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Progress Report

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Äspö Hard Rock Laboratory

Status Report
April – June 2008

Svensk Kärnbränslehantering AB

September 2008

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Äspö Hard Rock
Laboratory

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of the client.

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 second 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.

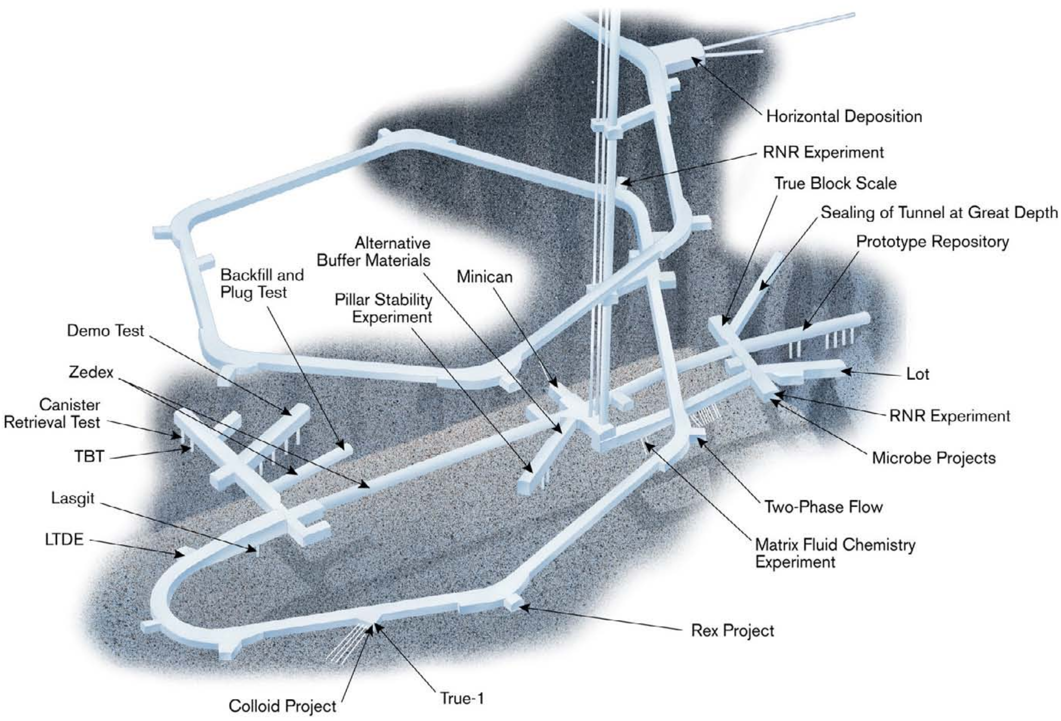


Figure 1-1. *Allocation of some of the experimental sites from the -220 m to -450 m level in Äspö HRL.*

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. The reaming of the heater holes in the Tasq-tunnel for the project Counterforce Applied to Prevent Spalling is shown in Figure 2-1.

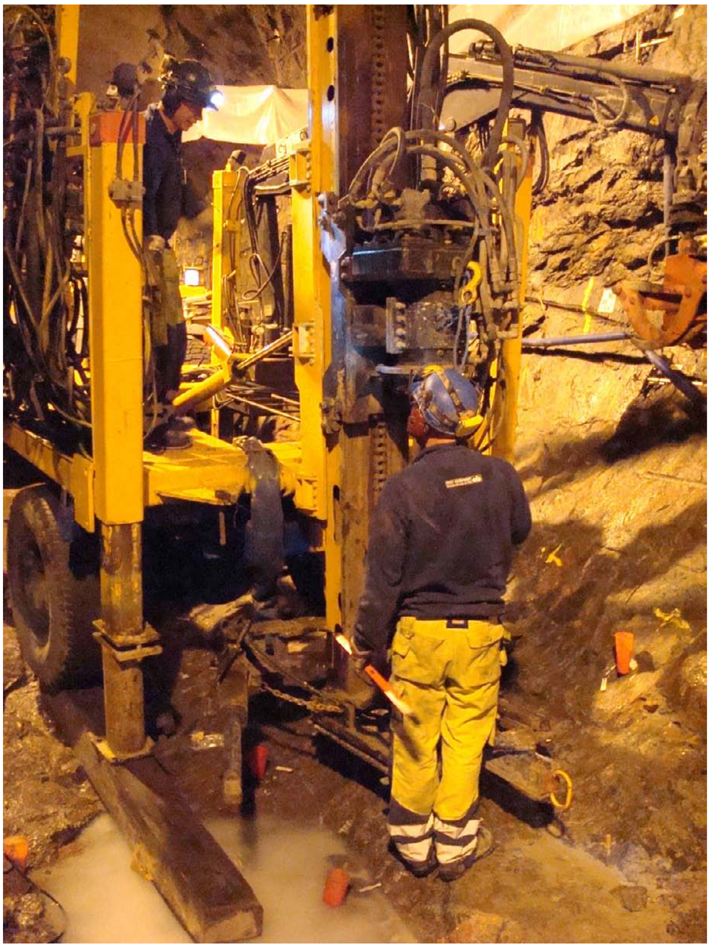


Figure 2-1. *Reaming of the heater holes.*

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. In addition, development of new methods in the field of geology is a major responsibility. As a part of the latter, the continuation of the Rock Characterisation System (Rocs) project is being conducted.

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 second 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 six tunnel fronts has taken place between section 20.74 and 45.7 m (Figure 2-2), as well of the roof and walls between section 20.74 and 32.9 m. Data and drawings have been fed into the TMS (Tunnel Mapping System). The results of the laser scanning combined with digital photography performed in the section 0-20.74 have been analysed (see the Rocs project).
- In the Tasq-tunnel, the reaming of the boreholes for the project "Counterforce Applied to Prevent Spalling" is now completed. The logging of the cores is ongoing.
- The modelling work that commenced in 2005 concerning water bearing fractures at the -450 m level is finished. The report that has been completed and sent for review has just returned for adjustments.
- Some old mapping of tunnels and deposition holes still needs to be entered into the TMS. All data that has been entered is, however, now checked.
- SKB is executing a study regarding possible differences in the procedure and results of geological mapping performed in a drilled and blasted tunnel and a TBM bored tunnel respectively.

Figure 2-2. *The tunnel front section at 45.72 m of the Tass-tunnel, 2008-06-13.*

2.2.2 Rocs – Method Development of a New Technique for Underground Surveying

The first laser scanning session of the Tass-tunnel. The Leica scanner and a computer on the tripod.

A feasibility study concerning geological mapping techniques has been completed. This study was conducted as a SKB-Posiva joint-project. The purpose was to investigate if a new system for rock characterisation has to be adopted when constructing a final repository. The major reasons for the project are aspects on objectivity of the data collected, traceability of the mappings performed, saving of time required for mapping and data treatment and precision in mapping. These aspects all represent areas where the present mapping technique may not be adequate.

Based on the knowledge from the feasibility study SKB has commenced a new phase of the Rocs project. The project will concentrate on finding or constructing a new geological underground mapping system. Laser scanning in combination with digital photography will, at least at the time being, be a part of that system. The resulting mapping system shall operate in a colour 3D environment where the xyz-coordinates are known.

Achievements

In spite of what was written in the status report for the first quarter of 2008 it has been decided that the continuation of Rocs after all shall be a separate project.

During the first half of 2008, the work with a new project plan and a project decision document has begun. The latter is almost completed. During the same period, the results of the laser scanning combined with digital photography that so far has been performed in the Tass-tunnel at Äspö HRL have been studied and a number of software have been tested to handle the data.

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

During the second quarter 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

An additional sampling campaign was conducted focusing on sampling points accessible from sections between the -420 m and -450 m level in the Äspö tunnel. The aim of this extra monitoring campaign is to follow possible changes in groundwater chemistry in adjacent areas to the new Tass-tunnel being constructed during 2007-2008. This has also been a suitable occasion for the training of the new personal at the chemistry laboratory performing both the field sampling and the chemistry analysis.

The sampling points are mainly boreholes, with packed-off sections, situated around the Prototype Repository, the Microbe laboratory and the collecting point from which drainage from the lowest level is pumped up (MA3426G “PG5”). Only one surface borehole was sampled (KAS09, at 150 m depth). In total nine sampling points are analysed.

All parameters are analysed except environmental and trace elements. In addition, analysis of total organic carbon and carbon isotopes are to be conducted and also colloids and radon. No sampling for ATP (adenosine triphosphate) was performed since the methods are still under evaluation. Preliminary results of the main hydrochemical components are expected during the next quarter while the results for isotopes can take up to six month to finalise (from sampling until receiving and registration in the database).

Sampling of gases (one point) has been performed in the vicinity of the Prototype Repository (KA3510A) in June and earlier in April (KA3110A). In April the gas phase was sent for isotope analysis. Sampling was performed in conjunction with the Microbe project. The results will be used for determine suitable sampling and analytical methods to be used in the future in the Äspö tunnel.

