International Progress Report

IPR-07-11

Äspö Hard Rock Laboratory

Status Report
April – June 2007

Svensk Kärnbränslehantering AB

September 2007

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Report no.	No.
IPR-07-11	F50K
Author	Date
Kemakta	September 2007
Checked by	Date
Approved	Date
Anders Sjöland	2007-09-19

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Keywords: Äspö HRL, Status Report

Overview

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

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

This Äspö HRL Status Report is a collection of the main achievements obtained during the second 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.

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.

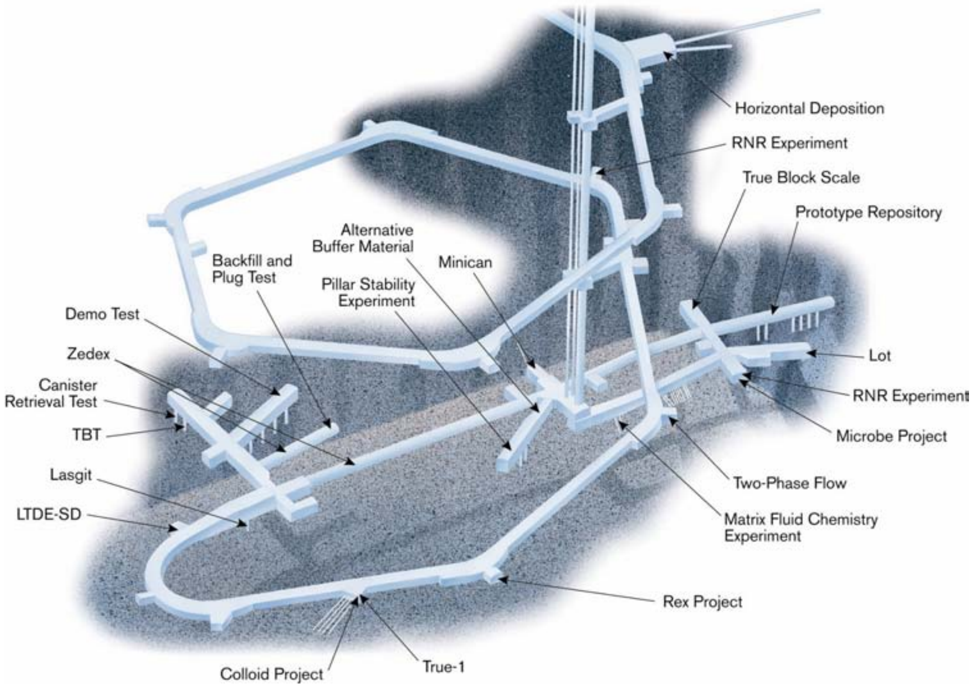


Figure 1-1. *Allocation of some of the experimental sites in Äspö HRL from -220 m to -450 m level.*

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

TASI-tunnel, drilling before installation of casing in one of the holes for the coming TASS-tunnel (photo Oskar Sigurdsson)

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 second quarter of 2007 have been:

- The quality control of the geological mapping of the niche NASQ0036A that earlier has been digitised and associated data fed into TMS (Tunnel Mapping System) is now completed. Some earlier mapping still needs to be entered into the TMS.
- The work to put up information signs showing some of the deformation zones in the Äspö tunnel is completed. These zones are already established and named on the ground surface and the same names have been used underground.
- The core logging facilities at Äspö have been equipped with a digital camera for taking photos of the cores and core boxes.
- Three core boreholes, each about 100 m long, have been drilled from the TASI-tunnel (approximately at the -450 m level) to investigate the rock and water conditions at the location of the coming TASS-tunnel (Tests on grouting with Silica sol and cement). Logging of the cores is in progress.
- The modelling work that commenced in 2005 concerning water bearing fractures at the -450 m level is still in progress.
- The "road bed" of the inner half of the TASQ-tunnel (Pillar Stability Experiment) has been removed and the rock floor has been cleaned. Geological mapping of the floor began in June.

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

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

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

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

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

Achievements

The RoCS feasibility report (State-of-the-art in 3D surveying technology) has been published as an IPR report /Magnor et al. 2007/. The conclusions of the feasibility study are that laser scanning combined with digital photography are believed to be suitable tools in a new rock characterisation system.

The report by ATS (Advanced Technical Solutions AB) concerning the laser scanning of the TASQ-tunnel in 2006 is not yet completed.

In the autumn the RoCS-project will be slightly reorganised and the focus will be on geological mapping.

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 model of hydraulically conductive structures at the main experimental levels below –400 m level continues.

The effects of blasting 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. In the next step, possible effects of blasting for the Clab-2 construction will be investigated. The effects of 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 second quarter have been:

- Continued implementation of the measurement system for temperature, humidity and pressure of tunnel air.
- Quality check and calibration of data from the tunnel in April and from the surface boreholes in May.
- Continued preparations for automatic transfer of data from the HMS to the site investigation 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 a report /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.

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

2.3.1 Monitoring of Groundwater Chemistry

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

Achievements

Continued quality assurance of the hydrogeochemistry data in the database Sicada is in progress. The development of the monitoring programme has continued, e.g. the selection of additional sampling points. In the last campaign, the measurements to determine the total amount of microorganisms (measured parameter is ATP) failed. It has, however, been decided to try again.

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 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. However, the RVS (rock visualisation system) modelling was started up in the beginning of 2007.

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.

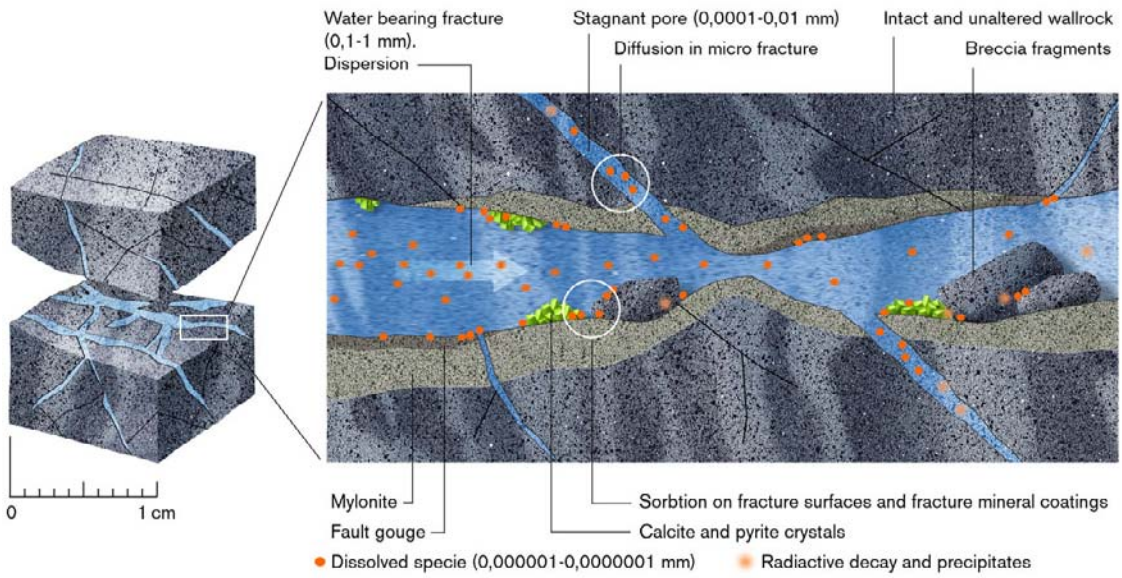
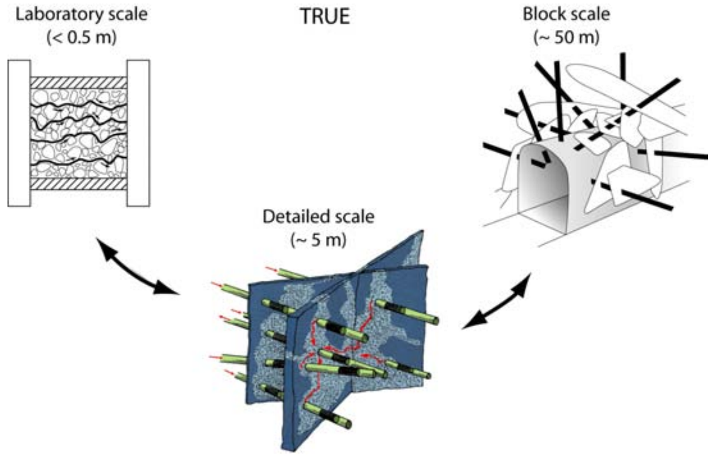


Figure 3-1. *Processes that influence migration of species along a natural rock fracture.*

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

Within the continuation of the True Block Scale project (BS3), work during 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 (Kd, Ka etc) has been deepened including comparison of estimations with the experimental data. A final draft of this report has been submitted mid June.

The remainder of the year will be devoted to finalisation of manuscripts of a two part series of scientific papers devoted to "Sorptive tracer tests from single to multiple fractures in crystalline rock at Äspö". In the first paper, the methodology and procedures for performed blind predictions of the sorbing tracer tests are presented. The prediction results of the SKB analysis team is compared to the experimental data and the reasons for deviations between predictions and experimental data are analysed and discussed. The second paper covers the evaluation of the sorbing tracer tests and infers effective retention properties. Properties of the structures involved and possible network effects are assessed. Finally, material retention properties are evaluated.

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). In addition, this project includes production of a series of scientific articles based on the True-1 project and, furthermore, performance of the Fault Rock Characterisation project, the latter in parts a dress rehearsal for True-1 Completion.

Achievements

The first two in a series of three papers on the True-1 have been accepted for publication in Water Resources Research: Experimental set up and micro-scale characterization of retention parameters and Transport model and effective parameter estimation. The finalisation of the third paper - Effects of micros-scale heterogeneity – is in progress.

