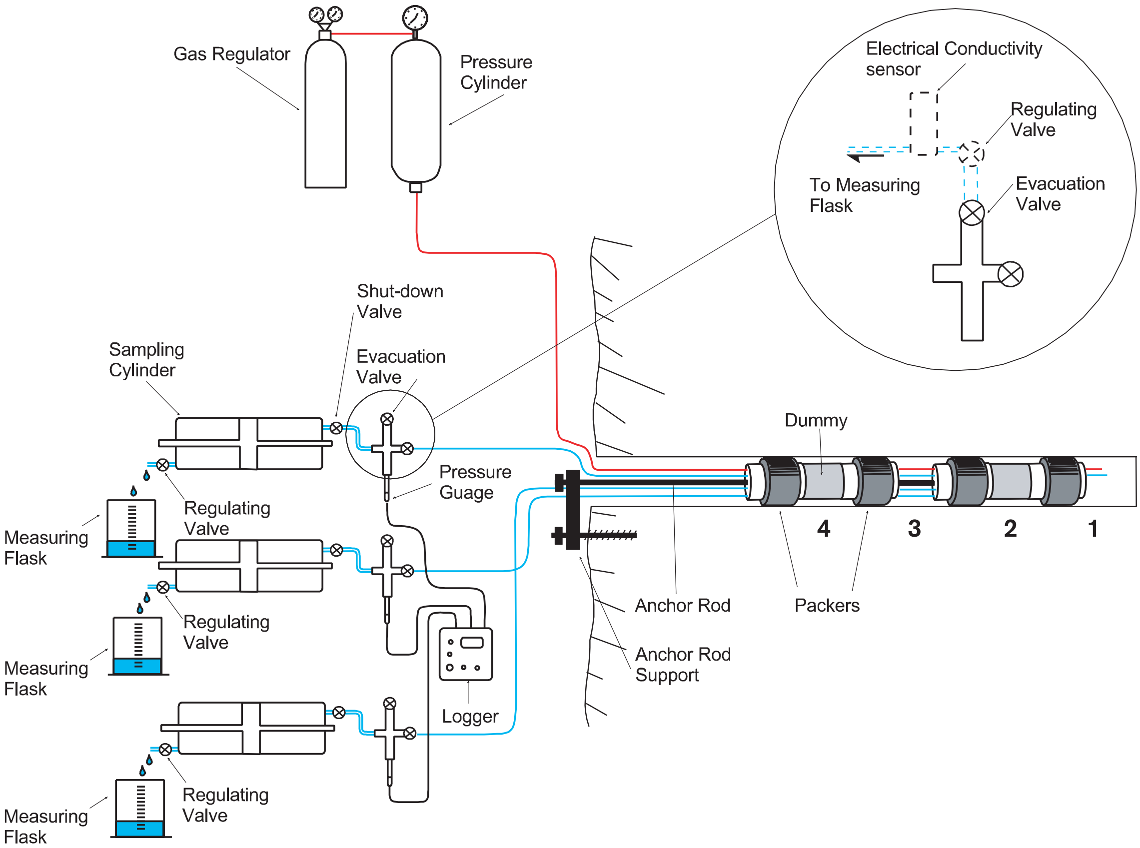
The main Microbe site is on the -450 m level where a laboratory container with benches, an anaerobic gas box and an advanced climate control system is located. Three core drilled holes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures are connected to the Microbe laboratory via tubings. Each borehole has been equipped with a circulation system offering 2000 cm^2 of test surface.

Retention of naturally occurring trace elements in the groundwater by Biological Iron Oxides is investigated at a site at tunnel length 2200 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 x 30 x 20 cm artificial channels that mimic ditches in the tunnel. The channels have rock and artificial plastic support that stimulate Biological Iron Oxide formation.