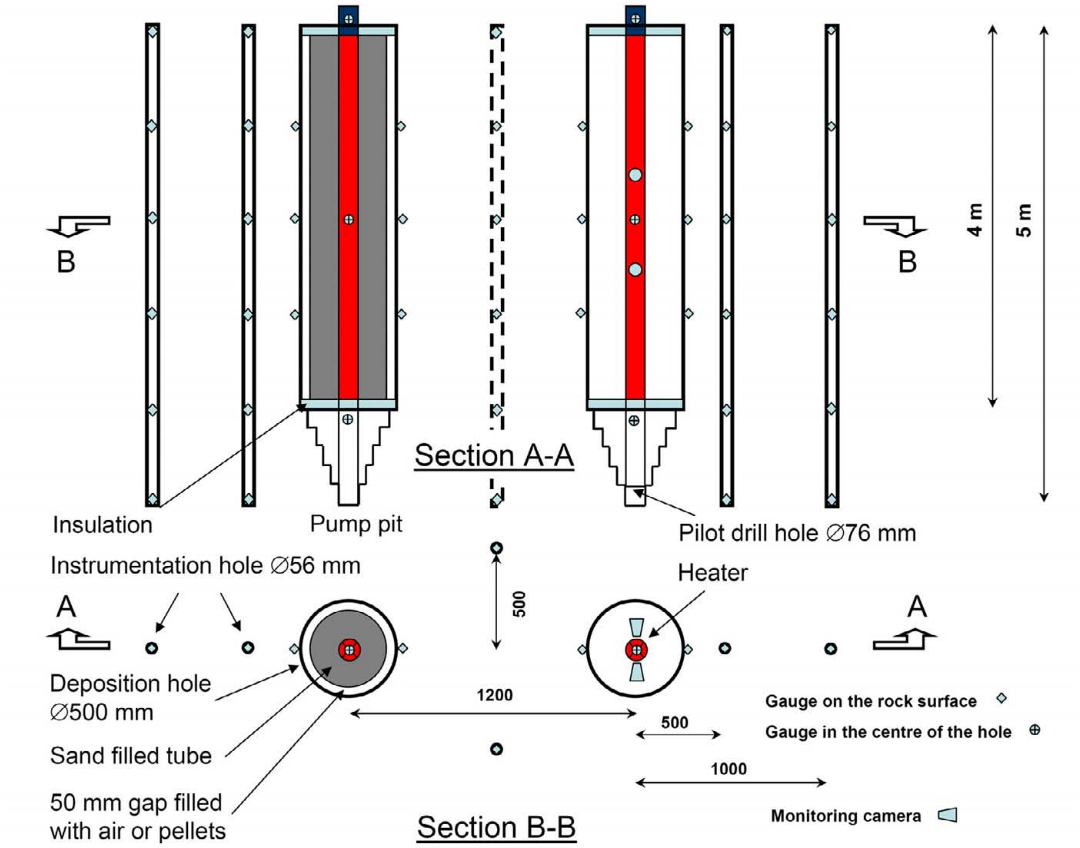
2.5 Rock Mechanics

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 mainly 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.

In addition, a project called Caps (Counterforce Applied to Prevent Spalling) comprising field test in Äspö HRL and numerical modelling is ongoing.

2.5.1 Counterforce Applied to Prevent Spalling



Configuration of the test holes and the positioning of instruments in the experiments in the Tasq-tunnel.

The field experiment within the Caps has been initiated as a demonstration experiment to determine if the application of dry bentonite pellets is sufficient to suppress thermally-induced spalling in KBS-3 deposition holes. The experience gained from the Äspö Pillar Stability Experiment, conducted between 2002 and 2006, indicated that spalling could be controlled by the application of a small confining stress in the deposition holes.

The field tests, that include four pairs of heated half-scale KBS-3 holes, will be carried out as a series of demonstration experiments in the Tasq-tunnel at Äspö HRL.

Each test consists of two 0.5 m diameter boreholes of 4 m depth separated by a 0.7 m pillar, which are surrounded by a number of boreholes for installation of instruments. The first step in the testing sequence includes heating of one pair of open holes to ensure that spalling will occur and can be observed in the test holes. The next step includes heating and observation of spalling in separate pair of holes. The 50 mm gap created between an inner tube and the borehole wall, is filled with a loosely placed pellets substitute. The final step is a complementary test that will be carried out to address questions that arise during the previous tests.

Achievements

The preparations for the field experiment have been in progress during the second quarter. The drilling of the heater holes is finished and drilling of the surrounding instrument holes were completed in mid July. The instruments are calibrated and installation of the monitoring system is ongoing. Laboratory experiments to select a suitable pellets substitute are carried out at SP (Swedish National Testing and Research Institute). The first test in the Caps project is schedule for takeoff in mid August.

3 Natural barriers

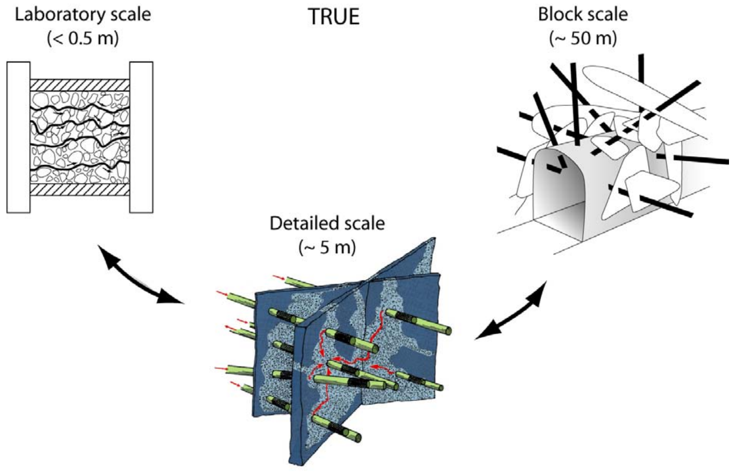
3.1 General

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. *Fracture surface with thin coating of mainly chlorite, calcite, clay minerals and epidote. The length of the base of the photograph is 46 mm.*

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

During the second quarter, draft versions of the first two in the planned series of scientific papers accounting for results of the True Block Scale/True Block Scale Continuation have been produced. The two papers will now be subject to internal review within the project group and subsequent update.

The titles of the three-part series of papers are "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 Fracture network flow simulations and global retention properties.
- III A macro-scale retention model and impact of micro-scale heterogeneity.

Paper 1 reports the results from an evaluation of the True Block Scale/True Block Scale Continuation breakthrough data and a calibration of the retention parameters. The paper makes a point of setting the limits for what can be inferred from breakthrough curves alone. A novel sensitivity analysis is introduced that provides an indication as to which are the most sensitive parameters depending on tracer and part of the breakthrough curve analysed.

Paper II uses a hydraulic DFN model (ConnectFlow) and simulates flow in the deterministic structures interpreted in the True Block Scale rock volume. The DFN simulations are designed to infer water residence time and the hydrodynamic retention parameter β. From these the "active specific surface area" *sf* is calculated. A first comparison is made between simulated and calibrated water residence times. The DFN results are also used to propose a robust retention model for Äspö diorite. The main finding is that the DFN model can predict measured mean residence time fairly well. Also, the proposed retention model (based on True-1 results) jointly with DFN simulations of the advective transport in the True Block Scale rock volume, predict fairly well the calibrated values of the main parameter group.

Paper III, which explores the effects and implications of introducing heterogeneity along and away from the fracture, is in progress. The main point of this paper will be the analysis of the impact of porosity trends in the fracture rim zone, and in particular its effect on effective parameter definitions. In this paper attempts will also be made to reconcile the statistics of parameters as inferred in Paper I with the global values proposed in Paper II.

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 included 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 True-1 Continuation during the first half of 2008.

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 was 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 were performed prior to the epoxy injection. These tests were aimed to secure important information from Feature A and the True-1 site before the destruction of the site.

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. The major activity during the last quarter was planning of the upcoming analysis of the cores from KXTT3 and KXTT4. The analysis itself will start during the coming fall. However, the activity during the last quarter within the project was generally rather low due to heavy involvement of the project members within SKB's site investigation programmes.

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. 34 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.

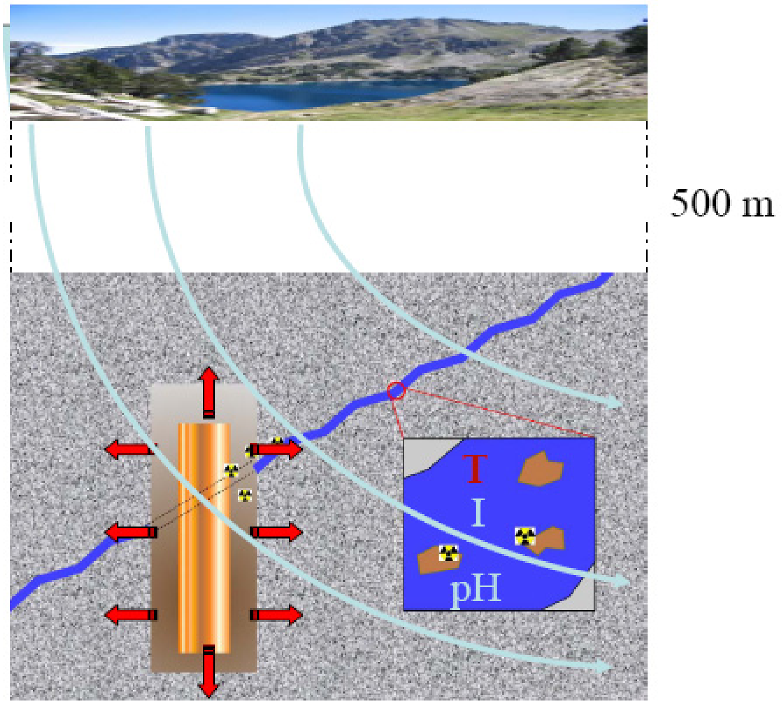
Drilling of sample cores from matrix rock surrounding the test section in the small diameter extension borehole.

Achievements

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

Preparations are ongoing for the analysis of the non γ-emitting tracers (^{99}Tc, ^{102}Pd, ^{236}U, ^{237}Np, ^{35}S, ^{36}Cl and ^{63}Ni) in crushed samples from 4 sample cores extracted from fracture surface on the core stub and 4 sample cores extracted from the matrix rock. The tracer content will, after leaching and/or dissolution of the crushed material, be analysed by means of mass-spectrometry and liquid scintillation.

3.4 Colloid Project



The Colloid Project is a continuation of the Colloid Dipole Project which was ended in the beginning of 2008 and final reporting is in progress. 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 to study the equilibrium concentrations of colloids generated from compacted bentonite and the sedimentation of colloids are finished. An article is soon to be sent for publishing.

Studies of sorption on montmorillonite colloids exposed to irradiation are in progress. The aim is to study if the sorption characteristics of the montmorillonite colloids change upon irradiation. Cs and Eu are used in the sorption experiments to represent a "weaker" and a "stronger" sorbing radionuclide. The results will be presented during the fall in a diploma work.

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 in well characterised cores and on larger scales (in situ tests in Grimsel, Switzerland). The collaboration in the Colloid Formation and Migration Project (CFM) in Grimsel is now ongoing and tracer tests as pre tests for bentonite colloid transport has just been performed.

