International Progress Report

IPR-06-33

Äspö Hard Rock Laboratory

Status Report
July – September 2006

Svensk Kärnbränslehantering AB

November 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 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 2006a/.

This Äspö HRL Status Report is a collection of the main achievements obtained during the third quarter 2006.

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. Studies are performed within the projects: Geological Mapping and Modelling, Method Development of a New Technique for Underground Surveying, Seismic Influence on the Groundwater System, Inflow Predictions, Hydro Monitoring Programme, Monitoring of Groundwater Chemistry, Rock Mechanics and Äspö Pillar Stability Experiment.

Buffer materials and backfill technology

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 decided to build a Bentonite Laboratory at Äspö designed for studies of buffer and backfill materials. The laboratory, a hall with dimensions 15×30 m, will include 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.

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

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, 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, Alternative Buffer Materials, 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

Important parts of the Äspö facility are the administration, operation, and maintenance of instruments as well as 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 2006.

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 a selection 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. During 2006, 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 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 2006a/ for more background information. The Annual Report will in detail present and summarise new findings and results obtained during the present year. The Annual Report presenting the achievements obtained during 2005 is published /SKB 2006b/.

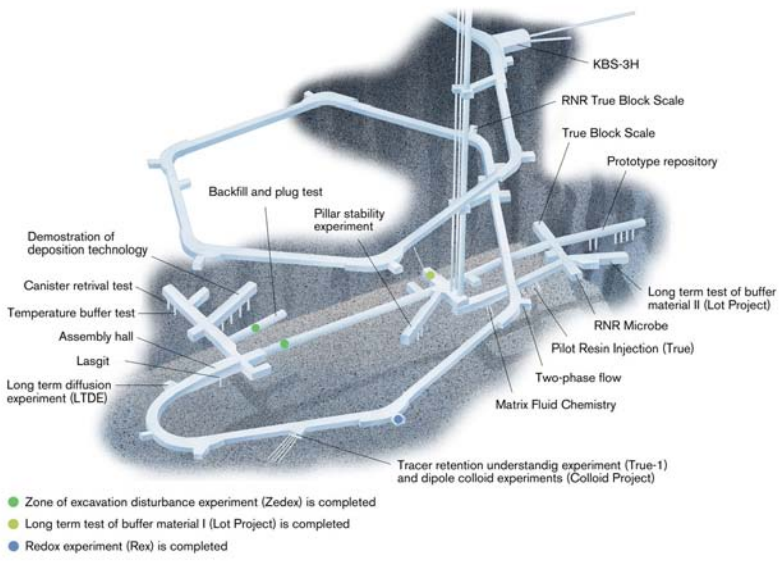


Figure 1-1 *Allocation of some of the experimental sites in Äspö HRL from -220 m to -450 m level.*

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 major aims can be summarised as:

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

The activities further aim to provide geoscientific base data and to ensure high quality of experiments and measurements related to geosciences.

2.1 Geology

2.1.1 Geological Mapping and Modelling

Orientation of drill core by use of magnetic compass, test in the A-tunnel (TASA) of Äspö HRL.

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

During the third quarter a new Bips (borehole image processing system) survey has been undertaken in the new niche (NASQ0036A) for the Alternative Buffer Material Project in the TASQ tunnel as the previous Bips images from the core holes KQ0032G01, KQ0036G01 and KQ0040G01 were too dark. New images have now been produced. In addition, Vattenfall Power Consultant AB (Gothenburg office) has performed core logging of the cores from the bore holes. The Bips images and the core logging of the three bore holes indicate that there is nothing that should obstruct the continuation of the Alternative Buffer Material experiment, see Section 5.10.

Water bearing fractures of the two horizontal deposition holes (DA1619A02 and DA1622A01) at the KBS-3H site on the -220 m level have been coloured blue in the tunnel mapping system (TMS) to separate them from the non-water bearing ones in black. The locations of the water bearing fractures and the general rock quality in the short horizontal deposition hole DA1622A01 indicate that the planned steel plug can be accommodated.

A report concerning the use of magnetic anisotropy to detect the true width of deformation zones has been delivered by GeoVista. The test was performed in the A-tunnel (TASA) of Äspö HRL. The report will be reviewed soon.

Some earlier mappings as well as the mapping of the latest niche (NASQ0036A) are still not digitised. The work to enter associated geological data into the TMS will continue. In addition, the modelling work of the -450 m level of the Äspö HRL will continue.

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

Laser scanning. The laser scanner is on the tripod and the computer that collects the scanning data is on the box on the floor.

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

The major reasons for the RoCS (Rock Characterization System) 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.

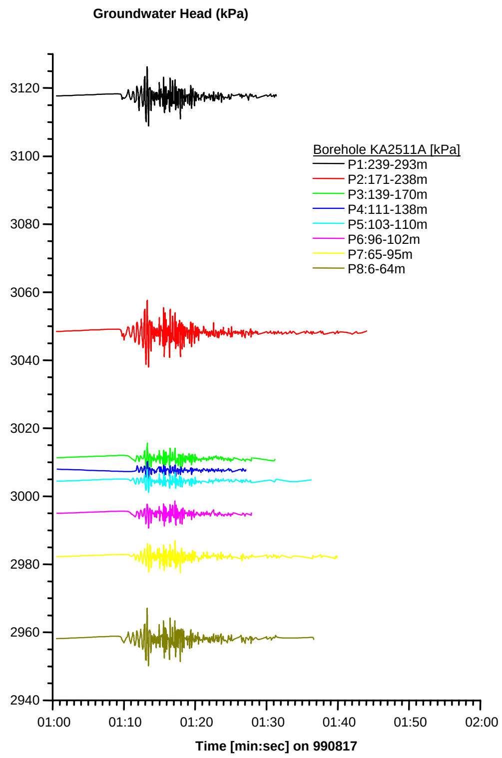
Achievements

The work during the third quarter have been concentrated to adjustments of the RoCS feasibility report (phase 1) after its return from the review by BGS (British Geological Survey). The results from the feasibility study show that it appears promising to include laser scanning together with digital photography in a new rock characterization system. However, the continuation of the RoCS project will be delayed.

The report concerning laser scanning of the TASQ (Q-tunnel) has not yet been delivered by Advanced Technical Solutions AB.

2.2 Hydrogeology

2.2.1 Seismic Influence on the Groundwater System



Hydraulic response at Äspö HRL to the Kocaeli earthquake in Turkey

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. The seismic events also include blasting activities in and around the Äspö HRL.

By analysing the data on changes in the piezometric head at Äspö, connections to specific seismic events are expected to be established. The work is a reference for the understanding of dynamic influences on the groundwater around a final repository.

Achievements

The main activities during July–September have been collection and storage of data in the HMS. In the same way as earlier the data are stored waiting for future analyses. No analyses have yet been done. A compilation of pressure disturbances that can be coupled to blasting in the Äspö HRL is planned to be done during 2006 and the effects of the earthquakes will be examined during 2007.

2.2.2 Inflow Predictions

SKB has conducted a number of large field tests where predictions of inflow into tunnels or deposition 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:

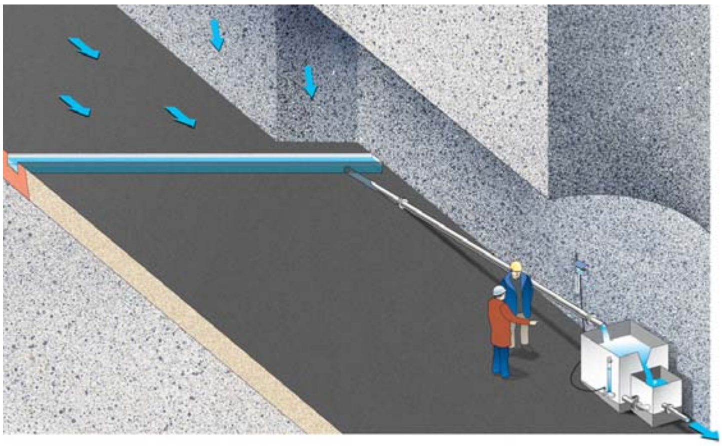
- Evaluation of experimental results from Äspö HRL. A good understanding of the mechanisms controlling inflow would improve the possibilities for good experimental set-ups and accurate result interpretation.
- Evaluation and comparisons between potential repository sites. It is desirable to be able to predict the inflow 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 about the hydro-mechanical data acquisition project at the Äspö pillar stability site is available /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 pillar. To better understand the data acquired, a three dimensional mechanical modelling study of the de-stressing of the Apse pillar has been carried out using the code 3DEC /Itasca 2003/. The results from this modelling exercise show the stress redistribution in the tunnel during the drilling of the de-stressing slot. The status is the same as previous quarter, the report is finalised and is under revision.

The next stage of the studies involved the drilling of two 30 mm diameter boreholes. 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 have been conducted on three large fracture samples cut from the mentioned boreholes. The surfaces of the fracture walls have been scanned using a 3D-laser scanner and the geometrical properties of the fracture plane have been characterised. Variograms and contour maps of the aperture have been produced for each fracture. The results of the coupled stress-flow laboratory tests have been analysed.

2.2.3 Hydro Monitoring Programme



The monitoring of water level in surface boreholes started in 1987 while the tunnel excavation began to affect the groundwater level in many surface boreholes during the spring 1991. The computerised Hydro Monitoring System (HMS) implemented in the Äspö HRL and on the nearby islands was introduced in 1992. The HMS collects data on-line of pressure, levels, flow and electrical conductivity of the groundwater. Manual levelling is also obtained from the surface boreholes on a regular basis. The data are recorded by numerous transducers installed in boreholes, of which many are equipped with hydraulically inflatable packers, 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. Groundwater pressure or levels are measured by about 280 transducers. Water seeping through the tunnel walls is diverted to trenches and further to 25 weirs where the flow is measured. All data are transmitted to the main office at Äspö, by cable or radio.

