International Progress Report

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Äspö Hard Rock Laboratory

Status Report

July – September 1999

October 1999

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Summary

Investigations and experiments

The barrier function of the host rock

The Tracer Retention Understanding (TRUE) aim at further developing understanding of radionuclide migration and retention processes and evaluation of different approaches to modelling such processes. The TRUE-1 tests are performed over distances of about 5 m in a fracture at approximately 400 m depth. Modelling of STT-1 and STT-1b have been performed using a modified double porosity model assuming mass transfer into the rock matrix and mass transfer into stagnant zones of water. It was possible to estimate a consistent set of transport parameters for all tracers, using laboratory-estimated sorption distribution coefficients.

Four pilot boreholes have been drilled using triple tube technique to identify new sites for the TRUE-2 and Long Term Diffusion Experiments (LTDE). BIPS borehole TV logging and POSIVA flow logging in combination have identified a series of suitable candidate fractures for the planned experiments.

The TRUE Block Scale project aims at studying the tracer transport in a fracture network over distances up to 50 m. The main field activity during the period has been drilling and characterisation of the new borehole KI0025F03. In addition a modelling workshop has been held in Bålsta. This meeting served as a platform for defining a strategy for predictive modelling of tests with sorbing tracers.

This Long-Term Diffusion Experiment is intended as a complement to the dynamic in-situ experiments and the laboratory experiments performed in the TRUE Programme. The basic idea is to locate a static tracer experiment to unfractured rock mass with the intention to characterise diffusion of radionuclides into the rock matrix. Performed scoping calculations using available diffusivity data indicates that diffusion will range from mm:s for the strongly sorbing tracers to dm:s for the weakly sorbing tracers over a period of four years. Two potential experimental sites have been identified and data from these sites are scrutinised.

The detailed scale redox experiment (REX) studies the behaviour of oxygen that will become trapped in the tunnels when the repository is closed. Both replica experiment at CEA Cadarache, and the *in-situ* experiment at Äspö are completed. The data collected is being interpreted in order to obtain a mechanistic model for the O_2 consumption rates. The drillcores used in the replica and field experiments have been examined for mineralogical changes and biofilm formation. Final project reports are being drafted.

The CHEMLAB probe has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. A new CHEMLAB site has been equipped in the J-tunnel to host the two systems, CHEMLAB I and II, together with experiments related to the microbial activity. Preparations for the radiolysis experiments have been completed. A licence to carry out the Radiolysis experiments has been received from the Swedish Radiation Protection Institute.

The objectives for the investigations of degassing of groundwater and two-phase flow are to show if degassing of groundwater at low pressures has significant effects on measurements of hydraulic properties in boreholes and drifts. A new procedure has been

devised to estimate the characteristic relations for unsaturated flow when data on aperture statistics is limited.

The Matrix Fluid Chemistry experiments has the aim to determine the origin and age of matrix fluids and to establish to what extent the composition of matrix fluid has been influenced by diffusion processes. A ’Matrix Fluid Experiment Workshop’ was held at Äspö on September 6/7 when initial results were presented and discussed, and future plans were laid down. Two drillcore sections from the matrix fluid borehole have been selected for mineralogical and geochemical scoping studies.

The Task Force is a forum for the organisations supporting the Äspö Hard Rock Laboratory Project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. An overall evaluation of Task’s, 4C and 4D (to predict groundwater drawdown and solute transport in a single fracture), has been undertaken and reported in the technical report series as SKB TR-99-04.

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. An application for EC-funding of the project under the 5th Framework Programme has been submitted. Drilling of the six deposition holes in the experimental tunnel has been completed.

The Backfill and Plug Test comprises full scale testing of backfill materials, filling methods, and plugging. The backfilling of the test drift started at the end of 1998 and was completed in July 1999. The plug to seal the test drift was cast on September 23 by pumping about 70 m^3 concrete into the mould. The panels and the tube system for measuring water pressure in the rock and for the flow testing have been installed in the data collection house. Registration of data from the 200 gauges has successively started.

The Long Term Tests of Buffer Material aim to validate models and hypotheses concerning long term processes in buffer material. The planning and construction of the four long-term test parcels (5-20 years) and the extra one-year parcel are completed. All parcels are/will be equipped with titanium filters in order to admit artificial water supply. The one year test parcel (A0) will be connected by tubes to a water supply hole. All instruments and heat controlling equipment for the two parcels have been installed and are found to work properly with the exception of one optical sensor. Both were equipped with instruments , bacteria and the latter with the radioactive tracer Co-60 according to plans. Laboratory characterisation of the test material has started and will continue during the rest of the year.

