International
Progress Report

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Äspö Hard Rock Laboratory

Status Report
October – December 2002

May 2003

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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, 2001a/. The information given in the RD&D-Programme related to Äspö HRL annually detailed in the Äspö HRL Planning Report /SKB, 2002/.

This Äspö HRL Status Report is a collection of the main achievements obtained during the fourth quarter 2002. Detail presentations and summarise of the findings and results achieved will be given in the Annual Report for 2002.

Natural barriers

At Äspö HRL experiments are performed at conditions that are expected to prevail at repository depth: Tracer Retention Understanding Experiments, Long Term Diffusion Experiment, Radionuclide Retention Experiment, Colloid Project, Microbe Project, Matrix Fluid Chemistry, and PADAMOT.

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.

Disposal 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: Prototype Repository, Backfill and Plug Test, Canister Retrieval Test, Long Term Test of Buffer Material, Äspö Pillar Stability Experiment, Low-pH cementitious products, KBS-3 method with horizontal emplacement, and Cleaning and sealing of investigation bore holes.

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.

International co-operation

The Äspö HRL has so far attracted considerable international interest. Eight organisations from seven countries have participated during 2002 in the co-operation in addition to SKB. In addition, SKB takes parts in several EC projects and is through Repository Technology co-ordinating three EC-contracts.

Contents

1 General

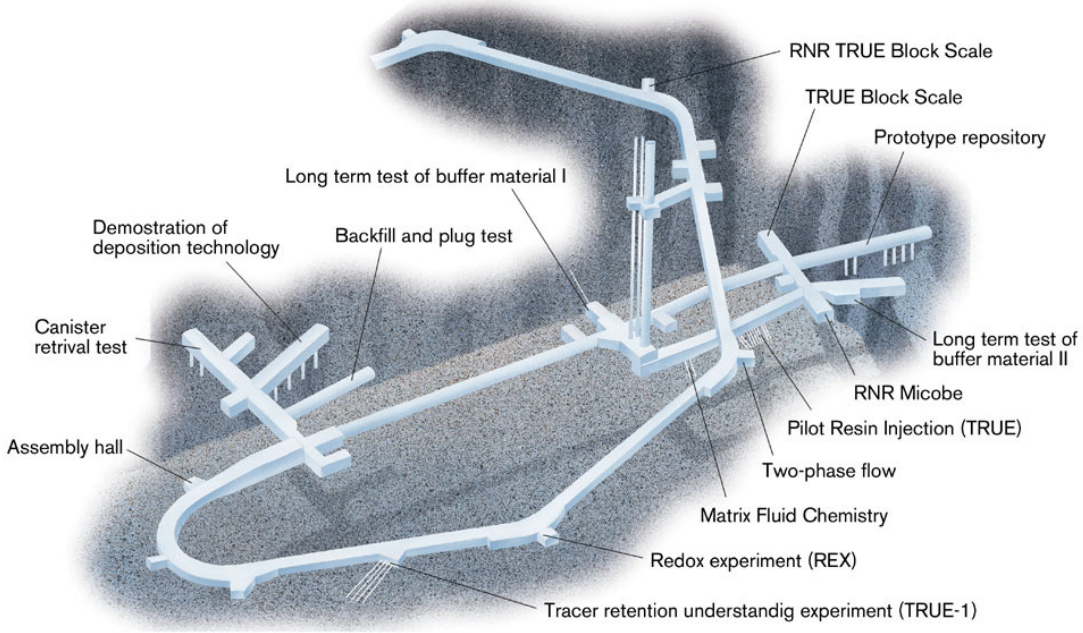
The Äspö Hard Rock Laboratory (HRL) constitutes an important part of SKB's work to design and construct a deep geological repository for spent nuclear fuel and to develop and test methods for characterisation of a suitable site.

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 the experiments performed at the Äspö HRL. Underground excavations at the 300–460 m levels and the allocation of experimental sites are shown in the figure below.

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, 2001a/. 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.

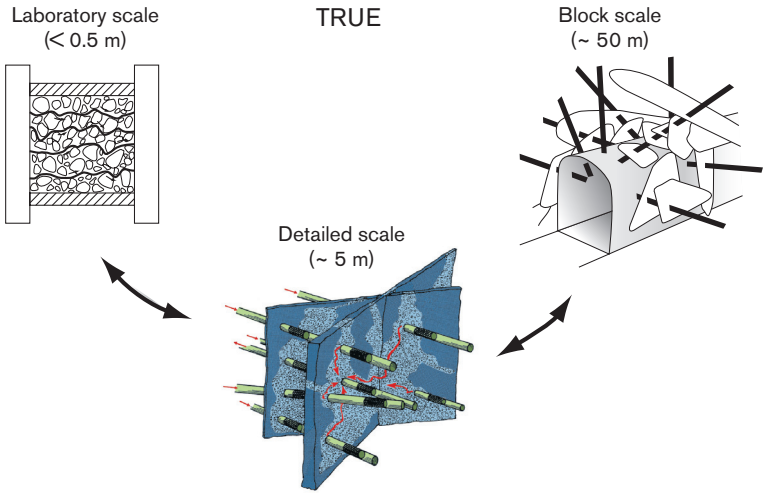
This Status Report concentrates on the work in progress and refers to the Planning Report /SKB, 2002/ for more background information. The Annual Report will in detail present and summarize new findings and results.



2 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.

2.1 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 have come to their respective conclusion. Complementary field work and modelling are currently performed or being planned 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 an investigated feature and to study fixation of sorbing radioactive tracers.

Prior to the application of resin injection technology 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 on Fault Rock Zones. Furthermore, attempts are made to assess fracture apertures using radon concentrations in groundwater.

Achievements − TRUE Block Scale

The experimental work for TRUE Block Scale project was “officially” terminated in November 2000. Evaluation and final reporting was completed in 2002. The TRUE Block Scale project is reported in a series of four final report volumes:

- Characterisation and model development /Andersson *et al.*, 2002a/.
- Tracer tests in the block scale /Andersson *et al.*, 2002b/.
- Modelling of flow and transport /Poteri *et al.*, 2002/.
- Synthesis of flow, transport and retention in the block scale /Winberg *et al.*, (in print)/.

The evaluation and reporting period was crowned by an International Seminar, held in Oskarshamn, November 2002, focused on the results and conclusions of project.

Achievements − TRUE Block Scale Continuation

The TRUE Block Scale Continuation (BS2) project is focussed on the existing TRUE Block Scale site. The TRUE Block Scale Continuation is divided into two separate phases:

BS2a Continuation of the TRUE Block Scale (Phase C) pumping and sampling till the end of 2002 including employment of developed enrichment techniques to lower detection limits. Complementary modelling work in support of *in situ* tests.

BS2b Additional *in situ* tracer tests based on the outcome of the BS2a analysis. *In situ* tests are preceded by reassessment of the need to optimise/remediate the piezometer array. The specific objectives of BS2b are to be formulated on the basis of the outcome of BS2a.

A project plan for phase BS2a has been prepared for the modelling. Complementary field-work in terms of prolonged Phase C sampling and analysis has been performed as part of the TRUE Block Scale Continuation project /Byegård, 2002a/.

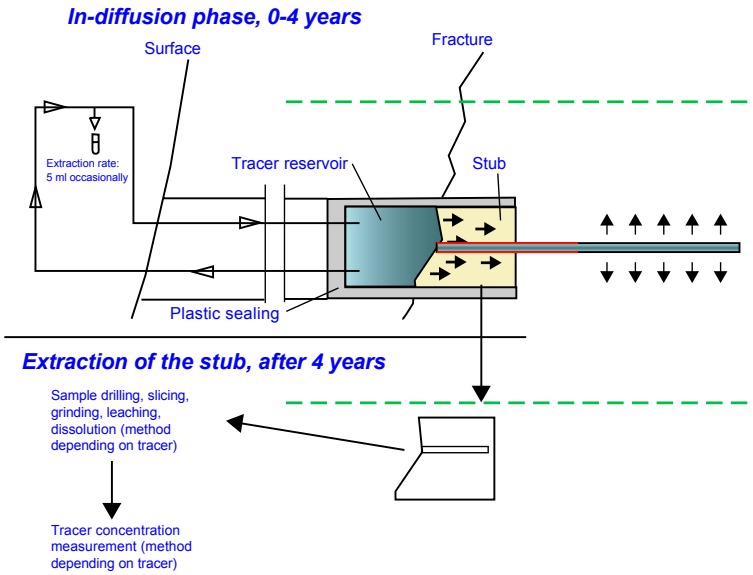
A comprehensive groundwater sampling campaign was conducted in the TRUE Block Scale borehole array in December 2002. A total of 23 test sections were sampled according to Class 5 and were also sampled for radon content. Selected sections were also sampled for analyses of U, Th, Cs, La, Yb using ICP (SGAB) and ^{226}Ra, ^{228}Ra, ^{222}Rn and U- and Th-isotopes (Studsvik). The remaining 19 sections were sampled according to Class 2 (including ^{18}O, ^{2}H, and ^{3}H). Analysis results are expected during the first half of 2003. The results are expected to provide additional information in support of the hydrostructural model and the interpretation of the groundwater flow conditions in the TRUE Block Scale rock volume.

Achievements − TRUE-1 Continuation

The TRUE-1 Continuation project is a continuation of the TRUE-1 experiments, and the experimental focus is here mainly on the TRUE-1 site. In the case of the fault rock zone characterisation the sampling of a drill core of fault gouge material extracted from one of the zones (NE-2 at 1/600 m) has been successful. The core will be subject to laboratory experiments to test out optimal resin recipes and dye additives. These tests have been initiated.

Initial experimental activities performed in order to investigate the possibility of assessing fracture apertures from radon concentrations in groundwater have been performed earlier /Byegård 2002b/. A new method for sampling groundwater and maintaining overpressure during the γ-spectrometry measurement has shown that reproducible results can be obtained. Results from the measurements at the TRUE-1 site indicate that radon concentrations are very similar for waters sampled from the same geological structures. During December 2002 additional sampling at the TRUE Block Scale site and subsequent radon measurements has been performed. Evaluation is under way.

