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Progress Report

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Äspö Hard Rock Laboratory

Status Report
January– March 2007

Svensk Kärnbränslehantering AB

June 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

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Author
Kemakta
Date
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Checked by
Date

Approved
Anders Sjöland
Date
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Overview

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

The plans for SKB's research and development of technique during the period 2005–2010 are presented in SKB's RD&D-Programme 2004 /SKB 2004/. The information given in the RD&D-Programme related to Äspö HRL is annually detailed in the Äspö HRL Planning Report /SKB 2007/.

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

Geoscience

Geoscientific research is a natural part of the activities at Äspö HRL and is conducted in the fields of geology, hydrogeology, geochemistry (with emphasis on groundwater chemistry) and rock mechanics. The major aims are to establish and maintain geoscientific models of the Äspö HRL rock mass and to establish and develop the understanding of the Äspö HRL rock mass properties as well as the knowledge of applicable measurement methods. Studies are performed within the projects: Geological Mapping and Modelling, Method Development of a New Technique for Underground Surveying, Hydro Monitoring Programme, Monitoring of Groundwater Chemistry, Rock Mechanics and Äspö Pillar Stability Experiment.

Natural barriers

Many experiments in Äspö HRL are related to the rock, its properties and *in situ* environmental conditions. The goals are to increase the scientific knowledge of the safety margins of 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, Radionuclide Retention Experiments and Swiw-tests with synthetic groundwater.

Tests of models for groundwater flow, radionuclide migration and chemical/biological processes are one main purpose of the Äspö HRL. The major project is the Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes.

Engineered barriers

One of the goals for Äspö HRL is to demonstrate technology for and function of important parts of the repository system. This implies translation of current scientific knowledge and state-of-the-art technology into engineering practice applicable in a real repository. A number of large-scale field experiments are therefore conducted or planned at Äspö HRL: Prototype Repository, Long Term Test of Buffer Material, Alternative Buffer Materials, Backfill and Plug Test, Canister Retrieval Test, Temperature Buffer Test, KBS-3 Method with Horizontal Emplacement, Large Scale Gas Injection Test, In Situ Corrosion Testing of Miniature Canisters, Cleaning and Sealing of Investigation Boreholes, Rock Shear Experiment and Earth Potentials.

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

Äspö facility

The Äspö facility comprises of the Hard Rock Laboratory that was taken in operation in 1995 and the Bentonite Laboratory that was constructed during 2006 and the inauguration took place in March 2007. An important part of the activities at the Äspö facility is the administration, operation, and maintenance of instruments as well as the development of investigation methods. The Public Relations and Visitor Services group is responsible for presenting information about SKB and its facilities e.g. the Äspö HRL. They arrange visits to the facilities all year around as well as special events.

Environmental research

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

International co-operation

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

Contents

1 General

The Äspö Hard Rock Laboratory (HRL), in the Simpevarp area in the municipality of Oskarshamn, constitutes an important part of SKB's work with design and construction of a deep geological repository for final disposal of spent nuclear fuel.

One of the fundamental reasons behind SKB's decision to construct an underground laboratory was to create an opportunity for research, development and demonstration in a realistic and undisturbed rock environment down to repository depth. The underground part of the laboratory consists of a tunnel from the Simpevarp peninsula to the southern part of Äspö where the tunnel continues in a spiral down to a depth of 460 m. The rock volume and the available underground excavations have to be divided between all the experiments performed at the Äspö HRL. In Figure 1-1, the allocation of a selection of the experimental sites in Äspö HRL is shown.

The Äspö HRL and the associated research, development and demonstration tasks have so far attracted considerable international interest. During 2007, nine organisations from eight countries participate in the co-operation or in related activities at Äspö HRL.

SKB's overall plans for research, development and demonstration during the period 2005–2010 are presented in SKB's RD&D-Programme 2004 /SKB 2004/. The 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 2007/ for more background information. The Annual Report will in detail present and summarise new findings and results obtained during the present year.

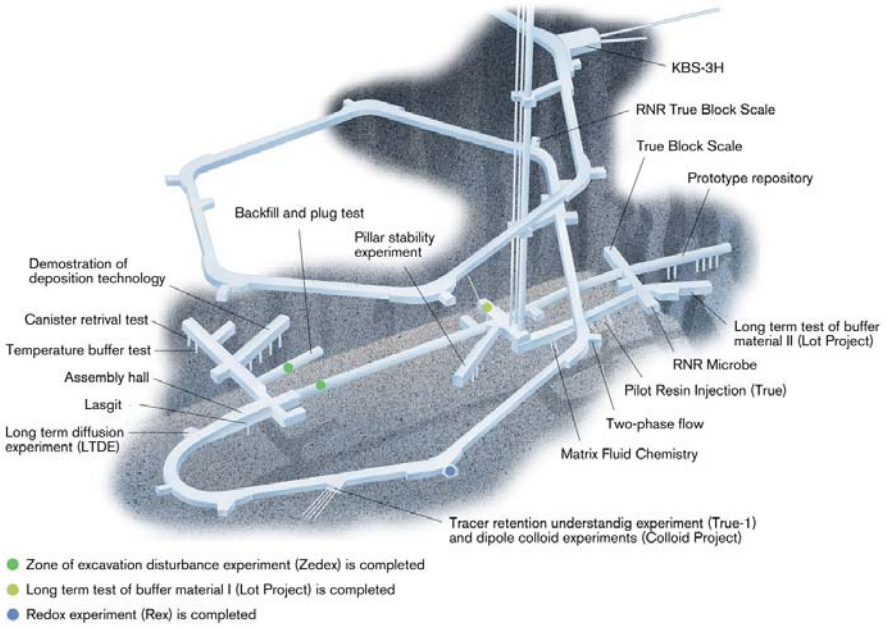


Figure 1-1. *Allocation of some of the experimental sites in Äspö HRL from -220 m to -450 m level.*

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

The activities further aim to provide geoscientific base data and to ensure high quality of experiments and measurements related to geosciences. From 2006 the work at Äspö HRL follows a geoscientific programme. The yearly updating of the programme, covering the period 2007–2009, is in progress. The work with a project plan for the development of Äspö Site Description 2008 has just started. This more long-term geoscientific work is, however, delayed due to limited personnel resources.

2.1 Geology

Geological work at Äspö HRL is focused on several main fields. Major responsibilities are mapping of tunnels, deposition holes and drill cores, as well as continuous updating of the geological three-dimensional model of the Äspö rock volume and contribution with input knowledge in projects and experiments conducted at Äspö HRL. In addition, development of new methods in the field of geology is a major responsibility. As a part of the latter, the Rock Characterisation System (RoCS) feasibility study is being conducted.

2.1.1 Geological Mapping and Modelling

Ultrasonic measurements performed in the TASQ (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.

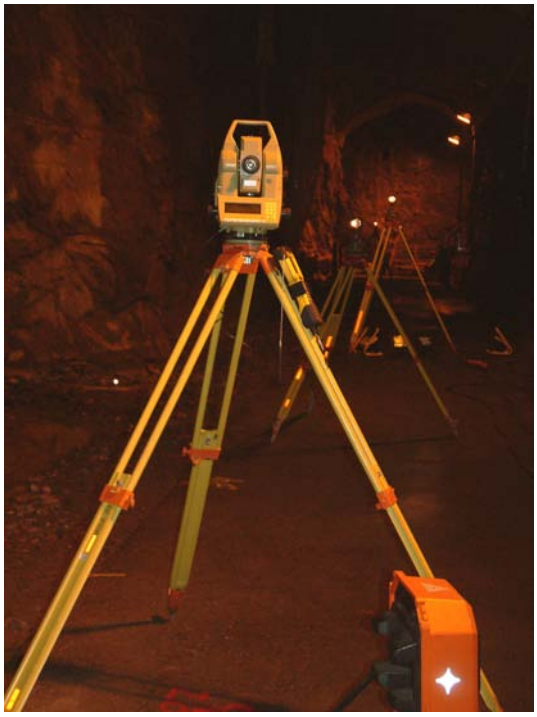
Achievements

The main activities during the first quarter of 2007 are:

- The GeoVista report concerning magnetic anisotropy as a tool to verify the true width of deformation zones is now published /Mattsson 2006/.
- Decovalex drill cores from the TASQ-tunnel have been logged.
- The geological mapping of the niche NASQ0036A has been digitised and associated data fed into TMS (Tunnel Mapping System). However, quality control remains and some earlier mapping still needs to be entered into the TMS.
- The core logging facilities at Äspö has been equipped with a new computer and screen and the Äspö rock types can once again be used in the logging tool Boremap.
- The work to put up signs showing some of the deformation zones in the Äspö tunnel is almost completed, see Figure 2-1. These zones are already established and named on the ground surface and therefore the same names have been used underground.

Figure 2-1. *A part of what has been defined as a plastic-brittle deformation zone in the Äspö tunnel (photo: Björn Magnor).*

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 Rock Characterisation System (RoCS) is conducted as an SKB-Posiva joint-project.

The purpose is to investigate if a new system for rock characterisation has to be adopted when constructing a final repository. The major reasons for the RoCS project are aspects on objectivity of the data collected, traceability of the mappings performed, saving of time required for mapping and data treatment and precision in mapping. These aspects all represent areas where the present mapping technique may not be adequate.

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

Achievements

A draft version of a report concerning the suitability of using laser scanning to measure the geometry of a deposition hole has been delivered. Parameters such as coneness, wall roughness, longitudinal steps and waviness of the hole were measured to see if these parameters were within tolerable limits. The report has been reviewed and returned to the authors (Berg Bygg Konsult AB) for adjustments.

The RoCS feasibility report is delayed and is now waiting for the “approval and review page” to be signed by and returned from Posiva in order to finalise the report. The conclusion is that laser scanning combined with digital photography is believed to be suitable tools in a new rock characterisation system.

A meeting was held in February where ATS (Advanced Technical Solutions AB) demonstrated the proceedings of the results of the laser scanning (see Figure 2-2) and also delivered a viewer with which scan-data could be handled to a certain extent. A report concerning the laser scanning of the TASQ-tunnel is in progress.

Figure 2-2. *Laser scanning of a vertical deposition hole performed by Berg Bygg Konsult AB. The laser scanner (not shown in the picture) had to be mounted up side down under the lift cage.*

2.2 Hydrogeology

The major aims of the hydrogeological activities are to:

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

One main task is the development of the integrated Äspö site description. The numerical groundwater flow and transport model is an important part of the site description. The groundwater model is to be continuously developed and calibrated. The intention is to develop the model to a tool that can be used for predictions, to support the experiments, and to test hydrogeological hypotheses. The work with a more detailed hydro-structural model of the –450 m level continues.

Another task is the development of a more detailed model of hydraulically conductive structures at the main experimental levels below –400 m level.

The effects of blasts in and around the Äspö HRL and the impact of earthquakes in Sweden and abroad will be analysed and documented. As a first step, any disturbances that can be coupled to the blasting of the TASQ-tunnel will be identified, and as a second step, possible effects of some blasts for the Clab-2 construction will be investigated. The effects of the earthquakes will also be documented. The work is a reference for the understanding of dynamic influences on the groundwater around a future final repository.