Achievements

The site selection of the Microbe laboratory in the F-tunnel of Äspö has, until now, assured stable conditions. However, the situation has changed since the drilling of boreholes in January 2005 at the -450 m level for the "In situ corrosion testing of miniature canisters" (Minican). This drilling caused a significant drainage of the formation from which Microbe takes groundwater. Until now (November 2005) more than 15 000 m^3 groundwater have been drained from KA3386A01. This is a very significant drainage. A completely new mixing situation has developed in the Microbe formation during 2005. There is an ongoing transient in the microbial and chemical situation, including dissolved gas, caused by the so called Minican drainage. New measurements will constitute a platform for follow up measurements once the situation has stabilised at new levels. Significant increases in chloride concentrations indicate that deeper and saltier water is moving up from large depths towards the Microbe formation. It remains to analyse the mixing history with M3 modelling. This should be done when the pressure and drainage conditions have been restored. Complete class 5 analyses must be performed to establish the new chemical conditions that have originated as a result of the drainage. Deeper water is expected to carry more hydrogen and noble gases, and less CO_2. Although the gas data are a bit erratic, some individual gas analyses also suggest that deeper water is moving up towards the Microbe boreholes. However, intensive mixing is expected with the measured drainage and this mixing may introduce variability over time. Variability of groundwater pressure due to opening and closing of boreholes, tide effects etc. may introduce wobbling effects over time that masks clear trends. The data on microbes has changed from being very reproducible to being very variable after the Minican drainage started. Microorganisms are very sensitive to changes in the environmental conditions. New analyses of microbes must be performed once the conditions have returned to those prevailing before the drainage. However, it will be a totally new situation, because the introduction of new, deeper water to the Microbe formation.

4.6 Matrix Fluid Chemistry



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

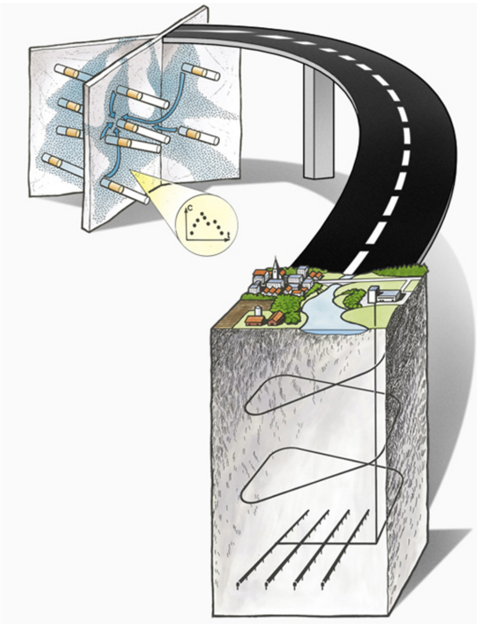
Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied to determine their contribution, if any, to the composition of the matrix fluids/groundwaters.

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

Achievements

During this quarter several achievements have been completed. In November 29th a final sampling of matrix water was made from fracture-containing lengths of the borehole and the samples were sent to the University of Bern for analysis; these data will complement the samples taken on April 22nd. Immediately following sampling the packer system was removed, modified and reinstalled to carry out the programme of hydrotesting. These tests, to be conducted on fracture-containing and fracture-free portions of the borehole earlier sampled and characterised, are scheduled to continue at least until March, 2006. Successful completion of the tests will coincide with the termination of the Matrix Continuation Project.

4.7 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 − Performance Assessment Modelling Using Site Characterisation Data, and in Task 7, which addresses a long-term pumping test in Olkiluoto, Finland. The status of the specific modelling tasks is given within brackets in Table 4-1.