International Cooperation

Nine organisations from eight countries are currently (June 1999) participating in the Äspö Hard Rock Laboratory.

Groundwater sampling is carried out in Laxemar area in the deep borehole KLX02 as a part of the on-going SKB-Posiva Hydrochemical stability project. The aim is to test the functioning and field operation of PAVE, Posivas pressurised groundwater sampling equipment, in deep borehole conditions. Four sections have been selected to be sampled with the PAVE sampler. Flow rates for the three sections tested so far have varied from 450 ml/h to 6 l/h. Flow measurements have been carried out in borehole KI0025F03 at the True Block Scale site on September 21-22. Posiva's detailed flow logging method was used with 1 m section length and 0,1 m depth increments.

Facility Operation

The ”five year inspection” of the underground facility started this summer. The work will be completed during the autumn. The result so far has pointed out a few areas were intense reinforcement is necessary. Systematic bolting and mesh/spray concrete will probably be used.

Data Management and Quality systems

A project is in progress to implement a common management system for SKB to break down all requirements from legislator, authorities and from other interested parties and also internal requirements of our own organisation. The aim of the project is to certify SKB according to the Environmental Management System ISO 14001 and also to the new quality management standard ISO 9001 by October 1st year 2000.

Groundwater head and chemistry monitoring

The results from the groundwater sampling in October 1998 have been presented in TD-99-22. The results from the Monitoring program undertaken since 1995 have been presented in IPR-99-13. Sampling of 45 borehole sections has been performed during weeks 939 and 940.

Information activities

During the third quarter of 1999 3719 visitors visited the Äspö HRL. The groups have represented the general public, communities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries

During the summer there has been two ”Urberg 500” tours per day, in the weekends one tour per day. There has been a lot of interest in the tour and 1771 persons visited ”Urberg 500”. The visitors filled in a questionnaire, the result was that 98% of the visitors found the tour good or very good.

Because of the large interest from the public, ”Urberg 500” will continue every weekend until Christmas.

Contents

1 General

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

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

1 Verify pre-investigation methods

demonstrate that investigations on the ground surface and in boreholes provide sufficient data on essential safety-related properties of the rock at repository level.

2 Finalise detailed investigation methodology

refine and verify the methods and the technology needed for characterisation of the rock in the detailed site investigations.

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

further develop and at repository depth test methods and models for description of groundwater flow, radionuclide migration, and chemical conditions during operation of a repository and after closure.

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

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

2 Methodology for detailed characterisation of rock underground

2.1 General

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

Detailed characterisation will facilitate refinement of site models originally based on data from the ground surface and surface boreholes. The refined models will provide the basis for updating the layout of the repository and adapting it to local conditions. Due to the heterogeneity of the rock, the layout of the repository needs to be adapted to the gradually refined model of rock conditions. This approach has a long tradition in underground construction and it should be used also for a deep repository. During 1999 an updating of the geoscientific models of Äspö HRL will be performed.

2.2 Updating of the geoscientific models of Äspö HRL

Background

Some basic research that is not project-related is conducted at the Äspö HRL. This work is aimed at providing support for the research, development and demonstration projects by conducting and comparing measurements of common interest for all projects. According to SKB's planning, the suitability of geological formations for deep disposal of spent nuclear fuel will be evaluated with the aid of geoscientific models of the site in question, including:

- geological model,
- geohydrological model,

- groundwater chemical model,
- geomechanical model,
- heat transport model,
- radionuclide transport model.

These models are compiled in conjunction with a site investigation and present an aggregate of existing knowledge on a site.

On Äspö, geoscientific information has been systematically collected during the pre-investigation and construction phases. Data continues to be collected from the various tests and projects that are being conducted. The information that has been gathered up to now and including completion of the main tunnel down to a level of 450 metres has been used to devise site-specific models of the conditions on Äspö. The models contain dimensionality, material properties, method for specification of properties in the whole model, boundary conditions, numerical or mathematical tools, and what parameters the model depicts (Olsson et al., 1994). Structure and content are described in greater detail in Rhén et al. (1997). The purpose of constructing these models has primarily been to verify our ability to foresee the properties of a rock mass on the basis of information from completed site investigations.

The existing geological, geohydrological and groundwater chemical models of Äspö will gradually be revised, particularly in the light of the new information that is constantly obtained from the projects described later. A test plan for this modelling exercise, which is given the name GeoMode, was presented early 1999. The rock mass to be modelled cover the last tunnel spiral from the level of 340 m down to 460 m.

A heat transport model and a radionuclide transport model will also be developed but outside the GeoMode project.

