International
Progress Report

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# Äspö Hard Rock Laboratory

## Status Report
## January – March 2004

Svensk Kärnbränslehantering AB

August 2004

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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 deep 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 2002–2007 are presented in SKB's RD&D-Programme 2001 /SKB, 2001/. The information given in the RD&D-Programme related to Äspö HRL is annually detailed in the Äspö HRL Planning Report /SKB, 2004/.

This Äspö HRL Status Report is a collection of the main achievements obtained during the first quarter 2004.

### *Technology*

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 and supporting activities are therefore conducted at Äspö HRL: Canister Retrieval Test, Prototype Repository, Backfill and Plug Test, Long Term Test of Buffer Material, Cleaning and sealing of investigation boreholes, Injection grout for deep repositories, KBS-3 method with horizontal emplacement, Large Scale Gas Injection Test, Temperature Buffer Test, New experimental sites, and Learning from experiences.

### *Geo-science*

Geo-scientific research is a natural part of the activities at Äspö HRL. Studies with the major aims to increase the understanding of the rock mass material properties and to increase the knowledge of measurements that can be used in site investigations are important activities: Geological mapping and modelling, Rock stress measurements, Rock creep, Äspö Pillar Stability Experiment, Heat transport, and Seismic influence on the groundwater system.

### *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 the deep repository and to provide data for performance and safety assessment. The experiments performed at conditions expected to prevail at repository depth are: Tracer Retention Understanding Experiments (TRUE Block Scale Continuation and TRUE-1 Continuation), Long Term Diffusion Experiment, Radionuclide Retention Experiments, Colloid Project, Microbe Project, and Matrix Fluid Chemistry.

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.

### Äspö facility

An important part of the work at the Äspö facility is the administration, operation, and maintenance of instruments as well as development of investigation methods. Other issues are to keep the stationary hydro monitoring system (HMS) continuously available and to carry out the programme for monitoring of groundwater head and flow and the programme for monitoring of groundwater chemistry.

### International co-operation

The Äspö HRL has so far attracted considerable international interest. Seven organisations from six countries participate during 2004 in the co-operation apart from SKB. In addition, SKB takes parts in several EC-projects and is through the Repository Technology department co-ordinating three EC-projects.

# Contents

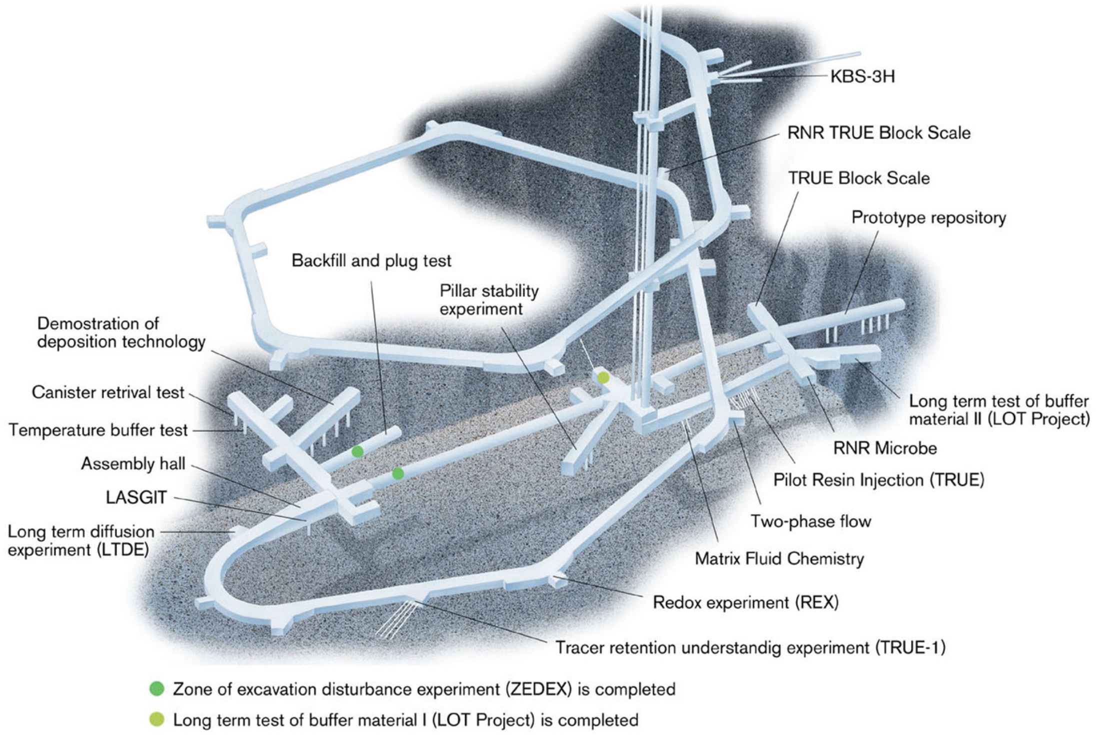
# 1 General

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

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 the figure below the allocation of the experimental sites in Äspö HRL are shown.

The Äspö HRL and the associated research, development, and demonstration tasks, managed by the Repository Technology Department within SKB, have so far attracted considerable international interest.

SKB's overall plans for research, development, and demonstration during the period 2002-2007 are presented in SKB's RD&D-Programme 2001 /SKB, 2001/. The planned activities related to Äspö HRL are detailed on a yearly basis in the Äspö HRL Planning Report. The role of the Planning Report is also to present the background and objectives of each experiment and activity. This Status Report concentrates on the work in progress and refers to the Planning Report /SKB, 2004/ for more background information. The Annual Report will in detail present and summarise new findings and results obtained during the present year.

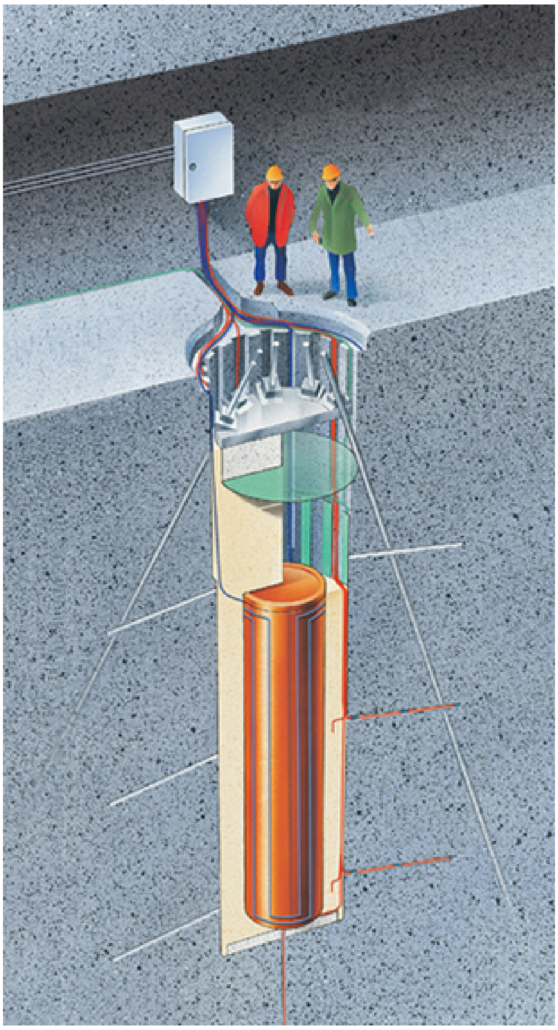


# 2 Technology

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.

## 2.1 Canister Retrieval Test



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

In the Canister Retrieval Test two full-scale deposition holes have been drilled 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.

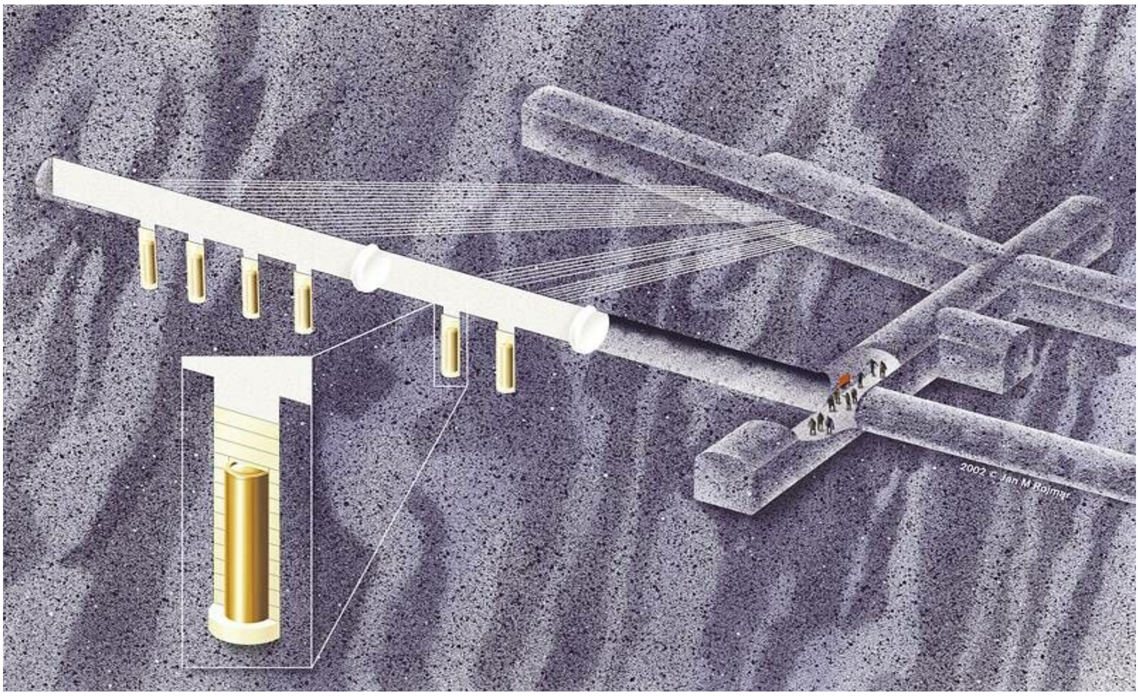
The test has been running for more than three years with continuous measurements of the wetting process, temperature, stresses, and strains.

### *Achievements*

The artificial water supply to the bentonite has continued and the water pressure in the mats that distribute the water has been maintained at 800 kPa during the entire reporting period. The filters in the mats were back-flushed on March 16 to avoid clogging.

The measurements of a large number of parameters to study the THM-processes and to provide a basis for e.g. modelling purposes have continued. Modelling of pressure, water content etc in the buffer during the saturation process is in progress. Predicted saturation time for the test is 2-3 years in the 350 mm thick buffer along the canister and 5-10 years in the buffer below and above the canister. The relative humidity sensors indicate that the bentonite between the rock and the canister is close to water saturation although the wetting seems to be somewhat uneven.

## 2.2 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 deep repository system regarding geometry, materials, and rock environment.

