International Progress Report

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Äspö Hard Rock Laboratory

Status Report

April - September 2000

December 2000

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Summary

Investigations and experiments

The barrier function of the host rock

The Tracer Retention Understanding (TRUE) aim at further developing understanding of radionuclide migration and retention processes and evaluation of different approaches to modelling such processes. The TRUE-1 tests are performed over distances of about 5 m in a fracture at approximately 400 m depth. The tracer experiments were completed in the end of 1998. A number of laboratory studies to support the interpretation of the breakthrough curves have been completed. The final report of the First TRUE Stage has been published and the results discussed at the Fourth Äspö International Seminar held at Äspö in September.

The Long-Term Diffusion Experiment is intended as a complement to the *in-situ* dynamic experiments and the laboratory experiments performed within the TRUE Programme. The objectives are to study diffusion into the rock matrix and to obtain data on sorption processes and properties. The experimental concept is based on a large diameter borehole, which exposes a fracture surface. This fracture is packed off with a cap, similar to what was used in the REX experiment. A suitable target fracture has been identified at the 410 m level. The drilling of the telescoped test borehole (diameter 300/200 mm) has been completed. The core stub in which diffusion is to take place became 16 cm long compared to the targeted 5 cm. Modelling and measurements on core samples have been undertaken to evaluate what effects this might have on the experiment. Preparations have continued at the experimental site.

The TRUE-2 experiment has been postponed awaiting the outcome of the TRUE Block Scale Experiment.

The TRUE Block Scale project aims at studying the tracer transport in a fracture network over distances up to 50 m. Phase A of the Tracer test Stage involved use of two alternative sink sections, including about 70 tracer dilution tests and 8 tracer injections. The Phase A tests were preceded by model predictions using the existing DFN, Channel network and Stochastic Continuum models which had been updated with the March'99 structural model and all available information including the interference and tracer dilution tests made as part of the Phase A tests. The subsequent Phase B tests were run in two parts, Phase B1 with a 50% reduction relative to maximum pump rate and Phase B2 where maximum pump rate was employed (approximately 2 l/min). This staged approach was employed to enable identification of stronger retardation of the more diffusive He-gas at reduced flow rate. During the Phase B2 tests, 6 sections were used for tracer injection. The results show more than 80 % recovery (stipulated recovery to allow injection of radioactive sorbing tracers) for three injection sections each involving 1-4 structures along the pathway. In the Phase C tracer test 4 injection sections were used. In order to test the hypotheses of possible higher retardation for tracers when transported over larger time scales, a cocktail of tracers including both a weakly sorbing (like Na, Ca and Sr) and a more strongly sorbing (eg Rb, Ba and Cs) were used for each injection. One of the planned injections constitute injection of tracers subject to partial hydrolysis/surface complexation. The Phase C experiments will be the subject of blind model predictions and hence no results will be presented until the predictions have been filed.

Evaluation of the Phase A tests has continued within all three model concepts (Stochastic Continuum, Discrete Feature Network and Channel Network). Model updates making use of the results of Phase B are under way. The updated models will form the base for model predictions of the Phase C tests.

The CHEMLAB probe has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. Preparations of the glove box for the actinide experiment have been done. Also the arrangement of experimental cell and radioactive tracers in CHEMLAB 2 are done. Practical arrangements have been made for the start up of the radiolysis experiment in CHEMLAB 1.

The final report of the EQUIP project has been submitted to EU.

The Matrix Fluid Chemistry experiment has the aim to determine the origin and age of matrix fluids and to establish to what extent the composition of matrix fluid has been influenced by diffusion processes. Since the last status report, activities carried out have involved the continuation of: a) mineralogical/petrophysical studies, b) crush/leaching experiments, c) Äspö diorite permeability test, d) fluid inclusion characterisation, and e) compilation and interpretation of groundwaters sampled and analysed from the TRUE Block Scale, Prototype Repository and 'J' Niche (Chemlab/Microbe) experiments.

The Stability and Mobility of Colloids (SMC) Project has been initiated to investigate the potential for colloidal transport in natural groundwater. Studies will be made of colloid concentration at Äspö HRL and the role of bentonite clay as a source for colloid generation. Two nearby boreholes at HRL will be selected for the SMC experiment. One of the boreholes will be used as an injection borehole and the borehole downstream will be used as a monitoring borehole. The boreholes intersect the same fracture and have the same basic geological properties. The detailed time planning has started and some pre-laboratory tests have been performed by analysing bentonite colloid formation from water samples with different salinities in contact with the bentonite clay.

A set of microbiology research tasks for the performance assessment of high level nuclear waste (HLW) disposal has been identified. A test site, called the MICROBE site, has been prepared at the 450 m level. Groundwater chemistry, cultivable microorganisms, stable isotope and gas data have been obtained from the MICROBE boreholes.

The Task Force is a forum for the organisations supporting the Äspö Hard Rock Laboratory Project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. Within the modelling groups works has been towards producing the final modelling results and the final report of Task 4E&F and Task 5. A workshop was held 14-15 September at Arlandastad, Sweden, with objective to compile a proposal for Task 6. This will be presented at the next International Task Force meeting, #14, to be held 14-16 November at Säröhus, Sweden.

Technology and function of important parts of the repository system

The Prototype Repository experiment is located in the last part of the TBM tunnel at the 450 m level and will include 6 deposition holes in full scale. The aims of the Prototype Repository are to demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions. The kick-off of the EC project took part on September 19-20 at Äspo, in the presence of the EC officers Bertus Haijtink and Christophe Davies, and with the Major of Oskarshamn, Mr Torsten Carlsson, conducting the official inauguration.

The reporting of results from the geoscientific characterisation phase has continued. Reporting has also been made on design results, e g instrumentation of buffer and backfill, and plug and slot. The pre-test of the deposition sequence has been completed. Physical activities in the Prototype Repository tunnel have been: Finalising the excavation of the slots for the two plugs; Preparation of the roadbed for instrumentation of the rock; Initiation of drilling of holes for thermocouples and resistivity measurements; Initiation of drilling the 27 lead-throughs from the G-tunnel.

The Backfill and Plug Test comprises full scale testing of backfill materials, filling methods, and plugging. The entire test setup with backfilling, instrumentation and building of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through the filter mats started in November 1999.

The Demonstration of Repository Technology project aims to show in a perceptible way the different steps in encapsulation, transport, deposition, and retrieval of spent nuclear fuel for specialists and the public. After completion of the site test program mid May the deposition machine was handed over to SKB.

The retrieval test aims at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite has swollen. All preparatory activities prior to start of installation of one hole with a canister, buffer and instrumentation have been completed. Installation of bentonite blocks and instrumentation has been completed.

The Long Term Tests of Buffer Material aim to validate models and hypotheses concerning long-term processes in buffer material. Five boreholes have been filled with highly compacted bentonite and a heater. The bentonite parcels are equipped with instruments, bacteria, copper coupons and with radioactive tracers. The intended test temperatures of 90°C in the standard type parcels and 130°C in the adverse condition parcels have been reached.

International Cooperation

Nine organisations from eight countries are currently (September 2000) participating in the Äspö Hard Rock Laboratory.

Testing of the Posiva flowmeter continued in borehole KLX02 in May-June 2000 with the second campaign for difference flow measurements in detailed mode. A methodology study was added to the second campaign.

Facility Operation

A new power supply line to Äspö has been taken in operation.

Building an additional parking space at the Äspö site has started with filling and levelling a suitable area.

Data Management and Quality systems

A Geographical Information System (GIS) based on ArcInfo and ArcView has been and are still used successfully by SKB in the ongoing feasibility-study projects. GIS will also be an important tool in the planning and performance of the site-investigation phase.

The SICADA administration organisation has been extended with a new employee.

Groundwater head and chemistry monitoring

The HMS program has continued running real time data acquisition in support of the various project undertaken in the Äspö Hard Rock Laboratory. The system has been utilized mainly by the TRUE and the Prototype Repository projects.

The monitoring programme has been reduced to one sampling period a year. In October, the sampling for year 2000 was performed and the results will be presented within three months.

Information activities

During the second and third quarters of 2000, 8417 persons visited the Äspö HRL. 3700 persons represented the six communities where SKB performs feasibility studies.

Contents

1 General

The scientific investigations within SKB's research programme are part of the work conducted to develop and test methods for identification and characterisation of suitable repository sites and for design of a deep repository. This requires extensive field studies of the active processes and properties of the geological barrier and the interaction between different engineered barriers and host rock. The Äspö Hard Rock Laboratory provides an opportunity for research, development and demonstration of these issues in a realistic setting. Important tasks for the Äspö Hard Rock Laboratory are:

- to increase scientific understanding of the safety margins of the deep repository,
- to test and verify technology that provide cost reductions and simplifies the repository concept without compromising safety,
- to demonstrate technology that will be used in the deep repository,
- to provide experience and training of staff, and
- to inform about technology and methods to be used in the deep repository.

A set of Stage Goals have been defined for the work at the Äspö HRL. The Stage Goals were redefined in the SKB Research Development and Demonstration (RD&D) Programme 95, which was submitted to the Swedish Authorities in September 1995. An updated program RD&D Programme 1998 was submitted in September 1998. This programme is the basis for the planning and execution of the current work.

The Stage Goals for the Operating Phase of the Äspö HRL are as follows:

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 function of the host rock

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 and after closure.

4 Demonstrate technology for and function of important parts of the repository system

test, investigate and demonstrate on a full scale different components of importance for the long-term safety of a deep repository system and to show that high quality can be achieved in design, construction, and operation of system components.

2 Methodology for detailed characterisation of rock underground

Background

A programme for detailed characterisation will be devised before detailed characterisation is initiated on a selected site and construction of the surface and underground portions of the deep repository is commenced. In conjunction with the driving of the Äspö tunnel, several different investigation methods have been tried and the usefulness of these methods for detailed characterisation for a deep repository is being evaluated. Preliminary experience from Äspö shows that there is a need for refinement of these methods to enhance the quality of collected data, boost efficiency and improve reliability in a demanding underground environment. Furthermore, the detailed characterisation programme needs to be designed so that good co-ordination is obtained between rock investigations and construction activities.

The objectives are:

- to try out existing and new methods to clarify their usefulness for detailed characterisation. The methods to be tested are chosen on the basis of their potential use within the detailed characterisation programme,
- to refine important methods in a detailed characterisation programme to enhance data quality, efficiency and reliability.

Detailed characterisation will facilitate refinement of site models originally based on data from the ground surface and surface boreholes. The refined models will provide the basis for updating the layout of the repository and adapting it to local conditions. Due to the heterogeneity of the rock, the layout of the repository needs to be adapted to the gradually refined model of rock conditions. This approach has a long tradition in underground construction and it should be used also for a deep repository.

Results

An evaluation of performed MWD (Measurement While Drilling) used during drilling of 2 855 metres of percussion probe holes during the excavation of the Äspö HRL tunnel has been performed. During drilling of 20 m long probe holes on either side of the tunnel a logging instrument from Bever Control A/S was used. Data like rate of penetration, feed pressure, rotational pressure and percussion pressure was monitored every 10th centimetre. An evaluation of the data has been performed and presented like hardness and fracturing of the rock. The result is that the hardness can be evaluated relatively good, the fracturing needs denser data sampling like one point per centimetre which is possible with the technique today. Today it is also possible to monitor water flow and water pressure which can give information of the waterbearing fractures in the rock.

3 Test of models for description of the barrier function of the host rock

3.1 General

The Natural Barriers in the deep geological repository for radioactive wastes are the bedrock, its properties and the on-going processes in the rock. The function of the natural barriers as part of the integrated disposal system can be presented as *isolation, retention* and *dilution*. The common goal of the experiments within Natural Barriers is to increase the scientific knowledge of the safety margins of the deep repository and to provide data for performance and safety assessment calculations. The strategy for the on-going experiments on the natural barriers is to concentrate the efforts on those experiments which results are needed for the planning of the future candidate site investigations, planned to start in 2002. For this focus there is also a need to involve experts of the different geoscientific disciplines into the on-going experiments in order to make them familiar with the work and quality procedures adopted.

Isolation is the prime function of the repository. It is obtained through the co-function of the engineered and the natural barriers. For deep geological disposal, the flow of water to the canister/waste containment is largely determining the magnitude at which the corrosion and the dissolution of the waste form can take place. For a good isolation it is thus necessary to minimise the groundwater flow to the waste containment. Additional conditions that affect the isolation are the chemistry of the groundwater and the mechanical stability of the rock.

Conceptual and numerical groundwater flow models have been developed through the entire Äspö project up to now. During 2000 focus is on further development of the numerical tools used for groundwater flow and transport calculations.

Hydrochemical stability and potential variability is assessed within several ongoing projects. These aim at explaining possible chemical conditions in a repository host rock based on assumption of different climate conditions in the future. The project will be reported during year 2000. Input to this reporting is provided from EQUIP, TASK#5, REX, Matrix Fluid Chemistry and other experiments. Some of these have not been completed yet. For instance the characterisation of the chemistry of water in the pores and micro fractures.

The *retention* of radionuclides dissolved in groundwater is the second most important barrier function of the repository. Retention will be provided by any system and process that interacts with the nuclides dissolved in the groundwater when eventually the water has come in contact with the waste form and dissolved radionuclides. Retention is provided by the physical and chemical processes, which occur in the near-field and far-field. Some elements are strongly retarded while others are escaping with the flowing groundwater. The major emphasis in the safety assessment calculations has therefore been on the weakly retarded nuclides even if they are not dominating the hazard of the waste.

Tracer tests are carried out within experiments in the TRUE-projects. These are conducted at different scales with the aim of identifying detailed scale (5m) and block scale (50m) flow paths, retention of weakly and moderately sorbing tracers and the effect of matrix diffusion. During 2000 the goals are to complete the experimental part of TRUE Block Scale and to start the Long Term Diffusion Experiment (LTDE). Modelling of the experiments is done by several groups associated to the Äspö Task Force for modelling of groundwater flow and transport of solutes.

CHEMLAB experiments are conducted with the moderately and highly sorbing nuclides. Experiments are carried out in simulated near field conditions (bentonite) and in tiny rock fractures. During 2000 experiments including effects of radiolysis will be carried out in the CHEMLAB 1 unit. In the CHEMLAB 2 unit experiments using actinides will be started.

Colloids could affect the transport of radionuclides in the case these exist in a high enough concentration. The investigations made at Äspö and elsewhere give a concentration that it is not possible to detect. That concentration has no impact on the transport of radionuclides. New findings of colloidal transport and the existence of more sensitive instruments are the reasons for a new programme on different aspects of colloid transport.

Microbes are of particular interest since they can directly influence the chemistry of the groundwater, and indirectly transport nuclides attached to them. For continuing the basic studies of the microbes in the Äspö laboratory, a site has been allocated in the J-niche at 430 m dept.

3.2 Tracer Retention Understanding Experiments

Background

The safety of a KBS-3 type repository relies heavily on the engineered barrier system that contains the waste. In the case that the engineered barrier fails, the geosphere provides the remaining waste containment. Realistic estimates and predictions of transport times through the geosphere and release rates to the biosphere are thus critical for any safety assessment. Of particular interest in this regard is the rock adjacent to the canister holes and storage tunnels.

The plans for tracer experiments outlined in the SKB RD&D Programme 92 comprised experiments in the Detailed and Block Scales. The experiments in the Detailed Scale consisted of three; Pore Volume Characterisation (PVC), Multiple-Well Tracer Experiment (MWTE), and the Matrix Diffusion Experiment (MDE). During 1994 detailed Test Plans were prepared for MWTE and MDE. Following review and evaluation the SKB HRL Project management decided to integrate the Detailed and Block Scale experiments within a common framework. This framework is described in a "Program for Tracer Retention Understanding Experiments" (TRUE) (Bäckblom and Olsson, 1994). The basic idea is that tracer experiments will be performed in cycles with an approximate duration of 2 years. At the end of each tracer test cycle, results and experiences gained will be evaluated and the overall program for TRUE revised accordingly.

The general objectives of the TRUE experiments (Bäckblom and Olsson, 1994) are;

- Develop the understanding of radionuclide migration and retention in fractured rock.

- Evaluate to what extent concepts used in models are based on realistic descriptions of rock and if adequate data can be collected in site characterisation.
- Evaluate the usefulness and feasibility of different approaches to model radionuclide migration and retention.

3.2.1 Long Term Diffusion Experiment (LTDE)

Background

The Long-Term Diffusion Experiment is intended as a compliment to the *in-situ* dynamic experiments and the laboratory experiments performed within the TRUE Programme.

The objectives of the planned experiment is to ;

- To investigate diffusion into matrix rock from a natural fracture in situ under natural rock stress conditions and hydraulic pressure and groundwater chemical conditions .
- To obtain data on sorption properties and processes of some radionuclides on natural fracture surfaces
- 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.

The test plan presents an experimental concept centred on establishment of an experimental (large diameter) borehole which exposes a natural fracture surface. This fracture surface is packed off with a cap which seals off the exposed rock cylinder in the bottom of the borehole, similar to the approach used in the REX experiment, cf. *Figure 3-1*. The intention is to establish an experimental chamber in which a tracer solution is circulated over a period of four years. Performed scoping calculations using available diffusivity data indicates that axial diffusion will range from mm:s for the strongly sorbing tracers to dm:s for the weakly sorbing tracers considered. Apart from tracers used in the TRUE-1 experiment, also PA-relevant tracers (^{99}Tc and ^{241}Am) are being proposed. The principal feat of the experiment is to establish axial diffusion from a natural fracture, through the rim zone of fracture mineralisation and alteration, into the unaltered rock matrix, without any advective component (towards the tunnel). This is resolved using a multi-packer system which effectively shields off the gradient. In addition, an intricate pressure regulation system is devised which will effectively allow the pressure in the experiment chamber to adapt to the ambient conditions without causing pressure differences, and hence no advective transport. The reference pressure is obtained either from a from a packed-off pilot borehole in the immediate vicinity of the large diameter experimental borehole, or from a section in the large diameter borehole itself. The former borehole has also been used to identify the target fracture to be investigated.

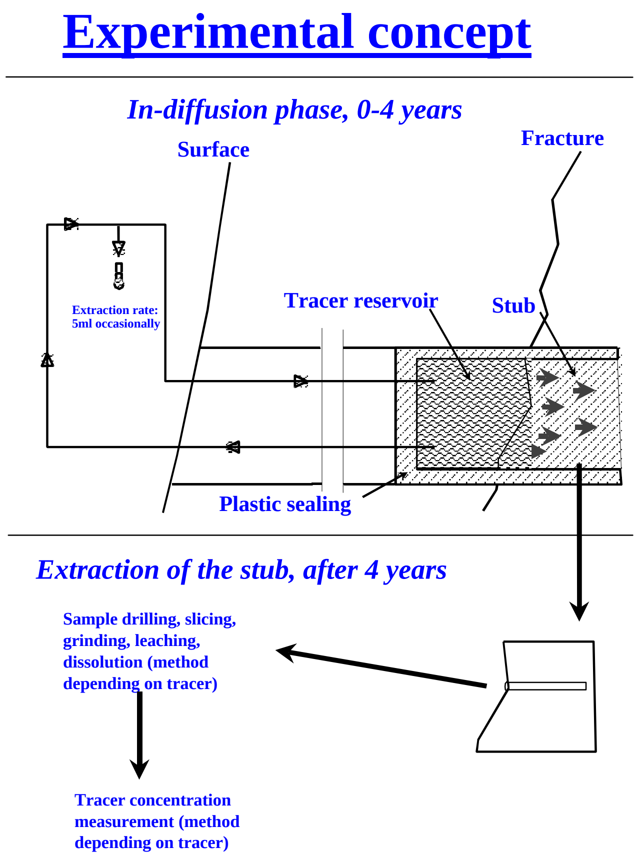


Figure 3-1 *Schematic of LTDE experimental concept including injection borehole in contact with a fracture surface, combined with excavation and penetration profile studies*

The characterisation of the large diameter borehole includes ia. measurements with various logs (borehole imaging (BIPS) and flow logging). The type of logs restricted by the diameter of the borehole. In the neighbouring 76 mm pilot borehole flow logging and resistivity logs will be run. The idea with the latter log being to enable coupling between the electrical resistivity and diffusivity. In addition the coresfrom the two boreholes will be analysed using mineralogical, petrophysical and geochemical methods.

A suitable target fracture has been identified in borehole KA3065A02 at a depth of 9.81 m. This structure constitutes a chlorite splay (141/81) to a main fault, the latter on which slicken lines on the surface are evident. It shows mylonitic character in diorite/greenstone with an increasing alteration towards the fault centre. The total inflow at this zone is about 16 l/min. The target structure constitutes the lower fringe of the zone and is followed by a long > 0.5 m long intact section of Äspö diorite.

Construction and manufacturing of prototypes of downhole borehole and sampling and monitoring equipment has been underway since 1999. Samples of the proposed material used for the downhole equipment (PEEK and polyurethane) have been analysed at CTH-Nuclear Chemistry in Gothenburg to characteristics and possible influence on the experiment. A mock-up borehole has been manufactured of a steel tube trying to imitate the inner part of the borehole involving the core stub. The sealing rubber has been manufactured and tested in a mock-up borehole.

