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Äspö Hard Rock Laboratory

Status Report

April - June 2001

September 2001

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Summary

Investigations and experiments

The barrier function of the host rock

The Tracer Retention Understanding (TRUE) aims at further developing the understanding of radionuclide migration and retention processes and evaluation of different approaches to modelling such processes.

One of the TRUE programme projects is the Long-Term Diffusion Experiment, which is intended as a complement to the *in-situ* dynamic experiments and the laboratory experiments performed within TRUE. 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 bore hole at 410 m level, which exposes a fracture surface through which diffusion can be studied. Geo-scientific investigations and modelling of mechanical disturbance have been carried through on the core from the large diameter bore hole with the objective to define the suitable way of setting up the test. The prime alternative is to core a central small diameter bore hole in the centre of the large diameter bore hole that extends into the undisturbed rock, and study migration at two places in the same set-up – through a fracture surface and in rock with virgin rock stress conditions.

The TRUE Block Scale project aims at studying the tracer transport in a fracture network over distances up to 50 m. The monitoring of tracer break-through has been prolonged (Phase C), but some break-throughs have still not taken place for strongly sorbing ^{83}Rb and ^{137}Cs in 35 and 100 m flow paths respectively. Modelling of Phase B and prediction of Phase C has been completed, and a workshop on modelling result and reporting has been held.

The CHEMLAB probe has been constructed and manufactured for validation experiments *in-situ* at undisturbed natural conditions. The results from experiments with diffusion in bentonite have been reported, the results being in accordance with previous findings. The experiments with migration of actinides, Am, Np and Pu in Chemlab #2, which came to an early stop due to malfunction, is being reported

The Matrix Fluid Chemistry experiment has the aim to determine the origin and age of matrix fluids and to establish to what extent diffusion processes have affected the composition of matrix fluid. Detailed sampling of a rock profile perpendicular to the micro-fissure has been carried out in preparation for detailed study to investigate any evidence of in- or out-diffusion processes. Both bore hole sections, Section 4 (already sampled) and Section 2 have continued to show steady pressure increase although Section 4 has now levelled out. Sampling of this bore hole sections has been planned for October this year. Fluid inclusion characterisation as well as mineralogical and petrophysical studies have continued.

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. A project decision to perform the project was taken during December 2000, and work conducted so far has been focused on laboratory studies. Preliminary results indicate a low rate of natural colloid formation at the salinity concentrations in the Äspö HRL. When this is confirmed the experiment will be planned accordingly.

A set of microbiology research tasks for the performance assessment of high level nuclear waste (HLW) disposal has been identified. A test site at the 450 m level, called the MICROBE site, is in operation consisting of three core drilled holes intersecting water conducting fractures at 12.7, 43.5 and 9.3 m respectively. Each bore hole is equipped with metal-free packer systems that allow controlled sampling from each fracture. The laboratory at 450 m level is still under development and some vital equipment still remains to be ordered.

The Task Force is a forum for the organisations supporting the Äspö HRL Project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. The final reporting of Task 5 is going. Within Task 6 the base cases for sub-tasks 6A and 6B were defined.

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. Physical activities in the Prototype Repository tunnel have been:

- Installation of cable packages in the lead-throughs in Section I
- Installation of bentonite blocks and canisters in holes # 2, 3 and 4, and instruments in the buffer blocks in hole #3

The canister in hole #3 showed a cross-circuit inside after installation, and had to be retrieved for opening of the lid. This was done in August where after the canister was re-installed into hole #2.

The Backfill and Plug Test comprises full scale testing of backfill materials, filling methods, and plugging. The entire test set-up with backfilling, instrumentation and building of the plug was finished late September 1999 and the wetting of the 30/70 mixture through the filter mats started in November 1999. Water filling of the outer test sections (0/100) has continued and is still not completed since the plug has not been tight. The filling is made slowly and stepwise since when the water level has been raised water has leaked out through the plug between the rock surface and the concrete without providing water to the bentonite O-ring so it can seal off 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. Only the sensors placed in the first layers (about 20 cm from the mat) in the 30/70 section have been clearly water saturated. Sensors 40 cm away indicate increased water content. The interface between the plug and the rock was grouted at the end of June in order to provide for saturation of the O-ring of bentonite.

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. Demonstrations have taken place a number of times.

Canister Retrieval Test aims at demonstrating the readiness for recovering of deposited canisters also after the time when the bentonite has swollen. The heaters as well as the system for artificial saturation were turned on in October 2000 and have been running during the period as planned. On February 13th the thermal power was increased from 1700 W to 2600 W in order to reach 90°C on the surface of the single canister in this particular test. The temperature in the inner part of the steel insert has increase to 102°C at mid-height, while the temperature at the same horizon but on the outside of the canister has reached 91°C, and 84°C in the bentonite 60 mm from the canister's surface. The low temperature difference between the steel insert and the copper mantle thus has sustained.

The Long Term Tests of Buffer Material aim to validate models and hypotheses concerning long-term processes in buffer material. Five bore holes have been filled with highly compacted bentonite and one 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. Saturation and heating has been going on. No one of the parcels has yet reached full saturation.

International Co-operation

Nine organisations from eight countries are currently (July 2001) participating in the Äspö HRL, though the NIREX participation will come to a stop in the third quarter of 2001.

The EC project CROP, a Thematic Network project, focused the work on the first two work packages, collecting of data for country annexes on repository concepts and experimental procedures in URLs.

Facility Operation

The status of the facility is good.

OKG´s (the NPP operator) policy to outsource among other things service activities has now reached full effect for Äspö HRL, and service contracts, which earlier were signed with OKG are now being established directly with each contractor.

A project for hands-free registration of underground visits is in progress. The main objective is to improve the safety in case of any incident/accident. After implementation the system also will help in energy conservation as the ventilation system then can operate in accordance to the need of personnel, equipment and vehicles actually being underground.

The two-storey barrack, with 16 new office rooms, in the Äspö research village has been taken in use.

Data Management and Quality systems

The development of GIS, SICADA and RVS has been focused on the implementation of ESRI/ArcSDE and ArcIMS. ArcSDE requires Oracle RDBMS. These have been ordered and a couple of new Windows NT servers have been purchased and configured.

A new version called SICADA Admin is being introduced by upgrading the old version of SICADA with GTAdmin by using the programming environment Delphi.

RVS version 3.0 is being implemented. The work is separated into five stages and stage two has just been finalised.

Groundwater head and chemistry monitoring

A project is ongoing performing an overall evaluation of the Hydro Monitoring Programme and a draft report has been compiled.

The Tidal Fracture Zone analysis project, which aims at evaluating the feasibility of utilising tidal fluctuation of monitoring data in order to calculate fracture orientation, has delivered the final report in draft.

Information activities

During the period April-June, 2001, 3758 persons (2331 during last period) visited the Äspö HRL. These persons represented the public, municipalities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries. 1566 persons represented the six municipalities where SKB has performed feasibility studies.

Table of contents

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, design of a deep repository as well as excavation and operation of such a repository. This requires extensive field studies of the active processes and properties of the geological barrier, the interaction between different engineered barriers and host rock, means of construction, and ways of disposal and backfilling. The Äspö Hard Rock Laboratory (Äspö HRL) provides an opportunity for research, development and demonstration of these issues in a realistic setting. Important tasks for the Äspö HRL 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 bore holes 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 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

1 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 excavation 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 bore holes. 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

No new results.

Planned work

A report on underground investigation methods used during the construction phase of the Äspö HRL will be published during mid 2001. The report will describe the different methods used with regard to instrument or other working tools and measurement methodology. Resolution and accuracy of the measured values as well as general aspects of errors will be discussed. The evaluation part will address the usefulness and feasibility of the methods. Recommendations on possible modifications etc. will also be given.

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

2.1 Natural Barriers

General

The Natural Barriers in the deep geological repository for radioactive wastes are the bedrock, its properties and the on-going physical, chemical and biological 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 geo-scientific 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 KBS-3 type 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 2001 focus is on further development of the numerical tools used for groundwater flow and transport calculations. A major part of this work will be to start the TASK#6 modelling work.

Hydrochemical stability and potential variability is assessed within several projects that were completed during 1999 and 2000. The final project report will be printed during 2001.

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 don't dominate the hazard of the waste.

The fission products, Cs, Sr, I, Tc, and the transuranic elements Am, Np, and Pu cause the large amount of activity in a repository. The transuranics, Cs, and Tc are, if dissolved, effectively sorbed in the near field. However, in case neptunium and technetium are oxidised to neptonyl and pertechnetate by radiolyses from the waste they might be transported into the bentonite buffer before they are reduced to the insoluble tetravalent state.

Strontium and all negatively charged elements will be transported through the bentonite buffer by diffusion. They will then be retarded by the interaction with the fracture minerals in the flow paths of the rock and through the diffusion into the rock matrix. The effective retention of these nuclides is a combination of radioactive decay, sorption and diffusion.

The more long-lived and the weaker the sorption of the nuclide, the more important is the actual groundwater flow for the migration. The chemical composition of the groundwater is important for the magnitude of sorption for some of the nuclides. Negatively charged nuclides are retarded from the groundwater flow only through the diffusion into the stagnant pores of the rock matrix.

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 2001 the goals are to report the TRUE Block Scale experiment and to plan future tracer experiments. The Long Term Diffusion Experiment (LTDE) will be running for 3 to 4 years to assess the matrix diffusion into an isolated fracture surface. 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 2001 experiments including effects of radiolysis and migration of actinides in a rock fracture.

COLLOID investigations made previously at Äspö and elsewhere give a concentration that it was not possible to detect. New findings of colloidal transport and more sensitive instruments for colloid measurements has triggered a new project with the purpose to study the natural concentration, the stability and the mobility of colloids.

Microbes are of particular interest since they can directly influence the chemistry of the groundwater, and indirectly transport nuclides attached to them. Experiments will start within the project MICROBE.

Dilution is the third barrier function. It will take place in the rock volume surrounding the repository. The magnitude of dilution is very much depending on the site specific conditions, and for performance assessment calculations on the conceptualisation of the flow. In the geosphere the dilution is caused by the dispersion in the groundwater flow.

No specific experiment is focussing on dilution. However, this process is included in TASK#6 within the Äspö Task Force for groundwater flow and transport of solutes.

2.2 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.

2.2.1 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 are 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.

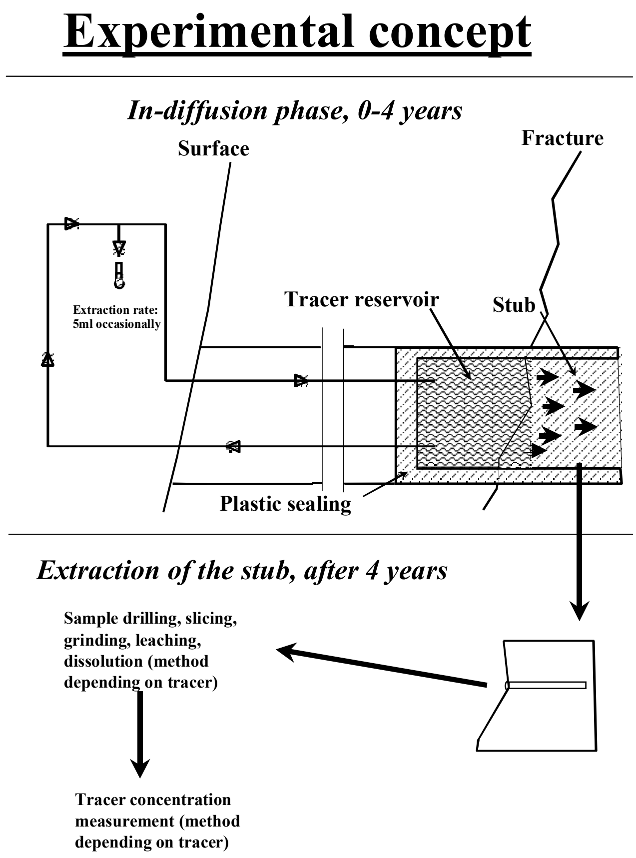

Figure 2-1 *Schematic of LTDE experimental concept including injection bore hole in contact with a fracture surface, combined with excavation and penetration profile studies*

The test plan presents an experimental concept centred on establishment of an experimental (large diameter) bore hole, 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 bore hole, similar to the approach used in the REX experiment, cf. Figure 2-1. 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 (e.g. ^{99}Tc and ^{241}Am) are being proposed. The principal challenge of the experiment is to establish axial diffusion from a natural fracture, through the rim zone of fracture mineralisation and alteration, into the unaltered intact rock matrix, without being affected by any advective component (prevailing hydraulic gradient directed 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, eliminating advective transport. The reference pressure is obtained either from a packed-off pilot bore hole in the immediate vicinity of the large diameter experimental bore hole, or from a section in the large diameter bore hole itself. The former bore hole has also been used to identify the target fracture to be investigated.