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 third quarter have been:

- Introduction of pocket computer aid for the manual levelling in surface boreholes and weirs.
- Calibration of pressure transducers in the tunnel.
- Quality check and calibration of data from the tunnel in August.
- Preparations for the establishment of a new management organisation for HMS.

The system has been performing well and the monitoring points have been maintained. However, maintenance and improvements are continuously made on the monitoring system to increase the performance. A report describing instrumentation, measurement methods and summarising the monitoring during 2005 is available /Nyberg *et al*. 2006/.

2.3 Geochemistry

2.3.1 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. The sampling started the 25th September and is scheduled to take two weeks.

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.

During 2006 work will mainly be performed within the following projects:

- Stress measurements and stress interpretation methods.
- Äspö Pillar Stability Experiment.

2.4.1 Stress Measurements - Core Disking

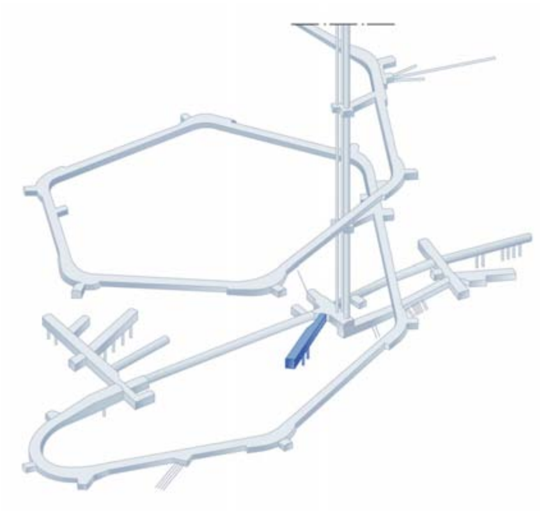
The purpose of the project is to study the conditions under which core disking occur by drilling in the vicinity of the area for the Äspö Pillar Stability Experiment.

A total of four holes were drilled vertically in the tunnel floor (KQ0062G05, KQ0062G06, KQ0061G10 and KQ0062G04). Core disking in solid and hollow cores was observed in the first three of these. Two successful installations of a Borre probe used for stress measurements were made.

Achievements

The development of a 3D RVS (rock visualisation system) model of the experimental area was needed to interpret the influence of geological structures on the local stress conditions. This work was delayed due to lack of resources as the ongoing site investigations took all resources this summer. The RVS modelling has however been started up, and is estimated to be completed in December.

2.4.2 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

During this period two papers presenting the design and the rock mass response to coupled excavation-induced and thermal-induced stress have been submitted for review. The papers will be published in the International Journal Rock Mechanics and Mining Sciences in a special issue about Äspö HRL.

The doctoral thesis, that will describe the design of the experiment, observations and interpretations of results, is in its final stage and will be finished during the last quarter 2006.

A report that presents the geological mapping of the pillar blocks has been published /Lampinen 2006/.

3 Buffer materials and backfill technology

Before the construction of 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 decided to build a Bentonite Laboratory at Äspö designed for studies of buffer and backfill materials. The laboratory, a hall with dimensions 15×30 m, will include two deposition holes 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 further development of techniques for the backfilling of deposition tunnels.

Achievements

The Bentonite Laboratory is under construction and at the moment the construction work is expected to be ready in March next year. The construction activities on the site were initiated in May 2006 when the excavation of rock started. Prior to the installation of the two deposition holes, by using prefabricated concrete elements, the bottom of the excavated cavity in the rock was prepared with base course gravel (Figure 3-1) in August.

Since then the lower most foundations has been completed and the 8 m deep cavity in the rock has been backfilled. The upper parts of the two deposition holes can be seen above the backfilling material in Figure 3-2. Currently, the bedding of the entire mat foundation is prepared. The complete building structure will be delivered to Äspö in mid November.

Figure 3-1 *The excavated cavity in the rock was prepared with base course gravel.*

Figure 3-2 *The upper parts of the two deposition hole constructions can be seen above the backfilling material.*

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 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 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.

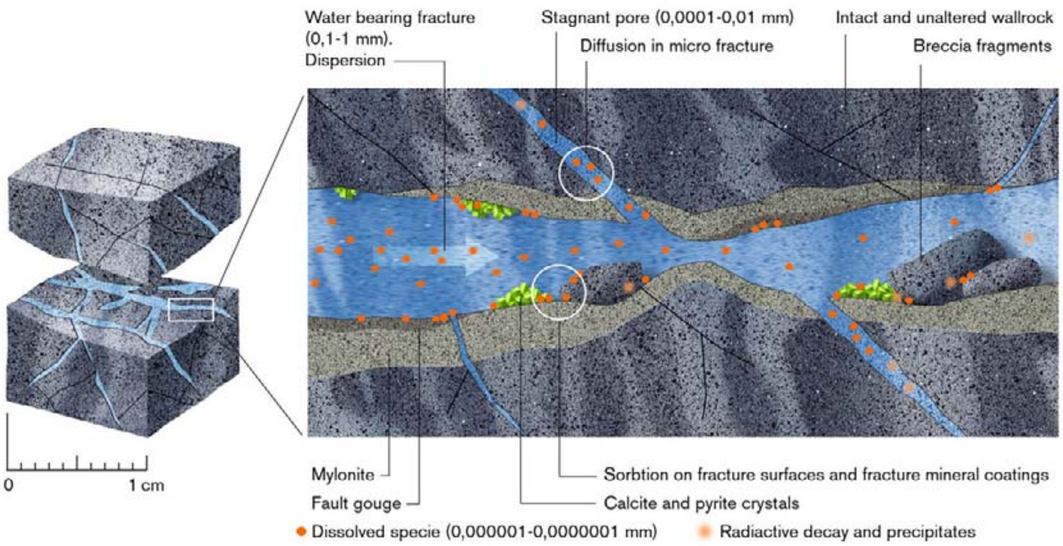
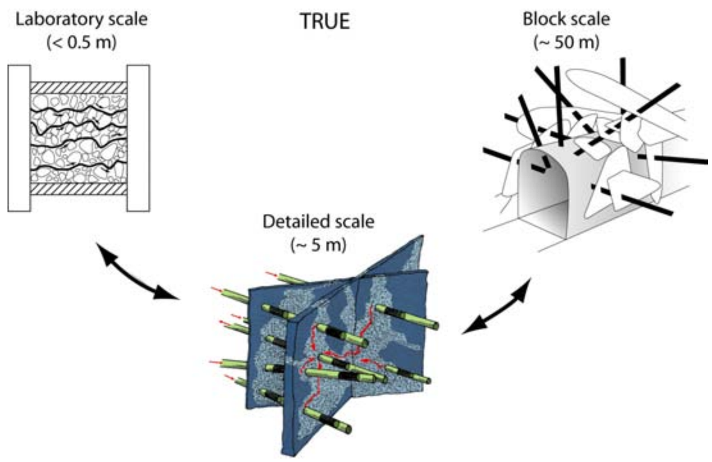


Figure 4-1 *Processes that influence migration of species along a natural rock fracture.*

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.

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. 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.

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.

In the aftermath to the BS2 project a discussion has been in process to set up a second step of continuation of the True Block Scale (BS3). This step would not have specific experimental components, but rather emphasise consolidation and integrated evaluation of all relevant True data and findings collected thus far. This integration would not necessarily be restricted to True Block Scale, but could also include incorporation of True-1 and True-1 Continuation results.

Achievements

The main achievements during the period have been finalisation of the reviewing and editing of three of the supporting documents which account for the modelling (prediction and evaluation) of the BS2 experiments. The fourth report is also underway. Hence, also preparations are underway for finalisation of the final report for the project True Block Scale Continuation.

Furthermore, two abstracts have been submitted to the "American Geophysical Union's Fall Meeting" that will be held in December. These papers accounts for the overall results and conclusions of the BS2b tests and associated modelling.

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 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

The first two in a series of three articles accounting for the True-1 *in situ* experimentation, laboratory analyses and modelling have been submitted to the editors of Water Resources Research.

4.1.3 True-1 Completion

True-1 Completion is a sub-project of the True-1 Continuation project with the experimental focus placed on the True-1 site. True-1 Completion will be performed at the True-1 site and will be a complement to already performed and ongoing projects. The main activity within True-1 Completion is the injection of epoxy with subsequent over-coring 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 main achievement of the period is the complementary characterisation of the flow situation within Feature A assumed inflicted by observed physical changes of Feature A. The extent of the physical changes of Feature A was studied through a series of dilution tests in borehole KXTT4. The dilution tests showed that that the observed changes are real and affect the flow to the extent that the prerequisites for the cation exchange capacity (CEC) test have been changed. Furthermore, a pre-test was successfully performed using the set up, flows and concentrations planned in the upcoming CEC-test. The equipment and test set up at the True-1 site have also been refined and fine-tuned.