3.1.3 True-1 Completion

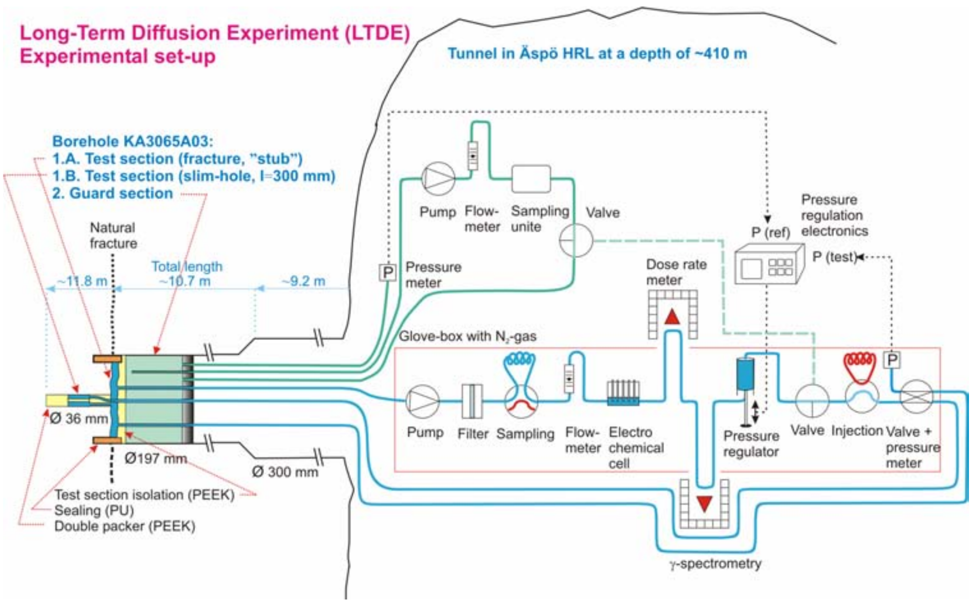
True-1 Completion is a sub-project of the True-1 Continuation project with the experimental focus placed on the True-1 site. True-1 Completion will be performed at the True-1 site and will be a complement to already performed and on-going projects. The main activity within True-1 Completion is the injection 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 major activity during the period was over-coring of borehole KXTT3 at the True-1 site. The over-coring was performed with 300 mm core drilling down to 14.65 m borehole depth. The core was retrieved gradually during the drilling. In the target section, KXTT3: S3, uranine tagged epoxy from the previous injection was visible in several fractures. Unfortunately, the forces acting on the core during drilling and/or retrieving were too large in order to keep the core intact around some fractures in the target section. However, these fractures are still considered to provide a lot of valuable information in coming analysis. The over-coring continues with borehole KXTT4 which is planned to be finalised in August.

Final evaluation of previously performed tracer tests as well as comparison between the tests and reporting of the results is on-going.

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.

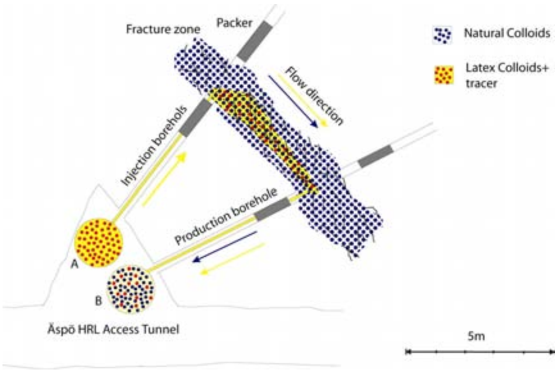
A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole and a small-diameter borehole is drilled through the core stub and beyond into the intact unaltered bedrock. Tracers were circulated over a period of 6 ½ months after which the borehole was over cored. This activity will be followed by analyses of tracer content.

Achievements

The in situ sorption diffusion experiment was finished according to plan on April 12th. After final sampling subsequent epoxy resin injection, removal and dismantling of borehole equipment and over coring were completed May 4th. The over coring turned out successfully and a 1.1 metre long and 278 mm diameter core was retrieved in one piece. The core comprises of the stub with the target fracture in one end and matrix rock surrounding the test section in the small diameter (36 mm) extension borehole. Geological mapping and detailed planning have been carried out for the extraction of small diameter sample cores (22 mm) from the large core, see Figure 3-2. Sample cores will be drilled both on the fracture surface on the core stub and in the matrix rock surrounding the test section.

Figure 3-2. *Geological mapping of the 278 mm diameter core from LTDE-SD, including the 177 mm diameter core stub and rock surrounding the small diameter extension borehole.*

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 second quarter of 2007 have been:

- Studies of bentonite and organic colloid stability as well as radionuclide and colloid interactions in Äspö-waters at the laboratory at FZK-INE. An annual report is written and an abstract is submitted to Migration 2007 conference.
- Laboratory experiments on 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 has been submitted to the Migration 2007 conference and an article will be submitted for publication in August.
- Bentonite colloid stability experiments in varying conditions are 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.
- Bentonite colloid stability experiments with varying pH and temperature have been performed at the Royal Institute of Technology. The evaluation is finished and a manuscript is in preparation.
- Modelling of colloid transport, with data from the experiments performed at AECL, is performed at the Royal Institute of Technology.
- Collaboration with the Colloid Formation and Migration Project (CFM) performed at Grimsel has been initiated. This means that the in situ experiments can be performed in dilute groundwater to mimic intruding glacial water.

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

Microbiological decomposition and production of organic material depend on the energy sources and electron acceptors present. Organic carbon and methane and reduced inorganic molecules, including hydrogen, are possible energy sources in the subterranean environment. During the microbial oxidation of these energy sources, microbes preferentially use electron acceptors in a particular order (as depicted in Figure 3-3): first oxygen, and thereafter nitrate, manganese, iron, sulphate, sulphur, and carbon dioxide are utilised. Simultaneously, fermentative processes supply the metabolising microorganisms with, for example, hydrogen and short-chain organic acids. As the solubility of oxygen in water is low, and because oxygen is the preferred electron acceptor of many bacteria that utilise organic compounds in shallow groundwater, anaerobic environments and processes usually dominate at depth in the subterranean environment.

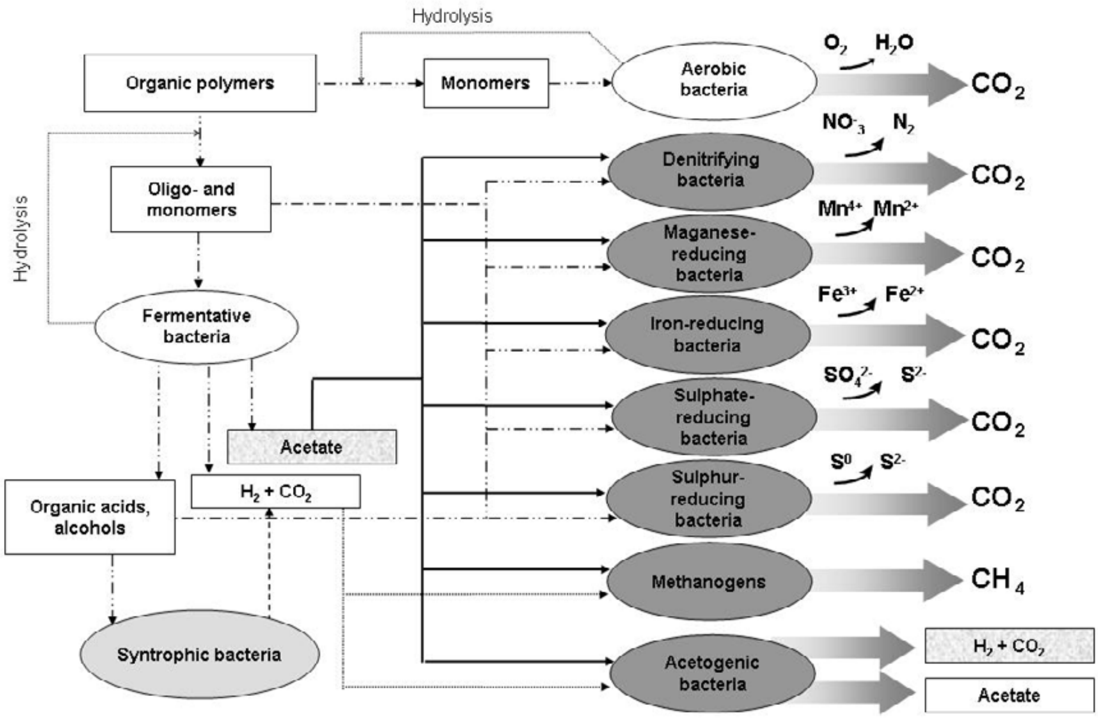


Figure 3-3. *Microbial oxidation of different energy sources.*

The reduction of microbial electron acceptors may significantly alter groundwater chemistry. Dissolved nitrate is reduced to gaseous nitrogen, solid manganese and iron oxides are reduced to dissolved species, and the sulphur in sulphate is reduced to sulphide. In addition, the metabolic processes of some microorganisms produce organic carbon, such as acetate, from the inorganic gases carbon dioxide and hydrogen, while other microorganisms produce methane from these gases; these processes generally lower the redox potential, E_h. Most of those microbiologically mediated reactions will not occur in a lifeless groundwater environment without the catalysing enzymes of microorganisms. The mere presence of sulphide in a low-temperature granitic groundwater provides undisputable evidence of microbiological sulphate reduction. However, concentrations of reduced electron acceptors alone will not reveal when, where and at what rate the individual microbial processes take place. Hence, robust, sound, and reproducible methods for estimating the total number of viable microorganisms in groundwater, their diversity, and the rate at which their microbial processes run have been developed.

