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Äspö Hard Rock Laboratory

Planning Report for 2010

Svensk Kärnbränslehantering AB

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Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel and Waste Management Co

Box 250, SE-101 24 Stockholm
Phone +46 8 459 84 00

Äspö Hard Rock Laboratory

The Äspö Hard Rock Laboratory
Planning Report for 2010

This report presents the planned activities for the year 2010. The report is revised annually and details the programme carried out in the Äspö Hard Rock Laboratory as described in SKB's Research, Development and Demonstration Programme 2007, and serves as a basis for the management of the laboratory. The role of the Planning Report is to present the plans and scope of work for each project. Thereby the Status Reports may concentrate on work in progress and refers to this Planning Report for scope of work over the year. Background information on the projects is given in the Annual Report as well as findings and results.

Svensk Kärnbränslehantering AB

Mats Ohlsson

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1 General

1.1 Background

The Äspö Hard Rock Laboratory (HRL), located in the Simpevarp area in the municipality of Oskarshamn, constitutes an important part of SKB's work with design and construction of a deep geological repository for final disposal of spent nuclear fuel. This work includes the development and testing of methods for use in the 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. Most of the research is concerned with processes of importance for the long-term safety of a future final repository and the capability to model the processes taking place. Demonstration addresses the performance of the engineered barriers and practical means of constructing a repository and emplacing the canisters with spent fuel.

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, see Figure 1-1. The total length of the tunnel is 3,600 m where the main part of the tunnel has been excavated by conventional drill and blast technique and the last 400 m have been excavated by a tunnel boring machine (TBM) with a diameter of 5 m. The underground tunnel is connected to the ground surface through a hoist shaft and two ventilation shafts.

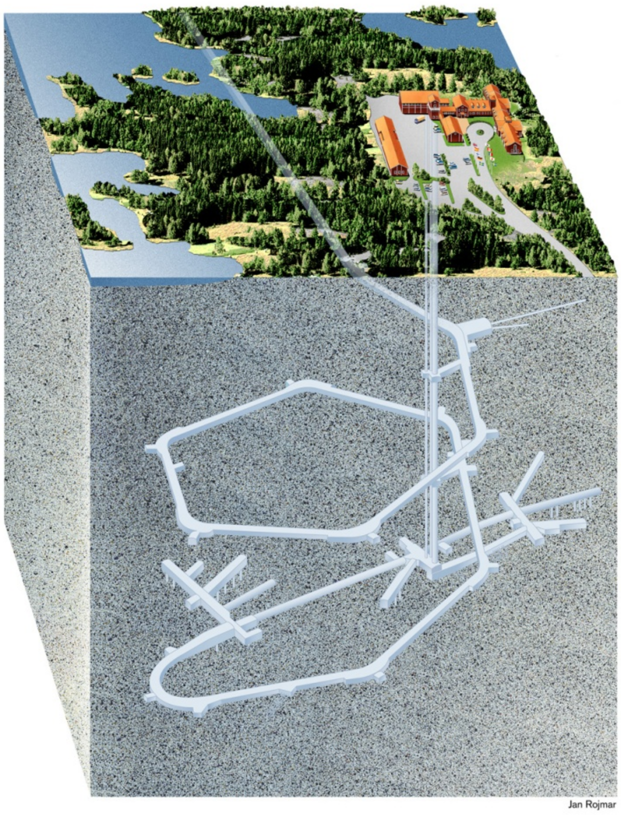


Figure 1-1. *Overview of the Äspö Hard Rock Laboratory.*

1.2 Goals

To meet the overall time schedule for SKB's RD&D work, the following stage goals were initially defined for the work at the Äspö HRL:

1. *Verify pre-investigation methods*. Demonstrate that investigations on the ground surface and in boreholes provide sufficient data on essential safety-related properties of the rock at repository level.

2. *Finalise detailed investigation methodology*. Refine and verify the methods and the technology needed for characterisation of the rock in the detailed site investigations.

3. *Test models for description of the barrier functions at natural conditions*. Further develop and at repository depth test methods and models for description of groundwater flow, radionuclide migration and chemical conditions during operation of a repository as well as after closure.

4. *Demonstrate technology for and function of important parts of the repository system*. In full scale test, investigate and demonstrate the different components of importance for the long-term safety of a final repository and show that high quality can be achieved in design, construction and operation of repository components.

The tasks in stage goals 1 and 2 were after completion at Äspö HRL transferred to the Site Investigations Department of SKB. The investigation methodology has hereafter been developed in the site investigations performed at Simpevarp/Laxemar in the municipality of Oskarshamn and at Forsmark in the municipality of Östhammar.

In order to reach present goals (3 and 4) the following important tasks are today performed at the Äspö HRL:

- Develop, test, evaluate and demonstrate methods for repository design and construction as well as deposition of spent nuclear fuel and other long-lived waste.
- Develop and test alternative technology with the potential to reduce costs and simplify the repository concept without sacrificing quality and safety.
- Increase the scientific understanding of the final repository's safety margins and provide data for safety assessments of the long-term safety of the repository.
- Provide experience and train personnel for various tasks in the repository.
- Provide information to the general public on technology and methods that are being developed for the final repository.
- Participate in international co-operation through the Äspö International Joint Committee (IJC) as well as bi- and multilateral projects.

In 2007 the inauguration of the Bentonite Laboratory took place and at the laboratory studies on buffer and backfill materials are performed to complement the studies performed in the rock laboratory. In addition, Äspö HRL and its resources are available for national and international environmental research.

1.3 International participation

The Äspö HRL has so far attracted considerable international interest. During 2010, nine organisations from eight countries will in addition to SKB participate in the Äspö HRL or in Äspö HRL-related activities. For each partner the co-operation is based on a separate agreement between SKB and the organisation in question.

The participating organisations are:

- Agence Nationale pour la Gestion des Déchets Radioactifs (Andra), France.
- Bundesministerium für Wirtschaft und Technologie (BMWi), Germany.
- Central Research Institute of Electric Power Industry (CRIEPI), Japan.
- Japan Atomic Energy Agency (JAEA), Japan.
- Nuclear Waste Management Organisation (NWMO), Canada.
- Posiva Oy, Finland.
- Korea Atomic Energy Research Institute (Kaeri), Korea.
- Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle (Nagra), Switzerland.
- Radioactive Waste Repository Authority (Rawra), Czech Republic.

Andra, BMWi, CRIEPI, JAEA, NWMO and Posiva together with SKB form the Äspö International Joint Committee (IJC), which is responsible for the co-ordination of the experimental work arising from the international participation. Task Forces are another form of organising the international work. Several of the international organisations in the Äspö co-operation participate in the two Äspö Task Forces on (I) Modelling of Groundwater Flow and Transport of Solutes and (II) Engineered Barrier Systems. SKB also takes part in several international EC-projects and participates in work within the IAEA framework.

1.4 Allocation of experimental sites

The rock volume and the available underground excavations are divided between the experiments performed in Äspö HRL. It is essential that the experimental sites are allocated so that interference between different experiments is minimised. The allocation of the experimental sites in the underground laboratory is shown in Figure 1-2.

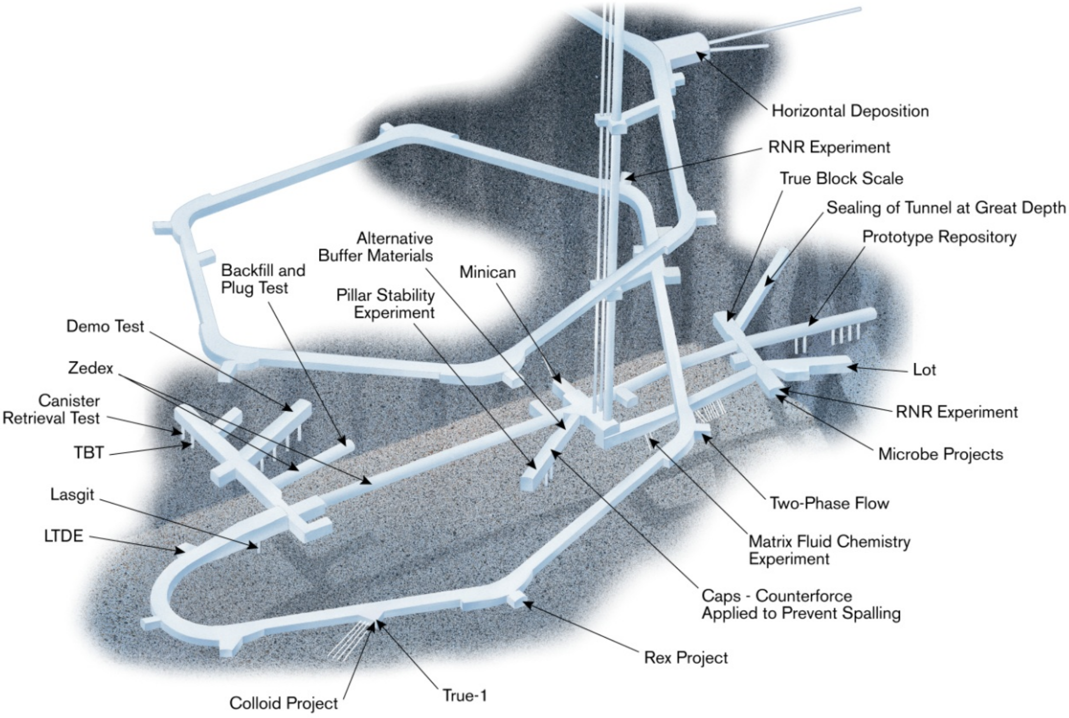


Figure 1-2. *Allocation of experimental sites from -220 m to -450 m level.*

1.5 Reporting

SKB's plans for research and development of technique during the period 2008–2013 are presented in SKB's RD&D-Programme 2007 /SKB 2007/. The information given in the RD&D-Programme related to Äspö is detailed in the Äspö HRL Planning Report. This plan is revised annually and the current report gives an overview of the planned activities for the calendar year 2010. Detailed account of achievements to date for the activities performed at Äspö can be found in the Äspö HRL Annual Report that is published in SKB's Technical Report series. In addition, Status Reports are issued three times per year.

Joint international work at Äspö HRL, as well as data and evaluations for specific experiments and tasks, are reported in Äspö International Progress Report series. Information from Progress Reports is summarised in Technical Reports at times considered appropriate for each project. SKB also endorses publications of results in international scientific journals. Data collected from experiments and measurements at Äspö are mainly stored in SKB's site characterisation database, Sicada.

2 Geoscience

2.1 General

Geoscientific research is a part of the activities at Äspö Hard Rock Laboratory as a complement and an extension of the stage goals 3 and 4, see Section 1.2. Studies are performed in both laboratory and field experiments, as well as by modelling work. The objectives are to:

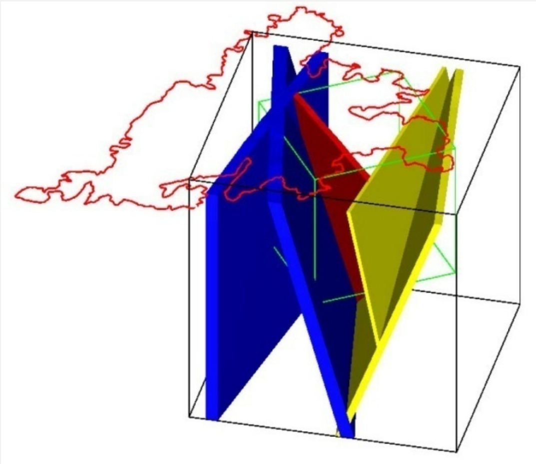
- Establish and develop geoscientific models of the Äspö HRL rock mass and its properties.
- Establish and develop the knowledge of applicable measurement methods.

Experts in the fields of geology and hydrogeology are stationed on site at Äspö HRL, an expert in geochemistry is stationed in Stockholm and there is a vacancy in rock mechanics. The responsibility of the experts in respectively geoscientific field involves maintaining and developing the knowledge and methods of the scientific field as well as geoscientific support to various projects conducted at Äspö HRL.

The main task within the geoscientific field is the development of an Äspö Site Descriptive Model (SDM), see Section 2.2. The activities further aim to provide basic geoscientific data to the experiments and to ensure high quality of experiments and measurements related to geosciences.

During 2010 there are no major activities planned within the field of rock mechanics why this project not will be described further within this report.

2.2 Äspö Site Descriptive Model



The development of an Äspö Site Descriptive Model (SDM) will facilitate the understanding of the geological, hydrogeological and geochemical conditions at the site and the evolution of the conditions during operation of the facility.

The SDM also provides basic geoscientific data to support predictions and planning of experiments performed in Äspö HRL.

The aim is also to ensure high quality of experiments and measurements related to geosciences.

Present status

The present, most updated descriptive model of the Äspö site includes data collected up to 2002 and was published in a series of reports in 2005 /Berglund et al. 2003; Vidstrand 2003; Laaksoharju and Gurban 2003; Hakami 2003/.

The report concerning the detailed 3D structural geological and hydrogeological model of the -450 m level is now almost completed. The model is based on available data from earlier investigations.

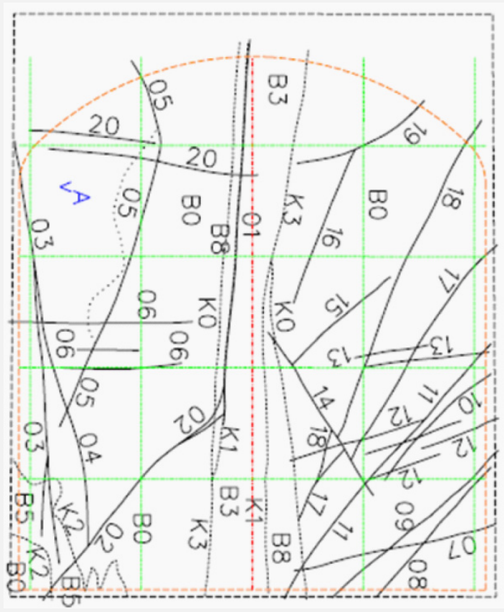
Scope of work for 2010

The intention is to develop the Äspö Site Descriptive Model (SDM) including data up to 2009 into a dynamic working tool, suitable for predictions in support of the experiments in the laboratory. In addition, the report on the detailed 3D model for the -450 m-level will be completed in 2010.

2.3 Geology

The geological work at Äspö HRL is covering several fields. Major responsibilities are mapping of tunnels, deposition holes and drill cores, as well as continuous updating of the geological three-dimensional model of the Äspö rock volume. In addition, the development of new methods in the field of geology is a major responsibility. As a part of the latter, the continuation of the Rock Characterisation System (Rocs) project is being conducted, see Section 2.3.2.

2.3.1 Geological Mapping and Modelling



The end of the Tass-tunnel, section 80.7 m and geological map of the tunnel face (right)

All rock surfaces and drill cores at Äspö are mapped. This is done in order to increase the understanding of geometries and properties of rock types and structures, which is subsequently used as input in the 3D-modelling of the rock volume together with other input data.

Present status

At present no exposed rock surfaces or drill cores from the Äspö rock volume are unmapped. The latest major mapping has been performed in the Tass-tunnel (accommodating the project Sealing of Tunnel at Great Depth) up to section 80.7 m where the tunnel was completed. All mapping has been digitised and adherent data entered into the rock characterisation system TMS (Tunnel Mapping System). There are, however, earlier mappings that still have not been entered into TMS. A report concerning the geology of the Tass-tunnel is in preparation.

Most tunnels of the Äspö HRL have earlier been photographed with ordinary film. These analogue photos have some years ago been converted into digital photos that are now being labelled.

Scope of work for 2010

The major tasks in 2010 will be the planning and the pre-investigations for new tunnels in Äspö HRL. The expansion is necessary to accommodate new experiments in the underground laboratory.

Some work related to the geological mapping of the Tass-tunnel will continue during the spring 2010. Work with “old” tunnel and deposition hole mappings not yet digitised and with geological data not entered into the rock characterisation system TMS will also continue. In addition, the maintenance of the TMS will proceed and it is still suggested that the TMS shall be upgraded to at least Microstation V8. To convert the TMS into a 3D version is no longer an option. A completely new mapping system developed within the Rocs-project appears to be a better solution, see Section 2.3.2.

Method descriptions and instructions concerning the geological work at the rock laboratory will be written during 2010 and labelling of photos will continue.

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

The new version of Faro scanner with a digital camera mounted on top.

A feasibility study concerning geological mapping techniques has been completed /Magnor et al. 2007/. Based on the knowledge from the feasibility study SKB has commenced a new phase of the Rocs project, here referred to as Rocs-II.

The purpose is to investigate if a new system for rock characterisation has to be adopted when constructing a final repository. The major reasons for the project are aspects on objectivity of the data collected, traceability of the mappings performed, saving of time required for mapping and data treatment and precision in mapping. These aspects all represent areas where the present mapping technique may not be adequate.

The project will concentrate on finding or constructing a new geological underground mapping system. Laser scanning in combination with digital photography and/or photogrammetry will be a part of that system. The resulting mapping system shall operate in a colour 3D environment where the xyz-coordinates are known.

Present status

The Rocs-II project is ongoing and a number of tests have been performed, mostly at Äspö HRL but also in Posiva’s underground facility Onkalo (Finland). The company Created Tools has demonstrated the SpheronCam camera once again, the company 3G Software & Measurements has demonstrated their mapping system based on photogrammetry and the company ATS (Advanced Technical Solutions AB) has demonstrated a new version of the Faro laser scanner combined with digital photography in the Tass-tunnel at Äspö HRL. The Australian company Adam Technology has demonstrated their mapping system based on photogrammetry in Onkalo.

The evaluation of the tests is almost completed. Unfortunately the demonstrated systems do not fulfil the requirements set up by SKB concerning database linking. Therefore SKB has now considered developing software concerning mapping and database linking which can be connected to the system themselves. In this case a system similar to the core mapping system Boremap will be developed. A number of software that can handle laser scan data and point clouds has also been tested.

The authors of the feasibility study /Magnor et al. 2007/ suggest that laser scanning together with digital photography should be a part of the new rock characterisation system. After the present tests it appears as if photogrammetry may be even more suitable to obtain tunnel geometries.

ATS executed laser scanning combined with high resolution digital colour photography of the entire Tasq-tunnel in 2006 and the scan data was delivered. However, the report was not printed until 2009 /Berlin and Hardenby 2008/.

Scope of work for 2010

One of the major issues in 2010 is to organise a group of people to create the new mapping software concerning mapping and database linking. In addition, the storage of scanning/photo and mapping data in the Sicada database is an issue that has to be solved.

2.4 Hydrogeology

The objectives of the hydrogeological work are to:

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

The intention is to develop the model into a dynamic working tool suitable for predictions in support of the experiments in the laboratory as well as to test hydrogeological hypotheses. Another part of the work with the site description is the continued development of a more detailed model of hydraulic structures at the main experimental sites.

2.4.1 Hydro Monitoring Programme

The hydro monitoring programme is an important part of the hydro-geological research and a support to the experiments undertaken in Äspö HRL. The monitoring of water level in surface boreholes started in 1987 while the computerised Hydro Monitoring System (HMS) was introduced in 1992.

The HMS collects data on-line of pressure, levels, flow and electrical conductivity of the groundwater. The data are recorded by numerous transducers installed in boreholes. The number of boreholes included in the monitoring programme has gradually increased, and comprise boreholes in the tunnel in the Äspö HRL as well as surface boreholes on the islands of Äspö, Ävrö, Mjälen, Bockholmen and some boreholes on the mainland at Laxemar. To date the monitoring programme comprises a total of about 140 boreholes (about 40 surface boreholes and 100 tunnel boreholes). Many boreholes are equipped with inflatable packers, dividing the borehole into sections. Water seeping into the tunnel is diverted to trenches and further to 25 weirs where the flow is measured.

Weekly quality checks of preliminary groundwater head data are performed. Absolute calibration of data registered with HMS is performed three to four times annually. This work involves comparison with groundwater levels checked manually in boreholes.

The data collected in HMS is transferred to SKB's site characterisation database, Sicada.

Present status

The hydrogeological monitoring has been ongoing where the monitoring points were maintained and the equipment installed in the tunnel is performing well. Two surface drilled boreholes which were refurbished, KAS03 and KAS09, are likely to be operational with on-line monitoring in early 2010. Presently the surface drilled Äspö boreholes are only measured manually and discontinuously.

Scope of work for 2010

Supporting and corrective measures for the surface boreholes will continue and the monitoring of the Äspö tunnel continues with undiminished efforts. Part of the monitoring system from the site investigations at Oskarshamn is planned to be incorporated in the monitoring system for Äspö.

The monitoring work is reported quarterly through quality control documents and annually describing the measurement system and results. A number of Q/A documents for hydrogeological measurements are to be produced. In addition, the work with upgrading the Äspö site descriptive model will continue.

2.5 Geochemistry

The major aims within geochemistry are to:

- Establish and develop the understanding of the hydrogeochemical properties of the Äspö HRL rock volume.
- Maintain and develop the knowledge of applicable measuring and analytical methods.
- Ensure that experimental sampling programmes are performed with high quality and meet overall goals within the field area.

There is a need to develop method descriptions for the actual sampling procedures at field (underground, excavation of tunnel) for the hydrogeochemical work. In addition, instructions for procedures for quality assurance of hydro-chemical data to be included in the site characterisation database Sicada need to be established. The main task is to develop quality control and quality assurance procedures in the field of hydrochemistry and geochemistry.

2.5.1 Monitoring of Groundwater Chemistry

Water sampling in a tunnel at Äspö HRL.

During the Äspö HRL construction phase, water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. The samples were obtained from boreholes drilled from the ground surface and from the tunnel. At the beginning of the operational phase, sampling was replaced by a groundwater chemistry monitoring programme, with the aim to sufficiently cover the evolution of hydrochemical conditions with respect to time and space within the Äspö HRL.

The monitoring programme is designed to provide information to determine where, within the rock mass, the hydrogeochemical changes are taking place and at what time stationary conditions are established.

Present status

The yearly monitoring campaign for groundwater chemistry was performed as planned. However, several boreholes in the upper bedrock (-50 to -100 m) in the tunnel were dried out or not able to sample due to too low groundwater flows. The surface boreholes KAS03 and KAS09 were not sampled this year due to uptake of instrumentation. The analysis of the groundwater samples and the reporting of the results from the monitoring campaign are ongoing.

Scope of work for 2010

The yearly sampling campaign is as earlier years planned to take place during October. Water samples are taken from varying depths in the Äspö HRL and hopefully also from some boreholes drilled from the surface (if they are instrumented again, decision pending). In addition, all projects at Äspö HRL can request additional sampling of their sites to be coordinated within the monitoring programme.

