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Äspö Hard Rock Laboratory

Planning Report for 2007

Svensk Kärnbränslehantering AB

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Svensk Kärnbränslehantering AB

Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19



**Äspö Hard Rock
Laboratory**

The Äspö Hard Rock Laboratory Planning Report for 2007

This report presents the planned activities for year 2007 with background, objectives, experimental concepts (where applicable) and scope of work. It details the programme for the Äspö Hard Rock Laboratory described in SKB's Research, Development and Demonstration Programme 2004, and serves as a basis for the management of the laboratory. The plan is revised annually. The activities are further detailed in activity plans for the Repository Technology department covering a time period of five years.

The role of the Planning Report is to present the background and objectives of each experiment. Thereby the Status Reports may concentrate on work in progress and refer to the Planning Report for more background information. The Annual Report will in detail present new 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), 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.

The work with Äspö HRL has been divided into three phases: Pre-Investigation phase, Construction phase and Operational phase.

During the *Pre-Investigation phase*, 1986–1990, studies were made to provide background material for the decision to locate the laboratory to a suitable site. The natural conditions of the bedrock were described and predictions made of geological, hydrogeological, geochemical and rock-mechanical conditions to be observed during excavation of the laboratory. This phase also included planning for the Construction and Operational phases.

During the *Construction phase*, 1990–1995, comprehensive investigations and experiments were performed in parallel with construction of the laboratory. The excavation of the main access tunnel to a depth of 450 m and the construction of the Äspö Research Village were completed.

The *Operational phase* began in 1995. A preliminary outline of the programme for this phase was given in SKB's Research, Development and Demonstration (RD&D) Programme 1992. Since then the programme has been revised every third year and the basis for the current programme is described in SKB's RD&D-Programme 2004 /SKB 2004/.

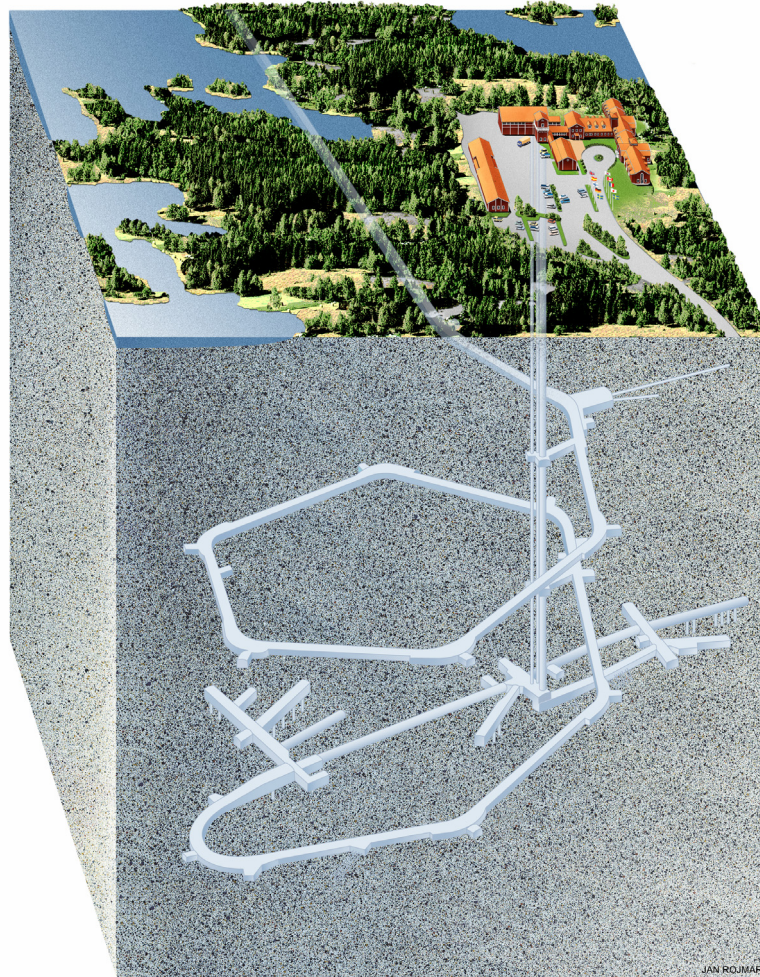


Figure 1-1 Overview of the Äspö HRL facilities.

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 have been transferred to the Site Investigations Department of SKB which performs 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.

1.3 Organisation

SKB's work is organised into six departments: Technology, Nuclear Safety, Site Investigations, Operations, Environmental Impact Assessment (EIA) and Public Information and Business Support. The research, technical development and safety assessment work is organised into the Technology department, in order to facilitate co-ordination between the different activities. Within the Technology department a Technical-Scientific council has been set up in order to prepare technical and scientific issues concerning the research and development of the KBS-3 method. The Council shall in different issues continuously judge the state of development and the need of further work as well as advice on on-going and planned new projects aimed at development and scientific verifying of the different parts of the KBS-3 method.

The director of the Technology department is the chair of the Technical-Scientific council and there is one executive secretary appointed responsible for the preparation of issues and the documentation and follow-up of standpoints taken by the council. Other members of the council are the managers of the units within the Technology department responsible for research and development as well as the director of the Site Investigations department of SKB.

The executive secretary in the Technical-Scientific council act as a representative between on one hand the clients within Repository Technology and Safety and Science and on the other the performing organisation at Äspö HRL. The executive secretary is also responsible for the co-ordination of the research performed in international co-operation.

The Äspö Hard Rock Laboratory is one of five units organised under the Technology department and is responsible for the operation of the Äspö facility and the co-ordination, experimental service and administrative support of the research performed in the facility. The Äspö HRL unit is organised in four operative groups and a secretariat.

- *Project and Experimental service (TDP)* is responsible for the co-ordination of projects undertaken at the Äspö HRL, 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 at Äspö and the test and development of repository technology at Äspö HRL to be used in the final repository.
- *Facility Operation (TDD)* is responsible for operation and maintenance of the Äspö HRL offices, workshops and underground facilities and for development, operation and maintenance of supervision systems.
- *Relations and Visitor Services (TDI)* is responsible for presenting information about SKB and its facilities with main focus on the Äspö HRL. The HRL and SKB's other research facilities are open to visitors throughout the year.

Each major research and development task 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 the Äspö HRL. The staff at the site office provides technical and administrative service to the projects and maintains the database and expertise on results obtained at the Äspö HRL.

1.4 International participation in Äspö HRL

The Äspö HRL has so far attracted considerable international interest. During 2007, nine organisations from eight countries will in addition to SKB participate in the Äspö HRL or in Äspö HRL-related activities. The participating organisations are:

- Agence Nationale pour la Gestion des Déchets Radioactifs (Andra), France.
- Bundesministerium für Wirtschaft und Technologie (BMW), 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.
- Empresa Nacional de Residuos Radiactivos (Enresa), Spain.
- Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle (Nagra), Switzerland.
- Radioactive Waste Repository Authority (RAWRA), Czech Republic.

For each partner the co-operation is based on a separate agreement between SKB and the organisation in question.

Andra, BMW, 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.

1.5 Allocation of experimental sites

The rock volume and the available underground excavations are divided between the experiments performed at the 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 Äspö HRL is shown in Figure 1-2.

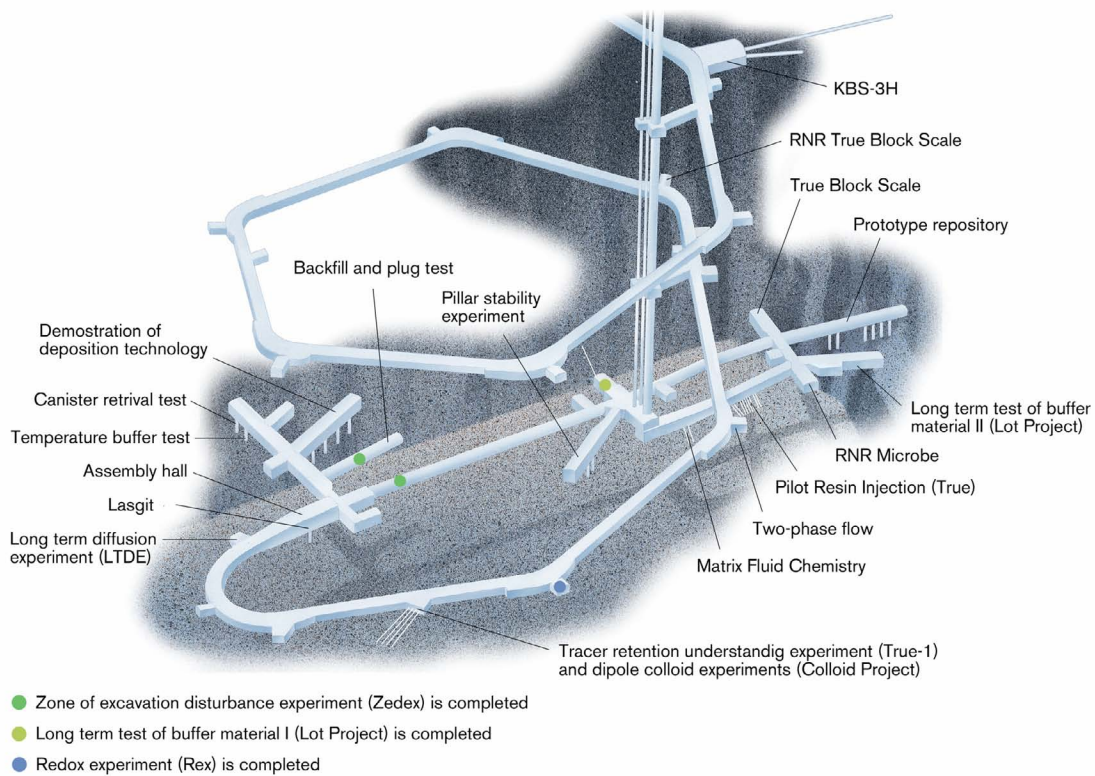


Figure 1-2 Allocation of some of the experimental sites from -220 m to -450 m level.

1.6 Reporting

Äspö HRL is an important part of SKB's RD&D-Programme. The plans for research and development of technique during the period 2005–2010 are presented in SKB's RD&D-Programme 2004 /SKB 2004/. The information given in the RD&D-Programme related to Äspö HRL 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 2007. Detailed account of achievements to date for the Äspö HRL can be found in the Äspö HRL Annual Reports that are published in SKB's Technical Report series. In addition, Status Reports are prepared quarterly.

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. Table 1-1 provides an overview of Äspö HRL related documents and the policy for review and approval.

Data collected from experiments and measurements at Äspö HRL are mainly stored in SKB's site characterisation database, Sicada.

Table 1-1 Overview of Äspö HRL related documents.

Report	Reviewed by	Approved by
SKB RD&D-Programme – Äspö HRL related parts	Executive Secretary, Technical-Scientific Council	SKB
Planning Report – Detailed plans covering each calendar year	Contributors	Executive Secretary, Technical-Scientific Council
Annual Report – Summary of work covering each calendar year	Contributors	Executive Secretary, Technical-Scientific Council
Status Reports – Short summary of work covering each 3 month period	Principal Investigators or Project Managers	Executive Secretary, Technical-Scientific Council
Technical Reports (TR)	Project Manager	Executive Secretary, Technical-Scientific Council
International Progress Reports (IPR)	Project Manager	Executive Secretary, Technical-Scientific Council
International Technical Documents (ITD)	Case-by-case	Project Manager
Technical Documents (TD)	Case-by-case	Project Manager

1.7 Management system

SKB is since 2001 certified according to the Environmental Management System ISO 14001 as well as the Quality Management Standard ISO 9001. Since 2003 SKB is also certified according to the up-graded ISO standard 9001:2000.

The structure of the management system is based on procedures, handbooks, instructions, identification and traceability, quality audits etc. The overall guiding documents for issues related to management, quality and environment are written as quality assurance documents. The documentation can be accessed via SKB's Intranet where policies and quality assurance documents for SKB (SD-documents) as well as specific guidelines for Äspö HRL (SDTD-documents) can be found. Employees and contractors related to the SKB organisation are responsible that work is performed in accordance with SKB's management system.

SKB is constantly developing and enhancing the security, the environmental labours and the quality-control efforts to keep up with the company's development as well as with changes in circumstances. One of the cornerstones of both the existing operations and in the planning of new facilities is the efficient utilisation of available resources.

The guiding principles of all SKB's activities and each employer's work are expressed in three key words:

- Safety
- Efficiency
- Responsiveness.

Project process

SKB has developed a project process for the implementation of projects. The aim of the process is to create an effective and uniform management of all projects and establishment of the requirements for initiation, implementation, and delivery of projects.

According to the project process each project shall have a client within the SKB line organisation. The client initiates a project through the project decision document containing details for the project in terms of specifications, resources, time and budget. A project manager is chosen by the client and is responsible for preparing of the project plan containing details on implementation of the project, a risk analysis and a quality plan. The realisation of the project shall be done according to the project plan. As a delivery of the project the project manager puts together an evaluation report containing the clients' reflections on the project implementation and result and the project organisation experiences, evaluation of risk management and possible improvements for further projects.

Environmental management

SKB manages Sweden's spent nuclear fuel and radioactive waste in order to safeguard the environment and people's health in both the short and long term. This task is a key element of the national environmental objective of a safe radiation environment.

SKB also makes every effort to minimise the impact of ongoing operations and activities on the environment. This environmental work is goal-oriented and the progress versus goals is assessed every three months. Key assessment parameters for the selection of suppliers include security, environmental aspects and quality.

1.8 Structure of this report

The work planned at Äspö HRL during 2007 is in this report described in seven chapters:

- Geoscience – experiments, analysis and modelling to increase the knowledge of the surrounding rock.
- Natural barriers – experiments, analysis and modelling to increase the knowledge of the repository barriers under natural conditions.
- Engineered barriers – demonstration of technology for and function of important engineered parts of the repository barrier system.
- Buffer materials and backfill technology – demonstration of technologies and studies of material properties.
- Äspö facility – operation, maintenance, data management, monitoring, public relations etc.
- Environmental research.
- International co-operation.

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 HRL 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. 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. From 2006 the work follows a yearly geoscientific programme.

Scope of work for 2007

An important part of the planned work is to start the development of the new Äspö site descriptive model. The integrated site description is planned to be published 2008 and to be updated every third year.

Method descriptions for underground geoscientific investigation methods will be developed as a part of the quality control of Äspö HRL. The purpose of method descriptions is to ensure that things are performed in the right way and that the results are repeatable. A method description contains directions to how the method should be performed, a description of the results that are produced (including the accuracy), and directions to how the results should be processed.

2.2 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 and contribution with input knowledge in projects and experiments conducted at Äspö HRL. Also, development of new methods in the field of geology is a major responsibility. As a part of the latter, the Rock Characterisation System (RoCS) feasibility study is being conducted, see Section 2.2.2.

2.2.1 Geological Mapping and Modelling

Background and objectives

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

Present status

At present no exposed rock surfaces (including those from the new TASQ niche NASQ0036A) or drill cores from Äspö rock volume are unmapped. New drill cores from TASQ are on their way however. There are earlier mappings that have still not been digitised and adherent data not entered into the rock characterisation system TMS (Tunnel Mapping System). Possibilities to catch up have, however, increased as one more TMS station is in operation since summer 2005. The Sicada operators that were intended to assist in data entering and quality control have unfortunately been busy during most of the year of 2006 in conducting their work with the Sicada database. Little time has thus been given in assisting in the TMS work.

New data have been collected but no up-dating has been performed of the geological 3D model of Äspö rock volume that was presented in the GeoMod report /Berglund *et al.* 2003/. The work with the detailed 3D structural geological and hydrogeological model of the -450 m level is in progress. The model will be based on all available data from earlier investigations.

The report from the magnetic anisotropy (AMS) project with the purpose to establish true width of deformation zones has been written and delivered to SKB for printing. /Mattsson 2006/.

Scope of work for 2007

The main activities planned for 2007 are:

- Core logging will take place as new cores are produced.
- The plan to excavate a new tunnel (for injection tests) at Äspö HRL will call for an increase in resources for geological mapping of the rock surfaces as well as for core logging.
- The development of the TMS will proceed. In order to increase the usability of the TMS, suggestions to make it compatible with RVS will be examined. In any case upgrading to Microstation V8 is suggested during next year. If two TMS stations shall still be in operation during the year of 2007 a new TMS-database and a system how to handle the drawings should be considered.
- Discussions should begin with the Sicada group about how to store geological mapping data from Äspö HRL and how to coordinate the nomenclature with the one used by the site investigations.
- The model of the -450 m level will continue and will be completed during the spring 2007.
- A minor revision or up-date of the present Äspö HRL 3D geological model will be considered.
- Continued computer work with regard to “old” tunnel and deposition hole mappings not yet digitised and with geological data not entered into the TMS rock characterisation system.

2.2.2 Rock Characterisation System

Background and objectives

A feasibility study concerning geological mapping techniques is performed beside the regular mapping and modelling tasks. The project Rock Characterisation System (RoCS) is conducted as an SKB-Posiva joint-project. The purpose is to investigate if a new system for rock characterisation has to be adopted when constructing a future final repository. The major reasons for the RoCS 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. In this initial feasibility study-stage, the major objective is to establish a knowledge base concerning existing and possible future methods and techniques to be used for a mapping system suitable for SKB's and also Posiva's requirements.

Present status

The first part of the feasibility study, establishing of the technical state-of-the-art, is completed. Tests of data collection methods have been performed using both digital photogrammetry and laser scanning. Also, several complementary techniques, like geophysical survey methods, have been investigated, as well as software applications. The draft of the report was completed during the spring of 2006. The report has during the summer been reviewed by BGS (British Geological Survey) and adjusted according to some of the suggestions that were given by the reviewers. The authors of the report (SKB International Progress Report IPR-06-07, in prep.) suggest that laser scanning together with digital photography should be a part of the new rock characterisation system. At the time being there is more than half a year delay of the project.

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 RoCS-project the results will be of great interest for the project. Due to refinement of the method, ATS will not be able to deliver all test results at the end of 2006 as planned and the final report will be delayed.

Scope of work for 2007

A major task for 2007 will be to establish a detailed specification of requirements for a new rock characterisation system to be used in a future final repository. These requirements should according to the project plan have been acquired already during the year of 2006. According to the original intentions the requirements taken into consideration will be both external from public authorities, as well as internal from all user groups (besides geologists for example rock mechanics, design teams and tunnel maintenance teams) that could benefit from a new rock characterisation system. It may, however, be favourable to concentrate on the requirements for the part of RoCS that considers a new geological mapping system and although not in 2007 to get that in operation as soon as possible.

2.3 Hydrogeology

Background and objectives

The major aims of the hydrogeological activities are to:

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

Present status

A hydro-structural model of the –450 m level has been compiled during 2006 based on existing small-scale models and observed water conducting features in tunnels and boreholes.

The project Äspö models 2005 has resulted in a new generation of numerical groundwater models for Äspö. New modelling technology allows a detailed description of the Äspö rock volume embedded in a model domain of regional scale. Different model setups have been done to study palaeohydrogeology and effects of the Äspö HRL tunnel.

Hydrogeological support is provided to active and planned experiments at Äspö.

Scope of work for 2007

One of the main tasks is the development of the integrated Äspö site description. The numerical groundwater flow and transport model is an important part of the site description. The groundwater model is to be continuously developed and calibrated. The intention is to develop the model to a tool that can be used for predictions, to support the experiments, and to test hydrogeological hypotheses.

Another task during 2007 is to continue the development of a more detailed model of hydraulically conductive structures at the main experimental levels below about –400 m level.

The effects of blasts in and around the Äspö HRL and the impact of earthquakes in Sweden and abroad will be analysed and documented. As a first step, any disturbances that can be coupled to the blasting of the TASQ-tunnel will be identified, and as a second step, possible effects of some blasts for the Clab-2 construction will be investigated. The effects of the earthquakes will also be documented. The work is a reference for the understanding of dynamic influences on the groundwater around a future final repository.

The work during 2007 also comprises activities concerning the Hydrogeological Monitoring, see Section 2.3.1.

2.3.1 Hydro Monitoring Programme

Background

The hydro monitoring programme is an important part of the hydrogeological research and a support to the experiments undertaken in the HRL. The programme had also had legal grounds. It was conditioned by the water rights court, when granting the permission to execute the construction works for the tunnel, that a monitoring programme should be put in place and that the groundwater head conditions should continue to be monitored until the year 2004.

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 and in the tunnel. 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, Mjälén, Bockholmen, and some boreholes on the mainland at Laxemar. The tunnel construction started in October 1990 and the first pressure measurements from tunnel drilled boreholes were included in the HMS in March 1992. The tunnel excavation began to affect the groundwater level in many surface boreholes during the spring 1991.

Objectives

The scientific grounds of maintaining the hydro monitoring programme are:

- To establish a baseline of the groundwater head and groundwater flow situations.
- To provide information about the hydraulic boundary conditions for the experiments in the HRL.
- To provide data to various model validation exercises, including the comparison of predicted head with actual head.

Present status

The measuring system is at present working satisfactorily. 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 different sections, and the pressure is measured by means of pressure transducers. During the last years a number of surface boreholes have been handed over to SKB's site investigations in Oskarshamn, and some malfunctioning packer systems in boreholes have been removed. Water seeping into the tunnel is diverted to trenches and further to 25 weirs where the flow is measured. During 2006, transducers for measurements of temperature, humidity and pressure of tunnel air have been installed. The measured data is relayed to a central computer situated at the Äspö office through cables and radio-wave transmitters. Manual levelling is also obtained from the surface boreholes once a month. Weekly quality controls of preliminary data are performed. Calibration of data is performed three to four times annually. This work involves comparison with the levels checked manually in boreholes and weirs. Once a year, the data is transferred to SKB's site characterisation database, Sicada.

Scope of work for 2007

The activities during 2007 comprise operation, maintenance and documentation of the HMS system. In particular the management organisation will be improved. Equipment that is out of order will be exchanged or renovated, and the measuring points from the previous years will be maintained. However, automatic monitoring in surface boreholes is successively replaced by monthly manual levelling. Semi-automatic transfer of data from HMS to Sicada three to four times annually will be implemented.

2.4 Geochemistry

Background and objectives

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.

One of the overall main tasks within the geoscientific program is to develop an integrated site description of the Äspö HRL. The use of the achieved knowledge will facilitate the understanding of the geochemical conditions and the development of underground facilities in operation. The intention is to develop the model as to be used for predictions, to support and plan experiments, and to test hydrogeochemical hypotheses. This is important in terms of distinguishing undisturbed and disturbed conditions. In general hydrogeochemical support is provided to active and planned experiments at Äspö HRL.

Present status

The current groundwater model of Äspö refers to the work performed in 2002 in the Geomod project. A large number of new geochemical data from the groundwater system both at depth and from surface boreholes has been collected since then and a new modelling exercise is needed in order to up-grade the groundwater mixing model which continues to be an issue in the geochemical description of the Äspö site. Integrated work has also been performed within the project Äspö models 2005.

Oxygen penetration into the basement rock is one of the crucial questions to be understood in the site descriptive models developed within SKB site investigation programme whereas redox parameters are only measured within one project, the Prototype Repository, and consequently needed for the efforts of an up-graded Äspö model as well. Previous works, suggest that further data is needed from groundwater as well as fracture minerals in order to better understand the redox-processes involved.

Scope of work 2007

It is suggested that a multi-component modelling exercise will be developed to better define the end-members. A key element in this is the review and improvement of the current conceptual model of groundwater mixing at Äspö, similarly to what has been performed in SKB's work with site descriptive models within their site investigation programme.

Using a combination of tools, including isotope techniques, the major hydrogeological characteristics of groundwater and redox changes should be studied in the Äspö tunnel at different depth. As a complement to ongoing microbial studies at Äspö, a general task may be set up to support, qualitative and quantitative, changes within the tunnel and with depth as to give a baseline for several parameters (redox-related parameters).

These studies should be made in two phases. Initially this activity needs to have a focus on a) a review of what has been made to date and, b) identify the needs for future activities. The second phase should include the formulation of the experimental activity. The outcome of these studies may also be used to develop the measured parameters within the groundwater monitoring program (see Section 2.4.1).

2.4.1 Monitoring of Groundwater Chemistry

Background

- During the Äspö HRL construction phase, different types of 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.

Objectives

- 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

- All ongoing projects at Äspö HRL have the possibility to request additional sampling of interest for their projects in conjunction to the sampling campaign set to be performed around September - October each year. The results from year 2006 are in the same range as previous years with some exception. In the last campaign biogeochemical parameters (ATP) were sampled and analysed. The aim was to see whether interesting data may be added to the programme and to provide new analysis to projects performed at Äspö HRL. Unfortunately sample preparation gave unstable results using the same analytical measuring protocol (and instrument) as at the Clab laboratory (where this analysis is routine). Whether this analysis is interesting for the future is now being discussed.

Scope of work for 2007

The tasks to be performed during 2007 are:

- Evaluation of time series of collected data (i.e. the monitoring programme).
- Continued development of the monitoring programme as additional sampling points may be needed to fulfil additional needs of this monitoring programme or SKB's programme for site descriptive models.
- Continued development of the analysis tools and methods.
- Inventory of needs of new field sampling instruments.
- Reviews and updates of method descriptions belonging to the Äspö HRL.

2.5 Rock mechanics

Rock Mechanics 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 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.
- During 2007 work will mainly be performed within the Äspö Pillar Stability Experiment, see Section 2.5.2.

2.5.1 Stress measurements, core dinking

Background and objectives

The purpose of the project is to study the conditions under which core dinking occur by drilling in the vicinity of the area for the Äspö Pillar Stability Experiment (Apse).

Experimental concept

A total of four holes were drilled vertically in the tunnel floor (KQ0062G05, KQ0062G06, KQ0061G10 and KQ0062G04). Core dinking in solid and hollow cores was observed in the first three of these. Two successful installations of a Borre probe used for stress measurements were made.

Present status

A three-dimensional RVS model of fracturing around the Apsé experimental volume has been developed with the purpose to better understand the possible displacements and stress re-distributions that may have occurred during the development of the Äspö Pillar Stability Experiment.

Scope of work for 2007

To complete the project a three-dimensional equivalent-continuum simulation of the volume around the Pillar Stability Experiment will be carried out.

2.5.2 Äspö Pillar Stability Experiment

Background

Very little research on the rock mass response in the transitional zone (accelerating frequency of micro-cracking) has been carried out. It is therefore important to gain knowledge in this field since the spacing of the canister holes gives an impact on the optimisation of the repository design.

A Pillar Stability Experiment was therefore initiated at Äspö HRL as a complement to an earlier study at URL (Underground Research Laboratory) performed by AECL in Canada. AECL's experiment was carried out during the period 1993–1996 in an almost unfractured rock mass with high *in situ* stresses and brittle behaviour. The major difference between the two sites is that the rock mass at Äspö is fractured and the rock mass response to loading is elastic. The conditions at Äspö HRL therefore make it appropriate to test a fractured rock mass response in the transitional zone.

Objectives

The Äspö Pillar Stability experiment is a rock mechanics experiment which can be summarised in the following three main objectives:

- Demonstrate the capability to predict spalling in a fractured rock mass.
- Demonstrate the effect of backfill (confining pressure) on the propagation of micro-cracks in the rock mass closest to the deposition hole.
- Comparison of 2D and 3D mechanical and thermal predicting capabilities.

Experimental concept

To achieve the objectives a new drift was excavated in Äspö HRL to ensure that the experiment was carried out in a rock mass with a virgin stress field. In the new drift a vertical pillar was constructed in the floor between two large boreholes, each with a diameter of 1.8 m. The pillar was designed in such a way that spalling will occur in the walls of the boreholes when the pillar is heated.

The two large vertical holes were drilled in the floor of the tunnel so that the distance between the holes is one metre. To simulate confining pressure in the backfill (0.7 MPa), one of the holes was subjected to an internal water pressure via a liner. Convergence measurements, linear variable displacement transducers (LVDT), thermistors and an acoustic emission system were used to monitor the experiment. The experiment drift has a rounded floor, see Figure 2-1, to concentrate the stresses in the centre of the drift.



Figure 2-1 The Apse experimental drift shortly after the excavation.

Present status

All field work is finished and the final reporting is practically finished. The major reference for the experiment will be published as a TR-report which also will be published as a doctoral thesis. Those publications will be printed the first quarter of 2007.

All monitoring data from the experiment has been stored in SKB's site characterisation database Sicada.

Three journal papers describing the experiment design, the integrated analysis and numerical modelling have been submitted for review and will hopefully be published during 2007.

The methodology and results from the back calculation of the temperatures in the experiment volume has been presented at the GeoProc 2006 conference in Nanjing, China /Andersson *et al.*, 2006/.

Scope of work for 2007

The work planned for 2007 is mainly editing of final reports and papers. Observations and numerical back calculations of the rock mass response during the experiment is planned to be presented at the 1st Canada – U.S. Rock Mechanics Symposium in Vancouver, Canada.

3 Natural barriers

3.1 General

To meet Stage goal 3, experiments are performed to further develop and test methods and models for description of groundwater flow, radionuclide migration, and chemical conditions at repository depth, see Figure 3-1.

The experiments are related to the rock, its properties and *in situ* environmental conditions. The programme at Äspö HRL includes projects with the aim to evaluate the usefulness and reliability of different conceptual and numerical models and to develop and test methods for determination of parameters required as input to the models. The overall purposes are to:

- Improve the scientific understanding of the final repository's safety margins and provide input data for assessments of the repository's long-term safety.
- Obtain the special material needed to supplement data from the site investigations in support of an application for a siting permit for the final repository.
- Clearly present the role of the geosphere for the barrier functions: isolation, retardation and dilution.

