International Progress Report

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Äspö Hard Rock Laboratory

Status Report
January – March 2008

Svensk Kärnbränslehantering AB

June 2008

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Äspö Hard Rock Laboratory

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Overview

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

The plans for SKB's research and development of technique during the period 2008–2013 are presented in SKB's RD&D-Programme 2007 /SKB 2007/. The information given in the RD&D-Programme related to Äspö HRL is annually detailed in the Äspö HRL Planning Report /SKB 2008/.

This Äspö HRL Status Report is a collection of the main achievements obtained during the first quarter of 2008.

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, Long Term Sorption Diffusion Experiment, Colloid Dipole Project, Microbe Projects, 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, Sealing of Tunnel at Great Depth, In Situ Corrosion Testing of Miniature Canisters and Cleaning and Sealing of Investigation Boreholes.

THM processes and gas migration in buffer material are addressed in the Task Force on Engineered Barrier Systems and in a parallel Task Force geochemical processes in engineered barriers are studied.

Äspö facility

The Äspö facility comprises of the Hard Rock Laboratory and the Bentonite Laboratory that was taken in operation in 1995 and 2007 respectively. 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. The municipality of Oskarshamn and SKB have formed a research and education platform, Nova FoU, based at Nova Centre for University Studies Research and Development in Oskarshamn. SKB and Kalmar University is presently working with the integration of the Äspö Research School in the Nova FoU.

International co-operation

The Äspö HRL has so far attracted considerable international interest. Eight organisations from seven countries participate in the co-operation or in Äspö HRL related activities, apart from SKB, during 2008.

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 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 2008, 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 2008–2013 are presented in SKB's RD&D-Programme 2008 /SKB 2007/. 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 2008/ for more background information. The Annual Report presents and summarise new findings and results obtained during the present year.

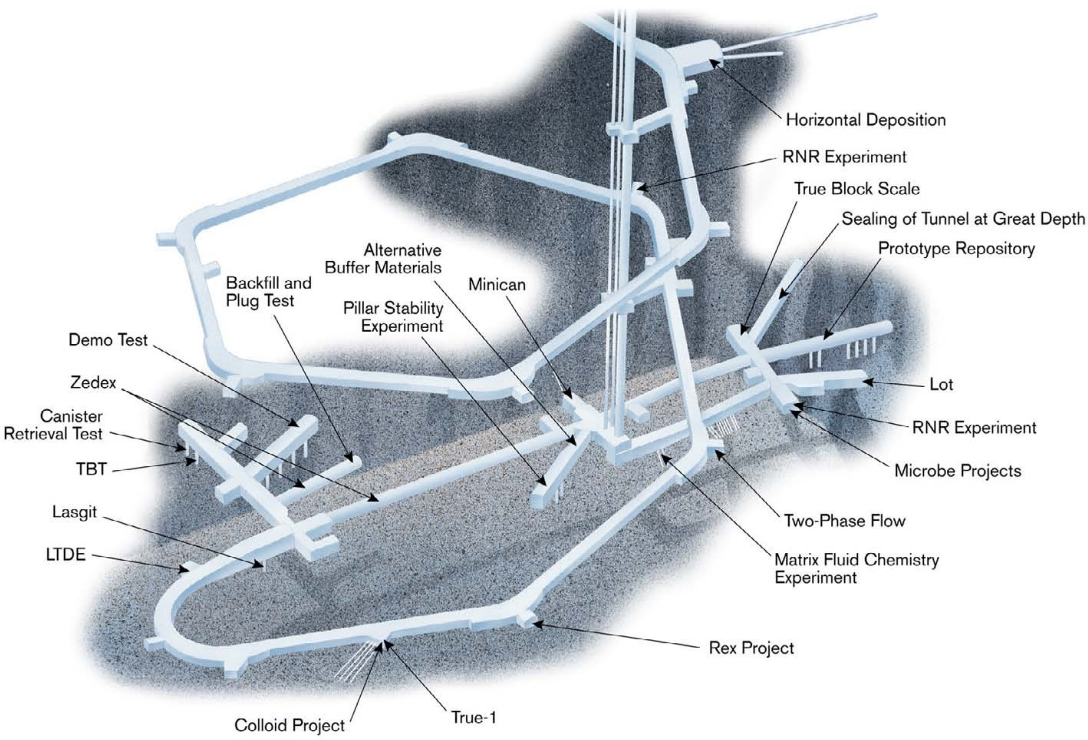


Figure 1-1. Allocation of some of the experimental sites from the -220 m to -450 m level.

2 Geoscience

2.1 General

Geoscientific research is a natural part of the activities at Äspö HRL and is conducted in the fields of geology, hydrogeology, geochemistry and rock mechanics. Studies are performed in laboratory and field experiments as well as by modelling work. The objectives are to:

- Establish and develop geoscientific models of the Äspö HRL rock mass and its properties.
- Establish and develop the knowledge of applicable measurement methods.

The main task within the geoscientific field is the development of an Äspö Site Descriptive Model (SDM) integrating the information from the fields of geology, hydrogeology, geochemistry and rock mechanics. The activities further aim to provide basic geoscientific data to the experiments and to ensure high quality of experiments and measurements related to geosciences.

2.2 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. Also, development of new methods in the field of geology is a major responsibility.

The previous project Rock Characterisation System (Rocs) will now continue as a sub-project in Geological Mapping and Modelling.

2.2.1 Geological Mapping and Modelling

Mapping of the tunnel floor of the Tasq-tunnel

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

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

Achievements

The main activities during the first quarter of 2008 have been:

- The excavation of the new tunnel Tass ("Sealing of Tunnel at Great Depth") at the -450 m level has continued. Geological mapping of five tunnel fronts has taken place as well as that of the roof, walls and floor up to section 20.74 m, see Figure 2-1. Data and drawings have been fed into the TMS (Tunnel Mapping System). Laser scanning combined with digital photography within the same tunnel section has been performed.
- The geological mapping of the floor in Tasq-tunnel was finished during July. The input of the geological mapping data into the TMS is completed. Quality control of all data is now performed.
- The modelling work that commenced in 2005 concerning water bearing fractures at the -450 m level is finished and the report is almost completed.
- Some old mapping of tunnels and deposition holes still needs to be entered into the TMS.
- The previous project Rocs continues as a sub-project and will in the future concentrate on the characterisation of rock. The work with a new project plan has recently commenced.

Figure 2-1. *Tass-tunnel, geological mapping of the tunnel front, section 20.74 m. Water leakage from borehole KI0014B01.*

2.3 Hydrogeology

The objectives of the hydrogeological work 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.

The main task is the development of the integrated Äspö Site Descriptive Model. An important part of the site description is the numerical groundwater model which 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. Another part of the work with the site description is the continued development of a more detailed model of hydraulic structures at the main experimental levels below -400 m.

2.3.1 Hydro Monitoring Programme

The hydro monitoring programme is an important part of the hydrogeological research and a support to the experiments undertaken in Äspö HRL. 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. 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. To date the monitoring programme comprises a total of about 140 boreholes (about 40 surface boreholes and 100 tunnel boreholes). Many boreholes are equipped with inflatable packers, dividing the borehole into sections. Water seeping into the tunnel is diverted to trenches and further to 25 weirs where the flow is measured.

Weekly quality checks of preliminary groundwater head data are performed. Absolute calibration of data registered with HMS is performed three to four times annually. This work involves comparison with groundwater levels checked manually in boreholes.

The data collected in HMS is transferred to SKB's site characterisation database, Sicada.

Achievements

The monitoring system has been performing well and the monitoring points have been maintained. However, maintenance and improvements are continuously made on the system to increase the performance.

Initial tests of existing gas sampling equipment have been performed and samples were sent for analysis of new parameters. Preliminary data suggests methane to be present in the gas phase. Further sampling and analysis are needed to get more reliable data of concentrations and whether this is enough for further analysis of the isotopic composition in the gas phase.

2.4 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.

The overall main task is development of the integrated Site Descriptive Model of the Äspö HRL. The use of the achieved knowledge will facilitate the understanding of the geochemical conditions at the site and the evolution of the conditions during operation of the facility. The intention is to develop the model as to be used for predictions, to support and plan experiments and to test hydrogeochemical hypotheses. In general hydrogeochemical support is provided to active and planned experiments at Äspö HRL.

2.4.1 Monitoring of Groundwater Chemistry

Water sampling in a tunnel at Äspö HRL.

During the Äspö HRL construction phase, water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. The samples were obtained from boreholes drilled from the ground surface and from the tunnel. At the beginning of the Äspö HRL operational phase, sampling was replaced by a groundwater chemistry monitoring programme, with the aim to sufficiently cover the evolution of hydrochemical conditions with respect to time and space within the Äspö HRL.

The monitoring programme is designed to provide information to determine where, within the rock mass, the hydrogeochemical changes are taking place and at what time stationary conditions are established.

Achievements

Criteria for the design and choice of sampling points and parameters in the monitoring programme are being set up for another upcoming sampling campaign during spring 2008. New parameters are being considered, such as additional analysis of isotopes (S, O, C, H and N), organic parameters and gas composition (qualitatively). For instance ATP (adenosine triphosphate) is to be tested again as a biogeochemical parameter.

New project activities have been initiated comprising sampling of gas, see Section 2.3.1. The field work is done in co-operation with the Microbe projects. Further plans are being set up for the development of sampling of gases during spring. It is of major importance to be able to analyse isotopes both in the gas- and liquid-phase, to further study migration of gases, implication for sulphate reduction, microbial influence, biomineralisation in general and trace possible sources of deeper gases. Initial results indicate methane concentrations of about 0.33 ml/L considering about 5-6% of gas volume.

2.5 Rock Mechanics

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

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

2.5.1 Counterforce Applied to Prevent Spalling

In the assessment of the long term safety of a deep repository for spent fuel in Sweden, SR-Can /SKB 2006/, the preliminary assumption was that spalling enhances the hydraulic conductivity between buffer and rock by 1-2 orders of magnitude. In order to refine the data on impact of spalling in the next assessment of the long term safety, SR-Site, several key parameters are required:

- Geometry of spalled zone and its evolution with time.
- Hydraulic properties of spalled zone and their evolution with time.

Assuming that spalling will occur at both Forsmark and Laxemar, the Swedish candidate sites, and that spalling will negatively impact the safety of the repository if left uncontrolled, a programme has been initiated to assess if a solution can be found that will prevent spalling from negatively impacting the safety of the KBS-3 repository. In Figure 2-2 the cross section through the spalled zone in the Pillar Stability Experiment (Apse) is shown.

It is therefore decided to start a new project called Counterforce Applied to Prevent Spalling (Caps). This project will comprise both field test to be carried out at Äspö HRL (Caps-Exp) and numerical modelling (Caps-Dem). The field test, that will include three or four pairs of heated half-scale KBS-3 deposition holes, will be carried out as a series of demonstration experiments. If successful, the field test is an important source of experimental data for verification of the modelling approaches being developed within Caps-Dem. The project is planned to be completed during 2008.

Figure 2-2. *Cross section through spalled zone in the Pillar Stability Experiment (Apse) /Andersson 2007/.*

Achievements

Field test has been planned and test areas on the floor in the Tasq-tunnel has been selected and pilot hole drilling for the first experiment is on-going.