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

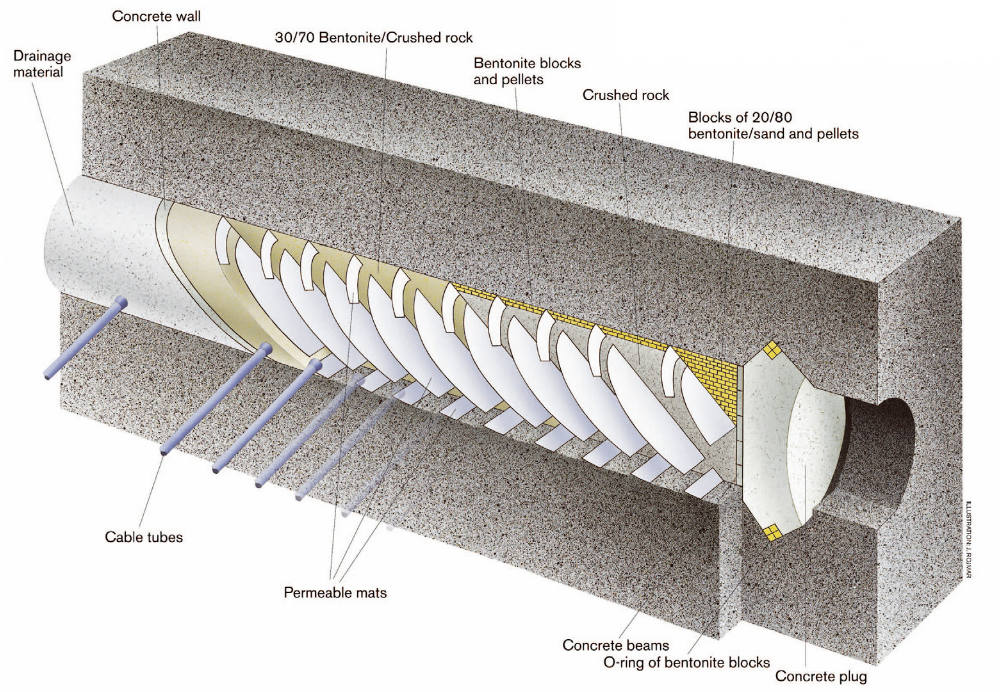
The inner tunnel (Section I) was installed and the plug cast in 2001 and the heaters were turned on one by one. The outer tunnel (Section II) was backfilled in June and the tunnel plug with two lead-throughs was casted in September 2003.

### *Achievements*

The data collection system comprises temperature, total pressure, pore water pressure, relative humidity and resistivity measurements in buffer and backfill, as well as temperature and water pressure measurements in boreholes in the rock around the tunnel. The collection of data is in progress and data report No. 8 covering the period up to 1$^{st}$ of December 2003 has been published /Goudarzi and Johannesson, 2003/. Overhauling of the data acquisition system is going on and is planned to proceed also during the next quarter.

Chemical measurements in buffer and backfill, i.e. sampling and analyses of gas, has been approved and the preparatory work on site has been carried out. The sampling and analyses methods to be applied have been developed in co-operation with the Microbe project. In addition, a ventilation and drying system for the cable lead throughs to the G-tunnel has been installed. The system is installed to protect the cables from corrosion.

## 2.3 Backfill and Plug Test




The Backfill and Plug Test includes tests of backfill materials and emplacement methods and a test of 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 the filter mats started in late 1999. Wetting of the backfill has continued since then.

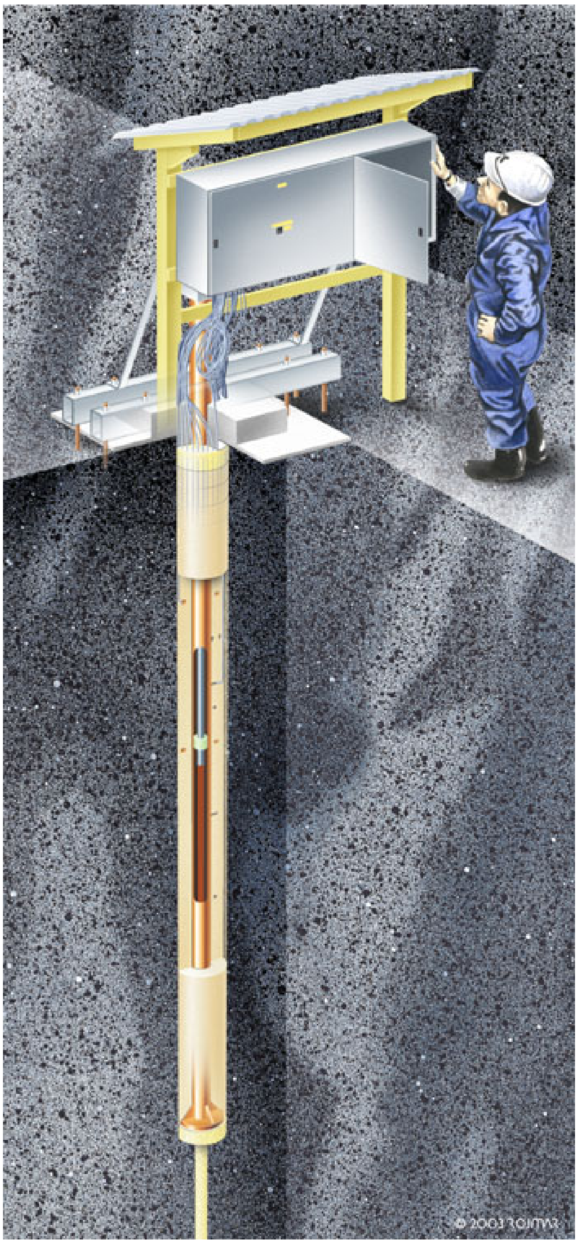
### *Achievements*

Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured and registered according to plan and a data report covering the period up to 2004-01-01 /Goudarzi *et al.*, 2004a/ have been released.

Flow testing of the backfill materials is now in progress and the strategy for the testing has been in the first stage to successively decrease the water pressure in the mat sections (each section comprises three mats) starting with the mats at the plug. The pressure should be decreased in steps of 100 kPa and the hydraulic gradient kept for such long time that a steady flow could be observed. The water pressure is now 500 kPa in all mats in the 30/70 section and 400 kPa in all mats in the crushed rock section. Due to problems with pressure pulses the hydraulic system for pressurising the mats with 500 kPa has been changed. The pressure regulating pump has been replaced and the pressure is now regulated by a tank with water placed at the right level in the ramp to yield 500 kPa pressure in the same way as the lower pressure (400 kPa) is regulated.

Relevant measurements of the flow through the first layer of 30/70 mixture for evaluating the large-scale field hydraulic conductivity is now going on for the first time.

## 2.4 Long Term Test of Buffer Material



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

Five 300 mm diameter test holes with a depth around 4 m have been drilled and instrumented. Five test parcels were installed in 1999. The intended test temperatures of 90°C and 130°C have been reached. In 2001 a one-year parcel was extracted from the rock by overlapping core drilling. The remaining four long term test parcels are functioning well.

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

### *Achievements*

The analysing work and testing with material from the extracted one-year parcel A0 is completed. The compilation of results is in progress and a technical report will be issued.

The equipment for the data collection has been maintained and some measures have been taken for example improved alarm functions. The remaining four long term test parcels have functioned well and temperature, total pressure, water pressure, and water content are continuously measured and registered every hour. The monthly check of the collected data has been done. The next extraction of a parcel is expected to take place during 2005.

## 2.5 Cleaning and sealing of investigation boreholes

A project, with the aim to identify and demonstrate the best available techniques for cleaning and sealing of investigation boreholes, was initiated in 2002.

The project comprises two phases. Phase 1 was mainly an inventory of available techniques, and Phase 2 aims to develop a complete cleaning and sealing concept and to demonstrate it.

A laboratory test program on candidate sealing materials is part of the project. Short and long boreholes from the surface and from tunnels underground, will be used to demonstrate the plugging concept.

The project is run in co-operation between SKB and Posiva.

### *Achievements*

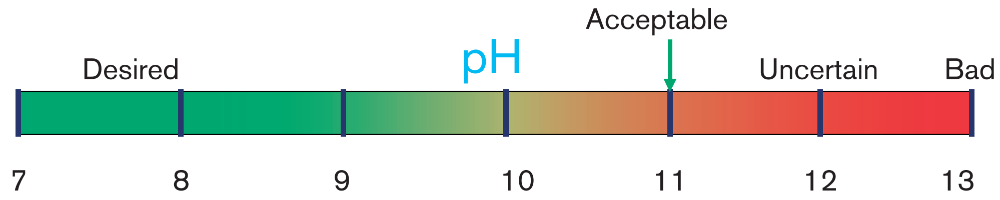
The first phase, an inventory of available techniques, is completed and the major conclusions were that smectite clay has been used successfully for borehole plugging and is recommended as main candidate material in the forthcoming work. The second phase focuses on the development of a complete concept for cleaning and sealing of boreholes and will comprise three parts; (i) Completion of a borehole plugging concept, (ii) Laboratory tests, and (iii) Field tests.

The present design for the borehole seals consist of cylindrical pre-compacted clay blocks contained in perforated copper tubes that are jointed in conjunction with insertion into the holes. The copper tubes provide mechanical protection against abrasion in the application phase. The clay is preferably rich in the smectite type montmorillonite. The plugs mature by hydration of the clay cores, which expand and give off clay that migrates through the perforation of the tubes and ultimately embeds them in homogeneous, dense clay. During this quarter calculations and detailed design of the copper/bentonite tubes are topics in progress. An investigation on the present know-how on cleaning of boreholes has also been initiated. In addition, two candidate deep investigation boreholes at Äspö, KAS06 and KAS07, are being investigated as a preparation for the field test.

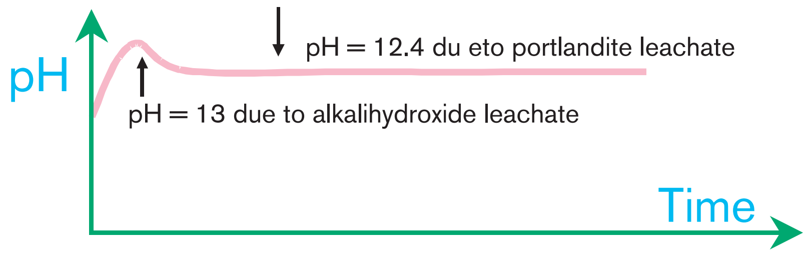
A project group meeting with Posiva and other delegates have been held in Stockholm in the middle of March.

## 2.6 Injection grout for deep repositories

**SAFETY ASSESSORS´ VIEW ON pH**




**PRINCIPLES FOR pH-EVOLUTION OF STANDARD CEMENT**




The use of low-pH products in the deep repository will probably be necessary in order to get leachates with a sufficiently low pH (≤11). A project concerning the use of low-pH cementitious products started in 2001 as a co-operation between SKB, Posiva, and NUMO.

