International
Progress Report

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Äspö Hard Rock Laboratory

Status Report
October – December 2008

Svensk Kärnbränslehantering AB

March 2009

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Äspö Hard Rock
Laboratory

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Overview

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

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

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

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.

The activities have since 2003 been concentrated to the Äspö Research School. When the activities in the school were concluded as planned in September 2008, the remaining and new research activities were transferred within the frame of a new co-operation, Nova Research and Development (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, eight organisations from seven countries participated 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 2007 /SKB 2007/. The planned activities related to Äspö HRL are detailed on a yearly basis in the Äspö HRL Planning Report /SKB 2008/. This Status Report presents main achievements during the fourth quarter of 2008. In the Annual Report more detailed information is given of new findings and results obtained during the whole year.

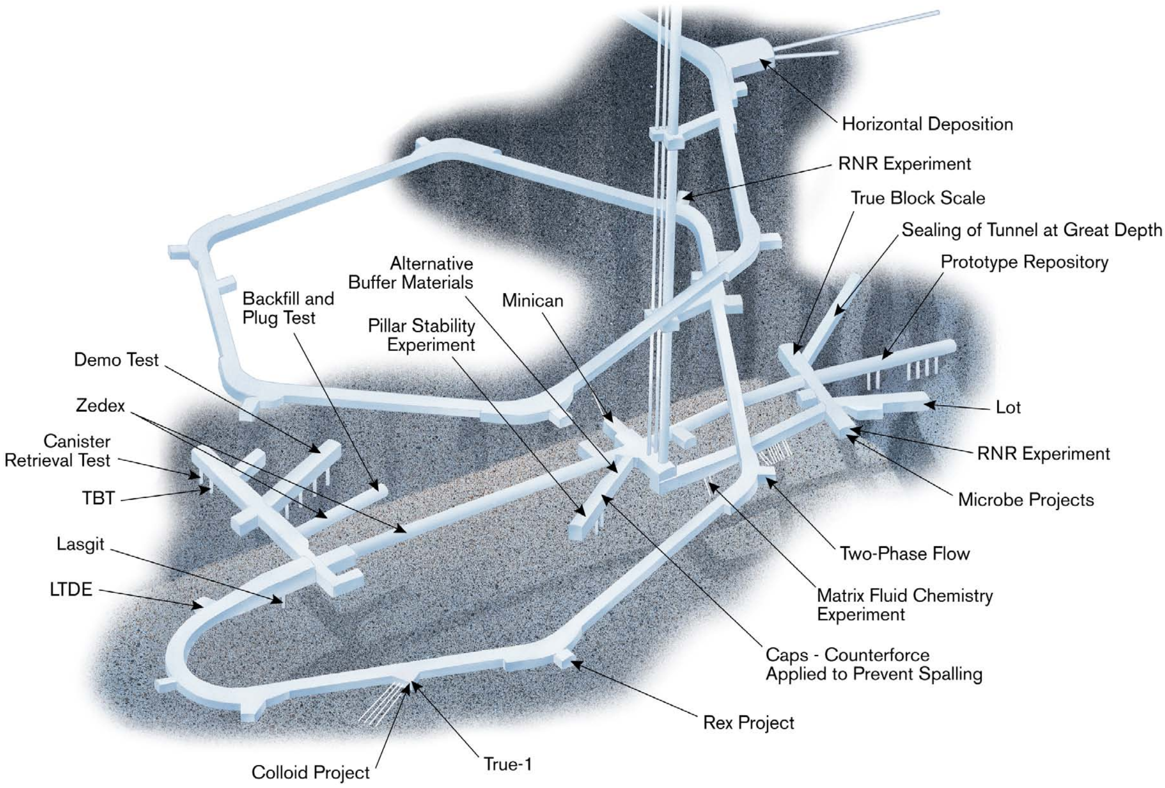


Figure 1-1. *Allocation of some of the experimental sites from the -220 m to -450 m level in Äspö HRL.*

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.
- Establish and develop the understanding of the Äspö HRL rock mass material properties as well as 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 and geochemistry. The activities further aim to provide basic geoscientific data to the experiments and to ensure high quality of experiments and measurements related to geosciences. In Figure 2-1 water inflow measurement performed in the Tass-tunnel is shown.

Figure 2-1. *Water inflow measurement in the Tass-tunnel, section 0-48.67 m.*

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

Geological mapping of the floor in the Tass-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 fourth quarter of 2008 have been:
- The excavation of the Tass-tunnel (the tunnel for sealing fractures at great depth) has continued. Geological mapping of the tunnel (fronts, walls, roof and floor) has at the end of the year been completed up to section 64.6 m. In addition, four tunnel fronts up to the end of the tunnel at section 80.7 m have been mapped. Data and drawings have been fed into the TMS (Tunnel Mapping System). Since the last status report laser scanning combined with digital photography has been performed in the section 48.67 - 64.6 m. The laser data have partly been analysed and used for modelling work (see the Rocs project).
- The modelling work that commenced in 2005 concerning water bearing fractures at the -450 m level is completed. Adjustments in the report after being returned from the review are still ongoing.
- The report on possible differences in the mapping procedure for a drilled and blasted tunnel and a TBM bored tunnel, including differences in the results achieved from the geological mapping, has now been completed and handed in for printing.

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

Reference markers are put up on the tunnel wall before the laser scanning can begin.

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 or photogrammetry will be a part of that system. The resulting mapping system shall operate in a colour 3D environment where the xyz-coordinates are known.

Achievements

The project plan is waiting for approval. The work with specification of requirements concerning various parts of the project is ongoing, for example requirements for the geological mapping and how to handle laser scan or photogrammetric data.

The third laser scanning event combined with digital photography in the Tass-tunnel has been completed and the data are delivered. Scanning and digital photography has now been performed in section 0-64.6 m of the tunnel. The scan data has been used to create 3D-models of the Tass-tunnel. The work concerning tests of software to handle the laser data continues.

A new test with photogrammetry has been performed in the Tass-tunnel. A SheronCam HDR camera equipped with a light source was used and showed promising results.

2.3 Hydrogeology

The objectives of the hydrogeological work are to:

- Establish and develop applicable methods for measurement, testing and analysis for the understanding of the hydrogeological properties of the Äspö HRL rock mass.
- Ensure that experiments and measurements in the field of hydrogeology are performed with high quality.

The main tasks are firstly to initiate works for further development of quality control and quality assurance procedures in the field of hydrogeology and secondly to initiate an upgrade of the existing Äspö Site Descriptive Model. The main features are the inclusion of additional data collected from various experiments and the adoption modelling procedures developed during the site investigations. The intention is to develop the model into a dynamic working tool suitable for predictions in support of the experiments in the laboratory as well as 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 sites.

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 fourth quarter, the hydrogeological monitoring system has been performing well and the monitoring points in the tunnels have been maintained. However, in the surface drilled boreholes a gradual deterioration of the equipment has taken place over the years, to the extent that presently most of the Äspö boreholes are only measured manually or discontinuously. An investigation of potential supporting and corrective measures for the surface boreholes is underway. The monitoring is reported quarterly through the quality control documents and annually by describing the measurement system and achieved results.

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

The yearly monitoring campaign for groundwater chemistry was conducted as planned during September and October. Several boreholes in the upper bedrock (-50 to -100 m) in the tunnel have been dried out and discarded from the sampling programme. Also KAS03 was discarded from being sampled due to problems with no groundwater pressure and failing packed-off sections. In the upper sections in KAS09, no sampling was possible as the groundwater level seems to have been lowered. New packer installations in these boreholes may be conducted in the near future. Decision on the continuous program and full reporting is expected during the second quarter of 2009.

Extra volumes of samples were taken for short time storage. ATP (adenosine triphosphate) and additional isotope analysis (or other parameters) are thus possible to conduct. Quality assurance of the data is still ongoing and several samples are sent for external analysis of different parameters.

Results from sampling of gases in (KA3510A) in June and earlier in April (KA3110A) performed in conjunction with the Microbe project are now reported. No further samples seemed to have been sent for isotopic determination of the gas phase. Methods for analysis of gases are further tested. Existing gas sampling equipment has been used and proven to be applicable in the underground facility. Further sampling and analysis are however needed to get more reliable data of concentrations and to evaluate whether sampled volumes are enough for analysis of the isotopic composition in the gas phase.

Monitoring of the water chemistry is continuously performed at a few points in the Tass-tunnel. Effects and residues from blasting are minor in the cracks but can be considerable in the solid material which is normally removed from the tunnel. Colloidal concentrations are also monitored but needs to be further evaluated.

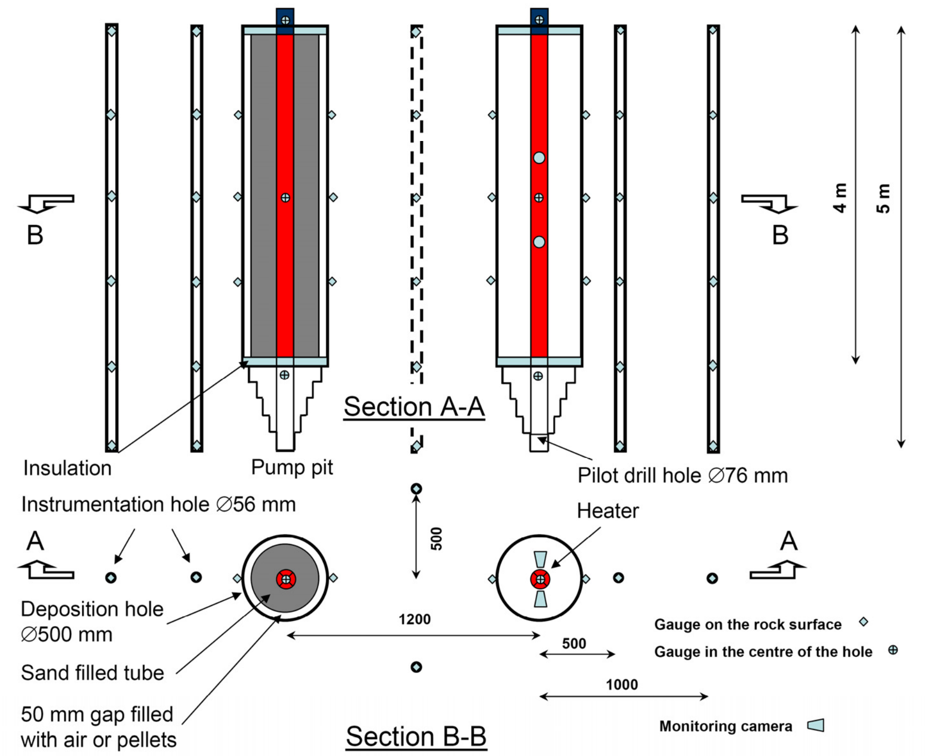
2.5 Rock Mechanics

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 tests 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 Counterforce Applied to Prevent Spalling (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 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 second test in the Caps project was performed in November with a heating period of little more than two weeks. The performed actions to prevent the rock from drying up during the second test did not result in a more uniformed spalling in the heating holes as was expected. The results in the second test showed even larger heterogeneity of the observed spalling between the heating holes. Compared to the first test, the amount of spalling increased in the hole with larger natural humidity, while the amount of spalling was almost equal in the other hole with smaller natural humidity.