3 Natural barriers

3.1 General

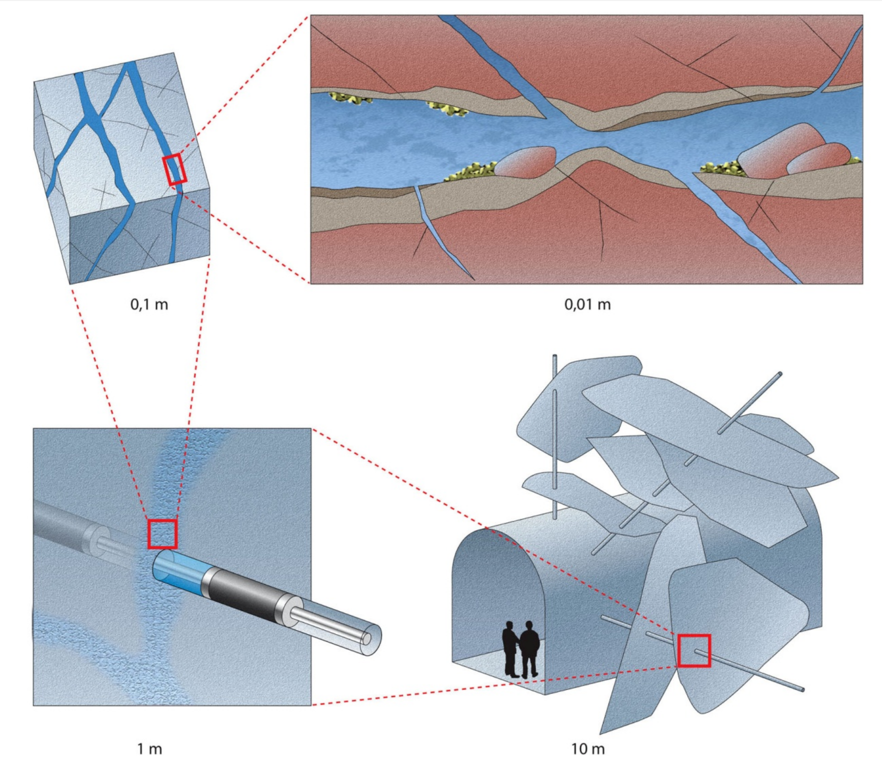
To meet Stage goal 3, experiments at Äspö HRL are performed at conditions that are expected to prevail at repository depth, see Section 1.2. The natural barriers consist of the bedrock and the physical and chemical properties defined by the rock. Emphasis is put on obtaining data and knowledge that is relevant for the understanding of processes in the rock which are of major importance for the long-term performance of a repository.

Models for groundwater flow, radionuclide migration and chemical/biological processes are developed and tested. The aim is to evaluate the usefulness of models and test methods for determination of parameters required as input to the models.

The ongoing experiments and projects within the Natural barriers are:

- Tracer Retention Understanding Experiments.
- Long Term Sorption Diffusion Experiment.
- Colloid Transport Project.
- Microbe Projects.
- Matrix Fluid Chemistry Continuation.
- Radionuclide Retention Experiments.
- Padamot.
- Fe-oxides in fractures.
- Investigation of Sulphide Production Processes in Groundwater.
- Swiw-tests with Synthetic Groundwater.
- Äspö Model for Radionuclide Sorption.
- Task Force on Groundwater Flow and Transport of Solutes.

3.2 Tracer Retention Understanding Experiments



Schematic illustration of various scales of heterogeneity addressed by the TRUE experimental programme, ranging from block scale to micro scale. The micro scale illustration (upper right) shows a cross-section of a conductive fracture that includes a zone of enhanced porosity (light brown), fault gouge (dark brown), idiomorphic crystals (yellow) in a hydrothermally altered rim zone (red).

Tracer tests with non-sorbing and sorbing tracers are carried out in the TRUE family of projects. These are conducted at different scales; laboratory scale (< 0.5 m), detailed scale (<10 m) and block scale (up to 100 m) with the aim to improve understanding of transport and retention in fractured rock.

The work includes building of hydrostructural models and conceptual microstructure models. Numerical models are used to assess the relative contribution of flow-field related effects and acting processes (diffusion and sorption) on in situ retention.

The first in situ experiment (TRUE-1) /Winberg et al. 2000/ performed in the detailed scale and the TRUE Block Scale series of experiments /Winberg et al. 2003/ have come to their respective conclusion. Complementary field work and modelling have been performed as part of two separate, but closely coordinated, continuation projects.

The TRUE Block Scale Continuation (BS2) project, which was a continuation of TRUE Block Scale (BS1), aimed at obtaining additional understanding of the TRUE Block Scale site /Andersson et al. 2007/.

A further extension of the TRUE Block Scale Continuation (BS3) involves production of peer reviewed scientific papers accounting for the overall TRUE findings, and in particular those of BS1 and BS2.

In the TRUE-1 Continuation and Completion projects the objectives are to obtain insight in the internal structure of the investigated feature and to study fixation of sorbing radioactive tracers. Prior to the resin injection in Feature A, complementary hydraulic and tracer tests are performed to better understand Feature A and its relation to the surrounding fracture network. In addition, a dress rehearsal of in situ resin injection is realised through a characterisation project focused on fault rock zones.

Additional work includes complementary laboratory sorption investigations on fracture rim and fault gouge materials, plus a series of three scientific articles on the TRUE-1 experiment.

3.2.1 TRUE Block Scale Continuation

In the aftermath to the BS2 project, a second step of the continuation of the TRUE Block Scale (BS3) was set up. This step had no specific experimental components and emphasised consolidation and integrated evaluation of all relevant TRUE data and findings collected thus far in the form of scientific articles. This integration is not necessarily restricted to TRUE Block Scale, but may include incorporation of relevant TRUE-1 and TRUE-1 Continuation results. The series of articles is divided in two series, one which is focused on the TRUE Block scale results and effects related to the high-porosity fracture rim zone. The second series is more focused on generalisation of results in two papers directed to more high-profiled scientific journals. A forthcoming BS4 includes follow-up in the Tass-tunnel of the TRUE Block Scale target Structure #20 and a desk-top study aiming at consolidation of porosity measures employed by SKB, including their conceptual and discipline-specific interrelations.

Present status

All three manuscripts of the first BS3 series have been resubmitted to Water Resources Research following review (one more general on the effect of the rim zone as observed in the TRUE tests and two related to TRUE Block Scale/Block Scale Continuation tests):

- Significance of fracture rim zone heterogeneity for tracer transport in crystalline rock /Cvetkovic 2010/,
- Transport and retention from single to multiple fractures in crystalline rock at Äspö (Sweden): 1. Evaluation of tracer test results and sensitivity analysis /Cvetkovic et al. 2010/,
- Transport and retention from single to multiple fractures in crystalline rock at Äspö (Sweden): 2. Fracture network simulations and generic retention model /Cvetkovic and Frampton 2010/.

A first draft of a more high-profiled paper directed towards Science was prepared and circulated during the summer. Based on comments received, the paper will be subdivided in two parts. One paper will be more technical directed towards Geophysical Research Letters (GRL), retaining the more technical content of the paper. The other paper, directed towards Science, will focus on comparison with literature and will feature physical demonstration of retention in crystalline as given by the results of TRUE-1 Completion. An overruling objective is to convey the notion that field-scale retention is controlled by diffusion and sorption, and furthermore, that robust model predictions are feasible and extrapolation of results to other scales is possible.

Scope of work for 2010

During 2010, the two papers directed to GRL and Science, respectively, will be finalised. A follow-up study of TRUE Block Scale Structure #20 in the Tass-tunnel will also be carried out (observations in tunnel pilot boreholes, core mappings, pressure registrations during drilling, tunnel mapping etc.). In addition a study on porosity measures, including scale dependencies and interrelations will be performed. Work includes bridging between different disciplines, graphical illustrations and tentative quantification.

3.2.2 TRUE-1 Continuation

The TRUE-1 Continuation project is a continuation of the TRUE-1 experiments and the experimental focus is primarily on the TRUE-1 site. The continuation included performance of the injection of epoxy resin in Feature A at the TRUE-1 site and subsequent overcoring and analysis (TRUE-1 Completion). In addition, this project includes production of a series of scientific articles based on the TRUE-1 project, complementary laboratory sorption experiments on fracture rim zone and fault gouge material and, furthermore, performance of the Fault Rock Characterisation project, the latter involving epoxy resin injection in fractured zones with subsequent overcoring and analysis of pore spaces, partly constituting a dress rehearsal for TRUE-1 Completion.

Present status

The progress in the TRUE-1 Continuation project has been affected by the strong involvement of the project team in the site characterisation and site modelling, up till the first half of 2009. However, the Fault Rock Zones Characterisation Project, the report presenting the results of the image analysis of the epoxy resin injection in fault rock zones /Hakami and Weixing 2005/ has been published, to be followed by finalisation of the associated final report early 2010.

Scope of work for 2010

During 2010, work will be conducted only within TRUE-1 Completion, see Section 3.2.3.

3.2.3 TRUE-1 Completion

TRUE-1 Completion is a sub-project of the TRUE-1 Continuation project and is a complement to already performed and ongoing projects. The main activity within TRUE-1 Completion was the injection of epoxy with subsequent overcoring of the fracture and following analyses of pore structure and, if possible, identification of sorption sites. Furthermore, several complementary in situ experiments were performed prior to the epoxy injection. These tests were aimed to secure important information from Feature A and the TRUE-1 site before the destruction of the site.

The general objectives of TRUE-1 Completion are:

- To perform epoxy injection and through the succeeding analyses improve the knowledge of the inner structure of Feature A and to improve the description and identification of the immobile zones that are involved in the noted retention.
- To perform complementary tests with relevance to the ongoing SKB site investigation programme, for instance in situ Kd- and Swiw-test (single well injection withdrawal).
- To improve the knowledge of the immobile zones where the main part of the noted retention occurs. This is performed by mapping and mineralogical-chemical characterisation of the sorption sites for Cs.
- To update the conceptual micro-structural and retention models of Feature A.

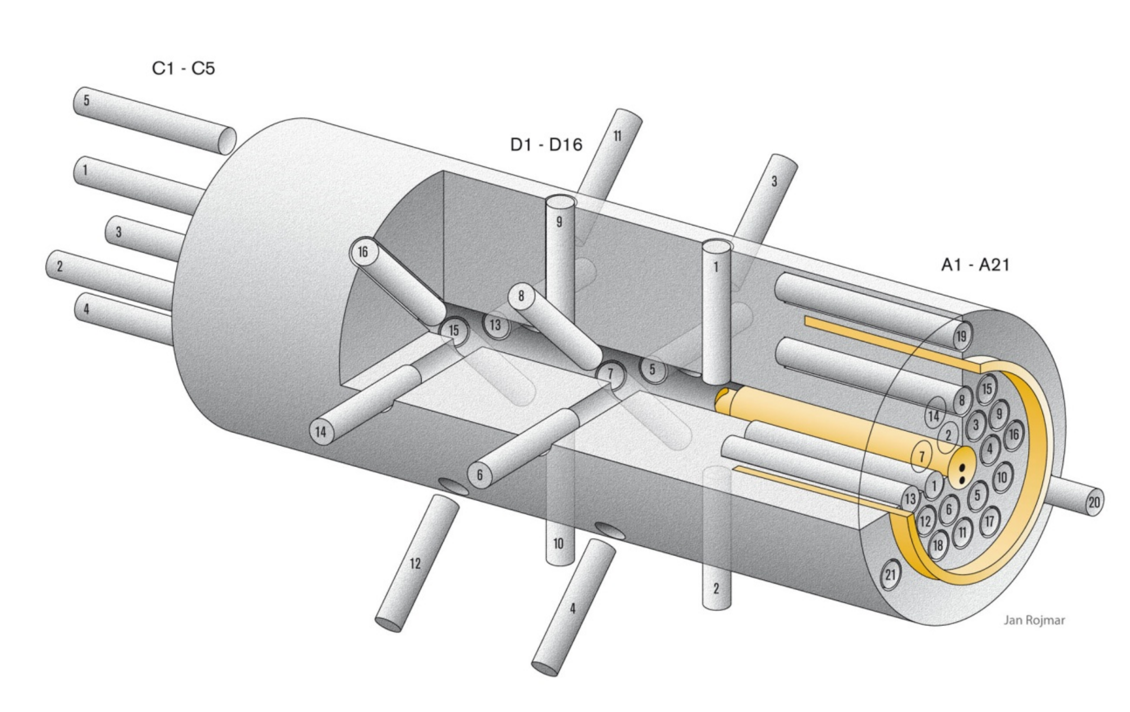
Present status

The major activity during 2009 has been the analyses of core material from the target sections of the boreholes KXTT3 and KXTT4. The main part of the analyses consisted of photography and image analyses of epoxy impregnated fractures, mineral analyses and analyses of caesium in the core material. The majority of analyses are finalised and the reporting is ongoing. Other activities during 2009 have been reporting of tracer tests as well as epoxy injection and subsequent overcoring previously performed within the project.

Scope of work for 2010

The plan for 2010 is to produce and print a report that summarise the results and findings of TRUE-1 Completion and to update the conceptual micro-structural and retention models of Feature A. This report will lead to the finalisation of TRUE-1 Completion which is scheduled for the first six months of 2010.

3.3 Long Term Sorption Diffusion Experiment



Sample cores taken out from the over core: the fracture surface on the core stub (A1 – A18), the matrix rock surrounding the small diameter extension borehole (D1 – D16), control cores taken outside core stub (A19 – A21) and beyond the test section in the small diameter borehole (C1- C5).

This experiment is performed to investigate diffusion and sorption of solutes in the vicinity of a natural fracture into the matrix rock and directly from a borehole into the matrix rock. The aims are to improve the understanding of diffusion and sorption processes and to obtain diffusion and sorption data at in situ conditions.

A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole and a small-diameter borehole is drilled through the core stub and beyond into the intact unaltered bedrock.

Tracers were circulated over a period of 6 ½ months after which the borehole was over cored. This activity is followed by analyses of tracer content.

Small diameter (24 mm) sample cores have been extracted from the 1.1 m long and 278 mm diameter large core retrieved from the over coring. 34 sample cores have been extracted both from the fracture surface on the core stub and from the matrix rock surrounding the test section in the small diameter (36 mm) extension borehole.

Present status

A method for Ni separation in dissolved rock core samples has been developed and the method has been adopted on crushed and dissolved rock slices extracted from the fracture surface on the core stub and on samples extracted from the matrix rock. Preliminary results from the subsequent analyses of ^{63}Ni, using liquid scintillation (LSC), indicate a strong surface sorption and a penetration depth within a few millimetres.

All crushed and intact rock slices selected for subsequent leaching and LSC analysis of ^{36}Cl, have been analysed for γ-emitting tracers (^{22}Na, ^{57}Co, ^{75}Se, ^{85}Sr, ^{95}Zr, ^{110m}Ag, ^{109}Cd, ^{113}Sn, ^{133}Ba, ^{137}Cs, ^{153}Gd, ^{175}Hf, (^{226}Ra) and ^{233}Pa) using a HPGe γ-detector. Analyses of the other samples and leaching and subsequent analysis of ^{36}Cl in crushed and intact rock slices are ongoing.

The batch sorption tests and sorption/diffusion tests with intact rock pieces from the core of the small diameter extension borehole, the replica core stub and the pilot borehole core were finalised in late April. Some completing sampling and tracer analyses have been done and are ongoing, as well as evaluation of the resulting experimental data.

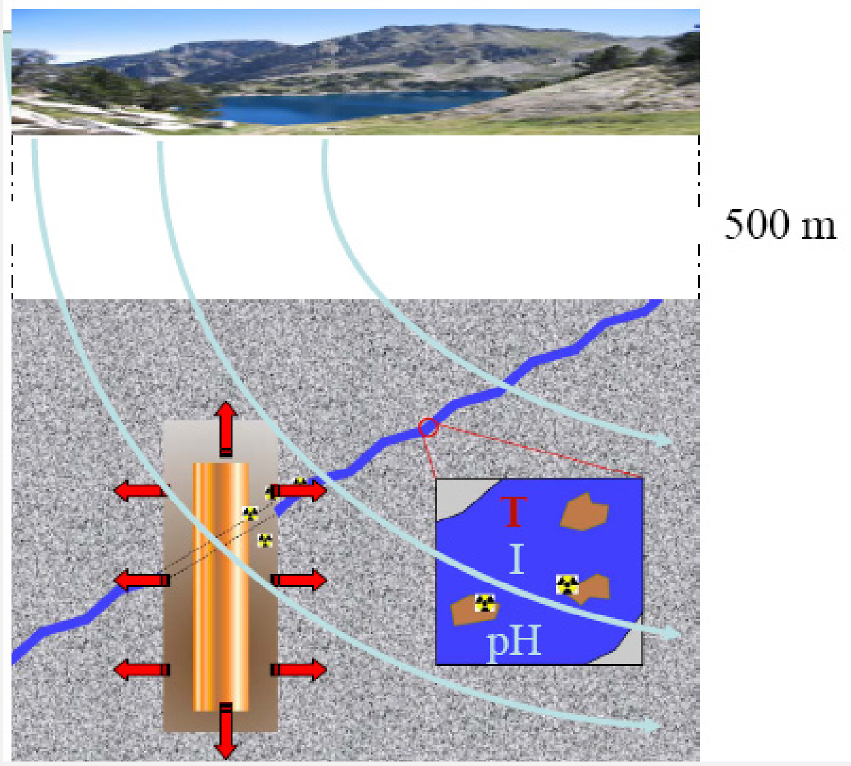
Scope of work for 2010

Data on experimental conditions and all primary data on tracer penetration profiles from the in situ experiment as well as experimental data from the supporting laboratory experiment will be checked and stored in SKB's site characterisation database, Sicada.

The data from Sicada will be used for evaluation and inverse modelling to fit experimental results and determine sorption (Kd, Ka) and diffusion (De) coefficients. The sorption on the fracture surface on the core stub and sorption/diffusion through the fracture rim into the intact matrix rock and also sorption directly on matrix rock surface and sorption/diffusion directly into unaltered matrix rock will be studied.

The results from the laboratory experiments at Chalmers University of Technology (CTH) and the experiments performed at AECL in 2005 will be used to compare laboratory derived diffusion and sorption coefficients for the investigated rock fracture system with the sorption behaviour observed from the in situ experiment. In addition, how representative laboratory scale sorption results are for larger scales will also be evaluated. The final evaluation of results and findings from the project will be performed and reported in 2010.

3.4 Colloid Transport Project



Colloid transport of montmorillonite colloids with or without radionuclides attached.

The main goal for the project is to answer the questions when colloid transport has to be taken into account in the safety assessment, and how the colloid transport can be predicted in modelling.

In the beginning of the lifetime of a deep bedrock repository the groundwater will be quite saline and montmorillonite as well as natural colloids are not stable. Therefore colloid transport can be neglected during this time period.

In the scenario of intrusion of dilute glacial meltwater the conditions for colloid stability can drastically change. Bentonite erosion may give conditions for transport away from the barrier giving loss of material leading to a decrease in the barrier functionality. Also, in the scenario of a leaking canister, strongly sorbed radionuclides to montmorillonite colloids may be transported out from the barrier. Even if the conditions are such that bentonite erosion is favourable, it is not necessarily so that the transport out from the barrier is fast. Retention mechanisms as physical filtration and sorption may significantly reduce the mobility of the colloids.

Present status

The Colloid Transport Project was initiated in 2008 and the knowledge on colloid transport will be summarised in a report which will be finalised in the end of 2010.

The project is in the Colloid Formation and Migration (CFM) collaboration and in situ experiments are performed at the Grimsel Test Site in Switzerland. A large in situ experiment to study bentonite generation from the bentonite barrier is under planning with the partners in this collaboration. An extensive amount of experimental work is undertaken at laboratories of all the collaborators to be able to optimise the in situ experiment.

In Sweden colloid stability tests as well as colloidal characterisation are performed in the laboratory. Also transport experiments in fracture filling material are performed to quantify filtration of colloids in this material. Modelling efforts are ongoing, where retention mechanisms can be included in the models. The aim is to separate the retention into the physical and chemical process such as filtration, sorption and sedimentation.

Scope of work for 2010

Stability experiments: The stability of montmorillonite colloid in varying groundwater conditions is well studied, however, there is still an open question on how montmorillonite colloid stability is affected by γ-radiation. Experimental data indicated that the stability increase after being irradiated. The explanation is not clear wherefore extended experiments will be performed to study the stability as well as changes in colloidal characteristics upon radiation.

Characterisation of structure: Investigations with scanning X-ray microspectroscopy show that bentonite colloids which have equilibrated for a year have a spherical geometry with parts of lower density gel around as well as inside the colloids. Fresh montmorillonite colloids have a planar geometry and therefore it is important to study how these colloid structures evolve with time. The structure of the colloids are highly needed to model transport of these colloids in water bearing fractures to give reasonable assumptions on the interaction of the colloids and the fracture.

Colloid transport: Colloid transport in water bearing fractures is complex and is affected by flow, aperture distribution, surface roughness, groundwater chemistry, colloid characteristics, surface charge and size distribution. Fracture minerals and the presence of fracture filling material will also have an impact on the colloid transport. Colloid transport experiments in varying conditions will therefore continue to be performed within the project.

Modelling activities: Modelling will be performed on all transport data. As a first step modelling will be performed to fit experimental data and in the second step to quantify the effect of different processes and to further develop predictive models. Predictive modelling is preceding the in situ bentonite generation experiment in Grimsel.

3.5 Microbe Projects

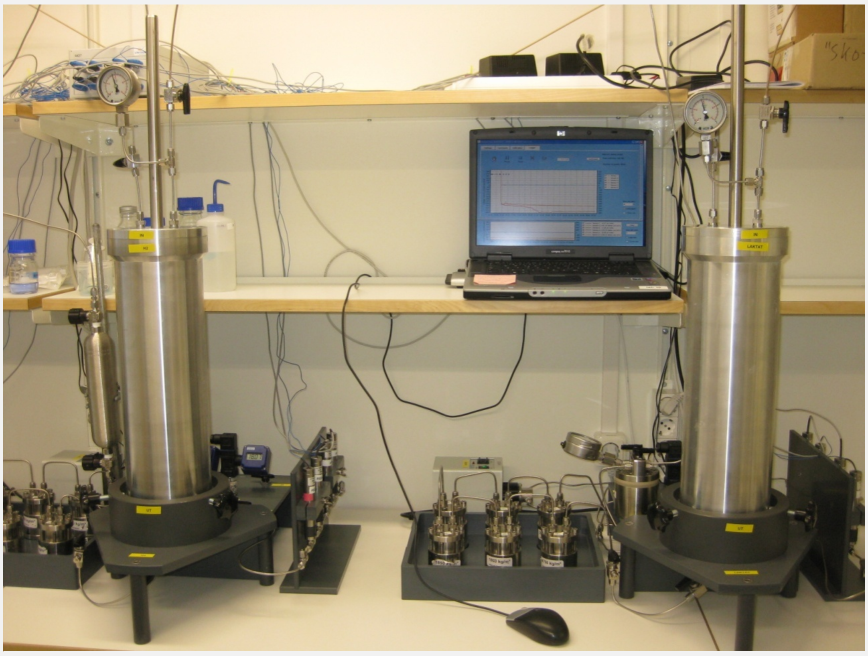
Microorganisms interact with their surroundings and in some cases they greatly modify the characteristics of their environment. Several such interactions may have a significant influence on the function of a repository for spent fuel /Pedersen 2002/. There are presently four specific microbial process areas identified that are of importance for proper repository functions. They are: bio-mobilisation of radionuclides, bio-immobilisation of radionuclides, microbial effects on the chemical stability of deep groundwater environments and microbial corrosion of copper.