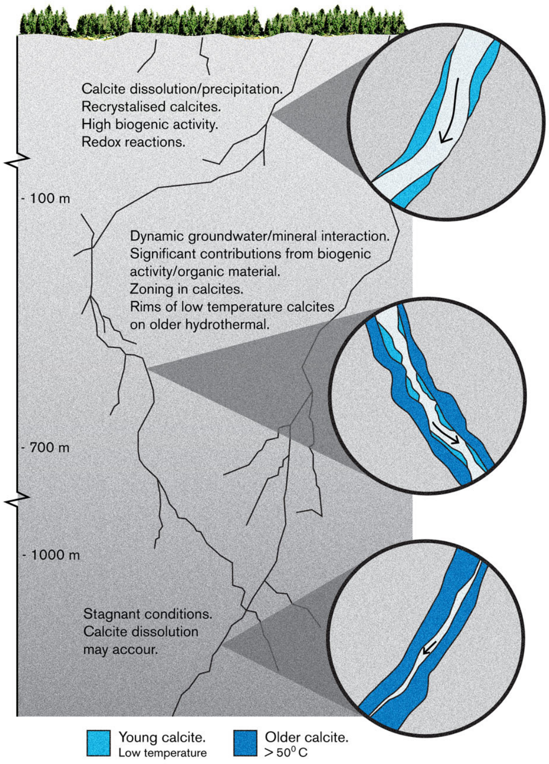
Task 6 tries to bridge the gap between Performance Assessment (PA) and Site Characterisation (SC) models by applying both approaches for the same tracer experiment. It is hoped that this will help to identify the relevant conceptualisations (in processes/structures) for long term PA predictions and identify site characterisation data requirements to support PA calculations. The review report for Tasks 6A, 6B and 6B2 has been printed /Hodgkinson and Black 2005/. Also, the review report for Task 6C has been printed /Black and Hodgkinson 2005/. Seven out of eight draft reports on Task 6E has been delivered by the Modelling Groups. It was decided that Tasks 6D, 6E, 6F and 6F2 are to be reported together, and the work with this combined report is in progress. A summary of the outcome of Task 6 will be published in a scientific paper.

Task 7 addresses modelling of the KR24 long-term pumping test at Olkiluoto in Finland. The task will focus on methods to quantify uncertainties in PA-type approaches based on SC-type information; along with being an opportunity to increase the understanding of the role of fracture zones as boundary conditions for the fracture network and how compartmentalisation affect the groundwater system. The possibilities to extract more information from interference tests will also be addressed. A Task Description for Task 7A has been sent out to the modellers. Planning for the 21st Task Force meeting in March 2006 is on-going.

Table 4-1 Task descriptions and status of the specific modelling sub-tasks.

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 2000 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. (Draft reports available and review in progress).
6E	This sub-task extends the sub-task 6D transport calculations to a reference set of PA time scales and boundary conditions. (Draft reports available and review in progress).
6F	Task 6F is a sensitivity study, which is proposed to address simple test cases, individual tasks to explore processes, and to test model functionality. (Draft reports available and review in progress).
7	Long-term pumping experiment. (Initiated).

4.8 Padamot



Potential calcite-groundwater interaction at various depths at Äspö.

Padamot (Palaeohydrogeological Data Analysis and Model Testing) is an EC-project and will investigate 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.

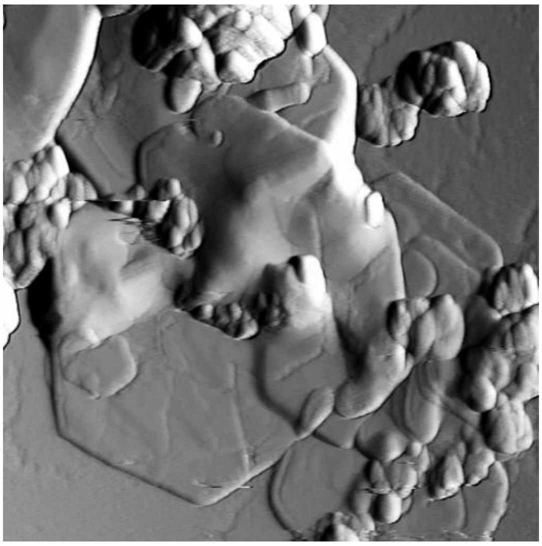
The objectives of Padamot are to:
- Improve understanding and prioritise palaeo-hydrogeological information for use in safety assessments.
- Collect chemical/isotopic data using advanced analytical methods.
- Construct a database of relevant information and develop numerical models to test hypotheses.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

The project comprises analytical and modelling tasks. Deep borehole cores from rocks at the Äspö Underground Laboratory and Laxemar (KXL01) are used in the analytical study.

