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Äspö Hard Rock Laboratory

Planning Report for 2009

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 2009

This report presents the planned activities for the year 2009. 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

Anders Sjöland

Executive Secretary of the Technical-Scientific Council

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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 high-level nuclear waste.

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.

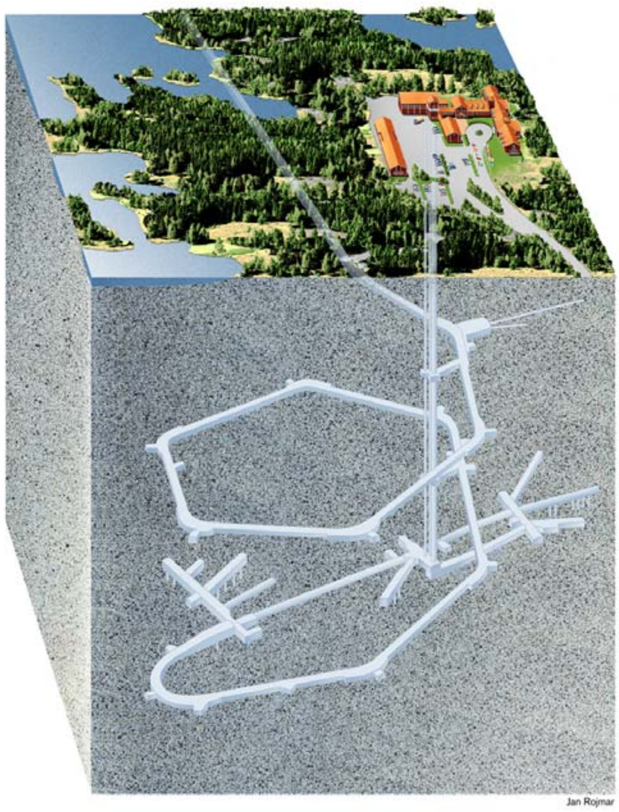


Figure 1-1. *Overview of the Äspö Hard Rock Laboratory.*

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.

Stage goals 1 and 2 have been concluded at Äspö HRL and the tasks were transferred to the Site Investigations Department of SKB which has performed site investigations 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 Äspö HRL. In addition, 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 2009, eight organisations from seven 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.
- 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 (a) Modelling of Groundwater Flow and Transport of Solutes and (b) 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 some of the experimental sites within the underground laboratory is shown in Figure 1-2.

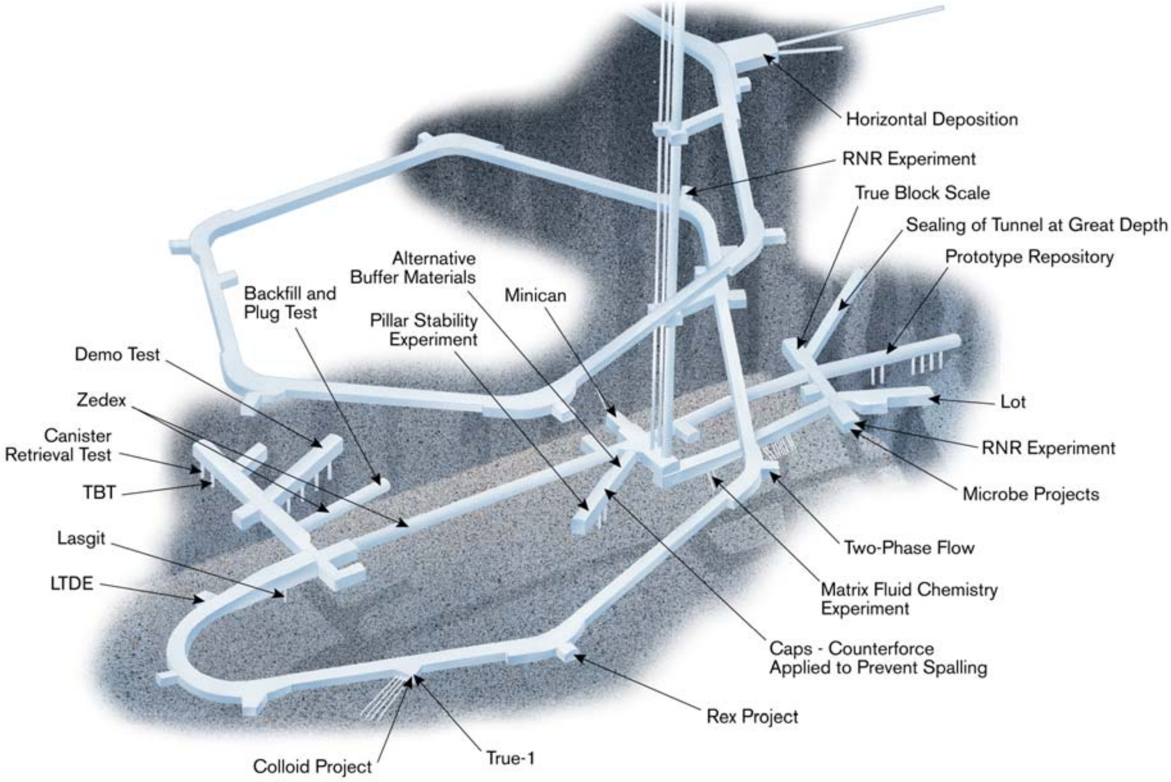


***Figure 1-2**. Allocation of some of the experimental sites from -220 m to -450 m level.*

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 2009. 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

During the pre-investigations for the Äspö HRL in the late 1980's the first geoscientists came to Äspö. Most of them were consultants that mainly worked off-site. A new site organisation was developed when the rock laboratory was taken into operation 1995. Posts as site geologist and site hydrogeologist were then established. These posts have been broadened with time, and today the responsibility of the holder involves maintaining and developing the knowledge and methods of the scientific field, as well as scientific support to various projects conducted at Äspö. Geoscientific research and activities are conducted in the fields of geology, hydrogeology, geochemistry (with emphasis on groundwater chemistry) and rock mechanics.

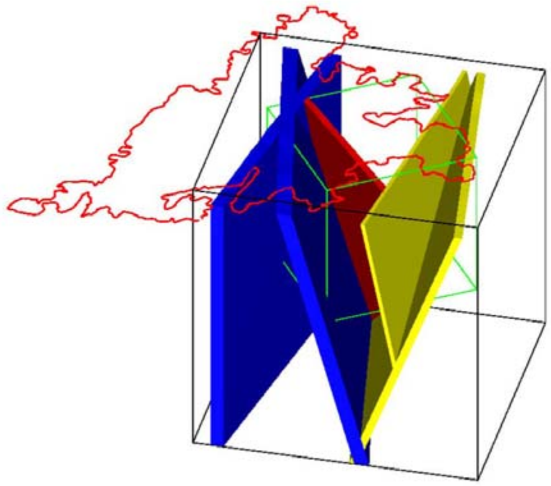
Geoscientific research is a part of the activities at Äspö HRL as a complement and an extension of the stage goals 3 and 4, see Section 1.2. Studies are performed in both laboratory and field experiments, as well as by modelling work. From 2006 the work follows a yearly geoscientific programme. The overall aims are to:

- Establish and develop geoscientific models of the Äspö HRL rock mass.
- Establish and develop the understanding of the Äspö HRL rock mass material properties as well as the knowledge of applicable measurement methods.

The activities further aim to provide basic geoscientific data and to ensure high quality of experiments and measurements related to geosciences, see Figure 2-1.

Figure 2-1. *Installation of test equipment in Tasq-tunnel for the project Counterforce Applied to Prevent Spalling.*

2.2 Äspö Site Descriptive Model



The main task within the geoscientific field is to develop the Äspö Site Descriptive Model (SDM). The model 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 model includes data collected up to 2002 and was published in 2005.

Scope of work for 2009

The intention is to develop the model including data up to 2008 into a dynamic working tool, suitable for predictions in support of the experiments in the laboratory.

2.3 Geology

Geological work at Äspö HRL is focused on several main fields. Major responsibilities are mapping of tunnels, deposition holes and drill cores, as well as continuous updating of the geological three-dimensional model of the Äspö rock volume. In addition, the development of new methods in the field of geology is a major responsibility.

2.3.1 Geological Mapping and Modelling

Preparations before mapping of the Tass-tunnel (photo: Oskar Sigurdsson)

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 mapping has been performed in the Tass-tunnel (the tunnel for the project Sealing of Tunnel at Great Depth) up to section 64.5 m. 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.

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 2009

Work related to the geological mapping of the Tass-tunnel will continue to be one of the major tasks. After each round (drilling, blasting and unloading) front mapping was made and after a number of rounds walls, roof and floor were mapped.

The work with "old" tunnel and deposition hole mappings not yet digitised and with geological data not entered into the rock characterisation system TMS will 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 or may be even better to version XM. To convert the TMS to a 3D version may be a part-solution for the project RoCS, see Section 2.3.2.

A number of method descriptions and instructions concerning the geological work at the rock laboratory will be written during 2009.

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

New equipment (SpheronCam HDR) is tested in the Tass-tunnel. (photo: Carljohan Hardenby)

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.

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 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 will, at least at the time being, 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 new phase of the Rocs project is ongoing and will in spite of what has been reported last year continue as a separate project. A foundation for decision making about how to continue with the project has been presented. The idea is that the new phase of the project will concentrate on the characterisation of the rock. 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. The project is, however, still open for testing other imaging methods such as SpheronCam HDR (the camera takes pictures even in total darkness with the help of the two lights mounted on each side of the lens) to form the base for geological mapping of the tunnels. In this case photogrammetry is used to obtain tunnel geometries.

ATS (Advanced Technical Solutions AB) executed laser scanning combined with high resolution digital photography of the entire Tasq-tunnel during the first half of the year of 2006. Although this scanning event is only partially a concern of the project the results will be of great interest for the project. ATS has delivered most of the test results but the final report has been delayed.

Scope of work for 2009

One of the major issues in the early 2009 is to complete a specification of requirements concerning the software to be used. Other issues during 2009 are to test the software and computers in tunnel environment and to store scanning and mapping data in the Sicada database. In addition, the scanning report for the Tasq-tunnel must be completed in the year of 2009.

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.

There is a need to improve the routines and method descriptions for hydrogeological work as well as the procedures for documentation at Äspö. The main task is to develop quality control and quality assurance procedures in the field of hydrogeology.

2.4.1 Hydro Monitoring Programme

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

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

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

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

Present status

The hydrogeological monitoring has been ongoing where the monitoring points were maintained and the equipment installed in tunnels is performing well. However, in the surface drilled boreholes a gradual deterioration of the equipment has taken place over the years, to the extent that presently most of the Äspö boreholes are only measured manually or discontinuously.

Scope of work for 2009

A review of potential supporting and corrective measures for the surface drilled boreholes is underway. The monitoring of the boreholes in the tunnels will continue with undiminished efforts. The work is reported quarterly through quality control documents and annually describing the measurement system and results.

Another part of the work is the continued development of a more detailed model of hydraulic structures at the main experimental sites below -400 m.

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.

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 Äspö HRL operational phase, sampling was replaced by a groundwater chemistry monitoring programme, with the aim to sufficiently cover the evolution of hydrochemical conditions with respect to time and space within the Äspö HRL.

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

Present status

The yearly monitoring campaign for groundwater chemistry has been performed as planned. However, several boreholes in the upper bedrock (-50 to -100 m) in the tunnel were dried out and discarded from the sampling programme. The reporting of the results from the monitoring campaign is ongoing.

In addition, sampling of gases has been performed in conjunction with the Microbe project. The results will be used to determine suitable sampling and analytical methods to be used in the future in the Äspö tunnel.

Scope of work for 2009

The yearly sampling campaign is planned to take place during October. Water samples are taken from varying depths in the Äspö HRL and also from some boreholes drilled from the surface. In addition, all projects at Äspö HRL can request additional sampling of their sites to be coordinated within the monitoring programme.

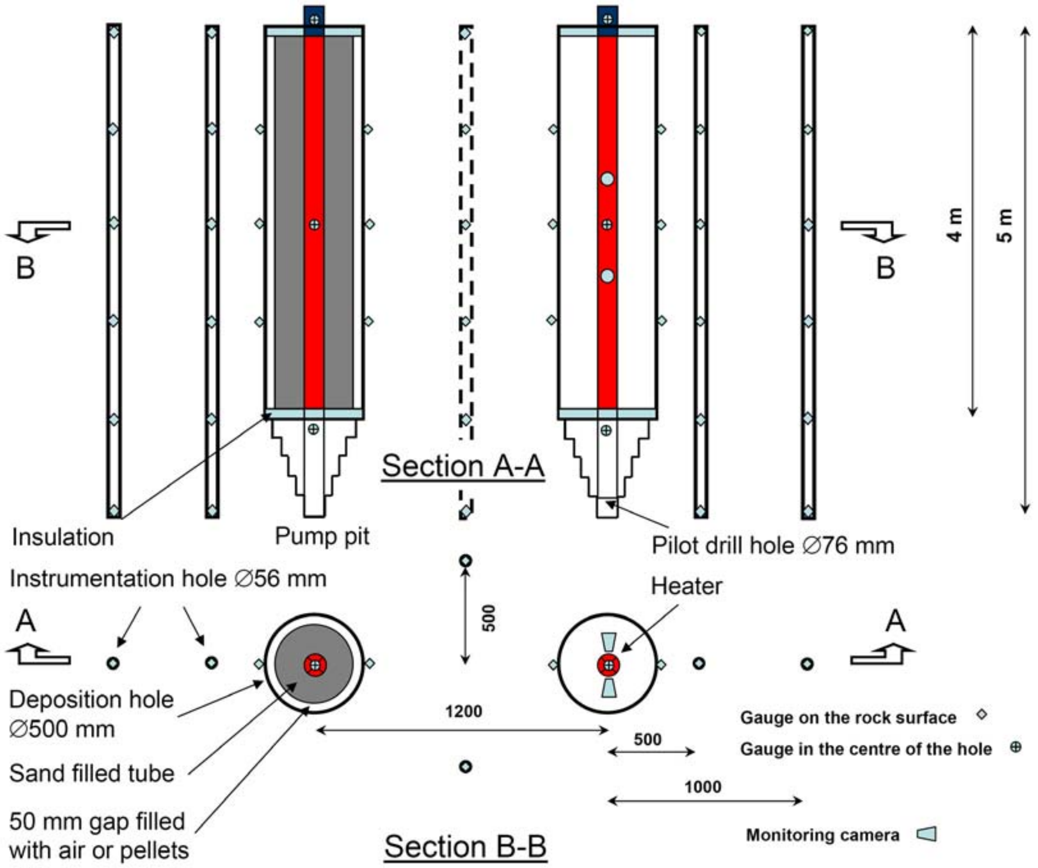
2.6 Rock Mechanics

Rock mechanic studies are performed with the aims to increase the understanding of the mechanical properties of the rock but also to recommend methods for measurements and analyses. This is mainly done by laboratory experiments and modelling at different scales and comprises:

- Natural conditions and dynamic processes in natural rock.
- Influences of mechanical, thermal and hydraulic processes in the near-field rock including effects of the backfill.

In addition, a project called Caps (Counterforce Applied to Prevent Spalling) comprising field test in Äspö HRL and numerical modelling is ongoing.

2.6.1 Counterforce Applied to Prevent Spalling



Configuration of the test holes and the positioning of instruments in the experiments in the Tasq-tunnel as original design with one open and one pellet filled hole. In reality the tests have been performed in two pairs of open holes and two pairs of pellet filled holes.

The field experiment within Counterforce Applied to Prevent Spalling (Caps) has been initiated as a demonstration experiment to determine if the application of dry bentonite pellets is sufficient to suppress thermally-induced spalling in KBS-3 deposition holes. The experience gained from the Äspö Pillar Stability Experiment, conducted between 2002 and 2006, indicated that spalling could be controlled by the application of a small confining pressure in the deposition holes.

The field tests, that include four pairs of heated half-scale KBS-3 holes, will be carried out as a series of demonstration experiments in the Tasq-tunnel at Äspö HRL.