The third test was performed in December, promptly after the second test had been finished. This test included loosely placed pellets of LECA (Light Expended Clay Aggregates) in both of the heating holes in a 50 mm gap created between a large inner tube and the borehole wall (Figure 2-2). The preliminary results from this test indicate that the pellets cannot prevent the holes from cracking, whereas it might keep the rock chips in place and by this preserving the shape of the holes. The tasks remaining to be carried out during 2009 are the final test, the evaluation and the reporting of the test results.

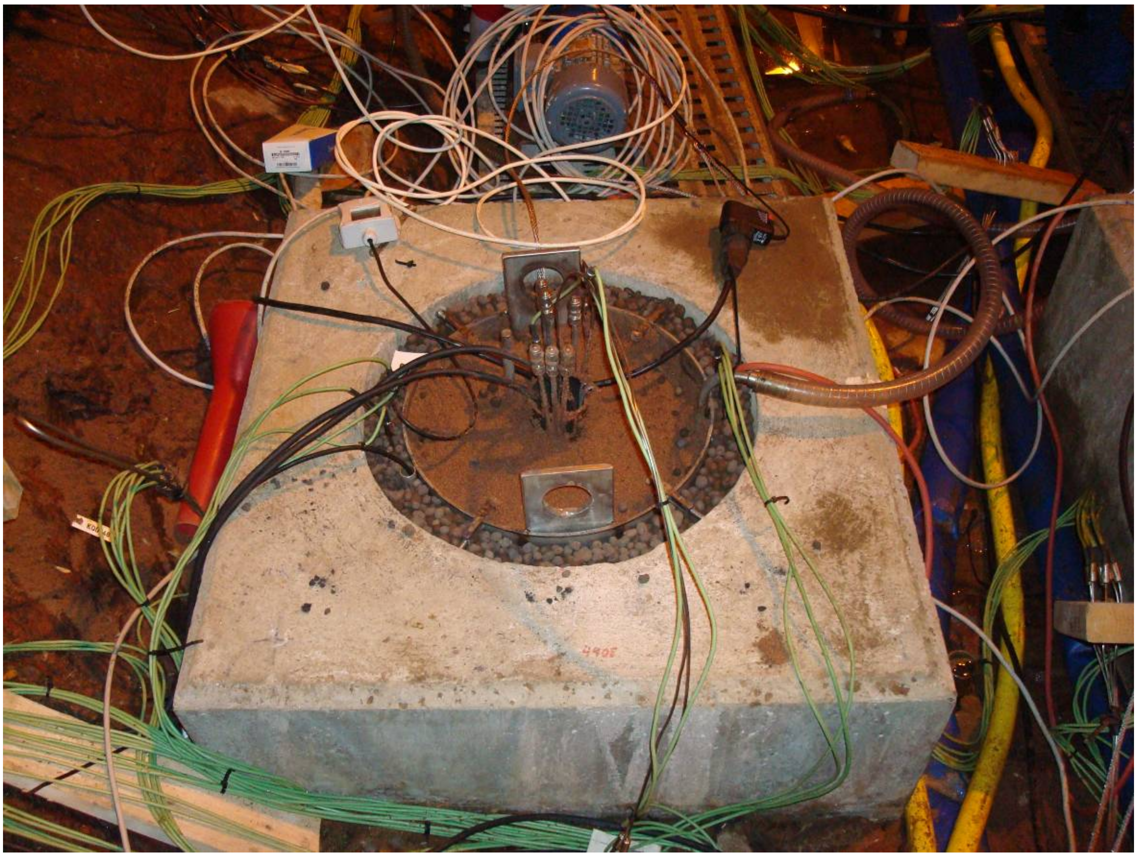


Figure 2-2. *One of the heating holes in the third test, the large inner tube is filled with sand and the surrounding slot is filled with LECA pellets.*

3 Natural barriers

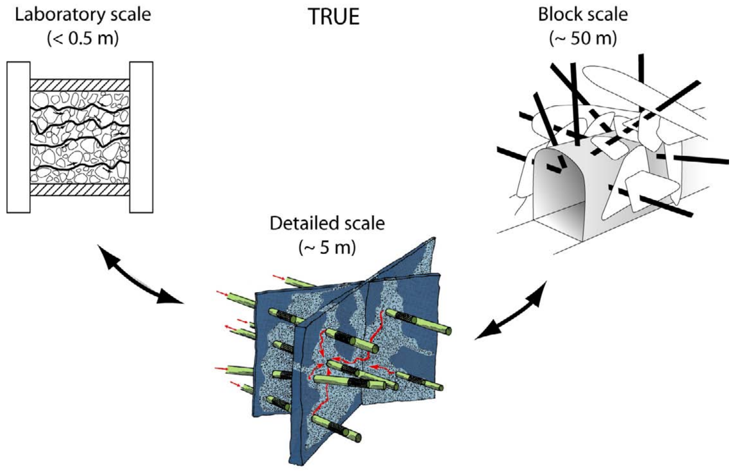
3.1 General

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. 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. The sampling of a fracture surface for microbial presence in a new-drilled rock core within the Microbe Project, Micomig (section 3.5.3) is shown in Figure 3-1.

Figure 3-1. *Sampling of a fracture surface for analysis of DNA and RNA in biofilms.Tracer Retention Understanding Experiments.*

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.

3.2.1 True Block Scale Continuation

In the aftermath to the BS2 project, a second step of the continuation of the True Block Scale (BS3) was set up. This step has no specific experimental components and emphasise consolidation and integrated evaluation of all relevant True data and findings collected thus far. This integration is not necessarily restricted to True Block Scale, but may include incorporation of relevant True-1 and True-1 Continuation results.

Achievements

The planned series of articles covering the True Block Scale experiments have been transformed into one two-part series of papers entitled "Transport and retention from single to multiple fractures in crystalline rock at Äspö (Sweden)":

I Evaluation of tracer test results and sensitivity analysis

II Fracture network flow simulations and global retention properties

This series is flanked by a standalone paper, submitted prior to the above series, entitled "The role of enhanced porosity adjacent to fractures for tracer transport in crystalline rock".

During the fourth quarter the internal review of the above series of articles has been completed and updating of the two articles is underway, followed by a formal delivery to Water Resources Research. Furthermore, a draft version of the stand alone article on the role of enhanced porosity has been prepared, and has been subject to a limited internal review. The findings of the latter article emphasises the importance of the zone of enhanced porosity (EPZ) as the "entrance" to the tighter rock matrix beyond. This importance is notable even if the EPZ is of limited thickness, only fractions of a millimetre.

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 second half of 2008, with the exception of work performed within True-1 Completion, see below.

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

During the last quarter the activity plan for analysis of the cores from KXTT3 and KXTT4 was written. However, the cost for the planned analyses is higher than previously estimated. Due to this, a project meeting is scheduled to January 2009 for discussion and decision about the coming analyses. The activity plan is not yet delivered for review and approval since decisions at the project meeting may change its content. The analyses of cores is planned to start in February of 2009. However, this may change depending on decisions made at the project meeting in January.

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.

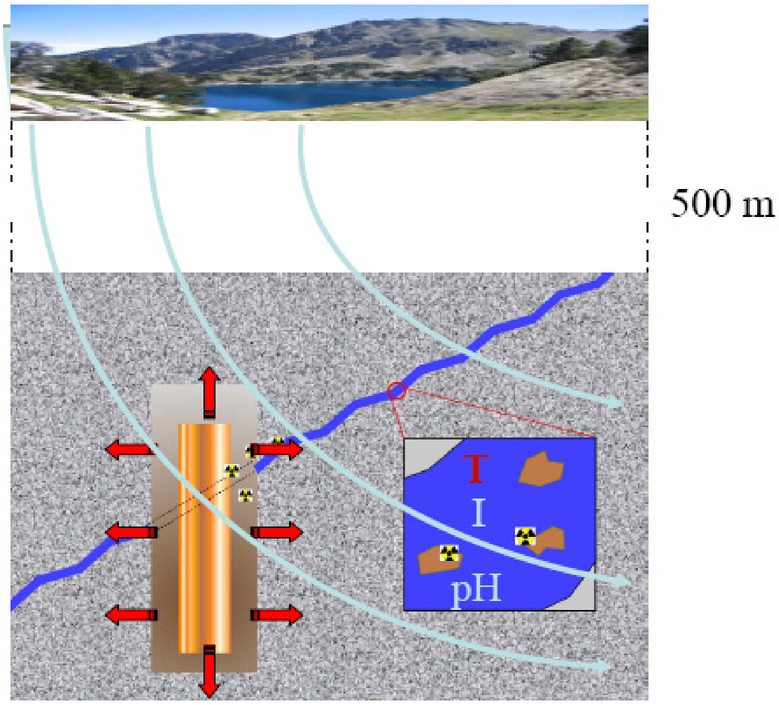
Achievements

Rock slices from half amount of the sample cores have been crushed, grinded and divided into sub-samples (series a and b). Crushed samples (series a), from 5 sample cores extracted from fracture surface on the core stub and 4 sample cores extracted from the matrix rock have been selected for the ongoing dissolution and subsequent analysis of ^{99}Tc, ^{102}Pd, ^{236}U and ^{237}Np using mass-spectrometry (ICP-SFMS) and analysis of ^{63}Ni using liquid scintillation (LSC). The results of mass spectrometry measurements show ^{237}Np in amounts well above reporting limit but only in the first slice, i.e. the slice in contact with the tracer labelled groundwater. However, also the presence of ^{236}U is indicated in some first slice samples. To prevent cross contamination during drilling for extraction of the sample cores the rock surface was coated with epoxy resin. There are indications that tracers adsorbed on the rock surface were removed with the epoxy coating. This is now under further investigation.