Two contributions from the project (Retardation processes of colloid transport in fractured media and modelling of retardation processes in the quarried block) are sent for presentation at Material Research Society in Boston in December 2008

Submitted articles:

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. Accepted for publication in Applied Clay Science.

Garcia-Garcia S, Wold S and Jonsson M, 2008. Effects of temperature on the stability of montmorillonite colloids at different pH and ionic strength. Accepted for publication in Applied Clay Science.

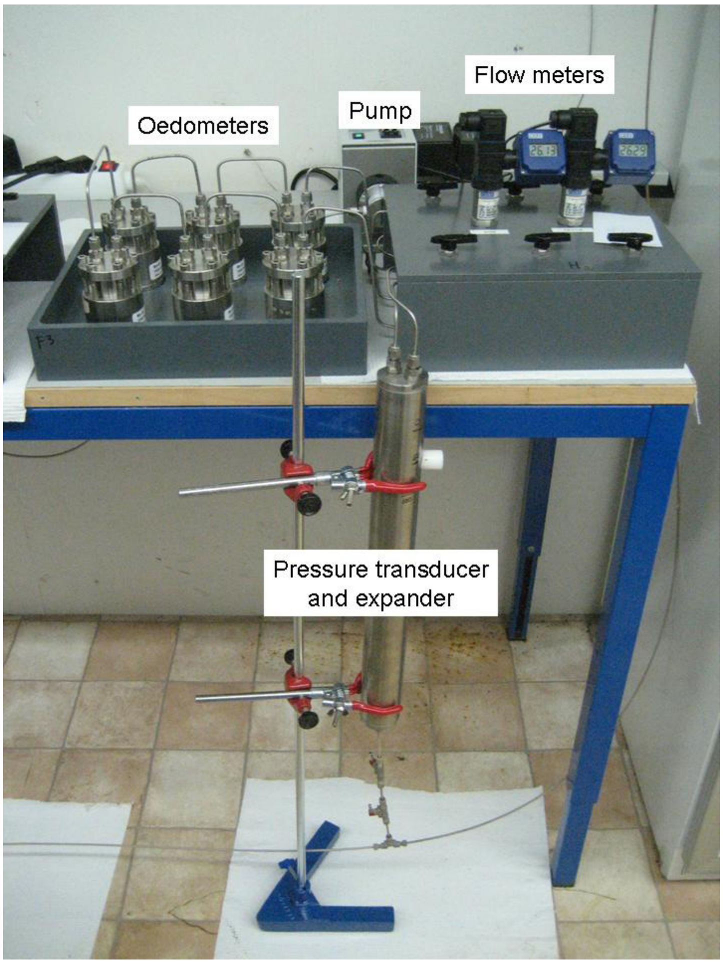
Vilks P, Miller N H, Vorauer A, 2008. Laboratory bentonite colloid migration experiments to support the Äspö Colloid Project. Accepted for publication in Physics and Chemistry of the Earth.

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



Configuration of one of the three experimental units used to investigate bio-corrosion in compacted bentonite. The white knob on the pressure transducer indicates the position of the interior piston.

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

Microbial sulphide production in compacted bentonite has been found to be related to the saturated density. In previous experiments, it has been seen that the numbers of surviving microbes after initial additions to the clay rapidly decreased with increasing densities above 1,800 kg/m^3 /Motamedi et al. 1996; Pedersen et al. 2000a-b/. New experiments were designed in 2001 to 2003 to investigate the density limit. It was judged important to set up the experiments as close as possible to repository in situ conditions with respect to groundwater pressure and sulphate reducing bacteria. Experiments were, therefore, conducted 450 m underground at Äspö HRL. The results showed that copper corrosion by sulphide from sulphate reducing bacteria occurred at all densities tested i.e. at 1,500; 1,800 and 2,000 kg/m^3 /Masurat et al. 2008/. However, as there was a short period in the total experimental time frame of 80 days where the bentonite compaction was below the required values, it was deemed possible that some of the sulphate-reducing activity occurred before full compaction. New experiments were designed where the bentonite was set to full compaction before the start of the corrosion tests. This design would ensure that the analysed copper corrosion only could be due to sulphide diffusing from the outside of the bentonite and from microbial sulphate reduction inside the bentonite at the tested densities. By application of a range of densities from 1,750 up to 2,000 kg/m^3 it was deemed possible to establish if there is a density limit at which all sulphide production inside the bentonite cease.

The activity of sulphate reducing bacteria in Wyoming bentonite MX-80 saturated with groundwater from 450 m underground was investigated in situ. Groundwater from borehole KJ0052F01 in the HRL tunnel was used. The borehole is 76 mm in diameter and intersects a groundwater-bearing fracture 43.7 m into the bedrock from the tunnel face at a depth of 450.5 m /Pedersen 2005 (Table 2-4a)/. The groundwater was circulated under an in situ pressure of 2.6 MPa, via polyetheretherketone (PEEK) tubing, through experimental systems in the Microbe laboratory. A bypass PEEK tube connected the circulating groundwater to the experimental set-up as described briefly next.

The bentonite was compacted to densities of 1,750; 1,800; 1,850; 1,900; 1,950 and 2,000 kg/m^3. Three experimental units with copper test surfaces were installed at the Microbe laboratory site. Groundwater from KJ0052F01 was connected under in situ pressure for 30 days and thereafter circulated through a titanium filter over the bentonite and back to the borehole for an additional 30 days. This configuration simulated experiments performed previously on the Microbe site. The bentonite in the oedometers was first allowed to reach full swelling pressures and water saturation under a period of 60 days. Thereafter, various additions were made to the experimental units resulting in three different cases. The first case was denoted “Control”, the second case was denoted “H_2/CO_2” and the third case was denoted “Lactate”. All three cases were added with 2.39 mL of a solution with 5.0 mCi $^{35}SO_4$. The corresponding specific activity was 55.5 TBq/mmol. The total amount of added $^{35}SO_4$ was 3.84×10^{-8} M. In addition, the H_2/CO_2 case was added with 56 mL of a gas mixture with 80 % hydrogen and 20 % carbon dioxide. The “Lactate” case was added with 1 mL of a 5.7 M solution of lactate in water. The resulting concentration of lactate became 30 mM. The three units were then left for incubation under in situ pressure for 120, 130 and 130 days, respectively. At the end of incubation, the units were detached and transported to the laboratory in Gothenburg for sampling and analysis. The amount of sulphide that reached the copper surfaces was modelled with a three-dimensional diffusion program. The amount of sulphide that could be ascribed to diffusion from the circulating water outside the bentonite was separated from the amount of sulphide produced inside the compacted bentonite.

In conclusion, a density related limit for microbial sulphide production in compacted bentonite could not be confirmed in the work reported here. A small, but significant sulphide producing activity was found in the compacted bentonite at all densities tested up to 2,000 kg/m^3. The amounts of sulphide found were in the same order as was found previously in similar in situ experiments /Masurat et al. 2008/.

3.5.2 Micored

The input panel of the simulation program Microbe29. This program calculates in situ growth and activity of microorganisms in groundwater. The background data for program functions and constants have been generated at the Microbe site and in the laboratory with microorganisms isolated from Äspö HRL.

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

A conceptual model program, tentatively denoted Microbe29, has been developed. The Microbe29 program was developed to be able to simulate the development of conditions over time in a confined space resembling a fracture in bedrock. The conditions simulated by Microbe29 are the concentrations of acetate, sulphate, sulphide, hydrogen gas and microorganisms. The way to achieve this was to develop a simulation approach and a simulation model (SM) with a set of properties and describe in mathematical terms how these properties interact with initial conditions in the SM and how these conditions change over time. The following conceptual microbial reactions /Hallbeck and Pedersen 2008/ are considered by Microbe29 and related versions:

Autotrophic acetogens: $H_2 + CO_2 \rightarrow$ acetate (1)

Iron-reducing bacteria: acetate + $Fe^{3+} \rightarrow Fe^{2+} + CO_2$ (2)

Sulphate-reducing bacteria: acetate + SO_4^{2-} (+ H_2) $\rightarrow H_2S + CO_2$ (3)

Sulphate-reducing bacteria: DOC + $SO_4^{2-} \rightarrow H_2S + CO_2$ (4)

Methanogens and sulphate-reducing bacteria:
$CH_4 + SO_4^{2-} \rightarrow H_2 + CO_2 + SO_4^{2-} \rightarrow H_2S + CO_2$ (5)

Microbe29 will further be added with the following inorganic processes:

$H_2S + 2FeOOH \rightarrow S^0 + 2Fe^{2+} + 4OH^-$ (6)

$H_2S + Fe^{2+} \rightarrow FeS + 2H^+$ (7)

$3FeS + 3S^0 \rightarrow Fe_3S_4 + 2S^0 \rightarrow 3FeS_2$ (8)