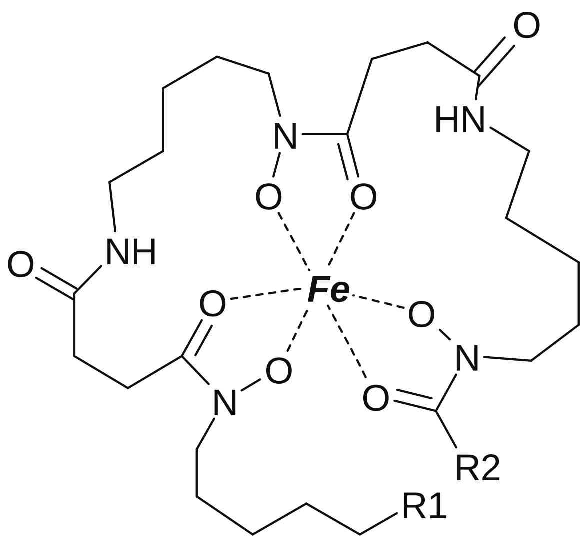
To this end, a set of cultivation methods was adapted and applied in analysing the diversity of microorganisms using different electron acceptors and energy donors in deep groundwater. Groundwater from boreholes at the Microbe site was analysed using the cultivation methods, and the results were compared to hydrogeochemical analysis data. The reproducibility of the cultivation methods was tested and evaluated. Methods for analysing microbial process rates were developed and tested under open and closed in situ conditions in the Microbe laboratory. Groundwater containing microorganisms from a fracture adjacent to the laboratory was circulated under in situ pressure and chemistry via flow cells that mimicked the conditions of fractured rock. The focus was on determining the reduction rate of sulphate to sulphide and the production rate of acetate from hydrogen and carbon dioxide. A conceptual model of microbial processes that can be coupled to hydrogeochemical modelling have been outlined. The results have been compiled in a manuscript submitted for publication to Applied Geochemistry:

Published or submitted papers that involve Äspö HRL investigations:

Eydal HSC and Pedersen K, 2007. Use of an ATP assay to determine viable microbial biomass in Fennoscandian Shield groundwater from depths of 3-1000 m. (Journal of Microbiological Methods, doi:101016/jmimet200705012)

Hallbeck L, Pedersen K, 2007. Characterization of microbial processes in deep aquifers of the Fennoscandian Shield. (Submitted to Applied Geochemistry)

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

Pyoverdins are bacterial siderophores produced by ubiquitous fluorescent *Pseudomonas* species They have great potential to bind and thus transport actinides in the environment. Therefore, the influence of pyoverdins secreted by microbes on the migration processes of actinides must be taken into account. The unknown interaction between uranium and curium(III) and the pyoverdins released by *Pseudomonas fluorescens* (CCUG 32456) isolated from the granitic rock aquifers at Äspö HRL has been investigated in co-operation with scientists at Institute of Radiochemistry, Forschungszentrum Dresden, Germany. The interaction between soluble species of curium(III) and pyoverdins was studied at different trace curium(III) concentrations using time-resolved laser-induced fluorescence spectroscopy (TRLFS). Three Cm^{3+}-*P. fluorescens* (CCUG 32456) pyoverdin species, $M_pH_qL_r$, could be identified from the fluorescence emission spectra, CmH_2L^+, CmHL, and CmL^-, having peak maxima at 601, 607, and 611 nm, respectively. The large formation constants, log β_{121} = 32.50 ± 0.06, log β_{111} = 27.40 ± 0.11, and log β_{101} = 19.30 ± 0.17, compared to those of other chelating agents illustrate the unique complexation properties of pyoverdin-type siderophores. An indirect excitation mechanism for the curium(III) fluorescence was observed in the presence of the pyoverdin molecules, see Figure 3-4.

The formation of complexes of UO_2^{2+} with the pyoverdins released by the studied groundwater bacterium has also been studied. A drastic change in the intrinsic fluorescence properties, e.g. static fluorescence quenching, occurred due to the complex formation with UO_2^{2+}. Species containing UO_2^{2+} of the type $M_pL_qH_r$ were identified from the dependencies observed in the ultraviolet visible and time-resolved laser-induced fluorescence spectroscopy spectra at pyoverdin concentrations below 0.1 mM. The following average formation constants were determined: log β_{112} = 30.00 ± 0.64 and log β_{111} = 26.00 ± 0.85 at ionic strength I = 0.1 M ($NaClO_4$). The determined stability constants can be used for calculations of the mobilizing effect of released pyoverdins on uranium.

Submitted manuscripts on the interactions between pyoverdins and radionuclides:

Moll H, Johnsson A, Schäfer M, Pedersen K, Budzikiewicz K, Bernhard G, 2007. Curium(III) complexation with pyoverdins secreted by a groundwater strain of Pseudomonas fluorescens. (Submitted to Biometals)

Moll H, Glorius M, Bernhard G, Johnsson A, Pedersen K et al., 2007. Uranium(VI) Complexation with Pyoverdins Secreted by a Subsurface Strain of Pseudomonas fluorescens. (Submitted to Geomicrobiology)

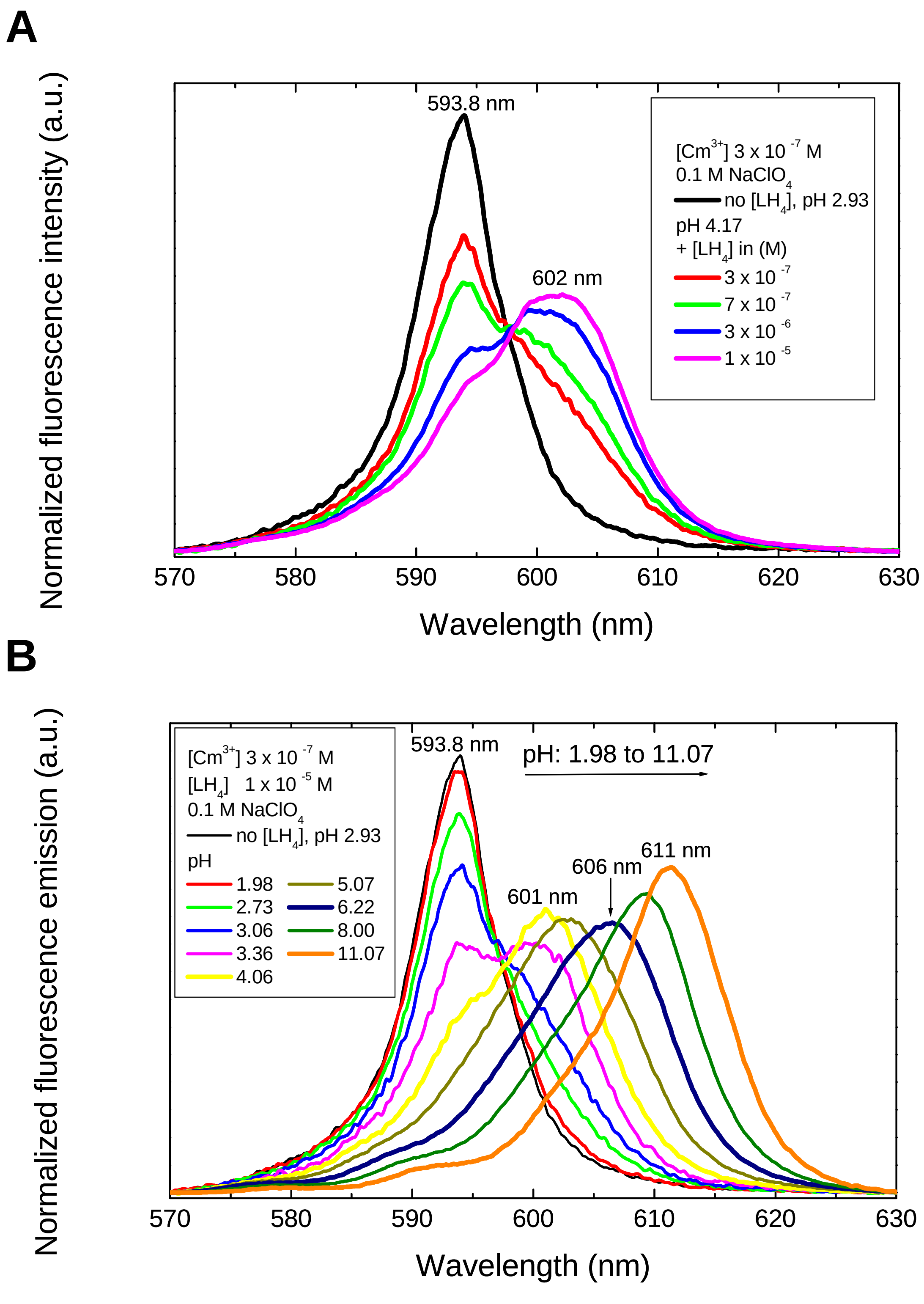
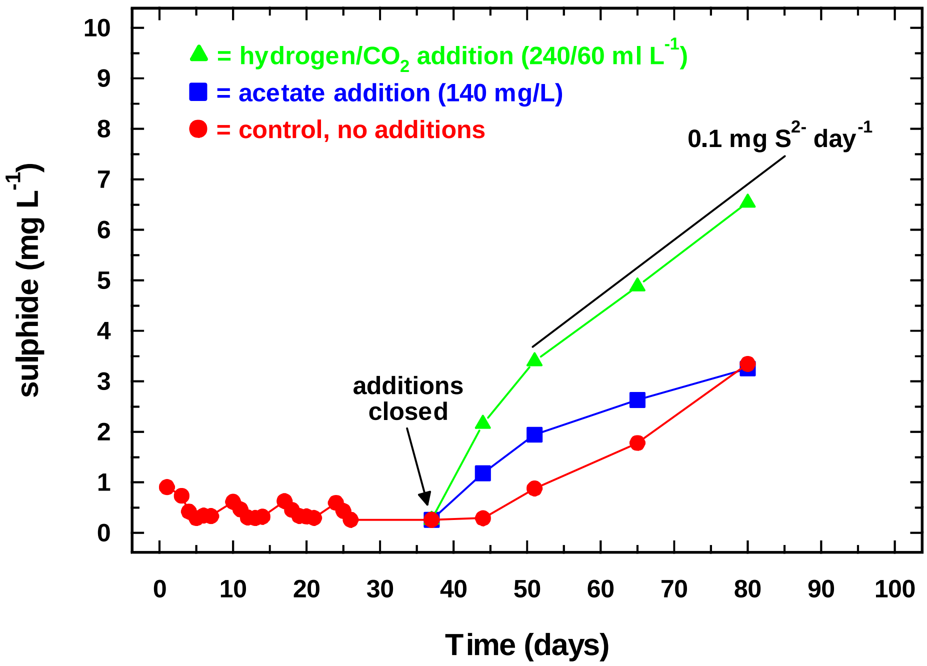


Figure 3-4. *The image shows fluorescence emission spectra of 3×10^{-7} M curium(III) measured: A) as a function of the pyoverdin concentration, LH_4, at pH 4.17 in 0.1 M $NaClO_4$; and B) at a fixed pyoverdin concentration of $[LH_4]$ 1×10^{-5} M as a function of pH. The spectra are scaled to the same peak area.*

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

A methodology that analysed microbial process rates have been developed and tested under open and closed controlled in situ conditions in a circulation system in the Microbe laboratory. The sulphide and acetate production rates were determined to be 0.08 and 0.14 mg L^{-1} day^{-1} respectively, see Figure 3-5. The numbers of sulphide- and acetate-producing microorganisms increased concomitantly in the analysed circulating groundwater. Flushing the sampled circulation aquifer created an artefact, as it lowered the sulphide concentration. Microbial and inorganic processes involved in sulphur transformations have been summarised in a conceptual model, based on the observations and results presented here. The model outlines how dissolved sulphide may react with ferric and ferrous iron to form solid phases of iron sulphide and pyrite. Sulphide will, consequently, continuously be removed from the aqueous phase via these reactions, at a rate approximately equalling the rate of production by microbial sulphate reduction.