Achievements

The EC part of the project is now finished and reported in EC series of reports. The continuation involving the inter-laboratory study of Uranium-series analyses of fracture fillings are presently planned and materials suitable for analyses will be selected.

4.9 Fe-oxides in fractures



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

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

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

Achievements

A fast, effective and precise method for analysis of stable Fe isotope fractionation using double spike MC-ICP-MS (inductively coupled plasma mass spectroscopy) has been published. As a result, a procedure has been developed to differentiate between several types of Fe-oxides found as fracture fillings in granite, drilled from the Oskarshamn – Äspö area. Together with data from Mössbauer spectroscopy, X-ray diffraction (XRD) and rare earth element (REE) analysis, three genetic environments for Fe-oxide formation have been demonstrated. Crystalline hematite with grain-size about 100 nm, that formed from hydrothermal waters, could be distinguished from finer-grained (10-30 nm) crystalline hematite that formed more recently from low-temperature oxidising solutions. Drilling activities at Oskarshamn and Forsmark sometimes resulted in very recent, X-ray amorphous (< ~ 10 nm), low temperature Fe-oxides where metallic iron and maghemite, a common corrosion product of steel, were also present in minor amounts. The natural, low-temperature, recent Fe-oxides likely formed from weathering of chlorite fracture linings. From the samples studied, no evidence was found to indicate penetration of oxidising, low temperature solutions below a depth of about 100 m below current ground level. Although results suggest that deep penetration of oxidising water as a result of future deglaciation is unlikely, the sample size was small (10 samples) and from essentially only two drill cores.

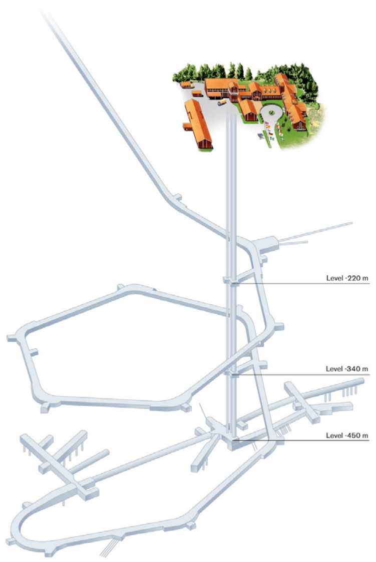
Investigations of green rust (GR) have shown that existing literature data for structure and composition are incorrect. Revised data, which are required for PA modelling, have been produced and more are coming. Methods for investigating GR reactivity have been developed by using Cr(VI) reduction to Cr(III) as a model redox active compound. GR was oxidised by CrO_4^{2-} and the reduced Cr was immobilised in the structure of goethite as the end-product of GR transformation. Preliminary studies with Np(V) and Se(VI) show the same behaviour. Investigations continue to determine GR stability in natural conditions and the potential mobility of green rust colloids.

Reactive transport modelling has commenced recently by Enviros (Spain).

5 Äspö facility

An important part of the Äspö facility is the administration, operation, and maintenance of instruments as well as development of investigation methods. Other issues are to keep the stationary hydro monitoring system (HMS) continuously available and to carry out the programme for monitoring of groundwater head and flow and the programme for monitoring of groundwater chemistry.

5.1 Facility operation



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 in the Hard Rock Laboratory.