Objectives

The aim of the project is to develop tools for constructing geological, geomechanical, geohydrological and groundwater chemical models as a basis for the different experiments to be conducted at Äspö HRL. The specific objectives are to:

- describe the rock volume in the last tunnel spiral
- define the initial and boundary conditions of importance to the different experiments
- integrate the knowledge for the different disciplines
- develop and refine tools for the model construction

The main goal is to construct an integrated model by June 2001. The individual geological, geomechanical, geohydrological and groundwater chemical models should be presented in January 2000. Necessary tools for input and visualisation of data, e.g. RVS and SICADA, should be further developed until September 2000.

Results

The project GeoMode started with planning and preparation of a test plan. The test plan has been sent for review and the test plan will be updated according to the comments. The test plan was printed in June 1999. A short course on geological modelling was held in June.

Planned work

A definition of the boundary conditions for the different subjects will be performed. A screening of data for the different subjects will then be performed. Input of data will follow and the first visualisation will be performed in early 2000.

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

3.1 General

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

Isolation is the prime function of the repository. It is obtained through the joint 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 1999, focus is on the sporadic high permeable features (HPF:s) which normally are not detected by remote sensing tools, e.g. borehole radar and other geophysical tools. The consequences to repository lay-out and implementation into numerical models will be assessed.

Hydrochemical stability and potential variability is assessed within several ongoing projects. These aim at explaining possible chemical conditions in a repository host rock based on assumption of different climate conditions in the future. Of special importance are redox conditions and microbial activity, which will be reported within the REX project during 1999.

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 which 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 that 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 put on the weakly retarded nuclides even if they are not dominating the hazard of the waste.

Tracer tests are carried out within experiments in the TRUE-projects. These are conducted at different scales with the aim of identifying detailed scale (5m) and block scale (50m) flow paths, retention of weakly and moderately sorbing tracers and the effect of matrix diffusion. During 1999 the goals are to complete the first detailed scale experiment (TRUE-1), complete the characterisation for the block scale experiment (TRUE-Block Scale) and initiate the matrix diffusion experiment (LTDE). Modelling of the experiments is done by several groups associated to the Äspö Task Force for modelling of groundwater flow and transport of solutes.

CHEMLAB experiments are conducted with the moderately and highly sorbing nuclides. Experiments are carried out in simulated near field conditions (bentonite) and in tiny rock fractures. During 1999 diffusion experiments will be completed and experiments including effects of radiolysis will start. A second CHEMLAB unit will be used for experiments with redox sensitive nuclides and transuranics also starting during 1999.

A particular transport phenomenon could be caused by gas which may carry nuclides from depth to surface. This two phase flow phenomenon is investigated in an on-going experiment conducted by GRS and BGR. During 1999 the outcome of this experiment will be modelled in cooperation with the GRS/BGR team.

3.2 Tracer Retention Understanding Experiments

Background

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

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

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

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

3.2.1 TRUE-1

Modelling of STT-1 and STT-1b have been performed in cooperation with Roy Haggerty. The aim of the performed continued evaluation is to evaluate the coherence in sorption and diffusivity data between laboratory derived and field estimated data. Breakthrough curves were evaluated using a modified double porosity model assuming mass transfer into the rock matrix and mass transfer into stagnant zones of water. The majority of parameters in the model were obtained directly from laboratory and field measurements. A total of 4 transport parameters were estimated simultaneously from 4 of the BTC data sets. By doing this, it was possible to estimate a consistent set of transport parameters for all tracers, using laboratory-estimated sorption distribution coefficients.

While laboratory sorption data allowed good predictions of transport for some tracers , poorer predictions resulted for other tracers. Therefore, the sorption coefficients were also interpreted individually from the field data, resulting in improved fits for some tracers. Field-estimated sorption coefficients for Co, Rb, Ba and Cs agreed within a factor of 4 with experimentally obtained sorption coefficients using mm-sized crushed particle fractions or diffusion experiments. The laboratory and field-estimated sorption coefficients for the weakly sorbing Na and Sr agreed within an order of magnitude. The discrepancy between field- and lab-estimated sorption coefficients may be due to experimental artefacts, material disturbances (pressure release, crushing etc), lack of representative material and oversimplified sorption models.

Limited sorption reversibility was needed in the model to fit Cs and Co data. The tails of the breakthrough curves could not be modelled using diffusion into the wall rock only. Diffusion into stagnant zones of water within the fracture plane was used for modelling and also interpreted as the main cause for the observed tailing in the breakthrough curves. The flow path was interpreted as being channelled, with a channel width of a few centimetres. More exact information on the properties of various rock matrices along the flow path is needed before any comparisons between inputed laboratory input and model-derived in-situ diffusivities can be made.