2.2 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.

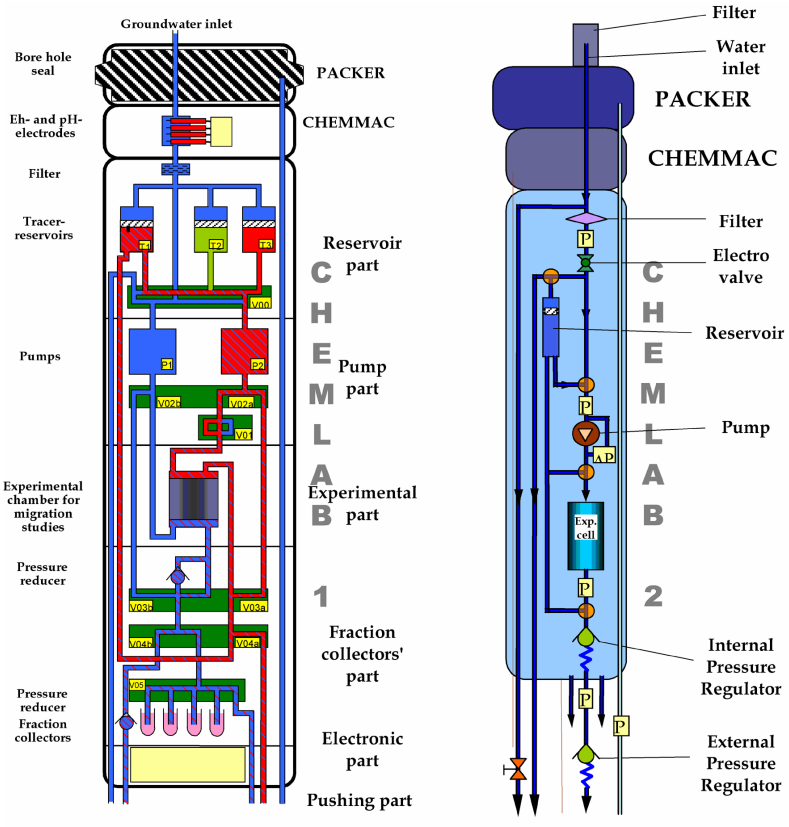
The aim is to improve the understanding of diffusion and sorption processes and to obtain diffusion and sorption data. A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped bore hole and a small-diameter bore hole is drilled through the core stub and beyond into the intact unaltered bedrock. Tracer will be circulated over a period of 3–4 years after which the bore hole is overcored and analysed for tracer content.

Achievements

The equipment in the telescoped bore hole (KA3065A03) is installed and the electricity installations in the experimental containers are finalised. Preliminary tests with the experimental set up in the bore hole were performed during December. Analysis of water samples indicated that the occurrence of bacteria may be a potential problem in the future. Due to this and other identified problem areas it was decided in December to suspend the planned activities and focus on the impact of the unresolved issues on the experiment. It was also decided to set up activity plans for how to handle these areas. The identified problem areas are:

- Excavation work at two sites in Äspö HRL during 2003 is expected to produce hydrological interference at the LTDE site. In order to avoid pressure variations and transients and several practical interferences, LTDE will start when more stable conditions are achieved in Äspö HRL.
- Microbes have been detected in water from the experimental test section in LTDE. Precautions will be taken to avoid uncontrolled build-up of bacteria and the formation of bio-films.
- Instrumentation of the experimental bore hole KA3065A03 is complicated. A test programme has been initiated in order to control the behaviour of the borehole instrumentation under extreme conditions.
- The control unit for pressure regulation did not work properly during installation and has now been repaired. In order to avoid similar future problems, a test programme for each electronic device and subsequently a total system test under extreme conditions is planned.

2.3 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. contents of colloids, organic matter, and bacteria in the groundwater.

The experiments are carried out in special borehole probes, CHEMLAB 1 and CHEMLAB 2, designed for different kinds of *in situ* experiments. Experiments can be carried out at simulated near field conditions and in tiny rock fractures in drill cores.

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 redox-sensitive actinides in a rock fracture).

Achievements − Radiolysis experiments

Since oxidizing species are produced at water radiolysis, there is a possibility that redox-sensitive radionuclides are oxidized. For some nuclides, such as technetium, neptunium, plutonium and uranium, a change in the valence state will increase their mobility. The radiolysis experiments will be diffusion experiments in compacted bentonite clay, where the water will be irradiated and, thus, the influence of radiolysis will be studied.

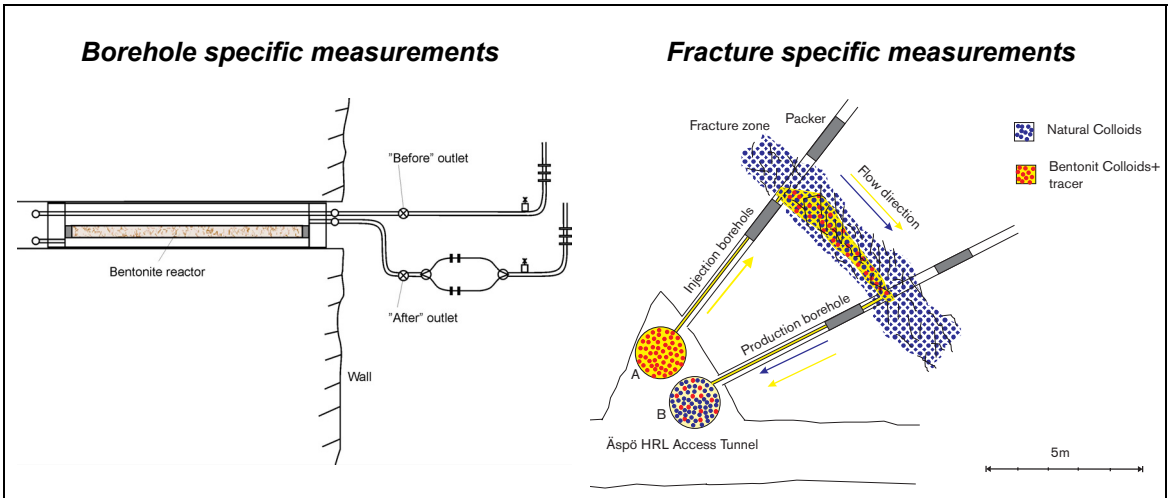
In the end of 2002, two kinds of radiolysis experiments were started. In one the water will be irradiated before it comes in contact with the cell. The radicals produced from water radiolysis will not reach the experiment cell, but the molecular products (H_2O_2, O_2, and H_2) will influence the redox chemistry of the experimental cell. In the other type of experiment the irradiation source will be placed in the experiment cell, close to the reduced technetium, and thereby the radicals produced will play a role. The radiolysis experiments are planned to be terminated in the beginning of April 2003.

Achievements − Migration of actinides

In these experiments a cocktail containing actinides is added to the groundwater before pumping it through a longitudinal natural fracture in a drill core placed in CHEMLAB 2. The first experiment carried out in CHEMLAB 2 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 /Römer *et al*., 2002/.

The third actinide experiment in Äspö HRL was started at the end of 2002 and it is delayed and still under completion due to several technical problems with CHEMLAB 2.

2.4 Colloid Project

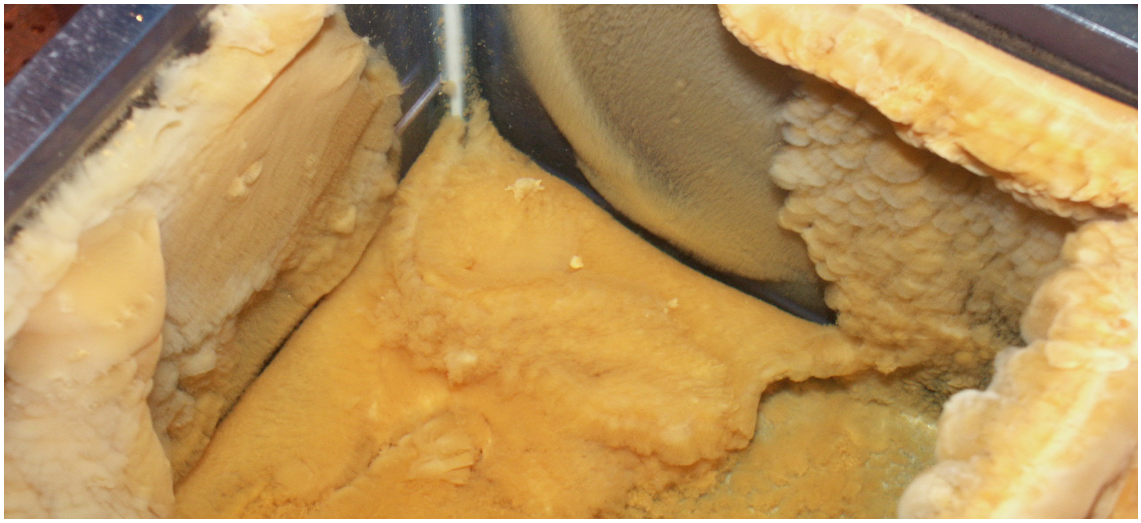


In the Colloid Project the concentration, stability, and mobility of colloids in the Äspö environment are studied. The project comprises studies of the potential of colloids to enhance solute transport and the potential of bentonite clay as a source for colloid generation. The Colloid Project includes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

Achievements

The final reporting of the laboratory experiments and the background measurements is ongoing. The laboratory experiments carried out in order to optimise the design of the "bentonite reactor" (filter textile with bentonite clay) to be used in the borehole specific measurements are finalized. The bore holes used in the borehole specific measurements are selected to cover the natural variation in the groundwater composition at Fenno-scandia. The necessary installations in the four bore holes along the Äspö tunnel and in the two bore holes at Olkiluoto in Finland have been finalised. During the measurements the groundwater is in contact with the bentonite clay adapted in the "bentonite reactor" in the bore hole and the colloid content in the water is measured prior and after it has been contact with the bentonite clay. The colloid content is measured by using conventional filtering and ultra filtration. According to present plans the measurements will be performed during January–April 2003.

