International Progress Report

IPR-07-04

Äspö Hard Rock Laboratory

Status Report
October – December 2006

Svensk Kärnbränslehantering AB

February 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

Äspö Hard Rock Laboratory

Report no.	No.
IPR-07-04	F50K
Author	Date
Kemakta	February 2007
Checked by	Date
Approved	Date
Anders Sjöland	2007-03-01

Äspö Hard Rock Laboratory

Status Report
October – December 2006

Svensk Kärnbränslehantering AB

February 2007

Keywords: Äspö HRL, Status Report

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 fourth 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 has been published /SKB 2006b/.

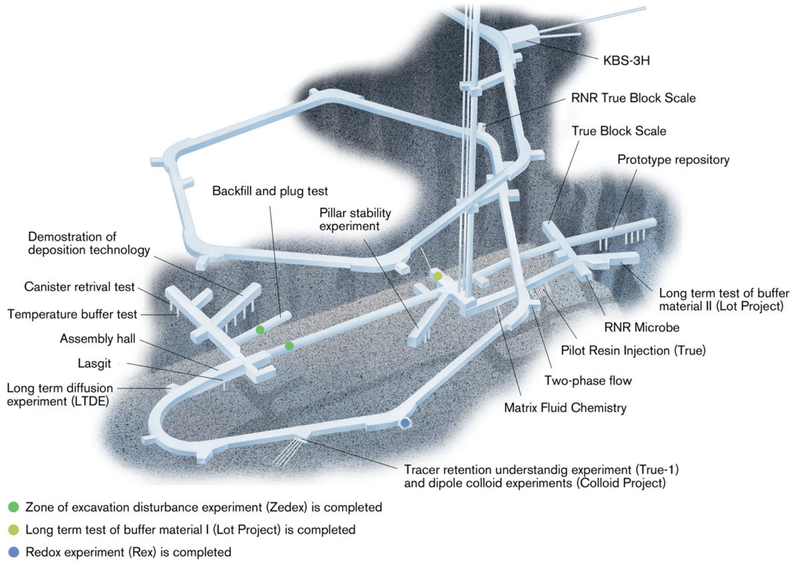


***Figure 1-1** Allocation of some of the experimental sites in Äspö HRL from -220 m to -450 m level.*

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

Ultrasonic measurements performed in the TASQ by BGR and BBK, November 2006 (photo Ann Bäckström, BBK)

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

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

Achievements

The modelling work concerning the 450 m-level at Äspö HRL has continued and will soon be completed.

The report by GeoVista concerning the use of magnetic anisotropy to detect the true width of deformation zones in the TASA-tunnel has been adjusted after being reviewed and is now waiting for approval to be printed.

Tyréns have logged some short drill cores from the wall of the Retrieval Test deposition hole. The core logs have been delivered to SKB.

Eight 3 m long cored boreholes have been drilled in the TASQ-tunnel as a part of the Decovalex-project. Ultrasonic measurements are performed by BGR (Bundesanstalt für Geowissenschaften und Rohstoffe) and BBK (Berg Bygg Konsult AB) to investigate the extent of the EDZ (excavation damage zone). BIPS (borehole image processing system) measurements will later take place and the cores will be logged.

Some earlier mappings as well as the latest niche (NASQ0036A) mapping are still not digitised and associated geological data not entered into the TMS (Tunnel Mapping System). This work will continue when time allows.

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

Geoiden AB surveying reference points to be used later when laser scanning takes place.

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 Characterisation 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

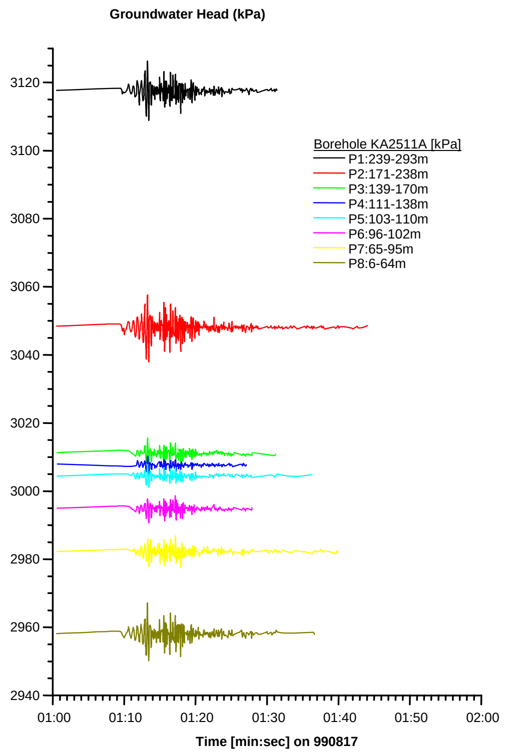
The adjustments of the RoCS feasibility report are almost completed. A part of the report has been sent on a complementary review by BBK (Berg Bygg Konsult AB) and a permit from BGS (British Geological Survey) to use one of the pictures in the report is still missing. Hopefully the report will be sent for approval to be printed before the end of the year. The conclusion is still that laser scanning with digital photography will be a part of a new rock characterisation system.

The continuation of the RoCS project will be delayed due to the status of the RoCS feasibility report.

ATS (Advanced Technical Solutions AB) has delivered a DVD with laser data from the TASQ-tunnel. The report from ATS concerning the laser scanning of the TASQ will be delivered shortly.

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 October–December have been collection and storage of data in the HMS (hydro monitoring system). In the same way as earlier the data are stored waiting for future analyses. No analyses have yet been done. Compilations of pressure disturbances that can be coupled to blasting in the Äspö HRL and earthquakes are planned to be done 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.

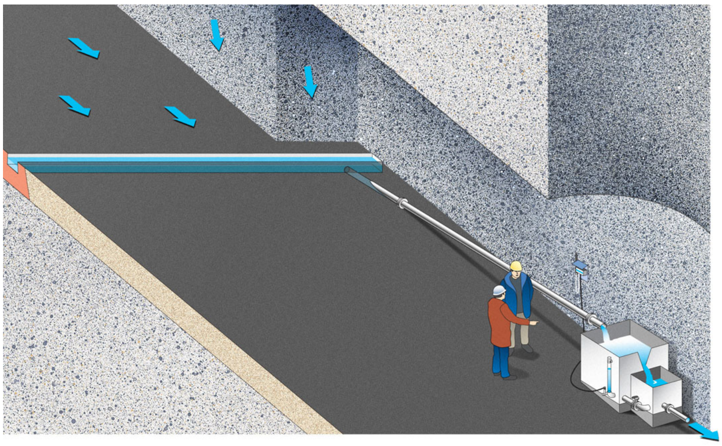
The ability to predict inflow is of importance from several aspects:

- 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.

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 fourth quarter have been:

- Initiation of measurements of temperature, humidity, and pressure of the tunnel air.
- Calibration of pressure transducers in the tunnel.
- Quality check and calibration of data from the tunnel in December.
- Preparations for automatic transfer of data from the HMS to the data base Sicada.
- 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

Geochemistry is an important part of the geoscientific issues in the planning of the future repository. For establishment and development of the current geochemical model for Äspö HRL new data and findings may be used and complementary parameters added.

The use of the achieved knowledge will facilitate the understanding of the geochemical conditions and the development of underground facilities in operation. This is important in terms of distinguishing undisturbed and disturbed conditions.

The main activities during 2006 have been planning next year's activities and discussing priority based on the latest version of the overall geoscientific program.

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 hydro geochemical 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 hydro geochemical changes are taking place and at what time stationary conditions are established.

Achievements

During the last months the monitoring campaign has been performed as planned. Analysis are still ongoing and data will be reported to the database Sicada during next year.

Reporting is to be done as an internal Chemistry Report and followed up by a TD report.

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 be performed within the following projects:

- Coupled processes in rock including dynamic processes at natural conditions.
- Stress measurements and stress interpretation methods.
- Äspö Pillar Stability Experiment.

2.4.1 Stress Measurements - Core Disking

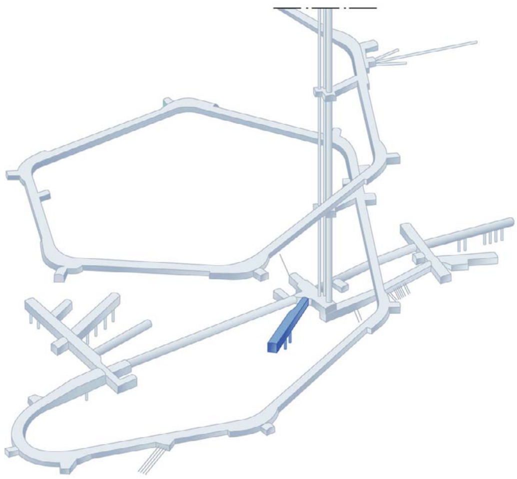
The purpose of the project is to study the conditions under which core disking occur by drilling in the vicinity of the area for the Äspö Pillar Stability Experiment.

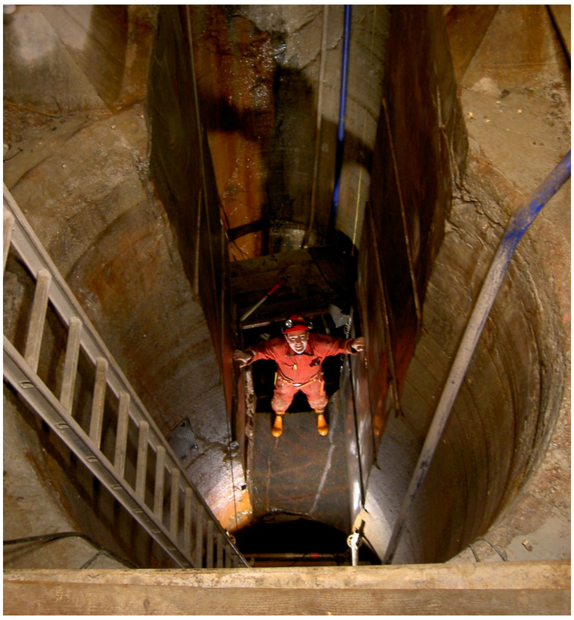
A total of four holes were drilled vertically in the tunnel floor (KQ0062G05, KQ0062G06, KQ0061G10 and KQ0062G04). Core disking in solid and hollow cores was observed in the first three of these. Two successful installations of the Borre probe used for stress measurements were made.

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.

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

All experimental work are finalised and the reporting work has continued. A report in the TR-series that in detail presents the experiment and its results will be published during the first quarter 2007.

3 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.

