International Progress Report

IPR-04-20

Äspö Hard Rock Laboratory

Status Report
October – December 2003

Svensk Kärnbränslehantering AB

April 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, 2003/.

This Äspö HRL Status Report is a collection of the main achievements obtained during the fourth quarter 2003.

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, Low-pH cementitious products, 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: GeoMod Project, Rock stress measurements, Rock creep, Äspö Pillar Stability Experiment, Heat transport, Seismic influence on the groundwater system, and Inflow predictions.

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 2003 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

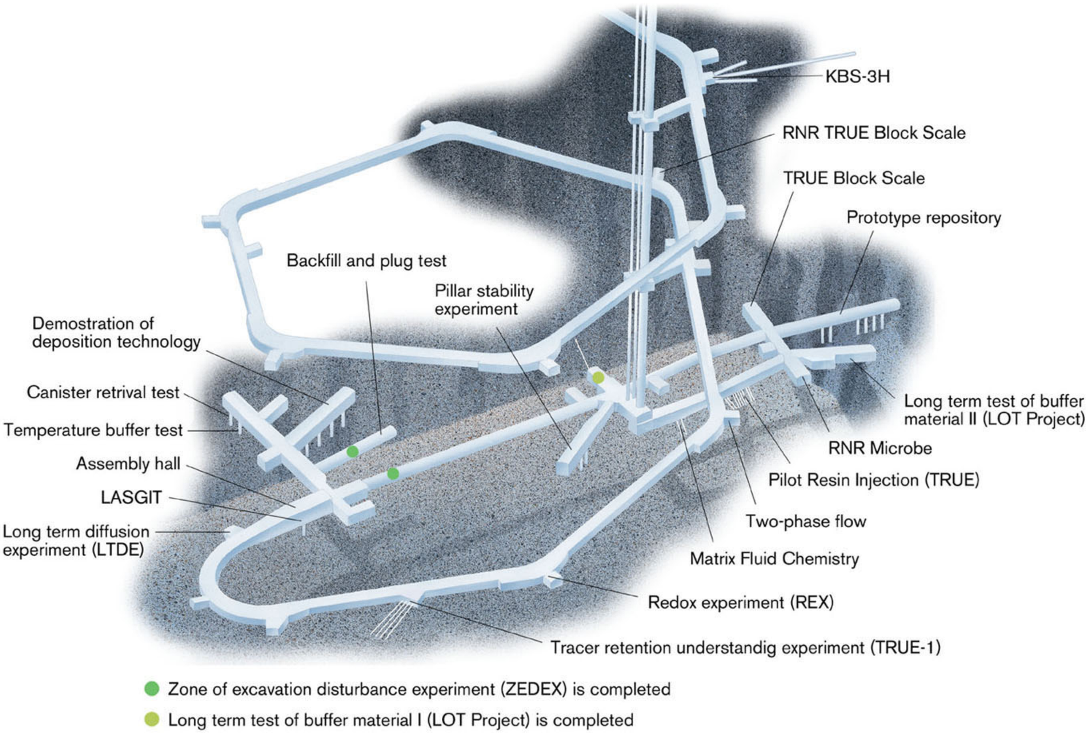
1 General

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, 2003/ for more background information. The Annual Report will in detail present and summarise new findings and results obtained during the present year.

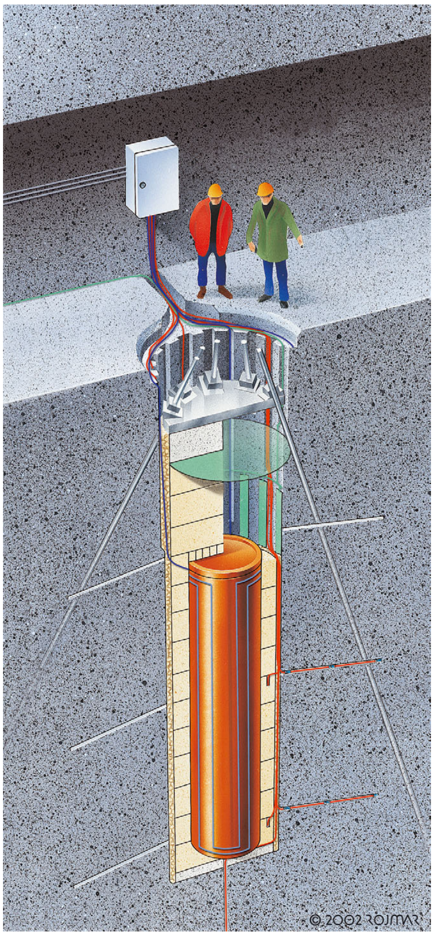


2 Technology

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 almost three years with continuous measurements of the wetting process, temperature, stresses, and strains.

Achievements

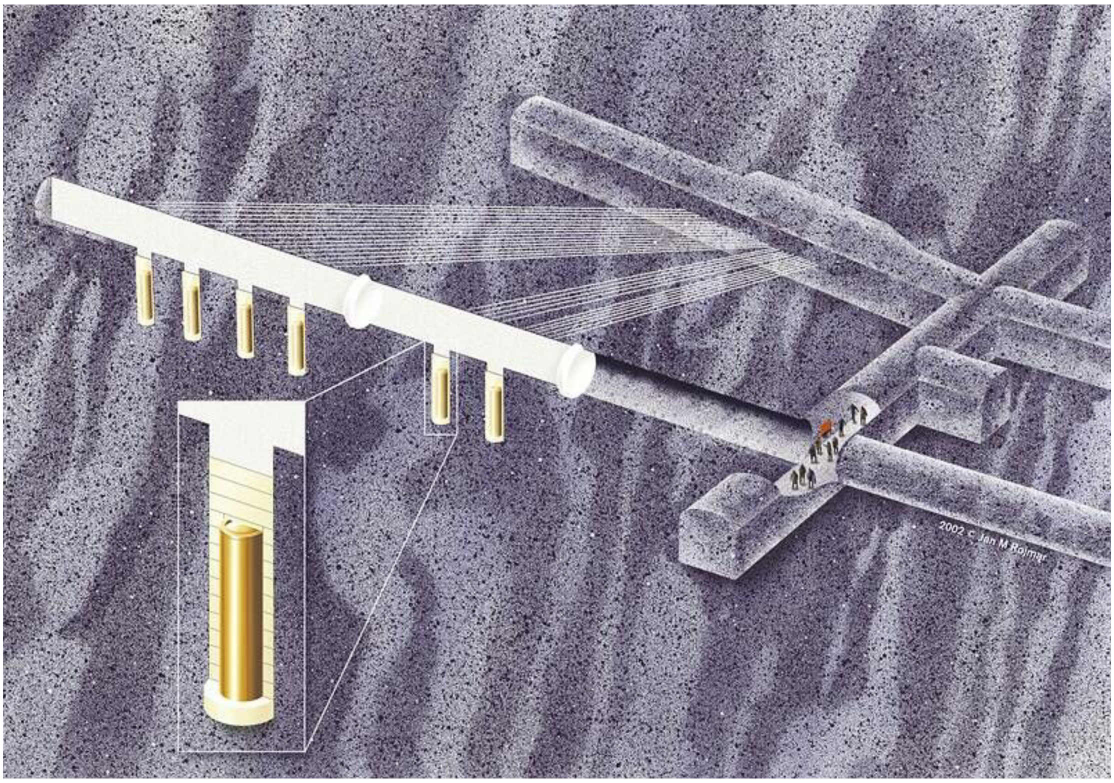
During the forth quarter the artificial water supply to the bentonite has continued and the water pressure in the mats that distribute the water has been maintained at 800 kPa according to plan.