The characterisation of the large diameter bore hole includes i.a. measurements with various logs (bore hole imaging (BIPS) and flow logging). The type of logs restricted by the diameter of the bore hole. In the neighbouring 76 mm pilot bore hole 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 cores from the two bore holes will be analysed using mineralogical, petrophysical and geochemical methods.

A suitable target fracture has been identified in bore hole 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 down hole bore hole and sampling and monitoring equipment has been under way since 1999. Samples of the proposed material used for the down hole equipment (PEEK and polyurethane) have been analysed at CTH-Nuclear Chemistry in Gothenburg to characteristics and possible influence on the experiment. A mock-up bore hole has been manufactured of a steel tube trying to imitate the inner part of the bore hole involving the core stub. The sealing rubber has been manufactured and tested in a mock-up bore hole.

A telescoped bore hole, denoted KA3065A03, has been drilled parallel to the existing pilot bore hole KA3065A02. Drilling with 300 mm (280 mm core) was made to a depth of 9.25 m. after which the bore hole 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 length of 0.05 m.

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 along the mantel surface and stress redistribution within the core stub which provide enhanced porosity/diffusivity will invalidate the possibility to reach the intact rock beyond the root of the core stub. Results of seismic 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 acoustic emission data from the Prototype and the ZEDEX projects. The results from LTDE 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 controlled vehicle with a video camera and a 6 mm camera in the 9.75 mm slot between the stub and the bore hole 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.

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 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 everywhere and in all directions.

In the field, components of the planned pre-test program have been completed. These include a detailed flow logging using a single packer in the interior of bore hole KA3065A03, in the interval L=10.083 to 10.883 m. A total of 9 measurements were made which will be differentiated to 0.05 m sections. Pressure responses were collected in the neighbouring bore holes including KA3067A, KA3065A02, KA3068A

Numerical modelling has been performed to simulate the desaturation and resaturation of the core stub as a consequence of the bore hole being opened, and subsequently being shut-in. The simulation results indicate for reasonable assumed values of hydraulic conductivity and specific storage ($K=10^{-14} - 10^{-12}$ m/s and $S_s=10^{-8} - 10^{-6}$ m^{-1}), the initial response is fast (order days or less) but that complete steady state conditions are instated after longer time.

New results

The micro-seismic investigations of the cores described in the previous section were followed by thin section analyses to assess the core damage (Li, 2001). The damage was assessed using thin sections produced from samples, which had been saturated with a fluorescent resin after partial vacuum. Subsequently, thin sections were produced and micro-fractures were mapped perpendicular and along the core axis (177 mm core) and in a series of radial section perpendicular to the core axis for the 45 mm sample. In the case of the 177 mm thin sections the average number of cracks is 2.7 cracks/mm in the first 3 mm and rapidly drops to a level of 1-1.3 cracks/ mm, or lower, beyond 3 mm (measurement in radial direction). In sections oriented parallel to the core axis the density is 0.7-1 crack/mm. The latter observation may suggest that cracks develop preferentially in the radial direction, parallel to the core axis.

Subsequent numerical modelling has focused on assessment of the state of stress in the core stub and its immediate environment. The results show that a zone of tensional stress develop in the 150 mm (as well as in the originally intentioned 50 mm core stub). This entails that existing micro fractures and grain boundaries will inevitably be widened. Original scopings assuming homogeneous conditions projected diffusion depths of a few decimetres, thus catering to diffusion also in rock beyond the core root unaffected by stress unloading. However, any heterogeneity in the core stub could in essence inhibit diffusion into the intact rock.

Plans for further work

The growing concern related to the projected inability to reach the intact rock resulted in a search for alternate experimental concepts. These included split of the experiment in an *in-situ* sorption part in KA3065A03 and an *in-situ* diffusion part in a zone of intact rock in another bore hole which is subsequently overcored. However, the latter alternative was abandoned because of budget constraints. This alternative has its drawback in that that it is difficult to correlate results from the two experiments, plus the fact that costs would increase (drilling, overcoring and analysis). Instead an experimental concept has been put forward where a slim bore hole is drilled through the centre of the core stub and into intact and unaffected rock. Two separated test sections are established on the cylindrical core surface and in the bottom of the slim hole. The part of the hole through the core stub itself is lined with PEEK in order to separate diffusion/sorption in the axial direction through the core and radial diffusion from the slim hole through any damaged zone into the intact rock. After termination of the experiment the affected rock is overcored. Assuming a 36 mm slim hole drilled in the centre of the stub and that at a maximum 2 bore hole diameters of rock are affected by stress relief, leaves a cylindrical shell 60 mm thick where diffusion in intact rock can be analysed.

Initial assessments deemed the concept technically feasible, but problem areas are; 1) prediction of fracturing ahead of the core stub, 2) drilling of the slim hole without damaging the core stub and extracting slim core. In relation to time and budget the priority lies in assessment of diffusion in the intact rock. Adaptation of the down hole equipment is expected to be relatively minor and once the technical difficulties have been resolved, the process of installation of equipment and furnishing the experimental container will continue.

The include performance of the remaining part of the pre-test program which includes both hydraulic tests and tracer tests. The tracer test work is focused on characterisation of the connectivity of the investigated rock volume, simulation of release scenarios in case of accidental leakage from the test section.

2.2.2 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 five basic stages;

- Scoping Stage
- Preliminary Characterisation Stage
- Detailed Characterisation 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 bore holes, 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 bore holes, 75 mm in diameter, are gently inclined (I=20 degrees) and complement the existing 56 mm bore holes, KA2511A and KA2563A, the latter drilled as a pilot bore hole as part of the TRUE Block Scale Scoping Stage. The latter bore holes have been drilled with a higher inclination from a higher elevation in the laboratory. The bore holes 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 bore holes 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 north-easterly and sub-horizontal 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 bore hole, 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 bore holes, KI0025F03. Characterisation has included flow and pressure build-up tests with observation of pressure responses in the neighbouring bore holes. The qualitative interpretation showed responses consistent with the reconciled March'99 structural model. The bore hole 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.

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 (e.g. 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. 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-C3 and 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.

A reporting structure for TRUE Block Scale has been developed. A series of four final reports will be produced;

#1 Characterisation and model evolution

#2 Tracer tests in the block scale

3 Modelling of flow and transport

#4 Synthesis of flow, transport and retention in the block scale

A first reporting workshop was held late November in Lerum, east of Gothenburg at which the detailed disposition and contents of the first two reports were discussed.

New results

The monitoring of the tracer breakthrough in the Phase C is prolonged after the official termination early November 2000. It is found that the relative order of breakthrough follows the same order as that observed in previous laboratory experiments and the TRUE-1 experiments. Of particular interest is the non-breakthrough of the strongly sorbing ^{83}Rb (C3) and ^{137}Cs (C2) in 35 and 100 m flow paths, respectively, after some 6 months of sampling.

Modelling of the Phase B tests and predictive modelling of the Phase C tests were completed early 2001 using five different concepts; stochastic continuum, discrete feature network and channel network models, the so-called POSIVA approach and the LaSAR approach extended to the block scale. Predictions provide cumulative mass arrival times t_5, t_{50} and t_{95} for the predicted tracers as well as the predicted mass recovery. Interestingly, the models largely which are largely calibrated to the preceding TRUE-1 experiments, overall project breakthrough over the time frame for the two tracers indicated above which did not show breakthrough. The results show good correspondence between predictions and experimental outcome on a 15 m length scale (C1). However, for the longer and more complex source-sink pairs (C2 and C3) the results are not as good, fc. Figure 2-2.

^{14}C PMMA analyses of wall rock and fault breccia pieces (1-3 cm) and from intercepts of structures involved in the Phase C experiments have been performed. PMMA analyses performed on fault breccia pieces and fault breccia fragments show porosities in the order of 0.4-0.8% (with small areas with highs of about 10%), and 1.3-11%, respectively. The wall rock exhibit a porosity which is similar to the breccia pieces. In general, the porosity constitutes micro-fractures and porous mineral phases (secondary or altered minerals). Figure 2-3 shows the results of assessment of porosity of a cm sized fault br5eccia piece from Structure #20 in bore hole KI0023B at L=69.9 m.

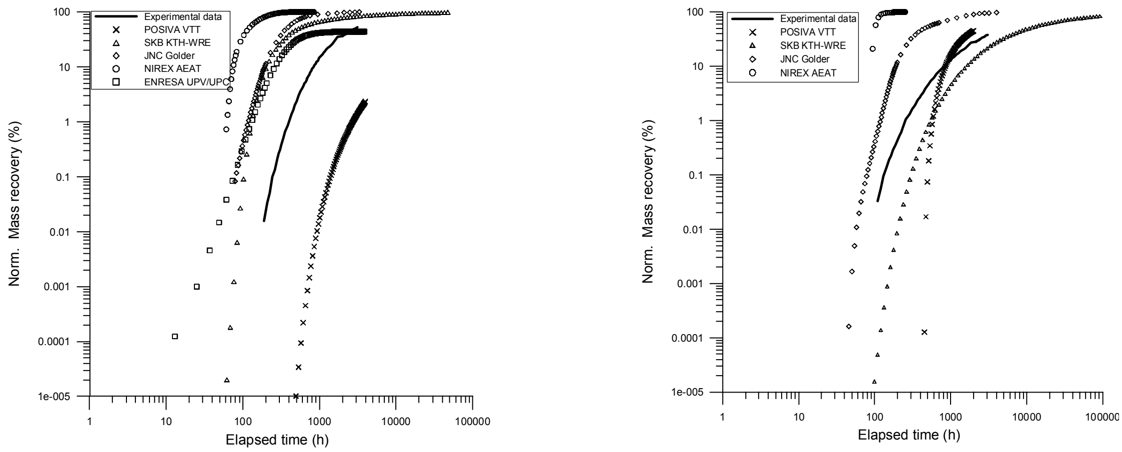

__Figure 2-2__ Comparison between predicted cumulative normalised mass recovery (%) and the corresponding experimental break-through. a) C1 (Cs-137), b) C3 (Sr-86).

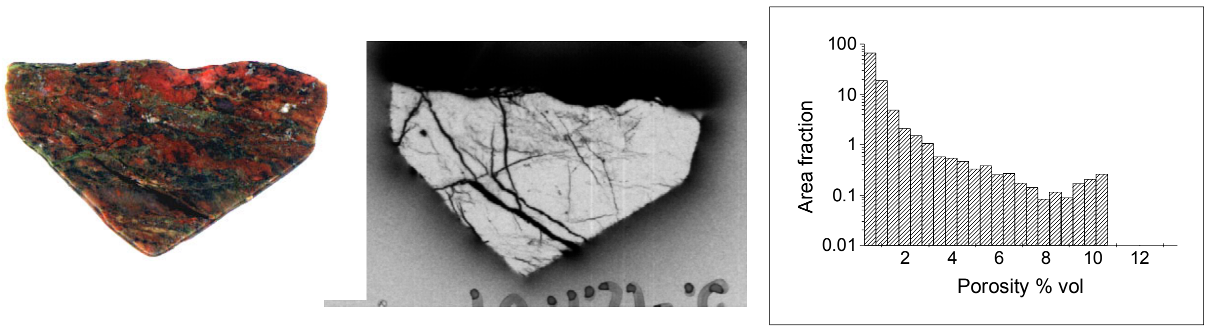

__Figure 2-3__ TRUE Block Scale: Composite showing a cut surface of a cm sized PMMA impregnated fault breccia piece, the associated autoradiograph and the a histogram accounting for the area distribution of porosity. The total porosity assessed from the exposed surface is 0.8 %.

Included in Final Report #1 is a detailed description of the structures involved in the Phase C tracer tests have been made. This includes detailed mineralogical and geochemical description, schematic conceptual models of individual intercepts as well as simplified models of complete structures along their extent. In addition, a compilation is given of relevant retention parameters in terms of distribution coefficients and diffusivities. In the latter context, an attempt has also made to quantify the distribution coefficients of breccia materials using cation exchange capacities, and ambient mineralogy and groundwater chemistry.

A second reporting workshop was held in Barcelona in late February where the results of the model predictions were discussed and the reporting of the modelling was discussed in detail.

A 4th TRUE Block Scale Review meeting was held in late March where the layout and status of the evaluation and reporting were presented and discussed.

2.2.3 TRUE Continuation

Since mid 2000 plans have been under way to define the continuation of the TRUE Programme following the completion of TRUE-1 (Winberg et al. 2000) and the almost completed TRUE Block Scale project. SKB has decided that any continuation will be conducted within the framework of one single project. Being one project does not, however, rule out the possibility of performing parts of continued filed work at different site.