Achievements

The Bentonite Laboratory is under construction. The construction activities on the site were initiated in May 2006 when the excavation of rock started. The complete building structure was delivered to Äspö during this quarter and at the moment the construction work is expected to be ready in March 2007, see Figure 3-1. The final inspection of the building is planned to March 9.

Figure 3-1 Bentonite Laboratory under construction.

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.

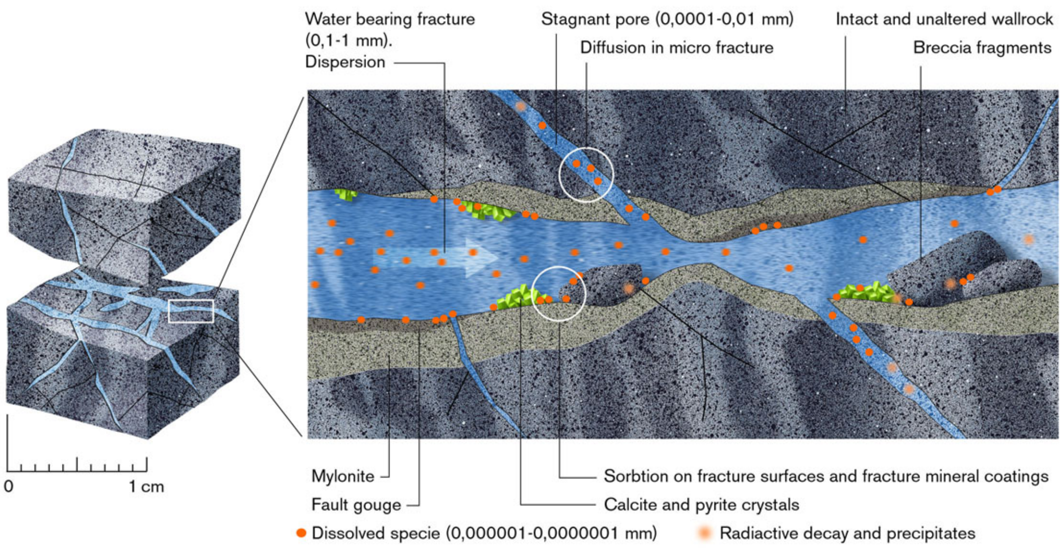
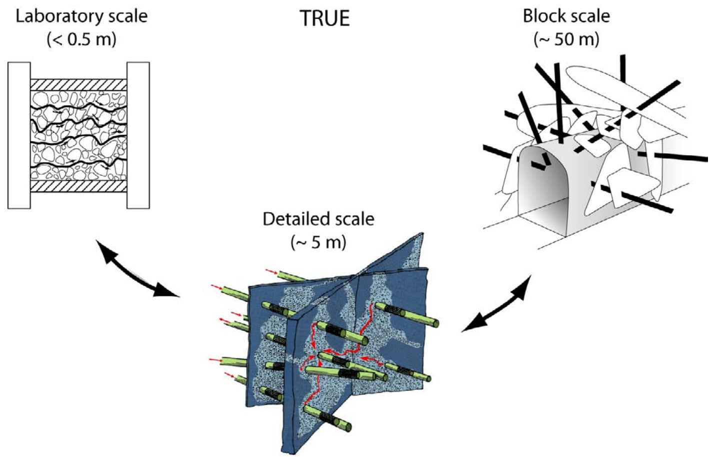


Figure 4-1 *Processes that influence migration of species along a natural rock fracture.*

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

During the period a complete draft of the True Block Scale Continuation Final Report (TR-06-42) has been prepared. The report has been submitted to the True Block Scale Steering and Technical committees for review.

Furthermore, the four evaluation reports from the four modelling teams are published /Poteri 2005, Billaux 2005, Fox *et al*. 2005, Cheng and Cvetkovic 2005/.

The essence of the True Block Scale Continuation project was presented in two papers at the "American Geophysical Union's Fall Meeting" in San Francisco, December 2006:

- Illustration of uncertainties in assessments of flow and transport in a block scale fracture network – an example from the Äspö Hard Rock Laboratory, Sweden. /Poteri *et al.* 2006/
- Estimating retention properties of components of a block scale fracture network – an example from the Äspö Hard Rock Laboratory, Sweden. /Cheng *et al.* 2006/

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 over coring 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

An incomplete draft of the sorption part of the complementary laboratory experiments has been delivered.

Review comments received on the two submitted True-1 papers from three anonymous Water Resources Research reviewers. Updating process initiated.

No activity in the Fault Rock Zones Characterisation and Complementary laboratory experiments.

4.1.3 True-1 Completion

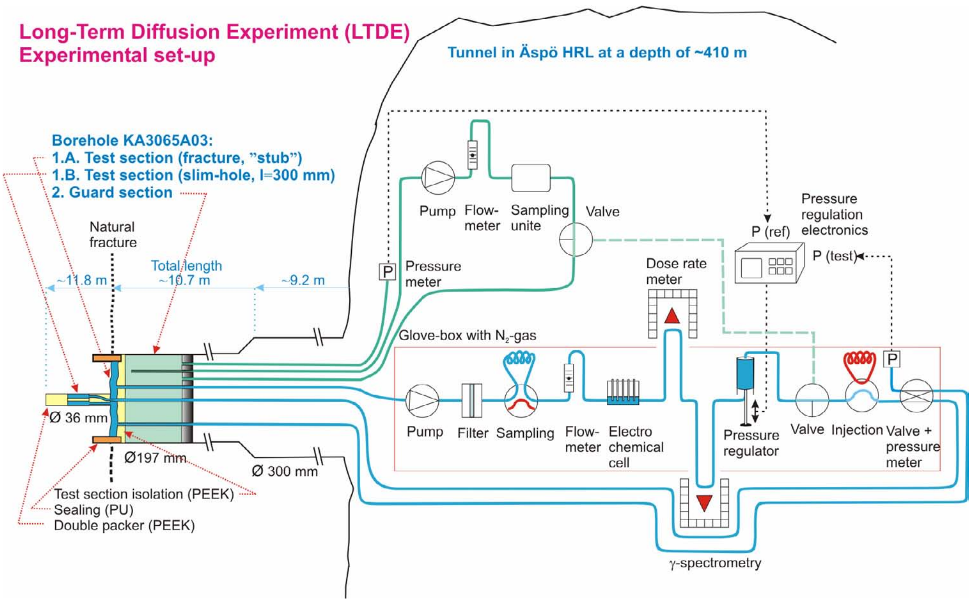
True-1 Completion is a sub-project of the True-1 Continuation project with the experimental focus placed on the True-1 site. True-1 Completion will be performed at the True-1 site and will be a complement to already performed and ongoing projects. The main activity within True-1 Completion is the injection 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 realisation of the remaining complementary tracer tests have been the major activity during 2006. The extent of the physical changes of Feature A was studied through a series of dilution tests in KXTT4. The dilution tests showed 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 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.

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 sorption diffusion *in situ* experiment has been running since the injection of 22 radionuclides was carried out 27 September. The radionuclide cocktail included the range from non-sorbing (^{36}Cl, ^{35}S) to strongly sorbing tracers (^{175}Hf, ^{236}U). During October – December the radioactivity concentration of the gamma emitting tracers in the test section groundwater have been measured on-line by an HPGe-detector (high-purity germanium a gamma-ray detector). The test-section has also been sampled on a regular basis by extracting small volumes of water to be analysed for the non-gamma emitting tracers by means of scintillation or mass spectrometry, depending on tracer. Results from the on-line HPGe measurements the first 24 hours after injection are shown in Figure 4-2. The groundwater in the test-section was rapidly mixed and the most sorbing tracers decreased fast from water phase while the non to slightly sorbing tracers, e.g. ^{22}Na, level out on a constant concentration.

The experiment, with on-line HPGe measurement and sampling is planned to continue until February/March 2007. Thereafter the core stub and the rock surrounding the small diameter extension borehole will be extracted by over core drilling.

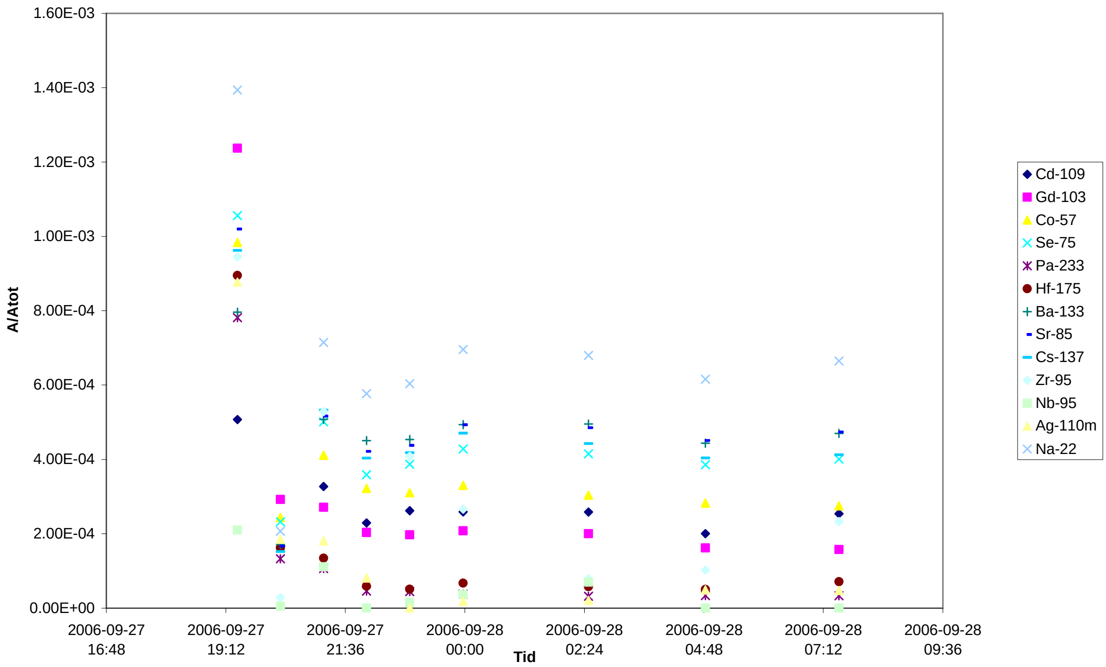
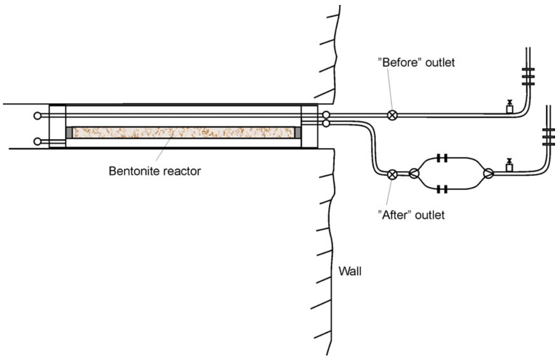


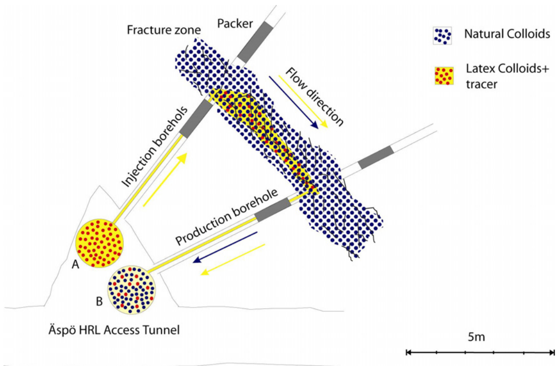
Figure 4-2 *Sorption diffusion in situ experiment. Radionuclide concentration (normalised) in test section groundwater the first 24 hours after injection.*

4.3 Colloid Project

Borehole specific measurements



Colloid dipole experiment



In the Colloid Dipole 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.