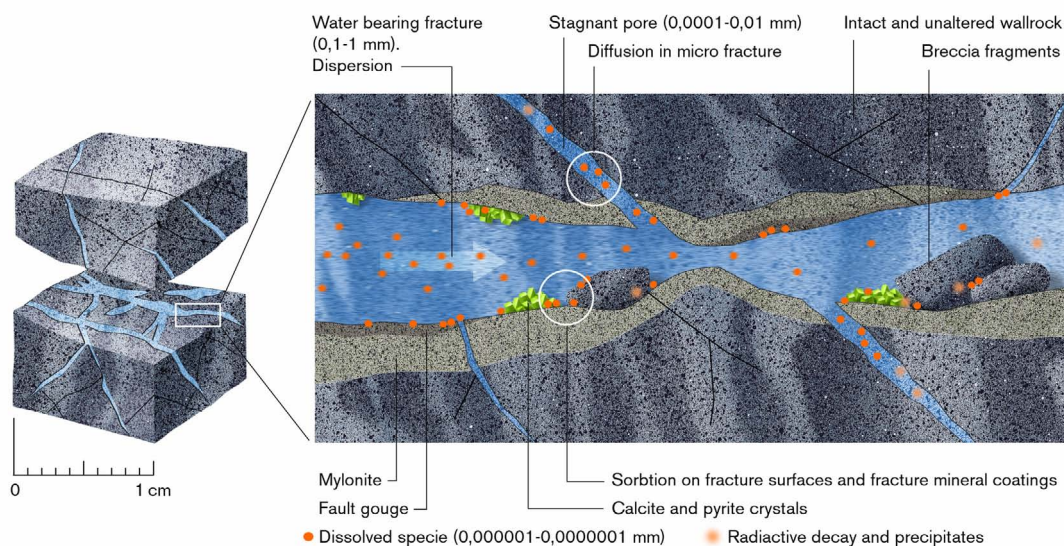


Figure 3-1 Illustration of processes that influence migration of species along a natural rock fracture.

The ongoing experiments and projects within the Natural Barriers at Äspö HRL are:

- Tracer Retention Understanding Experiments.
- Long Term Sorption Diffusion Experiment.
- Colloid Dipole Project.
- Microbe Projects.
- Matrix Fluid Chemistry Continuation.
- Radionuclide Retention Experiments.

- Padamot.
- Fe-oxides in fractures.
- Swiw-tests with Synthetic Groundwater.
- Äspö Task Force on Groundwater Flow and Transport of Solutes.

3.2 Tracer Retention Understanding Experiments

Background

A programme has been defined for tracer tests at different experimental scales, the so-called Tracer Retention Understanding Experiments (True) /Bäckblom and Olsson 1994/. The overall objective of the defined experiments is to increase the understanding of the processes which govern retention of radionuclides transported in crystalline rock, and to increase the credibility in models used for radionuclide transport calculations used in licensing of a repository.

Objectives

The True experiments should achieve the following general objectives:

- Improve understanding of radionuclide transport and retention in fractured crystalline rock.
- Evaluate to what extent concepts used in models are based on realistic descriptions of rock and whether adequate data can be collected during site characterisation.
- Evaluate the usefulness and feasibility of different approaches to modelling radionuclide migration and retention. Provide *in situ* data on radionuclide migration and retention.

During 2001, it was decided to collect all future True work in two separate projects: True Block Scale Continuation and True-1 Continuation. Although the experimental focus is placed on the respective True experimental sites developed at the Äspö HRL, integration and co-ordination of experimental activities at and between the sites is emphasised in the planned future work.

Experimental concept

The basic idea is to perform a series of *in situ* tracer tests with progressively increasing complexity. In principle, each tracer experiment will consist of a cycle of activities beginning with geological characterisation of the selected site, followed by hydraulic and tracer tests. An option is to characterise the tested pore space and analyse tracer fixation using epoxy resin injection. Subsequently, the tested rock volume will be excavated and analysed with regards to flow-path geometry and tracer concentration.

Together with supporting laboratory studies of diffusion and sorption characteristics made on core samples, the results of the *in situ* tests will provide a basis for integrating data on different scales, and testing of modelling capabilities for radionuclide transport up to a 100 m scale, see Figure 3-2. A test of the integration and modelling of data from different length scales and assessment of effects of longer time perspectives, partly based on True experimental results, is made as part of Task 6 in the Task Force on Modelling of Groundwater Flow and Transport of Solutes, see Section 3.11.

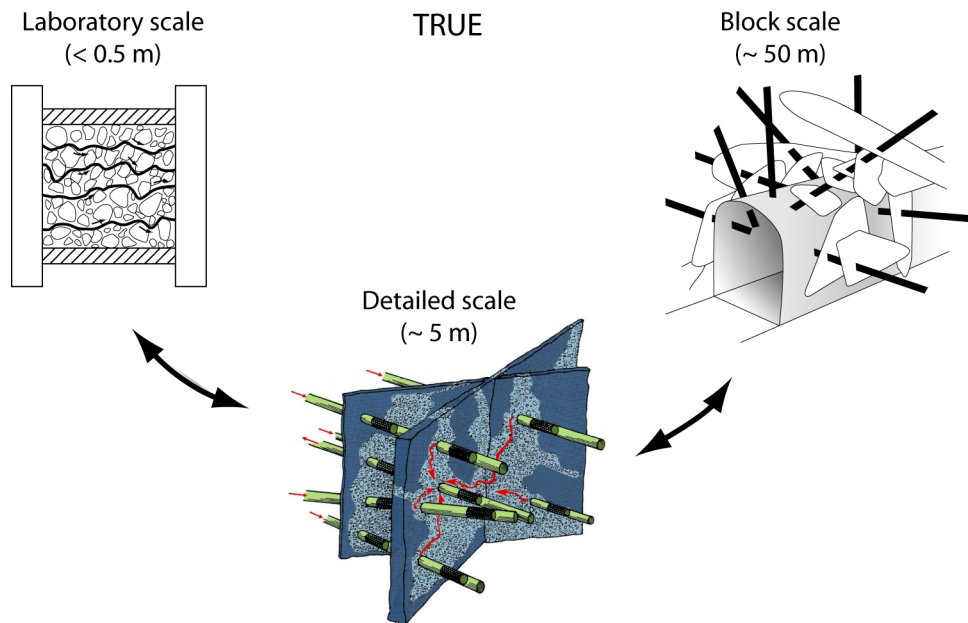


Figure 3-2 Schematic representation of transport scales addressed in the True programme.

3.2.1 True Block Scale Continuation

The True Block Scale Continuation (BS2) project has its main focus on the existing True Block Scale site. The True Block Scale Continuation is divided into two separate phases:

- BS2a Complementary modelling work in support of BS2 *in situ* tests. Continuation of the True Block Scale (phase C) pumping and sampling including employment of developed enrichment techniques to lower detection limits.
- BS2b Additional *in situ* tracer tests based on the outcome of the BS2a analysis. *In situ* tests are preceded by reassessment of the need to optimise/remediate the piezometer array. The specific objectives of BS2b are to be formulated on the basis of the outcome of BS2a.

Objective

The overall objective of BS2 can be summarised as: “Improve understanding of transport pathways at the block scale, including assessment of effects of geometry, macro-structure and micro-structure”. Special consideration is in this context put on the possibility to explore the role of more low-permeable parts of the studied fracture network, including background fractures, the latter without developed wall rock alteration and fault gouge signatures.

Present status

During the year the four evaluation reports produced by the four modelling teams /Poteri 2005, Billaux 2005, Fox *et al.* 2005, Cheng and Cvetkovic 2005/ have been finalised and printed. Furthermore, the final report of the project (will be published as SKB TR-06-42) has been produced in a final draft version, submitted to the Steering and Technical Committees.

The principal results of the project were given in two papers presented at the AGU (American Geophysical Union) Fall meeting in San Francisco, December 2006.

Scope of work for 2007

The remaining work involves updating and finalisation of the final report taking received review comments into account.

3.2.2 True Block Scale Continuation (BS3)

In the aftermath to the BS2 project a discussion has been in process to set up a second step of continuation of the True Block Scale (BS3). This step would not have specific experimental components, but rather emphasise consolidation and integrated evaluation of all relevant True data and findings collected so far. This integration would not necessarily be restricted to True Block Scale, but could also include incorporation of True-1 and True-1 Continuation results.

Scope of work for 2007

Three manuscripts for journal papers are planned to be prepared summarising True Block Scale and True Block Scale Continuation results.

The first one would focus on modelling flow and advective transport, based on the structural and hydraulic information. This is an important topic where the possibilities and limitations of such modelling will be elaborated. Predictive modelling would be compared to outcomes of *in situ* tests and interpreted. Finally, a calibration would be used to infer flow-related transport parameters. Both True Block Scale and True Block Scale Continuation test results would be presented.

The second two manuscripts would be presented as a series. In these papers results and interpretations of tests from True Block Scale and True Block Scale Continuation would be presented. These latter tests increase the transport scale to 10-20 m, they provide additional evidence for retention and most importantly provide (indirect) information about retention properties of background (non-fault, Type 2) versus (fault, Type 1) fractures.

- In Part 1 experimental results and predictions will be summarised for retention properties, i.e. using information from micro- and macro-characterisation (independent of obtained breakthrough curves in the field) to “predict” the outcome of *in situ* tests; this will show the difficulties involved and some elements of success.
- In Part 2 the evaluation results are summarised where effective retention properties are estimated, along similar lines as when evaluating the True-1 experiments, see also Section 3.2.3. The estimated effective retention properties will be compared to those inferred from micro-scale characterisation. A discussion will be included on the possible extension to PA scales (in the spirit of Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes Task 6, see Section 3.11).

3.2.3 True-1 Continuation

The True-1 Continuation project is an extension of the True-1 experiments, and the experimental focus is primarily on the True-1 site. The continuation includes performance of the planned injection of epoxy resin in Feature A at the True-1 site and subsequent overcoring and analysis (True-1 Completion, see Section 3.2.4). Additional activities include: (a) test of the developed epoxy resin technology to fault rock zones distributed in the access tunnel of the Äspö HRL (Fault Rock Zones Characterisation project), (b) laboratory sorption experiments for the purpose of verifying K_d -values calculated for altered wall rock and fault gouge, (c) writing of scientific papers relating to the True-1 project. A previously included component with the purpose of assessing fracture aperture from radon data has been omitted due to resources prioritisation.

Objectives

The objectives of True-1 Continuation are:

- To obtain insight into the internal structure of the investigated Feature A, in order to allow evaluation of the pore space providing the observed retention in the experiments performed (see section on True-1 Completion below).
- To provide an improved understanding of the constitution, characteristics and properties of fault rock zones (including fault breccia and fault gouge) (Fault Rock Zones Characterisation).
- To provide quantitative estimates of the sorption characteristics of the altered rim zone and fault rock materials of fault rock zones.

The scope of work for the field and laboratory activities includes:

- Characterisation of a number of typical fault rock zones of variable thickness. Injection of epoxy resin and subsequent sampling. Assessment of pore space and quantification of *in situ* porosity of fault gouge material.
- Writing of three scientific papers accounting for the SKB True Project team analysis of the True-1 experiments.
- Batch sorption experiments on rim zone and fault gouge materials from the True Block Scale site and from other locations along the access tunnel.
- Injection of epoxy resin into the previously investigated Feature A, with subsequent excavation and analyses (True-1 Completion, see below).

Present status

The progress within the project is in part seriously hampered by the heavy involvement of the project participants in the SKB Site characterisation and site modelling programmes.

The first two of the scientific articles on True-1 have been submitted to Water Resource Research and review comments have been received from three anonymous reviewers (Part 1. Experimental results, conceptual model and effective parameter estimation, Part 2. Micro-scale characterisation of retention parameters).

A draft report is available on the image analysis of the sectioned resin impregnated structures. Likewise, an incomplete draft of the complementary sorption and leaching experiments on rim zone and fault gouge material has been produced.

Scope of work for 2007

Work for 2007 include updating of the two journal articles submitted to Water Resources Research followed by submittal of the concluding article in the planned series (Part 3 - Effect of micro-scale heterogeneity).

Furthermore, plans are to at least complete the Fault Rock Zones image analysis report and produce a first draft of the final report of the Fault Rock Zones Characterisation project.

Finally, the draft report on the complementary laboratory sorption and leaching experiments will be updated to full top copy.

3.2.4 True-1 Completion

The True-1 Completion project is a sub-project of the True-1 Continuation project with the experimental focus placed on the True-1 site. True-1 Completion constitutes a complement to already performed and ongoing projects. The main activity within True-1 Completion is the injection of epoxy with subsequent over-coring of the fracture and following analyses of pore structure and, if possible, identification of sorption sites. Furthermore, several complementary *in situ* experiments will be performed prior to the epoxy injection. These tests are aimed to secure important information from Feature A and the True-1 site before the destruction of the site, the latter which is the utter consequence of True-1 Completion.

The True-1 Completion project is collaborating with the Colloid Project in the planning and realisation of *in situ* tracer tests with latex colloids in Feature A.

A complication for the scheduling of planned future work at the True-1 site lies in the fact that the True-1 and LTDE sites are hydraulically connected. In view of the urge for a relative hydraulic tranquillity on the part of LTDE, a priority for advancing LTDE has been set by SKB. Consequently, the resin impregnation at the True-1 site will be postponed until vital parts of LTDE have been accomplished. According to the present plans resin injection will be possible 2007 at the True-1 site.

Objectives

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 tracer tests with relevance to the ongoing SKB site investigation programme, for instance *in situ* K_d - 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 by mineralogical-chemical characterisation of the sorption sites for Cs.
- To update the conceptual micro structural and retention models of Feature A.

The scope of work for identified field and laboratory activities related to the True-1 site includes:

- Re-instrumentation of boreholes KXTT3 and KXTT4 in order to; a) ensure that the planned activities at the True-1 site do not in anyway interfere with the other projects at Äspö HRL in general and LTDE in particular and b) successfully perform the complementary tracer tests, the epoxy injection and the subsequent over coring of KXTT3 and KXTT4.
- Complementary tracer tests, Swiw-tests and cation exchange capacity (CEC) tests.
- Epoxy injection, over coring of KXTT3 and KXTT4, and dismantling of infrastructure at the True-1 site.
- Analysis of core material using picture analysis, microscopy and chemical mineralogy aiming to improve the description of the inner structure of Feature A and possible identification of the immobile zones involved in the noted retention.

Present status

The realisation of the remaining complementary tracer tests have been the major activity during 2006. The performance of the tests was challenged by the observed physical changes of Feature A. The observed changes have resulted in complementary characterisation of the flow situation within Feature A assumed inflicted by observed physical changes of Feature A. The extent of the physical changes of Feature A was studied through a series of dilution tests in KXTT4. The dilution tests showed that the observed changes are real and affect the flow to the extent that the prerequisites for the CEC-test have been changed. Furthermore, a pre-test was successfully performed using the set up, flows and concentrations planned in the upcoming CEC-test.

The magnitude of the observed flow changes in borehole KXTT4 exceeds a 50% decrease in flow compared to the measured flows during the multi hole reciprocal cross flow tests performed in May of 2006. In comparison to the historic flows of the sorbing tracer tests (STT) in the late 1990-ties the decrease are somewhat smaller, approximately 30%. It can be expected that the flow will vary over time due to changes in the hydraulic boundary conditions caused by e.g. water sampling and seasonal variations. However, the magnitude and the abruptness of the observed changes implicate a physical nature of the changes. At present there is no unambiguous theory to the cause of the physical changes. There are two main theories of contributing factors to the observed physical changes; the blasting to widen a tunnel at the -450 m level and microbial activities. Important observations, such as precipitation of Mn_3O_4 and significant contents of total carbon in water samples, were made at the True-1 site at the time of the blasting. However, the observed changes did not appear until two months later. The observed physical changes may be a delayed effect of the blasting but may also be due to microbial activity. Microbes often form different kinds of slime that in conjunction with colloids and loosened gouge material may very well contribute to the clogging of flow paths.

Furthermore, the preliminary results from the multi hole reciprocal cross flow tests with the objective to examine and evaluate effects of channelling in Feature A implicate that the flow in Feature A differ from the homogeneous case and that channelling is more developed with higher pumping flows. The final evaluation of the tests is ongoing.

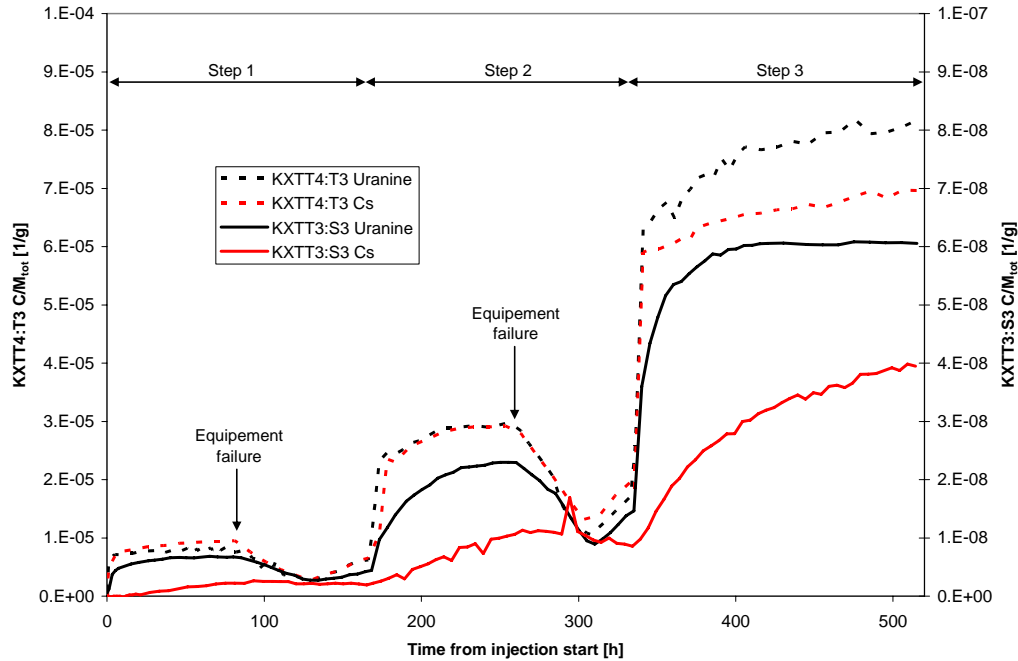


Figure 3-3 Tracer injection (KXTT4:T3) and breakthrough (KXTT3:S3) curves from the CEC-test.

The CEC-test, with the objective to study the cation exchange capacity of Cs *in situ* in a single fracture, was performed in November – December 2006. The observed changes of Feature A have altered the prerequisites for the CEC-test. The test was originally planned to be performed under the same conditions as the STT in 1999. Due to the physical changes of Feature A the pumping flow in KXTT3 had to be doubled in order to maintain the desired flow in Feature A in KXTT4. The increase in pumping flow will, in accordance with the results of the multi hole reciprocal cross flow tests, lead to a more developed channelling in the flow path. This is however not deemed to affect the results of the test. Results from the CEC-test indicate an almost complete recovery of the injected Uranine and significant retardation of Cs, see Figure 3-3. Further analysis and evaluation of the CEC-test is ongoing.

Scope of work for 2007

The main tasks for 2007 are:

- Concluding evaluation and reporting of the performed complementary tracer tests.
- Epoxy injection and dismantling of the infrastructure of the True-1 site.
- Over-coring experimental boreholes after sufficient time of decay for the radioactive Cs-131 used in CEC-test.
- Preparation of core samples and subsequent picture analysis, γ -spectroscopy, microscopy and chemical mineralogy.

3.3 Long Term Sorption Diffusion Experiment

Background

The Long Term Sorption Diffusion Experiment (LTDE-SD) constitutes a complement to performed diffusion and sorption experiments in the laboratory, and is a natural extension of the performed *in situ* experiments, e.g. the True-1 and the True Block Scale experiments. The difference is that the longer duration (approximately 5-7 months) and the well controlled geometry of the experiment is expected to enable an improved understanding of diffusion and sorption both in the vicinity of a natural fracture surface and in the matrix rock.

Matrix diffusion studies using radionuclides have been performed in several laboratory experiments. Some experimental conditions such as pressure and natural groundwater composition are however difficult to simulate with good stability in long-term laboratory experiments. Investigations of rock matrix diffusion at laboratory scale imply that one uses rock specimens in which damage due to drilling and unloading effects (rock stress redistribution) may have caused irreversible changes of the rock properties. Matrix diffusion in non-disturbed rock is therefore preferably investigated *in situ*. Through the proposed experimental technique one will also obtain some information of the adsorption behaviour of some radionuclides on exposed granitic rock surfaces.

Objectives

The LTDE Sorption Diffusion experiment aims at increase the scientific knowledge of sorption and diffusion under *in situ* conditions and to provide data for performance and safety assessment calculations. Specific objectives of LTDE-SD are:

- To obtain data on sorption properties and processes of individual radionuclides on natural fracture surfaces and internal surfaces in the matrix.
- To investigate the magnitude and extent of diffusion into matrix rock from a natural fracture *in situ* under natural rock stress conditions and hydraulic pressure and groundwater chemical conditions.
- To compare laboratory derived diffusion constants and sorption coefficients for the investigated rock fracture system with the sorption behaviour observed *in situ* at natural conditions, and to evaluate if laboratory scale sorption results are representative also for larger scales.

Experimental concept

A core stub with a natural fracture surface is isolated in the bottom of a large diameter telescoped borehole. In addition a small diameter borehole is drilled through the core stub into the intact undisturbed rock beyond the end of the large diameter borehole. A cocktail of non-sorbing and sorbing tracers are circulated in the test section for a period of approximately 5-7 months after which the core stub is over-cored, and analysed for tracer content and tracer fixation, see Figure 3-4.

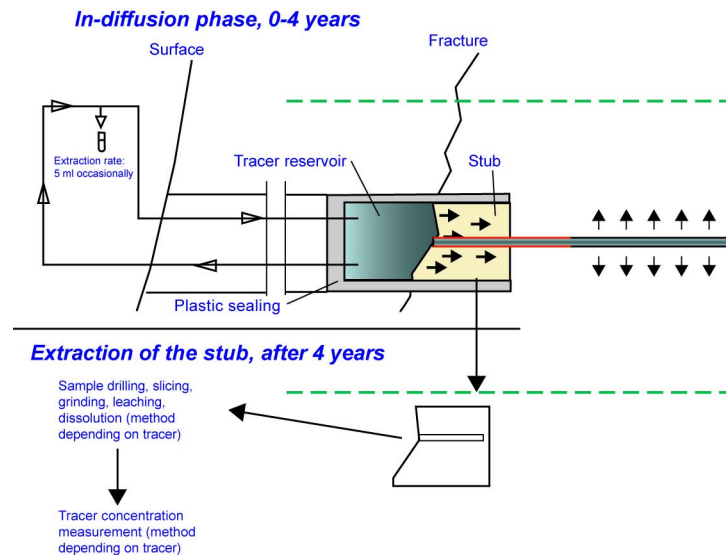


Figure 3-4 LTDE-SD experimental concept including injection borehole in contact with a fracture surface.

The experiment is focussed on a typical conductive fracture identified in a pilot borehole (KA3065A02). A telescoped large diameter borehole (300/197 mm) (KA3065A03) is drilled sub-parallel to the pilot borehole in such a way that it intercepts the identified fracture some 10 m from the tunnel wall and with an approximate separation of 0.3 m between the mantle surfaces of the two boreholes.

The natural fracture as seen on the surface of the stub is sealed off with a polyurethane cylinder and a peek lid, which constitutes a “cup-like” packer. The remainder of the borehole will be packed off with a system of one mechanical and two inflatable packers. The small diameter (36 mm) extension is packed off using a double packer system leaving a 300 mm long section that will be exposed for the radionuclides. The system of packers and an intricate pressure regulating system will be used to eliminate the hydraulic gradient along the borehole, see Figure 3-5.

During the circulation of tracer, samples of water will be collected at various times over the duration of the experiment. The redox situation in the circulation loop will be monitored continuously with a flow through an electrochemical cell, which will measure pH, Eh and temperature. Strategically positioned filter will ensure limited build-up of microbes in the water circulation loop. After completion of tracer circulation, the core stub will be over-cored, sectioned and analysed for different radionuclide tracers.

The project also involves a variety of mineralogical, geochemical and petrophysical analyses. In addition, laboratory experiments with the core material from KA3065A03 (Ø 277, 177 and 22 mm) and the fracture “replica” material will be performed. Both “batch” sorption and through diffusion experiments are planned.

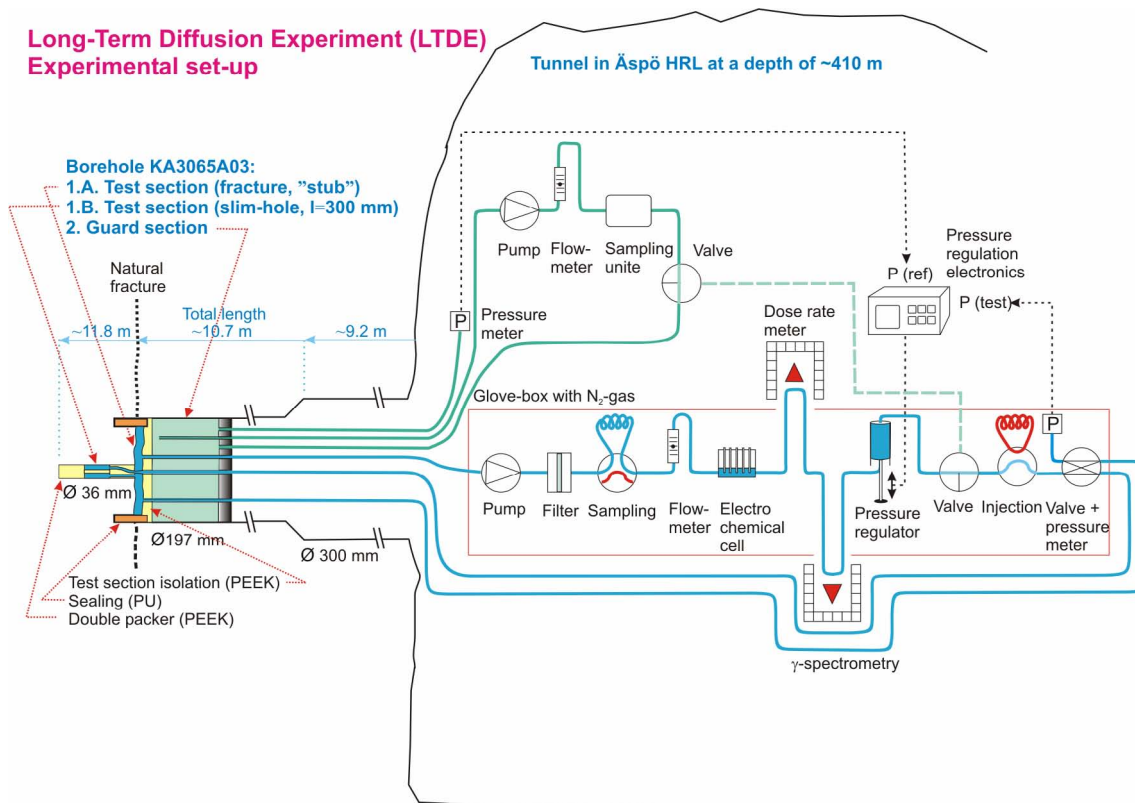


Figure 3-5 LTDE-SD experimental set-up in the experimental borehole including the water circulation system to the test-section and the hydraulic pressure control system.

Present status

Adjustments and modifications of the test equipment were carried out during the first six months 2006 in order to improve the experimental set-up prior to start of the *in situ* diffusion and sorption test. A new cooling device was installed in the experimental container making it possible to reduce the temperature from 30 °C down to 16-20 °C. The small leakage in the circulation and pressure regulating equipment in the experimental container was identified and stopped. The automatic alarm functions in the system were updated. The electrochemical flow cell (pH, Eh and temperature measurements) in the glove box was equipped with extra shield and ground connections to reduce disturbances in the data signals. The location in the glove box was also changed in order to facilitate practical work with injection and water sampling.

The *in situ* sorption diffusion experiment was started on September 27th. A tracer cocktail with 22 radionuclides, which included the range from non-sorbing (³⁶Cl, ³⁵S) to strongly sorbing tracers (¹⁷⁵Hf, ²³⁶U), was injected. The results from the test running of experiment before injection of radionuclides showed that it is not possible to keep redox potential at negative values in the test section groundwater. However the three redox sensitive radionuclides ⁹⁹Tc, ²³⁶U and ²³⁷Np was included in the tracer cocktail since ²³⁶U and ²³⁷Np are relatively strong sorbing even under oxidising conditions (K_d 0.01). It is also anticipated a redox front existing a few centimetres into the rock making stronger sorption of ²³⁶U, ²³⁷Np and also ⁹⁹Tc sorbing at short distance from fracture surface.