Each test consists of two heating holes of 0.5 m diameter and 4 m depth separated by a 0.7 m pillar, which are surrounded by a number of boreholes for installation of temperature gauges.

The first step in the testing sequence includes heating of one pair of open holes to ensure that spalling will occur and can be observed in the test holes. The next step includes heating and observation of spalling in separate pair of holes. A 50 mm gap created between a large inner tube and the borehole wall is filled with a loosely placed pellets substitute. The final step is a complementary test that is carried out to address questions that arise during the previous tests.

Present status

The heating period in the first test was initiated on August 29th. Compared to the original plans, the heating period was prolonged from two to four weeks, due to a larger heat loss and a slower temperature increase than expected in the test. The cause for the larger heat loss was mainly the system of circulating water that controlled the temperature of the observation cameras installed in the heating holes, which worked as a number of heat exchangers in the holes. Test equipment used in the first test is shown in Figure 2-2.

The first test showed large differences in the proportion of observed spalling between the heating holes. The observations indicated that the inflow of water and the natural humidity in the holes had significant influence of the results and that it was important to control this parameter during the tests. The heating and the system of compressed air to keep the camera lenses free from mist resulted in a reduced humidity in the heating holes during the first test. Least amount of spalling was observed in the heating hole with lowest relative humidity. The drying-up of the boreholes was assumed to have caused a slight apparent confinement of the borehole wall due to suction within the borehole boundary.

The heterogeneity in the spalling observed in the first pair of heating holes resulted in the decision to perform the next test as a repetition of the first, however, with controlled humidity in the holes this time. The second test was performed in November with a heating period of little more than two weeks. It was accomplished with improved sealing of the heating holes and with a system to moistening the holes through generation of steam by the heating tubes. Furthermore, the observation cameras were excluded in the second test and the occurrence of spalling was instead observed by regular visual inspection and a mobile video camera.

The performed actions to prevent the rock from drying up did, however, not result in more uniformed spalling in the heating holes as was expected. The results in the second test showed even larger heterogeneity of the observed spalling in the heating holes. Compared to the first test, the amount of spalling increased in the hole with largest water inflow, while the amount of spalling was almost equal in the other hole with smaller inflow. The third test was performed in December 2008, promptly after the second test had been finished. This test included loosely placed pellets (light expended clay aggregates) in both of the heating holes in a 50 mm gap created between a large inner tube and the borehole wall. The preliminary results from this test indicate that the pellets cannot prevent the holes from cracking, whereas it might keep the rock chips in place and by this preserving the shape of the holes.

Scope of work for 2009

The tasks remaining to be carried out during 2009 are the final test, the evaluation and the reporting of the test results. In the final test the heating and cooling will be performed in a more gradually mode to slow up the rate of temperature change of the rock. The focus will be of the capability of the pellets to preserve the shape of the hole with the fractured slabs in place. It is also considered to do some post characterisation of the fractured zone regarding its hydraulic conductivity. The test period will be at least two months and the final test will probably not be finished before mid April. The evaluation of the results will be ongoing during the spring term and a draft report should be ready during the first half of 2009.

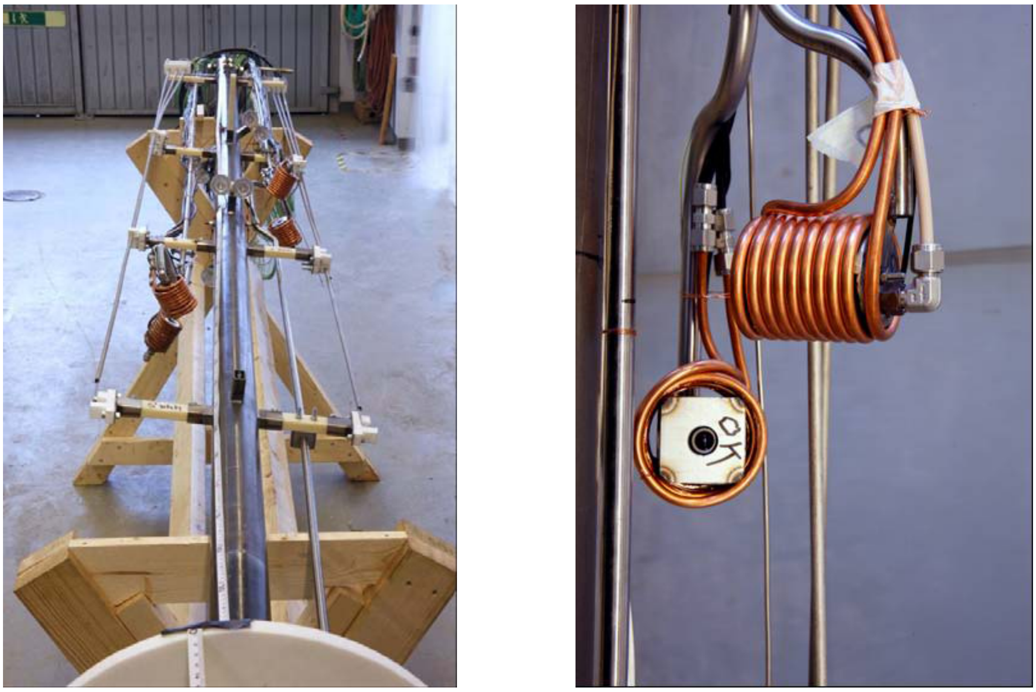


Figure 2-2. *Test equipment used in the first test with a close up of the monitoring cameras.*

3 Natural barriers

3.1 General

To meet Stage goal 3, experiments at the Äspö HRL, are performed at conditions that are expected to prevail at repository depth. The experiments are related to the rock, its properties and in situ environmental conditions (Figure 3-1). The goals are to increase the scientific knowledge of the safety margins of the repository and to provide data for performance and safety assessment and thereby clearly present the role of the geosphere for the barrier functions: isolation, retardation and dilution.

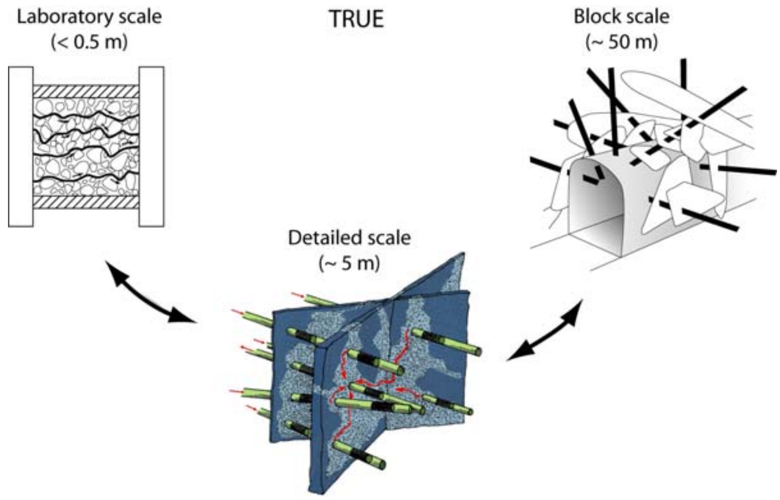
Tests of models for groundwater flow, radionuclide migration and chemical/biological processes are one of the main purposes of the Äspö HRL. The programme includes projects with the aim to evaluate the usefulness and reliability of different models and to develop and test methods for determination of parameters required as input to the models.

Figure 3-1. *Fracture surface with thin coating of mainly chlorite, calcite, clay minerals and epidote. The length of the base of the photograph is 46 mm.*

The ongoing experiments and projects within the Natural Barriers are:

- Tracer Retention Understanding Experiments.
- Long Term Sorption Diffusion Experiment.
- Colloid Project.
- Microbe Projects.
- Matrix Fluid Chemistry Continuation.
- Radionuclide Retention Experiments.
- Padamot.
- Fe-oxides in fractures.
- 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



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

The True Block Scale Continuation (BS2) project had its main focus on the existing True Block Scale site. Work performed included in situ tracer tests with sorbing tracers and subsequent assessment of the relative retention in flow paths made up of fault rock zones and background fractures. Results verified lower retention material properties in the background fractures flow path but also showed a higher overall retention in this flow path owing to the much lower flow rate therein /Andersson et al. 2007/. In the aftermath to the BS2 project, a second step of the continuation of the True Block Scale (BS3) was set up. This step has no specific experimental components and emphasise consolidation and integrated evaluation of all relevant True data and findings collected thus far. This integration is not necessarily restricted to True Block Scale, but may include incorporation of relevant True-1 and True-1 Continuation results.

Present status

Draft version has been prepared of the first two papers (in a three part series) titled "*Transport and retention from single to multiple fractures in crystalline rock at Äspö (Sweden):*

1. Evaluation of tracer test results and sensitivity analysis

2. Fracture network flow simulations and global retention properties.

The first paper deals with evaluation of BS1/BS2 tracer tests evaluation, including inference of effective parameters. Part 2 explores the BS1/BS2 flow and advective transport using DFN simulations. These two papers will be submitted to Water Resources Research.

The third paper in the series is being developed and will be submitted on the basis of received comments from the editors on the first two papers. The paper is tentatively named:

3. A macro-scale retention model and impact of micro-scale heterogeneity.

Scope of work for 2009

In the third paper the impact of micro-structural heterogeneity on retention will be studied, in particular the depth-wise trend in the matrix porosity; constraints imposed by porosity trends on effective retention properties will be assessed. In addition the predictive capability for effective retention properties will be analysed.

During 2009 work will also continue with a second series of papers which is aimed at the broader scientific community focused on evidences for retention of solutes in crystalline rock and synthesis of True results.

3.2.2 True-1 Continuation

The True-1 Continuation project is a continuation of the True-1 experiments and the experimental focus is primarily on the True-1 site. The continuation included performance of the injection of epoxy resin in Feature A at the True-1 site and subsequent overcoring and analysis (True-1 Completion). In addition, this project includes production of a series of scientific articles based on the True-1 project and, furthermore, performance of the Fault Rock Characterisation project, the latter in parts a dress rehearsal for True-1 Completion.

Present status

The progress in the True-1 Continuation project has been affected by heavy involvement of the project team in site characterisation and site modelling during 2008. No work has been done on the Fault Rock Zones Characterisation project and the Complementary laboratory tests on rim zone and fault gouge materials.

The third and last of the papers on the True-1 experiment, focusing on effects of microscale heterogeneity on tracer retention, was submitted late 2007 /Cvetkovic and Cheng 2008/. Thereby completing the full three-part series of papers /Widestrand et al. 2007; Cvetkovic et al. 2007/.

Scope of work for 2009

The activities during 2009 will consist of completion of reporting associated with the Fault Rock Zones Characterisation Project and completion of remaining analysis and reporting associated with the Complementary laboratory tests on rim zone and fault gouge materials.

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 heavy engagement within the site investigation programmes of the project participants was identified in the Äspö Planning report for 2008 /SKB 2008/ as a major risk for the planned activities during 2008. Unfortunately, this also became reality with the consequence of only little activity within the project during 2008. Still, a project meeting could be arranged with the purpose of discussion the coming analyses of the retrieved cores from KXTT3 and KXTT4. The project meeting resulted in outlines for the activity plan which was produced during the autumn of 2008.

Scope of work for 2009

The analyses of the cores from KXTT3 and KXTT4 will probably start in January 2009. Regardless, most of 2009 will be required for the analyses and reporting of the analyses. The core from KXTT4 locally show levels of radioactivity above the radiological clearance with the consequence that it has to be handled in localities and by personnel with the necessary permits. The core from KXTT3 on the other hand does not require any specific permits or locals regarding radiation safety. The two cores will therefore be handled separately in the analysis process. The plan is to start with the core from KXTT3 and continue with the core from KXTT4.

The plan is to finalise the analyses of the cores during the third quarter of 2009. The updating of the models and finalisation of the project will then follow. However, due to the delays during 2008 it is anticipated that the project will continue into 2010.

3.3 Long Term Sorption Diffusion Experiment

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

The aims are to improve the understanding of diffusion and sorption processes and to obtain diffusion and sorption data at in situ conditions.

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

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

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

Drilling of sample cores from matrix rock surrounding the test section in the small diameter extension borehole.

Present status

The small diameter (24 mm) sample cores have been scanned with scintillation detector and mass spectrometry to get a first measure of total activity before they were geologically mapped in detail. The sample cores, 18 from the core stub and 16 from the matrix rock, have subsequently been cut into thin slices and scanned with autoradiography followed by geological mapping to get a qualitative measure on the distribution of the tracers in the rock slice. To allow determination of sorption and penetration profiles of all tracers used in the experiment, ^{99}Tc, ^{102}Pd, ^{236}U, ^{237}Np, ^{63}N-, ^{35}S, ^{36}Cl, ^{22}Na, ^{57}Co, ^{75}Se, ^{85}Sr, ^{95}Zr, ^{110m}Ag, ^{109}Cd, ^{113}Sn, ^{133}Ba, ^{153}Gd, ^{175}Hf, (^{226}Ra) and ^{233}Pa, several sample preparation methods and analysis techniques have been necessary to adopt. Rock slices from half of the sample cores have been crushed, grinded and divided into sub-samples, series (a) and (b). Crushed samples, series (a), from 5 sample cores extracted from fracture surface on the core stub and 4 sample cores extracted from the matrix rock have been selected for the ongoing dissolution and subsequent analysis of ^{99}Tc, ^{102}Pd, ^{236}U, ^{237}N using mass-spectrometry (ICP-SFMS) and analysis of Ni-63 using liquid scintillation (LSC).

Analysis of the γ-emitting tracers, ^{22}Na, ^{57}Co, ^{75}Se, ^{85}Sr, ^{95}Zr, ^{110m}Ag, ^{109}Cd, ^{113}Sn, ^{133}Ba, ^{153}Gd, ^{175}Hf, (^{226}Ra) and ^{233}Pa, are in progress for sub-samples series (b) using a high performance germanium (HPGe) γ-detector.

At the SKB Baslab laboratory at Clab the γ-detector and belonging electronics have been changed. A more efficient detector and recently checked and served electronic have been installed aiming at speeding up measurements and reliability in operation.

Laboratory experiments with specimen from the core of the small diameter extension borehole, the replica core stub and the pilot borehole core are ongoing at Chalmers University of Technology (CTH) according to the experimental plan. Same tracer cocktail as for the in situ experiment, with HTO added, is used.

Scope of work for 2009

Analysis of the γ-emitting tracers in crushed sub-samples series (b) will continue and be finalised. Following the HPGe analysis these samples will be leached in water (with added salt, e.g. NaCl) and chemical separations made on the leachate for subsequent analyses of ^{35}S and ^{36}Cl, using LSC.

Out of the sliced, but not crushed, sample cores the γ-emitting tracers, ^{22}Na, ^{57}Co, ^{75}Se, ^{85}Sr, ^{95}Zr, ^{110m}Ag, ^{109}Cd, ^{113}Sn, ^{133}Ba, ^{153}Gd, ^{175}Hf, (^{226}Ra) and ^{233}Pa) will be analysed by HPGe in the slices from 5 sample cores emanating from the fracture surface on the core stub and 4 sample cores emanating from the matrix rock. Following the HPGe analysis the samples will be leached in water (with added salt, e.g. NaCl) and chemical separations made on the leachate for subsequent analyses of ^{35}S and ^{36}Cl, using LSC.