Analysis of the γ-emitting tracers ^{22}Na, ^{57}Co, ^{75}Se, ^{85}Sr, ^{95}Zr-95, ^{110m}Ag, ^{109}Cd, ^{113}Sn, ^{133}Ba, ^{137}Cs, ^{153}Gd, ^{175}Hf, (^{226}Ra) and ^{233}Pa in sub-samples (series b) and intact rock slices are in progress at SKB Baslab using a HPGe γ-detector. Preliminary results for six sample cores show penetration depth to about 35 and 45 mm for ^{137}Cs and ^{22}Na respectively.

Laboratory experiments with specimen from the core of the small diameter extension borehole, the replica core stub and the pilot borehole core are ongoing at Chalmers University of Technology (CTH). The same tracer cocktail as for the in situ experiment, with tritiated water added, is used for batch sorption tests and diffusion tests. Based on preliminary results from four samples the effective diffusivity (De) is calculated to about 4×10^{-14} m^2/s, which is in accordance with the results obtained from the supporting laboratory experiments performed by AECL Whiteshell laboratories /Vilks et al. 2005/, on specimen from the large diameter core (270 mm).

3.4 Colloid Transport 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

To determine geometry and structure of Ca- and Na-bentonite colloids in solution X-ray microspectroscopy analysis has been performed at PSI in Switzerland. Results show that the structures of montmorillonite colloids in solution are not planar but spherical or elliptoidical.

Laboratory studies show that tri- and tetravalent radionuclides show sorption reversibility kinetics on bentonite in a system with Grimsel groundwater, fracture filling material and bentonite colloids.

Modelling of bentonite colloid transport in the "Quarried Block" shows that the retention in the system can be coupled to physical filtration (mass loss) and attachment/detachment (just delay). Larger colloids experience more physical filtration and smaller more attachment/detachment with the rationale that the smaller travel closer to the fracture walls in the flow field.

Mockup tests of erosion/generation of Na- and Ca-montmorillonite show that the gel propagation is significantly affected by the groundwater composition. The difference between gel propagation rate in a dilute water and Grimsel groundwater, with 0.001 M Na and 0.0001 M Ca is quite large. Ca-bentonite acts as expected very differently from Na-bentonite.

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

Three of the circulation systems in the Microbe laboratory

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

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

Three boreholes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures are connected to the Microbe Laboratory via tubing. Each borehole has been equipped with a circulation system offering 2,112 cm^2 of test surface.

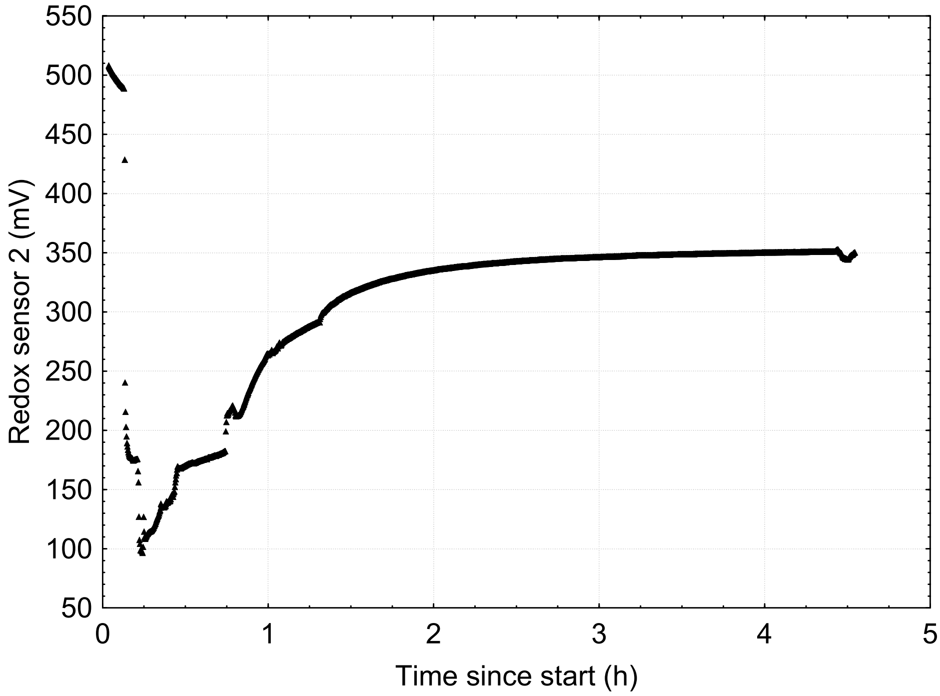
The major objectives are to:

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

Achievements

During the fourth quarter, the Microbe laboratory was used as a base for investigations performed at the site for In Situ Corrosion Testing of Miniature Canisters, see Section 4.11. Gas composition was analysed in groundwater from all five canister installations as was the composition of microorganisms. In particular, acetogenic bacteria that produce acetate from hydrogen and carbon dioxide, and sulphate reducing bacteria were analysed. The amount of biomass was also analysed.

3.5.2 Micored



Output from a Unisense redox pressure resistant platinum micro-electrode (0.5 mm tip) with an Ag/AgCl electrode as a reference. At time zero, before start of drainage, aerated water was in the sensor which gave a high potential that quickly decreased when water from the fracture started to flow. As the drainage flow from KA3110A (-414 m) continued, the redox potential increased, while sulphide decreased correspondingly (not shown).

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 these gases. 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

Observations of surface and tunnel boreholes have shown elevated concentrations of sulphide. Pilot investigations on the effect of drainage on a borehole have previously been performed. It was found that the number of sulphate reducing bacteria was strongly correlated inversely with the amount of water drained. The pilot experiment has been followed up with repeated drainage experiment in the boreholes KA3110A, KA3510A and KJ0052F01. During these drainage experiments, microelectrodes for pH and redox potential were installed under in situ pressure and flow conditions. A good correlation between decreasing sulphide concentration and pH with increasing redox potential was observed. The results from these experiments will assist the modelling of observed sulphide production in boreholes.

3.5.3 Micomig

Intersected fracture with filling material obtained during drilling for analysis of DNA and RNA in biofilms

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.

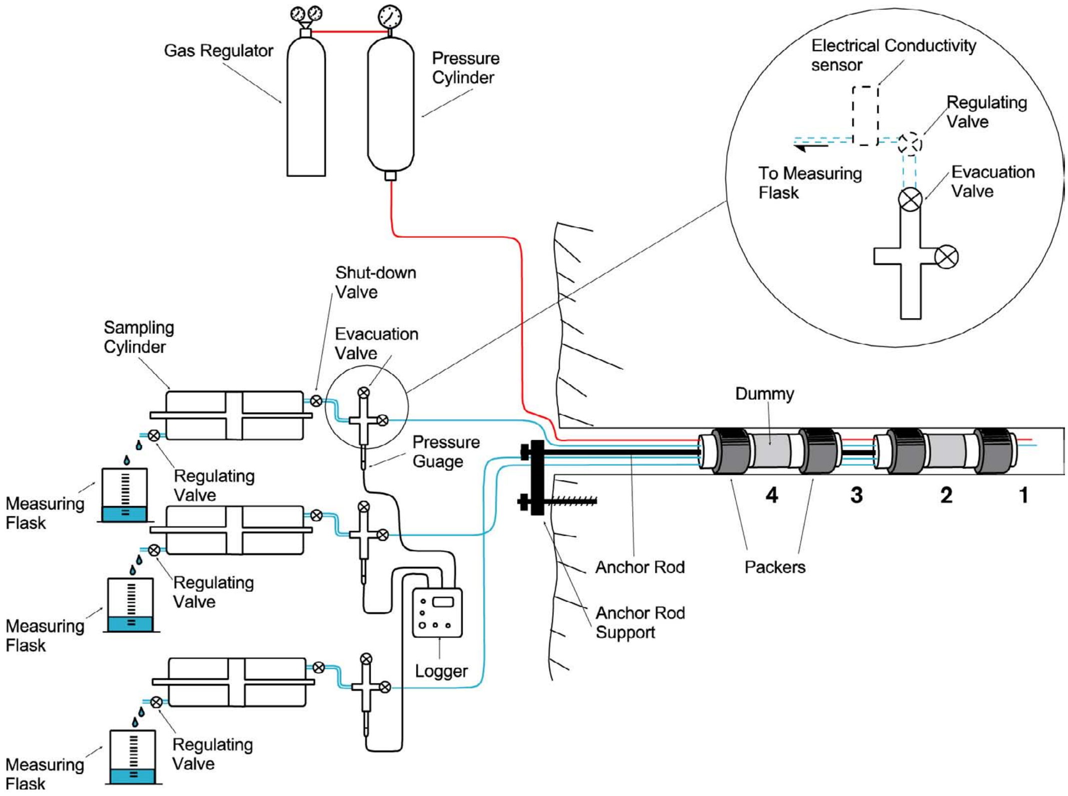
The work within Micomig will:

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

Achievements

Water conducting fractures in the Äspö tunnel have been over-cored. In October 300 mm core drilling was performed at tunnel length 1,362 m in a small niche and a 500 mm long drill core with fracture surfaces was produced. Protocols were developed to sample DNA and RNA from the fracture surfaces. In November, new drillings were made, with methods developed and based on the first drilling occasion. This time 76 mm cores were drilled across a water conducting fracture at the inner wall of the niche. Five drill cores were obtained that intersected the fracture at a range of 90 cm to 467 cm from the opening in the niche. The drilling went very well and sampling was successful. The surfaces carried black, white and purple fracture filling material with biofilms. A total of 60 samples distributed over the five cross sections were obtained for DNA and RNA analysis. The flowing groundwater and the drill water were also analysed for DNA and RNA. In addition, some chemical analyses were performed. The samples are presently being analysed.