The present objectives of the project are to achieve quantified, tested and approved low-pH injection grouts. The project is divided into four sub projects:

- SP1 Low-pH cementitious injection grout for larger fractures.
- SP2 Non-cementitious low-pH injection grout for smaller fractures.
- SP3 Field testing in Finland.
- SP4 Field testing in Sweden

The test to be carried out at the Äspö HRL is part of SP4 – Field testing in Sweden. The sub-project comprise injection field tests with Silica Sol and the aim is to test if it penetrates into small fractures (< 100 µm). The proposed test site is a rock pillar at the tunnel TASM, section 0/670.

Further, the possibilities to couple the behaviour of grout in a sand column to the behaviour in a rock fracture is evaluated. Results obtained in the Äspö field test is compared to the results from a sand column test carried out in a laboratory at Chalmers.

### *Achievements*

Preparations of the site prior to the grouting test were initiated already during the previous quarter and hydraulic pre-tests were carried out at the site in February. Hydraulic aperture of fracture is 50 µm. Grouting test with silica sol, was performed in March and a minimum grout spread of 0.4 m was observed in an adjacent hole. The grouting will be followed up by core drilling at the site and complementary hydraulic tests. The visual observation of cores will verify if grout has spread and the hydraulic tests will give more direct information about the effect of the grouting.

## 2.7 KBS-3 method with horizontal emplacement



The possibility to modify the reference KBS-3 method and make serial deposition of canisters in long horizontal drifts (KBS-3H), instead of vertical deposition of single canisters in the deposition hole (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 horizontal drifts 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 cost during the construction phase.

### *Achievements*

The site for the demonstration of the method is located at 220 m depth in Äspö HRL. A chamber, with a height of about 8 m and a bottom area of 25 x 15 m that will form the work area, has been excavated. Exploration drilling for two deposition drifts with a length of 30 m and one with length of 100 m has been performed and the exploratory drill holes has been mapped and investigated with BIPS-measurements prior to this quarter.

Water-loss measurements and grouting of the core-drilled exploration boreholes has been finished and core drilling of the controlling boreholes for the grouting has been started and will be finished during week 13. Additional, water-loss measurements and grouting will take place during week 14.

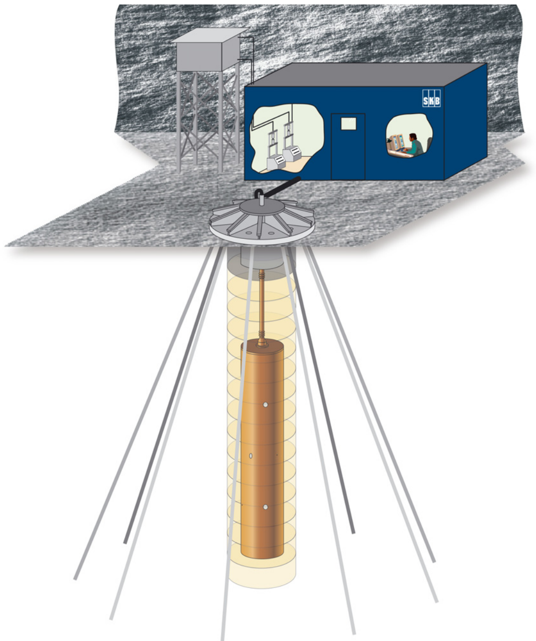
During February and March both water cluster technology and horizontal raiseboring were compared with respect to technical, economical and scientific aspects. It was finally decided that the three drifts will be excavated by blind horizontal raise boring and that the straightness of the pilot hole will guaranteed by the use of continuously steering. The drilling of the pilot hole is planned to start in august this year.

The work with compiling request for proposal regarding deposition equipment was initiated during the period as well as some additional design of the machine equipment based on further water cushion tests made during February. SKB has also initiated detailed design of the super container and distance blocks.

The barrier performance of the KBS-3H concept is studied by Posiva and the reporting is in progress. Laboratory tests of the buffer behaviour performance are carried out by

Clay Technology to study occurrence of erosion and piping in the buffer as well as plugs for sealing. Tests are performed both in scale of 1:10 and full scale. The test program will be finalised and evaluated by august this year. The two year test on distance blocks scale of 1:1 is planned to start during September.

## 2.8 Large Scale Gas Injection Test




A full-scale canister (without heaters) and a bentonite buffer will be installed in an available bored deposition hole in Äspö HRL. Water will be artificially supplied to the buffer at isothermal conditions. When the buffer is fully saturated gas injection will start, first with small gas volumes and finally with volumes corresponding to gas formation from a defect full-size canister.

SKB has during several years performed a number of experiments with gas injection on MX-80 bentonite. Today, there is a relatively good understanding of the processes determining the gas transport. One remaining question is, however, the importance of the scale. All bentonite experiments so far have been performed in the centimetre scale and the extrapolation of the results from these experiments to repository scale is unclear. Therefore, the Large Scale Gas Injection Test (LASGIT) has been initiated.

The major aims of the project are to:
- Perform and evaluate full-scale gas injection tests based on the KBS-3 concept.
- Answer questions related to up-scaling.
- Get additional information on gas-transport processes.
- Obtain high quality data for testing and validation of models.
- Demonstrate that gas formation in a canister do not have obvious negative consequences for the repository barriers.

### *Achievements*

The planning of and the preparations for the installation of the test are in progress. The test will take place in an existing deposition hole (DA3147G01) in the TBM drift. The information available on the hole is sufficient and no new characterisation is planned.

The main activities during this quarter have been:

- Almost all equipments have been installed in the laboratory container and it is planned to be delivered to Äspö HRL in April.
- The boreholes for anchoring of the lid have been bored.
- The lid, that shall withstand a swelling pressure from the bentonite of 20 MPa, has been delivered. The design of the lid is very similar to the one used in the Temperature Buffer Test.
- Preparations of the canister are in progress, e.g. the installation of filters.

The project is delayed compared to the original time plan, and the second phase – the hydration phase – may hopefully start during the autumn.

## 2.9 Temperature Buffer Test

The French organisation Andra carries out the Temperature Buffer Test (TBT) at Äspö HRL in co-operation with SKB. The variable nature of the French geological environment requires research to be carried out to relax the temperature constraints on the dimensioning of clay engineered barriers in order to produce more compact designs.

The aims of the TBT are to evaluate the benefits of extending the current understanding of the behaviour of engineered barriers to include high temperatures, above 100°C, and the experimental resources needed to achieve this. 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. They are 3 m long and 610 mm in diameter, and are constructed in carbon steel. Each one simulates a different type of confinement system: a bentonite buffer only (bottom section) and a bentonite buffer with inner sand backfill (upper section).

### *Achievements*

The TBT-test is in the operation and data acquisition phase since March 2003. Two canisters with heaters, bentonite buffer, and sand infilling are installed in the deposition hole together with a system for artificial watering and a large number of sensors and cables for registration of e.g. saturation, pressures and temperatures. The collection of data is in progress and data report No. 1 covering the period up to 1$^{st}$ of September 2003 has been published /Goudarzi *et al.*, 2004b/.

Data acquisition is continuously ongoing and data is reported on a monthly basis. A data link from Äspö to Andra's head office in Paris has been established. The data evaluation modelling programme was issued in March 2004.

## 2.10 Shearing of canister in deposition hole

This project aims at observing the forces that would act on a KBS-3 canister if a displacement of 100 mm would take place in a horizontal fracture that crosses a deposition hole. Such a displacement is considered to be caused by an earthquake, and the test set-up need to provide a shearing motion along the fracture that is equal to an expected shearing motion in real life. The first phase, which will last all of 2004, is a pre-study of design and feasibility. Scoping calculations are assumed to indicate the forces and shearing speed needed and thereby provide the basis for the design of the test set-up.

The *in situ* test set-up is planned to be installed at the site of the Äspö Pillar Stability Experiment when the rock mechanics test has been completed. Two full scale deposition holes then exist with a rock pillar of 1 m in between. One deposition hole will be used for the buffer and canister, while the other deposition hole is used for the shearing equipment.

### *Achievements*

The first phase comprises a pre-study of design and feasibility of the test.

## 2.11 Learning from experiences

In this project, reference techniques for emplacement of buffer, canisters, backfilling, and closure are to be identified. Emplacement of buffer and canisters, and backfilling of tunnels have been experienced in Canister Retrieval Test, Prototype Repository and Backfill and Plug Test. These experiences are documented and the result evaluated with respect to possible improvements as well as limits with respect to water inflows.

The work comprises:

- Compilation of the results from more then ten years of performed engineering experiments in Äspö HRL.
- Compilation and evaluation of experience from emplacement of buffer and canisters, backfilling of tunnels, and estimation of acceptable water inflows for the applied methods.

### *Achievements*

A draft report that describes the large series of experiments related to engineered barrier systems that have been conducted in SKB’s underground laboratories and construction sites during the time period 1981 to 2003 is available. The review of the draft report is in progress. The report will be published as an IPR report in Äspö´s report series.

## 2.12 Task Force on Engineered Barrier Systems

The Task Force on Engineered Barrier Systems is still on stand-by while the prioritised work on modelling of THMC-processes in buffer during saturation is conducted on data from the Prototype Repository within the EC-project. The stand-by will last as long as the EC-project is operative, i.e. through the first quarter of 2004.

# 3 Geo-science

Geo-scientific research is a natural part of the activities at Äspö HRL. Studies with the major aims to increase the understanding of the rock mass material properties and to increase the knowledge of measurements that can be used in site investigations are important activities.

## 3.1 Geological mapping and modelling

This project aims at developing a new method and system for underground mapping to be used in the construction of a deep repository. The major reasons to develop a new system for underground mapping are aspects on time required, precision in mapping and traceability. Required mapping time will be unreasonably high with the present system. An increased precision in geological mapping is required for geological features when constructing a deep repository. Increased traceability means that SKB will have better possibilities to establish the tunnel environment pre-rock support and pre-backfilling, thereby showing foundations for interpretations concerning geology, rock mechanics and tunnel maintenance. At this initial stage, the major objective is to decide whether SKB should use a system based on laser scanning, digital photos or another alternative method. Contact has been taken with Posiva, in order to establish a possible co-operation in finding an efficient system for digital underground mapping.

### *Achievements*

During summer and autumn 2003 the new 71 m long TASQ-tunnel has been mapped. Digitized maps and associated data have been fed into the Tunnel Mapping System (TMS) database. A report from the geological mapping is in progress.

The work of updating the three dimensional RVS models of Äspö will continue. Data from mapping and modelling of the TASQ-tunnel will be added to the present RVS models. Further improvements in the models will be added as deformation zones and other geological features are established.

## 3.2 Rock stress measurements

It is important to know the limitations and shortcomings of different rock stress measurement techniques to be able to make correct assessments of the *in situ* stress field from the measured results. Rock stress measurements with different techniques (bore probe, doorstopper and hydraulic fracturing) have during the years been performed as well as numerical modelling of the stress. The strategy for rock stress measurements will be presented in a report.