A large number of parameters are measured during the test to study the THM-processes and to provide a basis for e.g. modelling purposes. The transducers have been working well and the measurements and collection of data have continued. A data report covering the period up to 1st of October has been published /Goudarzi *et al.*, 2003/.

Large parts of the buffer between the canister and the rock are fully saturated although the saturation is rather uneven. The filters in the mats have been back-flushed during the quaternary since clogging of the filters is thought to be one of the reasons for the uneven saturation.

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.

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.

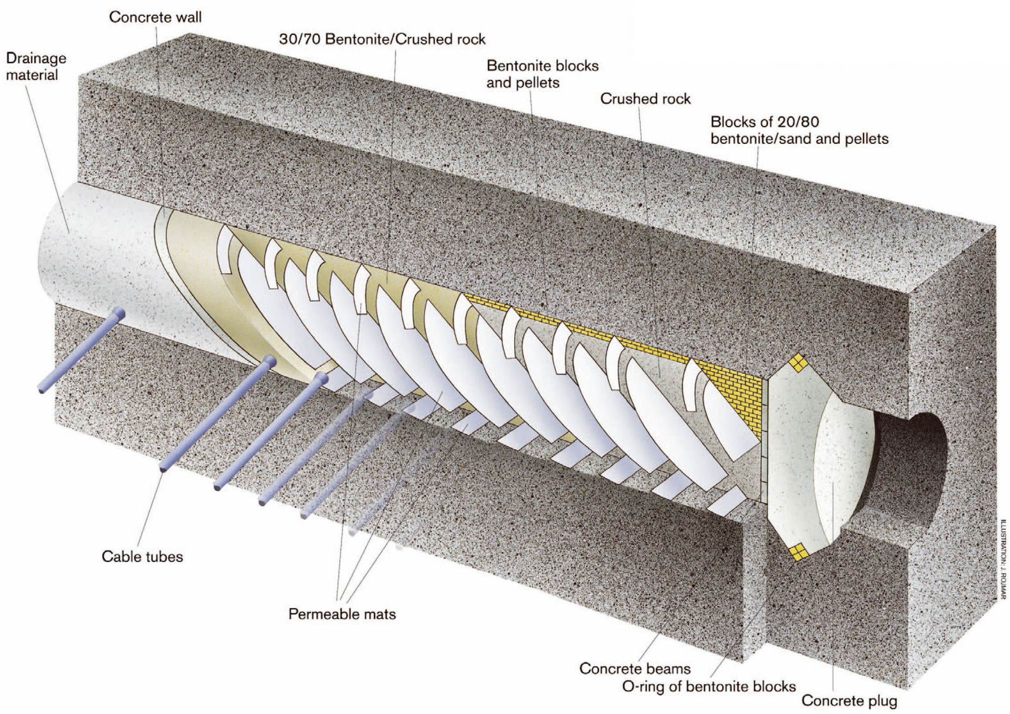
Achievements

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.

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. A data report covering the period up to 1st of September has been published /Goudarzi and Johannesson, 2003/.

A system for corrosion protection of the lead-throughs between the Prototype tunnel and the G-tunnel has been built in the G-tunnel. The system is ventilating the lead-throughs with de-humified air. Three sections for flow measurements have been built outside the outer plug and the site has been prepared for visitors with an information board and a wooden bridge with hand rail.

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.

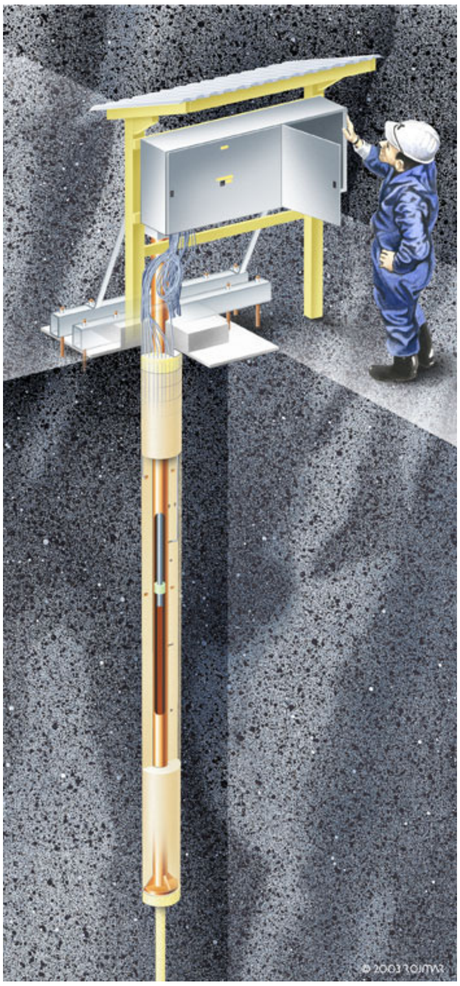
Achievements

Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured and registered. Since the turn of the year 2002/2003 the measurements show that the backfill is fully saturated and a decision was taken in March 2003 to shift to the next phase in the project, which comprise flow testing.

The strategy of the flow testing is 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. During this quarter the flow testing with measurements and data collection were initiated. In the end of November 2003 the water pressure in three mat sections, in the tunnel backfilled with crushed rock close to the plug, had been decreased to 400 kPa.

A new project decision was approved the 30th of September covering the period up to mid 2006.

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 planned to run for at least five years.

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 in one and a half year.

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 is mainly an inventory of available techniques, and Phase 2 aims to develop a complete cleaning and sealing concept and 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 of this project is now completed. A state of the art report summarising the developments of the sealing and cleaning techniques during the last 10–15 years has been published as an internal report (TD) titled "Borehole plugging – State of art". 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. Cement is concluded to serve less good, primarily because of questionable chemical stability.

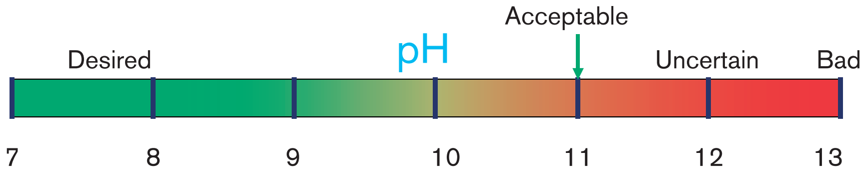
In November the decision was taken to continue with the second phase of the project. This phase focuses on cleaning and sealing of boreholes and will comprise three parts; (i) Completion of a borehole plugging concept, (ii) Laboratory tests, and (iii) Field tests.

During this quarter the main activities have been:

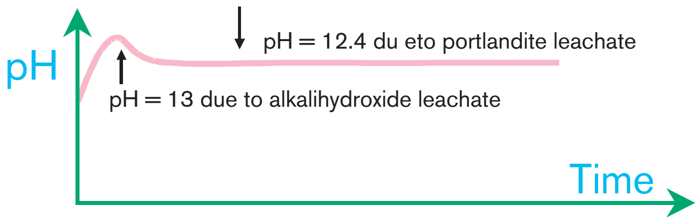
- Detailed time and activity planning of the second phase of the project.
- Initiated study on techniques for manufacturing perforated copper pipes and lengthening of the tubes.
- Preparation of proposals for laboratory tests on low pH materials, e.g. cement and quartz.