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 porewater 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.

A continuation phase of the project started 2004 with the aim to focus on areas of uncertainty which remain to be addressed.

Achievements

There have been no major achievements in the project during 2008. Final reporting of the matrix borehole hydraulic studies is presently ongoing.

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.

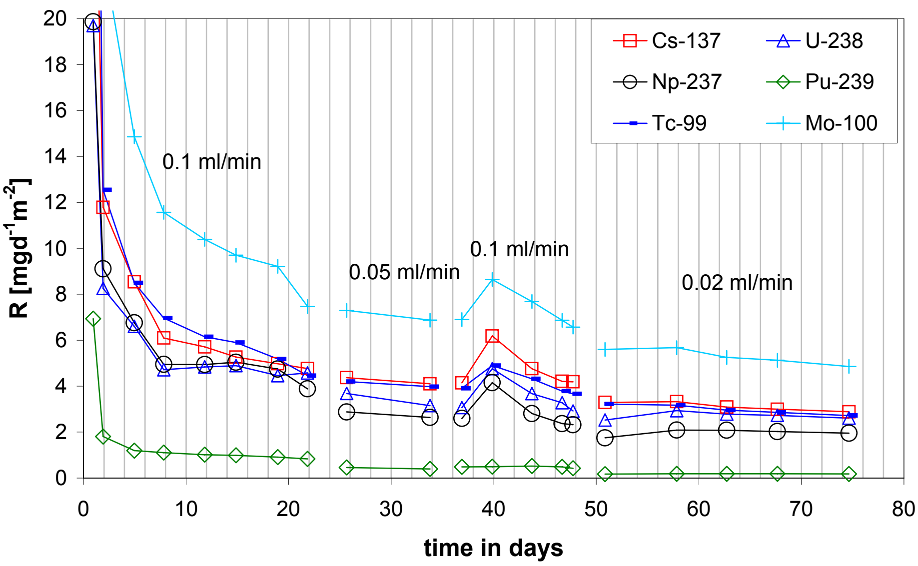
Experiments in Chemlab 1:

- 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.

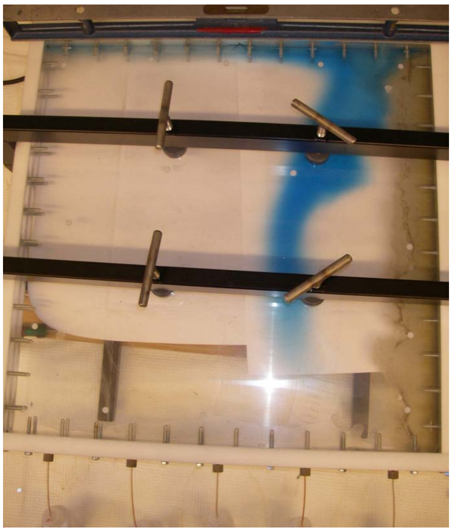
The in situ experiments will be preceded by laboratory experiments where the scope is both to examine parameters that may influence the leaching as well as testing the equipment to be used in the field experiments.

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 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.

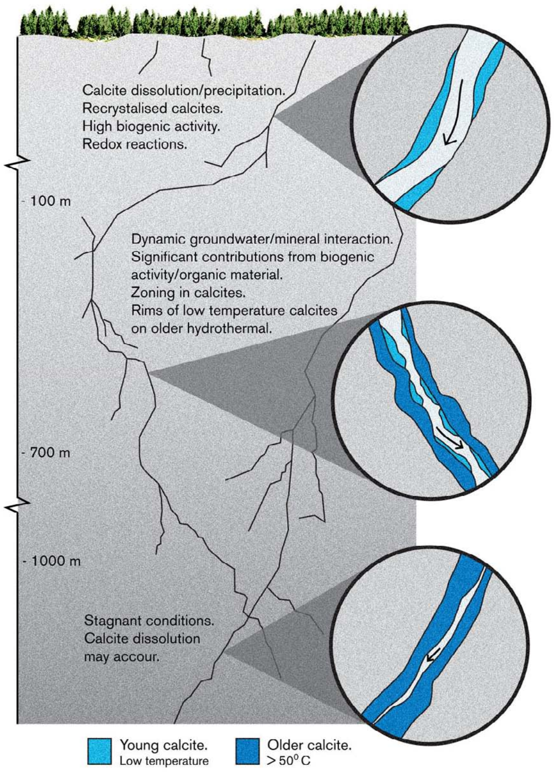
The transport resistance is concentrated to the interface between the bentonite buffer and the rock fracture. The mass transfer resistance due to diffusion resistance in the buffer is estimated to only 6% and the diffusion resistance in the small cross section area of the fracture in the rock to 94% /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 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.

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 disequilibrium (USD) analyses applied on fracture mineral samples.
- The use of these analyses in hydrogeochemical studies in order to demonstrate redox conditions along flow paths over the last 1 Ma.
- A summary of the experiences from the palaeohydrogeological studies carried out at Äspö.

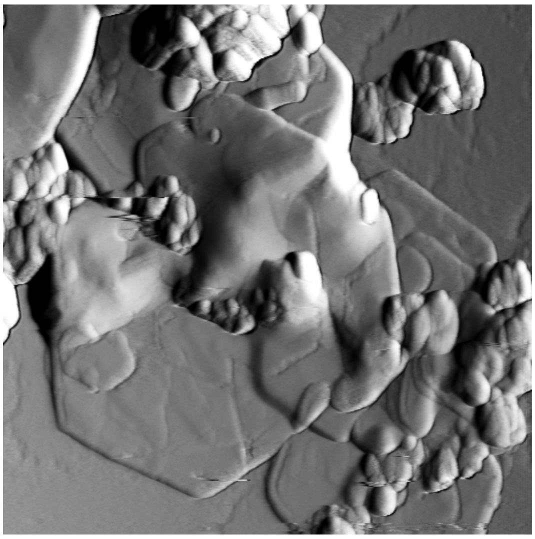
The analyses are carried out on split samples of fracture material from a surface borehole drilled at Äspö (KAS17). This borehole penetrates the large E-W fracture zone called the Mederhult zone.

Achievements

Different analytical techniques for uranium series disequilibrium (USD) analysis and repeated analyses on the same set of samples are performed at two different laboratories. Bulk analyses as well as analyses of different fractions by applying sequential extraction are carried out. The samples used are from six open fractures in a borehole (KAS17) and represent depth ranging from 15 m to about 150 m.

The analytical work is almost finished and all the analyses will be available early 2009. Detailed interpretations will then be reported. It is however demonstrated already at this stage, that the sampled fractures covers a depth were oxidising conditions rapidly changes to reducing (in the upper 15-20 metres). It is also shown that fractures with a spacing of less than one metre show very different conditions in terms of uranium leaching and deposition. The results from the sequential extraction analyses generally support the finding from the bulk analyses but yield more information about e.g. the amounts of uranium deposited and also add information about the complexity of the uranium deposition/removal processes that have occurred in the fractures.

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

The continuation phase of the project was based on a study of Fe-oxides currently present in the water-bearing fractures from investigated sites at Äspö, Oskarshamn and Laxemar. These Fe-oxides were investigated to test if they could provide information about the redox conditions during their formation, which in turn, could indicate any deep introduction of oxidised waters as a result of present and/or past meteoric recharge, or resulting from past glaciation or de-glaciation events in this part of Sweden. The continuation phase of the study has been completed and reported during the last quarter, and now awaits publication as an Äspö IPR report. It will be submitted also for publication to Geochimica et Cosmochimica Acta.

From the various sites studied, three types of natural Fe-oxides have been identified:

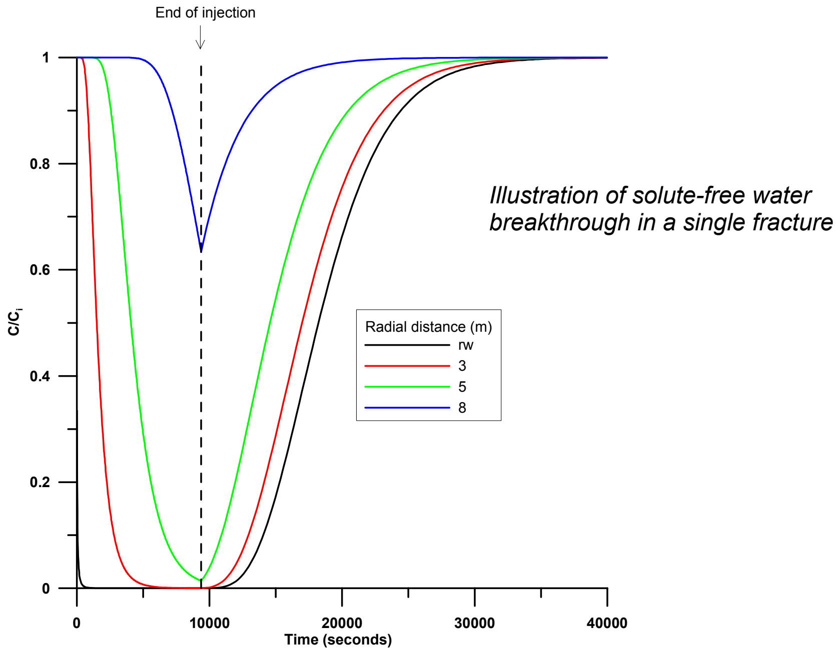
Type I - Hematite with a large particle size and little variation in Fe isotope composition, occurring at depths ranging from the surface to 800 m.

Type II - Crystalline Fe-oxides (goethite, magnetite, hematite with smaller particle sizes) occurring at depths down to 110 m below surface.

Type III - X-ray identified amorphous, nanometre-sized Fe-oxides occurring at depths down to 50 m below surface.

In general, the studies indicate that the fractures of the upper 50 m are currently experiencing episodes of oxidation (i.e. meteoric recharge), whereas earlier events of low temperature oxidation have occurred down to depths of 110 m below surface for brief periods (i.e. meteoric recharge and/or glacial melt waters).A goethite-bearing sample from about 90 m depth and adjacent silicates were analysed for O isotopes to test a possible relationship to glacial waters. The results indicate that the goethite formed from meteoric water or from older seawater suggesting that oxidising waters may penetrate to depths of about 90 m without glacial influence. In the samples studied, no evidence has been found of natural, low-temperature formation of Fe-oxides below 110 m.