3 Natural barriers

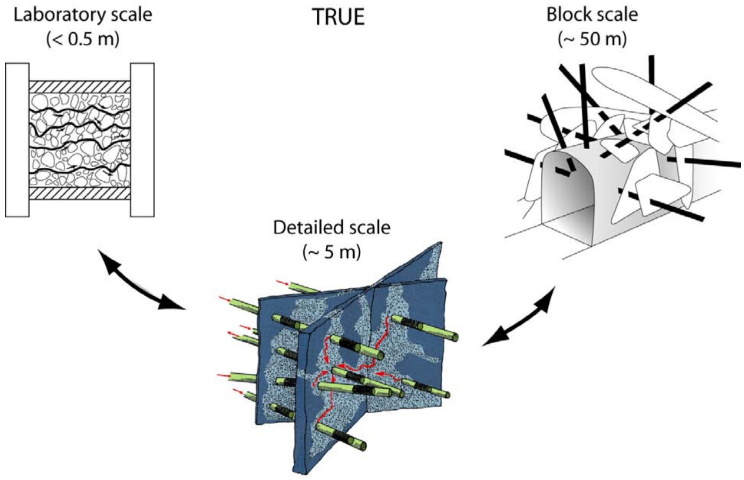
3.1 General

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 (Figure 3-1). 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.

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. *Experimental activities outside the Microbe Laboratory in Äspö HRL.*

3.2 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) /Winberg et al. 2000/ performed in the detailed scale and the True Block Scale series of experiments /Winberg et al. 2003/ have come to their respective conclusion.

Complementary field work and modelling have been performed as part of two separate, but closely coordinated, continuation projects.

The True Block Scale Continuation (BS2) project aimed at obtaining additional understanding of the True Block Scale site /Andersson et al. 2007/. A further extension of the True Block Scale Continuation, (BS3), involves production of peer-reviewed scientific papers accounting for the overall True findings, and in particular those of BS1 and BS2.

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. Additional work includes complementary laboratory sorption investigations on fracture rim and fault gouge materials, plus a series of three scientific articles on the True-1 experiment.

3.2.1 True Block Scale Continuation

The True Block Scale Continuation (BS2) project had its main focus on the existing True Block Scale site. Work performed included in situ tracer tests with sorbing tracers and subsequent assessment of the relative retention in flow paths made up of fault rock zones and background fractures. Results verified lower retention material properties in the background fractures flow path but also showed a higher overall retention in this flow path owing to the much lower flow rate therein /Andersson et al. 2007/. In the aftermath to the BS2 project, a second step of the continuation of the True Block Scale (BS3) was set up. This step has no specific experimental components and emphasise consolidation and integrated evaluation of all relevant True data and findings collected thus far. This integration is not necessarily restricted to True Block Scale, but may include incorporation of relevant True-1 and True-1 Continuation results.

Achievements

The working titles of the three-part series of papers were regrouped as: Transport and retention from single to multiple fractures in crystalline rock at Äspö (Sweden):

I Evaluation of tracer test results, effective properties and sensitivity.

II Structural and hydro-dynamic modelling.

III A macro-scale retention model and impact of micro-scale heterogeneity.

Evaluation and inference of effective parameters from the True Block Scale and True Block Scale Continuation tracer tests is the main topic of Part I which was carried out during 2007. An important novelty of this work is an explicit quantification of sensitivity of the transport model to different hydrodynamic and retention parameters. In Part II, to be carried out during 2008, the flow and advective transport properties in True Block Scale (BS1)/Block Scale Continuation (BS2) will be investigated using a DFN simulation tool for the purpose of setting realistic constraints on the range of retention material properties, as presented in Part I; by doing so, also including an analysis of macro-structural properties and possible network effects for evaluating sorbing tracer test results. Part III is intended to study the impact of micro-structural heterogeneity on retention, in particular the depth-wise trend in the matrix porosity. The novelty in the latter work will be to assess the constraints set by porosity trends on effective retention properties and to assess our predictive capability of effective retention properties for the Äspö diorite. Part III will also include a synthesis of the entire True programme in terms of the improved understanding of retention, predictive capability and implications for site characterisation.

During the first quarter of 2008 a final draft of Part I article was finalised, to be reviewed internally in the True Project group before submittal to the editors of the designated scientific journal. Part I provides a significant development in the evaluation of True tracer tests in general and True Block Scale tests in particular. It paves the way for Part II to provide the macro-scale (hydro-structural) constraints and Part III to provide the micro-scale (rim zone structural) constraints, for more reliable estimation of in situ retention properties, as well as for providing a global scale, effective retention model for Äspö diorite.

Work has also progressed with Part II where the entire True Block Scale rock volume with all its deterministic features and boundary conditions, has been set up in ConnectFlow (for assessing BS1/BS2 results). A sensitivity study of simulated flow and advective transport for the True BS1/BS2 tests is currently in progress (with and without internal fracture variability and random background fractures respectively).

During this period, a code has been completed and tested for a simulation of transport and diffusion-sorption in a single fracture with depth-wise and longitudinal variability in matrix porosity. The structure and outline of Part III has been updated and completed.

3.2.2 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 injection of epoxy resin in Feature A at the True-1 site and subsequent overcoring 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

No work has been performed within the project during the first quarter.

3.2.3 True-1 Completion

True-1 Completion is a sub-project of the True-1 Continuation project and is a complement to already performed and ongoing projects. The main activity within True-1 Completion is the injection of epoxy with subsequent overcoring 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

As discussed in previous status reports, the outcome of the over-coring was not according to the original plan whereas an overview of the upcoming analysis was necessary. Hence, a project meeting was arranged at Äspö during the last quarter in order to present an opportunity for the project members to inspect the cores from KXTT3 and KXTT4 and to discuss the upcoming analysis. The outcome of the meeting will result in an updated timetable for the project and some minor changes of the analysis plan, however the major outlines in the original project plan for the analysis will remain.

3.3 Long Term Sorption 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 is followed by analyses of tracer content.

Small diameter (24 mm) sample cores have been extracted from the 1.1 m long and 278 mm diameter large core retrieved from the over coring. Sample cores have been extracted both from the fracture surface on the core stub and from the matrix rock surrounding the test section in the small diameter (36 mm) extension borehole.

Drilling of sample cores from matrix rock surrounding the test section in the small diameter extension borehole.

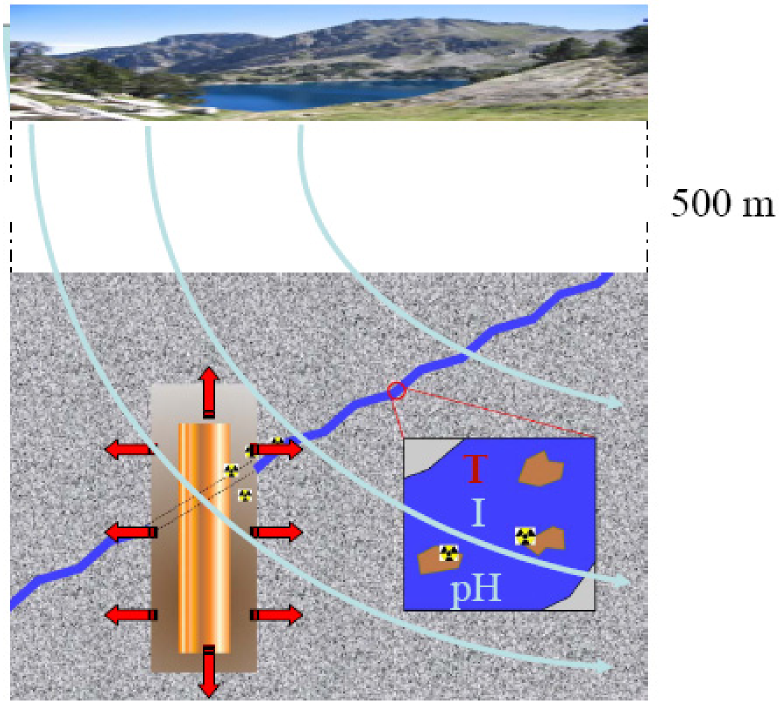
Achievements

The 34 sample cores, extracted from the fracture surface on the core stub and from the matrix rock surrounding the test section in the small diameter (36 mm) extension borehole, have been cut into thin slices and scanned with autoradiography. Scanning of the first few slices showed that radionuclide tracers had been transported by the drill bit along the envelope surface on the sample cores during drilling of the cores. To remove this contamination the following sample cores were sawed into square profile bars before slicing. After autoradiography the slices have been geologically mapped in detail and photographed.

The radionuclide specific penetration profiles will be determined by analysis of radionuclide tracer content in the thin slices. For the non γ-emitting tracers, the tracer content will be analysed by means of mass-spectrometry and liquid scintillation. To allow analysis by these methods the slices from 17 sample cores have been crushed and will further be leached and/or dissolved.

Laboratory experiments with specimens from the core of the small diameter extension borehole, the replica core stub and the pilot borehole core have been initiated. The same tracer cocktail as for the in situ experiment will be used.

3.4 Colloid Project



The Colloid Project is a continuation of the Colloid Dipole Project which is ending in the beginning of 2008 with a final report. The overall goal for the Colloid Project is to answer the questions when colloid transport has to be taken into account in the safety assessment, and how the colloid transport can be modelled.

In the beginning of the lifetime of a deep repository, in bedrock with groundwater of high ionic strength, bentonite and natural colloids are not stable, and colloid transport can be neglected. Of special concern is bentonite erosion, since that could give loss of material leading to a decrease of the barrier function of the bentonite buffer.

In the scenario of intrusion of dilute glacial water the conditions for colloids stability drastically changes. The transport might be the limiting factor in this scenario and has to be taken into account.

In the case of a leaching canister, the bentonite colloids can possibly facilitate the transport of sorbed radionuclide towards the biosphere. In the project, also the transport of organic colloids and other natural colloids are studied and their effect on especially actinide mobility.

The ambition is further to include studies on the transport of colloids which are formed in the spent nuclear fuel.

Achievements

The experiments where the equilibrium concentrations of colloid generated from compacted bentonite and the sedimentation tests have been finished. The evaluation of the data is just finished and an article is in progress.

Studies of sorption on montmorillonite colloids exposed to irradiation are in progress to study if the sorption characteristics of the montmorillonite colloids change upon irradiation. Both radionuclides sorbing by cation exchange and surface complexation are used in the experiments.

Modelling of the transport of bentonite and latex colloids in the quarried block, on different scales and with different flows, is performed. Both breakthrough curves and colloid deposition on the fracture walls are being modelled. The data from the quarried block is used as test sets for further modelling on both smaller scales (well characterised cores) and on larger scales (in situ tests in Grimsel, Switzerland). The collaboration in the Colloid Formation and Migration Project (CMF) in Grimsel is now on-going and tracer tests as pre tests for bentonite colloid transport has just been performed.

Submitted articles in review process:

Holmboe M, Wold S, Jonsson M, Garcia-Garcia S, 2008. Detrimental effects of ionizing radiation on the buffer capacity of the bentonite barrier in a deep bedrock repository for spent nuclear fuel. – Effects of γ-irradiation on Na-montmorillonite colloid stability.

Garcia-Garcia S, Wold S, Jonsson M, 2008. Effects of temperature on the stability of montmorillonite colloids at different pH and ionic strength.

Article accepted for publication in Physics and Chemistry of the Earth:

Vilks P, Miller N H, Vorauer A, 2008. Laboratory bentonite colloid migration experiments to support the Äspö Colloid Project.