Achievements

In Canada AECL is performing experiments on bentonite colloid migration in a water bearing fracture (Quarried Block). During this quarter experiments in the Quarried Block have been performed where transport of bentonite colloids in saline waters are studied. The results from the Quarried Block so far will be presented in an OPG-report, which will be included in an IPR-report.

The main activities concerning the Colloid Dipole experiment (performed at the True-1 site in boreholes KXTT3 and KXTT4 during March-April) have comprised:

- Evaluation of data from laboratory experiments to predict CCC-values (critical coagulation concentration) for Na- and Ca-montmorillonite colloids in NaCl and $CaCl_2$ have been performed.
- Laboratory experiments where effects of pH and temperature on bentonite stability, as well as the effect of the presence of mineral surfaces on bentonite colloid stability are performed.

Planning for new transport experiments of colloids at Äspö is ongoing. A suitable site would be the True-Block site, since Swiw-tests will be performed there in beginning of 2007, and therefore all equipment needed is established anyway.

Planning for the Colloid-Actinide experiments is ongoing and a suitable borehole KA2512A has been selected because of its (relatively) low Ca-concentration and (relatively) low ionic strength. The major problem with this type of experiment is that bentonite colloids are not stable in Äspö groundwater; however, as a demonstration experiment the activity is very valuable. Preparation studies for the Colloid-Actinide have been performed in the laboratory where bentonite colloid stability in Äspö waters have been studied in coagulation studies in the absence and presence of fulvic acids. Interaction studies of radionuclides with bentonite colloids have also been performed.

A method to predict stability and determine CCC-values have been determined. A manuscript is under preparation and will be sent in for publication very soon. An IPR-report which will cover all results from the project is planned to be written in February.

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

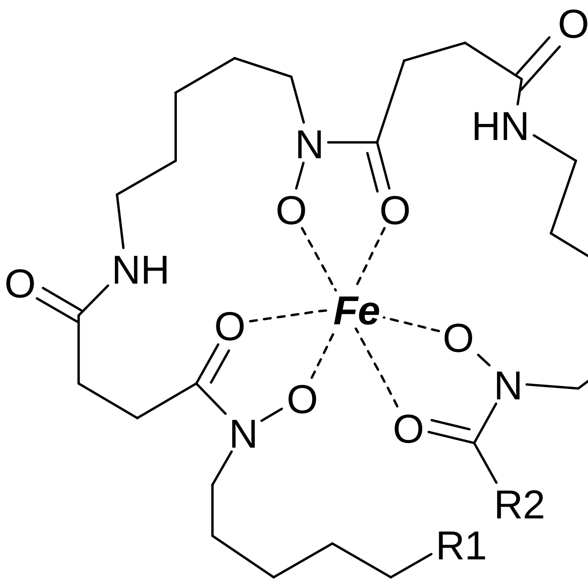
The main activities during October to December have been several extensive field work projects. One was in collaboration with scientists from Canada. The image shows Rachel James and Jennifer Kyle, University of Toronto, analysing biological iron oxides from the 2,200 m Bios tunnel site. In total, two professors and three PhD students from Canada visited Äspö 30th October to 10th November. They were Professor Grant Ferris, Rachel James, Jennifer Kyle and Kerry Tokaryk, University of Toronto, and Danielle Foretain, Univiversity of Ottawa. At most, a total of ten scientists and personnel from Microbial Analytics Sweden AB were active simultaneously with this project and the Biocorrsion and the Prototype Repository projects described below.

The Microbe site was also employed for field work performed within the Prototype Repository project. Samples were taken and partly analysed in the laboratory underground for gas and microbes in the groundwater inside and around the Prototype Repository.

A project on Biocorrosion of copper was closed down in November. The results are being processed. Reporting will occur during 2007.

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

4.4.2 Micomig



Ferrioxamine

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

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

Biofilms in aquifers will influence the retention processes of radionuclides in groundwater. Recent work indicates that these surfaces adsorb up to 50% of these radionuclides in natural conditions with retention factors (Ka) approaching 10^5 and 10^6 (m) for Co and Pm respectively.

The work within Micomig will:
- Evaluate the influence from microbial complexing agents on radionuclide migration.
- Explore the influence of microbial biofilms on radionuclide sorption and matrix diffusion.

Achievements

The main activity in October to December has been the publication and defence of a thesis that treats bioligands in microbe-metal interactions. The abstract of the thesis is given below.

Thesis title: The role of bioligands in Microbe-Metal interactions. Emphasis on subsurface bacteria and actinides /Johnsson 2006/.

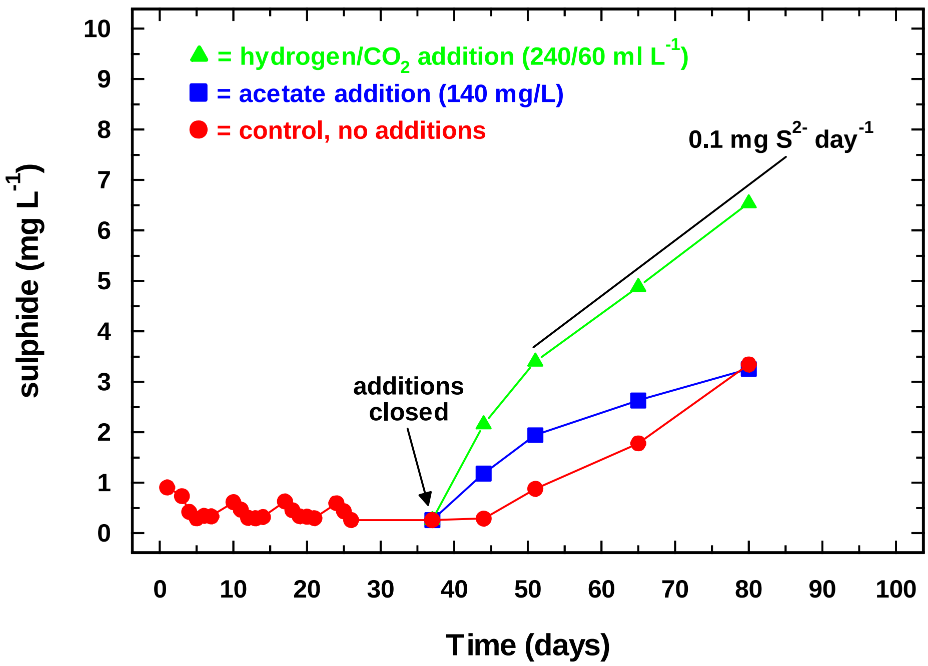
Abstract: Metallic contaminants are continually being introduced into environments such as the terrestrial subsurface by various processes. One important group of metallic contaminants are the radioactive actinides, which can cause damage to living organisms by their radioactive decay. To be able to cause damage, however, the metal needs to reach the living organism, it needs to be mobile. Most of the environments studied on Earth contain microorganisms and it is well known that microorganisms can influence metal mobility. This thesis compiles studies on how microorganisms from the terrestrial subsurface can influence the mobility of primarily actinides by means of producing and consuming bioligands.

Three species of bacteria isolated from subsurface environments, *P. fluorescens, P. stutzeri* and *S. putrefaciens*, were shown to excrete siderophore-type bioligands under aerobic conditions. In addition, P. stutzeri and S. putrefaciens, excreted bioligands under anaerobic conditions. The potential of these bioligands, as well as the commercially available siderophore deferoxamine mesylate (DFAM), to affect the solid-aqueous phase partitioning of metals, was tested in some set-ups. P. fluorescens efficiently mobilised U from uranium ore. This mobilisation was attributed to the complexation of U to pyoverdin secreted by P. fluorescens, since the pyoverdin was found capable of forming a pyoverdin - UO_2^{2+} complex with a log β112 of 30.5±0.4 and a log β111 of 26.6±0.4. The other two species did not mobilise U but instead mobilised V, Cr and Mo from the uranium ore. The solid-aqueous partitioning of Fe, Pm, Th and Am was studied in the presence of quartz sand or TiO_2 powder and secretions from aerobically cultured P. fluorescens, P. stutzeri and S. putrefaciens and anaerobically cultured P. stutzeri and S. putrefaciens. In the quartz set-up siderophore-containing supernatants from aerobic cultures were efficient in partitioning not only Fe but also the actinides Th and Am to the aqueous phase, with more than 50% of the total added amount remaining in solution. The anaerobic supernatants were most efficient at maintaining Am in solution with 40% of the total amount left in solution. In samples with the more fine-grained TiO_2 the overall amounts of metal in solution were lower; however, again aerobic supernatants were able to maintain Fe and also Th in solution. Anaerobic supernatants maintained Fe and Th in solution as well, albeit to a much lesser extent. In another study, the dissolution behaviour of spent nuclear fuel pellet fragments in the presence of DFAM and the pyoverdin of P. fluorescens was observed. The pyoverdin maintained significantly higher concentrations of Np and Pu in solution than the control. Furthermore both the pyoverdin and the DFAM leached Ru from the fuel pellet fragments.

Bioligands may also be present in the subsurface as a result of other processes than microbial excretion. Included therefore in the thesis is a study on the degradation of the actinide-mobilising ligand isosaccharinic acid by anaerobic subsurface microorganisms. The tested metabolic groups did not seem capable of degrading the isosaccharinic acid during the incubation period. This result is in accordance with other studies indicating the low biodegradability of isosaccharinic acid.