2.2.1 Hydro Monitoring Programme

The hydro monitoring programme is an important part of the hydrogeological research and a support to the experiments undertaken in the HRL. The programme had also had legal grounds. It was conditioned by the water rights court, when granting the permission to execute the construction works for the tunnel, that a monitoring programme should be put in place and that the groundwater head conditions should continue to be monitored until the year 2004.
The monitoring of water level in surface boreholes started in 1987 while the computerised Hydro Monitoring System (HMS) was introduced in 1992. The HMS collects data on-line of pressure, levels, flow and electrical conductivity of the groundwater. The data are recorded by numerous transducers installed in boreholes and in the tunnel. The number of boreholes included in the monitoring programme has gradually increased, and comprise boreholes in the tunnel in the Äspö HRL as well as surface boreholes on the islands of Äspö, Ävrö, Mjälen, Bockholmen, and some boreholes on the mainland at Laxemar. The tunnel construction started in October 1990 and the first pressure measurements from tunnel drilled boreholes were included in the HMS in March 1992. The tunnel excavation began to affect the groundwater level in many surface boreholes during the spring 1991.
Weekly quality checks of preliminary groundwater head data are performed. Absolute calibration of data is performed three to four times per year. This work involves comparison with groundwater levels checked manually in boreholes.

Achievements

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

- Extension of the measurement system for temperature, humidity and pressure of tunnel air.
- Quality check and calibration of data from the surface boreholes in January.
- Preparations for automatic transfer of data from the HMS to the data base Sicada.

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. Instrumentation, measurement methods and the monitoring during 2005 is described in /Nyberg *et al.* 2006/.

2.3 Geochemistry

The major aims within geochemistry are to:

- Establish and develop the understanding of the hydrogeochemical properties of the Äspö HRL rock volume.
- Maintain and develop the knowledge of applicable measuring and analytical methods.
- Ensure that experimental sampling programmes are performed with high quality and meet overall goals within the field area.

One of the overall main tasks within the geoscientific programme is to develop an integrated site description of the Äspö HRL. The use of the achieved knowledge will facilitate the understanding of the geochemical conditions and the development of underground facilities in operation. The intention is to develop the model as to be used for predictions, to support and plan experiments, and to test hydrogeochemical hypotheses. This is important in terms of distinguishing undisturbed and disturbed conditions. In general hydrogeochemical support is provided to active and planned experiments at Äspö HRL.

2.3.1 Monitoring of Groundwater Chemistry

During the 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

Major emphasis has been put into completing the quality assurance of the data in the Sicada database regarding hydrogeochemistry data reported during the last years regarding all the Äspö projects.

2.4 Rock Mechanics

Rock Mechanic studies are performed with the aims to increase the understanding of the mechanical properties of the rock but also to recommend methods for measurements and analyses. This is done by laboratory experiments and modelling at different scales and comprises:

- Natural conditions and dynamic processes in natural rock.
- Influences of mechanical, thermal, and hydraulic processes in the near-field rock including effects of the backfill.

2.4.1 Stress Measurements - Core Disking

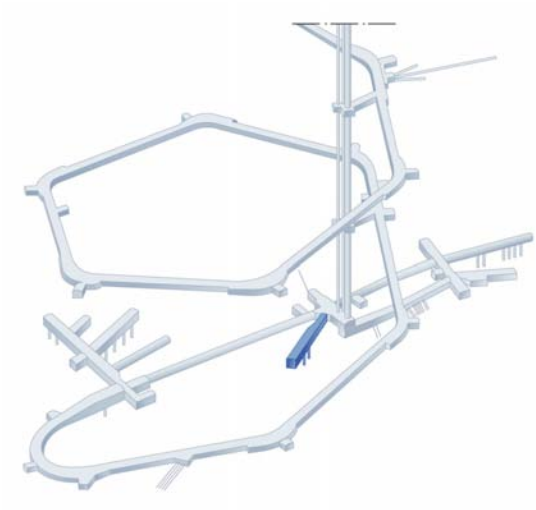
The purpose of the project is to study the conditions under which core disking occur by drilling in the vicinity of the area for the Äspö Pillar Stability Experiment.

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 is needed to interpret the influence of geological structures on the local stress conditions. This work has been delayed due to lack of resources as the on-going site investigations took all resources. 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. The project was finalised during 2006.

Achievements

The project was successfully finished during 2006. The results have been published both as a PhD thesis /Andersson 2007a/ and as an SKB report /Andersson 2007b/. Important findings are that the yielding strength of the rock mass has been successfully determined, low confinement pressures significantly affects the onset of yielding, the primary mode of fracture initiation and propagation is extensional, no significant time dependency of the yielding process was observed. The unloading studies also indicate that what appeared to be shear bands likely was a propagating zone of extensile failure that weakened the rock so that displacements in the shear direction could occur.

3 Natural barriers

At the Äspö HRL, experiments are performed at conditions that are expected to prevail at repository depth. The experiments are related to the rock, its properties, and *in situ* environmental conditions. The goals are to increase the scientific knowledge of the safety margins of the repository and to provide data for performance and safety assessment and thereby clearly present the role of the geosphere for the barrier functions: isolation, retardation and dilution. As an example, the processes that influence migration of species along a natural rock fracture are shown in Figure 3-1.

Tests of models for groundwater flow, radionuclide migration and chemical/biological processes are one of the main purposes of the Äspö HRL. The programme includes projects with the aim to evaluate the usefulness and reliability of different models and to develop and test methods for determination of parameters required as input to the models.

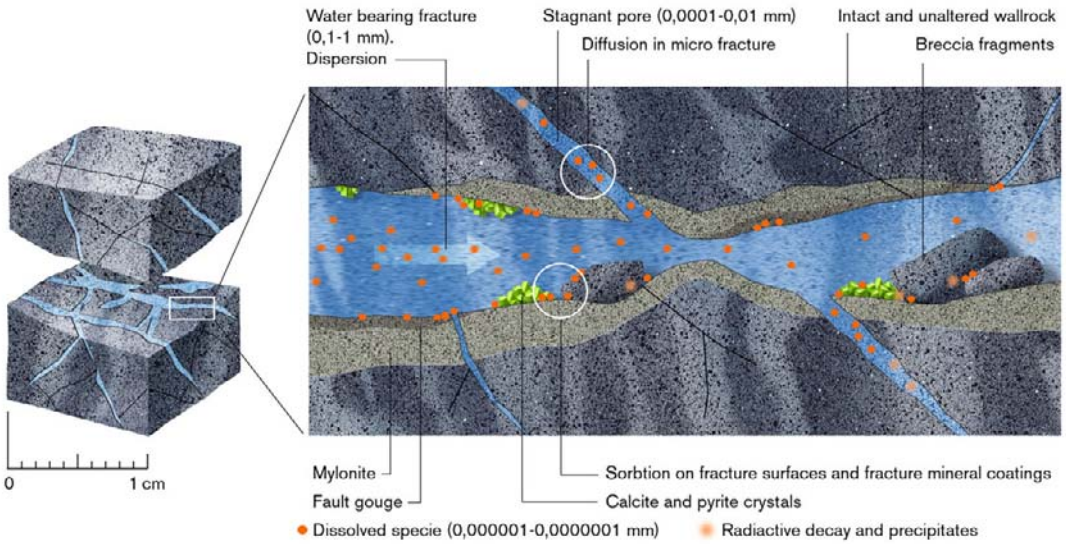
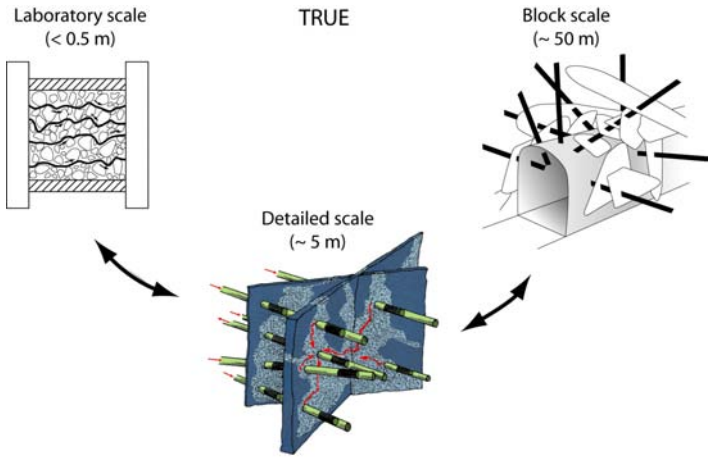


Figure 3-1. *Processes that influence migration of species along a natural rock fracture.*

3.1 Tracer Retention Understanding Experiments



Tracer tests with non-sorbing and sorbing tracers are carried out in the True family of projects. These are conducted at different scales; laboratory scale (< 0.5 m), detailed scale (<10 m) and block scale (up to 100 m) with the aim to improve understanding of transport and retention in fractured rock. The work includes building of hydrostructural models and conceptual microstructure models. Numerical models are used to assess the relative contribution of flow-field related effects and acting processes (diffusion and sorption) on *in situ* retention.

The first *in situ* experiment (True-1) performed in the detailed scale and the True Block Scale series of experiments have come to their respective conclusion. Complementary field work and modelling are performed as part of two separate but closely coordinated continuation projects.

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

In the True-1 Continuation and Completion projects the objectives are to obtain insight in the internal structure of the investigated feature and to study fixation of sorbing radioactive tracers. Prior to the resin injection in Feature A complementary hydraulic and tracer tests are performed to better understand Feature A and its relation to the surrounding fracture network. In addition, a dress rehearsal of *in situ* resin injection is realised through a characterisation project focused on fault rock zones.

3.1.1 True Block Scale Continuation

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

Achievements

The project True Block Scale Continuation (BS2) is now completed and the final report is published /Andersson *et al*. 2007/.

Within the continuation of the True Block Scale project (BS3), work during the first quarter of 2007 has so far mainly been focused on the incorporation of new experimental data (image analysis of fault gouge and sorption experiments on fault gouge and rim zone materials) for constraining True retention parameter estimates. The analysis of available experimental data (K_d, K_a etc) has been deepened including comparison of estimations with the experimental data. A draft report on this activity has been prepared with a final draft to be delivered in April.

3.1.2 True-1 Continuation

The True-1 Continuation project is a continuation of the True-1 experiments and the experimental focus is primarily on the True-1 site. The continuation includes performance of the planned injection of epoxy resin in Feature A at the True-1 site and subsequent 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

During the period work has been made in conjunction with production of True-1 papers, Fault Rock Zones Characterisation project and on Complementary sorption experiments on fault gouge and fracture rim zone material.

True-1 papers: The first two of a series of three papers have been updated according to reviewers' comments and have been submitted to the Water Resources Research journal. Upon acceptance of the articles the third concluding paper will be submitted.