A telescoped borehole, denoted KA3065A03, has been drilled parallel to the existing pilot borehole KA3065A02. Drilling with 300 mm (280 mm core) was made to a depth of 9.25 m. after which the borehole was continued with 196.5 mm (177 mm core) down to a depth of 10.40 m (from the tunnel face). The structural and geological model was successively updated during the drilling and the projected depth to the target structure adjusted accordingly. The correspondence between the predicted structure geometry and outcome is good, with the exception of the innermost parts of KA3065A03. Poor visibility impairing BIPS imaging combined with an apparent convergence of structures seen in KA3065A02 resulted in a stub which is about 0.16 m long. This should be compared with the desired 0.05 m stub.

New results

Given that the stub turned out about 0.1 m longer that projected, about 50 % of the projected diffusion length of the weakly sorbing tracers will be within the stub. For strongly sorbing tracers, the whole diffusion length will be within the stub. This poses the question whether damage/stress redistribution along the mantel surface of the stub will provide enhanced diffusivity which may invalidate the assumption of natural in situ conditions. Results of P-wave measurements on 45 mm core from KA3065A02 show an average velocity of about 5550 m/s. The velocity in the 177 mm core is higher, 5780 m/s. The P-wave velocity in undisturbed Äspö bedrock with no, or few macro fractures, is about 5900-6000 m/s based on results from the Prototype and the ZEDEX projects. The results from LTDE hence indicate a more profound (relative) damage of the 45 mm cores compared to the results from the 177 mm core.

The surface of the stub and the competence of the remaining stub was inspected with remote vehicle operated video camera and a 6 mm camera in the 9.75 mm slot between the stub and the borehole wall. The stub was found to be fully intact and no fractures were detected. Using the video information, total station measurements from the collar and the remains of the “mate” of the stub, the mineral distribution and relief of stub face was reconstructed

As previously indicated, problems to correlate structures between the two boreholes in the inner part of KA3065A03 were evident. To rule out possible effects of the BIPS imaging, which had been done with different systems in the two boreholes, a repeated BIPS imaging was made with the RAAX BIPS 4 system in both boreholes. The results indicated reproduction of the initial data so BIPS-derived artefacts were ruled out. In addition, the structural model constructed in RVS was rebuilt from scratch. Again, reproduction was possible. Consequently, despite the distance between the two boreholes which is less that 0.5 m, there is there is a problem to correlate structures between the two boreholes. In order top improve the basis for correlation, mineralogical and geochemical analyses will be expanded to provide support for the correlation.

In order to assess the rock mechanical effects on the stub in terms of drilling and stress unloading/redistribution, the LTDE situation has been reviewed using results presented by Hakala (1999). Using the geometry of LTDE with examples from Hakala where $\sigma_H = \sigma_1$ = 25 MPa parallel to the fracture surface and with $\sigma_v = \sigma_h \sim$ 10 MPa., a tensile strength of 16 MPa and a uniaxial compressive strength = 195 MPa, a Hoek-Brown failure parameter m_i = 7-25, and a slot to diameter ratio of 0.11, the basic assumptions to enable use of Hakala’s results are fulfilled. Under these circumstances no core damage in terms of new induced fractures takes place. This applies to both new fractures at the stub root (bottom of the hole) and new radial fractures. With regards to development of tangential fractures along the core axis, none of the primary loads is found to produce high enough radial tension which is needed to produce tangential fractures. It should however be noted that stress relaxation would open any existing micro fracture, and such relaxation and associated opening widening would occur in all directions.

In order to produce the best possible basis for customising the polyurethane part of the cup which fills the slot, and the connecting PEEK lid over the exposed fracture surface, a plaster cast of the stub surface has been made in the borehole during the period. The plaster cast was made with a special tool which included a latex liner which contained the plaster. A special plaster formula with a retarder was employed. In conjunction with these activities, the length measurements to the bottom of the borehole and to the mid point of the stub were improved.

During the period design and manufacturing of a chemical flow-through cell has been initiated. The cell is planned to be positioned in the circulation loop to monitor any changes in the hydrogeochemical stability in the loop, in particular leakage of oxygen to the loop. The cell is made of PEEK, and is fitted with 6 electrodes ; pH (glass), Eh 8 (Au, Pt, Glassi-carbon), reference and temperature. To further reduce the likelihood of oxygen leakage into the circulation loop, critical components (flow cell and pressure control cylinder) are planned to be positioned in plexiglass boxes with continuous flow through of N_2 gas.

During the period a number of preparations has been conducted on site. The pilot borehole KA3065A02 has been fitted with a multi-packer system made up of four packers. A customised container has been manufactured and has been positioned underground in the niche at 3/067 m. An installation rack has been manufactured which will facilitate installation of the equipment in the large diameter borehole. Ongoing work include connecting the experimental niche at 3/067 m to the Äspö computer network, the Alfa system (data acquisition and alarm management) and furnishing the container with the necessary infrastructure.

Plans for further work

Continued structural modelling of the area in the close proximity of the target structure with the aid of mineralogical and geochemical information.

Performance of a pre-test program which include both hydraulic tests and tracer tests. The hydraulic tests include detailed flow logging of the large diameter experimental borehole. In addition an attempt will be made to carry out a slug tests on the surface of the stub. The latter result has bearing on ongoing model assessments of the effects of exposing the stub to a significantly reduced head, and the time aspects of reinstating the pressure in the stub. This in order to enable preventive action to building up of a hydraulic gradient between the stub and the test section. The tracer test work is focused on characterisation of the connectivity of the investigated rock volume, simulation of release scenarios in case of of accidental leakage from the test section.

Plans are to install the down hole equipment after necessary preparations in the second half of October. The installation of equipment in the experimental container is scheduled to commence early November.

An application for a permit to use selected radionuclides is presently being prepared and will be submitted in mid October.

Initiation of the actual experiment is scheduled for second half of January, 2001.

3.2.2 Second TRUE Stage (TRUE-2)

The TRUE-2 experiments has been postponed awaiting the outcome of the TRUE-1 seminar this Fall and the outcome of the TRUE Block Scale Experiment. The outcome of the TRUE-1 seminar can be summarised in the following main bullets:

– There is a general consensus that the observed retardation observed in the TRUE-1 experiments requires diffusion into geological material to be an active process. This supported by the –3/2 slope noted in log-log BTCs. Whether this is due to diffusion (and subsequent sorption) in the altered matrix rock, or in possible fault gouge cannot be differentiated with available data,

– Some researchers claim that the observed enhanced retardation may be explained by diffusion into stagnant water pools, pure surface sorption, or may be due to an underestimation in the flow-wetted surface area. The latter effect may be attributed to a more complex flow path (multi-layered structure) or three-dimensional effects,

– A clear differentiation between the principal active process can only assessed by resin injection and subsequent excavation and analysis,

– It was identified that experiments of TRUE type are important for improving the understanding of retention processes. However, this type of experiment may not necessarily be part of a site characterisation programme,

– It was recommended to broaden the data base from the TRUE-1 site before characterising pore space with resin techniques. This includes tracer dilution tests using sinks in other features than Feature A.

The final results of the TRUE Block Scale Experiment are still pending, cf. Section 3.2.3.

3.2.3 TRUE Block Scale

Background

Work on the TRUE Block Scale Project started in mid 1996. This subproject of TRUE broadens the perspective from an address of a singular feature in TRUE-1, to flow and transport processes in a network of fractures and a spatial scale between 10 and 50m. The specific objectives of the TRUE Block Scale Project are to;

1) increase understanding and the ability to predict tracer transport in a fracture network,

2) assess the importance of tracer retention mechanisms (diffusion and sorption) in a fracture network,

3) assess the link between flow and transport data as a means for predicting transport phenomena,

A set of desired experimental conditions have been defined and a flexible iterative characterisation strategy has been adopted. The project is divided into a five basic stages;

- Scoping Stage
- Preliminary Characterization Stage
- Detailed Characterization Stage
- Tracer Test Stage
- Evaluation (and reporting) Stage

The total duration of the project is approximately 4.5 years with a scheduled finish at the end of the year 2000. The project was originally organised as a multi-partite project involving ANDRA, NIREX, POSIVA, and SKB. During 1997, also ENRESA and PNC have joined the project.

During 1997, two boreholes, KI0025F and KI0023B, have been drilled using the triple-tube method from the I-tunnel at L=3/510 m in the access tunnel. These boreholes, 75 mm in diameter, are gently inclined (I=20 degrees) and complement the existing 56 mm boreholes, KA2511A and KA2563A, the latter drilled as a pilot borehole as part of the TRUE Block Scale Scoping Stage. The latter boreholes have been drilled with a higher inclination from a higher elevation in the laboratory. The boreholes have been characterised using different geological, geophysical and hydrogeological methods. Based on the collected data the structural model of the block has been updated sequentially.

During 1998 the Preliminary Characterisation Stage was concluded with elaborate cross-hole interference tests which involved all available boreholes in the investigated rock block. The primary aim of the tests was to investigate the hydraulic connectivity with the block, and specifically the existence, relative role of northeasterly and subhorizontal structures. In addition the tests involved performance of tracer dilution tests in selected test sections, whereby not only the drawdown due to an applied disturbance was obtained, but also the change in flow rate through the selected sections. One of the pumpings was driven long enough to study breakthrough of tracer.

The cross-hole interference data together with 3D seismic data were used together with data from KI0023B to produce the September 1998 structural model update.

During the Fall 1998 another borehole, denoted KI0025F02, was drilled as part of the Detailed Characterisation Stage from the I-tunnel, between KI0023B and KI0025F, was characterised and completed. In this hole the POSIVA flow log was used for the first time in the project. In addition a series of short time cross-hole interference tests and associated tracer dilution tests were performed.

The status of the project per November 1998 was presented at the 2nd TRUE Block Scale Review Seminar held Nov 17, in Stockholm. At this meeting, apart from presenting a conceptual model of groundwater flow, the project group also presented their tentative strategy for upcoming future tracer tests.

During the Spring of 1999 an intensive planning effort has been conducted which has resulted in definition of the important issues of the planned future tracer tests. A set of hypotheses related to the issues of conductive geometry, heterogeneity and retention have been put forward in a Tracer Test Programme. Further design calculations related to the effects of fracture intersections have been performed. In addition, a series of Pre-tests, in essence a series of three interference tests with associated tracer dilution tests have been performed. As a final field activity a multi-injection tracer test was performed which demonstrated breakthrough from four out of four injection sections, two of which showed high recovery in pathways involving multiple structures (>1)). The Tracer Test Programme also defines a tentative strategy for the future tracer tests which will be conducted in three consecutive phases, A through C. The first Phase, A, is a test of alternative sink sections, combined with complementary tracer dilution tests. The focus of Phase B is on the selected sink section, tests over both short and longer distances. The final Phase C is fully devoted to tests with sorbing tracers.

During the Fall of 1999 drilling and characterisation was performed in the last of the boreholes, KI0025F03. Characterisation has included flow and pressure build-up tests with observation of pressure responses in the neighbouring boreholes. The qualitative interpretation showed responses consistent with the reconciled March'99 structural model. The borehole was subsequently instrumented with a multi-packer system consisting of 9 sections, two of which prepared with metal lines for injection of helium as a tracer.

Phase A of the Tracer Test Stage involved use of two alternative sink sections, and comprised about 70 tracer dilution tests and 8 tracer injections. The results of the tests, co-assessed with existing results from previous tests, indicated that the sink in KI0023B showed the best prospects of producing breakthroughs with a high mass recovery over reasonable time scales. This sink will be used in the subsequent Phase B which is includes demonstration of high mass recovery and test of helium as a tracer.

The Phase A tests have been preceded by model predictions using the existing DFN, Channel network and Stochastic Continuum models which has been updated with the March'99 structural model and all available information including the interference and tracer dilution tests made as part of the Phase A tests.

The subsequent Phase B tests were run in two parts, Phase B1 with a 50% reduction relative to maximum pump rate and Phase B2 where maximum pump rate was employed (approximately 2 l/min). This staged approach was employed to enable identification of stronger retardation of the more diffusive He-gas at reduced flow rate. During the Phase B2 tests, 6 sections were used for tracer injection. The results show > 80 % recovery (stipulated recovery to allow injection of radioactive sorbing tracers) for three injection sections (KI0025F03:P5 (#20), KI0025F03:P7 (#23) and KI0025F03:P3 (#21), involving 1-4 structures along the pathway.

Results

<u>Tracer tests Phase</u> C

Given the identified constraints (time, recovery, tracers, equipment) it was identified that 5 injections were possible to achieve within the framework of Phase C. In order to test the hypotheses of possible higher retardation for tracers when transported over larger time scales, a cocktail of tracers including both a weakly sorbing (like Na, Ca and Sr) and a more strongly sorbing (eg Rb, Ba and Cs) will be used for each injection. One of the planned injections (C4) constitute injection of tracers subject to partial hydrolysis/surface complexation. Table 3-1 provide an overview of the performed tracer injections.

Table 3-1. Objectives and hypotheses addressed with Phase C tracer. The structural interpretation and notation refers to the updated March 2000 model, cf. Figure 3-2 (Doe & Hermanson, in prep.)

Test #	Flow path	Structures involved	Objective	Hypotheses addressed
C1	KI0025F03:P5 – KI0023B:P6	20, 21	Network and FIZ effects on retention	2, 3
C2	KI0025F03:P7 – KI0023B:P6	23, 20, 21	Network and FIZ effects on retention	2, 3
C3	KI0025F02:P3 – KI0023B:P6	21	Retention in a singe fracture	2, 3
C4	KI0025F03:P5 - KI0023B:P6	20, 21	To demonstrate the importance of alternative sorption mechanisms (partial radiolysis and surface complexation)	n.a.
C5	KI0025F02:P6 - KI0023B:P6	22, 20, 21	Network and FIZ effects on retention	2, 3

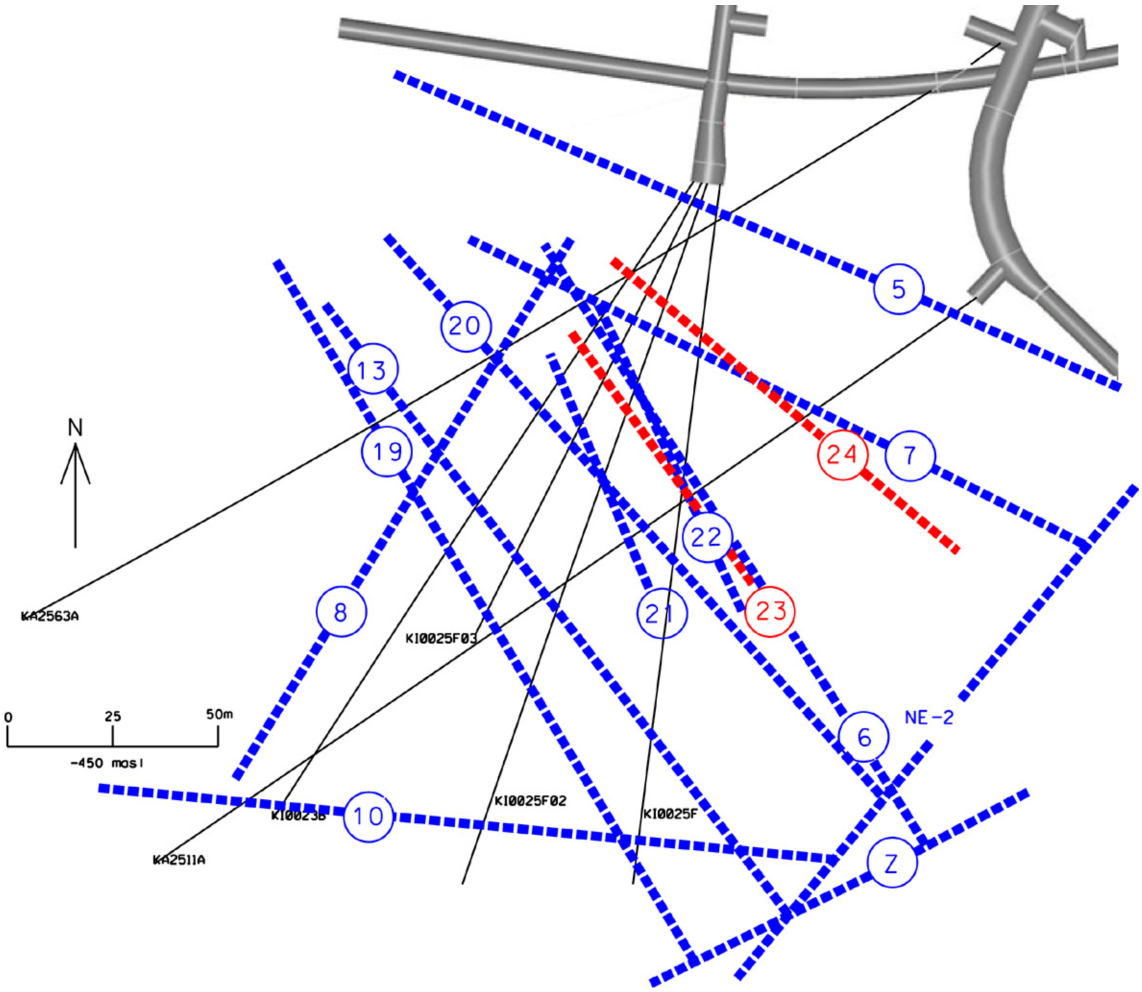


Figure 3-2 March 2000 structural model. Structures indicated in red are new structures.

A permit for performance of the planned tests was obtained from the Swedish Radiation and Protection Board (SSI) early June. So far four of the injections (C1-C4) have been conducted. Injection C5 have been omitted due to poor performance of the selected injection section.

The Phase C experiments will be the subject of blind model predictions and hence no results will be presented until the predictions have been filed.

Numerical modelling

Evaluation of the Phase A tests has continued within all three model concepts (Stochastic Continuum, Discrete Feature Network and Channel Network). Model updates making use of the results of Phase B are under way. The updated models will form the base for model predictions of the Phase C tests.

Stochastic Continuum

During the period April till August 2000 the modelling work has focused on the generation of multiple realisations of the investigated rock volume, all of them consistent with the measured data, and the evaluation of the performance of the generated hydraulic conductivity fields in the prediction of tracer tests. Furthermore, attention was paid to the detected inconsistent flow and transport predictions by the two models developed by the UPV and UPC groups, respectively.

Inverse modelling of groundwater flow in the TRUE Block Scale volume has continued at UPV. No fundamental changes in the model have been made. The POSIVA flow log data were introduced in the model, thus increasing the number of hydraulic conductivity data points for the ”matrix rock” to 270. The structural model was not modified and consequently Structure #23 is not introduced in the model. It can be argued that the relative coarse discretization in the UPV model results in Structure #23 coinciding more or less with Structure #6. Additional steady state head data and drawdown responses to transient tests were also used in the inverse modelling. At the end of August, 10 realisations conditioned to steady state head data had been generated, 9 of which were also conditioned to five short-term tests, and further 7 of were also conditioned to the A4 pre-test. The A4 test is chosen because the pumping location coincides with the pumping location used in the subsequent Phase B and Phase C tests. The 7 realisations conditioned to steady sate head data, short-term tests and the A4 test have been sent to the UPC-team for the prediction of the outcomes of the Phase B and Phase C tracer tests. The continued work at UPV will be focused on generating more realisations, to study the role of possible subhorizontal structures in the TRUE Block Scale rock volume and to do particle tracking calculations.

The modelling of transport at UPC has been continued with the model developed at the beginning of the year using the most recent conditioned conductivity fields. The tracer tests of Phase B (B-1 and B-2) have been simulated using this field and the calibrated transport parameters of the tracer tests A-4 and A-5. It was found that the correspondence between simulated and measured mass recovery was improved compared to those made for Phase A. The next step consists of using as many of the conditioned conductivity fields as possible for predicting the Phase C tracer tests.

<u>DFN</u>

AEA Technology has completed the update of its DFN model using the so-called March 2000 structural model. The model is largely unchanged compared to the March 1999 model with the exception of the addition of a new structure, #24. Preliminary indications from the modelled simulations show that the net impact of Structure #24 on the tracer configurations is small.

Current modelling effort is focussing on the completion of the evaluation of the Phase B tracer tests. This is due to be completed by the end of October. A collection of tracer flow paths, simulating the B-2g test is illustrated in *Figure 3-3*. The focus of the current interpretations follows two routes for practical reasons:

- The use of a phenomenological relationship between hydraulics and transport (a quick way to explore the relevance of hydraulic tests in relation to predicting tracer tests);
- The development of a plausible geostatistical model.

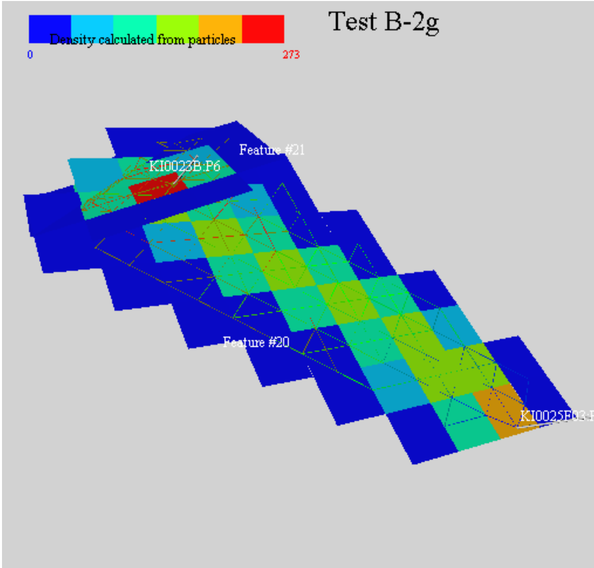


__Figure 3-3__ An illustration of simulation of Test B-2g. Tracer is released from KI0025F03:P5 (#20) with a sink at KI0023B:P6 (#21) at a pumping rate of 2300 ml/min. The colours indicate the frequency of visiting particles, giving an indication of the width of the tracer plume for the model discretised on a 2m scale.