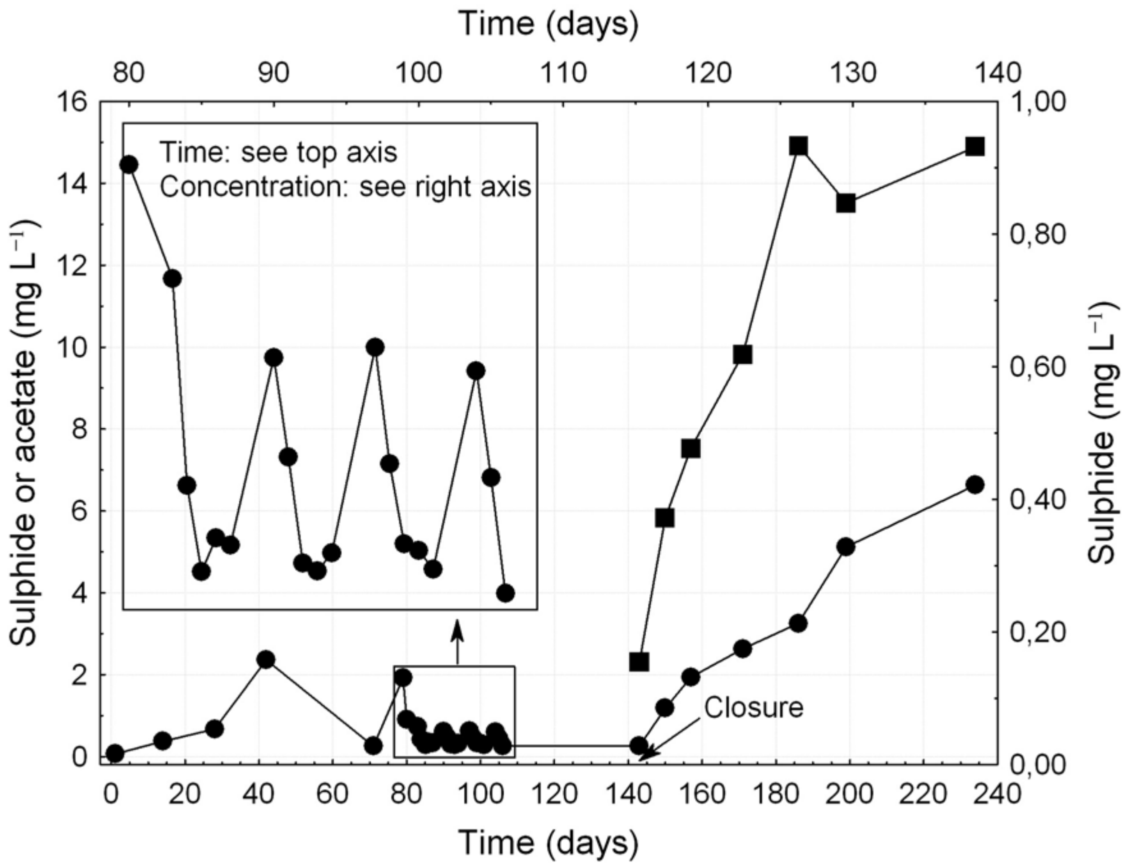
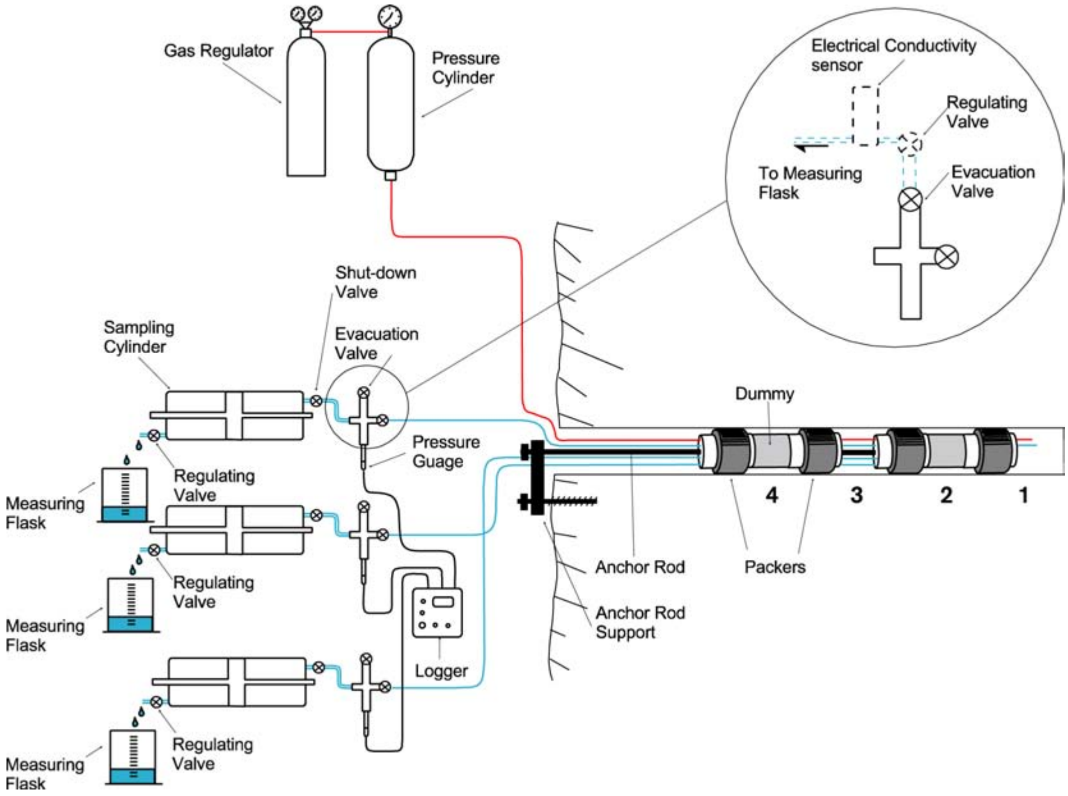


Figure 3-5. *The concentration of produced sulphide (dots) and acetate (squares) in the circulation system as a function of time.*

3.5 Matrix Fluid Chemistry Continuation



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

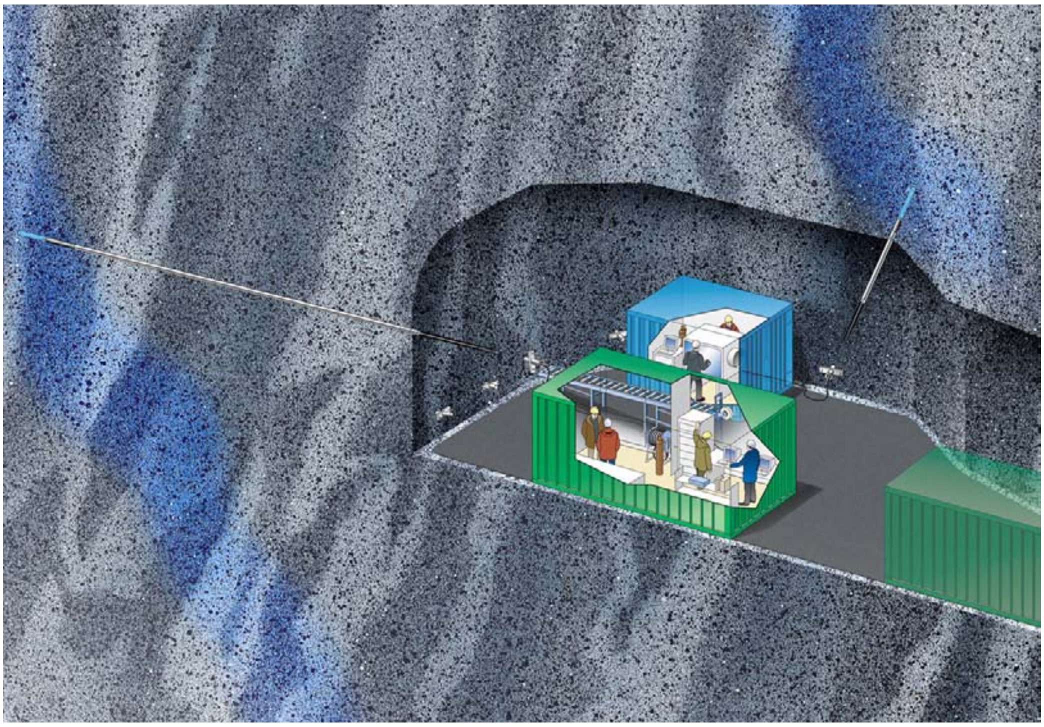
Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied to determine their contribution, if any, to the composition of the matrix fluids/groundwater.

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

Achievements

The final reporting of matrix fluid chemistry and matrix borehole hydraulic testing as TD reports are still outstanding due to site investigation priorities.

3.6 Radionuclide Retention Experiments



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

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

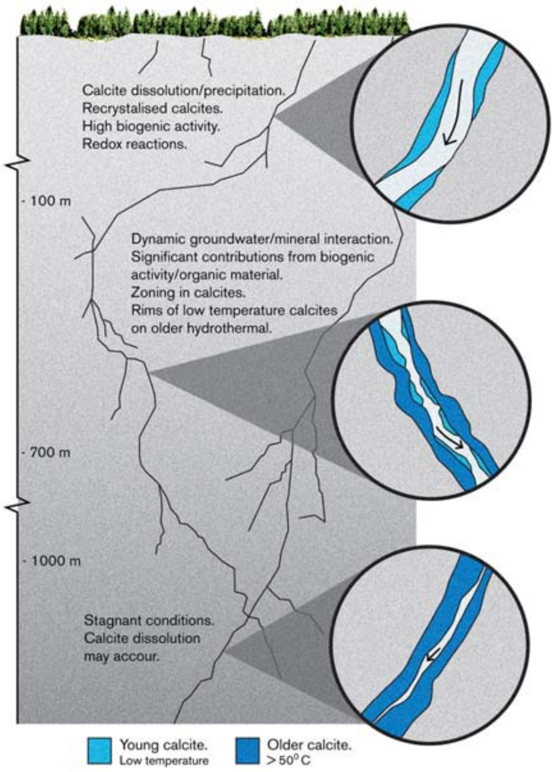
Chemlab 1:
- Investigations of the influence of radiolysis products on the migration of the redox-sensitive element technetium in bentonite (finalised).
- Investigations of the transport resistance at the buffer/rock interface (planned).

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

Achievements

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

3.7 Padamot



Potential calcite-groundwater interaction at various depths at Äspö.