The study of microbial processes in the laboratory gives valuable contributions to our knowledge about microbial processes in repository environments. However, the results obtained by laboratory studies must be tested in a repository like environment. The reasons are several. Firstly, at repository depth, the hydrostatic pressure reaches close to

50 bars, a setting that is very difficult to reproduce in the laboratory. The high pressure will influence chemical equilibrium and the content of dissolved gases. Secondly, the geochemical environment of deep groundwater, on which microbial life depends and influence, is complex. Dissolved salts and trace elements, and particularly the redox chemistry and the carbonate system are characteristics that are very difficult to mimic in a university laboratory. Thirdly, natural ecosystems, such as those in deep groundwater, are composed of a large number of different species in various mixes /Pedersen 2001/. The laboratory is best suited for pure cultures and therefore the effect from consortia of many participating species in natural ecosystems cannot easily be investigated there. The limitations of investigations arrayed above in a laboratory situated on ground have resulted in the construction and set-up of an underground laboratory in the Äspö HRL tunnel. The site is denoted the Microbe Laboratory and is situated at the -450 m level.

Six underground circulation systems with flow cells for biofilm development have been installed in the Microbe Laboratory at 450 m depth in the Äspö HRL. They connect directly to aquifers at the in situ pressure of approximately 20 bars. The systems can be isolated from the aquifer and groundwater with indigenous microbes is then circulated through the flow cells without contact with the aquifer. In the open mode, biofilms develop on the surfaces in the flow cells. When the systems are turned to the closed mode, the in situ pressure, and the anaerobic and reduced conditions are kept as in the open mode. These systems were for example used to investigate the effect of hydrogen and acetate on microbial processes.

3.5.1 The Microbe Laboratory



Pressure resistant micro-electrodes are used to analyse redox and pH in the circulation systems.

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

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

Three boreholes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures are connected to the Microbe Laboratory via tubing. The laboratory is equipped with six circulation systems offering 2,112 cm^2 of test surface per system.

The major objectives are to:

- Offer proper circumstances for research on the effect of microbial activity on the long-term chemical stability of the repository environment.
- Provide in situ conditions for the study of bio-mobilisation of radionuclides.
- Present a range of conditions relevant for the study of bio-immobilisation of radionuclides.
- Enable investigations of bio-corrosion of copper under conditions relevant for a high level radioactive waste repository.
- Constitute a site for research within other projects that require an underground site for microbiological investigations.

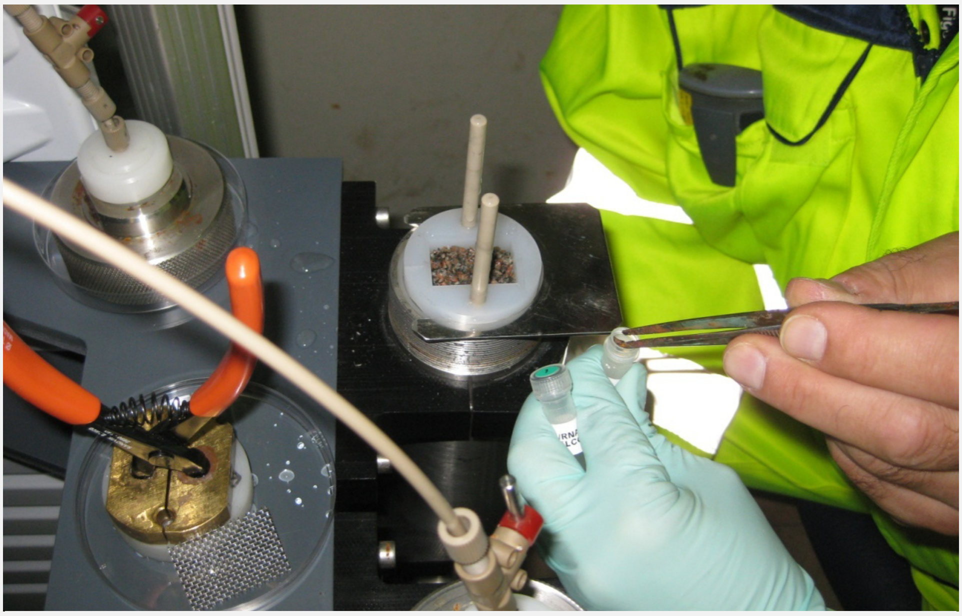
Present status

The microbe laboratory has acted as a base for several different microbiological tunnel research activities during 2009. Samples from the Prototype experiment was analysed in May and November. In addition, Micored experiments have also been performed with the microbe site as a base.

Scope of work for 2010

Several main activities are planned for 2010 with the aim to increase the understanding of microbiological processes. Redox related processes, including sulphide production, will be studied in the Micored project. The importance of dissolved gases in groundwater and the rock matrix for microbial processes will be investigated. The Microbe Laboratory will also be utilised during sampling of engineered barrier projects such as the Prototype Repository and In Situ Corrosion Testing of Miniature Canisters.

3.5.2 Micored



Sampling of rock pieces that have been exposed in a flow cell to circulating groundwater in one of the circulation systems on the Microbe site. Subsequently, DNA analysis reveals amount and types of microorganisms that have attached and grown on the rock pieces.

Microorganisms can have an important influence on the chemical situation in groundwater. Especially, they may execute reactions that stabilise the redox potential in groundwater at a low level.

It is hypothesised that hydrogen and possibly also methane from deep geological processes contributes to the redox stability of deep groundwater via microbial turnover of this gas. These metabolisms will generate secondary metabolites such as ferrous iron, sulphide, acetate and complex organic carbon compounds.

The work within the Micored project will:

- Clarify the contribution from microorganisms to stable and low redox potentials in groundwater.
- Demonstrate and quantify the ability of microorganisms to consume oxygen in the near- and far-field areas.
- Explore the relation between content and distribution of gas and microorganisms in deep groundwater.

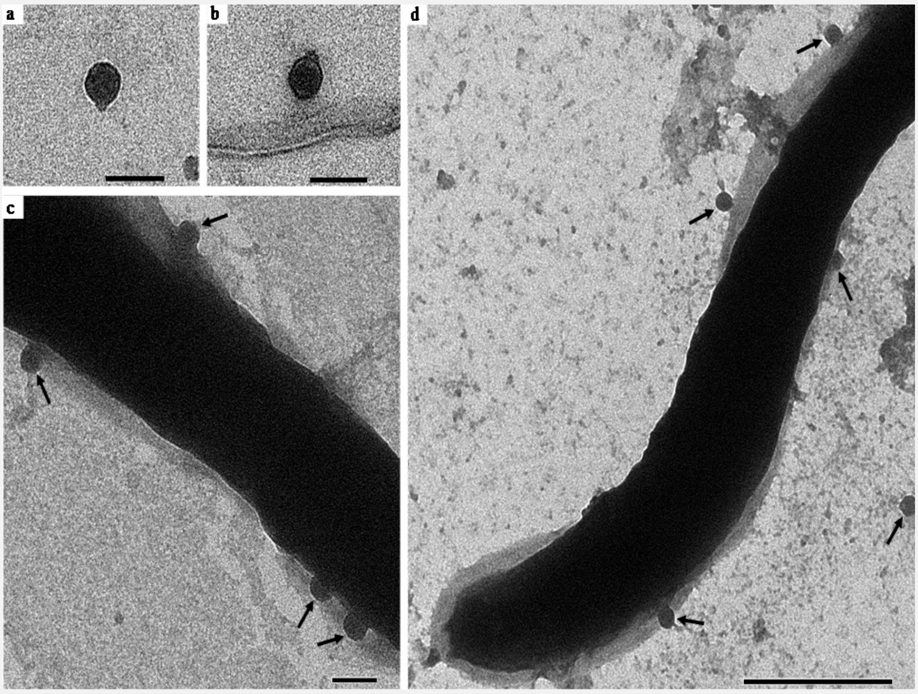
Present status

The distribution, diversity and activity of sulphate reducing bacteria (SRB) in boreholes along the Äspö tunnel have been investigated, with emphasis on *Desulfovibrio aespoeensis*. A significant diversity of SRB was found. The influence of virus on sulphate reducing bacteria was investigated as well /Eydal et al. 2009/. Growth experiments are being conducted where the influence of hydrogen and acetate on growth of microbial biofilms and the redox potential are being investigated.

Scope of work for 2010

The circulation systems at the Microbe Laboratory will be used to collect data for modelling work. Pressure resistant electrodes will continue to be employed for on-line analysis of redox potential and pH as a function of microbial processes. Boreholes in the tunnel will be analysed for gas content as a function of drainage volumes and times of rest. Drill cores are planned to be sampled and analysed for matrix content of gas.

3.5.3 Micomig



The morphologies of phages isolated from deep groundwater lytic to Desulfovibrio aespoeensis growing in a medium for sulphate-reducing bacteria are shown in transmission electron micrographs a and b. Images c and d show phages (arrows) at the surface of a bacterium The scale bar is 100 nm in a–c and 500 nm in d. /Figure from: Eydal et al. 2009/.

It is well known that microbes can mobilise trace elements. Firstly, unattached microbes may act as large colloids, transporting radionuclides on their cell surfaces with the groundwater flow. Secondly, microbes are known to produce ligands that can mobilise soluble trace elements and that can inhibit trace element sorption to solid phases.

Almost all microorganisms are attacked by viruses. A successful attack may result in several hundred new viruses. The size of virus is well within the range of colloids. The influence of such viruses on colloid related processes can be significant, as the numbers of viruses in groundwater may reach several billion particles per litre.

Biofilms in aquifers will influence the retention processes of radionuclides in groundwater. Previous research at Äspö HRL indicated that biofilms may enhance or retard sorption, depending on the radionuclide in question.

The major objectives are to:

- Evaluate the influence from microbial complexing agents on radionuclide migration.
- Explore the influence of microbial biofilms on radionuclide sorption and matrix diffusion.
- Analyse the possibility of a colloidal effect from viruses in groundwater on radionuclide mobility.

Present status

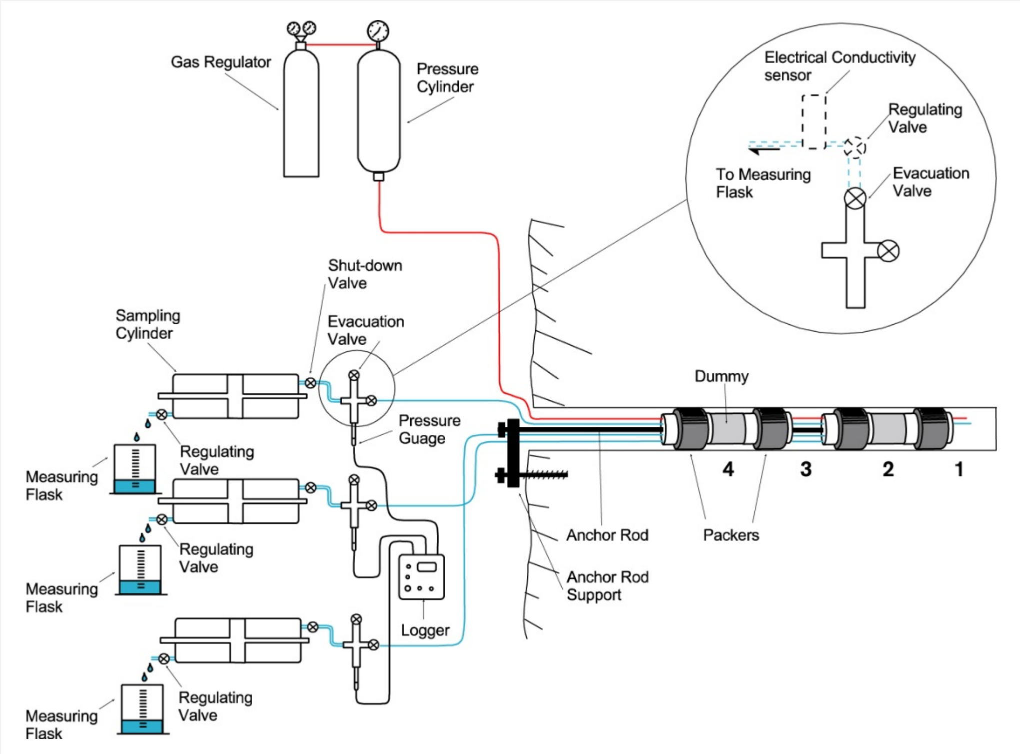
Water-conducting fractures intersected by the Äspö tunnel have been drilled and analysed for the presence of biofilms. Biofilm organisms were characterised with cultivation and molecular DNA methodology.

The content of lytic phages infecting the indigenous bacterium *Desulfovibrio aespoeensis* in Äspö groundwater was analysed using a most probable number technique for phages. Using transmission electron microscopy, these were characterised and found to be in the *Podoviridae* morphology group, see figure above.

Scope of work for 2010

A scientific paper on microorganisms that grow as biofilms on fracture surfaces is being compiled for publication during 2010.

3.6 Matrix Fluid Chemistry Continuation



The main objectives of the Matrix Fluid Chemistry experiment are to understand the origin and age of fluids/groundwater in the rock matrix pore space and in micro-fractures, and their possible influence on the chemistry of the groundwater from the more highly permeable bedrock. Matrix fluids are sampled from a borehole drilled into the rock matrix. Fluid inclusions in core samples have also been studied to determine their contribution, if any, to the composition of the matrix fluids/groundwater.

A first phase of the project is finalised and reported /Smellie et al. 2003/. The major conclusion is that porewater can successfully be sampled from the rock matrix and there is no major difference in chemistry compared to groundwater from more highly conductive fracture zones in the near-vicinity.

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

- The nature and extent of connected porewaters in the Äspö bedrock.
- The nature and extent of the microfracture groundwaters which penetrate the rock matrix and the influence of these groundwaters on the chemistry of the porewaters.
- The confirmation of rock porosity values previously measured in the earlier studies.

Present status

The experimental phase of the project has been completed and is presently being reported and integrated with the results from the earlier Matrix Fluid Chemistry Experiment.

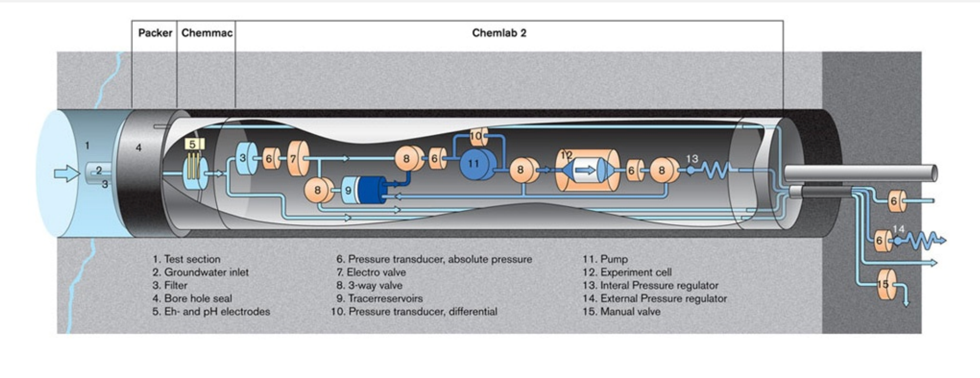
Scope of work for 2010

The work during 2010 will consist of integration of results and finalisation of the reporting. A SKB technical report is envisaged.

3.7 Radionuclide Retention Experiments

Most of the Radionuclide Retention Experiments that have been and are planned to be carried out, have 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 performed in two different unique borehole laboratories, Chemlab 1 and Chemlab 2. The Chemlab probes contain a number of valves, pumps, fraction collectors, etc., all to make it possible to perform a set of different experiments.

3.7.1 Spent Fuel Leaching



Principal drawing of Chemlab 2.

In the Spent Fuel Leaching experiments, to be performed within the framework of the programme for in situ studies of repository processes, the dissolution of spent fuel in groundwater will be studied.

The objectives of the experiments are to:

- Investigate the leaching of spent fuel in laboratory batch experiments and under in situ conditions.
- Demonstrate that the laboratory data are reliable and correct for the conditions prevailing in the rock.

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

In the field experiments spent fuel leaching will be examined with the presence of H_2 (in a glove box situated in the gallery) as well as without the presence of H_2 (in Chemlab 2).

Present status

A test plan for a pre-study is under preparation and the pre-study will include:

- Order and purchase of alpha-doped uranium dioxide.
- Contacts with the Swedish Radiation Safety Authority in order to inform and discuss whether spent nuclear fuel shall be used in the glove-box experiments or not and, if needed, to get a permission to use spent nuclear fuel at Äspö.
- Selection of borehole for the experiments, since the borehole used in previous Chemlab 2 experiments is suspected to accumulate oxygen when it has been closed for longer periods of time.
- Make an inventory of and purchasing equipment required for the project. The status of the glove box that has been used in the actinide migration project must be investigated; the glove box needs to be equipped with fraction collectors,

a pump, a balance, a web camera, etc. An oven needs to be purchased to sinter the fuel before use, Chemlab 2 needs to be serviced, equipment for monitoring Eh of the water used in the experiment.

- Preparation of a project plan describing not only the experiment but also evaluates how to couple the in situ experiments to laboratory studies.
- Assignment of project personnel.

Scope of work for 2010

During 2010, the planned pre-study will be performed.

3.7.2 Transport Resistance at the Buffer-Rock Interface

The expansion of bentonite into an artificial fracture.

If a canister fails and radionuclides are released, they will diffuse through the bentonite buffer. If there is a fracture intersecting the deposition hole, the water flowing in the fracture will pick up radionuclides from the bentonite buffer.

The transport resistance is concentrated to the interface between the bentonite buffer and the rock fracture. The mass transfer resistance due to diffusion resistance in the buffer is estimated to only 6% while the diffusion resistance in the small cross section area of the fracture in the rock to 94%. The aim of the project is to perform studies to verify the magnitude of this resistance.

The experiment will be performed in the laboratory, where a fracture is simulated as a 1 mm ‘fracture’ between two Plexiglas plates. The equipment for the laboratory experiments has been used in the Bentonite Erosion project.

The equipment includes a water pump for very low flow rates. The design of field experiments depends on the outcome of the laboratory experiments.

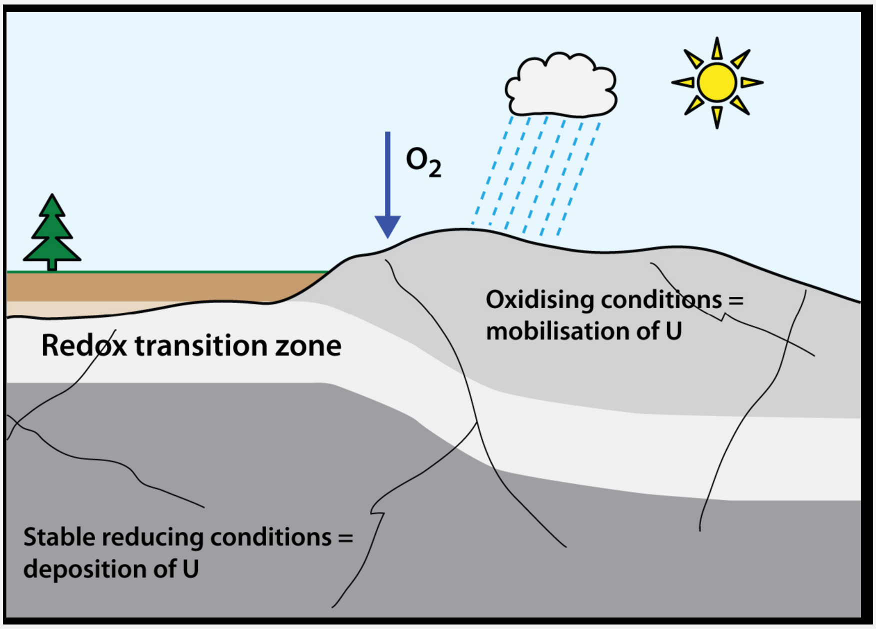
Present status

The laboratory studies have started. At least initially a dye will be used as tracer that is released into the fracture. The dye that has been selected for this is fluorescein, which is a dye with relatively low solubility and very high extinction coefficient in fluorescence spectroscopy. Kinetic studies on the dissolution rate of the dye are presently ongoing.

Scope of work for 2010

The dye will be used in the artificial fracture. The dye will be contained in a container. Perpendicularly to the container, water will be pumped with a very low flow rate. The expectation is that the release into the fracture will be observed visually. Since the dye becomes green when illuminated by UV-light, even low concentration of dye in the fracture will be possible to observe. The outlet from the fracture will also be collected and analysed.

3.8 Padamot



Oxygen entering the bedrock via recharge water will be consumed by organic and inorganic processes along the bedrock fractures. This transition can be detected by studies of uranium and uranium isotopes.

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

The EC-part of the project was finalised and reported in 2005. The Padamot continuation project comprises:

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

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

Present status

Uranium series analyses have been applied on six samples from drillcore KAS 17 located in the north-eastern part of the island Äspö. The samples represent core lengths selected from 19.6 to 196 m borehole core length. The amount of sample material possible to extract from each water-conducting structure varied considerably and therefore this was a deciding factor for the scope of the analyses possible to carry out.

All six samples were analysed for U and Th content by ICP at ALS Scandinavia AB in Luleå. Bulk uranium series analyses (USD) were applied on all six samples by the Helsinki University, with duplicate analyses carried out on three. In addition, two samples were analysed by SUERC. Sequential extraction was applied to four samples by the Helsinki University (2 to 4 steps depending on amount of available sample). SUERC applied sequential extraction on two samples using a similar approach (applying 4 leaching steps). Samples from 19.6 m and 20.38 m (the uppermost samples showing distinct disequilibria) were analysed by both laboratories using both bulk analyses and sequential extraction. In addition, U and Th contents were analysed on these samples by a third laboratory.

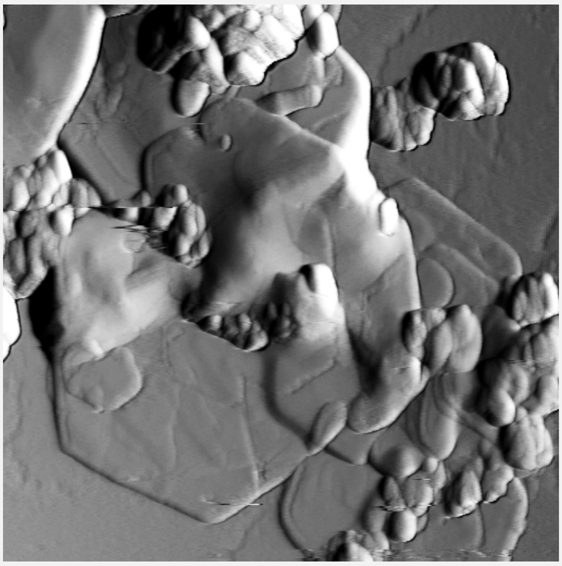
The uppermost core length samples 19.6, 20.3 and 20.38 m represent a transition zone with changing redox conditions and thereby a shift from uranium mobilisation to uranium deposition. Only the uppermost sample (19.6 m) indicates uranium mobilisation. However, this sample also has the highest uranium content (around 25 ppm) suggesting older uranium precipitation (before the last 1 million years). Recent deposition was obvious in sample 20.38 m whereas sample 20.3 m showed much less influence of recent redistribution, once again underlining the inhomogeneity in the bedrock fracture system. The deepest samples, 156 and 196 m, show activity ratios approaching equilibrium, whereas sample 102 m shows uranium deposition, considered older than the last deglaciation.

It can thus be concluded that the present redox zone is situated in the upper 15 to 20 m (if the core lengths are recalculated to vertical depth) and shifts from uranium mobilisation to uranium deposition within a very short distance, depending on changes in groundwater flow and chemistry (maybe annual variations).