To enable the results of the modelling to be properly understood two approaches are being adopted:

- The use of the τ, and the β parameters of Cvetkovic et al (2000);
- The use of the WL/Q parameter as advocated by Hautojärvi.

The net 'loss' of tracer still provides challenges that have still not been satisfactorily resolved; i.e. the simulations consistently show relatively high recovery compared to what is seen in the results from the in situ tests.

In preparation of the Phase C modelling a reactive tracer data set is being compiled. This takes in consideration:

- MIDS ("Modelling Input Data Set") used as part of the modelling of the TRUE-1 tracer tests (Winberg et al., 2000, Cvetkovic et al., 2000)
- subsequent evaluation performed by Cvetkovic et al (2000) of the TRUE-1 modelling,
- anomalous behaviour illustrated by the more strongly sorbing tracers, such as Caesium.
- A range of concepts for retention in a fracture and its environs (rim zone, presence of gouge material, …)

Channel Network Modelling

Over the past two months, the JNC/Golder team have implemented the latest structural model (March 2000) used for the TTS tests. FIZ pipes have been added at the intersections between structures #13/21 and #20/21, and between these FIZ pipes and borehole injection sections including Structures #13, #20, and #21. No pipe was included for KA2511A because it was not used for tracer injection.

Extensive simulations have been carried out with the updated model to match distance/drawdown responses of the Phase A experiments. Distance/drawdown runs have also been made for the Phase B experiments. The latter analysis have not yet produced an acceptable match. The problem with the poor match is believed to be related to insufficient connectivity. Alternative hypotheses for connectivity are being explored, including changes to FIZ pipes, background fractures and sub-horizontal structures.

Simulations have been carried out of tracer dilution tests A1, A2, and A3, and tracer test simulations of tests A4, A5, B1a, B1b, and B1c. The matches for A4 and A5 are reasonable when expressed as normalized mass recovery. However, there exists a need to increase the FIZ pipe effects to further reduce recovery.

Over the next month, model refinements will be finished and run the Phase C predictions will be started up.

Planned work

4th quarter 2000

LTDE

- Start up of laboratory work
- Model study of dynamics of pore pressure reinstatement in the stub
- Work to obtain CE acceptance
- Application to SSI
- Installation of equipment
- Pre-tests

TRUE Block Scale

Tracer Test Stage

- Continued monitoring of Phase C tracer tests
- Prediction of Phase C experiments

Evaluation and Reporting Stage

- First in a series of two reporting workshops

3.3 Radionuclide retention

Background

The retention of radionuclides in the rock is the most effective protection mechanism if the engineering barriers have failed and the radionuclides have been released from the waste form. The retention is mainly caused by 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 on solubility and migration of the long lived nuclides e.g. Tc, Np, and Pu indicate that these elements are so strongly sorbed on the fracture surfaces and into the rock matrix that they will not be transported to the biosphere until they have decayed. In many of these retention processes the sorption could well be irreversible and thus the migration of the nuclides will stop as soon as the source term is ending.

Laboratory studies under natural conditions are extremely difficult to conduct. Even though the experiences from different scientists are uniform it is of great value to demonstrate the results of the laboratory studies in situ, where the natural contents of colloids, organic matter, bacteria, etc. are present in the experiments. Laboratory investigations have difficulties to simulate these conditions and are therefore dubious as validation exercises. The CHEMLAB borehole has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions.

Figure 3-4 illustrates the principles of the CHEMLAB 1 and CHEMLAB 2 units.

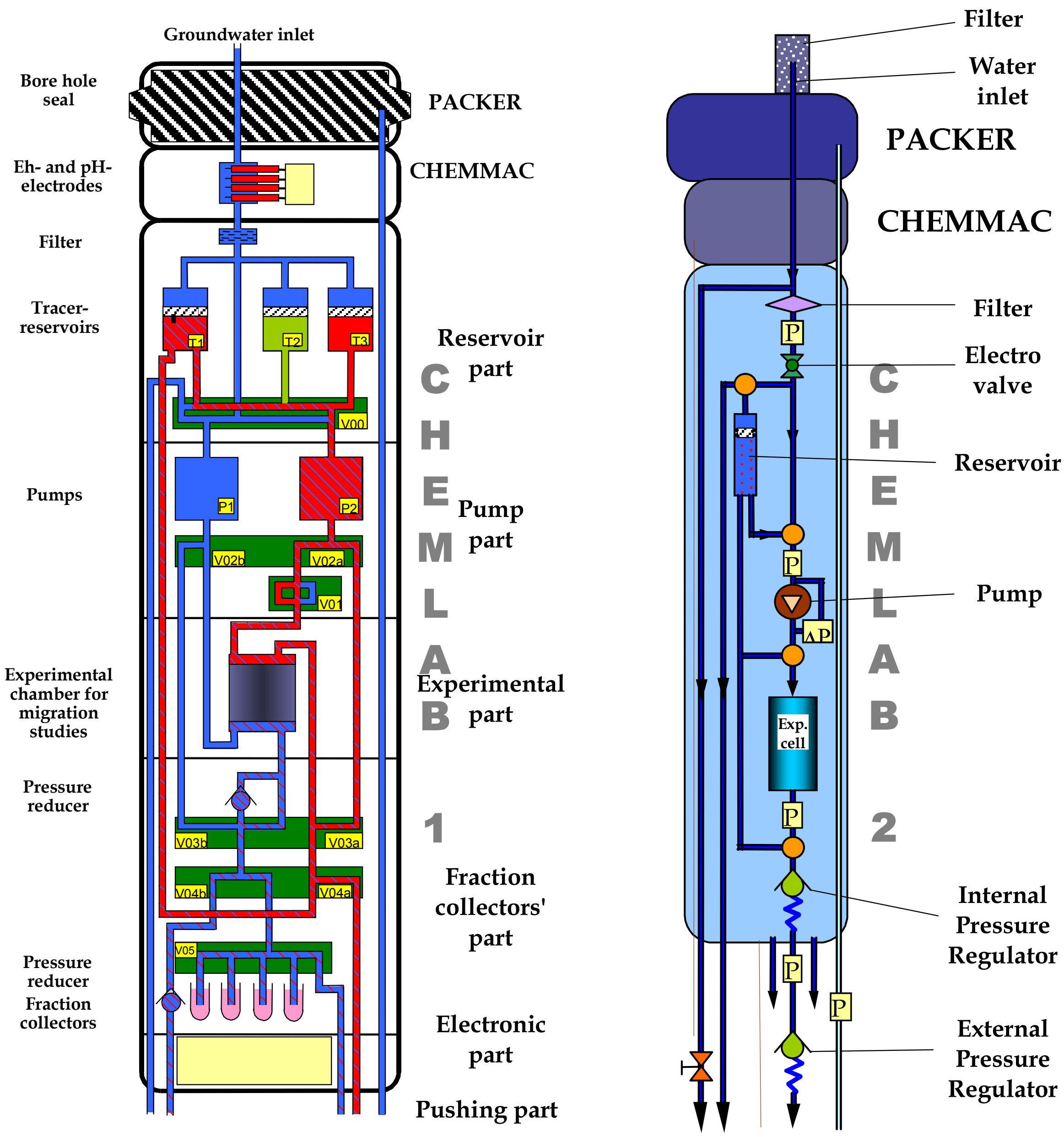


Figure 3-4 *Schematic illustration of CHEMLAB 1 and 2.*

Objectives

The objectives of the Radionuclide Retention (CHEMLAB) experiments are:

- To validate the radionuclide retention data which have been measured in laboratories by data from in situ experiments in the rock
- To demonstrate that the laboratory data are reliable and correct also at the conditions prevailing in the rock
- To decrease the uncertainty in the retention properties of relevant radionuclides

Experimental concept

CHEMLAB is a borehole laboratory built in a probe, in which migration experiments can be carried out under ambient conditions regarding pressure and temperature and with the use of the formation groundwater from the surrounding rock.

Initially one “all purpose” unit was constructed in order to meet any possible experimental requirement. This unit CHEMLAB 1 has been used for the “diffusion in bentonite” experiments and will now be used for similar experiments including the effects of radiolysis. Others to follow are:

- Migration from buffer to rock
- Desorption of radionuclides from the rock
- Batch sorption experiments

The CHEMLAB 2 unit is a simplified version of CHEMLAB 1, designed to meet the requirements by experiments where highly sorbing nuclides are involved. These are:

- Migration of redox sensitive radionuclides and actinides
- Radionuclide solubility
- Spent fuel leaching

New Results

Preparations of the glove box for the actinide experiment have been done. Also the arrangement of experimental cell and radioactive tracers in CHEMLAB 2 are done. Practical arrangements have been made for the start up of the radiolysis experiment in CHEMLAB 1.

Planned Work

- Start of the actinide experiment in CHEMLAB 2
- Start of the radiolyses experiment in CHEMLAB 1
- Final report of the diffusion experiments

3.4 Hydrochemical modelling/Hydrochemical stability

Background

The chemical properties of the groundwater affect the canister and buffer stability and the dissolution and transport of radionuclides. It is therefore important to know the possible changes and evolution of the groundwater chemistry during the repository life time. Important questions concern the understanding of the processes which influence and control the salinity, occurrence, character and stability of both saline and non-saline groundwaters.

At present this project is carried out within the framework of the Äspö agreement between SKB and Posiva. It also covers the technical parts of the participation in the EC EQUIP project and the modelling Task #5 within the framework of the Äspö Task Force for modelling of groundwater flow and transport of solutes.

Objectives

The objectives of this project are:

– To clarify the general hydrochemical stability (= groundwater chemistry of importance for canister and bentonite durability and radionuclide solubility and migration)

– To describe the possible scenarios for hydrochemical evolution at Äspö over the next 100.000 years, separated into time slabs of 0-100, 100-1000, 1000-10000 and 10.000-100.000 years.

– To develop a methodology to describe the evolution at candidate repository sites, e.g. Olkiluoto.

Model concepts

Geochemical interpretation of groundwater-rock interaction along flow paths makes use of the results from groundwater chemical investigations, i.e. chemical constituents, isotopes and master variables pH and Eh in combination with the existing mineralogy, petrology and termodynamic data. Useful tools for these calculations are reaction path codes like NETPATH and equilibrium-mass balance codes like EQ 3/6. These codes are frequently used in hydrochemical studies.

A newly developed concept and code, M3, start from the assumption that it is mixing and not chemical reactions that is the dominating process affecting the chemical composition of the groundwater within the investigated system. The principal assumptions behind this concept is that the varying hydraulic conditions of the past have created the complex mixing pattern presently observed. When the effects of mixing has been evaluated, mass balance calculations (resulting from chemical reactions) are then made to explain the difference between the ideal mixing and the observations.

The modelling strategy for the Hydrochemical Stability project involve:

– Identification of the dominant (chemical) processes for Finnish and Swedish sites.

– Geochemical mixing for Äspö and Olkiluoto.

– Site intercomparison and comparison between the M3 and NETPATH techniques based on data from Olkiluoto.

– Transient hydrodynamic modelling for Äspö and Olkiluoto.

The intention with the strategy is to be able to compare the results of the traditional hydrochemical modelling with the results from M3 and to compare the outcome of the hydrodynamic modelling with the results from M3. The latter comparison is done within the Task #5 of the Äspö Task Force for modelling of groundwater flow and transport of solutes.

The Equip project has the specific objective to trace the past hydrochemical conditions through investigation of (calcite)fracture filling minerals. The outcome will beused to check the conclusions from hydrogeological and hydrochemical models.

New Results

The final report of the EQUIP project has been submitted to EU. Evaluation of the Task#5 work has started.

Planned work

- Modelling reports for Task#5 will be published in the ICR series.
- The final report of the Hydrochemical Stability project will be sent for review.
- Results of KLX02 groundwater sampling and analyses will be published as a Technical Document.

3.5 Matrix Fluid Chemistry

Background

Knowledge of matrix fluids and groundwaters from rocks of low hydraulic conductivity will complement the hydrogeochemical studies already conducted at Äspö, for example, matrix fluids are suspected to contribute significantly to the salinity of deep formation groundwaters. It will also provide a more realistic chemical input to near-field performance and safety assessment calculations, since deposition of spent fuel will be restricted to rock volumes of similar hydraulic character.

Objectives

The main objectives of the task are:

- to determine the origin and age of the matrix fluids,
- to establish whether present or past diffusion processes have influenced the composition of the matrix fluids, either by dilution or increased concentration,
- to derive a range of groundwater compositions as suitable input for near-field model calculations, and
- to establish the influence of fissures and small-scale fractures on fluid chemistry in the bedrock.

Experimental concept

The experiment has been designed to sample matrix fluids from predetermined, isolated borehole sections. The borehole was selected and drilled on the basis of: a) rock type, b) mineral and geochemical homogeneity, c) major rock foliation, d) depth, e) presence and absence of fractures, and f) existing groundwater data from other completed and on-going experiments at Äspö. Special equipment has been designed to sample the matrix fluids 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 uranine content, f) the collection of fluids (and gases) under pressure, and g) convenient sample holder to facilitate rapid transport to the laboratory for analysis.

Migration of matrix fluids will be facilitated by small-scale fractures and fissures. Therefore the matrix fluid chemistry will be related to the chemistry of groundwaters present in hydraulically-conducting minor fractures (K= 10^{-10}-10^{-9}ms^{-1}), since it will be these groundwaters that may initially saturate the bentonite buffer material.

New results

Since the last status report, activities carried out have involved the continuation of: a) mineralogical/petrophysical studies, b) crush/leaching experiments, c) Äspö diorite permeability test, d) fluid inclusion characterisation, and e) compilation and interpretation of groundwaters sampled and analysed from the TRUE Block Scale, Prototype Repository and 'J' Niche (Chemlab/Microbe) experiments.

Mineralogy, petrography and geochemistry

Drillcore samples have been selected and studied with particular attention being paid to the two sections earmarked for matrix fluid sampling (i.e. Section 2: 8.85-9.55 m; Section 4: 4.66-5.26 m). Results show that, together with other studies at Äspö and also Stripa, the mineralogy conforms to a general monzogranite-type rock. Within the matrix drillcore length two main rock-types are represented, an Äspö porphyritic diorite type adjacent to the tunnel, and an Ävrö Granite type away from the tunnel, with the transition being located between borehole Sections 2 and 4 at around 8.40-8.50 m. This is supported by the drillcore logging and the downhole BIPS images.

The main rock-forming mineral phases constituting the drillcore are, in decreasing volume amounts, plagioclase, quartz, K-feldspar, biotite, epidote, chlorite, sphene and muscovite with accessory amounts of opaque phases, apatite and zircon. The modal values of the major mineral phases show a clear distinction between the Äspö diorite and the Ärvö granite where the latter contains more plagioclase and mafic phases and less quartz and K-feldspar. Macroscopically this can be seen as a colour change in the drillcore. The feldspars consist of microcline and oligoclase; microcline is sometimes perthitic. Occasionally myrmeckite is observed at the grain boundaries of oligoclase. Alteration is sometimes considerable within the feldspar grains giving it an almost opaque character under transmitted light.

The grain size of quartz varies; most have an equigranular texture with fluid inclusions often outlining grain boundaries. Occasional larger quartz grains occur which may be more primary. Evidence of small-scale tectonic effects are common in both types. In many places the centres of quartz grains show healed fractures now outlined with fluid inclusions. Even open delimited fractures may be observed in the centre of quartz grains.

In terms of whole-rock chemistry, the Äspö diorite exhibits higher FeO, MgO, TiO_2, CaO, Na_2O and Rb than the Ävrö granite, but is lower in SiO_2, K_2O and Ba due to its higher content of plagioclase, biotite and epidote/chlorite.

Petrophysical studies

From earlier measurements carried out from several experimental sites at Äspö, the average total or physical interconnected porosity values characteristic for the Äspö area (based on between 50 to 100 measurements) are:

Fine-grained granite	0.2 vol% ±0.1
Ävrö granite	0.35 vol% ±0.1
Äspö diorite	0.45 vol% ±0.1

There is a distinct difference in interconnected porosity between all three major rock-types.

Determination of effective or connected porosity on 5 samples from the Äspö diorite portion of the matrix drillcore and 4 samples from the Ävrö granite portion gave average values of 0.32 vol% and 0.35 vol% respectively; the average densities are correspondingly 2756 and 2679 kg/m^3. The variation in density is, however, larger for the diorite (2721-2752) than the granite (2675-2679) indicating the greater heterogeneity (and greater mafic content) of the Äspö diorite.

Compared to the average Äspö porosity values quoted above, the Ävrö granite is similar but the Äspö diorite differs markedly (0.32 vs 0.45 vol%). This may reflect the structural orientation of the measured rock section; if this is true, the interconnected porosity may be expected to be less when measured perpendicular to the foliation. To resolve this issue oriented samples (i.e. parallel and perpendicular to the foliation) are presently being measured. Furthermore, attempts are being made to determine the non-connected porosity in relation to the measured interconnected porosity, and consideration is also being given to assessing the potential effect of destressing following removal of the drillcore.

Crush/leaching experiments

In addition to earlier reported studies, three additional drillcores have been crushed and leached; the leachates are presently being analysed. These drillcores have been selected from a lithological viewpoint, i.e. more mafic and less mafic than those representing the Äspö diorite and Ävrö granite characteristic of the matrix drillcore. The objective is to determine not only the influence of lithology on the overall chemistry of crush leachates, but with special emphasis on the chlorine, strontium and boron isotopes. It is hoped that this will contribute to a more quantitative interpretation of the matrix fluid chemistry.

Permeability test

Since August 1999 a high pressure experimental set-up has been operating at the University of Waterloo essentially trying to force double distilled (Ultrapure) water through a drillcore portion (100x50 mm) in order to extract unbound, intragranular matrix fluid. The drillcore portion, selected adjacent to Section 4, has been mounted in a moisture proof membrane with an applied hydrostatic stress of 11.7 MPa (i.e. equivalent to the lithostatic stress at the Matrix Borehole location in Tunnel 'F') and a pore pressure of 6 MPa has been applied to the distilled water. Up until October 1999 no movement was observed and the pore pressure was accordingly increased to 9.5 MPa. Some activity was observed in November, 1999 which subsequently slowed down. Since then no further movement has been observed even though a loss of distilled water (100 mL) has been measured. Whether this is due to the filling up of empty pore space is not yet known. This, and other possibilities are being presently followed up.

Fluid inclusion studies

Fluid inclusions are mostly observed in quartz. There are three types of quartz: a) large primary irregular grains, b) small, recrystallised equigranular grains in a heptagon matrix, and c) vuggy quartz. The fluid inclusions are mainly associated with the coarse-grained primary magmatic quartz and later fine-grained recrystallised quartz. They show a diverse distribution where grain boundary inclusions, and fracture bound inclusions dominate. Multi-phase liquid, solid and gas fluid inclusion types are commonly associated with the primary quartz and mostly liquid phase types with the recrystallised quartz. Three-phase inclusions have been observed with a probable calcite daughter mineral and evidence of decrepitated inclusions have also been recorded.

Preliminary microthermometric studies show that the fluid inclusions identified in the coarse-grained magmatic quartz and the fine-grained recrystallised quartz mostly represent highly saline populations. Salinity ranges from 8.2-20.9 wt% $NaCl_{eq}$ in the former types and from 4.3-10.8 wt% $NaCl_{eq}$ in the latter types. In addition, several other fluid inclusion types containing non-fluorescent gas-rich inclusions (CO_2 or CH_4) have also been revealed; these may even dominate the grain boundary inclusion populations.

Matrix fluid

Pressure is continuing to increase in borehole Sections 2 and 4, demarcated for matrix fluid sampling. *Figure 3-5* shows that Section 4 is refilling after being sampled in December 1999 and that Section 2 is still slowly filling for the first time. Both sections will be sampled when adequate water is indicated.