3.5 Microbe Projects

Microorganisms interact with their surroundings and in some cases they greatly modify the characteristics of their environment. Several such interactions may have a significant influence on the function of a repository for spent fuel /Pedersen 2002/. There are presently four specific microbial process areas identified that are of importance for proper repository functions and that are best studied at the Microbe Laboratory. They are: bio-mobilisation of radionuclides, bio-immobilisation of radionuclides, microbial effects on the chemical stability of deep groundwater environments and microbial corrosion of copper.

The study of microbial processes in the laboratory gives valuable contributions to our knowledge about microbial processes in repository environments. However, the concepts suggested by laboratory studies must be tested in a repository like environment. The reasons are several. Firstly, at repository depth, the hydrostatic pressure reaches close to 50 bars, a setting that is very difficult to reproduce in the laboratory. The high pressure will influence chemical equilibrium and the content of dissolved gases. Secondly, the geochemical environment of deep groundwater, on which microbial life depends and influence, is complex. Dissolved salts and trace elements, and particularly the redox chemistry and the carbonate system are characteristics that are very difficult to mimic in a university laboratory. Thirdly, natural ecosystems, such as those in deep groundwater, are composed of a large number of different species in various mixes /Pedersen 2001/. The university laboratory is best suited for pure cultures and therefore the effect from consortia of many participating species in natural ecosystems cannot easily be investigated there. The limitations of university laboratory investigations arrayed above have resulted in the construction and set-up of an underground laboratory in the Äspö HRL tunnel. The site is denoted the Microbe Laboratory and is situated at the -450 m level.

3.5.1 The Microbe Laboratory

Working with corrosion experiments at the Microbe Laboratory.

The Microbe Laboratory has been installed in the Äspö HRL for studies of microbial processes in groundwater under in situ conditions.

The Microbe site is on the -450 m level (image above) where a laboratory container with benches and an advanced climate control system is located.

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.

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.

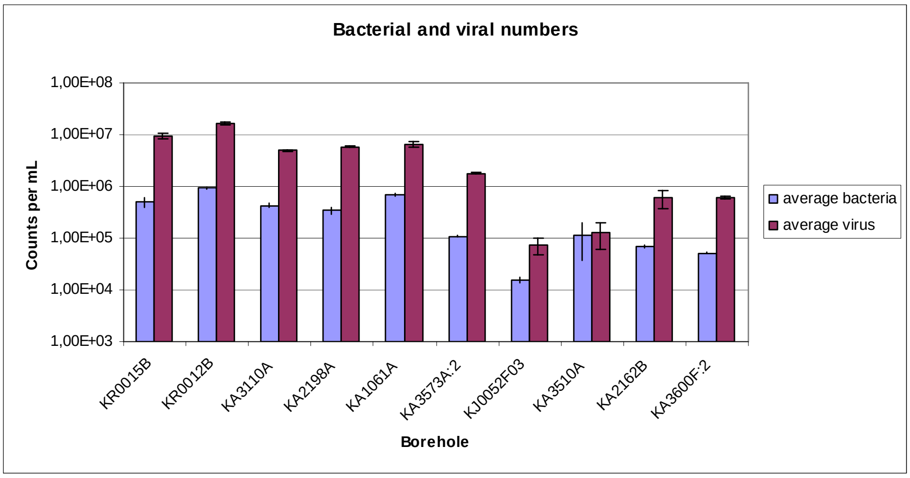
Achievements

Bio-corrosion research has been on-going in periods at the Microbe laboratory. Two new papers have been accepted that relate to survival and activity of sulphate-reducing bacteria. The first paper describes the presence of *Desulfovibrio aespoeensis* in Wyoming bentonite MX-80 /Masurat et al. 2008a/. Recently, the same species was found by and independent laboratory in Friedland bentonite. This species seems to be adapted to survive in bentonite. The second paper deals with the potential for sulphide production in compacted bentonite /Masurat et al. 2008b/. This work has been continued and the new data are presently being analysed and modelling of diffusion and production of sulphide in compacted bentonite is on-going.

Summary of /Masurat et al. 2008a/: The presence of sulphate-reducing bacteria (SRB) indigenous to the Wyoming MX-80 bentonite was investigated. Bentonite was used as an inoculum for enrichment cultures with a medium selective for SRB. The enrichment cultures were re-inoculated to achieve pure cultures, and DNA was extracted from these. The phylogenetic analysis demonstrated that 16S rDNA gene sequences in all the pure cultures were similar to that of *Desulfovibrio africanus*. Further experiments revealed that SRB from the enrichment cultures could grow in temperatures of up to 40°C and sulphide production was detected in the enrichment cultures growing in salt concentrations from 0.7% to 4.0%. These results, combined with a sigmoid morphology of cells in the pure cultures, supported our conclusion that *D. africanus* was present in the bentonite. In addition, dry bentonite was treated for 20 h in 100°C dry heat before incubation in the growth medium. SRB in the bentonite survived and were viable after this treatment. The results indicate that SRB are present in commercial bentonite and that they can survive in a state of desiccation in bentonite at high temperatures and salinity.

Summary of /Masurat et al. 2008b/: The activity of SRB in Wyoming bentonite MX-80 saturated with groundwater from 450 m underground was investigated in situ. The bentonite was compacted to densities of 1.5, 1.8, and 2.0 g cm^{-3}. Lactate was added to the bentonite as a source of energy and organic carbon for SRB. Radioactive sulphur ($^{35}SO_4^{2-}$) was used as a tracer of sulphide production. The copper sulphide ($Cu_x{}^{35}S$) that was produced was localised and quantified using electronic autoradiography. The mean copper sulphide production rates observed were $1.5 \cdot 10^3$, $3.1 \cdot 10^2$, and $3.4 \cdot 10^1$ fmol Cu_xS mm^{-2} day^{-1} [1] at densities of 1.5, 1.8, and 2.0 g cm^{-3}, respectively. The use of sterile-filtered (0.2 μm) groundwater resulted in sulphide production of $1.5 \cdot 10^2$ and $2.4 \cdot 10^1$ fmol Cu_xS mm^{-2} day^{-1} at densities of 1.5, 1.8, and 2.0 g cm^{-3}, respectively. Additional in situ experiments were performed with sterile-filtered (0.2 μm) groundwater and bentonite that had been heated to 120°C for 15 h. Sulphide production rates in the heated bentonite were 1.3–16 times lower than in controls treated at 25°C. These results reveal bentonite to be a source of SRB, in addition to the groundwater. Furthermore, all experiments demonstrated that increasing bentonite density correlated with decreasing copper sulphide production rates. According to the results presented here, sulphide production rates in bentonite compacted to 2.0 g cm^{-3} are hundreds to thousands of times below the rate needed to corrode through the copper capsule over 100,000 years.

3.5.2 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 and possibly also methane from deep geological processes contributes to the redox stability of deep groundwater via microbial turnover of this gas. These metabolisms will generate secondary metabolites such as ferrous iron, sulphide, acetate and complex organic carbon compounds.

The work within the Micored project will:

- Clarify the contribution from microorganisms to stable and low redox potentials in groundwater.
- Demonstrate and quantify the ability of microorganisms to consume oxygen in the near-and far-field areas.
- Explore the relation between content and distribution of gas and microorganisms in deep groundwater.
- Create clear connections between investigations of microorganisms in the site investigations for a future repository and research on microbial processes at Äspö HRL.

Achievements

The Microbe site is a valuable resource for the control and calibration of site investigation methods and models for site related geomicrobiology purposes. A new paper is coming out that describes the integrated work on microbiology between Äspö and the site investigations at Forsmark and Laxemar /Hallbeck and Pedersen 2008/.

Summary of /Hallbeck and Pedersen 2008/: Microorganisms must be included in any hydrogeochemical modelling efforts in the on-going Swedish programme to characterise potential sites for the geological disposal of spent nuclear fuel. The paper presents the development and testing of several methods for estimating the total numbers of microorganism groups and amounts of their biomass in groundwater, their diversity, and the rates of microbial processes. The enumeration and cultivation methods were tested and evaluated on groundwater from boreholes at 450 m depth in the Äspö HRL and from the two potential sites for a final repository of spent nuclear fuel, Forsmark and Laxemar. The reproducibility of the methods between parallel samples and over time was investigated and found to be excellent. Nitrate-, iron-, manganese- and sulphate-reducing bacteria, acetogens and methanogens were found in numbers up to approximately 87,000 cells L^{-1} groundwater from the studied sites. A methodology that analysed microbial process rates was developed and tested under open and closed controlled in situ conditions in a circulation system situated 447 m underground in the Microbe laboratory at the Äspö HRL. The sulphide and acetate production rates were determined to be 0.08 and 0.14 mg L^{-1} day^{-1} respectively. 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, see Figure 3-2. Microbial and inorganic processes involved in sulphur transformations are 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.

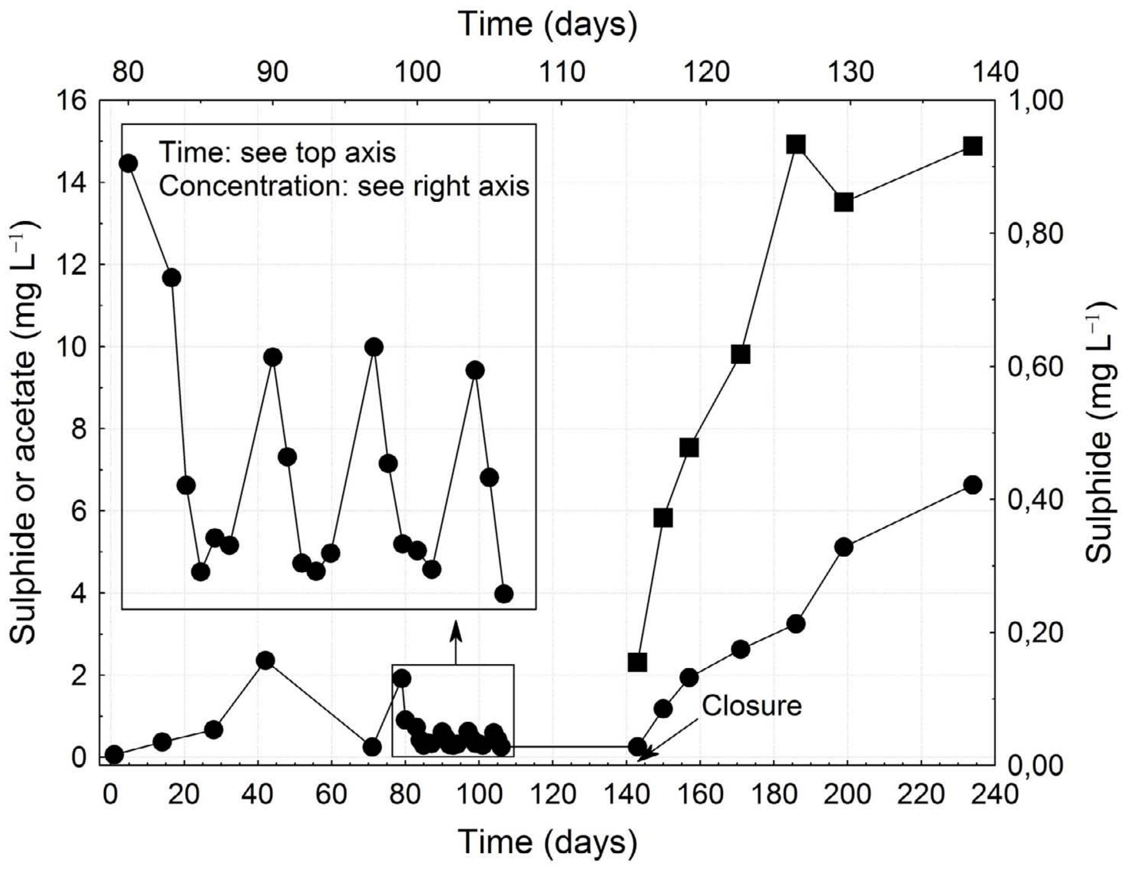
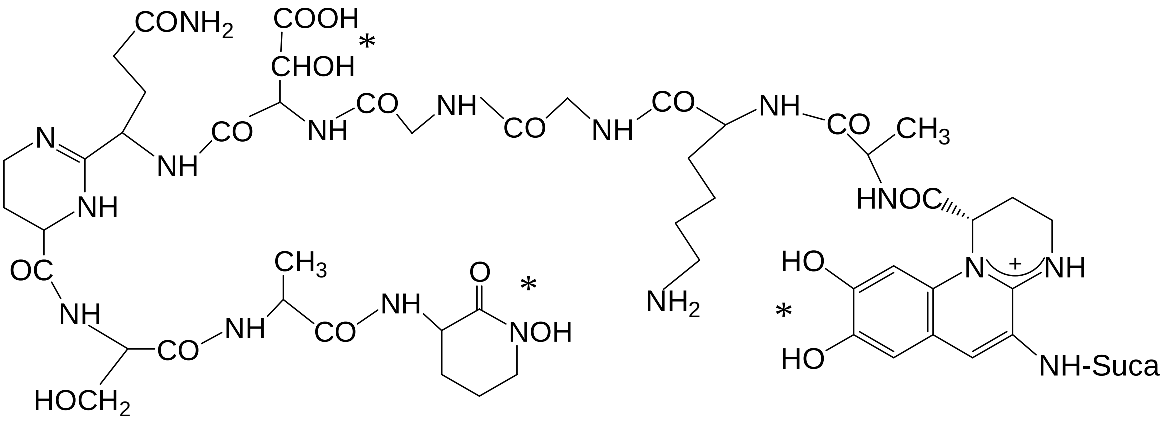