Fault Rock Zones Characterisation: During the first quarter, the work on the final report has continued. And internal review of progress report reporting the methodology and results of the image analysis of overcored and sectioned samples from borehole KA2423A03 has been performed. Update of the report to final version remains.

Complementary laboratory sorption experiments on fault gouge and rim zone materials: Internal review of the completed parts of the report accounting for experimentation on materials from various localities along the Äspö HRL access tunnel has been performed. The results of the leaching part remain to be done followed by completion of the report.

3.1.3 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 on-going 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.

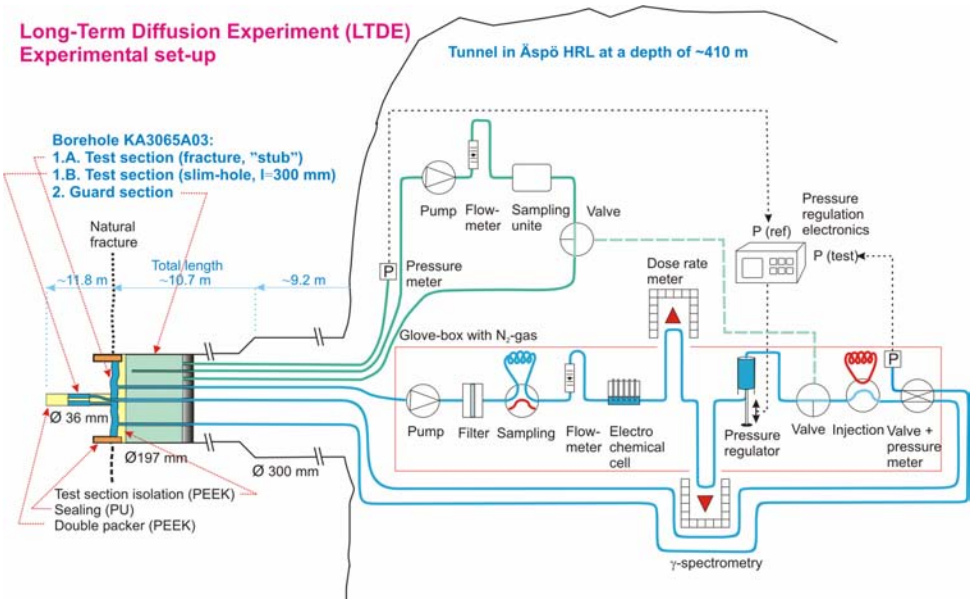
Achievements

The tracer tests performed in field during 2006 was evaluated during the first quarter of 2007. Preliminary results from the cation exchange capacity (CEC) test display a higher CEC than expected prior to the test. Final evaluation of the tests as well as comparison between the tests and reporting of the results are on-going.

Up-coming activities were extensively planned during the period. These activities include epoxy injection, over-coring and subsequent analysis of the core material.

During the last week of the period, epoxy was injected in two borehole sections. 4.1 litre epoxy was injected in KXTT3:S3. It was more difficult to inject epoxy in KXTT4:T3. Hence, only 0.4 litre epoxy was injected there. However, despite the relatively small volume of epoxy injected in KXTT4:T3, it was still considered enough to facilitate the sub-sequent over-coring and analysis.

3.2 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 have been circulated over a period of 5-7 months after which the borehole will be over-cored and analysed for tracer content.

Achievements

During the first quarter 2007 the sorption diffusion experiment has been running according to plan. The radioactivity concentration of the gamma emitting tracers in the test section groundwater has been measured on-line by an HPGe-detector (High-Purity Germanium). 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. Normalised radionuclide concentrations in groundwater in the test section are shown in Figure 3-2.

Preparations have been carried out for final sampling and extraction of the core stub and the rock surrounding the small diameter extension borehole by over-core drilling.

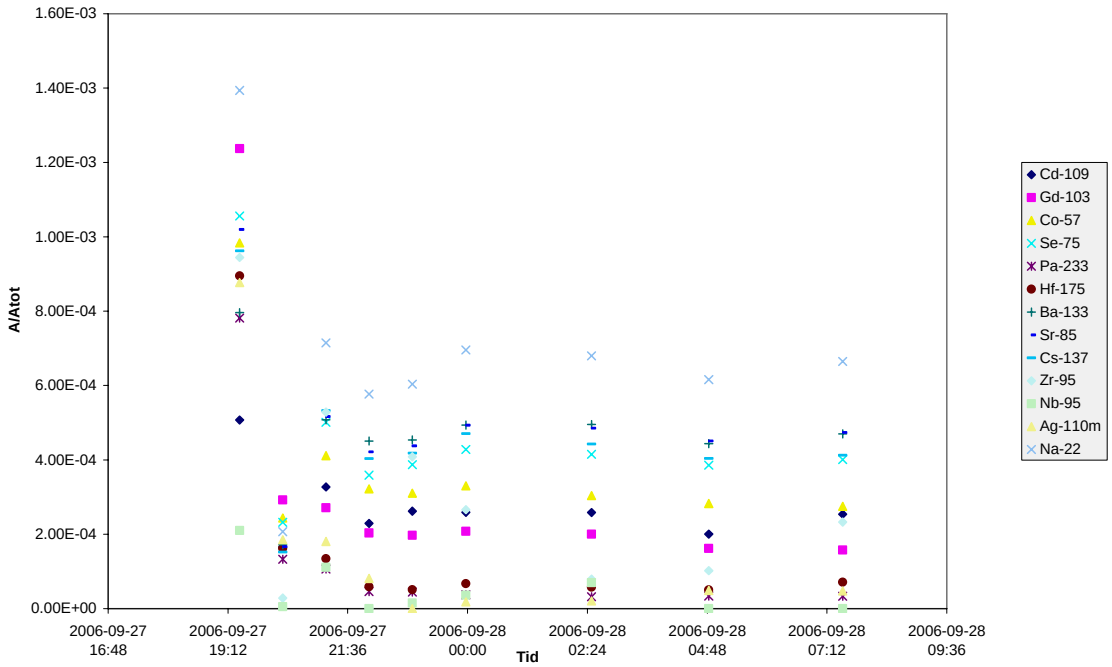
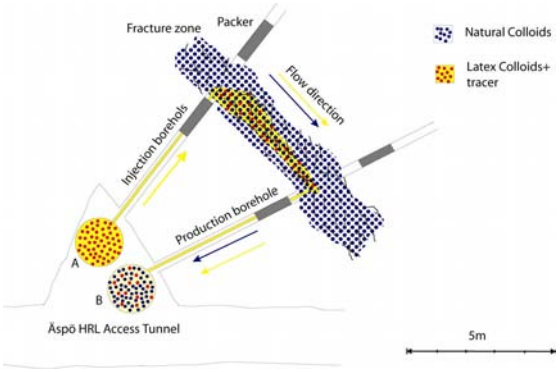


Figure 3-2. *Sorption diffusion in situ experiment. Radionuclide concentrations (normalised) in test section groundwater the first 24 hours after injection.*

3.3 Colloid Project



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

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

Achievements

The main activities during the first quarter 2007 are:

- Bentonite colloid studies in Äspö groundwater performed at FZK-INE (Forschungszentrum Karlsruhe Institut für Nukleare Entsorgung). An abstract is submitted to Migration conference and the article will be written in August.
- Bentonite and latex colloid transport in low to higher flows in diluted waters in a water bearing fracture in a quarried block in the laboratory at AECL, Whiteshell, Canada. An abstract is submitted to Migration conference and the article will be written in August.
- Bentonite colloid stability experiments in varying conditions performed in the laboratory at the Royal Institute of Technology. The aim is to establish critical coagulation concentrations (CCC) for Na- and Ca-bentonite by kinetic studies. Submitted for publication the 1st of April 2007.
- Bentonite colloid stability experiments with varying pH and temperature performed at the Royal Institute of Technology. Evaluation of the data is finished and a manuscript is in preparation.
- Modelling of colloid transport data from quarried block at AECL in progress at the Royal Institute of Technology.
- Preparation of a new project plan.

3.4 Microbe Project

3.4.1 The Microbe laboratory and the Bios site

The Microbe laboratory and the Bios site have been installed in the Äspö HRL for studies of microbial processes in groundwater under *in situ* conditions. The major objectives are to:

- Offer proper circumstances for research on the effect of microbial activity on the long-term chemical stability of the repository environment.
- Provide *in situ* conditions for the study of bio-mobilisation of radionuclides.
- Present a range of conditions relevant for the study of bio-immobilisation of radionuclides.
- Enable investigations of bio-corrosion of copper under conditions relevant for a high level radioactive waste repository.
- Constitute a reference site for testing and development of methods used in the site investigations.

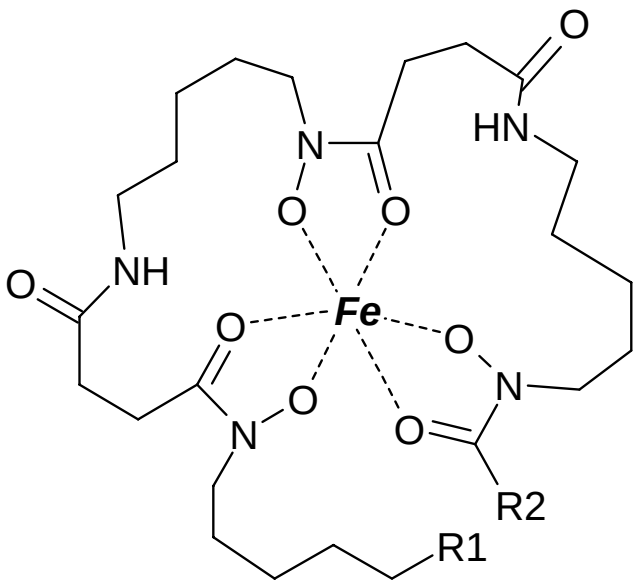
The Microbe site is on the -450 m level where a laboratory container with benches, an anaerobic gas box and an advanced climate control system is located (image above). Three boreholes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures are connected to the Microbe laboratory via tubing. Each borehole has been equipped with a circulation system offering 2,112 cm^2 of test surface.

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

Achievements

The main activities during January to March have been use of Microbe as a base laboratory for sampling of the Prototype repository and Bios at 2,200 m tunnel length. New results comprise the discovery of bacteriophages in Äspö groundwater. A phage is a virus that infects bacteria. This result came out of the Canadian-Swedish joint work executed in November 2006. Reporting and publication is on-going. High sulphide concentrations up to 57 mg L^{-1} and high concentrations of hydrogen (7-15 mL L^{-1}) in water extracted from the backfill of the Prototype was obtained in February. It is assumed that the hydrogen originates from anaerobic corrosion processes in the Prototype. New sampling and measurements will be performed during spring 2007 to further explore this new finding.

3.4.2 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.