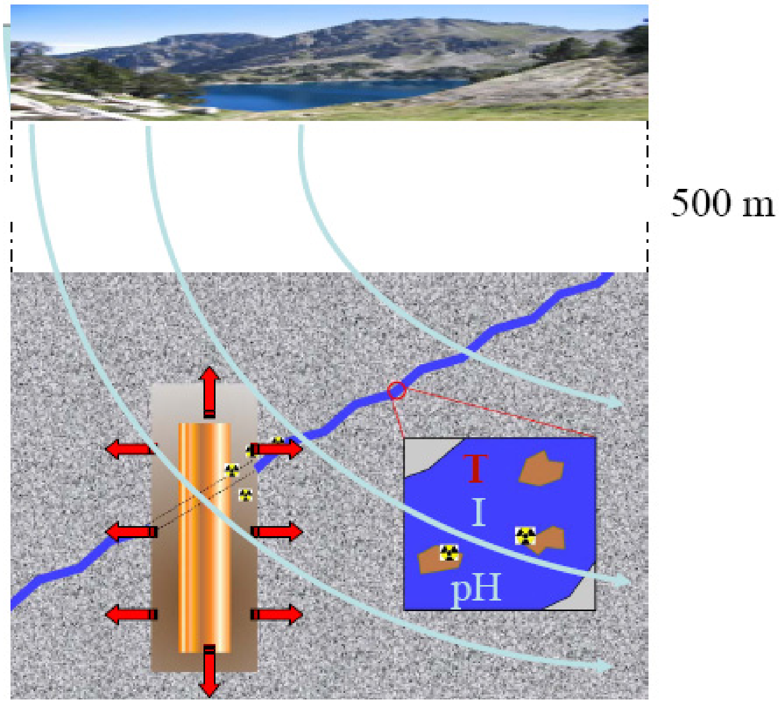
The sorption on the fracture surface on the core stub and axial diffusion-sorption through the fracture rim into the intact matrix rock will be studied by performing analyses, i.e. inverse modelling, of the determined penetration profile of the different tracers used. Sorption on matrix rock surface and radial diffusion-sorption directly into unaltered matrix rock will also be studied, utilising the same methodology. The work will be reported in SKB International Progress Report (IPR).

The evaluation and modelling of the laboratory experiments performed at CTH will be reported in an Äspö HTL International Progress Report.

The results from the laboratory experiments and the experiments performed at AECL 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, the representativeness of laboratory scale sorption results also for larger scales will be evaluated.

Project final evaluation, results and findings will be reported in a SKB technical report.

3.4 Colloid Transport Project



The Colloid Project is a continuation of the Colloid Dipole Project which was ended in the beginning of 2008 and final reporting is in progress. The overall goal for the Colloid Project is to answer the questions when colloid transport has to be taken into account in the safety assessment, and how the colloid transport can be modelled.

In the beginning of the lifetime of a deep repository, in bedrock with groundwater of high ionic strength, bentonite and natural colloids are not stable, and colloid transport can be neglected. Of special concern is bentonite erosion, since that could give loss of material leading to a decrease of the barrier function of the bentonite buffer.

In the scenario of intrusion of dilute glacial water the conditions for colloids stability drastically changes. The transport might be the limiting factor in this scenario and has to be taken into account.

In the case of a leaching canister, the bentonite colloids can possibly facilitate the transport of sorbed radionuclide towards the biosphere. In the project, also the transport of organic colloids and other natural colloids are studied and their effect on especially actinide mobility.

The ambition is further to include studies on the transport of colloids which are formed in the spent nuclear fuel.

Present status

The Colloid Transport Project was initiated 2008 and will be finalised in 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 the collaboration. An extensive amount of experimental work is undertaken at laboratories of all the collaborators to optimise the in situ experiment.

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

Scope of work for 2009

The following topics are covered in the Colloid Transport Project and activities will be performed during 2009:

- Bentonite colloid transport in well characterised fractures in different scales (borecores, granite block and in situ in Grimsel). Grimsel groundwater is going to be used to mimic dilute melt water. Reducing conditions will represent the time in the repository prior to intrusion of melt water. Oxidising conditions on the other hand, will represent the conditions at the time for intrusion of oxygenated melt water.

- Colloid transport in fracture filling material is studied to get information on filtration and sorption processes. Sand of different size fractions, as well as natural fracture filling material as biotite will be used as filling material in column experiments. Well defined latex colloids of different size distributions as well as bentonite colloids will be injected and the transport followed. Synthetic Grimsel groundwater will be throughout all experiments.

- Actinide transport in the absence and presence of bentonite colloids in well characterised bore cores will be performed. These experiments will be carried out in both reducing and oxidising conditions in varying flows. The cocktails will contain of HTO, ^{22}Na, ^{133}Ba, ^{137}Cs, ^{237}Np, ^{243}Am, ^{233}U, ^{232}Th and ^{242}Pu. Also experiments with organic degradation products such as fulvo or humic acid are planned.

- Bentonite erosion/generation experiments will be performed in granite block with a well characterised fracture with an aperture distribution around 1 mm. Plugs of bentonite mixed with latex colloids will be installed in the block. Grimsel groundwater will be injected in a homogenous flow, and bentonite and latex be monitored.

- Studies on montmorillonite colloid structure in solution are performed with X-ray microspectroscopy on the SLS (Swiss Light Source) to get information on how Ca- and Na-bentonite colloids in equilibrium is affected by the surrounding environment. Further the aim is to determine the density of these types of colloids.

- Modelling on different scales are performed to be able to predict colloid transport in any fracture with different aperture distributions, fracture surface roughness and mineral composition, as well as with bentonite as well as natural colloids with varying structures, surface potentials and size distributions.

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. They connect directly to aquifers at the in situ pressure of approximately 24 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 used to investigate the effect of microbial processes on groundwater chemistry, pH and redox potential.

3.5.1 The Microbe Laboratory

Three new circulation systems in the Microbe laboratory were installed during 2008.

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 (three systems are shown in the image above).

The major objectives are to:

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

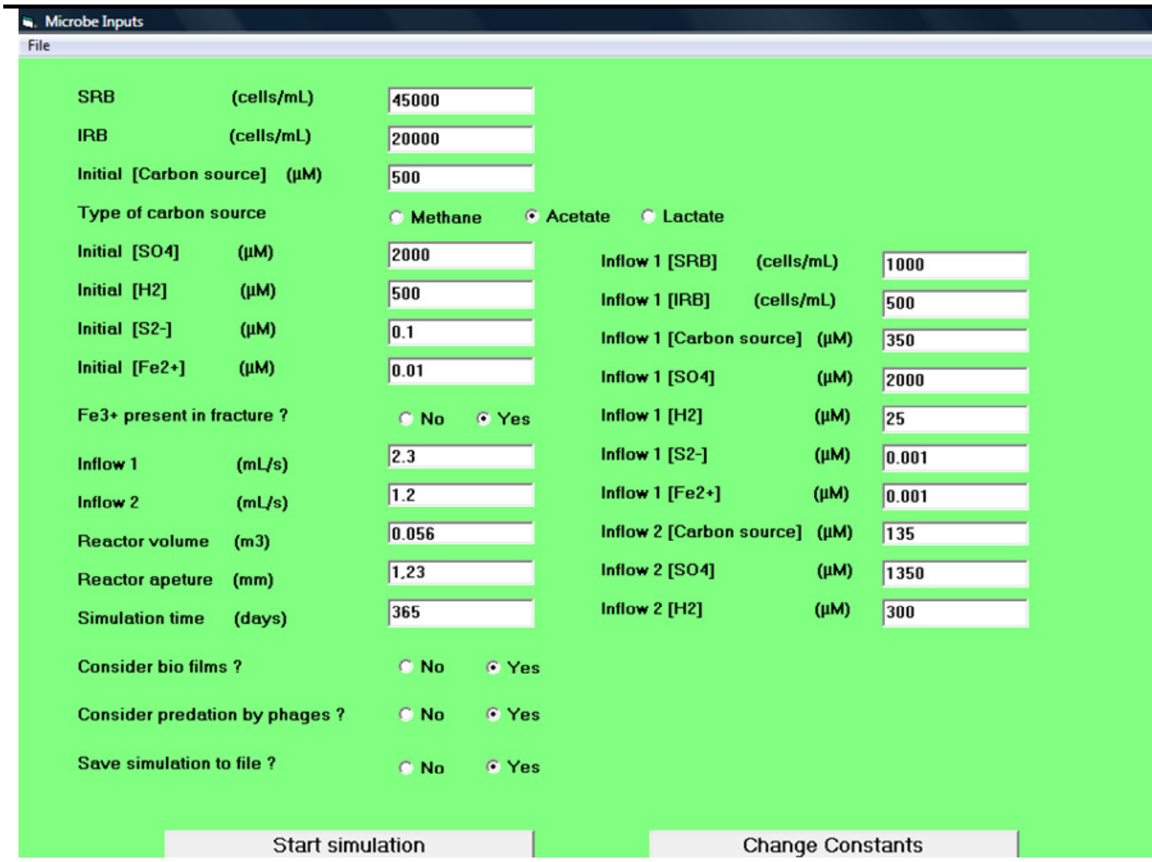
Present status

The microbe site has acted as a base for several different microbiological tunnel research activities during 2008. The Minican experiment was analysed in October. Micomig and Micored experiments have also been performed with the microbe site as a base.

Scope of work for 2009

Two main activities are planned for 2009. They both aim at the collection of data for modelling of microbiological processes. Natural biofilms will be analysed in the Micomig project and redox related processes, including sulphide production will be studied in the Micored project. The microbe site will also be utilised during sampling of engineered barrier projects such as Long Term Test of Buffer Material, Alternative Buffer Material and the Prototype Repository.

3.5.2 Micored



The input panel of the simulation program Microbe39. The program calculates in situ growth and activity of microorganisms in groundwater. The background data for program functions and constants have been generated at the Microbe site and in the laboratory with microorganisms isolated from Äspö HRL. SRB=sulphate reducing bacteria; IRB=iron reducing bacteria.

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

It is hypothesised that hydrogen and possibly also methane from deep geological processes contributes to the redox stability of deep groundwater via microbial turnover of 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.
- Create clear connections between investigations of microorganisms in the site investigations for a future repository and research on microbial processes at Äspö HRL.

Present status

The distribution, diversity, activity of sulphate reducing bacteria in boreholes along the Äspö tunnel is being investigated, with emphasis on *Desulfovibrio aespoeensis*. The effect from flow rate, geochemistry and sampling procedures are being investigated and analysed. The influence of virus on sulphate reducing bacteria is investigated as well.

Scope of work for 2009

The circulation systems at the Microbe laboratory will be used to collect data for modelling work. Pressure resistant electrodes will be employed for on-line analysis of redox potential and pH as a function of microbial processes.

3.5.3 Micomig

Sampling a new-drilled fracture surface for microbial presence and activity using DNA/RNA analysis methods.

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

A large group of microbes catalyse the formation of iron oxides from dissolved ferrous iron in groundwater that reaches an oxidising environment with oxygen. Such biological iron oxide systems (Bios) will have a retardation effect on many radionuclides.

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

The work within Micomig will:

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

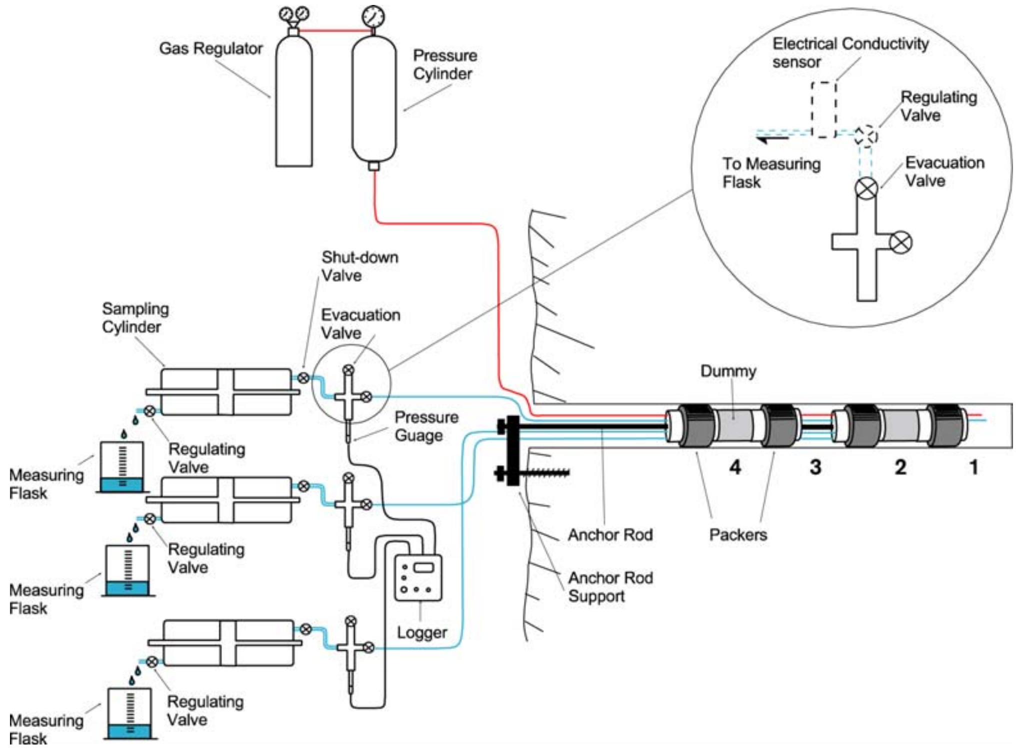
Present status

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. A total of 10 boreholes along the Äspö HRL tunnel were sampled for analysis for the most probable number of nitrate reducing bacteria with ability to produce complexing agents. Dominating species have been isolated, subcultured and identified with DNA technology. Their ability to produce siderophores is presently analysed. This will give an overview of the distribution of microorganisms that produce complexing agents in the Äspö groundwater.

Scope of work for 2009

Additional water-conducting fractures intersected by the Äspö tunnel will be drilled and analysed in the same way as done during 2008. Results obtained during 2008 suggest that the presence of biofilms indicates wetted fracture surfaces with groundwater flow. This will be further investigated during 2009.

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 pore water 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 Matrix Fluid Chemistry Continuation phase of the experiment has been completed and is presently being reported and integrated with the earlier Matrix Fluid Chemistry Experiment.

Scope of work for 2009

The work during 2009 will consist of finalisation of the reporting and integration. A SKB technical report is envisaged.

3.7 Radionuclide Retention Experiments

Radionuclide Retention Experiments are carried out with the aim to confirm results of laboratory studies in situ, where natural conditions prevail concerning e.g. redox conditions, contents of colloids, organic matter and bacteria in the groundwater. The experiments are carried out in special borehole laboratories, Chemlab 1 and Chemlab 2, designed for different kinds of in situ experiments. The laboratories are installed in boreholes and experiments can be carried out on for instance bentonite samples and on tiny rock fractures in drill cores.

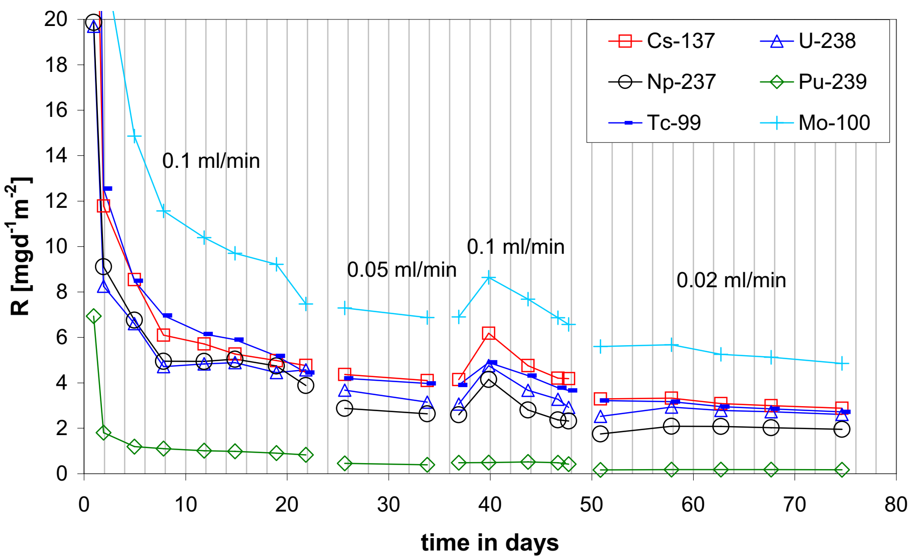
Experiments in Chemlab 1:

- Investigations of the influence of radiolysis products on the migration of the redox-sensitive element technetium in bentonite (finalised).
- Investigations of the transport resistance at the interface between buffer and rock (planned, see section 3.7.2).