Description of the analysed processes

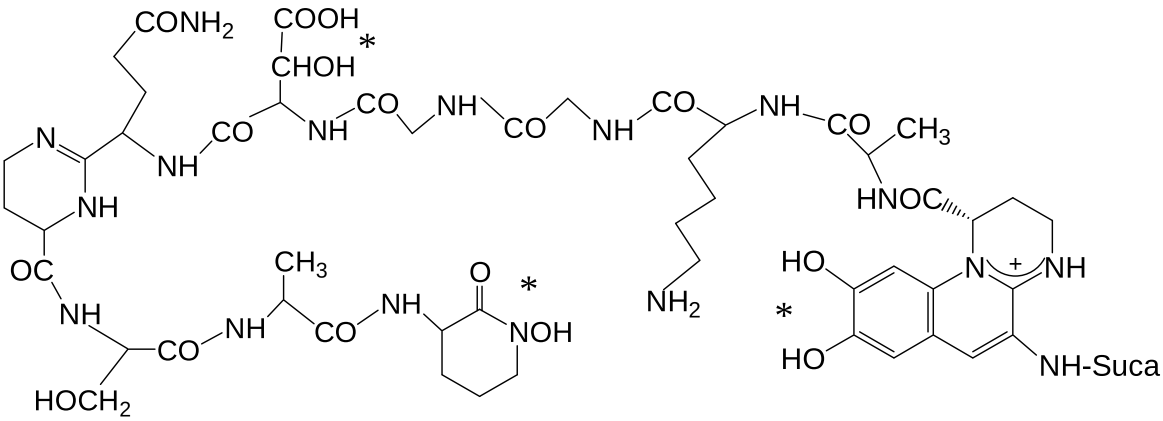
In an arbitrary aquifer at the repository depth, autotrophic acetogens (AA) produce acetate from hydrogen and carbon dioxide at a rate determined by the inflow of hydrogen (Eq. 1). The produced acetate can be utilised by iron reducing bacteria as a source of carbon and energy; as a result, ferrous iron and carbon dioxide are formed from ferric iron minerals and acetate, respectively (Eq. 2). Sulphate-reducing bacteria (SRB) oxidise the acetate produced by AA to carbon dioxide, while sulphate is reduced to sulphide (Eq. 3). Several genera of SRB can oxidise acetate, but species belonging to *Desulfovibrio* need hydrogen to be able to utilise acetate. If degradable organic carbon is available, SRB will also produce sulphide and carbon dioxide from this energy and carbon source (Eq. 4). A special type of sulphate reduction is coupled to anaerobic methane oxidation (Eq. 5). This reaction is common in many marine, sedimentary environments, but has not yet been demonstrated in deep groundwater. If present, it would have a significant impact on any sulphide production model, because the analysed concentration of methane in deep groundwater is generally much higher than the analysed hydrogen /Pedersen et al. 2008/. Microbial reactions 1–5 result in the production of sulphide, ferrous iron, acetate, and carbon dioxide. Hydrogen sulphide from reactions 3–5 may reduce iron in minerals such as goethite with the formation of elemental sulphur and ferrous iron (Eq. 6). The ferrous iron produced in reactions Eq. 2 and Eq. 6 can form iron sulphide with hydrogen sulphide (Eq. 7). This is a solid compound, and the dissolved sulphide that reacts with ferrous iron in reaction Eq. 7 will leave the groundwater and precipitate. Finally, pyrite may form (Eq. 8) when over-saturation occurs.

The simulation model Microbe29

The simulation model (SM) in Microbe29 is cylindrical with volume and aperture of reactor specified by the user. The reactor is filled with water holding concentrations of acetate, sulphate, sulphide, hydrogen and microorganisms (input panel shown in Figure above). The microorganisms in the water metabolise acetate, sulphate and hydrogen. They also produce sulphide and reproduce. The microorganisms do not die unless they are predated by phages. The rate of reproduction and predation of the microorganisms and the metabolic rates of the microorganisms is calculated on the basis of constants and inputs from the user of Microbe29. In the SM there are also phages. The inside of the SM is completely covered by an infinitely thin bio-film consisting of microorganisms that metabolises acetate, sulphate and hydrogen and produces sulphide. The surface cell density of the bio-film is presently set as a constant and thus does not change during a simulation. There are two separate inflows into the SM. The flow rates of the two inflows are specified by the user and there is always an outflow from the SM that is equal to the sum of the two inflows. The contents of these inflows are specified by the user. Concentrations in the SM are always homogenous.

Microbe29 is presently used to analyse and define proper conditions for in situ experiments at the Microbe site during fall 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.

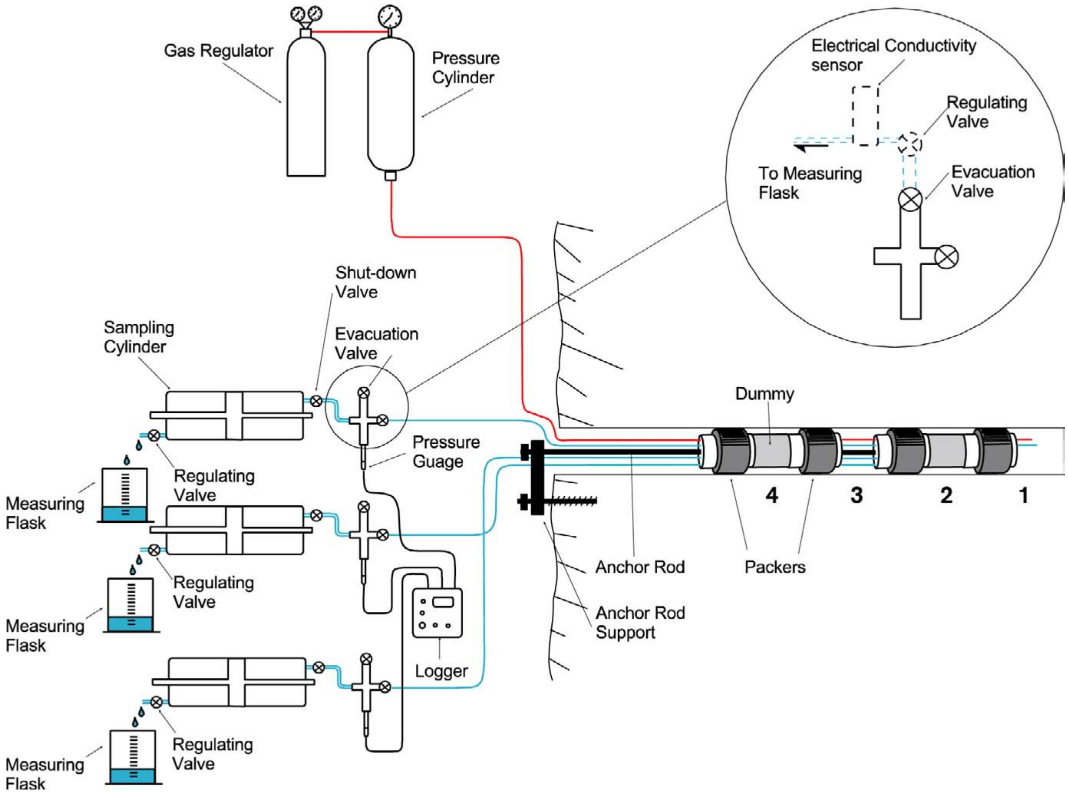
The work within Micomig will:

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

Achievements

Ten boreholes along the Äspö HRL tunnel were sampled for analysis for the most probable number of nitrate reducing bacteria. The boreholes were: KR0012B, KR0015B, KA1061A, SA1328A, KA2162B, KA2198A, KA3110A, KA3510A, KJ0052F01 and KJ0052F03. The cultures are presently under cultivation. Subsequently, dominating species will be isolated, sub-cultured and identified with DNA technology. Their ability to produce siderophores will be scanned. This will give an overview of the distribution of microorganisms that produce complexing agents in the Äspö groundwater.

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 half 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.

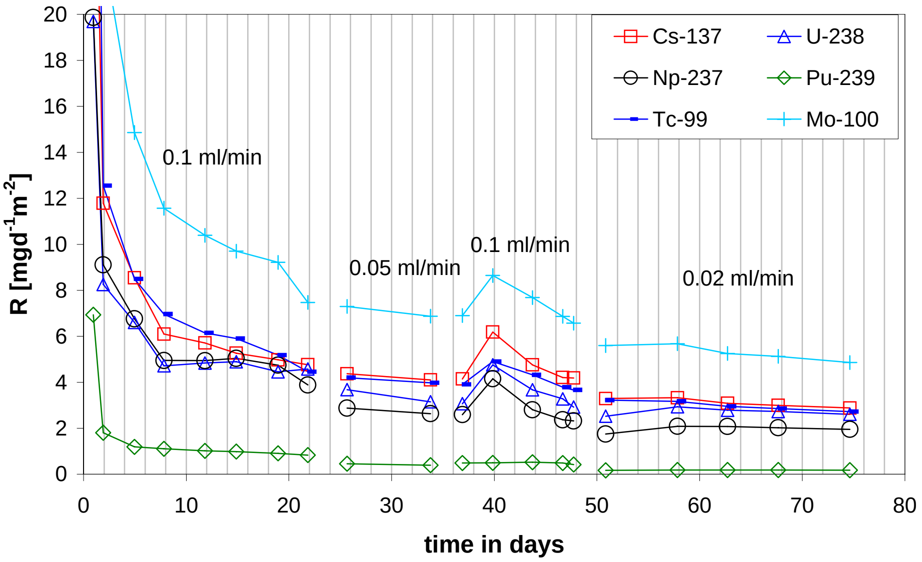
Experiments in Chemlab 1:

- 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.

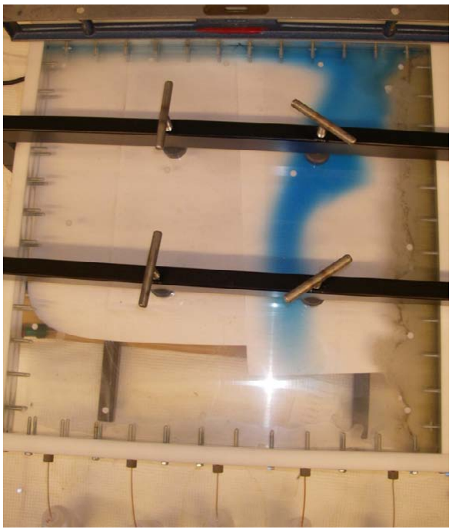
The in situ experiments will be preceded by laboratory experiments where the scope is both to examine parameters that may influence the leaching as well as testing the equipment to be used in the field experiments.

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 half 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.