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

The objectives of Padamot are to:

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

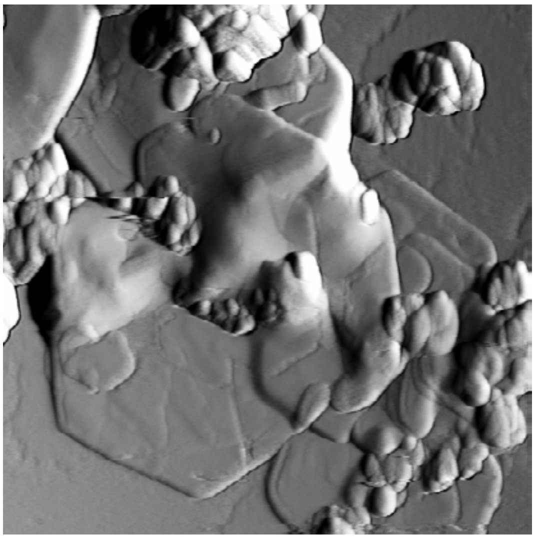
The EC-part of the project was finalised and reported in 2005. The present project comprises analytical and modelling tasks mainly based on uranium series analyses. Material from borehole KAS17 at Äspö is used in this study.

Achievements

The new phase of the project concerns uranium series measurements where different approaches will be tested by two different laboratories. The analyses will be carried out on split samples of fracture material from a surface borehole drilled at Äspö (KAS17). This borehole penetrates the large E-W fracture zone called the Mederhult zone and several sections with fractured rocks are intersected by the borehole. Six samples from different depths (from 19 to 200 m core length) are analysed.

The preliminary results from Helsinki University indicate: (a) the amount of uranium is high enough to allow USD (Uranium Series Disequilibrium) analyses with different techniques and (b) recent mobilisation-deposition of uranium indicates that the sampled depth covers the depth interval with changing redox conditions (the redox zone). A project meeting was held in Helsinki 14-15 May 2007 and a presentation at the Migration conference in Münich, August 2007 will be given.

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 on-going studies, the aim is to establish the penetration depth of oxidising water below ground.

The approximately 60 samples collected in September 2006 have been examined with optical microscopy and half have been selected for more detailed study. These samples have been characterised with X-ray diffraction and are awaiting analysis with Mössbauer spectroscopy (MS). Following MS the samples will be studied using scanning electron microscopy (SEM).

Once the solid phase has been characterised completely, the material will be dissolved for iron-isotope analysis and, possibly, for dating with uranium-decay series. For a few selected samples, a small amount of solid material will be saved with the aim of performing analysis of their oxygen-isotope content.

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.

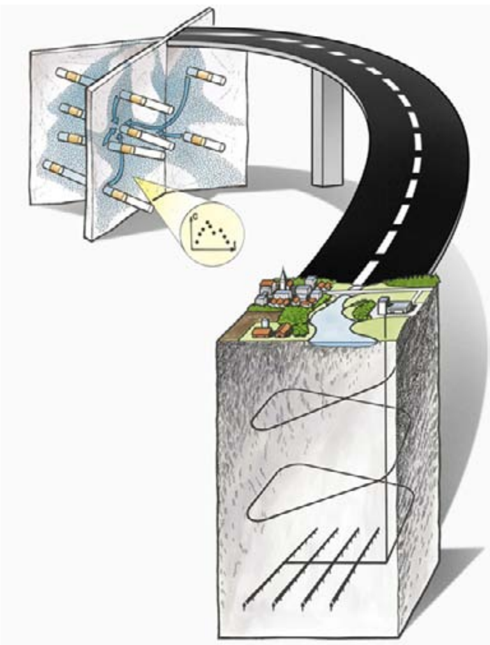
The original location in mind for the tests was the True Block Scale site and the well characterised Structures #19 and #20. The two structures have been object to a large number of tracer tests, possess different characteristics and are located on different distances from the tunnel. The usage of the 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. As pointed out previously, the planned new tunnel nearby may alter the conditions in True Block Scale drastically. The tunnelling is planned to be finished in October 2008 so even if the conditions in True Block Scale is more or less unaltered by the new tunnel, the site will not be accessible for Swiw-tests with synthetic groundwater until then. Hence, today it seems that an alternative site has to be found for this experiment. Results from the feasibility study show that it is possible to detect differences in the breakthrough curve 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.

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 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 sub-task reports 6D, 6E and 6F from the modelling groups have been printed and the review report for these sub-tasks is in the printing process. A summary of the outcome of Task 6 will be submitted to a scientific journal. Work is on-going for this matter. In addition, four modelling groups have written papers for submittal in the same scientific journal, and in conjunction with the summary paper.

Task 7 addresses modelling of the OL-KR24 long term pumping test at Olkiluoto. 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 influence the groundwater system. The possibilities to extract more information from interference tests will also be addressed. Task 7 is divided into several sub-tasks. A task description for the sub-task 7A has been sent out to the modellers and preliminary results from the modelling were presented at the Task Force meeting in Stockholm, January 2007. Updated Task 7 information and data deliveries have been made. In June, a workshop on Task 7 was arranged in Gothenburg, Sweden.

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	Sub-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 sub-task 7A1 and A2 presented at the Task Force Workshop in June).

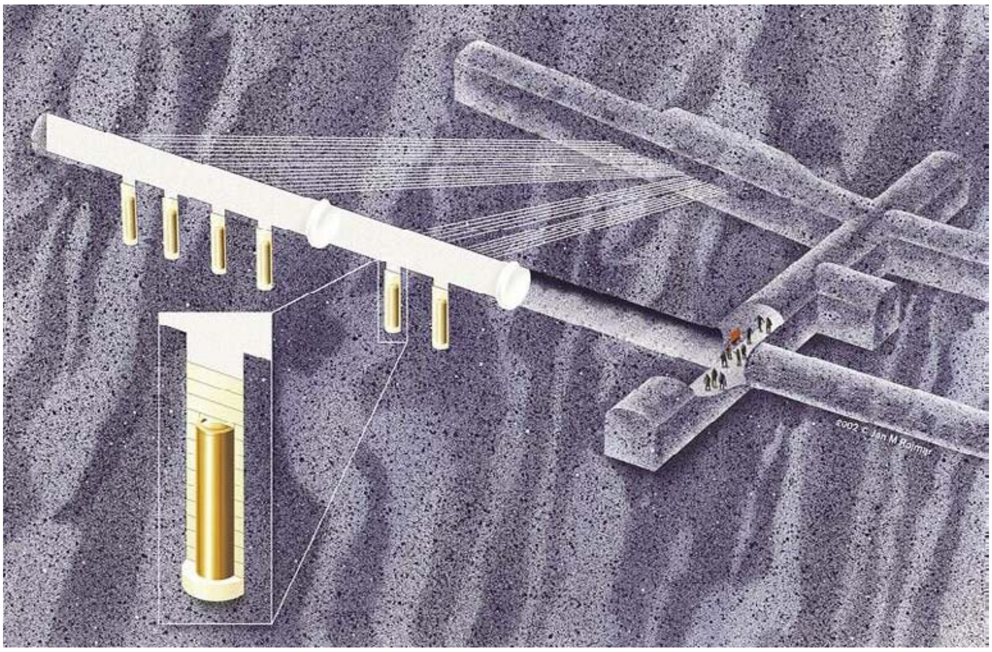
4 Engineered barriers

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 KBS-3H deposition machine inside the horisontal deposition hole.*

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 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 available /Goudarzi and Johannesson 2006/.

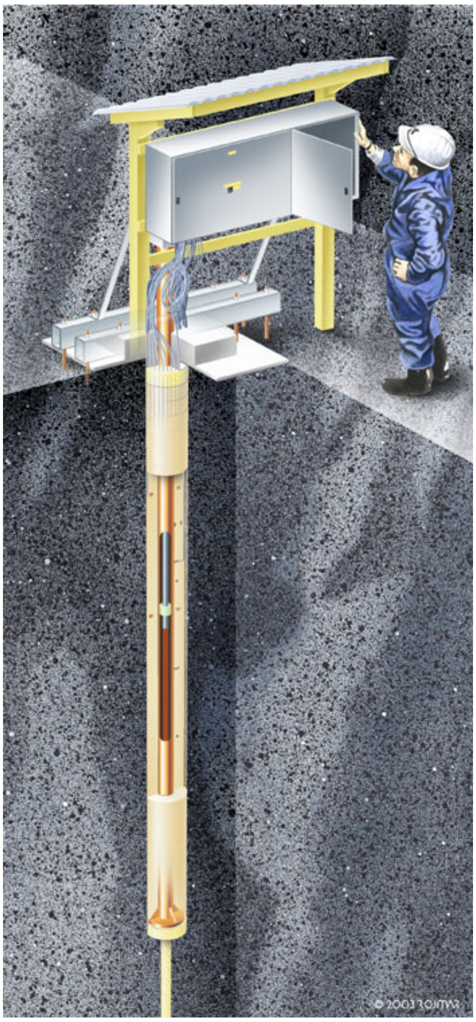
Measurements of pH and Eh of water samples taken from boreholes in Section I and II of the Prototype Repository and the G-tunnel is on-going. The work will be reported after the summer.

A programme for sampling and analyses of gases and microorganisms in the backfill and buffer has started and the first and second campaign has been finalised and reported in a technical document. A third campaign is on-going.

Acoustic emission and ultrasonic monitoring results from deposition hole 5 and 6 have been reported for the period between April 2006 and September 2006 /Haycox and Pettitt 2006/. The acoustic emission and ultrasonic monitoring are continuing.

A thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been developed. The 1D THM modelling of the buffer in deposition hole 1 and 3 has been finished. Furthermore, a 2D TH modelling of an entire deposition hole is in progress. 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.

Seven test parcels containing heater, central tube, clay buffer, instruments and parameter controlling equipment have been placed in boreholes with a diameter of 300 mm and a depth of around 4 m.

Temperature, total pressure, water pressure and water content, are measured during the heating period. At termination of the tests, the parcels are extracted by overlapping core-drilling outside the original borehole. The water distribution in the clay is determined and subsequent well-defined mineralogical analyses and physical testing of the buffer material are made.

The test parcels are also used to study related processes such as bentonite diffusion properties, microbiology, copper corrosion and gas transport in buffer material under conditions similar to those expected in a deep repository.

Achievements

The on-going three tests (see Table 4-1) are functioning well and field data have been inspected and stored in the Sicada database. Laboratory results concerning the A2 test (adverse conditions) have been reported to the Sicada database and the compilation of a final Technical Report including all results from the test is in progress.