3.10 Swiw-tests with Synthetic Groundwater



The Single Well Injection Withdrawal (Swiw) tests with synthetic groundwater constitute a complement to performed tests and studies on the processes governing retention, e.g. the True experiments as well as Swiw tests performed within the SKB site investigation programme.

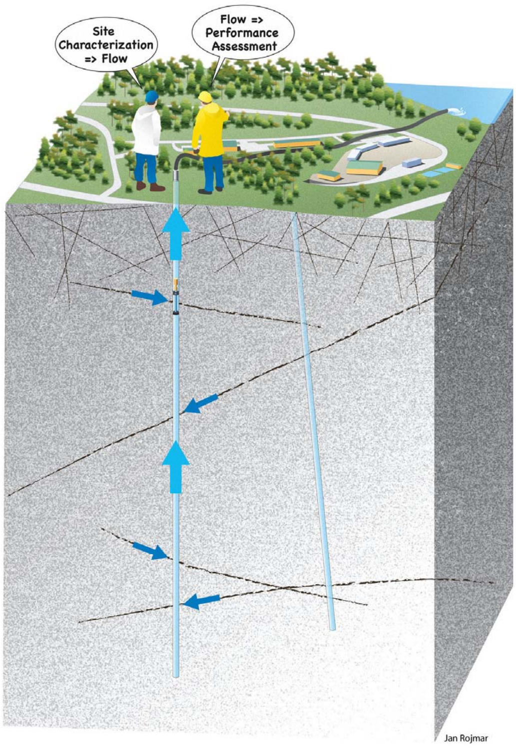
The general objective of the Swiw test with synthetic groundwater is to increase the understanding of the dominating retention processes and to obtain new information on fracture aperture and diffusion. The basic idea is to perform Swiw tests with synthetic groundwater with a somewhat altered composition, 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 only activity within the project during the last quarter has been work with the project decision and project plan. However, these were not finished during the last quarter as scheduled earlier, since the finalisation of these products was not as critical as before for the total time plan of the project. This is due to a delay with about four months in the project Sealing of Tunnel at Great Depth, see Section 4.10. The consequence for Swiw-tests is that the potential test site at True Block Scale will be inaccessible until July 2009. Instead of finalisation of the project decision and project plan, work within other more critical SKB projects was prioritised during the last quarter.

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

During the fourth quarter of 2008, work has been in progress in Task 6 - Performance assessment modelling using site characterisation data, and in Task 7, which addresses a long-term pumping test in Olkiluoto, Finland. The status of the specific modelling tasks within Task 6 and 7 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. All sub-task reports from the modelling groups have been printed. 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 in conjunction with the summary paper. An essay describing the framework for all these papers is also accepted. Editorial modifications of all the papers have been made.

At the 23rd Task Force meeting, a modification of the Task 7 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. The 24th international Task Force meeting was held at Äspö in September.

The presentations were mainly addressing modelling results on sub-task 7B. The discussions on the continuation of Task 7 and also the start up of Task 8 were constructive. Task 8 will be a joint effort with the Task Force on Engineered Barriers, and will be addressing the processes at the interface between the rock and the bentonite in deposition holes. The minutes of this venue have been distributed to the Task Force. Planning for a workshop for Task 7 and 8 in Lund, January 2009, has been on-going and the first notice of this meeting has been distributed to the modellers.

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 sub-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. (Preliminary results presented at Task Force meeting 24).
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

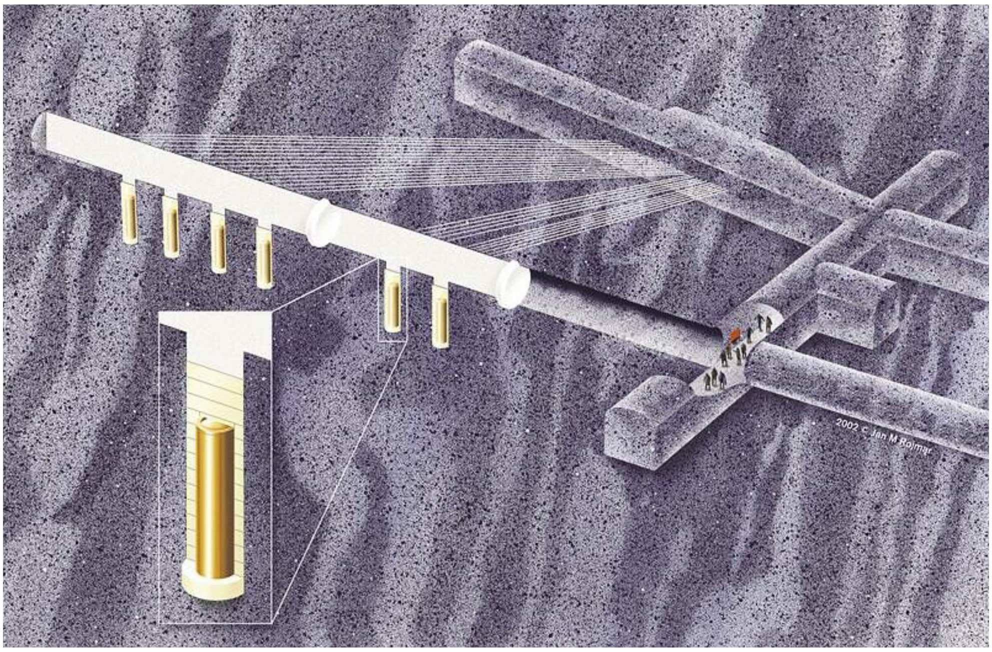
4.1 General

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. The experiments focus on different aspects of engineering technology and performance testing and will together form a major experimental programme. The excavation of a rock notch for the compartment plug in the deposition tunnel for the KBS-3 concept with horizontal emplacement is shown in Figure 4-1. The excavation is done by sawing parallel cuts and breaking away the rock discs. The result is a good rock notch suitable for the upcoming casting of the fastening ring.

Figure 4-1. *KBS-3 Method with Horizontal Emplacement - Excavation of compartment plug rock notch.*

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.

The inner tunnel (Section I, deposition hole 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, deposition hole 5 - 6) was backfilled in June 2003 and the tunnel plug with two lead-troughs was cast in September the same year.

Installed 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.

Achievements

The data collection system comprises temperature, total pressure, porewater pressure, relative humidity and resistivity measurements in buffer and backfill, as well as temperature and water pressure measurements in boreholes in the rock around the tunnel. The collection of data is in progress and the data report No. 19 covering the period up to June 2008 has been published /Goudarzi and Johannesson 2008/. Overhauling of the data acquisition system is in progress.

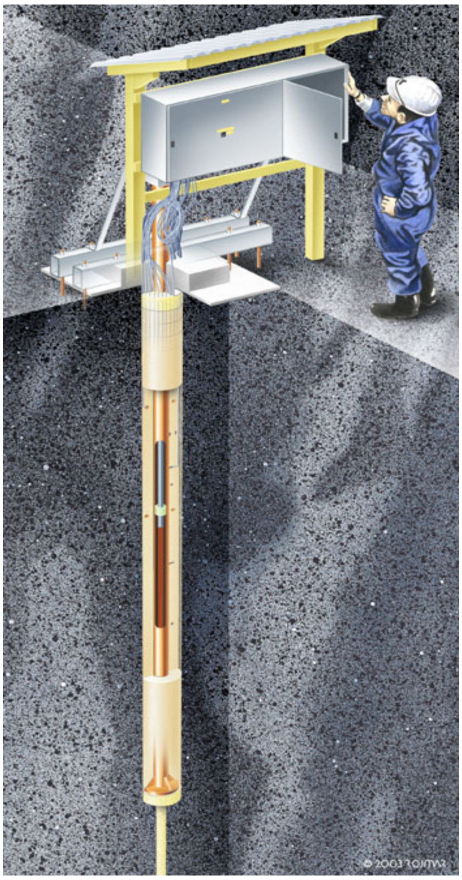
Hydraulic tests and deformation measurements during operation phase have been performed (Test campaign 9). The objective of the tests is to estimate the transmissivity of the Hydro Mechanical (HM) test sections equipped with deformation sensors. The results from the tests will soon be published.

In a monitoring programme the evolution of the water chemistry, gas, and microbial activity in the backfill and buffer is investigated. The results from the analyses performed during the period 2004 to 2007 are available in Eriksson /2007/ and a programme for the next year has been initialised.

Acoustic Emission and Ultrasonic monitoring from the rock around deposition hole 5 and 6 is continuing. A report covering the measuring period 1st October 2007 to 29th Mars 2008 has been finalised and will soon be published.

Studies using the thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters are reported /Kristensson and Hökmark 2007/ and 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. The THM modelling of the Prototype Repository according to the initial planning has been delayed.

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

During the fourth quarter, all the equipment has been working well and data from the three ongoing test parcels have been collected and controlled, see Table 4-1. The field results have been analysed and finally also the last parcel (S3) seems to be fully water saturated. The report on laboratory experiments and analyses of the A2 parcel is finalised and is being reviewed.

A project meeting, with participants from all involved organisations, was held in Lund in the beginning of December 2008. The uptake of the next test parcel was discussed at an internal SKB meeting in mid December. No decision was made but a priority list of ongoing Äspö field tests will be prepared within the Äspö organisation in the near future.