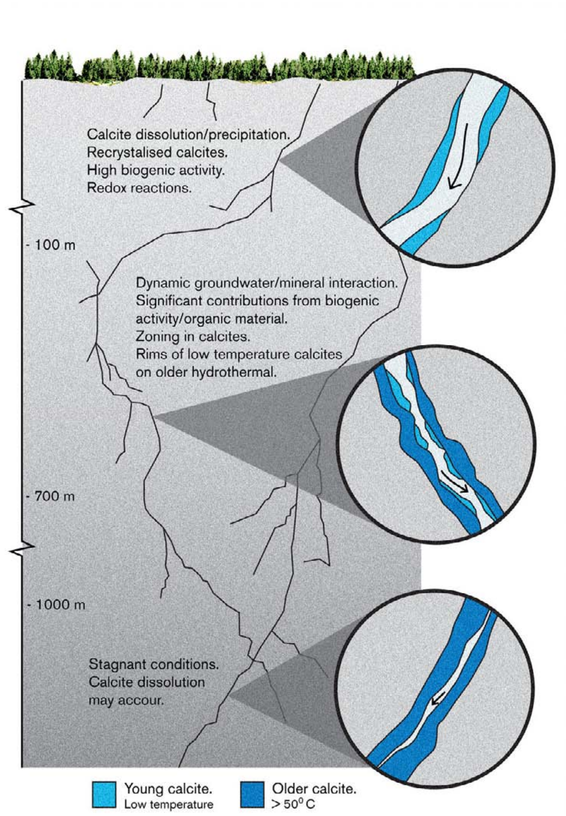
The transport resistance is concentrated to the interface between the bentonite buffer and the rock fracture. The mass transfer resistance due to diffusion resistance in the buffer is estimated to only 6% and the diffusion resistance in the small cross section area of the fracture in the rock to 94% /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 half 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 EC-part of the project was finalised and reported in 2005. The Padamot continuation project comprises:

- Further developments of analytical techniques for uranium series analyses applied on fracture mineral samples.
- The use of these analyses for determination of the redox conditions during glacial and postglacial time.
- A summary of the experiences from the palaeohydrogeological studies carried out at Äspö.

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.

Achievements

Bulk analyses of uranium decay series isotopes of fracture coating samples from borehole KAS17 have been carried out showing changes from mainly uranium mobilisation in the upper 20 m depth, switching to uranium deposition at larger depth. As a complement to these bulk analyses sequential extraction has been applied to four samples. The analyses have been carried out at the University of Helsinki. The first step in the sequential extraction scheme (ammonium acetate – AAC) dissolves loosely bound uranium i.e. the phase usually most interactive with the present groundwater: The largest deviation from equilibrium is indicated in these samples an example is shown in Figure 3-2. The second and third step dissolves uranium bound in Fe-oxides and more tightly bound uranium, whereas the fourth step (aqua regia - AR) dissolves the residue.

The analyses carried out confirms the results of the bulk analyses and add also more details in that the isotope ratios of the most mobile phase can be determined separately and show also to even larger extent the intensity of the recent mobilisation, deposition or the combination of both.

Ongoing analyses at SUERC in Glasgow will follow the same analytical scheme and the interlaboratory comparison will proceed.

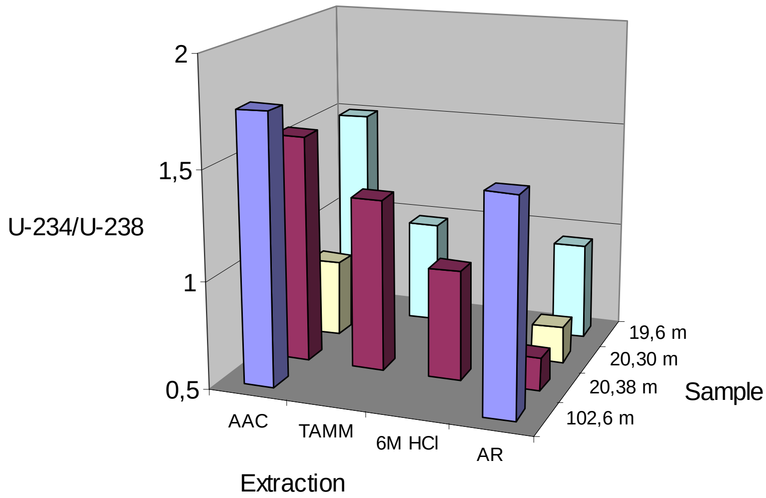
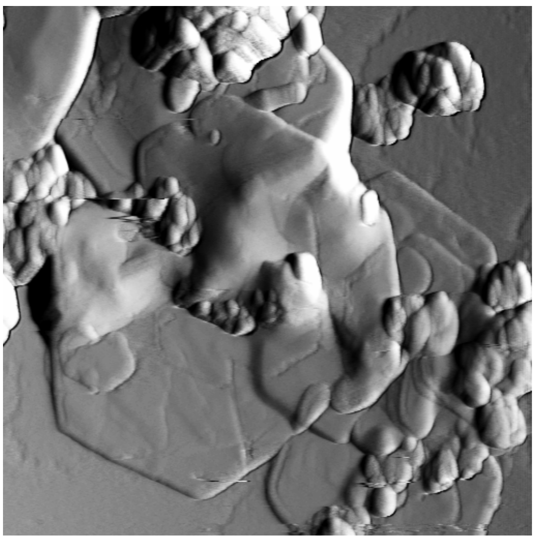


Figure 3-2. *$^{234}U/^{238}U$ activity ratio in sequentially extracted phases. High activity ratios in AAC extractable phase (first step) indicate recent U accumulation.*

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

Preliminary 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. However, during the second quarter of 2008 there have been no activities in the project.

3.10 Swiw-tests with Synthetic Groundwater

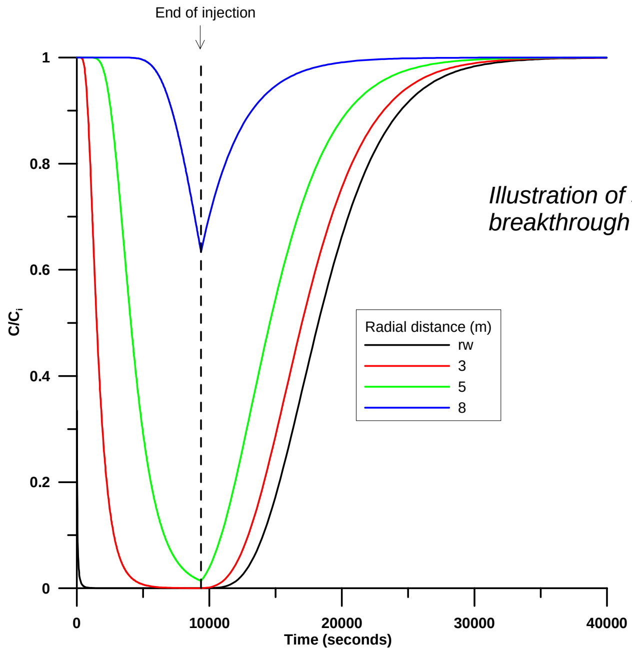


Illustration of solute-free water breakthrough in a single fracture

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.

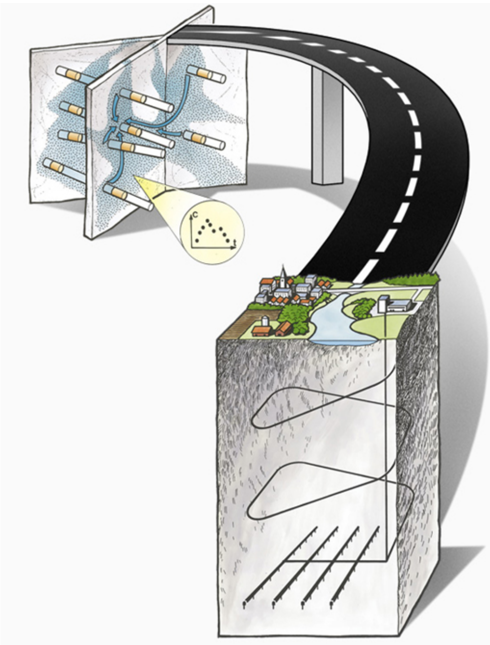
The general objective of the Swiw test with synthetic groundwater is to increase the understanding of the dominating retention processes and to obtain new information on fracture aperture and diffusion. The basic idea is to perform Swiw tests with synthetic groundwater with a somewhat altered composition, 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

The report from the feasibility study was reviewed during the last quarter and will be printed next quarter after some minor changes. A meeting where the progress of the project will be discussed will take place on the 29th of August. The key issues for the meeting will be the time table and the selection of test site for the project.

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 second quarter of 2008. The status of the specific modelling tasks is given within brackets in Table 3-1.

Task 6 tries to bridge the gap between Performance Assessment (PA) and Site Characterisation (SC) models by applying both approaches for the same tracer experiment. It is hoped that this will help to identify the relevant conceptualisations (in processes/structures) for long term PA predictions and to identify site characterisation data requirements to support PA calculations. All, except one, of the Task 6D, 6E and 6F reports from the modelling groups have been printed, but work is ongoing to be able to print it rather soon. A summary of the outcome of Task 6 has been accepted for publishing in a scientific journal. In addition, papers from four modelling groups have also been accepted by the same scientific journal and in conjunction with the summary paper. An essay has also been submitted to describe the framework for all these papers.

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. An updated task description for the sub-task 7B and more data have been sent out to the modellers. A workshop for Task 7 was held in May where modelling approaches and plans for the future modelling were presented and discussed. Work is ongoing for the minutes of this venue that took place in Oxford.