Experiments in Chemlab 2:

- Migration experiments with actinides in a rock fracture (almost finalised).
- Study of spent fuel leaching at repository conditions (planned, see section 3.7.1).

3.7.1 Spent Fuel Leaching



Dissolution rates based on different monitors. The spent fuel was leached with 10 mM $NaHCO_3$ under oxidising conditions. Constant dissolution rates could be achieved after some days.

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

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

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

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

Present status

The spent fuel leaching project is in a planning state, and the project plan will soon be finalised.

Scope of work for 2009

If a decision will be taken to perform the project it will be divided into three different activities; laboratory investigations, in situ experiments and predicting/modelling.

The laboratory investigations will be performed at Nuclear Chemistry at Chalmers University where spent nuclear fuel will be leached with Äspö groundwater in autoclaves. Different experimental conditions will be studied.

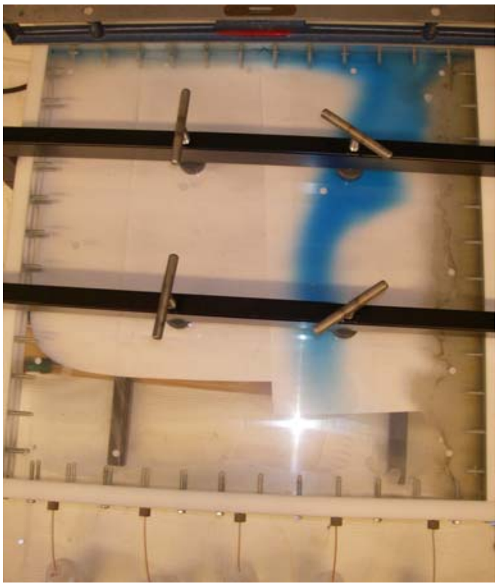
The in situ experiments can be divided into two parts; Chemlab experiments and glove box experiments. In the Chemlab experiments alpha doped uranium dioxide will be used, since the radiological handling is practically too difficult to handle

In the other in situ study an experiment will be set up in a glove box. The water to be used will be taken from the Chemlab borehole. Whether alpha doped uranium dioxide or real spent nuclear fuel will be used is not decided yet and will depend on what the Swedish authorities require.

Predictions of the outcome of the different studies will be predicted by a research group at Nuclear Chemistry, KTH.

The in situ studies will at the earliest be started during autumn 2009, while the experiments at Chalmers will start as soon as the necessary equipment has been purchased.

3.7.2 Transport Resistance at the Buffer Rock Interface



The equipment intended for the laboratory experiments. The equipment is currently used in another SKB project, Bentonite Erosion.

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

The transport resistance is concentrated to the interface between the bentonite buffer and the rock fracture. The mass transfer resistance due to diffusion resistance in the buffer is estimated to only 6% and the diffusion resistance in the small cross section area of the fracture in the rock to 94% /Neretnieks 1982/. The aim of the Transport Resistance at Buffer-Rock Interface project is to perform studies to verify the magnitude of this resistance.

The experiment will be performed in the laboratory, where a fracture is simulated as a 1 mm space between two Plexiglas plates. The equipment includes a water pump for very low flow rates. The design of field experiments depends on the outcome of the laboratory experiments.

Present status

There have been no activities in the project during 2008 since the resources needed for this project are currently used in another SKB project. However, a project plan exists and a project decision has been taken.

Scope of work for 2009

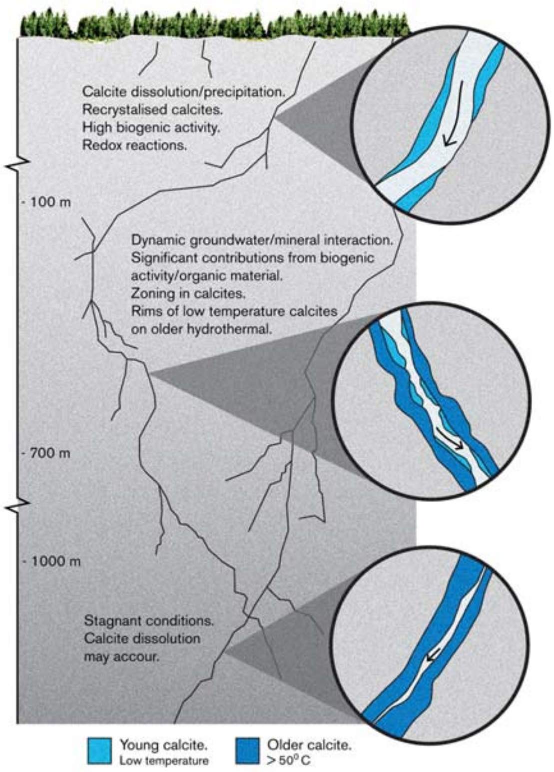
The experimental studies will start during spring 2009. The equipment for the investigations in the laboratory has been used in the project"Bentonite Erosion" and is now available.

The experimental equipment consists of two Plexiglas slabs separated by spacers to simulate a fracture. At one side is a distributor which distributes the ingoing flow evenly over the fracture entrance. At the opposite side of the distributor are five slots for collecting water on the outgoing side. At one side perpendicular to the flow is a container situated. The container will be filled with a medium and saturated with a tracer to study.

If the tracer is coloured and since it is Plexiglas it will be possible to study the development of the distribution of the tracer with time. This together with the concentration distribution at the outlet slots will be the in-data for the modelling and evaluation of the experiment.

The investigations during 2009 will only comprise laboratory studies, no in situ experiments.

3.8 Padamot



Potential calcite-groundwater interaction at various depths at Äspö.

Padamot (Palaeohydrogeological Data Analysis and Model Testing) investigates changes in groundwater conditions as a result of changing climate. Because the long term safety of an underground repository depends on the stability of the repository environment, demonstration that climatic impacts attenuate with depth is important. 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

The ongoing part of this project aims at evaluating the use of uranium-series analyses for the interpretations of hydrochemical changes (for example changes in redox conditions) that might have taken place in the last 1 million years.

The bulk analyses of uranium decay series isotopes of fracture coating samples from borehole KAS17 show changes from mainly uranium mobilisation in the upper 20 m depth, switching to uranium deposition at larger depth. As a complement to these bulk analyses, sequential extraction has been applied to four samples. The analyses have been carried out at the University of Helsinki. The first step in the sequential extraction scheme (ammonium acetate – AAC) dissolves loosely bound uranium i.e. the phase usually most interactive with the present groundwater. The largest deviation from equilibria is indicated in these samples (exemplified by Figure 3-2). The second and third steps dissolves uranium bound in Fe-oxides and more tightly bound uranium, whereas the fourth step (Aqua Regia, AR) dissolves the residue.

The analyses carried out confirms the results of the bulk analyses and add also more details in that the isotope ratios of the most mobile phase can be determined separately and show also to even larger extent the intensity of the recent mobilisation, deposition or the combination of both.

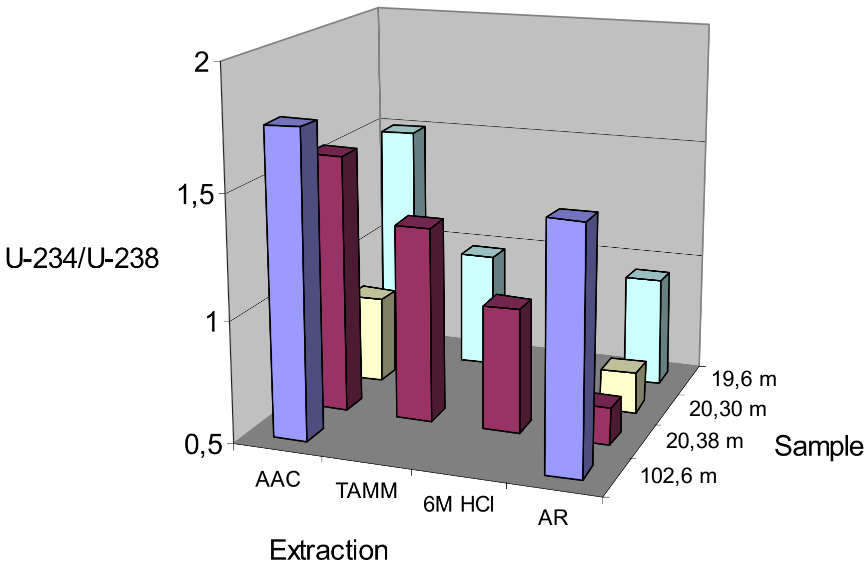
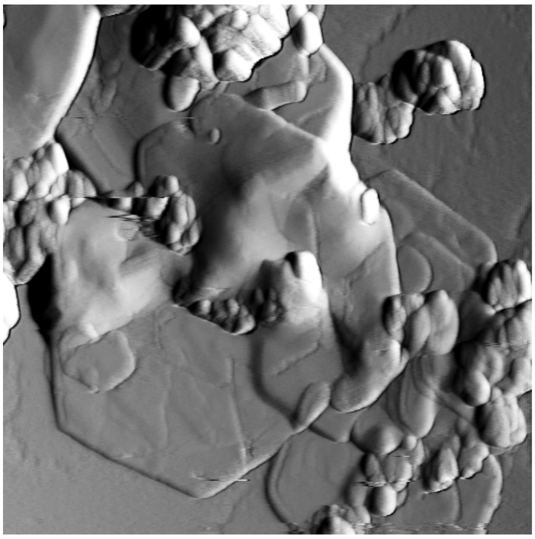


Figure 3-2. *$^{234}U/^{238}U$ activity ratio in sequentially extracted phases. High activity ratios in ammonium acetate extractable phase indicate recent U accumulation.*

Scope of work for 2009

The remaining analytical work will be performed at SUERC in Glasgow. The results from different analytical techniques and inter-laboratory comparisons will be evaluated and the project will be reported during 2009.

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

Present status

Preliminary results suggest that iron oxides have formed at low-temperature down to 50 m below surface and possibly even down to a depth of approximately 90 m. Unfortunately, the lower boundary for the passage of oxidised water is constrained by having only two hydrothermal samples. To resolve this situation, additional three samples from the longer drill core KLX09A have been made available to look for Fe-oxides at greater depth. The Continuation phase of the study has now been completed and the reporting of the project is presently ongoing.

Scope of work for 2009

The work during 2009 will consist of final completion of the reporting. Two Äspö HRL International Progress Reports are envisaged.

3.10 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

The activity within Swiw with synthetic groundwater during 2008 was rather low due to the heavy engagement of project members in SKB's site investigation programme. However, the feasibility study started earlier was finalised during the year and the report will be printed.

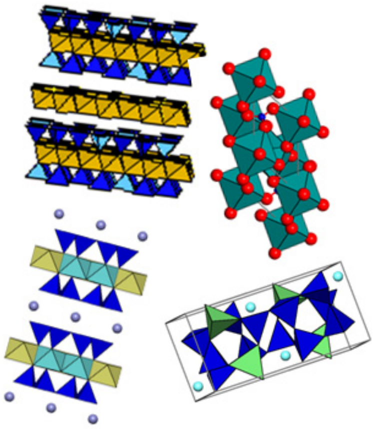
Following the feasibility study a meeting was held to discuss the progress of the project. A critical issue for the project discussed at the meeting is the site selection for the field tests. Three general candidates are identified; True Block Scale, other test site in the tunnel and test site at the surface. Several of the desirable characteristics of the site are common for the project Swiw Tests with Synthetic Groundwater and the project Oxygen Consumption and Redox Changes in a Fracture Zone. The oxygen project comprises both Multiple well tests and Swiw tests. Hence, desires and demands from the oxygen project as well as coordination benefits should be considered in the site selection process.

Scope of work for 2009

The project decision and project plan presently under preparation will determine the work during 2009 and coming years. However, a preliminary order of activities in the project plan will be; site selection, investigations of the selected site, Swiw pre tests, Swiw main tests and finally evaluation and reporting of the tests. Initially, the field activities were scheduled to take place during 2009 assuming that the selected test site already exists and no further drilling of new borehole is required. However, the project Sealing of Tunnel at Great Depth will continue until late June 2009 instead of early March 2009, as earlier announced. Due to the fact that the activities within this project influence the conditions at the True Block Scale site and since this site still is one of the major candidates, the preliminary time plan for the Swiw project is now to perform the field activities from August 2009 to April 2010 followed by the evaluation and reporting.

3.11 Äspö Model for Radionuclide Sorption

Batch sorption experiments.



Example structures of minerals in the granite

Today, geochemical retention of radionuclides in the granitic environment is commonly modelled assessed using distribution coefficients (Kd). 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 (CA) 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.

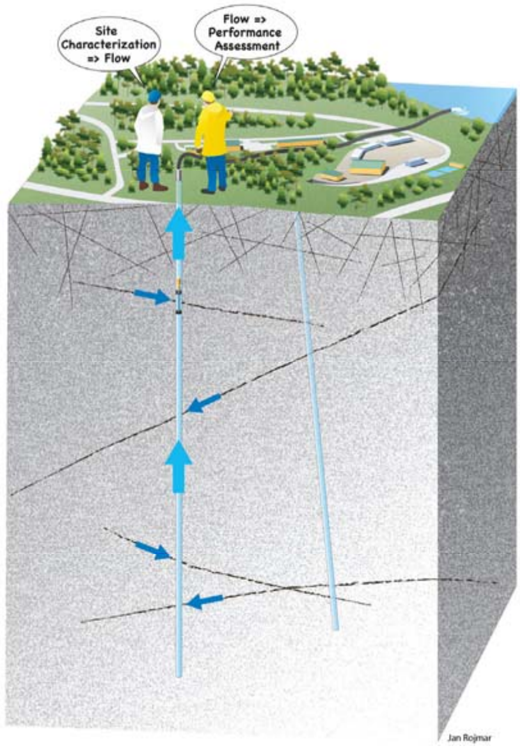
Present status

The project was initiated during 2008, and this is the first time that the project is reported in the Äspö reports. During the initial period of this project, the scientific literature on radionuclide sorption onto pure, granitic minerals and granitic rocks is compiled. Furthermore, Äspö geological material to be used within the project is carefully selected, along with appropriate radionuclides and test water compositions. A surface area (so called “BET-area”) and porosity analysator and an autoradiograph have been acquired and is being installed and tested.

Scope of work for 2009

During 2009, laboratory batch experiments on radionuclide sorption onto Äspö geological material will be initiated, using a few different radionuclides and water compositions. This work is expected to help resolving the particle size dependence of sorption of radionuclides that sorb with either an ion-exchange mechanism or a surface complexation mechanism. Furthermore, the geological material will be characterised in terms of porosity and surface area, thereby allowing assessment of the effects of these properties on sorption. The use of autoradiographic methods to assess association of radionuclides with specific minerals or rock features, such as grain boundaries, will also be preliminary explored.

3.12 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

In the Task Force, work has been in progress in Task 6 - Performance Assessment Modelling Using Site Characterisation Data, and in Task 7, which addresses a long-term pumping test in Olkiluoto, Finland. The status of the specific modelling tasks within Task 7 is given within brackets in Table 3-1.

Task 6 tries to bridge the gap between Performance Assessment (PA) and Site Characterisation (SC) models by applying both approaches for the same tracer experiment. It is hoped that this will help to identify the relevant conceptualisations (in processes/structures) for long term PA predictions and to identify site characterisation data requirements to support PA calculations. All of the sub-task reports within task 6 from the modelling groups have been printed. A summary of the outcome of Task 6 has been accepted for publishing in a scientific journal. In addition, papers from four modelling groups have also been accepted by the same scientific journal and in conjunction with the summary paper. An essay describing the framework for all theses papers have also been submitted and accepted. Editorial modifications remain to be done for all papers before they can be published.

Task 7 addresses modelling of the OL-KR24 long-term pumping test at Olkiluoto in Finland. At the 23rd Task Force meeting, a modification of the task title was suggested as "Reduction of Performance Assessment uncertainty through modelling of hydraulic tests at Olkiluoto, Finland". The task will focus on methods to quantify uncertainties in PA-type approaches based on SC-type information; along with being an opportunity to increase the understanding of the role of fracture zones as boundary conditions for the fracture network and how compartmentalisation influence the groundwater system. The possibilities to extract more information from interference tests will also be addressed. Task 7 is divided into several sub-tasks. An updated task description for the sub-task 7B and more data have been sent out to the modellers.