The results of the performed TRUE-1 analysis and evaluation work is planned to be reported in a series of four papers aimed at internationally renowned scientific journals.

3.2.2 Second TRUE Stage (TRUE-2)

A tentative planning document for the Second TRUE Stage was presented at the combined LTDE/TRUE-2 Review Meeting, March 8-9. The overall goal of TRUE-2 is to address diffusion, and particularly diffusion from a fracture into the matrix, in a dynamic *in-situ* experiment. In order to realise this goal there is a need to establish an experimental situation with a low hydraulic gradient such that pumping at low flow rates can be employed without loosing tracer mass.

A second TRUE-2 Review Meeting is scheduled for early 2000, with a scheduled detailed characterisation of the selected site starting in February 2000.

SELECT-2

During the period four pilot boreholes have been drilled using triple tube technique; KA2377A, KA2865A01, KXTT5 and KA3065A01. During the summer, BIPS borehole TV logging and POSIVA flow logging in combination have identified a series of suitable candidates for LTDE and for TRUE-2, cf. 4.3.2.

Characterisation of gouge material

A programme will be conducted on material from; NE-1, EW-1, the REDOX zone, and Structures #6 and 20 from the TRUE Block Scale volume. The analyses planned include mineralogy, geochemistry including Uranium series, porosity determination. The planned transport experiments include dynamic diffusion experiments (Dynamic Saturation and Leaching) possibly combined with ordinary column experiments. In addition batch sorption experiments are performed on selected size fractions. BET measurements are also planned.

During the period a quality plan has been devised, and measures have been taken to bring the characterisation of the geological material to the same level of detail.

3.2.3 TRUE Block Scale

Background

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

1. increase understanding and the ability to predict tracer transport in a fracture network,
2. assess the importance of tracer retention mechanisms (diffusion and sorption) in a fracture network,
3. assess the link between flow and transport data as a means for predicting transport phenomena,

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

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

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

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

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

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

During the Spring of 1999 an intensive planning effort has been conducted which has resulted in definition of the important issues of the planned future tracer tests. A set of hypotheses related to the issues of conductive geometry, heterogeneity and retention have been put forward in a Tracer Test Programme. Further design calculations related to the effects of fracture intersections have been performed. In addition, a series of Pre-tests, in essence a series of three interference tests with associated tracer dilution tests have been performed. As a final field activity a multi injection tracer test was performed which demonstrated breakthrough from four out of four injection sections, two of which showed high recovery in pathways involving multiple structures (>1)). The Tracer Test Programme also defines a tentative strategy for the future tracer tests which will be conducted in three consecutive phases, A through C. The first Phase, A, is a test of alternative sink sections, combined with complementary tracer dilution tests. Phase B will focus on the selected sink section, tests over both short and longer distances. Initiation of tests with weakly sorbing tests over longer distances and He may be foreseen towards the end of Phase B. The final phase, C, is fully devoted to tests with sorbing tracers. It is also recommended in the Tracer Test Programme to drill another borehole to facilitate shorter flow paths over in which tests with moderately sorbing tracers could be performed. In addition, this borehole serves as a verification of the reconciled March'99 model.

Overview of activities during the period

The main field activity during the period has been drilling and characterisation of the new borehole KI0025F03. In addition a modelling workshop has been held in Bålsta. This meeting served as a platform for defining a strategy for predictive modelling of tests with sorbing tracers.

Site characterisation

The new 76mm borehole KI0025F03 was drilled in early August in between KI0023B and KI0025F02, cf. Figure 3-1, to a depth of 141.7 m. The borehole has an inclination of 30 degrees down. The projected locations of interpreted structures have largely been verified by observed structures and inflows in the borehole, as well as observed pressure responses in neighbouring packed-off boreholes.

The performed site characterisation comprise BIPS borehole TV logging, BOREMAP core logging, POSIVA continuous mode flow logging. Flow and pressure build up tests combined with observations of pressure responses in neighbouring boreholes. Some 12 tests with a flow period of 30 minutes will be performed. The target fractures comprise both identified structures and fractures belonging to the so-called background fracture population. The results of these measurements will be used to select a suitable configuration of the multi-packer system. The system will be made up of all together 9 sections where pressure will be monitored. Five sections will be equipped to allow injection/abstraction of water and tracer. Two sections will be equipped with steel tubing to allow injection of He without risking diffusion through the lines.