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 2,000 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.**
7A	Long-term pumping experiment. (Final results of sub-task 7A1 and 7A2 are presented. Draft reports in review).
7A1	Hydrostructural model implementation.
7A2	Pathway simulation within fracture zones.
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. (Has started).
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

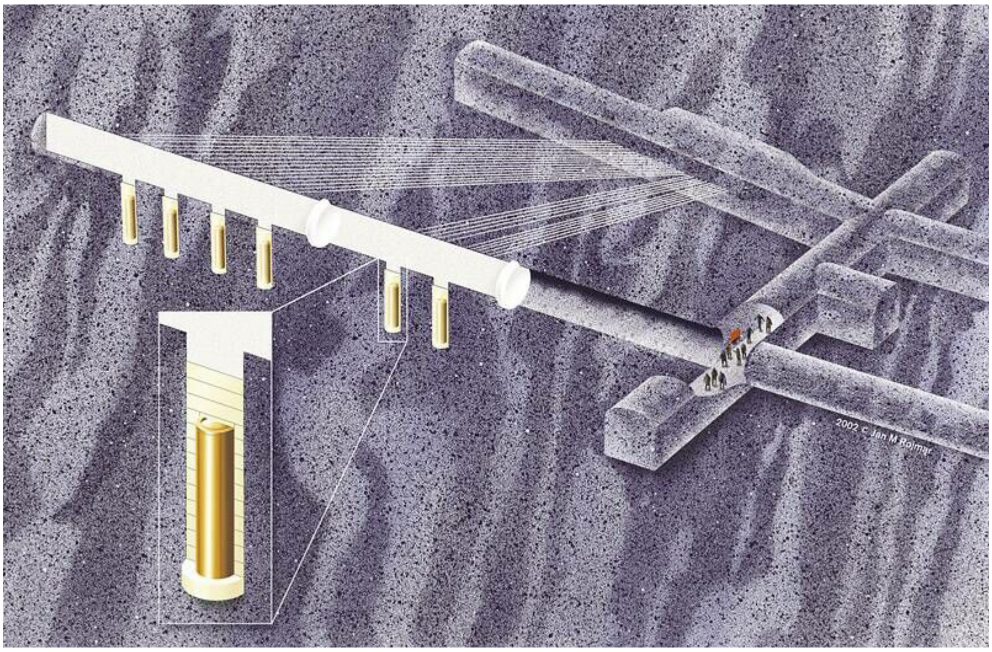
4.1 General

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).*

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 the data report covering the period up to May 2007 is available /Goudarzi and Johannesson 2007/ and the data report No. 18 covering the period up to December 2007 has been delayed but will soon be published. Overhauling of the data acquisition system is in progress and hydraulic tests of the rock mass have been performed.

A programme for sampling and analyses of gases and microorganisms in the backfill and buffer has been finalised and reported /Eriksson 2007/. The measurements will continue.

Acoustic Emission and Ultrasonic monitoring from the rock around deposition hole 5 and 6 is continuing. A new report covering the measuring period 1st April 2007 to 30th September 2007 has been finalised and will soon be printed.

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 1 D 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 three ongoing field experiments (see Table 4-1) are running according to plans, and only data acquisition and checking has been made.

Reporting of laboratory experiments and analyses concerning the A2 parcel material has been ongoing and is planned to be finalised during the summer.

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	Ongoing
S	2	90	T	>5	Ongoing
S	3	90	T	>>5	Ongoing

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.

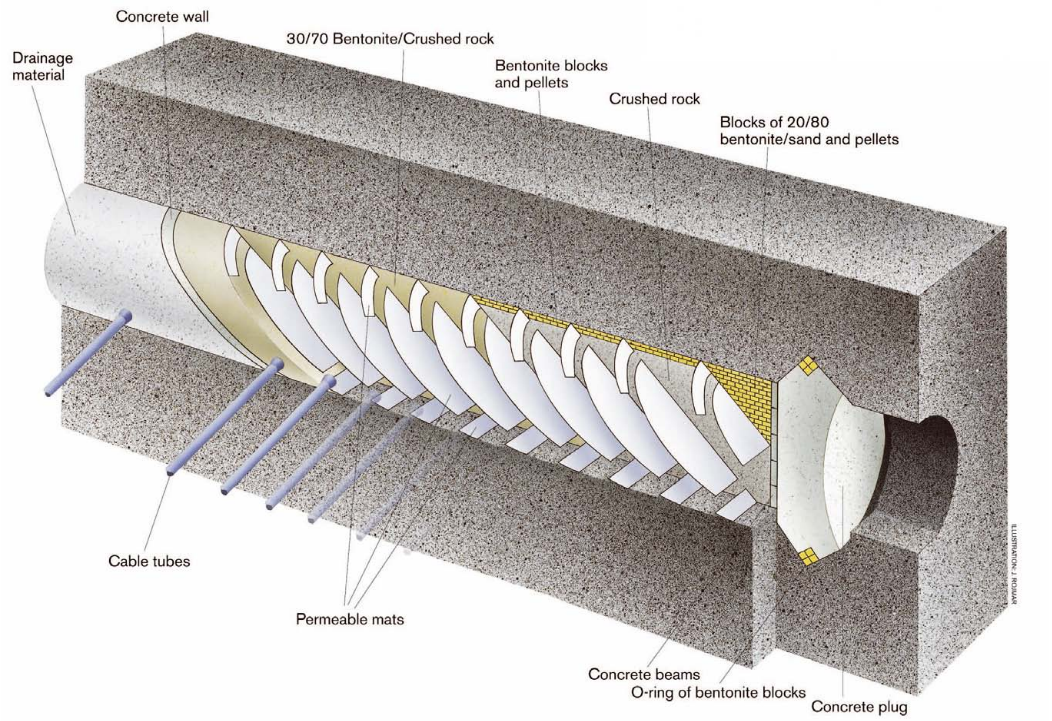
Achievements

During the period there has been a small leakage in package one. This caused the pressure of the saturation system to drop. For that reason it was decided to temporarily shut down the saturation system to allow for the leakage to heal. During this time the power to the heaters was lowered to avoid water boiling within in the package.

After some time the saturation system was carefully started and the pressure gradually increased. The system is now in normal operation and no leakage is observed. The power to the heaters has also been increased to normal levels.

The installation report for the project has been printed /Eng et al. 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.

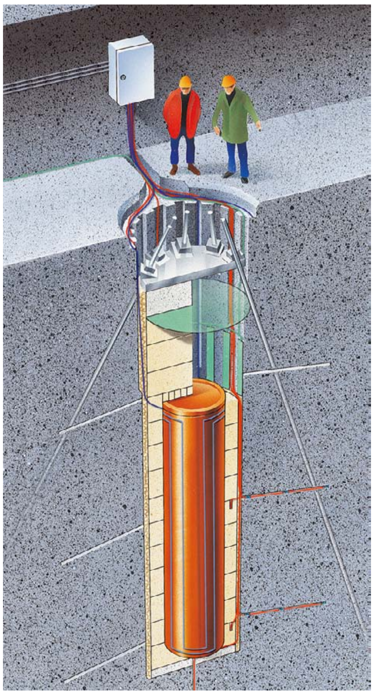
From the end of 2006 until the end of 2007 the compressibility of the backfill was tested by the four pressure cylinders mounted in the roof and the floor.

Achievements

The main work during the second 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/ and the work on next report is in progress.

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

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

Reporting of the buffer disintegration /Nirvin 2007a,b/ and the results from dismantling and sampling of the buffer /Johannesson 2007/ is available. The buffer analyses have continued at Clay Technology during the second quarter and the reporting of the results is postponed to the third quarter due to lack of resources.

Modelling of the buffer within the Task Force on Engineered Barrier Systems has continued during the second quarter 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.

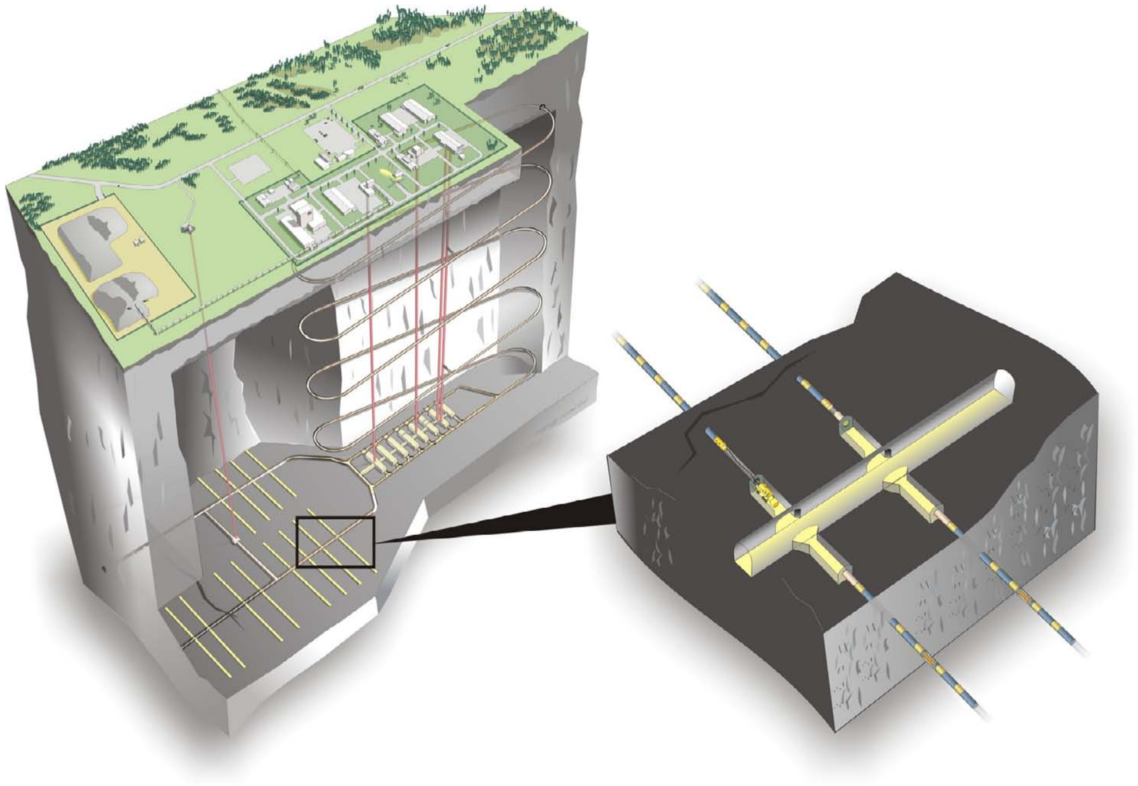
Achievements

The TBT-test is in the operation and data acquisition phase since March 2003. Data acquisition is continuously ongoing 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 six monthly data reports have been distributed during January-June 2008.

The hydration of the sand shield has been completed. The total amount of water injected during the first hydration attempt and the continuous pressurisation was approximately 540 litres, which can be compared with the estimated available pore volume of 580 litres. The following preliminary hydraulic test confirmed that the buffer around the sand shield was not tight. The leakage could possibly occur through the array of external thermo-couples or through the slots cut out for the heater cables. The planned hydraulic tests and gas injection tests will therefore not be carried out.

A plan for the remaining project period has been elaborated. The dismantling of the test is currently scheduled for the period 2010-2011.