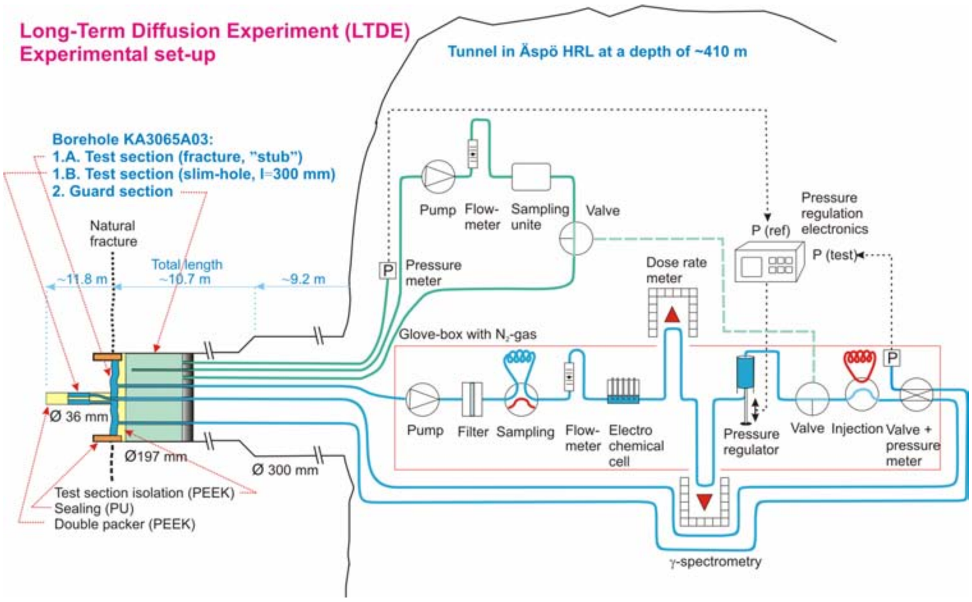
The magnitude of the observed flow changes in borehole KXTT4 exceeds a 50% decrease in flow compared to the measured flows during the multi hole reciprocal cross flow tests performed in May 2006. In comparison to the historic flows of the sorbing tracer tests (STT) in the late 1990-ties the decrease are somewhat smaller, approximately 30%. It can be expected that the flow will vary over time due to changes in the hydraulic boundary conditions caused by e.g. water sampling and seasonal variations. However, the magnitude and the abruptness of the observed changes implicate a physical nature of the changes. At present there is no unambiguous theory to the cause of the physical changes. There are two main theories of contributing factors to the observed physical changes; the blasting to widen a tunnel at the -450 m level and microbial activities. Important observations, such as precipitation of Mn_3O_4 and significant contents of total carbon in water samples, were made at the True-1 site at the time of the blasting. However, the observed changes did not appear until two months later. The observed physical changes may be a delayed effect of the blasting but may also be due to microbial activity. Microbes often form different kinds of slime that in conjunction with colloids and loosened gouge material may very well contribute to the clogging of flow paths.

Furthermore, the preliminary results from the multi hole reciprocal cross flow tests with the objective to examine and evaluate effects of channelling in Feature A implicate that the flow in Feature A differ from the homogeneous case and that channelling is more developed with higher pumping flows. The final evaluation of the tests is ongoing.

Final planning and preparations for the realization of the cation exchange capacity (CEC) test are ongoing. The test start is planned for November 2006. The observed changes of Feature A have changed the prerequisites for the cation exchange capacity (CEC) test. The test was originally planned to be performed under the same conditions as the sorbing tracer tests (STT). In order to maintain the desired flow in Feature A in borehole KXTT4, the pumping flow in KXTT3 had to be doubled. The increase in pumping flow will, in accordance with the results of the multi hole reciprocal cross flow tests, lead to a more developed channelling in the flow path. This is however not deemed to affect the results of the test.

Furthermore, planning and preparations for the upcoming epoxy injection and subsequent over coring are in progress.

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 5-7 months after which the borehole is over-cored and analysed for tracer content.

Achievements

The main activities in the Long Term Diffusion Experiment project during the third quarter have been:

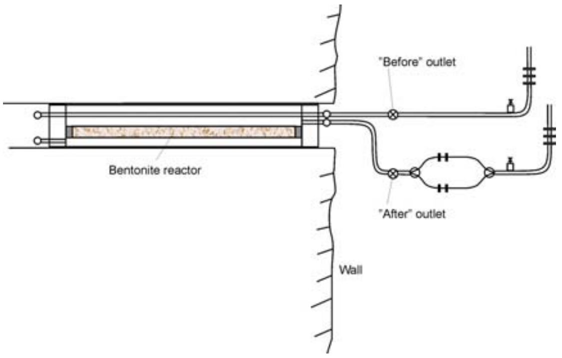
- Complementary measures on the test equipment.
- At the experimental site and at Baslab, preparations have been made for carrying out injection of the radionuclide tracers and sampling during the course of the main sorption-diffusion experiment.
- Start of main sorption diffusion experiment with injection of 22 radionuclides including the range from non-sorbing (^{36}Cl, ^{35}S) to strongly sorbing (^{175}Hf, ^{236}U).

The tracer injection in the main sorption-diffusion experiment has been delayed about four month compared to initial schedule due to extended work with complementary measures on the test equipment.

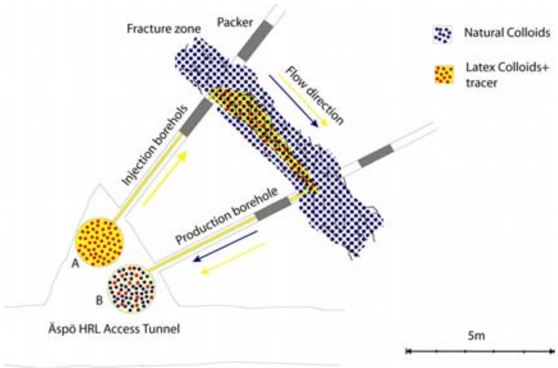
The results from pre tests, before injection of radionuclides, showed that it is not possible to keep the redox potential at negative values. However, three redox sensitive radionuclides (^{99}Tc, ^{236}U, and ^{237}Np) were included in the tracer cocktail since ^{236}U and ^{237}Np are relatively strong sorbing even under oxidising conditions (Kd 0.01). In addition, it is anticipated that a redox front will exist a few centimetres into the rock making ^{236}U and ^{237}Np to sorb stronger and also ^{99}Tc to sorb at short distance from fracture surface..Äspö International Progress Reports from the hydraulic pre tests and the functionality test are in review and foreseen to be printed before the end of 2006.

4.3 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 radionuclide transport and the potential of bentonite clay as a source for colloid generation. The Colloid Project includes laboratory experiments, background colloid measurements, borehole specific measurements, colloid dipole experiments and *in situ* experiments where the colloidal effect on actinide transport in a water bearing fracture will be studied at Äspö HRL.

Achievements

Data analysis and modelling efforts of data from the Colloid Dipole experiment (performed at the True-1 site in boreholes KXTT3 and KXTT4 during March-April) have been performed. In the experiments the latex colloids of 50 and 100 nm in size travelled quite fast with high recoveries. Due to a lot of noise in the data, filtration coefficients for colloids and exact recoveries could not be calculated, but the experiments indicate that almost all of the latex mass is recovered. The experiments point out the necessity to continue with similar experiments with refined analysis and maybe other types of colloids. Discussion on new sites for these types of experiments is ongoing.

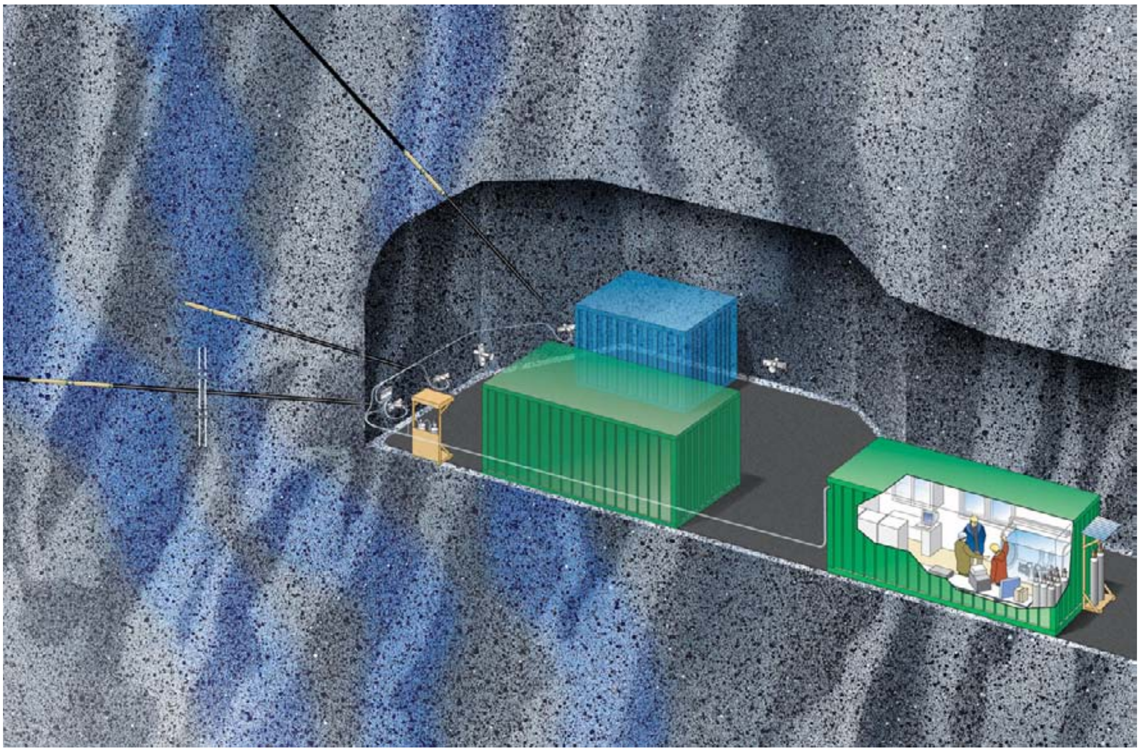
In Canada AECL is performing experiments on bentonite colloid migration in a water bearing fracture (quarried block). The transport of bentonite colloids in diluted waters in low to high pumping flow rates has been tested. An experiment with bentonite colloids in mimicked Äspö water at moderate flow rate has also been performed. The transport experiments in the quarried block indicate that for high water flows and dilute waters the bentonite colloids travel quite fast with high recoveries. Where as for low flow rates, close to natural conditions, the recoveries are very low. In mimicked Äspö water the bentonite colloids coagulated and sedimented and there were no indication of transport.

In laboratory experiments CCC-values (critical coagulation concentration) for Ca^{2+} and Na^{+} in bentonite have been studied kinetically. In addition, temperature and pH effect on bentonite stability is studied as well as the effect on bentonite colloid stability of the presence of mineral surfaces. The results from the experiments are under evaluation.

Planning for Colloid-Actinide experiments is ongoing where suitable sites are under consideration. Laboratory experiments for studying how high concentrations of bentonite colloids that can be achieved in Äspö water have been performed where also the stabilising effect of fulvic acids have been studied.