Microorganisms can affect the mobility of metallic contaminants in the environment by affecting the pool of bioligands that can form metal-complexes. In this thesis it was shown that some subsurface microorganisms are capable of excreting bioligands under both aerobic and anaerobic conditions. These bioligands were able to affect the solid-aqueous phase partitioning of various metals including actinides. Processes like these may impact the mobility of these elements in a variety of environments.

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 activity in October to December has been the publication and defence of a thesis that treats microbial diversity in repository environments. The abstract of the thesis is given below.

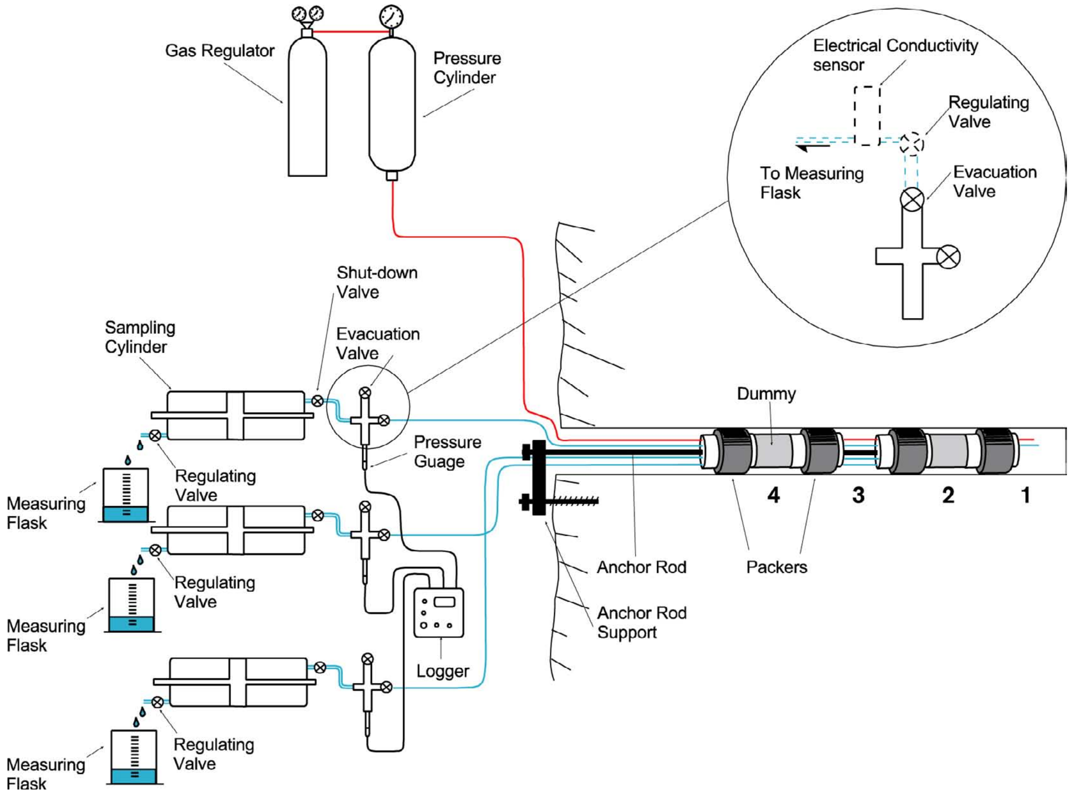
Thesis title: Molecular characterisation of the microbial diversity in natural and engineered intraterrestrial environments - A focus on igneous rock aquifers /Chi Fru 2006/.

Abstract: Microbial diversity in natural and engineered intraterrestrial environments in igneous rock aquifers used or targeted for the disposal of spent nuclear fuel (SNF) was investigated using 16S rRNA and functional gene-based techniques. Methods were optimised including DNA acquisition from bentonite to selective application of a combination of molecular techniques to enhance specificity and accuracy of community diversity estimates. Investigated systems included biofilms in an operating interim SNF disposal basin located ~30 m underground, deep granitic rock groundwater (70-1000 m) and accompanying realistic simulated SNF disposal systems.

In some systems total microbial community diversity was estimated while in others specific groups of microorganisms were in focus. Results indicated that in the interim SNF storage facility a *Meiothermus* sp. was the dominant biofilm forming organism and posed corrosion-related problems for the steel linings of the storage pool. In the oxygenated and microaerophilic tunnel environments at Äspö, a *Gallionella* dominated bacteriogenic iron oxides (Bios) community was found to sustain several metabolic life styles from sulfate, iron, and manganese reducers to nitrite, ammonia, methane, iron, hydrogen and sulfur oxidising bacteria communities to aromatic hydrocarbon degraders. In five year old bentonite retrieved from 450 m deep simulated SNF disposal systems bacilli were singly detected at temperatures as high as 110 ^{o}C. *Desulfosporosinus*, clostridia and pseudomonads were prominent at temperatures of 19 and 35-67 ^{o}C. Generally 84.1% of the investigated microbial diversity in the buffer was gram positives with bacilli constituting a majority.

In granitic groundwater from over nine boreholes at Äspö (70-626 m) screened for sulfate-reducing prokaryotes (SRP) by targeting the dissimilatory sulfite reductase (*dsrAB)* and 16S rRNA gene sequencing, it was revealed that SRP at Äspö were diversed, ancient with yet-to culture lineages and that *Desulfovibrio aespoeensis* was dominant and widespread. Finally, by targeting the α-subunit of the particulate methane monooxygenase gene (*pmoA*) and with the use of type I and II specific 16S rRNA fluorescent *in situ* hybridisation gene probes, thirty sampled boreholes (3 to ca. 1000 m depths) distributed over three geographical distant regions in the Fennoscandian Shield were demonstrated to contain several lineages of aerobic methanotrophs. Up to 5000 methanotrophs mL^{-1} of groundwater was estimated. Type I methanotrophs dominated in an SNF Prototype Repository with estimated numbers greater than for surrounding rock-logged groundwater. Altogether the pmoA gene phylogeny exhibited site and geographical dependence. The implications of the studies in relation to the safe disposal of SNF in underground engineered barriers are several; many lineages of the detected microorganisms fall into categories that can reduce, mineralise or bioaccumulate radioactive metals such as U(VI) (e.g. SRP and bacilli), can induce the corrosion of SNF storage canisters and metal linings (e.g. SRP, *Meiothermus, clostridia.*), can influence the migration of radioactive metals through the production of complexing agents (e.g. pseudomonads) and provides large reactive surfaces for metal adsorption (e.g. *Gallionella* produced Bios), and can potentially eradicate oxygen trapped in closed SNF repositories (e.g. methanotrophs).

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.

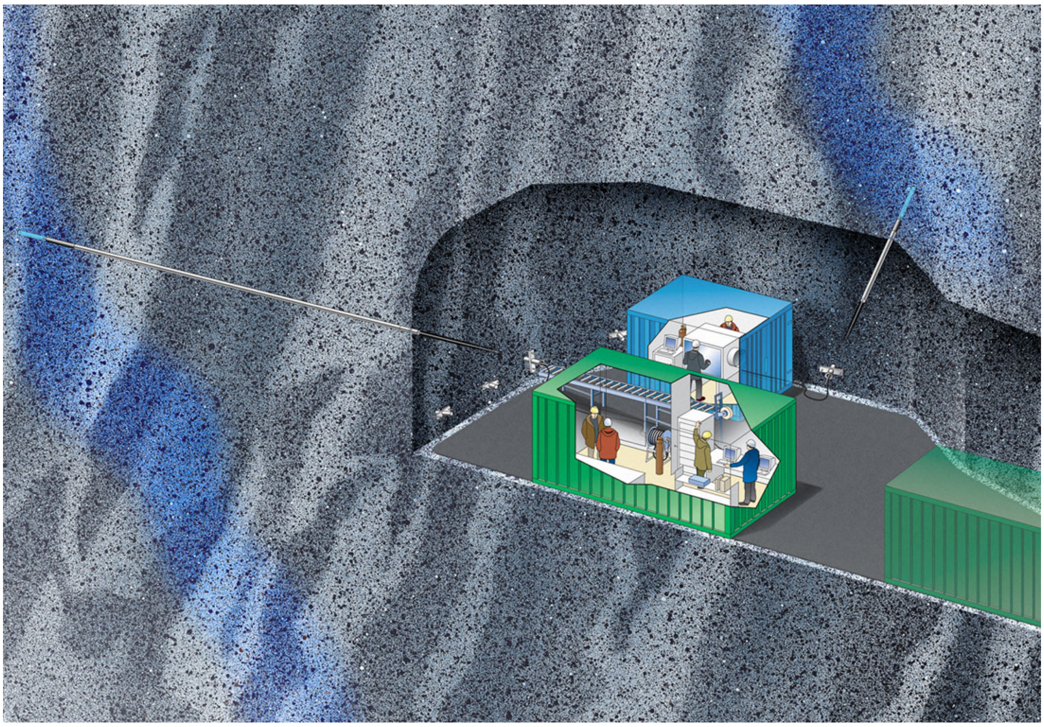
A first phase of the project is finalised and reported /Smellie *et al*. 2003/. The major conclusion is that pore water can successfully be sampled from the rock matrix and there is no major difference in chemistry compared to groundwaters from more highly conductive fracture zones in the near-vicinity.

Achievements

The main activity during October-December has been the reporting of the matrix borehole hydraulic measurements which were completed during the last quarter.

With respect to the chemistry of the matrix borehole waters sampled on two occasions in 2005, it is hoped that these data will be compiled and reported.

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:

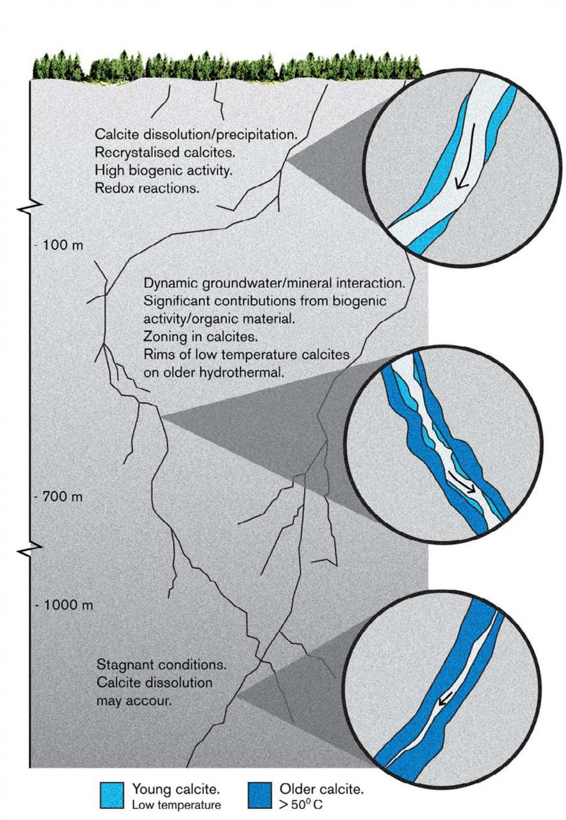
- Migration experiments with actinides in a rock fracture (almost finalised).
- Study leaching of spent fuel at repository conditions (planned).