### *Achievements*

A co-operation with Posiva with the objective to quality-assure overcoring data has been initiated.

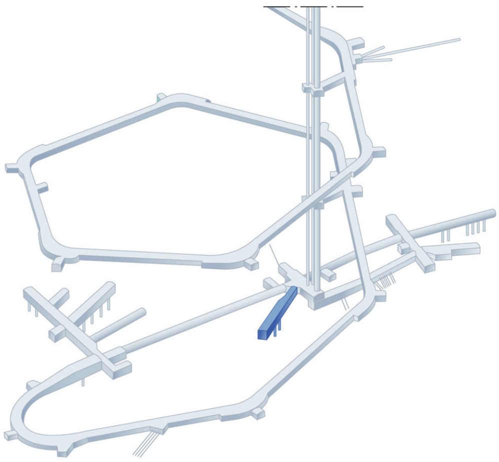
## 3.3 Rock creep

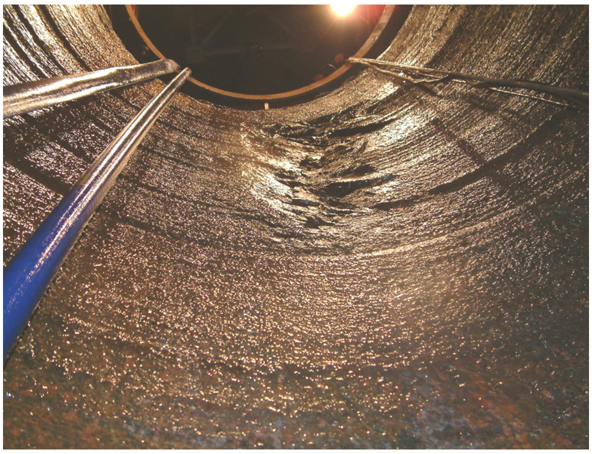
The aim with this project is to increase the understanding of the material properties of rock and rock-mass and to develop better conceptual models for the influence of the rock damaged zone and rock creep on rock stability.

### *Achievements*

A literature study and scooping numerical modelling with a three-dimensional coupled hydromechanical computer code (3DEC) have been performed. The results from the modelling and the literature study will be presented in a report. The literature study is under review.

## 3.4 Äspö Pillar Stability Experiment





A Pillar Stability Experiment is in progress in Äspö HRL to complement an earlier study performed at URL in Canada. The major aims are to demonstrate the capability to predict spalling in fractured rock mass and the effect of backfill on the propagation of micro cracks. In addition, the capabilities of two- and three-dimensional mechanical and thermal predictions will be compared.

The pillar is created between two vertical deposition holes drilled in the floor of the tunnel. The stress in the pillar will be further increased by a thermal load to reach a stress state that induces brittle failure and spalling. One of the boreholes will be subjected to an internal water pressure via a bladder simulating the confining presure in the backfill (0.8 MPa).

A new drift has been excavated in Äspö HRL to ensure that the experiment is carried out in a rock mass with a virgin stress field. The site is located at the -450 m level. The arched drift bottom is designed to concentrate the stresses in the centre of the floor. The arched floor was excavated separately as a bench to minimize the excavation damaged zone in the floor.

### *Achievements*

The excavation of the tunnel at the -450 m level was finalised in July 2003. The first of the two deposition holes was bored in December and the second one was completed during this quarter. The confinement pressure in the first hole was applied before the drilling of the second hole was commenced. Spalling was observed at the pillar side in both of the deposition holes, minor in the first hole but more pronounced in the second hole. The end of the spalled zone, approximately 2m down the second hole (see figure) will be the location for some of the instruments that will be used for displacement monitoring.

Acoustic emission monitoring was performed during the excavation of the holes and the responses coincide very well with the spalling observed in the holes. The AE responses and the location of the spalling in the holes verified that the earlier assessed direction of the major principal stress was correct.

The reporting of the final numerical predictive modelling of the test as well as the geological model covering the test site is in progress and will be printed shortly.

## 3.5 Heat transport

The aim with this project is to develop a strategy for site descriptive thermal modelling and to use the strategy to develop and test a thermal model for the Äspö Rock volume. The work includes measurements of thermal properties of the rock and examination of the distribution of thermal conductivities. Another aim is to analyse the thermal properties in different scales and clarify relevant scales for the thermal process by sensitivity analyses.

### *Achievements*

Three reports dealing with heat transport were completed during 2003 and a strategy for the thermal model development during site investigations has been presented.

## 3.6 Seismic influence on the groundwater system

The Hydro Monitoring System (HMS) registers at the moment the piezometric head in 409 positions underground in the Äspö HRL. An induced change of the head with more than 2 kPa triggers an intensive sampling. All measured data are stored in a database.

The data in the database are assumed to bear witness of different seismic activities in Sweden but also abroad, dependent on the magnitude of the event. By analysing the data on changes in the piezometric head at Äspö connections to specific seismic events are expected to be established. In addition, the effects of blasts in Äspö HRL as well as in CLAB, during the extension of the underground storage capacity, will be analysed.

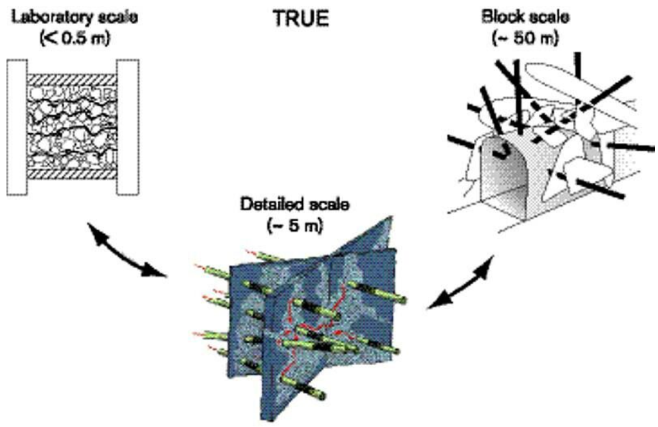
### *Achievements*

Data from the HMS are stored in the data base pending analysis. A special computer code is under development that may run and compare the HMS data base with other data bases, like SICADA or the national seismological data base.

# 4 Natural barriers

At the Äspö HRL experiments are performed at conditions that are expected to prevail at repository depth. The experiments are related to the rock, its properties, and *in situ* environmental conditions. The goals are to increase the scientific knowledge of the safety margins of the deep 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.

## 4.1 Tracer Retention Understanding Experiments




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

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

The TRUE Block Scale Continuation project aims at obtaining additional understanding of the TRUE Block Scale site.

The TRUE-1 Continuation project is a continuation of the TRUE-1 experiment. According to present plans the TRUE-1 site will be injected with resin and excavated and analysed. 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. Furthermore, attempts are made to assess fracture apertures using radon concentrations in groundwater.

### 4.1.1 TRUE Block Scale Continuation

The objective of TRUE Block Scale Continuation (BS2) is to improve the understanding of transport pathways at the block scale, including assessment of effects of geometry, macrostructure, and microstructure, and the ability to predict retention using geological information. The project is focussed on the existing TRUE Block Scale site and it comprises two separate phases:

BS2A Continuation of the TRUE Block Scale (Phase C). Pumping and sampling until the end of 2002 including employment of developed enrichment techniques to lower detection limits. Complementary modelling work to support the BS2B *in situ* tracer tests.

BS2B *In situ* tracer tests based on the outcome of the BS2A analysis. *In situ* tests are preceded by reassessment of the need to optimise/remediate the piezometer array. The specific objectives of BS2B are to be formulated on the basis of the outcome of BS2A.

#### *Achievements*

The main work in progress is on BS2B. Reporting of three cross hole interference tests (CPT-1 through CPT-3) aimed at identifying suitable sink and injection sections for the planned injection tests is in progress. These tests singled out a pump section in KI0025F03 including structure #19. During this quarter long term tests with non-sorbing tracers (CPT-4a and CPT-4b) have been complemented by repeated forced injections (CPT-4c) in order to verify sufficiently high mass recovery. Results show that two flow paths can be used for BS2B sorbing test (injections in KI0025F02:R3 (#19) and KI0025F02:R2 (#25) with pumping in KI0025F03:R3 (#19). Bundled results from CPT-4a through CPT-4c were delivered to the modelling teams late March.

On site preparations for BS2B sorbing test have continued during the period. Detectors and alarms have been primed and the experimental containers have been furnished with the necessary equipment. The steering committee decide to carry out BS2B sorbing tracer test in March.

Revisions to the structural model and the microstructure model of the structures #19 and #25 have been made and are to be delivered to the modelling teams. Important progress in this context have been made by the Fault Rock Zones Characterisation project (TRUE-1 Continuation) where results from *in situ* epoxy injections and subsequent overcoring and analysis are expected to provide additional important conceptual and quantitative data on immobile pore spaces.

In addition, two reports have been printed /Dershowits *et al*., 2002; Dershowitz and Klise, 2002/ and the Minutes from the TRUE Block Scale International Seminar November 19-20, 2003 distributed to the participants in March.

### 4.1.2 TRUE-1 Continuation

The TRUE-1 Continuation project is a continuation of the TRUE-1 experiments, and the experimental focus is mainly on the TRUE-1 site, although work is also made at other locations at Äspö HRL. The main components of the test are: complementary *in situ* tests /Andersson *et al*., 2002/, radon investigations /Byegård *et al*., 2002/, fault rock zone characterisation studies (including epoxy resin injection), and investigations in the laboratory of the sorption characteristics of rim zone and fault gouge material.