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

Type	No.	max T (°C)	Controlled parameter	Time (years)	Remark
A	2	120-150	T, $[K^+]$, pH, am	5	Reporting in progress
A	3	120-150	T	5	On-going
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 packages illustrating the mixing of the different compacted buffer discs.

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

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

The objectives are to:

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

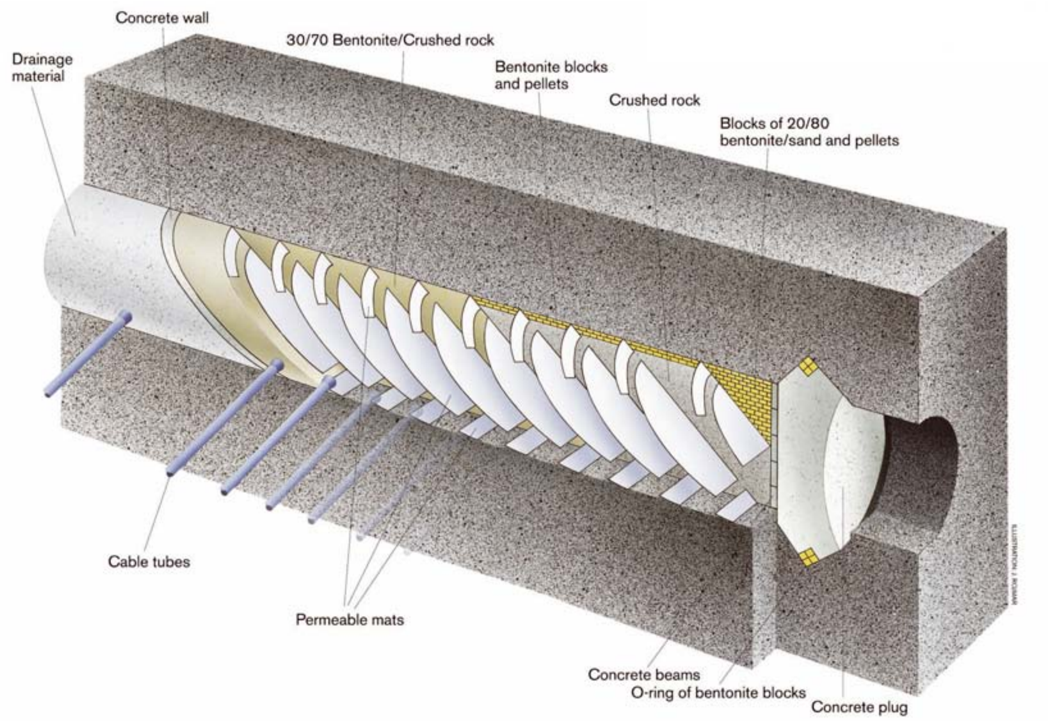
The field tests started during 2006 at Äspö HRL. Eleven different clays have been chosen to examine effects of smectite content, interlayer cations and overall iron content. Also bentonite pellets with and without additional quartz are being tested. The different clays are assembled in three packages.

Achievements

During the second quarter 2007 the temperature in the experiment packages has been raised in steps. Current temperature is just below 100°C. The goal temperature is 130°C.

The concrete blocks holding the experiment packages in position in the boreholes have fractured again. The fractures are insignificant and the function of the concrete blocks is not challenged. Leakage of buffer has not been observed in the fractures or at the boundary between concrete blocks and rock. There is no plan to grout the fractures since the function of the blocks so far is satisfactory.

4.4 Backfill and Plug Test



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

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

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

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

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

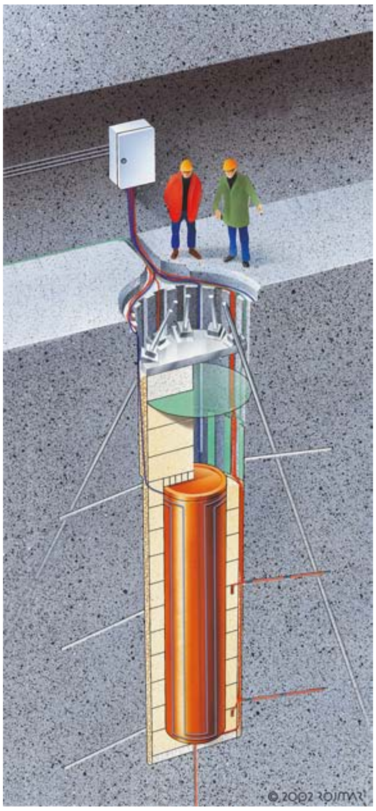
Achievements

The main work during the second 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 cylinders in the 30/70 section have been used for testing the compressibility during this quarter. So far the tests with the cylinder in the floor have been finished (stepwise pressurised to 5 MPa) and the tests with the corresponding cylinder in the roof are on-going. The preliminary results indicate a rather high compressibility.

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

At the Canister Laboratory in Oskarshamn, further sampling of corrosion products has been conducted on the retrieved canister. These samples are taken between the copper canister and the steel cylinder. The samples will be analysed and reported together with earlier taken samples. In addition, a report will be compiled that summarises the results and finding of what caused the heater failure.

Clay Technology has delivered a draft of the report of the first buffer analyses. They will now continue with the more detailed analyses of 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 and the data link from Äspö to Andra's head office in Paris has been functioning well. Three monthly data reports have been distributed during April-June 2007 and the sensor data report covering the period up to 1st January 2007 is compiled and printed /Goudarzi et al. 2007/

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.

The quality of the water used for hydration was changed on April 17; from formation water to deionised water. The reason for this was to avoid precipitation of salts from the formation water.

The dry gas venting activity has been launched and is on-going. The aim of this is to deplete the dry gas in the sand shield around the upper heater. It has been found that the injection points in the shield have a high flow resistance. A project meeting was held in Weimar in May 2007 to discuss the on-going dry gas venting activity and the future of the project.

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

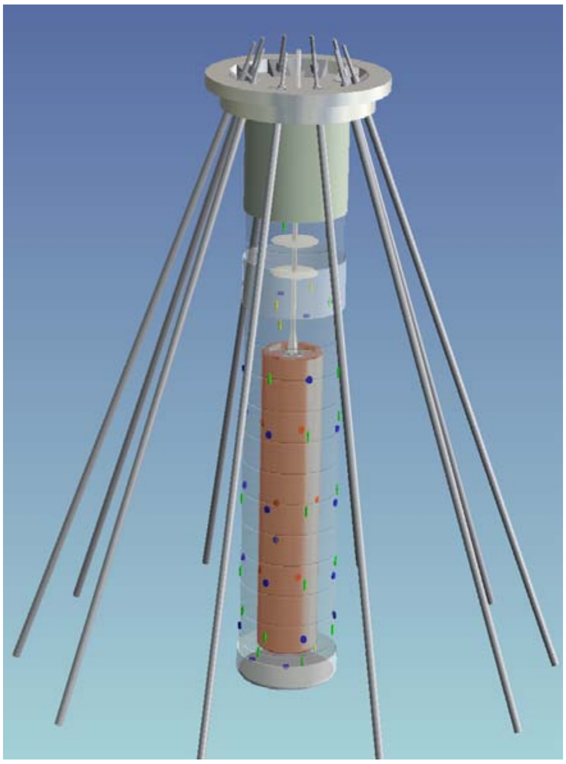
The test and demonstration of the deposition equipment in the 95 m long hole have continued. The Supercontainer has been transported in total roughly 4,500 m since the test started in February. In addition, transportation of distance blocks with the deposition equipment has been accomplished.

Steel plugs are planned to be used to seal off sections in the deposition hole with too high water inflow. The KBS-3H steering group has, however, decided that no plugs will be manufactured and installed during this project phase. The installation has instead been pushed forward to a possible next project phase. The notch that the steel plug will be installed in will be excavated in order to test the sawing method.

Laboratory tests on low-pH concrete (without additives to prevent shrinkage) are after two months showing shrinkage and microfractures, but no large fractures are observed. Tests with additives in the low-pH concrete are planned at Swedish cement and concrete research institute (CBI).

The Mega Packer is a special device for grouting of the rock around horizontal deposition holes. The Mega Packer has been ordered and delivery is expected in September. The seals to the Mega Packer have already been delivered to Äspö and the pump to be used in the planned tests are being developed by SKB staff.

4.8 Large Scale Gas Injection Test



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

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

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

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

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

In February 2005 the deposition hole was closed and the hydration of the buffer initiated. When the buffer is fully saturated a series of gas injection tests will be undertaken to examine the mechanisms governing gas flow in KBS-3 bentonite.

Achievements

A preliminary gas injection history will be performed during 2007 with a view to verifying the operation and data reduction methodologies outlined in the original concept report and to provide qualitative data on hydraulic and gas transport parameters for a bentonite buffer during the hydration process (i.e. under locally saturated conditions). These tests will be designed to minimise the effect of reintroducing gas into the system at this stage of the hydraulic process. With this in mind, activities during the second quarter have focused on: (a) the continued hydration of the bentonite buffer; (b) leak-testing of key experimental systems in anticipation of gas testing later this year and (c) start of hydraulic measurements for the determination of baseline hydraulic properties.

Given the current state of saturation within the buffer, preliminary mass transport measurements will be undertaken in one of the 100 mm filters positioned in the lower canister array (i.e. FL901 or FL903). In May 2007, the lower filter arrays were isolated from all neighbouring test circuits and the pressures allowed to decay to provide information on the spatial distribution of local porewater pressures in the vicinity of each filter. This information is a required parameter for interpretation of future gas tests.

In the target filter selected for future gas testing, a constant head test will be undertaken in June, with the objective of providing additional information on the baseline hydraulic properties of the bentonite. During hydraulic testing the remaining filters in the lower level will continue to be isolated from the artificial hydration system and their pressure allowed to evolve in order to provide temporal data on local porewater pressures within the buffer clay. Simultaneously artificial hydration will continue through all remaining canister filters and hydration mats. Analysis of the experimental data indicates that isolation of the FL filters, signifying the start of hydraulic testing, has had no discernable effect on the monitored values of stress and porewater pressure within the Lasgit system.

Current porewater pressures within the clay remain rather low ranging from 160 kPa to 510 kPa. This is in contrast to the water pressure measured at the face of the deposition hole which ranges from 1,100 kPa to 2,500 kPa and is non-uniformly distributed across the rock face (Figure 4-2a). Monitored radial stress around the canister continues to increase steadily ranging in value from 1,600 kPa to 5,360 kPa (Figure 4-2b), with an average value of 4,100 kPa.