2.5 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 aims are to study: bio-immobilisation of radionuclides, microbial effects on the chemical stability of deep groundwater environments, and microbial corrosion of copper.

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 tubing. Each bore hole has been equipped with a circulation system offering a total of 500 cm^2 of test surface.

Retention of naturally occurring trace elements in the groundwater by the BIOS (Biological Iron Oxide Systems) is investigated at a site at tunnel length 2200A m. There is a vault with a bore hole that delivers groundwater rich in ferrous iron and iron oxidizing bacteria. The bore hole 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 BIOS 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 BIOS channels at 2200 m.

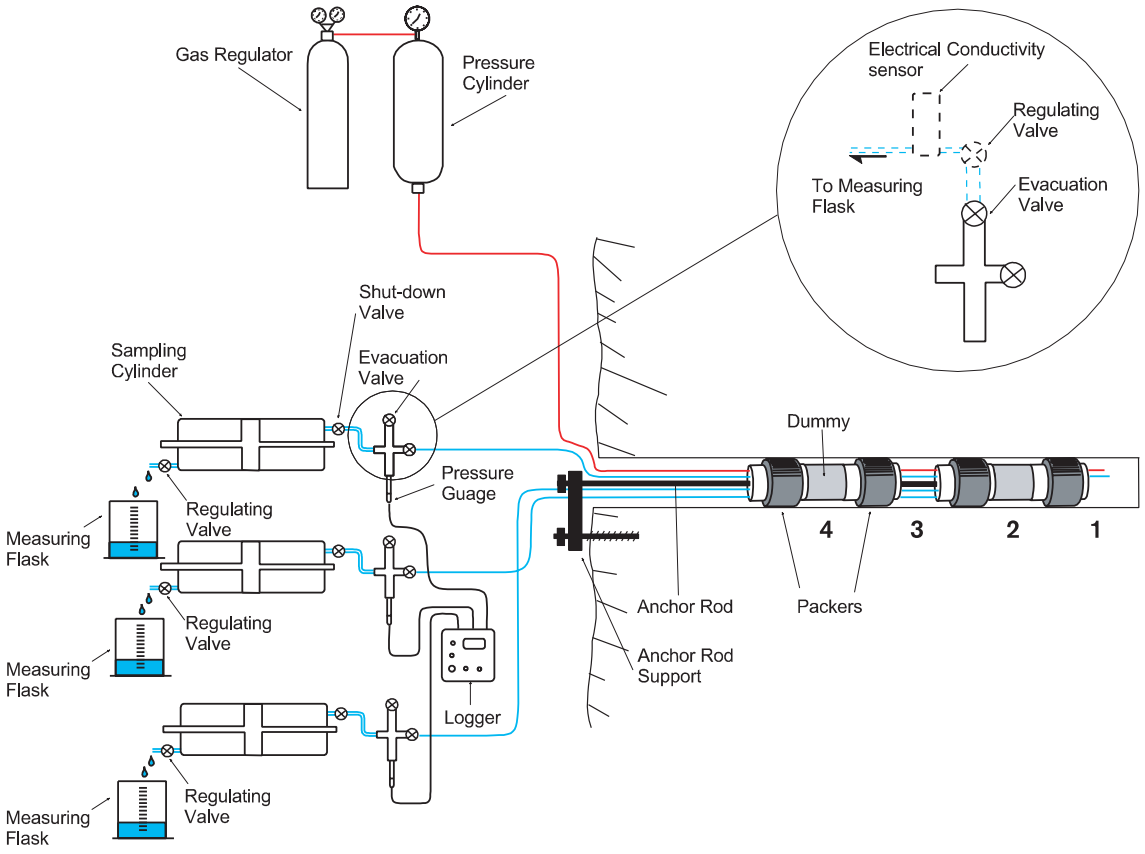
Achievements

A laboratory container has been installed with laboratory benches, an anaerobic gas box, and an advanced climate control system. The climate system did not function as expected from the beginning. The temperature, which should be 20 ± 1 °C, varied too much for the analysis instruments installed in the container. Large efforts have been spent to adjust the climate system.

In December a series of experiments, to study the microbial corrosion of copper in bentonite at *in situ* conditions, were started at the MICROBE 450 m site. The experiments are run at *in situ* pressure in groundwater with naturally occurring sulphate reducing bacteria (bore hole KJ0052F03).

The work performed to study the retention of naturally occurring trace elements in the groundwater by BIOS (Biological Iron Oxide System) is being summarised in a document that will be published. Parts of this work have been performed at 2200 m tunnel length and in the 907 m ditch.

2.6 Matrix Fluid Chemistry



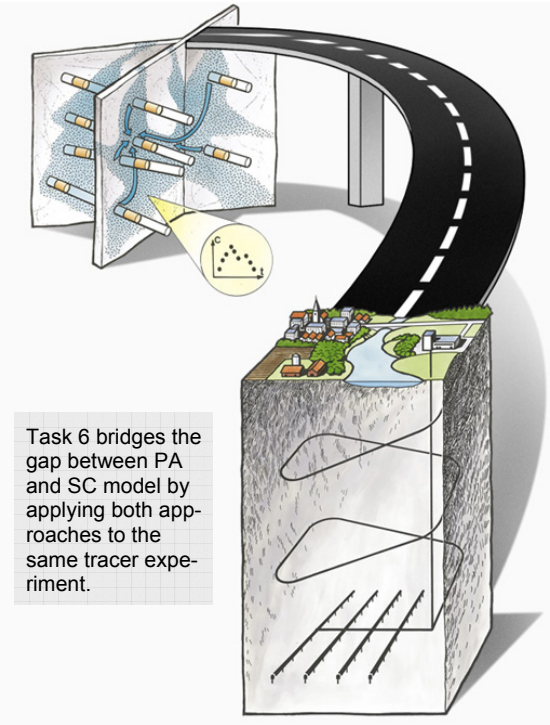
The main objectives of the Matrix Fluid Chemistry experiment are to understand the origin and age of fluids/groundwaters in the rock matrix pore space and in micro-fractures, and their possible influence on the chemistry of the groundwaters from the more highly permeable bedrock.

Matrix fluids are sampled from a bore hole 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

Achievements

The experimental part of the project is completed and the focus during 2002 has been on final reporting. The main issues during this time period have been working towards the completion of the reports, including two major Synthesis Reports and a first draft of the Final Report.

2.7 Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes



Task 6 bridges the gap between PA and SC model by applying both approaches to the same tracer experiment.

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

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

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

Achievements

In the Task Force work has been made on the following tasks during 2002:

Task 4: Tracer Retention and Understanding Experiment (TRUE), 1st stage.

Task 5: Coupling between hydrochemistry and hydrogeology.

Task 6: Performance Assessment Modelling Using Site Characterisation Data.

The modelling conducted within *Task 4* has been finalised and evaluated. The overall evaluation of Task 4 with the purpose to address understanding, methodologies and motivation/expectations from the viewpoint of the participating organisations is near to be complete and reported.

The modelling exercises within *Task 5* have been completed and the ten modelling teams have prepared modelling reports. Based on the modelling reports, work was made to compile results and summarise approaches, executions and conclusions of Task 5 into one summary report. Also, an evaluation of the task was initiated and performed by external reviewers. Preliminary outcomes from the summary work and the review are presented in Morosini /2002/.

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. The following specific modelling tasks have been defined:

Sub-task 6A Model and reproduce selected TRUE-1 tests with a PA model and/or a SC model to provide a common reference.

Sub-task 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.

Sub-task 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).

Sub-task 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.

Sub-task 6E This sub-task extends the sub-task 6D transport calculations to a reference set of PA time scales and boundary conditions.

The modelling work is completed for sub-tasks 6A and 6B. During 2002, work on modelling reports of sub-task 6A, B and B2 have been made by the modelling groups.

The work with sub-task 6C to construct the model is near to be completed. The developed model is to be used as input data to sub-task 6D.

2.8 Numerical Modelling of Groundwater Flow (NUMMOD)

The general objective of the NUMMOD project is to improve the concept and the numerical tool (DarcyTools) for modelling of flow and transport but also to update the regional and local scale groundwater flow models for the Äspö HRL.

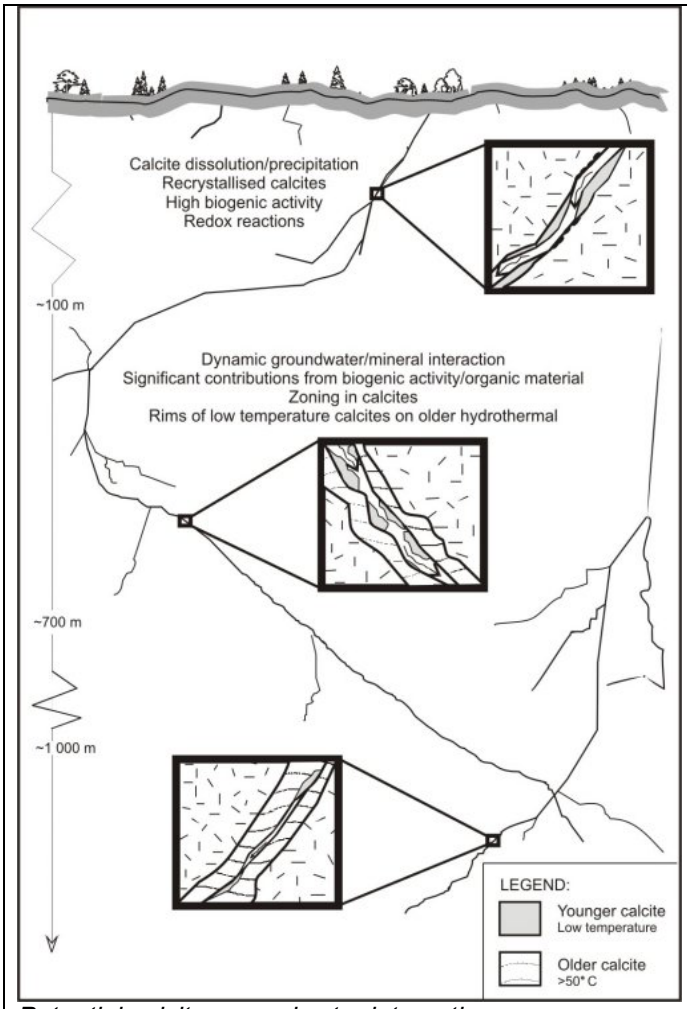
Achievements

DarcyTools version 1.0 was launched during 2002 and contains the major code development performed within Part 1 of NUMMOD. Part 1 of NUMMOD has been published in two reports:

- DarcyTools – Concepts, Method, Equations and Tests, version 1.0 (SKB TS-02-06).
- DarcyTools – Software description and documentation, version 1.0 (SKB TS-02-05).