Hydraulic considerations

At an early stage in the experiment, estimated times to accumulate 250 mL matrix fluid (approximating to the respective volumes of Sections 2 and 4 earmarked for sampling) were predicted based on a range of hydraulic conductivity values. Both radial and spherical Darcian flow were considered assuming differential pressures within 10–35 bar and a radius of influence 5–10 m. The results of the predictions are shown in *Figure 3-6*. At a conductivity of $1{\cdot}10^{-13}$ ms^{-1} an accumulation of 250 mL matrix fluid would require 2–9 months, and at a conductivity of $1{\cdot}10^{-14}$ ms^{-1} it would need from 16 months to 7 years. Contrastingly, at a conductivity of $1{\cdot}10^{-12}$ ms^{-1} only 5 days to one month would be required. The increase in pressure in borehole Section 4 after 15 months

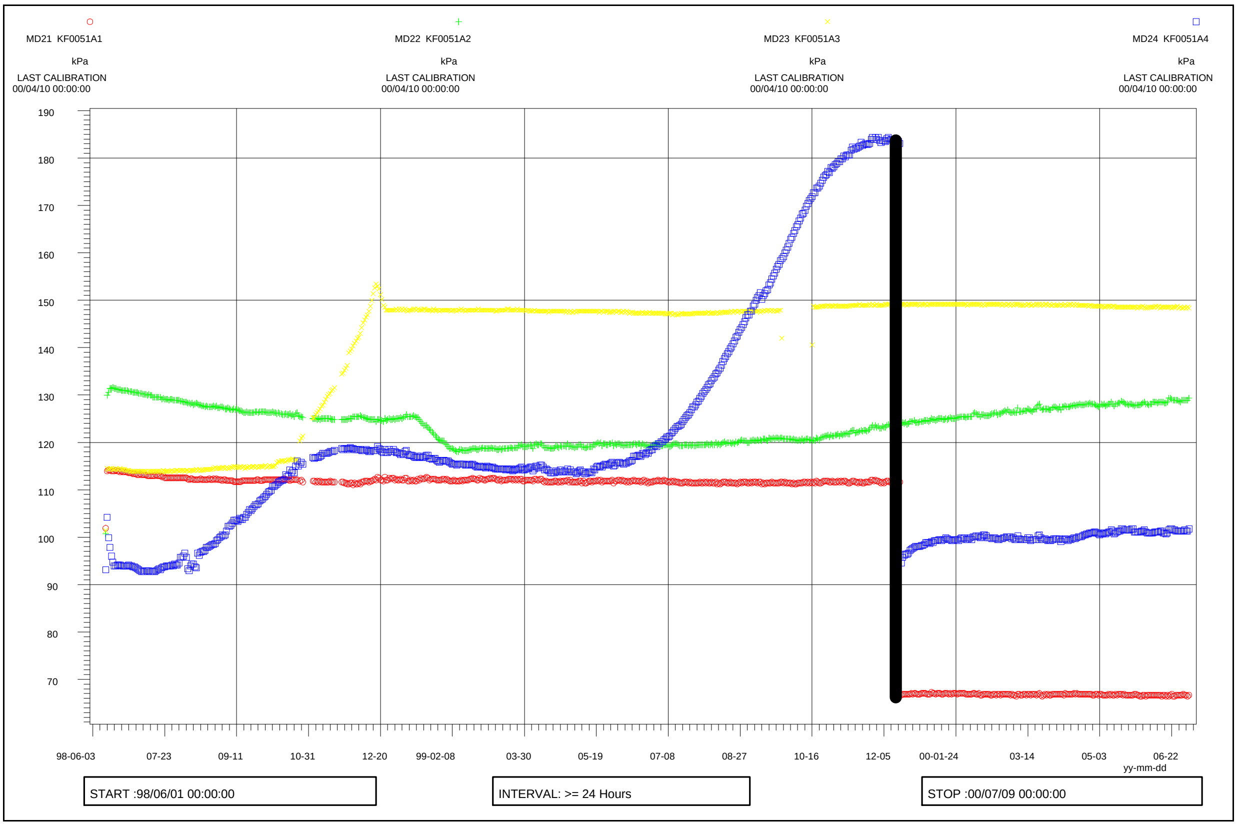


Figure 3-5 *Pressure monitoring curves for each of the four isolated borehole Sections; 1(red), 2 (green), 3 (yellow) and 4 (blue). Sections 2 and 4 are demarcated for matrix fluid sampling. The break in the curves (black line) indicates the occasion when sections 1 and 4 were opened for sampling in December 1999.*

Figure 3-5 suggests that the hydraulic conductivity in the matrix rock block lies somewhere around 10^{-14}-10^{-13} ms^{-1}.

Following the opening of the two borehole sections in December 1999, when 160 mL of water was recovered from Section 4, out of a maximum of about 180 mL (around 20 mL residual volume was inaccessible due to packer/borehole geometry), further calculations were made. From the measured inflow rate, the actual pressure in the borehole section, and an estimate of pressure in the surrounding rock creating differential pressures within 10-35 bar and radius of influence 5-10 m, the hydraulic conductivity of the matrix rock block was calculated. Even though there are uncertainties in estimated pressure and the assumed flow regime, both radial and spherical Darcian flow, the calculated hydraulic conductivity of $1{\cdot}10^{-14}$-$6{\cdot}10^{-14}$ ms^{-1} of the matrix rock block is judged reasonable and in accordance with the earlier predictions.

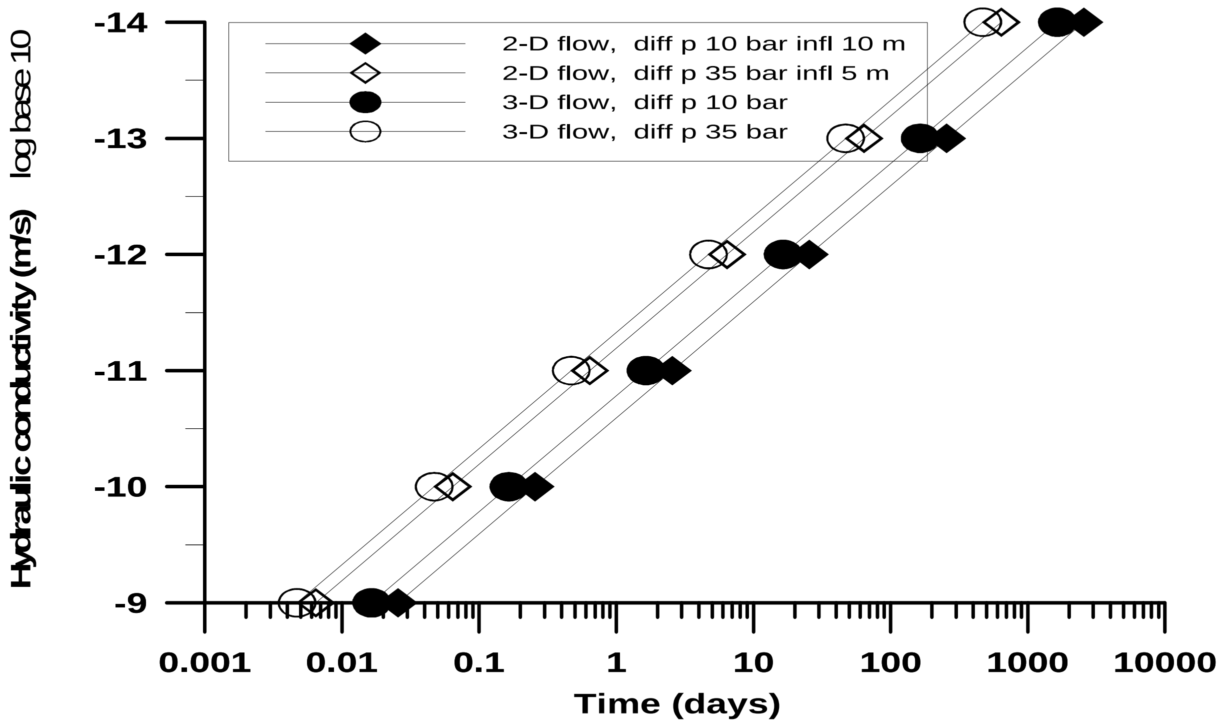


__Figure 3-6__ Predicted times to accumulate 250 mL of matrix fluid, .based on a range of hydraulic conductivities, considering both radial and spherical Darcian flow and assumed differential pressure within 10–35 bar and radius of influence 5–10 m.

Fracture groundwaters sampled in the near-vicinity of the Matrix Fluid Experiment

Groundwater samples have been collected from fractures of low transmissivity in coordination with the Prototype Repository, TRUE Block Scale and 'J' Niche (Chemlab/Microbe) experiments **(***Figure 3-7***).**

The general chemical character of the groundwaters from each of the sampled sites can be seen from the PCA plot in *Figure 3-8*. The exact location of the 'matrix' sample is uncertain as all the chemical and isotopic parameters are not known due to the small volume of water obtained. Priorities had to be set, and this excluded tritium isotope determinations; furthermore the alkalinity value is uncertain because of microbial influences during titration and the carbon-14 values are not reported as the sample was inadvertently contaminated. Nevertheless, substituting some groundwater chemical values from 'J' Niche borehole KJ0052F03 (section 9.23-9.43 m), located near the matrix experimental site and potentially a source for some of the 'matrix' water collected, a good approximate location has been plotted.

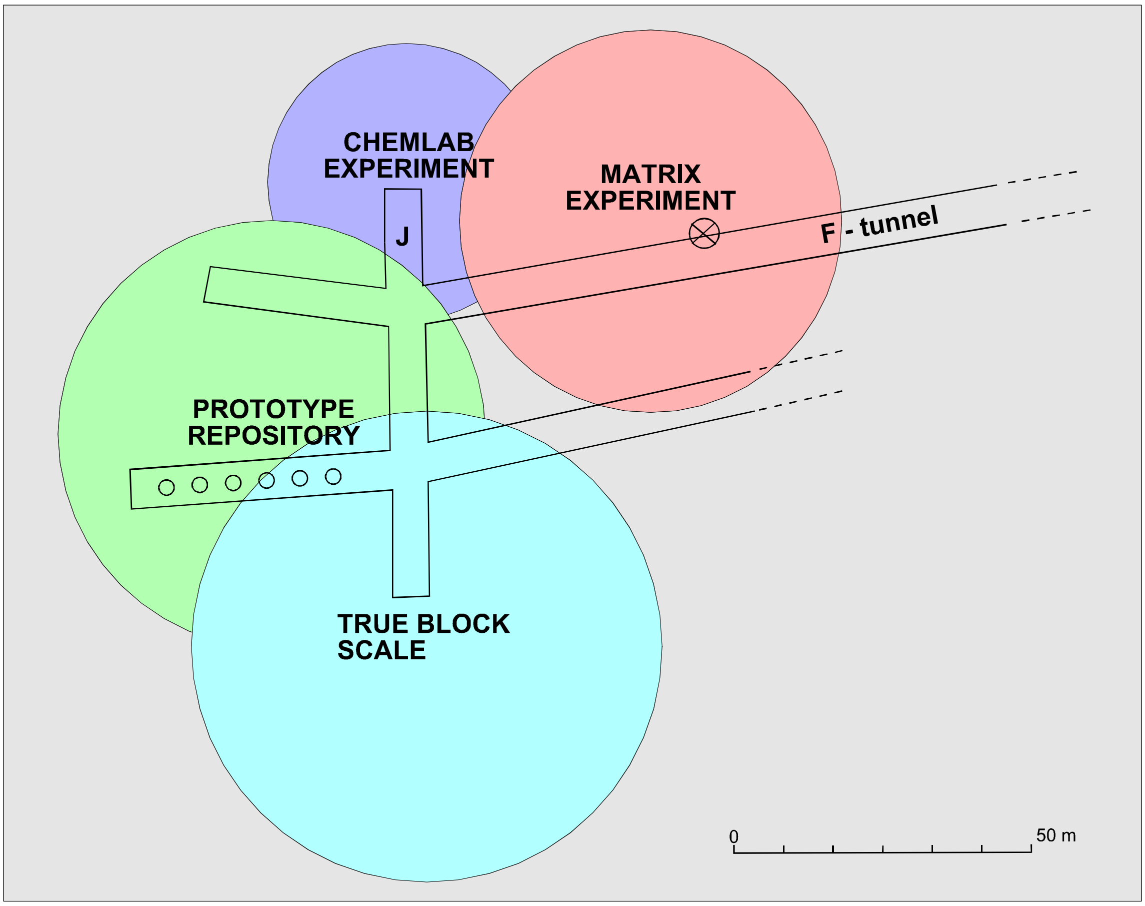
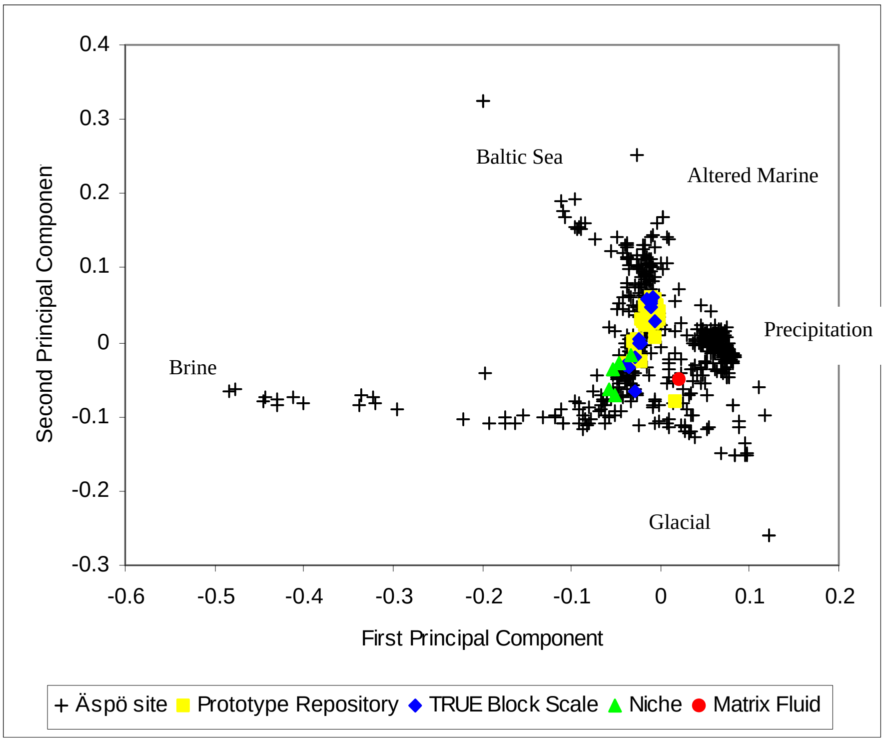


Figure 3-7 *The three areas of available hydraulic and .hydrochemical data in the near-vicinity of the Matrix Fluid Experimental borehole.*

Figure 3-8 shows a clear separation of the 'J' Niche and Prototype Repository samples with the TRUE Block Scale samples extending over the full range of both groupings; the 'Matrix' sample and that of KA3572G01 (Prototype Experiment) are clearly separate. The distribution of the plotted data is controlled by variation of the saline, glacial and Baltic Sea components; the greater the Baltic component, the less the glacial (and saline) component. This may be due to the hydraulic drawdown initiated by the tunnel excavation, whereupon modern Baltic Sea and meteoric precipitation components are introduced at these depths and may have diluted or displaced the older glacial and saline components.



First Principal Componet = - 0.49[Na] - 0.03[K] - 0.01[Ca] - 0.03[Mg] + 0.13[HCO_3] + 0.24[Cl] + 0.16[SO_4] - 0.17[D] + 0.75[^{18}O] + 0.25[^{3}H]

Second Principal Component = - 0.25[Na] + 0.35[K] + 0.04[Ca] + 0.45[Mg] + 0.31[HCO3] - 0.69[Cl] - 0.18[SO4] - 0.09[D] + 0.06[O18] - 0.003[Tr]

Variance:
Comp. 1 = 40%
Comp. 1+2 = 70%

Matrix Fluid sample, chemical composition:
Na= 2200; K= 11.4; Ca= 964; Mg= 7.76; HCO_3 = 185; Cl= 5180; SO_4= 26; D= -87.9; O^{18}= -11.6; H^3= 0

Note: Matrix Fluid sample; HCO_3=185 mg/L mean value (HCO_3 ranges 170-200 mg/L) and H^3 = 0

Figure 3-8 *PCA plot showing distribution of groundwaters from the .TRUE BlockScale, Prototype Repository and 'J' Niche (Chemlab/Microbe) experimental sites. These data are related to the overall Äspö database and to the approximate position of the 'Matrix Fluid' sample.*

To date the general conclusion from these studies is that over the range of hydraulic conductivity represented by the sampled fractures, most show little obvious correlation with groundwater chemistry. The data indicate an influx of a modern groundwater component, such as Baltic Sea and meteoric precipitation waters, associated with the hydraulic drawdown caused by tunnel construction, to the detriment of older saline and glacial melt water components which have been diluted or removed. This has been particularly apparent with the Prototype samples, despite the generally low transmissive character of the sampling locations, probably due to their near-vicinity to the excavated tunnel opening. Nevertheless there are indications that at least one of the lower transmissive fractures (KA3572G01; 10^{-9} m^2s^{-1}) has been less influenced by the drawdown due to a longer response time, retaining a lower Mg content and more negative ^{18}O signature, together with an overall higher TDS content. This may reflect a different fracture orientation than the other sampled fractures.

Drawdown effects are less evident from the ‘J’ Niche (Chemlab/Mcrobe) and TRUE Block Scale sites probably due to the sampling locations being further from the excavated tunnel opening. It would appear therefore that to achieve a more sensitive correlation between hydraulic properties and groundwater chemistry, smaller ranges of hydraulic transmissivity (e.g. 10^{-12}-10^{-10} m^2s^{-1}) need to be investigated at greater distances away from these open tunnel conditions.

The ‘matrix’ sample, whilst reflecting a generally similar major ion character to nearby fracture compositions (with the exception of SO_4 and Mg), exhibits anomalous chlorine isotope and strontium isotope signatures and higher contents of most trace elements which may be more characteristic of a ‘true’ matrix component. Interestingly, the anomalously low $^{87}Sr/^{86}Sr$ ratio (0.714561) is similar to the Prototype sample KA3572G01 (0.714990); both $^{87}Sr/^{86}Sr$ ratios are significantly lower than all other measured groundwaters at Äspö. Furthermore, these two samples record the lowest Mg values (7.8 vs 24.8 mg/L) which may further support that they have so far been least affected by the drawdown Baltic Sea component which figures strongly in the other samples. This would certainly be expected from the matrix sample. Finally, a more negative oxygen-18 value (-11.6 ‰) for the matrix sample, similar to the average for the ‘Niche’ samples (-10.6 ‰), which are characterised by low tritium contents (i.e. very little modern Baltic sea or meteoric water component), would also support that an older glacial water component has been present in the matrix prior to tunnel construction.

It is hoped that the sampling from borehole Section 2 scheduled for later later this year will shed more light on the matrix fluid chemistry and its origin.

Planned work

Planned work for the immediate future will include:

- continuation of drillcore crush/leach experiments with specific emphasis on lithological variation and porosity profiles,
- continuation of the permeability test,
- continuation of fluid inclusion mineralogical/petrographical characterisation and chemistry,
- expand coverage of drillcore porosity measurements (some integrated with the crush/leach experiments) to achieve a better idea of large-scale heterogeneity or homogeneity in the matrix block, and also to further characterise the Ävrö granite rock type,
- detailed study of 1-2 micro-fractures/fissures with respect to in- or out-diffusion processes. This will include whole-rock measurements of the U-decay series, ^{37}Cl, ^{11}B, ^{86}Sr and ^{87}Sr along profiles perpendicular to the fracture intersection with the drillcore,
- simple leaching of drillcore material using distilled water,
- scoping study to locate further examples of low transmissive features already characterised to increase the hydrogeological/hydrochemical database, and
- eventual sampling of borehole Section 2 (and possibly a second sampling of Section 4) when indications show that enough water has accumulated.

3.6 Colloids

Background

Colloids are small particles in the size range 10^{-3} to 10^{-6} mm these colloidal particles are of interest for the safety of spent nuclear fuel because of their potential for transporting radionuclides from a faulty repository canister to the biosphere.

Therefore, SKB has for more than 10 years conducted field measurements. The outcome of those studies performed nationally and internationally concluded that the colloids in the Swedish granitic bedrock consist mainly of clay, silica and iron hydroxide and that the mean concentration is around 20-45 ppb which is considered to be a low value. The low colloid concentration is controlled by the large attachment factor to the rock which reduces stability and the transport capacity of the colloids in the aquifer.

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 that plutonium is associated with the colloidal fraction of the groundwater. The $^{240}Pu/^{239}Pu$ 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. Based on these results SKB decided to initiate a project in the Äspö-HRL to study the Stability and Mobility of Colloids (SMC).

Objectives

The objectives of the SMC project is to:

1. Verify the colloid concentration at Äspö-HRL
2. Investigate the potential for colloidal transport of nuclides in natural groundwater flow paths
3. Study the role of bentonite clay as a source for colloid generation
4. Demonstrate the colloid stability/instability at prevailing conditions

Experimental concept

The role of the bentonite clay as a source for colloid generation will be studied in a laboratory experiment performed at Claytech. The background colloid concentration associated with the different water types found at Äspö will be sampled at specific locations along the Äspö HRL-tunnel. For the fracture specific measurements two nearby boreholes at HRL will be selected for the SMC experiment. One of the boreholes will be used as an injection borehole and the borehole downstream will be used as a monitoring borehole. The boreholes intersect the same fracture and have the same basic geological properties. The experiment will be performed in association with the TRUE-trace experiment programme. The boreholes and the optimum time for the experiment will be selected in co-operation with the co-ordinator for the TRUE experiment.

After assessing the natural colloid content in the groundwater bentonite clay will be dissolved in ultra pure water to form colloidal particles. These clay colloids will be labelled with a water conservative tracer. The mixture will be injected into the injection borehole. From the monitoring borehole the colloidal content will be measured with the laser, the water will be filtered and the amount of tracers will be measured. The following results are of interest 1) is the colloid content lower after the transport, 2) is the nuclide association irreversible on the colloids and 3) is the bentonite clay a potential source for colloid generation. The signature of the bentonite/natural colloids will be traced by using multivariate statistics. The outcome of the experiment is used to check the calculations in the safety assessment report TR 91-50 to be used in future colloid transport modelling.