The proposed general objectives (no yet ratified) of the TRUE continuation are;

- Demonstrate and validate a process for defining the critical geologic element/-s for flow and transport/retention and their transport properties,
- Define, at different scales, the pore space (responsible for/necessary to explain) transport, diffusion, sorption and loss of tracer,
- Integrate experimental results from the laboratory, detailed scale and block scale to obtain a consistent and adequate description of transport to serve as a basis for modelling transport from canister to biosphere,
- Through interaction with Äspö Task Force (Task 6), provide an experimental context in which to test modelling approaches on larger length scales.

In terms of work scope three main components are identified;

1. BS2 2a Continued monitoring of the TRUE Block Scale Phase C experiments. Complementary modelling of the new data with the objective of identifying new hypotheses to test by *in-situ* experiments.
2. BS 2b Complementary in-situ experiments in the TRUE Block Scale rock volume. Address of new hypotheses may entail use of alternative sinks and source sections as well as reversal of sink-source pairs.
3. Complementary work at the TRUE-1 site. This part of the work scope include in the short term complementary tracer dilution /tracer tests and the long-term (3 years from now) resin injection and subsequent excavation and analysis.

Planned work

LTDE

- Adaptation of down hole equipment.
- Manufacturing of 36 mm packers.
- Drilling of slim bore hole.
- Installation of packer equipment in KA3065A03/carrying out of parts of Pre-tests.
- Installation of equipment in the experiment container.

- Application to Swedish Radiation Protection Board (SSI).
- Continued work to acquire CE acceptance.

TRUE Block Scale

Tracer Test Stage

- Reporting of Phase C experiments (modelling).

Evaluation and Reporting Stage

- Finalisation of Final Reports number 1 through 4

TRUE Continuation

Complementary tracer dilution and tracer tests

2.3 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 bore hole-laboratory has been constructed and manufactured for validation experiments *in-situ* at undisturbed natural conditions. Figure 2-4 illustrates the principles of the CHEMLAB 1 and CHEMLAB 2 units.

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 bore hole 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

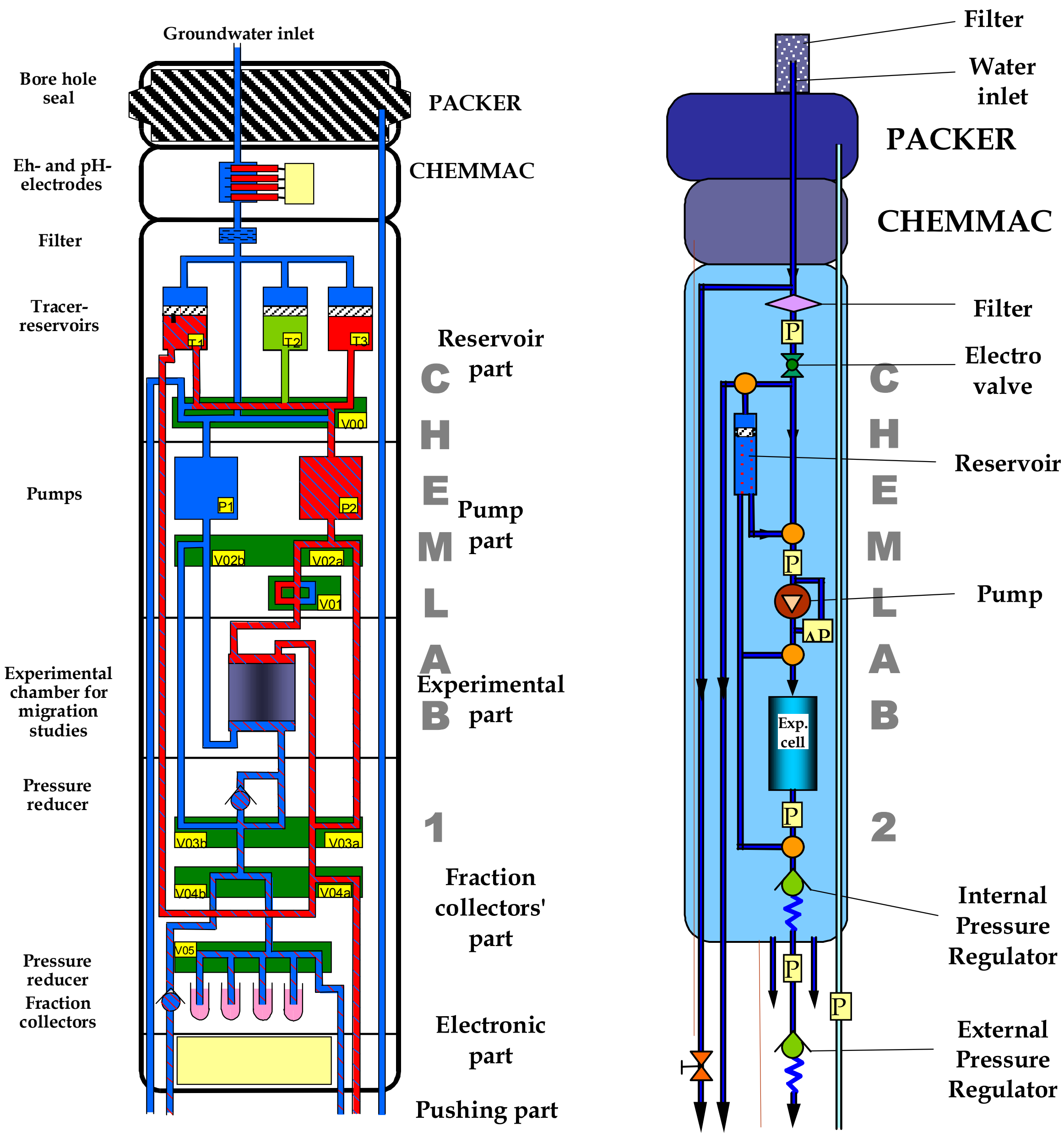

Figure 2-4 *Schematic illustration of CHEMLAB 1 and 2.*

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

The results from experiments with diffusion in bentonite have been evaluated and reported in SKB Technical Report 01-14. Diffusivity and porosity have been evaluated for Sr, Cs, Co, TcO_4, and I. The results are in accordance with previous findings.

The first experiment carried out in CHEMLAB-2 was the migration of actinides, Americium, Neptunium and Plutonium, in a rock fracture. Due to a failure in the CHEMLAB 2 unit the experiment was stopped in advance. However, some results were obtained and will be reported by Institut für Nuklear Endsorchung in Karlsruhe, INE.

Planned work

The next actinide migration experiment will start in august in CHEMLAB 2.

Experiment with radiolysis is planned to start in October in CHEMLAB 1.

2.4 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 bore hole sections. The bore hole 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, progress to the midway stage of the matrix experiment has been published as an Äspö International Progress Report (IPR-00-35), "Status Report of the Matrix Fluid Experiment: June 1998 – June 2000". This essentially contains results up to December 2000.

Within the various disciplines work has continued with: a) mineralogical and petrophysical studies, b) crush/leaching experiments, c) Äspö diorite permeability test, and d) fluid inclusion characterisation. In addition, drill core lengths sampled in collaboration with the rock stress bore hole drilled into 'matrix-type' rock in the 'F' Tunnel, have been sent to the University of Bern for leaching experiments under laboratory conditions. It is hoped that this experiment will indicate more closely the nature of the matrix fluid composition than those data reported from the crush/leaching experiments.

4. The fluid inclusion studies have confirmed the presence of at least four different types of inclusions:

5. High temperature types (> 400 °C; aqueous liquid + solid + vapour; relative abundance ± 5%) likely representing primary inclusions during magmatic crystallisation of quartz,

6. Moderate temperature types (80-400 °C; aqueous liquid + vapour; relative abundance ± 10%) which are secondary and formed as a result of healed micro-fractures in quartz grains and along grain boundaries,

7. Lower temperature secondary types (relative abundance ± 20%) containing only an aqueous liquid phase and located within grains or along grain boundaries,

8. Final group of inclusions (relative abundance ± 65%) are secondary, contain only a low density vapour phase (H_2O), and primarily occur along grain boundaries.

Since Type (1) contains approx. 30 eq.wt% NaCl, Type (2) contains 3.4-26 eq.wt% NaCl and Type (3) contains 1.7-10.5 eq.wt% NaCl, there exists a substantial source of matrix fluid salinity provided these fluids can access the rock matrix. Textural studies have indicated that some fracturing of the quartz has occurred, possibly accompanied by a release of saline inclusion fluids into the rock matrix.

Detailed sampling of a rock profile perpendicular to the micro-fissure (located intersecting the bore hole at some 56.5 cm from Section 4 towards the tunnel) has been carried out in preparation for detailed study which will include mineralogy, petrophysical measurements (porosity) and whole-rock measurements of major and trace elements, U-decay series isotopes, ^{37}Cl, ^{11}B, ^{86}Sr and ^{87}Sr. These data will be used to investigate any evidence of in- or out-diffusion processes. As a first step, 1-2 samples presently are being characterised mineralogically and crushed to remove the quartz fraction. This should give an idea as to whether there will be an adequate matrix component to carry out the isotopic and chemical analysis.

The long-term permeability experiment has still not shown any release of fluid, which may be matrix in origin.

Both bore hole sections, Section 4 (already sampled) and Section 2, have continued to show steady pressure increases within the last six months although Section 4 has now levelled out. Sampling of these bore hole sections has been planned for October 15/16; both water and gas contents will be analysed.

The last six months have seen the completion of several draft International Technical Documents which will soon be submitted for publication. These have included:

- Matrix Fluid Experiment: Porosity and density measurements in samples from drill core KF0051A01, Äspö Hard Rock Laboratory (Eva-Lena Tullborg)
- Matrix Fluid Chemistry Experiment: Hydraulic character of the rock matrix (Erik Gustafsson)
- Matrix Fluid Experiment: Mineralogy and fluid inclusion studies (Nick Waber)
- Matrix Fluid Experiment: Fluid inclusion investigation of quartz from the Äspö Hard Rock Laboratory (Alec Blyth)

Planned work

Planned work for the immediate future will include:

- continuation of drill core crush/leach experiments with specific emphasis on lithological variation and porosity profiles,
- continuation of the permeability test,
- reporting and synthesis of the fluid inclusion studies,
- expand coverage of drill core 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 a micro-fracture/fissure 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 drill core,
- leaching of drill core section under inert laboratory conditions (Univ. Bern),
- eventual sampling of bore hole Section 2 (and possibly a second sampling of Section 4) when indications show that enough water has accumulated,
- Final Matrix Fluid Experiment Workshop, scheduled for October 17/18 in Stockholm.

2.5 Colloids

Background and objectives

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.

SKB has for more than 10 years conducted field measurements of colloids. 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 (Laaksoharju et al., 1995). 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 (Kersting et al., 1999). Based on these results SKB decided year 2000 to initiate the project COLLOID at Äspö-HRL to study the stability and mobility of colloids. The objectives of the colloid project is to:

1. Study the role of bentonite clay as a source for colloid generation
2. Verify the colloid concentration at Äspö-HRL
3. Investigate the potential for colloidal transport in natural groundwater flow paths

Experimental concept

The experimental concept for the Colloid project is: laboratory experiments, background measurements and fracture specific measurements. These concepts are described below:

Laboratory experiments

The role of the bentonite clay as a source for colloid generation at varying groundwater salinities has been studied in a laboratory experiment performed at KTH (Royal Institute of Technology) and at the company Clay Technology during the time period December-June 2001. The results from the laboratory test (Wold and Eriksen, 2001) conducted at KTH indicate that the bentonite colloid formation is strongly correlated with the ionic strength of the solution. Very low concentration of colloids formed in suspensions with ionic strengths 0.1 and 1 M. This is valid for experiments both with dry (Figure 2-5) and wet prepared bentonite. At 0 and 0.01 M colloids were formed in the experiments with wet prepared bentonite. In the case with dry prepared bentonite where the solutions are shaken initially, the sedimentation is so slow that no measurement was possible. At high ionic strength the colloid formation is minor. At ionic strength 0.01 M where colloid formation is favourable the colloid formation seems to increase when using a temperature of 60 ° C for the solution compared with a solution of 20 ° C. These results will be compared with the experiments conducted at Clay Technology by Ola Karnland who conducts parallel experiments. In addition Clay Technology is using “washed” bentonite in order to avoid interference from the clay on the solution. The chemical changes in the solution and formation of small particles will be studied in detail during the time period August-October 2001.