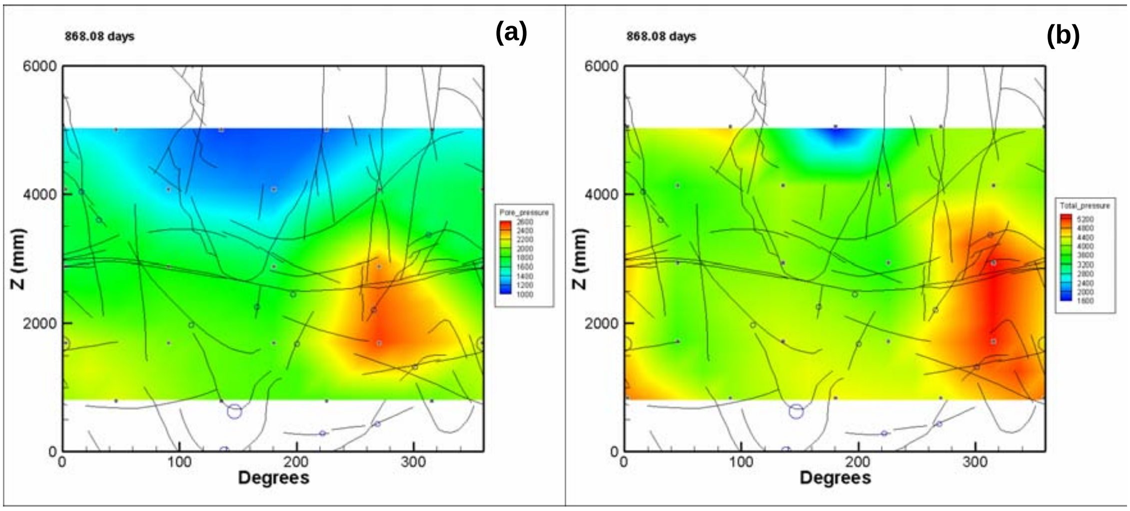
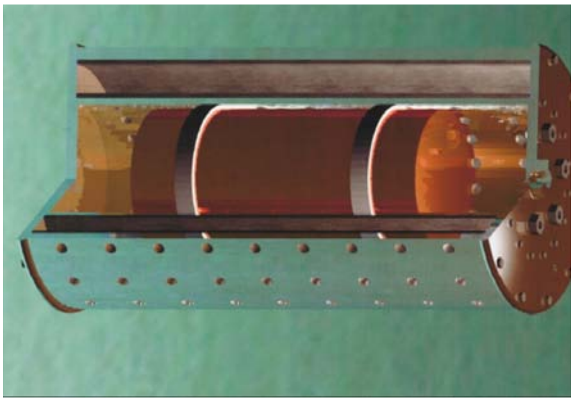


Figure 4-2. *The distribution of porewater pressure (a) and radial stress (b) measured at the rock face of the deposition hole at an elapse time of 868 days.*

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 4,600 kPa and 4,800 kPa, which are comparable with the average value of radial stress monitored on the rock face. Axial stress within the clay ranges from 4,830 kPa to 6,000 kPa with an average of 5,231 kPa, and is non-uniformly distributed across the major axis of the emplacement hole.

The test has been in successful operation for in excess of 870 days. 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 have been set up in five boreholes with a diameter of 30 cm and a length of 5 m at the Äspö HRL. The canisters are mounted in support cages, four of which contain bentonite, and are exposed to natural reducing groundwater. Together with corrosion test coupons which are also in the boreholes, the canisters will be monitored for several years. The corrosion will take place under realistic oxygen-free repository conditions that are very difficult to reproduce and maintain for long periods of time in the laboratory.

Achievements

All five miniature canisters were installed in the beginning of 2007. Data relating to the environmental conditions, corrosion behaviour of the test specimens and dimensional changes are continuously collected and analysed. An annual technical report summarising the installation of the experiments and collected data will be prepared at the end of 2007. Examples of electrochemical potential data that have been acquired in Experiment 3 (miniature canister where groundwater can pass through the bentonite easily) are shown in Figure 4-3 and Figure 4-4.

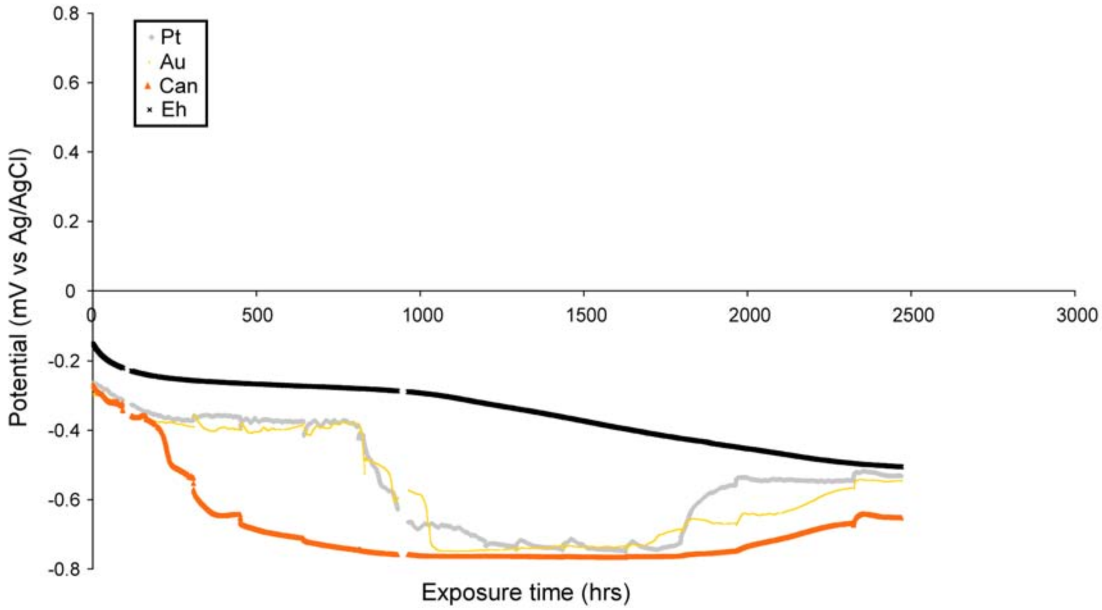


Figure 4-3. *Electrochemical potentials of platinum (grey), gold (yellow), miniature canister (red) and Eh probe (black) in Experiment 3.*

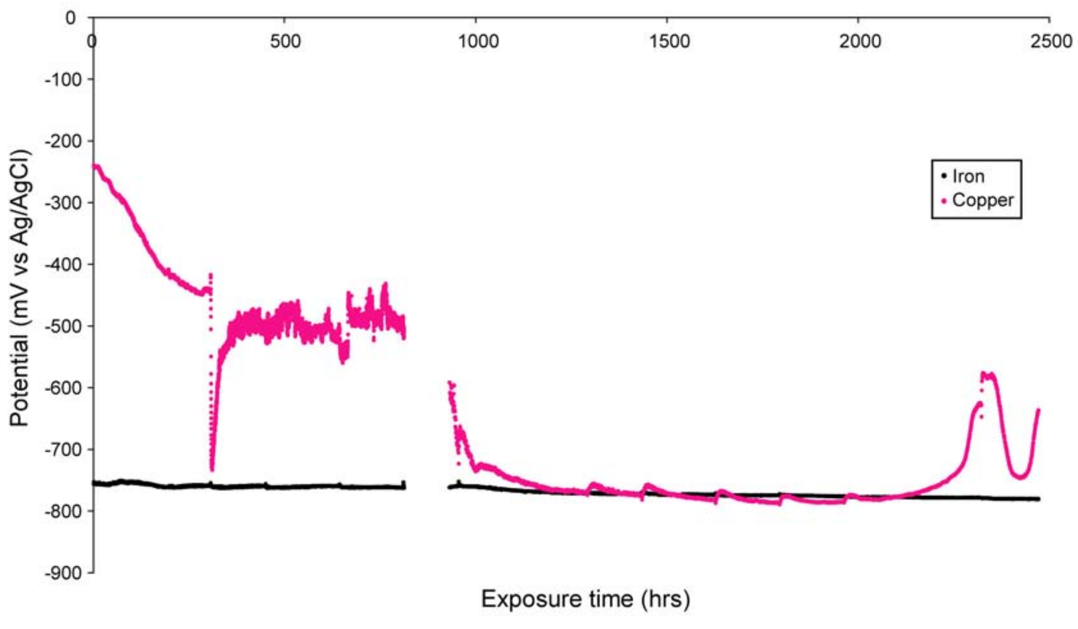
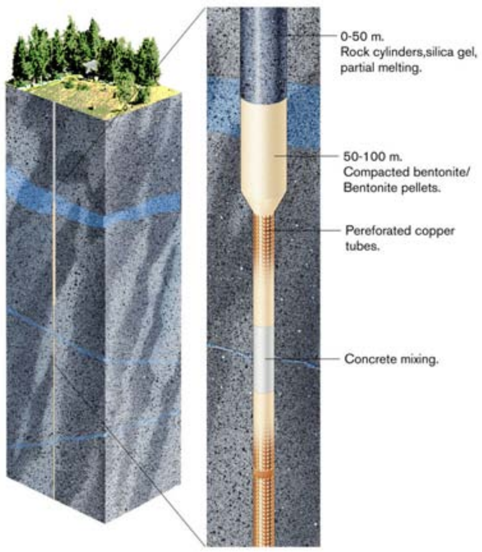


Figure 4-4. *Corrosion potential of iron and copper in Experiment 3.*

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.

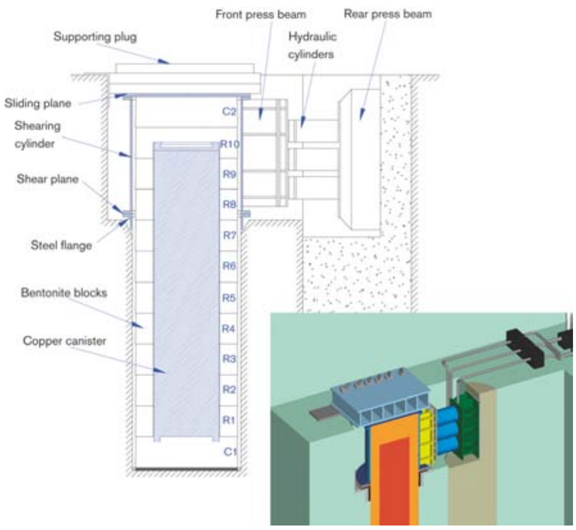
Achievements

The field testing in sub-project 4 is finished. Two types of plugs have been installed and tested in 200 mm wide holes in the Äspö HRL, see Figure 4-5. One plug is made of copper with a conical central part surrounded by coarse lamellae that are pressed out into a recess reamed out in the rock. The other plug is made of quartz/cement (low-pH) that is cast in the hole equipped with the same type of recess as the copper plug.