4.4 Microbe Project

4.4.1 The Microbe laboratory and the Bios site



The Microbe laboratory and the Bios site have been installed in the Äspö HRL 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 (image above) 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 tubing. Each borehole has been equipped with a circulation system offering 2,112 cm^2 of test surface.

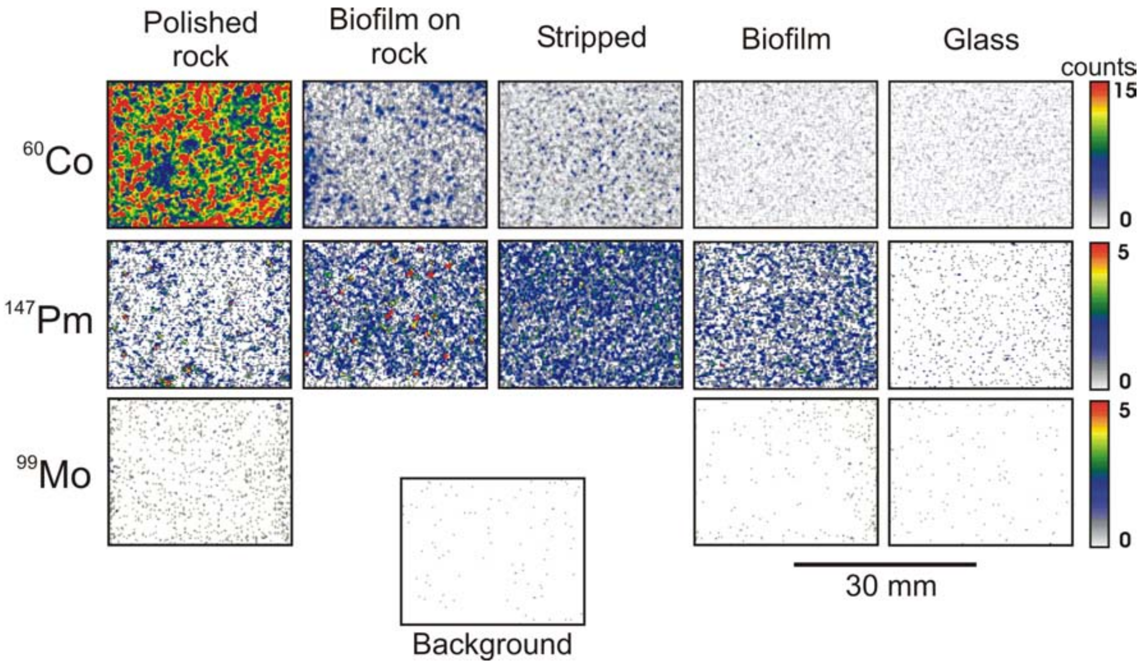
Retention of naturally occurring trace elements in the groundwater by Biological Iron Oxides (Bios) is investigated at a site at tunnel length 2,200 m. There is a vault with a borehole that delivers groundwater rich in ferrous iron and iron oxidising bacteria. The borehole is connected to two 200 × 30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

Achievements

The main activities during July to September have been an upgrade of the circulation systems. New fans were installed in the incubators. A project on biocorrosion of copper was installed in July and will last until the end of October.

In addition, activities related to the Micomig and the Micored projects have been executed, as described below.

4.4.2 Micomig



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 (image above).

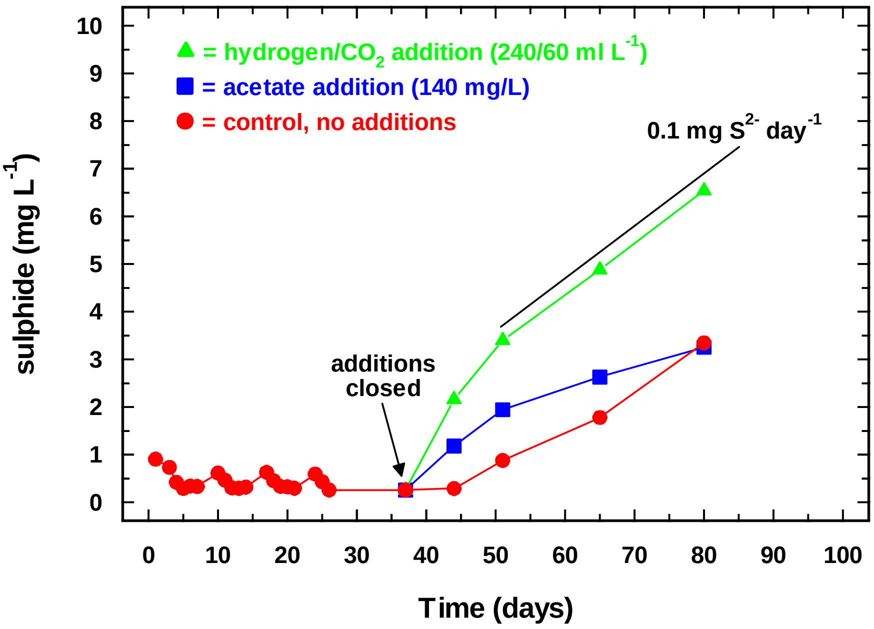
The work within Micomig will:

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

Achievements

The main activities during the third quarter have been analysis and description of pyoverdins produced by microorganisms isolated from deep groundwater of Äspö. The results so far show that the microbes produce several important siderophores under laboratory conditions. However, such compounds could not be detected when analysed for in samples from microbial growth under *in situ* conditions in the Microbe laboratory. Reporting in the form of one publication and a thesis contribution is under way.

4.4.3 Micored



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.

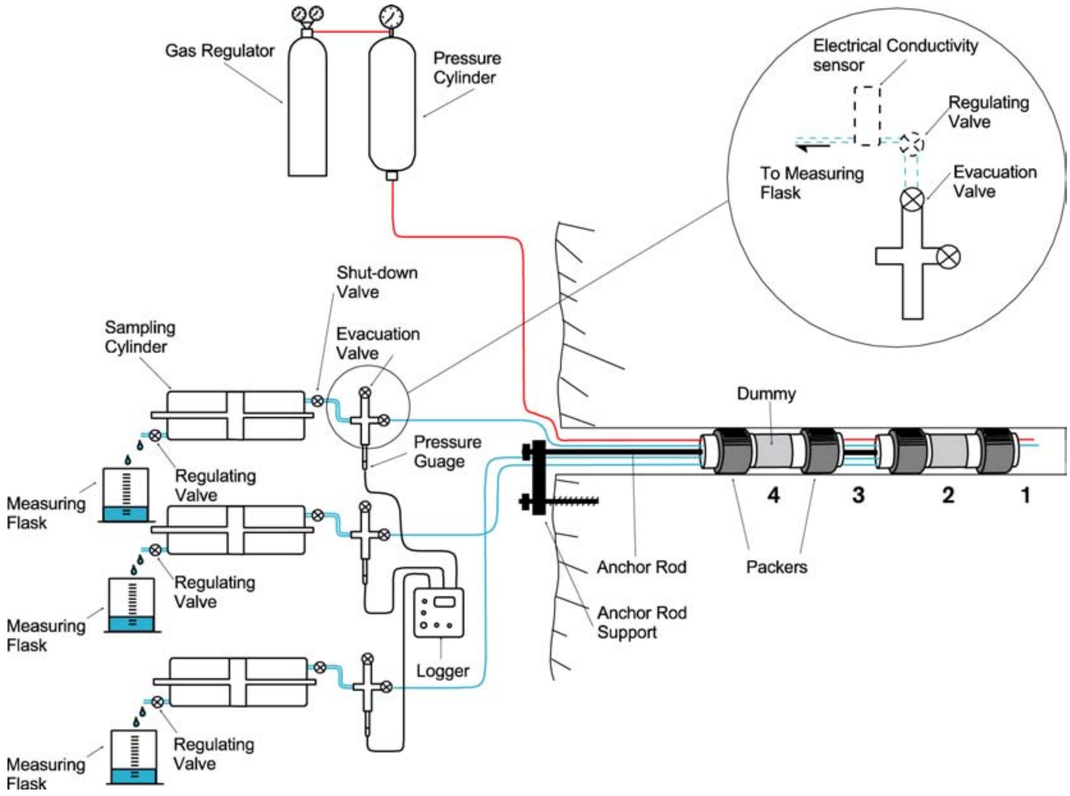
The work within the Micored project will:

- 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

The main activities during the third quarter have been analysis and compilation of data from the growth experiments conducted between March and July 2006. The analyses take up to 10 weeks before they are ready, due to the slow growth time of many microbes from the underground. The results showed a significant sulphide production that was stimulated by the addition of hydrogen and carbon dioxide to the microbes (image above). Acetate also had an initial effect. The numbers of sulphate reducing bacteria increased from about 5000 up to 220,000 cells mL^{-1} over a four week period. A large data set was generated and will be reported as an Äspö International Progress Report during fall 2006.

4.5 Matrix Fluid Chemistry Continuation



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.