The colloid content will be measured on-line from the boreholes and off-line from the laboratory experiments by using a modified laser based equipment LIBD (Laser-induced Breakdown-Detection) which has been developed by INE in Germany. The advantage is that the resolution of this equipment is higher compared with standard equipment of this type. It is therefore possible to detect the colloid contents at much lower concentrations than previously possible. The outcome of these measurements will be compared with standard type of measurements such as particle counting by using Laser Light Scattering (LLS) at KTH (Royal Institute of Technology) and INE. Standard type of filtration performed on-line at the boreholes or off-line from the laboratory experiments are used in order to be able to compare/transform these results to all the earlier colloid sampling campaigns at Äspö.

New Results

The detailed time planning has started and some pre laboratory tests have been performed by analysing bentonite colloid formation from water samples with different salinities in contact with the bentonite clay. These results will be used for further planning of the laboratory test.

Planned Work

A test plan will be prepared at the end of November.

3.7 Microbe

Background

A set of microbiology research tasks for the performance assessment of high level nuclear waste (HLW) disposal has been identified. Those with a potential for study at the MICROBE site are:

Microbial influence on radionuclide migration. To what extent can bacterial dissolution of immobilised radionuclides and production of complexing agents increase radionuclide migration rates?

Microbial corrosion of copper. Bacterial corrosion of the copper canisters, if any, will be a result of sulphide production. Two important questions arise: Can sulphide producing bacteria survive and produce sulphide in the bentonite surrounding the canisters? Can bacterial sulphide production in the surrounding rock exceed a performance safety limit?

Microbial production and consumption of gases. Will bacterial production and consumption of gases like carbon dioxide, hydrogen, nitrogen and methane influence the performance of repositories?

These tasks have been addressed in a range of projects, of which several is ongoing. Important conclusions have been obtained based on laboratory and field data. While some results seem very solid with general applicability, others are pending inspection at *in situ* conditions. This is especially true for data generated at the laboratory only. *In situ* generated data must be obtained for microbial activities in the far- and near-field environment at realistic HLW repository conditions. This can only be achieved at an underground site, developed for microbiological research, using circumstantial protocols for contamination control during drilling and operation. An *in situ* site allows experiments at natural pressure with correct gas content in groundwater which is of great importance for microbial activity and very difficult to obtain in vitro. Such a site was drilled in May 1999 in the J-niche at Äspö HRL, 450 m underground. Three boreholes were produced.

Objectives

The major objectives for the microbe site are:

To assay microbial activity in groundwater at *in situ* conditions. Their influence on redox conditions, radionuclide migration and gas composition and consumption will be in focus.

To establish data on hydrogen generation and flow in granitic rock environments. The flow of hydrogen form where it is produced will determine the possible rate of long term microbial subterranean activity.

To enable experiment where the engineered barriers, bentonite, backfill and copper can be investigated for the influence of microorganisms at realistic and controlled conditions with a significant knowledge about the microbiology of the groundwater used.

To generate accurate data about rates of microbial reactions at repository conditions for performance assessment calculations.

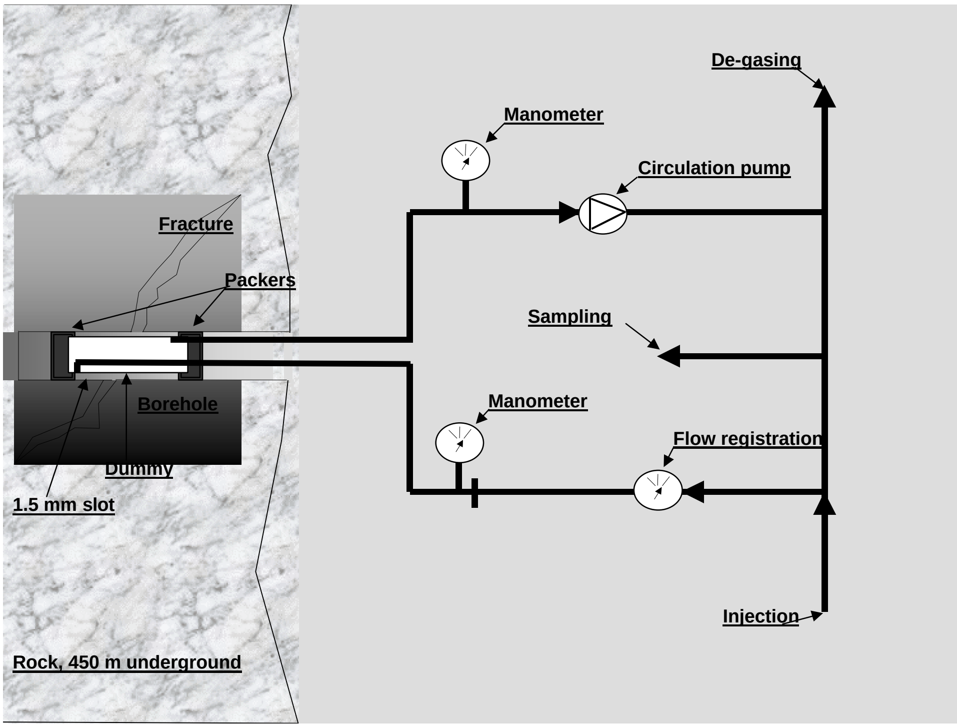


Figure 3-9 The planned circulation system for the MICROBE .boreholes.

Experimental concept

The microbe site consists of three core-drilled boreholes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures at 12.7, 43.5 and 9.3 m respectively. Each borehole is equipped with metal free packer systems that allow controlled sampling of respective fracture. An underground laboratory, approximately 7 x 2.5 m was installed in spring 2000 close to the site and is equipped with a large anaerobic chamber and possibility for set up of on line measurements of dissolved gases. Tubing from the boreholes will be connected to the laboratory via a circulating system, as depicted in *Figure 3-9*.

New results

Groundwater chemistry, cultivable microorganisms, stable isotope and gas data have been obtained from the MICROBE boreholes. A progress report is in preparation and will be submitted during November 2000.

Planned work

A system that allows circulation of groundwater under full formation pressure is presently being designed. This system should enable work with microbes at very close to *in situ* conditions. It will hopefully be operative at the end of fall 2000. A system for sensible measurement of hydrogen and other gases will be developed. We will use a reduction gas detector (Trace Analytical, USA), having a detection limit for hydrogen, carbon monoxide and methane close to 1 ppb. This system will be used for characterisation of hydrogen generation and flow in granitic rock environments. The results will be compared with theoretical calculations performed at KTH, Stockholm.

3.8 The Task Force on modelling of groundwater flow and transport of solutes

Background

The Task Force shall be a forum for the organisations supporting the Äspö Hard Rock Laboratory 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 work within the Task Force is being performed on well defined and focused Modelling Tasks. The table show on-going tasks

Task No	Modelling Issues	Cooperating organisations
4E	Modelling of tracer test with sorbing tracers in one fracture.	ANDRA, BMWi, CRIEPI, DOE, JNC, NAGRA, POSIVA, SKB
4F	As Task 4E but with half the flowrate.	ANDRA, BMWi, CRIEPI, DOE, JNC, NAGRA, POSIVA, SKB
5	Compare and integrate hydrology and chemistry through modelling of Äspö tunnel drainage impact on hydraulic and chemical parameters.	ANDRA, BMWi, CRIEPI, ENRESA, JNC, POSIVA, SKB

New results

Within the modelling groups works has been towards producing the final modelling results and the final report of Task 4E&F and Task 5.

No reports were published during this quarter.

A workshop was held 14-15 September at Arlandastad, Sweden, with objective to compile a proposal for Task 6. This will be presented at the next International Task Force meeting, #14, to be held 14-16 November at Säröhus, Sweden.

Planned work

For the next quarter we plan to perform are the following tasks:

- Continued work to produce final reports within both Task 4E&F and Task 5.
- Publish the results of the deconvolution of breakthrough curves from Task 4F
- Organise Task Force meeting #14.

4 Demonstration of technology for and function of important parts of the repository system

4.1 General

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

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

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

- To furnish methods, equipment and procedures required for excavation of tunnels and deposition holes, near-field characterisation, canister handling and deposition, backfilling, 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*, objectives are:

- To test and demonstrate the function of components of the repository system.
- To test and demonstrate the function of the integrated repository system.

4.2 Prototype Repository

Background

Particular aspects of the repository concept have previously been tested in a number of in-situ and laboratory tests. There is a need to test and demonstrate the integrated function of the repository in full scale and with state-of-the art technology. It is envisaged that this technology can be tested, developed and demonstrated in the Prototype Repository. The design, construction and testing of the prototype repository is aimed at a simulated deposition sequence starting from detailed characterisation of the host rock to resaturation of the backfilled deposition holes and tunnel. The Prototype

Repository experiment is located in the inner part of the TBM tunnel at 450 m level and will include 6 deposition holes in full scale.

The aims of the Prototype Repository are:

- To demonstrate the integrated function of the repository components and to provide a full-scale reference for comparison with models and assumptions.
- To develop and test appropriate engineering standards, quality criteria and quality systems.

The Prototype Repository will be a long-term test divided into two sections, separated by a concrete plug. One section is planned to be decommissioned after about 5 years and the second section after more than 10 years.

New results

The kick-off of the EC project took part on September 19-20 at Aspo, in the presence of the EC officers Bertus Haijtink and Christophe Davies, and with the Major of Oskarshamn, Mr Torsten Carlsson, conducting the official inauguration.

The Project Group, consisting of basically Task Leaders, met regularly during the period (approx. once each six weeks) with the objective to plan those activities that were scheduled to take place in the near future. The meetings have been open to the participants in the EC project for their information and input, when needed.

The reporting of results from the geoscientific characterisation phase has continued. Reporting has also been made on design results, e g instrumentation of buffer and backfill, and plug and slot.

The pre-test of the deposition sequence has been completed. It took place in the deposition hole in the assembly hall and covered:

- Deposition of blocks and canister
- Equipment for these operations
- Method for backfilling with pellets in the slot between block and rock
- Method for climate control in the deposition hole during deposition of blocks and afterwards until filling with pellets starts.

Concrete blocks were replacing bentonite blocks in the testing but one test was also made with a bentonite block. The results indicated that the methods worked to satisfaction, but also that adjustments and trimming are required. One major adjustment concerns the climate control system, so that the relative humidity may be kept homogeneous in the slot between blocks and rock, which was not the case in the test.

__Figure 4-1__ A block (in this case of concrete) is being attached to the gripping device

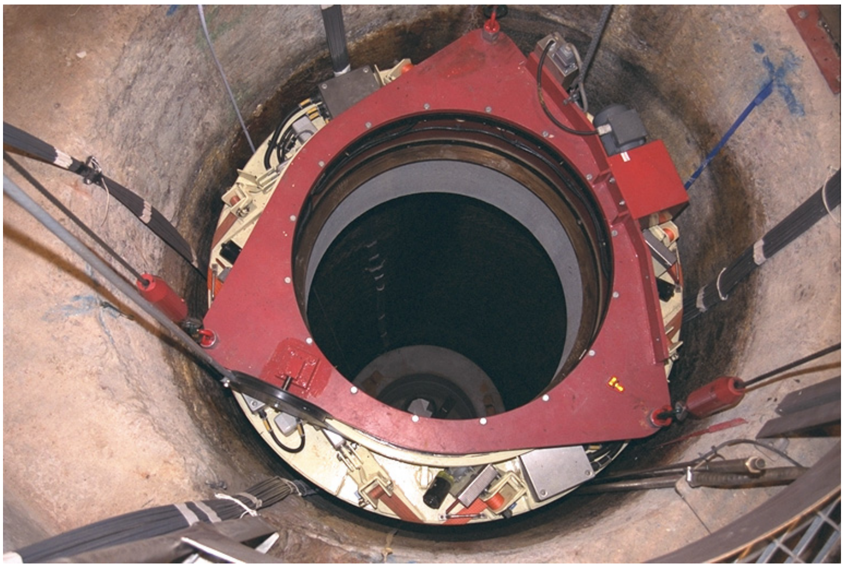


__Figure 4-2__ The block is lowered down into the deposition hole

The analysis of data from measurements of cutter forces during boring of the second deposition hole in the Canister Retrieval Test tunnel has continued at Luleå Technical University with the compilation of the final report.

Physical activities in the Prototype Repository tunnel have been

- Excavation of the slots for the two plugs
- Measurement of in-flowing water both into the tunnel and into each deposition hole with specific attention to the distribution of the inflow into the holes. Field work has also been carried out regarding measurement of the elastic properties of the rock in the Prototype Repository tunnel in situ.
- Preparation of the roadbed for instrumentation of the rock
- Initiation of drilling of holes for thermocouples and resistivity measurements
- Initiation of drilling the 27 lead-throughs from the G-tunnel

The topic of the unrealistic result on directions of rock stresses has been solved by identifying the wrong co-ordinates of the core-drilled hole, that where used in the data evaluation phase.

The feasibility studies on microbiology and hydrochemistry has continued with the objectives of being able to monitor the function of the Prototype Repository and to verify models and hypotheses. The programme aims at addressing the following questions:

- How fast does entrapped O_2 disappear?
- What are the redox conditions in the different parts of the repository?
- Does sulphate reduction take place? Even when sulphate reducing bacteria are added?
- What salts precipitate from the pore waters in the bentonite buffer as a result of the temperature gradient?
- What happens with the organic material present in the bentonite?
- Is it possible to detect bentonite colloids migrating away from the deposition holes?
- Is the copper canister attacked with the expected corrosion rate?
- What copper corrosion products are formed in the bentonite?

The progress is that equipment to measure pH and redox potentials in situ and at prevailing conditions (pressure ≈ 40 atm, temperature ≈ 15°C) has been designed and is being tested. Special electrodes have been manufactured and tested successfully under laboratory conditions at high pressure. The measurement in the Äspö tunnel failed, however, and the reasons for this malfunction is being investigated.

Samples of cellulose enclosed in cement will be tested for degradation processes under in-situ conditions. Cellulose samples have been collected as typical waste products from the Swedish nuclear power programme. The design and planning of the cement sample holders is in progress.

Planned work

Detail planning of different parts of the Prototype Repository project will continue.

The design of all handling of cables and tubes including lead-throughs remains after the basically completed compilation of how many cables and tubes there will be and to which lead-through each of them will be taken.

An instrumentation plan has been compiled and the next step is to purchase the listed components.

Canisters are manufactured in the Canister Manufacturing project but final preparation and assembly of the canister packages are the responsibility of the Prototype Repository project. The main topic in the nearby future is to select the type of heaters to be used.

Fabrication of bentonite blocks and backfill material will start by selection of bentonite qualities – the backfill may from a scientific point of view consist of an European bentonite quality -, purchase of selected qualities and preparation of rock crushing and backfill mixing. Bentonite blocks are made in Ystad when the press there is available.

Modification of equipment will take place as described in "Demonstration of deposition technology". In addition to the equipment described there the compacting plate for the backfilling needs up-grading, and probably a unit for stand-by.

The preparation work in the Prototype Repository tunnel, prior to start of installation, is schedule to be ready in May , 2001. It concerns:

- Finalising the drilling of instrument holes
- Finalising the drilling of lead-throughs
- Excavation of cones in the lead-throughs´ mouths in the Prototype Repository tunnel
- Installation of casing in the lead-throughs
- Installation of all cables and pipes in the lead-throughs (done prior to start of installation)
- Connection of cables to the monitoring system in the G-tunnel
- Preparation of the roadbed for deposition of canisters and easy removal during backfilling
- Installation of bentonite packers in Section I
- Installation of thermocouples in rock in Section I
- Installation of drainage system in the tunnel and in the deposition holes

The first come-together meeting in the modelling group is scheduled to take place on December 12, 2000.

4.3 Backfill and Plug Test

Background

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

The entire test setup with backfilling, instrumentation and building of the plug was finished in the end of September 1999 and the wetting of the 30/70 mixture through the filter mats started in late November.

New results

Figure 4-3 shows an illustration of the experimental setup. The following main work has been carried out and results reached during the second quarter of 2000:

- There has been a water pressure of about 100 kPa applied in the filter mats in the 30/70 mixture.
- Water filling of the outer test sections (0/100) has started by filling the filter at the plug. Approximately 1 m at the roof is left to fill. The filling is made slowly and stepwise since when the water level is raised water leaks out through the plug between the rock surface and the concrete until the bentonite o-ring has enough water to seal the slot at that level.
- Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured and recorded.
- The psychrometer measurements indicate that most 30/70 sections are water saturated at the perpendicular distance 20 cm from the mats and that an increased wetting has reached 40 cm but not to the centre of the backfill sections 60 cm from the mats.
- Reporting of the experimental setup is in progress.
- Reporting of measurement results will be done every quarter of the year.

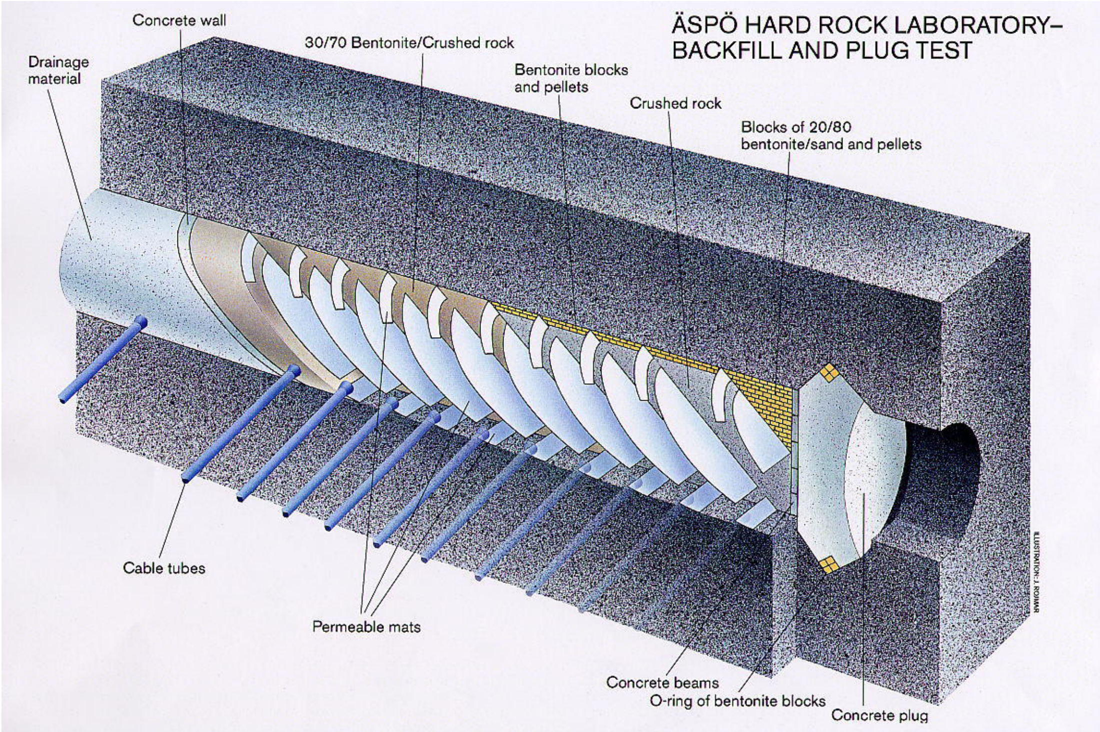


Figure 4-3 *Illustration of the experimental setup of the Backfill and Plug Test.*

Planned work

The water saturation and the measurement of water inflow, water pressure, total pressure and wetting will continue

4.4 Demonstration of repository technology

The development and testing of methodology and equipment for the encapsulation and deposition of spent fuel in the deep repository is an important part of SKB:´s programme. In addition to the technical aspects, it is also important to be able to show in a perceptible way the different steps in encapsulation, transport, deposition, and retrieval of canisters with spent fuel for specialists and the public. As part of the overall programme an Encapsulation Laboratory has been constructed in Oskarshamn and was taken in operation late 1998. Demonstration of deposition and retrieval of canisters will be made at the Äspö Hard Rock Laboratory. The demonstration project complements the Prototype Repository, the Canister Retrieval Test and the Backfill and Plug Test which focus on the integrated function of the engineered barriers in a realistic environment.

The objective of the demonstration of repository technology are:

- To develop and test methodology and equipment for encapsulation and deposition of spent nuclear fuel,
- to show in a perceptible way for specialist and the public the different steps in encapsulation, transport, deposition, and retrieval of spent fuel and

- to develop and test appropriate criteria and quality systems for the deposition process.

The demonstration of deposition technology is made in a tunnel south of the ZEDEX drift excavated by drill and blast. This location will provide good rock conditions, a realistic environment for a future repository, and allow transport of heavy vehicles to this area.

The testing of the equipment needed for handling of compacted bentonite buffer material and canisters for the Canister Retrieval Test and the Prototype Repository has been made in the assembly hall at level at level 420.

New results

The installation of the full size deposition machine for deposition of copper canisters started in June 1999 and was completed in September 1999. The picture below shows the deposition machine in the demonstration tunnel at Äspö in May 2000.