### *Achievements*

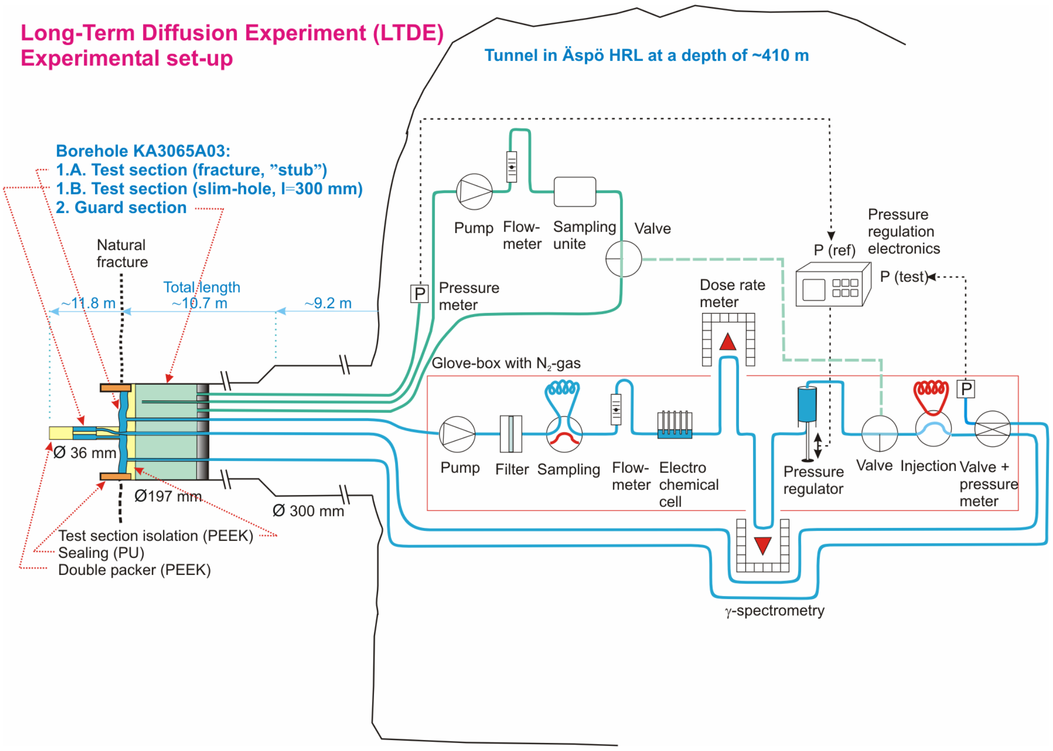
The major work performed during this quarter is within the Fault Rock Zones Characterisation. A draft report has been produced which accounts for the overcoring work and documents the overcored structures in detailed maps and photo images.

Joint visual inspection of overcored 277 mm cores in March indicated a wealth of information ranging from the overall pattern of connected pore space on a metre scale down to highly variable types and shapes of pores down to microscopic scale. An optimised sectioning plan for the available material will be set up. Before sectioning professional photo documentation of the complete cores will be performed.

Work is in progress on two fronts to assess the porosity of selected samples of clay-rich samples from Zone NE-2 collected from borehole KA1596A04. Samples have been sent to the University of Helsinki for PMMA impregnation and to the Swedish National Testing and Research Institute in Borås for porosity and BET measurements. Great care was taken to retain the moisture content of the samples including moisture locks.

In addition, laboratory experiments on sorption characteristics of rim zone and fault gouge materials are under way. Preliminary results will be available early April 2004.

## 4.2 Long Term Diffusion Experiment




This experiment is performed to investigate diffusion and sorption of solutes in the vicinity of a natural fracture into the matrix rock and directly from a borehole into the matrix rock.

The aims are to improve the understanding of diffusion and sorption processes and to obtain diffusion and sorption data at *in situ* conditions. A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole and a small-diameter borehole is drilled through the core stub and beyond into the intact unaltered bedrock. Tracers will be circulated over a period of three to four years after which the borehole is overcored and analysed for tracer content.

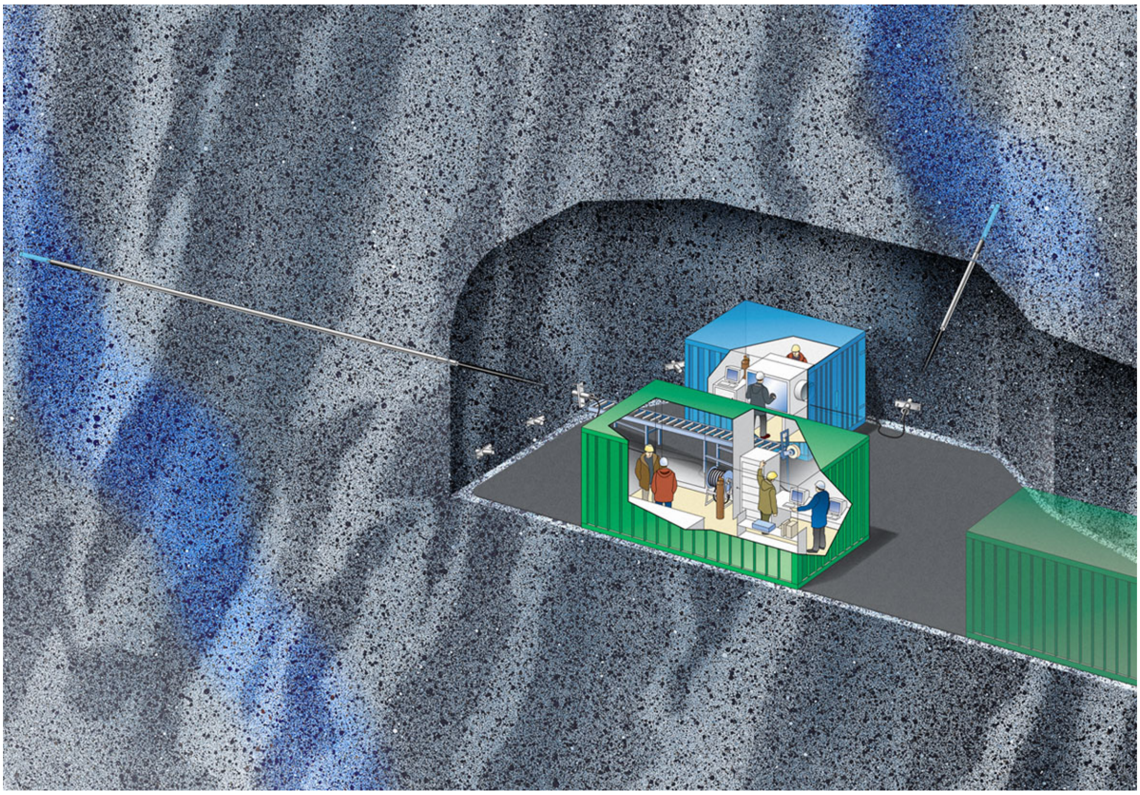
### *Achievements*

The LTDE experiment has been through an external reviewed by Peter Vilks, AECL as a quality control prior to the start of the main test which is at the earliest in September. The review comprised both the experimental concept and the experimental set-up, and will result in a report to OPG and SKB.

During this quarter the installation of electronic equipments is in progress and some modifications of the InTouch program  to fit the current experimental set-up has been performed. The installation tests (e.g. PLC, electrochemical cell, pressure regulator etc.) are being continued.

In addition, the planning of laboratory experiments are in progress and a strategy for the performance of the laboratory experiments are being defined.

## 4.3 Radionuclide Retention Experiments



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

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

The present focus is on:

- Radiolysis experiments in CHEMLAB 1, influence of radiolysis products on the migration of the redox-sensitive element technetium in bentonite.
- Migration of actinides in CHEMLAB 2, experiments with actinides in a rock fracture.

### *Achievements − Radiolysis experiments*

In the end of 2002, two kinds of radiolysis experiments were started. In the indirect radiolysis experiments the groundwater is irradiated before it comes in contact with the experiment cell containing bentonite and reduced technetium. Radicals produced from water radiolysis will not reach the experiment cell, but the molecular products ($H_2O_2$, $O_2$, and $H_2$) will influence the redox chemistry in the cell. In the other type, direct radiolysis experiments, the irradiation source is placed in the experiment cell, close to the reduced technetium, and thereby the radicals produced may play a role.

The experiments have been analysed and the major conclusions are that technetium was to some extent oxidised in the direct radiolysis experiment and had started to diffuse whereas in the indirect radiolysis experiment technetium was only found at its original position and had probably not been oxidised. The final evaluation of data and the preparation of a final report are planned to be finished in June. No additional experiments are presently in progress or planned.

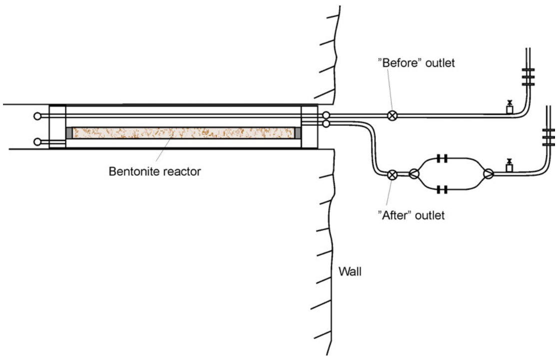
### *Achievements − Migration of actinides*

In these experiments a cocktail containing actinides is added to groundwater before pumping it through a longitudinal natural fracture in a drill core placed in CHEMLAB 2. The last *in situ* experiment (in borehole KJ0044F01) is planned to start in April 2004. The laboratory reservoir containing the tracer cocktail (uranium and technetium) is prepared by FZK/INE. Recent problems with the pump have delayed the experiment a few weeks.

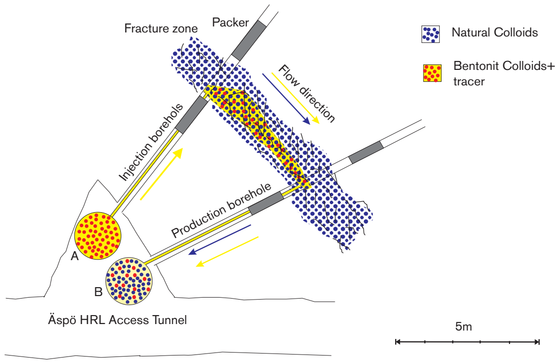
The first experiment comprised migration of the actinides americium, neptunium, and plutonium. The second experiment was carried out in the beginning of 2002 and the results has been evaluated and published /Kienzler *et al.,* 2003a/. The third actinide experiment in Äspö HRL was started at the end of 2002. This experiment was expired due to several technical problems e.g. corrosion in the probe. The expired experiment provided, however, few water samples that have been analysed and evaluated by FZK/INE. The results from the third field experiment are reported in a technical report from Forschungzentrum, Karlsruhe /Kienzler *et al*., 2003b/.

## 4.4 Colloid Project

***Borehole specific measurements***




***Dipole colloid experiments***




In the Colloid Project the concentration, stability, and mobility of colloids in the Äspö environment are studied. The project comprises studies of the potential of colloids to enhance solute transport and the potential of bentonite clay as a source for colloid generation.

The Colloid Project includes laboratory experiments, background measurements, borehole specific measurements, and dipole colloid experiments.

### *Achievements*

The borehole specific measurements that were initiated in January 2003, when six “colloid reactors” were installed in four boreholes in the Äspö tunnel and in two boreholes at Olkiluoto, have all been finalised. The status report for these measurements is delayed, the reason is that the results from Olkiluoto have not been reported and they are crucial for the inter comparison of the results from the measurements performed at Äspö and Olkiluoto. A draft version of the status report is expected in the end of August.

The status report including the results from the laboratory experiments and background measurements was printed in March 2003 /Laaksoharju, 2003/. The compilation of the final report including laboratory experiments, background measurements and borehole specific measurements will be ready in October.

The preparations for the fracture dipole colloid experiments that will be carried out in co-operation between SKB, INE and Posiva is in progress. Based on results from tests with conservative tracers, Feature B at the TRUE-1 site has been selected for the experiments.