Scope of work for 2010

The aim of the project has been not only to make inter laboratory comparisons but also to suggest methodologies for future studies. This will be one of the challenges for the final reporting during 2010. A review of the palaeohydrogeological methodology used during the site investigations will also be included in the report.

3.9 Fe-oxides in Fractures



Atomic Force Microscopy image of green rust sulphate. Image is 2.5 x 2.5 microns.

Proof of reducing conditions at repository depth is fundamental for the safety assessment of radioactive waste disposals. Fe(II) – minerals are common in the bedrock and along fracture pathways and constitute a considerable reducing capacity together with organic processes. Another area of interest is the radionuclide retention capacity provided by Fe-oxides and –oxyhydroxides in terms of sorption capacity and immobilisation.

The basic idea of the project is to examine Fe-oxide fracture linings, in order to explore for suitable palaeo-indicators for their formation conditions, while at the same time learning about the behaviour of trace component uptake in general, both from the natural material as well as through testing of behaviour in controlled parametric studies in the laboratory.

Following the original project, a continuation phase with the aim to establish the penetration depth of oxidising water below ground level was started. The oxidising waters may represent present-day recharge, or reflect penetration of glacial melt waters during the last glaciation.

Present status

In 2007, a new method to determine the penetration depth of oxidising waters using Fe-oxides as proxies and a limited set of samples from Äspö, Oskarshamn and Laxemar were investigated. In 2008 this method was applied to a larger sample suite (28 samples) taken from the upper approximately 110 m of drillcore material from the Laxemar site. From the various sites studied, three types of natural Fe-oxides have been identified:

> **Type I:** Hematite with a large particle size and little variation in Fe isotope composition, occurring at depths ranging from the surface to a depth of 800 m.
>
> **Type II:** Crystalline Fe-oxides (goethite, magnetite, hematite with smaller particle sizes) occurring at depths down to 110 m below surface.
>
> **Type III:** X-ray identified amorphous, nanometre-sized Fe-oxides occurring at depths down to 50 m below surface.

In the samples studied, no evidence has been found of natural, low-temperature formation of Fe-oxides below 110 m. Due to other priorities, the final reporting of the continuation phase of the project was not completed during 2009.

Scope of work for 2010

The work during 2010 will consist of publishing the continuation phase of the project as an Äspö HRL International Progress Report. This report, together with all earlier progress reports and publications in the open literature, will be combined in a SKB technical report.

3.10 Investigation of Sulphide Production Processes in Groundwater

A black precipitate with a smell of hydrogen sulphide in the water standpipes of borehole KAS03. The borehole equipment (iron bars, plastic tubing and rubber packers) was installed more than 20 years ago for groundwater monitoring purposes.

Elevated sulphide concentrations in groundwater have been observed in some boreholes during the site investigations at Laxemar and Forsmark as well as in boreholes investigated during the pre-investigation phase at Äspö. Since sulphide can react with the copper canister, assessment of the sulphide concentration in groundwater is of outmost importance in the waste disposal programme.

The project is proposed to meet the demand for a better understanding of the processes behind sulphide production (microbial sulphate reduction) in groundwater from core drilled boreholes and also to assess any possible influence of the borehole and borehole equipment on the sulphide concentration.

Core drilled boreholes are equipped for monitoring purposes. The equipments are manufactured from stainless steel, iron, different kinds of plastics and rubber. The water standpipes constitute the part of the borehole equipment with a range from the ground level to up to tens of meters down. A plastic tubing connects the water in the standpipe to the water in the section.

When sampling the section water, a portable pump (connected to an empty tubing) is lowered down to the bottom of the standpipe and the water is reaching the ground surface due to the principle of levelling out.

Present status

Analysis data are presently being evaluated. The data were derived from field investigations, performed in core drilled boreholes at Äspö (KAS03, KAS09) and at Laxemar (KLX06). Discrete samples of water were taken from the standpipes and sections in KAS03 (127-252 m and 860-1,002 m) and in KAS09 (116-150 m). In KLX06 (554-570 m) the sampling was performed as time-series during continuous pumping of water and turnover of more than 100 section volumes. The analysis programme has included general parameters (such as SO_4^{2-}, Fe^{2+}, HCO_3^-, DOC), isotopes (such as ^{34}S and ^{13}C), stable isotopes in gases ($\delta^{13}C$ and δ^2H), gas composition and microbiological analyses.

Scope of work for 2010

Investigation of sulphide production in one or two boreholes (sections) in the Äspö tunnel will be completed in the beginning of 2010. Remaining work of this project is sorted into a new project ordered from the Spent Fuel programme. In the new project, all aspects of sulphide in the repository are handled. Detailed planning of the new project is ongoing.

3.11 Swiw-tests with Synthetic Groundwater

Injection of tracer in fracture.

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

The general objective of the Swiw test with synthetic groundwater is to increase the understanding of the dominating retention processes and to obtain new information on fracture aperture and diffusion. The basic idea is to perform Swiw tests with synthetic groundwater with a somewhat altered composition, e.g. replacement of chloride, sodium and calcium with nitrate, lithium and magnesium, compared to the natural groundwater at the site.

Sorbing as well as non-sorbing tracers may be added during the injection phase of the tests. In the withdrawal phase of the tests the contents of the "natural" tracers (chloride sodium and calcium) as well as the added tracers in the pumping water is monitored. The combination of tracers, both added and natural, may then provide desired information on diffusion, for example if the diffusion in the rock matrix or in the stagnant zones dominates.

Present status

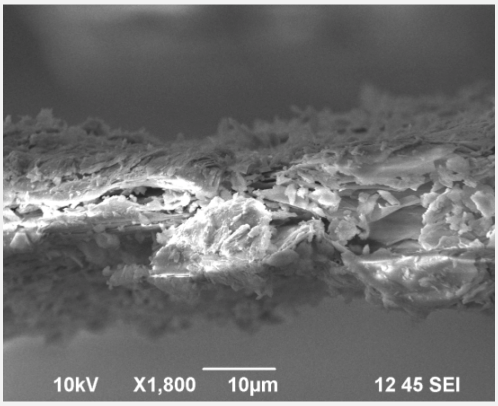
In June 2009 the project decision and project plan were approved. The first activity after the project decision was to produce a supporting document for field test site selection. As mentioned in the planning report for 2009 /SKB 2009/, the main candidate for the site was TRUE Block Scale. However, during the site selection process it was found that the new Tass-tunnel in the vicinity of TRUE Block Scale had affected the hydraulic conditions at the site so that it no longer was suitable for execution of Swiw-tests with synthetic groundwater. The search for a suitable field test site has been ongoing and an anomaly in the Rex-niche has been selected. Another ongoing activity is scoping calculations regarding analyses of radon in the Swiw-tests with synthetic groundwater.

Scope of work for 2010

The main activities planned for 2010 are pre tests, main tests, evaluation and reporting. The pre tests will be initiated in the beginning of 2010 and the project should be finalised during 2010. If the pre-test show that the existing test site is not suitable, an option of establishing a new test site is present in the project plan. However, if this option must be used, the project will be delayed with four to eight months and will continue in 2011.

3.12 Äspö Model for Radionuclide Sorption

BET-analysator for determination of specific surface areas of geological materials.



A SEM image of a chlorite particle /Zazzi et al. 2009/.

Today, geochemical retention of radionuclides in the granitic environment is commonly assessed using Kd-modelling. However, this approach relies on fully empirical observations and thus to a limited degree contribute to the evaluation of the conceptual understanding of reactive transport in complex rock environments.

In the literature, the process based component additivity approach, which relies on a linear combination of sorption properties of different minerals in a geological material, has been suggested for estimation of sorption properties.

For adoption of this approach to granitic material, the particle size/surface area dependence of radionuclide sorption and effects of grain boundaries need to be resolved. Furthermore, it is desirable to verify sorption of radionuclides to specific minerals within the rock.

The overall objective of this project is to formulate and test process quantifying models for geochemical retention of radionuclides, in granitic environments, using a combined laboratory and modelling approach.

Present status

During 2009 a new gas adsorption instrument for determining specific surface area and porosity has been taken into operation. A method to determine the specific surface area of centimetre sized pieces of geological material has been adopted, tested and modified. Specific surface areas as low as 0.001 m^2/g have been measured with good precision, using krypton gas adsorption through the BET-method.

A number of pure mineral samples have been acquired for the experimental work in this project and are now being characterised. The characterisation aims at confirming the identity of the minerals and determining their chemical composition and purity. The early preparation of mineral samples particularly included preparation of up to centimetre pieces for specific surface area and porosity determinations. Both the large pieces and the crushed material will be used in subsequent laboratory sorption experiments. Currently, the specific surface area of the centimetre pieces and the crushed material is being determined.

Planned batch experiments for radionuclide sorption onto pure minerals and geological material from Äspö have been postponed and are awaiting an ongoing evaluation of the methodology employed within SKB for batch sorption experiments.

A co-operation with researchers at Nuclear Chemistry and Inorganic Chemistry at The Royal Institute of Technology, on the model interpretation of the specific surface area and radionuclide sorption properties of the mineral chlorite has been initiated. As part of this co-operation, a surface complexation model for Ni^{2+} sorption onto chlorite as function of pH in small scale laboratory experiments was tested for two different chlorite samples. It was found that despite an order of magnitude difference in the specific surface area between the two chlorites, the sorption could be modelled with the same model, due to similar sorption strengths of the two samples. It was proposed that this similarity in sorption reactivity is due to similar reactive surface areas between the samples, despite difference in the total specific surface area as determined by N_2 sorption through the BET-method /Zazzi et al. 2009/. From theory it was shown that this situation may occur, for example, if the basal plane of the chlorite is rough or the particle partly disintegrated, as had been observed by SEM (Scanning Electron Microscopy) for one of the chlorite samples used. Preliminary results of the modelling work were presented at the 12th Goldschmidt conference in Davos in June 2009 /Dubois et al. 2009/.

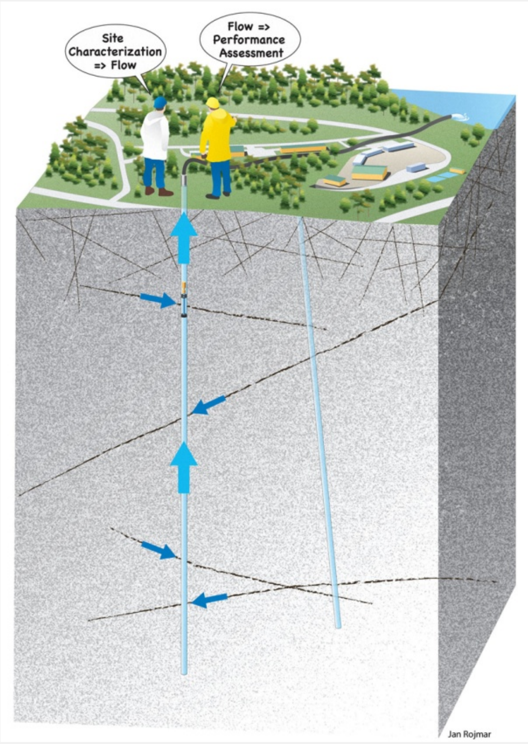
Scope of work for 2010

During 2010, the determination of surface area and porosity as a function of particle size will be finished and the data will be analysed. The ongoing characterisation of the geological material will be finalised. Furthermore, the material will be characterised by microscopy and SEM. Based on the findings, samples will be selected for further investigations, aiming at through autoradiographic methods collecting information on the localisation of the sorption of radionuclides at the geological surface, e.g. association with specific minerals, grain boundaries and/or surface features.

Batch and in-diffusion experiments using radioactive isotopes (Cs, Sr, Eu and Ni/Co) and pure mineral samples and geological material similar to those in the LTDE experiment will furthermore be initiated. These experiments aim at establishing the dependence of sorption on specific surface area, cation exchange capacity and/or particle size.

Methods for studying the sorption of radionuclides on geological surface through radiographic methods will be adopted from the literature, tested and modified.

3.13 Task Force on Modelling of Groundwater Flow and Transport of Solutes



Task 7 - Reduction of Performance Assessment uncertainty through modelling of hydraulic tests at Olkiluoto, Finland.

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

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

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

Present status

During 2009, work has mainly been performed in Task 7 - Reduction of Performance Assessment (PA) uncertainty through modelling of hydraulic tests at Olkiluoto, Finland. Task 7 is focusing on methods to quantify uncertainties in PA-type approaches based on Site Characterisation CS-type information; along with being an opportunity to increase the understanding of the role of fracture zones as boundary conditions for the fracture network and how compartmentalisation influence the groundwater system. The possibilities to extract more information from interference tests are also addressed. Task 7 is divided into several sub-tasks and updated task descriptions for the sub-tasks 7B and Task 7C including more data have been sent out to the modellers. The status of the specific modelling tasks within Task 7 is given within brackets in Table 3-1.

In addition, papers on Task 6 have been published in Hydrogeology Journal. Task 6, which tried to bridge the gap between PA- and SC-models by applying both approaches for the same tracer experiment, is thereby finalised. Task 8 – Interface between engineered and natural barriers, has started up in terms of planning and scoping calculations. The experimental part of Task 8 is still in the planning phase.

Task 8 is a joint effort with the Task Force on Engineered Barriers, and will be addressing the processes at the interface between the rock and the bentonite in deposition holes.

The 25th international Task Force meeting was held in Mizunami, Japan, in October. The presentations were mainly addressing modelling results on sub-tasks within 7B, sub-task 7C and initial scoping calculations of Task 8. The discussions on the continuation of Task 7 and also the continuation of Task 8 were constructive. A workshop on Task 7 and 8 was held in Lund, January 2009, and the minutes have been distributed to the Task Force.

Table 3-1. Descriptions and status (within brackets) of the specific modelling sub-tasks in Task 7.

7	**Reduction of Performance Assessment uncertainty through modelling of hydraulic tests at Olkiluoto, Finland.**
7A	Long-term pumping experiment. (Final results of sub-task 7A are reported as ITDs).
7B	Sub-task 7B is addressing the same as sub-task 7A but in a smaller scale, i.e. rock block scale. Sub-task 7B is using sub-task 7A as boundary condition. (Updated results presented at the 25th Task Force meeting).
7C	Here focus is on deposition hole scale issues, resolving geomechanics, buffers, and hydraulic views of fractures. (Preliminary results presented at the 25th Task Force meeting).
7D	Sub-task 7D concerns integration on all scales (Tentative).

Scope of work for 2010

The main activities targeted to be accomplished during 2010 are summarised below:

- Perform modelling and reporting within Task 7.
- The external review of Task 7 will continue.
- Start up the experimental part of Task 8, a common task with the Task Force on Engineered Barriers.
- Perform scoping calculations and modelling in support to Task 8.
- Organise the Task 7 and 8 workshop, hosted by Posiva.
- Organise the 26th international Task Force meeting, preliminary in May.

4 Engineered barriers

4.1 General

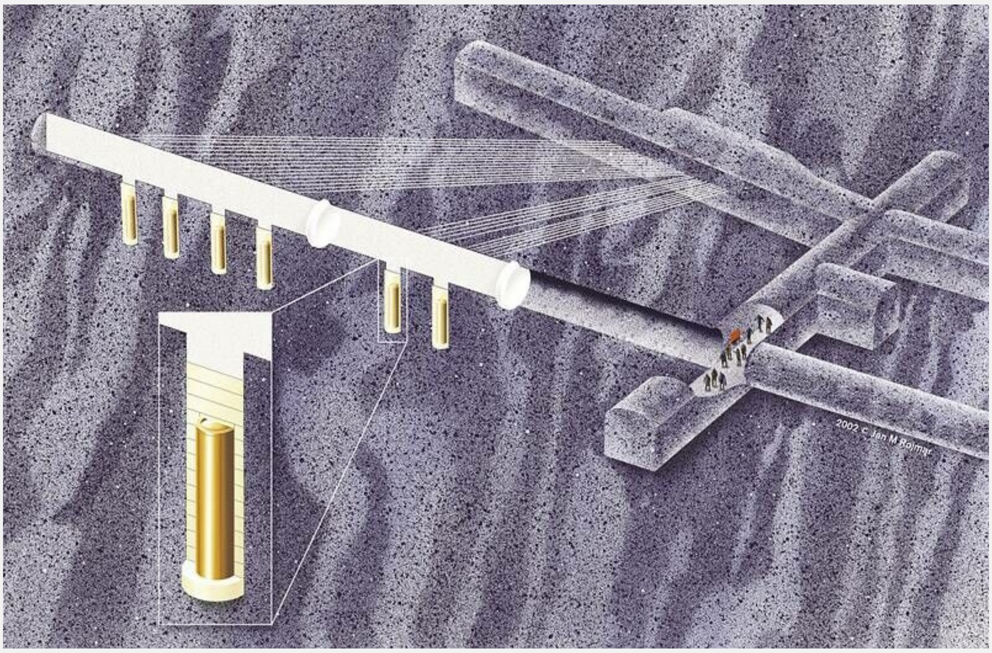
To meet stage goal 4, to demonstrate technology for and function of important parts of the repository barrier system, work is performed at Äspö HRL. This implies translation of current scientific knowledge and state-of-the-art technology into engineering practice applicable in a real repository.

It is important that development, testing and demonstration of methods and procedures, as well as testing and demonstration of repository system performance, are conducted under realistic conditions and at appropriate scale. A number of large-scale field experiments and supporting activities are therefore conducted at Äspö HRL. The experiments focus on different aspects of engineering technology and performance testing and will together form a major experimental programme.

The ongoing experiments and projects within the Engineered Barriers are:

- Prototype Repository.
- Long Term Test of Buffer Material.
- Alternative Buffer Materials.
- Backfill and Plug Test.
- Canister Retrieval Test.
- Temperature Buffer Test.
- KBS-3 method with Horizontal Emplacement.
- Large Scale Gas Injection Test.
- Sealing of Tunnel at Great Depth.
- In Situ Corrosion Testing of Miniature Canisters.
- Cleaning and Sealing of Investigation Boreholes.
- Concrete and Clay.
- Low-pH Programme.
- Drilling Machine for Deposition Holes.
- Development of End Plugs for Deposition Tunnels.
- Task Force on Engineered Barrier Systems.

4.2 Prototype Repository



The Prototype Repository is located in the TBM-tunnel at the -450 m level and includes six full scale deposition holes. The aims of the Prototype Repository are to demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions.

The Prototype Repository should, to the extent possible, simulate the real repository system regarding geometry, materials and rock environment.

The inner tunnel (Section I, canisters #1-#4) was installed and the plug cast in 2001 and the heaters in the canisters were turned on one by one. The outer tunnel (Section II, canisters #5-#6) was backfilled in June 2003 and the tunnel plug with two lead-troughs was cast in September the same year. The surface between the rock and the outer plug was grouted in October 2004 and the drainage of the tunnel was closed at the beginning of November.

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

Present status

After the grouting and the closure of the drainage of the tunnel, the pore pressure in the backfill and the buffer increased and about one month after the closing of the drainage, damages of the heaters in two of the canisters were observed. The power to all of the heaters was then switched off, the drainage of the tunnel was opened again and an investigation of the canisters with damaged heaters started. The power to all the canisters except for canister #2 was switched on and the drainage of the tunnel was kept open. At the beginning of September 2005 new damages of the heaters in canister #6 was observed. The power to this canister was then switched off but at the beginning of November 2005 the power was switched on again. New damages of the heaters in canister #6 were observed at the beginning of August 2005 and the power to this canister was switched off during two months. Due to additional problems with the heaters in canister #6 the power was reduced in May 2008.

Although the tunnel is drained, the pore pressure in the backfill in both sections is continuing to increase. Both the measured pressure and the water outflow from the tunnel have been affected by the work with the new tunnel near by the site.

The data collection system comprises temperature, total pressure, porewater pressure, relative humidity and resistivity measurements in buffer and backfill as well as temperature and water pressure measurements in boreholes in the rock around the tunnel. Furthermore rock mechanical measurements are ongoing. The measurements comprise registration of stress and strain in the rock mass around the two outer deposition holes. The data from the readings is presented in data reports (two per year).

Chemical measurements in buffer, backfill and surrounding rock are ongoing. Tests for evaluating the groundwater pressure and groundwater flow in the rock have also been performed. Acoustic measurements in the rock are ongoing with the purpose to study how the temperature evolution is affecting the properties of the rock. A thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been developed. A one dimension THM modelling of the buffer in deposition hole #1 and #3 has been finished.

Scope of work for 2010

The instrument readings in the two sections and the chemical measurements in buffer, backfill and surrounding rock will continue. In addition, new tests for evaluation of the hydraulic conditions in the rock will be made and the modelling teams will continue the comparison of measured data with predictions. THM modelling of the buffer and the backfill will continue. This work will be focused on homogenisation of the buffer in a deposition hole (1D-model) and on how the boundary conditions are affecting the saturation of the buffer (2D-model). Furthermore, also the thermo-mechanical evolution of the Prototype Repository rock mass is modelled in order to study the consequences of the thermally induced stress field. Issues like the possibility of spalling in KBS-3 deposition holes may be evaluated from these types of calculations.

The dismantling of the outer section will start during 2011. The planning of the excavation will be made during 2010. The planning comprises a cost and resource estimation and creation of an organisation for the work.

4.3 Long Term Test of Buffer Material

Schematic drawing of a test parcel.

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

Seven test parcels containing heater, central tube, clay buffer, instruments and parameter controlling equipment have been placed in boreholes with a diameter of 300 mm and a depth of around 4 m.

Temperature, total pressure, water pressure and water content, are measured during the heating period. At termination of the tests, the parcels are extracted by overlapping core-drilling outside the original borehole. The water distribution in the clay is determined and subsequent well-defined mineralogical analyses and physical testing of the buffer material are made.

The test parcels are also used to study other processes in bentonite such as cation diffusion, microbiology, copper corrosion and under conditions similar to those expected in a KBS-3 repository.

Present status

Four test parcels have been retrieved, analysed and the results have been reported, see Table 4-1. The remaining three parcels in the series are well functioning and have been heated to target temperatures for almost 10 years. Various kinds of testing and analyses of the A2 parcel material have been made during the past year.

Scope of work for 2010

A project meeting is planned to the end of April and an important item at the meeting will be if a new parcel should be retrieved during 2010. Further mineralogical laboratory analyses are planned to be performed on the A2 parcel material.

Table 4-1. Buffer material test series.

Type	No.	max T	Controlled parameter	Time (years)	Remark
A	1	130	T, [K^+], pH, am	1	Reported
A	0	120-150	T, [K^+], pH, am	1	Reported
A	2	120-150	T, [K^+], pH, am	5	Reported
A	3	120-150	T	>>5	Ongoing
S	1	90	T	1	Reported
S	2	90	T	>5	Ongoing
S	3	90	T	>>5	Ongoing

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

4.4 Alternative Buffer Materials

Installation of one of the three test parcels. The photo illustrates the mixing of different compacted buffer blocks.

In the Alternative Buffer Material test, ABM, eleven buffer materials with different amount of swelling clay minerals, smectite counter ions and various accessory minerals are tested.

The test is performed in the rock at repository conditions except for the scale and the adverse conditions (the target temperature is set to 130°C). Three parcels containing heater, central tube, pre-compacted clay, buffer, instruments and parameter controlling equipment have been emplaced in vertical boreholes with a diameter of 300 mm and a depth of 3 m. Parallel to the field tests, laboratory analyses of the reference materials are going on.