The 24th international Task Force meeting was held at Äspö in September. The presentations were mainly addressing modelling results on sub-task 7B. The discussions on the continuation of Task 7 and also the start up of Task 8 were constructive. Task 8 will be a joint effort with the Task Force on Engineered Barriers, and will be addressing the processes at the interface between the rock and the bentonite in deposition holes.

Table 3-1. Task 7 - descriptions and status (at the end of 2008).

7	**Long-term pumping experiment.**	
7A	Long-term pumping experiment. (No more results expected. Draft reports of the sub-tasks 7A1-7A5 are available).	
	7A1	Hydrostructural model implementation.
	7A2	Pathway simulation within fracture zones.
	7A3	Conceptual modelling of PA relevant parameters from open hole pumping.
	7A4	Quantification of compartmentalisation from open hole pumping tests and flow logging.
	7A5	Quantification of transport resistance distributions along pathways.
7B	Sub-task 7B is addressing the same as sub-task 7A but in a smaller scale, i.e. rock block scale. Sub-task 7B is using sub-task 7A as boundary condition. (Preliminary results presented at the 24th Task Force meeting).	
7C	Here focus is on deposition hole scale issues, resolving geomechanics, buffers, and hydraulic views of fractures (In preparation for modelling).	
7D	Tentatively sub-task 7D concerns integration on all scales (Still tentative).	

Scope of work for 2009

The main activities targeted to be accomplished during 2009 are summarised below:

- Start up Task 8, a common task with the Task Force on Engineered Barriers.
- Organise the Task 7 and 8 workshop in January, hosted by SKB.
- Perform modelling and reporting within Task 7.
- The external review of Task 7 will continue.
- Organise the 25th International Task Force meeting preliminary in May, hosted by JAEA.

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 (Figure 4-1). The experiments focus on different aspects of engineering technology and performance testing and will together form a major experimental programme.

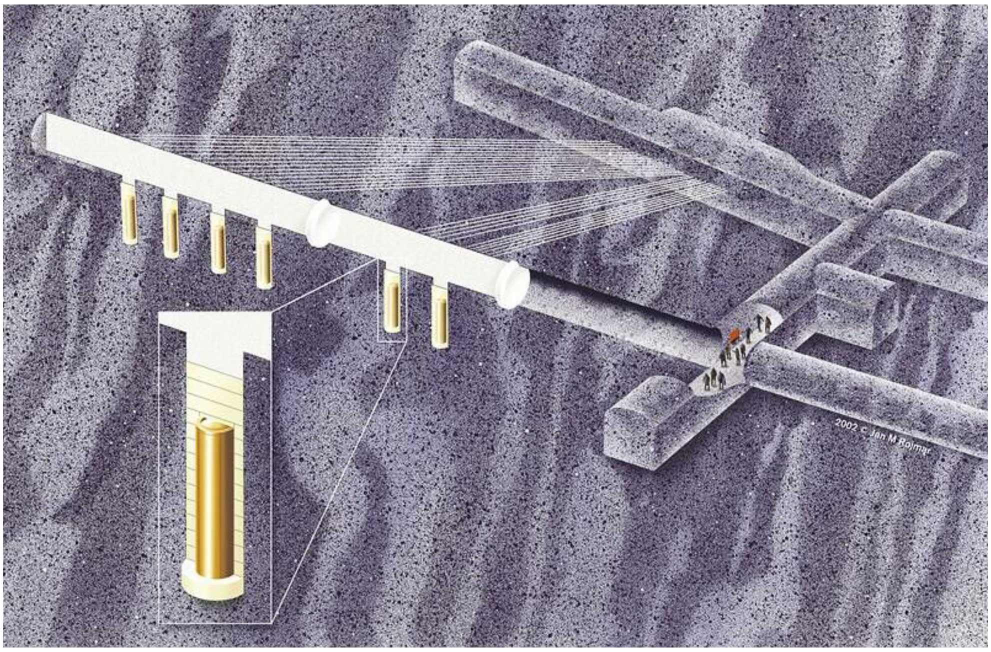
Figure 4-1. *Water filled measuring weir in the project Sealing of Tunnel at Great Depth.*

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.
- 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.

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

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 2004. Subsequent 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 with 200 W 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 are 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. The instruments in buffer, backfill and rock in the two sections are continuously read. The data from the readings are presented in data reports, issued twice each year (for the latest report, see Goudarzi and Johannesson /2008/). Chemical measurements in buffer, backfill and surrounding rock are ongoing. Tests for evaluating the ground water pressure and ground water 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. One-dimensional THM modelling of the buffer in deposition hole #1 and #3 has been finished.

Scope of work for 2009

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 get additional perspectives on the possibility of spalling in KBS-3 deposition holes. The excavation of the outer section has been postponed to 2011.

4.3 Long Term Test of Buffer Material

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.

The test concerns realistic repository conditions except for the scale and the controlled adverse conditions in four parcels.

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

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

Present status

Four test parcels have been retrieved and analysed so far, see Table 4-1. The A2 parcel has been further analysed with respect to porewater chemistry and changes in mineralogy at laboratories in Finland, France, Germany, Sweden and Switzerland. Additional analyses have been made concerning bacteria, copper corrosion and cation diffusion. The common report has been delayed but is now in the SKB review process and will thereafter be published. The remaining three parcels are well functioning and have been heated to target temperatures for almost nine years.

A conceptual model of compacted bentonite has been developed in order to serve as a base for geochemical modelling, and a paper dealing with the basic properties of diffusion in bentonite has been published.

Scope of work for 2009

Uptake of one additional test parcel is planned, likely the S2 parcel, to take place during 2009. In order to optimise resources, the detailed planning will be made in conjunction with the uptake of the first parcel in the experiment Alternative Buffer Materials, see Section 4.4. After retrieval of the S2 parcel analyses concerning physical properties, mineralogy, bacterial activity, tracer diffusion and copper corrosion will go on for the rest of 2009. Mineralogical analyses are also planned to be made by Andra, BGR, Nagra and Posiva.

Geochemical modelling will be performed in the Lot-modelling project along two lines, i.e. development of modelling tools for the specific conditions in bentonite and modelling of measured results from the A2 parcel.

Table 4-1. Buffer material test series.

Type	No.	max T (°C)	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	Report on review
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 parcels illustrating the mixing of the different compacted buffer discs.

In the Alternative Buffer Materials project different conceivable buffer materials are tested. The aim is to further investigate the properties of the alternatives to the SKB reference bentonite (MX-80).
The objectives are to:

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

Eleven different clays were chosen to examine effects of smectite content, interlayer cations and overall iron content. Also bentonite pellets with and without additional quartz are being tested.

The field test started during 2006 and is carried out in the same way and scale as the Long Term Test of Buffer Material (Lot). 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.

Present status

The parcels were deposited 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) carefully was raised in steps to the goal temperature of 130 degrees which was reached in December 2007. The heating of parcel 2 (three year test) started in August 2008. The temperature in this test is presently set to 100 degrees.

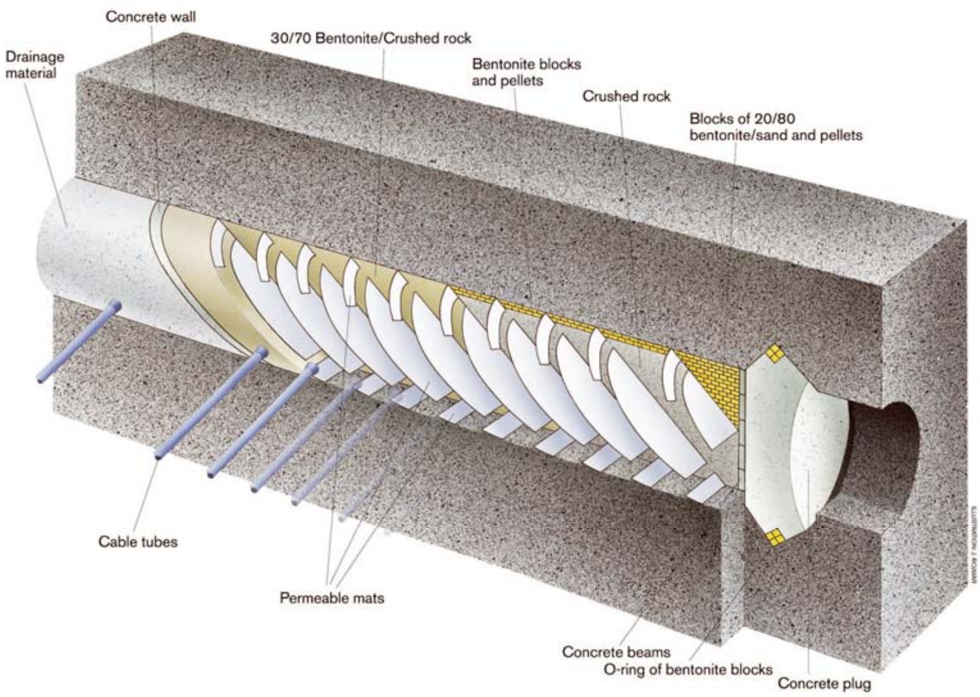
Analyses of the different buffer materials have been performed during 2008. In addition, to the bentonite blocks deposited in the three parcels, identical bentonite blocks are stored to monitor the effects of storage.

Scope of work for 2009

The following activities will be accomplished during 2009:

- Parcel 1, the one year test, is planned to be finished and dismantled at the beginning of 2009.
- Analyses of the reference materials will be reported during 2009.
- Work with analyses of the buffer material from parcel 1 will start.

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

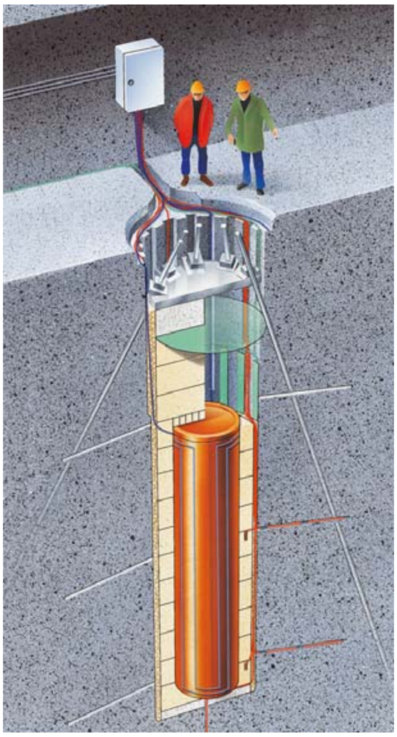
The present ongoing work includes monitoring. The collected data are presented in data reports (for the latest report, see Goudarzi et al. /2008a/), issued once each year. In addition, to the monitoring, measurement of local hydraulic conductivity in the zone with crushed rock through installed equipments ("CT-tubes") has started.

Scope of work for 2009

The following activities will be accomplished during 2009:

- Hydraulic testing of the local hydraulic conductivity of the crushed rock with the so called "CT-tubes".
- Continued data collection and reporting of measured water pressure, water flow and total pressure.
- Maintenance of equipment and supervision of the test.

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

Laboratory work concerning analyses of the retrieved buffer, that were planned up to this point, has progressed at Clay Technology and is close to be finalised. The laboratory work has produced data of the mechanical strength, the swelling pressure/hydraulic conductivity and the chemical/mineralogical constitution.

The Canister Retrieval Test (CRT) was selected to be one of the large scale field tests in the Task Force on Engineered Barrier Systems. At the meeting (12-13 November 2008) several teams presented modelling results.

Scope of work for 2009

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 buffer material characteristics by comparing samples retrieved from the CRT buffer with reference material. When the present laboratory data has been analysed additional studies are to be taken under consideration.

The modelling in the Task Force will be continued in 2009. There are two different tasks within the modelling of CRT. The first one focus on a detailed THM analysis of the engineered barrier at canister mid-height where the processes in 1) the inner slot 2) the bentonite block and 3) the pellet filled outer slot are studied. The second task focuses on the entire deposition hole, which is modelled and the THM processes are studied on a larger scale.

4.7 Temperature Buffer Test

The French organisation Andra carries out the Temperature Buffer Test (TBT) at Äspö HRL in co-operation with SKB.

The aims of the TBT are to evaluate the benefits of extending the current understanding of the THM behaviour of engineered barriers during the water saturation transient to include high temperatures, above 100°C.

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

The test is located in the same test area as the Canister Retrieval Test, which is in the main test area at the -420 m level.

The TBT experiment includes two heaters in the axis of the deposition hole, one on top of the other, separated by a compacted bentonite block. The heaters are 3 m long and 610 mm in diameter and are constructed in carbon steel. Each one simulates a different type of confinement system: a bentonite buffer only (bottom section) and a bentonite buffer with inner sand shield (upper section).

An artificial water pressure is applied in a slot between the buffer and rock, which is filled with sand and functions as a filter.

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 thermal, hydraulic and mechanical (THM) models of buffer materials at high temperatures, well over 100°C. Moreover, the experimental setup is characterised by stationary, well defined, boundary conditions. Data acquisition is continuously ongoing and data are published in data reports (for the latest report, see Goudarzi et al. /2008b/).

This implies that the experimental activities at the test site 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, 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/. 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 consists 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 thermo, hydro, mechanical and chemical (THMC) processes, with operation at high temperatures, is the main point of interest.

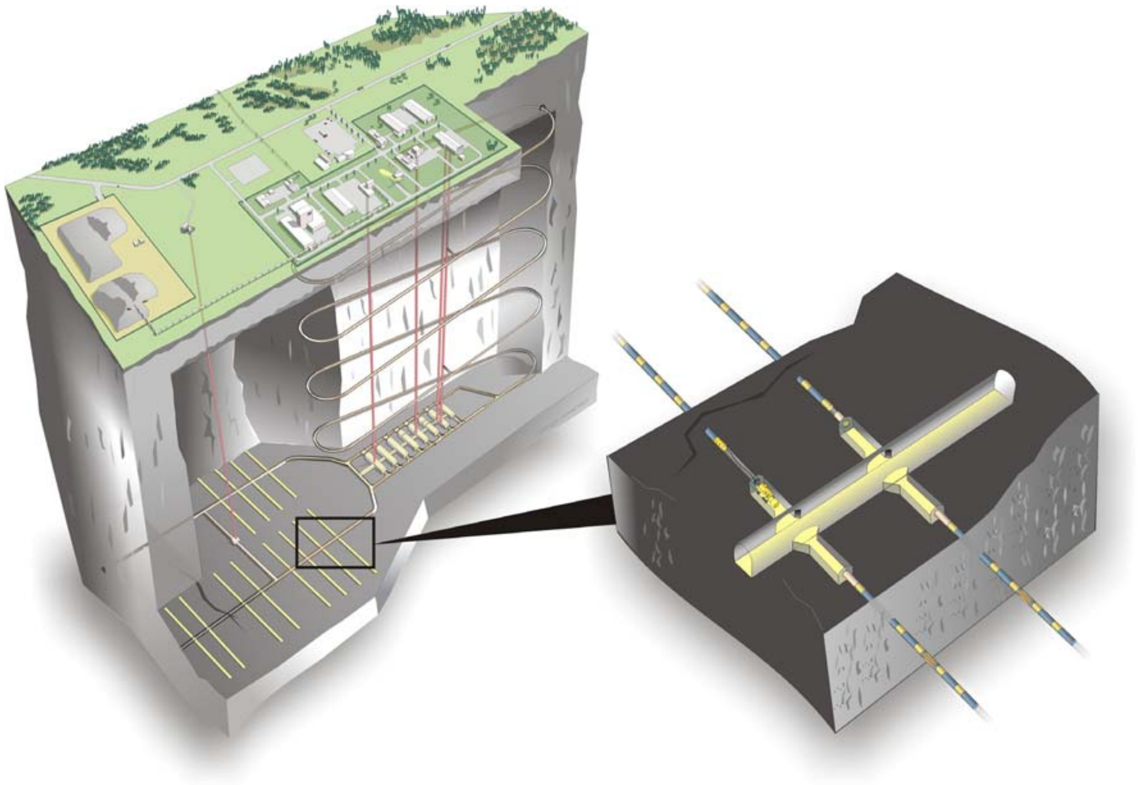
Previously, it was also planned to perform a gas injection test through pressurising the sand shield around the upper heater. During the hydration of this shield and the following preliminary hydraulic test it was however revealed that the buffer around the sand shield was not sufficiently tight. The gas injection tests will therefore not be carried out.