On-line measurement of the radioactivity concentration of the gamma emitting tracers in the test section groundwater is ongoing since start of experiment. Test section has also been sampled on a regular basis by extracting small volumes of water to be analysed for the non-gamma emitting tracers by means of scintillation or mass spectrometry, depending on tracer. Test section was rapidly mixed and the concentration of the strongest sorbing tracers decreased relatively fast from the water phase as expected, while the non to slightly sorbing tracers levels out on a more or less constant concentration.

Scope of work for 2007

The *in situ* experiment, with on-line HPGe measurement and sampling is planned to continue until February/March 2007. Thereafter the core stub and the rock surrounding the small diameter extension borehole will be extracted by over core drilling. This activity will be followed by sectioning and analyses of tracer content and fixation in removed core stub and rock core encompassing the small diameter borehole.

Laboratory diffusion and sorption measurements on core samples from the small diameter extension borehole, initially planned for 2006, will be performed using the same radionuclides as in the *in situ* experiment. The results from the laboratory experiments above 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* experiments. In addition, the representativeness of laboratory scale sorption results also for larger scales will be evaluated.

3.4 Colloid Project

Background

Colloids are small particles in the size range 10^{-6} to 10^{-3} mm. The colloidal particles are of interest for the safety of a repository for spent nuclear fuel because of their potential to transport radionuclides from a defect waste canister to the biosphere. Colloids are also of interest, since the bentonite barrier can release colloids when in contact with dilute glacial waters, and give bentonite erosion. SKB has for more than 10 years conducted field measurements of colloids. The outcome of the studies performed nationally and internationally concluded that the colloids in the Swedish granitic bedrock consist mainly of clay, silica and iron hydroxide particles and that the mean concentration is around 20–45 ppb which is considered to be a low value /Laaksoharju *et al.* 1995/. The low colloid concentration is controlled by filtration in filling material etc., which reduces both the stability of the colloids and their mobility in aquifers.

It has been argued that e.g. plutonium is immobile owing to its low solubility in groundwater and strong sorption onto rocks. Field experiments at the Nevada Test Site, where hundreds of underground nuclear tests were conducted, indicate however that plutonium is transported as colloids in the groundwater. The $^{240}\text{Pu}/^{239}\text{Pu}$ isotope ratio of the samples established that an underground nuclear test 1.3 km north of the sample site is the origin of the plutonium /Kersting *et al.* 1999/.

The findings of potential transport of solutes by colloids and access to more sensitive instruments for colloid measurements motivated a Colloid Project at Äspö HRL. The project was initiated by SKB in 2000 and in the end of 2006 the Colloid Dipole project started as a continuation.

Objectives

The aims and objectives of the Colloid Project are to study:

- The stability and mobility of colloids.
- Measure background colloid concentration in the groundwater at Äspö.
- Bentonite clay as a source for colloid generation in the scenario of intrusion of diluted glacial water.
- The potential of colloids to enhance radionuclide transport.

The results from the project will be used mainly in the future development of safety assessment modelling of radionuclide migration in the presence of bentonite as well as natural colloids.

Experimental concept

The Colloid Project comprises laboratory experiments as well as field experiments – Background measurements, Borehole specific measurements and the Colloid Dipole experiment. The Colloid Dipole experiment is on going whereas the following parts are finalised and reported:

- *Laboratory experiments* were performed to investigate in detail the chemical changes, size distribution and the effects from Na versus Ca rich bentonite associated with colloid generation /Wold and Eriksen 2002, Karnland 2002/.
- *Background measurements* were performed to measure the natural background colloid concentrations in eight different boreholes during 2002, representing groundwater with different ionic strength, along the Äspö HRL-tunnel. The colloid content at Äspö was found to be less than 300 ppb and at repository level it is less than 50 ppb /Laaksoharju and Wold 2005/.
- *Borehole specific measurements*, with the aim to measure the colloid generation properties of bentonite clay in contact with groundwater prevailing at repository depth, were made in 4 boreholes along the Äspö tunnel and 2 boreholes at Olkiluoto in Finland. The results indicate that the colloid release from the bentonite clay at prevailing groundwater conditions is small and an increased water flow did not increase the colloid release from the bentonite /Laaksoharju and Wold 2005/.

Colloid Dipole experiment

The Colloid Dipole experiment is a fracture specific experiment performed within the Colloid Project during the time period 2004–2007. According to present one experiment has been performed in two nearby boreholes having the same basic geological properties, KXTT3 and KXTT4 intersecting Feature A at the True-site, were selected for the Colloid Dipole experiment. One of the boreholes will be used as an injection borehole (KXTT4) and the downstream borehole (KXTT3) will be used for monitoring. Since bentonite colloids are not stable in the saline groundwater at Äspö, fluorescent latex colloids was used. A cocktail containing three different latex with 50, 100 and 200 nm mean sizes plus a colour tracer will be injected into the injection borehole, see Figure 3-6. The colloidal content was measured with a fluorospectrophotometer and a Single Particle Counter (SPC). The result of major interest is the changes in colloid content prior and after the transport through the fracture, i.e. to get the filtration factors (α) for colloids. The outcome of the experiment was planned to be used to check performed model calculations and to develop future colloid transport modelling.

In addition, the actinide transport will be studied in the presence of colloids in a water bearing fracture. A core will be placed in a glove box and connected to a borehole in Äspö HRL, which one is not yet decided.

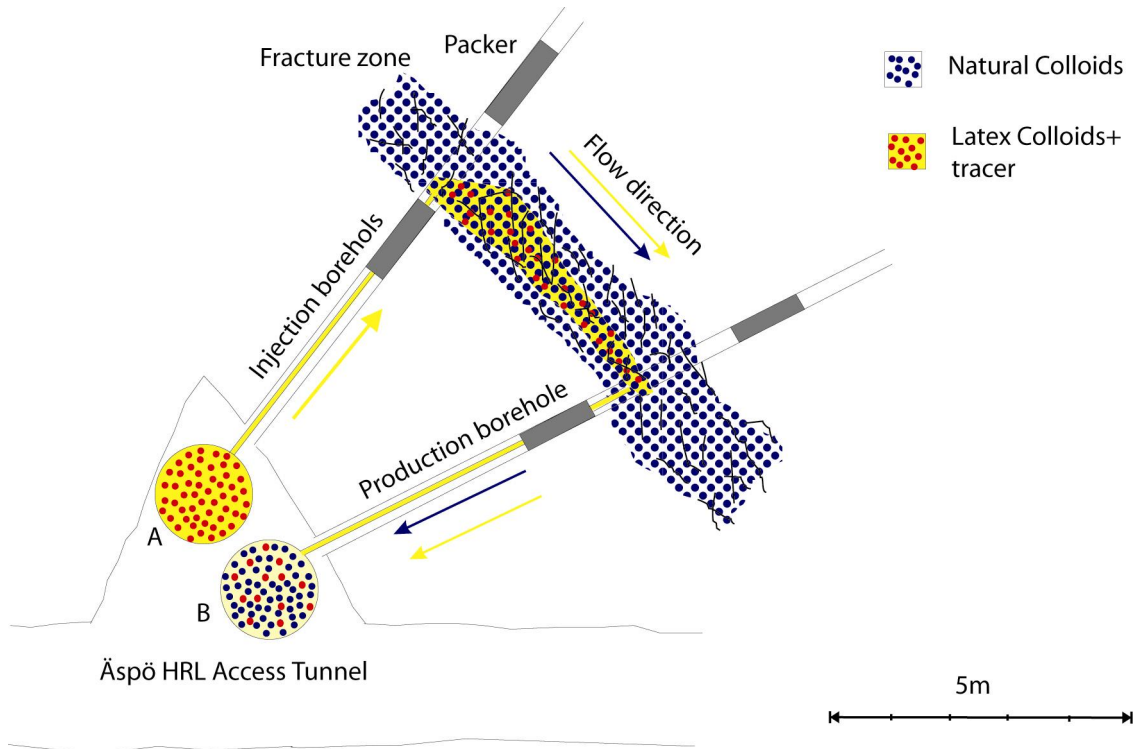


Figure 3-6 Colloid Dipole experiments – injection of latex colloids and monitoring of the injected and natural colloids in the production borehole.

Present status

Stability tests of bentonite colloids at different conditions have been performed in the laboratory at the Royal Institute of Technology.

The groundwater composition strongly influences processes as colloid erosion and colloid stability. A kinetic method to predict stability and determine critical coagulation concentration (CCC-values) for Na- and Ca-montmorillonite colloids in NaCl and CaCl₂ electrolyte has been developed. The results are summarised in a manuscript which will be sent for publication.

The influence of temperature on the stability of bentonite colloids has been studied in 10⁻³ M NaCl solutions. The results were published in Journal of Colloids and Interface Science in 2006 /García-García *et al.*, 2006/. This study will be extended to wider concentration ranges of NaCl and CaCl₂ as well as studies on other colloids.

The charge of the Al-OH groups in the edges of bentonite particles is pH-dependent due to protonation/deprotonation. A study is ongoing to investigate the stability of bentonite particles at different temperatures and the pH-range 3-10.

The interaction between mineral surfaces (e.g. granite) and bentonite colloids is currently studied to identify and quantify the effect on the stability of bentonite colloids.

Laboratory experiments at AECL in Canada have also been performed in the Quarried Block (QB) sample, a 1 m×1 m×0.7 m block of granite containing a single, complex, but well characterised, through-going, variable aperture fracture. The purpose of this experimental program was to provide additional information that cannot be obtained on the field-scale at Äspö regarding bentonite versus latex sphere colloid transport, particularly at low flow rates. Dipole tracer tests were performed with a separation distance of 380 mm. Five experiments using bentonite of the type MX-80 and 100 nm latex colloids were performed using deionised water at flow rates of 510, 45, and 6.2 mL/h. An additional experiment was performed by injecting a bentonite colloid (suspended in deionised water) into the Quarried Block, after it had been saturated with saline Äspö type water. The main findings are:

- In dilute water at high flow velocities of 0.4 m/h, typical of field-scale tracer tests, bentonite and latex colloids have similar transport properties, and are mobile with good recoveries.
- At lower flow velocities, closer to those of natural conditions, colloid transport is significantly reduced, particularly for bentonite. Bentonite and 100 nm latex colloids begin to display different transport behaviour, possibly due to differences in size distribution and surface properties. Transported bentonite colloids appear to be mainly in the small 4 to 15 nm size range, with the larger bentonite colloids remaining in the fracture.
- In saline ground waters bentonite colloids are flocculated and are not mobile.
- Bentonite colloids can become mobilised to some extent if saline water is replaced by dilute water under conditions of high flow.
- Colloid migration properties appear to influence the transport of co-injected solute tracer.

Lab experiments are ongoing at FZK-INE (Forschungszentrum Karlsruhe Institut für Nukleare Entsorgung) aiming at investigating the radionuclide behaviour in colloid-groundwater-fracture infill mineral system. Colloid stability ratios (W) were calculated from coagulation rates of MX-80 colloids measured as a function of the ionic strength varying from 0.001 M up to 1 M in NaCl or CaCl₂ media by Photon Correlation Spectroscopy (PCS) in the pH range 4-10. Additional laser induced breakdown detection (LIBD) measurements of the supernatants by decanting solutions after 1 and 4 months were performed. Both analytical methods show clearly the instability of colloids at the high ionic strength of the Äspö groundwater. Coagulation rate of bentonite colloids were determined in presence of fulvic acid (FA) 0.2 M (CaCl₂ solution) and pH~ 7.5. No significant change in the measured stability ratios could be observed as compared to the experiments in absence of organic matter. Additional performed LIBD measurements of supernatants, after 1 and 4 months colloid sedimentation, showed that colloids were still detectable. First experiments indicate that the conditioning of bentonite with FA prior to increase of the ionic strength increases colloid stability.

Interaction of radionuclides with bentonite colloids have been studied in batch experiments by water spiked with Sr, Cs, Am, Np, U and Pu at pH 7.5. In a second batch, MX-80 bentonite colloids were added. Evolution of the radionuclide and bentonite colloid concentrations was followed over 2 months by direct analysis of the solution and after ultracentrifugation. Radionuclide concentrations were analysed by LSC (liquid scintillation counter) and ICP-MS (inductively coupled plasma mass spectrometry).

Cs(I), Sr(II), and U(VI) spiked to the Äspö groundwater do not show any significant colloidal behaviour in presence or absence of MX-80 bentonite colloids. This result is in agreement with the behaviour of naturally occurring Cs, Sr and U in the investigated groundwater. The bentonite colloids are unstable under these conditions and sediment after 2 days. Am(III) and Pu(IV) exist as colloids when spiked to the Äspö groundwater in presence and absence of MX-80 bentonite colloids. Np(V) is at least partly reduced after 2 months to Np(IV) and appears to show comparable colloidal behaviour as seen for Pu(IV). These colloidal species are unstable and disappear from both solutions (presence and absence of clay colloids) after 2 months.

Colloid Dipole experiments have been performed with latex colloids of 50 and 100 nm in size which travelled quite fast with high recoveries. Due to a lot of noise in the data, exact recoveries could not be calculated, but the experiments indicate that almost all of the latex mass is recovered. Filtration coefficients for colloids could not be calculated from these experiments due to the noise in the data. The experiments point out the necessity to continue with similar experiments with refined analysis. Discussion on new site for these types of experiments is ongoing. Evaluation of tracer test data has been carried out and a few key parameters determined. The evaluation results as well as the results of scoping calculations are to be summarised in an interim report with title: Modelling for the Colloid Dipole experiment: Scoping calculations and evaluation results that will be included or integrated into the project report.

Scope of work for 2007

Further investigations on bentonite colloidal stability in different conditions will be performed. Interaction of colloids and colloid-borne radionuclides with fracture infill mineral surfaces will also be studied. This will be done by simulating the presence of organic matter by adding FA. Experiments will be carried out with crushed fracture filling material from the Äspö site and with untreated fracture surfaces from Äspö bore cores. The latter experiments aim to identify preferential mineral surfaces for colloid attachment.

Planning for Colloid-Actinide experiments is ongoing and a suitable borehole KA2512A has been selected because of its (relatively) low Ca-concentration and (relatively) low ionic strength. The major problem with this type of experiment is that bentonite colloids are not stable in Äspö groundwater; however, as a demonstration experiment the activity is very valuable. Preparation studies for the Colloid-Actinide have been performed in the laboratory where bentonite colloid stability in Äspö waters have been studied in coagulation studies in the absence and presence of fulvic acids. Interaction studies of radionuclides with bentonite colloids have also been performed. The Colloid-Actinide is planned to start in February-March 2007 and the experiment will go on at least to the end of the year.

Planning for new transport experiments of colloids at Äspö is ongoing. A suitable site would be the True-Block site, but if this is not possible, another place should be identified. Stability tests on silica colloids and other possible colloids will be performed to see if their higher stability in saline waters than bentonite colloids, make them potential colloids for the transport tests.

Experiments in the Quarried Block will be performed to further study colloidal transport with focus on bentonite colloid transport. Especially the effect of size on transport will be studied as well as to determine if monodisperse bentonite colloids will change during transport as a result of flocculation and dispersion processes. During 2007 all transport experiments performed in the Quarried Block and also *in situ* will be modelled to try to find filtration constants etc for colloidal transport in water bearing fractures in a deep granitic bedrock repository.

The laboratory program will continue where especially colloid stability in varying conditions will be studied.

3.5 Microbe Projects

Microbial processes

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 future deep repository for spent fuel /Pedersen 2002/. The study of microbial processes in the laboratory gives valuable contributions to our knowledge about microbial processes in repository environments. However, the concepts suggested 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 microbiology 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 university 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 university laboratory investigations arrayed above 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.

There are presently four specific microbial process areas identified that are of importance for proper repository functions and that are best studied at the Microbe laboratory. 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.

3.5.1 The Microbe laboratory

Objectives

The major objectives for the Microbe laboratory are:

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

Experimental concept

The Microbe laboratory is situated at the -450 m level in the F-tunnel (Figure 3-7). A laboratory container has been installed with laboratory benches and a climate control system. Three core drilled boreholes, KJ0050F01, KJ0052F01 and KJ0052F03, intersect water conducting fractures at 12.7, 43.5 and 9.3 m, respectively. They are connected to the Microbe laboratory via 1/8" PEEK (thermoplastic) tubing. The boreholes are equipped with metal free packer systems that allow controlled circulation of groundwater via respective fracture /Pedersen 2000/. Each borehole has been equipped with a circulation system offering a total of 2,112 cm² of test surface in each circulation flow cell set up (four flow cells) for biofilm formation at *in situ* pressure, temperature and chemistry conditions. The systems operate at pressures around 30 bars. The flow through the flow cells is adjusted to 25-30 ml per minute, which corresponds to a flow rate over the surfaces of about 1 mm per second. Temperature is controlled and kept close to the *in situ* temperature at around 15-16°C. Remote alarms and a survey system have been installed for high/low pressure, flow rate and temperature. A detailed description of the Microbe laboratory can be found in an International Progress Report /Pedersen 2005a/.

Present status

The Microbe laboratory is now working very well with respect to installed equipment /Pedersen 2005a/. The site selection of the Microbe laboratory in the F-tunnel of Äspö had, until January 2005, assured stable conditions. However, the situation changed dramatically during the time period January to December 2005. The drilling for *In Situ* Corrosion Testing of Miniature Canisters (Minican) caused a significant drainage of the formation from which Microbe takes its groundwater, see Figure 3-8. A completely new mixing situation developed in the Microbe formation during 2005, with up-coning of deep and high salinity groundwater as the main effect from the Minican installation. Once the drainage was stopped in December 2005, the Microbe site microbiology stabilised at a new level, generally with higher numbers of microorganisms than what was found before the up-coning was created. A detailed description can be found in a recent International Progress Report /Pedersen 2005b/.

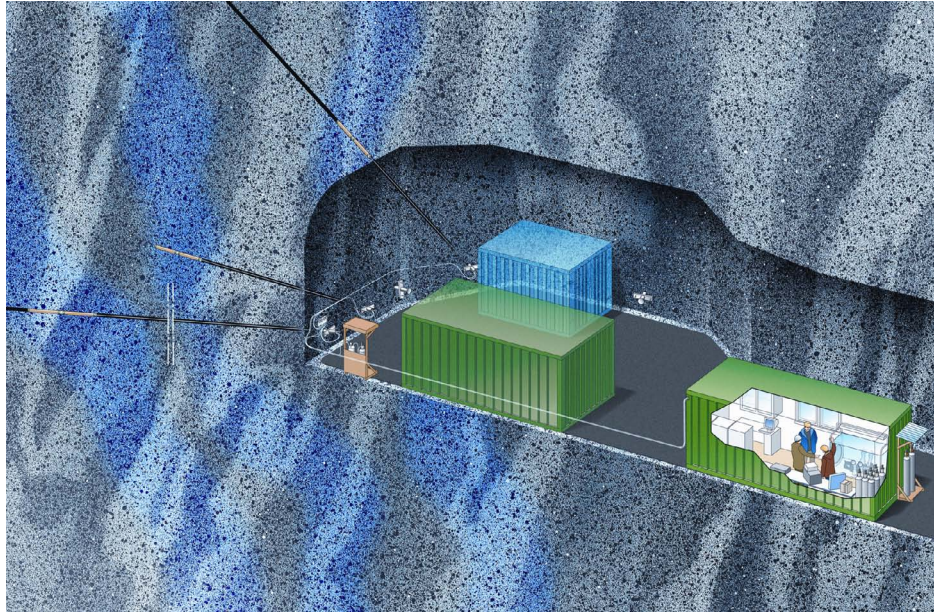


Figure 3-7 The artists view of the Microbe -450 m site and the metal free packer configuration. The laboratory is situated in a steel container and connected to three discrete fractures in the rock matrix. PEEK tubing connects the systems in the lab with the groundwater (See Pedersen /2005a/ for details).

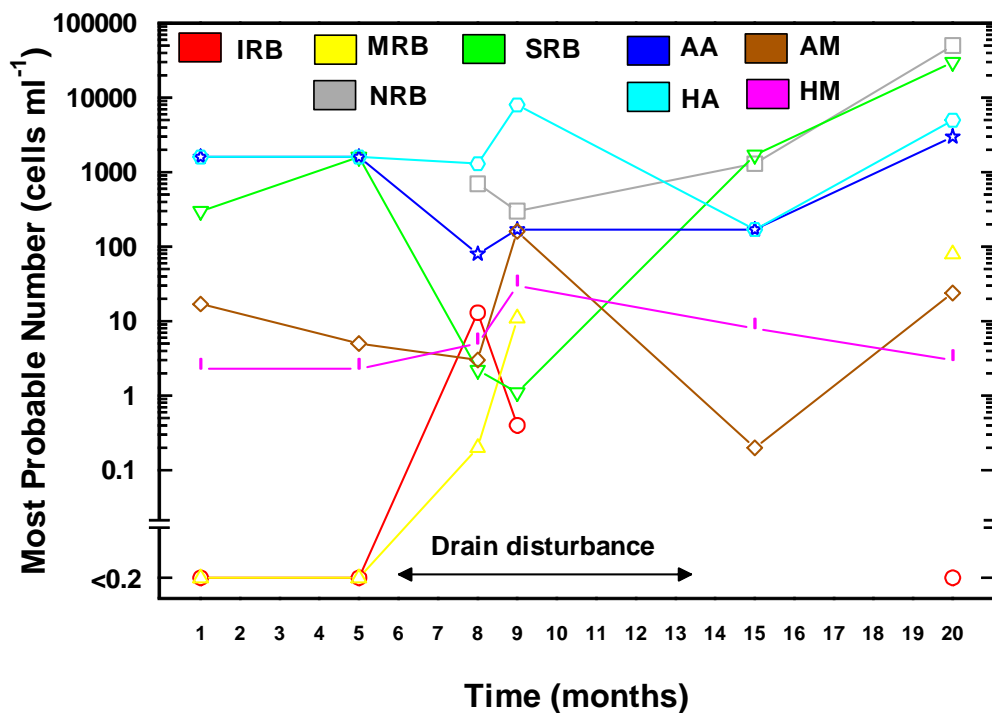


Figure 3-8 MPN of analysed physiological groups in KJ00542F01 at the Microbe site over a period ranging from September 2004 to April 2006. The drain disturbance from the Minican installation is marked with an arrow. Abbreviations: IRB - Iron Reducing Bacteria, MRB - Manganese Reducing bacteria, NRB – Nitrate Reducing Bacteria, SRB - Sulphate Reducing Bacteria, AA - Autotrophic Acetogens, HA - Heterotrophic Acetogens, AM - Autotrophic Metanogens, HM - Heterotrophic Metanogens.

Scope of work for 2007

The Microbe laboratory will continue to act as a base for different projects and programs within geobiology and radioactive waste disposal. In addition to the projects described here, studies on biocorrosion and related to the Prototype Repository Project and projects within international co-operations will be executed.

3.5.2 Micored

Background

Micro-organisms can have an important influence on the chemical situation in groundwater /Haveman and Pedersen 2002/. 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 from deep geological processes contributes to the redox stability of deep groundwater via microbial turnover of this gas. Hydrogen, and possibly also carbon mono-oxide and methane energy metabolisms will generate secondary metabolites such as ferrous iron, sulphide, acetate and complex organic carbon compounds. These species buffer towards a low redox potential and will help to reduce possibly introduced oxygen. The circulations in the Microbe laboratory have microbial populations that are reproducible in numbers and species distribution over time under stable hydrological conditions as exemplified in Figure 3-8. All groups execute influence on the redox situation. Anaerobic microbial ecosystems generally force the redox potential towards the range of redox in which they are active. Iron and manganese reducing bacteria are active at higher redox potentials (approximately -100 to -200 mV) than the methanogens and acetogens (approximately -300 to -400 mV). Sulphate reducing bacteria are most active between the optimal redox potentials for those groups (approximately -200 to -300 mV). The stable populations of sulphate reducing bacteria and methanogens and acetogens at the Microbe laboratory makes it very well suited for research on the influence of microorganisms on the evolution and stability of redox potential in groundwater.

Objectives

- To clarify the contribution from microorganisms to stable and low redox potentials in near- and far-field groundwater.
- To demonstrate and quantify the ability of microorganisms to consume oxygen in the near- and far-field areas.
- To explore the relation between content and distribution of gas and microorganisms in deep groundwater.
- To create clear connections between investigations of microorganisms in the site investigations for a future repository and research on microbial processes at Äspö HRL.

Experimental concept

Pressure resistant electrodes for redox potential, pH and dissolved oxygen will be adapted and installed in the circulations in the Microbe laboratory. The circulations will be run with biofilms under various conditions with additions of the variables hydrogen, acetate, methane and oxygen. There are presently three circulations that will be coupled in series. This will allow simultaneous testing of two variables with one control at the time.

Present status

The work started 2006 with a configuration experiment with additions of acetate and hydrogen + carbon dioxide as variables. It was found that the numbers of microorganisms, and the sulphide and the acetate concentrations increased most in the circulation with hydrogen addition. This supports the hypothesis that the deep biosphere is hydrogen driven /Pedersen 2001/.

Scope of work for 2007

Three more circulation systems will be ready for operation in January 2007. Those will be constructed of stainless steel in difference from the existing three systems that are made of poly-ether-ether-keon (PEEK). The steel system will be more diffusion tight compared to the PEEK systems, which will give a more stable gas environment in the circulating groundwater. Pressure resistant electrodes for redox potential and dissolved oxygen will be adapted and installed in the circulations in the Microbe laboratory. The consumption of hydrogen, methane, acetate and oxygen will be monitored together with redox measurements. The diversity of the active microorganisms will be analysed with a genetic approach combined with cultivation efforts. The production of carbon dioxide, sulphide, acetate and microbial biomass will be analysed as were successfully done during the configuration experiment performed 2006. This work is planned to start spring 2007.

3.5.3 Micomig

Background

It is well known that microbes can mobilise trace elements /Pedersen 2002/. 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 /Johnsson *et al.* 2006/.

A large group of microbes catalyse the formation of iron oxides from dissolved ferrous iron in groundwater that reaches an oxidising environment /Ferris *et al.* 1999, 2000/. Such biological iron oxide systems (BIOS) will have a retardation effect on many radionuclides. Typically, microbes form stalks and sheaths that increase the volume of the iron oxides from densely packed inorganic oxides to a fluffy, rust-like material with water contents of up to 99%. The microbes contribute to the exposure of a large oxide area to trace elements flowing by with the groundwater and the organic biological material adds a strong retention capacity in addition to iron oxides /Anderson and Pedersen 2003/.

Biofilms in aquifers will influence the retention processes of radionuclides in groundwater. Recent work /Anderson *et al.* 2006/ indicate that these surfaces adsorb up to 50% of these radionuclides in natural conditions with K_a (m) approaching 10^5 and 10^6 for Co and Pm respectively. The formation of colloids accounted for a further 20% to 40% of aqueous Co and Pm complexation. The anaerobic biofilms and rock surfaces share similar adsorption capacities for Pm but not for Co. The biofilms seemed to isolate the rock surface from the groundwater as diffusion to the rock surface must first proceed through the biofilms. The possible suppression of adsorption by biofilms needs further research. So far this has been observed only with one biofilm type in one Microbe laboratory circulation.

Objectives

- To evaluate the influence from microbial complexing agents on radionuclide migration.
- To explore the influence of microbial biofilms on radionuclide sorption and matrix diffusion.

Experimental concept

In situ formation of complexing agents in the Microbe laboratory circulations will be investigated. The experimental concept from laboratory work /Arlinger *et al.* 2004, Johnsson *et al.* 2006/ will be adapted to the field. Pressure safe containers will be amended with radionuclide cocktails and groundwater from closed and active Microbe laboratory circulations will be added under ambient pressure, pH and redox potential. The distribution of the radionuclides between solid and liquid phases will be analysed as previously done in the laboratory.

New experiments with biofilm effects on radionuclide migration will utilise the tested and recently published experimental concept /Anderson *et al.* 2006/. Different groundwater will be analysed. The types of biofilm microorganisms will be analysed.

Present status

The work is ongoing.

Scope of work for 2007

The metal free PEEK systems will be employed for the migration experiments.

Methods for the search of complexing agents in deep groundwater will be adapted.

Biofilms from the ongoing Micoired project will be utilised for further research on microbial effects on radionuclide migration.

3.6 Matrix Fluid Chemistry Continuation

Background

The first phase of the Matrix Fluid Chemistry experiment (1998–2003) increased the knowledge of matrix pore space fluids/groundwaters from crystalline rocks of low hydraulic conductivity ($K < 10^{-10} \text{ ms}^{-1}$), and this complemented the hydrogeochemical studies already conducted at Äspö. The results of this first phase were published in early 2004 /Smellie *et al.* 2003/.

The continuation phase (2004–2006) focussed on areas of uncertainty which remain to be addressed:

- The nature and extent of the connected pore waters in the Äspö bedrock (chemical, hydraulic and transport properties).
- The nature and extent of the microfracture groundwaters which penetrate the rock matrix (chemical, hydraulic and transport properties) and the influence of these groundwaters (by in- and out-diffusion) on the chemistry of the pore waters.
- The confirmation of rock porosity values previously measured in the earlier studies.

This continuation phase also saw the completion of a feasibility study to assess the effects on the matrix borehole and its surroundings due to the untimely excavation of a new tunnel for the Äspö Pillar Stability Experiment carried out in April/May, 2003. There was concern that repercussions from this excavation may have influenced the hydraulic (and therefore the hydrochemical) character of the matrix borehole and the host rock vicinity.