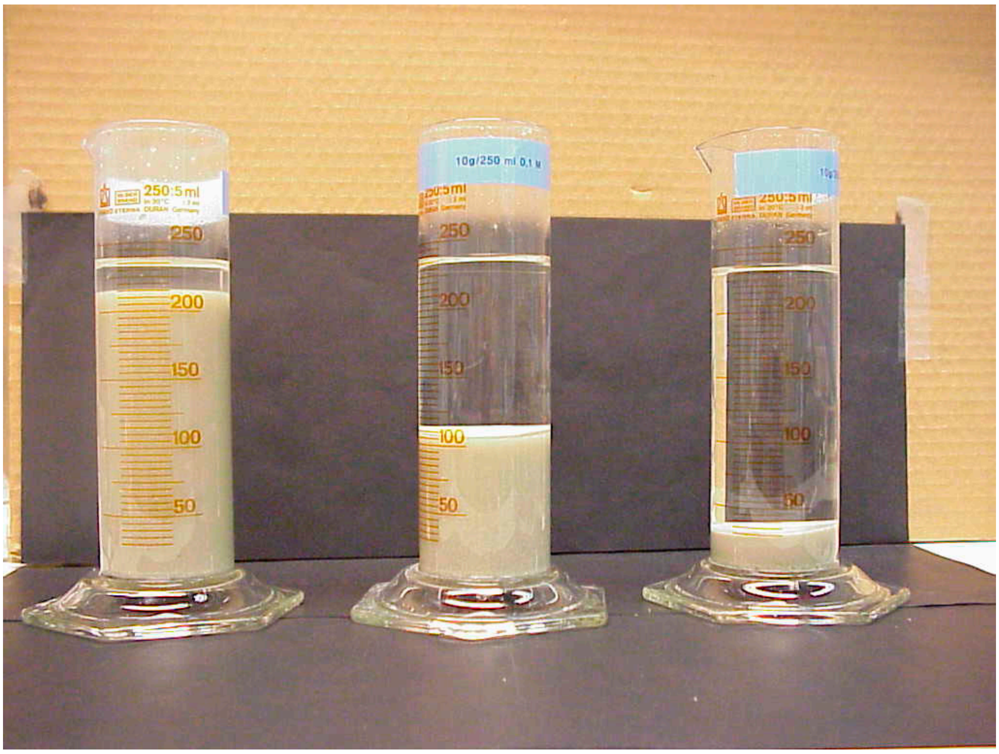

Figure 2-5 *The salinity of the water affects the colloid generation. The experiment show different degrees of sedimentations of bentonite clay dependent of the ion content in the water. The experimental conditions: Dry bentonite, 10 g/250 ml, 0.01, 0.1 and 1 M solution at 20 °C after 1.5 weeks (Wold and Eriksen, 2001).*

Background measurements

The background colloid concentration associated with the different water types found at Äspö will be sampled at specific locations along the Äspö HRL-tunnel during October-December 2001. The colloid content will be measured on-line from the bore holes by using a modified laser based equipment LIBD (Laser-induced Breakdown-Detection) which has been developed by INE in Germany (Figure 2-6). The advantage is that the resolution of this equipment is higher compared with standard equipment. 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 and at INE. Standard type of filtration performed on-line at the bore holes are used in order to be able to compare/transform these results to all the earlier colloid sampling campaigns at Äspö.

Figure 2-6 *The equipment for Laser-induced Breakdown-Detection (LIBD) of colloids is installed in a van in order to allow mobility and on-line measurements at a bore hole.*

Fracture specific measurements

For the fracture specific measurements two nearby bore holes at HRL will be selected for the experiment during the time period January-June 2002. One of the bore holes will be used as an injection bore hole and the bore hole downstream will be used as a monitoring bore hole. The bore holes intersect the same fracture and have the same basic geological properties. 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 bore hole (Figure 2-7). From the monitoring bore hole the colloidal content will be measured with laser (LIBD/LLS), the water will be filtered and the amount of tracers will be measured.

The following results are of interest 1) is the bentonite clay a potential source for colloid generation and, 2) are the colloid content lower after transport. The outcome of the experiment is used to check the calculations in the safety assessment report such as TR 91-50 and to be used in future colloid transport modelling.

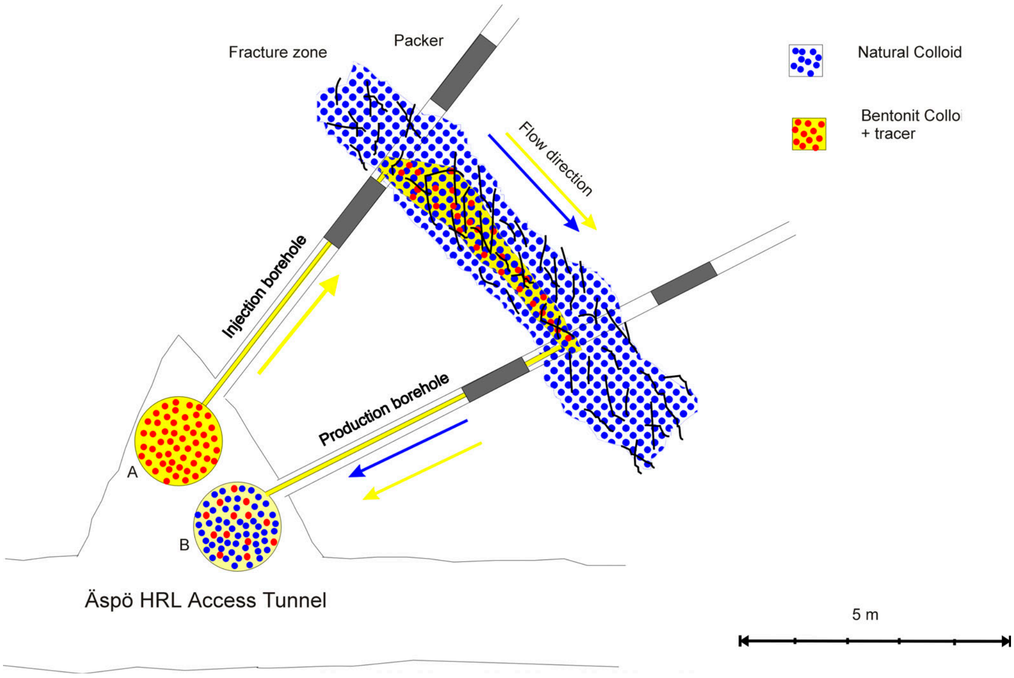

Figure 2-7 *Injection of bentonite colloids and a tracer at the injection bore hole and monitoring of the injected and natural colloids in the production bore hole.*

Time table

The project is conducted during the time period 2000-2002. The time plan for the project is:

- Laboratory tests January-October, 2001.
- Field test, background colloid content October 2001 – December 2001.
- Fracture specific test January - June 2002.
- End of project December 2002.

Ongoing and planned work

The scope of the work for 2001 contains planning and preparation work for the project. The first part of the laboratory work has been performed as described above. The preliminary laboratory results show low colloid formation at prevailing salinity concentrations at Äspö this may affect how the final fracture specific experiment is conducted. The review by Claude Degueldre concerning the first step of the project has been performed and is used when planning the extension of the laboratory study. For the period June to October 2001 the detailed planning of the background measurements is conducted where the bore holes are identified. There are plans concerning the measurements of humic substances with Gunnar Buckau (INE) and for microbes with Karsten Pedersen (Göteborgs Universitet). The discussion with POSIVA concerning their participation is taking place in August.

2.6 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 bore holes 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 micro-organisms 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.

Experimental concept

The microbe site consists of three core drilled bore holes, KJ0050F01, KJ0052F01 and KJ0052F03, intersecting water conducting fractures at 12.7, 43.5 and 9.3 m respectively. Each bore hole 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. Tubings from the bore holes have been connected to the laboratory.

New results

Laboratory facilities have been installed, including cupboards and laboratory benches. Circulation pumps have been ordered for the circulating systems. Quote for a reductive gas analytic field system has been sent out. The result will be evaluated during July 2001.

Planned work

Copper corrosion experiments have been initiated in June 2001. Hydrological characterisation of the bore holes will start in September. Radionuclide retention and mobility experiments will start in September as well. Redox experiments are planned to begin during October 2001.

2.7 The Äspö 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. Table 3-1 shows the on-going tasks.

Table 3-1. Modelling tasks addressed by the Task Force on modelling of groundwater flow and transport of solutes

Task No	Modelling Issues	Co-operating 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 flow rate.	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
6	Apply PA[1] and SC[2] approaches for the same tracer experiment and PA boundary conditions. Aims at identifying relevant conceptualisations for longer term PA predictions and identify site characterisation data requirements to support PA calculations.	ANDRA, CRIEPI, JNC, POSIVA, SKB (1) PA: Performance Assessment (2) SC: Site Characterisation

New results

No new results has been produced during this quarter. Work has progressed on the final reporting for Task 5. The report on the Task 4E and 4F Evaluation was printed as TR-01-12.With regard to Task 6 the definition of base cases for sub-task 6A and 6B was established and distributed to the modelling teams.

Planned work

For the next quarter work will continue on the modelling for Task 6, final reporting for Task 5 and on the reporting for the Task 4 Overall Evaluation. The 15th International Task Force meeting and Task 6C Workshop will be organised in Goslar, Germany.

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

3.1 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.

3.2 The 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 re-saturation 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 Project Group, consisting of basically Task Leaders, met only once during the period (with the objective to plan the activities that are scheduled to take place in the near future), in favour of the project management core group planning meetings taking place each Friday for discussion and decision on activities during the following week. Those meetings are documented but considered to be internal meetings.

The completion of instrument installation as well as preparation for start of installation of bentonite blocks and canisters in Section I has progressed according to plans. The basic activities have been to install the bentonite packers in investigation holes and to pull through cable packages in lead-throughs in Section I (9 out of 16 units). The first bentonite block was installed on May 7th (in test hole # 2 from the tunnel front) and the canister on May 10th.

After installation it was discovered that the canister had a cross-circuit between two electrical cables to the heaters. It was also clear that this malfunction was inside the canister close to the lid. An opening of the lid for finding the spot and take necessary measures was judged necessary. (This was made in August and it was found that the isolating plastic shield on two cables had been pealed to long so they got into contact with each other. This was quickly adjusted and the lid could was mounted again.)

The installation continued with holes # 3 and # 4 before the summer holiday.

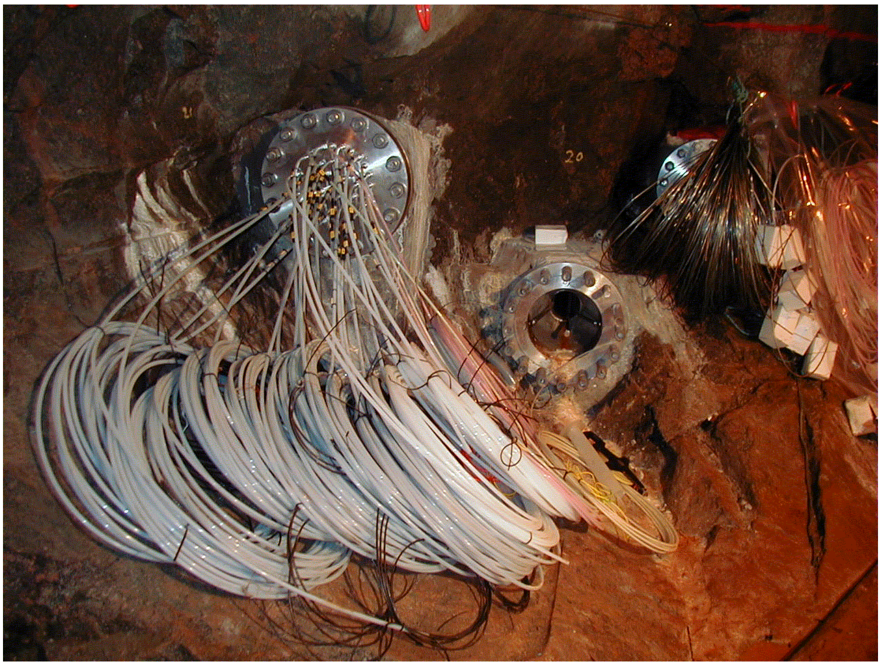

Figure 3-1 *Installed lead-throughs with cables and instruments in the Prototype tunnel ready to be placed in the bentonite blocks in deposition hole # 3. The empty lead-through is for the electrical cables to the heaters and the fibre optical cables.*

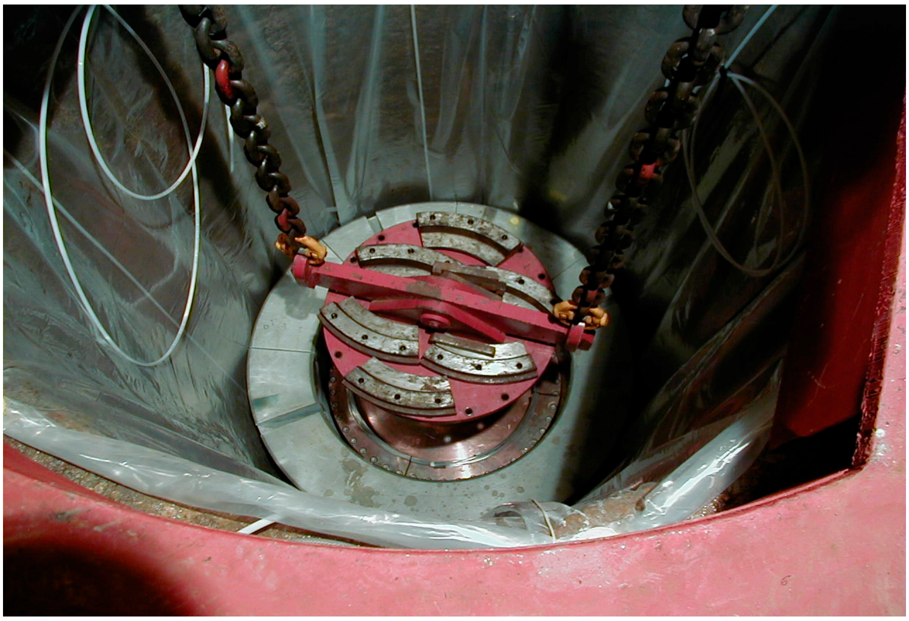

Figure 3-2 *The canister is in place inside the column of bentonite cylinders in hole # 2. The gripping device has been made free from the lid and is being raised. The plastic covering the walls is installed for protection of the bentonite because of the long time between installation of blocks and backfilling of the tunnel, and will be removed before the slot is filled with bentonite pellets.*

The canister C9 with only 30 mm copper thickness was delayed due to late delivery of the cast insert, so this canister will be placed in the last hole to be installed in Section I, i e hole #1 from the front, instead of in hole # 3 from the front. The difference between the holes is that the canister in hole # 3 will reach the highest temperature, estimated to be approx. 90°C, and the rock around this hole is more densely instrumented.