Achievements

Another project with higher priority has allocated all resources for the Radionuclide Retention Experiments during 2006.

The final report on the influence of radiolysis products on the migration of redox-sensitive Tc is published /Jansson *et al*. 2006/.

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:

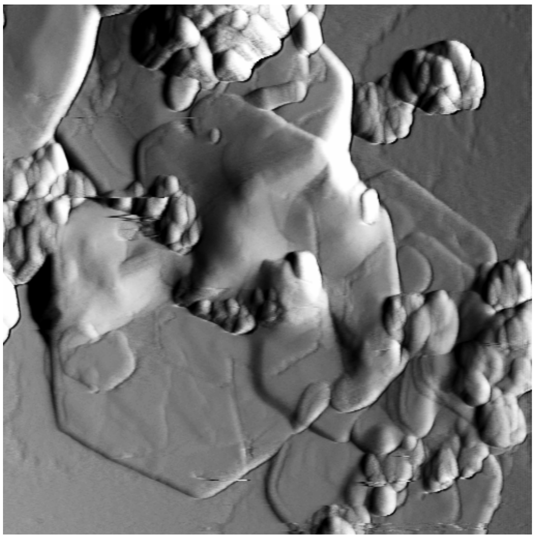
- Improve understanding and prioritise palaeo-hydrogeological information for use in safety assessments.
- Collect chemical/isotopic data using advanced analytical methods.
- Construct a database of relevant information and develop numerical models to test hypotheses.
- Integrate and synthesise results 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 concerns Uranium-series measurements where different approaches will be tested by different laboratories. The USD analyses will be carried out on split samples of fracture material from a surface borehole drilled at Äspö (KAS17). This borehole penetrates the large E-W fracture zone called the Mederhult zone and several sections with fractured rocks are intersected by the borehole. Six samples from different depths (from 19 to 200 m core length) have been prepared for U-series analyses, i.e. mineral identification and chemical analyses. The chemical analyses and X-ray diffractometry for mineral identification have been carried out and show that the sampled material consist of quartz, K-felspar, albite, chlorite, calcite and clay minerals of mixed layer clay type. U contents in the samples varied from 6 to 27 ppm. Samples have also been distributed to Helsinki University and to SUERC in Glasgow for 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 last quarter two reports from the University of Copenhagen have been finalised for publication in IPR format. These are:

- A transformational, structural and natural occurrence study of green rust /Christiansen 2006/.
- Reduction of hexavalent chromium by green rust sulphate: Determination of end product and reduction mechanism /Skovbjerg 2005/.
- Fe-oxides in fractures: Thermodynamics and trace component uptake. Enviros Progress Report which presently is under internal review (Grivé, Colàs and Domènech, 2006).

In terms of future work (i.e. Continuation Project), fracture samples collected in August are undergoing preparation for analysis during the first quarter 2007.

4.9 Swiw-test with Synthetic Groundwater

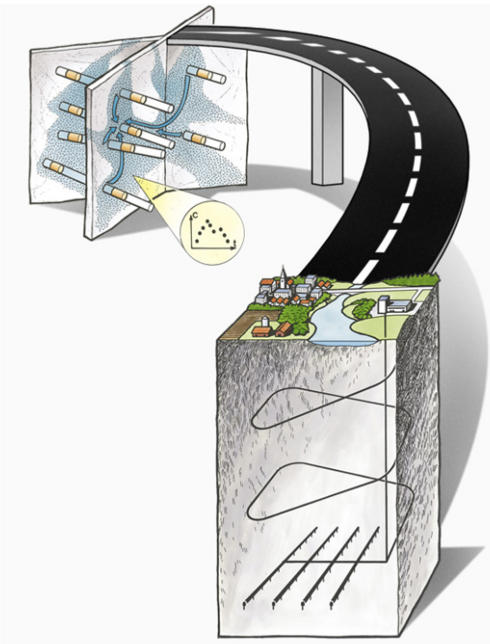
The project constitutes a complement to performed tests and studies on the processes governing retention, e.g. the True-1 and the True Block Scale experiments. This project aims to deepen the understanding for the processes governing retention. Swiw-tests (single well injection withdrawal) with synthetic 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 usage of the True Block Scale site facilitates the unique possibility to calibrate the concept of single hole tracer tests, Swiw, to multiple borehole tracer tests. The results from such a calibration can be applied directly to the Swiw-tests performed within the SKB site investigation programme.

Achievements

The major activities comprise comprehensive planning and a feasibility study.

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, which addresses a long-term pumping test in Olkiluoto, Finland. The status of the specific modelling tasks is given within brackets in Table 4-1. Planning and preparations for Task Force meeting 22 in January are ongoing.

Task 6 tries to bridge the gap between Performance Assessment (PA) and Site Characterisation (SC) models by applying both approaches for the same tracer experiment. It is hoped that this will help to identify the relevant conceptualisations (in processes/structures) for long term PA predictions and to identify site characterisation data requirements to support PA calculations. Several of the Task 6 D, E and F reports from the modelling groups are in the printing process. 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. Work is on-going for this matter. In addition, some modelling groups have indicated interest in publishing papers in the same scientific journal, and in conjunction with the summary paper. So far two modelling groups have submitted papers.

Task 7 addresses modelling of the KR24 long-term pumping test at Olkiluoto in Finland. The task will focus on methods to quantify uncertainties in PA-type approaches based on SC-type information; along with being an opportunity to increase the understanding of the role of fracture zones as boundary conditions for the fracture network and how compartmentalisation affect the groundwater system. The possibilities to extract more information from interference tests will also be addressed. A task description for the sub-task 7A has been sent out to the modellers and preliminary results from the modelling were presented at the workshop in Rauma, September 2006. It was decided at the meeting to divide Task 7 into several sub-tasks. Updated Task 7 definitions and data deliveries have been made.

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 September 2006).

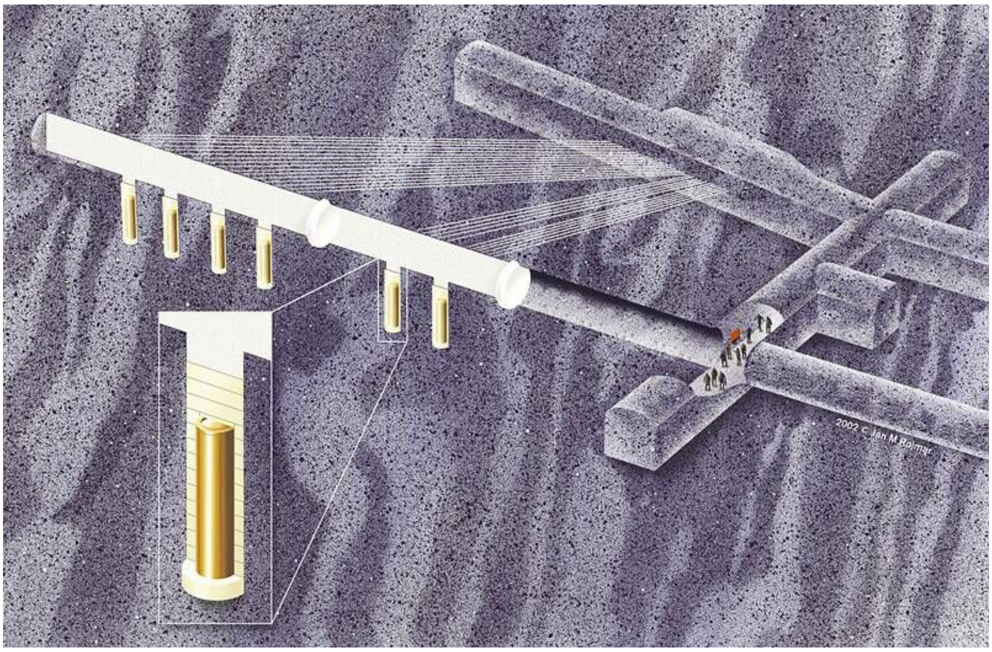
5 Engineered barriers

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 *Sampling of the buffer in the Canister and Retrieval Test.*

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 casted in September the same year.

Achievements

The data collection system comprises temperature, total pressure, pore water pressure, relative humidity and resistivity measurements in buffer and backfill, as well as temperature and water pressure measurements in boreholes in the rock around the tunnel. The collection of data is in progress and the data report No. 15 covering the period up to June 2006 is now available /Goudarzi and Johannesson 2006/. Overhauling of the data acquisition system is in progress and hydraulic tests of the rock mass have been performed.

Groundwater flow measurements with tracers (Test campaign 2) in the rock around the Prototype Repository have been started and will be finalised at the end of this year. The objective of the tests is to estimate the transmissivity of the rock.

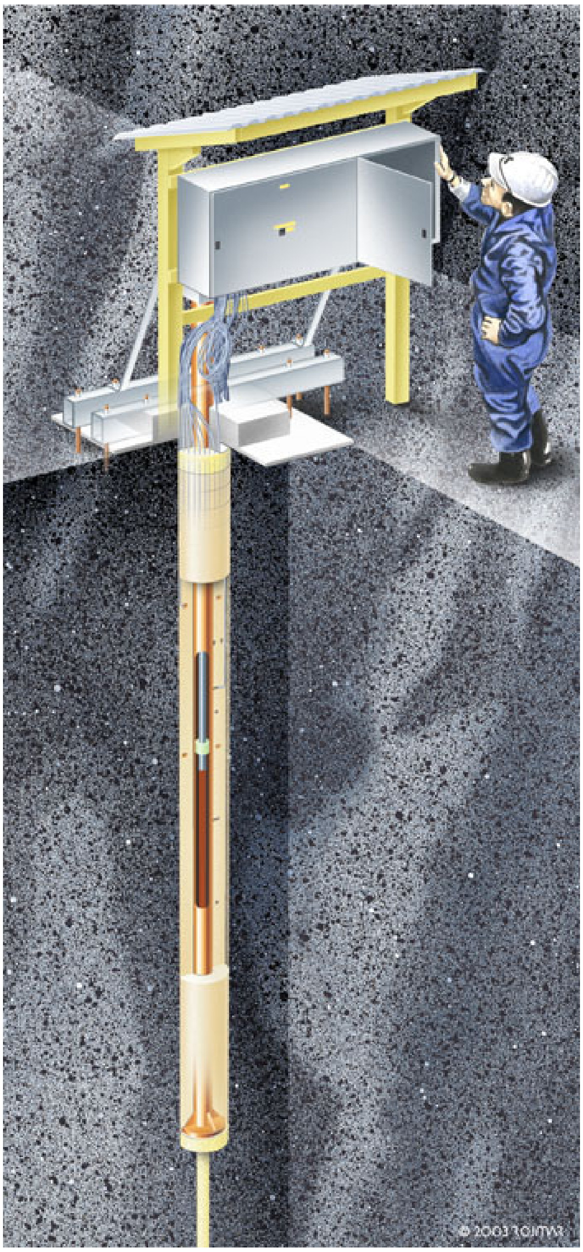
Measurements of pH and Eh of water samples taken from boreholes in Section I and II of the Prototype Repository and the G-tunnel is ongoing.