The second part of the NUMMOD project will not be performed as planned. Instead, the development foreseen within NUMMOD Part 2 is now handled within the Safety and Technology and the Site investigations departments. However, some of the development and tests planned for NUMMOD Part 2 were already addressed within NUMMOD Part 1 during 2002. These activities primarily include an external assessment/review of version 1.0, development of user-friendly input/output interfaces, and additional verification and validation studies using version 1.0.

2.9 PADAMOT



Potential calcite-groundwater interaction at various depths at Äspö.

When the previous EQUIP project ended in 2000 /Bath *et al*., 2000/ there was a need for continued fracture mineral investigations and model testing of the obtained results and therefore a new EC-project was initiated in the beginning of 2002.This project is called PADAMOT (Palaeohydrogeological Data Analysis and Model Testing). The research being carried out is contributing to our understanding of the long-term safety of placing radioactive wastes in underground repositories.

PADAMOT 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.

Achievements

The present status is that the work has continued from the base created in the EQUIP study, with sample preparation and analyses of the samples from drill core KLX01. The basic idea behind the sampling/analysis programme is to distinguish and characterise the possible recent low temperature calcites and this is made by using stable isotope analyses, microscopy and trace element analyses.

The KLX01 bore hole is situated on the mainland (Laxemar) west of the location for the Äspö HRL. Compared with the fracture calcite samples taken from drill cores from Äspö the fracture samples from the KLX01 drill core reflect a deeper influx of meteoric water and past melt water.

In 2–3th of October a workshop was held in Brussels on the theme of Palaeohydrogeology organised by the PADAMOT co-ordinators. In addition to a good discussion about how to optimise palaeohydrogeological investigations the workshop provided possibilities for knowledge exchange, which was acknowledged.

The work performed during 2002, the first year of PADAMOT, has been reported to the EC-project co-ordinator.

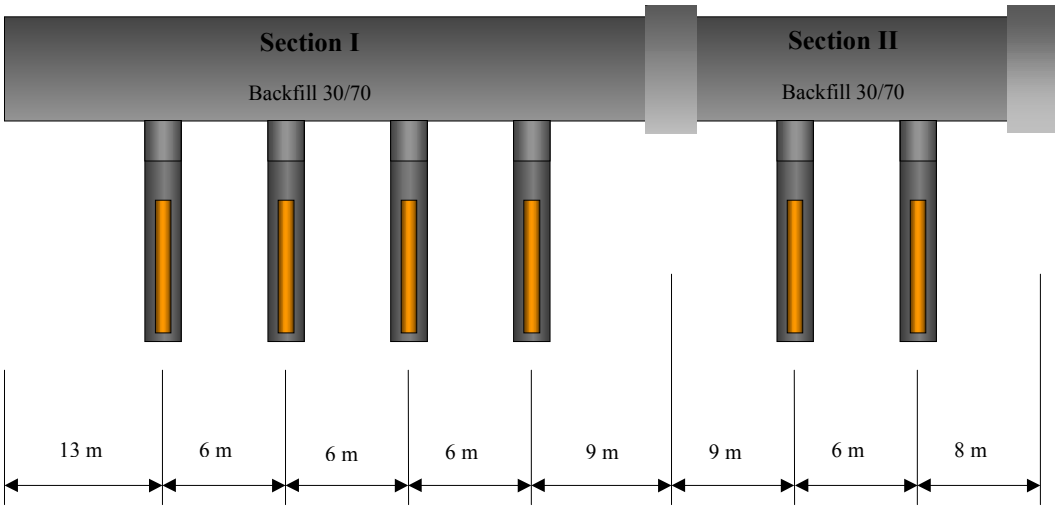
3 Disposal technology

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

3.1 Demonstration of repository technology

The project Demonstration of repository technology provides a full-scale example of canister emplacement under radiation-shielded conditions and works with testing of canister handling in full size deposition holes. Testing and demonstration of the deposition process is ongoing, e.g. in the Prototype Repository. The whole system of different machines and equipment needed in a deep repository will be identified and developed to a feasibility stage as part of the ongoing design studies of the deep repository.

3.2 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.

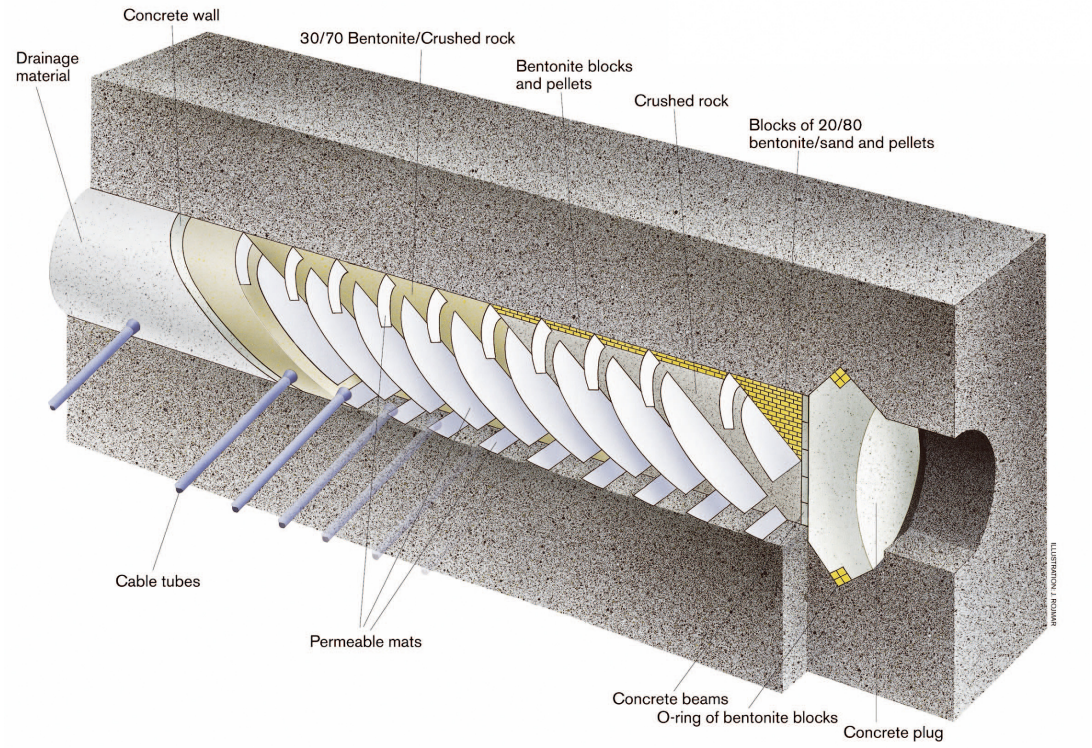
Instrumentation is used to monitor processes and properties in the canister, buffer material, backfill, and the near-field rock.

Achievements

The inner section was installed and the plug cast in 2001 and the heaters were turned on one by one. Since then the temperature, total pressure, pore pressure, relative humidity and resistivity in buffer and backfill is measured and registered to study the ongoing THM-processes.

In early 2002 a malfunction in the electrical insulation in the heaters to all four canisters was discovered and the installation of the two canisters in the outer section was post-poned. The malfunction has now been dissolved and the installation of the outer section is ready to start.

3.3 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. It is a test of the integrated function of the backfill material and the near-field rock in a deposition tunnel excavated by blasting. 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 (0/100) and bentonite blocks and pellets at the roof. The test is also a test of the hydraulic and mechanical functions of a concrete plug.

The entire test set-up with backfill, instrumentation and building 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 than.

Achievements

Wetting of the backfill from the filter mats and the rock has continued. The water pressure in all filters was increased in steps of 100 kPa to 500 kPa from October 2001 to January 2002. The water pressure in the permeable mats and the drained inner part of the drift has been kept constant at 500 kPa during the entire quarter. Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured and recorded. A data report up to 2003-01-01 /Goudarzi *et al*., 2003a/ has been released.