The project is carried out using materials that are possible as future buffer candidate materials. The main objectives are to:

- Compare different buffer materials concerning mineral stability and physical properties, both in laboratory tests of the reference materials but also after exposure in field tests.
- Study the interaction between metallic iron and bentonite. This is possible since the central heaters are placed in tubes made of straight carbon steel.

Present status

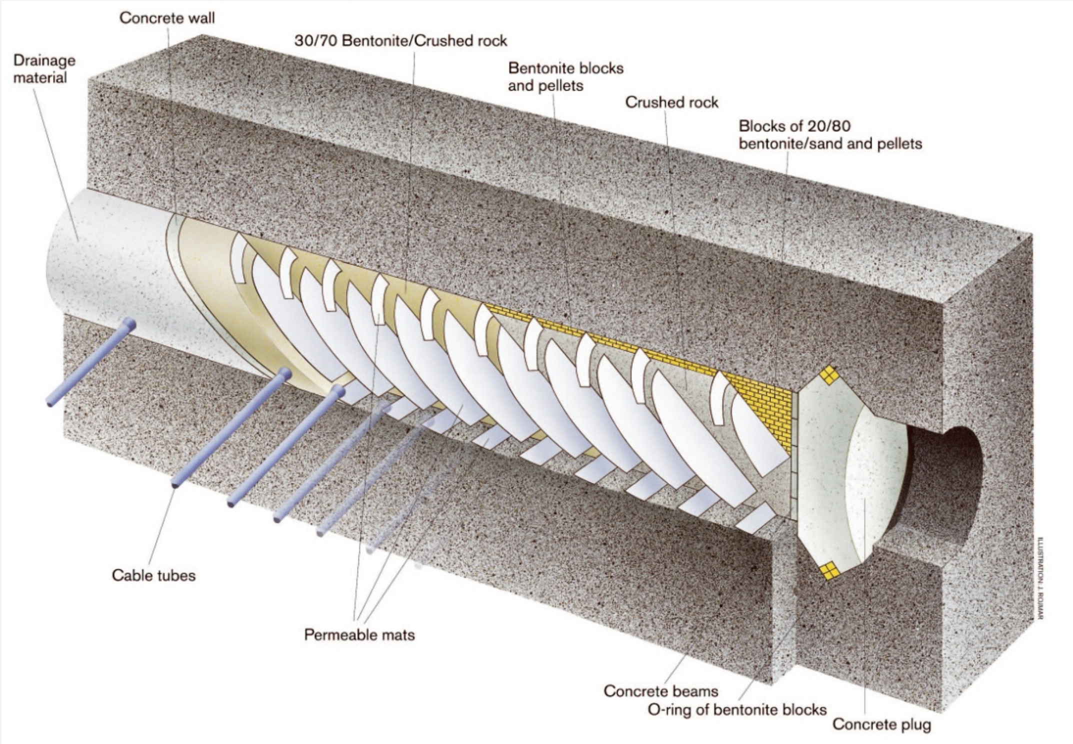
The three test parcels were installed and the operational phase initiated in November 2006. During 2007 the power to the heaters in parcel 1 (one year test) and 3 (five year test) was raised in steps to the target temperature 130°C. The heating of test parcel 2 (three year test and bentonite saturated before heating) was started in August 2008 but was then delayed depending on cracking and movements of the concrete plug.

Test parcel 1 was retrieved in May 2009. The buffer blocks were divided and samples sent out to the different participating organisations for analysis.

Scope of work for 2010

During 2010, the work with analyses of the reference material will be reported. The laboratory work regarding material from test parcel 1 started immediately after termination of the test and will continue during 2010. A project meeting will be held in Lund in April.

4.5 Backfill and Plug Test



The Backfill and Plug Test includes tests of backfill materials, emplacement methods and a full-scale plug. The inner part of the tunnel is filled with a mixture of bentonite and crushed rock (30/70) and the outer part is filled with crushed rock and bentonite blocks and pellets at the roof.

The integrated function of the backfill material and the near-field rock in a deposition tunnel excavated by blasting is studied as well as the hydraulic and mechanical functions of the full-scale concrete plug.

The entire test set-up with backfill, instrumentation and casting of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through filter mats started in late 1999. The backfill was completely water saturated in 2003 and flow testing for measurement of the hydraulic conductivity was running between 2003 and 2006.

The monitoring comprise continuous measurements and registrations of water pressure and total pressure in the backfill and water pressure in the surrounding rock as well as leakage of water through the plug.

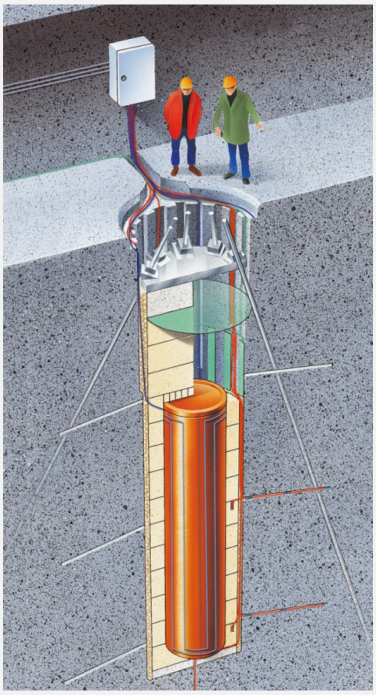
Present status

The present ongoing work includes continuous measurements and registrations of water pressure and total pressure in the backfill and water pressure in the surrounding rock as well as leakage of water through the plug. Measurement of local hydraulic conductivity in the zone with crushed rock through installed equipments (CT-tubes) is also ongoing.

Scope of work for 2010

During 2010 a new project plan will be made and a project decision will be taken on how to continue and finalise the project. Regardless of the outcome of the decision, continued data collection and reporting of measured water pressure, water flow and total pressure will be carried out during 2010. Also maintenance of equipment and supervision of the test will be performed.

4.6 Canister Retrieval Test



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

In the Canister Retrieval Test two full-scale deposition holes have been drilled, at the -420 m level, for the purpose of testing technology for retrieval of canisters after the buffer has become saturated.

These holes have been used for studies of the drilling process and the rock mechanical consequences of drilling the holes.

Canister and bentonite blocks were emplaced in one of the holes in 2000 and the hole was sealed with a plug, heater turned on and artificial water supply to saturate the buffer started.

In January 2006 the retrieval phase was initiated and the canister was successfully retrieved in May 2006. The saturation phase had, at that time, been running for more than five years with continuous measurements of the wetting process, temperature, stresses and strains.

Present status

The laboratory work has produced data concerning the mechanical character, the swelling pressure/hydraulic conductivity and the chemical/mineralogical constitution. There is some additional laboratory work of the buffer analyses to be performed at Clay Technology. Additional analyses of the penetration of the lubricant, used when manufacturing the buffer blocks, have been done.

In the Task Force on Engineered Barrier Systems one of the full scale assignments concerns modelling of the Canister Retrieval Test (CRT), see Section 4.13. At the latest Task Force meeting (25^{th}-26^{th} May 2009) several teams presented results within this assignment. Both SKB Team 1 and SKB Team 2 presented new findings within their modelling.

During 2009 a significant amount of work has been devoted to the safety assessment where CRT is used as an example for verifying the models concerning natural buffer homogenisation.

Scope of work for 2010

The next step in the laboratory work is to analyse the obtained data and to continue with reporting of the findings. The work aims at investigating if there have been any changes in the material characteristics by comparing properties of samples retrieved from the CRT buffer with the properties of reference material. When the present laboratory data has been analysed additional studies are to be taken under consideration.

Currently an article, where results of the buffer analyses will be presented, is in progress. The article is intended to be presented in a scientific journal to make the findings of the buffer analyses public.

The modelling within the Task Force will be continued in 2010. A lot of the simulations so far have been focused on detailed studies of the homogenisation at canister mid height. During 2010 the aim is to simulate the experiment at full scale, where issues like the heave of the plug and forces on the plug will be investigated.

Hopefully, an abstract submitted to the conference "Clays in Natural & Engineered Barriers for Radioactive Waste Confinement" (Nantes, 29th March – 1st April, 2010) will be accepted. The work to be presented concerns modelling of the homogenisation process in the CRT experiment, where obtained results are verified against the experimental data.

4.7 Temperature Buffer Test

The French organisation Andra carries out the Temperature Buffer Test (TBT) at Äspö HRL in co-operation with SKB. The aims of the TBT are to evaluate the benefits of extending the current understanding of the THM behaviour of engineered barriers during the water saturation transient to include high temperatures, above 100°C.

The scientific background to the project relies on results from large-scale field tests on engineered barrier systems, notably Canister Retrieval Test, Prototype Repository and Febex (Grimsel Test Site).

The test is located in the same test area as the Canister Retrieval Test, which is in the main test area at the -420 m level. The experiment includes two heaters in the axis of the deposition hole, one on top of the other, separated by a compacted bentonite block. The heaters are 3 m long and 610 mm in diameter and are constructed in carbon steel. Each one simulates a different type of confinement system: a bentonite buffer only (bottom section) and a bentonite buffer with inner sand shield (upper section). An artificial water pressure is applied in a slot between the buffer and rock, which is filled with sand and functions as a filter.

Data acquisition is continuously ongoing and data is transferred by a link from Äspö to Andra's head office in Paris.

Present status

The Temperature Buffer Test aims at verifying and possibly improving current THM models of buffer materials at high temperatures, well over 100°C. Moreover, the experimental setup has been characterised by stationary, well defined, boundary conditions. This implies that the experimental activities at the test site up till 2006 have been run mostly at a routine basis, while the focus has been on different modelling tasks and general successive evaluation of obtained results. The evaluation of THM processes has been made through analysis of sensors data (for the latest report, see /Goudarzi et al. 2009/), through numerical modelling /Hökmark et al. 2007; Åkesson 2006a/ and through evaluation and numerical modelling of parallel lab-scale mock-up tests /Åkesson 2006b; Åkesson 2008; Åkesson et al. 2009/. The final evaluation of the field test will be made when data from the future dismantling and sampling will be available.

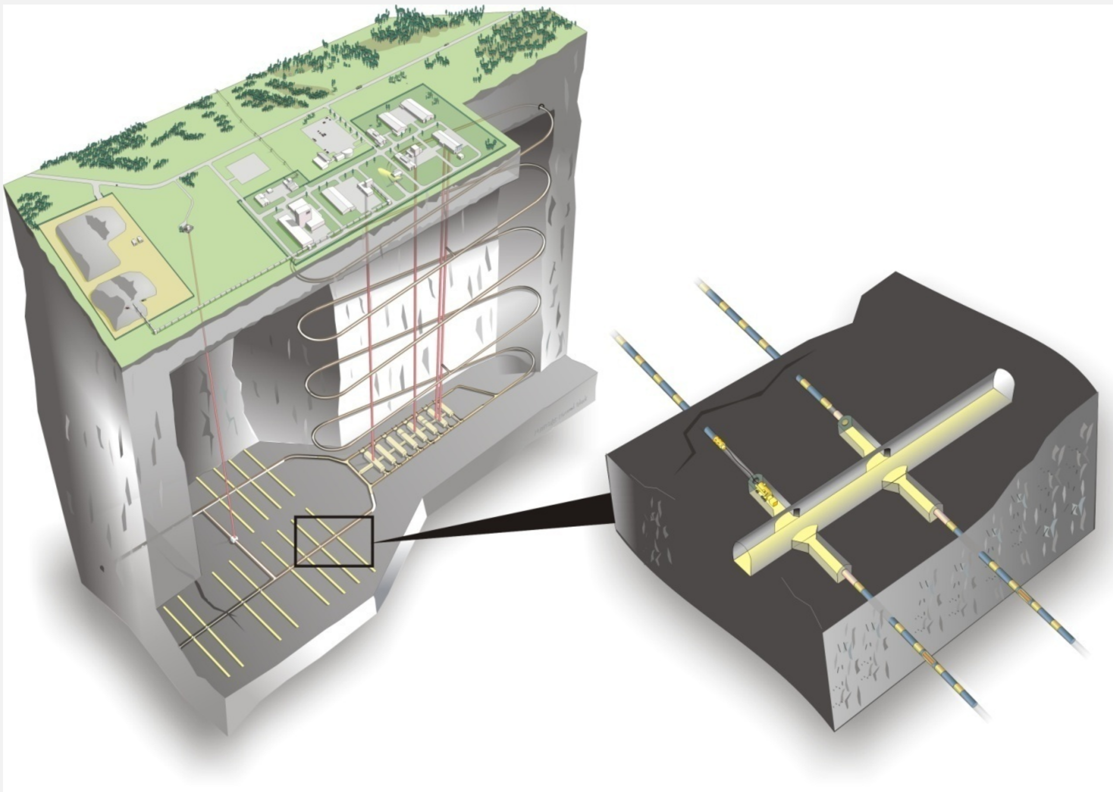
The overall planning for the continued operation has consisted of a number of activities. The main point of interest for the upper package is: (i) the evaluation of the THM processes, and (ii) a retrieval test. For the lower package, the evaluation of the THMC processes, with operation at high temperatures, is the main point of interest. In order to promote mineralogical alteration processes in the lower package, the thermal output from the heaters was changed at the end of 2007. The output from the lower heater was increased from 1,600 to 2,000 W, while the output from the upper heater was decreased from 1,600 to 1,000 W.

The dismantling activities started in October 2009 and the heating and the hydration was therefore terminated in August 2009. One important part of the dismantling operation is to concurrently perform characterisations of density and water content on samples taken during the dismantling.

Scope of work for 2010

The plan is to continue with and finalise the dismantling operation during 2010. After this, a number of analyses and characterisations of samples taken during the dismantling will be initiated. A new modelling task will be defined and initiated after the summer.

4.8 KBS-3 Method with Horizontal Emplacement



The possibility to modify the reference KBS-3 method and make serial deposition of canisters in long horizontal deposition holes (KBS-3H), instead of deposition of single canisters in vertical deposition holes (KBS-3V), is studied in this project.

One reason for proposing the change is that the deposition tunnels in KBS-3V are not needed if the canisters are disposed in long horizontal deposition holes and the excavated rock volume and the amount of backfill can be considerably reduced. This in turn reduces the environmental impact during the construction of the repository and also the construction costs.

The site for the demonstration of the method is located at -220 m level. A niche with a height of about 8 m and a bottom area of 25×15 m forms the work area.

Two horizontal deposition holes have been excavated, one short with a length of about 15 m and one long with a length of about 95 m. The deposition equipment is being tested in the long hole and the short hole will be used for testing of different drift components.

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

Present status

During 2009 tests have continued at Äspö. Compartment plug tests were initiated in January and are ongoing. The results are so far very promising and the leakage levels are acceptable. Further testing and analyses will be done in order to draw final conclusions.

The results from the pipe removal test have initiated work aiming at minimising the need for pipe removal. New tests are in progress to evaluate the proposed changes. The test will be ongoing until the beginning of 2010.

The work to plan for the next project phase with full scale tests have begun. The work will produce a plan covering the different tests to be performed of components (separately or in combination) in the KBS-3H system.

The deposition machine has run approximately 50 kilometres in the 95 meter drift. During the operation time components have been exchanged to increase functionality. The overall result from the test is that the concept works. The machine will however need updates and further testing to verify the robustness. A study to evaluate necessary improvements, taking into consideration what's necessary to secure for a reliable function for the full scale tests and what's necessary for the development for the next generation of the deposition equipment.

Scope of work for 2010

The current project phase is ending in the second half of 2010. Until then remaining tests and reports should be finished. This will include evaluation of the compartment plug and possible also further pipe removal tests.

The work with the test plan for the next project phase should also be finalised and will be approved at the end of 2010.

4.9 Large Scale Gas Injection Test

Panorama of the laboratory of the Large-scale gas injection test (Lasgit) at -420 m level in Äspö HRL.

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

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

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

Its objectives are:

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

In February 2005 the deposition hole was closed and the hydration of the buffer initiated. During 2007 preliminary hydraulic and gas transport tests were performed. These were repeated in 2009, giving information on the maturation of the buffer in order to examine the temporal evolution of these properties. When the buffer is fully-hydrated a comprehensive series of gas injection tests will be undertaken to examine the mechanisms governing gas flow in bentonite.

Present status

Activities in 2009 were dominated by the second series of gas and hydraulic tests that were conducted during the ongoing hydration of the bentonite buffer. These tests will continue into 2010.

The first quarter of 2009 began with a full calibration of Lasgit instrumentation in readiness for the second stage of gas testing. At this time, the interface vessel used in gas testing was reconnected and pressurised with around 1 litre of helium in order to confirm the leak tightness of the system. This was left at pressure for the remainder of the quarter which verified that the vessel was indeed gas tight.

Soon after calibration was complete (day 1472; 11th February) the hydraulic test was initiated. As in the previous test stages all artificial hydration filters were allowed to decay, including FL903 – the filter selected for gas testing. The pressure in FL903 was raised to 4,250 kPa and the hydraulic flux into the buffer was monitored; permeability and storage were calculated from these results. Analysis of the flow data clearly indicates the permeability of the clay around FL903 has reduced since the previous hydraulic tests performed in 2007.

Following hydraulic testing, the system was recalibrated and setup ready for gas testing (day 1577; 28th May). This time a known quantity of neon gas was introduced into the interface vessel, the pressure of which was then increased to a value equal to that observed in the clay around injection filter FL903 (1,300 kPa). During this time the gas pressure was held constant (for approximately 4 weeks) while neon moved into solution in the fluid contained within the interface vessel.

The second gas injection test began on day 1606 using neon, rather than helium, which was used in the initial test. Neon was selected as its chemical signature is absent in the groundwater at the Äspö HRL. In contrast to the initial gas test, it was decided to increase gas pressure more slowly for the second test and to hold the gas pressure constant at three defined stages, at specific values below the previous pressure required to achieve major gas breakthrough. The purpose of this pressurisation method is to provide additional information on the small-scale gas fluxes into the clay observed during the first test. Gas was introduced into the injection system at a pressure of 1,300 kPa, and was increased in steps of approximately 10 – 14 days to 2,550, 3,800 and 5,050 kPa. At each continuous pressure step flow was monitored for between 14 and 28 days. As seen in the previous gas injection, at each constant pressure step, flow in to the clay greatly reduced following the change from constant flow to constant pressure.

The final gas injection stage was initiated on day 1742 (12th November) with a slow gas injection rate. Similarly to previous pressure steps, gas flow into the clay rapidly increased following the start of gas injection. Pressure continued to rise until it reached a maximum of 5,872 kPa after 25 days of injection and this was followed by a spontaneous negative pressure transient.

The test has been in successful operation for in excess of 1,700 days. The Lasgit experiment continues to yield high quality data amenable to the development and validation of process models aimed at repository performance assessment.

Scope of work for 2010

Following the completion of gas testing of filter FL903, expected in the first half of 2010, a repeat hydraulic head test will be conducted followed by recalibration of the system. If time is available a small diameter filter located on the top array of canister filters will be selected for hydraulic and gas testing. Acknowledging the heterogeneous properties of the clay, this will provide initial data on the effect of filter size and its impact on the transport mechanisms governing gas flow within the clay. Following gas testing, the system will revert to a third period of artificial hydration, expected to last at least 12 months.

4.10 Sealing of Tunnel at Great Depth

The Tass-tunnel in Äspö HRL.

Although the repository facility will be located in rock mass of good quality with mostly relatively low fracturing, sealing by means of rock grouting will be necessary. Ordinary grouts based on cement cannot penetrate very fine fractures and due to long term safety reasons a sealing agent that produces a leachate with a pH below 11 is preferred. In the sealing project at Äspö HRL a cement-based low-pH grout and a solution grout consisting of silica sol are used and evaluated. Newly developed understanding and design methods are taken into use and evaluated.

Another issue for the planned repository is the contour and status of the remaining rock after blasting. Drilling and blasting are given special attention and subsequent adjustments aim at successive improvements.

Present status

The tunnel reached its final length, 80 m, in spring 2009. The field test had a flexible planning in order to adapt to the encountered rock conditions, results and experience gained. The outcome was six grouting fans. The work consisted of the following stages:

1. Fan 1. A short fan drilled from the start of the tunnel with boreholes outside the contour. The equipment was tested as well as grouting with both cement based grout and silica sol.
2. Fans 2 and 3. The fans are 20-25 m long with boreholes outside the tunnel contour.
3. Fan 4, 5 and 6. The fans are 20 m long with boreholes within the tunnel contour. At the position of fan 4, large rock blocks where cut out to study the excavated damaged zone (EDZ). Based on not so good results and experiences from fan 4 the design was adjusted for the coming fans 5 and 6.
4. Probing and hydraulic tests from the tunnel face. A few boreholes were drilled from the face and since the inflow was very small further excavation was stopped.
5. Post-grouting in the position of fan 4.

The largest inflow before grouting measured in grouting boreholes was around 60 L/min. The pre-investigation and analysis of what inflow could be expected without any grouting was around 90 L/min for a 100 m long tunnel. Increased tightness after each grouting round was shown by comparing the inflows in control holes before and after grouting.

The inflow is measured in three weirs and the project target max 1 L/min and 60 m tunnel is distributed proportionally to the length of the section measured. The inflow to stage 2, fans outside the contour, section 10-34 m measured in weir is 0.3 L/min which corresponds to, or is smaller than, the target set for the section, max 0.4 L/min.

Within stage 3, boreholes within the tunnel contour, the design was adjusted after the first fan, fan 4 (section 34-48 m), as the inflow target was not met. The theoretically sealed zone was believed to be too small and along fans 5 and 6, section 48-80 m, the design was radically changed to produce a sealed zone with sufficient extent. The inflow was measured to 0.4 L/min and the target of maximum 0.5 L/min was met. The control holes show a tightness corresponding to a transmissivity of around $1 \cdot 10^{-11}$ m^2/s. The conclusion is that it is possible to seal a tunnel only with boreholes inside the contour, but to accomplish this; the extent of the sealed zone needs to be carefully considered in the design. The inflow to the tunnel section that is post-grouted (34-48 m) is still not satisfactory and is under evaluation. A report with the first results is published /Funehag 2008/.

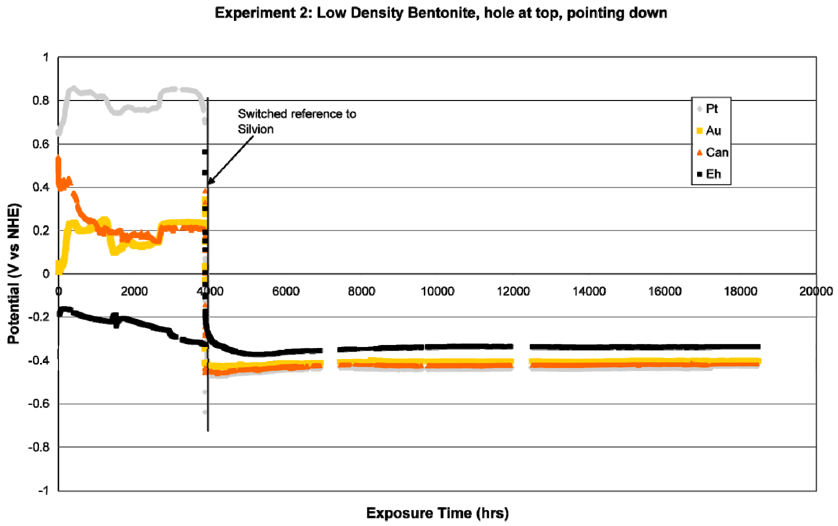
Special attention was given to drilling, charging and blasting. The results were followed very closely and subsequent adjustments made. The use of electronic detonators was introduced from section 32 meters and was found favourable. Blasting holes are clearly visible along major parts of the rock wall. A report with the first results is published /Malmtorp et al. 2008/.