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 project decision and the project plan for the next KBS-3H project phase "Complementary studies of horizontal emplacement KBS-3H" have been approved. The project is divided into two sub-projects and covers the period 2008 to mid 2010.

Sub Project Demonstration

The sub project plan for the phase 2008-2010 has been written and reviewed and is now awaiting approval.

The second and last Mega-packer test phase was completed during the first quarter 2008 and the results were evaluated and reported during the second quarter. A draft report has been delivered to SKB for review and discussion.

Work with preparation of the compartment plug test has continued during the period. The compartment plug is now ordered and delivery is estimated in October 2008.

The second Pipe Removal test was carried out in April and May. Results are similar to the results from the first test. Planning of a third test has also been done. The main difference in the upcoming test setup is that the buffer will have access to water, which will simulate water bearing fractures in the drift.

Sub Project Operation and Production

Regarding the deposition equipment new and upgraded cushions have been ordered and installed on the water cushion palette. These cushions are stiffer than the previous. Further tests with the machine have started and will continue until August.

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.

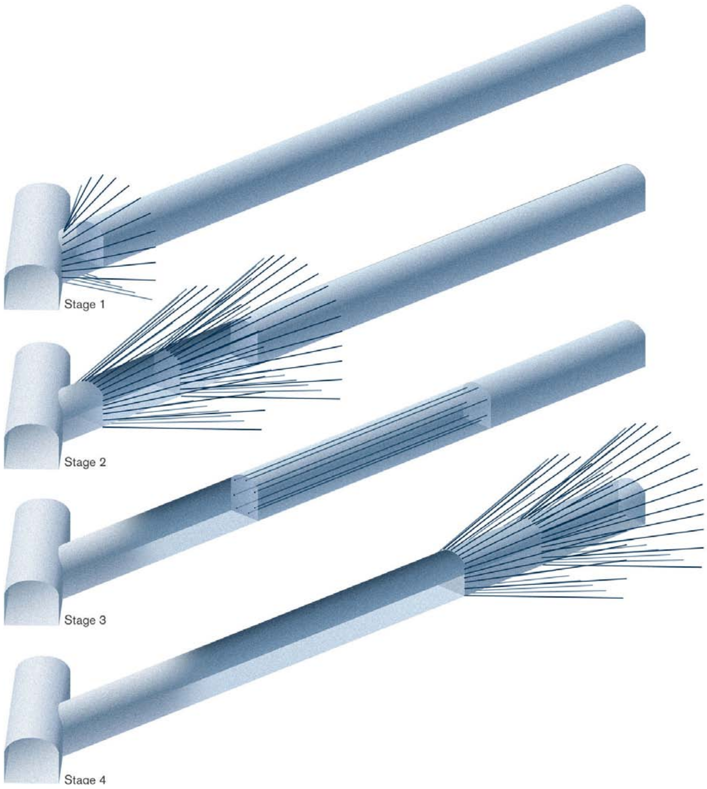
Achievements

Activities during the second quarter have centred on high precision quality control of the data recorded. During April it was noted that the movement of the metal lid anchored above the deposition hole accelerated. Quality control of all of the data was undertaken to ensure that the movements were not the result of mechanical failure of the rock anchors. During a site visit, discussions with SKB engineers explored all possible explanations for the observations. The primary aim was to ensure that the lid was not causing a change in boundary condition of the experiment. After careful consideration of all data, it would appear that the accelerated movements of the lid are seasonal and may reflect temperature variations within the tunnel; this is superimposed on a constant displacement of the lid that is occurring during hydration. Two more displacement transducers will be attached to the lid in order to measure the lateral movements to fully map the 3D orientation of the lid and to investigate this phenomenon. It is felt that the observed movements are not the result of mechanical failure of the rock anchors and reflect true displacement as the result of the hydration of the bentonite buffer.

The modified daily quality control procedure allows all data channels to be cross-checked and is showing new information that was not previously available. This is leading to a greater understanding of the interaction of stresses and pore pressures within the experiment.

A site visit was conducted in the end of May in order to undertake routine maintenance and to present results of the experiment to the meeting of the Technical Evaluation Forum (TEF) held at Äspö.

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, and may also include local draining or waterproofing as well as infiltration of water. Sealing will be achieved by means of grouting, which means filling the water-conducting fractures with grout so that the permeability of the rock mass close to the tunnel or rock cavern is reduced.

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 to seal to the preliminary tightness requirement for a deposition tunnel at this water pressure.

To achieve this, the construction was started of an approximately 100 m long tunnel at the Äspö HRL. 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 project implements and evaluates grouting characterisation methods and grout spread models as developed by KTH and Chalmers.

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 further the repository includes a backfill with a defined density in the rock openings. Thus the requirement is to minimise the Excavation Damage Zone (EDZ), and the resulting contour after blasting should follow the theoretical with very small deviations, to allow for efficient and controlled backfilling. Special attention is therefore given to drilling and blasting. The results are followed and evaluated closely and subsequent adjustments made.

To be able to evaluate the EDZ through direct observation of the fractures induced by blasting, the project now also includes the excavation of rock blocks from the tunnel wall. The blocks will be divided in 0.1 m thick slices in order to examine the character of the EDZ.

Achievements

The excavation started in October 2007 and at the end of June 2008 a 45 m long tunnel that now reaches section 48 is blasted. It includes two ordinary grouting fans outside the contour (fans 2 and 3) and one fan (fan 4) consisting of grouting holes within the contour. The last excavation rounds (section 32-48) were blasted using electronic detonators.

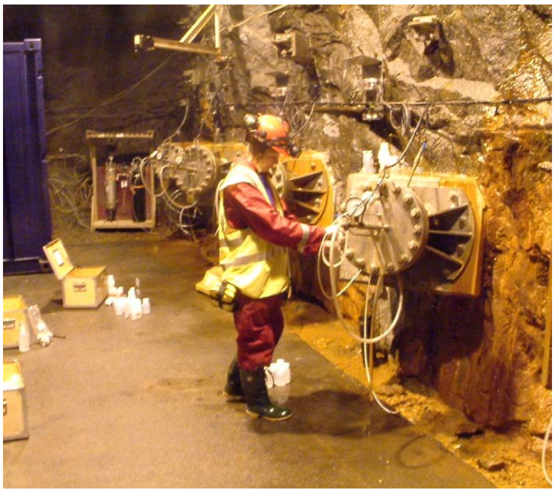
At the beginning of the period, grouting fan 3 was completed. Only silica sol was used in the fan. Before the fan was grouted, holes were drilled in the tunnel front and grouted with cement. After the grouting it could be noticed that the earlier 1 litre spot leakage in the tunnel wall remaining from fan 2 had disappeared.

After excavation of the section along fan 3, spot leakages of 0.1 litres and 0.2 litres respectively can be seen in the left wall, while the roof is fairly dry. According to plan a measuring weir was constructed to cover the inflow along fans 2 and 3 (at section 10). Getting inflow results measured from the weir has proved not to be straightforward, and it remains to ensure that the measured value is stable.

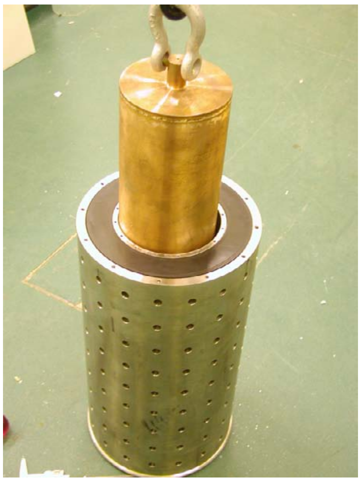
Grouting of fan 4 was carried out with silica sol and holes within the contour. Evaluation is under way. Inflow measurements in control holes before and after grouting show a reduction in rock permeability. It can be noticed after excavation that parts of the rock walls are wet.

The blasting of section 32-48 using electronic detonators was favourable. Blasting holes are clearly visible along major parts of the rock wall. Rock blocks for EDZ characterisation will be cut from this section.

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.

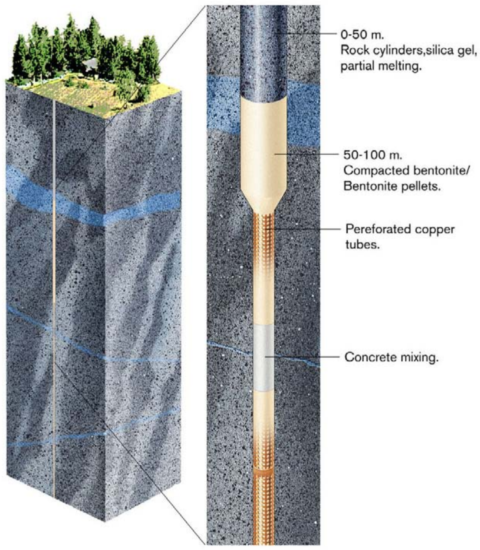
Miniature canisters with a diameter of 14.5 cm and containing 1 mm diameter defects in the outer copper shell have been set up in five boreholes with a diameter of 30 cm and a length of 5 m at the Äspö HRL. All five canisters were installed in the beginning of 2007.

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 the second 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 until autumn of 2007. No further analyses have been carried out to allow the experiment to reach equilibrium. A report on the set up of the experiments and the first year's activities and results is in preparation. Discussions have been held regarding further water analyses (including water chemistry, dissolved gas and microbial analysis) and a new analysis campaign will start later in 2008.

4.12 Cleaning and Sealing of Investigation Boreholes



The project dealing with identifying and demonstrating the best available techniques for cleaning and sealing of investigation boreholes was initiated in 2002 and up to now Phase 1 to 3 have been finalised. The present work that makes up Phase 4 is performed in co-operation between SKB and Posiva and focuses on:

- 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.

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. The holes should represent typical rock conditions with respect to frequency, size and properties of permeable and unstable fracture zones.