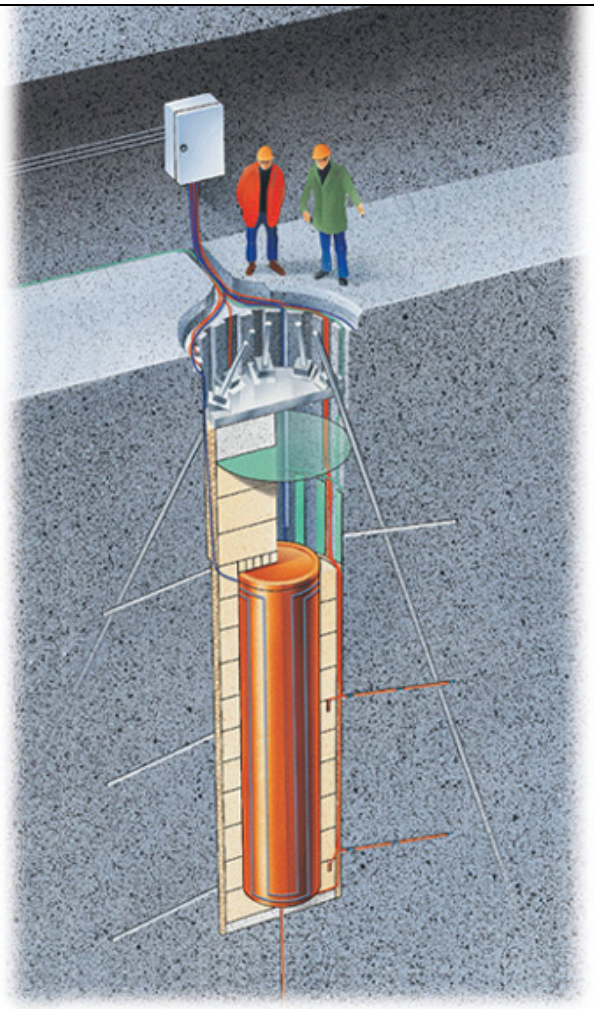
Planned work

According to the measured data the entire backfill seems to be completely water saturated which means the flow testing will start in 2003 as planned. The strategy of the flow testing is in the first phase to successively decrease the water pressure in the mat sections starting with the mat at the plug. The flow from the mat section that still has 500 kPa pressure and the flow into the neighbouring mat section where the pressure just has been decreased will be measured. The water pressure must be kept equal in all three

mats in each mat section in order to prevent water flow between the mats in a section. 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 flow to and from the two mats sections surrounding the tested backfill section will be measured separately in the three mats in the mat layers. If the measurements indicate that large air pockets are present in the backfill or mats it may be necessary to increase the water pressure in the mats to 1–2 MPa in order to reduce the influence of enclosed air.

3.4 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 also 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 during 2000, the hole was sealed with a plug, heater turned on and artificial water supply to saturate the buffer started.

Achievements

A large number of parameters are measured during the test to provide a basis for the modelling purposes. A data report covering the period up to 2002-11-01 /Goudarzi *et al.*, 2003b/ has been released. An example of measured data is shown in Figure 3-1 where the relative humidity in the buffer along one line on top of the canister is shown. 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 and the total pressure has not reached the expected values yet. Entrapped air and clogging of the filters may explain the inhomogeneous appearance. The filters are now flushed regularly in order to avoid such effects.

Planned work

The artificial water saturation of the bentonite will be continued and the power of the canisters maintained at 2100 W, which is a reduction compared to the originally planned 2600 W.

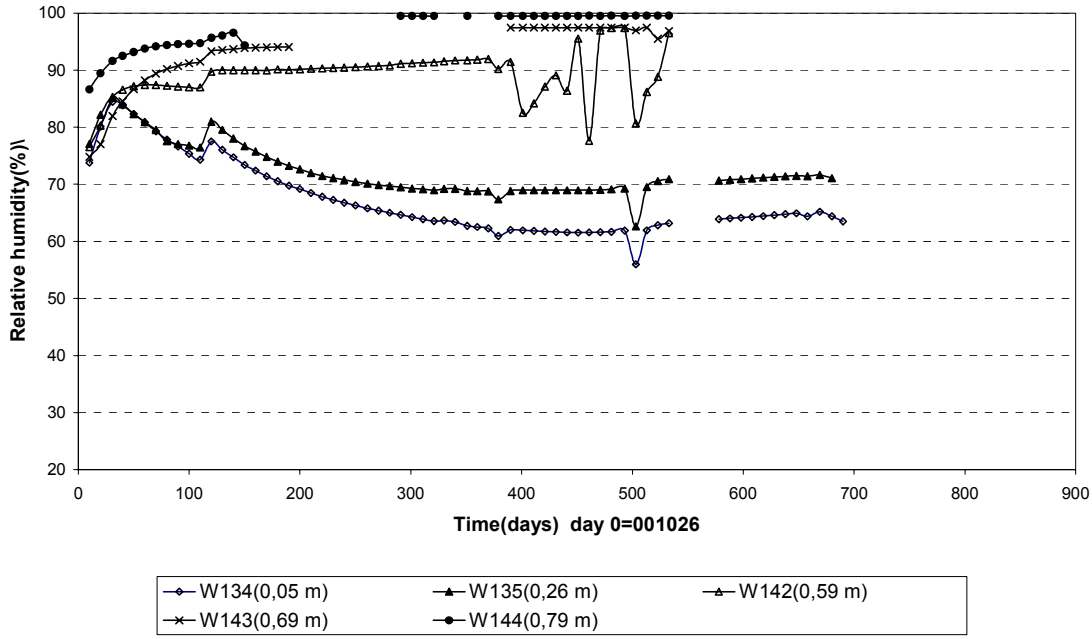
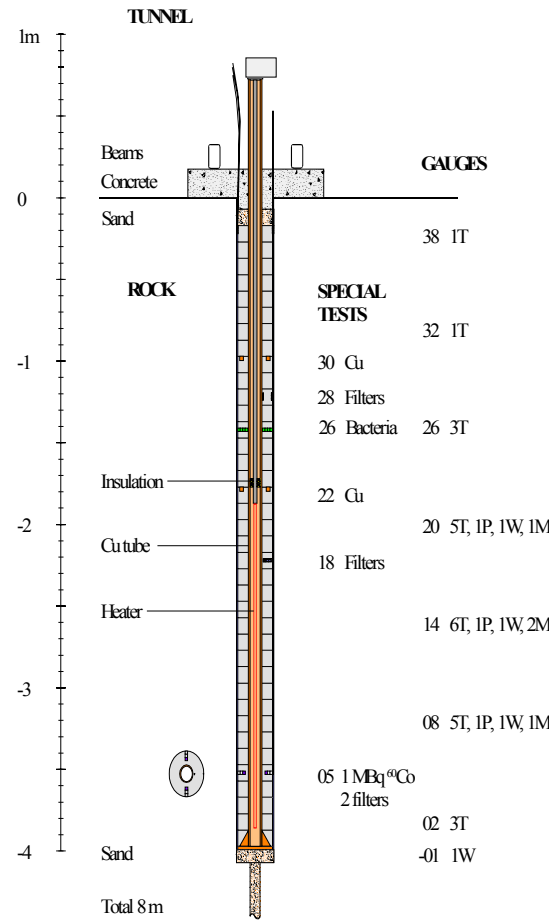


Figure 3-1. *Relative humidity in buffer as a function oft the time from start. The sensors are located at the top of the canister along the same radial line (distance to the centreline within parenthesis).*

3.5 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 and of related processes such as bentonite degradation, microbiology, copper corrosion and gas transport in buffer material under conditions similar to those expected in a repository. Five 300 mm diameter test holes 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 planned to run for at least five years.

Achievements

The analysing work with material from the one-year parcel A0 is almost completed and the results are presently being reported.

A large number of tests and analyses concerning physical properties have been made. The results show that the clay material was not fully water saturated and the water ratio and bentonite density decrease from the rock to the warmest parts. Swelling pressure and hydraulic conductivity measurements show no sign of deterioration of the sealing properties.

The distribution of radioactive tracers (^{57}Co and ^{134}Cs) was measured at the Nuclear Chemistry department at KTH, Stockholm, and the results are in accordance with previous laboratory and CHEMLAB field-test results.

The clay and pore water analyses made at Reactor department at VTT, Helsinki, shows minor cation exchange reactions, minor redistribution of original ions and pH changes in the range of 7 to 9.

The analyse results from the A0 parcel have been used for modelling the chemical and mineralogical evolution in the buffer by Enviros, Barcelona. The modelling was made by use of a transport code coupled with a geochemical code (PHAST) and was aimed at improving previous modelling by taking the prevailing temperature gradient into account.

Corrosion of embedded copper coupons was analysed by Rosborg Consulting/Studsvik Material, Nyköping, and shows an average corrosion rate of less than 4 µm per year, which is the same value as was found for the pilot test parcel (S1).

The remaining ongoing four long-term test parcels have functioned well, and temperature, total pressure, water pressure and water content have been continuously measured and registered every hour. The bentonite swelling pressure is still increasing in all parcels, although the tests have been running for more than 3 years, showing that water uptake is still ongoing (Figure 3-2).

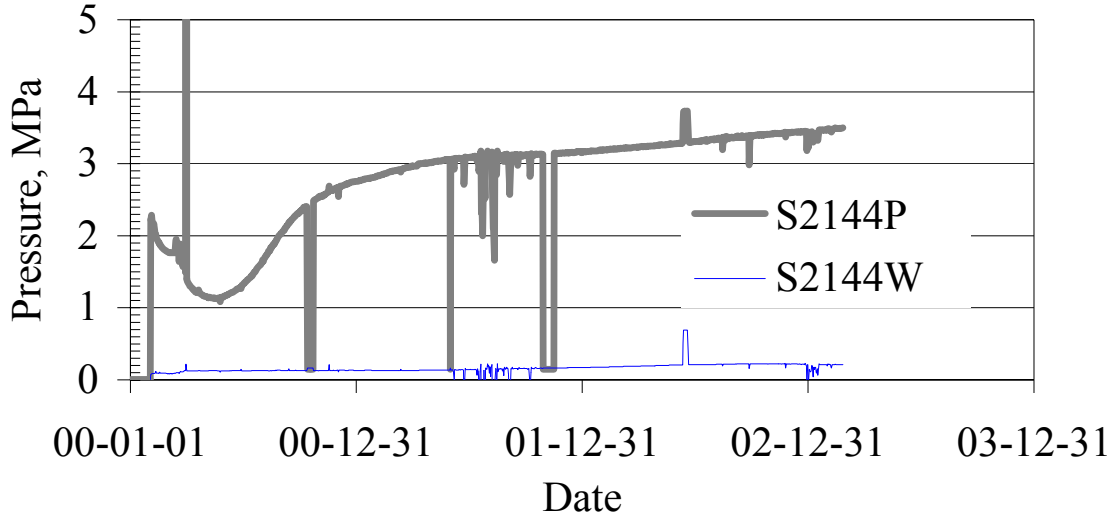
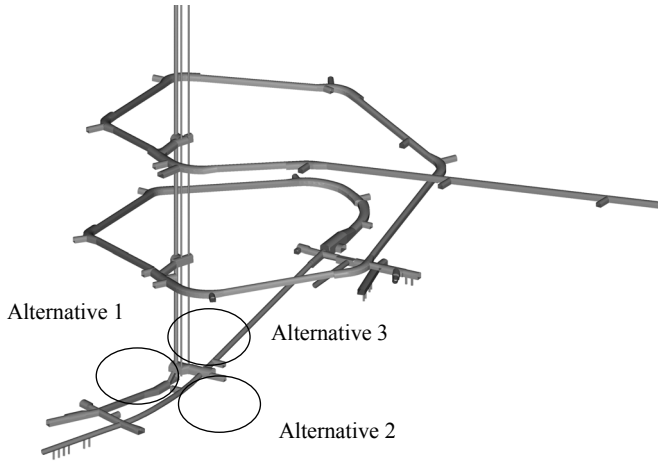


Figure 3-2. *Measured total pressure (upper curve) and water pressure in warmest part of parcel S2 from test start. No water pressure build-up is expected before full swelling pressure is reached.*

3.6 Äspö Pillar Stability Experiment



A Pillar Stability Experiment has been initiated 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.