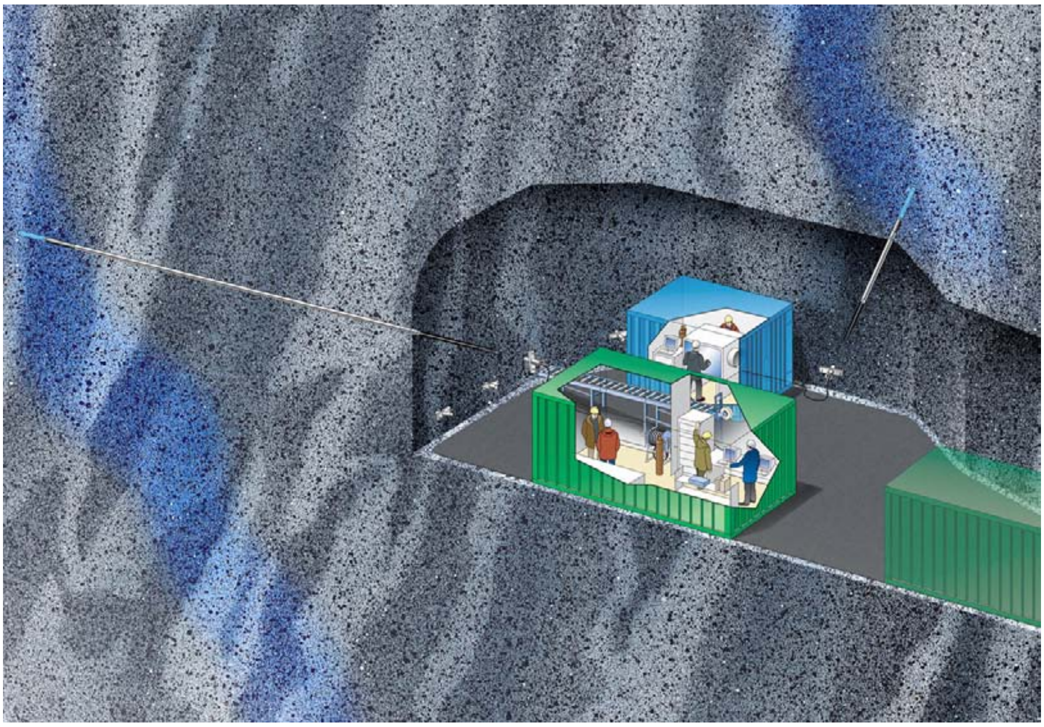
A first phase of the project is finalised and reported /Smellie *et al*. 2003/. The major conclusion is that pore water can successfully be sampled from the rock matrix and there is no major difference in chemistry compared to groundwaters from more highly conductive fracture zones in the near-vicinity.

Achievements

The work during the third quarter has been directed mainly towards the continuation of hydraulic testing in the Matrix borehole KF0051A01 (July –August) and towards documentation of preliminary results (August).

The results so far show that according to inflow rates, the hydraulic transmissivity is in the order of 1×10^{-14}-1×10^{-13} m^2s^{-1} for both fracture-free and microfracture-containing borehole sections. The hydraulic tests gave nearly similar hydraulic transmissivities in the microfracture-containing sections, i.e. Features A and B. These results are in accordance with earlier performed predictions and hydraulic transmissivities determined from inflow rates in the fracture-free sections.

4.6 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).

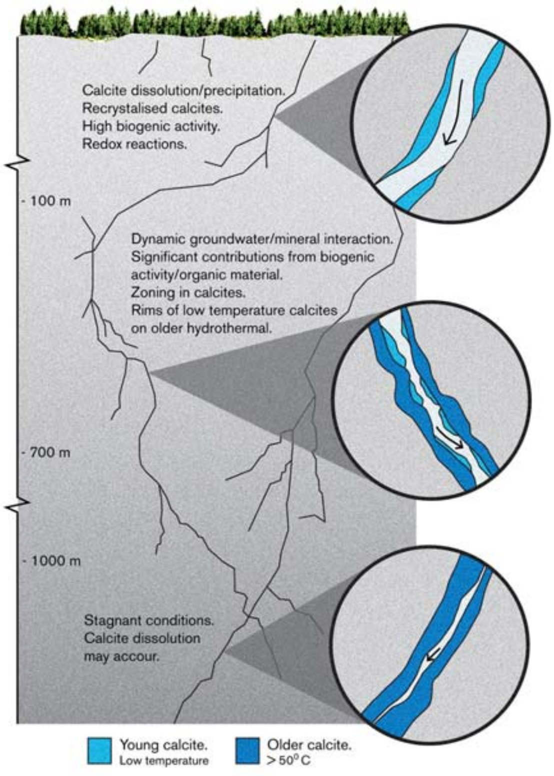
Chemlab 2:
- Migration experiments with actinides in a rock fracture (almost finalised).
- Study leaching of spent fuel at repository conditions (planned).

Achievements

All resources in the project have been involved in other SKB projects with higher priority and nothing has been produced in the project during the third quarter.

The 27th of October a meeting will be held where plans will be made on how to prioritize the forthcoming time.

4.7 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:

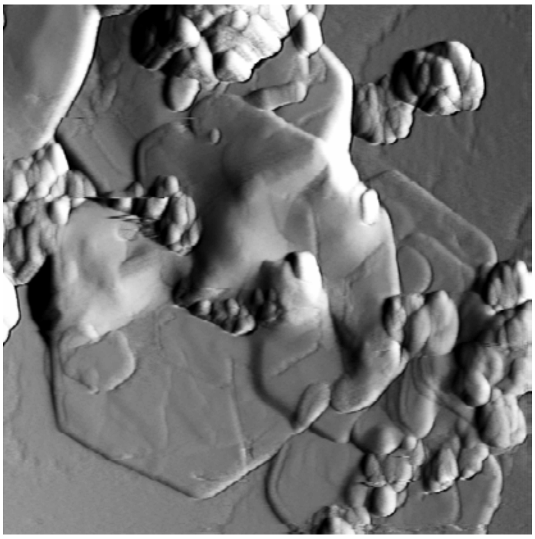
- Improve understanding and prioritise palaeo-hydrogeological information for use in safety assessments.
- Collect chemical/isotopic data using advanced analytical methods.
- Construct a database of relevant information and develop numerical models to test hypotheses.
- Integrate and synthesise results 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. Deep borehole cores from rocks at the Äspö HRL and Laxemar (KXL01) are used in the analytical study.

Achievements

The new phase of the project which concerns Uranium-series measurements using different techniques had a start-up meeting in July where different approaches were discussed and fracture material from a surface borehole drilled at Äspö (KAS17) were sampled. This borehole penetrates the large E-W fracture zone called the Mederhult zone and several sections with fractured rock were sampled as well as several sections with gouge rich material. Six samples from different depth (from 19 to 200 m core length) have been prepared for U-series analyses such as mineral identification and chemical analyses.

4.8 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 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

During the third quarter, a new campaign of drillcore sampling (up to 40 samples) from the site investigations in Laxemar in Oskarshamn was made. The samples were sent in the end of August to the University of Copenhagen for further microscopy and analysis.

During the project two MSc. theses have been submitted and passed. These have been modified for publication as Äspö International Progress Reports, scheduled for November 2006.

4.9 Swiw-test with Synthetic Groundwater

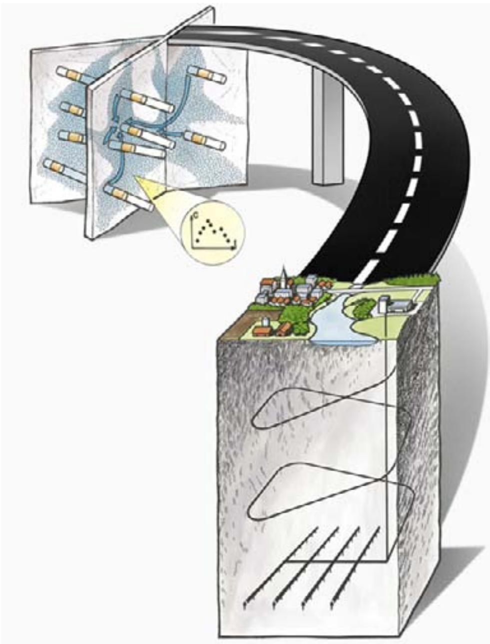
The project constitutes a complement to performed tests and studies on the processes governing retention, e.g. the True-1 and the True Block Scale experiments. This project aims to deepen the understanding for the processes governing retention. Swiw-tests (single well injection withdrawal) with synthetic 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 location for the tests will be 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 revisit of the True Block Scale site facilitates the unique possibility to ”calibrate” the concept of Swiw-tests 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 planned activities comprise comprehensive planning and a feasibility study. The feasibility study is scheduled to start in the middle of October 2006.

4.10 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 (Performance Assessment Modelling Using Site Characterisation Data) and in Task 7 (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 Task 6D, 6E and 6F is available as a draft. A summary of the outcome of Task 6 will be published in a scientific paper. In addition, some modelling groups have indicated interest in publishing papers in the same scientific journal, and in conjunction with the summary paper.

A workshop on Task 7 was held in September in Rauma in Finland and hosted by Posiva. The minutes from the meeting are written and distributed. 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 affects the groundwater system. The possibilities to extract more information from interference tests will also be addressed. A task description for the sub-task 7A has been sent out to the modellers and preliminary results from the modelling were presented at the workshop in Rauma. Work is ongoing to update the task definition of Task 7A.

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. (Preliminary results presented at the workshop in Rauma).

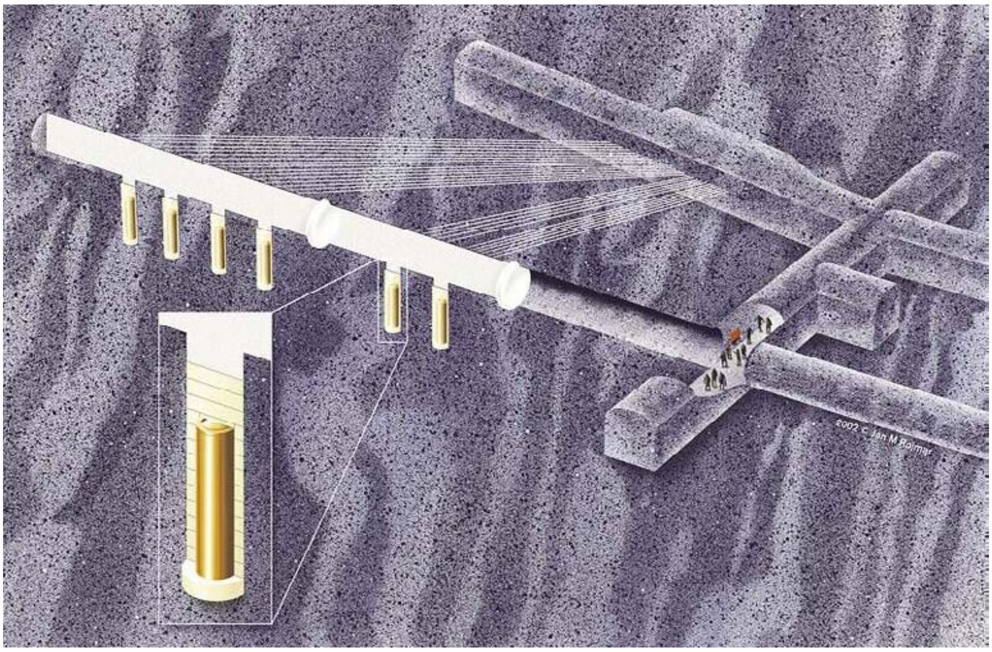
5 Engineered barriers

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 5-1. The experiments focus on different aspects of engineering technology and performance testing and will together form a major experimental programme.