Objectives

Because of the possibility that the hydraulic and hydrochemical character of the matrix borehole and the host rock vicinity has been disturbed, the following objectives were identified:

- To establish the impact of tunnel construction on the matrix borehole by evaluating the monitored pressure profiles in the hydro monitoring system (HMS) registered on the isolated borehole sections during the period of construction (small-scale).
- To establish the impact of tunnel construction on boreholes located in the near-vicinity of the matrix borehole in the F-tunnel by similar means (large-scale).
- If the evaluation indicates that the rock hosting the matrix borehole has been unaffected by tunnel construction, the experiment will proceed first to hydrochemically and hydraulically characterise the presently isolated borehole sections containing microfractures and, secondly, to hydrochemically and hydraulically characterise the original fracture-free borehole sections.
- To carry out additional porosity measurements on drillcore samples to be compared with values already measured.

Experimental concept

The first phase of the Matrix Fluid Chemistry Experiment was designed to sample matrix pore water from predetermined, isolated borehole sections. The borehole was selected on the basis of: (a) rock type, (b) mineral and geochemical homogeneity, (c) major rock foliation, (d) depth in the tunnel, (e) presence and absence of fractures, and (f) existing groundwater data from other completed and ongoing experiments at Äspö HRL.

Special downhole equipment, see Figure 3-9, was constructed ensuring: (a) an anaerobic environment, (b) minimal contamination from the installation, (c) minimal dead space in the sample section, (d) the possibility to control the hydraulic head differential between the sampling section and the surrounding bedrock, (e) in-line monitoring of electrical conductivity and drilling water content, (f) the collection of pore waters (and gases) under pressure and (g) convenient sample holder to facilitate rapid transport to the laboratory for analysis.

This experimental equipment, with some modifications, is being used in the continuation phase to sample groundwaters from the microfractures, to measure the hydraulic parameters of the microfractures and the rock matrix, and finally to conduct the long term *in situ* diffusion experiment.

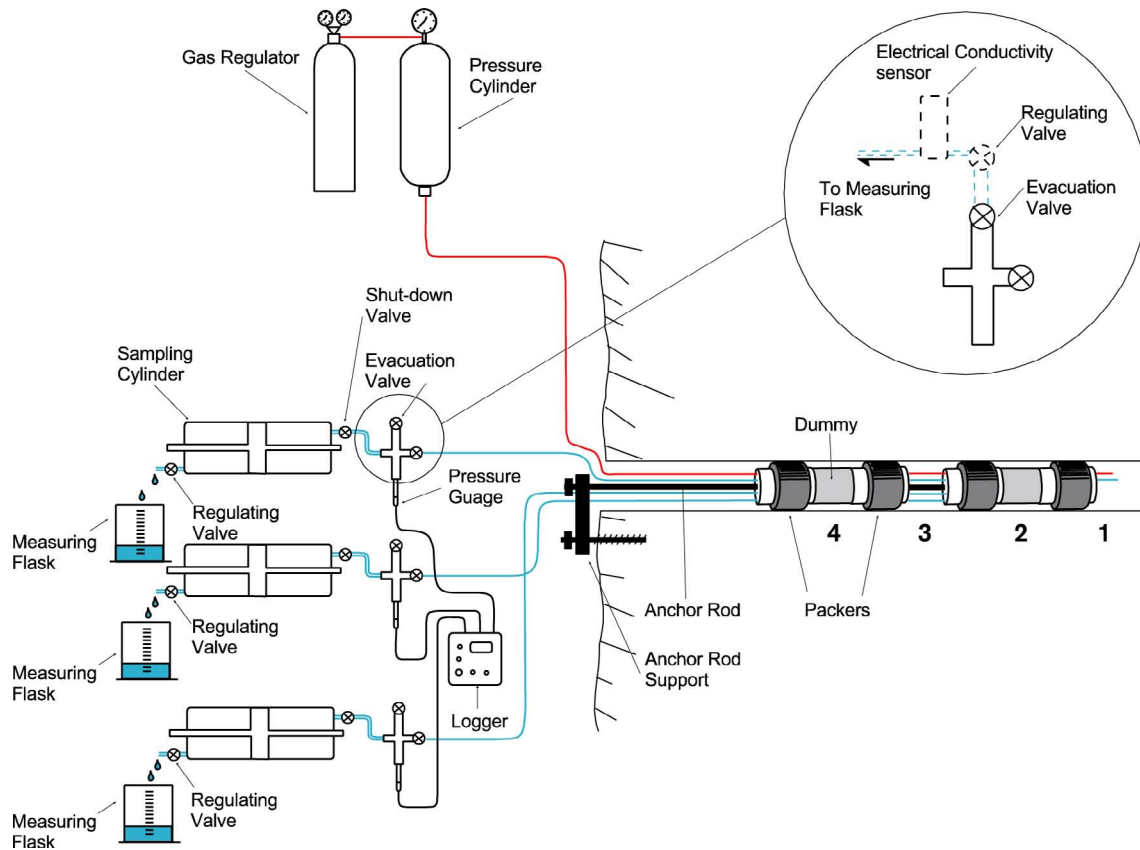


Figure 3-9 Matrix Fluid Chemistry Experimental set-up. Borehole sections 2 and 4 were selected to collect matrix fluid, sections 1-4 were continuously monitored for pressure.

Present status

The hydraulic characterisation of the matrix borehole KF0051A01, initiated in November 2005, was successfully carried out during 2006 and completed in November 2006. The results are presently being documented, interpreted and reported as an International Technical Document (ITD) scheduled for the end of May 2007. The downhole equipment will be removed in June 2007. This marks the end of the Matrix Borehole Continuation Experiment data production from the tunnel site.

The chemical and isotopic analyses on matrix borehole waters sampled in April and November 2005 have been completed. The data have still to be documented and compiled in an ITD report, scheduled for May 2007. Some of these data and their interpretation form part of an article submitted to a Special Issue of Applied Geochemistry dedicated to the methodological approaches used in the on-going site investigations at Oskarshamn and Forsmark.

With respect to the porosity measurements on drillcore material (borehole KA2599G01) to supplement data from the Matrix Fluid Chemistry Experiment borehole, these data during 2006 have been published both as an ITD and also internationally in Engineering Geology /Tullborg and Larson, 2006/

Scope of work for 2007

By the end of May 2007 it is hoped to have at hand the three ITD reports produced during this matrix continuation project. These reports will be synthesised and integrated and related to the earlier results from the Matrix Fluid Chemistry Experiment /Smellie *et al.* 2003/. The synthesis and integration report is scheduled for November, 2007.

3.7 Radionuclide Retention Experiments

Background

The retention of radionuclides in the rock is the most effective protection mechanism when the engineered barriers fail and radionuclides are released from the waste form. The retention is mainly due to the chemical properties of the radionuclides, the chemical composition of the groundwater, and to some extent also by the conditions of the water conducting fractures and the groundwater flow.

Laboratory studies of radionuclide retention under natural conditions are extremely difficult to conduct. Even though the experiences from different scientists are uniform it is of great value to be able to demonstrate the results of the laboratory studies *in situ*, where the natural contents of colloids, organic matter, bacteria etc. are present in the groundwater used in the experiments. A special borehole probe, Chemlab, has been designed for different kinds of *in situ* experiments where data, representative for the properties of groundwater at repository depth, can be obtained.

The results of experiments in Chemlab will be used to validate models and check constants used to describe radionuclide dissolution in groundwater, the influence of radiolysis, fuel corrosion, sorption on mineral surfaces, diffusion in the rock matrix, diffusion in buffer material, transport out of a damaged canister and transport in an individual fracture. In addition, the influence of naturally reducing conditions on solubility and sorption of radionuclides will be studied.

Objectives

The objectives of the radionuclide retention experiments are to:

- Validate the radionuclide retention data and fuel dissolution data which have been measured in laboratories by data from *in situ* experiments.
- Demonstrate that the laboratory data are reliable and correct also at the conditions prevailing in the rock.
- Decrease the uncertainty in the retention properties of relevant radionuclides.

Experimental concept – Chemlab

Chemlab 1 and 2 are borehole laboratories built into probes, in which *in situ* experiments can be carried out under ambient conditions with respect to pressure and temperature, and with the use of natural groundwater from the surrounding rock, see Figure 3-10. Initially one “all purpose” unit, Chemlab 1, was constructed in order to meet any possible experimental requirement. At a later stage, a simplified version, the Chemlab 2 unit, was designed to meet the requirements by experiments where highly sorbing nuclides are involved. In Figure 3-11 the principles of the borehole laboratories are given. In already completed or almost completed experiments the following have been studied:

- Diffusion of cations (Cs^+ , Sr^{2+} , and Co^{2+}) and anions (I^- and TcO_4^-) in bentonite.
- The influence of primary and secondary formed water radiolysis products on the migration of the redox-sensitive element technetium. The final report is published /Jansson *et al.* 2006/.
- Migration of actinides (americium, neptunium, and plutonium) in a rock fracture. The final report will be finished during spring 2007.

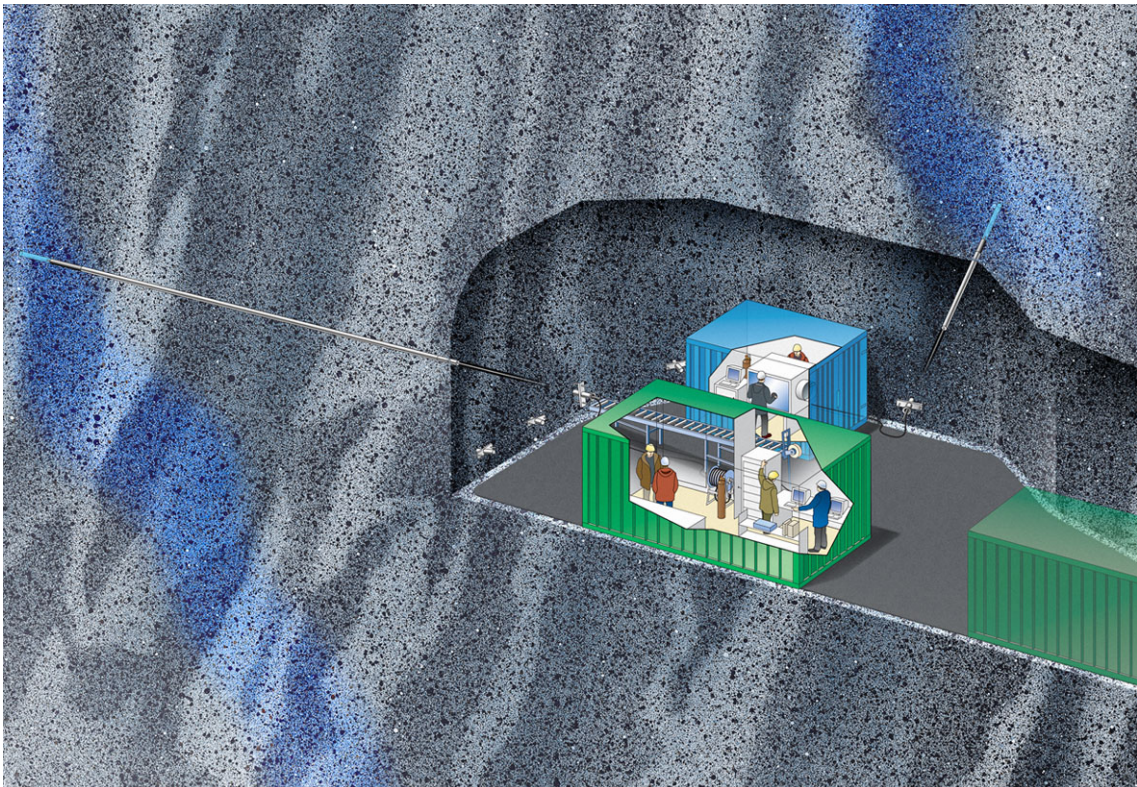


Figure 3-10 Illustration of the experimental set-up of the Radionuclide Retention Experiments.

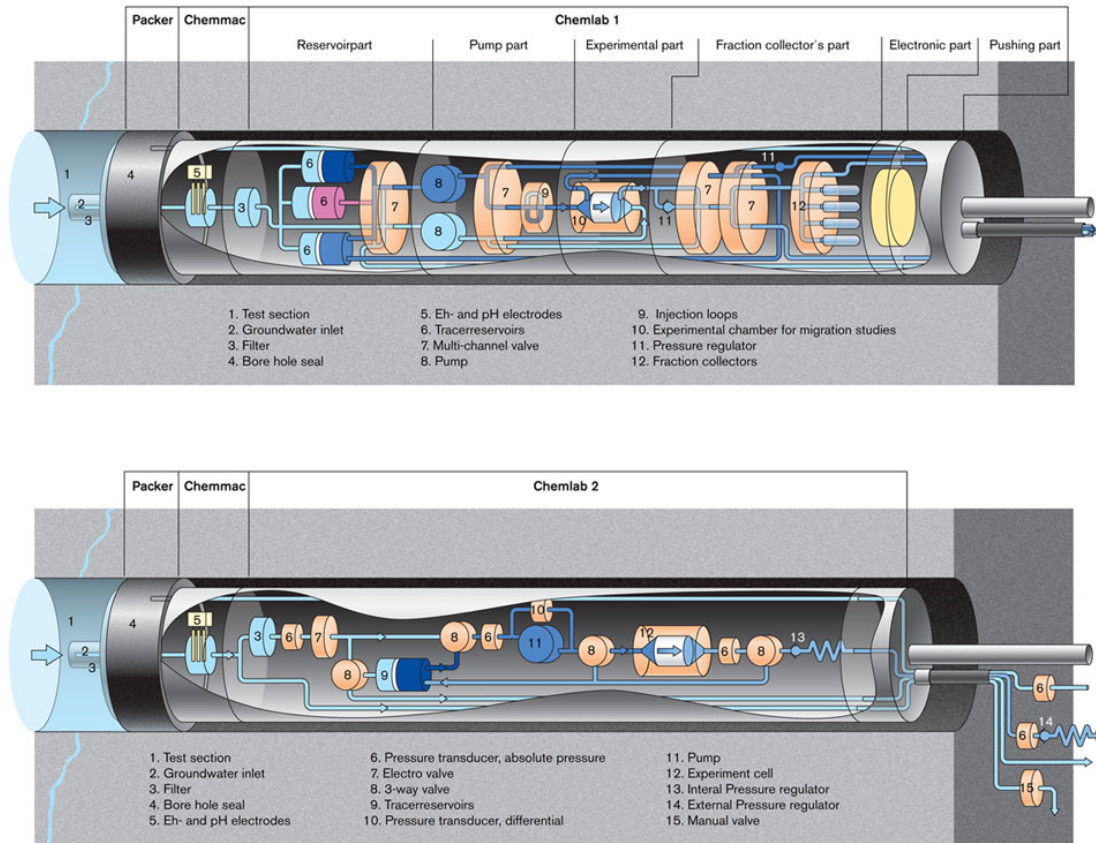


Figure 3-11 Schematic illustration of Chemlab 1 and 2 borehole laboratories.

3.7.1 Spent Fuel Leaching

Background and objectives

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.

Experimental concept

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 H₂ (in a glove box situated in the gallery) as well as without the presence of H₂ (in Chemlab 2).

Present status and Scope of work for 2007

The design of the experiment is finalised and contact has been taken with Chalmers for the laboratory experiments. The planning of the experiments is, however, delayed due to other obligations and the scope of work for 2007 is not defined.

3.7.2 Transport Resistance at the Buffer-Rock Interface

Background and objectives

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

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 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.

Experimental concept

The experiment will be performed in the laboratory, where a fracture is simulated as a 1 mm space between two Plexiglas plates, see Figure 3-12. 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 and Scope of work for 2007

The laboratory equipment that will be used to study the phenomenon has been manufactured. However, due to other priorities the experimental equipment has been used by another SKB-project (Bentonite Erosion) and the above experiments has been postponed. The experiments are planned to start during 2007, though.

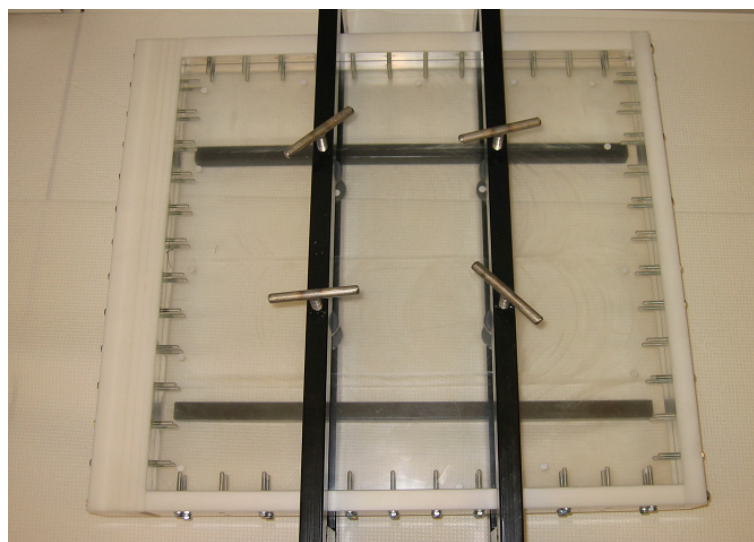
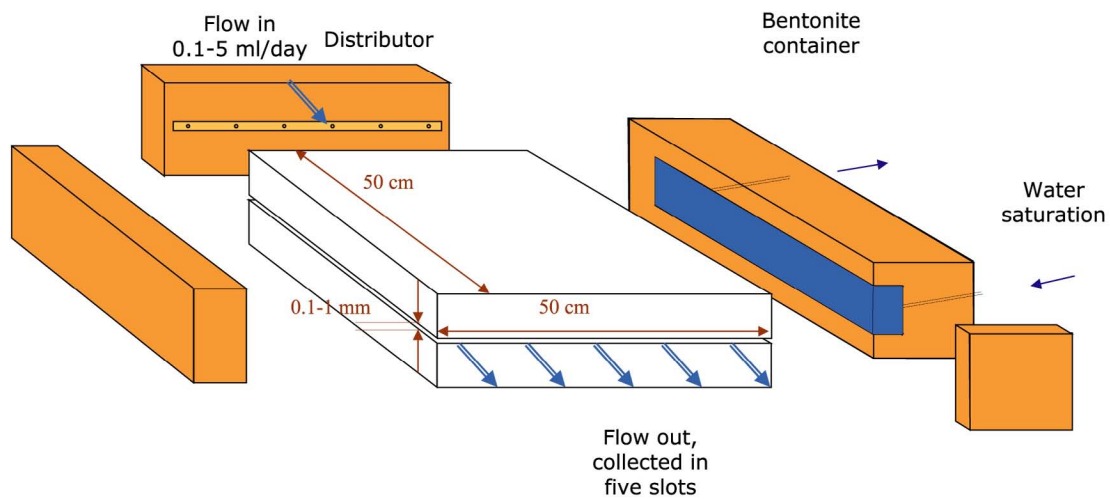


Figure 3-12 Illustration and photo of experimental set-up.

3.8 Padamot

Background

Palaeohydrogeology is a relatively new term used as a common name for information from fracture minerals that is used for interpretations of past hydrogeochemical and hydrogeological systems. The need for such interpretations has become evident in the geological/hydrogeological modelling of sites within the radwaste programmes of several countries. An EC founded 3 year project with the name Equip (Evidences from Quaternary Infills for Palaeohydrogeology) was therefore started in 1997. When the Equip project ended in 2000 /Bath *et al.* 2000/ there was a need for continued fracture mineral investigations and model testing of the obtained results. A new EC-project called Padamot (Palaeohydrogeological Data Analysis and Model Testing) was therefore initiated in the beginning of 2002 and this was ended and reported to EC in 2005. A continuation of the Swedish part of the project at Äspö has thereafter been agreed by SKB. This is called Padamot Continuation.

Background

Palaeohydrogeology is a relatively new term used as a common name for information from fracture minerals that is used for interpretations of past hydrogeochemical and hydrogeological systems. The need for such interpretations has become evident in the geological/hydrogeological modelling of sites within the radwaste programmes of several countries. An EC founded 3 year project with the name Equip (Evidences from Quaternary Infills for Palaeohydrogeology) was therefore started in 1997. When the Equip project ended in 2000 /Bath *et al.* 2000/ there was a need for continued fracture mineral investigations and model testing of the obtained results. A new EC-project called Padamot (Palaeohydrogeological Data Analysis and Model Testing) was therefore initiated in the beginning of 2002.

Objectives

The objectives for the Padamot Continuation project include:

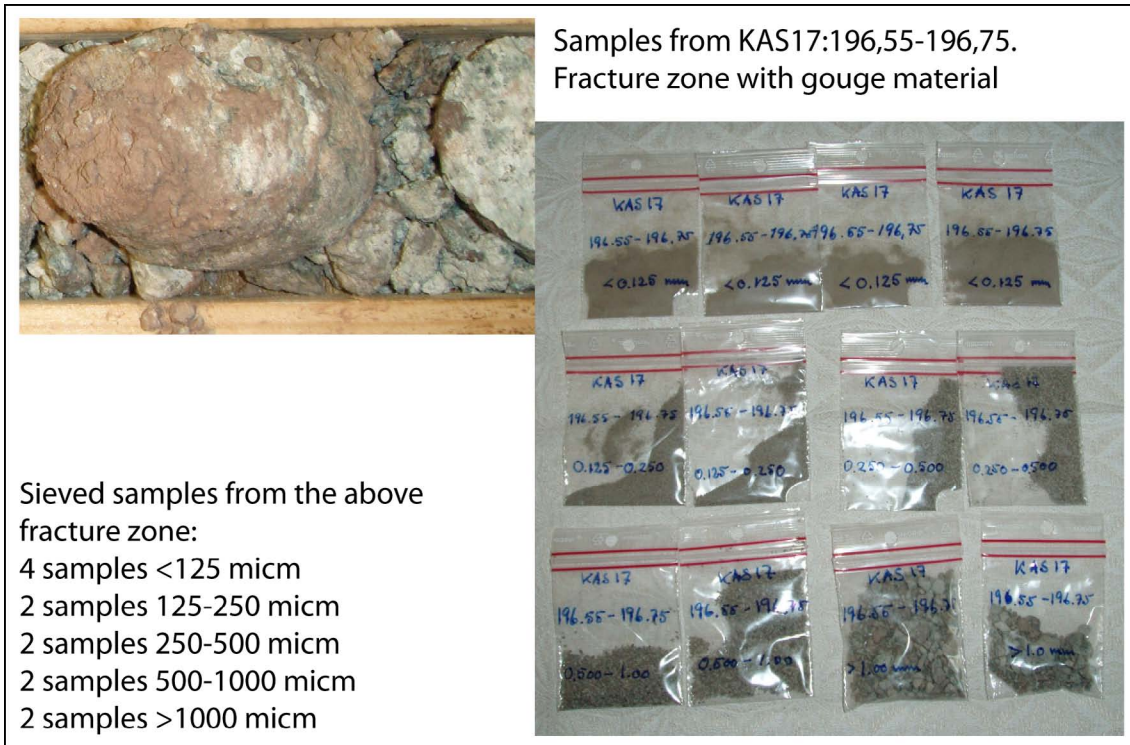
- Further developments of analytical techniques for Uranium series analyses applied on fracture mineral samples
- Focus on the use of these analyses for determination of the redox conditions during glacial and postglacial time
- Summarise the experiences of palaeohydrogeological studies carried out at Äspö

Present status

A paper presenting the methodology for palaeohydrogeological studies applied in the presently ongoing site investigations at Forsmark and Simpevarp is now in the review processes of Applied Geochemistry.

Concerning the Uranium series disequilibrium (USD) analyses the status is as follows. During the Project start-up meeting on Äspö in late July 2006 the drill core from borehole KAS17 was sampled, see Figure 3-13. This borehole penetrates the large E-W fracture zone called the Mederhult zone and several sections with fractured rocks are intersected by the borehole. Six samples from different depths (ranging from 19 to 200 m core length) have been sieved into different grain sizes and the most fine grained (usually <0.125 µm) fractions have been split into three (and if possible four) parts. Two for USD analyses at the different laboratories and one for Inductively Coupled Plasma (ICP) analyses (chemical characterisation) which also included determination of the ratio $^{234}\text{U}/^{238}\text{U}$ with mass spectrometry. The fourth part was used for X-ray diffractometry (XRD) in order to determine the mineralogical composition. The results from the ICP and XRD analyses are already available and show that the sampled material consist of quartz, K-felspar, albite, chlorite, calcite and clay minerals of mixed layer clay type. U contents in the samples varied from 6 to 27 ppm.

Split samples have been distributed to Helsinki University and to SUERC in Glasgow for analyses. The USD analyses will be carried out using different techniques (whole sample analysis and sequential leaching) applied by the two laboratories and results will be interpreted in common.



Sieved samples from the above fracture zone:
 4 samples <125 micm
 2 samples 125-250 micm
 2 samples 250-500 micm
 2 samples 500-1000 micm
 2 samples >1000 micm

Figure 3-13 Photo of sample from a fracture zone at 196.55-196.75 m in borehole KAS 17 at Äspö.

Scope of work for 2007

The USD analyses will be carried out during the spring and experiences of the laboratory work will be discussed at a planned project meeting preliminary hold in Helsinki in May 2007. Reporting of results and evaluation of the applied techniques are planned for the autumn 2007.

3.9 Fe-oxides in fractures

Background

Uptake of radioactive elements in solid phases can lead to immobilisation, thus minimising the release to the environment. Uptake extent depends on solution conditions such as concentration, pH, Eh, temperature, pressure and the presence of other species. Transition metals, lanthanides and actinides are often incorporated by identical processes. Therefore, better understanding of the behaviour of the two first groups mentioned strengthens the understanding also of the actinides, which are difficult to study. Moreover, presence of trace components in minerals can provide information about a mineral's genesis conditions and history.

Fractures lined with Fe-oxides are found in the Äspö bedrock and they are present as minor components nearly everywhere at the Earth's surface. Their affinity for multivalent species is high but Fe-oxide uptake of lanthanides and actinides has not been studied to any great extent. Fe(II)-oxihydroxides, known as "green rust", form in Fe-bearing solutions under reducing conditions and are associated with the early stages of corrosion. Their uptake capacity during formation and transition to Fe(III)-oxides is essentially unknown at present. These minerals could be an important sink for

radioactive species where Fe is abundant in the natural fractures or in materials brought into the repository. Fe itself can be an indicator of redox state. Fe-isotope fractionation, a very new topic of research, might give clues about redox conditions during Fe-mineral formation or as a result of its inclusion in other secondary fracture minerals.

There are three questions relevant for radioactive waste disposal in fractured granite:

- How extensive is the capacity for Fe(III)-oxides, in fracture linings, to take up and retain radionuclides or other toxicants from solutions, and what happens during transformation of the oxides to more stable phases?
- What capacity do the reduced Fe(II)-oxides have for uptake and retention?
- Does the suite of trace components and isotopes measured in minerals from fracture linings provide information about conditions of the water that passed through them in the past?

These questions can be rephrased more specifically, for direct application to problems for Swedish waste disposal, as:

- Can more detailed information about the uptake of higher valent elements such as Eu^{3+} provide a model for actinide behaviour and Cr^{3+} as a palaeo-redox-indicator?
- Can stable Fe-isotopes from Fe-oxides or from other minerals tell us anything about solution conditions during genesis?
- What is the uptake and retention capacity of green rust under solution conditions relevant for Äspö?
- Is it possible to find evidence to support or dispute the hypothesis that, at the time of glacier retreat, oxidising water might have penetrated to or below the depth of the planned final repository?
- How might secondary Fe-minerals affect the migration of radionuclides released from a repository?

Objectives and experimental concept

The basic idea of the project is to examine Fe-oxide fracture linings, in order to explore suitable palaeo-indicators and their formation conditions. At the same time knowledge about the behaviour of trace component uptake can be obtained from natural material as well as through studies in the laboratory under controlled conditions.

A glove-box set-up, where Atomic Force Microscopy is possible *in situ*, will be used to investigate green rust under a stable atmosphere at reducing conditions. More possibilities for extracting chemical information from the secondary Fe-oxides will be tested and the merits of stable Fe- and O-isotope fractionation as well as Mössbauer (MS) and energy dispersive X-ray (EDS) spectroscopy will be examined.

Present status

The major emphasis during 2006 was reporting and the initiation of a project continuation with the title "To establish the penetration depth of oxidising waters below ground". Sampling of fracture material for this project was carried out in August on drillcores from the Laxemar site investigation programme. This period also saw the completion of the data compilation and modelling by the Enviro group in Barcelona within the project entitled. "Fe-oxides in fractures: Genesis and trace component uptake". Reporting during the year has involved the reports in Table 3-1.

Table 3-1 Reporting during 2006. The status of the report is given within brackets.

-
- Skovbjerg L, Stipp S, Utsunomiya S, Ewing R, 2006.** The Mechanisms of Reduction of Hexavalent Chromium by Green Rust Sodium Sulphate: Formation of Cr-goethite (Resubmitted in February 2006 to *Geochimica et Cosmochimica Acta*).
- Dideriksen K, Christiansen B, Baker J, Frandsen C, Balic-Zunic T, Tullborg E, Mørup S, Stipp S, 2006.** Fe-oxide fracture-fillings as a palæo-temperature and redox indicator: Structure, crystal form, REE content and Fe isotope composition (Accepted for publication, May 2006, in *Geochimica et Cosmochimica Acta*).
- Dideriksen K, Stipp S, 2006.** Iron Oxides in Fractures at Äspö. A feasibility study to test the possibility of finding a geothermometer or a palæo-redox indicator. IPR-06-09, Svensk Kärnbränslehantering AB.
- Christiansen B, 2006.** A transformational, structural and natural occurrence study of green rust. IPR06-24, Svensk Kärnbränslehantering AB.
- Skovbjerg L L, 2005.** Reduction of hexavalent chromium by green rust sulphate: Determination of end product and reduction mechanism. IPR-06-25, Svensk Kärnbränslehantering AB.
- Grivé M, Colàs E, Domènech C, 2006.** Fe-oxides in fractures: Thermodynamics and trace component uptake. *Enviros Progress Report*. (under review).
-

Scope of work for 2007

Work will continue on the continuation project with completion scheduled for June 30th 2007.