Planning for instrumentation of Section II has started.

Two EC Milestones have been met:

- Sensors and sampling equipment for installation in buffer, backfill and rock in Section I delivered to Äspö.
- Selection of THMBC models for use in the project.

Planned work

The installation of hole # 1 will be completed.

Backfilling will start with the inner part of the section where a more permeable material is used in order to provide for drainage in the same way as was done in the inner part of the Backfill and Plug test. A pump will be installed for drainage during the backfilling process and the pump will be left in place. (Also similar to the procedure in the Backfill and Plug test.)

Just before each installed hole is going to be covered with regular backfill (consisting of 70% crushed rock and 30% bentonite) the slot between the rock and the bentonite blocks is filled with pellets and possibly water, if the natural inflow is not too large for providing quick swelling of the bentonite in the hole. The situation is presently being analysed. Only a part of the Section I will be completed during the third quarter of 2001 with the aim to be ready with the whole section in early December.

Deliverables coupled to the EC project due during the third quarter of 2001:

- D2: Instrumentation of buffer and backfill in Section I.
- D4: Instrumentation for hydraulic measurements in Section I.
- D7: Instrumentation for gas and water sampling in buffer and backfill in Section I.
- D9: Instrumentation for resistivity measurements in buffer, backfill and rock in Section I.
- D12: Preparation of deposition holes prior to emplacement of buffer and canister in Section I.
- D33: Selection of THMCB models.

EC is also asking for:

- Annual report on scientific and technical achievements.
- Second 6-month presentation of progress in relation to work and time plans.
- Annual report on incurred costs.

No EC Milestones are due during the third quarter of 2001.

3.3 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 set-up 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 1999. Wetting of the backfill from the filter mats and the rock has continued during the year 2000.

New results

Figure 3-3 shows an illustration of the experimental set-up. The following main events and results from the second quarter of 2001 can be mentioned:

The water pressure applied in the filter mats in the 30/70 mixture and at the plug has been kept at 100 kPa.

- Water saturation, water pressure and swelling pressure in the backfill and water pressure in the surrounding rock have been continuously measured and recorded. Figure 3-4 and Figure 3-5 show example of measured results. Figure 3-4 shows the water pressure in the rock measured in the short bore holes about 30 cm below the floor of the tunnel. Figure 3-5 shows the suction (negative pore water pressure) measured in the centre of different layers of 30/70. Only the sensors placed in the first layers (about 20 cm from the mat) have been clearly water saturated. A slow decrease in suction in transducers W17 and W20 started in September, which indicates that wetting has reached 40 cm from the mats and that it continues in a slow rate.

- Reporting of the experimental set-up is in progress.

- The interface between the concrete plug and the rock was grouted in the last week of June. The grouting was made through three perforated plastic tubes that were installed on the rock wall before casting of the plug. The three tubes are running tangentially in the slot at different distances from the outer intersection between the slot and the tunnel. The inner and outer tube were injected with cement and the central tube was injected with polyurethane-based grout.

Planned work

In the third quarter of 2001 the water saturation will continue with consecutive measurement of water inflow, water pressure, total pressure and wetting.

The tightness of the plug after the grouting will be measured by applying different overpressures in the mat inside the plug and measure the flow through the plug.

If the plug is tight enough the stepwise increase in water pressure in the permeable mats will start, in order to reduce the time to reach saturation.

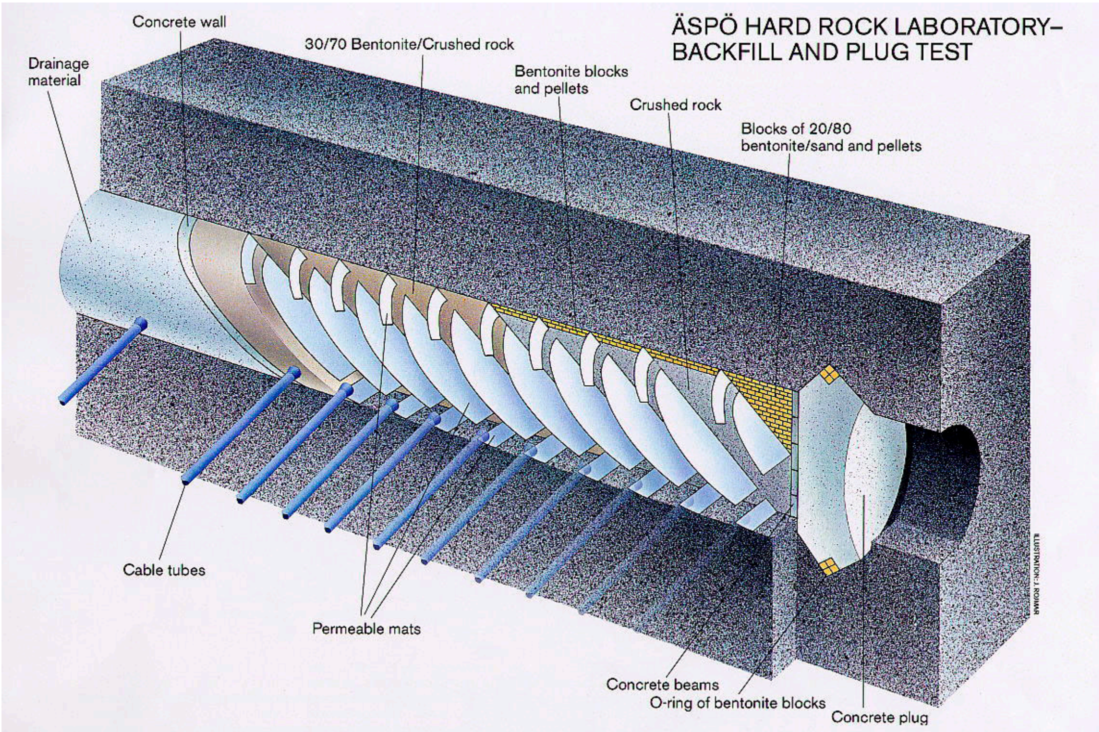

Figure 3-3 *Illustration of the experimental set-up of the Backfill and Plug Test.*

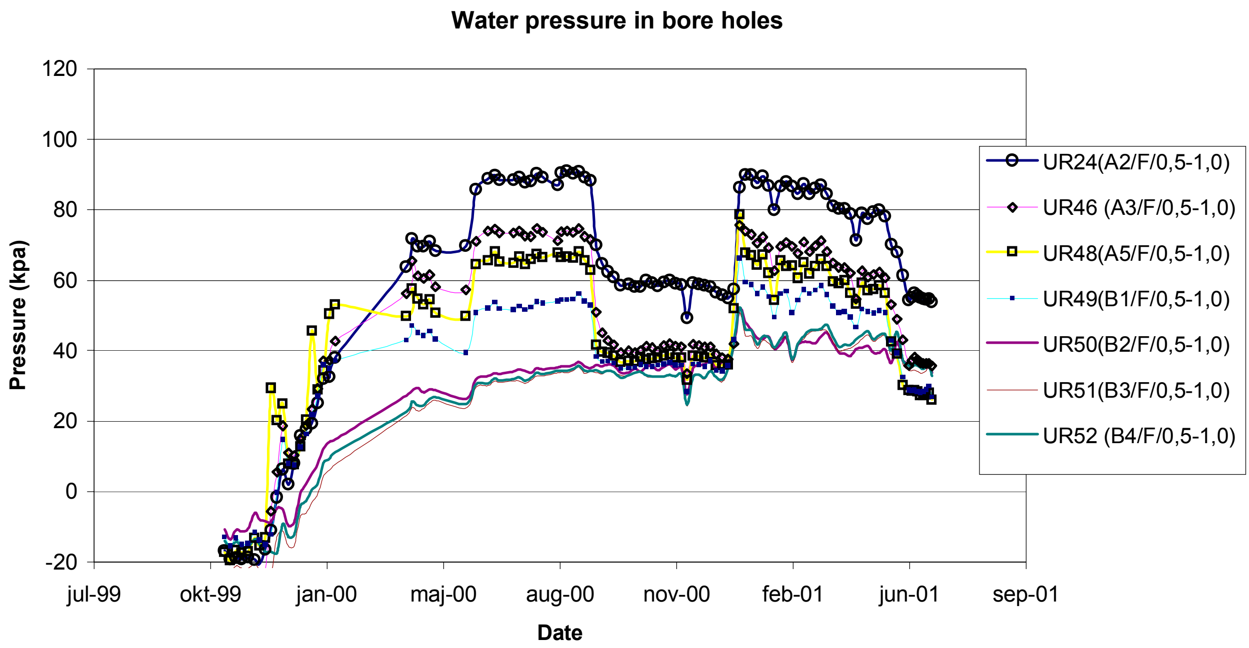

Figure 3-4 *Water pressure measured in the rock 30 cm below the floor. UR24, 46, 48 and 49 are placed in the 30/70 sections and the rest in the 0/100 sections.*

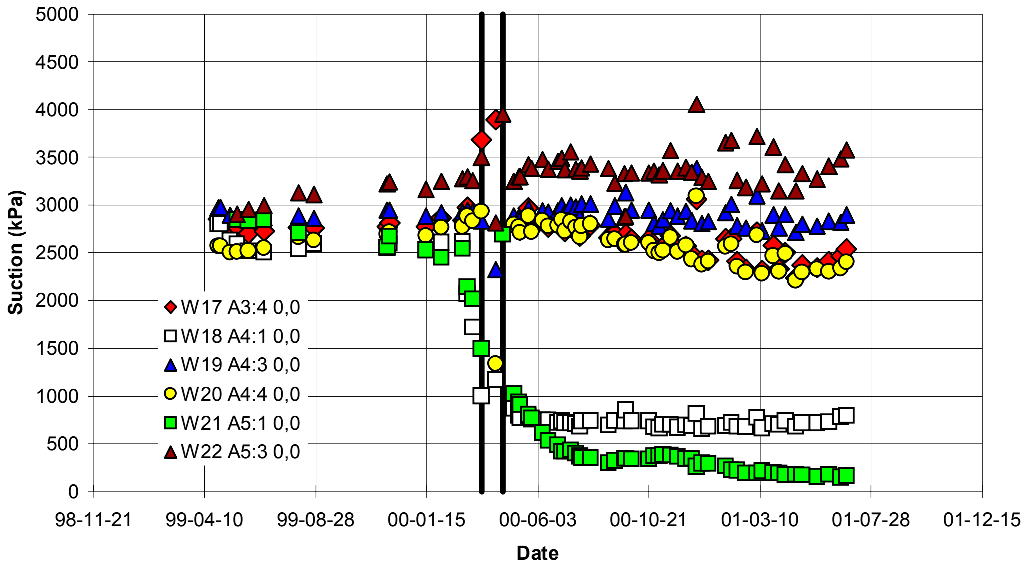

Figure 3-5 *Suction measured in the centre of different layers in the 30/70 backfill. W18 and W21 are placed in the first layer about 20 cm from the mats. W17 and W20 are placed 40 cm and W19 and W22 are placed 60 cm from the mats.*

3.4 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 disposed canisters also after the time when the bentonite has swollen. The process covers the retrieval up to the point when the canister is safely resting 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.