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	Report on review
A	3	120-150	T	>>5	On-going
S	2	90	T	>5	On-going
S	3	90	T	>>5	On-going

A = adverse conditions, S = standard conditions, T = temperature, [K^+] = potassium concentration, pH = high pH from cement, am = accessory minerals added

4.4 Alternative Buffer Materials

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

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

The objectives are to:

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

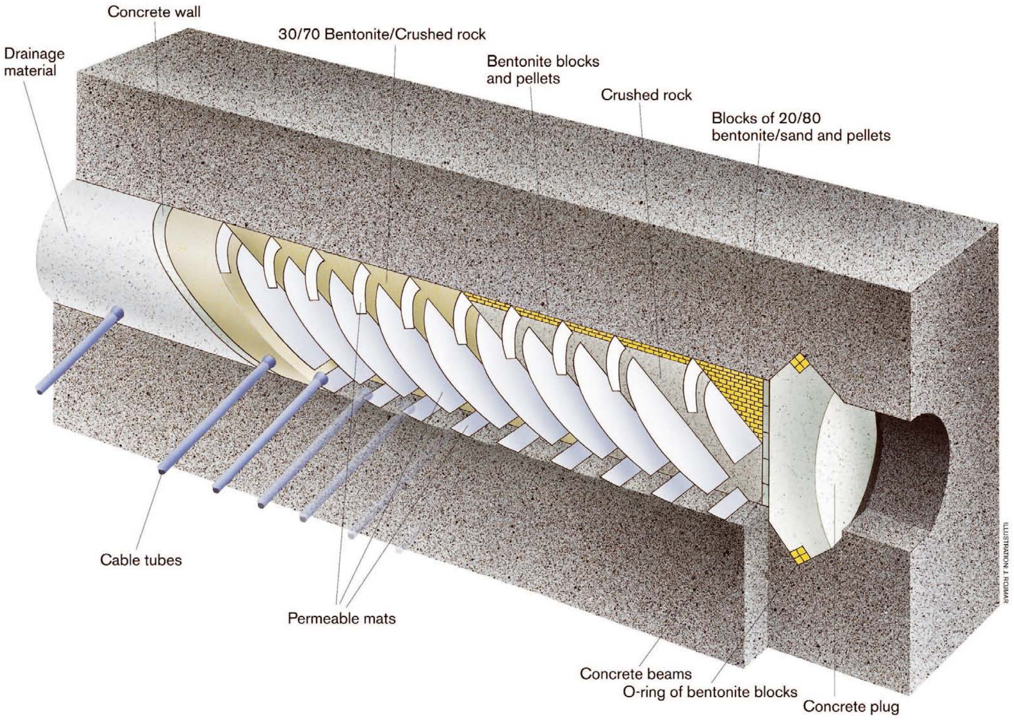
The field tests started during 2006. Eleven different clays have been chosen to examine effects of smectite content, interlayer cations and overall iron content. Also bentonite pellets with and without additional quartz are being tested. The different clays are assembled in three packages.

Achievements

A report describing the experimental set-up and the installation of the three packages is available /Eng et al. 2007/. In test package 1 and 3 the heating was started directly and they are running at the target temperature i.e. 130°C. The heating of test package 2 was started in August 2008 when the temperature was increased in a first step to about 50°C (the heating of this package should start after saturation of the buffer). Since some cracks were formed on the upper concrete plug together with movements it was decided that additional increase of the temperature should wait until the concrete plug has been repaired. The planning of reparation and reinforcement of the concrete plug has started and an activity plan for this work will be made.

A project meeting was held in Lund the 4th of December. At the meeting it was decided to retrieve test package 1 during April 2009. The work with analyses of the reference materials has continued during this period.

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.

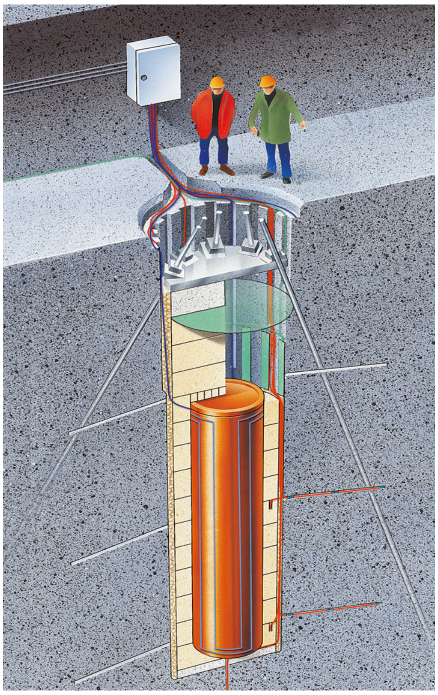
From the end of 2006 until the end of 2007 the compressibility of the backfill was tested by the four pressure cylinders mounted in the roof and the floor.

Achievements

The main work during the fourth 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. 2008a/.

Measurement of local hydraulic conductivity in the zone with crushed rock through installed equipments (“ CT-tubes”) is ongoing but delayed.

4.6 Canister Retrieval Test



The Canister Retrieval Test (CRT) 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

The samples retrieved from the upper part of the buffer have been analysed. The performed analyses concerns: chemistry/mineralogy, swelling pressure/hydraulic conductivity and investigations of the mechanical characteristics. The preliminary results from the analyses show that:

- No significant differences have been found in chemistry/mineralogy in buffer samples close to the canister and above the canister. The lubricant used when manufacturing the bentonite blocks complicated the analyses somewhat.
- The buffer samples show insignificant differences in both hydraulic conductivity and swelling pressure when compared with referential material.
- An increased brittle character in the mechanical behaviour has been found in the buffer samples close to the canister.

When it comes to the chemical/mineralogical analyses an investigation of the penetration of the lubricant will be performed. To obtain higher statistical significance when studying the mechanical characteristics of the material close to the canister, yet 10 samples are to be tested.

In the Task Force on Engineered Barrier Systems (EBS Task Force) the Canister Retrieval Test was selected to be one of the full scale assignments. In the present period the modelling by the EBS Task-Force teams has progressed and results were presented at the meeting held at 12th - 13th November 2008, see Section 4.13. One of the results to present in the assignment is the dry density profile after homogenisation. The EBS Task-Force teams will continue with the modelling of the CRT experiment and present their new results at the next meeting (25th – 26th May 2009).

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.

The TBT-test is in the operation and data acquisition phase since March 2003.

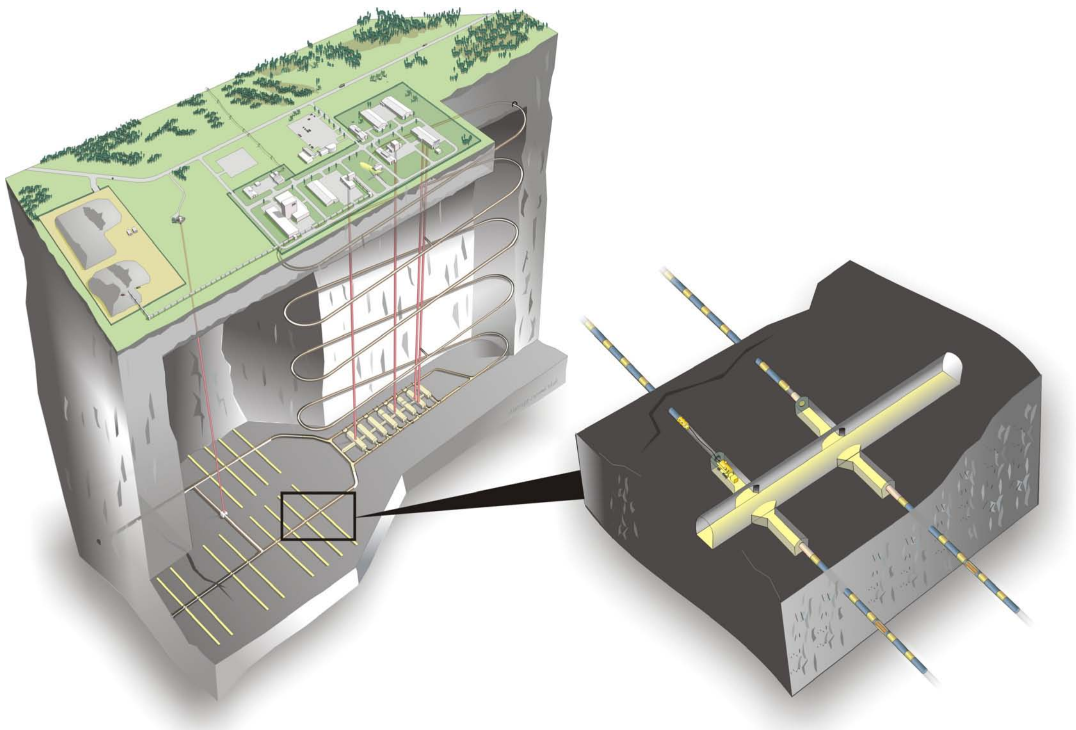
Achievements

Data acquisition is continuously ongoing and the data link from Äspö to Andra's head office in Paris has been functioning well. A sensor data report covering the period up to 1st January 2008 is available /Goudarzi et al. 2008b/ and three monthly data reports have been distributed during October-December 2008. A modelling report evaluating the TBT_3 mock-up test has been published /Åkesson 2008/.

A significant pressure decrease was registered during August and September 2008 in the innermost part of Ring 3. The total pressure (PB204) decreased from approximately 7 to 4 MPa and the pore pressure (UB201) from approximately 1 to 0.3 bar. This pressure decrease had not recovered at the end of 2008.

A dismantling planning meeting was held in Lund in December 2008. The current plan is to perform a retrieval test of the upper heater, and to dismantle and sample the test during the period from November 2009 to February 2010. The planning of this operation will continue during 2009.

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 project is a joint project between SKB and Posiva. Now the next phase of the project “Complementary studies of horizontal emplacement KBS-3H” is ongoing. The main goal of the complementary studies (2008-2010) is to develop KBS-3H solution to such a state that the decision on full-scale testing and demonstration can be made.

Achievements

The report on the Megapacker tests has during the fourth quarter been revised after review and the report will soon be finalised. The results from the grouting tests are very good with a high sealing factor of the water bearing fracture zones.

Installation of the compartment plug began in December 2008. The fastening ring was installed in the excavated rock notch. The installation was straight forward and no issues were encountered. The casting of the fastening ring was however unsuccessful at the first attempt. The problem is within the concrete recipe and minor adjustments will be done before new casting attempts in January 2009.

The analyses of the results from the pipe removal tests in the Bentonite Laboratory were completed at the end of the fourth quarter. The tests have been performed to verify the ability to remove the saturation pipes for the DAWE design.

Tests with the KBS-3H deposition equipment have continued. The additional tests with the deposition machine were after several months of delay finally finalised during December. The results looks promising but necessary improvements have to be considered to make the equipment more robust. Compilation of test data and reporting will be carried out during the first quarter of 2009.