Additional reporting is on-going, for example a manuscript for green rust structure is almost completed, and on the laboratory side experiments will continue focussing on selenium uptake on green rust. Finally some work on green rust colloids is drawing to a close and will be reported soon.

3.10 Swiw-tests with Synthetic Groundwater

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-1 and the True Block Scale experiments. This project aims to deepen the understanding for the processes governing retention. Swiw-tests with synthetic groundwater facilitate the study of diffusion in stagnant water zones and in the rock matrix. It also facilitates the possibility to test the concept of measuring fracture aperture with the radon concept.

The original location in mind for the tests was the True Block Scale site and the well characterised Structures #19 and #20. The two structures have been object to a large number of tracer tests, possess different characteristics and are located on different distances from the tunnel. The usage of the True Block Scale site facilitates the unique possibility to "calibrate" the concept of single hole tracer tests, Swiw, to multiple borehole tracer tests. The results from such a calibration can be applied directly to the Swiw-tests performed within the SKB site investigation programme.

However, there are plans of establishing a new tunnel in the vicinity of True Block Scale. This new tunnel may alter the hydraulic conditions in True Block Scale significantly so that a performance of Swiw-tests there may be unsuitable or impossible. Hence, a new site to perform the Swiw-tests may be necessary to find.

Objectives

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.

Experimental concept

The basic idea is to perform Swiw-tests with radon free synthetic groundwater with a somewhat altered composition, e.g. replacement of chloride with nitrate and the exclusion of potassium and strontium, compared to the natural groundwater at the True Block Scale site. Sorbing as well as non-sorbing tracers are added during the injection phase of the tests. In the withdrawal phase of the tests the contents of the “natural” tracers, radon, chloride, potassium and strontium, as well as the added tracers in the pumping water is monitored. The breakthrough curves contain the desired information on diffusion.

Present status

The ongoing feasibility study has the objectives to evaluate the possibility to perform and evaluate a Swiw-test with synthetic groundwater at True-Block Scale and optimise such a test, including pre-tests, by the aspects of test site, test performance and evaluation. The scope of the feasibility study:

- Inventory of the hydraulic properties such as conductivities, distances and changes in gradient over time at True-Block Scale.
- Inventory of earlier tests and experiences at True-Block Scale and True-1 as well as from Swiw tests within SKB’s site investigation programme.
- Scoping simulations of Swiw tests with a dominating diffusion from stagnant water as well as from the rock matrix with tracers of different sorption.
- Investigation of the possibility to produce synthetic groundwater with very low concentration of a salt component (e.g. chloride).
- Design calculations in order to find limitations and preferable characteristics of a test site in general (such as time span, hydraulic gradient and conductivity).
- Compile, and report subtasks 2-6 and propose design of pre tests and Swiw-test with synthetic groundwater.

Scope of work for 2007

The main tasks for 2007 are:

- Reporting of the findings of the feasibility study
- Determine the scope of the project and writing of a project plan
- Planning and preparation for pre-tests and main tests

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

Background

The work within Äspö Task Force on modelling of groundwater flow and transport of solutes constitutes an important part of the international co-operation within the Äspö HRL. The group was initiated by SKB in 1992 and is a forum for the organisations to interact in the area of conceptual and numerical modelling of groundwater flow and transport. A Task Force delegate represents each participating organisation and the modelling work is performed by modelling groups. The Task Force meets regularly about once to twice a year.

Different experiments at the Äspö HRL are utilised to support the Modelling Tasks. To date modelling issues and their status are as follow:

Task 1: Long term pumping and tracer experiments (completed).

Task 2: Scooping calculations for some of the planned detailed scale experiments at the Äspö site (completed).

Task 3: The hydraulic impact of the Äspö tunnel excavation (completed).

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

Task 5: Coupling between hydrochemistry and hydrogeology (completed).

Task 6: Performance assessment modelling using site characterisation data (ongoing).

Task 7: Long-term pumping experiment (ongoing).

Occasionally, there is work done in so-called Meta Tasks, which are normally not directly coupled to a specific modelling task, but have an overview perspective. Such a task is on-going. It is dedicated to updating the Issue Evaluation Table, which is intended to provide a basis for identification and evaluation of key issues in performance assessment of a final geological repository /Ström 1998/.

Objectives

The Äspö Task Force is a forum for the organisations supporting the Äspö HRL project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. In particular, the Task Force shall propose, review, evaluate, and contribute to such work in the project. The Task Force shall interact with the principal investigators responsible for carrying out experimental and modelling work for Äspö HRL of particular interest for the members of the Task Force.

Much emphasis is put on building of confidence in the approaches and methods in use for modelling of groundwater flow and migration in order to demonstrate their use for performance and safety assessments.

The ongoing Task 6 was initiated in 2001, and is now in the final reporting stage. Task 6 does not contain experimental work but it uses experimental results of the former Task 4 and True Block Scale project. Task 4 included a series of tracer tests performed in a single feature over transport distances of about 5 m using simple flow geometry and both conservative and sorbing tracers. In True Block Scale, a series of tracer tests was performed in a fracture network over tens of metre distances. The main objectives of Task 6 are to:

- Assess simplifications used in performance assessment (PA) models.
- Assess the constraining power of tracer experiments for PA models.
- Provide input for site characterisations programme from PA perspective.
- Understand the site-specific flow and transport at different scales using site characterisation models.

These sub-tasks have been defined within Task 6:

- 6A Model and reproduce selected True-1 tests with a PA model and/or a site characterisation (SC) model to provide a common reference.
- 6B Model selected PA cases at the True-1 site with new PA relevant (long term/base case) boundary conditions and temporal scales.
- 6B2 Similar to Task 6B, but uses a different boundary condition, a linear source term and the tracers are analysed at a fracture intersecting Feature A.
- 6C Develop semi-synthetic, fractured granite hydrostructural models. Two scales are supported (200 m block scale and 2,000 m site-scale).
- 6D This modelling task is similar to sub-task 6A, and is using the semi-synthetic structural model in addition to a 50 to 100 m scale True Block Scale tracer experiment.
- 6E This modelling task extends the sub-task 6D transport calculations to a reference set of PA time scales and boundary conditions.
- 6F Task 6F is a sensitivity study, which is proposed to address simple test cases, individual tasks to explore processes, and to test model functionality.
- 6F2 The purpose of the Task 6F2 sensitivity study is to exploit the model setup within Task 6E and 6F to perform additional studies evaluating specific topics of concern for the modelling of transport in fractured rock.

Task 7 was presented at the 19th International Task Force meeting in Finland, 2004. Hydraulic responses during construction of a final repository are of great interest because they may provide information for characterisation of hydraulic properties of the bedrock and for estimation of possible hydraulic disturbances caused by the construction. Task 7 will focus on the underground facility Onkalo at the Olkiluoto site in Finland, and is aimed at simulating the hydraulic responses detected during a long-term pumping test carried out in borehole KR24. In addition, Task 7 is addressing the usage of PFL data and issues related to open boreholes.

Present status

One Task Force meeting and one workshop have been held during year 2006. The 21st International Task Force meeting, hosted by Andra was held in March in Paris. At this meeting, the modelling groups presented the final Task 6 results and conclusions. In fact, the meeting was the grand final for Task 6. The workshop was held in Rauma, Finland in September. At this workshop, modelling for Task 7 was presented and discussed. In addition, the planned sub-tasks were discussed.

The work within the Task Force has been in progress after the meeting and workshop. Minutes from the meetings are published on Member Area of the Task Force Website (www.skb.se/taskforce). In the planning group, telephone meetings are held on a regular basis. Most of the integrated reports on Task 6D, 6E, 6F and 6F2 written by the modelling groups are printed. The review report on Task 6D, 6E, 6F and 6F2 is pending on the printing process. In addition, it is planned to submit papers on the modelling and review on Task 6D, 6E, 6F and 6F2.

A specification on Task 7 has been sent out to the Task Force members, which has been followed by a task definition. Based on the discussions mainly at the workshop, Task 7 has been modified and the specifications have been updated. Data for Task 7 are published on the Member Area mentioned above.

Scope of work for 2007

The main activities targeted to be accomplished during 2007 are summarised below:

- Organise the 22nd International Task Force meeting in January, hosted by SKB. Plan and organise the 23rd Task Force meeting in the autumn.
- Finalise printing modelling reports of sub-task 6D, 6E, 6F and 6F2.
- Finalise the external review process of Task 6.
- Publish the review and modelling papers of Task 6 in a scientific journal.
- Perform modelling within Task 7.
- Continue to update the Issue Evaluation Table.

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 future repository.

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

With respect to technology demonstration important overall objectives of this programme are:

- To furnish methods, equipment and procedures required for excavation of tunnels and deposition holes, near-field characterisation, canister handling and deposition, backfill, sealing, plugging, monitoring and also canister retrieval.
- To integrate these methods and procedures into a disposal sequence, that can be demonstrated to meet requirements of quality in relation to relevant standards, as well as practicality.

With respect to repository function, the objectives are to test and demonstrate the function of the engineered barriers as well as the function of the integrated repository system.

The main experiments that are installed in Äspö HRL or under way 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.
- *In situ* Testing of Miniature Canisters.
- Rock Shear Experiment.

4.2 Prototype Repository

Background

Many aspects of the KBS-3 repository concept have been tested in a number of *in situ* and laboratory tests. Models have been developed that are able to describe and predict the behaviour of both individual components of the repository, and the entire system. However, processes have not been studied in the complete sequence, as they will occur in connection to repository construction and operation. There is a need to test and demonstrate the execution and function of the deposition sequence with state-of-the-art technology in full-scale. In addition, it is needed to demonstrate that it is possible to understand and qualify the processes that take place in the engineered barriers and the surrounding host rock. This technology was developed and is tested and demonstrated in the Prototype Repository.

The execution of the Prototype Repository is a dress rehearsal of the actions needed to construct a final repository from detailed characterisation to resaturation of deposition holes and backfill of tunnels. The Prototype Repository provides a demonstration of the integrated function of the repository and provides a full-scale reference for test of predictive models concerning individual components as well as the complete repository system. The Prototype Repository should demonstrate that the important processes that take place in the engineered barriers and the host rock are sufficiently well understood.

The installation of the Prototype Repository has been co-funded by the European Commission with SKB as co-ordinator. The EC-project started in September 2000 and ended in February 2004. The continuing operation of the Prototype Repository is funded by SKB.

Objectives

The main objectives for the Prototype Repository are to:

- Test and demonstrate the integrated function of the final repository components under realistic conditions in full-scale and to compare results with model predictions and assumptions.
- Develop, test and demonstrate appropriate engineering standards and quality assurance methods.
- Simulate appropriate parts of the repository design and construction processes.

The evolution of the Prototype Repository should be followed for a long time, possible up to 20 years. This is made to provide long term experience on repository performance to be used in the evaluation that will be made after the initial operational stage in the real deep repository.

Experimental concept

The test location chosen is the innermost section of the TBM-tunnel at the -450 m level. The layout involves altogether six deposition holes, four in an inner section and two in an outer, see Figure 4-1. The sections are backfilled with a mixture of bentonite and crushed rock (30/70). A massive concrete plug, designed to withstand full water and swelling pressures, separates the test area from the open tunnel system and a second plug separates the two sections. This layout provides two more or less independent test sections. Canisters with dimension and weight according to the current plans for the

final repository and with heaters to simulate the thermal energy output from the spent nuclear fuel have been positioned in the holes and surrounded by bentonite buffer. The deposition holes are placed with a centre distance of 6 m. This distance was evaluated considering the thermal diffusivity of the rock mass and the maximum acceptable surface temperature of the canister.

The decision when to stop and decommission the test will be influenced by several factors including performance of monitoring instrumentation, results successively gained, and the overall progress of the deep repository project. It is envisaged that the outer test section will be decommissioned after approximately five years to obtain interim data on buffer and backfill performance. Instrumentation is used to monitor processes and evolution of properties in canister, buffer material, backfill and near-field rock. Examples of processes that are studied include:

- Water uptake in buffer and backfill.
- Temperature distribution in canisters, buffer, backfill and rock.
- Displacements of canisters.
- Swelling pressure and displacement in buffer and backfill.
- Stresses and displacements in the near-field rock.
- Water pressure build up and pressure distribution in rock.
- Gas pressure in buffer and backfill.
- Chemical processes in rock, buffer and backfill.
- Bacterial growth and migration in buffer and backfill.

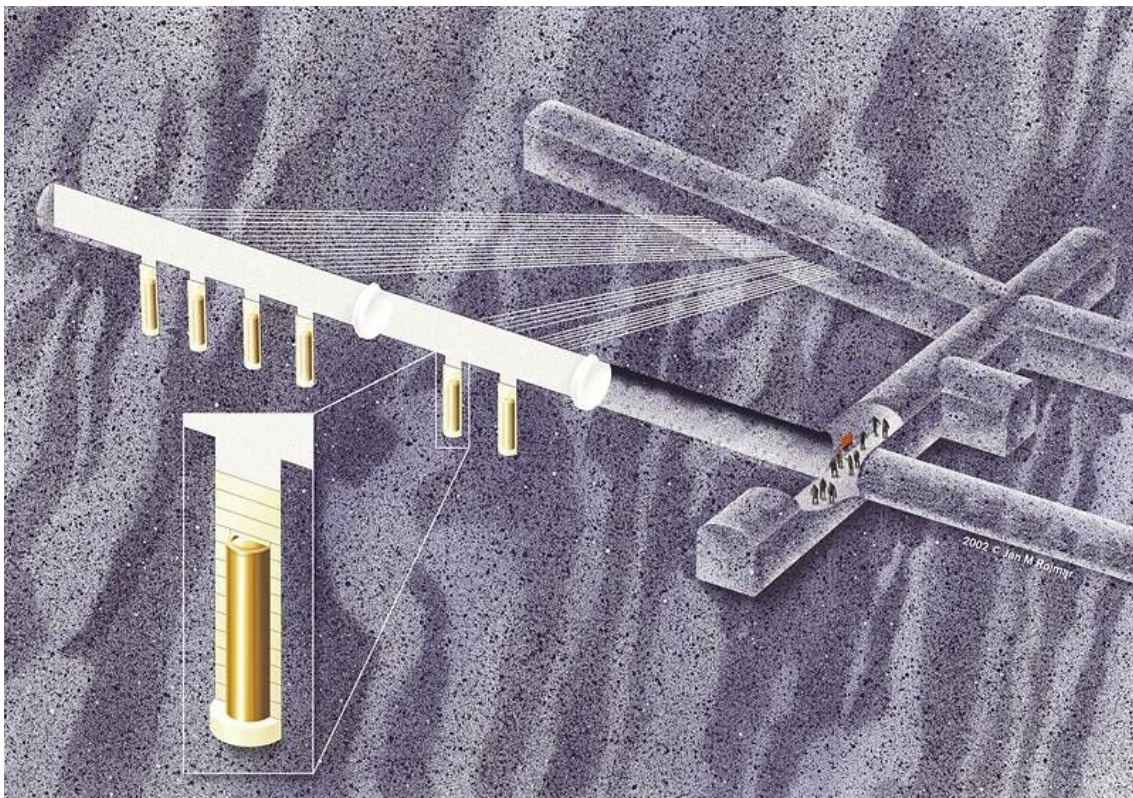


Figure 4-1 Schematic view of the layout of the Prototype Repository (not to scale).

Present status

The buffer and the canisters (#1 to #4) in the inner section were installed and the plug cast in 2001. Heaters were turned on one by one during September–October 2001 and the monitoring of processes was started and has yielded the expected data flow since then. The buffer and the canisters (#5 and #6) in the outer section were installed at the beginning of 2003. Immediately after the installation of the buffer, the tunnel section was backfilled and the heaters were turned on. This work was finished at the end of June 2003. At these stages the monitoring of processes in section two was started. The construction and casting of the outer plug started in August and were finished in September 2003. 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 but is now switched on again.

The instruments in the two sections in buffer, backfill and rock are continuously reading. 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. A thermal FEM model for the Prototype Repository including the rock, backfill, buffer and the six canisters has been developed. A one dimension THM modelling of the buffer in deposition hole #1 and #3 has been finished.

Scope of work for 2007

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.

4.3 Long Term Test of Buffer Material

Background

Bentonite clay has been proposed as buffer material in several concepts for HLW repositories. In the Swedish KBS-3 concept the demands on the bentonite buffer are to serve as a mechanical support for the canister, reduce the effects on the canister of a possible rock displacement, and minimise water flow over the deposition holes.

The decaying power from the spent fuel in the HLW canisters will give rise to a thermal gradient over the bentonite buffer by which original water will be redistributed parallel to an uptake of water from the surrounding rock. A number of laboratory test series, made by different research groups, have resulted in various buffer alterations models.

According to these models no significant alteration of the buffer is expected to take place at the prevailing physico-chemical conditions in a KBS-3 repository, neither during nor after water saturation. The models may to a certain degree be validated in long-term field tests. Former large-scale field tests in Sweden, Canada, Switzerland and Japan have in some respects deviated from possible KBS-3 repository conditions and the testing periods have generally been dominated by initial processes, i.e. water uptake and temperature increase.

Objectives

The present test series aims at validating models and hypotheses concerning the evolution of bentonite buffer properties. In the tests related processes regarding microbiology, radionuclide transport, copper corrosion and gas transport under conditions similar to those expected in a KBS-3 repository are studied. The expression “long-term” refers to a time span long enough to study the buffer performance at full water saturation, but obviously not “long-term” compared to the lifetime of a repository. The objectives may be summarised in the following items:

- Collect data for validation of models concerning buffer performance under quasi-steady state conditions after water saturation, e.g. swelling pressure, cation exchange capacity and hydraulic conductivity.
- Check of existing models on buffer-degrading processes, e.g. illitisation and salt enrichment.
- Collect data concerning survival, activity and migration of bacteria in the buffer.
- Check of calculation results concerning copper corrosion, and information regarding type of corrosion.
- Check existing models for diffusive transport of cations.
- Collect information, which may facilitate the realisation of the full-scale test series, with respect to clay preparation, instrumentation, data handling and evaluation.

Experimental concept

The testing principle for all tests is to emplace parcels containing heater, central tube, pre-compacted clay buffer, instruments and parameter controlling equipment in vertical boreholes with a diameter of 300 mm and a depth of around 4 m, see Figure 4-2. The test series concern realistic repository conditions except for the scale and the controlled adverse conditions in three tests, see Table 4-1.

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	Analysed
A	2	120–150	T, [K ⁺], pH, am	5	Analysed
A	3	120–150	T	5	On-going
S	1	90	T	1	Reported
S	2	90	T	5	On-going
S	3	90	T	>>5	On-going

A = adverse conditions

S = standard conditions

T = temperature

[K⁺] = potassium concentration

pH = high pH from cement

am = accessory minerals added



The first figures in the columns “special tests” and “gauges” denote block number and second figures in the column “gauges” denote the number of sensors. T denotes thermocouple, P total pressure sensor, W water pressure sensor, and M moisture sensor.

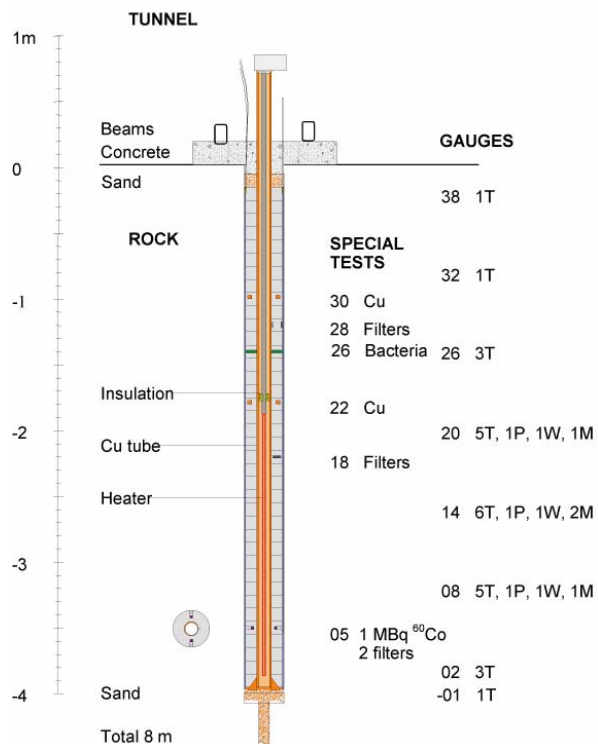


Figure 4-2 Illustration of the experimental set-up in the Long Term Test of Buffer Material (left) and a cross-section view of one S-type parcel (right).

Adverse conditions in this context refer to high temperatures, high temperature gradients over the buffer, and additional accessory minerals leading to for example high pH and high potassium concentration in clay pore water. The central copper tubes are equipped with heaters in order to simulate the decay power from spent nuclear fuel. The heater effect are regulated or kept constant at values calculated to give a maximum clay temperature of 90°C in the standard tests and in the range of 120 to 150°C in the adverse condition tests.

Each parcel contains 25 thermocouples, 3 total pressure gauges, 3 water pressure gauges, 4 relative humidity sensors, 7 filter tubes, and 12 water sampling cups. The power is controlled and temperature, total pressure, water pressure and water content are continuously being measured.

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 chemical, mineralogical analyses and physical testing is performed.

Present status

The A2 parcel has been analysed with respect to pore-water 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. A work-shop meeting was held in November where results were presented. Some additional tests will be made concerning carbon content, cation exchange capacity, layer charge and rheologic properties.

Scope of work for 2007

Water pressure, total pressure, temperature and moisture in the three remaining parcels will be continuously measured and stored every hour. The data are being checked monthly and the results are analysed more carefully in April and October. The analyses of the A2 parcel material including the additional tests and analyses will be reported in the end of January 2007. The results from the A2 parcel will be used in order to determine the value a retrieval of the next parcel (S2). In the case of a retrieval decision, the planning will start in February and retrieval will be made during the spring 2007, and subsequent analyses and reporting during the rest of 2007. In case of no retrieval, the meantime will be used in order to develop and test new analysing techniques.

4.4 Alternative Buffer Materials

Background

Bentonite clay has been proposed as buffer material in several concepts for HLW repositories. In the Swedish KBS-3 concept the demands on the bentonite buffer are to serve as a mechanical support for the canister, reduce the effects on the canister of a possible rock displacement and minimise water flow over the deposition holes. The MX-80 bentonite from American Colloid Co (Wyoming) has so far been used by SKB as a reference material. A large scale programme to study the use of possible alternative buffer material has been initiated, mainly to correlate the physical and chemical properties to fundamental mineralogical properties.

A number of commercial bentonite materials, from large producers, have been investigated with respect to mineralogy and swelling properties. So far the investigations have been done on the reference material MX-80, four samples from India (Ashapura) and one sample from Greece (Silver and Baryte). This project aims at studying the long term stability of bentonite and the influence by the accessory minerals in the materials.

Objectives

The project will be carried out using material that according to laboratory studies are conceivable buffer materials. The experiment will be carried out in the same way and scale as the Lot experiment at Äspö HRL. The project 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 THM and geochemical models.

Experimental concept

The testing principle is just as in the Lot experiment, see Section 4.3. Parcels containing heater, central tube, pre-compacted clay buffer, instruments and parameter controlling equipment will be emplaced in vertical boreholes with a diameter of 300 mm and a depth of 3 m.

In addition to the deposited bentonite blocks in the parcels, identical bentonite blocks will be stored to monitor the effects of storage.

The final experiment design is not completed. The layout of the parcels regarding bentonite type as well as the conditions of the experiment regarding temperature, artificial water saturation etc. are also to be decided.

Present status

A lot of work has been done during 2006. The experiment design has been finalised and approved by the participating organisations. All work with the manufacturing of experiment buffer blocks and other equipment has been finished and the experiment packages are now installed in the deposit holes. The heaters in package 1 and 3 were started in December 2006.

Initial discussions with the participating project partners on the analysis program are in progress.

Scope of work for 2007

During 2007 the experiment packages will be monitored closely as the buffer starts to saturate. The power to the heaters will be checked and adjusted to ensure that the temperature is as close to the goal temperature of 130 degrees along the entire package.

The buffer test plan will be finalised and the first analyses of the reference samples will be conducted.

An installation report will be written and distributed to the participating organisations.

4.5 Backfill and Plug Test

Background

The Backfill and Plug Test include tests of backfill materials and emplacement methods and a test of a full-scale plug. It is a test of the integrated function of the backfill material and the near-field rock in a deposition tunnel excavated by blasting. It is also a test of the hydraulic and mechanical functions of a plug. The test was partly a preparation for the Prototype Repository.

Objectives

The main objectives of the Backfill and Plug Test are to:

- Develop and test different materials and compaction techniques for backfilling of tunnels excavated by blasting.
- Test the function of the backfill and its interaction with the surrounding rock in full-scale in a tunnel excavated by blasting.
- Develop technique for building tunnel plugs and to test the function.

Experimental concept

The test region for the Backfill and Plug Test is located in the old part of the Zedex drift. Figure 4-3 shows a 3D visualisation of the experimental set-up. The test region, which is about 30 m long, is divided into the following three test parts:

- The inner part filled with a mixture of bentonite and crushed rock (six sections).
- The outer part filled with crushed rock and bentonite blocks and pellets at the roof (four sections).
- The concrete plug.

The backfill sections were applied layer wise and compacted with vibrating plates that were developed and built for this purpose. It was concluded from preparatory tests that inclined compaction should be used in the entire cross section from the floor to the roof and that the inclination should be about 35 degrees.

The inner test part is filled with a mixture of bentonite and crushed rock with a bentonite content of 30%. The composition is based on results from laboratory tests and field compaction tests. The outer part is filled with crushed rock with no bentonite additive. Since the crushed rock has no swelling potential, but may instead settle with time, a slot of a few decimetres was left between the backfill and the roof. The slot was filled with a row of highly compacted blocks, with 100% bentonite content, in order to ensure a good contact between the backfill and the rock. The remaining irregularities between these blocks and the roof were filled with bentonite pellets.

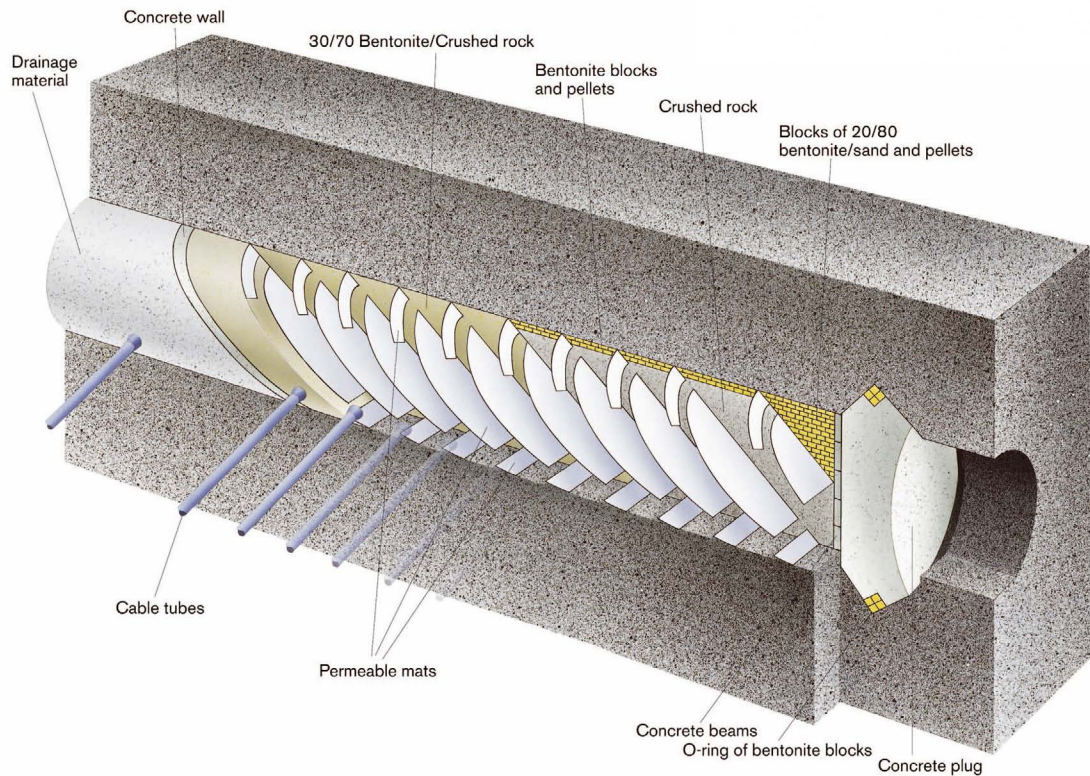


Figure 4-3 Illustration of the experimental set-up of the Backfill and Plug Test.