Figure 3-2. *The concentrations of sulphide and acetate over an open (0–140 days) and a closed (140–230) period in a circulation system under in situ pressure (0.3 Mpa) and chemistry conditions at 450 m in the Äspö Hard Rock Laboratory. (●) Sulphide, (■) Acetate. It is obvious that sampling disturbed the concentration of sulphide (from /Hallbeck and Pedersen 2008/).*

3.5.3 Micomig



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

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

Biofilms in aquifers will influence the retention processes of radionuclides in groundwater. Recent work indicates that biofilms may enhance or retard sorption, depending on the radionuclide in question.

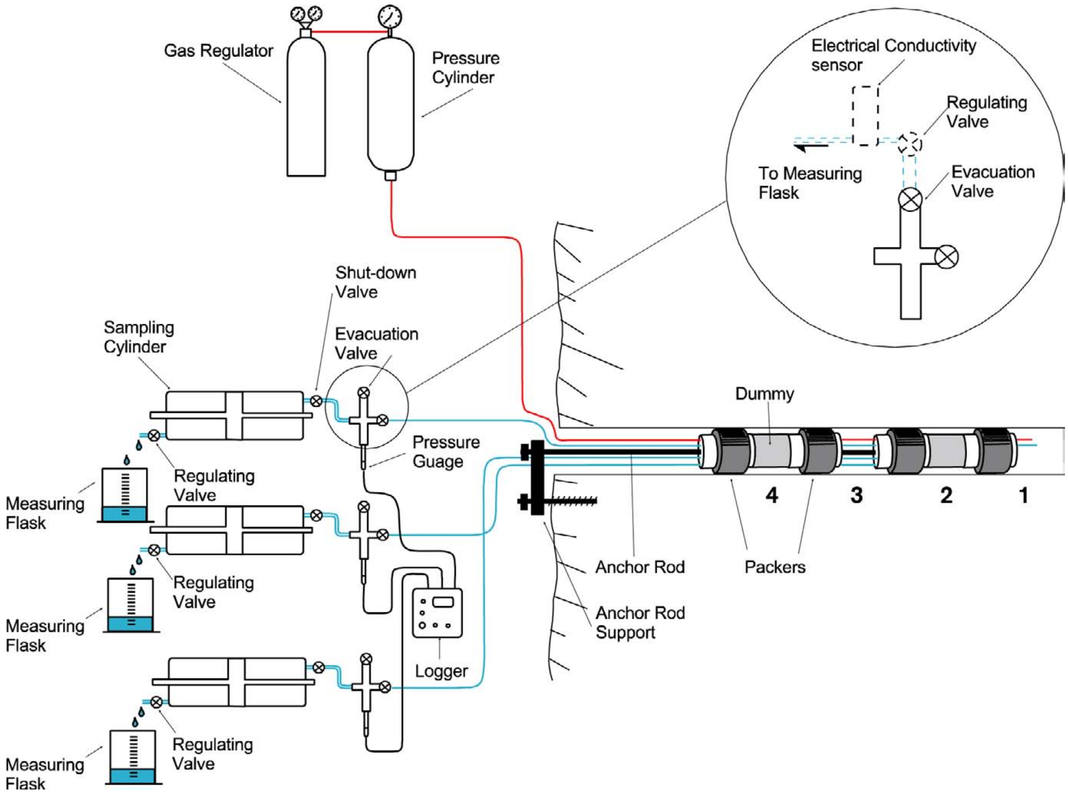
The work within Micomig will:

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

Achievements

There was no field activity within the Micomig project the first three months of 2008. However, preparations have been on-going in the laboratory on ground for analysis of the possible presence and activity of microorganisms that produce complexing agents in groundwater. A set of boreholes along the Äspö tunnel, from -69 to -450 m will be analysed in April.

3.6 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

There have been no activities in the project during the first quarter of 2008.

3.7 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 for instance bentonite samples and on tiny rock fractures in drill cores.

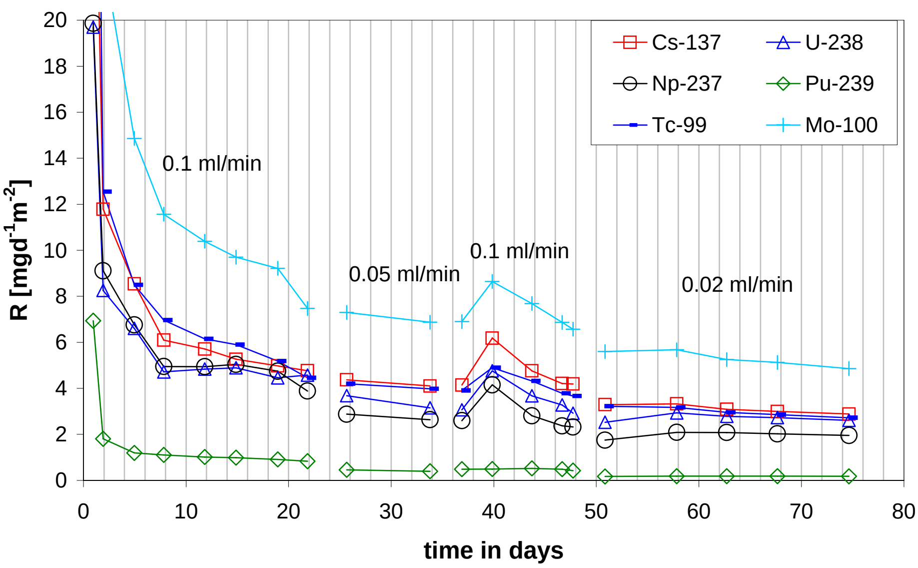
Experiments in Chemlab 1:

- 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).

Experiments in Chemlab 2:

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

3.7.1 Spent Fuel Leaching



Dissolution rates based on different monitors. The spent fuel was leached with 10 mM $NaHCO_3$ under oxidising conditions. Constant dissolution rates could be achieved after some days.

In the Spent Fuel Leaching experiments, to be performed within the framework of the programme for in situ studies of repository processes, the dissolution of spent fuel in groundwater relevant for repository conditions will be studied. The objectives of the experiments are to:

- Investigate the leaching of spent fuel in laboratory batch experiments and under in situ conditions.
- Demonstrate that the laboratory data are reliable and correct for the conditions prevailing in the rock.

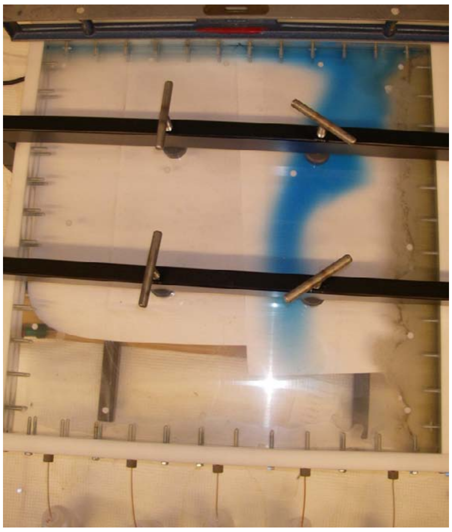
The in situ experiments will be preceded by laboratory experiments where the scope is both to examine parameters that may influence the leaching as well as testing the equipment to be used in the field experiments.

In the field experiments spent fuel leaching will be examined with the presence of H_2 (in a glove box situated in the gallery) as well as without the presence of H_2 (in Chemlab 2).

Achievements

There have been no activities in the project during the first quarter of 2008. However, the experimental set-ups are designed and the laboratory experiments will be performed at Nuclear Chemistry at Chalmers University of Technology with groundwater from Äspö HRL.

3.7.2 Transport Resistance at the Buffer-Rock Interface



The equipment intended for the laboratory experiments. The equipment is currently used in another SKB project, Bentonite Erosion.

If a canister fails and radionuclides are released, they will diffuse through the bentonite buffer. If there is a fracture intersecting the deposition hole, the water flowing in the fracture will pick up radionuclides from the bentonite buffer.

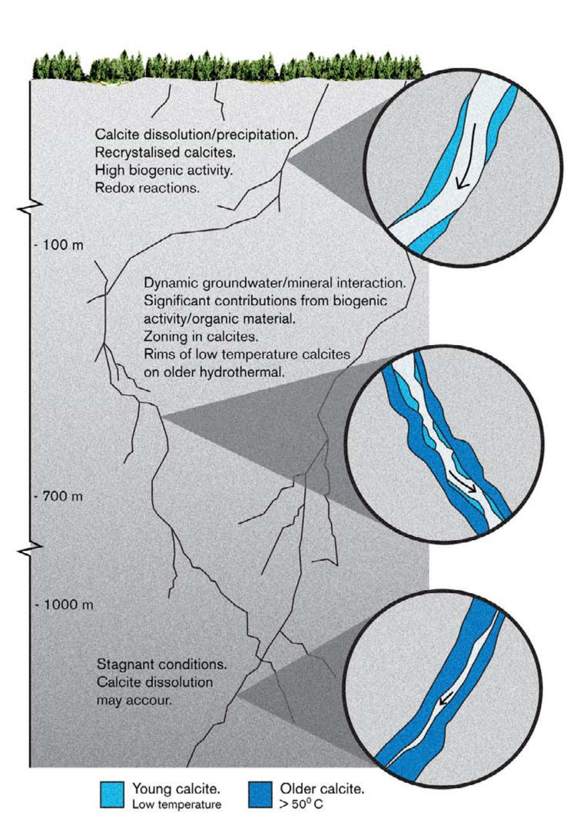
The transport resistance is concentrated to the interface between the bentonite buffer and the rock fracture. The mass transfer resistance due to diffusion resistance in the buffer is estimated to only 6% and the diffusion resistance in the small cross section area of the fracture in the rock to 94% /Neretnieks 1982/. The aim of the Transport Resistance at Buffer-Rock Interface project is to perform studies to verify the magnitude of this resistance.