A new short tunnel will be excavated in Äspö HRL to ensure that the experiment is carried out in a rock mass with a virgin stress field. The presently preferred site at the 450 m level is Alternative 3 in the figure above.

The pillar will be created between two vertical holes drilled in the floor of the tunnel. When the pillar is heated spalling will occur.

Achievements

A feasibility study has been performed in which the location of the new tunnel and the general design of the experimental area have been studied. Three different sites have been studied at the 450 m level. The sites have been evaluated from a practical point of view and with quite extensive geological and hydrogeological characterization in four new core bore holes. The preferred site for the experiment is shown above.

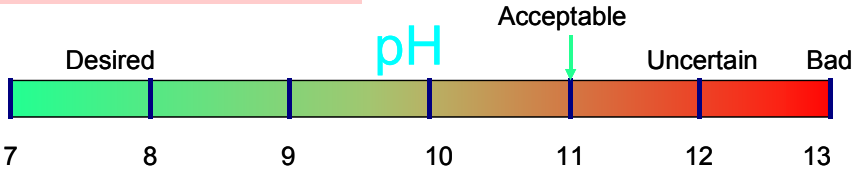
Predictive modelling has been performed with different codes: FRAC3D (coupled tree-dimensional TM-modelling), FRACOD (two-dimensional fracture stability modelling, and JobFem (coupled two-dimensional TM-modelling).

A liner which is intended to simulate the confining pressure in the backfill has been delivered.

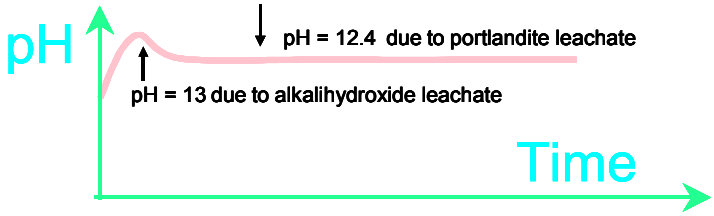
Work with six reports describing the work performed during 2002 (IPR-reports) is ongoing.

3.7 Low-pH cementitious products

SAFETY ASSESSORS' VIEW ON pH



PRINCIPLES FOR pH-EVOLUTION FOR STANDARD CEMENT

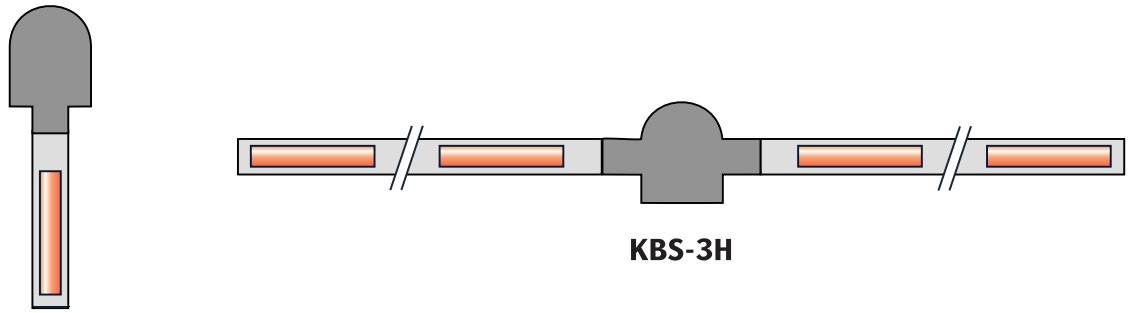


A project concerning the use of low-pH cementitious products in the deep repository started in 2001 as a co-operation between SKB, Posiva, and NUMO. The objectives of the project are to develop recipes for cementitious products to be used as grouting and mortar for anchoring of rock bolts and to demonstrate the usage of these products in small field experiments in Äspö HRL.

Achievements

It has been more difficult than expected to find suitable injection grouts giving leachates with pH below 11. A small field test that was planned to take place during 2002 has been cut out from the project and the focus is put on finding suitable recipes for injection grouts. It seems possible to grout fracture apertures down to approximately 100 μm with cement based low-pH grouts. Finer fractures need other grouts, where silica sol and periclase (MgO) are strong candidate materials.

3.8 KBS-3 method with horizontal emplacement



KBS-3V

The possibility to modify the reference KBS-3 method and make serial deposition of canisters in long horizontal drifts instead of vertical deposition of single canisters in the deposition hole is studied in this project.

One reason for proposing the change is that the deposition tunnels 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. Another reason is that it is easier to verify the quality of the near zone around the canister when the bentonite and the canister is assembled into a prefabricated disposal container in a reloading station.

Late 2001 SKB published an R&D programme for KBS-3H /SKB, 2001b/, a variant of KBS-3 with horizontal emplacement of the canisters. The R&D programme is divided into four parts: Feasibility study, Basic design, Construction and testing at the Äspö HRL, and Evaluation.

Achievements

The Feasibility Study was finalised in October 2002 and reported to the SKB board in November. The results show that the KBS-3H concept is worth further development from a technical, economical, and long-term safety point of view.

A decision to continue work within the R&D-programme was taken by the SKB board in December 2002 and the next phase is the Basic Design. One important part of the Basic Design is to select a site in Äspö HRL where demonstration deposition drifts can be excavated. Other parts of Basic design include equipment for construction of deposition drifts and handling of the disposal container. The Project is carried out in co-operation with Posiva.

3.9 Cleaning and sealing of investigation bore holes

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

The first phase of this project comprises identification of available techniques, complementary laboratory experiments with potential sealing materials, and investigations of the status of two bore holes at Äspö.

The two bore holes are planned to be used for the demonstration of cleaning techniques, i.e. removing of lost equipment in the holes.

Achievements

The first Phase of this project is about to be completed. A state of the art report summarising the developments of the sealing and cleaning techniques during the last 10–15 years has been put together. The report will be reviewed in the beginning of 2003 and printed thereafter. In addition, data from the two potential bore holes (KAS 06 and KAS 07) has been gathered to find out where in the holes the field tests can be performed.

The planning for a seminar that will be held in 27 February 2003 is ongoing. The seminar will be attended by representatives from the oil industry.

The first Phase will be followed by a second Phase, for which a project plan will be established during next year.

3.10 Task Force on Engineered Barrier Systems

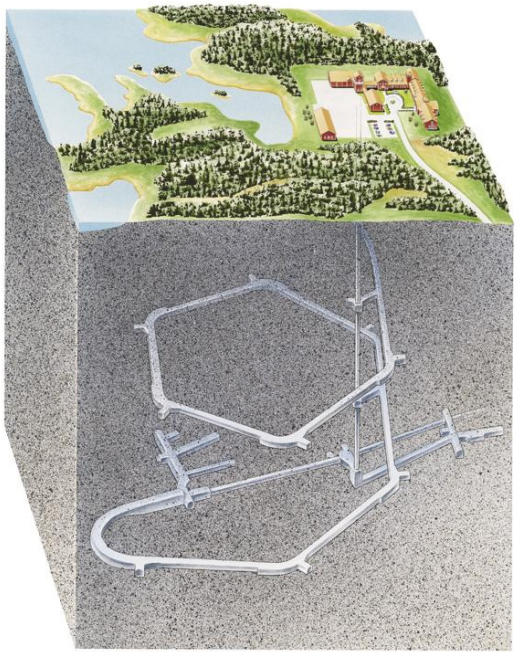
A Task Force on Engineered Barrier Systems has been initiated. The preparatory workshop suggested that the prior focus should be on the water saturation process in buffer, backfill and near-field rock. Since the water saturation process is also a part of the modelling work in the Prototype Repository, the work of the Task Force was consequently linked together with modelling work within the EC-project concerning the Prototype Repository.

No meeting has been held during this time period and the work with the Work Packages proceeds according to plans.

4 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.

4.1 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 underground laboratory.

Achievements

Maintenance and operation of the above and underground facilities are running as well as safety and work environment activities. The availability in the underground-related systems (ventilation, hoist, lightning, pumps etc) has been high, about 98%, during the fourth quarter.

Some road works between Ävrö Village and the bridge over Lindströmmen have been carried out which now are completed.

The extension of the office space in the Ventilation building is progressing. The house walls were in place in the middle of October and the work with the completion of the interior is progressing according to plans.

The automatic registration and object-monitoring system has been installed but is unfortunately not yet in operation since there has been problems with the soft- and hardware as well as the system interfaces. A number of measures is in progress.

4.2 Hydro Monitoring System

The Hydro Monitoring System (HMS) collects data on-line of groundwater head, salinity, electrical conductivity of the water in some borehole sections, and Eh and pH in some other bore holes. The data are recorded by more than 400 transducers installed in bore holes on Äspö as well as in bore holes located in the tunnel. Similar system will be set up at candidate sites for the deep repository. 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 annually. This work involves comparison with groundwater levels checked manually in percussion drilled bore holes and in core drilled bore holes, in connection with the calibration work.

Achievements

The Hydro Monitoring System (HMS) has been performing well and no main maintenance activity has taken place.