2.6 Low-pH cementitious products

SAFETY ASSESSORS´ VIEW ON pH



PRINCIPLES FOR pH-EVOLUTION OF 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

The use of low-pH cementitious products is necessary in order to get leachates with a sufficiently low pH (≤11). A pre-study was carried out in 2001, followed by a feasibility study in 2002 - mid 2003. The Feasibility study is reported both as a SKB working report and a Posiva R&D report /Bodén and Emmelin, 2003/. In the feasibility study a specific need for development of injection grouts both for larger and smaller fractures as well as testing them in field tests was identified.

In June 2003 a joint project "Injection grout for deep repositories" between Posiva, SKB and Nuclear Waste Management Organization of Japan (NUMO) was initiated. The current project aims at achieving some well quantified, tested and approved low-pH injection grouts. The project is divided into four sub-projects:

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

Preparations fort the field tests to be performed at Äspö HRL in 2004 are in progress.

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 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 are assembled into a prefabricated disposal container in a reloading station.

Achievements

A Feasibility Study was finalised in October 2002 and the SKB board decided in December 2002 to continue the project with the next phase. This phase comprise three main issues; (i) Development of equipment for construction of deposition drifts and handling of the disposal container, (ii) Barrier performance, and (iii) Preparation for a demonstration in Äspö HRL.

The site for the demonstration of the method is located at 220 m depth in Äspö HRL. A niche, 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.

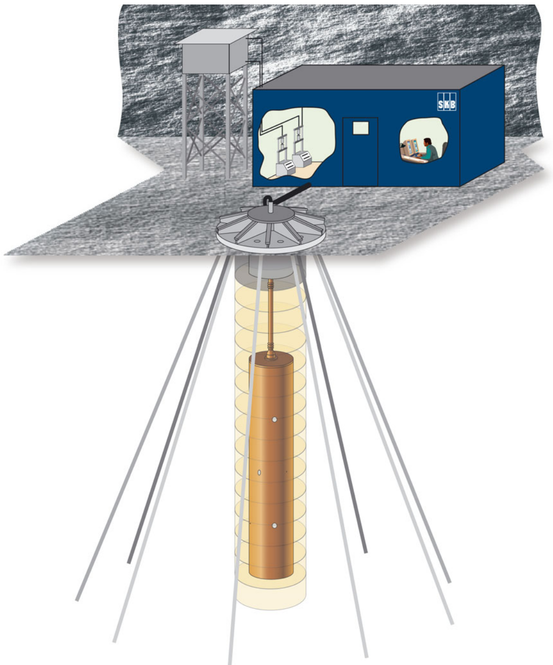
A cluster boring technique has been developed for boring of the deposition drifts. The deposition hole is drilled in three steps with a subsequent increased diameter. In the first step a hole with a diameter of 0.3 m is drilled, in the second step the diameter is widened to 1.4 m and in the third step to 1.85 m. The equipment has been tested in Norway, see figure below. The result showed that the cluster technology can produce drifts which meet the strict quality requirements but the system (cluster frames, drillrig, high pressure pumps and water handling system) still needs further optimisation. The excavation of three drifts at Äspö during 2004 will be proceeded by an evaluation of possible excavation technologies with respect to requirement fulfilment and total cost.

A deposition container holding the copper canister and bentonite rings will be used for the emplacement in the horizontal drift. The total weight of the container and its contents is about 50 tonnes. Different techniques for heavy transports are available. A technique where the deposition container is carried by water cushions has been found to be more advantageous than an air cushion. One reason is the lower heat evolution in the deposition drift due to less energy consumption. The technique is developed by the Finish company Solving. Test equipment has been constructed with four pairs of cushions and a capacity to lift a deposition container in scale 1:4 with a total weight of 12.5 tonnes.

The barrier performance is studied by Posiva and the reporting is in progress. Laboratory tests of the barrier performance are carried out by Clay Technology to study occurrence of erosion and piping in the buffer as well as plugs for sealing. Tests performed on scale of 1:10 are finalised and under evaluation. The two year test on distance blocks scale of 1:1 will be initiated next year.

The KBS-3H related work done during 2003 will be reported 2004.

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:

- Packer tests on the rock wall in the deposition hole to investigate e.g. the occurrence of an excavation disturbed zone. The tests do not show any indication of a disturbed zone.
- The design of the lid for the upper part of the deposition hole has been set and final drawings prepared. The lid shall withstand a swelling pressure from the bentonite of 20 MPa. The lid will be very similar to the one used in the Temperature Buffer Test.
- The instrument, e.g. the gas injection filters, has been developed by BGR. Three types of filters with different diameters (100 mm, 50 mm and 10 mm) have been manufactured and delivered to Äspö.
- Measurements of the water inflow to the deposition hole during one week have been made as a background for predictions of the time needed for water saturation of the bentonite buffer.

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

Two canisters with heaters, bentonite buffer, and sand infilling have been 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 (see Figure 2-1).

The operation and data acquisition phase of the test was initiated during the end of March 2003 first with reduced heater effect and water supply, which both have been increased in accordance with the plan. 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. Early results from the predictive modelling of the test were presented at a workshop in Sitges, Spain.