Achievements

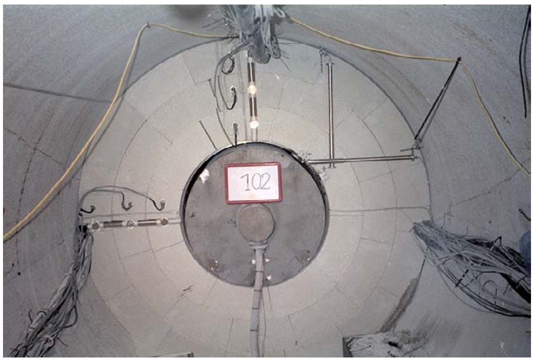
The following achievements have been reached during the period April-June, 2008:

- Identification of boreholes for detailed examination and modelling, three boreholes at Laxemar (KLX04, 06, 10), three at Forsmark (KFM07A, 09A, 09B) and one at Äspö (KA 3386A01).
- Hydraulic modelling will be made of each site assuming holes to be (1) perfectly plugged and as tight as the surrounding rock, (2) all holes open and (3) degradation of the plugs in one of the holes at either site. The purpose is to determine the impact of plugs with specific hydraulic conductivities on the hydraulic performance of "repository rock".
- During the second quarter, work has focused on the boreholes at Forsmark. The preliminary location of different plugs has been made for two boreholes.
- To find out what the impact of varying borehole diameter, curvature of the hole etc have on the detailed design and constructability of plugs in a complex but realistic hole, one of the holes at each site is examined in great detail using data base information.
- Detailed plug design has been initiated for borehole KFM09A at Forsmark.

The hydraulic modelling has started and the first results are expected to be at hand in September this year. The examination and selection of detailed design, including stabilisation, have been initiated and a first presentation for preliminary evaluation will be made.

The principle of design and construction of plugs outlined in Phase 1 in the project will be followed, i.e. to seal those parts of the boreholes that intersect water-bearing fracture zones with a concrete that is rich in suitably graded quartz sand/gravel and poor in (low-pH) cement (“QC”), and to seal the parts that are located in fracture-poor rock, with clay plugs (“L”). The “Basic type” concept, perforated copper tubes containing strongly compacted blocks of smectite-rich clay, will be used in the design of clay plugs. The potentially better “Container” plug concept will not be used in the present phase since it has not been tested in practice.

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 work to model the two Canadian experiments the Buffer/Container Experiment and the Isothermal Test (Task 1.2.1) has been finished and reporting is ongoing. The work with modelling of the Canister Retrieval Test at Äspö HRL(Task 1.2.2) has continued during this quarter. A Task Force meeting was held on the 26th – 27th of May at Äspö HRL where the modelling teams reported their progress. Altogether 7 teams have worked with the modelling of this benchmark.

The task to model the Canister Retrieval Test is divided into two parts where the first part deals with modelling of the thermo-hydro-mechanical behaviour of a central section of the test hole with given boundary conditions. The second task deals with modelling of the whole test. Most teams have been working with the first part and presented their results on the first task. The rest of the year will be devoted to finishing this task and also to continue with the model of the entire test.

Task Force Geochemistry

Material from the Long Term Test of Buffer Material (Lot) test A2 has been used for a percolation study at both room and elevated temperature at the University of Bern. The transport of a number of species has been modelled by use of the Phreeqc code and compared to the measured data.

Several kinds of laboratory tests concerning diffusion in bentonite have been performed at Clay Technology in Lund. A computer code has been produced in order to evaluate the results from the perspective of the new conceptual theory for diffusive transport in bentonite.

Laboratory and modelling results were presented and briefly discussed at the Task Force meeting at Äspö in May 2008. Specific Phreeqc features were also shown in detail by Tony Appelo. A second specific workshop for a more detailed penetration of test and modelling results is planned to take place in the beginning of September.

5 Äspö facility

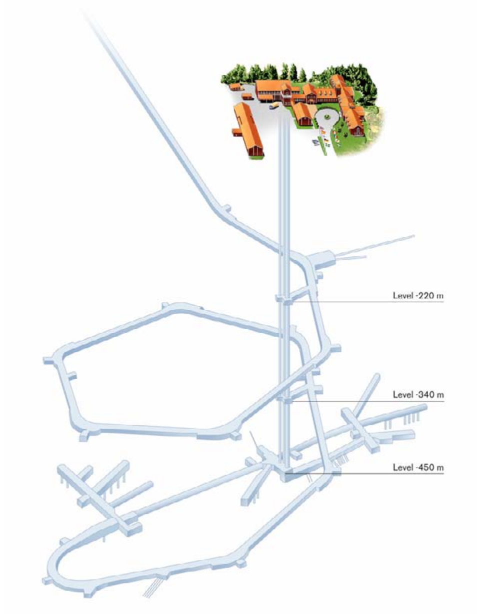
5.1 General

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 almost 100% operational during the second quarter of 2008 and no incidents have occurred within the internal system. However, on the 16th of July the electric power supply from OKG was knocked out by a violent thunderstorm, making it necessary to couple the reserve supply to the local network. After four hours, the fault was remedied, allowing a return to normal operation. During the power cut, the server room and the computer traffic was fully operational using the diesel generator which was installed in 2007. During the fourth quarter the underground monitoring system will be extended so that the whole system can operate for at least 5 hours in the event of a power cut. In addition, new cable trenches are being built in preparation for installation of a below-ground ring-supply of high-tension current, so that underground operations are ensured in the event of cable fault.

An agreement with OKG has been signed which means that SKB take over all responsibility for maintenance of the facility. The agreement ensures that OKG will provide electricity and water and take care of SKB's waste-water. Inspection of all the systems is being carried out after the take-over and a maintenance plan will be developed. However, the hand-over of documentation from OKG lead to significantly more work than expected.

The rust-damage to the elevator cage has been repaired and the maximum-load limit which was in place has been lifted. The whole elevator cage will be blasted and painted during the summer. During the painting work, limits have been imposed on the underground activities. Rock-maintenance is continuing as planned. A new technique with limited mechanized scaling of the rock has been introduced by the contractor in order to prevent injury to personnel.

The construction of an archive has begun and is planned to be completed and ready for final inspection by the 1st December 2008. The construction of a catering and dining room for employees and visitors is being planned and an application for a building permission has been submitted to the municipality of Oskarshamn. This matter has become acute, as OKG will no longer allow external visitors access to their restaurant after 1st October. The need for office-space is increasing continually and the available space is not sufficient for the activities planned for 2009. Fitting and furnishing of a loft space is being planned in order to provide a further ten office spaces. For the extension of the car-park at Äspö HRL the excavated rock-masses from the project Rock Sealing at Great Depth are used.

The planned waste-water drain from Äspö laboratory to OKG's sewage treatment plant is delayed by about a year as a number of questions remain from consultations with owners of fishing-rights.

The system for registration of personnel (RFID) has been approved and the system will be transferred to administration under the Alfa surveillance system and will be called Alfagate. New routines for use of the system will be written during the third quarter.

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

A lot of activities have been ongoing in the Bentonite Laboratory during the second quarter of 2008. Many tests have been performed, the bentonite mixer has been trimmed and materials for the blocks have been mixed.

Tests concerning piping and erosion in buffer have been performed and will continue during the autumn (Figur 5-1). The tests with the new tool for buffer installation will continue during 2008. The Factory Acceptance test is performed and approved and tests of installation of buffer in deposition holes will start during the fourth quarter.

Half-scale test for backfilling have recently been completed for evaluation and reporting. The number of tests within the programme for method and technical development concerning backfilling has decreased during the second quarter due to work with reporting and evaluation. A new programme for further method and technical development shall be established during the autumn. However, a series of running tests to handle module stability (Figure 5-2) have been performed.

A question which was raised during the second quarter is how the chamfer to the deposition hole shall be backfilled and the influence on backfilling (Figure 5-3). A series of tests will start during August.

The continuation of the development of buffer protection, bottom plate and installation of pellets in the deposition hole has been studied during the second quarter. Recommended methods shall be tested from the end of 2008 and beginning of 2009.

Figure 5-1. *Piping and erosion test in the Bentonite Laboratory.*

Figure 5-2. *Module stability test.*

Figure 5-3. *Test of backfilling of chamfer in deposition hole.*

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 7,825 persons during the second quarter of 2008. The corresponding number for the same period last year was 6,292 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 April - June 2008
Central interim storage facility for spent nuclear fuel	564
Canister Laboratory	850
Äspö HRL	2,500
Final repository for radioactive operational waste (SFR)	2,923

A series of lectures with special connection to the research and development of techniques conducted at the Äspö facility started in 2007, and has continued during 2008. "The Environmental Day" at Äspö, was held on the 3rd of April in cooperation with Äspö Environmental Research Foundation. The event, which was a contribution to the environmental week in Oskarshamn, was divided in two parts, a conference during the day and lectures for the general public in the evening. Both parts of the event were well-filled.

The summer project "Urberg 500" with guided tours in Swedish and English started up at the end of June. Four summer guides have been employed to support the information group during the summer. Several bus-tours a day take visitors to the laboratory, where they are given information about ongoing research. The project will end in August.

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. Two Ph.D. students will be recruited and 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 30th of May, Ulf Lavergren defended his Ph.D. thesis focusing on the chemistry of sulphur and metals in an abandoned mining area where black shale has been burnt and processed /Lavergren, 2008/. Both the solid materials and aquatic phases were studied and the field site was Degerhamn on south western Öland.

Further, two papers have been published during the second quarter. The first paper is dealing with meteorological impacts on the water quality in the Pajuluoma acid sulphate soil area in western Finland /Österholm and Åström 2008/. The second paper is dealing with a comparison of the behaviour of rare earth elements in surface waters, overburden groundwaters and bedrock groundwaters in two granitoidic settings /Rönnback 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

During the period April – June 2008, the following reports have been published and distributed.

8.1 Äspö International Progress Reports

Eng A, Nilsson U, Svensson D, 2007. Alternative Buffer Material. Installation report. SKB IPR-07-15, Svensk Kärnbränslehantering AB.

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SKB, 2008. Äspö Hard Rock Laboratory. Status Report. January - March 2008. SKB IPR-08-14, Svensk Kärnbränslehantering AB.

8.2 Technical Documents and International Technical Documents

No technical documents have been published during the second quarter 2008.

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Goudarzi R, Johannesson L-E, Börgesson L, 2008. Backfill and Plug test. Sensors data report (Period 990601-070101) Report No:14. SKB IPR-08-02, Svensk Kärnbränslehantering AB.

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