A program for sampling and analyses of gases and micro-organisms in the backfill and buffer has started and the first campaign has been finalised and reported in a technical document. The second campaign is ongoing and will be finalised at the end of this year. Later, when more campaigns have been completed, the work will be published in an International Progress Report (IPR).

Acoustic Emission and Ultrasonic monitoring results from deposition hole 6 have been reported for the period between October 2005 and March 2006 /Haycox and Pettitt 2006/. The Acoustic Emission and Ultrasonic monitoring are continuing.

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 finished 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 deep repository.

Achievements

The main activities during October-December have been:

- Laboratory tests of test material from the A2 parcel including: swelling pressure tests, hydraulic conductivity tests, triaxial tests, and uniaxial tests
- Laboratory analyses of test material from the A2 parcel including: element distribution, cation exchange capacity, mineralogical composition, swelling capacity, bentonite pore water composition, cation diffusion (cobalt tracer material) and copper corrosion.
- Continuation of the S2, S3 and A3 parcels at Äspö, including supervision and data handling

The results from the A2 parcel so far show no or insignificant changes in the exposed bentonite material compared to 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 changes especially in the case of sulfates, has precipitated in the mid position between the rock and the copper tuber in the warmer parts. Copper uptake in the buffer is similar in the one and five year experiments with respect to both quantity and distribution. The redox potential was negative in the extracted porewater.

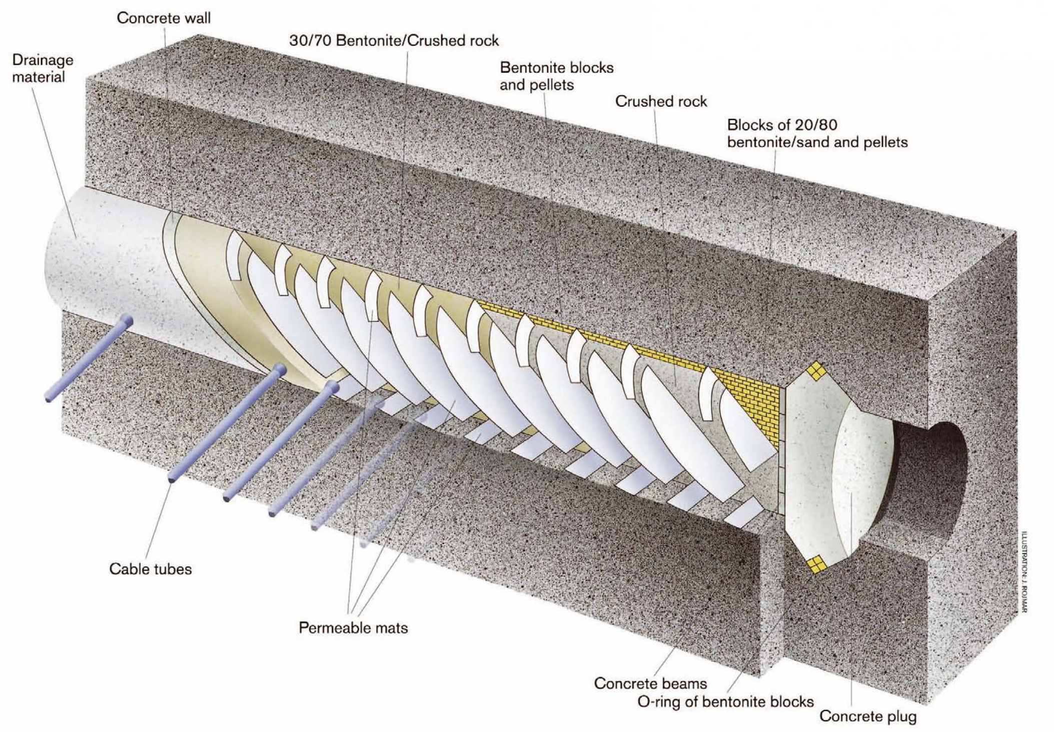
Partial reports are at hand concerning bacterial activity, copper corrosion, porewater chemistry. A project meeting have been held at Äspö during which the results were discussed. It was decided that the analyses and tests and analyses concerning the A2 parcel material should be reported to the project at January 31st, 2007 at the latest.

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.

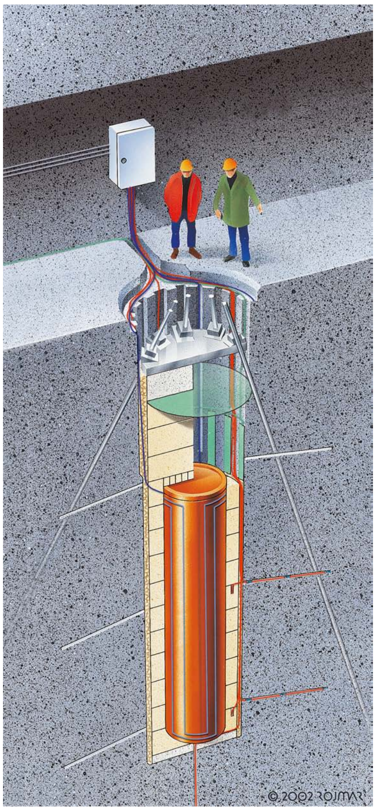
Achievements

The main work during the last quarter 2006 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. A 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.

The pressure cylinder tests have started during this quarter. So far the tests with the cylinder in the floor in the crushed rock section have been finished (stepwise pressurised to 5 MPa) and the tests with the corresponding cylinder in the roof are ongoing.

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 final data report has been delivered and will be printed.

Achievements - Retrieval phase

During the last quarter of 2006 work has been focused on analyses. Both the buffer and drill cores from the deposition hole are analysed.

The canister itself was earlier transported to SKB's Canister Laboratory in Oskarshamn. Several tests are performed on the canister. Dimension, tension, stress, corrosion etc will be examined. The testing is planned to be completed early 2007. When the outer tests are completed on the canister the lid can be removed and the heaters inside examined. This is a vital part to understand the conditions on the inside 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 Temperature Buffer Test 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. 8 is available /Goudarzi *et al*. 2006/. The data link from Äspö to Andra's head office in Paris has been functioning well.

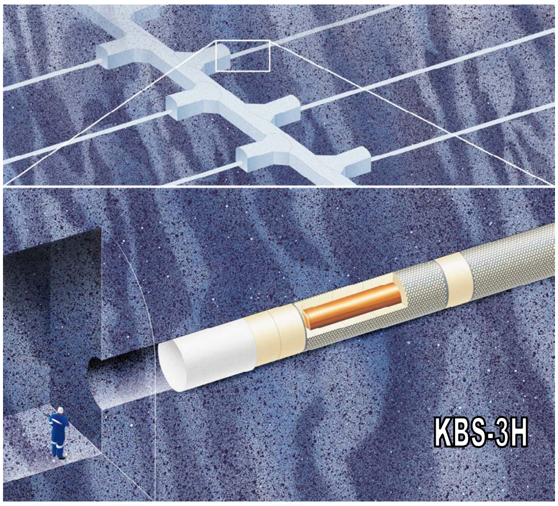
Evaluations of the artificial watering are in progress. The bentonite around the upper heater appears to be close to saturated, whereas the innermost parts of the blocks around the lower heater still are unsaturated.

A modelling meeting was held in Barcelona in November 2006 to discuss modelling results, evaluation of field test results, and the future operation of the field test.

Two tests are currently under consideration for possible implementation in the future. These are: a gas migration test in the vicinity of the upper heater, and a retrieval test of the upper heater. These tests are planned for 2008 and 2009, respectively.

To enable these tests, the buffer around the upper heater will have to be water saturated. This can be achieved through injecting water into the sand shield. The current plan is to saturate the shield during 2007.

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 fourth 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.
- Groundwater control by using a Mega Packer and steel plug.

Deposition Equipment

At deposition each copper canister and its buffer are assembled into a prefabricated Supercontainer. The tests that CNIM (Constructions Industrielles de la Mediterranee, France) performed in June showed that there are problems with the balance/rotation system for handling the Supercontainer. Therefore the equipment was modified (see earlier report) and tested in November. The balancing of the machine worked, but the cushions were still lifting to high. Test was done to lower the water pressure and several cushions were broken and these were sent to the manufacture for analysis. The plan today is to test new cushions in a Mock-up at ECA (subcontractor to CNIM) factory in December. The SAT will be performed when the deposition equipment works.

Low-pH shotcrete plug

The evolution by Esdred/AITEMIN from the test at Äspö is now presented in a report (Mod4-WP4-D8.1). Project KBS-3H will look into how and which parts that could be a benefit to this project.