The experiment will be performed in the laboratory, where a fracture is simulated as a 1 mm space between two Plexiglas plates. The equipment includes a water pump for very low flow rates. The design of field experiments depends on the outcome of the laboratory experiments.

Achievements

There have been no activities in the project during the first quarter of 2008 since the resources needed for this project are currently used in another SKB project. However, a project plan exists and a project decision has been taken.

3.8 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 the Padamot project at Äspö are to:

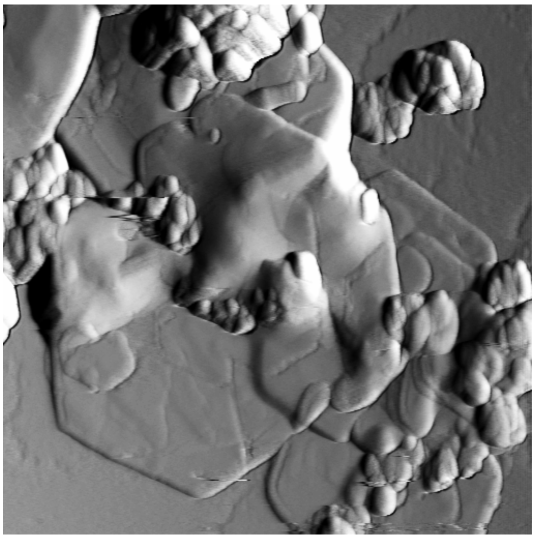
- Improve understanding and prioritise palaeo-hydrogeological information for use in safety assessments.
- Collect chemical/isotopic data using advanced analytical methods.
- Integrate and synthesise results to constrain scenarios used in performance assessments.
- Disseminate the results to the scientific 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 are tested by two different laboratories. The analyses are 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. At present analytical work is carried out which will be available for the next scheduled report.

3.9 Fe-oxides in Fractures



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

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

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

Achievements

Achievements during the last quarter within the continuation phase of the Fe-oxide project have centred on reporting preliminary mineralogy, Mössbauer spectroscopy and Fe-isotope data from fracture samples collected in the spring of 2007. This has shown that amorphous and very fine-grained Fe-oxides have been identified down to approximately 20 m and crystalline fine-grained Fe-oxides down to approximately 50 m. In addition, finer-grained goethite has been identified to depths of approximately 60 m and 90 m respectively, which is interesting because it is not usually found in such environments. By using iron isotope systematics it was possible to differentiate between hydrothermal haematites and both recent and older low temperature Fe-oxides. The results found that low-temperature Fe-oxides formed ≤ 100 m below surface, in a region of high hydraulic conductivity. Although the study is not complete, these results suggest that iron oxides have formed at low-temperature down to 50 m below surface and possibly even down to a depth of approximately 90 m.

Unfortunately, the lower boundary for the passage of oxidised water is constrained by having only two hydrothermal samples. To resolve this situation, additional three samples from the longer drill core KLX09A have been made available to look for Fe-oxides at greater depth.

3.10 Swiw-tests with Synthetic

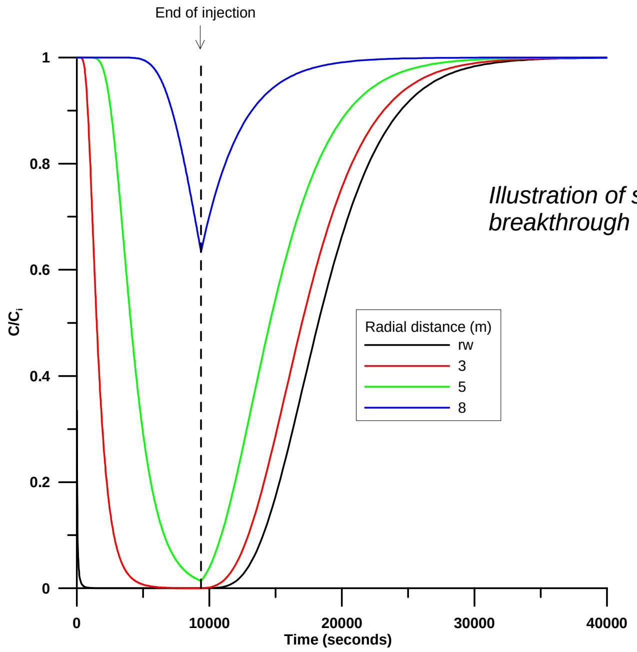


Illustration of solute-free water breakthrough in a single fracture

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 experiments as well as Swiw tests performed within the SKB site investigation programme.

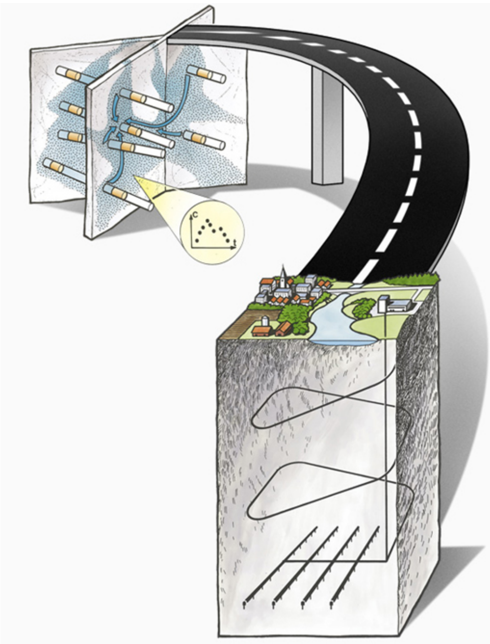
The general objective of the Swiw test with synthetic groundwater is to increase the understanding of the dominating retention processes and to obtain new information on fracture aperture and diffusion. The basic idea is to perform Swiw tests with synthetic groundwater with a somewhat altered composition, e.g. replacement of chloride, sodium and calcium with nitrate, lithium and magnesium, compared to the natural groundwater at the site.

Sorbing as well as non-sorbing tracers may be added during the injection phase of the tests. In the withdrawal phase of the tests the contents of the "natural" tracers (chloride sodium and calcium) as well as the added tracers in the pumping water is monitored. The combination of tracers, both added and natural, may then provide desired information on diffusion, for example if the diffusion in the rock matrix or in the stagnant zones dominates.

Achievements

No major activities were performed within the project during the last quarter since the report from the feasibility study was still under review and further steps within the project will depend on the outcome of the report.

3.11 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 Task Force constitutes an important part of the international co-operation within the Äspö HRL.

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, during the first quarter of 2008. The status of the specific modelling tasks is given within brackets in Table 3-1. The 23rd Task Force meeting was held in Toronto in the end of October and the minutes and proceedings have been sent out.

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. The review report for Task 6D, 6E and 6F is printed /Hodgkinson 2007/ and all, except one, of the reports from the modelling groups have been printed. A summary of the outcome of Task 6 has been submitted to a scientific journal. In addition, four modelling groups have submitted papers to the same scientific journal and in conjunction with the summary paper. The papers are being edited according to comments from the reviewers.

Task 7 addresses modelling of the OL-KR24 long-term pumping test at Olkiluoto in Finland. At the 23rd Task Force meeting, a modification of the task title was suggested as “Reduction of Performance Assessment uncertainty through modelling of hydraulic tests at Olkiluoto, Finland”. The task will focus on methods to quantify uncertainties in PA-type approaches based on SC-type information; along with being an opportunity to increase the understanding of the role of fracture zones as boundary conditions for the fracture network and how compartmentalisation 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 and data for the sub-task 7B have been sent out to the modellers. Planning for a Task 7 workshop in May is on-going.

Table 3-1. Task descriptions and status of the specific modelling sub-tasks.

6	**Performance Assessment (PA) modelling using Site Characterisation (SC) data.**
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 /Hodgkinson and Black 2005/.
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 /Hodgkinson and Black 2005/.
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 /Black and Hodgkinson 2005/.
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. - External review report /Hodgkinson 2007/.
6E	This sub-task extends the sub-task 6D transport calculations to a reference set of PA time scales and boundary conditions. - External review report /Hodgkinson 2007/.
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. - External review report /Hodgkinson 2007/.
7	**Long-term pumping experiment.**
7A1	Hydrostructural model implementation. Preliminary results will be presented at the Task Force Workshop in June.
7A2	Pathway simulation within fracture zones. Preliminary results will be presented at the Task Force Workshop in June.
7A3	Conceptual modelling of PA relevant parameters from open hole pumping.
7A4	Quantification of compartmentalisation from open hole pumping tests and flow logging
7A5	Quantification of transport resistance distributions along pathways
7B	Sub-task 7B is addressing the same as sub-task 7A but in a smaller scale, i.e. rock block scale. Sub-task 7B is using sub-task 7A as boundary condition
7C	Here focus is on deposition hole scale issues, resolving geomechanics, buffers, and hydraulic views of fractures
7D	Tentatively sub-task 7D concerns integration on all scales

4 Engineered barriers

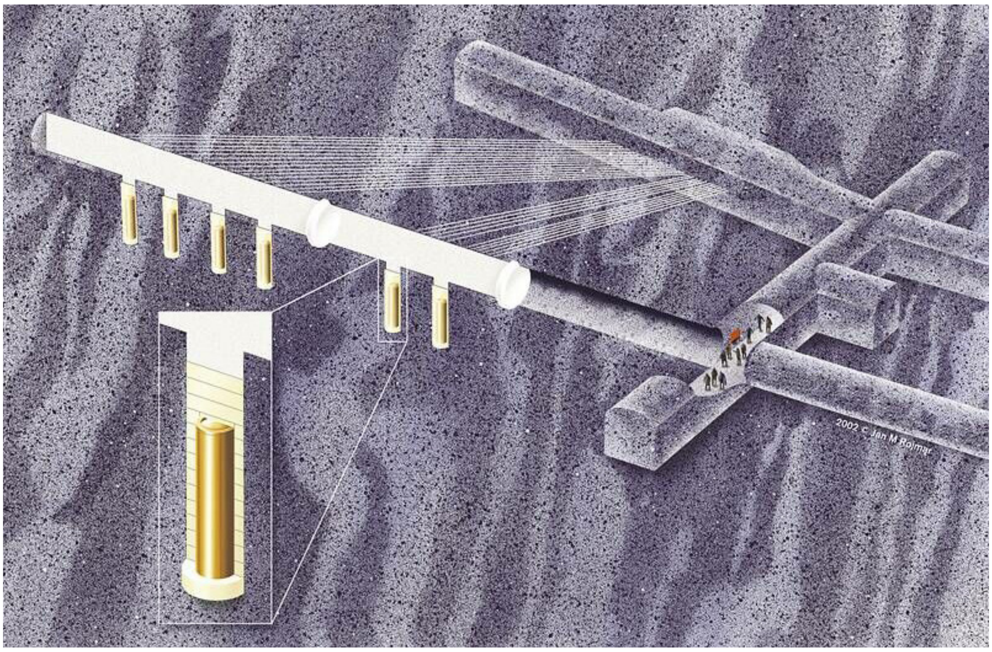
4.1 General

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 (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. *Checking of the equipment at the tunnel front in the experiment Sealing of Tunnel at Great Depth (photo: Curt-Robert Lindqvist).*

4.2 Prototype Repository



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

The Prototype Repository should, to the extent possible, simulate the real 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, canisters #1-#4) 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, canisters #5-#6) was backfilled in June 2003 and the tunnel plug with two lead-troughs was cast in September the same year.