The installation of the buffer material and the canister with instrumentation and heaters started mid September 2000 and was completed during October 2000 including the in-situ casting of the concrete plug on top of the bentonite buffer. The heaters were turned on and the artificial watering of the buffer material started in October, and the operation of the Canister Retrieval Test is planned to continue for some 4 to 5 years, until the bentonite buffer has been fully saturated. The concrete plug on top of the bentonite buffer is held in position with help of 9 wire ropes that are secured in the rock by grouting. The wire ropes are designed for a maximum swelling pressure of 5 MPa from the buffer material.

The experimental set up is shown in Figure 3-6.

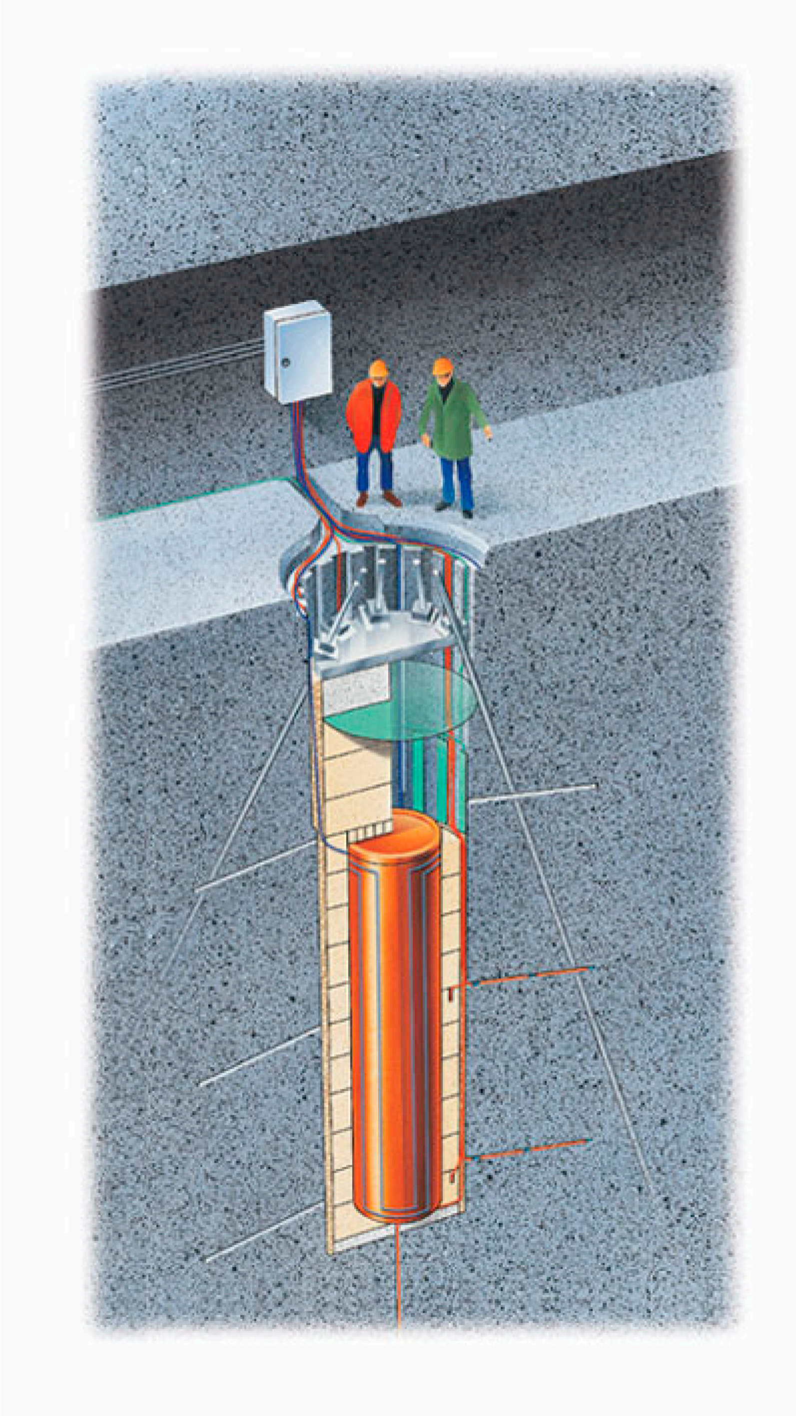

Figure 3-6 *Experimental set up. The horizontal holes are equipped with thermocouples and the sub-vertical holes indicate the anchoring ropes. Instruments in the buffer are placed on the same level as the three levels for thermocouples in the rock. Stripes of permeable mats are attached to the rock wall and fibre optical cables for temperature measurements are attached to the surface of the canister.*

New results

The artificial water supply to the surrounding permeable mats has continued and the flow registered. The final thermal load of 2600 W in the canister has been on since February 13th, and the sensor readings have continued.

The second sensor data report, covering the period from start of heating – October 26th, 2000 – up till May 1st, 2001, has been published.

The general conclusion is that the measuring system and transducers seem to work well but some problems have been noted. The strain measurements in the canister are presenting too high values, and a re-calibration is needed though uncertain to carry through. The evaluation of the stress and strain measurements in the rock is still in progress but is close to being completed. The fibre optical cable has periods with no data.

And, some Vaisala relative humidity transducers, located in ring 10 (top ring around the canister lid) have failed due to water saturation. These transducers can not work under full saturation condition, so the failures were expected.

Temperature inside the canister and in the bentonite buffer are shown in diagrams below, as well as the displacement of the plug on top. For further data readings please consult /IPR-01-25, Canister retrieval test, sensor data report (period: 001026-010501). Report No: 2/.

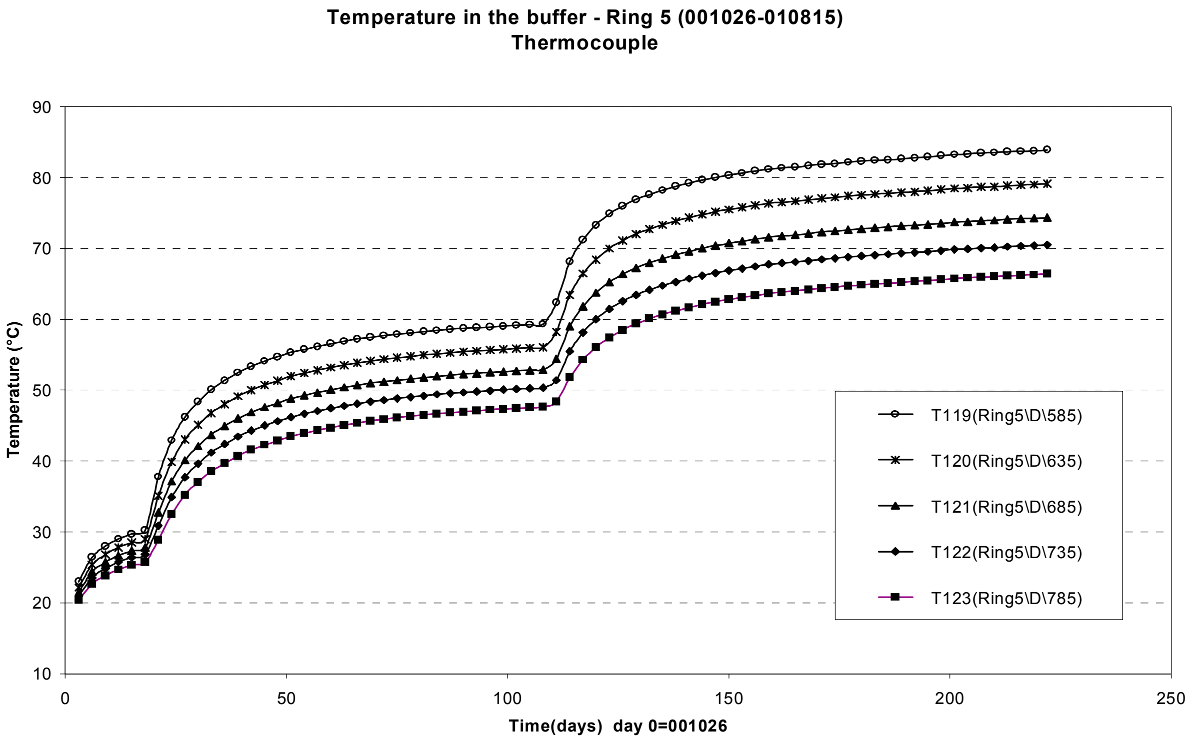

Figure 3-7 *Temperature in the bentonite at mid-height of the canister (each buffer ring is 500 mm high). Instrument T119 is located 60 mm from the canister.*

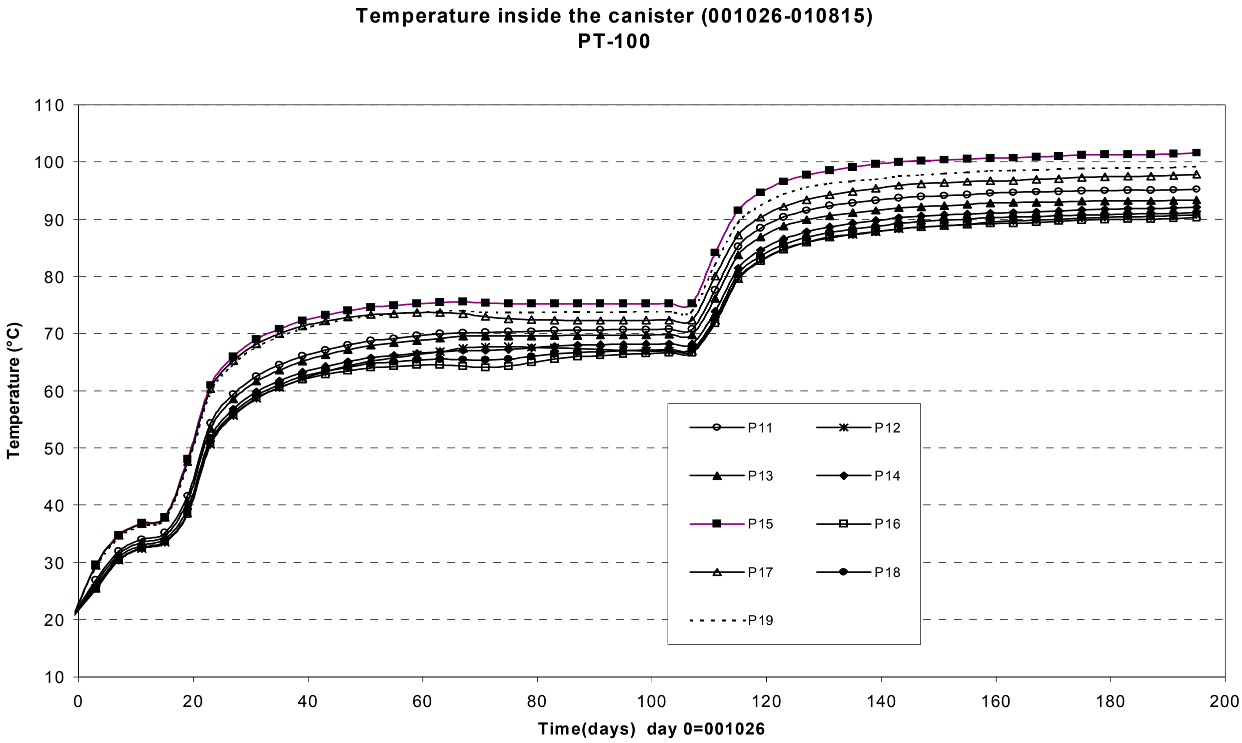

Figure 3-8 *Temperature inside the canister at different locations. P11, P12 and P13 are located on the outside of the steel insert at mid-height, while P14 and P15 are located in the centre of the cast insert at 200 mm and 2285 mm respectively from the top. P16 and P17 are located in one of the outer cells for assemblies at 200 mm and 2285 mm respectively from the top, and P18 and P19 in another of the outer cells also at 200 mm and 2285 mm respectively from the top.*

The temperature on the surface of the canister has at mid-height reached 91°C, which is the place where the highest temperature is experienced on the canister.