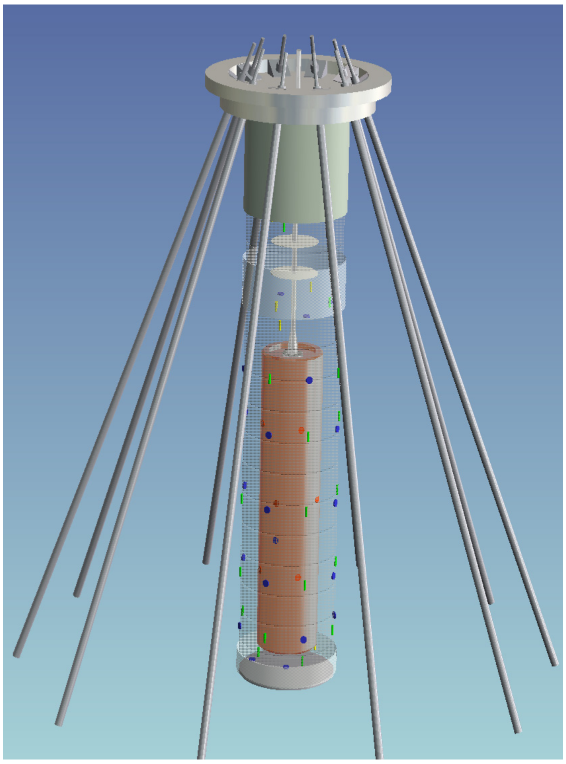
Mega packer

To handle inflow/leakage after the drifts are excavated there can be situations that need regrouting. A technique with a Mega packer will be tested in the 95 m drift. Inflow measuring has been done and shows five candidate fractures. A test of sealing band (at the manufacture) is planed and writing a test plan is in progress. The test of Mega packer at Äspö is planed to the second quarter of 2007.

Steel plug

If a drift has an inflow over 1 l/min from fractures and the grouting doesn't work as expected, the plan is to handle this by insulation between two steel plugs. A steel plug will be tested in the 15 m drift with the main objective to study the sealing efficiency and that the water leakage is maximum 0.1 l/min with 5 MPa (full hydrostatic pressure). Another objective is to study the strength of the steel plug. The documents for requirements and instrumentations are now being updated and the plan is to have the steel plug installed and ready for the test in the middle of May 2007.

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

Activities during this reporting period have focused on the continued hydration of the buffer. At present monitored porewater pressures within the clay remain rather low ranging from 85 kPa to 380 kPa. This is in contrast to the water pressure measured at the face of the deposition hole which ranges from 1240 kPa to 2605 kPa and is non-uniformly distributed across the rock face. Monitored radial stress around the canister continues to increase steadily ranging in value from 1450 kPa to 4970 kPa, with an average value of 3785 kPa. Analysis of the distribution in radial stress shows a narrow expanding zone of elevated stress propagating vertically upwards from the base of the hole. Stress measurements on the canister surface indicate radial stresses in the range 4350 kPa and 4550 kPa, which are comparable with the values of radial stress monitored on the rock face. Axial stress is significantly lower at 2920 kPa. Axial stress within the clay ranges from 3260 kPa to 5660 kPa and is non-uniformly distributed across the major axis of the emplacement hole. The average axial total stress within the bentonite is now greater than the initial pre-stress applied by the lid. Movement and distortion of the steel retaining lid has occurred following the installation and initial closure of packered intervals within the pressure relief holes.

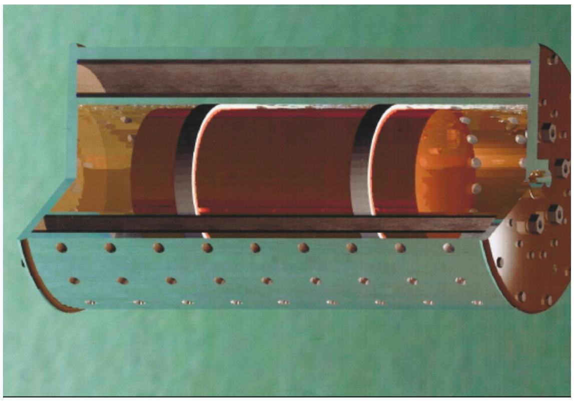
Estimates of effective stress (swelling pressure) at the rock face suggest values in the range of 70 to 3050 kPa with an average of around 1910 kPa. Suction data from devices located within the buffer above and beneath the canister indicate that a significant amount of the clay remains in suction.

Analysis of the flow data from the artificial hydration system suggests a disproportionably large flux from the canister filters compared to the hydration mats. This can be explained by a number of factors including compression of the filter mats (i.e. a reduction in permeability) or a zone of elevated permeability around the canister.

Problems of excessive pump wear caused by precipitation of dissolved mineral constituents from the Lasgit water supply have been investigated and remedial measures undertaken to prevent future problems.

The test has been in successful operation for in excess of 680 days. Since closure of the deposition hole there have been no instrumentation failures. The Lasgit experiment continues to yield high quality data amenable to the development and validation of process models aimed at repository performance assessment.

5.8 In Situ Corrosion Testing of Miniature Canisters



Miniature canister with support cage

Installation of first model canister assembly

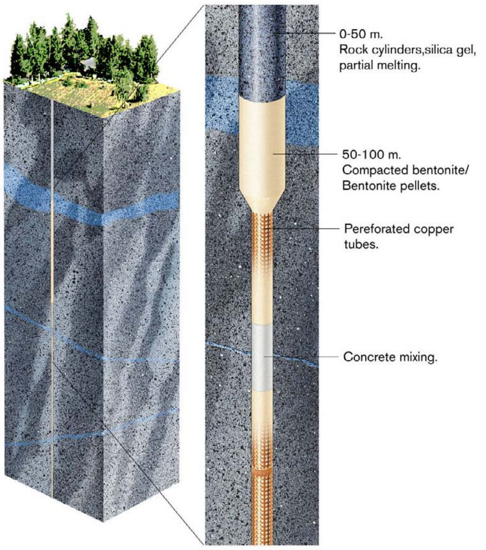
This project (MinCan) is designed to provide information about how the environment inside a copper canister containing a cast iron insert would evolve if failure of the outer copper shell were to occur. The development of the subsequent corrosion in the gap between the copper shell and the cast iron 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 October-December 2006 assembly of the last four model canisters at Culham in the UK was completed. The canisters were transported to the Äspö HRL in December. At the end of December three canisters were installed and installation of the remaining two will be completed in January 2007, at which point all five boreholes should be operational. One borehole will contain copper stress corrosion test pieces. The sensors in the canisters are being logged remotely and the data are being analysed at Culham. The experiments will be monitored for several years. A description of the experiment, together with preliminary results, will be presented at the Research in Progress symposium at the NACE Corrosion conference in the U.S. in March 2007.

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 project is in time and follows the original time schedule except for sub-project 4 (see below).

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”. Tests of the maturation rate are still in progress and will continue until the end of December. All data and experience from the sub-project will be presented in an IPR-report; a draft version was presented during December.

Sub-project 2 - Placement and testing of different borehole plugs in the 5 meters holes at the -450 m level in Äspö HRL. Field work is finished; the clay plugs are left in the holes at -450 m level. A draft version of the IPR-report was presented during 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. Clay plugs at -220 m level are not installed yet (low priority). The installation of the two plugs must be coordinated with the KBS-3H and other activities. A draft report will be presented during the end of December.

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. A copper plug has been installed at 3.5 m depth in one of the surface boreholes, after that a slot has been milled with the new tool. One slot has also been made in the second hole for the concrete plug. The slot is about 300 mm in height and 50 mm deep in the borehole wall. Casting of the quartz/cement plug in that hole was done during November. The field testing of the quartz/cement plug (QC-plug) at -450 m level will be delayed because of risk to disturb a hydro testing program that was going on until mid December.

Slot drilling for removing the plugs started during December. The rock column will be about 4.5 m in length and 0.6 m in diameter. Milling of all three holes at -450 m level was finished during November.

Shear testing of QC-plug has been made in the laboratory by CBI (Swedish Cement and Concrete Research Institute). A preliminary report has been delivered, and the results indicate that the shear strength is very high. According to the test the force to break a QC-plug should be up to 300 ton if the milled slot in the hole is 110 mm. The milling tools have been modified to make a 50 mm slot instead. Calculation and design of loading equipments for testing the shear strength of the plugs in the holes is in progress.

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 bentonite (MX-80).

The project will be carried out using material that according to laboratory studies are conceivable buffer materials. The experiment will be carried out in the same way and scale as the Long Term Test of Buffer Material (see section 5.2).

The objectives are to:

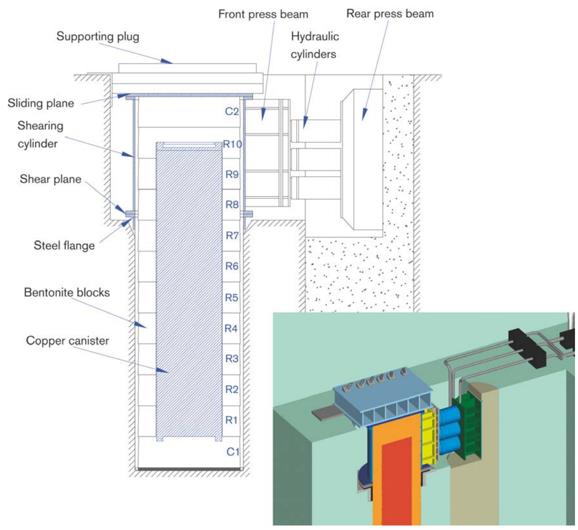
- Verify results from laboratory studies during more realistic conditions with respect to temperature, scale and geochemical circumstances.
- Discover possible problems with manufacturing and storage of bentonite blocks.
- Give further data for verification of thermo-hydro-mechanical (THM) and geochemical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

Achievements

During the last quarter the work with the assembly and installation of the packages was completed. All three packages are now installed. The monitor and heater systems are installed and tested. The artificial saturation system was installed and started in December 2006 together with the heaters.

A project meeting was held at Äspö and the project partners were informed about the development within the project. Discussions about the buffer analyses program were initiated. Daniel Svensson (SKB) is now responsible for the Analyses sub-project.

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 realise the plans has been taken but the time schedule is not yet set. No work has been done in 2006.

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 deep repository. 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 results from investigations concerning impact of copper ion in bentonite are available and a draft report is available. The investigations of transition from ion transfer in bentonite to electron transport in copper are still in progress, a draft report have been delivered, final report will be finished soon. All research and investigations will be compiled in a report were the focus will be on if and how geomagnetic induced currents or magnetic field could effect an underground repository.

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).

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

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

Achievements

A Task Force meeting was held in November in Barcelona where results from Tasks 1 and 2 were presented and discussed. In addition the new Task Force for geochemical processes was presented and a first meeting held.

For Task 1 three benchmark tests have been presented and modelled by the teams. Two tasks concerns the Spanish reference buffer material (Febex bentonite) and the other task concerns the Swedish reference buffer material (MX-80). The tasks were to model well documented laboratory tests of water uptake and temperature gradient induced water redistribution. The modelling results have been presented and compared to measurements. Decent agreements have been reached.