Achievements

The data collection system comprises temperature, total pressure, pore water pressure, relative humidity and resistivity measurements in buffer and backfill, as well as temperature and water pressure measurements in boreholes in the rock around the tunnel. The collection of data is in progress and the data report covering the period up to May 2007 is available /Goudarzi and Johannesson 2007/ and the report covering the period up to December 2007 will soon be published. Overhauling of the data acquisition system is in progress and hydraulic tests of the rock mass have been performed. Measurements of pH and Eh of water samples taken from boreholes in Section I and II of the Prototype Repository and the G-tunnel is on-going.

A programme for sampling and analyses of gases and microorganisms in the backfill and buffer has started. Three campaigns have been finalised and the first and second campaign have been reported in a technical document. A report of analysis of microorganisms, gases and chemistry in buffer and backfill 2004-2007 has been published /Eriksson 2007/. The measurements will continue.

Acoustic Emission and Ultrasonic monitoring from the rock around deposition hole 5 and 6 is continuing.

Studies using thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been reported /Kristensson and Hökmark 2007/. A report concerning 1D THM modelling of the buffer in deposition hole 1 and 3 will soon be published. A report concerning a 3D TM model of the entire experiment is in progress. In this report the possibility of spalling is investigated and also the stress state on a thought fracture plan is studied. Furthermore, a 2D TH modelling of an entire deposition hole is in progress and will be reported during 2008.

4.3 Long Term Test of Buffer Material

The project 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 other processes in bentonite such as cation diffusion, microbiology, copper corrosion and gas transport 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. Compilation of the laboratory results from the different laboratories concerning material from the A2 test is in progress. Additional laboratory tests are performed in order to give information concerning the previously noticed minor changes in cation exchange capacity and rheological properties of the A2 material.

The main effort within the modelling project during this quarter has been to develop a general theory for ion through diffusion in bentonite. This part of the modelling work has now been finalised and a scientific manuscript titled "Ion concentration discontinuities across bentonite/external solution interfaces – Consequences for diffusional transport" has been submitted for publication.

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	140	T, [K^+], pH, am	finalised	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, T = temperature, [K^+] = potassium concentration, pH = high pH from cement, am = accessory minerals added

4.4 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. The aim is to further investigate the properties of the alternatives to the SKB reference bentonite (MX-80). The project is carried out using material that according to laboratory studies are conceivable buffer materials. The experiment is carried out in the same way and scale as the Long Term Test of Buffer Material (Lot).

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.

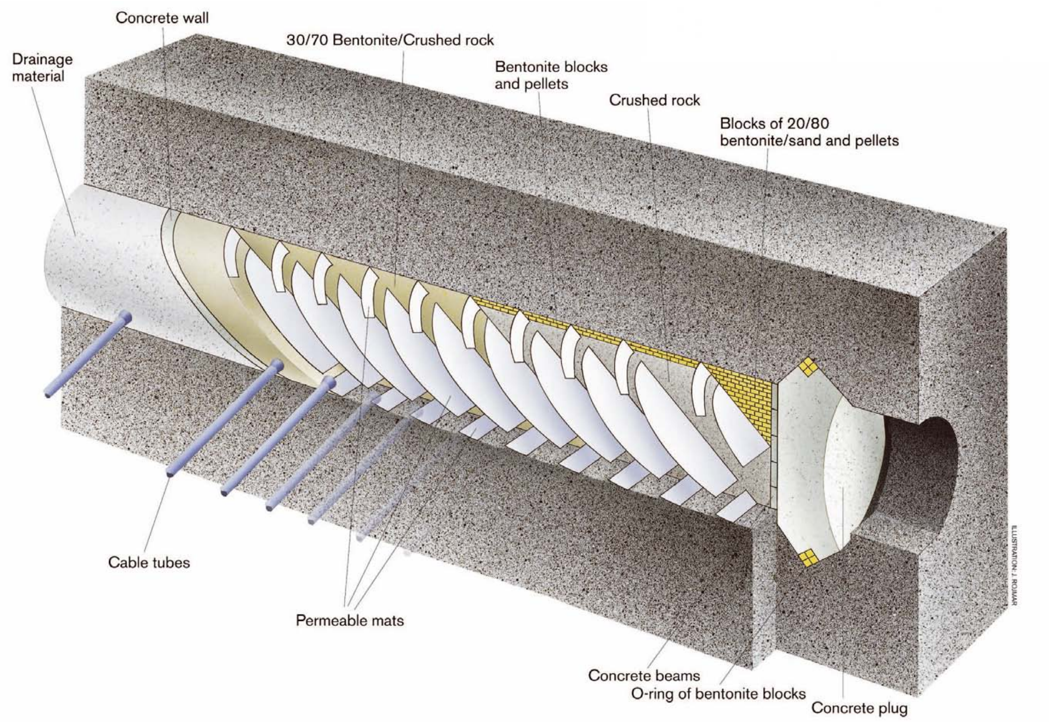
The field tests started during 2006. Eleven different clays have been chosen to examine effects of smectite content, interlayer cations and overall iron content. Also bentonite pellets with and without additional quartz are being tested. The different clays are assembled in three packages.

Achievements

The goal temperature of the heated packages (130°C) has now been reached after the exchange of the heaters to more powerful versions during the last quarter of 2007.

Work has been done to update the project plan for the analyses sub-project in accordance with the agreements from the project meeting in November 2007.

4.5 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.

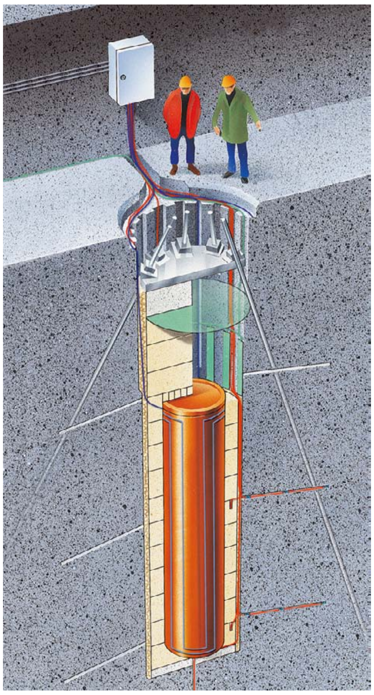
From the end of 2006 until the end of 2007 the compressibility of the backfill was tested by the four pressure cylinders mounted in the roof and the floor.

Achievements

The main work during the first quarter has included continuous measurements and registrations of water pressure and total pressure in the backfill and water pressure in the surrounding rock as well as leakage of water through the plug. The data report covering the period up to 1st January 2007 is available /Goudarzi et al. 2008/.

Measurement of local hydraulic conductivity, with the so called CT-tubes, has started in the zone backfilled with crushed rock.

4.6 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 in May 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

Buffer analyses have continued at Clay Technology during the first quarter and the results will be reported during the second quarter.

The report from the buffer disintegration has been approved and is being printed both in Swedish /Nirvin 2007a/ and English /Nirvin 2007b/.

Modelling of the buffer within the Task Force on Engineered Barrier Systems has continued during the period and will do so also during 2008.

4.7 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 engineered barrier systems, 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 shield (upper section).

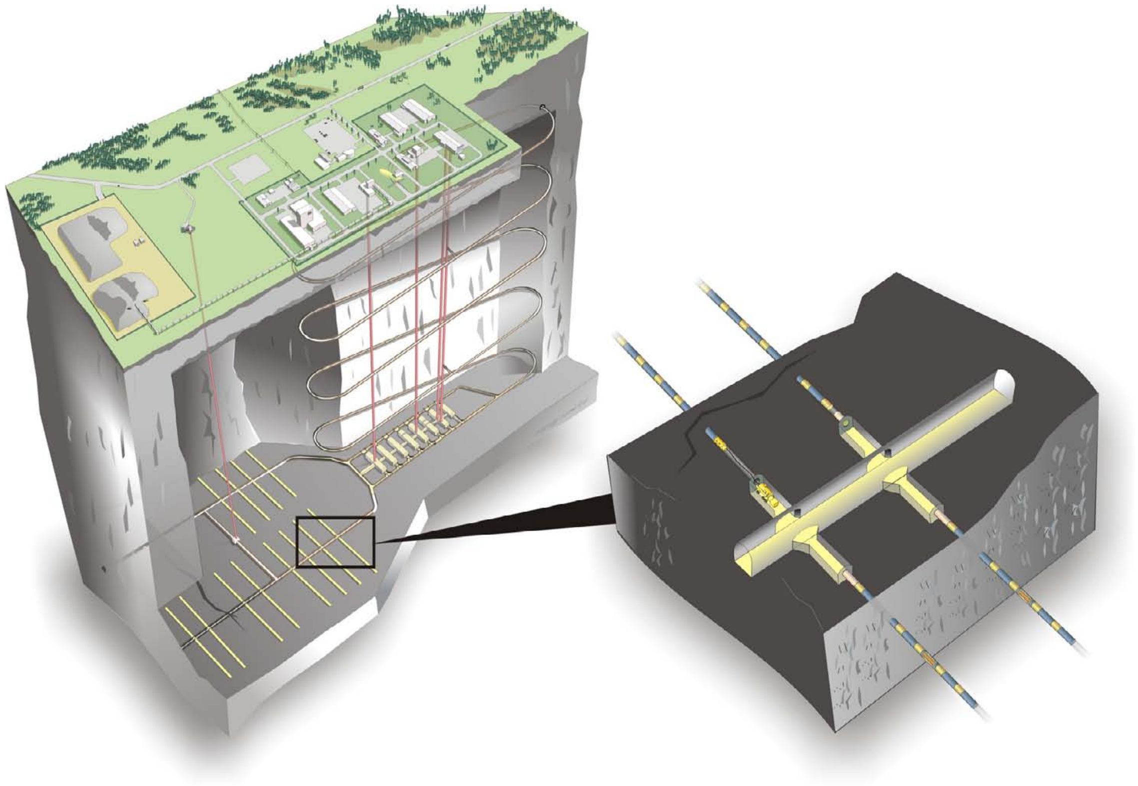
An artificial water pressure is applied in a slot between the buffer and rock, which is filled with sand and functions as a filter.

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. A data report covering the period up to 1st July 2007 /Goudarzi et al 2007/ is available and three monthly data reports have been distributed during January-March 2008.

The hydration of the sand shield is in its final phase. The aim of this has been to saturate the sand shield around the upper heater with water. An increase of shield pressure (as recorded by the pore pressure sensor in the shield) was observed in the second half of January. On February 10, the sensor connected to the CS202 port in the shield also showed an increase up to 4 bars. At the same time a significant leakage was observed from two of the slots at the lid, and the pressurisation of the shield as well as the filter was therefore reduced. The cumulative inflow was approximately 530 litre at that time, which can be compared with the estimated available pore volume of 580 litre. The injected volumes therefore appear to have entered the shield. The current interpretation is however that the leakage originated from the shield and not from the filter.