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.

Scope of work for 2009

The plan is to perform a retrieval test of the upper heater, and to dismantle and sample the test during the period 2010-2011. The scope of work for 2009 is to keep the boundary conditions (heater power outputs and filter pressures) as constant as possible, and to elaborate the plans for the retrieval test, the dismantling and the sampling.

4.8 KBS-3 Method with Horizontal Emplacement



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

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

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

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

The project is a joint project between SKB and Posiva. Now the next phase of the project "Complementary studies of horizontal emplacement KBS-3H" goes on. 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

Several tests both at the -220 m level at the Äspö HRL and at ground level has been performed. The Mega Packer, a post grouting device, has been tested in the long drift at the -220 m level. The results were very positive, since the water bearing fractures were almost completely sealed during the tests. The tests with the deposition equipment in the 95 m long drift have also continued.

Two design variants are considered for the KBS-3H design: the Basic Design and the DAWE (drainage, artificial watering and air evacuation) design. Small scale test to verify the ability to safely remove the water pipes in the DAWE concept has been carried out. These “Pipe Removal” tests are done in the Bentonite Laboratory. A preliminary result from the tests is that it is possible to remove the water pipes during the first days after use. If the pipes are not removed the force needed to pull them out of the buffer will be high, which could cause problems.

Preparations for a compartment plug test are being carried out. The installation of the compartment plug will begin as soon as possible after delivery. The notch that the plug will be installed in is excavated and tests have been done to find a good concrete to use.

Scope of work for 2009

In general work in the current project phase will more focus on design work and solve identified issues and uncertainties. Less work will be done regarding full-scale tests during 2009 and 2010. Following work is planned to be performed:

- Tests in the demonstration project will continue during 2009 in Äspö HRL. The full scale compartment plug test will be initiated during the first quarter of 2009. The test will be completed before the summer and analyses of the results will then begin.
- Tests with the deposition equipment in Äspö HRL will be reduced during 2009 and the tests will be more focused on maintenance operation. Work will be carried out to evaluate test results and what improvements should be performed on the equipment in a later stage.

In addition, planning of further full scale testing of system components in Äspö HRL for the next project phase will begin in 2009. Studies on possibilities, requirements and other aspects for a future KBS-3H prototype tests will also be performed in 2009 and 2010.

4.9 Large Scale Gas Injection Test

Panorama of the Large-scale gas injection test (Lasgit) 420 m below ground at Äspö HRL.

Most 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.

Thereafter preliminary hydraulic and gas transport tests were performed. These will be repeated as the buffer matures in order to examine the temporal evolution of these properties. Comprehensive series of gas injection tests will be undertaken in the saturated buffer to examine the mechanisms governing gas flow in KBS-3 bentonite.

Present status

During 2007 a preliminary gas injection test was undertaken with a view to verifying the operation and data reduction methodologies outlined in the original concept report and to provide qualitative data on hydraulic and gas transport parameters for the bentonite buffer during the hydration phase. This phase of testing was completed in February 2008, at which time artificial hydration of the clay recommenced through all available filters.

Analysis of the hydraulic data following gas injection clearly indicates that little if any significant change in permeability of the buffer has occurred due to the injection of gas. Detailed inspection of the data suggests a small change in hydraulic storage may have occurred, but based on the data available, the nascent gas pathways would appear to have no significant effect on the engineering performance of the buffer.

Upon cessation of this phase of testing in February 2008, the system was recalibrated and artificial hydration of the clay recommenced through all available filters. During this time flux into the deposition hole, total stress and porewater pressure were all monitored on a regular basis in order to track the evolution of the system.

In August 2008 Lasgit underwent routine recalibration. Shortly after this, time failure of the air compressor led to closure of all servo-assisted valves. This in term resulted in an unexpected opportunity to simultaneously measure the hydraulic properties of the clay in all 12 canister filters as water pressures in the system decayed.

Throughout the second phase of hydration a number of small discrete movements of the large steel retaining lid covering the Lasgit deposition hole have been noted. These are in addition to the normal background displacements caused by straining of the lid as the clay hydrates. As expected, data indicates deformation of the lid is greatest at its centre resulting in convexing of the lid in the area surrounding the Monel pipe. During the early part of 2008 a significant number of blasting events took place at the Äspö URL as new tunnels were excavated for ongoing research projects. However, in general these events did not correlate with either movements of the lid or changes in down hole pressure.

Following re-calibration of the test system in August 2008, two additional displacement sensors were added to the canister lid in order to measure lateral movements. Since restarting hydration (following the commissioning of the replacement compressor in October 2008), the lateral sensors have provided valuable data to help decipher subsequent lid movements which can now be correlated to downhole changes in load as the system continues to evolve.

In order to fully interpret the Lasgit results, it is necessary to understand fully the evolution of the boundary conditions during the complete test history. It is therefore vital to understand the movement of the lid.

The test has been in successful operation for in excess of 1,400 days. The first phase of the project comprised of the initial hydration, hydraulic and gas test stages was completed successfully with data distributed to the international project partners. 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 2009

During 2009 a second series of hydraulic and gas injection tests will be performed yielding important interim data on the temporal evolution of the transport properties of the buffer as it approaches saturation. The complexity of these and subsequent test programmes will increase, reflecting the continued evolution of the buffer, thereby generating additional data and process understanding. As before, these tests will be designed in such a way as to minimise the effect of reintroducing gas and will initially be performed in one of the lower filter arrays where the bentonite is locally saturated (a second filter/location may also be tested if time permits). The remaining filters on each level will be isolated from the artificial hydration system and their pressure allowed to evolve to provide temporal data on the development of porewater pressures locally within the clay. Where possible artificial hydration of the clay will simultaneously continue through all remaining canister filters and hydration mats.

The test history (Figure 4-2) will begin by determining the baseline hydraulic properties of the buffer using a combination of constant pressure (CP) and pressure decay (PD) techniques. Once complete, excess porewater pressures within the clay will be allowed to dissipate prior to starting the gas injection history. Depending on the available time, a number of controlled flow rate and constant pressure gas injection experiments will be performed in serial in one or more filters in order to determine the local gas transport parameters within the clay i.e. gas entry, steady-state and shut-in pressures. Data from stress and porewater pressures sensors located on the rock face and within the bentonite will be used to try and determine the passage of gas flow within the bentonite. As before, a second hydraulic test will be performed, in order to examine local changes in the hydraulic properties of the clay and to aide resealing of the clay.

In contrast to the preliminary gas injection tests performed during 2007, neon rather than helium will be used as the gas permeant. It is hoped that the passage of neon gas through the host rock may be detected as either a dissolved or free gas phase within the packered intervals of the neighbouring pressure relief holes, providing additional information on the movement of the gas phase within the fracture network surrounding the deposition hole. It may be possible to correlate these observations to any changes in stress and/or porewater noted in the clay during gas injection.

Upon completion of the second phase of gas injection, the system will revert to continue artificial hydration of the clay.

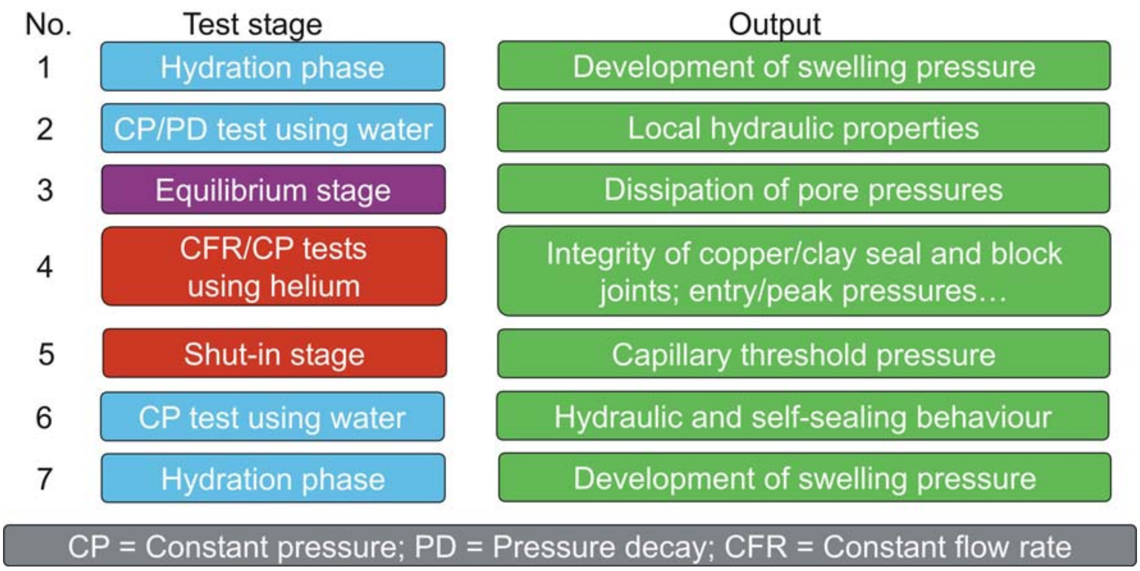


Figure 4-2. *Lasgit: preliminary test plan for 2009.*

4.10 Sealing of Tunnel at Great Depth

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.

Silica sol, which consists of nano-sized particles of silica in water, has shown to be a promising grout, and in the sealing project at Äspö HRL, the use of silica sol is tested at great depth. Low-pH cementitious grouts will also be used 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 main goals of the project are to confirm that silica sol is a useful grout at the water pressures prevailing at repository level and to confirm that it is possible at this water pressure to seal to the preliminary tightness requirement for a deposition tunnel. To achieve this, the Tass-tunnel is under construction at the Äspö HRL.

Investigations for the selection of site were carried out during the spring and summer of 2007. In spring 2007 a tunnel position extending from the Tasi-tunnel at the -450 m level was selected. The selection was based mainly on geo-hydrological modelling of the site and its surroundings, predictions of the singular fractures based on the results from examination of rock cores and geo-hydrological measurements. Contract works started in November 2007.

The tunneling front is now (January 2009) at section 80 meters. The tunnel includes a first short fan outside the contour, two grouting fans with holes drilled outside the contour (fans 2 and 3) and three fans (fans 4, 5 and 6) with holes drilled inside the contour. The groundwater pressure has been measured at 3.0 - 3.7 MPa.

It is shown along a 24 meter long section (fans 2 and 3) that it is possible to fulfil the project tightness requirement and reduce the inflow to a value corresponding to below 1.0 litre/minute and 60 m, using fans outside the contour.

The section along fan 4, where rock blocks are sawn from the tunnel wall for examination of EDZ, is isolated by weirs and an inflow of 0.7- 0.8 litre/minute can be recorded along the 16 m long section, corresponding to 2.6-3.0 litres/minute and 60 m.

The inner 30 meter long section along fans 5 and 6, is carried out with holes inside the contour and yields a low inflow, but the inflow is not yet confirmed as stabilised. Mapping and observations of walls and floor also indicate a good sealing result.

Both cement-based grout with low pH and silica sol have been used, the cement-based to a lower extent, though. The cement-based grout mixes that are developed especially for the final repository facility are found to be robust with the desired properties. The silica sol used has an average particle size of 25 nm and the accelerator is sodium chloride. Silica sol gelling time has been controllable, which is a necessity for controllable grouting.

The basic design methodology is based on the smallest fracture that has to be sealed, relates penetration length to grouting hole distance and also includes the adjustable parameters grouting time and pressure. It has worked for grouting fans with holes outside the contour. For fans with holes inside the contour a modification of the methodology is needed to achieve a “sealed zone” with sufficient extent.

Special attention is given to drilling, charging and blasting. The results are 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.

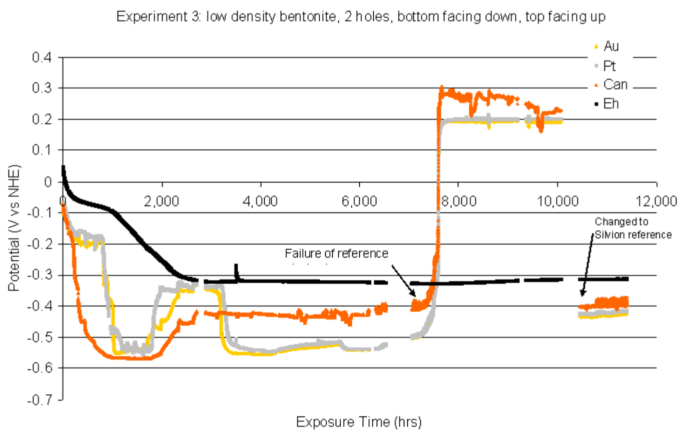
Scope of work for 2009

First, it is hoped that the preliminary sealing results with inflows smaller than the project requirement will be confirmed for the section with grouting fans with holes inside the contour (fans 5 and 6).

Work in the field will be finalised during 2009. The plan is one more fan with corresponding rock excavation. It will be designed and executed depending on the results from inflow measurements made in the section in question. Further plans include post-grouting. The future use and desired function and status of the tunnel have to be decided and the required measures have to be undertaken. This will include preparation to record and follow any changes in inflow.

Final project reporting is scheduled for early 2010. Observations of inflow will continue after this.

4.11 In Situ Corrosion Testing of Miniature Canisters



Example of electrochemical potential data obtained from one miniature canister.

Miniature canister with support cage

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

Miniature canisters with a diameter of 14.5 cm and containing 1 mm diameter defects in the outer copper shell have been set up in five boreholes with a diameter of 30 cm and a length of 5 m at Äspö HRL. All five canisters were installed in the beginning of 2007.

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

Data are transferred regularly to the UK for analysis through the internet link.

Present status

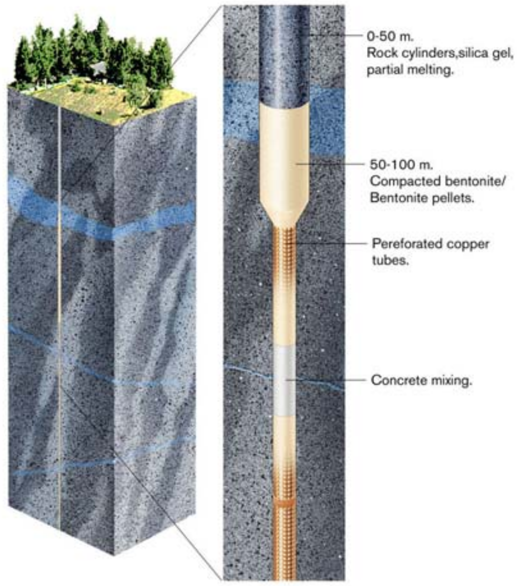
All five experiments are in operation and corrosion data are being collected as planned. This includes measurements of corrosion potential, corrosion rate and redox potential, using a range of electrochemical techniques. It was necessary to change to the back-up reference electrodes on all experiments due to failure of the small internal silver-silver chloride reference electrodes. Water analyses and microbial analyses of the local environment have been obtained. Strain gauges are used to monitor for any dimensional changes on two of the miniature canisters. A number of additional corrosion test coupons are in place in the boreholes. A draft report on the installation of the canisters and results obtained to May 2008 has been prepared and is under review.

Scope of work for 2009

During 2009, monitoring of the experiments will continue in the same way. No major changes to the experimental arrangements are envisaged although some changes may be made to the measurement parameters. Data analysis will continue, together with water sampling and analyses.

After analysis of the results from the water and microbial analyses performed in October 2008, the sampling scheme for 2009 will be determined. During 2009 planning will also be started for the dismantling of the canisters (time, sequence, types of analyses to be performed etc).