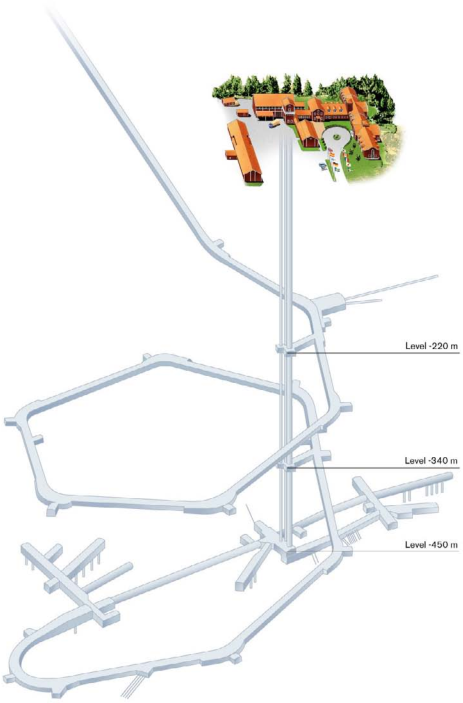
For Task 2 two benchmark tests have been presented and attempts made to model these tests. Both tasks concern gas break through in highly compacted water saturated MX-80. The modelling groups have had considerable problems in the modelling and so far the models used do not seem to be appropriate.

For Task 1 the subsequent modelling will concern large scale *in situ* tests. The Buffer/Container Experiment and the Isothermal Test carried out by AECL (Atomic Energy of Canada Limited) have been presented and will be modelled during next year.

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. Scheduled maintenance work has been performed on drainage system, elevator, electric- and ventilation systems. Extra maintenance work has been performed on the electric system of the elevator, where all sensors were replaced. The building of the laboratory for testing of bentonite materials is ongoing with planned completion of the building in March 2007.

Testing of the system for the registration of personnel (RFID) is ongoing with implementation of control of the ventilation system to the requirements. The system will be tested before the final inspection. The objective is to deliver the RFID-system to SKB during the first quarter 2007.

The reserve power system is being upgraded and a new emergency power and new cables in the tunnel are ordered. A new plan for work environment is ready and safety rounds have been performed according to the plan.

Environmental measurements of the air in the tunnel have been performed. The air quality is good and since the ventilation is increased from 18 to 22 m^3/s the concentration of radon is decreased about 25% to 310 Bq/m^3.

The final inspection of the building of the laboratory for testing of bentonite materials is put of to March 2007, due to delivery problems of building material.

The expansion of the fire alarm is put of until the first quarter of 2007 due to new regulations for the fire alarm centre. A new fire alarm centre will be installed in January 2007. SKB have decided to introduce a common entrance system for all facilities. A pre-study will be performed at the Äspö facility during January 2007. The time schedule for the new cables in the tunnel is put of to the first quarter due to scarcity of electricians.

Painting below ground will start up the first quarter 2007 with painting of machines and installations. During the last quarter 2006 the niche NASA 2715 A at -350 m has been painted as a test.

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 28,217 persons during 2006. Compared with last year this means an increase with 9%. The numbers of visitors to SKB's main facilities are listed in Table 6-1.

A new event introduces during 2006 was guided tours ended with a fire-eater show at -450 m level. The tours were open for the general public and held at the 11th of November and the 2nd of December. The arrangements were a success and a contribution to an event arranged by the municipality of Oskarshamn.

On the 9th of December the Äspö running competition was held in the Äspö-tunnel. Fifty participants ran all the way up from –450 meters depth. The length of the race is 3.5 km and the inclination is 14%. This has been an annual event since eight years.

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

SKB facility	Number of visitors 2006
Central interim storage facility for spent nuclear fuel	2,254
Canister Laboratory	2,653
Äspö HRL	10,768
Final repository for radioactive operational waste (SFR in Forsmark)	10,734

7 Environmental research

7.1 Äspö Research School

Kalmar University's Research School in Environmental Science at Äspö HRL, called Äspö Research School, started in October, 2002. This School is the result of an agreement between SKB and Kalmar University. It combines two important regional resources, i.e. Äspö HRL and Kalmar University's Environmental Science Section. The activity within the School will lead to: (a) development of new scientific knowledge, (b) increase of geo- and environmental-scientific competence in the region and (c) utilisation of the Äspö HRL for environmental research. Currently the scientific team consists of a professor of Environmental geology (Dr. Mats Åström), 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 October to December 2006, the following reports have been published and distributed.

9.1 Äspö International Progress Reports

Poteri A, 2005. True Block Scale continuation project. Evaluation of the BS2B sorbing tracer tests using the Posiva streamtube approach. IPR-05-36, Svensk Kärnbränslehantering AB.

Billaux D, 2005. True Block Scale continuation project. Analysis of reactive transport in a fault structure and associated background fractures. IPR-05-37, Svensk Kärnbränslehantering AB.

Fox A, Dershowitz W, Ziegler M, Uchida M, Takeuchi S, 2005. True Block Scale continuation project. BS2B experiment: Discrete fracture and channel network modeling of solute transport modeling in fault and non-fault structures. IPR-05-38, Svensk Kärnbränslehantering AB.

Cheng H, Cvetkovic V, 2005. TRUE Block Scale continuation project. Evaluation of the BS2B sorbing tracer tests using the LASAR approach. IPR-05-39, Svensk Kärnbränslehantering AB.

Haycox J R, Pettitt W S, 2006. Acoustic emission and ultrasonic monitoring results from deposition hole DA3545G01 in the Prototype Repository between October 2005 and March 2006. IPR-06-23, Svensk Kärnbränslehantering AB.

Christiansen B, 2006. A transformational, structural and natural occurrence study of green rust. IPR-06-24, Svensk Kärnbränslehantering AB.

Goudarzi R, Johannesson L-E, 2006. Prototype Repository. Sensors data report (Period: 010917-060601). Report No:15. IPR-06-26, Svensk Kärnbränslehantering AB.

Goudarzi R, Åkesson M, Hökmark H, 2006. Temperature Buffer Test. Sensors data report (Period: 030326-060701) Report No:8. IPR-06-27, Svensk Kärnbränslehantering AB.

Äspö Hard Rock Laboratory. Status Report. July - September 2006. IPR-06-33, Svensk Kärnbränslehantering AB.

9.2 Technical Documents and International Technical Documents

No Technical Document has been published during the fourth quarter 2006.

10 References

Billaux D, 2005. TRUE Block Scale continuation project. Analysis of reactive transport in a fault structure and associated background fractures. IPR-05-37, Svensk Kärnbränslehantering AB.

Börgesson L, Sandèn T, Johannesson L-E, Knutsson H, 2004. ROSE, Rock Shear Experiment. A feasibility study. IPR-06-13, Svensk Kärnbränslehantering AB.

Cheng H, Cvetkovic V, 2005. TRUE Block Scale continuation project. Evaluation of the BS2B sorbing tracer tests using the LASAR approach. IPR-05-39, Svensk Kärnbränslehantering AB.

Cheng H, Cvetkovic V, Winberg A, Dershowitz W, 2006. Estimating retention properties of components of a block scale fracture network – an example from the Äspö Hard Rock Laboratory, Sweden., Eos Trans. American Geophysical Union, 87(52), Fall Meet. Suppl., Abstract H13D-1434.

Chi Fru E, 2006. Molecular characterization of the microbial diversity in natural and engineered intraterrestrial environments – A focus on igneous rock aquifers. Thesis. Department of Cell and MolecularBiology, GöteborgUniversity, Göteborg, Sweden, ISBN 91-628-6955-8.

Christiansen B, 2006. A transformational, structural and natural occurrence study of green rust. IPR-06-24, Svensk Kärnbränslehantering AB.

Fox A, Dershowitz W, Ziegler M, Uchida M, Takeuchi S, 2005. TRUE Block Scale continuation project. BS2B experiment: Discrete fracture and channel network modeling of solute transport modeling in fault and non-fault structures. IPR-05-38, Svensk Kärnbränslehantering AB.

Goudarzi R, Johannesson L-E, 2006. Prototype Repository. Sensors data report (Period: 010917-060601). Report No:15. IPR-06-26, Svensk Kärnbränslehantering AB.

Goudarzi R, Åkesson M, Hökmark H, 2006. Temperature Buffer Test. Sensors data report (Period: 030326-060701) Report No:8. IPR-06-27, Svensk Kärnbränslehantering AB.

Haycox J R, Pettitt W S, 2006. Acoustic emission ultrasonic monitoring results from deposition hole DA3545G01 in the Prototype Repository, IPR 06-23, Svensk Kärnbränslehantering AB.

Itasca Consulting Group, Inc., 2003. 3DEC – 3 dimensional distinct element code. User's manual. Itasca, Minneapolis.

Jansson M, Eriksen T E, Moreno L, 2006. Influence of water radiolysis on the mobilization of Tc(IV) in bentonite clay. Results from field experiments at Äspö. TR-04-22, Svensk Kärnbränslehantering AB.

Johnsson A, 2006. The role of bioligands in Microbe-Metal interactions. Emphasis on subsurface bacteria and actinides. Thesis, Department of Cell and MolecularBiology, GöteborgUniversity, Göteborg, Sweden, ISBN-91-628-6976-0.

Mas Ivars D, 2005. Äspö Pillar Stability Experiment. Hydromechanical data acquisition experiment at the APSE site. IPR-05-21, Svensk Kärnbränslehantering AB

Nyberg G, Jönsson S, Wass E, 2006. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2005. IPR-06-14, Svensk Kärnbränslehantering AB.

Poteri A, 2005. TRUE Block Scale continuation project. Evaluation of the BS2B sorbing tracer tests using the Posiva streamtube approach. IPR-05-36, Svensk Kärnbränslehantering AB.

Poteri A, Cvetkovic V, Dershowitz W, Billaux D, 2006. Illustration of uncertainties in assessments of flow and transport in a block scale fracture network – an example from the Äspö Hard Rock Laboratory, Sweden., Eos Trans. American Geophysical Union, 87(52), Fall Meet. Suppl., Abstract H12A-07.

SKB, 2004. RD&D-Programme 2004. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste. TR-04-21, Svensk Kärnbränslehantering AB.

SKB, 2006a. Äspö Hard Rock Laboratory. Planning Report for 2006. IPR-06-06, Svensk Kärnbränslehantering AB.

SKB, 2006b. Äspö Hard Rock Laboratory. Annual Report 2005. TR-06-10, Svensk Kärnbränslehantering AB.

Skovbjerg L L, 2005. Reduction of hexavalent chromium by green rust sulphate: Determination of end product and reduction mechanism. IPR-06-25, Svensk Kärnbränslehantering AB.

Smellie J, Waberg N, Frape S, 2003. Matrix fluid chemistry experiment. Final report. June 1998-March 2003. TR-03-18, Svensk Kärnbränslehantering AB.