Each one of the two test parts is divided by drainage layers of permeable mats in order to apply hydraulic gradients between the layers and to study the flow of water in the backfill and near-field rock. The mats are also used for the water saturation of the backfill. The mats were installed in both test parts with the individual distance of 2.2 m. Each mat section was divided in three units in order to be able to separate the flow close to the roof from the flow close to the floor and also in order to separate the flow close to the rock surface from the flow in the central part of the backfill.

The outer test part ends with a wall made of prefabricated concrete beams for temporary support of the backfill before casting of the plug. Since *in situ* compaction of the backfill cannot be made in the upper corner, this triangle was instead filled with blocks of bentonite/sand mixture with 20% bentonite content.

The plug is designed to resist water and swelling pressures that can be developed. It is equipped with a filter on the inside and a 1.5 m deep triangular slot with an "O-ring" of highly compacted bentonite blocks at the inner rock contact.

The backfill and rock are instrumented with piezometers, total pressure cells, thermocouples, moisture gauges, and gauges for measuring the local hydraulic conductivity. The axial conductivities of the backfill and the near-field rock are after water saturation tested by applying a water pressure gradient along the tunnel between the mats and measuring the water flow. All cables from the instruments are enclosed in Tecalan tubes in order to prevent leakage through the cables. The cables are led through the rock in boreholes drilled between the test tunnel and the neighbouring demonstration tunnel hosting the data collection room.

Present status

The entire test set-up with backfill, instrumentation and building of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through the filter mats and continuous data collection and reporting started in late November 1999. Wetting of the backfill from the filter mats and the rock continued during the years 2000 to 2003. In order to increase the rate of water saturation the water pressure in the mats was increased to 500 kPa at the turn of the year 2001/2002. At the end of 2002 the moisture measurements indicated that the entire backfill of both backfill types was completely water saturated and during 2003 preparations and rebuilding of the wetting system for adapting it to the flow testing were done.

During 2004 and 2005 the flow testing of the bentonite/crushed rock mixture was performed. Evaluation of the results shows that the field hydraulic conductivity is in the same range as expected from the laboratory tests but rather high close to the roof due to poor compaction and close to the floor, probably due to the blast disturbed zone in the rock. In late 2005 and in large part of 2006 measurements of hydraulic conductivity in single points by pressurising filter equipped tubes and measuring the water flow into the backfill were performed. The results largely confirmed the other measurements. In autumn 2006 activation of the pressure cylinders mounted on the floor and in the roof started.

Scope of work for 2007

According to the time schedule, the Backfill and Plug Test was planned to be interrupted and the backfill excavated in autumn 2006. However, work prioritisation has delayed the activities and entailed a proposal to postpone the excavation.

The following activities will be accomplished presuming that no excavation will take place during 2007:

- Continued mechanical testing of the compressibility of the backfill with the four pressure cylinders. Two of them are placed in the roof and two on the floor.
- Continued data collection and reporting of measured water pressure, water flow and total pressure.
- Maintenance of equipment and supervision of the test.
- Supplementary modelling of the flow testing and evaluation of results.
- Supplementary laboratory testing for modelling and understanding of the hydro-mechanical properties of the backfill materials.

4.6 Canister Retrieval Test

Background

The stepwise approach to safe disposal of spent nuclear fuel implies that if the evaluation of the deposition after the initial stage is not judged to give a satisfactory result the canisters may need to be retrieved and handled in another way. The evaluation can very well take place so long after deposition that the bentonite has swollen and applies a firm grip around the canister. The canister, however, is not designed with a mechanical strength that allows it to be just pulled out of the deposition hole. The canister has to be made free from the grip of the bentonite before it can be taken up.

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 and has its maximum swelling pressure.

Objectives

The overall aim of the Canister Retrieval Test (CRT) is to demonstrate to specialists and to the public that retrieval of canisters is technically feasible during any phase of operation. The following was defined to fulfil the aim of the Canister Retrieval Test:

- Two vertically bored test holes in full repository scale, which fulfil the quality requirements deemed necessary for the real repository.
- Careful and documented characterisation of the properties of these holes including the boring disturbed zone.
- Emplacement of bentonite blocks, bentonite pellets and canisters with heaters, and artificial addition of water. However, only one of these deposition holes has been used for implementation of the Canister Retrieval Test.
- Saturation and swelling of the buffer are monitored under controlled conditions.
- Preparations for and demonstration of canister retrieval.

Boring of full-scale deposition holes and geometrical/geotechnical characterisation of holes as well as emplacement of bentonite and canister with heaters were made within sub-projects that concern also other tests in the Äspö HRL. In addition to the retrieval test, the results from monitoring of the buffer and the laboratory testing of excavated parts of the buffer will be used to increase the understanding of the THM processes in a deposition hole.

Experimental concept

The Canister Retrieval Test is located in the main test area at the -420 m level. The tunnel is excavated by conventional drill and blast techniques and is 6 m wide and 6 m high. The test period is separated into three phases:

Installation Phase	Boring of deposition holes and installation of instrumented bentonite blocks and canister with heaters in one hole. This hole is covered in the top with a lid of concrete and steel.
Saturation Phase	Saturation of the bentonite and evolution of the thermal regime with measurement of thermal, hydraulic and mechanical processes.
Retrieval Phase	Test of freeing the canister from the bentonite, docking the gripping device to the canister lid and lifting of the canister up to the tunnel floor and into the radiation shield on the deposition machine (reversed deposition sequence).

The buffer was installed in the form of blocks of highly compacted Na-bentonite, with a full diameter of 1.65 m and a nominal height of 0.5 m. Instruments for measuring temperature, relative humidity, total pressure and pore pressure were installed in the bentonite in many of the blocks. When the stack of blocks was 6 m high the canister equipped with electrical heaters was lowered down in the centre. Cables to heaters, thermocouples in the rock and strain gauges in the rock were connected, and additional blocks were emplaced until the hole was filled up to 1 m from the tunnel floor. On top,

the hole was sealed with a plug made of concrete and a steel plate as cover. The plug was secured against heave caused by the swelling clay with 9 cables anchored to the rock. The tunnel will be left open for access and inspections of the plug support. The experimental set-up is shown in Figure 4-4.

Artificial addition of water is provided evenly around the bentonite blocks by means of permeable mats attached to the rock wall. The design of the mats was done so that they are not disturbing the future test of retrieval.

Predicted saturation time for the test is 2–3 years in the 350 mm thick buffer along the canister and 5–10 years in the buffer below and above the canister. Decision on when to start the Retrieval Phase is dependent on the degree of saturation in the buffer. The instrumentation in the buffer is similar to the instrumentation in the Prototype Repository and yield comparable information during the Saturation Phase.

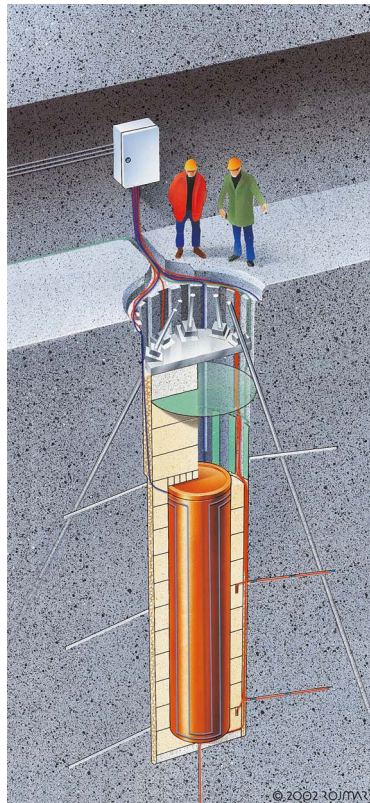


Figure 4-4 Illustration of the experimental set-up of the Canister Retrieval Test.

Present status

Based on information regarding saturation of the buffer and the problems with the heaters it was decided that the Retrieval Phase was started in January 2006. The Saturation Phase ended with the excavation and retrieval.

The buffer was manually excavated down to half the canister height. This allowed buffer samples to be taken and analysed. Both bentonite chemistry and biology is analysed.

Removal of the remaining buffer, from half the canister height and down, was done with the disintegration method. The bentonite was dissolved with a saline and pumped out of the deposit hole. The method was successful and the canister was freed from the buffer.

The canister has been retrieved from the deposition hole and delivered to the canister laboratory in Oskarshamn for analysis.

Malfunction of the canister heaters are so far considered to be caused by the heater power cables. The status of the heaters will be investigated when the canister is opened and the heaters can be retrieved.

Samples have been taken from the deposition hole rock and sent for analysis. The results will be compared with the analysis done on drill cores taken prior the experiment installation

Buffer analyses have been conducted during the year and a report on the first analyses is expected in fall 2007.

Scope of work for 2007

During 2007 the heaters will be analysed further. The result will be forwarded to other projects using the same type of heater setup at Äspö HRL e.g., the Prototype Repository.

Further buffer analyses will be conducted during 2007, this will be executed by Clay Technology in Lund.

Modelling of the buffer saturation and experiment progress is now part of the Task Force on Engineered Barrier Systems and will start during 2007.

Project reports will also be written during 2007.

4.7 Temperature Buffer Test

Background

The aim of the Temperature Buffer Test (TBT) is to evaluate the benefits of extending the current understanding of the behaviour of bentonite buffer to include high temperatures (above 100°C). The French organisation Andra is running the test in Äspö HRL in co-operation with SKB.

The scientific background to the project relies on results from large-scale field tests on engineered barrier systems carried out in underground laboratories: the Buffer Mass Test (Stripa), the Buffer/Container Experiment (URL in Canada), Febex (Grimsel Test Site), Canister Retrieval Test and Prototype Repository (Äspö HRL).

Objectives

The Temperature Buffer Test aims at improving the current understanding of the thermo-hydro-mechanical behaviour of clay buffers at temperatures around and above 100°C during the water saturation transient, in order to be able to model this behaviour.

Experimental concept

TBT is located in the same test area as the Canister Retrieval Test (CRT) at the -420 m level. Two identical heater probes, each 3 m long and 0.6 m in diameter, are stacked in a vertical 1.8 m diameter deposition hole. The principle design of the test and the experimental set-up are shown in Figure 4-5.

Two buffer arrangements are being investigated:

- One probe is surrounded by bentonite in the usual way, allowing the temperature of the bentonite to exceed 100°C locally.
- The other probe has a ring of sand between the probe and the bentonite, as thermal protection for the bentonite, the temperature of which is kept below 100°C.

The principle of the TBT test is to observe, understand and model the behaviour of the deposition hole components, starting from an initial unsaturated state under thermal transient and ending with a final saturated state with a stable heat gradient.

Heat transfer comes into play from the start of the test, possibly redistributing water being present in the buffers, with partial desaturation of very hot zones (>100°C). Inflow of water then causes saturation and consequent swelling of the bentonite.

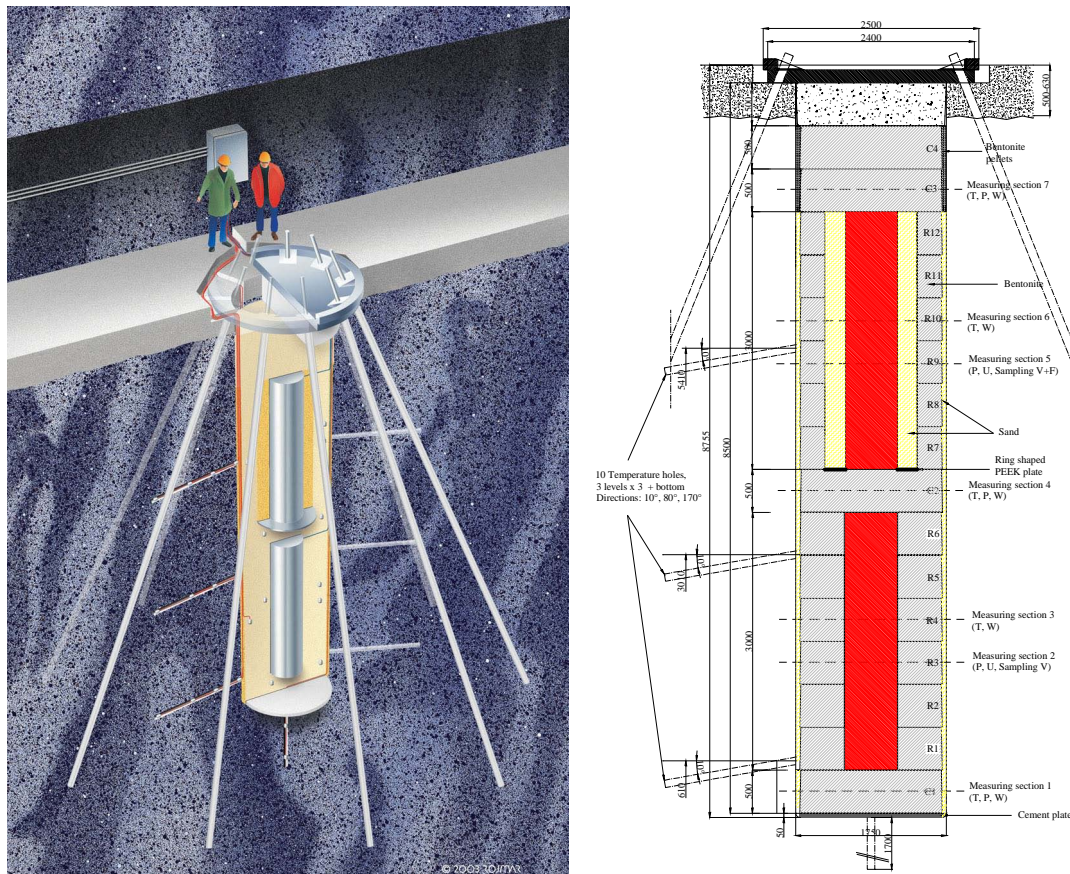


Figure 4-5 Principle design and experimental set-up of the Temperature Buffer Test.

The effects of a bentonite desaturation/resaturation cycle on the confinement properties are not well known. An open question which TBT is designed to answer is whether the mechanical effects of desaturation (cracking of the material) are reversible.

The similar geometries of CRT and TBT, the similar artificial water saturation systems, and the use of MX-80 bentonite buffer will facilitate interpretation of data and comparisons of results.

Present status

During 2002, TBT design modelling, procurement of instruments, fabrication of bentonite blocks were carried out by Clay Technology and heater probes built by Aitemin. Early 2003, the experiment was installed in Äspö HRL. The operation phase started late March 2003. Artificial water pressure and heater power have been set according to plan. The initial thermal shock has produced its effect showing local desaturation of the bentonite in place where temperature exceeded 100°C. No fluid pressure was measured in the sand of the composite buffer. Monitoring and sampling of experimental data are continuously ongoing. The data link from Äspö to Andra's head office in France has been functioning well.

A modelling group, formed with Swedish, Spanish and French teams, issued a preliminary predictive modelling report mid 2003. The predictions were compared with the first experimental results and presented in November 2003 at Sitges /Hökmark 2003/.

Two modelling tasks were conducted during 2004. The first one was predictive, and addressed the effect of increasing the output from the upper heater. From the results it was decided not to change the heat load. The second one emphasised on the evaluation of the development of stresses in Ring 9 and 10 around the upper heater /Åkesson 2006a/. A predictive modelling task was conducted during 2005. This concentrated on a mock-up test, denoted TBT 2 and conducted by CEA, designed to mimic the conditions at the interior of the buffer around the lower heater. The aim of the task was to determine the relationship between temperature gradients and levels on one hand, and extent of desaturation on the other /Åkesson 2006b/.

The TBT_3 modelling task was performed during 2006. This was similar to the TBT_2 task, with simultaneous blind predictive modelling and experimental work. The test followed a simpler and more efficient thermal protocol and the experimental setup was improved. A field-test modelling task was also launched during 2006. This task focus on replication of obtained high-confidence experimental results: stresses, cable forces and lid displacements.

Scope of work for 2007

Two tests are currently under consideration for possible implementation in the future. These are: (1) a gas migration test in the vicinity of the upper heater, and (2) a retrieval test of the upper heater. These tests are planned for 2008 and 2009, respectively.

To enable these tests, the buffer around the upper heater will have to be water saturated. This can be achieved through injecting water into the sand shield. The current plan is to saturate the shield during 2007.

4.8 KBS-3 Method with Horizontal Emplacement

Background

The KBS-3 method, which is based on the multi-barrier principle, has been accepted by the Swedish authorities and the government as a basis for planning the final disposal of spent nuclear fuel. It is possible to modify the reference method and make a serial deposition of canisters in long horizontal holes (KBS-3H) instead of vertical emplacement of single canisters in separate deposition hole (KBS-3V), which is SKB's reference concept, see Figure 4-6, has been considered since early nineties. The deposition process for KBS-3H requires the assembly of each copper canister and its buffer material in a prefabricated, so-called Super container.

Most of the positive effects of horizontal emplacement compared with vertical emplacement are related to the smaller volume of excavated rock. Examples of positive effects are:

- Less environmental impact during construction.
- Reduced disturbance on the rock mass during construction and operation.
- Reduced cost for construction and backfilling of the repository compared to KBS-3V. However, great efforts are required developing the KBS-3H concept.

At the end of 2001 SKB published an RD&D programme for the KBS-3 method with horizontal emplacement. The RD&D programme /SKB, 2001/ is divided into four parts: Feasibility study, Basic design, Demonstration of the concept at Äspö HRL and Evaluation. The RD&D programme is carried through by SKB in co-operation with Posiva. The development of the deposition equipment is partly funded by the European Commission ESDRED (Engineering Studies and Demonstration of Repository Design) Programme for studies on deposition equipment during the 2002-2006 period.

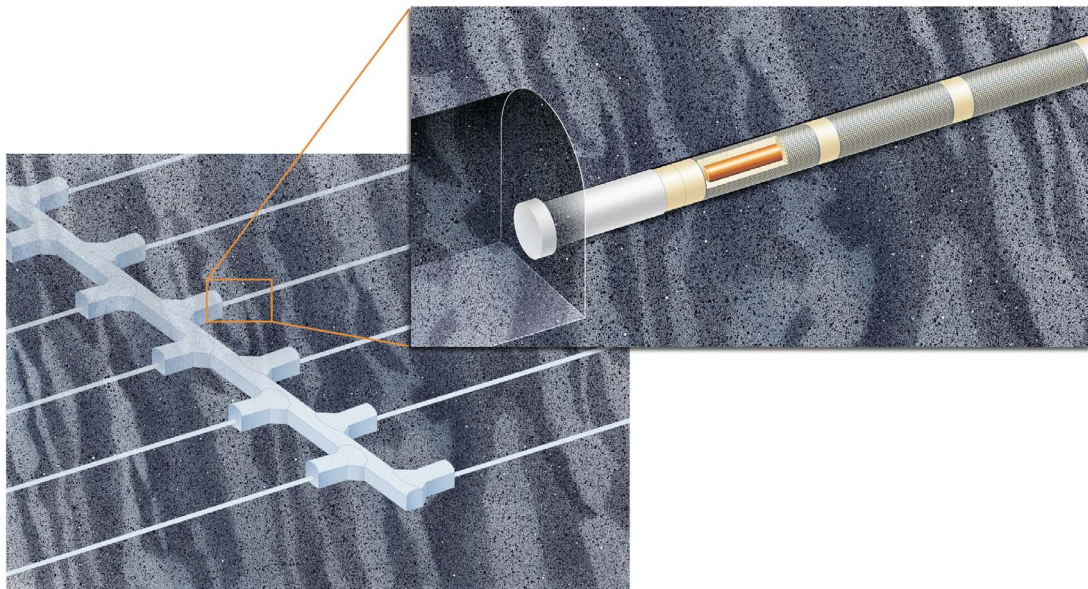


Figure 4-6 Schematic illustrations of KBS-3H.

Objectives

The objective of the first part of the project, the Feasibility study, was to evaluate whether horizontal emplacement is a realistic alternative, and if so, to give SKB and Posiva a basis for continued evaluation of KBS-3H. The feasibility study focused on differences compared to the reference concept KBS-3V. Highlighted tasks were excavation of the drifts, the deposition technique and the function of the buffer.

The second step, the Basic design study /Thorsager and Lindgren 2004/, focuses on technology for excavation of holes, emplacement of super containers, but also the design of the bentonite buffer inside the super containers. In addition, an evaluation of the long term safety of the concept was carried out.

The need to demonstrate the KBS-3H concept was foreseen in the KBS-3H feasibility study. Investigations into a suitable location and preparation of a demonstration site at Äspö HRL were decided upon. The demonstration site is located at the –220 m level in a niche with the dimensions 15 by 25 meters. The niche is designed to accommodate the vehicles, machinery and auxiliary equipment used for drilling the holes. Two horizontal holes with a diameter of 1.85 m have been excavated, one hole is 15 m long and the other is 95 m. The short hole will be used for construction and testing of e.g. a low-pH shotcrete plug and other design drift components, and the long hole will primarily be used for demonstration of the deposition equipment and also for some full-scale tests.

Present status

During 2006, the work has focused on the following topics:

- Test of the low-pH shotcrete plug
- Preparing for test of deposition equipment
- Test of the deposition equipment
- Repository drift design
- Buffer development
- Groundwater control
- Safety case.

Test of the low-pH shotcrete plug

In February/March 2006 the test with a low-pH shotcrete plug started in the short 15 m drift at Äspö HRL. The test was performed within the Esdred project, an integrated project within the 6th EC framework programme. However, the test showed that there are difficulties with adhesion between the plug and the rock surface. A long low-pH shotcrete plug test in a drift with a diameter of 3.5 m is now planned to be carried out at Grimsel HRL, Switzerland.

Preparing for test of deposition equipment

The niche, in front of the excavated 95 m long drift at Äspö, was prepared at the beginning of 2006 for testing and demonstration of the deposition equipment. A docking flange between the entrance of the drift and the deposition equipment has been installed. The position blocks for the transport support of the transport tube and the start launch have been constructed and several other preparations have been completed.

Test of the deposition equipment

The deposition equipment arrived in mid March and was installed. One of the two assembled supercontainers was transported from the assembly hall to the niche at the -220 m level. Figure 4-7 shows the deposition equipment in the niche at -220 m level at Äspö HRL. The official site acceptance test (SAT) was scheduled to commence in begin of April 2006. However, problems with the balancing system and the water cushion system were revealed during the manufacturers (CNIM) internal testing. The SAT is postponed until solutions to the problems have been found. The date for SAT is set to February 2007.



Figure 4-7 The deposition equipment in the niche at -220 m level at Äspö HRL.

After evaluating and testing different options for solving the balancing problems, it was decided to install guides to prevent rotation of the container. The guides were installed and tested in September. The results were positive and the super container was moved approximately 8 meters. Additional tests are needed to verify the trajectory of the container for longer distances and at full deposition speed.

Unfortunately a new problem with the water cushions was identified, which requires exchange of all the cushions before the continuation of the testing.

The deposition machine has also been provided with the following additional equipments which the testing has shown necessary:

- A third actuator.
- Lift sensors on the water cushion palette.
- A frequency converter to enable control of the flow from the water pump.

Repository drift design

At present there are two different candidate designs of KBS-3H:

- Basic Design (BD).
- Design based on Drainage, Artificial Watering and air Evacuation (DAWE).

BD alternative is based on the assumption that distance blocks will seal the supercontainer units in wet sections stepwise in sequence independently of each other. In the DAWE design the drift can be artificially filled with water after plugging one compartment with a steel plug and sealing the compartment. The distance blocks will then swell and isolate the supercontainer units simultaneously. These two KBS-3H candidate designs are at the moment being developed to the level of detail required to enable evaluation of the feasibility of the KBS-3H concept in 2007.

Buffer development

The distance block is an important component of the KBS-3H design. The design is based on distance blocks composed of compacted bentonite, which seal or isolate the super container units from each other. Design options, which would function in the expected environment, are being tested. To allow design of the distance blocks, several critical processes detrimental to the behaviour of bentonite are being studied and resolved.

Ground water control

Groundwater control measures will evidently have significant influence on the economic feasibility of the system and work is focusing on finding techniques for achieving an acceptable level of water inflow to the drift.

Safety case

A “difference analysis” between KBS-3V and KBS-3H has been performed. This is the basis of the work for the KBS-3H safety case. Only the significant differences with respect to KBS-3V are evaluated in detail, because the KBS-3H concept rests on the broad technical and scientific foundation of the KBS-3V experience with canister development, spent fuel studies, buffer studies, geosphere and biosphere issues and safety analysis. Draft versions of Process and Evaluation reports have been completed. Input from the Design description at the end of 2006 will make it possible to finalise the reports in June 2007. The iron-bentonite interaction is being studied. This work will continue.

Scope of work for 2007

The KBS-3H project will continue with following main activities:

- Demonstration of the KBS-3H concept at the Äspö HRL.
- Design of repository layout.
- Safety case.
- Evaluation and reporting of the KBS-3H concept.

Demonstration at the Äspö HRL

The test and demonstration of the deposition equipment will be performed. Three demonstrations/tests are planned in the 95 m drift at Äspö HRL:

- Site Acceptance Test of the Deposition Equipment.
- Demonstration of the KBS-3H deposition concept.
- Demonstration of the integrity of the super container and distance block during the emplacement process.

Techniques for ground water control (sealing) in the drift which will be tested are: a mega packer device for grouting with silica-sol in the 95 m long drift and a steel plug in the 15 m long drift.

Design of repository layout

The most important milestones for the development of the concept design are:

- Development of the design basis and verification of the function of the most important design components.
- Description of methods for control of groundwater inflow followed by a full-scale demonstration of the groundwater control techniques.
- Tests of the most important design components separately.
- Make an Olkiluoto specific repository layout adaptation.
- Description of the general design and most important design components.

Also, as part of that the development of designs, basic design for retrieval, feasibility study, and evaluation of the KBS-3H concept and reporting of results are planned to be carried out by 2007 in a preliminary Design report.

Safety case

Both the process and evolution reports will be completed in June 2007. THM modelling for the system will be included in the process report. Other main reports which will be compiled deal with radionuclide release and transport and complementary evaluations. Finally, a summary report on the safety case for KBS-3H for the reference site Olkiluoto will be written.

Long-term studies on the effect of iron on bentonite will be initiated. Also studies on the development of alternative materials and designs for super container and other steel components, including their impact on long-term safety will be initiated.

Evaluation and reporting of the KBS-3H concept

The main goal in 2007 is the compilation of all the knowledge gained within the R&D programme for the evaluation of the potential of the KBS-3H concept. To find out whether the concept can be regarded as a viable alternative to the KBS-3V concept the demonstration and design work will involve:

- Development of technology for excavation of the drift.
- Detailed studies on the function of the buffer bentonite, deposition equipment and methods for construction of drift end plugs.
- A preliminary safety case of the concept with Olkiluoto in Finland as a reference site.

- Cost compilation of the KBS-3H concept for a comparison with the KBS-3V concept
- Retrieval study.

A Summary study report of the KBS-3H concept will be finalised at the end of 2007 and will form a basis for decisions to be made by Posiva's and/or SKB's boards regarding whether or not the KBS-3H concept can be considered to be an alternative to the KBS-3V concept. At a positive decision a next phase of the project could start to develop the KBS-3H concept further.

4.9 Large Scale Gas Injection Test

Background

The bentonite buffer is an important barrier in the KBS-3 system. A key purpose of the buffer is to serve as a diffusion barrier between the canister and the groundwater in the rock. An important performance requirement on the buffer material is to not cause any harm to the other barriers. Gas build up from corrosion of the iron insert could potentially affect the buffer performance in three ways:

- Permanent pathways in the buffer could form at gas breakthrough. This could potentially lead to a loss of the diffusion barrier.
- If the buffer does not let the gas through, the pressure could lead to mechanical damage of the other barriers.
- The gas could de-hydrate the buffer.

Current knowledge pertaining to the movement of gas in initially saturated buffer bentonite is based on small-scale laboratory studies. While significant improvements in our understanding of the gas-buffer system have taken place, recent laboratory work has highlighted a number of uncertainties, notably the sensitivity of the gas migration process to experimental boundary conditions and possible scale-dependency of the measured responses. These issues are best addressed by undertaking large scale gas injection tests.

Objectives

The aim of the Large Scale Gas Injection Test (Lasgit) is to perform a gas injection test in a full-scale KBS-3 deposition hole. The objective of this experimental programme is to provide data to improve process understanding and test/validate modelling approaches which might be used in performance assessment. Specific objectives are:

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

The Lasgit project will end after two years of gas testing. At that stage a decision will be taken whether to dismantle the experiment or to continue with testing in a new project.

Experimental concept

Lasgit is a full-scale demonstration project conducted in the assembly hall area in Äspö HRL at a depth of -420 m. A deposition hole, 8.5m deep and 1.8m in diameter, has been drilled into the gallery floor. A full-scale KBS-3 canister (without heater) has been emplaced in the hole. Thirteen circular filters of varying dimensions are located on the surface of the canister to provide point sources for the injection of gas to mimic canister defects. Pre-compacted bentonite blocks with high initial water saturation have been installed in the deposition hole. The hole has been capped by a conical concrete plug retained by a reinforced steel lid capable of withstanding over 5,000 tonnes of force (Figure 4-8).