Development of new tracers

Work with development of enrichment techniques for fluorescent dye tracers has resulted in a method applying solvent extraction. From a slightly acidified (0.003M HCl) water phase, fluorescein (uranine) and some substituted fluoresceins have been found to extract quantitatively into a hexanol organic phase. A water phase volume of 100 ml, an organic phase volume of 5 ml and a tracer concentration of 1μM were used. Measurements were performed using absorbance spectrophotometry and it was found that the absorbance was increased 16-50 times (see table 3-1). However, difficulties in obtaining transparency of the organic phase was observed which increased the bias. This would have produced interferece had the concentrations been much lower. Improvements of the method, e.g., possibility to strip the tracer back to a new water phase, will be investigated.

Table 3-1. The ratio of the absorbance in the organic phase versus the water phase after the solvent extraction procedure described in the text

Tracer	Uranine	Eosine B	Eosine Y	Phloxine B	Rose Bengal
A_{org}/A_{water}	16	33	34	40	50

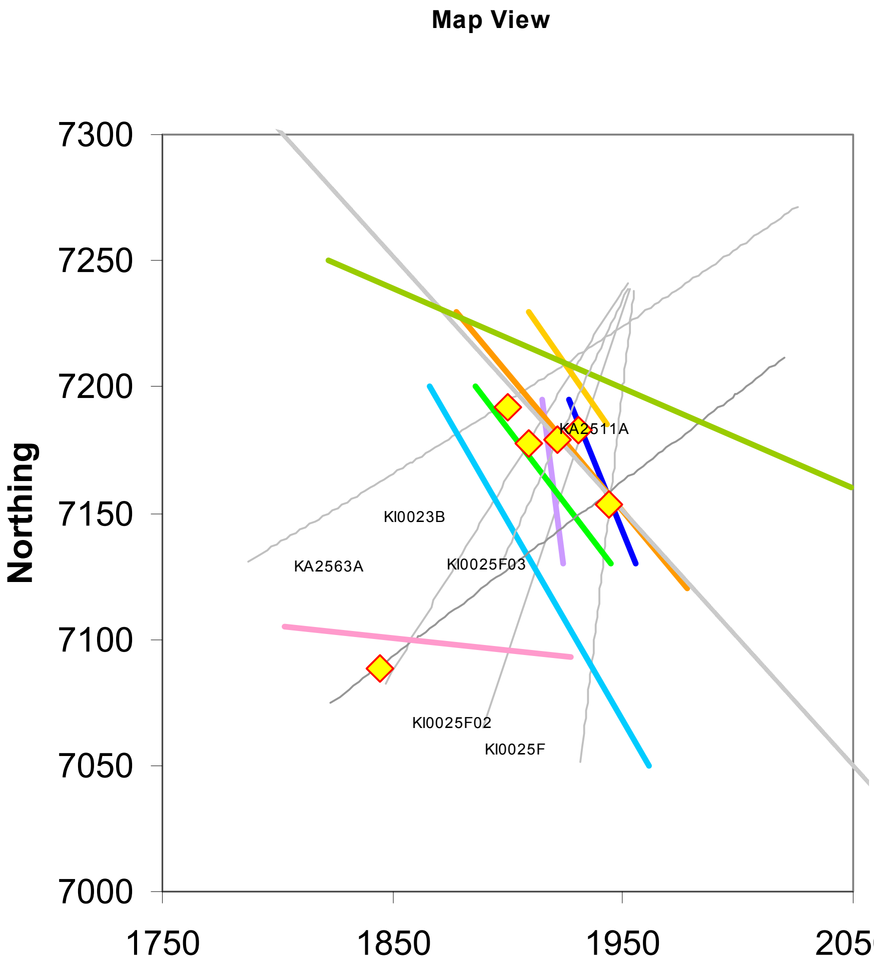

Figure 3-1 *Reconciled March'99 Structurel Model with new borehole KI0025F03 indicated. The shown deterministic structures with their interpreted extents are : Red = Structure #20, Light green = Structure #13, Violet = Feature #21, Dark Blue = Feature #22, Yellow = Structure #6, Light blue = Structure #19, Dark green = Structure #7, Pink = Structure #10.*

Planned work

4th Quarter, 1999

TRUE-1 reporting

- Finalisation of reporting

TRUE-2

- Initiation of gouge characterisation study
- Tentative location of experimental site for TRUE-2
- Test of new double packer and new injection scheme at the TRUE-1 site

LTDE

- Decision of SKB to launch the project
- Manufacturing of equipment
- Design of borehole geometry
- Drilling

TRUE Block Scale

Detailed Characterisation Stage

- Reporting

Tracer Test Stage

- Performance of Phase A tracer tests
- Performance of model predictions of Phase A tests using SC, DFN and CN models

3.3 Long Term Test of Diffusion in the Rock Matrix

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

The objectives of the planned experiment is to ;