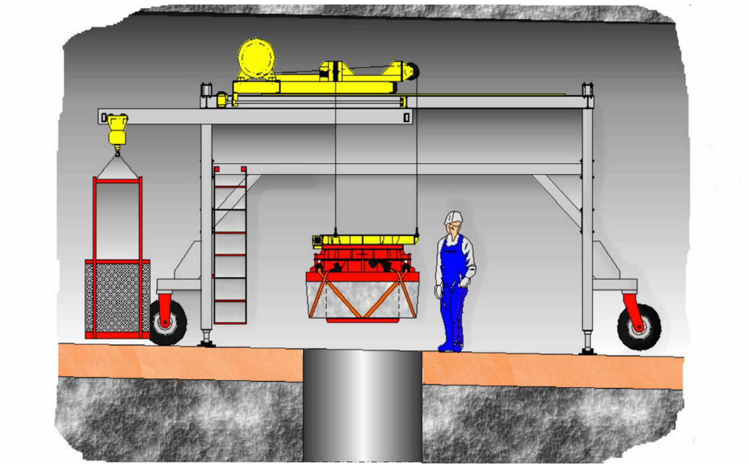
Main data for the machine:

Height	4.6 m
Width	3.7 m
Length	11.8 m
Weight, empty	90 tons
Weight, with shielded tube and canister	140 tons
Speed	0-10 m/s
Power supply	Cable
Capacity, main hoist	30 tons
Capacity, auxiliary hoist	5 tons
Capacity, hoist for bentonite top block inside machine	1 ton

The inauguration of the demonstration tunnel with its deposition machine took place on 9th March 2000. After completion of the site test program mid May the deposition machine was handed over to SKB.

The design and construction of the temporary equipment for handling and deposition of the buffer material and canisters for the Canister Retrieval Test and the Prototype Repository was completed early 2000. The test program with handling of buffer material and a copper canister was completed in June 2000.

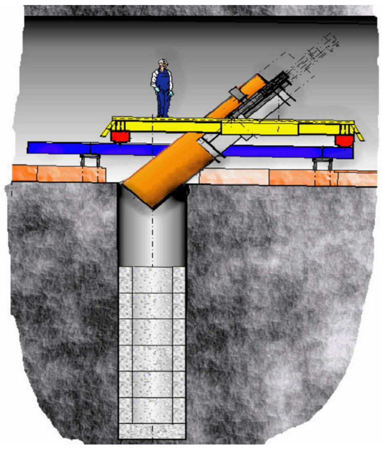
The gantry crane with tools for emplacement of the bentonite buffer into to deposition hole and the small deposition machine that will be used for these experiments are shown in the illustration below .



The main data and features of the gentry crane as follows:

Height: 4.3 m
Width: 2.8 m
Length: 8.5 m
Lifting capacity, main hoist: 3 metric tons
Lifting capacity, auxiliary hoist: 1 metric tons. The auxiliary hoist with the circular working cage can be lowered inside the pile of bentonite rings down in the deposition hole.

***Figure 4-4** Illustrations of the gantry crane for handling of the compacted buffer material*



The main data of the deposition machine are as follows:

Height: 4.6 m
Width: 3.7 m
Length: 10 m
Weight: 13 metric tons excluding the copper canister.

The limited height in the prototype repository require that the canister is tilted down into the deposition hole.

***Figure 4-5** Illustrations of the small deposition machine.*

Planned work

The installation of the buffer material and the canister with instrumentation and heaters and the casting of the concrete plug on top of the bentonite buffer will be completed during October 2000. The artificial watering of the buffer material can then start and the operation of the Canister Retrieval Test is planned to continue for some 4 to 5 years.

The gantry crane and the deposition machine will then be used in the Prototype Repository. Some modification will be needed and the deposition machine must be provided with four hydraulic jacks. A special wagon for transport of the deposition machine with canister down to the Prototype Repository will to be purchased and tested for the positioning of the machine at the deposition holes.

The equipment will be tested for operation in the prototype Repository in April and May 2001.

The installation of buffer material and canisters with heaters in the Prototype Repository is scheduled to start mid 2001.

The development work of the equipment needed in the future deep repository will also continue based on experiences from the ongoing work at Äspö. The different machines and transport and auxiliary equipment needed are planned developed to at leased to a feasibility stage as part of the ongoing design studies of the deep repository. Some of the equipment may also be designed and constructed and tested at the Äspö HRL at a later stage for verification of the function and suitability of the equipment.

4.5 Canister Retrieval Test

Background

SKB's strategy for the disposal of canisters with the spent nuclear fuel is based on an initial emplacement of about 10% of the number of canisters followed by an evaluation of the result before any decision is made on how to proceed. One outcome can be that the result is not accepted and that the canisters have to be recovered. In such case some, if not all, canisters can be surrounded by a saturated and swollen buffer, which holds the canister in such a grip that the canister can not just be pulled up. First the bentonite grip has to be released, for which two alternative principles can be applied; remove or shrink the bentonite. Then the canister is free to be lifted up to the tunnel and placed in a radiation shield. A concern is any type of radioactive contamination that the bentonite has been exposed to.

The retrieval test is aiming at demonstrating the readiness for recovering of emplaced canisters also after the time when the bentonite has swollen. The process covers the retrieval up to the point when the canister is safely emplaced in a radiation shield and ready for transport to the ground surface. The test is separated into two phases; Design and Set-up, and the actual Retrieval Test.

New results

Meetings

The project has many Task Leaders and others in the organisation, who are also engaged in the Prototype Repository. The discussions of scientific and technical solutions therefore take place in Project Group Meetings common for both projects. These meetings have been held regularly during 1999 and 2000 with a frequency of one per approx. six weeks. Since November a project Managing Group has been organised with frequent meetings, every two weeks, consisting of the Project Manager, the two Assistant Project Managers (for Science and for Methods and Techniques) and the Project Co-ordinator. A meeting concerning the practical realisation of the project was summoned in March, where representatives from all disciplines participated.

A last technical meeting before the planned start of the test has been held. Participating was Task Leaders and the project management. The objective with the meeting was to find and eliminate possible obstacles through an inter-disciplinary check.

A start-up meeting was held with personnel involved in the actual execution of the test, project co-ordinator and assistant project manager for methods and technique.

A separate technical meeting was held with the contractor for the restraining plug. Participants were representatives from the contractor, Task Leader for the bentonite buffer, the assistant Project Manager for methods and techniques and the Project Co-ordinator. The purpose was to illuminate risks involved that might be affected by the contractor's actions and to get reassurance regarding the successful outcome of the works planned by the contractor. All meetings except the start-up meeting are documented in minutes.

Project documents

Quality plans (activity plans) including descriptions of methods for the accomplishment of the test have been finalised and approved for all of the planned moments in accordance with the schedule. Remaining documents to prepare after the first phase of the test are an Installation Report, a Final Report and an Internal Evaluation Report.

Preparatory works

Preparations for the installation have concerned

- Sawing of grooves into the hole wall for cables and into the tunnel floor for connecting the cables in the deposition hole with the instrument cabin
- Boring of horisontal holes radially out from the deposition hole for thermocouples
- Boring of holes for and installation of cable bolts for anchoring of the plug
- Installation of the cone of the plug
- Installation of a wall across the tunnel for isolation of the climate inside from the climate outside (relative humidity)

The canister has been made ready for shipment from Malmö, bentonite blocks have been pre-prepared for instrumentation and instruments are being calibrated and prepared for the installation. Suitable type of permeable mats have been selected and ordered.

***Figure 4-6** View of the top of Canister Retrieval Test hole showing the.nine cable bolts and grooves between them for cables and pipes to pass the plug.*

Four cylindrical blocks and 10 ring shaped blocks of bentonite with the diameter 1.65 m and the height 0.5 m will form the main body of the buffer material in a deposition hole. The blocks for the Canister Retrieval Test hole have been compacted in advance and kept in airtight steel boxes. Five of the blocks have been prepared with clearances and slots for installation of instruments and cables.

The plan on instrumentation of the buffer has been completed and all instruments are delivered from the suppliers. Altogether the plan comprises 32 thermocouples for measuring temperature, 27 pressure-transducers for measuring total pressure, 14 pore pressure transducers for measuring positive pore water pressure and 55 sensors for measuring relative humidity. The transducers will be installed in each block directly after placement of the block.

The outer surface of the canister has been dressed with about 40 meters fibre optical cables that are capable of measuring temperature every half meter. The fibre optical cables are covered by tubes made by Inconel and put in small grooves in the copper surface.

40 thermocouples have been installed in boreholes drilled perpendicular to the rock surface of the test hole at levels and directions that correspond to the location of the transducers in the bentonite.

All cables from the pressure transducers and the relative humidity sensors are lead in tubes through the bentonite and out through the top plug for protection against the pressure and the swelling of the bentonite blocks. These tubes are made of titanium in order to withstand corrosion at the high temperatures that will occur in the bentonite and to prevent water leakage along the cables.

The lead-throughs in the canister lid are weak points and extra precaution has been taken in the design to prevent forces to act directly on these. The canister and heaters will only be grounded for personal safety due to the relatively short term of the test. The work on the design of the plugs on top of the holes has concentrated on a combined concrete/steel plug placed in the hole below the tunnel floor level. This plug will be anchored to the rock by means of cable bolts, which can resist a swelling pressure from the bentonite of up to 10 MPa (design pressure is 5 MPa). Three of the cable bolts will be equipped with stress measuring devices to be able to trace the stress development from the swelling bentonite on the plug. An instruction for tensioning and releasing of the nine cables have been developed to achieve an even displacement of the buffer and plug. The plug will be cast in-situ in a cone shaped steel-mould attached to the bore hole wall. This design is meant to reduce plug friction and hence facilitate measuring of stress development in the bentonite. A contractor has been awarded the assignment to perform the plug and rock anchoring.

In order to secure the wetting of the buffer material 16 filter strips with the width 100 mm have been installed vertically on the rock surface of the test hole. The filters will be supplied with water at both ends from tubes made by acid proof stainless steel, which are led through the plug to an installation with pressure tanks. The pressure tank installation is equipped with a very accurate differential pressure gauge, which will provide information about the total water inflow and the division of the flow between the filters.

All preparatory activities prior to start of installation have been completed.

Deposition process

Start of installation of bentonite blocks was launched in late September instead of the former starting date in mid August due to a late arrangement for transportation of the canister to the underground test site and also a late delivery of instruments.

Up to date the following activities have been carried out:

- Emplacement of bentonite bottom block and rings up to the top level for the canister.
- Successive installation of instruments in the bentonite buffer, that is all those located in the bottom block and in the rings surrounding the canister except for the top ring.
- The canister was placed inside the pile of bentonite rings but had to be retrieved and returned to the plant at Kockums due to malfunction of four heaters

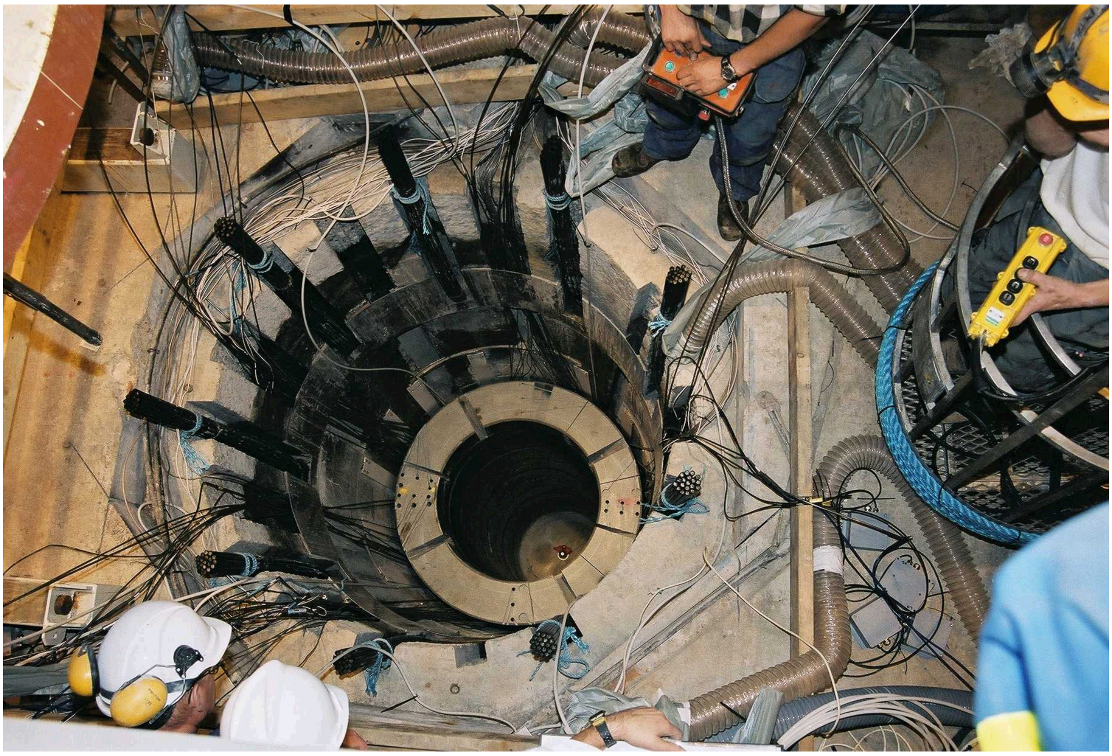


Figure 4-7 *The figure shows the test hole after installation of all the bentonite rings up to the top of the canister, i e shows the 11th bentonite block from the hole bottom. The surface of the block has been prepared for instruments and cable lines from these as well as from heaters and instruments inside and on the outside of the canister. Cables from installed instruments in blocks further down the pile of bentonite blocks are attached to the surface of the rock. The nine thick bundles along the rock wall are the cable bolts, which after casting of the plug shall anchor the plug and take the load caused by the saturated and swollen bentonite. The figure shows the conditions just before the emplacement of the canister started.*

<u>Non-conformance</u>

A few cases are noted as non-conforming to the expected outcome during the deposition. The first case is the eccentric placing of the bentonite pile. Three possible causes could be the reason; 1) erroneous calculation of the average centre-point, 2) erroneous setting out of the centre-point, 3) erroneous placing of the bottom block The second case is the too low average relative humidity (70-75% RH) in the deposition hole when the aim was 75-80% RH. A possible cause could be that the climate control was not designed to treat too dry air. Since the test was postponed, the seasonal effect with cold dry ventilation air was not accounted for. The reasons for non-conformance are not yet evaluated. The third case is the malfunctioning heaters. Four of the cables were too short, which caused the contacts to the heaters to loosen during mounting of the lid.

Planned work

As soon as the heaters have been repaired and checked and returned from the plant, the deposition process will continue with placing of the canister in the deposition hole. Thereafter, cables from the heaters and instrumentation of the canister shall be connected and lead through the canister lid. When this is finished the remaining parts of the bentonite buffer will be placed on top of the lid – in the form of bricks handable by man - and subsequently three bentonite blocks including an instrumentation level. Next step is to fill up the void between the rock wall and the bentonite rings with bentonite pellets. This will be done with a blowing machine with a special nozzle. The void shall also be filled with water to initiate and accelerate the swelling process. Preparations for in-situ casting of the plug will be taken as far as possible before water is injected to the pellets As soon as the bentonite has been sealed off from possible “contamination”, the casting of the plug will be made. The casting will be made in two steps where the first is the main body with the armouring and the second is the surface layer adapted to achieve good contact to the steel layer part of the plug. Intermediate hardening will be necessary. After the concrete part of the plug has been strong enough, a test lift shall be performed in order to guarantee that the effects on the plug from the swelling bentonite can be correctly measured. The steel part of the plug will be placed and the cable anchors pre-tensioned.

All instruments have been connected to data collection units and activated as soon as they are installed.

4.6 Long term test of buffer material (LOT)

Background

Bentonite clay has been proposed as buffer material in several concepts for HLW repositories. In the Swedish KBS3 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 alteration models. According to these models no significant alteration of the buffer is expected to take place at the prevailing physico-chemical conditions in a KBS3 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 KBS3 repository conditions and the testing periods have generally been dominated by initial processes, i.e. water uptake and temperature increase.

The present test series aims at validating models and hypotheses concerning physical properties in a bentonite buffer material and of related processes regarding microbiology, cation transport, copper corrosion and gas transport under conditions similar to those in a KBS3 repository. 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:

– Data for validation of models concerning buffer performance under quasi-steady state conditions after water saturation, e.g. swelling pressure, cation transport and gas penetration.

– Check of existing models concerning buffer-degrading processes, e.g. illitisation and salt enrichment.

– Information concerning survival, activity and migration of bacteria in the buffer.

– Check of calculation data concerning copper corrosion, and information regarding type of corrosion.

– Data concerning gas penetration pressure and gas transport capacity.

– Information which may facilitate the realisation of the full scale test series with respect to clay preparation, instrumentation, data handling and evaluation.

– The testing philosophy for all tests in the series (Table 4-1) is to place prefabricated units of clay blocks surrounding heated copper tubes in vertical boreholes. The test series are performed under realistic repository conditions except for the scale and the controlled adverse conditions in three tests.

The test series have been extended, compared to the original test plan, by the A0 parcel in order to replace the part which was lost during the uptake of the previous A1 parcel.

Table 4-1. Lay out of the ongoing Long Term Test series.

Type	No.	T °C	Controlled parameter	Time years
A	0	120<150	T, [K^+], pH, am	1
A	2	120<150	T, [K^+], pH, am	5
A	3	120<150	T	5
S	2	90	T	5
S	3	90	T	>>5

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

Adverse conditions in this context refer to high temperatures, high temperature gradients over the buffer, and additional accessory minerals leading to i.a. high pH and high potassium concentration in clay pore water. The central copper tubes are equipped with heaters in order to simulate the effect of 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. Test ”parcels” containing heater, central tube, clay buffer, instruments, and parameter controlling equipment are placed in boreholes with a diameter of 300 mm and a depth of around 4 m

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

New Results

The installation of the 5 parcels is now completed and the intended test temperatures of 90°C in the standard type parcels and 130°C in the adverse condition parcels are reached. Power regulation is now used instead of the initial temperature regulation. A new system for data handling and follow-up have been developed. The system is intended to be used also in the Backfill & Plug, CRT and Prototype tests. Laboratory diffusion tests have been planned and will start after summer at KTH, Stockholm.

Planned work

The monitored water pressure, total pressure, temperature and moisture in the parcels are regularly analysed, and monthly backup is made during the test period. Supplementary laboratory work will be made concerning gas penetration pressure and characterisation of the original bentonite material. Chemical analyses of ground-water and if possible of water from the “passive” filters in the bentonite will be made regularly during the test period.

5 Äspö facility operation

5.1 Facility operation

A new power supply line to Äspö has been taken in operation. The previous “mainland” feed has been replaced as it effected several underground power reliant systems with frequent unplanned power failures. The previous variations in the power supply that has effected the elevator has disappeared. The facilities now have two independent and stabile power lines and a third spare feed (the old “mainland feed”).

The complementary work with rock reinforcement, which was the result of last years underground rock-mechanical inspection is picking up speed. After finishing reinforcement in CLAB 2, SKANSKA has resumed their work at Äspö. At present shot-creeting is carried out in the TBM-hall. The work is expected to be finished in January 2001.

The operations monitoring system, ALFA, has been tested since the beginning of the year. After a functional control it was decided that the test period was to bee prolonged in order to eliminate bugs in the software. Main problem has so far been to overcome the negative time difference that occurs when changing from summer to winter time and automatic printing of reports. Final functional control is to be carried out in the beginning of November.

Reinforcement and widening of the Äspö-road has been carried out. The road is to be coated with tarmac during spring next year (2001).

Facility underground has been undergoing a fire protection analyses, performed by ÖSA (Öresund Safety Advisors). Analyses show that improvement of fire safety is required and a number of actions is suggested. Action plan has been made and will be initiated during this autumn. The work is planed to be completed in the summer of 2001

The project for hands free registration when going underground has been resumed. The project will be initiated with a study in order to determine the need, technical possibility and possible deliverer. The study is planed to be completed in November 2001

Building an additional parking space at the Äspö site has started with filling and levelling a suitable area. Request for offers of the remaining work has been sent out to local contractors and the bidding is to be completed in v41. The work is planned to start in November and to be completed in December.

Certification (ISO 9001 and 14001) is in progress. New instructions has been written and some old rewritten. A few is yet to be completed before the first edition is done.

5.2 Data management and data systems

Background

The regulatory authorities are following SKB's siting work. Before each new stage, they *examine and review the available data*. A repository will never be allowed to be built and taken into service unless the authorities are convinced that the safety requirements are met. Hence, SKB is conducting *general studies* of the entire country and *feasibility studies* in 5-10 municipalities. *Site investigations* will then be conducted on a couple of specific sites. With the result of the studies as supporting material, SKB will then apply for permission to carry out *detailed characterisation* of one of the sites. The licence application for detailed characterisation will include a *safety assessment* and the results will be reviewed under the Act on Nuclear Activities and the Act concerning the Management of Natural Resources by the regulatory authorities, the municipality and the Government.

Management of investigation data is a highly demanding and critical task in the presented licensing process. The safety assessment must be based on correct and relevant data sets. Hence, the data management routines need to be focused on the following aspects in a long term perspective:

- traceability,
- accessibility,
- data security and
- efficiency (system integration and user friendly applications).

A high quality baseline for the safety assessment will be established if the aspects specified above are met. The data needed in a typical safety assessment have been reported in Andersson et al /1998/.