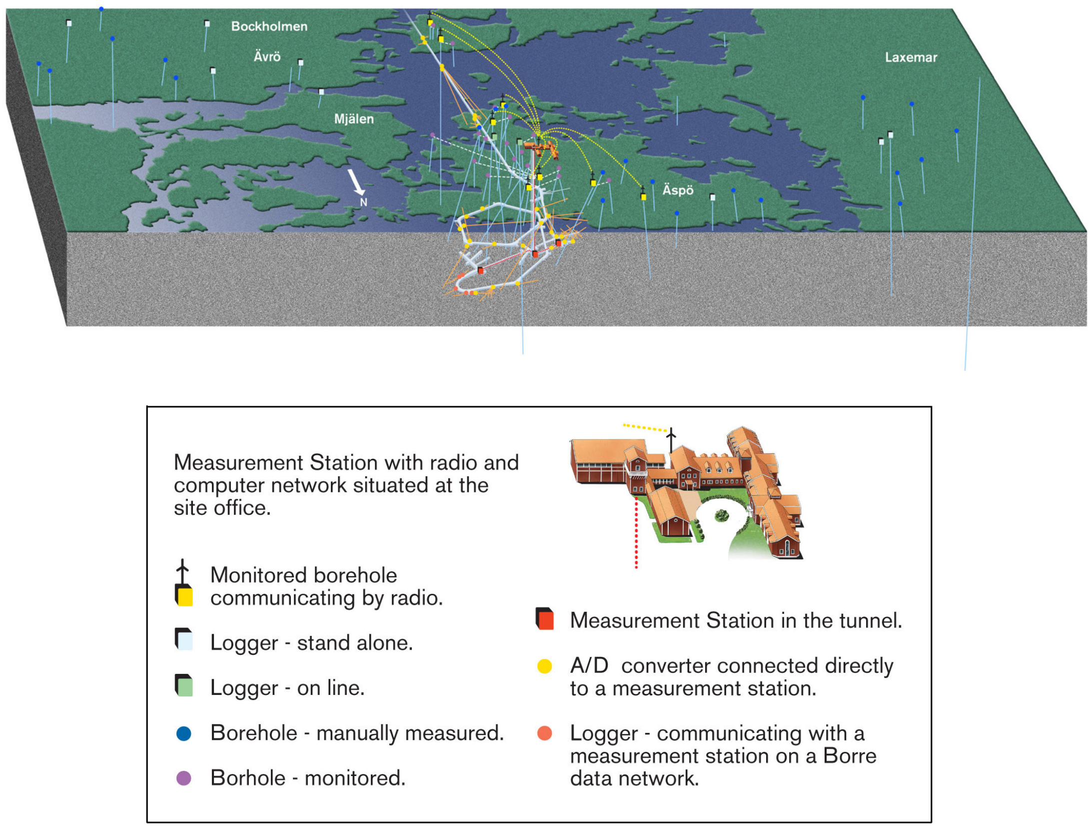
Achievements

Maintenance and operation of the above and underground facilities as well as improvements of the safety and working environment are running. The availability of the facility systems has been high during the fourth quarter. During this quarter the exchange of old electric installations has started and all pressure vessels have been inspected. The scrapping of rock in the tunnels started in the beginning of September and continued the rest of the year.

The development and testing of an automatic registration and object-monitoring system, based on radio frequency identification, is in progress. The system has been installed and the first of three operation tests was performed during some weeks in August and September. The second operation test started, after some adjustments, in October 2005 and will continue to the beginning of next year.

The data network with a system for administration including a server for storage of all experimental data, and a separated system for supervision of facilities has been functioning well.