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

The updated test plan presents an experimental concept centred on establishment of an experimental (large diameter) borehole which exposes a fracture surface. This fracture surface is packed off with a cap, similar to the one used in the REX experiment. The intention is to establish an experimental chamber in which a tracer solution is circulated over period of four years. Performed scoping calculations using available diffusivity data indicates that axial diffusion will range from mm:s for the strongly sorbing tracers to dm:s for the weakly sorbing tracers considered. Apart from tracers used in the TRUE-1 experiment, also PA-relevant tracers (^{99}Tc, ^{237}Np and ^{241}Am) are being proposed. The principal feat of the experiment is to establish axial diffusion from a natural fracture, through the rim zone of fracture mineralisation and alteration, into the unaltered rock matrix, without any advective component (towards the tunnel). This is resolved using a multi-packer system which effectively shields off the gradient. In addition, an intricate pressure regulation system is devised which will effectively allow the pressure in the experiment chamber to adapt to the ambient conditions without causing pressure differences, and hence no advective transport. The reference pressure is obtained from a packed-off pilot borehole in the immediate vicinity of the large diameter borehole. The former borehole has also been used to identify the target fracture to be investigated.

The characterisation of the large diameter borehole includes ia. measurements with various electrical geophysical logs (resistivity). The idea being to enable coupling between the electrical resistivity and diffusivity. In addition

Using the results of the characterisation in the SELECT-2 boreholes, primarily in KA2865A01 and KA3065A02, suitable experimental sites have been scrutinised. The available data indicate possible candidates structures in KA2865A01 at L=10.9 m, 14.5 m, 17.7 m and 23.7 m. Of these candidates, the former three anomalies either show lack of fracture coating and alteration rim zone, or the core pieces have been grounded down such that no coating is visible. The last of the possible target structures is located in a fine-grained granite. In KA3065A02, there is a large number of possible target structures. Some of these are disqualified because they are located too close to the tunnel (fear of EDZ effects), are part of a more geologically complex (greenstone) and sometimes highly conductive structures, the structure is sealed or with a disadvantageous geometry i relation to the borehole geometry, or are beyond the reach for the telescope large diameter drilling technique planned to be employed. The remaining candidates in KA3065A02 are L=9.81 m (141/81). This structure constitutes a chlorite splay 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 piece of Äspö diorite. The second candidate is a calcite-chlorite filled fracture in diorite with no or small rim zone located at L=12.6 m (115/90). Below the structure some 0.3 m of good rock is found. The angle of the feature in relation to the borehole axis is small, making it a somewhat more difficult target.

Of the identified target fractures, the structure at L=9.81 m is put forward. The main arguments for this recommendation are;

- Well defined structure with a long portion of good rock beneath the target fracture
- Well developed alteration zone
- Fracture mineral coating
- Conductive fracture
- Relatively short distance to target, beyond zone assumed affected by blasting

3.4 The REX-experiment

Background

A block scale redox experiment was carried out in a fracture zone at 70 m depth in the entrance tunnel to Äspö. In spite of massive surface water input, the fracture zone remained persistently anoxic. The main conclusion from that study was that the increased inflow of relatively organic-rich shallow groundwater instead of adding dissolved oxygen, it added organic compounds that acted as reductants in the deeper parts of the fracture zone. These conclusions are specific to this particular fracture zone, experimental conditions and the time scale (3 years) of the experiment, but are probably also relevant for other conductive fracture zones.

The detailed scale redox experiment (REX) is planned to focus the question of oxygen that is trapped in the tunnels when the repository is closed. Questions regarding the role of oxygen in this context are:

- Will oxygen penetrate into the rock matrix during construction and operation?
- If yes, how much of the rock will be oxidised and how long time will it take before oxygen is consumed?
- What happens to the oxygen in the backfill/buffer: how much is consumed by the rock, and how much by the buffer?

The REX project focuses on the first two of these questions, especially the second one. The third question is not included in the experiment.

The objectives of the experiment are:

- How does oxygen trapped in the closed repository react with the rock minerals in the tunnel and deposition holes and in the water conducting fractures?
- What is the capacity of the rock matrix to consume oxygen?

- How long time will it take for the oxygen to be consumed and how far into the rock matrix and water conducting fractures will the oxygen penetrate?

The emphasis of the project was on a field experiment involving motionless groundwater in contact with a fracture surface. To this aim a ≈20 cm borehole was drilled in the Äspö tunnel at 2861 m. Field data (hydrochemical and bacteriological) were used to establish the boundary conditions for the experiments.

The field study was supported by laboratory experiments to determine O_2 reaction rates and mechanisms, both for inorganic and microbially mediated processes. These laboratory investigations were performed with minerals, microbes and groundwaters from Äspö. A replica experiment was performed in France with the other half of the fracture surface obtained in the drilling procedure.