Scope of work for 2010

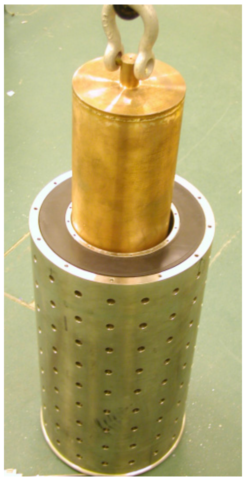
The inflow to the tunnel is being automatically monitored and a programme for mapping of inflows is established. The monitoring and mapping is for the time being considered a prioritised task, but the duration will depend on other SKB priorities.

Evaluation and reporting is under way. The project has provided ample data and further evaluation may be carried out in new projects.

4.11 In Situ Corrosion Testing of Miniature Canisters



Example of electrochemical potential data obtained from one miniature canister experiment.



Miniature canister with support cage.

The MiniCan project is designed to provide information about how the environment inside a copper canister containing a cast iron insert would evolve if failure of the outer copper shell were to occur. The development of the subsequent corrosion in the gap between the copper shell and the cast iron insert would affect the rate of radionuclide release from the canister. The information obtained from the experiments will be valuable in providing a better understanding of the corrosion processes inside a failed canister.

Miniature canisters with a diameter of 14.5 cm and containing 1 mm diameter defects in the outer copper shell have been set up in five boreholes.

The boreholes have a diameter of 30 cm and a length of 5 m. All five canisters were installed in the beginning of 2007 in Äspö HRL.

The canisters are mounted in support cages, four of which contain bentonite (three low density bentonite, one compact bentonite), and are exposed to natural reducing groundwater. Together with corrosion test coupons which are also in the boreholes, the canisters will be monitored for several years. The corrosion will take place under realistic oxygen-free conditions that are very difficult to reproduce and maintain for long periods of time in the laboratory.

Present status

All five experiments are in operation and corrosion data are being collected as planned. This includes measurements of corrosion potential, corrosion rate and redox potential, using a range of electrochemical techniques. Water analyses and microbial analyses of the local environment were obtained in 2007 and 2008. Strain gauges are used to monitor for any dimensional changes on two of the model canisters. A number of additional corrosion coupons are in place in the boreholes. Data are transferred regularly to the UK for analysis through the internet link. A report on the installation of the canisters and results obtained to May 2008 is printed /Smart and Rance 2009/. A progress report on the results to date was produced in June 2009 and a further report on the results obtained to December 2009 is in preparation. The water analysis has shown an increase in the iron concentration and a decrease in pH within the support cages, which may be due to microbial activity, in particular sulphate reducing bacteria activity. The corrosion rates measured on the iron and copper electrodes have increased to higher levels than expected and following a planning meeting in June 2009, it has been decided to remove one of the experiments for analysis and to compare the corrosion rates by direct observation of the specimens. A further progress report will be prepared for the end of 2009 and this will include an outline plan for removal and analysis of one experiment in 2010.

Scope of work for 2010

During 2010, monitoring of the experiments will continue. The planning to remove one of the experiments (Experiment 3, low density bentonite) will be done. This will involve constructing suitable equipment to enable the experiment to be removed and analysed whilst minimising the exposure to air. A detailed investigation will be carried out to characterise the corrosion phenomena, the microbial activity and the condition of the bentonite. Data analysis will continue on the remaining experiments, together with water sampling and analysis. A replacement experiment will probably be installed in the empty borehole.

4.12 Cleaning and Sealing of Investigation Boreholes

Installation of a copper plug in a 200 mm borehole.

The objective of the project is to work out a concept for rinsing, stabilising and plugging of deep boreholes drilled from the surface and repository level, such as they do not form significant transport paths for radionuclides from the repository to the biosphere. The project was initiated 2002 and Phase 1 to 3 have been finalised.

The Phase 4 of the project comprises the following sub-projects:

1. Characterisation and planning of borehole sealing
2. Quality assessment and detailed design
3. Sealing of two 300 mm underground boreholes
4. Interaction of clay and concrete plugs at 220 m depth

Present status

In 2009 the work has mainly been performed in first two the sub-projects, However in the autumn the project was extended with two sub-projects performed in Äspö HRL.

The work in sub-project 1 has comprised selection of reference holes for predicting suitable location of concrete and clay plugs, and determination of the importance of sustainable clay plugs for hydraulic separation of major intersected fracture zones. The roles of a number of practically important conditions and properties of the boreholes have been interpreted and assessed, like geometrical features including straightness and variations in diameter of the holes, and the existence of axial hydraulic gradients. The first mentioned determine the length of plug segments that can be installed without risk and the latter the quality of the concrete and clay plugs with respect to the risk of destruction by piping and erosion in the construction phase. A number of issues for improving the practicality in installation and the quality of the plugs have been identified and further development of plugging materials and techniques for installation have been specified.

The work in sub-project 2 has focused on how to identify suitable plug positions in the selected representative boreholes with respect to the hydraulic performance of identified practically important, intersected fracture zones. The importance of the sealing efficiency as a function of time has been investigated by calculating the change in piezometric pressure in a typical borehole left open and sealed by plugs of different quality. This work certified that long-lasting plugs installed in suitable positions is required for avoiding short-circuiting of the rock mass between the repository and the ground surface.

The work in sub-project 3 concerns preparation and placement of large-diameter clay plugs and casting concrete under high water inflow conditions. Two of the TRUE-1 boreholes, KXTT3-4 (diameter 300 mm and about 15 m long) have been plugged with a combination of clay and concrete. The strong inflow required drainage through a central tube that served to guide the pre-compacted clay blocks to their specified positions. The tube was finally filled with clay pellets after placing an upper set of clay blocks and casting the upper concrete plug that was anchored in a recess in the holes.

The aim of the work in sub-project 4 is to investigate the physico/chemical interaction of clay and concrete plugs under field conditions. In December 2009 one of the two reference boreholes at the -220 m level was over cored (5 m long concrete/clay plug). Samples of clay and contacting concrete have been taken from the retrieved core for analyses.

Scope of work for 2010

Further work should be focused on practical plugging techniques and assessment of the performance of plugs constructed at depth. This requires access to suitable deep holes for training, preferably at Laxemar, and Äspö. The need for certifying sufficient quality of constructed plugs suggests boring and plugging of a long hole that can be reached for extraction of plugs through nearby niches. A 700-800 m long hole parallel to the straight part of the ramp at Äspö would serve well.

4.13 Concrete and Clay

Introduction

The focus of the project is on studying the long term evolution of cementitious materials in host rock, its interactions with the host rock and embedded waste materials as well as with bentonite.

In the Äspö HRL a total of about 15 experiments will be prepared during 2010 and 2011. The experiments have different focus but with the common goal of increasing the knowledge of the evolution of cementitious materials in host rock and the degradation of different waste materials in such environments.

The experiments will with two exceptions be prepared ex situ as cylinders with a length of 3 meters and a diameter of 300 mm. In the experiments where both cement and bentonite are used the cement cylinder will be 100 mm in diameter. Two of the experiments will be grouted directly in the hole in the tunnel floor. The project is expected to run for up to 30-40 years but the first samples will be retrieved already after three years. Experiments will then be retrieved at regular intervals and only a few will be left for the entire 40 year period.

Present status

During 2009 the project plan has been finalised, the experiments have been designed and sites suggested for about 50% of the experiments.

Scope of work for 2010

During 2010 the working plans will be prepared and the experimental work initiated. The most important tasks will be to:

- Specify the exact details of each experiment.
- Prepare and characterise the sites for the different experiments.
- Prepare selected experiments. During 2010 it is planned to prepare the experiments that will be retrieved after 3 and 10 years. The remaining experiments will be prepared during 2011.

4.14 Low-pH Programme

Field test with low-pH shotcrete at Äspö HRL executed within the EC project ESDRED in 2006.

The purpose of this programme is to develop low-pH cementitious products that can be used in the final repository for spent nuclear fuel. These products would be used for sealing of fractures, grouting of rock bolts, rock support and concrete for plugs for the deposition tunnels.

SKB has for many years had a close co-operation with Posiva (Finland) and Numo (Japan) in this field. The main focus of the low-pH programme during 2008 and 2009 has mainly been on developing formulas for low-pH concrete to be used for construction of the sealing plugs for the deposition tunnels.

Present status

During 2009 SKB has performed field test with low-pH grout for rock bolts at Äspö HRL. In total, 20 bolts have been installed. These bolts will be monitored and over-cored after 1, 2 and 5 years for evaluation of the behaviour of the low-pH grout but also corrosion of the rock bolts.

During 2009 also field tests with low-pH shotcrete for rock support was executed in two tunnels at Äspö HRL, in NASA0408A and in the Tass-tunnel. One of the main experiences from the low-pH shotcrete test in 2006 was that proper mixing of the concrete is very important. Low-pH concrete requires a powerful mixer, preferably a paddle mixer. Inadequate mixing leads to problems with pumpability and insufficient homogeneity, which in turn gives an uneven pump pressure and bad quality of the shotcrete.

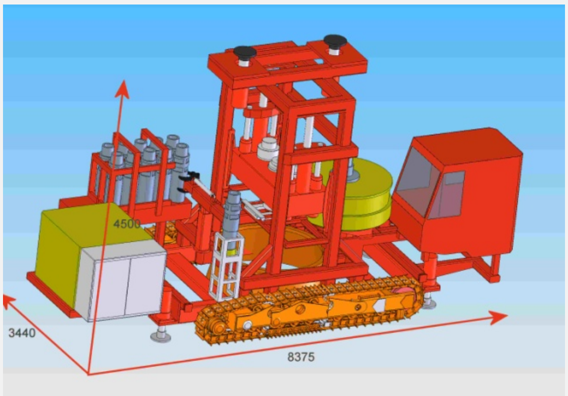
An international project for standardisation of pH measuring started mid 2008 as a joint project with the following participating organisations: SKB, Posiva, Nagra, Enresa, Numo and JAEA.

Scope of work for 2010

The work during 2010 is mainly limited to follow up the activities from 2009 with the rock bolts and rock support. The design work of the plugs for the deposition tunnel may require additional information about the material parameters of the low-pH concrete and that may require additional investigation.

The pH-measuring project will be ongoing during 2010 and is expected to be finalised mid 2011.

4.15 Drilling Machine for Deposition Holes



Artist impression of the drilling machine for deposition holes with preliminary dimensions.

For the drilling of the deposition holes for the installation of the canisters in the Prototype repository and the Canister Retrieval Test, SKB used a modified TMB machine. In total SKB has been drilling 17 deposition holes at Äspö HRL /Andersson and Johansson 2002/. For the final repository it was decided that new equipment would be needed and a "state of the art" investigation of available technologies was performed during 2006. The conclusion from the investigation was that the push reaming technique would be the method that could meet stringent requirement on the deposition hole and still have high production rate.

This technology has also been tested in Finland for drilling of three deposition holes in the research tunnel at Olkiluoto /Autio 1997/. The same technology has also been used for the excavation of the two KBS-3H deposition tunnels at -220 m level in Äspö HRL.

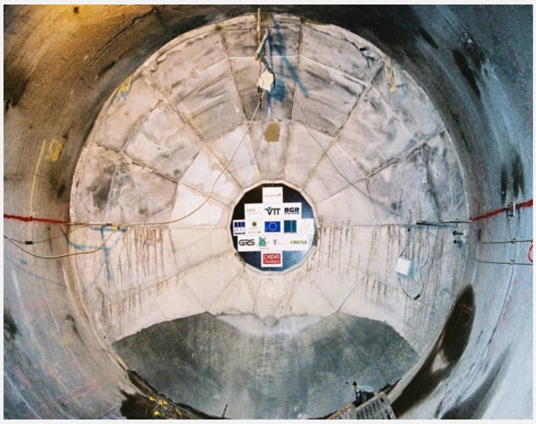
Present status

A feasibility study has been performed of a self propelled drilling machine using the push reaming technique. The feasibility study was completed late 2008. The requirements for the deposition holes are very stringent as well as production rate and costs for the drilling of the deposition holes. During 2009 SKB and Posiva have discussed to form a joint project for the continued work with the drilling machine and these discussions are still ongoing.

Scope of work for 2010

The scope of work is very much dependent if the continued work with development of the drilling machine will be a joint project with Posiva or not. SKB do not need new deposition holes at present but Posiva has the aim to demonstrate the drilling technique in a few years time.

4.16 Development of End Plugs for Deposition Tunnels



The plug installation for section I in the Prototype Repository

The development of end plugs for deposition tunnels has been an issue for SKB for several years. Two kinds of solutions have been investigated, vault plug and friction plug. To reach such water tight plug as possible, the choice for further development has been the vault plug. To improve the water-tightness, the concrete plug has in the reference design been complemented with a watertight seal and a filter, collecting water leaking from the backfilled deposition tunnel during the curing phase.

This principal solution is currently being evaluated and it is the analysed design that constitutes the reference design at this stage of development.

The detailed, as well as the principal solution, will be further developed before the construction of the final repository and deposition of encapsulated spent fuel commences.

Present status

SKB has performed extensive calculations of vault plugs (Figure 4-1) /Dahlström et al. 2009/ based on data from concrete recipes with low pH-concrete /Vogt et al. 2009/. In view of the fact that low pH-concrete shrinks more than standard concrete, there are risks that the reinforcement can cause a lot of smaller cracks. Reinforcement corrosion and time-saving during installation are further reasons to test a concrete plug that is not reinforced in coming full-scale test.

Vault plug without reinforcement has been analysed in comprehensive crack and stress calculations /Dahlström et al. 2009/ but the results need to be verified in a full scale test. Calculations of friction plug have also been executed and reported /Fälth and Gatter 2009/.

In the ongoing project regarding development of concrete plug, function, demands and assumptions have been documented. A risk analysis of the different variants has also been performed. An evaluation based on the foundation of the two construction alternatives indicated clearly that the vault plug is the most appropriate alternative. This is mainly based on the fact that it is a more massive construction. Denseness is an important parameter for the plug, even if the main task is to work as a holding up-construction against the backfilling in the deposition tunnel. But, the plug shall also initially prevent water flow through the plug and in the interface between rock and concrete.

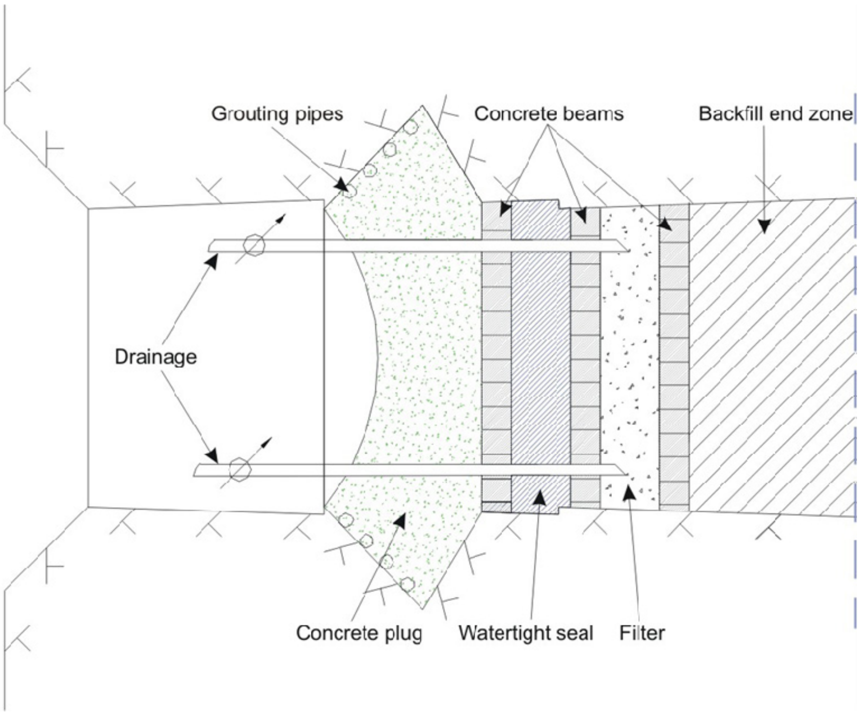


Figure 4-1. *The reference design for end plugs for deposition tunnels.*

Scope of work for 2010

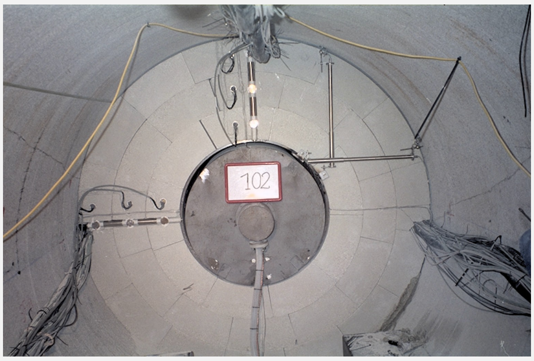
In the programme for further development, the achievments will be broadened and more intense during the next years. The objective is to test the design in a full-scale test during 2012. To manage this and to make the tests meaningful, the following is required:

- Modelling and tests of bentonite sealing and filter to be able to guarantee function.
- Demands for the density of the plug needs to be analysed.
- Concrete recipe shall, if possible, be adapted to the demands and assumptions for the plug. Some parameters, like shrinkage, tensile strength and creeping should be tested further.
- Control method with regards to tightness has to be developed.
- Production adapted to method for rock excavation of bevels has to be developed.

Besides the above mentioned items, a comprehensive planning is needed for test arrangement, press construction and instruments. In parallel with the efforts for a full scale test, the influence of reinforced low-pH concrete with regards to cracks related to shrinkage should be tested in detail.

In a longer perspective, the design should be optimised and adapted to production, i.e. if alternative solutions can bring the same quality, or better, with a lesser achievment. If the demands for density can be lower because of increased understanding of buffer erosion, there are possibilities to change and simplify the design in the future.

4.17 Task Force on Engineered Barrier Systems



The Task Force on Engineered Barrier Systems (EBS) is a continuation of the modelling work in the Prototype Repository Project, where also modelling work on other experiments concerning both field and laboratory tests is conducted. The Äspö HRL International Joint Committee has decided that in the first phase of this Task Force (initiated 2004) work should concentrate on:

Task 1 - THM modelling of processes during water transfer in buffer, backfill and near-field rock. Only crystalline rock is considered initially, although other rock types could be incorporated later.

Task 2 - Gas migration in saturated buffer.

The objectives of the tasks are to: (a) verify the capability to model THM and gas migration processes in unsaturated as well as saturated bentonite buffer, (b) refine codes that provide more accurate predictions in relation to the experimental data and (c) develop the codes to 3D standard (long-term objective).

Participating organisations besides SKB are at present Andra (France), BMWi (Germany), CRIEPI (Japan), Nagra (Switzerland), Posiva (Finland), NWMO (Canada) and Rawra (Czech Republic). All together 12-14 modelling teams are participating in the work.

Since the Task Force does not include geochemistry, a decision has been taken by IJC to also start a parallel Task Force that deals with geochemical processes in engineered barriers. The two Task Forces have a common secretariat, but separate chairmen.

Present status

Task Force THM/Gas

The first phase includes modelling of a number of laboratory and fields tests as complied in Table 4-2.

Benchmark 1 (laboratory tests) and benchmark 2.1 (the two URL tests) have been finished and the modelling results are reported during 2009. The modelling of the Canister Retrieval Test (benchmark 2.2) started in 2008 and has been ongoing during 2009.

The task to model the Canister Retrieval Test is divided into two parts where the first part concerns modelling of the thermo-hydro-mechanical behaviour of a central section of the test hole with given boundary conditions. The second task concerns modelling of the whole test. Most teams have now finished the first part and some also the second part. The status of the modelling was presented at the Task Force meeting in Pori in Finland in November.

Several new tasks for the next phase of the Task Force have been suggested. One of them is a task which has started in 2009 with the purpose to stimulate co-operation between the Task Force on Engineered Barrier Systems with the Task Force on Groundwater Flow. This task is a proposal to model a new field test named Brie (Bentonite Rock Interaction Experiment) that is to be installed in Äspö HRL. The purpose of the test is to study and model the hydraulic interaction between the rock and water unsaturated bentonite.

Table 4-2. Modelled tests in the first phase of the Task Force on Engineered Barrier System.

Benchmark 1 – Laboratory tests	
Task 1 – THM tests	
	1.1.1 Two constant volume tests on MX-80 (CEA)
	1.1.2 Two constant volume tests on Febex bentonite – one with thermal gradient and one isothermal (Ciemat)
	1.1.3 Constant external total pressure test with temperature gradient on Febex bentonite (UPC)
Task 2 – Gas migration tests	
	1.2.1 Constant external total pressure (BGS)
	1.2.2 Constant volume (BGS)
Benchmark 2 – Large scale field tests	
	2.1 URL tests Buffer/Container Experiment and Isothermal Test (AECL)
	2.2 Canister Retrieval Test in Äspö HRL (SKB)

Task Force Geochemistry

Molecular dynamics modelling have been made by Clay Technology for SKB during 2009. The work has focused on ion equilibrium in the montmorillonite/water system. The results have been presented at the EBS TF meetings, and a paper concerning Donnan equilibrium will be submitted for publication in the near future.

Ion diffusion is central in geochemical modelling, and in bentonite this is a complex matter due to the montmorillonite structure. The new view of the principles for diffusion in bentonite has been presented at the EBS task force meetings and at special seminars e.g. at PSI in Switzerland. An article summarising the theoretical treatment has been published in Geochimica et Cosmochimica Scripta. New laboratory results concerning ion equilibrium and ion diffusion in bentonite are planned to be published.

Scope of work for 2010

Task Force THM/Gas

For 2010 the following work is planned:

- Reporting of benchmark 2.2 (Canister Retrieval Test).
- General evaluation of the modelling results and auditing of the capability of different codes used by the modelling teams.
- Installation and modelling of the new Äspö test experiment Brie.
- Decision and start of other new tasks to be modelled in the next phase of the Task Force.
- Two Task Force meetings.

Task Force Geochemistry

For 2010 the following work is planned:

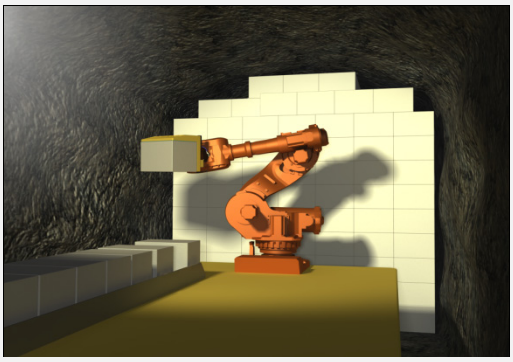
- Continuation of theoretical and laboratory work concerning diffusion and ion exchange in bentonite.
- Modelling of the Lot A2 parcel; identification of processes and calculations.
- Continuation of molecular modelling (MD) concerning ion distribution in montmorillonite.
- Publication of articles concerning mixed calcium/sodium montmorillonite, Comparison of Poisson-Boltzmann generated ion distribution with those obtained from MD simulations, and Water density variation in montmorillonite interlayer space.