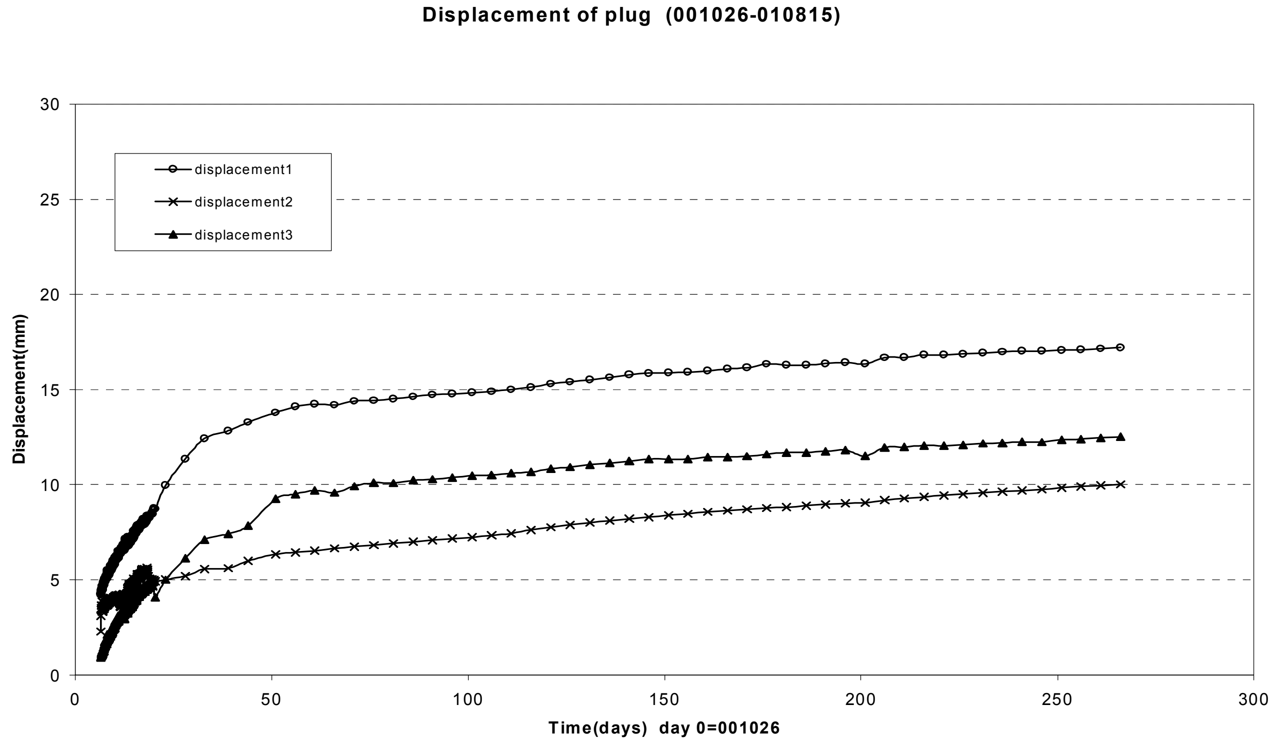

Figure 3-9 *The displacement of the plug is measured in three points. The initial tilting of the plug has ceased and the displacement is now equally large in all three point.*

Planned work

The plan is to continue the artificial water saturation of the bentonite and to continue the registration of sensor readings. No modelling work is planned for the next three-month period.

Stress and strain data from instruments in the rock are prepared for being reported on a regular basis.

3.5 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, radionuclide 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 3-1) is to place prefabricated units of clay blocks surrounding heated copper tubes in vertical bore holes. The test series are performed under realistic repository conditions except for the scale and the controlled adverse conditions in three tests.

Table 3-1. 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 bore holes 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 bore hole. The water distribution in the clay will be determined and subsequent well-defined chemical, mineralogical and physical testing will be performed.

New results

The data acquisition concerning temperature, water pressure, total pressure, and moisture has in principle been well functioning. The results show that the water uptake is not completed in any of the 5 parcels. The A0 parcel seems to be closest to full saturation, which is in accordance with the artificial water inlets at 3 levels in this parcel. However, the recorded maximum pressure is still significantly lower than expectation, and the pressure is in general increasing in all parcels Figure 3-10. Large differences between the parcels indicate significant differences in water supply from rock. Small temperature tendencies are visible and can be correlated to water uptake, rock heating, and temperature changes in the tunnel due to seasonal changes.

Planned work

Excavation and analyses of the A0 parcel, will be made during the end of the year. Planning and preparation for the uptake have started and the drilling for retrieval is planned to begin in October. An uptake-planning meeting will be held in mid September. Subsequent analyses of the bentonite material will start immediate after uptake and will be finalised during the spring 2002.

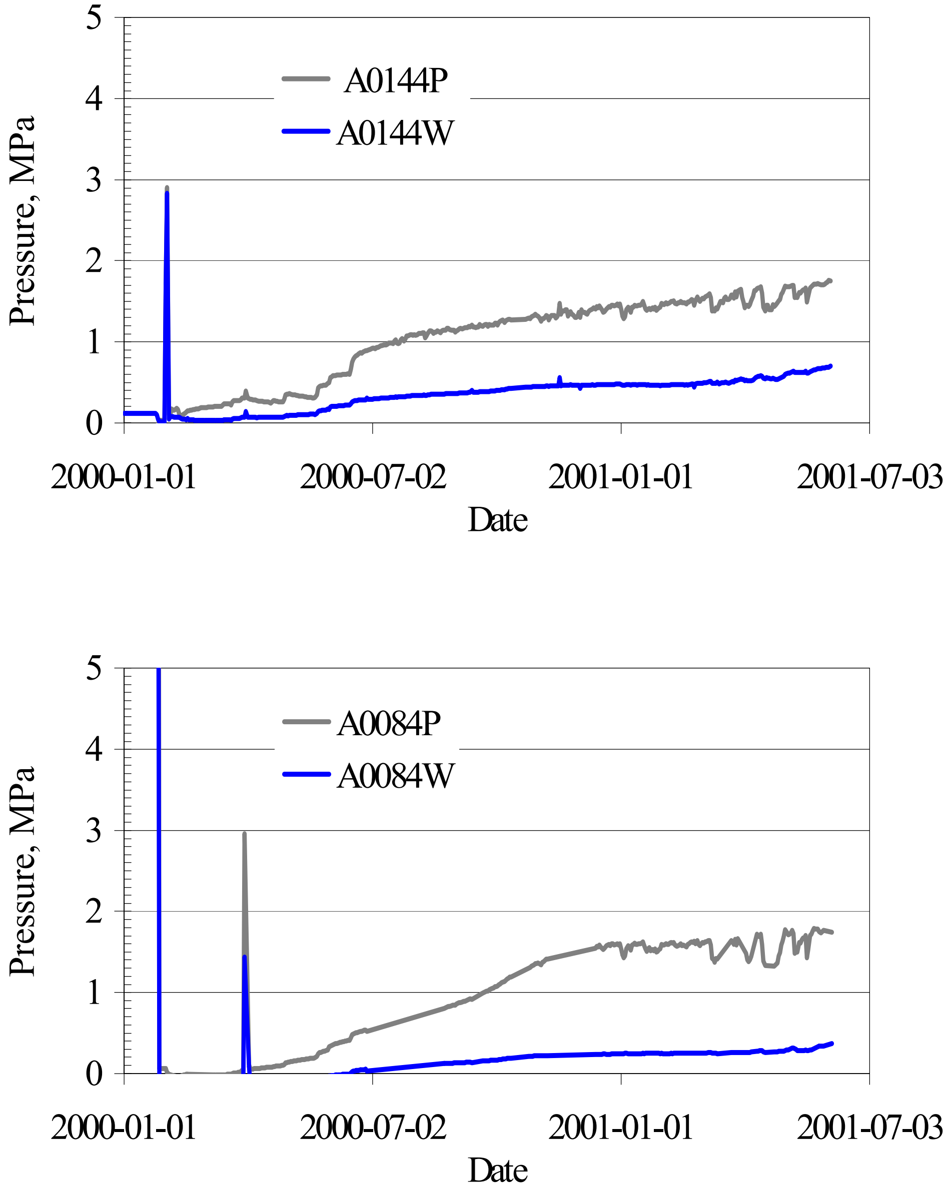

Figure 3-10 *Pressure data from the lower part in Parcel A0 as measured by vibrating wire technique (lower diagram), and from the central part as measured by optical sensor technique (upper diagram). Upper curves show total pressure and the lower ones show water pressure, respectively.*

4 Äspö facility operation

4.1 Plant operation

The status of the facility is good both from an environmental and operational point of view.

In order to lower cost and increase operational efficiency the maintenance agreement with the main contractor is looked over. Former services provided is harder to get due to the OKG reorganisation and outsourcing of maintenance groups. Opportunity to make maintenance-agreements with others has therefore emerged and is taking place.

The supplementary work with rock reinforcement was completed in February 2001. Critical parts in the tunnel have been reinforced in order to insure environmental and operational safety. The reinforcement work has expanded as it has proceeded and the need was nearly twice the volume that originally was planned.

The Äspö-road has been refurbished and coated with tarmac. The work with the road is to be completed with a final coating of gravel mixed with bitumen in mid July.

The project to improve fire safety is in progress. The project is based on suggestions from a fire risk analysis made in 1999. Traffic lights have been installed in a high-risk part of the tunnel and will continue with additional installation of fire detection system in the 420-m level and voice-alarm in strategic areas of the tunnel. The installation of the fire detection system is in progress and estimated to be in operation in July. Installation of voice-alarm is to follow and completion is estimated in Sept.

Due to lack of office-space and reorganisations to come, a two-storey barrack, housing 16 offices and 2 conference rooms has been built adjacent to the laboratory on ground. The work was completed in March and was taken in use during week #15 2001

The project for hands-free-registration going underground is in progress. As feasibility study was completed and a request for offers was sent out. The incoming offers have been evaluated and three companies where selected and invited to make a detailed study of the facility. One of the companies has been chosen as a feasible deliverer of the system. The plan is to sign a delivery agreement in August 2001.

4.2 Data management and data systems

Background

Management of investigation data is a highly demanding and critical task in the presented siting 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 are presented in the following subsections.

New results

GIS

In order to co-ordinate the development of GIS, SICADA and RVS a steering group has been formed. The first meeting was held on 4th May. At this meeting the system administration team recommended an implementation of ESRI/ArcSDE and ArcIMS. ArcSDE requires Oracle RDBMS. The steering group decided to follow this recommendation, and currently a project has been formed to execute the work to be done. A couple of new Windows NT servers are needed. They have already been ordered, delivered and configured. Oracle, ArcSDE and ArcIMs have been ordered.

SICADA

The data structure in SICADA is currently maintained with a system administration application called GTAdmin. This application is a relic of the era of text based user interfaces. Several improvements are needed as well. We have decided to improve and modernise GTAdmin by using the programming environment Delphi. The new version will be called SICADA Admin.

RVS

Programming of version 3.0 is ongoing. The efforts are focused on implementation of a new modelling concept developed by a PLU-project named GEOFUNK. The programming activities take place in five stages. Currently the ongoing work is following the time schedule of the project. Stage two has just been finalised.

Planned work

GIS

The following activities will be executed during the next period (July-September 2001):

- Implementation of Oracle and ESRI/ArcSDE
- Implementation of ESRI/ArcIMS
- Transfer of existing GIS data into ArcSDE
- Evaluation of the field application ESRI/ArcPAD

SICADA

SICADA Admin will be delivered in August 2001 and implemented in September 2001. This is a prerequisite before implementing new data structures supporting the investigation methods planned to be used in the planned site investigations.

RVS

Implementation of RVS version 3.0 is planned to take place in December 2001. The new version will be based on MicroStation V8. This new version of MicroStation will be released in the autumn 2001. MicroStation is a product of Bentley Systems Incorporated.

4.3 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 bore holes. Additionally, the electrical conductivity of the water in some bore hole sections and in the tunnel water is measured. The network includes bore holes on the islands of Äspö, Ävrö, Mjälen, Bockholmen and some bore holes 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 acquisition in support of the various project undertaken in the Äspö HRL.

This support consists of providing data from bore holes affected by an experiment and of utilising the HMS infrastructure for collection and monitoring of experiment-specific data.

A project is ongoing performing an overall evaluation of the Hydro Monitoring Program. This work is done in support of the Äspö activities where a feedback based on experience is due and also in support of the coming geo-scientific site characterisation. A draft report has been compiled.

The Tidal Fracture Zone analysis project has delivered draft final report. This project aims at evaluating the feasibility of utilising tidal fluctuation of monitoring data in order to calculate fracture orientation.

Planned work

For the next quarter it is planned to

- Continue to support various projects at Äspö with monitoring data.
- Continue and complete the overall evaluation and assessment of the Hydro Monitoring System by producing a final report.
- Complete the project on fracture orientation from tidal groundwater head fluctuations from HMS data by producing a final report.

4.4 Information

New results

During the second quarter of 2001, 3758 persons (2331 during the first quarter of 2001) visited the Äspö HRL. The groups represented the public, communities where SKB has performed feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries.

2170 persons represented the six communities where SKB has performed feasibility studies.

Urberg 500

The U500 tourist tours of 2001 had a "kick off" on June 5th , and opened for the general public on June 8th.

Two summer guides take care of the tours; two tours are offered every day except during weekends, when only one tour is made per day.

Äspö Day

On May 6th the yearly Äspö Day took place. This is a popular event for people living in the surrounding areas. New for this year was information on what a "Site investigation" means. For that purpose a special "site" was been built near Äspö research village.