New results

Both replica experiment at CEA Cadarache, and the *in-situ* experiment at Äspö have been completed. A series of O_2 injection pulses have been performed. The results show that concentrations of O_2 in the range 1 to 8 mg ℓ^{-1} are consumed in the experiments within a few days, both for the field and replica experiments.

The data collected is being interpreted in order to obtain a mechanistic model for the O_2 consumption rates. The drillcores used in the replica and field experiments have been examined for mineralogical changes and biofilm formation. Final project reports are being drafted.

3.5 Radionuclide retention (include CHEMLAB)

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 character of the radionuclides themselves, 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 of 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, of organic matter, of bacteria etc. are present in the experiments. Laboratory investigations have difficulties to simulate these conditions and are therefore dubious as validation exercises. Figure 3-2 shows the different sections of the entire probe.

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 the relevant radionuclides

Figure 3-2. *Photograph of the CHEMLAB probe sections. The entire length of the probe is 14 metres. The different sections are coated with steel tubes which are tightly connected to each other.*

Experimental concept

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

The full suite of planned experiments are:

- Diffusion of radionuclides in bentonite clay
- Migration of redox sensitive radionuclides and actinides
- Radionuclide solubility
- Desorption of radionuclides from the rock
- Migration from buffer to rock
- Radiolysis
- Batch sorption experiments
- Spent fuel leaching

New Results

- A new CHEMLAB site has been equipped in the J-tunnel to host the two systems, CHEMLAB I and II, together with experiments related to the microbial activity.
- Preparations for the radiolyses experiments have been completed
- Licence to carry out the Radiolyses experiments has been received from the Swedish Radiation Protection Institute.

Planned work

- Start the radiolyses experiments
- Accept the delivery of the CHEMLB II probe system.
- Prepare a license application for the actinide experiments

3.6 Fracture Classification and Characterisation (FCC)

Background

Groundwater flow and nuclide transport is taking place in water conducting paths that are transmissive due to their genesis. Therefore eventually parameter values used in the numerical transport calculations should reflect the type of water conducting feature.

Fracture characterisation and classification aim at suggesting suitable types of fractures for tracer tests and at giving parameter values for modelling of relevant flow paths for nuclide migration.

Objectives

The objectives of the study are:

– to develop a methodology for characterisation of fractures with respect to rock type, tectonic evolution, infillings and wallrock alteration,

and by means of this characterisation be able:

– to develop a methodology for classification of different features/fractures (fracture sets) in terms of their importance for radionuclide mass transfer.

New results

No work has been made during the last three month.

Planned work

- Complete the final report

3.7 Degassing and two-phase flow

Background

The objectives for the investigations of degassing of groundwater and two-phase flow are:

- To show if degassing of groundwater at low pressures has significant effects on measurements of hydraulic properties in boreholes and drifts.
- To study and quantify other processes causing two-phase flow near excavations in regionally saturated rocks such as air invasion due to buoyancy and evaporation.
- To show under what conditions two-phase flow will occur and be significant. Conditions expected to be of importance are gas contents, chemical composition of groundwater, fracture characteristics (aperture distribution and transmissivities), and flow conditions.
- To get a measure of time scales required for resaturation of a repository.
- To develop technology for measurements of parameters under unsaturated conditions.

This knowledge is essential for understanding observations of hydraulic conditions made in drifts, interpretation of experiments performed close to drifts and performance of buffer mass and backfill, particularly during emplacement and repository closure.

In-situ testing of degassing and changes in hydraulic conductivity has been performed by measuring the inflow to a borehole at different pressures. Non-linearities in the flow-pressure relationship should be indicative of two-phase flow effects.

This project was originally performed as one of the bilateral cooperation projects between USDOE and SKB for studies at the Äspö Hard Rock Laboratory in the Areas of Site Characterisation and Repository Performance. Contributions to the project have also been provided by NAGRA and PNC. A revision of the project scope was made as a consequence of the USDOE leaving the Äspö HRL cooperation in April 1996.

New results

We have investigated the applicability of the unsaturated flow relations, originally developed for degassing applications (see the previous Äspö HRL status report IPR 99-21, and Jarsjö and Destouni, 1998), for the interpretation of unsaturated flow occurring for other reasons than degassing. Specifically, we consider gas injection tests, which for instance have been performed at Äspö HRL by the German organisation BGR. For reproducing such field experiments, a key issue is how to use (limited) field measurements of the physical fracture aperture and its variability (as well as hydraulic test data) in the modelling.