4.12 Cleaning and Sealing of Investigation Boreholes



The project dealing with identifying and demonstrating the best available techniques for cleaning and sealing of investigation boreholes was initiated in 2002 and up to now Phase 1 to 3 have been finalised.

Phase 4 aims to give principles for selecting strategic positions of plugs in boreholes for preventing axial flow by use of clay material and cement-based plugs and focuses on:

- Characterisation and planning of borehole sealing
- Quality assessment and detailed design

The specific goal is to collect available characterisation data of selected reference boreholes for working out generalised rock structure models and for planning sealing of boreholes.

A number of representative boreholes will be considered and those suitable for sealing will be divided into categories for which conceptual designs will be worked out. The project will select boreholes at Äspö, Laxemar, and Forsmark, for detailed design. The holes should represent typical rock conditions with respect to frequency, size and properties of permeable and unstable fracture zones.

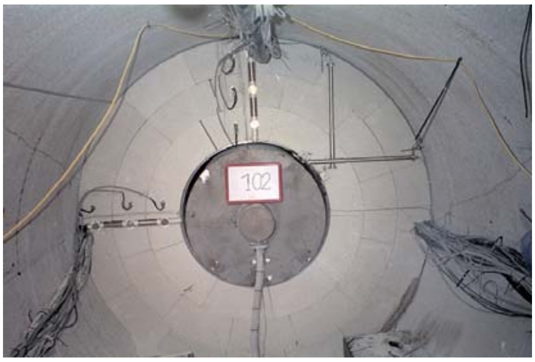
Present status

The ultimate goal of the project is to find out how investigation boreholes can be sealed to prevent radionuclides emanating from an underground repository to migrate through them and reach the biosphere. This requires development and selection of suitable sealing methods and to develop strategies for applying them in holes of different length and orientation. While earlier phases have indicated possible techniques for how borehole can be plugged, the work performed in 2008 has included characterisation of a number of investigation boreholes with respect to the frequency and nature of water-bearing and weak, fracture-rich zones, which provide difficulties in constructing borehole plugs. It has also comprised an attempt to model water flow along boreholes for estimating the risk of "short-circuiting" of plugged parts caused by hydraulic interaction of fractures that are located in the rock within some 10 to 20 m from the holes and that connect parts of the boreholes that are separated by tight plugs. This work makes use of a DFN model and further application of the model is presently under way. Plans for locating clay and concrete plugs, i.e. the two plug types intended to be used in practice, have been worked out for a number of reference boreholes at Forsmark, Laxemar and Äspö, and they form the basis of the technical and economical assessment that will be implemented in year 2009.

Scope of work for 2009

The major activity in year 2009, being part of Phase 4, will be to compare the sealing function of plugs of different types of boreholes expected in the vicinity of a KBS-3V repository, both deep investigation bore holes from the ground surface to large depths and holes extending laterally from repository rooms by about 30 to 70 m. The quality of the boreholes represent different stages of degradation, from initially being tighter than the surrounding rock to being absent by dissolution and erosion. An item that will be considered is the technical and economical assessment of plugging. A preliminary study, performed in year 2008, indicated that a strategy implying very stringent principles for placement of clay and concrete plugs according to hydraulic measurements and documentation of fracture frequencies in long holes, will lead to a very large number of plugs of different types. This would cause very long construction time and high cost. The principle decided to be followed is to identify major, important fracture zones that should be hydraulically separated. The results from the conceptual modelling work will be presented in a final report by the end of 2009.

4.13 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

THM/Gas

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

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)

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

The task to model the Canister Retrieval Test is divided into two parts where the first part is to model the thermo-hydro-mechanical behaviour of a central section of the test hole with given boundary conditions. The second part is to model the whole test. Most teams have finished the first part and are continuing modelling the entire test. The status was presented at the Task Force meeting in November 2008.

Geochemistry

Molecular dynamics modelling have been made by Clay Technology for SKB during 2008. The work has focused on ion equilibrium in the montmorillonite/water system, and the results have been presented and a paper is submitted for publication.

Ion diffusion is central in geochemical modelling, and in bentonite this is a complex matter due to the montmorillonite structure. A literature study of diffusion experiments has been made, and reinterpretations of some results have been made. A new view of the bentonite structure and of the principles for diffusion in bentonite have been presented at the EBS task force meetings, and an article summarising the theoretical treatment has been submitted to Geochimica et Cosmochimica Scripta.

Scope of work for 2009

THM/Gas

For 2009 the following work is planned:

- Finalisation and 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
- Start of a new task common with the Task Force on Modelling of Groundwater Flow and Transport of Solutes. The new task is a proposal for a field test to be installed in Äspö HRL in order to stimulate co-operation between the two Task Forces. The purpose is to study and model the hydraulic interaction between the rock and water unsaturated bentonite.

Geochemistry

For 2009 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 comprising comparison of Poisson-Boltzmann generated ion distribution with those obtained from MD simulations, and water density variation in montmorillonite interlayer space.

5 Äspö Facility

5.1 General

The Äspö facility comprises in addition to the Äspö Hard Rock Laboratory also the Bentonite Laboratory. The Bentonite Laboratory was built during 2006 and taken in operation in 2007. The Bentonite Laboratory enables full-scale experiments under controlled conditions and makes it possible to vary the experiment conditions in a manner which is not possible in the hard rock laboratory.

5.2 Organisation

The organisational unit at Äspö facility is responsible for the operation of the Äspö facility and the co-ordination of the research performed and providing experimental services and administrative support of. Activities related to information and visitor services are also of great importance for building confidence in SKB's overall commission. The Äspö unit is organised into four operative groups and a secretariat:

- *Project and Experimental service (TDP)* is responsible for the co-ordination of projects undertaken, for providing services (administration, planning, design, installations, measurements, monitoring systems etc.) to the experiments.
- *Repository Technology and Geoscience (TDS)* is responsible for the development and management of the geo-scientific models of the rock and the test and development of repository technology to be used in the final repository.
- *Facility Operation (TDD)* is responsible for operation and maintenance of offices, workshops and facilities and for development, operation and maintenance of supervision systems.
- *Public relations and Visitor Services (TDI)* is responsible for presenting information about SKB and its facilities with main focus on the Äspö HRL. The hard rock laboratory and SKB's other research facilities are open to visitors throughout the year.

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

The organisation described, which has been in place for a number of years, will be changed from the beginning of April 2009. The change involves integration of the present Äspö laboratory unit into the unit for Repository Technology, which is currently located in Stockholm. The new integrated unit, which will take over the name Repository Technology, will be organised into six groups with the following names:

- Administration, quality and planning (TDA)
- Geotechnical barriers and rock engineering (TDG)
- Mechanical- and system engineering (TDM)
- Project and Experimental service (TDP)
- Facility Operation (TDD)
- Public relations and Visitor Services (TDI)

An assistant manager will be appointed to support the manager for the new, comprehensive organisation and the activities of the unit. The unit will include personnel in both Äspö and Stockholm.

5.3 Bentonite Laboratory

Lifting of test buffer blocks in full 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 used for testing of different types of backfill material and the further development of techniques for the backfilling of deposition tunnels.

Present status

During the autumn 2008 tests have been performed to develop a method for backfilling of the bevel to the deposition holes. These tests have shown that it is possible to backfill the bevel with compacted bentonite granules, see Figure 5-1.

A number of tests with varying inflow to the backfill have been performed. The test results show that spot wise inflow of up to 0.5 litre/minute may be acceptable with respect to the erodability of the backfill. However, such high inflows will most probably require special means of discharging water and mud that reach the front. Today, there is no such technique but there are plans to work out methods for solving the problem.

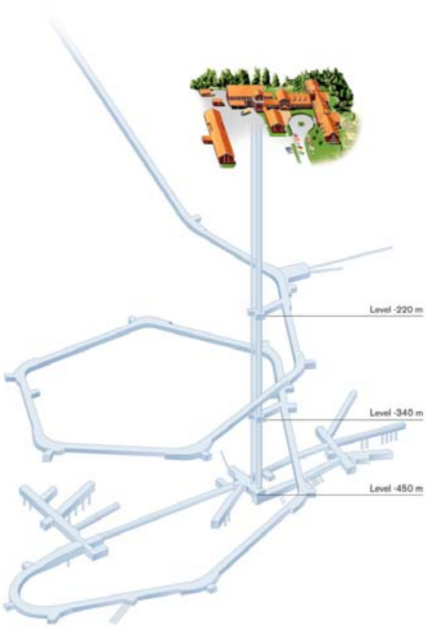
Figure 5-1. *Test set-up for the bevel to the deposition hole.*

Scope of work for 2009

A series of tests will be performed to study the influence of water inflow in deposition tunnels during backfilling. This work will be divided into two sub-projects; the purpose of the tests in sub-project 1 is to investigate the flow of water along rock/pellet contacts. The objective of the second sub-project is to investigate the water inflow into pellet fill in ”1/2-scale” tests using steel tunnels for determining the distribution of water entering from inflow spots simulating water-bearing fractures. Techniques for handling of discharged water at the backfilling front will be studied and tested during 2009.

Prior tests have shown that it is possible to fill the space between the rock and bentonite blocks with pellets, however the method can be refined in order to minimise dust and to stop each sequence with a steep front of pellets. It would be an advantage if a method can be developed where a higher installed pellets density can be achieved. Work concerning development of techniques for backfilling will therefore continue during 2009.

5.4 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

In 2008, the facility had no unplanned stoppages. During the year, SKB took over the facility maintenance, which was earlier carried out by OKG. SKB will use its own, or contracted personnel. During the summer, major maintenance work was carried out on the elevator shaft, which was rust-damaged. The rusty parts were replaced and the whole elevator shaft was painted.

Activity at the facility is increasing steadily, requiring more space and new premises. During 2008, a new archive, new offices and a storage area have been completed. A car park is being constructed using the rock waste from the excavation of the tunnel for the project Sealing of Tunnel at Great Depth. An upgrade of the burglar alarm and operational surveillance system was being carried out during the last quarter.

The object surveillance system developed by SKB has been approved and is now operational. Completion of the continued extension of the electricity network, which is being carried out in order to improve the network's safety, is planned for in the beginning of 2009.

Scope of work for 2009

Activities within the group (Facility Operation) will continue in the same way as earlier. The range of activities is increasing, which reflects the expansion of the facility both above- and below ground. The number of personnel in the operational group will be increased because of the group's increasing responsibilities. The activities can also be regarded as training for maintenance personnel for the future final disposal facility. A system for the surveillance of the facility and of personnel in the final disposal facility is being tested in the Äspö facility.

Due to their age, a number of constructions and installations are beginning to be faulty, and require comprehensive repairs. Examples are the elevator shaft and the ramp in the hard rock laboratory. The elevator's steering system also needs to be modernised in order to ensure the long-term availability of compatible components.

The water supply and the treatment of waste water need to be reviewed. The water supply is inadequate and when there is a stop in supply, underground activities must be stopped for safety reasons. A water reservoir of 20-40 cubic meters is a reasonable measure. In addition, tests will be made on equipment for the treatment of drainage water from drilling in the rock laboratory and from activities in the Bentonite Laboratory.

A study will be made of the possibilities for providing the premises required by NOVA-FoU, particularly with regard to chemistry laboratories.

5.5 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 Canister Laboratory. In 2002 site investigations started at Oskarshamn and Östhammar.

The main goal for the Public Relations and Visitor Services Group is to create public acceptance for SKB, which is done in co-operation with other departments at SKB. The goal will be achieved by presenting information about SKB, the Äspö facility, and the SKB siting programme on surface and underground. Furthermore the team is responsible for visitor services at Clab and 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.

As from autumn 2008 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 OKG's service according to agreement.

Present status

During the year 2008 the facilities in Oskarshamn (Äspö facility, Clab and Canister Laboratory) and the site investigation activities in Oskarshamn were visited by 14,177 visitors. The visitors represented general public, municipalities where SKB perform site investigations, teachers, students, politicians, journalists and visitors from foreign countries. The total number of visitors to all SKB facilities and site investigation activities in Oskarshamn and Forsmark was 24,133.

Planned special events for 2009

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

Due to the announcement of the site selection, there will be different activities for the team members to participate in. For example there is a tour planned with the ship Sigyn, and there will also be other information and celebrating activities.

A series of lectures with special connection to the research and development of techniques conducted at the Äspö facility started in 2007, and is to be continued during 2009. Special occasions which are planned are:

- 11^{th} – 12^{th} of September - “The Geology Day”, activities for the schools and for the general public.
- 25^{th} of September (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.

6 Environmental research

6.1 General

Äspö Environmental Research Foundation was founded 1996 on the initiative of local and regional interested parties. The aim was to make the underground laboratory at Äspö and its resources available for national and international environmental research. 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).

Nova-FoU is a joint research and development platform at Nova Centre for University Studies, Research & Development in Oskarshamn, Sweden. The platform is supported by SKB and the municipality of Oskarshamn. The platform can use SKB's facilities and competence in Oskarshamn as the base for research and development. The contract was signed at the end of 2007 and runs for five years.

One project within the Nova-FoU, "The Geochemistry Research Group", has started (see section 6.2 for further description). Another project, under the leadership of Professor Vladimir Cvetkovic, The Royal Institute of Technology, will start in 2009. The focus will be on integrating hydrological and catchment scale modelling with hydrochemistry and geochemistry, with the ultimate aim of increasing the understanding of sources and transport of chemical elements throughout the catchment all the way to the inner estuaries.

6.2 Geochemistry Research Group

Surface water sampling point at Laxemar catchments area

The Geochemistry Research Group is part of the NOVA-FoU platform. This research group is a continuation of the Äspö Research School and is financed mainly by SKB and the University of Kalmar.

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

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

Present status

In 2008, Pernilla Rönnback and Ulf Lavergren defended their PhD thesis. Rönnback's thesis is titled "Major and trace elements in surface and ground waters in two near-coastal granitoidic settings in eastern Sweden", and presents hydrochemical data collected during the site investigations and in Äspö HRL. Lavergrens thesis is titled "Metal dispersion from natural and processed black shale", and presents hydrochemical data, geochemical data and hydrochemical modelling results from an environmental study on Öland.

Scope of work for 2009

A new PhD student, Frédéric Mathurin, started in October 2008. His research will focus on the hydrochemistry of bedrock groundwaters. He will work with secondary data from both Äspö HRL and the site investigations, and will also participate in a sulphide production project which will be carried out at the Äspö HRL. He will also participate in an ion-exchange project, localised to Äspö HRL, which now is under planning.

Collaboration will be carried out with the Nova-FoU project led by Vladimir Cvetkovic which will focus on study of hydrological pathways and costal system.

A PhD project focusing on lanthanoids will be initiated. A PhD student will be hired, and the work will be to describe and model the sources, pathways and sinks of the lanthanoids within catchments in Laxemar. Determination of the behaviour of the redox sensitive lanthanoids (Ce, Eu) and fractionation patterns throughout the lanthanoid series will be important tools in order to characterise the behaviour of these metals. The lanthanoids are of particular interest as they have a behaviour similar to that of several actinides.

7 International co-operation

7.1 General

Eight organisations from seven countries will in addition to SKB participate in the co-operation at Äspö HRL during 2009, see Table 7-1. Six of them; Andra, BMWi, CRIEPI, JAEA, NWMO and Posiva together with SKB form the Äspö International Joint Committee (IJC), which is responsible for the co-ordination of the experimental work arising from the international participation.

Several of the participating organisations take part in the two Äspö Task Forces on: (a) Modelling of Groundwater Flow and Transport of Solutes, which is a forum for co-operation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock and (b) THMC modelling of Engineered Barrier Systems, which is a forum for code development on THMC processes taking place in a bentonite buffer and gas migration through a buffer. For 2009 there has been a proposal for a joint task 8 of the two Task Force projects, related to modelling hydraulic interaction of rock and bentonite.

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

Table 7-1. International participation in the Äspö HRL projects during 2009.