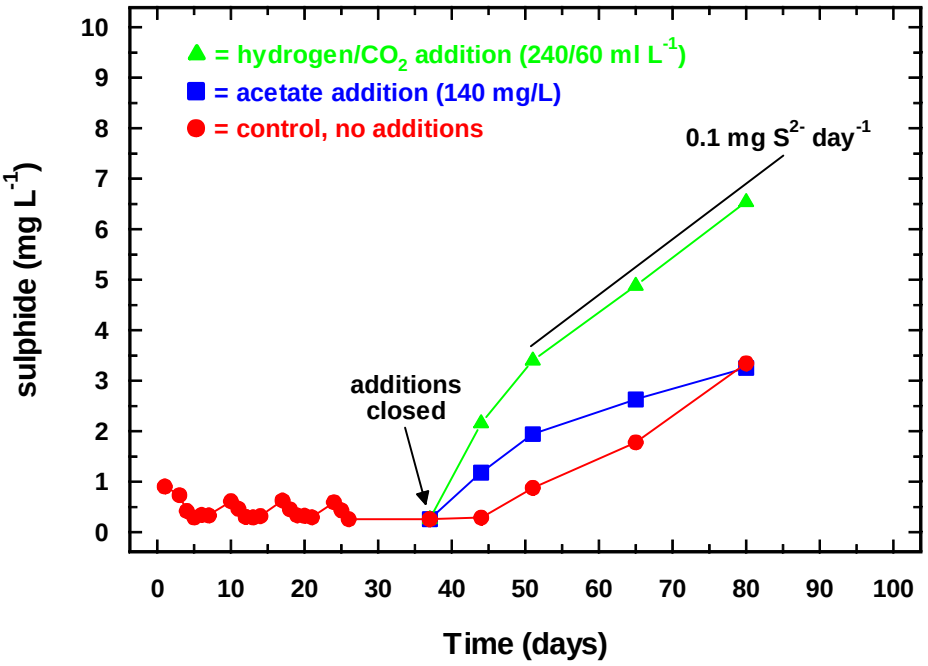
The work within Micomig will:

- 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 during January-March has been construction of new equipment for placement in the laboratory. It comprises three circulation systems that will be used for radionuclide transport experiments. Biofilms have been found to influence radionuclide retention processes /Anderson *et al.* 2006/. Work has, therefore, been initiated to explore the composition of microbial biofilms with molecular methods (DNA-technology).

3.4.3 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.

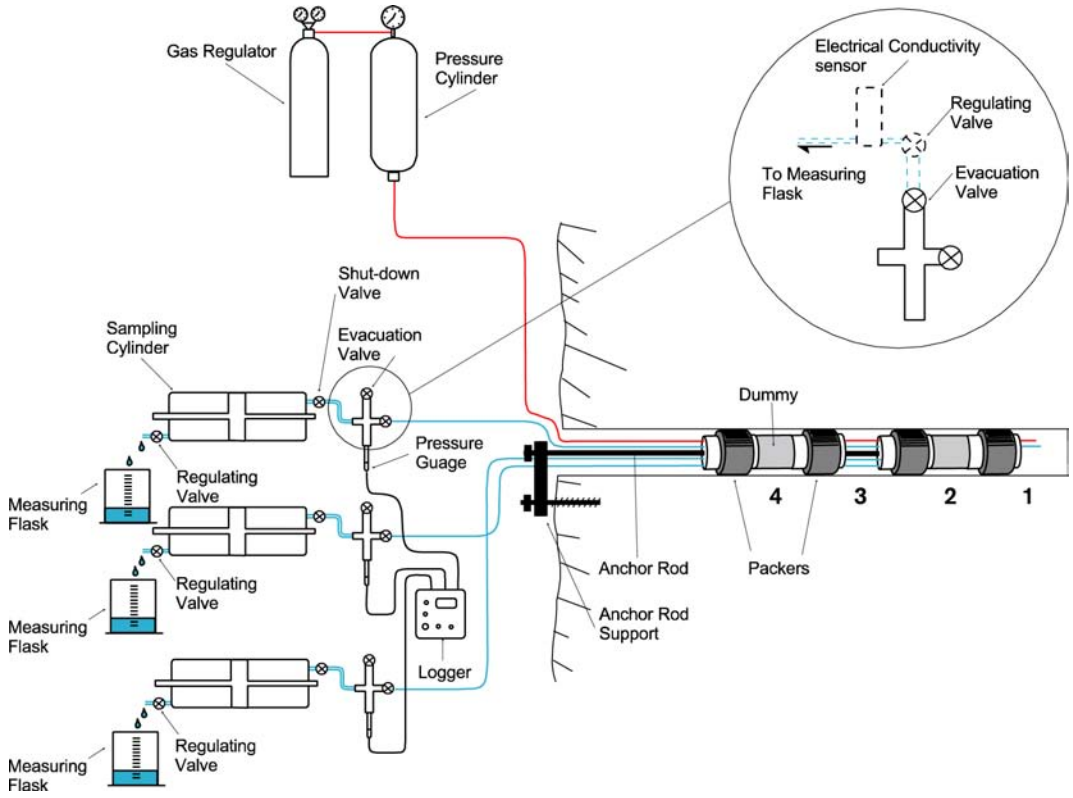
The work within the Micored project will:

- 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 understanding of microbial redox processes in repository environments requires data from controlled experiments with microorganisms in the laboratory. Therefore, an archive of pure cultures of anaerobic microorganisms from deep groundwater in Sweden and Finland is under construction. The growth cycle time for those organisms can be up to 10 weeks or more. This project is therefore a long time commitment. All microorganisms in the archive are characterised with molecular methods (DNA-technique). The archive organisms can be made accessible for organisations that need relevant microorganisms for their modelling work.

3.5 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.

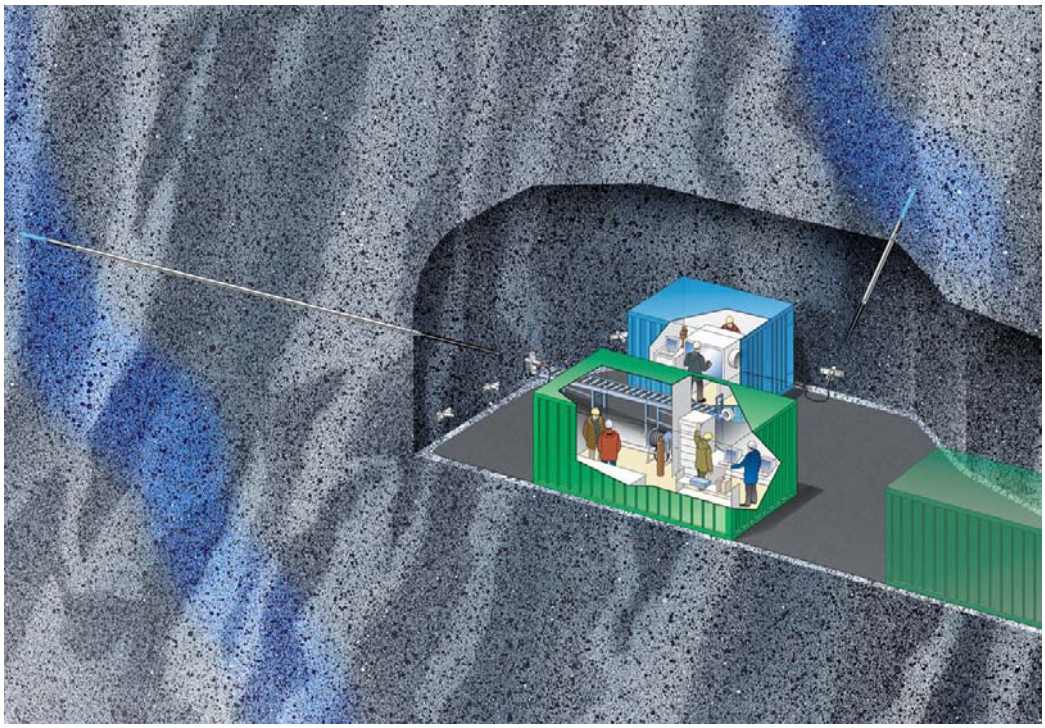
A first phase of the project is finalised and reported /Smellie *et al*. 2003/. The major conclusion is that pore water can successfully be sampled from the rock matrix and there is no major difference in chemistry compared to groundwaters from more highly conductive fracture zones in the near-vicinity.

Achievements

No results were expected from the first quarter of 2007. Analytical data for matrix water collected at the end of 2005 are almost complete.

Reporting of the hydraulic testing programme is underway and scheduled for the end of the next quarter.

3.6 Radionuclide Retention Experiments



Radionuclide Retention Experiments are carried out with the aim to confirm results of laboratory studies *in situ*, where natural conditions prevail concerning e.g. redox conditions, contents of colloids, organic matter and bacteria in the groundwater.

The experiments are carried out in special borehole laboratories, Chemlab 1 and Chemlab 2, designed for different kinds of *in situ* experiments. The laboratories are installed in boreholes and experiments can be carried out on bentonite samples and on tiny rock fractures in drill cores.

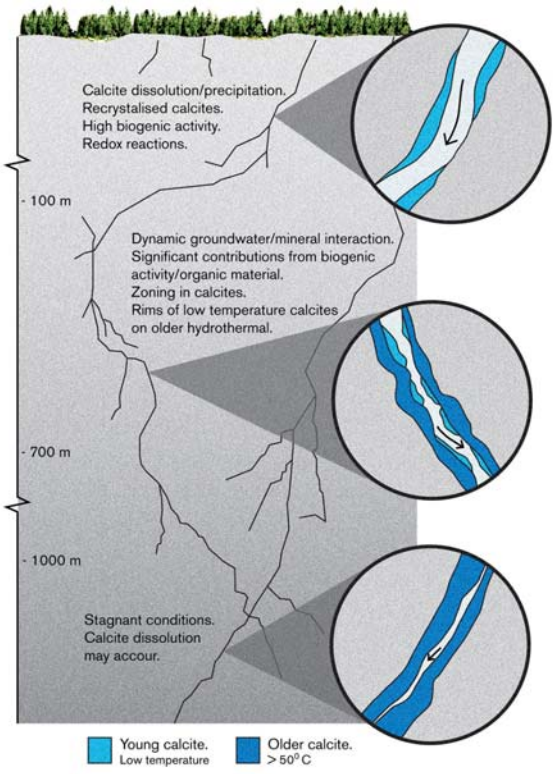
Chemlab 1:
- Investigations of the influence of radiolysis products on the migration of the redox-sensitive element technetium in bentonite (finalised).
- Investigations of the transport resistance at the buffer/rock interface (planned).

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

Achievements

Another project with higher priority has allocated all resources for the Radionuclide Retention Experiments and therefore there have been no activities in the project during the first quarter of 2007.

3.7 Padamot



Potential calcite-groundwater interaction at various depths at Äspö.

Padamot (Palaeohydrogeological Data Analysis and Model Testing) investigates changes in groundwater conditions as a result of changing climate. Because the long term safety of an underground repository depends on the stability of the repository environment, demonstration that climatic impacts attenuate with depth is important. Currently, scenarios for groundwater evolution relating to climate changes are poorly constrained by data and process understanding.