The different parts of SKB's Data Management System will be improved in conjunction with the ongoing and planned activities in SKB' siting work. This to fulfil the requirements expected from the regulatory authorities and the internal organisation as well. The current status and the actual plans of GIS, SICADA and RVS is presented in the following subsections.

New results

GIS

A Geographical Information System (GIS) based on ArcInfo and ArcView has been and are still used successfully by SKB in the ongoing feasibility-study projects. GIS will also be an important tool in the planning and performance of the site-investigation phase. A plan to implement GIS as a effective tool in the coming site-investigation phase has been decided, and as a first step some feasibility-study data sets have been set up at the Äspö Hard Rock Laboratory as a basis for different pilot cases planned by the PLUPS project.

A reference group has been set up in order to guide the GIS administration organisation in their work to implement and develop appropriate methods and routines supporting the site investigation program and safety assessment process. The reference group will guide the GIS organisation in their work to implement and develop appropriate methods and routines supporting the site investigation program and safety assessment process.

An introduction GIS course was held in August. The main users of GIS information, working in the PLU-project, was learned how to best utilise the power of ESRI´s GIS application ArcView.

A consultant from WM-data AB, an expert on both programming and using GIS application, has been engaged in programming minor GIS tools. The consultant is also producing different kind of GIS presentations ordered by the PLU-project.

SICADA

A set of new improvements in SICADA, defined in the first development stage during year 2000, have been programmed and implemented as planned.

The SICADA administration organisation has been extended with a new employee, assistant database administrator, as planned. The head database administrator will now have more time to focus on other important activities e.g. implementation of GIS methodology.

Initial efforts have been undertaken to improve a part of the data structure used for management of information about all co-ordinate systems handled in the database. The Rock Visualisation System requires the planned modifications. Required modifications will be implemented before the end of year 2000.

The licensing technique for CA/Ingres II and other CA-products, has earlier caused severe problems, have been replaced by a new technique.

RVS

The RVS review project has been finalised. The review have been carried out by Dr Matthew White and Dr Andy Lind at ENVIROSQUANTISCI in England. In the final report a set of recommendations have been presented. Those recommendation will be an important basis when planning further developments of SKB's Rock Visualisation System.

RVS version 2.2 has been implemented and the specification for version 2.3 is completed and the programming work has been started. Furthermore initial step have been taken to complete a specification for version 2.4. The last version mentioned is focused on implementation of improvements expected by the PLU-project named GEOFUNK.

Planned work

GIS

The following subjects will be under consideration during the next period (October-December 2000):

- Test and implement minor applications that will utilise the power of GIS and then implement them.
- Set up of a complete set of GIS data for the areas focused on in the pilot site investigations for some municipalities (PLUPS project).

SICADA

The data structure of SICADA will partly be modified during the next period and the SICADA administration application GTAdmin will be modernised and extended with some important and missing features. The last mentioned activity is planned to be completed during the first half of year 2001.

RVS

RVS version 2.3 will be delivered in the early November 2000. Based on earlier experiences it will take about one month to test and finally implement a new version of RVS. Meanwhile this process is ongoing specifications for version 2.4 will be completed. The plan is to order the next programming stage in the early December 2000. The implementation stage for version 2.4 will take place in the late March 2001.

5.3 Program for monitoring of groundwater head and flow

Background

The Äspö HRL operates a network for the monitoring of groundwater head, flow in the tunnel and electrical conductivity, as the core parameters. This system goes under the acronym of HMS (Hydro Monitoring System). Water levels and pressure head are collected from surface drilled and tunnel drilled boreholes. Additionally, the electrical conductivity of the water in some borehole sections and in the tunnel water is measured. The network includes boreholes on the islands of Äspö, Ävrö, Mjälen, Bockholmen and some boreholes on the mainland at Laxemar.

Data is transferred by means of radiolink, cable and manually to a dedicated computerised database. The HMS computer system runs on Pentium computers with the Windows NT operating system where a real time engine is accessing the HMS database. This engine provides integrated data acquisition, monitoring, data logging and report generation.

New results

The HMS program has continued running real time data aquisition in support of the various project undertaken in the Äspö Hard Rock Laboratory.

This support consists of providing data from boreholes affected by an experiment and of utilizing the HMS infrastructure for collection and monitoring of experiment specific data. The system has been utilized mainly by the TRUE and the Prototype Respository projects.

A project is ongoing performing an overall evaluation of the Hydro Monitoring Program.This work is done in support of the Äspö activites where a feedback based on experience is due and also in support of the coming geoscientific site characterization to come.

A project was initiated to evaluate the feasibility of utilising tidal flucuation of monitoring data in order to calculate fracture orientation.

Planned work

For the next quarter it is planned to

- Continued support to various projects
- Continue the overall evaluation and assessment of the HMS.
- Continue project to calculate fracture orientation from tidal groundwater head fluctuations from HMS data.

5.4 Program for monitoring groundwater chemistry

Background

During the construction phase of the Äspö Hard Rock Laboratory, 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 the cored boreholes drilled from the ground surface and from percussion and cored boreholes drilled from the tunnel.

Objectives

At the beginning of the operational phase, sampling was replaced by a groundwater chemistry monitoring program, aiming to sufficiently cover the hydrochemical conditions with respect to time and space within the Äspö HRL. This program should provide information for determining where, within the rock mass, the hydrochemical changes are taking place and at what time stationary conditions have been established.

New results

The results presented in report IPR-99-13 show that the groundwater chemistry at Äspö HRL, with a few exceptions, is constant. The sampling occassions have been reduced to one sampling period a year. In October, the sampling for year 2000 was performed and the results will be presented within three months.

Planned work

The monitoring programme has been reduced to one sampling period a year. Next sampling occasion is scheduled to take place w139 and 140.

5.5 Technical systems

Background

The monitoring of groundwater changes (hydraulic and chemical) during the construction of the laboratory is an essential part of the documentation work aiming at verifying pre-investigation methods. The great amount of data calls for efficient data collection system and data management procedures. Hence, the Hydro Monitoring System (HMS) for on-line recording of these data have been developed and will continuously be expanded along with the tunneling work and the increased number of monitoring points.

New results

The installation of the presentation system is finished. The test period has been extend because of some problems with the systems, however, the test period is planned to finish in the beginning of November. After the test period SKB take over the system. The system consist of two parts an PLC (Programable logic controller) and the Process system.

The PLC is made by Siemens and the Process system is made by IC(Intouch).

Planned work

The presentation system will be in full operation during Winter 2000/2001.

The equipment in borehole KBH02 is going to be disconnected from electricity supply and is going to be driven by battery and a sun-cell.

The Project LTDE is going to be connected to the HMS-system during November or December.

5.6 Information

Background

The information group’s main goal is to create public acceptance for SKB in co-operation with other departments at SKB. This is achieved by giving information about SKB, the Äspö HRL and the SKB siting programme. The visitors are also given a tour of the Äspö HRL. Today there is one visitor’s administrator and three public relations officers stationed at the Äspö HRL.

New results

During the second quarter of 2000, 4537 persons visited the Äspö HRL. During the third quarter 3880 persons visited the Äspö HRL. The groups have represented the general public, communities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries.

3700 persons represented the six communities where SKB performs feasibility studies.

Urberg 500

On June 19 the Urberg 500-tours opened to the general public. It is a two hours visit starting with information and after that a guided bus tour in the Äspötunnel. We offered three tours per day until the middle of August.

1700 persons have participated in the tours.

The general public tours will continue every weekend until Christmas.

Special Events

On May 7 ”Äspödagen” of 2000 took place. Around 550 people visited the Äspö HRL. The visitors could participate in many different events such as

- Tunnel tours by bus
- Information on Feasibility studies
- Guided tours on geology, birds and flowers
- Information from local associations
- A ”quiz promenade” along the Äspö nature path.

Grilled sausages were served to all guests.

The employees of CLAB where invited to Äspö on August 17.

The programme consisted a tunnel visit and supper. SKB´s president Mr Peter Nygårds gave information and appreciation to the visitors.

50 persons from CLAB came to this event.

Special projects

- A new booking system and Call Center SKB – OKG .

Planned work

- To concentrate the information more on the Feasibility Communities.
- To build up a faked drilling site on Äspö where we are able to inform the visitors on SKB´s Siting Programme.
- Education on the Siting Programme.

6 International cooperation

6.1 Current international participation in the Äspö Hard Rock Laboratory

Nine organisations from eight countries are currently (October 2000) participating in the Äspö Hard Rock Laboratory.

In each case the cooperation is based on a separate agreement between SKB and the organisation in question. Table 6-1 shows the scope of each organisation's participation under the agreements.

Most of the organisations are interested in groundwater flow, radionuclide transport and rock characterization. Several organisations are participating in the Äspö Task Force on groundwater flow and radionuclide migration, which is a forum for cooperation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock.

Table 6-1. Scope of international cooperation

Organization	Scope of participation
Agence Nationale pour la Gestion des Déchets Radioactifs, **ANDRA**, France.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
Bundesministerium für Wirtschaft und Technologie, **BMWi**, Germany	Two-phase flow investigations including numerical modelling and model calibration Participation in the Task Force on modelling of groundwater flow and transport of solutes by using "German" computer codes Participation in the geochemical modelling efforts in the Äspö HRL Work related to transport and retention of radionuclides and colloids in granitic rock In-situ geoelectrical measurements with respect to water saturation of rock masses in the near field of underground tunnels Work on design and performance of in-situe tests using methods and equipment similar to those used in the Grimsel investigations
Empresa Nacional de Residuos Radiactivos, **ENRESA**, Spain	Test of models describing the barrier function of the bedrock (TRUE Block Scale) Demonstration of technology for and function of important parts of the repository system, (Backfill and Plug Test)

Organization	Scope of participation
Japan Nuclear Cycle Development Institute, **JNC**, Japan. The Central Research Institute of the Electronic Power Industry**, CRIEPI,** Japan	The Tracer retention understanding experiments (TRUE) The detailed scale redox (REX) experiment Radionuclide retention experiments Task Force on modelling of groundwater flow and transport of solutes. Prototype repository project. Long-term test of buffer materials
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, **NAGRA**, Switzerland	Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
United Kingdom Nirex Limited, **NIREX**, Great Britain	TRUE Block Scale
POSIVA , Finland.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system – *Prototype repository*
USDOE/**Sandia National Laboratories**, USA	Test of models describing the barrier function of the bedrock

6.2 Summary of work by participating organisations

6.2.1 Flow measurements

As a part of the Joint Project between Posiva and SKB the testing of the Posiva flowmeter continued in borehole KLX02 in May-June 2000 with the second campaign for difference flow measurements in detailed mode. A methodology study was added to the second campaign.

The DIFF flowmeter monitors the flow of groundwater into or out from a borehole within a given section. A flow guide is used to separate the section to be measured. The flow guide maintains the section at the same hydraulic head as the rest of the borehole. Groundwater flowing through the section is guided past the flow sensor. Flow is measured using the thermal pulse and thermal dilution methods. Measured values are sent in digital form to a PC computer (Rouhiainen 1996).

The single point resistance electrode is located between the rubber disks at the upper end of the test section. The electrical conductivity (EC) electrode, located on the top of the flow sensor, is used for conductivity (salinity) measurement of water flowing from the fractures. These two methods can be used simultaneously with the flow measurement.

The flow measurements were carried out on May 26th – June 19th 2000. PRG-Tec Oy conducted the fieldwork. This campaign had two main objectives:

1. To evaluate possibilities to obtain transmissivities of individual fractures from the results of the flow measurements.

2. To perform detailed flow logging with EC (electric conductivity of groundwater) measurement to obtain flow rates of fractures and fracture specific EC from chosen fractures.

The measurements started with the methodology study. The borehole section 203-404 m was chosen for the methodology test because there are many flow anomalies according to the flow measurements done during the previous campaigns on spring 1999 and February 2000. Also the risk of the appearance of saline water was least at this section. Based on the measurements made earlier there should be only a small risk that saline water would appear with the drawdown less than 8 m. The field program for the methodology study consisted of the following:

- Measurements with normal mode (section 3 m, step 3 m) both without pumping and with 8 m drawdown. The trailer was placed in such a way that the same borehole depth sections can be measured as in the previous fieldwork on February 2000.

- A fast detailed flow logging was carried out (section 3 m, step 0,5 m) for checking both without pumping and with 8 m drawdown in the depth range of 203-404 m.

- Detailed mode measurements (section 0,5 m, step 0,1 m) with five drawdown levels (0 m, 1 m, 2 m, 4 m and 8 m) was carried out in the depth range of 203-404 m. The results will be used to evaluate the linearity of the system. Logarithmic steps of drawdown will be used because the flow rates will be presented in a logarithmic scale.

- Detailed flow logging (section 0,5 m, step 0,1 m) with thermal pulse will also be conducted both without pumping and with 8 m drawdown in the depth range of 200-225 m.

The results showed reversed flow directions without pumping and with pumping. Flow rate increased with increasing pumping rate. Some new flowing fractures appeared with increasing flow rate. The preliminary results for the first objective have been delivered to SKB. The benefits as well as the limitations of the method will be analysed later.

After the methodology study detailed flow logging was carried out systematically in the borehole (200-1400 m) and EC measurement for monitoring changes of the salinity was performed during the logging. Single point resistance was also measured during all flow loggings. The field program for the detailed mode measurements consisted of the following:

- Detailed flow logging along the entire measurable interval of the borehole (200-1400 m) was done with a drawdown of 22 m (with 55 l/min pump rate) (section 0,5 m, step 0,1 m). The drawdown of 22 m was also used for EC measurements of fracture specific water. These measurements began three days after the start of the pumping. The fractures for fracture specific EC measurements were chosen automatically during the measurement by their flow rate. EC was measured every 0,5 m without extra waiting time. Fractures with flow rate larger than 1,5 l/h were measured with extra waiting time. Some extra measurements of fractures with smaller flow rates were also carried out.

- An additional measurement was included in the field program in order to perform detailed flow logging of separate sections, specific for EC measurements, interval 723 – 815 m, with 22 m drawdown (section 0.5 m, step 0.1 m).

During the waiting time, after changing the drawdown, additional EC and temperature measurements were performed in the upper part of the borehole. No saline water was detected above the 400 m level during this measurement. A special feature of the EC results is the probable appearance of gas, which caused increased noise level both in the measured EC and flow rate. The preliminary results for the detailed flow logging have been delivered to SKB. The benefits as well as the limitations of the method will be analysed later.

7 Other matters

Documentation

During the period April-September 2000, the following reports have been published and distributed:

7.1.1 Äspö International Cooperation Reports

Cvetkovic V, Cheng H, Selroos J-O
First TRUE stage. Evaluation of Tracer Retention Understanding Experiments (first stage) at Äspö.
ICR-00-01

7.1.2 Äspö International Progress Reports

Birgersson L, Gale J, Hakami E, 2000
First TRUE stage. Pilot resin experiment. Summary report.
IPR-00-04

Birgersson L, Gale J, Hakami E, 2000
First TRUE stage. Pilot resin experiment. Background information.
IPR-00-05

Rhén I, 1999
Test plan for Groundwater flow modelling - natural barriers. Release 1.0.
IPR-00-06

Börgesson L, Hernelind J, 1999
Prototype repository. Preliminary modelling of the watersaturation phase of the buffer and backfill materials.
IPR-00-11

Laajalahti M, Aaltonen T, Kuoppamäki K, Maaranen J, Timonen J, 1999
Measurement with the He-gas methods of the disturbed zone caused by boring.
IPR-00-12

Äspö Hard Rock Laboratory, 2000
Planning report for 2000.
IPR-00-13

Sandén T, 2000
Canister retrieval test report on instrument positions and preparation of bentonite blocks for instruments and cables.
IPR-00-14

Äspö Hard Rock Laboratory, 2000
Status Report January - March 2000.
IPR-00-15

Morosini M (ed), 2000
Proceedings from the 13th Task Force Meeting at Carlsbad, NM, USA, February 8-11, 2000. Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes. IPR-00-16

18 Technical Document

7 International Technical Document

References

Andersson, P., Johansson, H., Nordqvist, R., Skarnemark, G., Skålberg, M,, Wass, E. 1998A. Parameters of importance to determine during geoscientific site investigation.
SKB Technical Report TR 98-02

Cvetkovic, V., Cheng, H. Selroos, J-O. 2000. Evaluation of Tracer Retention Understanding Experiments (first stage) at Äspö.
SKB Äspö Hard Rock Laboratory International Cooperation Report ICR-00-01

Hakala, M. 1999. Numerical study on core damage and interpretation of in situ state of stress.
POSIVA Technical Report POSIVA 99-25

Olsson O, Bäckblom G, Gustafson G, Rhén I, Stanfors R and Wikberg P, 1994. The structure of conceptual models with application to the Äspö HRL Project.
SKB Technical Report 94-08

Rhén I (ed), Gustafson G, Stanfors R and Wikberg P, 1997. ÄSPÖ HRL - Geoscientific evaluation 1997/5. Models based on site characterization 1986-1995.
SKB Technical Report 97-06

Rouhiainen P., 1996. Difference Flow Measurements at the Kivetty Site in Äänekoski, Boreholes KR1-3, KR5, KR8 and KR9. Helsinki, Finland: Posiva Oy. 58 p.
Work Report PATU-95-36.

Winberg, A., Andersson, P., Hermansson, J., Byegård, J., Cvetkovic, V., Birgersson, L. 2000. The Final Report of the First Stage of the Tracer Retention Understanding Experiments.
SKB Technical Report TR-00-07

Appendix A

MASTER SCHEDULE ÄSPÖ

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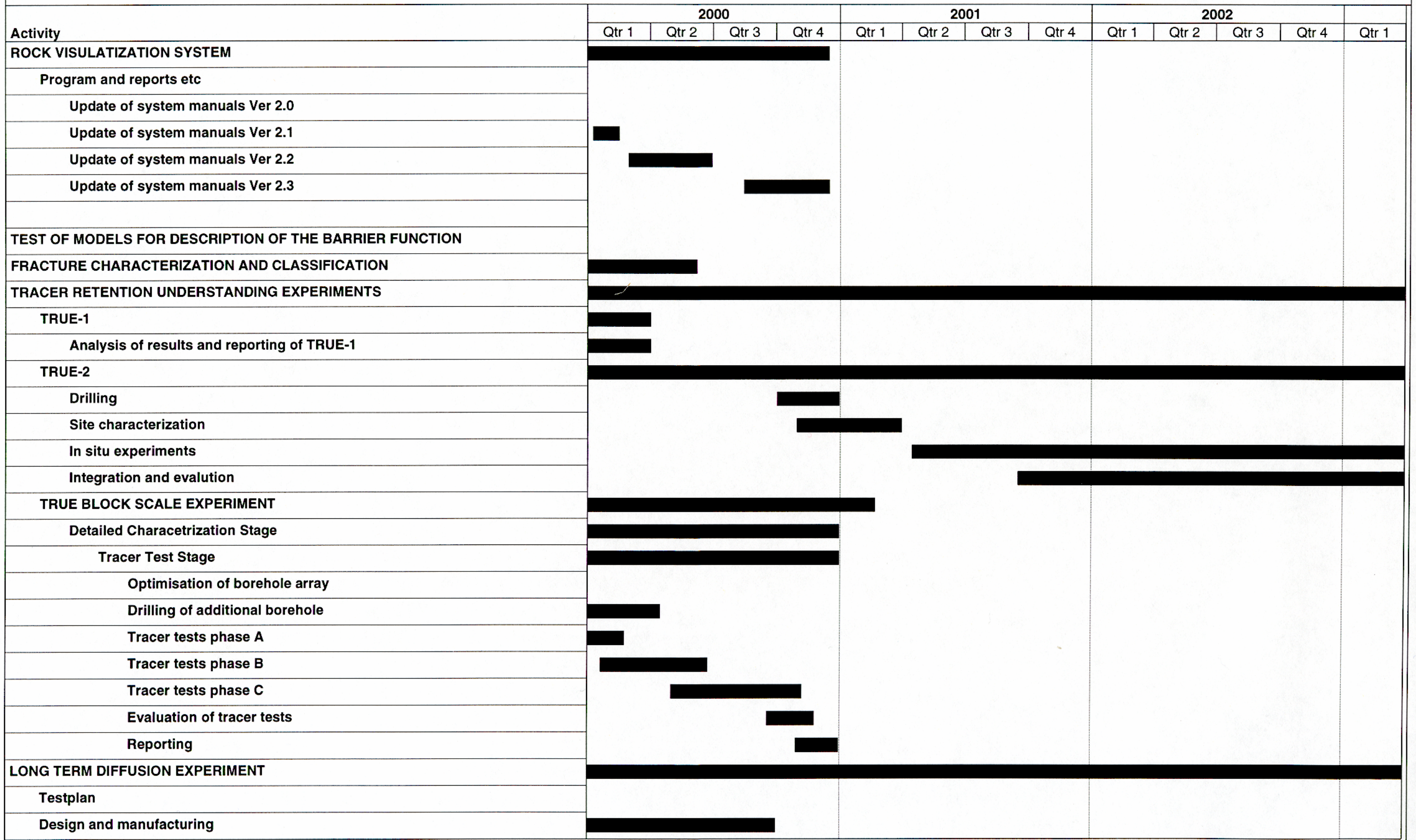