The 400 visitors were offered a tour in the Äspö HRL. There were also guided tours on flowers, birds, geology and ancient monuments on the Äspö island.

Special projects

- The exhibitions both in the exhibition hall and under ground in the tunnel are updated and renewed.
- Education on fire security and first aid.

5 International Co-operation

5.1 Current international participation in the Äspö HRL

Nine organisations from eight countries are currently (July 2001) participating in the Äspö Hard Rock Laboratory.

In each case the co-operation 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 characterisation. Several organisations are participating in the Äspö Task Force on groundwater flow and radionuclide migration, which is a forum for co-operation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock.

Tabell 5-1. Scope of international co-operation

Organisation	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 Prototype Repository CROP – Cluster repository project (EC project)
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* geo-electrical measurements with respect to water saturation of rock masses in the near field of underground tunnels Work on design and performance of *in-situ* tests

Organisation	Scope of participation
	using methods and equipment similar to those used in the Grimsel investigations Prototype Repository CROP – Cluster repository project (EC project)
Empresa Nacional de Residuos Radiactivos, **ENRESA**, Spain	Backfill and Plug Test Prototype Repository CROP – Cluster repository project (EC project)
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 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 Prototype Repository CROP – Cluster repository project (EC project)
United Kingdom Nirex Limited, **NIREX**, Great Britain	TRUE Block Scale
POSIVA , Finland.	Testing of models describing the barrier function of the bedrock Testing and demonstration of repository systems in full scale Verification of the function of repository system components Prototype Repository CROP – Cluster repository project (EC project)
USDOE/**Sandia National Laboratories**, USA	Test of models describing the barrier function of the bedrock

5.2 Prototype Repository – EC project

The Prototype Repository is co-funded by the European Commission during a 42 months period starting September 2000 with SKB as the co-ordinator. The EC part coincide with the project work (see Section 4.2 above) during that specific time with minor exemptions. The participants are shown in Table 6-2.

Tabell 5-2. Participants in the Prototype Repository EC project

Principal contractors	Associated contractors
SKB (co-ordinator)	GeoDevelopment, VBB VIAK and Clay Technology
Posiva (FI)	VTT
ENRESA (E)	AITEMIN and CIMNE
GRS (G)	
BGR (G)	
UWC – Univ Wales Cardiff (UK)	
JNC (J)	
ANDRA (F) (in process of joining)	

5.3 CROP – Cluster repository project

The CROP is a Thematic Network with the intention to form a basis for evaluating and developing concepts of final repositories for high-level radioactive waste. The objects are primarily: to work out a document that can serve as an aid for future repository design and construction with focus on EBS, and to create a forum for exchange of information on repository design, construction and operation. The European Commission funds the participation of the European organisations but not the non-European ones. The project time is 36 months from the start in February 2001 and SKB is the co-ordinator.

The work is separated into four Work Packages:

WP1. Design and construction of engineered barrier systems (EBS)

WP2. Instruments and experimental procedures

WP3. Assessment of the function of EBS and understanding of their performance and the capability to model important processes

WP4. System assessment and development of improved HLW concepts

In each WP one country annex is compiled by each of the participants, see Table 6-3, and one summary text. They make together the deliverable for that WP.

WP #1 and #2 have started and been in progress during the period. The deliverables are due12 months after the start of the project.

Contractor	**Member to Contractor**
SKB (co-ordinator)	**GeoDevelopment (S)**
SKC-CEN (B)	
POSIVA (FI)	
GRS (G)	
ENRESA (E)	
ANDRA (F)	
NAGRA (CH)	
OPG (CAN)	
USDOE CBFO (US)	
DBE (G) (in process of joining)	

6 Other matters

6.1 Documentation

During the period April – June 2001, the following reports have been published and distribuated:

6.1.1 Äspö International Co-operation Reports

None.

6.1.2 Äspö International Progress Reports

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

Svemar, C., Pusch, R., 2000
Prototype repository. Project description FIKW-CT-2000-00055.
IPR-00-30

Persson G., Broman O., 2000
Prototype repository. Project plan FIKW-CT-2000-00055.
IPR-00-31

Forsmark T., Andersson C., 2000
Prototype repository. Hydrogeology - Deposition and lead-through bore holes: Inflow measurements, hydraulic responses and hydraulic tests.
IPR-00-33

Smellie J., 2000
Status Report of the Matrix Fluid Experiment. June 1998-June 2000.
IPR-00-35

Pettitt, W., 1999.
Acoustic emission and ultrasonic monitoring during the excavation of deposition holes in the Canister Retrieval Test.
IPR-01-02

Li, C., 2001.
Long Term Diffusion experiment. Microscopic observation of distrubance in drill core samples from KA3065A02 and KA3065A03.
IPR-01-03

Holmqvist, M., Andersson, P., 2001.
TRUE project. In-situ test of borehole equipment for tracer injection, RC-4.
IPR-01-04

Goudarzi, R., Gunnarsson, D., Johannesson, L-E., Börgesson, L., 2001.
Sensor data report (Period 990601-010101). Backfill and Plug Test. Report No: 2.
IPR-01-05

Jansson, P., 1999.
Prototype Repository. Finite element analyses of heat transfer and temperature distribution in buffer and rock.
IPR-01-07

Laaksoharju, M., 2000.
Project description of the Äspö project COLLOID with the aim to investigate the stability and mobility of colloids.
IPR-01-08

Äspö Hard Rock Laboratory.
Status Report October - December 2000.
IPR-01-10

Äspö Hard Rock Laboratory, 2001.
Planning Report for 2001.
IPR-01-12

7 Technical Document

0 International Technical Document

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Concentrations of particulate matter and humic substances in deep groundwaters and estimated effects on the adsorption and transport of radionuclides.
SKB Technical Report TR 91-50

Andersson, J., Almén, K-E., Ericsson, L O., Fredriksson, A., Karlsson, F., Stanfors, R., Ström, A., 1998
Parameters of importance to determine during geoscientific site investigation
SKB TR 98-02

Bäckblom, G., Olsson, O., 1994.
Program for tracer retention understanding experiments.
SKB Progress Report PR 25-94-24

Cvetkovic, V., Cheng, H. and 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.

Goudarzi, R.; Börgesson, L., 2001
Äspö Hard Rock Laboratory. Canister Retrieval test. Sensor data report
(Period: 001026 - 010501) Report No: 2.
SKB International Progress Report IPR-01-25

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

Jansson, M;. Eriksen, T,. 2001
CHEMLAB. A probe for in-situ radionuclide experiments. Diffusion studies.
SKB Technical Report TR-01-14

Kertsting A, Efurd D, Finnegan D, Rokop D, Smith D, Thopmson J, 1999.
Migration of plutonium in the ground water at the Nevada Test Site. Nature, Vol 397, January 1999, pp 56-59.

Laaksoharju M, Degueldre C, Skårman C, 1995.
Studies of colloids and their importance for repository performance assessment.
SKB Technical Report TR 95-24

Li, C., 2001 :
Äspö Hard Rock Laboratory. Long-Term Diffusion Experiment. Microscopic observation of disturbance in drill core samples from KA3065A02 and KA3065A03.
SKB International Progress Report IPR-01-03

Smellie, J., (editor) 2000
Äspö Hard Rock Laboratory. Status report of the Matrix Fluid Experiment June 1998 - June 2000.
SKB International Progress Report IPR-00-35

Winberg, A., Andersson, P., Hermanson, 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.

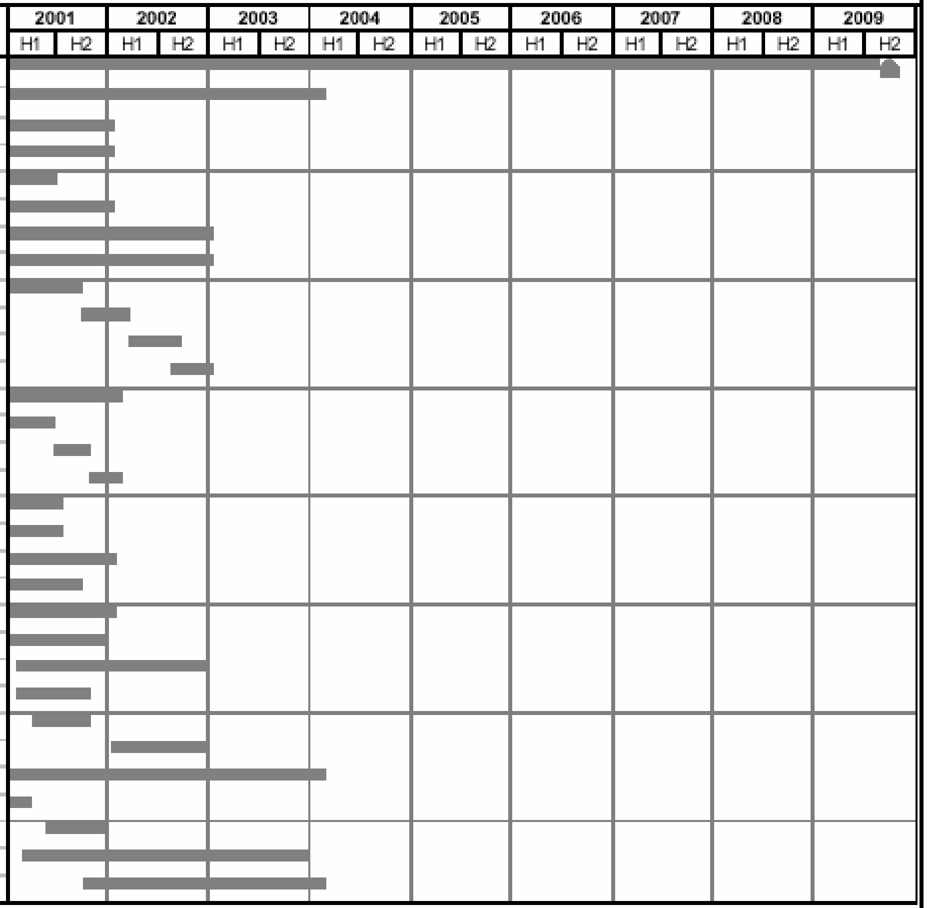
Appendix A

MASTER SCHEDULE ÄSPÖ

Christer Svemar

Äspö Plan Right
Version 2000.1

WBS	Namn
0	MASTER SCHEDULE ÄSPÖ
1	TEST OF MODELS OF THE BARRIER FUNCTION OF THE HOST ROCK
1.1	TRACER RETENTION UNDERSTANDING EXPERIMENTS
1.1.1	TRUE Blocks Scale
1.1.1.1	Tracer test stage
1.1.1.2	Evaluation and reporting stage
1.2	RADIONUCLIDE RETENTION
1.2.1	Actinideexperiment
[illegible]	Field experiments I
[illegible]	Field experiments II
1.2.1.3	Field experiments III
1.2.1.4	Reporting
1.2.2	Radiolysisexperiment
1.2.2.1	Laboratory work
1.2.2.2	Realization radiolysis
1.2.2.3	Reporting
1.3	LONGTERM STABILITY/HYDROCHEMICAL STABILITY
1.3.1	Realization
1.4	MATRIX FLUID CHEMISTRY
1.4.1	Drillcore study
1.4.2	Fluid sampling
1.4.3	Supplementary studies
1.5	COLLOIDS
1.5.1	Laboratory tests
1.5.2	Field tests
1.5.3	Reporting
1.6	MICROBE
1.6.1	Initiation
1.6.2	Preparation
1.6.3	Realization
1.6.4	Reporting



MASTER SCHEDULE ÄSPÖ

Christer Svemar

Äspö Plan Right
Version 2000.1

WBS	Namn
2	DEMONSTRATION OF TECHNOLOGY FOR THE REPOSITORY SYSTEM
2.8	PROTOTYPE REPOSITORY
2.8.1	Preparation of installation, inner section
2.1.2	Installation of inner section
2.8.1	Preparation of installation, outer section
2.1.4	Installation of outer section
2.2	BACLFILL AND PLUG TEST
2.2.1	Water saturation
2.2.2	Flow & Mechanical testing
2.2.3	Backfill excavation
2.2.4	Evaluation and reporting
2.3	CANISTER RETRIEVAL TEST
2.3.1	Saturation
2.3.2	Finish report
2.4	LONG TERM TEST OF BUFFER MATERIAL (LOT)
2.4.1	A0 Heating Tests
2.4.2	A2 Heating Tests
2.4.3	A3 Heating Tests
2.4.4	S2 Heating Tests
2.4.5	S3 Heating Tests
3	ÄSPÖ FACILITY OPERATION
3.1	EXTENTION FIRE ALARM UNDERGROUND
3.1.1	Initiation
3.1.2	Preparation
3.1.3	Realization
3.1.4	Reporting
3.2	ROCKA VISULATIZATION SYSTEM
3.2.1	Implementation version 3.0