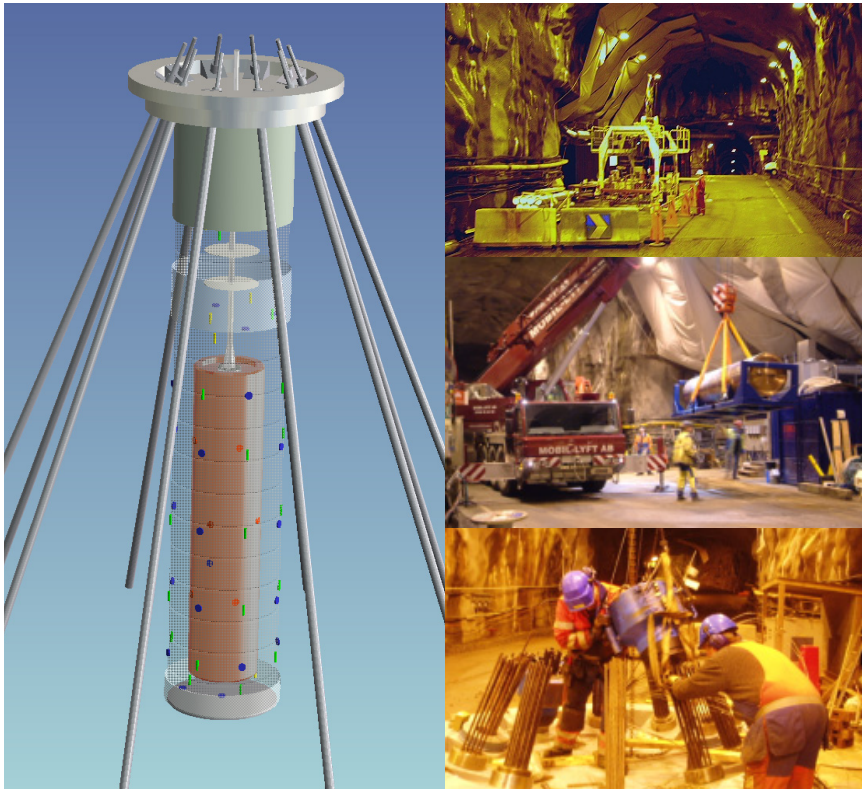


Figure 4-8 Layout of the Lasgit experiment showing the copper canister, the bentonite buffer, the location of some of the instrumentation, the plug and rock anchors. From top to bottom the photographs on the right-hand side show the Assembly Hall area, the movement of the copper canister prior to installation and the pre-tensioning of the steel lid.

In the field laboratory instruments continually monitor variations in the relative humidity of the clay, the total stress and porewater pressure at the borehole wall, the temperature, any upward displacement of the lid and the restraining forces on the rock anchors. The experiment is a "mock-up test" which does not use any radioactive materials.

The *installation phase* consists of the design, construction and emplacement of the experiment and it includes mainly:

- Characterisation of the deposition hole, hydraulic measurements and instrumentation of the wall.
- Development of a technique for the manufacturing of buffer blocks with exceptional high water content. Manufacturing of a set of blocks. Preliminary modelling of the hydration of the buffer.
- Preparation of a full-scale canister with gas injection equipment. Design and construction of a lid, which will seal the deposition hole and simulate the tunnel backfill.
- Design and construction of a gas injection and measurement field laboratory. Installation and testing of the equipment before deposition of the canister.
- Installation of canister, buffer, lid, and sealing of the deposition hole.

The aim of the *hydration phase* is to fully saturate and equilibrate the buffer. This will be done by:

- Water uptake from natural groundwater in the deposition hole.
- Artificial saturation by water injection through the gas injection ports mounted on the surface of the canister.
- Artificial saturation by water injection through mats located at a number of positions within the buffer and around the walls of the emplacement borehole.

The saturation will be monitored by measuring pore pressure, total pressure and suction at both the buffer/rock interface and key locations within individual clay blocks.

The hydration phase will provide an additional set of data for (T)HM modelling of water uptake in a bentonite buffer. However, no such modelling is planned within the project at this stage.

The *gas injection phase* will start when the buffer is considered to be fully saturated. A series of detailed gas injection histories will be performed examining the processes and mechanisms governing gas flow in bentonite.

Present status

The Lasgit deposition hole was closed on the 1st February 2005 signifying the start of the hydration phase. Groundwater inflow through a number of conductive discrete fractures resulted in elevated porewater pressures. This problem was addressed by drilling two pressure-relief holes in the surrounding rock mass. Artificial hydration began on the 18th May 2005 after 106 days of testing. Initial attempts to raise porewater pressure in the artificial hydration arrays often resulted in the formation of preferential pathways. These pressure dependent features were not focused in one location but occurred at multiple sites at different times in the test history. These pathways appear to be relatively short lived, closing when water pressure is reduced.

At present monitored porewater pressures within the clay remain rather low ranging from 85 kPa to 380 kPa. This is in contrast to the water pressure measured at the face of the deposition hole which ranges from 1240 kPa to 2605 kPa. Monitored radial stress around the canister continues to increase steadily ranging in value from 1450 kPa to 4970 kPa, with an average value of 3785 kPa. Analysis of the distribution in radial stress shows a narrow expanding zone of elevated stress propagating vertically upwards

from the base of the hole. Stress measurements on the canister surface indicate radial stresses in the range 4350 kPa and 4550 kPa, which are comparable with the values of radial stress monitored on the rock face. Axial stress is significantly lower at 2920 kPa. Axial stress within the clay ranges from 3260 kPa to 5660 kPa and is non-uniformly distributed across the major axis of the emplacement hole. The average axial total stress within the bentonite is now greater than the initial pre-stress applied by the lid. Movement and distortion of the steel retaining lid has occurred following the installation and initial closure of packered intervals within the pressure relief holes. Estimates of effective stress (swelling pressure) at the rock face suggest values in the range of 70 to 3050 kPa with an average of around 1910 kPa. Suction data from devices located within the buffer above and beneath the canister indicate that a significant amount of the clay remains in suction.

Analysis of the flow data from the artificial hydration system suggests a disproportionately large flux from the canister filters compared to the hydration mats. This can be explained by a number of factors including compression of the filter mats (i.e. a reduction in permeability) or a zone of elevated permeability around the canister.

The test has been in successful operation for in excess of 680 days. Since closure of the deposition hole there have been no instrumentation failures. 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 2007

During 2007 preliminary hydraulic and gas injection histories will be performed with a view to verifying the operation and data reduction methodologies for the experiment, providing qualitative data on hydraulic and gas transport parameters. The test will be designed in such a way as to minimise the effect of reintroducing gas and will be performed in one of the lower filter arrays where the bentonite is locally saturated. The remaining filters on that level will be isolated from the artificial hydration system and their pressure allowed to evolve to provide temporal data on local pore water pressures within the buffer clay. Simultaneously artificial hydration will continue through all remaining canister filters and hydration mats.

In addition, a contribution to the final report for the EC Integrated Project on the Near Field (NF-Pro) will be prepared.

4.10 In Situ Corrosion Testing of Miniature Canisters

Background

The evolution of the environment inside a copper canister with a cast iron insert after failure is of great importance for assessing the release of radionuclides from the canister. After failure of the outer copper shell, the course of the subsequent corrosion in the gap between the copper shell and the cast iron insert will determine the possible scenarios for radionuclide release from the canister. This has been studied experimentally in the laboratory and been modelled. The corrosion will take place under reducing, oxygen free conditions and such conditions are very difficult to create and maintain for longer periods of time in the laboratory. *Consequently in situ* experiments at Äspö HRL will be invaluable for understanding the development of the environment inside the canister after initial penetration of the outer copper shell.

Objectives

The objective of the project is to obtain a better understanding of the corrosion processes inside a failed canister. The results of the experiment will be used to support process descriptions and safety analyses.

Experimental concept

Miniature copper canisters, with a diameter of 150 mm, have been emplaced in boreholes, with a diameter of 300 mm. The canisters will be exposed to natural reducing groundwater for several years and the experiment will be monitored.

Present status

Grouting of the rock wall near the five boreholes for the Miniature Canister corrosion experiments was completed in 2006. Manufacture and procurement of all the test specimens and equipment were completed and the first experiment, which did not contain any bentonite, was set up in September 2006. At the end of December three canisters were installed and the remaining two will be installed early in 2007.

In the experiments, one will contain no bentonite, three will contain low permeability bentonite in a support cage around the canisters and the fifth will contain fully compacted bentonite in direct contact with the miniature copper canister. Two of the canisters will be monitored using strain gauges. All the canisters have one or more defects in the outer copper shell (1 mm diameter defects), in a range of different orientations. Cast iron and copper corrosion coupons are mounted in each experiment and the corrosion behaviour is being monitored electrochemically. In addition, cast iron and copper weight loss specimens are present. Each experiment contains a 'sandwich type' copper-cast iron specimen to investigate oxide jacking effects and galvanic corrosion. U-bend and wedge open loading stress corrosion specimens will be mounted in one of the boreholes in direct contact with the groundwater, to assess the possible risk of stress corrosion cracking of copper. Eh is being monitored using a combination of metal oxide, platinum and gold electrodes.

Scope of work for 2007

In 2007, installation will be completed and monitoring of the experiments will continue. The experiment is monitored continuously by computer-controlled equipment and the data is evaluated remotely. The water composition will be analysed regularly and microbial activity will be assessed. It is anticipated that the experiments will remain undisturbed for at least five years. Data from the experiments will be interpreted and reported at SKB progress meetings and in an annual project report.

4.11 Cleaning and Sealing of Investigation Boreholes

Background

Investigation boreholes are drilled during site investigations and detailed characterised in order to obtain data on the properties of the rock. These boreholes must be sealed, no later than at the closure of the final repository, so that they do not constitute flow-paths from repository depth to the biosphere. Sealing of the borehole aims at receiving conductivity in the borehole that is no higher than that of the surrounding rock.

Cleaning of the boreholes means that instrumentation that has been used in the boreholes during long time-periods, in a sometimes aggressive environment, is removed.

Sealing of boreholes with cementitious materials is commonly used in construction work and can be performed with well-known techniques. Earlier studies, e.g. the Stripa project, have shown that sealing with cementitious material include a potential risk for degradation due to leaching and the sealing can not be guaranteed over time-periods longer than hundreds of years. Another opportunity is to use swelling clay materials, such as compacted bentonite blocks or bentonite pellets. Sealing with bentonite blocks has been tested in the framework of the Stripa project, in boreholes with a length of 200 m, with very promising results. A further development of this technique is, however, required to show that boreholes with lengths of up to 1,000 m can be sealed. Since most of the investigation boreholes are instrumented, reliable technique is also needed to clean boreholes so that they can be sealed.

Objectives

The main objective of this project is to identify and to demonstrate the best available techniques for cleaning and sealing of investigation boreholes. The project comprises three phases. Phase 1, mainly an inventory of available techniques, was finalised in 2003. Phase 2 aims to develop a complete cleaning and sealing concept “Basic concept”. In phase 3, the techniques and handling will be tested and demonstrated in full scale. The work is divided in the four sub-projects described below.

Sub-project 1

This sub-project comprises the engineering of design solutions of borehole plugs of clay and cement, respectively. The development of design of the basic sealing concept, with highly compacted clay in perforated tubes primarily intended for use in boreholes longer than 100 m, comprises the following steps:

- Theoretical modelling of the hydration and maturation of clay components in perforated tubes, taking perforation geometry and clay density as main variables.
- Definition of most suitable density and water content of clay components according to the modelling.
- Lab and small-scale field testing of erodability of clay components in perforated tubes (Figure 4-9).
- Lab testing of the maturation rate for assessment of the theoretical model using different water salinities and perforation geometries.
- Manufacturing of clay components for plugging of short and long holes.
- Investigation and pre-testing of alternative methods for plugging short holes by use of clay.

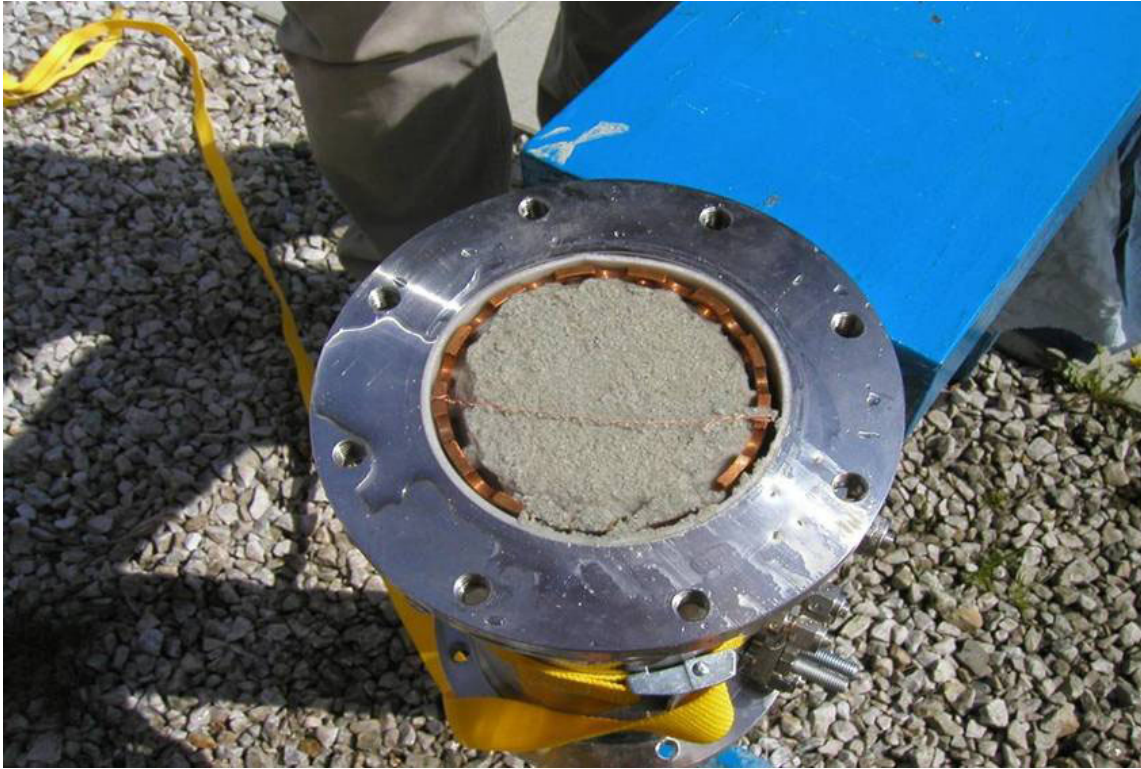


Figure 4-9 Lab and small-scale field testing of erodability of clay components in perforated tubes.

Sub-project 2

This sub-project will comprise plugging and testing of eight 5 m deep, 76-80 mm diameter boreholes at Äspö. While the basic clay plug concept for sealing longer holes than about 100 m implies use of perforated copper tubes with tightly fitting cylindrical blocks of highly compacted smectite-rich clay, simpler techniques are estimated to be applicable in shorter boreholes, especially in holes drilled from repository rooms within the near-field. Some of these techniques will be tested, taking the following issues into consideration:

- Practicality - This includes assessment of how doable the plugs are, estimation of the need for rigs and tools for placement and possible retrieval, and required forces for bringing the plugs into and out from the holes. Also, the techniques and costs of manufacturing, transporting and storing of the plug components must be estimated.
- Possibility to plug graded horizontal and upward-directed holes.
- Risk of failure in placement and retrieval of plugs by breakage and loss of clay and other components or problems related to too quick maturation of the clay.

Sub-project 3

This sub-project comprises preparation, stabilisation and installation of plugs in the 76 mm wide core hole OL-KR24 at Olkiluoto. The major issues are:

- Demonstration of the feasibility of the basic plugging method, i.e. placement of segments of jointed units of perforated copper tubes filled with highly compacted Na-bentonite columns (the basic concept).
- Demonstration of the feasibility of filling parts of the borehole that intersect fracture zones with chemically stable quartz-based fill.
- Demonstration and evaluation of a technique to bring down a dummy for checking the clearance of a real plug segment before installing it.
- Demonstration of the accuracy of replacing natural water in the hole by tap water.

Sub-project 4

The aim of this sub-project is to test the feasibility of three candidate techniques intended for mechanical securing of the tight seals emplaced lower in deep boreholes as outlined in the main Borehole Plugging Report.

This sub-project comprises plugging and testing of four 1.5 m long, 200 mm diameter boreholes at Äspö. The boreholes are located within the same area as the 5 m long holes at Äspö. The 200 mm holes are planned to be used for simulating sealing of the upper ends of deep boreholes.

Present status

For sub-projects 1 and 2 all the field and laboratories studies are finished. For sub-project 3 there will be two reference plugs installed in boreholes at Äspö. The work has to be coordinated with the KBS-3H program (see Section 4.8). In sub-project 4 the copper and quartz/cement (QC) plugs have been successfully installed in two boreholes at the surface. Milling of a slot for testing of QC-plugs with different mixing have been done in the 200 mm boreholes at -450 m level in Äspö HRL. A laboratory study of the shear strength of QC-plugs with different mixing have been done. The data from the report will be used as input for designing the field-test at Äspö. Design of loading device for shear testing is in progress.

Measurements of earth potentials have been made in 500 m deep boreholes at the two sites Forsmark and Laxemar where SKB perform site investigations. The results and evaluations from the measurements will be published in a report.

Scope of work for 2007

The QC-plugs at -450 m level will be tested, and the final report from the project will be delivered in June 2007.

4.12 Rock Shear Experiment

Background

Rock displacement is one out of a few processes, which can seriously damage a canister, and constitutes thereby a threat against the integrity of a final repository. The effect of the process is thus of importance to analyse and describe in an accurate way.

Fractures and fracture systems are natural components in granite rock, and can not be avoided totally in the repository areas. Deposition holes will be bored through such features and the issue for the final decision on accepting or rejecting a bored deposition hole will among other things be based on the properties of the fractures the deposition hole is crossing. One of these properties is the possible displacement along the fracture caused by seismic events. The buffer in KBS-3 is assumed to protect the canister from loosing its integrity for instant displacements up to 100 mm. The forces on the canister at such a major displacement have been modelled as well as analysed based on experiments in laboratory scale (up to 1:10 scale). The results are, however, proposed to be verified in larger scale than 1:10, if a significantly more accurate criterion shall be feasible to apply in the accepting/rejecting process.

Objectives

The project aims at observing the forces that act on a KBS-3 canister if a displacement of 100 mm would take place in a horizontal fracture that crosses a deposition hole at canister height. Such a displacement is considered to be caused by an earthquake, and the test set-up needs to provide a shearing motion along the fracture that is equal to an expected shearing motion.

Experimental concept

The test set-up is planned to use the site of the Äspö Pillar Stability Experiment since the rock mechanics test there has been completed. Two full scale deposition holes thus exist with a rock pillar of one metre in between. Figure 4-10 illustrates the present, schematic idea for a test set-up. The left deposition hole is used for the buffer and canister, while the right deposition hole is used for the shearing equipment. Half of the rock between the holes is removed (partly fractured after the pillar experiment) and replaced by a steel structure that has a plane for movements. Half of the upper part of the left hand hole is enlarged by sawing away about 200 mm in order to make room for the shear displacement. This upper part, which shall be sheared, is surrounded by a steel pipe, which is attached to the steel structure and is mobile in the direction of the shearing. The hole is plugged by a combined steel and concrete structure, which is anchored to the rock by a steel beam or by cable bolts as in Canister Retrieval Test and Temperature Buffer Test.

The shearing may not be done before the buffer has saturated. This time can, however, be reached after about two years by using highly saturated bentonite blocks, 95–98% saturation, and lining the hole with permeable mats for artificial water supply. Planned shearing speed is 0.1 m/s. For this shearing speed pistons may be used as shown in Figure 4-10.

Present status

A feasibility study has been done and is reported. The main conclusion of the study is that the test is feasible. A preliminary decision to realise the plans has been taken but the time schedule is not yet set.

Scope of work for 2007

The work 2007 will mainly include planning of supplementary laboratory tests. The main test will not be started until later.

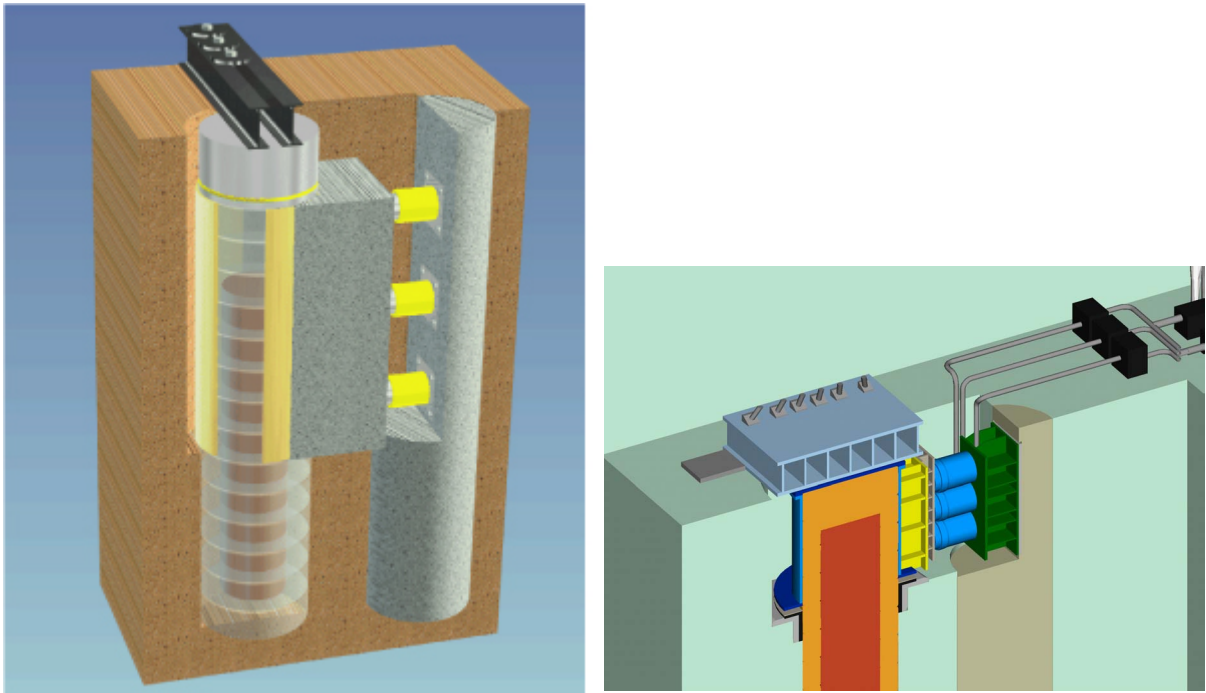


Figure 4-10 Schematic view of a possible test set-up for verification of the stress and strain a canister may exhibit during an instant shearing of about 100 mm.

4.13 Earth Potentials

Background

A stray current is a current flowing via a path other than the intended circuit. Due to the resistance variations in the path, a potential difference can be measured between different locations. If this current intersects a conducting (metallic) object, the point on the structure at which the current enters will be cathodically protected and the point at which the current leaves the structure and re-enters the ground path will be anodically polarised. Based on the source of the current, stray currents can be classified as either man-made or Geomagnetically Induced Currents (GIC).

Man-made currents result from interference from either direct current (DC) or alternating current (AC) power cables. Direct currents could also occur in AC installations if the system is not grounded purportedly. Corrosion is most severe for DC and stray currents are less of a problem for AC installations. Geomagnetically induced

currents arise from two sources, interaction of the earth's magnetic field with solar particles emitted from the sun and voltage gradients induced at the earth/sea interface by tidal movement. The magnitudes of GIC due to solar particles (often referred to as telluric currents) are greatest in polar and sub-polar regions.

Objectives

The main objectives of the project are to identify the magnitude of potential fluctuations and stray currents for GIC and man-made stray current sources at repository depth and by that estimate the potential problems that could occur.

The project will include the following investigations:

- Electromagnetic induced currents from natural sources.
- Electrochemical reactions in soil and rock.
- The transition from ion transfer in bentonite to electron transport in copper.
- Impact of copper ions on bentonite properties.
- Physical and chemical interactions between copper and bentonite.
- Basic processes in clay that are exposed to direct currents.
- Microbes as electron transmitters.

Present status

The results from the investigations concerning impact of copper ion in bentonite have been delivered and reported. The investigations of transition from ion transfer in bentonite to electron transport in copper are still in progress, a draft report was delivered in 2006 and final reporting is in progress.

Scope of work for 2007

All research and investigations will be compiled in a report where the focus will be on if and how geomagnetic induced currents or magnetic field could effect a underground repository.

4.14 Task Force on Engineered Barrier Systems

Background

The Task Force on Engineered Barrier Systems (EBS) was in 2000 decided to focus on the water saturation process in buffer, backfill and rock. Since the water saturation process also was a part of the modelling work in the Prototype Repository project, the work was transferred to the Prototype Repository project, and the Task Force was put on a stand-by position. As the European Commission funding of the Prototype Repository project ceased in February 2004 the Task Force on EBS was reactivated. A kick-off meeting was held in 2004 and two tasks were chosen for the Task Force work, namely:

Task 1: THM processes in buffer materials.

Task 2: Gas migration in buffer material.

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 on Engineered Barrier Systems does not include geochemistry a decision has been taken by the Äspö International Joint Committee (IJC) to also start a parallel task force that deals with geochemical processes in engineered barriers. The specific tasks have not yet been selected. The two task forces will have a common secretariat but separate chairmen.

Present status

The modelling is performed both for small scale tests in the laboratory (Benchmark 1) and large scale tests in the field (Benchmark 2).

For Task 1 three small scale tests (Benchmark 1) have been presented and modelled by the teams. The tests concern the Spanish reference buffer material, Febex bentonite, and the Swedish reference buffer material MX-80:

- Benchmark 1.1.1 - THM mock-up experiments on compacted MX-80 bentonite.
- Benchmark 1.1.2 - Large cell experiments on compacted Febex bentonite.
- Benchmark 1.1.3 - Thermal gradient test on compacted Febex bentonite with no water supply.

The aim was to model well documented laboratory tests of water uptake and temperature gradient induced water redistribution. The modelling results have been presented and compared to measurements. Decent agreements have been reached and written reports were delivered in the end of 2006.

For Task 2 two small scale tests (Benchmark 1) have been presented and attempts have been made to model these tests. Both tests concern gas breakthrough in highly compacted water saturated MX-80:

- Benchmark 1.2.1 - Gas tests with constant external total pressure.
- Benchmark 1.2.2 - Gas tests with constant volume.

The modelling groups have had considerable problems in the modelling and so far the models used do not seem to be appropriate.

Scope of work for 2007

In 2007 review and auditing of the modelling capabilities of the codes used for both Task 1 (THM related processes) and Task 2 (processes at gas break through) will be presented and discussed. The need for new small scale benchmark tests and further code developments will be considered.

For Task 1 the subsequent modelling will concern large scale *in situ* tests. The Buffer/Container Experiment and the Isothermal Test carried out by AECL (Atomic Energy of Canada Limited) have been presented and will be modelled during 2007. Another large scale test (the saturation phase of the Canister Retrieval Test in Äspö HRL) will be presented and modelling of that test will start in the autumn.

5 Buffer materials and backfill technology

5.1 Background

A number of experiments which are being carried out at the Äspö HRL (Canister Retrieval Test, Prototype Repository and Large Scale Gas Injection Test) have confirmed that, at full scale, it is possible to place pre-pressed blocks and rings of bentonite around a canister under both ideal and more demanding conditions. Conditions regarded as more demanding usually involve the inflow of groundwater in the deposition hole. Piping - usually flow channels between the rock wall and the buffer - arises when the inflow of groundwater in combination with the groundwater pressure are so great that the buffer is not able to swell quickly enough to counteract the pressures arising. When setting up the current experiments different solutions were applied to prevent flow channels forming or at least to stop the development of them. Before building a final repository, where the operating conditions include the deposition of one canister per day, further studies of the behaviour of the buffer under different installation conditions are required.

5.2 Objectives

SKB has decided to build a Bentonite Laboratory in the Äspö Research Village. This new laboratory will be designed for studies of buffer and backfilling materials. The Bentonite Laboratory will include two stations where the emplacement of buffer material at full scale can be tested under different conditions. The laboratory will also be used for continued testing of different types of backfill material and the further development of techniques for the backfilling of deposition tunnels.

5.3 Present status

Currently the Bentonite Laboratory is under construction. The construction activities on site were initiated in May 2006 when the excavation of rock started. The complete building structure was delivered to Äspö during the end of 2006 and construction work is scheduled to be finished in March 2007.

5.4 Scope of work for 2007

During 2007 the experimental work in the Bentonite Laboratory will commence. The aim of the new laboratory is to carry out various forms of tests and verifications under realistic conditions. The results will be techniques, methods, procedures and parameters for the buffer and backfilling materials as well as development of handling equipment to be used in the final repository.

6 Äspö facility

6.1 General

Important parts of the Äspö facility are the administration, operation, and maintenance of instruments as well as development of investigation methods. The Public Relations and Visitor Services group is responsible for presenting information about SKB and its facilities e.g. the Äspö HRL. They arrange visits to the facilities all year around as well as special events.

6.2 Facility operation

Background

The main goal for the operation is to provide a facility which is safe for everybody working in, or visiting it, and for the environment. This includes preventative and remedial maintenance in order to ensure that all systems such as drainage, electrical power, ventilation, alarm and communications are available in the underground laboratory at all times.

Present status

No shutdowns or unplanned service interruptions have occurred during the year. The facility is well maintained and the goal to have a degree of operational time of 98% during 2006 has been exceeded. The long term rock control and reinforcement programme has been continued to ensure safe and reliable rock conditions.