The objectives of Padamot are to:

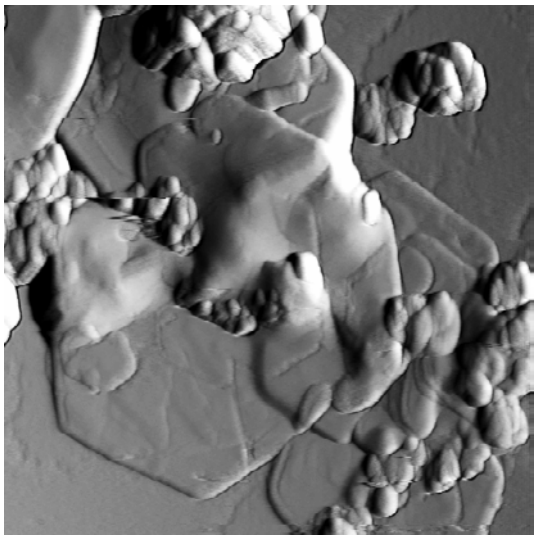
- Improve understanding and prioritise palaeo-hydrogeological information for use in safety assessments.
- Collect chemical/isotopic data using advanced analytical methods.
- Construct a database of relevant information and develop numerical models to test hypotheses.
- Integrate and synthesise results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

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

Achievements

The new phase of the project concerns uranium series measurements where different approaches will be tested by different laboratories. The analyses will be carried out on split samples of fracture material from a surface borehole drilled at Äspö. The analytical work on samples from borehole KAS 17 has started and the first results will be presented at the project meeting in Helsinki 14-15 May.

3.8 Fe-oxides in Fractures



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

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

The basic idea of the project 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

In terms of future work, with the aim to establish the penetration depth of oxidising waters below ground, fracture samples collected last spring are being prepared for analysis.

Draft modelling report from Enviros, Spain, is in the process of being reviewed by the University of Copenhagen. Following review and modifications, this will be printed as an Äspö International Progress Report.

3.9 Swiw-test with Synthetic Groundwater

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

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

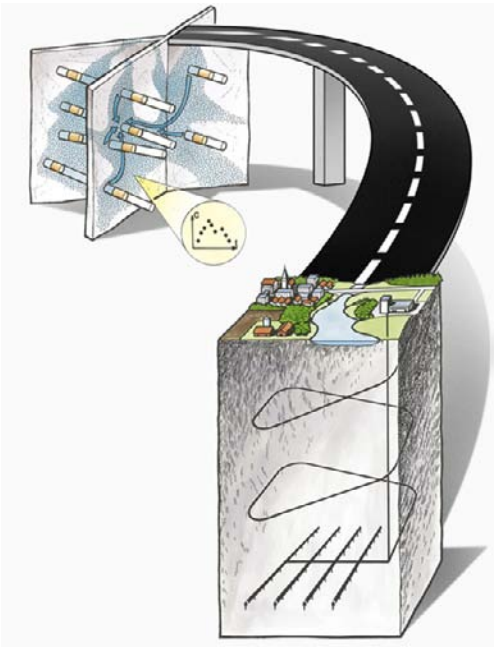
However, there are plans of establishing a new tunnel in Äspö HRL. This new tunnel, which will be located in the vicinity of the True Block Scale site, may alter the hydraulic conditions at the site significantly so that a performance of Swiw-tests there may be unsuitable or impossible. Hence, a new site for performing the Swiw-tests may be necessary to find.

Achievements

The major activity during the period was the on-going feasibility study. The inventory of characteristics of True Block Scale shows that it is suitable to perform the tests there. Preliminary results from the study show that the breakthrough curve shows whether the diffusion process is dominated by stagnant water zones or the rock matrix. It also reveals that it is possible to produce the amount and purity of synthetic groundwater that is necessary for the experiment.

However, it may be necessary to find a new site as a planned new tunnel nearby may alter the conditions at the site.

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



The Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes is a forum for the organisations supporting the Äspö HRL to interact in the area of conceptual and numerical modelling of groundwater flow and transport of solutes in fractured rock.

The Task Force shall propose, review, evaluate and contribute to the modelling work in the project. In addition, the Task Force shall interact with the principal investigators responsible for carrying out experimental and modelling works for Äspö HRL.

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

Achievements

In the Task Force, work has been in progress in Task 6 - 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 3-1. Task Force meeting 22 was held in January in Stockholm. The minutes from the meeting has been delivered according to send list.

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. All, except one, of the Task 6D, E and F

reports from the modelling groups have been printed. The review report for Task 6D, 6E and 6F is available as a final version. 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. All the expected modelling group papers have been received.

Task 7 addresses modelling of the OL-KR24 long-term pumping test at Olkiluoto in Finland. The task will focus on methods to quantify uncertainties in PA-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. Earlier it was decided at the meeting to divide Task 7 into several sub-tasks. A task description for the sub-task 7A has been sent out to the modellers and preliminary results from the modelling were presented at the Task Force meeting in Stockholm, January 2007. Updated Task 7 information and data deliveries have been made.

Table 3-1 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. (Most modelling reports printed and final review report available).
6E	This sub-task extends the sub-task 6D transport calculations to a reference set of PA time scales and boundary conditions. (Most modelling reports printed and final review report available).
6F	Task 6F is a sensitivity study, which is proposed to address simple test cases, individual tasks to explore processes and to test model functionality. (Most modelling reports printed and final review report available).
7	Long-term pumping experiment. (Preliminary results of Task 7A presented at the Task Force meeting in January 2007).

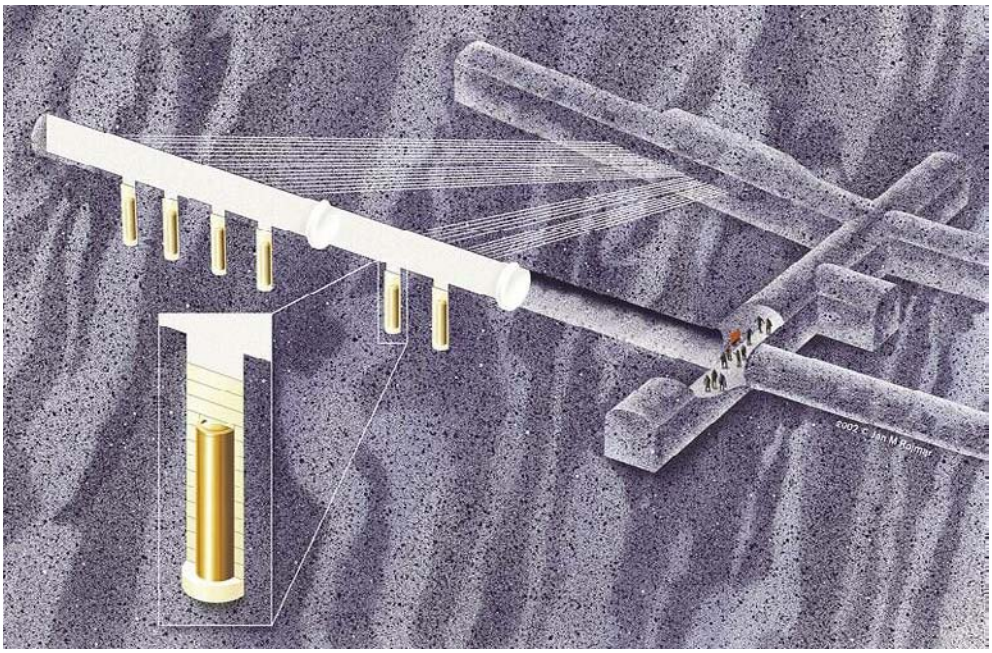
4 Engineered barriers

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

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

Figure 4-1. *The installation of the In Situ Corrosion Testing of Miniature Canisters.*

4.1 Prototype Repository



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

The Prototype Repository should, to the extent possible, simulate the real repository system regarding geometry, materials and rock environment.

Instrumentation is used to monitor processes and properties in the canister, buffer material, backfill and the near-field rock. The evolution will be followed for a long time.

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

Achievements

The data collection system comprises temperature, total pressure, 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. 16 covering the period up to December 2006 is in print /Goudarzi and Johannesson 2006/. Overhauling of the data acquisition system is in progress and hydraulic tests of the rock mass have been performed.

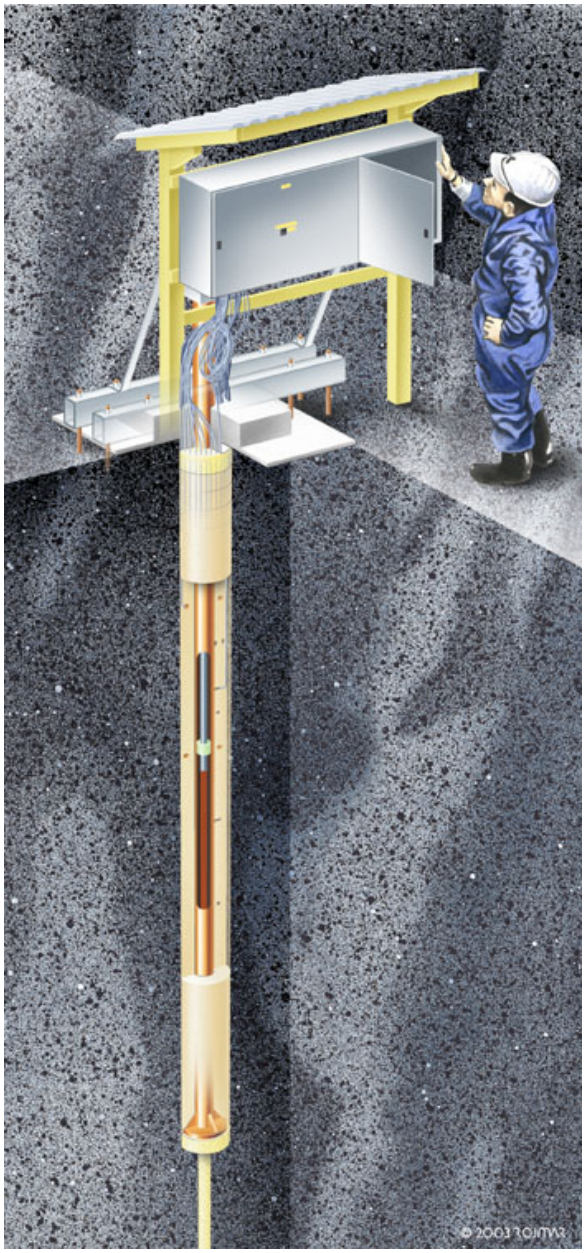
Groundwater flow measurements with tracers (Test campaign 2) in the rock around the Prototype Repository have been finalised and will soon be reported. The objective of the tests is to estimate the transmissivity of the rock.

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 on-going.

A programme for sampling and analyses of gases and micro-organisms in the backfill and buffer has started and the first and second campaign has been finalised and reported in a technical document. The work will soon be reported in an International Progress Report (IPR). New campaigns are planned for this year.

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 on-going. 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. The thermal model of the entire experiment has been extended to incorporate mechanical behaviour in order to evaluate whether occurrence of spalling is possible. Small THM-models have been developed in the Mathcad environment in order to calibrate an elasto-plastic material model to be used for the bentonite block and the outer slot filled with bentonite pellets.