4.3 Programme for monitoring of groundwater head and flow

The monitoring of water levels started in 1987 while the computerised HMS was introduced in 1992. The number of bore holes included in the network has gradually increased. The tunnel excavation started in October 1990 and the first pressure measurements from tunnel drilled bore holes were included in the HMS in March 1992.

To date the monitoring network comprises bore holes of which many are equipped with hydraulically inflatable packers, measuring the pressure by means of transducers. The measured data are relayed to a central computer situated at Äspö village through cables and radio-wave transmitters. Once a year the data are transferred to SKB's site characterisation database, SICADA. Manual levelling is also obtained from the surface bore holes on a regular basis. Water seeping through the tunnel walls is diverted to trenches and further to 21 weirs where the flow is measured. The scope of maintaining such a monitoring network has scientific as well as legal grounds.

Achievements

The monitoring points from the previous year have been maintained and no additional points are planned during 2002. The system will continue to support the experiments undertaken and meet the requirements stipulated by the water rights court.

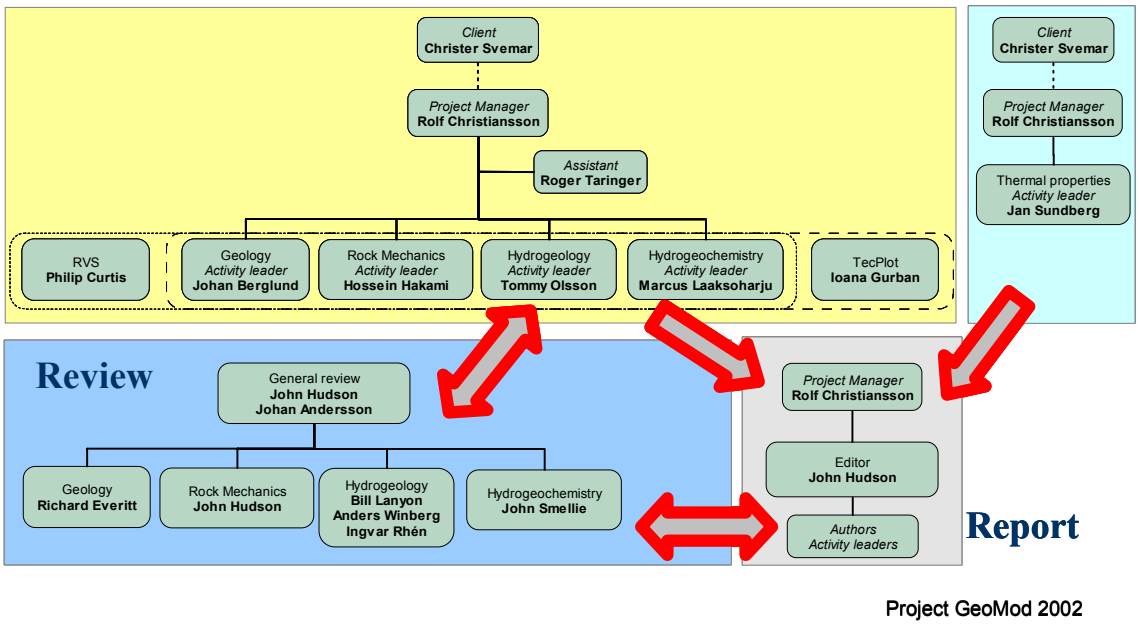
4.4 Programme for monitoring of groundwater chemistry

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 hydrochemical 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 monitoring points from the previous year have been maintained and a few additional points have been applied for 2002. The sampling took place in September 2002 and apart from a couple of points with too low fluidity the planned programme proceeded without any problems.

4.5 Geo-scientific modelling



Project GeoMod 2002

In the GeoMod project existing geological, geomechanical, hydrogeological and hydro-geochemical models of Äspö will be updated by integration of data collected since 1995. The different geoscientific models will also be integrated. A major part of the new data has been collected in the lower part of the Äspö HRL during the operational phase.

The updated models focus on a volume including the tunnel spiral volume from about 340 m to about 500 m.

In addition, the development of a geothermal model will be integrated in the project. This issue has earlier been run as a separate project.

Achievements

The models within each geo-scientific discipline have been assessed and results from the different projects conducted at Äspö has been utilised to modify or update the models. Draft reports are available from most of the geo-scientific disciplines.

A methodology for the integration of the different models has been developed where modelling results obtained in the different geo-scientific disciplines are compared.

5 International co-operation

Eight organisations from seven countries (see list below) are participating in the co-operation at Äspö HRL during 2002. Most of the 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.

International participation in Äspö HRL projects during 2002

Projects	ANDRA	BMWA	ENRESA	JNC	CRIEPI	NAGRA	Posiva	Sandia
Natural barriers								
Tracer Retention Understanding Experiments	X		X	X			X	
Radionuclide Retention Experiments		X						
Colloid Project		X					X	
Microbe Project		X						
Matrix Fluid Chemistry						X	X	
Task Force on Modelling of Groundwater Flow and Transport of Solutes	X	X	X	X	X	X	X	X
Technology								
Prototype Repository (EC-project)	X	X	X	X	X		X	
Backfill and Plug Test			X					
Long Term Test of Buffer Material							X	
Low-pH cementitious products							X	
KBS-3 method with horizontal emplacement							X	
Äspö Pillar Stability Experiment							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.

Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, NAGRA, Switzerland

Posiva, Finland.

USDOE Carlsbad Field Office/Sandia National Laboratories, USA

EC-projects

SKB is through Repository Technology co-ordinating three EC contracts: Prototype Repository, Cluster Repository Project (CROP) and the project NET.EXCEL. SKB takes part in several EC-projects of which the representation is channelled through Repository Technology in five cases: FEBEX II, BENCHPAR, ECOCLAY II, SAFETI and PADAMOT.

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 – 2003-12-31)

Co-ordinator: Empresa Nacional de Residuos Radiactivos, Spain

Participating countries: Belgium, Czech Republic, Finland, France, Germany, Spain, Sweden, and Switzerland

BENCHPAR – Benchmark tests and guidance on coupled processes for performance assessment of nuclear repositories (2000-10-01 – 2003-09-30)

Co-ordinator: Royal Institute of Technology (Dep. of Civil and Environmental Engineering), Sweden

Participating countries: Finland, France, Spain, Sweden and United Kingdom

ECOCLAY II – Effects of cement on clay barrier performance, phase II (2000-10-01 – 2003-09-30)

Co-ordinator: National Radioactive Waste Management Agency of France

Participating countries: Belgium, Finland, France, Germany, Spain, Sweden, Switzerland and United Kingdom

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 (2001-11-01 – 2004-11-01)

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 (2002-11-01–2004-01-31)

Co-ordinator: Swedish Nuclear Fuel and Waste Management Co, Sweden

Participating countries: Belgium, Finland, France, Germany, Spain, Sweden, Switzerland, and United Kingdom

6 Documentation

During the period October-December 2002, the following reports have been published and distributed.

6.1 Äspö International Progress Reports

Hermansson J, 1998. TRUE Block Scale project. October 1997 structural model; Update using characterisation data from KA2511A and KI025F.
SKB IPR-01-41. Svensk Kärnbränslehantering AB.

Hermansson J, 1998. TRUE Block Scale project preliminiary characterisation stage. September 1998 structural model; update using characterisation data from KI0023B.
SKB IPR-01-42. Svensk Kärnbränslehantering AB.

Adams J, 1998. TRUE Block Scale experiment. Preliminary results of selective pressure build-up tests in borehole KI0023B.
SKB IPR-01-43. Svensk Kärnbränslehantering AB.

Andersson P, Ludvigsson J-E, Wass E, 1998. TRUE Block Scale project. Preliminary characterisation stage. Combined interference tests and tracer tests. Performance and delivery evaluation.
SKB IPR-01-44. Svensk Kärnbränslehantering AB.

Gentzschein B, Morosini M, 1998. TRUE Block Scale project. Selective pressure build-up tests in borehole KI0025F.
SKB IPR-01-45. Svensk Kärnbränslehantering AB.

Rouhiainen H, 1998. TRUE Block Scale Project. Difference flow measurements in borehole KI0025F02 at the Äspö Hard Rock Laboratory.
SKB IPR-01-46. Svensk Kärnbränslehantering AB.

Ludvigson J-E, 1999. TRUE Block Scale Project. Preliminary characterization. Combined interference tests and tracer tests. Appendix volume - Evaluation plots.
SKB IPR-01-47. Svensk Kärnbränslehantering AB.

Rouhiainen P, Heikkinen P, 1999. TRUE Block Scale Project. Difference flow measurements in boreholes KA2563A and KA2511A at the Äspö HRL.
SKB IPR-01-48. Svensk Kärnbränslehantering AB.

Andersson P, 1999. TRUE Block Scale Project. Analysis of needs for re-instrumentation of boreholes KA2511A, KA2563A and KI0025F.
SKB IPR-01-49. Svensk Kärnbränslehantering AB.

Holton D, 1999. TRUE Block Scale Project. Boundary conditions for submodels at the Äspö TRUE Block Scale site. WBS 3.2.3.2.
SKB IPR-01-50. Svensk Kärnbränslehantering AB.

Gómez-Hernández J J, Hendricks Franssen H-J, 1999. TRUE Block Scale stochastic continuum modeling. Model assessment and first conditional model.
SKB IPR-01-51. Svensk Kärnbränslehantering AB.

Andersson P, Ludvigsson J-E, Wass E, Holmqvist M, 1999. TRUE Block Scale. Detailed characterisation stage. Interference tests and tracer tests PT-1 - PT-4.
SKB IPR-01-52. Svensk Kärnbränslehantering AB.

Doe T, 1999. TRUE Block Scale project. Reconciliation of the March '99 structural model and hydraulic data.
SKB IPR-01-53. Svensk Kärnbränslehantering AB.

Winberg A, 1999. TRUE Block Scale project. Tracer test stage. Strategy for predictive modelling of transport of sorbing tracers in a fracture network.
SKB IPR-01-54. Svensk Kärnbränslehantering AB.