The work with the operational and monitoring system has been successful. According to present plans the inspection of the system will be done early 2007. The system has information on where personal and visitors are present. This is useful information if an accident occurs. The operational and monitoring system will be included in the maintenance system, which facilitate the adjustment of the ventilation in the tunnel. The air quality in the below-ground facility was measured and the radon concentration in the air has decreased with 20% after an adjustment of the ventilation.

All buildings above-ground have been painted during this summer and problems with the heating and air-conditioning have been attended. A new laboratory for buffer and backfill technology is under construction, for more information see Chapter 5.

Scope of work for 2007

Work planned and goals for 2007 are summarised below:

- One of the main targets for a number of years has been to increase the reliability in the underground-related systems. The goal for 2007 is to provide a very high availability.
- To ensure the reliability, a redundant power supply cable will be installed below-ground.
- The inspection of the operational and monitoring system will be done early 2007.

- Safety of the personnel is of main concern and safety-related education and fire fighting training will be held, and the long term rock control and reinforcement programme will be continued.
- The energy consumption shall be optimised by applying new techniques.
- The waste water treatment plant at Äspö is under size and the waste water from the Äspö facility will in the future be treated in OKG's, the Oskarshamn NPP, waste water treatment plant. A sewer between Äspö and OKG will be constructed.
- The construction of the bentonite laboratory, with a building area of 450 m², will be finalised in March. In addition, there will be a 200 m² roof covered material storage. A cleaning plant with capacity for bentonite rich water has been constructed.
- An additional storage for vehicles and machines will be constructed as well as a new building intended for the computers and an archive.

6.3 Public Relations and Visitor Services

Background

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 HRL, and the SKB siting programme on surface and underground.

SKB operates three facilities in the Oskarshamn municipality: Äspö HRL, Central interim storage facility for spent nuclear fuel (Clab) and Canister Laboratory. In 2002 SKB began site investigations including drilling of deep investigation boreholes at the sites Simpevarp/Laxemar and Forsmark.

During the year 2006 the Äspö HRL and the site investigation activities were visited by about 11,000 visitors. The visitors represented the 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, Äspö HRL, Clab, Canister Laboratory and SFR was fully 28,000. The information group has a special booking team at Äspö HRL which books and administrates all visitors.

Planned special events for 2007

The inauguration of the new laboratory for testing of bentonite will take place during spring 2007. Date for the event is March 29th. Special guests will be invited and the inauguration will also be an open event for interested people.

A series of lectures with special connection to the research and development of techniques conducted at the Äspö facility is planned to start during the year 2007 and continue the coming years. The intention is to combine the lectures with guided tours to the underground laboratory.

During the year 2007 the summer-tours for the general public, "Urberg 500", will start at the end of June and finish up in August. The goal is to reach 2,750 visitors this year. Several bus-tours a day take visitors to the laboratory where they are given information about the ongoing research. In addition, the Äspö Running Competition will take place in December. This has been a yearly event the last eight years.

7 Environmental research

7.1 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. SKB's economic engagement in the foundation was concluded in 2003 and the activities thereafter concentrated to the Äspö Research School.

7.2 Äspö Research School

Kalmar University's Research School in Environmental Science at Äspö HRL, called Äspö Research School, started in October, 2002. This School is the result of an agreement between SKB and Kalmar University. It combines two important regional resources, i.e. Äspö HRL and Kalmar University's Environmental Science Section. The activity within the school will lead to: (a) development of new scientific knowledge, (b) increase of geo and environmental scientific competence in the region and (c) utilisation of the Äspö HRL for various kinds of research.

Present status

The Äspö Research school has over the first years of research activities focused on chemical processes in the surface environment. This includes studies on the leaching dynamics of black shales (a bedrock type rich in sulphur and metals), biogeochemical patterns in forest ecosystems in Laxemar, hydrochemical patterns in surface and ground water in Laxemar and Forsmark, the behaviour in boreal waters of uranium and niobium, and as a complement hydrogeochemical investigations in a contrasting climate zone. Most of these studies will be included in Ph.D theses, and when these are completed, the research focus will be direct towards the Äspö laboratory and its surroundings.

Scope of work for 2007

A Ph.D. course in bedrock-water-biosphere will take place in early autumn. Focus will be on bedrock characteristics, hydrogeological mechanisms, hydrochemical patterns and deep-bedrock microbiology. Experts within each field will be invited, and the aim is to attract Ph.D. students (and others) from Sweden and abroad. A subsequent course, focusing on the surface system, will be planned.

The research initiatives will focus on increasing the understanding of the behaviour of lanthanides, which consists of analogues for several radionuclides. The main focus is on characterisation of the dissolved, colloidal and particulate pools of aqueous lanthanides, and the behaviour of lanthanides in the mineral-water interface. Studies within the laboratory will be supported by studies in the surface environment in Laxemar.

8 International co-operation

8.1 General

Nine organisations from eight countries will in addition to SKB participate in the co-operation at Äspö HRL during 2007. 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. The committee meets once every year. In conjunction with each IJC meeting a Technical Evaluation Forum (TEF) is held. TEF consists of scientific experts appointed by each participating organisation. For each experiment the Äspö HRL management establishes a peer review panel consisting of three to four Swedish or international experts in fields relevant to the experiment. Presentations of the organisations represented in the IJC are given below.

Most of the organisations participating in the Äspö HRL co-operation are interested in groundwater flow, radionuclide transport, rock characterisation and THMC modelling. Several of the organisations are participating in the two Äspö Task Forces on (a) Modelling of Groundwater Flow and Transport of Solutes and (b) THMC modelling of Engineered Barrier Systems. These specific technical groups, so called Task Forces, are another form of organising the international work. The Task Force on Modelling of Groundwater Flow and Transport of Solutes, which is a forum for co-operation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock, has been working since 1992. The Task Force on Engineered Barrier Systems, a forum for code development on THMC processes taking place in a bentonite buffer and gas migration through a buffer, has been on stand-by but was activated during 2004 and will be increasingly active and a prioritised area of work in the coming years.

SKB also takes part in several international EC-projects and participates in work within the IAEA framework.

The international organisations are taking part in the projects, experiments and Task Forces described in Chapters 2, 3 and 4 (Geoscience, Natural barriers and Engineered barriers). The co-operation is based on separate agreements between SKB and the organisations in question. The participation by JAEA and CRIEPI is regulated by one agreement. The participation of each organisation is given in Table 8-1.

Table 8-1 International participation in the Äspö HRL projects during 2007.

Projects in the Äspö HRL during 2007	Andra	BMWi	CRIEPI	JAEA	NWMO	Posiva	Enresa	Nagra	RAWRA
Geo-science									
Äspö Pillar Stability Experiment					X	X			
Natural barriers									
Tracer Retention Understanding Experiments	X			X		X			
Long Term Diffusion Experiment					X				
Colloid Project		X				X			
Microbe Project		X							
Radionuclide Retention Project		X							
Task Force on Modelling of Groundwater Flow and Transport of Solutes	X		X	X	X	X			
Engineered barriers									
Prototype Repository	X	X		X		X			
Alternative Buffer Materials	X	X		X		X		X	X
Long Term Test of Buffer Materials						X			
Temperature Buffer Test	X	X					X		
KBS-3 Method with Horizontal Emplacement						X			
Large Scale Gas Injection Test	X	X			X	X			
Task Force on Engineered Barrier Systems	X	X	X		X	X		X	X
Participating organisations:									
Agence nationale pour la gestion des déchets radioactifs, Andra, France									
Bundesministerium für Wirtschaft und Technologie, BMWi, Germany									
Central Research Institute of the Electronic Power Industry, CRIEPI, Japan									
Japan Atomic Energy Agency, JAEA, Japan									
Nuclear Waste Management Organisation, NWMO, Canada									
Posiva Oy, Finland									
Empresa Nacional de Residuos Radiactivos, Enresa, Spain									
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, Nagra, Switzerland									
Radioactive Waste Repository Authority, Rawra, Czech Republic									

8.2 Andra

L'Agence Nationale pour la Gestion des Déchets Radioactifs (Andra) is fruitfully co-operating in the Äspö HRL for more than a decade.

The first actions were devoted to enhancing the understanding of flow and transport of solutes in fractured rock. On this topic, the True Block Scale Continuation is now ending with valuable results and the Task 7 of the Task Force on Modelling of Groundwater Flow is also almost achieved.

8.2.1 Prioritised activities during 2007

During 2007, most Andra involvement will be in research, development and demonstration (RD&D) related to the Engineered Barrier Systems (EBS) through various co-operative activities:

- Following Prototype Repository evolution through sensors data report analysis.
- Running the Temperature Buffer Test (TBT), which aims at extending current THMC understanding of bentonite buffer behaviour during saturation under high temperature. A gas migration test through the bentonite buffer being saturated will be implemented in a near future.
- Participating in the modelling of the Large Scale Gas Injection Test (Lasgit) to be implemented in 2007 and 2008.
- Contributing to the Alternative Buffer Materials project, which aims at comparing THC behaviour of various swelling clay materials comprising the Callovo-Oxfordian argillite from the French Meuse/Haute-Marne site, where an URL is located.
- Participating in the Engineered Barrier Systems modelling Task Force within THM tasks, gas migration tasks and possibly chemical ones.

8.3 BMWi

The first co-operation agreement between Bundesministerium für Wirtschaft und Technologie (BMWi) and SKB was signed in 1995. The agreement was extended in 2003 for a period of six 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 Karlsruhe GmbH Institut für Nukleare Entsorgung (FZK-INE), Forschungszentrum Dresden-Rossendorf (FZD), Gesellschaft für Anlagen- und Reaktorsicherheit mbH (GRS), and Bauhaus Universität Weimar. The purpose of the co-operation with the Äspö HRL programme is to improve the knowledge on the engineered barrier system and on potential host rocks for radioactive waste repositories in Germany. The topics of special interest are:

- Behaviour of the bentonite buffer.
- Characterisation of fracture zones in the rock mass and disturbed zones surrounding underground openings.
- Geochemical investigations of the migration behaviour especially of actinides under near-field and far-field conditions.
- Geochemical modelling of individual processes controlling migration.
- Thermodynamic databases for radionuclides relevant for long-term safety.
- Behaviour of colloids and microbes and their respective interaction with radionuclides.
- Groundwater flow and transport of solutes.

8.3.1 Prioritised activities during 2007

Colloid Project

Background of the experiment is the scenario “Potential release of clay colloids from the bentonite barrier into a repository and their subsequent transport with the groundwater flow in a water conducting fracture”. To obtain insight in the behaviour of colloids under conditions relevant to the situation in the vicinity of a repository in the deep underground a dipole experiment is planned. In this experiment the transport of colloids and the colloid facilitated transport of actinides are investigated. For preparation of such experiments, the stability of clay colloids prepared from MX-80 bentonite in solutions of varying ionic strength and pH and in a groundwater sampled at Äspö HRL (True-site, KXTT) has been studied. The colloids may sorb radionuclides and thus can act as carriers for the colloid-mediated radionuclide migration. For this reason, the impact of colloids on the speciation of various radionuclides including the actinides was observed in Äspö groundwater over a period of months.

An initial phase of this project carried out by FZK-INE was partly funded by the Colloid project. A report was submitted to SKB. The Äspö specific investigations are complemented by studies under different groundwater conditions such as in the Colloid Formation & Migration (CFM) project and two PhD theses within the BMWi project “Kollorado”. First results on the colloid stability are published.

An *in situ* colloid migration experiment is planned at the Äspö HRL in a dipole experiment carried out at a suitable site at the Äspö HRL. To provide boundary and initial conditions for the design of this experiment a series of preparatory laboratory experiments are required. Within 2007 it is planned to conduct following experiments:

- The interaction of colloids and colloid-borne radionuclides with fracture minerals will be studied. This will be done as well by simulating the presence of organic matter by adding fulvic acid. Experiments will be carried out with crushed fracture filling material from the Äspö site and with untreated fracture surfaces from Äspö bore cores. The latter experiments aim to identify preferential mineral surfaces for colloid attachment.
- Some experiments concerning colloid stability and radionuclide behaviour will be repeated with groundwater received from Äspö HRL borehole KA2512A.
- Considering the presently discussed scenario of low mineralised glacier melt water intrusion into the bentonite barrier, one should also discuss to extend the experiments to include low mineralised groundwater. Under those conditions, colloids may show higher stability and mobility.
- An Äspö bore core (with an open fracture) has now been installed in a glove box after complete characterisation by various methods including positron emission tomography. After characterisation of the hydraulics by conservative tracer tests, radionuclide and radionuclide/colloid migration experiment will be performed.
- Microscopic studies on the effect and possible differentiation of fracture surface roughness and/or charge heterogeneities on the colloid attachment probability with model colloids are continued.

As an outcome of these laboratory investigations, the design of an *in situ* colloid migration study will be defined.

Microbe Projects

A project is performed by the Forschungszentrum Dresden-Rossendorf, FZD, addressing the indirect interaction mechanism of a mobilisation of actinides by released bioligands in the aquifer system from relevant Äspö bacteria. The ongoing study is focused on: (i) isolation and characterisation of microbial ligands produced from a subsurface strain of *Pseudomonas fluorescens* 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 characterisation of the formed actinide complexes/compounds. The formation constants determined will be used directly in speciation and transport models. This project should help to identify the dominating process of the interaction between actinides and microbes (direct or indirect ones). The research performed in our project improves the understanding of the behaviour of colloids and microbes and their respective interaction with radionuclides. In 2007 the following activities are planned:

- Continuation of the isolation and fractionation of the bioligands produced by cells of the Äspö bacterium *Pseudomonas fluorescens* (CCUG 32456 A) by our Swedish colleagues at Göteborg University as part of the cooperation between the FZD/IRC (Institut für Radiochemie) and the group of Prof. K. Pedersen from the Göteborg University (Department of Cell and Molecular Biology).
- Continuation of the work to characterise the produced bioligands by mass spectrometry part of a co-operation between the FZD/IRC and Prof. H. Budzikiewicz and Dr. M. Schäfer from the Universität zu Köln (Institut für Organische Chemie).
- Continuation of investigations of the complexation of Cm(III) and U(VI) with model compounds (a) simulating the functionality of the bioligands (e.g., salicylhydroxamic acid, desferrioxamine, 6-hydroxyquinoline) and b) simulating the surface of the bacteria (e.g., peptidoglycan and lipopolysaccharide) by spectroscopic methods.
- Finishing of the complexation studies of U(VI) with the bioligands isolated from *P. fluorescens* (CCUG 32456 A) using different spectroscopic techniques.
- Complexation studies of Cm(III) with the bioligand-fraction isolated from *P. fluorescens* (CCUG 32456 A) using fluorescence spectroscopy.

Furthermore planned are, first structural investigations of the formed aqueous U(VI) complexes with the model systems and the isolated bioligands by X-ray absorption spectroscopy, complexation experiments of Np(V) with the model systems, and interaction experiments of cells of *P. fluorescens* (CCUG 32456 A) with U(VI).

Prototype Repository

GRS performed measurements of the electric resistivity distribution in the backfill, the buffer, and the rock between two of the deposition boreholes. Because there is a direct correlation between water 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 monthly. The recording unit for these arrays is controlled remotely from Braunschweig/Germany via a telephone connection.

The evaluation comprises the determination of the resistivity distribution around the electrode arrays by inverse modelling using the code SensInv2D. Results from laboratory measurement, 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, respectively.

To increase the confidence in the results of the inversions of the apparent resistivity measured *in situ*, a laboratory experiment has been performed in which controlled progressing water uptake in drift backfill was simulated and monitored by geoelectric measurements. This experiment is currently evaluated. 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 at least until mid 2007. Data evaluation will be performed in Braunschweig and contributions to SKB's sensor data reports will be provided on a quarterly basis. Whether the *in situ* measurements will be continued beyond mid 2007 is currently under discussion.

Alternative Buffer Materials

BGR is participating in this project in the framework of its national R&D activities on argillaceous materials (host rock and buffer). The work is focused at the mineralogical and physical characterisation of bentonite variants.

In 2007 BGR will perform laboratory investigations on basic material to be prepared for the investigations of *in situ* samples in the following years.

Temperature Buffer Test

Main focus of the work performed by DBE Technology will be the 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. Based on the well fitted temperature distribution achieved from the simulation work in the past the observed slow movement of injected water going from the outer sand filter into the bentonite will be numerically simulated. To do this, a new water retention curve will be implemented into the used source code FLAC. The new curve will be based on a water retention curve for higher temperatures developed by Ciemat. After having proved the proper work of the new constitutive law the observed water movement will be analysed taking into consideration the swelling behaviour of the bentonite as a function of water content. Based on the results coupled THM simulations will be performed and compared to the measurements.

Lasgit

The work being conducted by BGR as part of the Lasgit project 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 test - 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 2007 will focus on the modelling of processes in the engineered barriers system. Measured data from the Lasgit experiment will be used as reference. Different approaches for modelling gas migration will be tested (Task Force on Engineered Barrier Systems).

Task Force on Engineered Barrier Systems

The Task Force on Engineered Barrier Systems has the objectives to verify the ability to model THM 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).

It is divided into two Tasks: Task 1 THM processes in buffer materials, and Task 2 Gas migration in buffer materials. The tasks comprise of two phases. Each phase is based on benchmark exercises. In between, the codes are to be audited. In the first phase the codes are tested against well-controlled laboratory experiments and in the second phase against field experiments. GRS uses the codes RockFlow/RockMech (Tasks 1 and 2) and VapMod (Vapour diffusion/Task 1).

Having completed the first phase of benchmarking for Task 1 THM, phase 2 commences after distribution of the test case descriptions. Due to some delays and difficulties, Task 2 Gas is not as far developed as Task 1. Presently it is not clear if this task will be continued at all.

At GRS the theoretical background for extending the alternative isothermal modelling approach to non-isothermal conditions is already roughly set up and will be completed in 2007. The same applies to the related new code Viper that will be used for non-isothermal analyses. Even if phase 1 of Task 1 will be closed at least one of the test cases of this task will be used to check the new approach and the new code, respectively. After an appropriate testing period the Viper code will be used to model a test case of the second phase. First results will be presented at the next EBS Task Force Meeting in May 2007.

BGR was involved in the first two benchmarks for THM-coupled processes that have been successfully modelled in 2005. In the preparation phase for the modelling of gas migration, a two-phase flow study has been performed on the basis of the first benchmark in that task.

In 2007, the code RockFlow will be used to model the THM-benchmarks of large scale experiments. With respect to gas migration different approaches will be tested to model the corresponding benchmarks.

The work package of the Laboratory of Soil Mechanics at Bauhaus University Weimar is related to a system identification approach for coupled multi-field problems. Therefore, the software packages Varoopt and Optimisation Framework were developed and permanently updated. Boundary value problems treated up to now, using Code_Bright as forward solution, include both granular materials (wetting and drying of sand column) and expansive clays (multi step swelling pressure tests). Special attention is paid to the optimum design of laboratory and field tests using sensitivity analysis. Next meeting of EBS Task Force will be held at Bauhaus University Weimar at the end of May 2007.

8.4 CRIEPI

Central Research Institute of Electric Power Industry (CRIEPI) signed a contract with SKB for the Äspö HRL Project in 1991 and renewed it in 1995, 1999 and 2003. 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 works, groundwater dating, fault dating, measurement of velocity and direction of groundwater flow and study on impact of microbes on radionuclide retention etc., as well as participated in the Task Force on Modelling of Groundwater Flow and Transport of Solutes. CRIEPI has participated also in the Task Force on Engineered Barrier Systems since 2004.

8.4.1 Prioritised activities during 2007

During 2007, CRIEPI will participate in both of the Task Forces as well as exchange information about research, disposal technologies and methodologies for site investigations with SKB and the other participating organisations.

As to the Task Force on Modelling of Groundwater Flow and Transport of Solutes, CRIEPI will compile reports on modelling results for Task 6D, 6E and 6F and perform the modelling work for Task 7. As for the Task Force on Engineered Barrier Systems, CRIEPI will finish the report on the numerical results for Task 1 THM processes in buffer materials Benchmark 1 (laboratory scale experiments) and start the modelling work for Benchmark 2 (field experiments).

8.5 JAEA

On October 1, 2005, the Japan Atomic Energy Agency (JAEA) made its first steps as an independent administrative institution. JAEA is the result of the integration of the Japan Atomic Energy Research Institute (JAERI) and the Japan Nuclear Cycle Development Institute (JNC). The JAEA participation in the Äspö HRL is regulated by the trilateral project agreement between JAEA, CRIEPI and SKB.

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 2006 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 assessment in Japan.

8.5.1 Prioritised activities during 2007

JAEA will actively participate in Task 7 in the Task Force on Modelling of Groundwater Flow and Transport of Solutes. The aim is to evaluate the value of flow measurement during a long-term pumping test in terms of constructing hydrogeological models relevant to PA.

8.6 NWMO

In 2007, Ontario Power Generation (OPG) assigned the SKB / OPG Äspö Project Agreement to the Nuclear Waste Management Organization (NWMO). The prime objective of NWMO's participation at Äspö HRL is to enhance the Canadian technology base for a deep geological repository through international co-operation projects. The committed work on Äspö HRL projects to be carried out in 2007 is described below. Canada is also participating with SKB in work related to planning e.g. the Rock Shear Experiment.

8.6.1 Prioritised activities during 2007

Canada is providing supporting laboratory experiments with respect to the Äspö LTDE Sorption Diffusion Experiment and the Colloid Dipole Project. The colloid work has included parallel tests in the one metre scale Quarried Block test facility at AECL, and has explored complementary ranges of conditions, colloids and groundwater chemistry that are not accessible in the Äspö environment. Support for the LTDE experiment is continuing in 2007; however, given that field results will likely not be available until 2008 activities will consist of report and methodology peer reviews and possibly accounting for sorption processes in the LTDE-specific, Motif-model used in pre-test prediction..

Canada joined the Lasgit project in late 2004. The Canadian modelling group is Intera Engineering, and the reference code is Tough2 with a modified permeability function. In 2006, the planned code modifications were completed. In 2007, the work will focus on comparisons with laboratory gas migration experiments (BGS) and on modelling the preliminary gas injection phase (including exploring alternative test parameters to guide future test planning).

Canada is participating in the Task Force on Modelling of Engineered Barrier Systems, with respect to the THM modelling task. The Canadian modelling team is AECL, and the reference code is Code_Bright. In late 2006, a dataset based on the *in situ* Canadian Buffer-container Experiment and the parallel Isothermal Test were provided to the Task Force for use as the next THM model benchmark during 2007.

Canada is also participating in the Task Force on Groundwater Modelling, with respect to Task 7. The modelling team is from the Université Laval, and the reference code is Frac3DVS. In 2007, modelling activities will focus on completing sub-task 7A1 involving a 2-km scale hydrostructural model centred on the Onkalo site, as well as sub-task 7A2 involving pathway and travel time analyses.

In 2006, AECL conducted parallel microbial analyses on various Lot and Canister Retrieval Test buffer specimens. Further analyses would be provided in 2007, if new samples became available. This work is complementary to our laboratory tests, which are exploring the microbial behaviour under a range of salinity, density and temperature conditions.

8.7 Posiva

Posiva's co-operation with SKB continues with the new co-operation agreement signed in the autumn of 2006. The focus of the co-operation will be on encapsulation and 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:

- Prototype Repository
- KBS-3 Method with Horizontal Emplacement
- Large Scale Gas Injection Test
- Injection grout for deep repositories,
- Long Term Test of Buffer Materials
- Cleaning and Sealing of Investigation boreholes
- True Block Scale Continuation
- Task Force on Modelling of Groundwater Flow and Transport of Solutes.
- Task Force on Engineered Barrier Systems

Posiva's co-operation is divided between Äspö HRL and more generic work that can lead to demonstrations in Äspö HRL. The work planned to be performed within the different projects during 2007 is described below.

8.7.1 Prioritised activities during 2007

Prototype Repository

This co-operation concentrates to the ongoing Prototype Repository experiment, but utilises also the additional results available from the Long Term Test of Buffer Materials (Lot) and other buffer/backfill tests performed at Äspö. In the year 2006 existing data and knowledge on the subject has been evaluated. The work to be done during 2007 will be decided upon based on the previous evaluation results. Work will be performed on geochemical data-interpretation and modelling in collaboration with SKB.

Long Term Test of Buffer Materials

It is proposed that Posiva will continue participation in the Lot-project and join the Alternative Buffer Materials project, both of which are in progress in the Äspö HRL. This enables ready participation in medium-scale rock laboratory experiments and access to a European-level network of experts and their research facilities and experimental results.

It is suggested that the focus of the work to be carried out in Finland lies on chemical processes, subject to a thermal and/or hydraulic gradient, occurring in the bentonite. Integrated THC modelling is developed and applied for the interpretation of the Lot, Alternative Buffer Materials and laboratory experiments.

In 2007, the modelling work aims at the interpretation of the chemical phenomena observed in the Lot experiment. In particular, the work will focus on the behaviour of anions and cations within bentonite during saturation in the presence of a thermal gradient (e.g. redistribution of gypsum, cation exchange, chloride concentration, pH and Eh). Later, the modelling work will be extended to cover the results from well-controlled laboratory experiments and the Alternative Buffer Materials project.

The software to be used for the THC modelling is PetraSim, which is a graphical interface for the Tough2 and ToughReact simulators.

Cleaning and Sealing of Investigation Boreholes

A report on the ongoing Stage 3 of the joint SKB and Posiva programme will be published in early 2007. After assessing the results, the continuation of the project will be determined and topics defined. It is likely that more testing of materials and equipment and full-scale demonstrations are still needed for the different concepts to assess their technical feasibility and long-term performance as planned. Preliminarily, a 5-6-year programme is scheduled to start in 2007 consisting of following tasks:

- Development of clay-plugging method without perforated copper tubes.
- Development of a sealing system for long boreholes drilled from underground (such as for the long characterisation holes to be drilled from Onkalo).
- Development of means for sampling the installed plugs to test their effectiveness as required.
- Full-scale field test of the concept.

KBS-3 Method with Horizontal Emplacement

SKB and Posiva are engaged in an R&D programme over the period of 2002-2007 with the overall aim to investigate whether the KBS-3H concept can be regarded as a viable alternative to the KBS-3V concept. The demonstration phase is ongoing since 2004 and it includes test boring at Äspö HRL, planning the construction of the emplacement equipment and safety evaluations. The programme will end with the evaluation of the potential of the concept in 2007. The project is jointly executed by SKB and Posiva and has a common steering group. Posiva's main involvement in the project is in the evaluation of the long-term safety aspects.

Large Scale Gas Injection Test

This project will be jointly executed by SKB and Posiva and have a common steering group. The gas injection tests will start earliest in spring 2007 depending on the saturation rate of the bentonite buffer.

Task Force on Modelling of Groundwater Flow and Transport of Solutes

In the ongoing Task 7, data from Olkiluoto and from a pumping test is used to study how to use site characterisation data for performance assessment. In borehole KR24 at the Olkiluoto site in Finland a long-term pumping test has been performed in the upper part of the borehole.

Posiva and its consultants participate both in the Task Secretariat work and by a modelling team work in 2007 according to the agreed time schedule and task definitions of the Task Force.

Task Force on Engineered Barrier Systems

Posiva is taking part in the Task Force on Engineered Barriers in the part of THM modelling of processes during water transfer in buffer, backfill and near-field rock. During the year 2007 the purpose is to develop understanding of the THM(C) behaviour of EBS by simulations of Atomic Energy of Canada's large underground tests, the Buffer-Container Test and the Isothermal Test, as well as the Äspö HRL's Canister Retrieval Test.

8.8 Enresa

SKB and Empresa Nacional de Residuos Radioactivos, S.A. (Enresa) signed a project agreement in February 1997 covering the co-operation for technical work to be performed in the Äspö HRL. Both parties renewed the agreement in January, 2002. Due to the decision taken in the Spanish parliament in December 2004 to focus on a central interim storage of spent nuclear fuel before 2010, Enresa in 2004 chose not to renew this agreement and have now left the central and active core of participants.

Enresa is, however, still participating in the Temperature Buffer Test (TBT) in Äspö HRL. Enresa is also co-ordinating the integrated project Esdred within the 6th EU framework programme. Some of the demonstration work of the integrated project Esdred is carried out in Äspö HRL.

8.9 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 2007 Nagra is taking part in the Task Force on Engineered Barriers and the parallel task force that deals with geochemical processes in engineered barriers, chemical modelling of bentonite as well as in the Alternative Buffer Materials project.

8.10 RAWRA

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

8.10.1 Prioritised activities during 2007

In the Task Force on Engineered Barrier Systems the Czech Technical University will finish the testing of the computer code Delphin. This model is planned to be used for the Benchmark 1 (laboratory scale) calculations for Task 1 THM processes in buffer materials and also to validate the model for calculations of heat and water transfer. Delphin will subsequently be calibrated in future benchmark calculations for Task 1. Continuing activities will be based on the results of experiments realised in the project MockUP-CZ, including the benchmark calculations and interpretation.

Technical University of Liberec will complete the modifications of the calculation tools used for description of near field transport of liquid components. There will be defined input files that will be used for relevant calculations and their evaluation. The same procedure has to be followed for the following benchmark calculations.

After completing the gas transport models in 2006, Nuclear Research Institute Rez will prepare input files necessary for evaluation of gas formation and transport. The calculations will be finished in 2007. Simultaneously, a new task according to the new benchmark definition will be prepared considering advection and diffusion as principal transport processes.

8.11 IAEA framework

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.

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