4.9 Large Scale Gas Injection

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

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

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

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

Its objectives are:

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

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

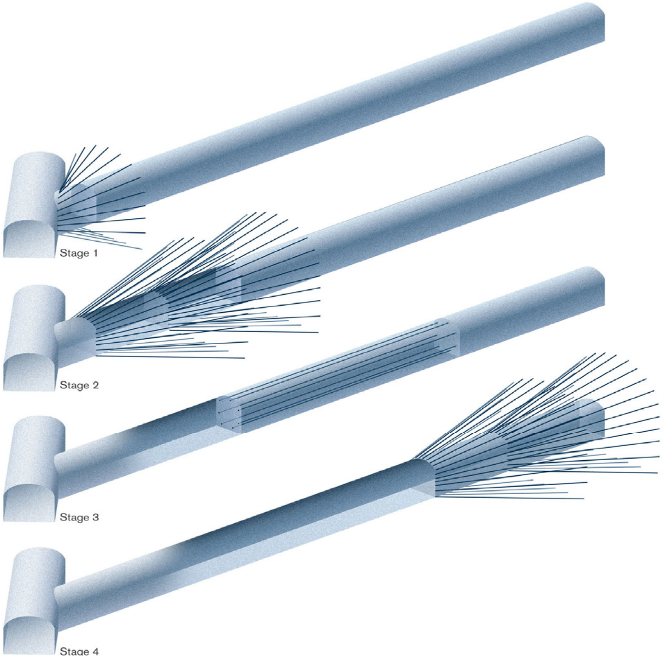
Achievements

The final quarter of 2008 saw a concerted effort placed on the quality assurance of the Lasgit data and the preparation of a detailed summary report. The latter document, which will be completed in the first quarter of 2009, contains an overview of all salient work performed in and around the Lasgit deposition hole and an extensive re-examination of the test data to date. Particular emphasis has also been placed on the interpretation of short- and long-term variations in parameters caused as a direct consequence of both buffer hydration (including hydraulic and gas testing) and external events such as blasting or seasonal change. In the latter case, these underlying relationships help to define the nature of the boundary conditions to the Lasgit test and provide important process understanding necessary for the full interpretation of data.

Recent analysis of data derived from the Lasgit experiment has highlighted a long-term declining porewater pressure trend observed in the host rock surrounding the deposition hole. Further investigation using data from neighbouring boreholes in Äspö HRL indicates a declining trend around the -420 to -450 m level. At present the cause for this temporal behaviour, which appears to predate Lasgit, is unclear.

In anticipation of the forthcoming gas injection tests scheduled for 2009, it was decided to monitor the neighbouring pressure relief holes for signs of gas discharge in order to provide additional information to help improve process understanding of the local fracture system and the movement of gas in the host rock surrounding the deposition hole. During this reporting period the design and specification of a sampling protocol has been agreed and neon selected as the gas to be used in the next stage of gas testing.

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. The project also includes the careful sawing and extraction of 0.5 m deep rock blocks from the tunnel wall along a 10 m long stretch, in order to be able to examine the EDZ.

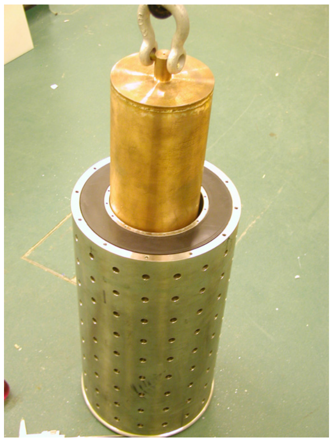
Achievements

The tunnelling front is now at section 80 metres. The tunnel includes two grouting fans outside the contour (fans 2 and 3) and three fans (fans 4, 5 and 6) inside the contour. It was earlier shown (along fans 2 and 3) that it is possible to reduce the inflow to a value below 1.0 litre/minute and 60 m, using fans within the contour.

The section along fan 4, where rock blocks are sawn from the tunnel wall for EDZ examination, is now isolated by weirs and an inflow of 0.7- 0.8 litres can be recorded along the 16 m long section. The inner 30 m long section along fan 5 and 6, carried out with holes inside the contour, yields a low inflow but the inflow is not yet confirmed as stabilised. Mapping and observations of walls and floor also indicate a good sealing result. Reporting that covers the grouting and excavation results up to 30th September 2009 is under preparation.

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.

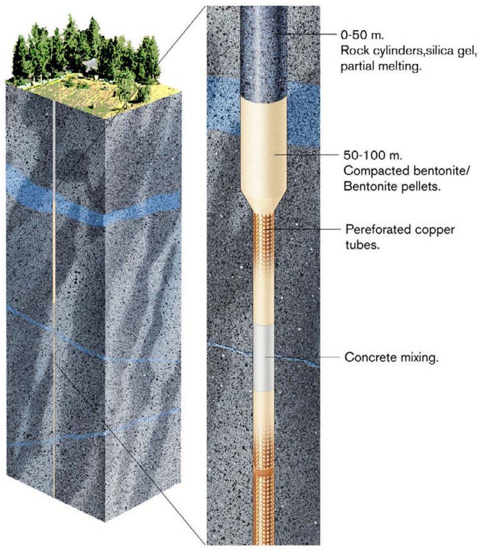
Achievements

During the fourth quarter, the 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.

Samples were taken from the miniature canisters during a week in October for analyses of water composition, gases and microbe content.

A draft report on the set up of the experiments and the results of the analyses up to May 2008 has been prepared and commented by SKB.

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 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 borehole sealing project is presently in its fourth phase. The aim is to work out principles for selecting strategic positions of plugs in boreholes that are located in repository rock for preventing axial flow by use of clay material and silica concrete for stabilising fractured rock and filling the holes where such stabilisation has been made. The hydraulic performance of the clay plugs at different times after placement will be evaluated and give information on their evolution and long-term performance.

The hydraulic function of the near field of the boreholes is investigated by use of DFN modelling. The modelling of three boreholes at Forsmark and Laxemar has been initiated and partly completed by Golder using the groundwater modelling code DarcyTools. Figure 4-1 illustrates the major rock structure features with intersecting boreholes at Forsmark. In the preceding period the groundwater flux through the rock volume surrounding the boreholes and the details of in- and outflows in the boreholes, have been in focus. Also the effect on advective transport time of particles released in the rock volume has been studied. The latter process has illustrated the importance of lasting borehole plugs.

Reference holes for detailed study of the rock/plug performance have been identified on the basis of length, estimated hydraulic impact respecting short-circuiting, frequency of intersected zones, assessed importance of considerable difficulties in performing stabilisation and plugging, (water inflow, unstable rock), and representativeness. The selected reference holes are KFM07 at Forsmark and KLX06 at Laxemar.

The curvature and diameter variations of boreholes to be plugged are of fundamental importance for the possibility to install the plugs. Data available for the boreholes have been examined and they indicate that further detailed analysis of the data are required. A preliminary list of location and type of plugs of clay and silica concrete has been made on the basis of the predicted performance of rock structural features and interacting plugs, and of estimated practical difficulties, taking also the estimated time for plug construction into consideration.

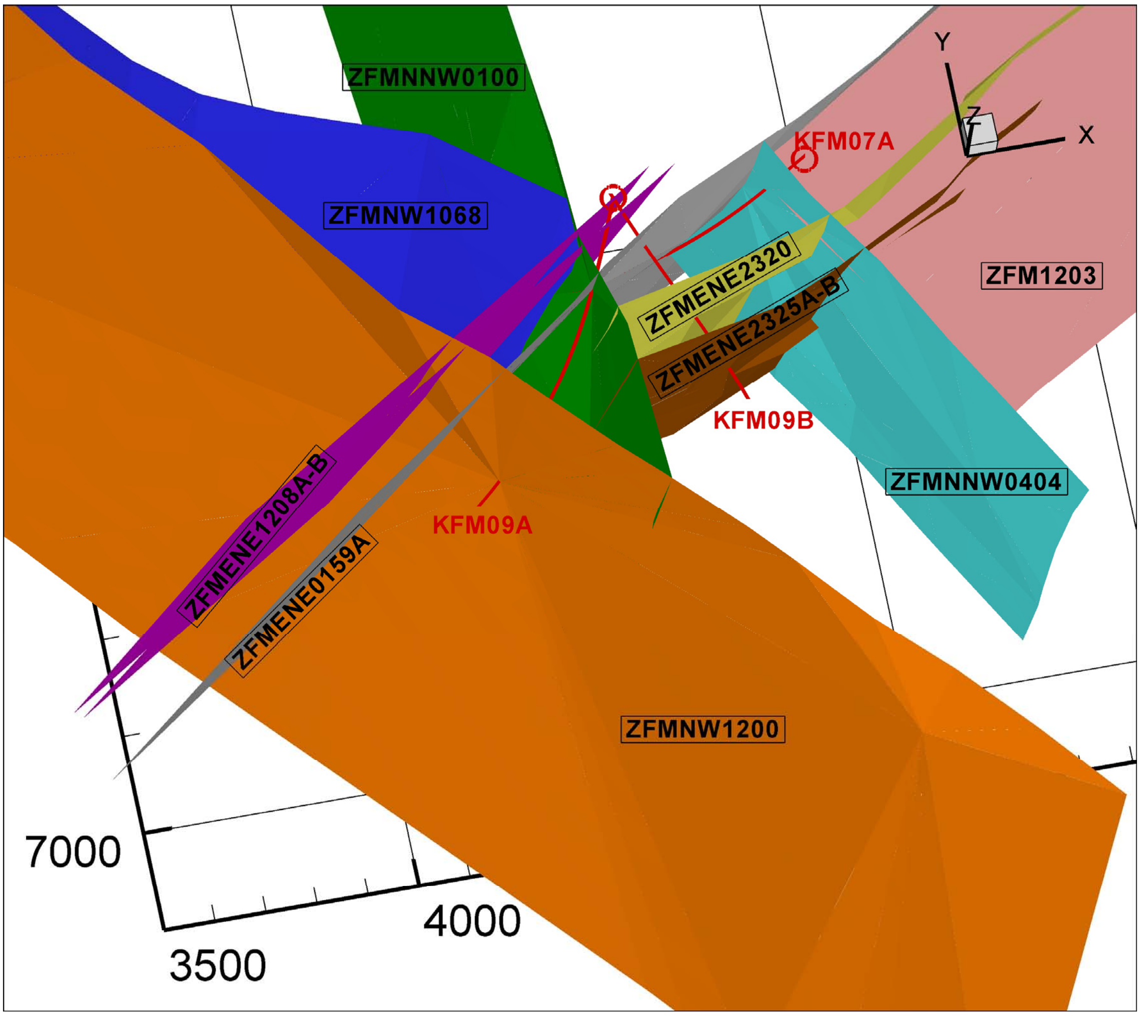
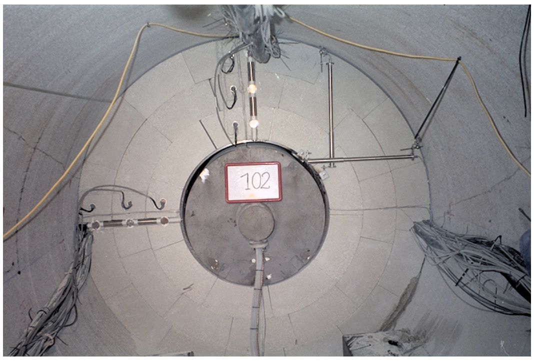


Figure 4-1. *Parallel perspective illustrating the major rock structure features intersecting the boreholes KFM07A, KFM09A and KFM09B in Forsmark.*

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), carried out by AECL, has been finished and reporting is ongoing.