4.8 KBS-3 Method with Horizontal Emplacement



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

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

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

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

Achievements

The second and last Megapacker test phase is now completed. The three remaining identified fracture zones in the 95 m long hole have been grouted with silica sol using the Megapacker. The results from the first and second test phase will now be evaluated and reported. Preliminary results show that the leakages in the fracture zones were significantly decreased. By grouting five of five fracture zones the total inflow in the drift was reduced from 4.4 L/min to 0.4 L/min. In the short hole (15 m) close to the long hole it was observed that the total inflow has increased from 0.06 L/min to 0.29 L/min.

Before the second phase of the test was carried out some improvements on the Megapacker was done. The issues were mostly related to work environment but minor upgrades in functionality was also implemented.

During the first quarter the first saturation pipe removal test has been completed in the Bentonite Laboratory. The test will now be evaluated. Preliminary results show that the force to pull out the pipes is according to design assumptions and indicate that pipes can be removed rapidly after wetting as planned. Further testing is required to verify results and a new modified experimental set up has been developed for the next test phase.

Planning of the next KBS-3H project phase “Complementary studies of horizontal emplacement KBS-3H” is on-going and a project decision and project plan will be approved in April.

4.9 Large Scale Gas Injection Test

Large-scale gas injection test (Lasgit) 420 m below ground at Äspö HRL. A scientist from the British Geological Survey (BGS) works next to the large steel lid anchored over the deposition hole.

Current knowledge pertaining to the movement of gas in a compacted bentonite buffer 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 gas phases of the test history are key 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:

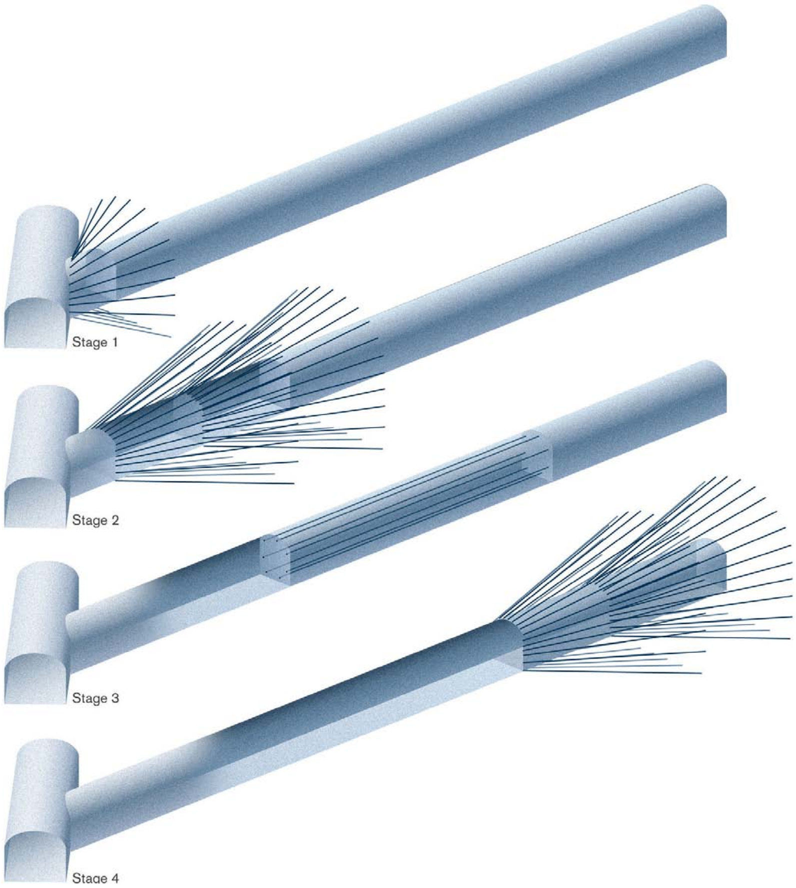
- Perform and interpret a large scale gas injection test based on the KBS-3V design concept.
- Examine issues relating to up-scaling and its effect on gas migration and buffer performance.
- Provide information on the process of hydration and gas migration.
- Provide high-quality test data to test/validate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

In February 2005 the deposition hole was closed and the hydration of the buffer initiated. During 2007 preliminary hydraulic and gas transport tests were performed. These will be repeated as the buffer matures in order to examine the temporal evolution of these properties. When the buffer is fully-saturated a comprehensive series of gas injection tests will be undertaken to examine the mechanisms governing gas flow in KBS-3 bentonite.

Achievements

The artificial hydration of the buffer in the Lasgit project will continue during the entire 2008 and no new gas injection tests will be performed during the year.

4.10 Sealing of Tunnel at Great Depth



The grouting work will be carried out in stages

Although the repository facility will be located in rock mass of good quality with mostly relatively low fracturing, control of the groundwater will be necessary. The measures to control groundwater will include the sealing of fractures that are conducting groundwater by grouting.

Experience from the grouting of road- and railroad tunnels shows that ordinary grouts based on cement cannot penetrate very fine fractures. Further, from a long-term safety view-point, a sealing agent that produces a leachate with a pH below 11 is preferred. Silica sol, which consists of nano-sized particles of silica in water, has shown to be a promising grout. When a salt is added to the sol, a gel is formed. The concentration of the salt determines the gelling time and thus the grouting can be controlled. However, the use of silica sol under high water pressures has to be tested and equipment and grouting designs evaluated.

The main goals of the project are to confirm that silica sol is a useful grout at the water pressures prevailing at repository level, and to confirm that it is possible at this water pressure to seal the water conduction fractures under construction at the Äspö HRL. The execution is step-wise and is planned to include grouting with grout holes inside the contour, tests with post-grouting and tests of the sealing of drips. Low-pH cementitious grout is also tested. The results of the work are scheduled to be reported in 2009.

Another issue for the planned repository is the contour and status of the remaining rock after blasting. The rock is a natural barrier in the KBS-3-system and thus the requirement is to minimize the excavation damaged zone (EDZ), and the resulting contour after blasting should follow the theoretical with small deviations. Special attention is therefore given to drilling and blasting. The results are followed and evaluated closely and subsequent adjustments made.

Achievements

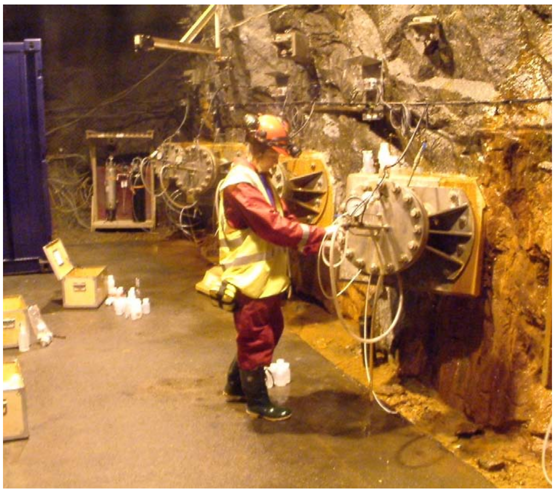
Investigations for the selection of site were carried out during the spring and summer of 2007. The major site requirements were the direction, intensity and size of fractures along the potential tunnel, a high groundwater pressure and a high-enough possibility to keep away from heavily water conducting zones. At an early stage a tunnel position extending from the Tasi-tunnel at the -450 m level was selected as a first alternative. Based on geo-hydrological modelling of the site and its surroundings, and predictions of the singular fractures based on the results from examination of rock cores and geo-hydrological measurements, the site selection was later confirmed.

In parallel with site investigation preliminary designs, drafting for new equipment and procurement for the constructional works were carried out. In September a contract with the contractor for rock works was signed. A silica sol pump with a control device specially designed for the use of silica sol at great depths was specified and manufactured within the project. Initial grouting experiments verified the theories for grout spread and erosion. The importance of putting grouting holes in the middle of the tunnel front to reduce the risk for erosion was observed.

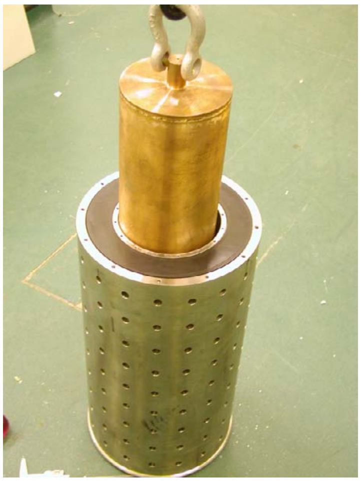
Contract works started in October 2007 with one short grouting fan (stage 1), followed by cautious blasting of the first few meters. The second stage comprises two full-sized ordinary grouting fans, and the first fan was completed in January. Both silica sol (Figure 4-2) and cement-based grout was used. The measurements in boreholes before and after grouting indicated a reduction of the inflow with a factor 1,000. The successful grouting was confirmed by the excavation that revealed a dry tunnel with limited dripping. A spot leakage of around 1 L/min was found in the tunnel wall. During the first week of April the second ordinary fan is being grouted, which will be directly followed by excavation rounds. During the mapping period that will then follow, the first readings of the resulting inflow from the second stage, covering 25 meters of tunnel, can be made in the measuring weir in the tunnel floor.

Figure 4-2. *Silica sol – control of gelling time (photo: Ann Emmelin).*

4.11 In Situ Corrosion Testing of Miniature Canisters



Operation of the five miniature canisters



Miniature canister with support cage

This MiniCan project 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.

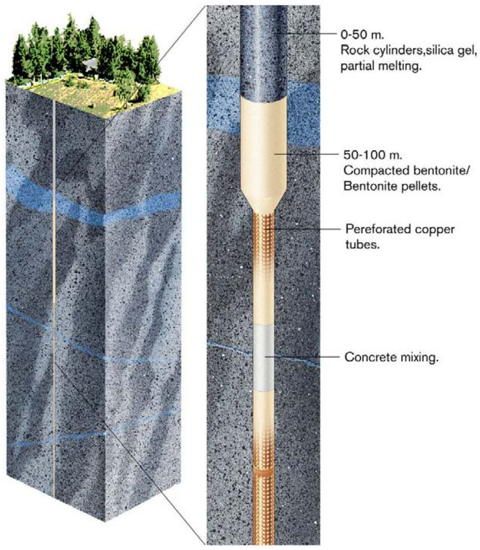
Miniature canisters with a diameter of 14.5 cm and containing 1 mm diameter defects in the outer copper shell have been set up in five boreholes with a diameter of 30 cm and a length of 5 m at the Äspö HRL. All five canisters were installed in the beginning of 2007.

The canisters are mounted in support cages, four of which contain bentonite (three low density bentonite, one compact 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 conditions that are very difficult to reproduce and maintain for long periods of time in the laboratory.

Achievements

During this quarter, monitoring of the miniature canister experiments has continued. Data are being collected for corrosion rate of copper and iron electrodes, and electrochemical potentials for a range of electrodes, including Eh, iron and copper. In addition, strain gauge data are being collected for two of the canisters. Water analysis, including analysis of microbial content of the water, has been carried out periodically. A report on the set up of the experiments and the first year’s activities and results is in preparation and are expected to be ready at the end of April.

4.12 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.