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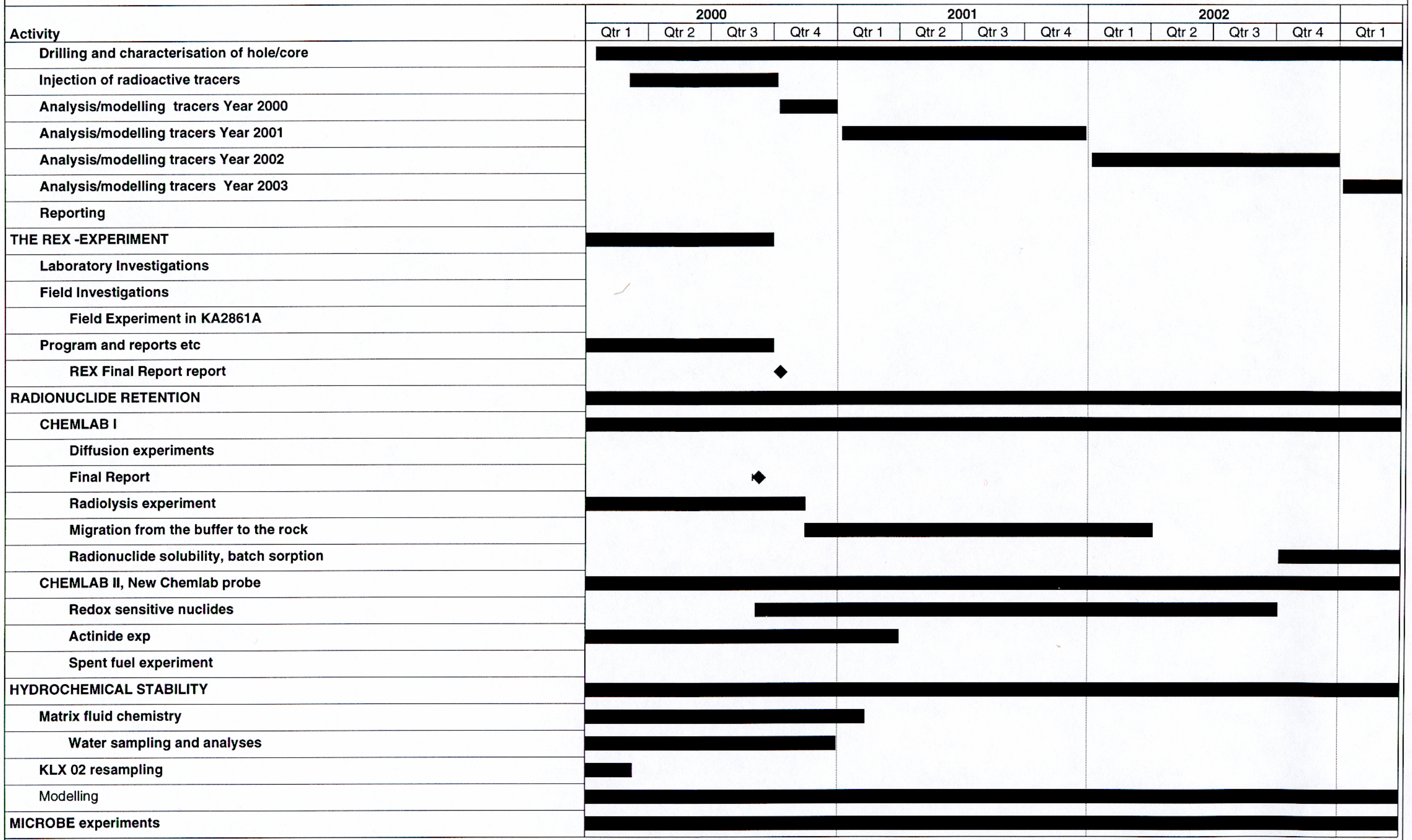

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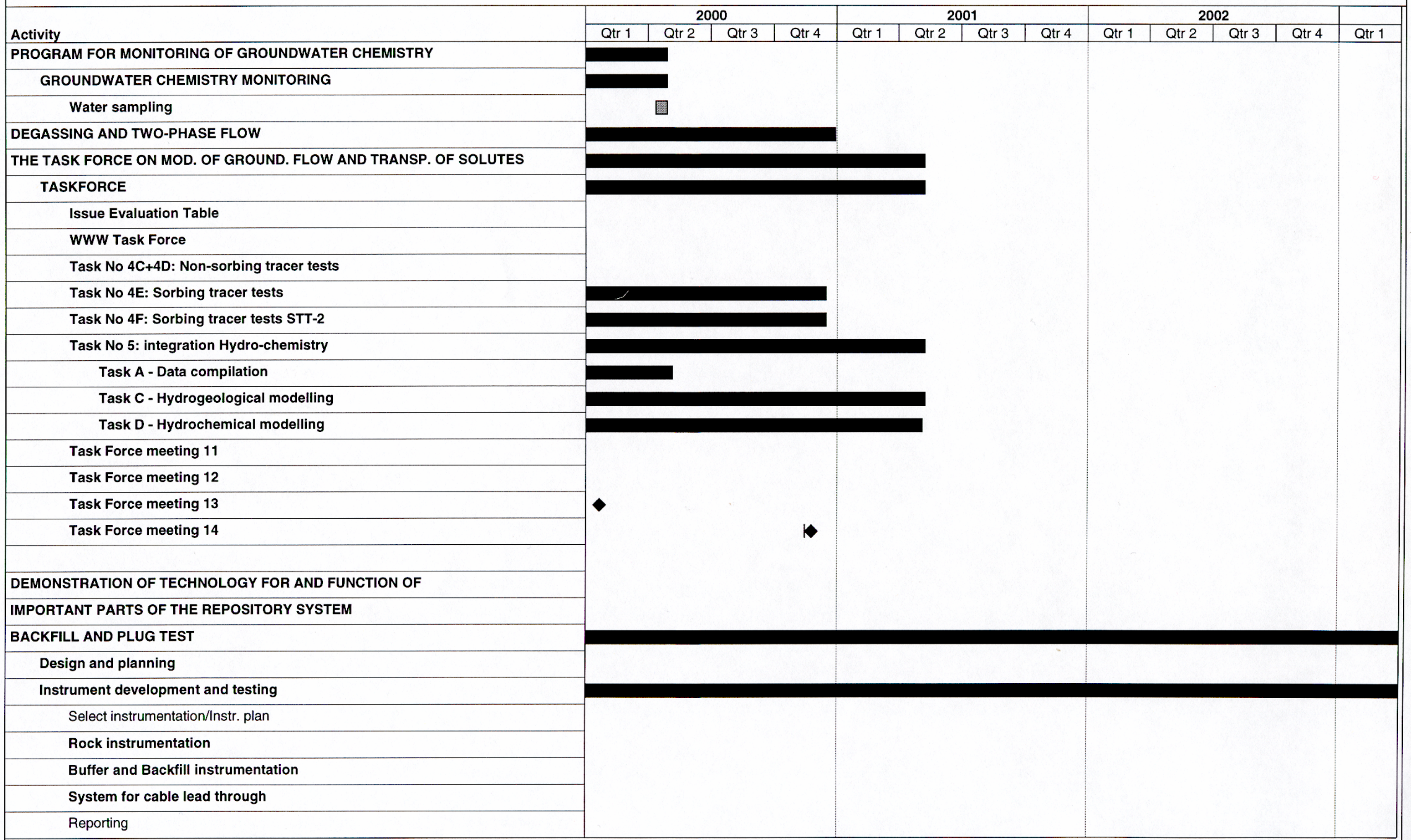

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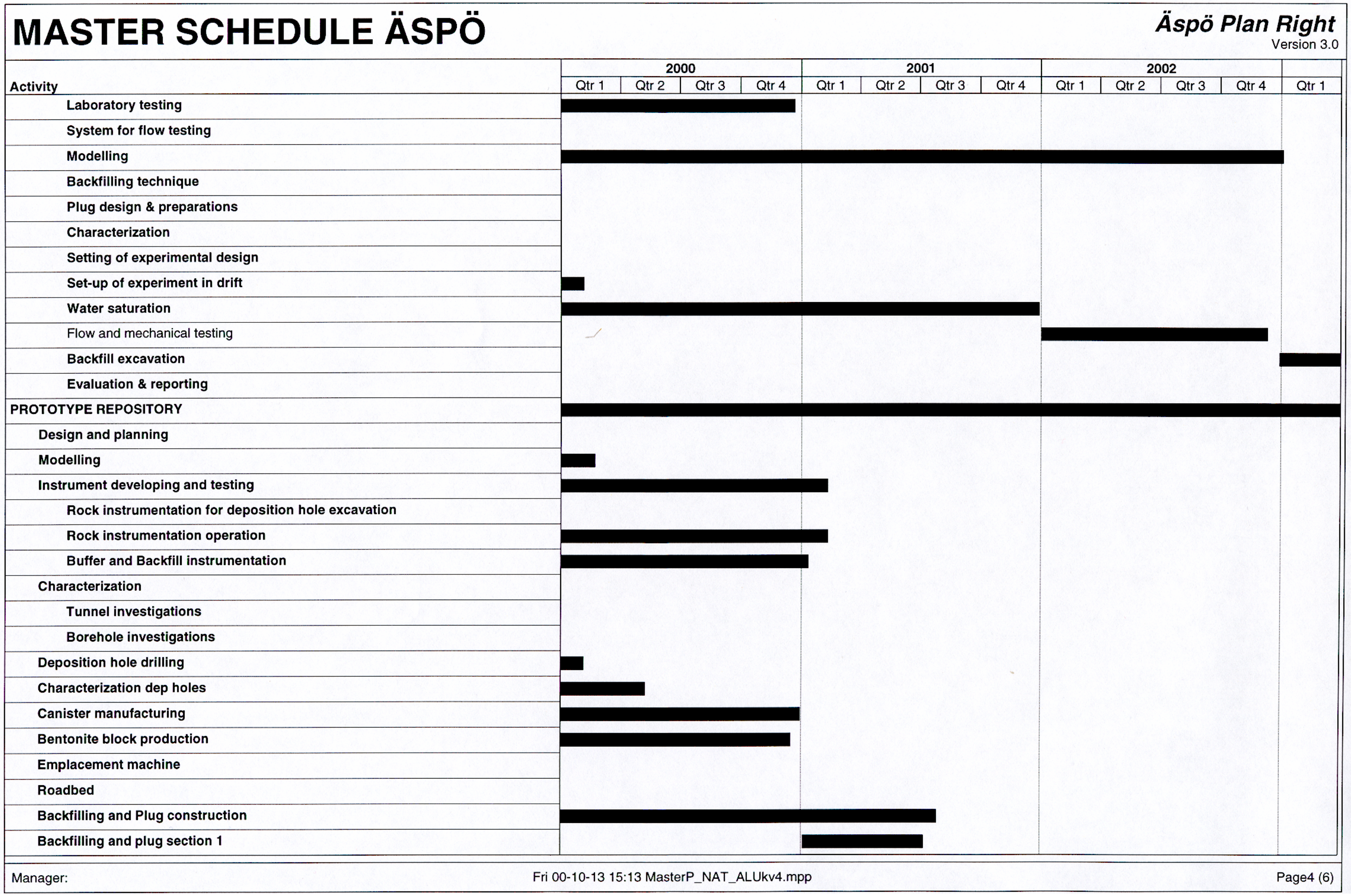
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Äspö Plan Right
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Activity
2000
2001
2002
Qtr 1
Qtr 2
Qtr 3
Qtr 4
Laboratory testing
System for flow testing
Modelling
Backfilling technique
Plug design & preparations
Characterization
Setting of experimental design
Set-up of experiment in drift
Water saturation
Flow and mechanical testing
Backfill excavation
Evaluation & reporting
PROTOTYPE REPOSITORY
Design and planning
Modelling
Instrument developing and testing
Rock instrumentation for deposition hole excavation
Rock instrumentation operation
Buffer and Backfill instrumentation
Characterization
Tunnel investigations
Borehole investigations
Deposition hole drilling
Characterization dep holes
Canister manufacturing
Bentonite block production
Emplacement machine
Roadbed
Backfilling and Plug construction
Backfilling and plug section 1
Manager:
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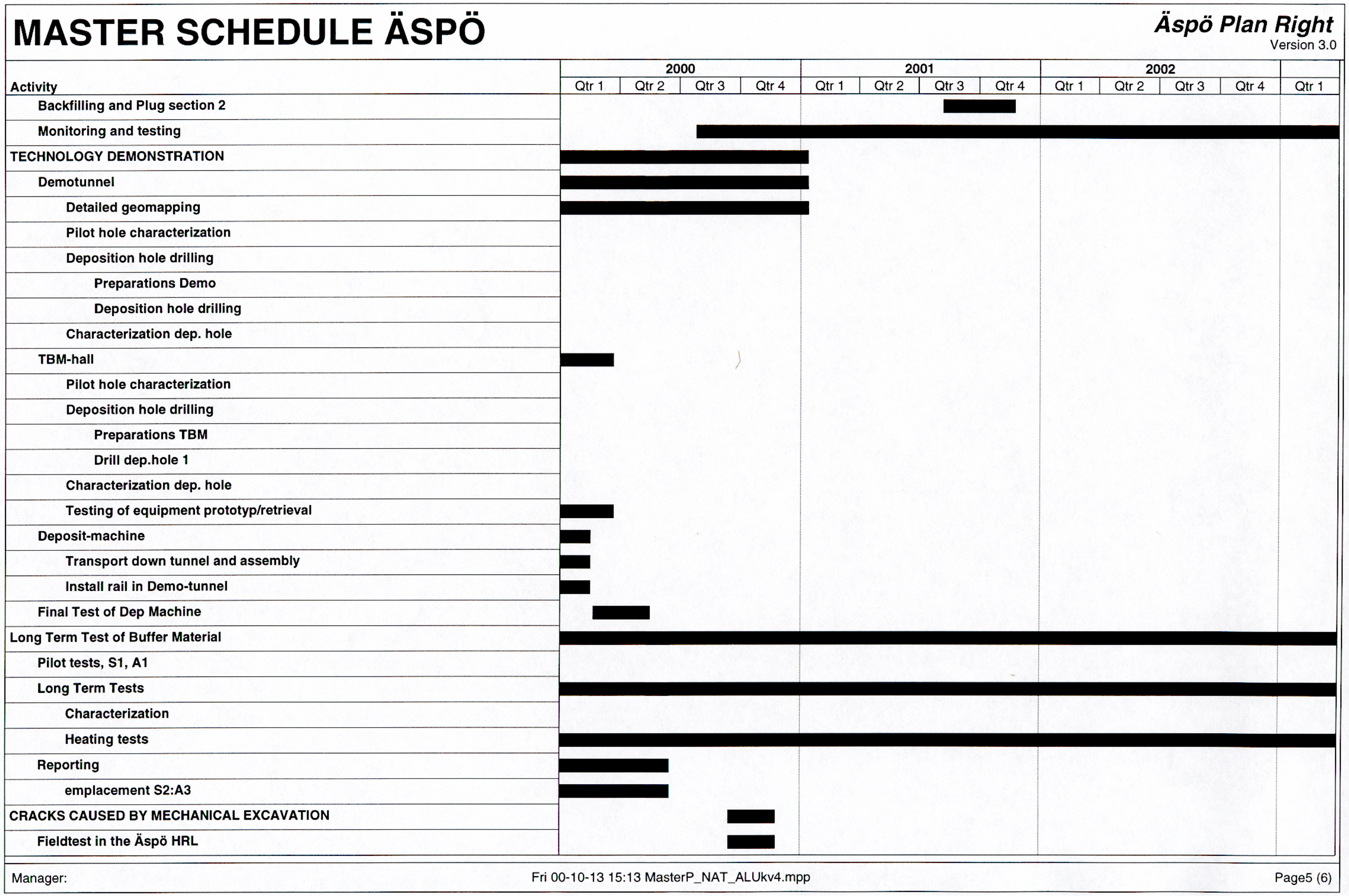
MASTER SCHEDULE ÄSPÖ
Äspö Plan Right
Version 3.0
Activity
2000
2001
2002
Qtr 1
Qtr 2
Qtr 3
Qtr 4
Backfilling and Plug section 2
Monitoring and testing
TECHNOLOGY DEMONSTRATION
Demotunnel
Detailed geomapping
Pilot hole characterization
Deposition hole drilling
Preparations Demo
Deposition hole drilling
Characterization dep. hole
TBM-hall
Pilot hole characterization
Deposition hole drilling
Preparations TBM
Drill dep.hole 1
Characterization dep. hole
Testing of equipment prototyp/retrieval
Deposit-machine
Transport down tunnel and assembly
Install rail in Demo-tunnel
Final Test of Dep Machine
Long Term Test of Buffer Material
Pilot tests, S1, A1
Long Term Tests
Characterization
Heating tests
Reporting
emplacement S2:A3
CRACKS CAUSED BY MECHANICAL EXCAVATION
Fieldtest in the Äspö HRL
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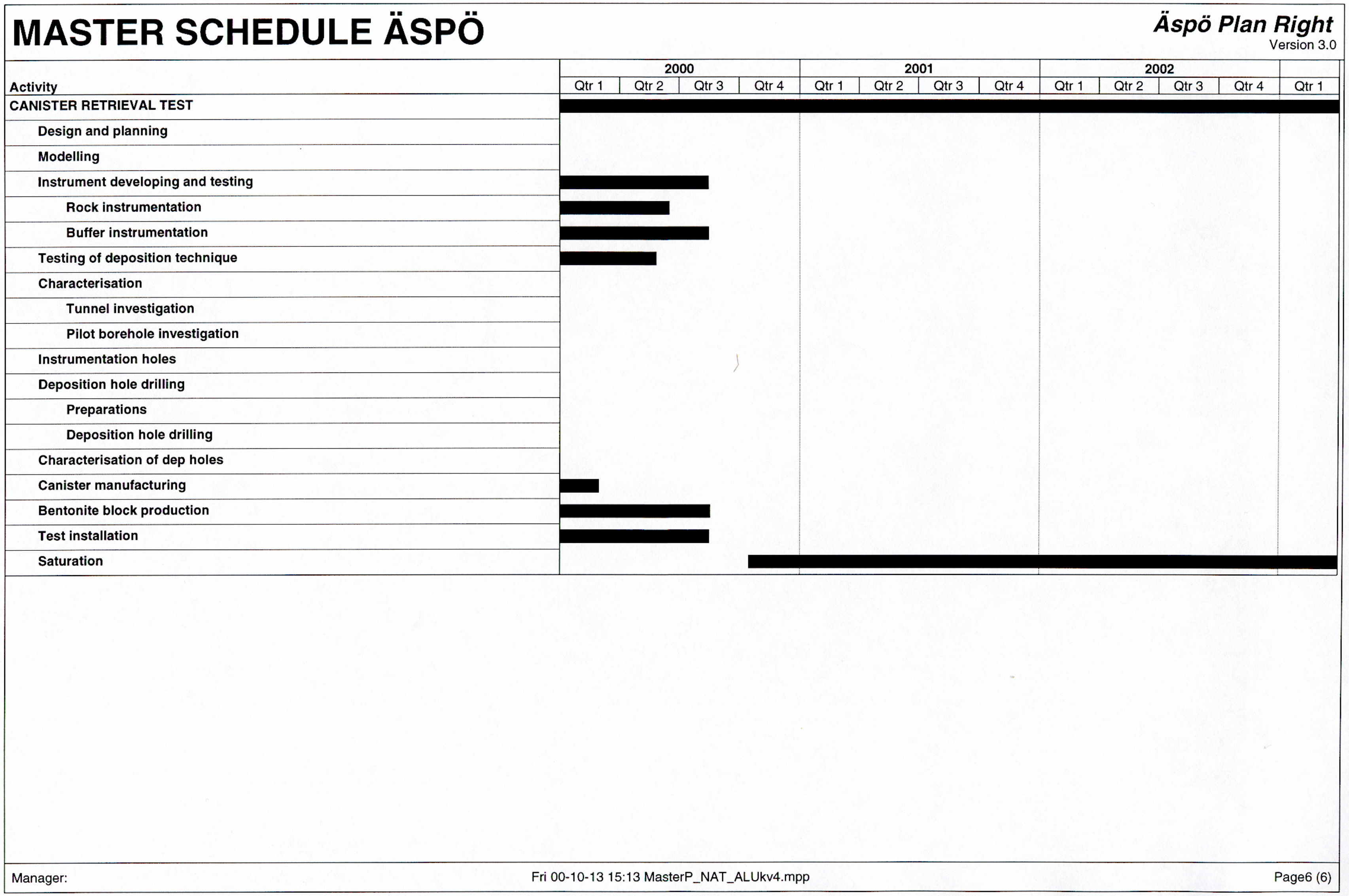
MASTER SCHEDULE ÄSPÖ
Äspö Plan Right
Version 3.0
Activity
2000
2001
2002
Qtr 1
Qtr 2
Qtr 3
Qtr 4
CANISTER RETRIEVAL TEST
Design and planning
Modelling
Instrument developing and testing
Rock instrumentation
Buffer instrumentation
Testing of deposition technique
Characterisation
Tunnel investigation
Pilot borehole investigation
Instrumentation holes
Deposition hole drilling
Preparations
Deposition hole drilling
Characterisation of dep holes
Canister manufacturing
Bentonite block production
Test installation
Saturation
Manager:
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