## 4.5 Microbe Project

The Microbe Project has been initiated in the Äspö HRL for studies of the microbial activity in groundwater at *in situ* conditions. The major objectives are:

- To offer proper circumstances for research on the effect of microbial activity on the long- term chemical stability of the repository environment.
- To provide *in situ* conditions for the study of bio-mobilisation of radionuclides.
- To present a range of conditions relevant for the study of bio-immobilisation of radionuclides.
- To enable investigations of bio-corrosion of copper under conditions relevant for a high level radioactive waste repository.

The main MICROBE site is on the 450-m level where a laboratory container has been installed with laboratory benches, an anaerobic gas box and an advanced climate control system. Three core drilled holes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures are connected to the MICROBE laboratory via tubings. Each borehole has been equipped with a circulation system offering a total of 2000 $cm^2$ of test surface.

Retention of naturally occurring trace elements in the groundwater by Biological Iron Oxides is investigated at a site at tunnel length 2200A m. There is a vault with a borehole that delivers groundwater rich in ferrous iron and iron oxidising bacteria. The borehole is connected to two 200 x 30 x 20 cm artificial channels that mimic ditches in the tunnel. The channels have rock and artificial plastic support that stimulate Biological Iron Oxide formation.

At 907A m tunnel length, a small vault supports a ditch with groundwater that is rich in ferrous oxides and iron oxidising bacteria This ditch is used as a natural analogue to the artificial channels at 2200A m. This site was destroyed by a flooding event fall 2003 and is probably lost.

A unique ecosystem of sulphur oxidising bacteria exists at tunnel length 1127B m, in the sulphur pond. Apart from being an intriguing site from a microbiological perspective, it offered possibility to investigate microbial effects on the sulphur cycle in underground environments. However, changes in groundwater flows during 2003 has dried out the site and it can not be used in the MICROBE experiments.

### *Achievements*

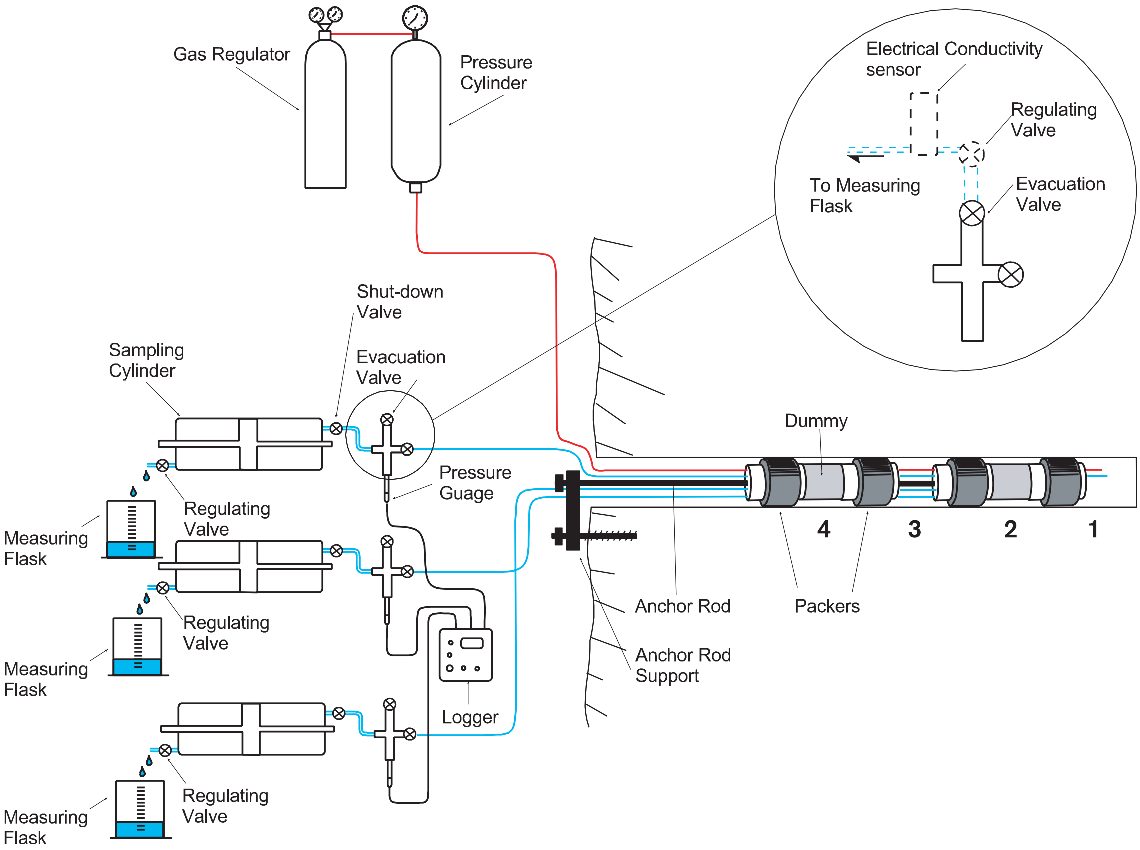
The main site is the MICROBE laboratory at the -450 m level. In addition, three more sites, two along the A-side of the tunnel at 907 and 2200 m tunnel length and one at the B-side of the tunnel at 1127 m, were established during 2002. However, a devastating flood event occurred summer 2003 at the 907-site, and filled it with sand. This site will, therefore, not be used during 2004. At the 1127-m site, the important inflow of groundwater with high concentration of sulphide diminished during 2002 and was almost completely lost during 2003. It is not clear, at present, if the inflow can be restored.

In the MICROBE laboratory, new biofilm experiments with mineral and glass surfaces have been loaded and started during mid February. In addition, immobilisation of radionuclides on the biofilms will be investigated at Nuclear Chemistry, Chalmers.

In the Prototype Repository a first test of sampling and analysis of gas was successful and demonstrated groundwater gases in the backfill. An activity plan for the detailed sampling and analysis procedures is presently being produced.

A research project investigating the effect from the Äspö tunnel on the sulphur and carbon cycles together with Kalmar research school is in progress. The first sampling in the tunnel took place in the end of March. Members from the Kalmar and Göteborg laboratories will participate in the project.

## 4.6 Matrix Fluid Chemistry




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

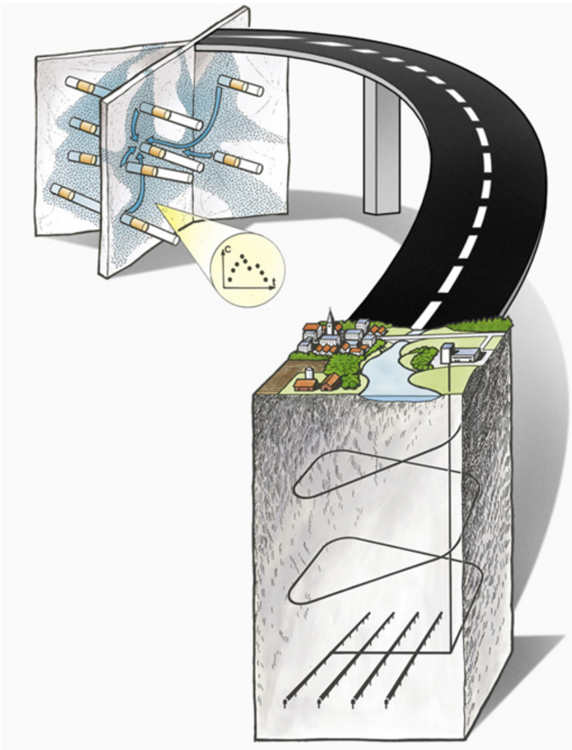
Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied to determine their contribution, if any, to the composition of the matrix fluids/groundwaters.

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

The final preparations for a second phase are finalised and the Matrix Continuation Experiment has been initiated. The project is proceeding as planned:

- A Pilot Study focussing on the impact of tunnel construction (Äspö Pillar Stability Experiment) on the hydrogeology and hydrochemistry in the vicinity of the experimental matrix borehole KF0051A01, has been completed and the results are presently being reported.
- Porosity measurements on drillcore material to supplement data from the Matrix Fluid Chemistry Experiment have been carried out and reporting is in progress.

## 4.7 Task Force on Modelling of Groundwater Flow and Transport of Solutes



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

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

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

### *Achievements*

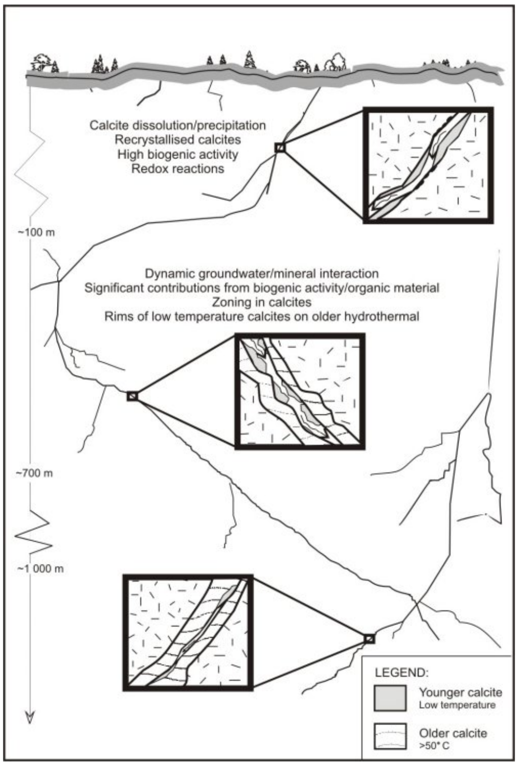
The 18th Task Force meeting was held at Äspö in January. In the Task Force work has been in progress mainly in Task 6 − Performance Assessment Modelling Using Site Characterisation Data. Task 6 tries to bridge the gap between Performance Assessment (PA) and Site Characterisation (SC) models by applying both approaches for the same tracer experiment. It is hoped that this will help to identify the relevant conceptualisations (in processes/structures) for long term PA predictions and identify site characterisation data requirements to support PA calculations.

Modelling and review of modelling are proceeding according to plan. However, at the Task Force meeting in January new modelling tasks were identified that will prolong the project with approximately two additional Task Force meetings. End of project will thus be delayed by approximately one year.

The status of the specific modelling tasks is given in brackets in the table below.

| Sub-task | Status |
|---|---|
| 6A | Model and reproduce selected TRUE-1 tests with a PA model and/or a SC model to provide a common reference. (Finalised, reported, and external review in progress). |
| 6B | Model selected PA cases at the TRUE-1 site with new PA relevant (long term/base case) boundary conditions and temporal scales. This task serves as means to understand the differences between the use of SC-type and PA-type models, and the influence of various assumptions made for PA calculations for extrapolation in time. (Finalised, reported, and external review in progress). |
| 6C | Develop semi-synthetic, fractured granite hydrostructural models. Two scales are supported (200 m block scale and 2000 m site-scale). The models are developed based on data from the Prototype Repository, TRUE Block Scale, TRUE-1, and Fracture Characterisation and Classification project (FCC). (Finalised and reported /Dershowitz *et al.*, 2003/). |
| 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. (In progress). |
| 6E | This sub-task extends the sub-task 6D transport calculations to a reference set of PA time scales and boundary conditions. (Specifications sent out). |

## 4.8 PADAMOT




*Potential calcite-groundwater interaction at various depths at Äspö.*

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

The objectives of PADAMOT are to:

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

The project comprises analytical and modelling tasks. Deep borehole cores from rocks at the Äspö Underground Laboratory and Laxemar (KXL01) are used in the analytical study.