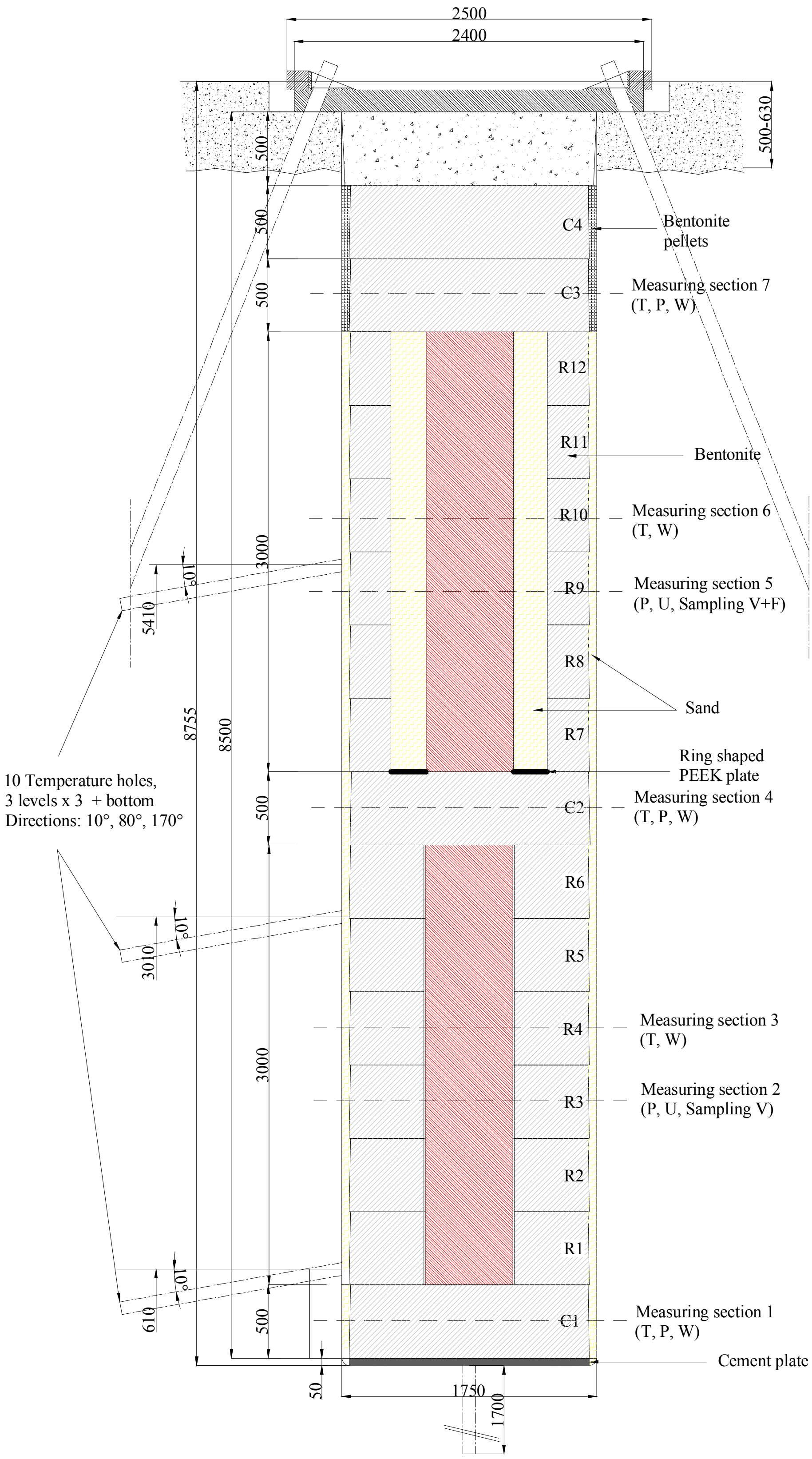


Figure 2-1 Layout of the Temperature Buffer Test.

2.10 New experimental sites

The major aims of this project have been to find new experimental sites at Äspö HRL for three large-scale experiments: Äspö Pillar Stability Experiment (APSE), Testing of low-pH grout, and KBS-3 method with horizontal emplacement (KBS-3H) and to carry through the necessary rock work for providing the tests with large enough openings. Another objective is to identify possible sites for two to three full scale deposition holes, which can be bored in conjunction with the boring of the two holes in the APSE project. No needs for these holes are presently identified, and the aim is to prepare for the future needs as new excavation will be prohibited for several years because of the impact this has on projects related to Natural barriers.

The use of explosives is known to cause disturbance in the hydraulic regime in the whole Äspö rock mass. However, the disturbances have been permanent only in very few cases. Another conflict with other experiments is that a penetration of a water-carrying fracture may change the hydraulic head in a large region around the place where the intersection takes place.

Achievements

Experimental sites were selected for APSE and the KBS-3H experiment during the first quarter 2003. The APSE site is located at the -450 m level and the KBS-3H site is located in a niche at the -220 m level. Testing of low pH grout can be made in existing tunnels or niches in the laboratory.

Most excavation work took place during the second quarter and the excavation work was finalised in July. During the excavation experiments dependent on a stable hydraulic environment were stopped and held on stand-by. An approximately 70 m long tunnel is excavated for APSE and a niche with an average height of 8 m and a bottom area of about 15 x 15 m is excavated for KBS-3H. From the niche exploratory boreholes with a total length of 160 m has been drilled.

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 analysed 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.

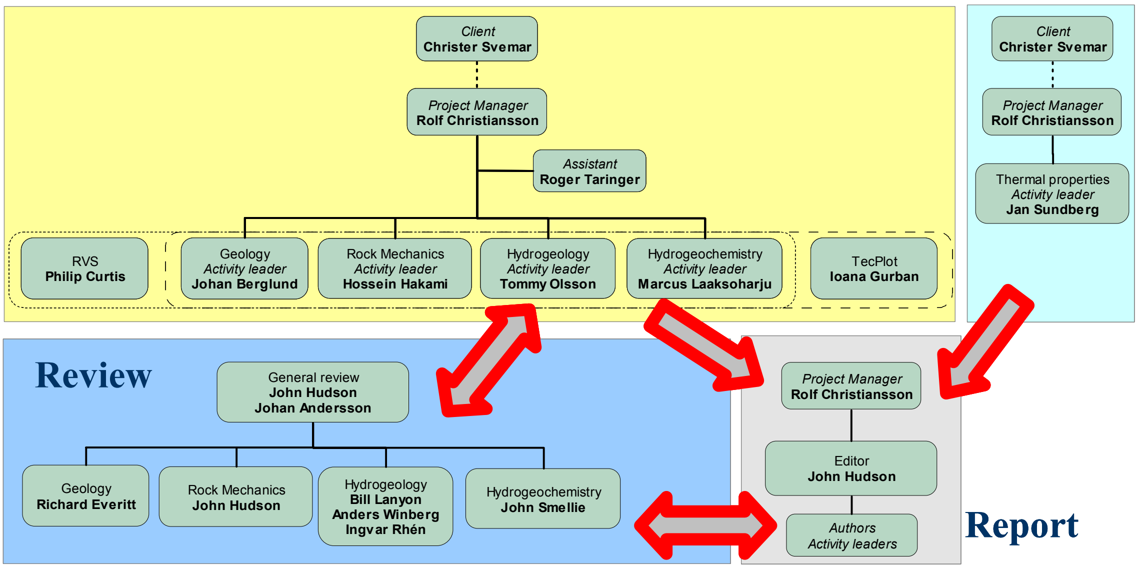
2.12 Task Force on Engineered Barrier Systems

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 GeoMod Project



In the GeoMod project existing geological, geomechanical, hydrogeological and hydro-geochemical models of Äspö are updated by integration of data collected since 1995. 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 down to about 500 m.

The project also aims to integrate the different geoscientific models. The development of a geothermal model is integrated in the project. This issue has earlier been run as a separate project.

Achievements

The models of Äspö 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. The new models will be used e.g. to facilitate future selection of experimental sites in the Äspö HRL. The reporting of the different geo-scientific disciplines is in progress.

3.2 Rock stress measurements

To be able to make correct assessments of the *in situ* stress field from results from different types of rock stress measurement techniques it is important to know the limitations and shortcomings of the different measurement techniques. 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. The first phase has been completed which includes development of a numerical tool for isotropic and elastic conditions.

SKB has contributed with seven articles to the special issue of the International Journal of Rock Mechanics and Mining Sciences /IJRMMS, 2003/ where ISRM's suggested strategy for rock stress measurements is presented.

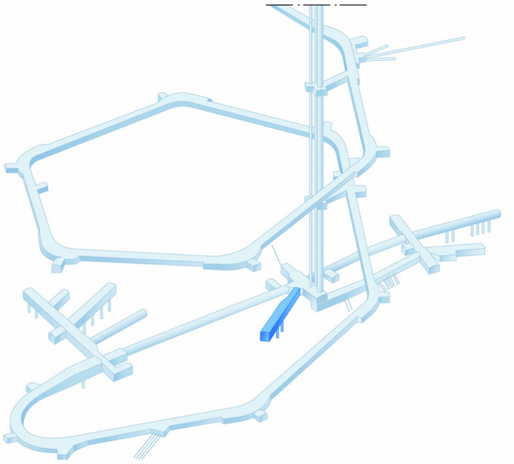
3.3 Rock creep

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 objectives are to demonstrate the capability to predict spalling in fractured rock mass and the effect of confinement pressure 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 spalling.