5.2 Hydro Monitoring System



The computerised Hydro Monitoring System (HMS), is a network of boreholes and measurement stations where e.g. data of groundwater head and electrical conductivity are collected on-line. The data are recorded by about 375 transducers installed in boreholes on Äspö as well as in boreholes located in the tunnel. All data are transmitted to the main office at Äspö, by radio or modems. Weekly quality controls 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

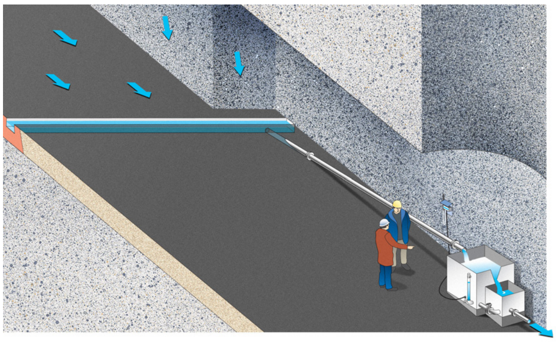
The system has been performing well. However, improvements are continuously made on the monitoring system to increase the performance of the system. Inspections and calibrations of HMS data have been performed during the fourth quarter. Erroneous data have been removed and calibration constants for some transducers have been adjusted.

5.3 Programme for monitoring of groundwater head and flow

The monitoring of water levels in surface based boreholes started in 1987. The tunnel excavation started in October 1990 and the first groundwater head (pressure) measurements from tunnel based boreholes were performed in March 1992.

The monitoring is administrated by the computerised hydro monitoring system (HMS), comprising a network of boreholes of which many are equipped with hydraulically inflatable packers, measuring the pressure by means of transducers. Manual levelling is also obtained from the surface boreholes on a regular basis.

Water seeping through the tunnel walls is diverted to trenches and further to 25 weirs where the flow is measured.



Achievements

Most monitoring points from the previous year have been maintained and some new have been installed. However, the number of measured sections in surface boreholes is somewhat lower than the year before. A number of boreholes have been handed over to the site investigation programme and some malfunctioning packer systems have been removed. Automatic monitoring in surface boreholes is also successively replaced by monthly manual levelling. Installation of new transducers for measurements of air temperature, air humidity, and air pressure has been going on throughout the whole tunnel during the fourth quarter. The monitoring proramme will continue to provide basic hydrogeological data and support the experiments undertaken. A report describing instrumentation, measurement methods, and summarising the monitoring during 2004 is available /Nyberg *et al*. 2005/.

5.4 Programme for monitoring of groundwater chemistry

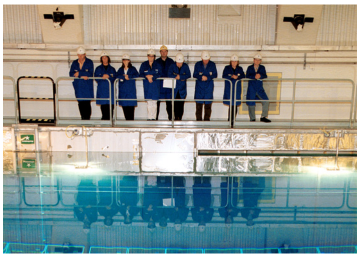
During the Construction Phase of the Äspö HRL, different types of water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. At the beginning of the Operational Phase, sampling was replaced by a groundwater chemistry monitoring programme, aiming at a sufficient cover of the 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.

Achievements

The annual water sampling campaign was in the same way as earlier years scheduled to take place in September – October. This year the sampling started the 31st August and was finalised in the middle of October.

5.5 Information and public relations





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

The main goal for the information and public relations group at Äspö HRL, is to in co-operation with other departments at SKB, present information about SKB and its activities and facilities.

Achievements

During the second half of 2005, SKB's facilities have been visited by 12 448 persons. This sum includes visitors to all SKB facilities in the Oskarshamn as well as the Östhammar area. The numbers of visitors to SKB's main facilities are listed below.

SKB facility	**Number of visitors July - December 2005**
Central interim storage facility for spent nuclear fuel	929
Canister Laboratory	1 419
Äspö HRL	6 048
Final repository for radioactive operational waste (SFR)	3 635

6 International co-operation

Nine organisations from eight countries participate in the Äspö HRL co-operation during 2005. Six of them; Andra, BMWA, CRIEPI, JAEA, OPG 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 at gas migration through a buffer.