The work with modelling of the Canister Retrieval Test (Task 1.2.2) at Äspö HRL (see Section 4.6) has continued during this quarter. Altogether 8 teams are working with modelling of this benchmark.

The task to model the Canister Retrieval Test is divided into two parts where the first part is to model the thermo-hydro-mechanical behaviour of a central section of the test hole with given boundary conditions. The second task is to model the whole test. Most teams have finished the first part and are continuing modelling the entire test. A Task Force meeting was held in Hergiswil in November and the status of the calculations was presented at that meeting. A new task was suggested. This task will be common with the Groundwater Task Force and focuses on the hydraulic interaction between the rock and the bentonite. SKB has decided to support such a test, which will be installed in Äspö HRL.

Task Force Geochemistry

Material from the A2 parcel from the Long Term Test of Buffer Material at Äspö HRL (see Section 4.3) 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 diffusional transport in bentonite.

Laboratory and modelling results were presented and briefly discussed at the Task Force meeting at Äspö in May. A second specific geochemistry 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.

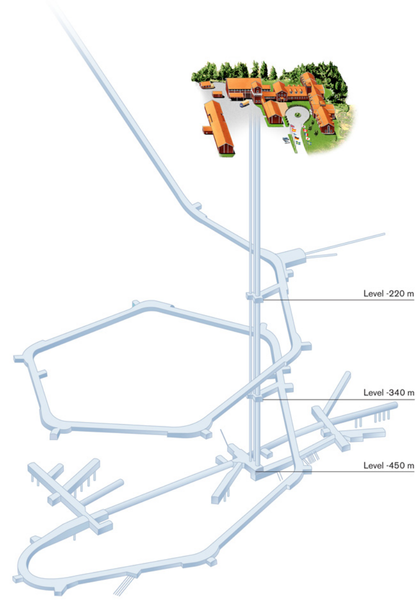
- *Repository Technology and Geoscience (TDS)* is responsible for the development and management of the geo-scientific models of the rock at Äspö and the test and development of repository technology at Äspö HRL to be used in the final repository.

- *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 fourth quarter and no incidents have occurred within the internal systems. Some installations, which were damaged during blasting have now been replaced or repaired.

Rock maintenance has been carried out as planned and the annual inspection of the elevator has been carried out and no problems were reported. During the fourth quarter, measures have been taken to ensure the underground operations in the event of a break in the high tension cable. In addition, the facility's break-in alarm system is being updated because the old system was no longer approved for the extension of the facility.

A roofed shelter is being built as a replacement for an older tent at the tunnel entrance. The building will also include a garage for the machines used for rock-work. The rock which is being driven up from the blasting work for the project Sealing Tunnel at Great Depth is being used for new parking spaces. The new archive was ready for inspection in the end of 2008. The new premises also include a storage area which will be used by the IT unit and a roof shelter where the previously purchased reserve-power generator will be placed. The alteration of loft-space to office space has been inspected and moving into nine new office-places has started. A construction firm has been contracted for a catering dining-room for personnel and visitors. The dining room, which will have space for 115 people, will be completed at the end of March 2009.

5.3 Bentonite Laboratory

Test set-up in half-scale (left) and excavation of experiment (right)

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. In the hall testing of different types of backfill material and the further development of techniques for the backfilling of deposition tunnels can be made.

Achievements

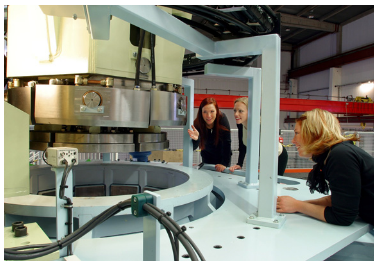
During the fourth quarter of 2008, the tests concerning impact of water inflow on buffer and backfill have continued. The tests concerning choice of method for backfilling and bearing capacity have continued for the bevel against the deposition hole. In the tests the time for breakthrough, amount of eroded material and inflow of water have been measured. After a settled time, the tests are interrupted and excavated. The results from the tests indicate that erosion do not control the speed of the backfilling process, rather, it is the water inflow which is the controlling factor.

Experiments to study water inflow to the buffer in the deposition hole have continued. The aim of the tests is, amongst other, to control the axial expansion of the buffer. The tests are done with an installation above the buffer simulating the counterpressure from the backfilling. Different amount of water inflow is used and the eroded material is measured.

The compression of backfilling material at the bevel against the deposition hole has to be done so that high bearing capacity is achieved. If the backfill blocks sink down in the material above the bevel, the block installation risks not reaching the demand for maximum allowed cavity. More tests concerning methods of compressing and choice of material have been performed. Preliminary results from the tests show that it is possible to compress granulated material to sufficient density so the block above the bevel will be stable and do not sink down more than the block placed on the buffer. A lot of work concerning methods and development of techniques for backfilling remain. Especially to make it more industrialised and production adapted.

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 Forsmark.

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 main facilities have been visited by 4,667 persons during the fourth quarter of 2008, and in total 24,133 persons during the year 2008. The numbers of visitors to the different facilities during the fourth quarter are listed in Table 5-1.

Special events that took place during the last quarter were:

- The inauguration of the new deposition machine manufactured in Germany took place in the Äspö tunnel the 19th of November. A name giving ceremony was held and local papers, magazines and television participated. Tours for the public and information on ongoing activities at Äspö were given during the day.

- A contribution to "Oskarshamn in Light" was held at Äspö on the 6th of December. The event consisted of a light-and-music-show down in the rock laboratory and 85 visitors took the chance to visit Äspö and at the same time see the show.

- The Äspö running competition took place in the Äspö tunnel the 13th of December and attracted 80 runners. This event has been a tradition for ten years and is much noticed by media.

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

SKB facility	Number of visitors Oct- Dec 2008
Central interim storage facility for spent nuclear fuel	658
Canister Laboratory	695
Äspö HRL	1,560
Final repository for radioactive operational waste (SFR)	1,650

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. Three doctor students have been examined since the start of the Äspö Research School and the fourth remaining doctor student will be examined in 2009.

When the Äspö Research School was concluded as planned on the 30th of September 2008, the remaining and new research activities were transferred within the frame of the new co-operation Nova Research and Development (Nova-FoU). Nova-FoU is a joint research and development platform at Nova Centre for University Studies, Research & Development in Oskarshamn, Sweden. The platform is supported by SKB and the municipality of Oskarshamn. The platform can use SKB's facilities and competence in Oskarshamn as the base for research and development.

6.2 Geochemistry Research Group

Surface water sampling point at Laxemar catchments area

The Geochemistry Research Group is part of the Nova-FoU platform. This research group is a continuation of the Äspö Research School.

The research topic is on chemical elements in soil, water and biota. The aim is to understand how major and trace elements are redistributed and transported in the environment, how they end up in streams and groundwaters, and how they are taken up by plants and animals.

Details on the research activities, the senior researchers and the PhD students are given at http://www.skb.se/asporesearch.

Achievements

The name ”Äspö Research School” was on the 1st of October changed to ”Högskolans i Kalmar miljögeokemiska grupp vid Äspölaboratoriet”. For simplicity, this group will be called ”Geochemistry Research Group”. During the fourth quarter two scientific publications were published /Åström et al. 2008, Brun et al. 2008/.

7 International co-operation

7.1 General

Eight organisations from seven countries 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 October – December 2008, the following reports have been published and distributed.

8.1 Äspö International Progress Reports

Eng A, 2008. Canister Retrieval Test. Retrieval phase. Project report.
SKB IPR-08-13, Svensk Kärnbränslehantering AB.

Goudarzi R, Johannesson L-E, 2008. Prototype Repository. Sensors data report (Period: 010917-080601). Report No:19.
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SKB IPR-08-19, Svensk Kärnbränslehantering AB.

Åkesson M, 2008. Temperature Buffer Test. Evaluation modelling TBT_ 3 Mock-up test. SKB IPR-08-09, Svensk Kärnbränslehantering AB.

Äspö Hard Rock Laboratory. Status Report. April - June 2008.
SKB IPR-08-20, Svensk Kärnbränslehantering AB.

8.2 Technical Documents and International Technical Documents

One International Technical Document has been published during the fourth quarter of 2008.

9 References

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Hodgkinson D P, Black J H, 2005. Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes: Review of Tasks 6A, 6B and 6B2. SKB TR-05-14. Svensk Kärnbränslehantering AB.

Kristensson O, Hökmark H, 2007. Prototype Repository. Thermal 3D Modelling of Äspö Prototype Repository. SKB IPR-07-01, Svensk Kärnbränslehantering AB.

Neretnieks I, 1982. ”Leach Rates of High Level Waste And Spent Fuel. –Limiting Rates as Determined by Backfill and Bedrock Conditions” In: Lutze, W. (Ed.), Scientific Basis for Nuclear Waste Management V, Materials Research Society Symposium Proceedings 11, North-Holland, New York, Amsterdam, Oxford, 1982, pp. 559– 568.

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