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 floor is designed to concentrate the stresses in the centre of the drift's floor. The invert was excavated separately as a bench to minimize the excavation damaged zone .

Achievements

The excavation of the tunnel at the -450 m level was finalised in July. The blasting was successful and the rock mass damping of the blasting induced vibrations was much higher than anticipated. Convergence measurements, giving excellent results, have been performed during the excavation. The stress field and Young's modulus has been back calculated using the results from these measurements. A paper concerning this topic was presented at the Sigma3 conference in Kumamoto, Japan in November.

The first of the two deposition holes that will create the pillar was drilled in December in section 0/0066. The hole has been geologically mapped and will be pressurized with water via a liner to 0.8 MPa. The confinement pressure will be gradually lowered at certain times during the experiment and the response in the hole wall and the pillar will be monitored. The second hole is planned to be drilled in March 2004.

The final numerical predictive modelling of the test as well as geological model covering the test site will be published. Draft versions of the reports were finished in November.

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

The model development strategy, the analysis of distribution and scaling factors and measured thermal properties at Äspö HRL are reported in three reports:

- Thermal site descriptive model — A strategy for model development during site investigations /Sundberg, 2003a/.
- Thermal properties at Äspö HRL — Analysis of distribution and scale factors /Sundberg, 2003b/.
- Comparison of thermal properties measured with different methods /Sundberg *et al,* 2003/.

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.

3.7 Inflow predictions

SKB has conducted a number of large field tests where prediction of groundwater inflow into tunnels or depositions holes has been a component; the Site Characterisation and Validation Test in Stripa, the Prototype Repository and the Groundwater Degassing and Two-Phase Flow experiments in Äspö HRL. The results from these tests show that when going from a borehole to a larger diameter hole, the inflow into the larger hole is often less than predicted, and the explanation for this is not yet well understood.

The major objectives with this project are to make better predictions of the inflow of groundwater into deposition holes, to confirm (or refuse) previous observations of reduced inflow into deposition holes and tunnels compared with boreholes, and also to identify the different mechanisms determining the inflow and quantify their importance.

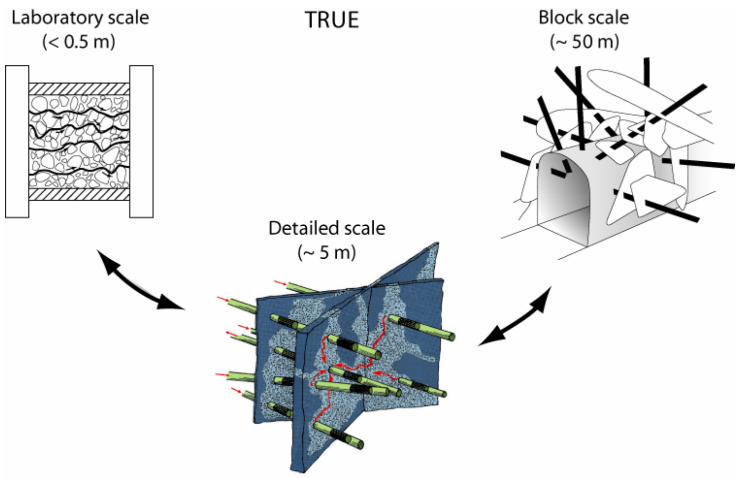
Achievements

Ongoing activities during this period have been numerical modelling. For this purpose the computer code 3DEC, which new version has the capability of performing fully coupled three-dimensional hydro-mechanical analyses, has been used. A generic study of the case of flow in a single fracture intersecting a deposition hole has been performed. In particular the influence of fracture properties, such as stiffness and orientation, has been evaluated. The conclusions from the predictions have not been finally drawn but is seems that the inflow is very much dependent on the fracture properties assumed.

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 RVS-model of the rock block has been updated and the supporting modelling is concluded. The reports from three modelling teams on effects of heterogeneity along flow pats, variability of geometry and properties of fracture rim zones, and usage of background fractures for *in situ* experimentation have been sent for printing.

In order to cater for the planned tests involving Structure #19 a rearrangement of the multi-packer systems in boreholes KI0025F02 and KI0025F03 was performed during the summer and early fall. During this quarter the pre-tests that precede the planned tests with radioactive sorbing tracers have been performed and evaluated. The hydraulic pre-tests (CPT1 through CPT3) were performed to identify a suitable sink in Structure #19 and also, through combined analysis of drawdown and tracer dilution anomalies, to identify suitable source sections for subsequent tracer experiments.The tracer tests with non sorbing tracers CPT-4a and CPT-4b were initiated 22 October and 18-20 November respectively. The tests show that experiments with injection of tracers in Structure #19 (KI0023B:P2, KI0025F02:R3) and in Structure #25 (KI0025F02:R2) produce satisfactory "mass recovery". The initiation of BS2b sorbing tests are planned to February 2004.