5 Mechanical- and system engineering

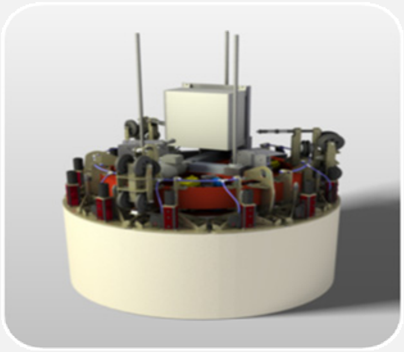
5.1 General

At Äspö HRL and the Canister Laboratory in Oskarshamn, technologies for the final disposal of spent nuclear fuel are being developed. Established as well as new technology will be used in the final repository. When it comes to mechanical- and system engineering, well known standard objects with secured function will be used to the fullest possible extent. With standard equipment as a basis needed adjustments, modifications and adaptations can be made for the intended function. Where no standard objects are available, new technical development will be necessary.

5.2 Technical development at Äspö HRL

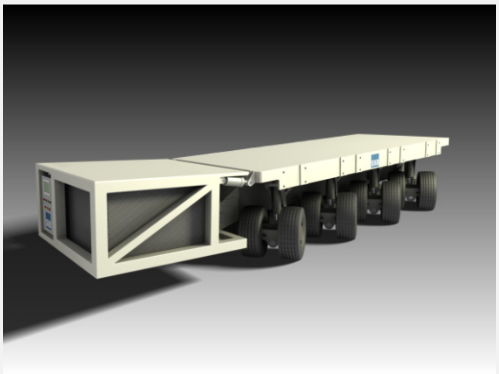


Backfilling equipment



Lifting tool for buffer emplacement

Deposition machine



Multi purpose vehicle

The technical systems, machines and vehicles that need to be developed for the future final repository have been identified by an inventory project and preliminary plans made about when each machine should be developed. A total of 175 different products and components known today are to be developed. The number of objects and affiliated information is due to change since the specifications are working documents.

The project started with a pre-study and a concept study, to determine when the production of machines must begin and when they should be completed, as well as deciding whether production of a prototype is necessary. The development of a model for costs has been included in the work. Several projects within mechanical- and system engineering are ongoing and the activities in some of the different projects are described in the text below.

Equipment for backfilling

This project is studying the machines that will be needed to place the backfill blocks in position at a speed of 350 ton/day. The conclusion from simulations of different robots, which were carried out in 2009, is that robot-technology is able to meet the demands made by the high speed of backfilling (6 m of tunnel in 8 hours). The continuation of the work includes further studies of the robots with tests and model-validation, as well as development of tools and a vision system. Further investigations will be made into a movable platform for robots and the pellets bed in the tunnel. Tests will be carried out both above and below ground, see Section 6.2.

Buffer emplacement

This project is investigating whether or not the buffer, in the shape of blocks and rings, can be placed in the deposition holes with the required degree of precision. Emplacement tests with bentonite rings and concrete discs show promising results. The coming work will be carried out under ground. In addition, the bottom-plate in the deposition hole and the protectionsheet for the buffer will be developed, see Section 6.2.

Ramp vehicle

During the period 2007-2009, a pre-study was carried out on suitable transport vehicles as well as a study of the demands that these vehicles should be able to meet. Five different concepts have been compared and the concept ”Self Propelled Modular Transporter” was shown to be the most suitable. This vehicle is built in modules, which means that it is easy to replace parts of the vehicle. The work with the load-carrying system and its interface with the canister transport holder, as well a basic and detailed design will continue throughout the period 2010-2013.

Deposition machine

The aim of the full-scale tests that are being carried out with completely automated operation is to collect data and evaluate the reliability and availability of the machine and the parts of the system, as well as the service requirements under continuous operation. The deposition machine for KBS-3V has been tested under manual operation and at the same time positioning- and navigation-system has undergone development. About 500 tests have been carried out during the test period and the machine seems to work well. Further work will include durability tests in which 1,000 depositions will take place.

Logistics study

The aim of a more detailed study is to develop the ability, in stages, to be able to simulate the logistics for all the activities in a final repository facility during the operational phase in the long term. A model will be built up within a six month period and the logistics will be developed over a period of several years. One issue which needs to be solved is how to couple autonomic systems with manual systems.

Multi purpose vehicle

Development is required of a multi purpose vehicle which, among other things, can carry out ramp-transports at Äspö HRL and act as a braking-vehicle for other heavy ramp-vehicles. In addition, the vehicle is needed for handling of material and equipment related to ongoing projects and experiments e.g. KBS-3H, retrieval of canisters in the Prototype Repository, as well as to be used to carry out tests of the function of the whole handling system.

Transport system

A study will be carried out in order to find a solution to the transport of buffer- and backfill material above and below ground. The project is in the start-phase and the transport solutions being studied include a pallet system and transport vehicles.

Drill

A pre-study will be carried out to construct a new drill that is capable of drilling vertical disposal holes with the required high degree of precision, see Section 4.15.

Production system

Within this project, a prototype is being developed of a comprehensive automatic system for the management and control of transport and production logistics for the final repository. Completion of the prototype is planned to take about two years.

6 Äspö facility

6.1 General

The Äspö facility comprises the Äspö Hard Rock Laboratory and the Bentonite Laboratory, the later taken into operation in 2007. The Bentonite Laboratory complements the underground Hard Rock Laboratory and enables full-scale experiments under controlled conditions making it possible to vary experimental conditions and to simulate different environments.

In May 2009 part of the Äspö operation underwent an organisational change as the units *Äspö Hard Rock Laboratory* and *Repository Technology*, both within the Technology department were united. This change was done to focus the remaining development of the repository technology and performing of experiments and tests in a realistic repository environment at Äspö HRL. The new and larger unit inherited the name *Repository Technology.* Äspö HRL is the residence of the unit but the unit includes employees in both Äspö and Stockholm. The main responsibilities of the unit are to:

- Perform technical development commissioned by SKB's programmes for nuclear fuel and for low- and intermediate level waste.
- Develop the KBS-3H concept.
- Perform experiments in the Äspö HRL.
- Secure a safe and cost effective operation of the Äspö HRL.
- Prosecute comprehensive visitor services and information activities in the Oskarshamn area.

The Repository Technology unit is organised in five operative groups and an administrative staff function:

- *Geotechnical barriers and rock engineering (TDG),* responsible for the development, testing and demonstration of techniques for installation of buffer, backfill and plugs in deposition tunnels, backfilling of the final repository and plugging of investigation boreholes.
- *Mechanical- and system engineering (TDM),* responsible for the development, testing and demonstration of equipment, machines and vehicles needed in the final repository.
- *Project and experimental service (TDP),* responsible for the co-ordination of projects undertaken at the Äspö HRL, providing services (administration, design, installations, measurements, monitoring systems etc.) to the experiments.
- *Public relations and visitor services (TDI)*, responsible for presenting information about SKB and its facilities with main focus on the Äspö HRL.
- *Facility operation (TDD),* responsible for the operation and maintenance of the Äspö HRL offices, workshops and underground facilities and for development, operation and maintenance of supervision systems.
- *Administration, quality and planning (TDA*), responsible for planning, reporting, QA, budgeting, environmental co-ordination and administration. The staffing of the Äspö reception and the SKB switchboard are also included in the function.

From autumn 2010 the Public relations and visitor services group, TDI, organisationally will transfer to the reorganised Communications department within SKB. The group and its personnel will however still be located at Äspö HRL and have a continuously close co-operation with the facility and the daily coordination of underground activities.

Each major research and development task carried out in Äspö HRL is organised as a project led by a Project Manager reporting to the client organisation. Each Project Manager is assisted by an on-site co-ordinator with responsibility for co-ordination and execution of project tasks at the Äspö HRL. The staff at the site office provides technical and administrative service to the projects and maintains the database and expertise on results obtained at the Äspö HRL.

6.2 Bentonite Laboratory

Test set-up for the deposition tunnel in half-scale.

Before building a final repository, where the operating conditions include deposition of one canister per day, further studies of the behaviour of the buffer and backfill under different installation conditions are required.

SKB has built a Bentonite Laboratory at Äspö, designed for studies of buffer and backfill materials. The laboratory, a hall with dimensions 15×30 m, includes two stations where the emplacement of buffer material at full scale can be tested under different conditions.

The hall is also used for testing of different types of backfill material and the further development of techniques for the backfilling of deposition tunnels.

Present status

Tests concerning impact of water inflow on backfill have continued during 2009. In the four tests, the time for breakthrough and the amount of inflow of water have been measured.

Eight pellet/rock tests on a pilot scale have been performed. The objective with these tests was to study the mechanisms that control the migration and distribution of water entering pellet fills from water-bearing rock fractures in order to get a deeper understanding of the flow of water along the pellet-rock interface.

Scope of work for 2010

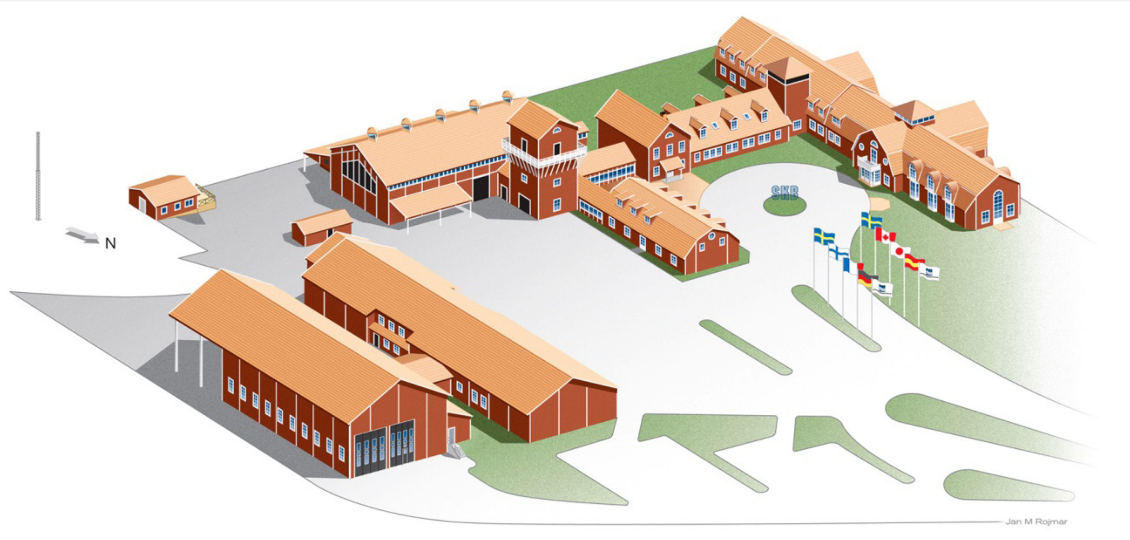
Work concerning development of techniques for backfilling and installation of buffer will continue during 2010.

In the deposition tunnels the properties of the bedding are important for the result of the block emplacement. The method for pellets installation can be refined in order to minimise dust and to stop each sequence with a steep front of pellets. Bed and pellet installation tests will be done during 2010. For the installation of the buffer in the deposition hole there is a need to develop and test the buffer protection and also develop and test the bottom plate in the deposition hole.

In a separate project the impact of water inflow in backfilled deposition tunnels will be investigated. The objective of the project is to investigate the impact of inflow from the rock on the constitution and properties of the pellet backfill in deposition tunnels. It is preceded by tests on different scales with similar intentions but without the present objective of identifying the detailed, actual process of water uptake of the pellet fill, and of determining realistic multi-point inflows corresponding to real rock structure.

Rock/pellet tests will be made to study the mechanisms that control migration and distribution of water entering pellet fills from inflow spots in the rock. The tests will be made on blasted rock slabs for identifying how water is taken up from “dry” and “wet” rock by pellet fills and flows along the rock/pellet contact. Results from these tests will be a complement in the interpretation of the half-scale tests. In these tests the inflow into a pellet fill in a steel tunnel of half scale is investigated, see figure above. A series of tests are made with inflow from sets of inflow spots that are connected and injected with Äspö water at realistic flow rates, preliminarily 0.1 to 0.2 L/min. The selection of the location of the spots is based on actual fracture mappings of water-bearing fractures in blasted Äspö tunnels. One test series is made so that wetted pellet fill is placed in contact with “dry pellets” for simulating the case of quick water saturation of parts of the tunnel backfill separated by less wet pellet fill into which water flows at a late stage.

6.3 Facility Operation



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

This includes preventative and remedial maintenance in order to ensure that all systems such as drainage, electrical power, ventilation, alarm and communications have a high degree of availability.

Present status

There have been no unplanned stops in the operation of the facility during 2009. During the summer the planned replacement of rusty electrical installations in the elevator shaft was carried out. After completion of the project Sealing of tunnel at great depth in the Tass-tunnel, restoration work has been carried out. The system which was developed by SKB for surveillance of objects underground has been approved and is now in operation. A major review of the alarm-centre has been carried out during the year and the surveillance of old objects that are no longer in use has been discontinued.

The activity at the facility is increasing steadily, which means that new space and buildings are required. A new dining-room with a kitchen has been completed. A new storage building has also been built during the year. A warehouse has been rented for the storage of bentonite in frost-free conditions. In addition, asphalting of the roads on and around Äspö island has been carried out in order to maintain the high standard of the roads.

After transfer of documentation from Oskarshamn NPP, a major project has been started with aim of updating all the facility's documentation.

Scope of work for 2010

Activities within the group will continue along the same lines as earlier. The scope of the work becomes wider all the time, which is a consequence of the expansion of the facility, both above- and underground. The work of the group also functions as a school for maintenance staff for a future final repository. A system for surveillance of the facility and personnel in the final repository is being tested at Äspö.

A number of constructions/installations are starting to fail due to age and therefore large-scale renovations are required. Examples are the installations in the elevator shaft and in the ramp. The elevator-steering system and motor need modernising in order to ensure the long-term availability of components.

Because of questions related to land-access, planned work with the water supply and sewage systems has not been able to be performed during 2009. A solution for ensuring the water supply is to build a reservoir of about 150 -200 cubic metres. Pumping of sewage to Oskarshamn NPP treatment plant via a pipe laid in the sea is planned.

6.4 Public Relations and Visitor Services

SKB operates three facilities in the Oskarshamn municipality: Äspö facility, Central interim storage facility for spent nuclear fuel (Clab) and the Canister Laboratory.

Site investigations have been performed during 2002-2009 in the municipalities Oskarshamn and Östhammar. In June 2009 SKB decided to select Forsmark as the site for the final repository for Sweden's spent nuclear fuel.

The main goal for the Public Relations and Visitor Services Group is to create public acceptance for SKB, which is done in co-operation with other departments at SKB. The goal will be achieved by presenting information about SKB's facilities and RD&D work e.g. at the Äspö facility. Furthermore the team is responsible for visitor services at Clab and the Canister Laboratory.

In addition to the main goal, the information group takes care of and organises visits for an expanding amount of foreign guests every year. The visits from other countries mostly have the nature of technical visits.

The team also has the responsibility for the production of SKB's exhibitions; stationary, temporary and on tour.

The information group has a special booking team at Äspö which books and administrates all visitors. The booking team also is at Oskarshamn NPP's service according to agreement.

Present status

During the year 2009 the facilities in Oskarshamn (Äspö facility, Clab and Canister Laboratory) and the site investigation activities in Oskarshamn were visited by 13,129 visitors. The total number of visitors to all SKB facilities and site investigation activities in Oskarshamn and Forsmark was 21,157 persons. The visitors represented general public, municipalities where SKB has performed site investigations, teachers, students, professionals, politicians, journalists and visitors from foreign countries. The statistics shows an increasing amount of visitors within the categories journalists, professionals and foreign guests, however other categories are decreasing.

Planned special events for 2010

Due to the site selection in June 2009, there has been an increasing interest from foreign countries to visit SKB's facilities to get information on the Swedish system for radioactive waste management but also the work with communication. A new concept will be developed during the first half of 2010 to handle the increased number of foreign requests and visits.

Tours for the general public are planned to take place during the summer and on some Saturdays during the year. Several bus-tours a day take visitors underground, where they are given information about ongoing research. The summer project will start at the end of June and finish up in August.

A series of lectures with special connection to the research and development of techniques conducted at the Äspö facility has been ongoing since 2007 and will continue during 2010. Special occasions which are planned are:

- September 11 - "The Geology Day", activities for the schools and for the general public.
- September 24 (preliminary date) - "Researchers Night", a European Union initiative.
- Autumn - "The Environmental Day", in co-operation with the Äspö Environmental Research Foundation.
- December -"Äspö Running Competition", a yearly event.
- Participate in the planning of the 25 year celebration of Äspö HRL and an international conference in connection with the jubilee.

7 Environmental research

7.1 General

Äspö Environmental Research Foundation was founded in 1996 on the initiative of local and regional interested parties. The aim was to make the underground laboratory at Äspö and its resources available for national and international environmental research. The activities have since 2003 been concentrated to the Äspö Research School. When the activities in the school was concluded as planned in 2008, the remaining and new research activities were transferred within the frame of a new co-operation, Nova Research and Development (Nova FoU).

7.2 Nova Research and Development (Nova FoU)

SKB and Äspö HRL have a general policy to broaden the use within the society concerning research results, knowledge and data gathered within the SKB research programme. Nova FoU (www. novafou.se) is the organisation which implements this policy and facilitates external access for research and development projects to SKB facilities in Oskarshamn. Nova FoU is a joint research and development platform at Nova Centre for University Studies and R&D supported by SKB and the municipality of Oskarshamn.

Nova FoU provides access to the following SKB facilities:

- Äspö Hard Rock Laboratory
- The Bentonite Laboratory at Äspö
- The Canister laboratory in Oskarshamn
- Site Investigation Oskarshamn (Laxemar)

Nova FoU can co-finance the projects by valuing the access to the SKB facilities, knowledge and data. The aim with the research and development projects through Nova FoU is to create long term spin-offs and business effects beneficial to the region. Nova FoU supports new and innovative research, for example environmental studies, where the extensive SKB data set from geological, hydrogeological, hydrogeochemical and ecological investigations and modelling can be used, see Figure 7-1.

The data can be used e.g. for assessing the consequences of natural resource management and pollution risks. The data and models can be used to estimate exposure both at individual and population levels. Development of monitoring and analytical systems can be performed relating to the management of various renewable natural resources in, for instance, agriculture, fisheries, forests and groundwater. Studies which give a better knowledge concerning pollution problems coupled to toxicological and epidemiological issues are possible.

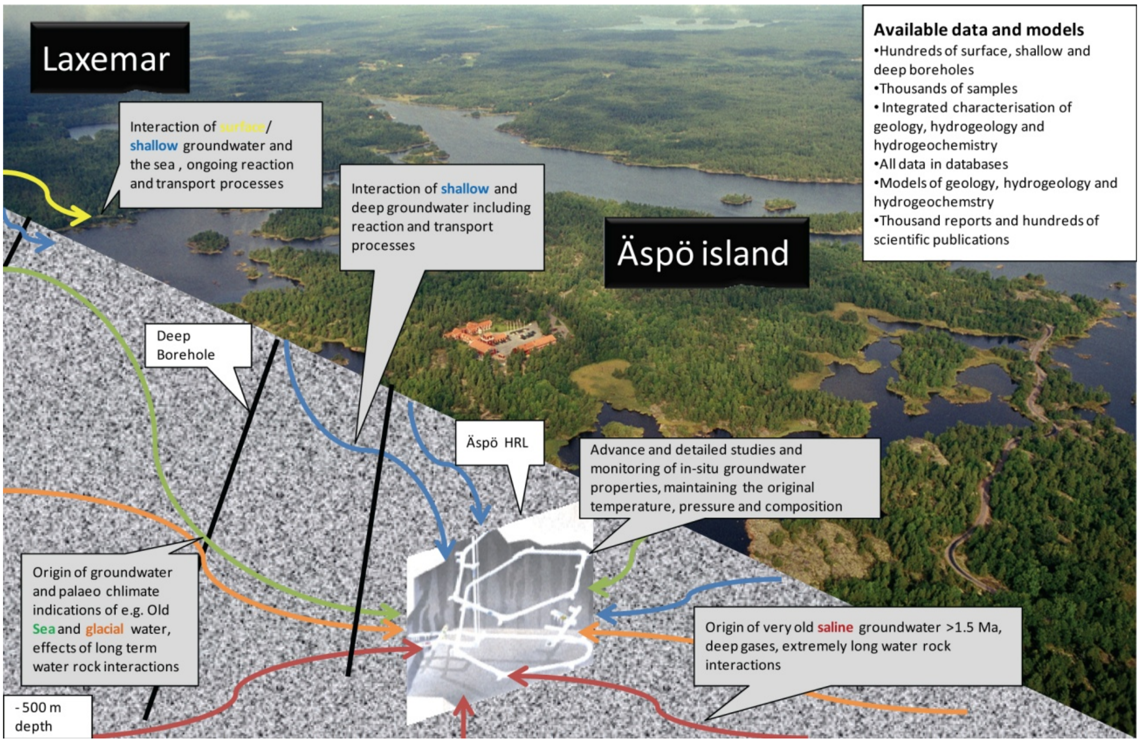


Figure 7-1. *The Äspö and Laxemar areas have been studied in terms of geology, hydrogeology, hydrogeochemistry and ecology.*

The research and education programme (at Äspö) is the most matured activity within Nova FoU and the activities within the Linné Geochemistry Group is therefore described in more detail in Section 7.2.1. Other possible studies are:

- Groundwater origin, mixing and evolution
- Interaction between surface/shallow groundwater with deep groundwater and sea
- Model and technology development
- Tunnel and borehole experiments

Present status and scope of work for 2010

Ongoing research and development projects, new project activities and marketing activities at Nova FoU are shown in Figure 7-2. The scope of work within Nova FoU for the year 2010 consists of increasing marketing efforts in order to start new research and development projects. The new offices and conference facilities at the former Laxemar site investigation office (Polstjärnan) help to develop and expand the activities within Nova FoU. The SKB mobile field laboratory is planned to be used for experiments run by the Linné Geochemistry Group.

Ongoing projects:

- Research and education
- Microbial project
- Coastal modelling
- 3D-identification system (RFID)
- Commercialisation of existing SKB-technique

Marketing activities:

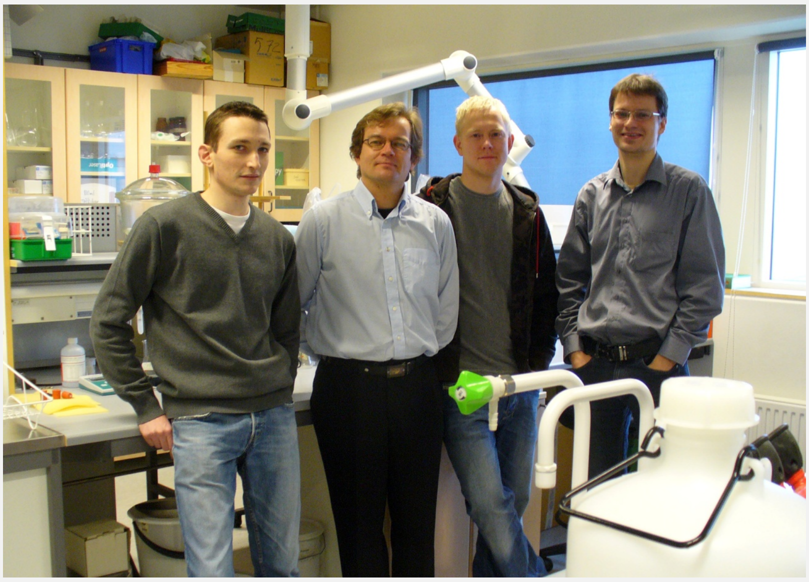
- Marketing meetings with EU, Vinnova, Formas, Mistra, VR
- Marketing activities together with SKB to invite universities
- Identification of research teams

New activities:

- RFID fire protection
- Microbial project (Univ. of Göttingen)
- Formation of an expert group
- Master education for nuclear power and final disposal
- Social research, spatial and time research (Univ. of Göteborg)
- Water management
- Energy efficiency
- Geology and health
- Geosphere institute at Äspö
- EU-project
- VR-project
- Added value discussion
- Monitoring programme for Laxemar

***Figure 7-2.** Ongoing projects and activities at Nova FoU.*

7.2.1 Linné Geochemistry Group



Four of the members of the Linné Geochemistry Group.