4.2 Long Term Test of Buffer Material



The Long Term Test of Buffer Material aims to validate models and hypotheses concerning mineralogy and physical properties in a bentonite buffer.

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 on-going three parcels (see Table 4-1) are well functioning and results are checked and stored monthly.

The results from tests and analyses of the A2 parcel have been received from all groups, except two international one. The missing data are being compiled at the moment and will be delivered in the near future. A final Technical Report including all results from the A2 parcel will be compiled during the first half of 2007.

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

Type	No.	max T (°C)	Controlled parameter	Time (years)	Remark
A	1	130	T, $[K^+]$, pH, am	1	Reported
A	0	120-150	T, $[K^+]$, pH, am	1	Analysed
A	2	120-150	T, $[K^+]$, pH, am	5	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

4.3 Alternative Buffer Materials

Installation of one of the three parcels illustrating the mixing of the different compacted buffer discs.

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

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

The objectives are to:

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

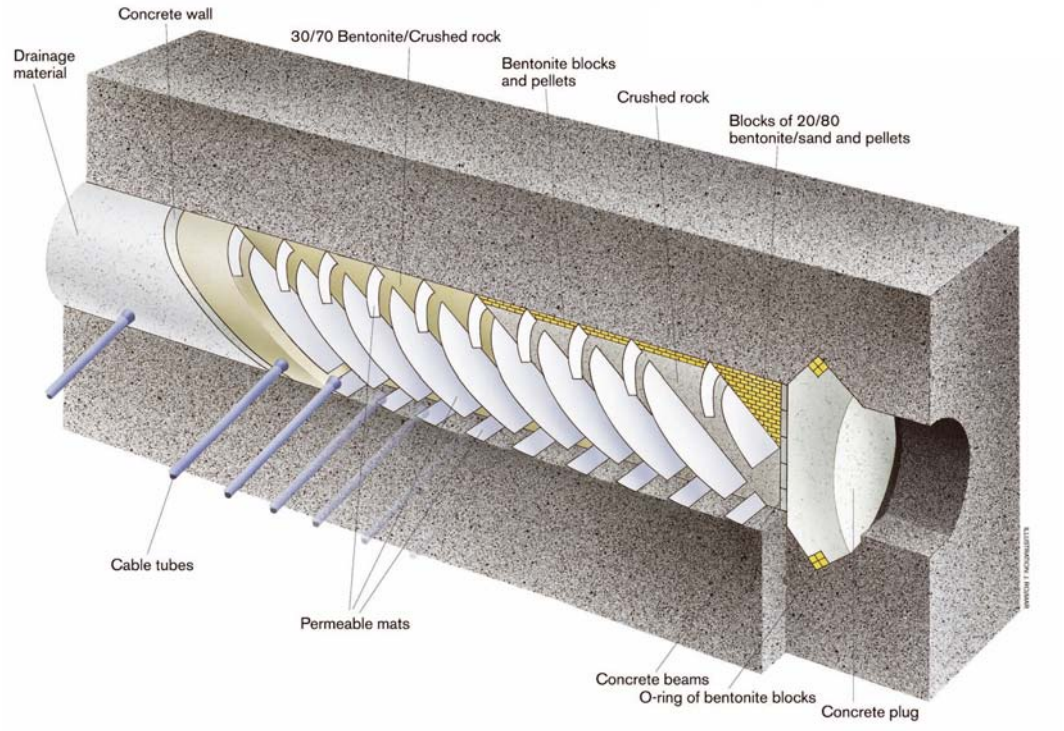
The field tests started during 2006 at Äspö HRL. Eleven different clays have been chosen to examine effects of smectite content, interlayer cations and overall iron content. Also bentonite pellets with and without additional quartz are being tested. The different clays are assembled in three packages.

Achievements

The packages were assembled and installed in December 2006. During the first quarter of 2007 the temperature in the experiment packages has gradually been increased and is now at approximately 70°C. The goal temperature is 130°C.

Two of the three concrete blocks casted on top of the packages have fractured due to the pressure from the clays. To prevent further fracturing additional support has been mounted on the supporting steel bars on top of the concrete blocks. The fractures have also been grouted to prevent water from leaking through the blocks.

4.4 Backfill and Plug Test



The Backfill and Plug Test includes tests of backfill materials, emplacement methods and a full-scale plug. The inner part of the tunnel is filled with a mixture of bentonite and crushed rock (30/70) and the outer part is filled with crushed rock and bentonite blocks and pellets at the roof.

The integrated function of the backfill material and the near-field rock in a deposition tunnel excavated by blasting is studied as well as the hydraulic and mechanical functions of the full-scale concrete plug.

The entire test set-up with backfill, instrumentation and casting of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through filter mats started in late 1999.

The backfill was completely water saturated in 2003 and flow testing for measurement of the hydraulic conductivity has been running since late 2003.

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

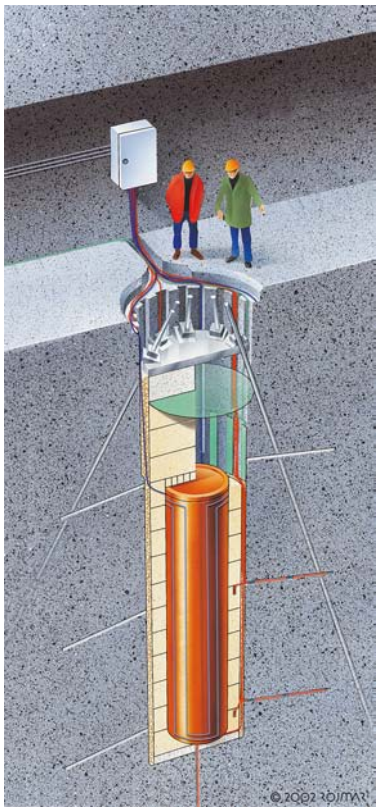
Achievements

The main work during this quarter have included continuous measurements and registrations of water saturation, water pressure and swelling pressure in the backfill as well as water pressure in the surrounding rock. A data report covering the period up to 1st July 2006 /Goudarzi *et al*. 2006/ is published and one covering the period up to 1st January 2007 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 of 0/100 have been finished during this quarter. The tests with the pressure cylinder in the floor in 30/70 have started. The equipment works well in spite of the long time that has passed since installation.

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.

4.5 Canister Retrieval Test



The Canister Retrieval Test is aiming at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite is fully saturated.

In the Canister Retrieval Test two full-scale deposition holes have been drilled, at the -420 m level, for the purpose of testing technology for retrieval of canisters after the buffer has become saturated.

These holes have been used for studies of the drilling process and the rock mechanical consequences of drilling the holes.

Canister and bentonite blocks were emplaced in one of the holes in 2000 and the hole was sealed with a plug, heater turned on and artificial water supply to saturate the buffer started.

In January 2006 the retrieval phase was initiated and the canister was successfully retrieved on May 12th 2006. The saturation phase had, at that time, been running for more than five years with continuous measurements of the wetting process, temperature, stresses and strains.

Achievements - Saturation phase

The water saturation phase is now completed and the final data report is compiled and printed /Goudarzi *et al*. 2005/. The reporting of the results from the excavation and comparisons with data measurements will be included in the retrieval phase.

Achievements - Retrieval phase

During the first quarter of 2007 the canister was opened at the Canister Laboratory in Oskarshamn. This allowed for the heaters to be sampled for analysis to be conducted in Studsvik. The heater analysis is the remaining activity in the search for the heater failure reasons. When the results are ready a report will be written compiling the results from all analyses regarding heater failure.

Clay Technology has been working on the report from the initial buffer analyses. The report is planned to be completed in April 2007. This summer the detailed buffer analyses will begin.

A draft version of a report describing the removal of the buffer has been compiled. Removal of the buffer, from half the canister height and down, was done with a disintegration method. The bentonite was dissolved with a saline solution and pumped out of the deposition hole. The method was successful and the canister was freed from the buffer.

4.6 Temperature Buffer Test

The French organisation Andra carries out the Temperature Buffer Test (TBT) at Äspö HRL in co-operation with SKB.

The aims of the TBT are to evaluate the benefits of extending the current understanding of the THM behaviour of engineered barriers during the water saturation transient to include high temperatures, above 100°C.

The scientific background to the project relies on results from large-scale field tests on EBS, notably Canister Retrieval Test, Prototype Repository and Febex (Grimsel Test Site).

The test is located in the same test area as the Canister Retrieval Test, which is in the main test area at the -420 m level.

The TBT experiment includes two heaters in the axis of the deposition hole, one on top of the other, separated by a compacted bentonite block. The heaters are 3 m long and 610 mm in diameter and are constructed in carbon steel. Each one simulates a different type of confinement system: a bentonite buffer only (bottom section) and a bentonite buffer with inner sand backfill (upper section).

An artificial water pressure is applied in a slot between the buffer and rock, which is filled with sand and functions as a filter.

Achievements

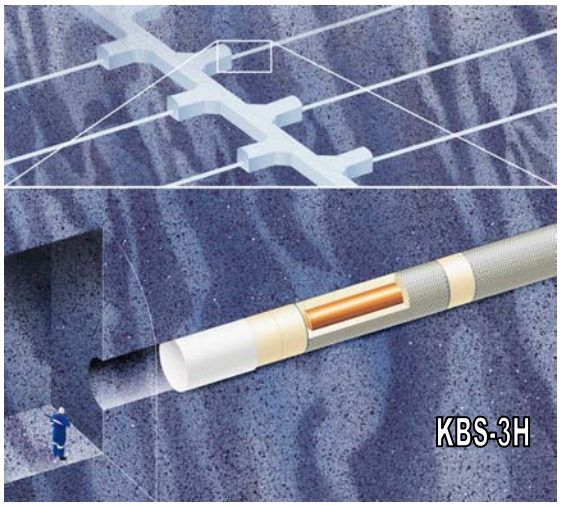
The TBT-test is in the operation and data acquisition phase since March 2003. Data acquisition is continuously on-going. The data link from Äspö to Andra's head office in Paris has been functioning well.

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.

Three monthly data reports have been distributed during January-March 2007. The Sensor data report for the period 030326-070101 (No. 9) is in progress. Several project-related abstracts have been submitted for the Lille Conference in September this year.

A protocol for the hydration of the sand shield is in progress. A major concern for the gas injection test, scheduled for 2008, and thus for the hydration of the shield is to make sure that to no pockets of dry gas remains in the shield. As a first step, the gas in the shield was therefore sampled and analysed in January 2007.

4.7 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. The KBS-3H project is a joint project between SKB and Posiva.

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

The site for the demonstration of the method is located at -220 m level. A niche with a height of about 8 m and a bottom area of 25×15 m forms the work area. Two horizontal deposition holes have been excavated, one short with a length of about 15 m and one long with a length of about 95 m. The deposition equipment will be tested in the long hole and the short hole will be used for testing of a low-pH shotcrete plug and of different drift components.