The draft reports from all the four sub-projects have been reviewed by the Steering group members.

__Figure 4-5__. Over cored copper plug (left) and quartz/cement plug (right).

4.11 Rock Shear Experiment



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

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

Achievements

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

4.12 Earth Potentials

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

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

Achievements

A final report is being compiled that summarise the following working reports:

- Expansion and cation exchange properties of MX-80 bentonite exposed to $CuCl_2$.
- Measurements of earth potentials at Forsmark.
- Possible effects of external electrical fields on the corrosion of copper in bentonite.
- Microbes and earth potentials.

4.13 Task Force on Engineered Barrier Systems

The Task Force on Engineered Barrier Systems (EBS) is a natural continuation of the modelling work in the Prototype Repository Project, where also modelling work on other experiments, both field and laboratory tests, are conducted. The Äspö HRL International Joint Committee (IJC) has decided that in the first phase of this Task Force (period 2004-2008), work should concentrate on:

Task 1 THM modelling of processes during water transfer in buffer, backfill and near-field rock. Only crystalline rock is considered initially, although other rock types could be incorporated later.

Task 2 Gas transport in saturated buffer.

The objectives of the tasks are to: (a) verify the capability to model THM and gas migration processes in unsaturated as well as saturated bentonite buffer, (b) refine codes that provide more accurate predictions in relation to the experimental data and (c) develop the codes to 3D standard (long-term objective).

Participating organisations besides SKB are at present: Andra (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 two Task Forces, THM/Gas and Geochemistry, have common secretariat but separate chairmen.

Achievements

A Task Force meeting with one THM/Gas session and one Geochemistry session was held in Weimar on May 29-30.

Task Force THM/Gas

For Task 1.1 (small scale THM tests) three benchmark tests have been modelled by the teams. Two tests concern the Spanish reference buffer material (Febex bentonite) and the other test 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. Reports from the modelling teams have been delivered. In earlier meetings the modelling results have been presented and compared with measurements. In the meeting in Weimar the final evaluation of the results and the codes used was presented by the chairman. An evaluation report will be published.

For Task 1 the subsequent modelling will concern large scale in situ tests (Task 1.2). The Buffer/Container Experiment and the Isothermal Test carried out by AECL have been presented and specifications delivered (Task 1.2.1). The modelling has started and the first results were presented at the meeting. Another task (Task 1.2.2) that concerns the Canister retrieval Test at Äspö HRL was presented during the meeting. Specifications will be delivered after summer.

For Task 2 (Gas) two benchmark tests have been presented and attempts made to model these tests. Both tests 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 for compilation and review.

Task Force Geochemistry

Molecular dynamics modelling have been made by Clay Technology for SKB for the last six month. The work has focused on the chemical potential of water in the montmorillonite interlayers from which e.g. swelling pressure may be interpreted, and on ion diffusion in the montmorillonite/water system.

Ion diffusion is central in geochemical modelling, and in bentonite this is a complex matter due to the montmorillonite structure. The Task Force meeting in Weimar therefore had the focus on how to treat this matter in forthcoming geochemical modelling. Four presentations concerning the fundamental principles and code development were given.

It was agreed in the steering committee that the continuation of the Chemistry part will start with identifications of two benchmark experiments, and modelling of these will be made by three groups representing SKB, Nagra and Posiva. The first results are expected to be presented at the Task Force meeting in Stockholm in November 2007.

5 Äspö facility

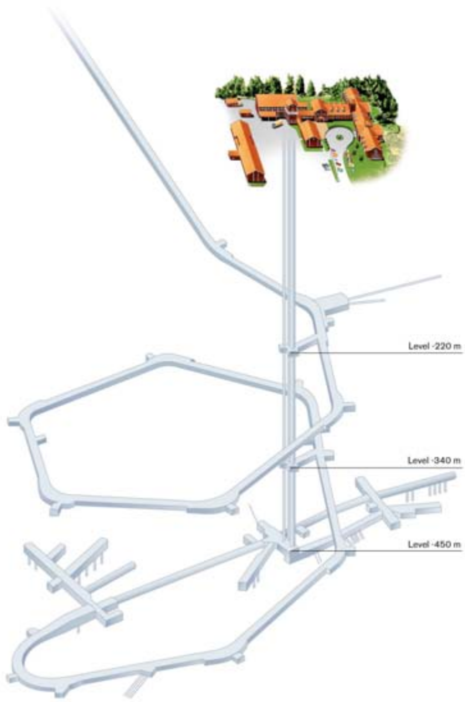
The organisational unit Äspö Hard Rock Laboratory is responsible for the operation of the Äspö facility and the co-ordination, experimental service and administrative support of the research performed in the facility. Activities related to information and visitor services are also of great importance not only to give prominence to Äspö HRL but also to build confidence for SKB's overall commission.

The Äspö HRL unit is organised in four operative groups and a secretariat:

- *Project and Experimental service (TDP)* is responsible for the co-ordination of projects undertaken at the Äspö HRL, for providing services (administration, planning, design, installations, measurements, monitoring systems etc.) to the experiments.
- *Repository Technology and Geoscience (TDS)* is responsible for the development and management of the geo-scientific models of the rock at Äspö and the test and development of repository technology at Äspö HRL to be used in the final repository.
- *Facility Operation (TDD)* is responsible for operation and maintenance of the Äspö HRL offices, workshops and underground facilities and for development, operation and maintenance of supervision systems.
- *Public relations and Visitor Services (TDI)* is responsible for presenting information about SKB and its facilities with main focus on the Äspö HRL. The HRL and SKB's other research facilities are open to visitors throughout the year.

Each major research and development task carried out in Äspö HRL is organised as a project that is led by a Project Manager who reports to the client organisation. Each Project Manager is assisted by an on-site co-ordinator with responsibility for co-ordination and execution of project tasks at the Äspö HRL. The staff at the site office provides technical and administrative service to the projects and maintains the database and expertise on results obtained at the Äspö HRL.

5.1 Hard Rock Laboratory



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

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

Achievements

The systems have been 100% operational except the elevator. The problem was due to corrosion of a cable which connects the different levels where the elevator stops. Moisture hade penetrated the plastic insulation and the metal had corroded. The cable has been replaced and the problem has thereby been resolved.

Extension of the reserve-electricity system continues. The computer-network, fire-alarm, evacuation-alarm, surveillance of operations and camera surveillance from -220 m to -450 m have been connected to new electricity supply-junctions which have battery back-up for electricity-cuts of at least six hours. New equipment will be installed to ensure back up electricity to the rest of the tunnel, network and surveillance-servers. Completion of the system for ring feeding of high voltage current to the transformers below ground is planned for the last quarter.

The work with the system for registration of personnel (RFID) is continuing as planned with quality assurance of the documentation and computer codes. Installation of aerials and screen-monitors at the tunnel entrance and the elevator entrance is planned to be complete in the end of September. The system installed can be further developed in the future.

5.2 Bentonite Laboratory

Before building a final repository, where the operating conditions include the deposition of one canister per day, further studies of the behaviour of the buffer and backfill under different installation conditions are required. SKB has built a Bentonite Laboratory at Äspö designed for studies of buffer and backfill materials. The laboratory, a hall with dimensions 15×30 m, includes two stations where the emplacement of buffer material at full scale can be tested under different conditions. The hall will also be used for testing of different types of backfill material and the further development of techniques for the backfilling of deposition tunnels.

Achievements

The inauguration of the Bentonite Laboratory took place in March 2007. During this quarter preparatory work for coming tests has been on-going. In addition, tests on methods and techniques for pellet installations and emplacement of blocks for backfilling of tunnels have been initiated. A mixer for bentonite has been ordered and is planned to be functional in the beginning of 2008.

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's facilities have been visited by 6,292 persons during the second quarter and in total 12,339 persons during the first six months 2007. The numbers of visitors to the main facilities are listed in Table 5-1.

The summer activities with guided tours in Swedish and English to the exhibition "Urberg 500" started in the end of June. Four summer guides have supported the information group during the summer. SKB was also this year represented by the information group at the music festival in Hultsfred in June.

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

SKB facility	Number of visitors April-June 2007
Central interim storage facility for spent nuclear fuel	511
Canister Laboratory	763
Äspö HRL	2,256
Final repository for radioactive operational waste (SFR)	2,055

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 lanthanides 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.

Four manuscripts have also been submitted:

- Uranium in waters in Forsmark, Laxemar and Äspö (Geochemistry: Exploration, Environment, Analyses).
- The chemical speciation in black shale and its oxidation products (Applied Geochemistry).
- The multi-element chemistry and sulphur isotope patterns in surface waters in Forsmark (Boreal Environment Research).
- Trace-element cycling in coniferous forests in Sweden (Soil and Plant).

7 International co-operation

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

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

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

Projects in the Äspö HRL during 2007	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Enresa	Nagra	RAWRA
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 April - June 2007, the following reports have been published and distributed.

8.1 Äspö International Progress Reports

Magnor B, Hardenby C, Kemppainen K, Eng A, 2007. Rock Characterisation System - RoCS. Final report - feasibility study, phase l. State-of-the-art in 3D surveying technology. IPR-06-07, Svensk Kärnbränslehantering AB.

Forsmark T, 2007. Prototype Repository. Hydraulic tests and deformation measurements during operation phase. Test campaign 7. Single hole tests. IPR-07-02, Svensk Kärnbränslehantering AB.

Äspö Hard Rock Laboratory. Planning Report for 2007. IPR-07-06, Svensk Kärnbränslehantering AB.

Äspö Hard Rock Laboratory. Status Report. January - March 2007. IPR-07-09, Svensk Kärnbränslehantering AB.

8.2 Technical Documents and International Technical Documents

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

9 References

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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Goudarzi R, Åkesson M, Hökmark H, 2007. Temperature Buffer Test. Sensors data report (Period 030326-070101) Report No:9. SKB IPR-07-07, Svensk Kärnbränslehantering AB.

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Haycox J R, Pettitt W S, 2006. Acoustic emission and ultrasonic monitoring results from deposition hole DA3545G01 in the Prototype Repository between April 2006 and September 2006. SKB IPR-06-36, Svensk Kärnbränslehantering AB.

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