Rouhiainen P, Pöllänen J, 1999. TRUE Block Scale project. Difference flow measurements in borehole KI0025F03 at the Äspö HRL.
SKB IPR-01-55. Svensk Kärnbränslehantering AB.

Adams J, Andersson P, Meier P, 1999. TRUE Block Scale experiment. Preliminary results of selective pressure build-up tests in borehole KI0025F02.
SKB IPR-01-56. Svensk Kärnbränslehantering AB.

Andersson P, Ludvigsson J-E, 1999. Tracer dilution tests during pumping in borehole KI0023B and short-term interference tests in KI0025F02 and KA3510A.
SKB IPR-01-57. Svensk Kärnbränslehantering AB.

Gentzschein B, Ludvigsson J-E, 2000. Single-hole hydraulic tests and short-term interference tests in KI0025F03.
SKB IPR-01-58. Svensk Kärnbränslehantering AB.

Cruz B de la, Fernández A M, Rivas P, Cózar J, Labajo M A, 2000. TRUE Block Scale Experiment. Tracer tests stage. Mineralogical and geochemical analyses of fracture filling materials (gouge and coutings) from drillcore samples.
SKB IPR-01-59. Svensk Kärnbränslehantering AB.

Goudarzi R, Börgesson L, Röshoff K, Bono N, 2002. Sensors data report (Period: 001026-020501) Canister retrieval test Report No:4.
SKB IPR-02-35. Svensk Kärnbränslehantering AB.

Dershowitz B, Uchida M, Shuttle D, Fox A, 1998. Preliminary 2 km scale modelling of geochemical pathways Äspö HRL, Äspö Sweden Task 5.
SKB IPR-02-36. Svensk Kärnbränslehantering AB.

Dershowitz B, Shuttle D, Klise K, Uchida M, Metcalfe R, Cave M, 2000. Fracman modelling of geochemical end-member transport patways Äspö HRL, Äspö Sweden Task 5.
SKB IPR-02-37. Svensk Kärnbränslehantering AB.

Wendling J, 2000. Hydrogeological and hydrochemical impact of the tunnel and shaft construction in the Äspö site. Phase 2 Task 5. concentration prediction and optimisation using concentration data.
SKB IPR-02-38. Svensk Kärnbränslehantering AB.

Grenier C, Benet L-V, 2000. Groundwater flow and solute transport modelling with support of chemistry data. Task 5.
SKB IPR-02-39. Svensk Kärnbränslehantering AB.

Billaux D, Paris B, 2001. Äspö HRL Task Force on numerical modelling Task 5. coupling geochemistry and transport.
SKB IPR-02-40. Svensk Kärnbränslehantering AB.

Luukkonen A, Kattilakoski E, 2001. Groundwater flow, mixing and geochemical reactions at Äspö HRL. Task 5. Äspö Task Force on groundwater flow and transport of solutes.
SKB IPR-02-41. Svensk Kärnbränslehantering AB.

Liedtke L, Klennert N, 2001. Modelling the hydraulic regime in the fracture system at the Äspö HRL on the basis of hydrochemical measurements. Task 5. Äspö Task Force on groundwater flow and transport of solutes.
SKB IPR-02-42. Svensk Kärnbränslehantering AB.

Molinero J, Samper J, Juanes R, 2001. Impact of the tunnel construction on the groundwater at Äspö. Task 5. Numerical modelling of the transient groundwater flow and conservative solute transport during the construction (1990/10/01-1997/01/01).
SKB IPR-02-43. Svensk Kärnbränslehantering AB.

Hasegawa T, Tanaka Y, Mahara Y, Igarashi T, 2001. Dynamic changes of groundwater flow and geochemical distribution during tunnel construction. Modelling Task 5. Impact of the tunnel construction on the groundwater system at Äspö, a hydrogeological - hydrochemical model assessment exercise.
SKB IPR-02-44. Svensk Kärnbränslehantering AB.

Svensson U, Laaksoharju M, Gurban I, 2002. Impact of the tunnel construction on the groundwater system at Äspö. Task 5, Äspö Task Force on groundwater flow and transport of solutes.
SKB IPR-02-45. Svensk Kärnbränslehantering AB.

Källgården J, Andersson P, Holmqvist M, 2001. True-1 Continuation project. History and current status on flow, pressure, water chemistry and installations at the True-1 site.
SKB IPR-02-46 . Svensk Kärnbränslehantering AB.

Andersson P, Wass E, Gröhn S, Holmqvist M, 2002. TRUE-1 Continuation projekt. Complementary investigations at the TRUE-1 site- Crosshole interference, dilution and tracer tests, CX-1 - CX-5.
SKB IPR-02-47. Svensk Kärnbränslehantering AB.

Mærsk Hansen L, Hermansson J, 2002. Äspö HRL Local model of geological structures close to the F-tunnel.
SKB IPR-02-48. Svensk Kärnbränslehantering AB.

Hardenby C, 2002. Äspö HRL. Tunnel for the canister retrieval test. Geological mapping of tunnel and deposition holes.
SKB IPR-02-49. Svensk Kärnbränslehantering AB.

Johannesson L-E, Börgesson L, 2002. Laboratory test on Friedland Clay. Friedland Clay as backfill material. Results of laboratory tests and swelling/compression calculations.
SKB IPR-02-50. Svensk Kärnbränslehantering AB.

Nilsson U R C, 2002. Inventory of instrumentation used in Äspö HRL.
SKB IPR-02-51. Svensk Kärnbränslehantering AB.

Gunnarsson D, 2002. Comparison between density measurements obtained with a nuclear meter and mass/volume determination.
SKB IPR-02-52. Svensk Kärnbränslehantering AB.

Goudarzi R, Börgesson L, 2002. Sensors data report (Period: 010917-020601) Prototype Repository Report No:2.
SKB IPR-02-53. Svensk Kärnbränslehantering AB.

Goudarzi R, Gunnarsson D, Johannesson L-E, Börgesson L, 2002. Backfill and Plug Test. Sensors data Report (Period 990601-020701) Report No:5.
SKB IPR-02-54. Svensk Kärnbränslehantering AB.

Pöllänen J, Rouhiainen P, 2002. Difference flow measurements in boreholes KA3386A01, KF0066A01 and KF0069A01 at the Äspö HRL.
SKB IPR-02-55. Svensk Kärnbränslehantering AB.

6.2 Technical Documents and International Technical Documents

1 Technical Document

No International Technical Document

7 References

Andersson P, Byegård J, Dershowitz B, Doe T, Hermansson J, Meier P, Tullborg E-L, Winberg A (ed), 2002a. Final report of the TRUE Block Scale project. 1. Characterisation and model development.
SKB TR-02-13. Svensk Kärnbränslehantering AB.

Andersson P, Byegård J, Winberg A, 2002b. Final report of the TRUE Block Scale project. 2. Tracer tests in the block scale.
SKB TR-02-14. Svensk Kärnbränslehantering AB.

Bath A, Milodowsk, A, Ruotsalainen P, Tullborg E-L, Cortés Ruiz A, Aranyossy J-F, 2000. Evidence from Mineralogy and Geochemistry for the Evolution of Groundwater Systems During the Quaternary for Use In Radioactive Waste Repository Assessment (EQUIP Project). Final Report, Contract No FI4W-CT96-0031. Euratom/EC-DG-Research, Report EUR 19613EN. 157 pp. European Commission, Luxembourg.

Byegård J, 2002a. TRUE Block Scale experiment, Phase C.
SKB IPR-02-69, Svensk Kärnbränslehantering AB.

Byegård J, 2002b. Some method developments, preliminary measurements, and laboratory experiments.
SKB IPR-02-68, Svensk Kärnbränslehantering AB.

Goudarzi R, Gunnarsson D, Johannesson L-E, Börgesson L, 2003a. Backfill and Plug Test. Sensors data report (Period 990601-030101). Report No:6.
SKB IPR-03-14. Svensk Kärnbränslehantering AB.

Goudarzi R, Börgesson L, Röshoff K, Bono N, 2003b. Canister Retrieval Test. Sensors data report (Period 001026-021101). Report no 5.
SKB IPR-03-08. Svensk Kärnbränslehantering AB.

Morosini M, 2002. Äspö Task Force on modelling of groundwater flow and transport of solutes. Proceedings from the 15th Task Force meeting at Goslar, Germany, September 11-13, 2001.
SKB IPR-02-07. Svensk Kärnbränslehantering AB.

Poteri A, Billaux D, Dershowitz W, Gómez-Hernández J J, Cvetkovic V, Hautojärvi A, Holton D, Medina A, Winberg A (ed), 2002. Final report of the TRUE Block Scale projekt. 3. Modelling of flow and transport.
SKB TR-02-15. Svensk Kärnbränslehantering AB.

SKB, 2001a. RD&D-Programme 2001. Programme for research, development and demonstration of methods for the management and disposal of nuclear waste.
SKB TR-01-30. Svensk Kärnbränslehantering AB.

SKB, 2001b. Forsknings-, utvecklings- och demonstrationsprogram för ett KBS-3-förvar med horisontell deponering.
SKB R-01-55. Svensk Kärnbränslehantering AB.

SKB, 2002. Äspö Hard Rock Laboratory. Planning Report for 2002.
SKB IPR-02-25. Svensk Kärnbränslehantering AB.

Römer J, Kienzler B, Vejmelka P, Soballa E, Görtzen A, Fuss M, 2002. Actinide Migration experiment in the HRL Äspö, Sweden: Results of laboratory and *in situ* experiments (Part II).
WB-FZKA 6770, October 2002, FZK-INE, Karlsruhe, Germany.

Winberg A, Andersson P, Byegård J, Poteri A, Cvetkovic V, Dershowitz W, Doe T, Hermanson J, Gomez-Hernandez J J, Hautojärvi A, Billaux D, Tullborg E-L, Holton D, Meier P, Medina A, (in print). Final report of the TRUE Blcok Scale project. 4. Synthesis of flow, transport and retention in the block scale
SKB TR-02-16. Svensk Kärnbränslehantering AB.