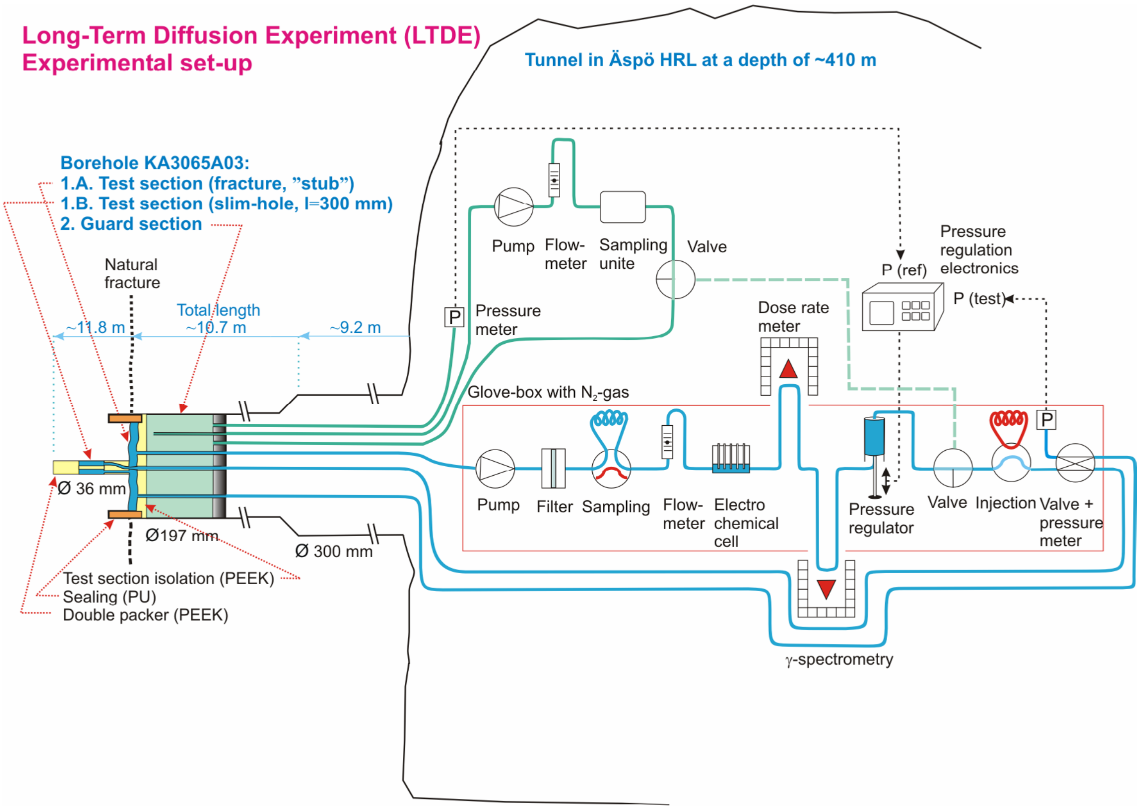
4.1.2 TRUE-1 Continuation

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 fault rock zone characterisation studies include injection of epoxy in a variety of structures of different dignity which all are characterised by fault rock zone. The injected sections are then over-cored and analysed for pore space. Four candidate sites have been selected for the injection test and 16 boreholes (76 mm), 3-6 m long, have been drilled at the selected sites. Subsequent hydraulic characterisation (injection tests, pressure monitoring) identified seven boreholes as being suitable for injection of resin. These were characterised by inflows of 0.001 -1 litre/min and stable natural formation pressures < 30 bars. Epoxy were injected in five boreholes during this period and have now been performed successfully in all seven exploration boreholes, three at 2/169 m, two at 1/596 m, one at 2/430 m and one at 2/545 m. The consumption of resin varied between about 0.1 litre at 1/596 m and about 1 litre at 2/169 m. The planning of the next step the overcoring has also been finalised.

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

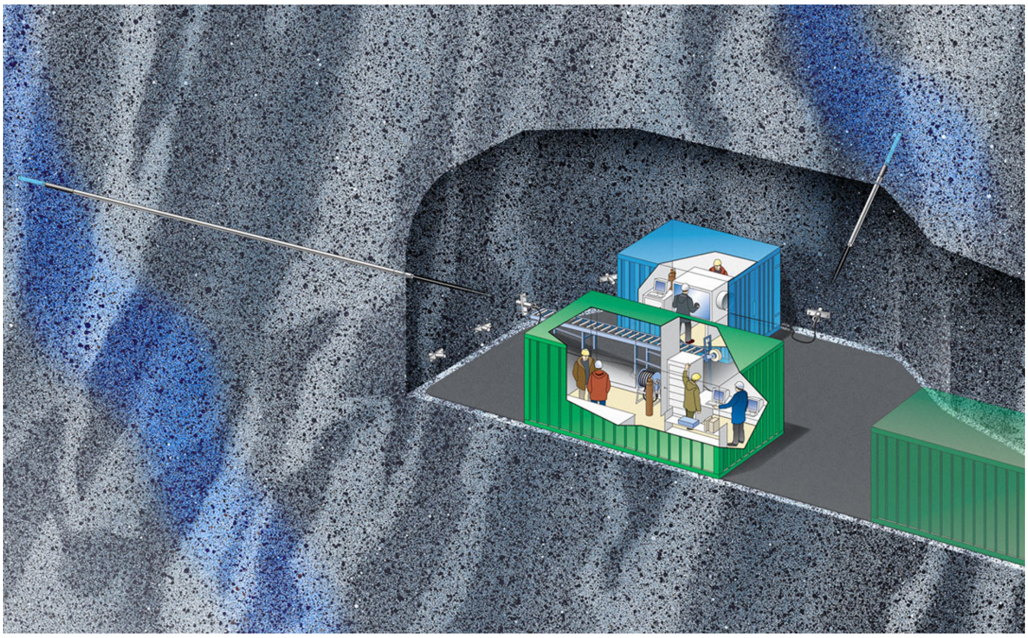
The installation phase of the project was resumed in September after an interruption during the tunnelling work at the APSE and KBS-3H sites. The installation was interrupted mainly to avoid disturbances from the excavation due to pressure variations and vibrations.During this time period important experimental equipments in borehole sections surrounding the LTDE set-up have been installed. This equipment is an important part of the experiment since leakages from the LTDE experiment can be monitored and the hydraulic gradient around the main experimental section supervised.

The results from the latest measurements of the occurrence of microbes showed a considerable increase of microbes in experimental section with stagnant water under normal section pressure. The growth of microbes occurred although the sections had been rinsed by water from a nearby borehole flowing through the set-up during a long time period, about two months. This results means that the new action plan has to been prepared since the earlier conclusion was that the rinsing would remove the microbes. The new plan may also include additional *in situ* tests.

The installation of the circulation equipment to the test section in the borehole in the glove box is in progress. Tests of the electrochemical flow cell continue according to plan. The work with supporting laboratory experiments on drill cores to study diffusion and sorption of solutes is in progress. This is done in co-operation with AECL.

Further, it has been decided to have an external review of the experimental concept during the spring 2004, i.e. prior to the start of the main test which is at the earliest in September 2004.

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 long 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 redox-sensitive 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 in its reduced form. The so far obtained results bring about a need for additional analysis, e.g. the distribution of technetium in bentonite probes not influenced by radiolysis. The final evaluation of data and the preparation of a final report are in progress and planned to be finished April 2004.

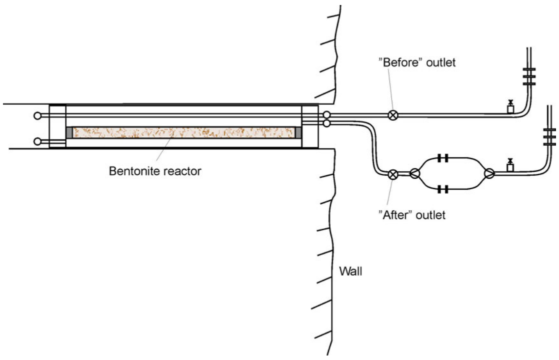
Achievements − Migration of actinides

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 will be prepared by FZK/INE. According to present plans the experiment will be ran with radioactive isotopes (uranium and technetium).

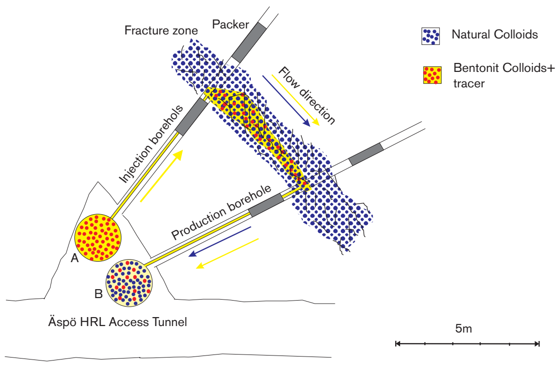
The first experiment comprised migration of the actinides americium, neptunium, and plutonium. The second experiment was carried out in the beginning of 2002 and the results has been evaluated and published /Kienzler *et al.,* 2003a/. The third actinide experiment in Äspö HRL was started at the end of 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, when six bentonite reactors were installed in four boreholes in the Äspö tunnel and in two boreholes at Olkiluoto, have all been finalised. The compilation of the final report including laboratory experiments, background measurements and borehole specific measurements is in progress and will be ready in June 2004. A status report including the results from the laboratory experiments and background measurements was printed in March /Laaksoharju, 2003/.