Figure 5-1 *Preparation of a test parcel with blocks of alternative buffer materials.*

5.1 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 cast in September the same year.

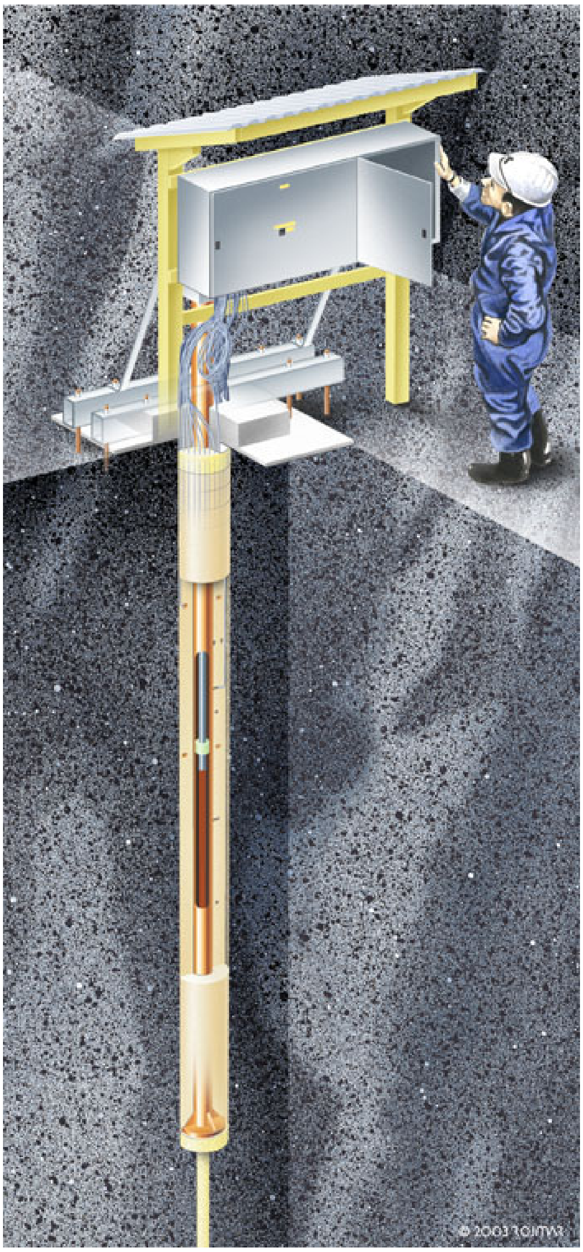
Achievements

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 the sensors data report No. 14 is available /Goudarzi and Johansson, 2005/ and the work with data report No. 15 covering the period up to June 2006 is ongoing. Overhauling of the data acquisition system is in progress and hydraulic tests of the rock mass have been performed.

Hydraulic tests (test campaign 7) of the rock around the Prototype Repository have been started. The objective of the tests is to estimate the transmissivity of the rock. Water sampling and chemical analysis of water from boreholes in Section I and II of the Prototype Repository and the G-tunnel have been finalised during the summer and will soon be reported (test campaign 3). A program for sampling and analyses of gases and microorganisms in the backfill and buffer has started and the first campaign has been finalised and documented. The second campaign will start at the end of this year. Later, when more campaigns have been completed, the work will be published in an Äspö International Progress Report. The acoustic emission and ultrasonic monitoring are continuing and results from deposition hole 6 have been reported for the period between October 2005 and March 2006.

A thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been developed and the reporting of the work is ongoing. The 1D THM modelling of the buffer in deposition hole 1 and 3 has been finalised and a report is in progress. Furthermore, a 2D TH modelling of an entire deposition hole is in progress and will soon be reported.

5.2 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.

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 final repository for spent fuel.

Achievements

The work during the third quarter has been directed mainly towards laboratory tests and analyses of test material from the A2 parcel, as well as continuation of the S2, S3 and A3 parcels (Table 5-1) including supervision and data handling.

In the laboratory swelling pressure tests, hydraulic conductivity tests, tri- and uni-axial tests have been made on material from the A2 parcel. In addition, analyses of element distribution, cation exchange capacity, mineralogical composition, swelling capacity, bentonite porewater composition, cation diffusion (cobalt tracer material) and copper corrosion have been made. Partial reports are at hand concerning bacterial activity, copper corrosion and porewater chemistry.

The results so far show no or insignificant changes in the exposed bentonite material compared to the reference material except for the following items:

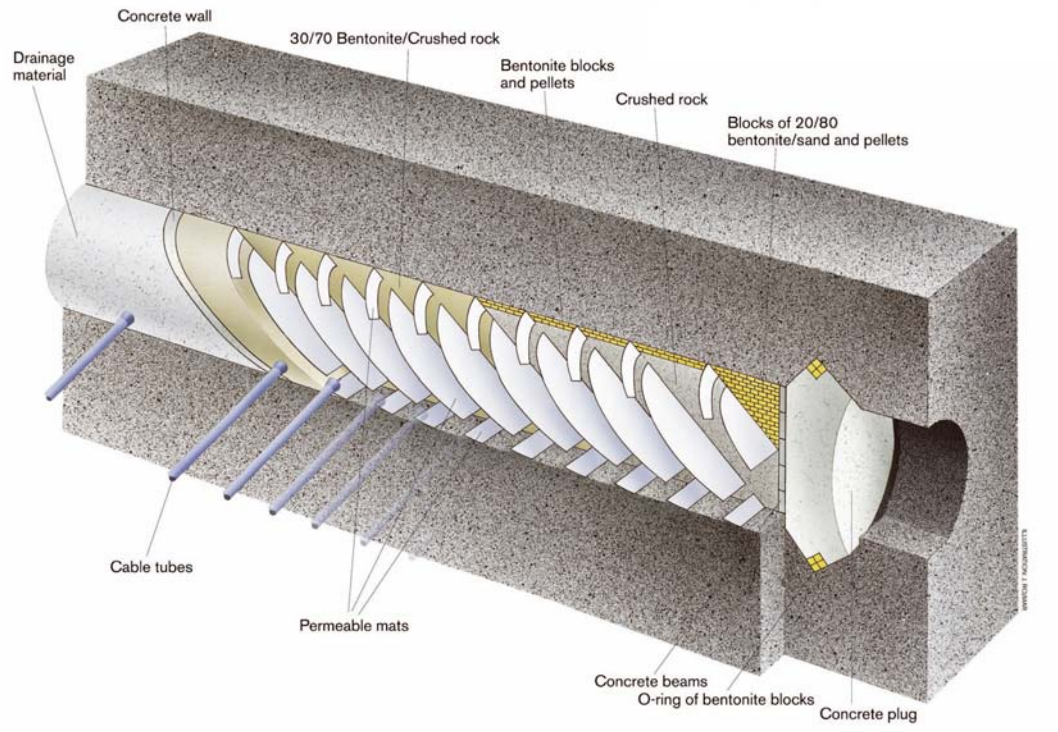
- Cation exchange capacity has increased in the warmer parts of the parcel.
- The chloride concentration in the bentonite porewater is significantly lower than in the surrounding groundwater.
- Minor mineral distribution change especially in the case of sulphates, which have precipitated in the mid position between the rock and the copper tube in the warmer parts.
- Copper uptake in the buffer is similar in the one year and five year experiments with respect to both quantity and distribution.

Table 5-1 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	Analysis on-going
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

5.3 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 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.

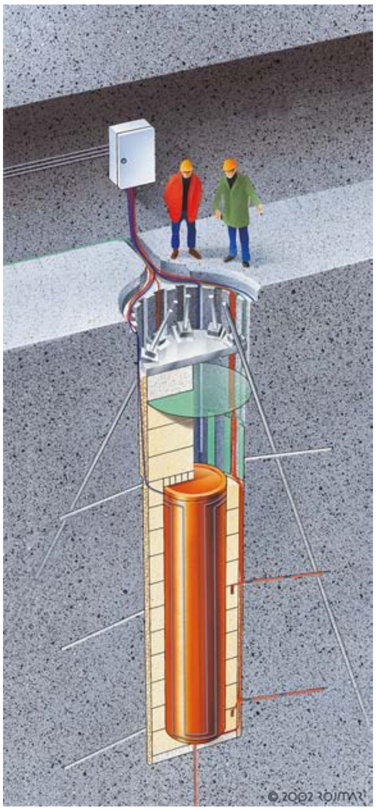
Achievements

The main work during the third quarter have included continuous measurements and registrations of water saturation, water pressure and swelling pressure in the backfill as well as water pressure in the surrounding rock. The sensors data report No. 12 covering the period up to 1st January 2006 is available /Goudarzi *et al*. 2006a/ and the new data report covering the period up to 1st July 2006 is under preparation. The results so far show that the transducers still work properly and that no startling results have been achieved.

Preparations for the pressure cylinder tests have been performed during this quarter, however, some delay in the pressure cylinder tests has occurred.

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

5.4 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. 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 - Saturation phase

The work during the third quarter has been directed mainly towards the compilation of the final data report which is planned to be printed in October. The results so far show that the transducers worked as expected until they were disconnected and no startling results were achieved.