### *Achievements*

The yearly PADAMOT meeting was held in Madrid. The results from the different groups were discussed and contributions have been put on the PADAMOT website hosted by British Geological Survey, UK.

The Palaeohydrogeological scenario, indicated by the Swedish results from core samples from Äspö, Laxemar, and Simpevarp, shows large variations in salinities over time and a significant compartmentalisation of groundwaters. Available results from the Scottish site Dunderee indicate the same tendencies.

Evaluation and integration of results continue. A small number of calcite samples with stable isotopes values that indicate biogenic content will be sent to Madrid University for biomarker test.

## 4.9 Fe-oxides in fractures

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 the 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 three year project on Fe-oxides started late autumn 2003. The work carried out during the first months concentrated on summing up the results from a pilot tests carried out during 2003.

During this quarter efforts have mainly put into the writing of three manuscripts. The manuscripts are prepared more or less simultaneously because the results overlap. In addition the last Fe isotope data are gathered for the method paper, as well as being prepared for publication.

Experimental work has also progressed; Transformation of green rust (GR) to other Fe-compounds at controlled redox conditions that are similar to natural conditions has been studied. The emphasis of this work is on immobilisation of contaminants, including Eu(III). In order to establish controlled redox state, thus allowing potentiometric control, the work is done in a glovebox and a three-electrode system in the AFM (atomic force microscope) fluid cell will be used. Up to now, the work has focussed on development of the method, mainly integrating the electrochemical component with the already established AFM-expertise in the group. The next step will be to study the morphological changes during the formation and transformation of green rust on a substrate of high purity metallic Fe at a variety of potentials to resemble different redox environments in the subsurface.

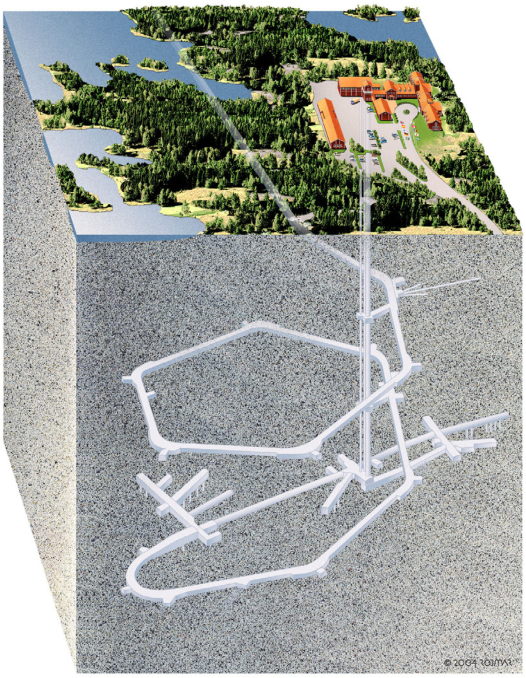
The transformation of Cr species in the presence of GR has been studied. Cr(VI) is carcinogenic and highly mobile, whereas Cr(III) is an important trace metal in mammal metabolism and is much less mobile. Reduction of Cr(VI) to Cr(III) is therefore desirable for groundwater remediation and waste treatment. It is known that GR reduces Cr(VI) to Cr(III) within minutes, and our experiments show that an effective sink for the Cr(III) is produced through this reaction. When Cr(VI) is reduced, GR is oxidized to Cr-ferrihydrite that recrystallises to Cr-goethite within hours. Goethite is highly insoluble and the incorporated Cr(III) stabilises the structure further, making the Cr-goethite stable on the longer term. No chromium is left in solution, provided that ample Fe(II) is present as GR to reduce the added Cr(IV). Combined, this makes GR a very good reducer of Cr(VI).

Contacts with the Greenland ice-coring group have been taken and we now have access to some of the frozen water that was found at the bottom of the hole drilled last summer.

# 5 Äspö facility

An important part of the Äspö facility is the administration, operation, and maintenance of instruments as well as development of investigation methods. Other issues are to keep the stationary hydro monitoring system (HMS) continuously available and to carry out the programme for monitoring of groundwater head and flow and the programme for monitoring of groundwater chemistry.

## 5.1 Facility operation



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

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

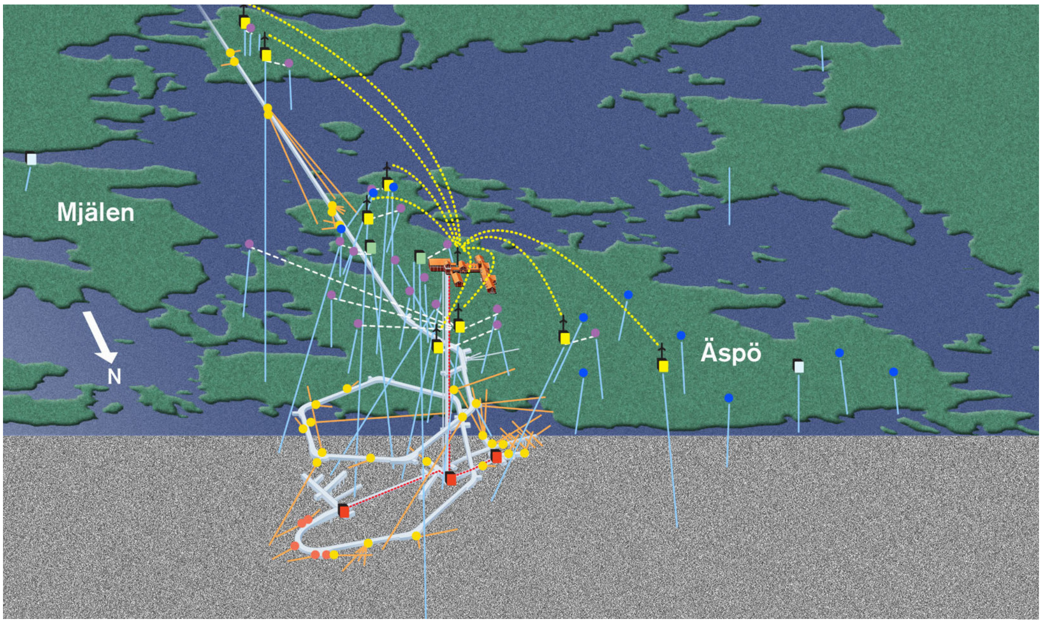
### *Achievements*

Maintenance and operation of the above and underground facilities are running as well as improvements of the safety and working environment. The availability of the facility systems has continued to be high, and the goal for 2004 is above 99%.

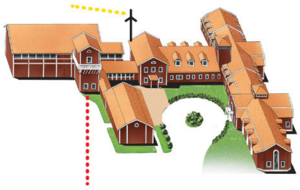
An automatic registration and object-monitoring system, with the aims of increasing personnel safety underground, was taken into operation for testing in the end of 2003. During January and February trouble shooting of the system has been on-going. However, the measurements taken by the supplier have so far not been sufficient and the system has still severe mal-functions. An alternative system from another supplier has to be considered if the supplier cannot get the system up and running.

The installation of a pipe from -340 to -440 m level which will supply water to the experiments an for fire protection has been finalised. A steering and control system for soft start of two pumps has been installed and is now in operation. The evaluation of this system is in progress and the results so far look promising. It was therefore decided that the remaining six pumps will be rebuilt and equipped with similar systems.

## 5.2 Hydro Monitoring System




Measurement Station with radio and computer network situated at the site office.



Monitored borehole communicating by radio.

Logger - stand alone.

Logger - on line.

Borehole - manually measured.

Borhole - monitored.

Measurement Station in the tunnel.

A/D converter connected directly to a measurement station.

Logger - communicating with a measurement station on a Borre data network.

The computerised Hydro Monitoring System (HMS), is a network of boreholes and measurement stations where e.g. data of groundwater head, salinity, electrical conductivity, Eh and pH are collected on-line. The data are recorded by more than 400 transducers installed in boreholes on Äspö as well as in boreholes located in the tunnel. All data are transmitted to the main office at Äspö, by radio or modems. Weekly quality controls of preliminary groundwater head data are performed. Absolute calibration of data is performed three to four times per year. This work involves comparison with groundwater levels checked manually in percussion drilled boreholes and in core drilled boreholes. The scope of maintaining such a monitoring network has scientific as well as legal grounds.

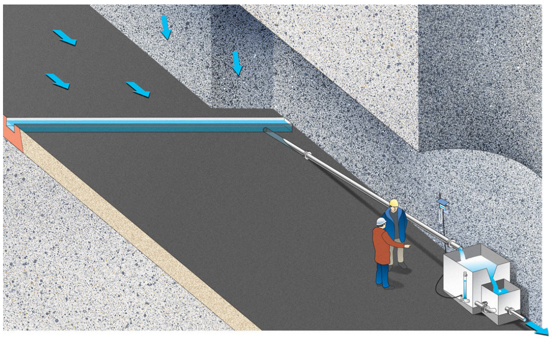
### *Achievements*

Presently, improvements are made on the monitoring system to increase the performance of the system. The system has been performing well and no main maintenance activity has taken place during this quarter.

## 5.3 Programme for monitoring of groundwater head and flow

The monitoring of water levels in surface based boreholes started in 1987. The tunnel excavation started in October 1990 and the first groundwater head (pressure) measurements from tunnel based boreholes were performed in March 1992.

The monitoring is administrated by the computerised hydro monitoring system (HMS), comprising a network of boreholes of which many are equipped with hydraulically inflatable packers, measuring the pressure by means of transducers. Manual levelling is also obtained from the surface boreholes on a regular basis. Water seeping through the tunnel walls is diverted to trenches and further to 21 weirs where the flow is measured.



### *Achievements*

The monitoring points from the previous year have been maintained. The system will continue to support the experiments undertaken and meet the requirements stipulated by the water rights court.

## 5.4 Programme for monitoring of groundwater chemistry

During the Construction Phase of the Äspö HRL, different types of water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. At the beginning of the Operational Phase, sampling was replaced by a groundwater chemistry monitoring programme, aiming at a sufficient cover of the hydrogeochemical conditions with respect to time and space within the Äspö HRL. This programme is designed to provide information to determine where, within the rock mass, the hydrogeochemical changes are taking place and at what time stationary conditions are established.

### *Achievements*

The annual water sampling campaign is in the same way as earlier years and is scheduled to take place in September – October. The previous sampling campaign took place in September 2003.