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 measurements.

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.

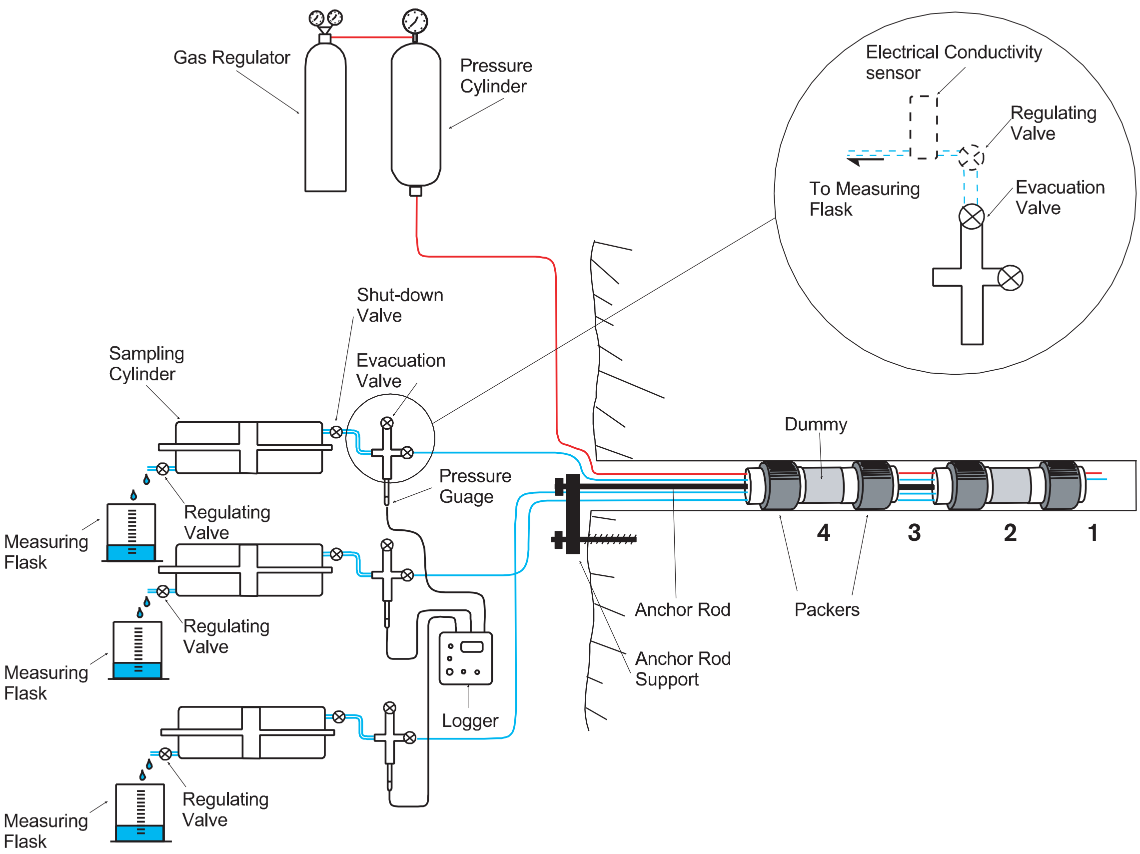
At 907A m tunnel length, a small vault supports a ditch with groundwater that is rich in ferrous oxides and iron oxidising bacteria This ditch is used as a natural analogue to the artificial channels at 2200A m. This site was destroyed by a flooding event fall 2003 and is probably lost.

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 laboratory container is in operation again after the interruption during the tunnel excavation at the APSE-site. The equipment functions well and new measurements of dissolved gas in the groundwater were made in December. New equipment to determine the occurrence of biomass has been brought to Äspö and the method based on detection of light from ATP (adenosine triphosphate available in all living species) has been adapted to measurements in deep groundwaters. Measurements on biofilms (BIOS) and groundwaters started in December. A new method to analyse oxygen reducing microorganiusms, so called methanotrophsis under development and some fieldwork was performed in December.

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.

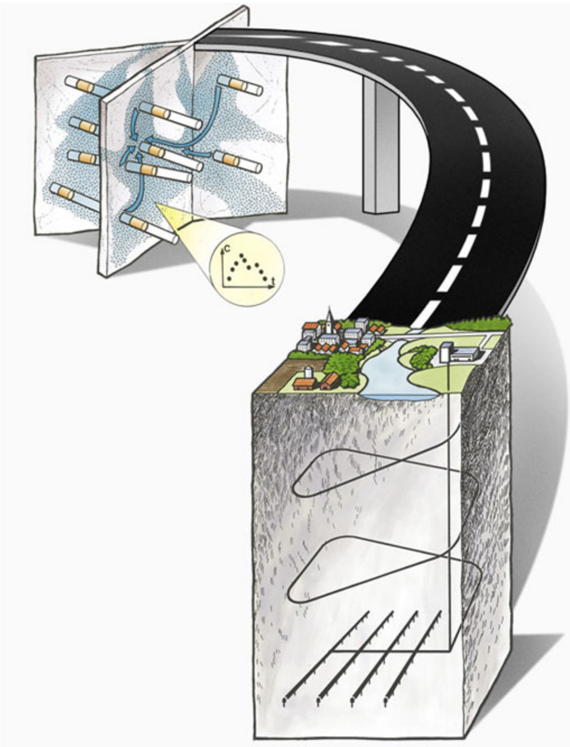
Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied to determine their contribution, if any, to the composition of the matrix fluids/groundwaters.

Achievements

The first part of the project is reported in two internal international technical documents and the final write-up in a technical report /Smellie *et al., 2003*./. The major conclusion from this phase is that pore water can successfully be sampled from the rock matrix. The sampled matrix waters at approximately 450 m depth consisted dominantly of groundwaters relatively similar in major chemistry to more transmissive fractures in the surrounding bedrock environment. There was little evidence of draw-down effects and that the salinity of the matrix groundwaters has been influenced by fluid inclusions. This similarity in composition with the surrounding bedrock environment was unexpected but can be explained by the highly transmissive nature of the Äspö site as a whole. In this respect Äspö is probably quite unique and other less transmissive sites would probably have given different results.

The final preparations of the test plan and project decisions for a second phase are in progress. The second phase will include a pilot study which will focus on the impact of tunnel construction (Äspö Pillar Stability Experiment) on the hydrogeology and hydrochemistry and porosity measurements on drillcore materials to supplement data from the first phase.

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

In the Task Force work activities have 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.