Achievements - Retrieval phase

The work during the third quarter of 2006 consists mainly of analyses. The buffer was analysed and a draft of the initial buffer analysis report is written. The heater cables have also been analysed in order to understand what caused the cable shield to break with power failure as a result. The analyses and the information have been forwarded to other projects at Äspö using similar solutions to heat canisters. Further analyses of the buffer will be initiated during the fall 2006.

Core drilling has been conducted in the deposition hole to investigate the effects on the rock during the experiment. The cores are to be analysed and the results compared with initial core studies done prior to deposition and experiment start.

The canister has been transported to the canister laboratory in Oskarshamn. Several tests will be made on the canister, e.g. dimensions, tension, stress and corrosion will be examined. When the canister lid is removed the heaters inside will be sampled and analysed. This is a vital part for understanding the conditions in the interior of the canister during the experiment.

5.5 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

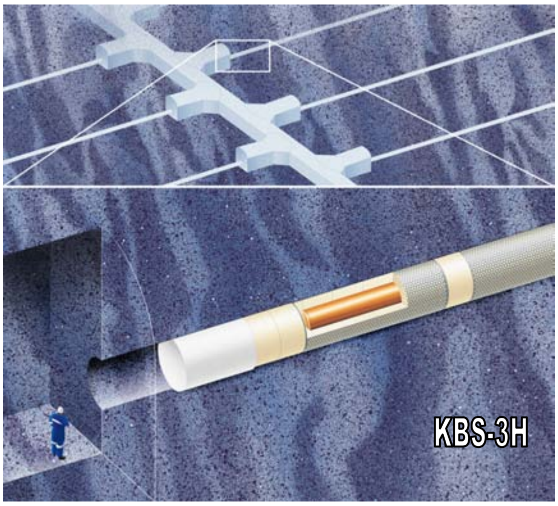
The TBT is in the operation and data acquisition phase since March 2003. Data acquisition is continuously ongoing and data is reported on a monthly basis. The sensors data report No. 7 covering the period to 1st of January 2006 is available /Goudarzi *et al*. 2006b/ and the work with data report No. 8 is in progress. The data link from Äspö to Andra's head office in Paris has been functioning well.

Evaluations of the artificial watering are in progress. The bentonite around the upper heater appears to be close to saturated, whereas the innermost parts of the blocks around the lower heater still are unsaturated.

An attempt to raise the sand filter pressure by increasing the main injection pressure was made during the period from August 7th to August 11th. The injection pressure was increased in steps from 6 to 10 bars (absolute). The change resulted in a clear increase in filter pressure from 1.5 to 3.4 bars.

Two modelling reports evaluating the on-going field test and the performed mock-up test conducted by CEA have been published /Åkesson 2006ab/.

5.6 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.

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 third quarter of 2006 work has been focused on the following parts:

- Preparation of the deposition equipment for the Site Acceptance Test (SAT).
- Low-pH shotcrete rock support.
- Invitations to tender for a steel plug.

Deposition Equipment

At deposition each copper canister and its buffer are assembled into a prefabricated Supercontainer. The tests that CNIM performed in June showed that there are problems with the balance/rotation system for handling the Supercontainer. Therefore the radius of the sliding plate has been slightly modified in order to raise the acting point of pushing forces of the cushions. The sliding plate was also equipped with guides on both sides of the sliding plate in order to limit the rotation of the container. The cushion pallet was equipped with height measuring sensors to observe the lifting height of the pallet during operation of the deposition machine. On the machine there were mounted a third actuator to the shield. The modifications were tested in the middle of September, and showed that the balancing of the machine worked but the cushions were still lifting to high. Tests were done to lower the water pressure on the cushions but this might cause problems with the cushions. Several cushions were broken and are now being sent to the manufacturer for analyses. New tests of the deposition equipment are planned late this year and the site acceptance test will not be performed until the deposition equipment works.

Low-pH shotcrete plug

The evolution from the test at Äspö is still not presented. The Esdred project has proposed to perform the test of a longer low-pH plug at Grimsel instead of at Äspö.

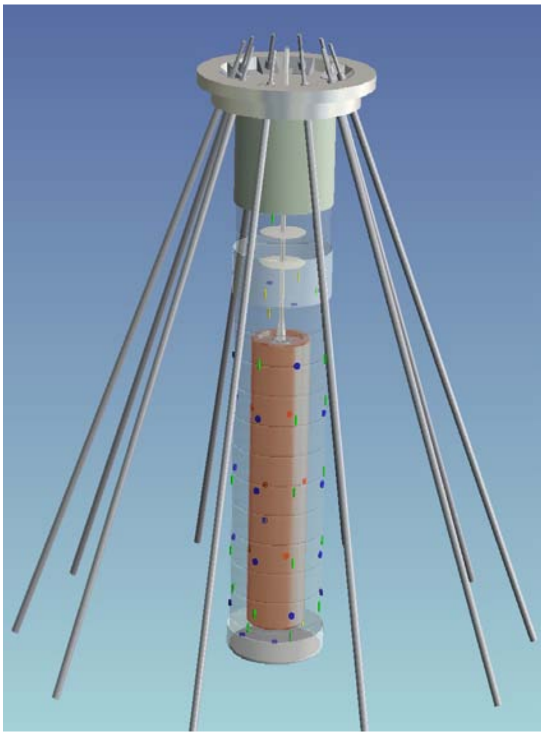
Low-pH shotcrete rock support

The evaluation of the tests with low-pH shotcrete in a niche (NASA 1504A) is presented in a report on selected recipe and result of pilot and field testing. The conclusions are that the mixing of concrete is an important factor and also that the accelerator have to be better distributed at the nozzle to have the right effect when the shotcreting is performed.

Steel plug

Invitations to tender for manufacturing and test of a steel plug in the short 15 m long drift at -220 m were sent out to manufactures and constructors in July. The offers were received in September and are now being evaluated.

5.7 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:

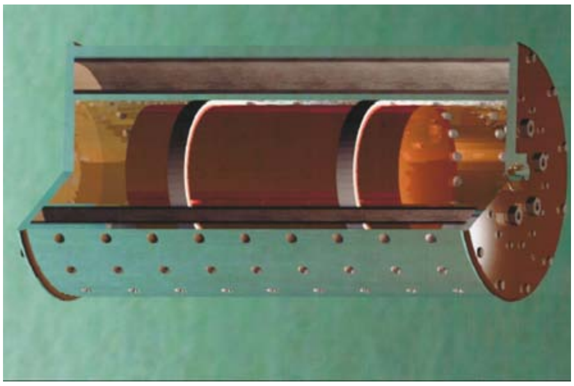
- Perform and interpret a large scale gas injection test based on the KBS-3 design concept.
- Examine issues relating to up-scaling and its effect on gas movement and buffer performance.
- Provide information on the process of hydration and gas migration.
- Provide high-quality test data to test/validate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

Lasgit is a full-scale demonstration project (performed under ambient isothermal conditions) conducted in the Assembly Hall Area of the Äspö HRL at a depth of 420 m. Interstitial water has been introduced into the system since February 2005. When the buffer is fully saturated a series of gas injection tests will be undertaken to examine the mechanisms governing gas flow in KBS-3 bentonite.

Achievements

The artificial wetting of the bentonite and the monitoring of the experiment have continued. The progress of the project was discussed at the 6th Lasgit project meeting held in Nottingham UK 23rd-24th October.

5.8 In Situ Corrosion Testing of Miniature Canisters



Miniature canister with support cage

Installation of first model canister assembly

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

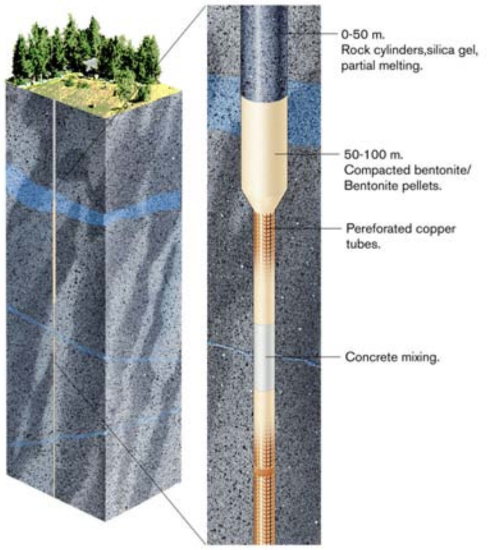
Miniature canisters with a diameter of 14.5 cm and containing 1 mm diameter defects in the outer copper shell are being set up in five boreholes with a diameter of 30 cm and a length of 5 m at the Äspö HRL. The canisters will be mounted in support cages, which will contain bentonite clay, and will be exposed to natural reducing groundwater. Together with corrosion test coupons which will also be 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 reporting period, the set-up of the miniature canister experiments have continued. Further grouting trials were carried out to reduce the water flow through the rock faces in the regions close to the boreholes and the grouting operation was successfully completed. Drilling of the boreholes to the final diameter was carried out and the first miniature canister was placed in the borehole in September (see photo above). This first experiment contains the miniature canister in its support cage, but with no bentonite present. The aim of this experiment is to examine how the model canister and the corrosion coupons behave when in contact with unconditioned groundwater.

A number of lessons were learnt during the process of installing the first experiment and a few small improvements will be made for the next four experiments, which will all contain bentonite in the support cage. Preparations are being made for installation of the remaining four canisters.

5.9 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 comprises three phases.
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 comprises large-scale testing of the sealing concept in boreholes.

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 work is divided into four sub-projects.

Sub-project 1 - Testing of three plug types, with dimensions equal to those tested at Äspö with respect to the required force to extrude them, has been made in Clay Technology's laboratory for investigating the conditions for "piping". The equipment was LiwInStone AB's modified version of the type used earlier in erosion tests. A major conclusion was that all the plugs had matured sufficiently much in 24 hours to resist the available water pressure (2 MPa) applied at one end of the tubes with plugs. Test arrangement, performance and results will be given in an Äspö International Progress Report in December.