# 6 International co-operation

Seven organisations from six countries participate in the co-operation at Äspö HRL during 2004. OPG (Canada) became a new participant in January 2004 and Nagra (Switzerland) will leave the central and active core of participants, but continue in the Matrix Fluid Chemistry project as well as in the Task Force on Modelling of Groundwater Flow and Transport of Solutes.

Most of the participating organisations are interested in groundwater flow, radionuclide transport and rock characterisation. Several organisations are participating in the Äspö Task Force on 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.

| **Projects in the Äspö HRL during 2004** | **Andra** | **BMWA** | **Enresa** | **CRIEPI** | **JNC** | **OPG** | **Posiva** |
|---|---|---|---|---|---|---|---|
| **Technology** | | | | | | | |
| Prototype Repository | X | X | X | X | X | | X |
| Backfill and Plug Test | | | X | | | | |
| Long Term Test of Buffer Material | | | | | | | X |
| Cleaning and sealing of investigation boreholes | | | | | | | X |
| Injection grout for deep repositories | | | | | | | X |
| KBS-3 method with horizontal emplacement | | | | | | X | X |
| Large Scale Gas Injection Test | | X | | | | | X |
| Temperature Buffer Test | X | | X | | | | |
| **Geo-science** | | | | | | | |
| Äspö Pillar Stability Experiment | | | | | | X | X |
| **Natural barriers** | | | | | | | |
| Tracer Retention Understanding Experiments | X | | | | X | | X |
| Radionuclide Retention Project | | X | | | | | |
| Colloid Project | | X | | | | | X |
| Microbe Project | | X | | | | | |
| Matrix Fluid Chemistry | | | | | | | |
| Task Force on Modelling of Groundwater Flow and Transport of Solutes | X | | | X | X | | X |

**Participating organisations:**
Agence nationale pour la gestion des déchets radioactifs, Andra, France
Bundesministerium für Wirtschaft und Arbeit, BMWA, Germany
Empresa Nacional de Residuos Radiactivos, Enresa, Spain
The Central Research Institute of the Electronic Power Industry, Criepi, Japan
Japan Nuclear Cycle Development Institute, JNC, Japan
Ontario Power Generation Inc., Canada
Posiva Oy, Finland

### *EC-projects*

SKB is through Repository Technology co-ordinating three EC contracts and takes part in several EC projects of which the representation in three projects is channelled through Repository Technology. SKB takes also part in work within the IAEA Network of Centres of Excellence.

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**Prototype Repository** – Full scale testing of the KBS-3 concept for high-level radioactive waste (2000-09-01 – 2004-02-29)
Co-ordinator: Swedish Nuclear Fuel and Waste Management Co, Sweden
Participating countries: Finland, Germany, Japan, Spain, Sweden and United Kingdom

**CROP** – Cluster repository project, a basis for evaluating and developing concepts of final repositories for high level radioactive waste (2001-02-01 – 2004-01-31)
Co-ordinator: Swedish Nuclear Fuel and Waste Management Co, Sweden
Participating countries: Belgium, Canada, Finland, France, Germany, Spain, Sweden, Switzerland and USA

**FEBEX II** – Full-scale engineered barriers experiment in crystalline host rock phase II (1999-07-01 – 2004-10-31 after prolongation with 10 months)
Co-ordinator: Empresa Nacional de Residuos Radiactivos, Spain
Participating countries: Belgium, Czech Republic, Finland, France, Germany, Spain, Sweden, and Switzerland

**SAFETI** – Seismic validation of 3-D thermo-mechanical models for the prediction of the rock damage around radioactive spent fuel waste (2001-09-01 – 2004-09-01)
Co-ordinator: The University of Liverpool (Dep of Earth Sciences), United Kingdom
Participating countries: France, Sweden and United Kingdom

**PADAMOT** – Paleohydrogeological data analysis and model testing (2001-12-01 – 2004-11-30)
Co-ordinator: Nirex Ltd, United Kingdom
Participating countries: Czech Republic, Spain, Sweden and United Kingdom

**NET.EXCEL** – Network of excellence in nuclear waste management and disposal (2002-11-01– 2004-03-31)
Co-ordinator: Swedish Nuclear Fuel and Waste Management Co, Sweden
Participating countries: Belgium, Finland, France, Germany, Spain, Sweden, Switzerland, and United Kingdom

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# 7 Environmental research

## 7.1 Äspö Research School

Äspö Environmental Research Foundation was founded 1996 on initiative of local and regional interested parties. The aim was to make the underground laboratory at Äspö and its recourses available for national and international environmental research. SKB's economic engagement in the foundation was concluded in 2003and the activities are now concentrated on the Äspö Research School, which was founded in 2002.

On the initiative of the Äspö Environmental Research Foundation the University of Kalmar has set up the Äspö Research School. The research school is a concrete commitment to provide conditions for today's and tomorrow's research concerning environmental issues. The research school has a special interest in the transport of pollutants and their distribution in rock, ground, water, and biosphere. The research school is co-financed by the municipality of Oskarshamn, SKB, and the University of Kalmar.

### *Achievements*

During 2003 detailed plans for the activities were worked out. A field test base in the Äspö Research Village will be established during 2004 and the first field test in the laboratory initiated.

A research project investigating the effect from the Äspö tunnel on the sulphur and carbon cycles together is in progress. The first groundwater sampling was carried out from 11 boreholes in the Äspö HRL tunnel at different depths. This activity was done during the time period 22-25.3.2004

# 8 Documentation

During the period January-March 2004, the following reports have been published and distributed.

## 8.1 Äspö International Progress Reports


**Dershowits W, Klise K, Fox A, Takeuchi S, Uchida M, 2002.** TRUE Block Scale project. Channel network and discrete fracture network analysis of hydraulic interference and transport experiments and prediction of Phase C experiments.
IPR-02-29, Svensk Kärnbränslehantering AB.

**Gómez-Hernández J-J, Hendricks Fransen H-J, Medina Sierra A, Marcuello A, Carrera J, Sendrós D, 2002.** TRUE Block Scale project. Stochastic continuum modelling of flow and transport.
IPR-02-31, Svensk Kärnbränslehantering AB.

**Sjöberg J, 2002.** Äspö Pillar Stability Experinent. 3D overcoring rock stress measurement in borehole KA3376B01 at the Äspö HRL.
IPR-03-16, Svensk Kärnbränslehantering AB.

**Bono N, Röshoff K, 2003.** Prototype Repository. Instrumentation for stress, strain and displacement measurement in rock.
IPR-03-19, Svensk Kärnbränslehantering AB.

**Darcel C, 2003.** True Block Scale continuation project. Assessment of the feasiblity of tracer tests with injection in "background fractures" using a model based on a power law fracture length distribution.
IPR-03-41, Svensk Kärnbränslehantering AB.

**Poteri A, 2003.** TRUE Block Scale continuation project. Retention processes discrimination for various assumptions of fracture heterogeneity.
IPR-03-42, Svensk Kärnbränslehantering AB.

**Cvetkovic V, 2003.** TRUE Block Scale continuation project. Significance of diffusion limitations and rim zone heterogeneity for tracer transport through fractures at the Äspö site.
IPR-03-43, Svensk Kärnbränslehantering AB.

**Bono N, Röshoff K, 2003.** Prototype Repository. Instrumentation of the outer plug to monitor strains and deformations.
IPR-03-44, Svensk Kärnbränslehantering AB.

**Goudarzi R, Gunnarsson D, Börgesson L, 2003.** Backfill and Plug test. Sensors data Report No: 7 .
IPR-03-45, Svensk Kärnbränslehantering AB.

**Goudarzi R, Johannesson L-E, 2003.** Prototype Repository. Sensors data report (Period: 010917-030901). Report No:7.
IPR-03-46, Svensk Kärnbränslehantering AB.

**Rothfuchs T, Hartwig L, Komischke M, Miehe R, Wieczorek K, 2003.** Prototype Repository. Deliverable D10. Instrumentation for resistivity measurements in buffer, backfill and rock in Section ll.
IPR-03-48, Svensk Kärnbränslehantering AB.

**Goudarzi R, Börgesson L, Röshoff K, Bono N, 2003.** Canister Retrieval Test. Sensors data report (Period 001026-031101) Report no: 7. IPR-04-01, Svensk Kärnbränslehantering AB.

## 8.2 Technical Documents and International Technical Documents

2 Technical Documents

1 International Technical Documents

# 9 References

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IPR-02-47. Svensk Kärnbränslehantering AB

**Byegård J, Ramebäck H, Widestrand H, 2002.** TRUE-1 Continuation Project. Use of radon concentrations for estimation of fracture apertures − Part 1: Some method developments, preliminary measurements and laboratory experiments.
IPR-02-68. Svensk Kärnbränslehantering AB

**Dershowitz W, Winberg A, Hermansson J, Byegård J, Tullborg E-L, Andersson P, Mazurek M, 2003.** Äspö Hard Rock Laboratory. Äspö Task Force on modelling of groundwater flow and transport of solutes. Task 6c. A semi-synthetic model of block scale conductive structures at the Äspö HRL.
IPR-03-13. Svensk Kärnbränslehantering AB

**Dershowitz W, Klise K , 2002.** TRUE Block Scale project . Evaluation of fracture network transport pathways and processes using the Channel Network approach.
IPR-02-34, Svensk Kärnbränslehantering AB

**Dershowits W, Klise K, Fox A, Takeuchi S, Uchida M, 2002.** TRUE Block Scale project. Channel network and discrete fracture network analysis of hydraulic interference and transport experiments and prediction of Phase C experiments.
IPR-02-29, Svensk Kärnbränslehantering AB.

**Goudarzi R, Börgesson L, Sandén T, Barcen, I, 2004b** Temperature Buffer Test. Sensors data report (Period: 030326-031001) Report No:1.
IPR-04-02, Svensk Kärnbränslehantering AB

**Goudarzi R, Johannesson L-E, 2003.** Prototype Repository. Sensors data report (Period: 010917-031201). Report No:8.
IPR-04-04, Svensk Kärnbränslehantering AB

**Goudarzi R, Gunnarsson D, Börgesson L, 2004a.** Backfill and Plug test. Sensors data Report No: 8 .
IPR-04-#. Svensk Kärnbränslehantering AB

**Kienzler B, Vejmelka P, Römer J, Fanghänel E, Jansson M, Eriksen T E, Wikberg P, 2003a.** Swedish-German actinide migration experiment at ÄSPÖ hard rock laboratory. Journal of Contaminant Hydrology 61 (2003) 219– 233

**Kienzler B, Vejmelka P, Römer J, Schild D, Enzmann F, Soballa E, Fuß M, Geyer F, Kisely T, Görtzen A, 2003b.** Actinide Migration Experiment in the ÄSPÖ HRL in Sweden: Results from Core #5 (Part III).
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**SKB, 2004.** Äspö Hard Rock Laboratory. Planning Report for 2004.
IPR-04-12. Svensk Kärnbränslehantering AB

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TR-03-18. Svensk Kärnbränslehantering AB