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

Achievements

During the first quarter of 2007, work has been focused on:

- Performed site acceptance test (SAT) of the deposition equipment.
- Preparation of test with Mega Packer and steel plug.
- Updates of project plans; for the KBS-3H Project and the sub-project Demonstration.

The problems with the balancing of the deposition equipment have been solved. To do this the machine had to be rebuilt with a guide system to prevent uncontrolled rotation of the Supercontainer.

To ensure a proper function of the guides the lifting height of the water cushions used for deposition of the Supercontainer must be limited. It was therefore decided to change to new cushions with less lifting height and with less sensitivity to load variations, see Figure 4-2. The new cushions were installed in January 2007. The palette of water cushions has also been provided with sensors indicating the lifting height.

Figure 4-2. *New water cushions being installed under the water cushion palette.*

The SAT, which commenced on February 7th 2007 was finally approved February 15th. Figure 4-3 shows the deposition equipment in the drift during the SAT. The demonstration of the KBS-3H deposition concept, as a whole, started directly thereafter and will continue until December 2007.

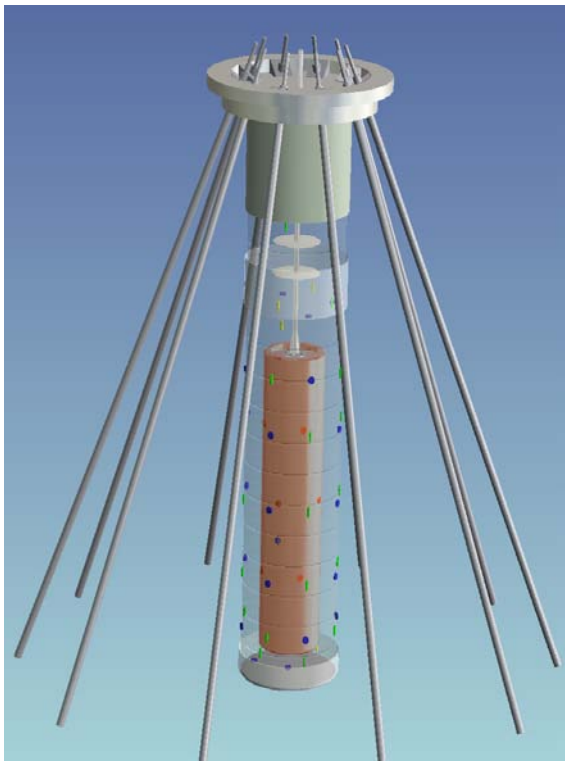
Figure 4-3. *(left) The deposition machine inside the 95 m long drift at -220 m level at Äspö HRL (right) The perforated end plate of the Supercontainer in the same drift.*

The work with preparations of drawings and documentation of the steel plug and the Mega Packer has continued during the first quarter of 2007. Steel plugs are used to isolate sections in the deposition hole with high water inflow. The Mega Packer is special device for grouting of the rock around horizontal deposition holes.

Tests have been performed to verify the reliability of the sealing of the Mega Packer. The rubber rings that will seal of the space between the Mega Packer device and the bedrock surface have been redesigned.

Manufacturing of the Mega Packer device and the steel plug will start during the next quarter. The steel plug will be tested in the 15 m long drift at -220 m level at Äspö HRL and the test with the Mega Packer device will be performed in the 95 m long drift at -220 m level.

4.8 Large Scale Gas Injection Test



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

Current knowledge pertaining to the movement of gas in a compact buffer bentonite is based on small-scale laboratory studies. These diagnostic tests are designed to address specific issues relating to gas migration and its long-term effect on the hydro-mechanical performance of the buffer clay.

Laboratory studies have been used to develop process models to assess the likely implications of gas flow in a hard-rock repository system. While significant improvements in our understanding of the gas-buffer system have taken place, a number of important uncertainties remain. Central to these is the issue of scale and its effect on the mechanisms and process governing gas flow in compact bentonite.

The question of scale-dependency in both hydration and subsequent gas phases of the test history are central issues in the development and validation of process models aimed at repository performance assessment. To address these issues, a Large Scale Gas Injection Test (Lasgit) has been initiated. Its objectives are:

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

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 the first quarter have focused on the continued hydration of the buffer. At present monitored porewater pressures within the clay remain rather low ranging from 100 kPa to 430 kPa. This is in contrast to the water pressure measured at the face of the deposition hole which ranges from 1,160 kPa to 2,575 kPa and is non-uniformly distributed across the rock face (Figure 4-4a). Monitored radial stress around the canister continues to increase steadily ranging in value from 1,500 kPa to 5,130 kPa (Figure 4-4b), with an average value of 3,900 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 4,430 kPa and 4,630 kPa, which are comparable with the values of radial stress monitored on the rock face. Axial stress is significantly lower at 3,300 kPa. Axial stress within the clay ranges from 4,488 kPa to 5,750 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 180 to 3,240 kPa with an average of around 2,075 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.

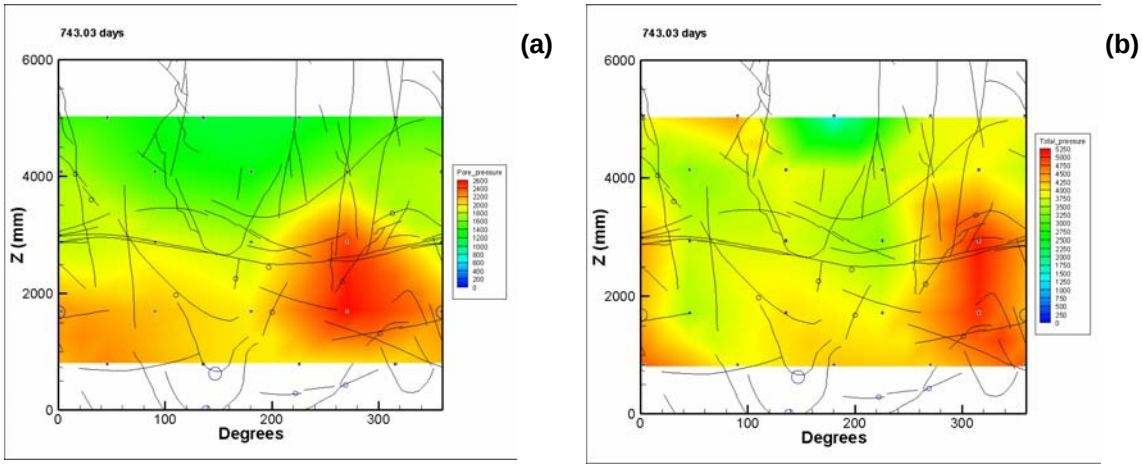
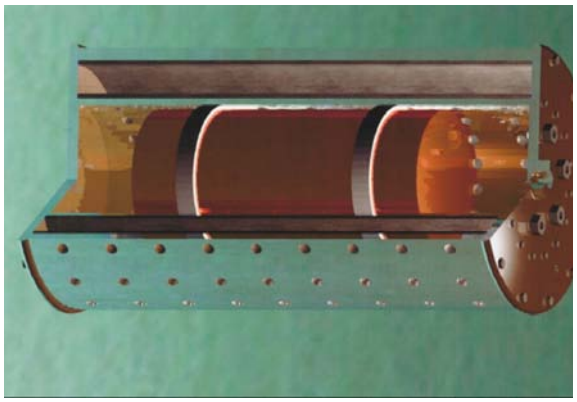


Figure 4-4. *(a) and (b) show the distribution of porewater pressure and radial stress respectively measured at the rock face of the deposition hole at an elapse time of 743 days. A narrow zone of elevated radial stress can be clearly seen in Figure 4-4b extending vertically upwards from the base of the deposition hole.*

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 750 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.

4.9 In Situ Corrosion Testing of Miniature Canisters



Miniature canister with support cage

Installation of first model canister assembly

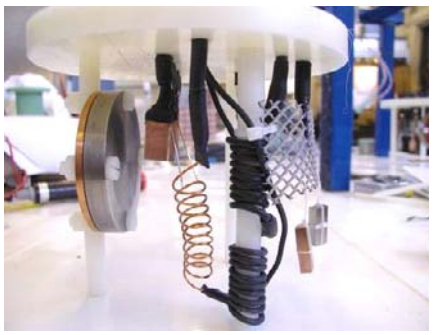
This project (MiniCan) is designed to provide information about how the environment inside a copper canister containing a cast iron insert would evolve if failure of the outer copper shell were to occur. The development of the subsequent corrosion in the gap between the copper shell and the cast iron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

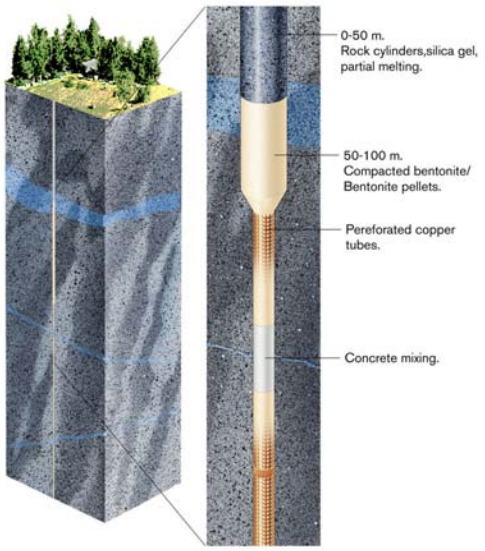
All five miniature canisters have now been installed and data relating to the environmental conditions, corrosion behaviour of the test specimens and dimensional changes are being collected and analysed. The complete installation in the Äspö HRL is shown in Figure 4-1.

The photos below show the bentonite mounted in the annulus of the support cage, the miniature copper canister being inserted into the support cage and the sensors held in the support cage.



A description of the experiment, together with preliminary results, was presented at the Research in Progress symposium at the NACE Corrosion conference in the U.S. in March 2007 /Smart *et al*. 2007/. An annual technical report summarising the installation of the experiments and summarising the data will be prepared at the end of 2007.

4.10 Cleaning and Sealing of Investigation Boreholes



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

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.

The now on-going Phase 3, is divided into four sub-projects, and comprises large-scale testing of the sealing concept in boreholes. Sub-project 1, 2 and 3 are all finished. The aim of sub-project 4 is to test the feasibility of candidate techniques intended for mechanical securing of the tight clay seals emplaced in deep boreholes. The physical conditions for constructing and testing the plugs are represented by three cored boreholes with 200 mm diameter and 1.9 m depth at about 400 m depth in the Äspö HRL.

Achievements

Sub-project 1, 2 and 3 are all finished and the results were presented and discussed during a seminar in February. Draft reports have been sent to the Steering group members for review.

Sub-project 4 has been delayed because of risk to disturb the hydro testing programme going on at the -450 m level until the end of December. The field testing started mid January. Quite recently an additional version of a metal plug has been proposed and added to the basic concepts. It has the form of an “expander”-type plug consisting of copper or Navy Bronze components in real deep boreholes but will be made of copper in the field tests of Sub-project 4.