Projects in the Äspö HRL during 2005	Andra	BMWA	Enresa	CRIEPI	JAEA	OPG	Posiva	Nagra	Rawra
Technology									
Prototype Repository	X	X			X		X		
Backfill and Plug Test									
Long Term Test of Buffer Material							X		
Cleaning and sealing of investigation boreholes							X		
Injection grout for deep repositories							X		
KBS-3 method with horizontal emplacement							X		
Large Scale Gas Injection Test	X	X				X	X		
Temperature Buffer Test	X	X	X						
Task Force on Engineered Barrier Systems	X	X		X		X	X	X	X
Geo-science									
Äspö Pillar Stability Experiment						X	X		
Natural barriers									
Tracer Retention Understanding Experiments	X				X		X		
Long Term Diffusion Experiment						X			
Radionuclide Retention Project		X							
Colloid Project		X					X		
Microbe Project		X							
Matrix Fluid Chemistry									
Task Force on Modelling of Groundwater Flow and Transport of Solutes	X	X		X	X	X	X		

Participating organisations:
Agence nationale pour la gestion des déchets radioactifs, Andra, France
Bundesministerium für Wirtschaft und Arbeit, BMWA, Germany
Empresa Nacional de Residuos Radiactivos, Enresa, Spain
Central Research Institute of the Electronic Power Industry, CRIEPI, Japan
Japan Atomic Energy Agency, JAEA, Japan
Ontario Power Generation Inc., OPG, Canada
Posiva Oy, Finland
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland
Radioactive Waste Repository Authority, Rawra, Czech Republic

7 Environmental research

7.1 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. Currently the scientific team consists of a professor of Environmental geology (Dr. Mats Åström), three assistant supervisors and six Ph.D. students. The research activity focuses 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 University of Kalmar, the School receives funding from the city of Oskarshamn.

Achievements

In accordance with the agreement, the Äspö Research School was during autumn evaluated by Prof. em. Gert Knutsson and documented in an internal report.

8 Documentation

During the period October to December 2005, the following reports have been published and distributed.

8.1 Äspö International Progress Reports

Diego M I, 2005. Äspö Pillar Stability Experiment. Hydromechanical data acquisition experiment at the APSE site. IPR-05 21, Svensk Kärnbränslehantering AB.

Eng A, Andersson C, 2004. Äspö Pillar Stability Experiment. Description of the displacement and temperature monitoring system. IPR-04-15, Svensk Kärnbränslehantering AB.

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Fälth B, Kristensson O, Hökmark H, 2005. Äspö Pillar Stability Experiment. Thermo-mechanical 3D back analyze of the heating phase. IPR-05-19, Svensk Kärnbränslehantering AB.

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Nyberg G, Jönsson S, Wass E, 2005. Hydro Monitoring Program. Report for 2004. IPR-05-26, Svensk Kärnbränslehantering AB.

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SKB, 2005. Äspö Hard Rock Laboratory. Status Report. April - June 2005. IPR-05-22, Svensk Kärnbränslehantering AB.

Wiborg M, Papp T, Svemar C, 2004. NET.EXCEL. Final Technical Report. IPR-04-54, Svensk Kärnbränslehantering AB.

8.2 Technical Documents and International Technical Documents

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Black J and Hodgkinson D, 2005. Review of Task 6C. SKB R-05-23, Svensk Kärnbränslehantering AB

Eng A, Andersson C, 2004. Äspö Pillar Stability Experiment. Description of the displacement and temperature monitoring system. IPR-04-15, Svensk Kärnbränslehantering AB.

Fälth B, Kristensson O, Hökmark H, 2005. Äspö Hard Rock Laboratory, Äspö Pillar Stability Experiment. Thermo-mechanical 3D back analyze of the heating phase. SKB report IPR-05-19.

Goudarzi R, Johannesson L-E, 2005. Prototype Repository. Sensors data report (Period: 010917-050601). Report No:13. IPR-05-28, Svensk Kärnbränslehantering AB.

Goudarzi R, Börgesson L, Röshoff K, Edelman M, 2005a. Canister Retrieval Test. Sensors data report (Period: 001026

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Nyberg G, Jönsson S, Wass E, 2005. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2004. IPR-05-26, Svensk Kärnbränslehantering AB

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