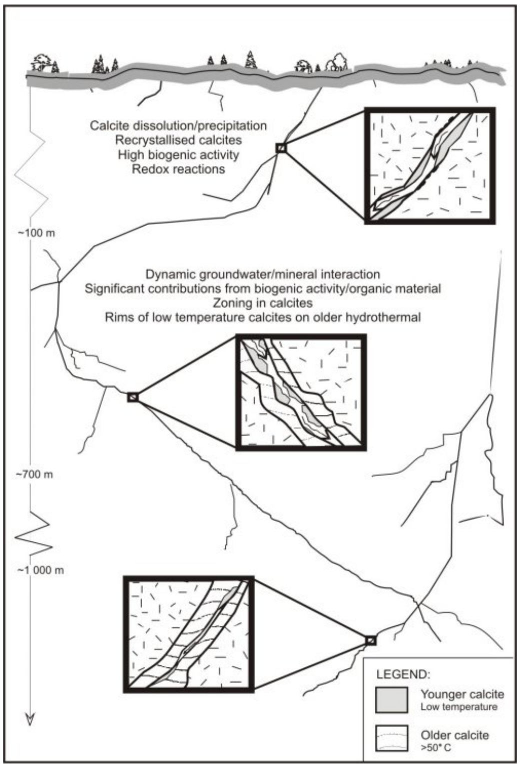
During this period the external review of Task 6 has continued and work has mainly been performed in modelling of subtasks 6D and 6E. The prognosis for the project is according to current plans. However, the Task Force meeting in January can lead to modifications. The status of the specific modelling 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. (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. (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	The scale is larger, but otherwise this sub-task is similar to sub-task 6A, and is using the semi-synthetic structural model developed under subtask 6C, 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. (In progress).

Other recent activities in the Äspö Task Force are:

- The proceedings of the 17th Task Force Meeting at Äspö HRL have been distributed according send list. Preparations have been done and second call for the 18th Task Force meeting has been sent out.
- The minutes of the Task 6 workshop, held at Krägga Herrgård, September 22-23, 2003, has been delivered.
- The external review of Task 6 reports is in progress. Preliminary comments from the reviewers will be presented at the 18th Task Force meeting.

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

Samples of fracture mineralization from sites in the United Kingdom, Sweden, Spain and the Czech Republic are being studied in the PADAMOT Project. A number of samples (from KLX01) have been selected that will be analysed with respect to stable isotope composition, chemical zoning and fluid inclusions. The work on the KLX01 drill core material has continued with sample preparation and analyses of calcite samples. The basic idea behind the sampling/analysis programme is to distinguish and characterise possible recent low temperature calcites.

Cathodoluminescence (CL) and fluid inclusion microthermometric analysis of a suite of samples from the SKB KLX-01 borehole have been carriet out at BGS. The CL imaging has allowed the recognition of five calcite generations which show evidence for significant fracture rejuvenation, reworking, brecciation, replacement and cementation by later calcite generations. These generations are consistent with those recognised during earlier work. Fluid inclusion microthermometric data has been acquired from all the generations.

The fluids are shown to have variable chemistries, with low-salinity (fresh water, typically <2 wt% $CaCl_2$ equiv.) inclusions occurring in close proximity to very saline solutions (up to 24 wt% $CaCl_2$ equiv.), even within the same calcite generation. The higher salinity inclusions are $NaCl$-$CaCl_2$- H_2O brines, with high $CaCl_2$ / ($NaCl$+$CaCl_2$)

ratios inferred for the highest salinity inclusions. The chemical species present in the low salinity inclusions are unknown.

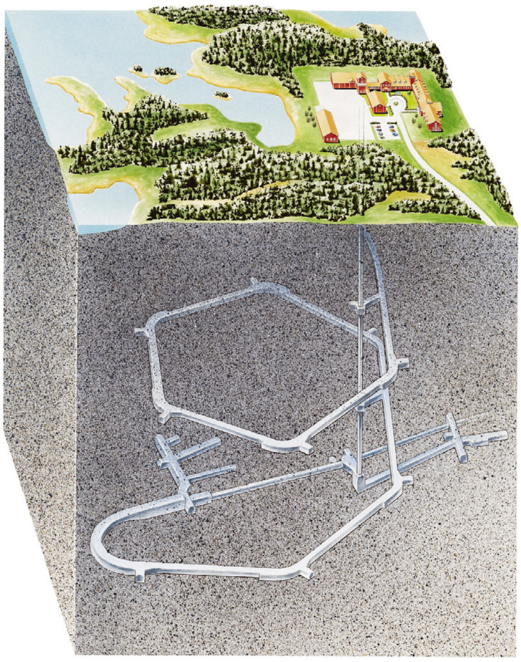
The presence of high salinity fluids even at shallow depths in the borehole (well within the present day freshwater zone that extents down to approximately 1000 m), indicates that the transition zone between the fresh and saline fluids was closer to ground level at some time during precipitation of these cements. Fresh water inclusions extend at least down to 840 m, but did probably not extends deeper than 1000 m.

Some, apparently systematic, variations in fluid chemistry are evident between the calcitegenerations but interpretation is hindered by the difficulty in distinguishing between primary and secondary inclusions due to the altered nature of the earlier generations.

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, above 99% according to preliminary calculations, and the status of the facility is good.

An automatic registration and object-monitoring system with the aims of increasing personnel safety underground was taken into operation for testing during December 2003. The control inspection of the lift wire of the underground elevator indicated wear and the wire was exchanged just before the year-end.

Work on increased fire safety is in progress. Safety-related education and fire fighting training has been held in co-operation with the local fire brigade. The installation of a pipe from -340 to -440 m level which will supply water to the ramp for fire protection and water to the experiments has been started.

5.2 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 other boreholes. 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 annually. This work involves comparison with groundwater levels checked manually in percussion drilled boreholes and in core drilled boreholes, in connection with the calibration work.

Achievements

The excavation work performed in Äspö HRL during this summer caused interruptions in the data collection and disturbances of the HMS. During this quarter monitoring system has been performing well and no main maintenance activity has taken place.

5.3 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 boreholes included in the network has gradually increased. The tunnel excavation started in October 1990 and the first pressure measurements from tunnel drilled boreholes were included in the HMS in March 1992.

To date the monitoring network comprises boreholes 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 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. 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. 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 sampling campaign took place in September (week 38-39). Samples were taken from 2 surface boreholes (KAS), 30 sections in boreholes drilled from the tunnel, and 20 sampling points along the tunnel. The results from the sampling period will be presented in a Technical Document in the beginning of 2004.

6 International co-operation

Seven organisations from six countries (see list below) are participating in the co-operation at Äspö HRL during 2003. Most of the organisations are interested in groundwater flow, radionuclide transport and rock characterisation. All organisations participate 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 2003	**Andra**	**BMWA**	**Enresa**	**JNC**	**Criepi**	**Nagra**	**Posiva**
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
Large Scale Gas Injection Test							X
Temperature Buffer Test (Andra test)	X		X				
Geo-science							
Äspö Pillar Stability Experiment							X
Natural barriers							
Tracer Retention Understanding	X		X	X			X
Radionuclide Retention Project		X					
Colloid Project		X					X
Microbe Project		X					
Matrix Fluid Chemistry						X	
Task Force on Modelling of Groundwater Flow and Transport of Solutes	X	X	X	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.

Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland

Posiva Oy, Finland.

Achievements

Discussions with OPG, Canada have progressed and an agreement has been drafted based on the standard Äspö cooperation premises. The aim is to finalise the agreement so that it may come in force on January 1st, 2004.

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 – 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

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– 2004-03-31)
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 Documentation

During the period October-December 2003, the following reports have been published and distributed.

7.1 Äspö International Progress Reports

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7.2 Technical Documents and International Technical Documents

No Technical Documents

No International Technical Documents

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