The Linné Geochemistry Group (previously called "Geochemistry Research Group") is part of the Nova FoU platform. It is financed mainly by SKB and the University of Kalmar. Details on the research activities, the senior researchers and the PhD students are given at http://www.skb.se/asporesearch.

Present status

In 2009 a new PhD student (Tobias Berger) and a post doc (Dr. Henrik Drake) have started. This has expanded the group which now consists of a professor, a research assistant, a post doc and three PhD students. Additionally there are three senior researchers closely linked to the group.

Scope of work for 2010

The modelling of the groundwater chemistry in bedrock will be further developed and expanded. The main focus is on work related to the development of the Äspö Site Descriptive Model, the understanding of sulphide production processes in groundwater and drilling-water contamination. These tasks will increase the understanding of the overall patterns and controls of groundwater chemistry in the Äspö bedrock, including the sulphur dynamics, and how drilling water affects the measured groundwater composition.

Focus will also be on the surface systems in Laxemar, in particular the stream "Kärrsviksån", which will be the site for characterisation of sources and pathways of fluoride plus major ions and cations. The work includes both existing data from the site investigations and additional field sampling and analyses of stream waters and overburden.

Minerals like calcite, barite, chlorite and sulphides are found on the walls of the fractures found within the Äspö and Laxemar bedrock. These minerals will be further characterised and compared with existing data on groundwater chemistry. The main focus will be on the youngest generation of sulphides, in order to unravel the redox changes and sulphur dynamics having occurred in the bedrock in relatively recent geological times. Important analytical tools will be electron microscopy and ICP-MS techniques to be carried out at Göteborg University, and sulphur-isotope analysis at a laboratory in Scotland.

In 2009 two nationwide seminars for PhD students working on geochemical issues related to areas of interest for SKB were held at Äspö. The seminars attracted a number of PhD students, senior researchers and other people. In 2010 the seminars will be repeated in January and August. According to the plan, two new PhD students shall start in 2010. The preliminary topics are cation-exchange processes in granitoidic bedrock and lanthanide dynamics.

8 International co-operation

8.1 General

Nine organisations from eight countries will in addition to SKB participate in the co-operation at Äspö HRL during 2010, see table 7-1. Six of them; Andra, BMWi, CRIEPI, JAEA, NWMO and Posiva together with SKB form the Äspö International Joint Committee (IJC), which is responsible for the coordination of the experimental work arising from the international participation. Numo (Nuclear Waste Management Organisation of Japan) had a representative observer at the IJC-meeting in May, 2009.

Several of the participating organisations take part in the two Äspö Task Forces on: (a) Modelling of Groundwater Flow and Transport of Solutes, which is a forum for co-operation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock and (b) THMC modelling of Engineered Barrier Systems, which is a forum for code development on THMC processes taking place in a bentonite buffer and gas migration through a buffer.

SKB also takes part in work within the IAEA framework. Äspö HRL is part of the IAEA Network of Centres of Excellence for training in and demonstration of waste disposal technologies in underground research facilities.

Table 8-1. International participation in the Äspö HRL projects during 2010.

Projects in the Äspö HRL during 2010	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Kaeri	Nagra	Rawra
Natural barriers									
Long Term Sorption Diffusion Experiment					X				
Colloid Transport Project		X			X				
Microbe Project		X							
Task Force on Modelling of Groundwater Flow and Transport of Solutes	X		X	X	X	X	X		
Engineered barriers									
Prototype Repository		X							
Alternative Buffer Materials	X	X				X		X	X
Long Term Test of Buffer Materials	X	X				X		X	
Temperature Buffer Test	X	X							
KBS-3 Method with Horizontal Emplacement						X			
Large Scale Gas Injection Test	X	X			X	X			
Task Force on Engineered Barrier Systems	X	X	X		X	X		X	X

Participating organisations :
Agence nationale pour la gestion des déchets radioactifs, Andra, France
Bundesministerium für Wirtschaft und Technologie, BMWi, Germany
Central Research Institute of the Electronic Power Industry, CRIEPI, Japan
Japan Atomic Energy Agency, JAEA, Japan
Nuclear Waste Management Organisation, NWMO, Canada
Posiva Oy, Finland
Korea Atomic Energy Research Institute, Kaeri, Korea
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland Radioactive Waste Repository Authority, Rawra, Czech Republic

8.2 Andra

The French radioactive waste management agency is developing the Meuse/Haute-Marne Underground Rock Laboratory (URL) within a sedimentary clay layer. French Planning Act of 2006 has opened the way towards a deep geological repository in such clay-rock. The large programme implemented in the Swedish hard rock laboratory at Äspö on bentonite based engineered barrier systems is considered highly valuable whatever host-rock is selected for a future repository.

Prioritised activities during 2010

An important activity for 2010 will be the dismantling operation of the Temperature Buffer Test (TBT) and the correlated analyses of samples from the tests. New THC data are expected from the hottest part of the test. The THM modelling will be resumed by Clay Technology and UPC-CIMNE.

The Large Scale Gas Injection Test (Lasgit) should continue to deliver gas transport data to modellers and notably to the Swiss modelling team at Colenco supported by Andra.

Andra still participate in the project Alternative Buffer Materials by performing analyses of buffer materials.

8.3 BMWi

In 1995, SKB and the Bundesministerium für Forschung und Technologie (BMFT) signed the first project agreement being the basis for co-operation in specific joint projects performed in the Äspö HRL. After a first extension in 2003, the agreement was once again extended in 2008 for a period of another five years. Several research institutes are performing the work on behalf of and funded by the Bundesministerium für Wirtschaft und Technologie (BMWi) which is responsible for site-independent R&D: the Federal Institute for Geosciences and Natural Resources (BGR), DBE Technology GmbH, Forschungszentrum Dresden (FZD), Gesellschaft für Anlagen- und Reaktorsicherheit mbH (GRS), and Ruhr-Universität Bochum. The main objectives of the co-operation within the Äspö HRL programme are to improve the knowledge on the engineered barrier system and – on a minor scale – to keep the information on alternative host rocks for radioactive waste repositories. Topics of special interest are:

- The behaviour of engineered barrier system and the interaction with the surrounding rock.
- The behaviour of the buffer material.
- The behaviour of microbes and colloids and their interaction with radionuclides.
- Geochemical investigations of the migration behaviour especially of actinides under near-field and far-field conditions.
- Characterisation of fracture zones in the rock mass and disturbed zones surrounding underground openings, and flow and transport of solutes.

Prioritised activities during 2010

Microbe Project

In the middle of 2009, a new project started at the Forschungszentrum Dresden. A part of the project focuses on the characterisation of interaction processes of selected actinides (U, Pu and Cm) with biofilms generated by Äspö relevant bacteria. In detail, emphasis is put on generating and characterising biofilms produced by Äspö bacteria under aerobic conditions, studying the interaction of actinides with these biofilms, and performing a spectroscopic characterisation of the formed actinide species. In 2010 activities will comprise the cultivation of biofilms generated by the Äspö bacterium *Pseudomonas fluorescens* in biofilm-reactors under aerobic conditions, the characterisation and quality control of the formed *P. fluorescens* biofilms, and first interaction experiments of U(VI) with these biofilms.

Prototype Repository

GRS intends to continue the measurements of the electric resistivity distribution in the backfill, the buffer and the rock between two of the deposition boreholes. These measurements are used to monitor the water uptake of the backfill and the buffer and potential desaturation of the rock. Tomographic dipole-dipole measurements using electrode arrays installed in the backfill and in the buffer at the top of deposition hole #5, as well as Wenner measurements along three electrode chains placed in boreholes located between the deposition holes #5 and #6 are automatically measured. The recording unit for these arrays is controlled remotely from Braunschweig/Germany and evaluated quarterly. By inverse modelling with code SensInv2D the resistivity distribution around the electrode arrays is determined. From laboratory results obtained during an earlier phase of the project, the resistivity distributions can be interpreted in terms of water content of the backfill, the buffer, and the rock, respectively. Because of the failure of a number of buffer electrodes the buffer measurements can no longer be evaluated by inversion. The backfill is largely saturated. The rock near the deposition hole #5 shows slight fluctuations in resistivity. The daily measurements of the electric resistivity distribution will be continued until shutdown and dismantling of Section II of the Prototype Repository. Data evaluation will be performed in Braunschweig and contributions to SKB's sensor data reports will be provided on a half-year basis. After shut-down of Section II of the Prototype Repository, samples will be taken from the buffer and the backfill and analysed in terms of water content and resistivity, and the reason for the electrode failure will be determined.

Long Term Test of Buffer Material

BGR's near-future plan for activities regarding the experiment will be the subject of discussions at a project meeting in April 2010.

Alternative Buffer Materials

In 2010 BGR intends to proceed with the characterisation of the different buffer materials samples applying special analytical techniques in order to clarify the remaining open questions (e.g. related to corrosion mechanisms and accumulation of organic matter at the interface). The near-future plan for the ABM test will be discussed at the project meeting in April 2010.

Temperature Buffer Test

DBE Technology intends to continue the work on the back analysis of the measured data obtained from the Temperature Buffer Test. In 2010 special focus will be on simulating the swelling of the bentonite and the development of swelling pressure as a function of saturation. An existing subroutine in the computer code FLAC3D calculating the swelling pressure in 2D has been extended to simulate the 3D problem. A couple of test runs are to be performed. After suitable verification of calculation results, it is intended to simulate the swelling of the bentonite as a function of increasing saturation and to identify the impact of the swelling on the hydraulic processes.

Large Scale Gas Injection Test

The work being conducted by BGR as part of the Lasgit project focuses on the investigation of processes and interactions that occur in the experiment and the behaviour and nature of the engineered barriers system as well as the excavation damaged zone (EDZ). Surface packer tests (with helium as gas tracer) have been performed to determine the permeability of the gallery wall. Test evaluation and modelling exercises are executed by using the finite-element code GeoSys/RockFlow (THMC-code).The work in 2010 will focus on the modelling of processes in the engineered barrier system. Measured data from Lasgit will be used as reference and different approaches for modelling gas migration will be tested.

Task Force on Engineered Barriers

In 2010, the Task Force on Engineered Barrier Systems will presumably start into a new phase. Among other things, it is considered to study the sensitivity of parameters in THM-coupled calculations. BGR is interested to participate in that task in the upcoming phase.

GRS intends to continue with modelling re-saturation using Code VIPER. As the results of some test cases showed, there is some further effort needed to understand the phenomena. For instance, it seems that a water transport process not considered so far may be of importance. In addition to a correct mathematical model, a more profound process understanding on a microscopic scale is needed accompanied by test calculations. Necessary theoretical work, implementation and modelling will be continued in 2010.

The participants of the Ruhr-Universität Bochum (formerly Bauhaus Universität Weimar) intend to continue with their research on model validation of numerical simulations of coupled THM-processes. Main focus will in 2010 be on sensitivity analysis regarding significant process parameters. By applying statistical analysis it will be possible to improve the weighting functions in the definition of objective functions and thereby identifying reliable global solutions.

8.4 CRIEPI

Central Research Institute of Electric Power Industry (CRIEPI) signed a contract with SKB for the Äspö HRL Project in 1991 and renewed it in 1995, 1999, 2003 and 2007. The main objectives of CRIEPI’s participation have been to demonstrate the usefulness of its numerical codes, develop its site investigation methods and improve the understanding of the mechanisms of radionuclide retention in fractured rock and the interaction between engineered barriers and surrounding rock. Since 1991, CRIEPI has participated in the exchange of information concerning research and technology for geological disposal of high-level radioactive wastes with other organisations within the Äspö HRL co-operation. In addition, CRIEPI has performed several voluntary tasks e.g. groundwater dating, fault dating, measurement of velocity and direction of groundwater flow and a study on impact of microbes on radionuclide retention. CRIEPI has participated in the Task Force on Modelling of Groundwater Flow and Transport of Solutes since 1992 and also in the Task Force on Engineered Barrier Systems since 2004.

Prioritised activities during 2010

During 2010, CRIEPI will participate in the two Task Forces as well as exchange information about research, technologies and methodologies for geological disposal of high-level radioactive wastes with SKB and the other participating organisations.

As to the Task Force on Modelling of Groundwater Flow and Transport of Solutes, CRIEPI will perform modelling work for sub-task 7C, Posiva Flow Logging characterisation and analysis of low permeable fractures and assessment of flow distribution pattern at shaft wall sections at Onkalo, Olkiluoto, Finland. CRIEPI will also conduct modelling work for Task 8, Interface engineered and natural barriers.

For the Task Force on Engineered Barrier Systems, CRIEPI has applied its own numerical code for the thermo-hydro-mechanical coupled behaviour, LOSTUF, to several benchmark issues. In 2010, it is planned to summarise the achieved results in benchmark 2 in the form of a final report.

8.5 JAEA

The JAEA participation in the Äspö HRL is regulated by the trilateral project agreement between JAEA, CRIEPI and SKB which was signed in 2006. JAEA is currently constructing underground research laboratories in fractured granite at Mizunami and in a sedimentary formation at Horonobe. The aims are to establish comprehensive techniques for investigating the geological environment and to develop a range of engineering techniques for deep underground applications. The results obtained from these laboratories will contribute to ensure the reliability of repository technology and to establish a safety assessment methodology. JAEA also continues to be active in the research at Äspö HRL, which is directly applicable to the Japanese programme. The objectives of JAEA’s participation in Äspö HRL during 2010 will be to:

- Develop technologies applicable for site characterisation.
- Improve understanding of flow and transport in fractured rock.
- Improve understanding of behaviour of engineered barriers and surrounding host rock.
- Improve techniques for safety assessment by integration of site characterisation information.
- Improve understanding of underground research laboratory experiments and priorities.

These objectives are designed to support high level waste repository siting, regulations and safety assessments in Japan.

Prioritised activities during 2010

JAEA will actively participate in Task 7 of Task Force on Modelling of Groundwater Flow and Transport of Solutes, especially to evaluate the uncertainty in performance assessment relevant parameters estimated by hydrogeological models based on the flow response measurement data during hydraulic interference test. JAEA will also partially participate in Task 8 to evaluate the uncertainty in hydrogeological model of heterogeneous flow paths of the fracture network structure and the variable fracture aperture, to address the canister near-field conditions.

In addition, for the Alternative Buffer Materials (ABM) project, preparation of several analyses (e.g. X-ray diffraction) for the parcel 1 (one year test) have been started with the aim to identify mineralogical changes in the Japanese bentonite (one of eleven clay materials used in the ABM-test parcels).

8.6 NWMO

The prime objective of Nuclear Waste Management Organisation's (NWMO's) participation at Äspö HRL is to enhance the scientific understanding and technology base for a deep geological repository through international co-operation research and development projects and demonstrations. The planned work on Äspö HRL projects to be carried out in 2010 is described below.

Prioritised activities during 2010

NWMO is supporting the Colloid Project. In 2010, NWMO intends to work collaboratively with SKB to prepare a final knowledge base report summarising research activities in the area of colloid stability, colloid characterisation, colloid erosion, retention and transport modelling.

NWMO is participating in the Task Force on Modelling Groundwater Flow and Transport of Solutes, with respect to Task 7. The Canadian modelling team is from the Université Laval and the reference code is FRAC3DVS. In 2010, project activities will include completion of modelling activities and reporting for sub-task 7C. Sub-task 7C is focused at the scale of single, low transmissivity fractures that contribute with flow at the shaft wall sections of the Onkalo facility in Olkiluoto. Numerical analyses are supported by shaft wall mapping, borehole-based fracture logs and hydraulic tests, including cross-hole Posiva Flow Log interference test measurements.

NWMO is providing modelling support for the Large Scale Gas Injection Test (Lasgit) using the Tough2 code modified with pressure-dependent permeability and capillary pressure to simulate microfracturing. In 2010, the modelling work will focus on simulating the gas injection tests conducted in 2009. The goal of this simulation work is to better understand the processes taking place during the gas injection portion of the Lasgit experiment. To this end, it will be useful to rule out processes that definitely do not contribute to the observed behaviour, and establish a reasonable understanding of processes that contribute to the observed gas flow behaviour in saturated, confined bentonite. In order to do this, it may be necessary to explore alternative numerical solvers or modelling systems. Such alternative modelling systems may need to include geomechanical processes, in addition to the two-phase flow considered in earlier work.

NWMO is participating in the Task Force on Engineered Barrier Systems, with respect to the THM modelling task. The Canadian modelling team is from AECL and the reference code is Code_Bright. In 2010, the planned modelling work will focus on completion of the numerical simulation of SKB's Canister Retrieval Test.

8.7 Posiva

Posiva's co-operation with SKB continues with the new co-operation agreement signed in the autumn of 2006. The focus of the co-operation will be on encapsulation, repository technology, long-term safety related studies and on bedrock investigations.

Posiva also contributes to several of the research projects within Natural barriers. The implementation and construction of the underground rock characterisation facility Onkalo at Olkiluoto in Finland give possibilities to co-operate within the research and development of underground construction technology. Posiva's co-operation is divided between Äspö HRL activities and more generic work that can lead to demonstrations in Äspö HRL. The main work planned to be performed within the different projects during 2010 is described below.

Prioritised activities during 2010

KBS-3 Method with Horizontal Emplacement

SKB and Posiva are engaged in an R&D with the overall aim to investigate whether the KBS-3H concept can be regarded as a viable alternative to the KBS-3V concept. The project is jointly executed by SKB and Posiva and has a common steering group. Present stage is complementary study stage, 2008-2010, where the target is to solve a number of pre-designed issues and conduct component tests in the field and select the most appropriate design. Also full-scale system tests in a representative environment will be planned.

Long Term Test of Buffer Materials

Posiva's task in this project is to study the porewater chemistry in the bentonite. The task is carried out at VTT. The aim of the work is to obtain data about the chemical conditions, which develop in the bentonite. The study gives information about the chemical processes occurring in the bentonite, but also supports other planned studies of the chemical conditions.

Alternative Buffer Materials

Posiva will contribute to the project with similar types of experimental studies as already done in the project Long Term test of Buffer material. The clay materials of interest in the Posiva's studies are MX-80, Deponit, Asha and Friedland Clay. The aim of the work is to get information about the pore structure and the evolution of chemical conditions in the clays.

Task Force on Modelling of Groundwater Flow and Transport of Solutes

Äspö Task Force Task 7 - "Reduction of Performance Assessment uncertainty through block scale modelling of interference tests in KR14-18 at Olkiluoto" - will continue in 2010. The modelling activities will concentrate on addressing questions on compartmentalisation of the hydrogeological regime, procedure from site characterisation data to performance assessment parameters, effect of variability of fracture characteristics etc. In addition to Task 7, a new Task 8 addressing the interaction between the near field bedrock and bentonite enclosed within a borehole section has been proposed. The study would in particular address the complex phenomena pertinent to the saturation of bentonite and its interplay with the groundwater flow in the surrounding sparsely fractured rock.

Task Force on Engineered Barrier Systems

During the year 2009 the THM behaviour of water saturation phase of the Canister Retrieval Test and TBT-test have been simulated and reported. Posiva is also participating in the work of the chemistry group in the Task Force. The activities of the year 2010 are currently under consideration.

Prototype Repository

Posiva will probably participate in the planning of the dismantling of the outer section of the Prototype Repository during 2010.

Bentonite laboratory

Part of the testing in Posiva-SKB joint work programme for backfilling and sealing of deposition tunnels will be implemented in the bentonite laboratory. Posiva participates to the planning and testing of the impact of water inflow to deposition tunnels.

8.8 Kaeri

Korea Atomic Energy Research Institute, Kaeri, was established in 1959. Since 2008 Kaeri has been a co-opted participant of the Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes. From 2010 Kaeri will participate as a member organisation of the mentioned Task Force.

8.9 Nagra

The Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, has the task to provide scientific and technical basis for the safe disposal of radioactive waste in Switzerland. Nagra has had agreements with SKB for participation in Äspö HRL since 1994 to include mutual co-operation and participation in Äspö HRL and Grimsel Test Site projects. The last agreement expired 2003 and Nagra left the central and active core of participants. Nevertheless, Nagra supports the Äspö activities and participates in specific projects.

Nagra will continue to take part in the Task Force on Engineered Barriers Systems and the parallel task force that deals with geochemical processes in engineered barriers, and chemical modelling of bentonite. Nagra will also participate in the Alternative Buffer Materials project and the Long Term Test of Buffer Material experiment. For these projects, Nagra’s activities focus on analysis of samples and performance of laboratory tests in Switzerland.

Discussions are also ongoing for co-operation in an EU co-funded project on the test and demonstration of emplacement methods. If approved, the project will start in the later part of 2010.

Task Force on Engineered Barrier Systems

Nagra participates in the modelling and steering meetings. Nagra's activities will continue to focus on modelling of gas transport processes in bentonite. A new task/benchmark, which is to be formulated, may be added to Nagra's activities.

In addition, Nagra is participating and supporting the group for the geochemical aspects within the EBS Task Force. New benchmark tasks for analysis of fully coupled THMC-process are to be decided for performance in 2010 and onwards.

8.10 Rawra

Radioactive Waste Repository Authority, Rawra, was established in 1997 and has the mission to ensure the safe disposal of existing and future radioactive waste in the Czech Republic and to guarantee fulfilment of the requirements for the protection of humans and the environment from the adverse impacts of such waste. Rawra became a participant in the Task Force on Engineered Barrier Systems in 2005 and also participates in the Alternative Buffer Materials project. The intention is to continue in the project tasks with the possibility to spread the activities to the chemical part.

Prioritised activities during 2010

The principal task would be to continue with gas modelling, using different calculation tools. The Nuclear Research institute as a contractor of Rawra will continue with gas experiments in the bentonite environment. Development of a universal model to describe the processes has to be started. Bentonite performance under different laboratory conditions and its alteration will be followed.

The team from the Technical University Liberec will continue the verification process of their model ISERIT. THM processes are the principal objectives of modelling. The code will be further developed to cover a wider set of phenomena and processes, with respect to generalisation possibilities of data input. Automatic calibration using the combination with inverse problem solution algorithm shall be a part of the activities.

Czech Experimental Geology Centre of the Technical University in Prague will continue with development of a special model that should be compared with data from the Canister Retrieval Test and the project Mockup-CZ. A new experimental site, mine Josef, will provide a support for experiments of phase transport and other technical issues.

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