Phase 1 of the project was mainly devoted to an inventory of available techniques, and the aim of phase 2 was to develop a complete cleaning and sealing concept.

Phase 3 was divided into four sub-projects, and comprised large-scale testing of the sealing concept in boreholes. Reports of the four sub-projects have been approved and printed as International Progress Reports. All the work from Phase 3 has been summarised in a final report.

SKB has decided on a continuation of the project Phase 4. The continuation is based on the preceding project Phases in which principles and techniques were outlined for borehole sealing. The specific goal is to characterise and plan conceptual and practical sealing so that the impact of the seals on the overall hydraulic performance of the repository rock can be predicted and evaluated.

Achievements

Depending on the location and performance of seals, the boreholes can be isolated from water-conducting zones so that they do not serve as short-circuits. This work requires outline of the major structural features of the host rock, which involves geological, hydrogeological and rock mechanical characterisation.

The Phase 4 of the project focuses on sealing of investigation boreholes and comprises the following two sub-projects:

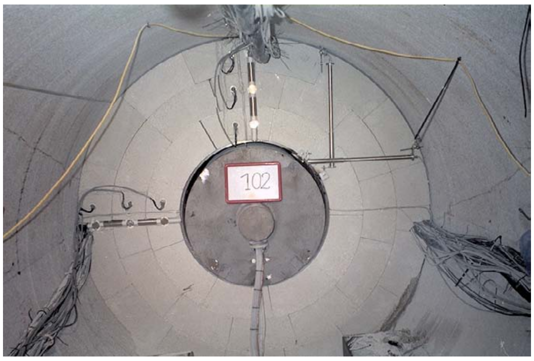
- Characterisation and planning of borehole sealing.
- Quality assessment and designation.

The specific goal of this project is to collect available characterisation data of selected reference boreholes for working out generalised rock structure models and for planning sealing of boreholes. This is done so that the impact of the seals on the overall hydraulic performance of the rock models can be predicted and evaluated.

A number of representative boreholes will be considered and those suitable for sealing will be divided into categories for which conceptual designs will be worked out. The project will select boreholes at Äspö, Laxemar, and Forsmark, for detailed design with special respect to the hydraulic performance, constructability and cost of suitable seals. The holes should represent typical rock conditions with respect to frequency, size and properties of permeable and unstable fracture zones. Conceptual seal designs will be worked out for the selected boreholes. Based on the design, needs for implementation will be investigated, which comprises collection of data characterising the holes with respect to geometry, orientation and hydraulic conditions, including also the need for stabilisation.

The needs for sealing should be connected to overall safety of the geological disposal.

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 concerning both field and laboratory tests is conducted. The Äspö HRL International Joint Committee has decided that in the first phase of this Task Force (period 2004-2008), work should concentrate on:

- Task 1 THM modelling of processes during water transfer in buffer, backfill and near-field rock. Only crystalline rock is considered initially, although other rock types could be incorporated later.
- Task 2 Gas transport in saturated buffer.

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

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

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

Achievements

Task Force THM/Gas

For Task 1 the modelling has concerned large scale in situ tests (Task 1.2). The two Canadian experiments the Buffer/Container Experiment and the Isothermal Test have been used for modelling in Task 1.2.1. The work to model these tests has been finished and reporting is on-going. The work with the other task (Task 1.2.2), which concerns modelling of the Canister Retrieval Test at Äspö HRL, has started.

Task Force Geochemistry

A meeting concerning diffusional transport models was held in the middle of March in Lund. Decisions concerning modelling tasks were taken: (a) percolation tests of Lot material performed at University of Bern, (b) redistribution of calcium and sulphate minerals in the Lot field test A2 and (c) previously published laboratory results from VTT. A paper concerning a new conceptual theory for diffusional transport in bentonite has been finalised and submitted for publication.

5 Äspö facility

5.1 General

The organisational unit at 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.

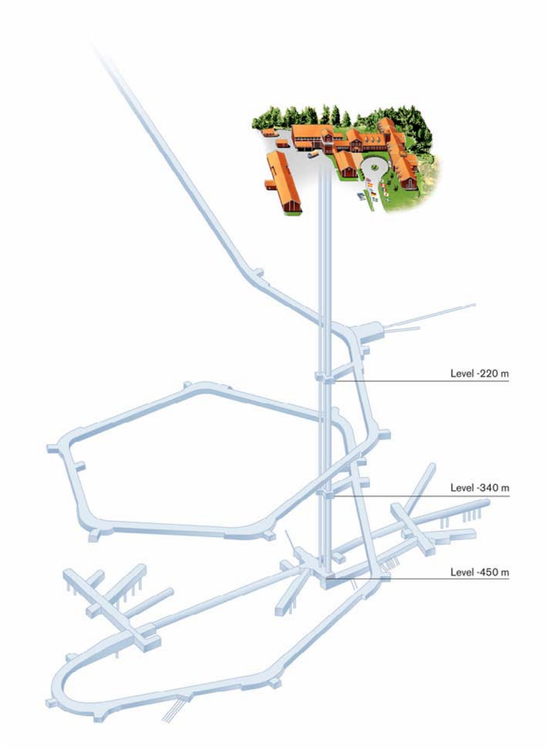
- *Repository Technology and Geoscience (TDS)* is responsible for the development and management of the geo-scientific models of the rock at Äspö and the test and development of repository technology at Äspö HRL to be used in the final repository.

- *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.

5.2 Äspö Hard Rock Laboratory



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

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

Achievements

The facility has been 100% operational and without incident during the first quarter. The maintenance agreement between Äspö HRL and OKG is being renegotiated. SKB will be responsible for the maintenance, starting from 1st March 2008, since OKG no longer are willing to carry out maintenance for external customers.

The maintenance work on the rock in the elevator shaft has been completed. The rust-damage that was reported in 2007 is being documented and a programme of remedial measures will be developed during the second quarter of 2008. During the period when work on the elevator-cage is being carried out, the maximum load will be reduced to 50% (1,000 kg). The weight limit does not create any safety problems, but the visitors programme will need to be replanned.

A diesel generator was installed during 2007 in order to ensure the operation of the server room during power cuts.

Invitations to make a tender for the planned archive-building were sent out, and three proposals have been received and an agreement contract will be signed during the second quarter of 2008.

The county administrative board in Kalmar has given permission for the planned sewer from Äspö HRL to OKG´s treatment works. The permit requires that consultations are held with all the parties concerned e.g. owners and owners of fishing-waters. The work can begin at the earliest during the third quarter of 2008, if all the necessary permissions are received. In order to reduce the risk of traffic accidents on the road to the Äspö HRL, trees and bushes have been removed to improve visibility at bends and crossroads.

The system for registration of personnel (RFID) will be completed during the second quarter and will be transferred to Äspö HRL management structure. The new system, called Alfagate, will be included in the Alfa surveillance system. Before the present system for registration of visits underground is taken out of operation, education of personnel will be carried out and routines for operation of the new system will be written.

5.3 Bentonite Laboratory

Stacking of test blocks in full scale

Before building a final repository, where the operating conditions include 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 Bentonite Laboratory is in full operation and different methods and techniques for installation of pellets and blocks in deposition tunnels have been tested. For example, tests on block installation have been performed with beddings of different materials and design. It can be concluded from these tests that the properties of the bedding determine the result of the installation.

The programme for backfill installation conditions with regards to piping and erosion continuous. The backfill tests in half-scale with blocks end pellets with different water inflow increase our knowledge about the assumption for the backfill operation, see Figure 5-1. The experience from the test is very useful for the development and choice of installation method.

Parallel with the piping and erosion tests, the development of methods and installation techniques progress, see Figure 5-2.

A bentonite mixer has been assembled and CE-approved. However, further adjustments must be made before the mixer is run-in. Measurement of dust levels will be made during mixing so that the working environment in the facility is monitored. Should there be problems with the dust levels, appropriate measures will be taken and new measurements will be made.

Figure 5-1. *Piping and erosion test. Left: Halve scale backfilling test. Right: Buffer test.*

Figure 5-2. *Left: Installation tool for the buffer. Right: Pellets installation test in backfill.*

5.4 Public Relations and Visitor Services

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

The main goal for the Public Relations and Visitor Services Group is to create public acceptance for SKB, which is done in co-operation with other departments at SKB. The goal will be achieved by presenting information about SKB, the Äspö HRL, and the SKB siting programme on surface and underground. The team is also responsible for visitor services at Clab and as from 2008 also the Canister Laboratory.

In addition to the main goal, the information group takes care of and organises visits for an expanding amount of foreign guests every year. The visits from other countries mostly have the nature of technical visits.

The information group has a special booking team at Äspö HRL which books and administrates all visitors. The booking team also is at OKG's service according to agreement.

Achievements

SKB facilities have been visited by 4,408 persons during the first quarter of 2008. The corresponding number for the same period last year was 5,038 persons. The numbers of visitors to SKB's main facilities are listed in Table 5-1.

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

SKB facility	Number of visitors Jan-March 2008
Central interim storage facility for spent nuclear fuel	440
Canister Laboratory	695
Äspö HRL	1,392
Final repository for radioactive operational waste (SFR)	1,725

6 Environmental research

6.1 General

Äspö Environmental Research Foundation was founded 1996 on the initiative of local and regional interested parties. The aim was to make the underground laboratory at Äspö and its resources available for national and international environmental research. SKB's economic engagement in the foundation was concluded in 2003 and the activities thereafter concentrated to the Äspö Research School. The agreement between SKB and Kalmar University, concerning Äspö Research School, is valid until 30th of September 2008.

The two parties cooperate actively and are involved in the quest to make Äspö Research School a part of Nova Research and Development and at the same time broaden the school's research field. The recruitment of two new Ph.D. students has begun by professor Mats Åström. The Ph.D. students will be stationed at the Äspö HRL with a prolonged time for their studies by one year to continuously be able to participate in the geoscientific research on site.

6.2 Äspö Research School

Surface water sampling point at Laxemar catchments area

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 various kinds of research.

Achievements

On the 29th of February, Christian Brun defended his Ph.D. thesis focusing on the chemistry of litter samples collected throughout Sweden during the 1970´s and 1980´s and others collected during the site investigations in Forsmark and Oskarshamn /Brun 2008/.

Further, a paper dealing with metal pollution of estuarine sediments caused by leaching of acid sulphate soils have been published /Nordmyr et al. 2008/.

7 International co-operation

7.1 General

Eight organisations from seven countries will in addition to SKB participate in the co-operation at Äspö HRL during 2008, 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.

SKB also takes part in work within the IAEA framework. Äspö HRL is part of the IAEA Network of Centres of Excellence for training in and demonstration of waste disposal technologies in underground research facilities.

Table 7-1. International participation in the Äspö HRL projects during 2008.

Projects in the Äspö HRL during 2008	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Nagra	RAWRA
Natural barriers								
Tracer Retention Understanding Experiments				X		X		
Long Term Sorption Diffusion Experiment					X			
Colloid Dipole Project						X		
Microbe Project		X						
Radionuclide Retention Project		X						
Task Force on Modelling of Groundwater Flow and Transport of Solutes			X	X	X	X		
Engineered barriers								
Prototype Repository	X	X		X		X		
Alternative Buffer Materials	X	X		X		X	X	X
Long Term Test of Buffer Materials					X	X	X	
Temperature Buffer Test	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
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland
Radioactive Waste Repository Authority, Rawra, Czech Republic

8 Documentation

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