Sub-project 2 - Placement and testing of different borehole plugs in the 5 meters holes at the -450 m level in Äspö HRL. Hydraulic jack equipments were installed in the boreholes before the clay plugs were inserted. Four different clay plugs (Basic Type, Pellets Type, Couronne Type and Container Type) were installed. Testing of the degrees of saturation and maturation under natural conditions were determined by applying a mechanical force by help of the hydraulic jacks in the bottom of the boreholes. The tests showed that maturation had proceeded significantly already after 2 days. The required force for displacing the plugs was a few tens of kN except for the pellet plug that underwent consolidation and shortening. The test in August demonstrated that only the pellet plug could be displaced by centimetres while the other three resisted an axial force of about 90 kN. Installation, predictions and results of the successfully completed tests will be published in an Äspö International Progress Report in December.

Sub-project 3 - Two new boreholes for investigation of physical and chemical interaction of quartz/cement and clay have been drilled at the -220 m level in Äspö HRL. Inflow measurement will be done before the installation of the plugs. The boreholes will act as reference holes for the Onkalo borehole OL-KR24.

Sub-project 4 - Construction of equipment for enlarging boreholes (194-300 mm), in order to construct a mechanical securing of the upper part of the boreholes, has started and will be completed in early October. Percussion drilling of two 200 mm wide boreholes at the surface for testing the enlarging equipments and plugs have been finished. The boreholes have been Bips-logged in order to find a suitable location for testing two different plugs.

5.10 Alternative Buffer Materials

In the Alternative Buffer Materials project different types of conceivable buffer materials will be tested in field scale. The aim is to further investigate the properties of the alternatives to the SKB reference MX-80 material.

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 (see Section 5.2).

The objectives are to:

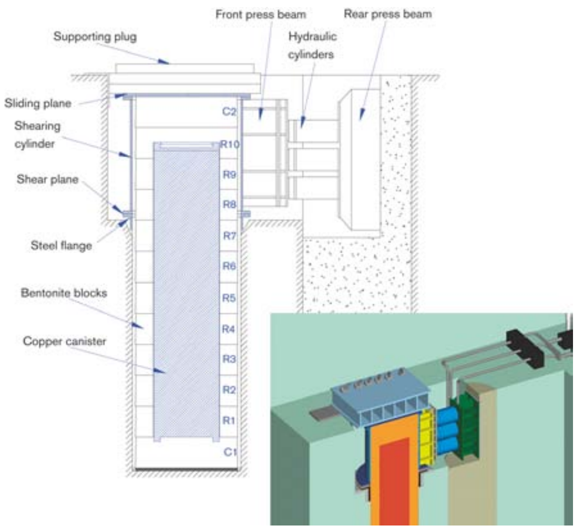
- Verify results from laboratory studies during more realistic conditions with respect to temperature, scale and geochemical circumstances.
- Discover possible problems with manufacturing and storage of bentonite blocks.
- Give further data for verification of thermo-hydro-mechanical (THM) and geochemical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

Achievements

A lot of work has been done during the third quarter of 2006. The experiment design was completed and distributed to the project partners to be commented upon. The design includes the order of the buffer blocks in the test parcels, sensor layout, installation guidelines etc. During the summer the buffer blocks were manufactured and transported to Äspö. The water saturation system was designed and parts manufactured. In addition, the sensors were delivered to Äspö HRL for testing and calibration.

In September the assembly of the test parcels was initiated. It took two days to assemble each parcel and one day for installation in the deposition hole. One test parcel was assembled and installed before the work on the next parcel started. In total three test parcels have been installed and it is planned that the operational phase can start in October.

5.11 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.

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

A pre-study of design and feasibility is completed and reported /Börgesson *et al*. 2004/. The main conclusion is that the test is feasible. A preliminary decision to realize the plans has been taken but the time schedule is not yet set. No work has been done in 2006 so far.

5.12 Earth Potentials

The main objective of the project is to identify the magnitude of potential fluctuations and stray currents at repository depth. The causes to these effects may be Geomagnetically Induced Currents (GIC) or man-made stray current sources. The aim is also to find out the problems these effects could cause in a final repository for spent fuel. The project will include the following investigations:

- Electromagnetic induced currents from natural sources.
- Electrochemical reactions in soil and rock.
- The transition from ion transfer in bentonite to electron transport in copper.
- Impact of copper ions on bentonite properties.
- Physical and chemical interactions between copper and bentonite.
- Basic processes in clay that are exposed to direct current (DC).
- Microbes as electron transmitters.

Achievements

The laboratory experiments, performed at Clay Technology in Lund, on the impact of copper ions on bentonite properties have been compiled in a draft report. The results will be discussed at the project meeting to be held early October.

Tests of the electric behaviours between copper and bentonite are going on at the Corrosion Institute in Stockholm. However, the test set-up has to be free of oxygen before any reliable measurement can be done.

Measurements of natural electromagnetic fields (magnetotelluric technique) have been carried out at the Forsmark site during the summer by Uppsala University. The measurements were done in a deep borehole at about -500 m level. Earth currents, natural and man-made, were registered during ten days. The data will be processed and presented during October.

5.13 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 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).

Beside SKB seven international organisations are participating in the Task Force. These organisations are funding 15 modelling teams.

Achievements

The work in Task 1 during the third quarter has focused on:

- Additional work with benchmark 1.1.1 (THM mock-up experiments on compacted MX-80 bentonite).
- Additional work with benchmark 1.1.2 (Large cell experiments on compacted Febex bentonite).
- Modelling of benchmark 1.1.3 (Thermal gradient test on compacted Febex bentonite with no water supply).

A preliminary evaluation report has been written for Task 1.Most modelling groups were able to model the processes during wetting of bentonite in Task 1 but there were some questions regarding the hydraulic confinement of the tests.

The work in Task 2 during the third quarter has focused on:

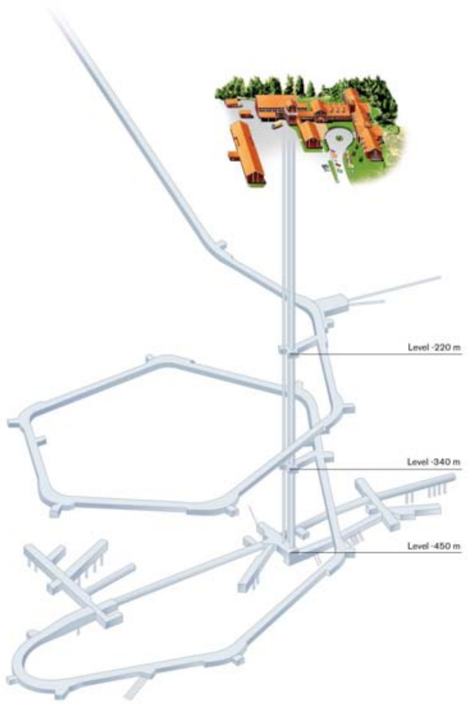
- Modelling and reporting of benchmark 1.2.1 (Gas tests with constant external total pressure).
- Modelling and reporting of benchmark 1.2.2 (Gas tests with constant volume).

The gas modelling shows that it is difficult to model gas breakthrough.

6 Äspö facility

Important parts of the Äspö facility are the administration, operation and maintenance of instruments as well as 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.

6.1 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.

Achievements

The facility has operated normally, without any disturbances and the office building has been painted externally. The building of the laboratory for testing of bentonite materials has started with the groundwork for the foundations of the building and the two test holes for deposition have been mounted. The completion of the building is now rescheduled to March next year. The reason for the delay is difficulties in finding a supplier for the framework of the building.

Testing of the system for the registration of personnel (RFID) is ongoing and the results of the test show that the system is functioning well. All visitors and vehicles in the tunnel are equipped with a transponder so that they can be located if an underground accident occur. The decision has been made to start a new project (RFID 3) with continued development of the system for registration of personnel. The project will focus on monitoring the activities in operation in tunnels in order to base control of the ventilation system on the requirements of the activities.

The restoration of the rock tip at Bockstrupen has been completed and the responsibility for the area has been passed to OKG.

Extension of a reserve power system is planned in order to minimise power cuts when underground cable are damaged. Above ground, a diesel driven generator is planned for all the safety systems.

6.2 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 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

SKB facilities have been visited by 9,022 persons during the third quarter 2006. Compared with the same period last year this means an increase with 18%. The numbers of visitors to SKB's main facilities are listed in Table 6-1.

The guided summer-tours "Urberg 500" started in the end of June and ended the 20th of August. The tours sat a new record with 2,886 visitors, which were 400 more visitors than the last year.

The official inauguration of "Geologins Dag" took place at Äspö the 15th of September. The county governor conducted the inauguration and the event was visited by 120 persons during the day.

Table 6-1 Number of visitors to SKB's main facilities

SKB facility	Number of visitors July – September 2006
Central interim storage facility for spent nuclear fuel	316
Canister Laboratory	338
Äspö HRL	3,969
Final repository for radioactive operational waste (SFR in Forsmark)	3,875

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 geoscientific and environmental 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), a research assistant, four assistant supervisors and five Ph.D. students. 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

The work within the Äspö Research School has continued during the period.

8 International co-operation

Nine organisations from eight countries participate in the Äspö HRL co-operation during 2006, see Table 8-1. Six of them; Andra, BMWi, 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.

Table 8-1 International participation in the Äspö HRL projects during 2006.

Projects in the Äspö HRL during 2006	Andra	BMWi	CRIEPI	JAEA	OPG	Posiva	Enresa	Nagra	RAWRA
Geo-science									
Äspö Pillar Stability Experiment					X	X			
Natural barriers									
Tracer Retention Understanding Experiments	X			X		X			
Long Term Diffusion Experiment					X				
Colloid Project		X				X			
Microbe Project		X							
Radionuclide Retention 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		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			
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
Ontario Power Generation Inc., OPG, 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

9 Documentation

During the period July to September 2006, the following reports have been published and distributed.

9.1 Äspö International Progress Reports

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