Projects in the Äspö HRL during 2009	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Nagra	RAWRA
Natural barriers								
Tracer Retention Understanding Experiments								
Long Term Sorption Diffusion Experiment					X			
Colloid Transport Project (Part of Colloid Formation and Migration CFM)		X			X			
Microbe Project		X						
Radionuclide Retention Project								
Task Force on Modelling of Groundwater Flow and Transport of Solutes			X	X	X	X		
Engineered barriers								
Prototype Repository		X				X		
Alternative Buffer Materials	X	X				X	X	X
Long Term Test of Buffer Materials					X	X	X	
Temperature Buffer Test	X							
KBS-3 Method with Horizontal Emplacement						X		
Large Scale Gas Injection Test	X	X			X			
Task Force on Engineered Barrier Systems	X	X	X		X	X	X	X

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

7.2 Andra

The French radioactive waste management agency is developing the Meuse/Haute-Marne URL within a sedimentary clay layer. French Planning Act of 2006 have opened the way towards a deep geological repository in such clay-rock, Andra has given up working on crystalline rock properties. But this does not mean that Andra will leave the participation in Äspö HRL since the large programme implemented in the Swedish HRL on bentonite based engineered barrier systems is considered highly valuable whatever host-rock is selected. That is why Andra renewed a four-year co-operation agreement with SKB in 2008.

Prioritised activities during 2009

Planning the Temperature Buffer Test (TBT) dismantling operation will be an important activity for 2009, benefiting from experience gained in previous Canister Retrieval Test (CRT) and Long term Test of Buffer Material (Lot) dismantling and sampling operations. TBT dismantling will begin in 2010 with a canister retrieval test.

French support to the Task Force on Engineered Barrier Systems will be provided by the Spanish UPC-CIMNE modelling team involved in Task 1, the THM test and the Swiss Colenco team in Task 2, the gas migration test.

New series of hydraulic and gas injection tests to be performed in the Large Scale Gas Injection test (Lasgit) will yield new gas transport data to the modellers.

Andra remains as a participant in (Lot) and Alternative Buffer Materials (sample analysis).

7.3 BMWi

The first co-operation agreement between Bundesministerium für Wirtschaft und Technologie (BMWi) and SKB was signed in 1995. After a first extension in 2003 the agreement is one again extended in 2008 for a period of another five years. Several research institutes are performing the work on behalf of and funded by BMWi: the Federal Institute for Geosciences and Natural Resources (BGR), DBE Technology GmbH, Forschungszentrum Dresden-Rossendorf (FZD), Gesellschaft für Anlagen- und Reaktorsicherheit mbH (GRS), and Bauhaus Universität Weimar. The main purpose of the co-operation within the Äspö HRL programme is 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. The topics of special interest are:

- Behaviour of engineered barrier system and the interaction with the surrounding rock.
- Behaviour of the buffer material.
- Behaviour of microbes and colloids and their respective 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 2009

Microbe Project

The project addressing the indirect interaction mechanism of actinides by released bioligands from the Äspö-bacterium *Pseudomonas fluorescens* was finished in 2008. This study focused on: (i) isolation and characterization of microbial ligands produced from a subsurface strain of *Pseudomonas fluorescence* isolated at Äspö, (ii) interaction of U(VI), Np(V), and Cm(III) with the microbial ligands including compounds simulating the functionality of the microbial ligands and the surface of the bacteria and (iii) spectroscopic characterization of the formed actinide complexes/compounds.

In 2009 it is planned to summarise the achieved results in the form of a final report. Furthermore, it is planned to extract important results, e.g. Neptunium(V) complexation with natural pyoverdins and related model compounds and to publish it together with the Swedish partners (group of Prof. K. Pedersen, Göteborg University).

Prototype Repository

GRS performed measurements of the electric resistivity distribution in the backfill, the buffer, and the rock between two of the deposition boreholes. Since there is a direct correlation between solution content and electric resistivity, these measurements can be 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 of the Sections I and II 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 performed on a daily basis and evaluated quarterly. The recording unit for these arrays is controlled remotely from Braunschweig/Germany via a telephone connection.

Evaluation comprises determination of the resistivity distribution around the electrode arrays by inverse modelling using the code SensInv2D. From laboratory measurement results obtained during an earlier phase of the project, the resistivity distributions can be interpreted in terms of solution content of the backfill, the buffer and the rock. Unfortunately, the buffer measurements can no longer be evaluated by inversion because of the failure of a number of buffer electrodes.

To increase the confidence in the results of the inversions of the apparent resistivities measured in situ, laboratory experiments have been performed in which controlled progressing water uptake in the backfill was simulated and monitored by geoelectric measurements. During the first test, the backfill material was, however, considerably drier than the material installed in situ. Therefore, a second experiment with relevant initial water content was performed. Comparison between the known state of water uptake and the results of the measurements will allow better assessment of the inversion accuracy.

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

In 2009 the BGR clay laboratory will proceed with the characterisation of bentonite samples from Long Term Test of buffer Materials (Lot) and/or Alternative Buffer Materials test.

The characterisation of the Lot samples (third and final parcel) will allow for the assessment of buffer performance within the last period of a decade. It will be of particular interest to investigate possible changes of the barrier properties which possibly occur after the first reactions which took place in the first years. The expected small differences of material properties can only be detected if exactly the same methodology is applied.

Alternative Buffer Materials

The characterisation of the Alternative Buffer Materials (ABM) test samples in which different bentonites are compared with each other will support the assessment of buffer performance. Here it will be essential to identify the probably small differences between the 11 different materials.

Currently it is planned to excavate the first ABM parcel in 2009. In order to detect systematic differences at least 5 samples per clay type have to be selected which results in 55 clay samples which have to be analysed in detail in 2009.

Temperature Buffer Test

DBE Technology intends to continue the work on the back analysis of the measured data obtained from the Temperature Buffer Test. A huge amount of data is available providing information on temperature evolution, pressure and pore pressure development as well as suction and humidity progress. The numerical back analysis of the observed slow movement of injected water going from the outer sand filter into the bentonite will be continued in order to improve the understanding of the ongoing processes. In 2009 special focus will be put on the simulation of the swelling of the bentonite and the swelling pressure development as a function of saturation. It is intended to identify the impact of the swelling on the hydraulic processes within the bentonite.

Large Scale Gas Injection Test

The work being conducted by BGR as part of the Large Scale Gas Injection Test (Lasgit) focuses both on the investigation of processes and interactions that occur in the experiment and the behaviour and nature of the engineered barriers system and the excavation damaged zone (EDZ). Surface packer tests - also 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 Rockflow (THMC-code).

The work in 2009 will focus on the modelling of processes in the engineered barriers system. Measured data from Lasgit will be used as reference. Different approaches for modelling gas migration will be tested.

Task Force on Engineered Barrier Systems

The Task Force on Engineered Barrier Systems has the objective to verify the ability to model thermal, hydraulic, mechanical, chemical (THMC) and gas migration processes in the buffer, to identify possible gaps in the conceptual models and to refine and to improve codes (coupling and 3D-capability). In the first phase the codes are tested against well-controlled laboratory experiments and in the second phase against field experiments. The results of the experiments are given together with the benchmark description and emphasis is laid on an open discussion of problems and solutions during modelling. The codes Rockflow/Rockmech (Tasks 1 and 2) and Viper (Vapour diffusion/Task 1) will be used.

GRS´s activities comprise the modelling of the re-saturation with Code Viper in the framework of the second phase. They will be continued aiming at two directions: Firstly, the work on the non-isothermal water uptake of bentonite in the Canister Retrieval Test in 2008 was partially successful but also indicated that the model becomes apparently inaccurate when very high degrees of saturation are reached. This appears to be consistent with the fact that the conceptual model underlying code Viper includes a late stage an uptake of liquid water that is not yet realised in the code. Necessary theoretical work, implementation and modelling are foreseen for spring 2009. Secondly, it is planned to tackle the problem of re-saturation of bentonite-sand-mixtures based on the tests in the Canadian URL. A scaled adsorption isotherm is to be used for this purpose to include the effect of the additional sand. First results are planned to be presented at the Task Force Meeting in spring 2009.

In 2008, BGR successfully modelled the field experiments suggested by AECL and SKB. The focus was directed both to test the capability of GeoSys/Rockflow to model large-scale models in three dimensions and to model multiphase flow. For 2009 it is planned to model the field experiments with improved approaches for the material behaviour of buffer materials.

Soil mechanics group at Bauhaus University Weimar will further do research on model identification on coupled THM-multifield applications. Our approach was successfully applied to small element tests from the laboratory (see paper to 1st European conference in Durham, UK in summer 2008). The next step is to simulate well controlled column tests under THM conditions from our laboratory using Ca-bentonite from Germany. By using Code-Bright we are optimistic to gain excellent results early 2009. The final step will be to do a back analysis of large column tests performed at TU Bergakademie Freiberg (Germany) using different types of bentonite and pore fluids. Additionally to back analysis we will apply sensitivity and correlation analysis in order to gain a better insight in processes involved.

7.4 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 2009

During 2009, CRIEPI will participate in the two Task Forces as well as exchange information about research, disposal technologies and methodologies for site investigations with SKB and the other participating organizations.

As to the Task Force on Modelling of Groundwater Flow and Transport of Solutes, CRIEPI will perform modelling work for sub-task 7B, block scale modelling of interference tests conducted in boreholes KR14-18 at Olkiluoto, Finland. CRIEPI will also compile an International Progress Report on modelling results for sub-tasks 7A and 7B. Sub-tasks 7A addresses reduction of performance assessment uncertainty through site scale modelling of long-term pumping in borehole KR24 at Olkiluoto.

For the Task Force on Engineered Barrier Systems, CRIEPI will conduct the computational work for benchmark 2.2 (large scale field tests). The test to be modelled by CRIEPI is the Canister Retrieval Test (CRT) conducted in Äspö HRL. In addition, the numerical results from the modelling will be reported.

7.5 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 2009 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 2009

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 PA relevant parameters estimated by hydrogeological models based on the flow response measurement data during hydraulic interference test.

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

7.6 NWMO

The prime objective of Nuclear Waste Management Organization'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 NWMO's committed work on Äspö HRL projects to be carried out in 2009 is described below.

Canada is also participating with SKB in work related to planning other projects at Äspö HRL.

NWMO is providing modelling support for the Long Term Sorption Diffusion Experiment. The Canadian modelling team is from AECL and the reference code is Motif. In 2009, modelling support will consist of post-test analyses using a previously developed Motif model to estimate in situ diffusion coefficients, and where appropriate sorbing coefficients, from concentration profiles for the suite of non-sorbing and variably-sorbing tracers used in the field scale experiment.

NWMO is providing supporting laboratory experiments for the Colloid Project. In 2009, a further series of laboratory bentonite colloid generation and transport experiments are planned using the 1-m scale Quarried Block test facility at Atomic Energy of Canada Limited (AECL) to improve the understanding of processes that could affect the long-term stability of bentonite buffer in contact with a fracture containing low ionic strength groundwater. These experiments will also contribute to the international Colloid Formation and Migration (CFM) experiment ongoing at the Grimsel Test Site.

NWMO is providing modelling support for the Large Scale Gas Ingestion Test (Lasgit) via the Canadian modelling group Intera Engineering using the Tough2 code modified with pressure-dependent permeability and capillary pressure to simulate micro-fracturing. In 2009, Lasgit modelling work will focus on simulating the preliminary gas injection tests conducted in 2007. A calibrated model will then be used to predict future responses to future gas injection tests. In addition, the use of structured heterogeneous permeability distributions to yield flow results consistent with laboratory scale experimental results will be investigated, and if determined to be a suitable approach, the approach will be applied to the full scale Lasgit model.

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 2009, the modelling work will focus on the numerical simulation of SKB's Canister Retrieval Test.

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 2009, project activities will include completion of modelling activities and reporting for sub-task 7B. Sub-task 7B is supported by detailed surface and borehole-based fracture logs and hydraulic tests, including the Posiva Flow Log, completed in the group of boreholes KR14 to KR18 at Olkiluoto.

7.7 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 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. The organisation is participating in the following projects:

- KBS-3 Method with Horizontal Emplacement
- Large Scale Gas Injection Test
- Sealing of Tunnel at Great Depth
- Long Term Test of Buffer Materials
- Alternative Buffer Materials
- Task Force on Modelling of Groundwater Flow and Transport of Solutes.
- Task Force on Engineered Barrier Systems
- Bentonite Laboratory

Posiva's co-operation is divided between Äspö HRL activities and more generic work that can lead to demonstrations in Äspö HRL. The work planned to be performed within the different projects during 2009 is described below.

Prioritised activities during 2008

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 it will be planned full-scale system tests in a representative environment.

Large Scale Gas Injection Test

SKB and Posiva have conducted a joint Lasgit-project during the years 2003-2008. After assessing the results the continuation of the project will be determined.

Sealing of Tunnel at Great Depth

SKB has initiated a project in order to develop practical grouting strategies for deep bedrock conditions. Posiva has concentrated on the development of low pH grouting cement to the fractures around 100 µm of an aperture and SKB on methods for sealing narrow fractures, which cannot be filled with cementitious materials. Co-operation is based on the information exchange between projects and experiences gathered during the construction of the tunnel. Posiva participates in the reference group of the project.

Long Term Test of Buffer Materials

Posiva's task in this project is to study the pore water 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 the other planned studies of the chemical conditions. During the year 2009 Posiva participates in the studies of the next retrieved parcel when the samples are available.

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. During the year 2009 Posiva participates in the studies of the first retrieved parcel when the samples are available. The aim of the work is to get information about the pore structure and the chemical conditions in the clays.

Task Force on Modelling of Groundwater Flow and Transport of Solutes

From Finland, Posiva together with Finnish Research Centre (VTT) and Pöyry Environment participates in the Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes. The target of the work for the following years is numerical modelling of multi-borehole interference experiment in Olkiluoto borehole KR14 to KR18 (was carried out in spring 2002).

Objectives are to quantify the reduction of uncertainty in the performance assessment through the utilisation of the Posiva Flow-logging (PFL) data when analysing the background rock (rock mass).

Moreover, a new task (Task 8) on the hydraulic interaction between bentonite buffer and host rock has been put forward.

Task Force on Engineered Barrier Systems

During the year 2008 the THM behaviour of water saturation phase of the Canister Retrieval Test has been simulated. The activities of the year 2009 are currently under consideration.

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 design and utilise the results in reporting the backfill design during 2009.

7.8 Nagra

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 has now left the central and active core of participants.

However, during 2009, Nagra is taking 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 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.

7.9 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 participates also in the Alternative Buffer Materials project.

Prioritised activities during 2009

Nuclear Research Institute, contractor of RAWRA, has continued to do an experiment series for better understanding of the gas migration process. A set of experiments with two types of bentonite with different properties has been performed; measured data have been described and analysed. The data only have confirmed complexity of migration process and presence of chaotic components in the gas migration process, so the creation of a universal model for simulating laboratory experiments presents a formidable task. Several simple models for estimation of this problem have been created in GoldSim environment on the basis of these data. Two-phase flow model in Tough2 is under development. In the nest period, there will be additionally set other experiments for deeper understanding of the process of gas paths creation in bentonite. Alterations in the bentonite structure after breakthrough will be followed. The results of the experiments should help in breakthrough process modelling. There will be created models using GoldSim and Tough2 code for simulating laboratory experiments and for simulating gas migration process in deep geological repository.

Technical university of Liberec (TUL) team, one of contractors of RAWRA, participated in 2008 in the "Task force on EBS", in modelling of AECL's "Buffer contained experiment", in situ thermo-hydro-mechanical test. Their own simulation code ISERIT was used for calculation of heat conduction and water distribution. For 2009, continuation of these activities is expected. The simulation code will be further developed to cover larger group of physical phenomena and more general input data. Either the BCE experiment will be recalculated to get better fit and/or other experiments (e.g. CRT in Äspö) in the Task force EBS. It is also planned to continue the progress in combining the simulation code with inverse problem solution algorithm (automatic calibration).

The third contractor of RAWRA, CEG of technical University in Prague, will continue with evaluation of Canister Retrieval Test. The results from especially developed model will be compared to experimental inputs. The model will also be used for evaluations of the experiments related to the project MockUP-CZ.

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