The principle of designing and performing this plug is shown schematically in Figure 4-5. The maximum load that the plug can take is determined by the shear strength of the rock and taking it as half the unconfined compressive strength, applying the Mohr failure criterion, one gets about 200 t for high-quality granite. A permanent load of 50-100 tonnes can be sustained by this type of plug.

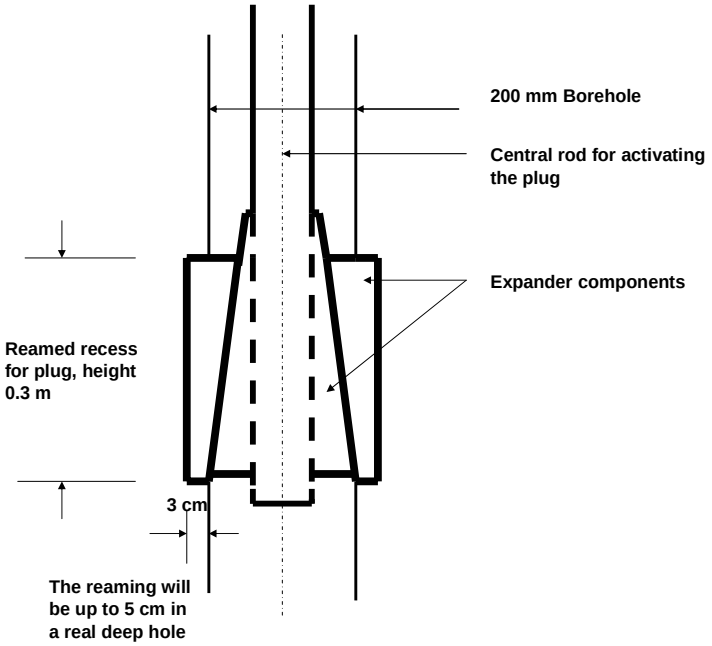
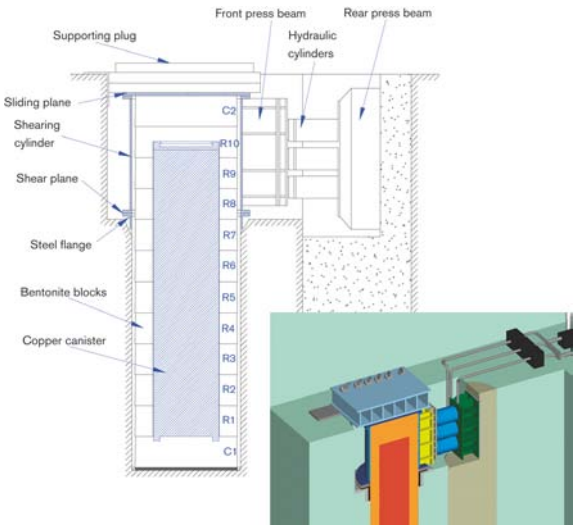


Figure 4-5. *Schematic section of "Cold-metal" plug. The outer expander component consists of two halves and rotating the rod tightens and locks the plug in the hole.*

4.11 Rock Shear Experiment



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

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*. 2006/. 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 during the first quarter of 2007.

4.12 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 work during the first quarter included evaluation and compilation of the results.

4.13 Task Force on Engineered Barrier Systems

The Task Force on Engineered Barrier Systems (EBS) is a natural continuation of the modelling work in the Prototype Repository Project, where also modelling work on other experiments, both field and laboratory tests, are conducted. The Äspö HRL International Joint Committee 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), BMWi (Germany), CRIEPI (Japan), Nagra (Switzerland), Posiva (Finland), NWMO (Canada) and RAWRA (Czech Republic). All together 12-14 modelling teams are participating in the work.

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

Achievements

For Task 1 three benchmark tests have been modelled by the teams. Two tasks concern 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 with measurements. Decent agreements have been reached. Written reports have been delivered during this quarter for compilation and review.

For Task 2 two benchmark tests have been presented and attempts made to model these tests. Both tasks concern gas breakthrough 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. Written reports have been delivered during this quarter for compilation and review.

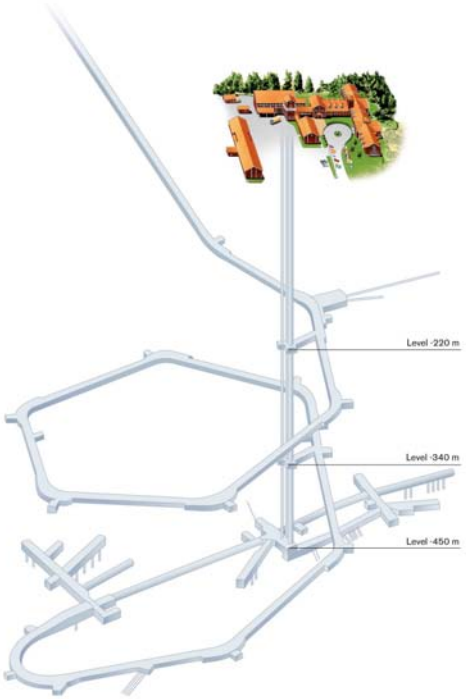
For Task 1 the subsequent modelling will concern large scale *in situ* tests. The Buffer/Container Experiment and the Isothermal Test carried out by AECL have been presented and specifications delivered. The modelling has started this quarter and first results will be presented at the next meeting.

5 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.

5.1 Äspö HRL

5.1.1 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 safety of the facility is good and all operating systems have been functioning well during the first quarter of 2007.

Also, the testing of the system for registration of personnel (RFID) is function well. However, the introduction of the system will be delayed because the work with the documentation took longer than planned. The introduction is now scheduled to the third quarter of 2007.

The upgrading of the reserve power system is on-going, however delayed due to the lack of electricians. The oldest part of the office is being painted.

The Bentonite Laboratory has been inaugurated, however, painting of the building exterior and asphalting of the access road will be done during the spring as soon as the weather allows.

5.2 Bentonite Laboratory

5.2.1 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

Within the SKB-Posiva Baclo-project, some initial tests concerning backfilling of deposition tunnels focusing on the placement of pellets has been made in the laboratory. Tests concerning water inflow into the block pellets system in a small scale test setup are on-going in the Äspö tunnel. These tests will be finished before the summer holiday and a draft report will be prepared

Preparations for the testing of temporary buffer protection in the full scale deposition hole in the laboratory have started and equipment has been ordered.

5.3 Public Relations and Visitors Service



SKB operates three facilities in the Oskarshamn municipality: Äspö HRL, Central interim storage facility for spent nuclear fuel (Clab) and Canister Laboratory. In 2002 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 5,938 persons during the first three months 2007. (4,884 persons the same period last year) The numbers of visitors to SKB's main facilities are listed in Table 5-1.

A series of lectures with special connection to the research and development of techniques conducted at the Äspö facility has started during 2007 and is planned to continue the coming years. The intention is to combine the lectures with guided tours to the underground laboratory. The first lecture was held 2nd of March by Christer Andersson when he took his doctor's degree. Title of his thesis is *"Rock Mass Response to Coupled Mechanical Thermal Loading Äspö Pillar Stability Experiment, Sweden"*. The event was visited by almost 80 persons.

The inauguration of the Bentonite Laboratory took place March 29th. Special guests were invited and the inauguration was also an open event for interested people. The event was visited by about 110 persons. The inauguration was conducted of the chairman of the Regional Council in Kalmar County.

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

SKB facility	Number of visitors Jan-March 2007
Central interim storage facility for spent nuclear fuel	632
Canister Laboratory	979
Äspö HRL	1,864
Final repository for radioactive operational waste (SFR)	2,027

6 Environmental research

6.1 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. 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

Two scientific papers have been accepted for publication. One will be published in Applied Geochemistry and discusses the behaviour of lanthanoides in bedrock groundwater, overburden groundwater and surface water in Forsmark and Laxemar. The other focuses on niobium and will be published in Geochemistry: Exploration, Environment, Analyses. The work with a manuscript focusing on the behaviour of uranium in waters in Forsmark, Laxemar and Äspö has continued.

7 International co-operation

Nine organisations from eight countries participate in the Äspö HRL co-operation during 2007, see Table 7-1. Six of them; Andra, BMWi, CRIEPI, JAEA, NWMO and Posiva together with SKB form the Äspö International Joint Committee (IJC), which is responsible for the co-ordination of the experimental work arising from the international participation.

Several of the participating organisations take part in the two Äspö Task Forces on: (a) Modelling of Groundwater Flow and Transport of Solutes, which is a forum for co-operation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock and (b) THMC modelling of Engineered Barrier Systems, which is a forum for code development on THMC processes taking place in a bentonite buffer and at gas migration through a buffer.

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

Projects in the Äspö HRL during 2007	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Enresa	Nagra	RAWRA
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			
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
Nuclear Waste Management Organisation, NWMO, Canada
Posiva Oy, Finland
Empresa Nacional de Residuos Radiactivos, Enresa, Spain
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland
Radioactive Waste Repository Authority, Rawra, Czech Republic

8 Documentation

During the period January to March 2007, the following reports have been published and distributed.

8.1 Äspö International Progress Reports

Cheng H, Cvetkovic V, 2006. Äspö Task Force on modelling of groundwater flow and transport of solutes. Modelling of Task 6D, 6E and 6F, flow and transport simulations in fracture networks. IPR-06-20, Svensk Kärnbränslehantering AB.

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Goudarzi R, Johannesson L-E, 2006. Prototype Repository. Sensors data report (Period: 010917-061201). Report No:16. IPR-07-05, Svensk Kärnbränslehantering AB.

Goudarzi R, Johannesson L-E, Börgesson L, 2006. Backfill and Plug test. Sensors data report (Period 990601-060701) Report No:13. IPR-06-34, Svensk Kärnbränslehantering AB.

Goudarzi R, Börgesson L, Röshoff K, Edelman M, 2005. Canister Retrieval Test. Sensors data report (Period 001026-060501) Report No:12. IPR-06-35, Svensk Kärnbränslehantering AB.

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Äspö Hard Rock Laboratory. Status Report. October - December 2006. IPR-07-04, Svensk Kärnbränslehantering AB.

8.2 Technical Documents and International Technical Documents

No Technical Document has been published during the first quarter 2007.

9 References

Anderson C, Jakobsson A-M, Pedersen K, 2006. Influence of in situ biofilm coverage on the radionuclide adsorption capacity of subsurface granite. *Environ Sci Technol* 41, 830-836.

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Andersson J C, 2007b. Äspö Hard Rock Laboratory. Äspö Pillar Stability Experiment, final report. Rock Mass Responce to Coupled Mechanical Thermal Loading. SKB TR 07-01, Svensk Kärnbränslehantering AB.

Andersson P, Byegård J, Billaux D, Cvetkovic V, Dershowitz W, Doe T, Hermanson J, Poteri A, Tullborg E-L, Winberg A (ed), 2007. TRUE Block Scale Continuation Project. Final Report. SKB TR-06-42, Svensk Kärnbränslehantering AB.

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