The unsaturated flow relations/ characteristic curves of Jarsjö and Destouni (1998) are based on physical fracture aperture statistics. Hence, for fracture regions where such aperture statistics is not available, one must find alternative procedures to estimate the characteristic relations. In the following, we outline such an alternative procedure (modified from the porous medium Leverett-scaling procedure), and test its relevance and applicability for fractured media.

The following site-specific information is needed for the above-mentioned scaling procedure:

(i) More detailed statistics on the physical fracture aperture for one subregion (corresponding to a ”cell” in the numerical model).

(ii) Some information/ statistics on either the mean aperture width, or the saturated transmissivity value, for the other subregions/ cells.

We further assume that the aperture distribution within each subregion/ cell is log-normally distributed, such that

$$f_{\ln}(a;\mu_{\ln a},\sigma_{\ln a}) = \frac{1}{a\sigma_{\ln a}\sqrt{2\pi}}\exp\left(-\frac{1}{2\sigma_{\ln a}^2}(\ln a-\mu_{\ln a})^2\right) \tag{1}$$

where a is the log-normally distributed random variable, $\mu_{\ln a}$ is the mean value of ln a and $\sigma_{\ln a}$ is the standard deviation of ln a.

The Leverett scaling relation, originally developed for scaling of characteristic curves in porous media (see p. 446 in Bear, 1972), may be expressed as:

$$p_c(S_w)_2 = p_c(S_w)_1\sqrt{k_1/k_2} \tag{2}$$

where subscripts 1 and 2 refer to the two different media. Hence the (unknown) capillary pressure p_c at a particular water saturation S_w in medium number 2 can be estimated on basis of the corresponding (known) capillary pressure at the same water saturation in medium number 1, and the permeability ratio k_1/k_2 between the media.

However, the most relevant measure of the hydraulic properties in fractured media is transmissivity (T), rather than permeability (k). With the aim to obtain a scaling relation based on fracture transmissivities, we therefore recall the following relation between permeability and transmissivity (originally developed for flow between parallel plates):

$$k = \frac{\mu T}{\rho g a_h} \tag{3}$$

where μ is the liquid viscosity, ρ is the liquid density, g is the gravitational constant and a_h is the hydraulic fracture aperture . Then, one can use the corresponding relation between a_h and k, $a_h = \sqrt{12k}$, to eliminate a_h from the above expression and obtain

$$k = \sqrt[3]{12}\left(\frac{\mu T}{\rho g}\right)^{2/3} \tag{4}$$

which, when inserted in relation (2) results in the following scaling relation:

$$p_c(S_w)_2 = p_c(S_w)_1 \sqrt[3]{T_1/T_2} \tag{5}$$

How does then the proposed scaling procedure of the characteristic curves, through (5), perform in comparison to direct estimates of the characteristic curves (see the previous status report IPR 99-21, p. 36, Equation (1))? We used the following steps to make a comparison:

(a) Consider two fractures F1 and F2, characterised by different $f_{\ln}(a;\, \mu_{\ln a}, \sigma_{\ln a})$.

(b) Calculate the characteristic curves (for T_{rel}) for fracture F1 and F2 through Equation (1), p. 36, in IPR 99-21 (with α=0).

(c) Estimate the saturated transmissivity ratio between these fractures through the expression

$$T_1/T_2 = \int_0^\infty a_1^{\,3} f_{\ln}(a_1; \mu_{\ln a1}, \sigma_{\ln a1})\, da_1 \Bigg/ \int_0^\infty a_2^{\,3} f_{\ln}(a_2; \mu_{\ln a2}, \sigma_{\ln a2})\, da_2 \tag{6}$$

which is consistent with Equation (1) in IPR 99-21 (α=0).

(d) Use Equation (6) and the modified Leverett function (5) to scale the characteristic curve obtained for fracture F1 (see step (b) above) to yield the characteristic curve for fracture F2. Compare with the curve for fracture F2, directly obtained in step (b) above.

First, we conducted steps (a) to (d) for two fractures 1 and 2, differing by their mean aperture values $\mu_{\ln a}$, but having the same standard deviation value $\sigma_{\ln a}$. Fracture 1 was characterised by $f_{\ln}(a_1;\, \mu_{\ln a1}=-4,\, \sigma_{\ln a1}=0.8)$ and fracture 2 was characterised by $f_{\ln}(a_2;\, \mu_{\ln a2}=-3,\, \sigma_{\ln a2}=\sigma_{\ln a1}=0.8)$. Figure 3-2 shows that for this case, the scaled curve for fracture 2 (crosses in Figure 3-2), based on the curve for fracture 1 (thick solid line), coincides with the curve for fracture 2 estimated directly from aperture statistics (thin solid line).

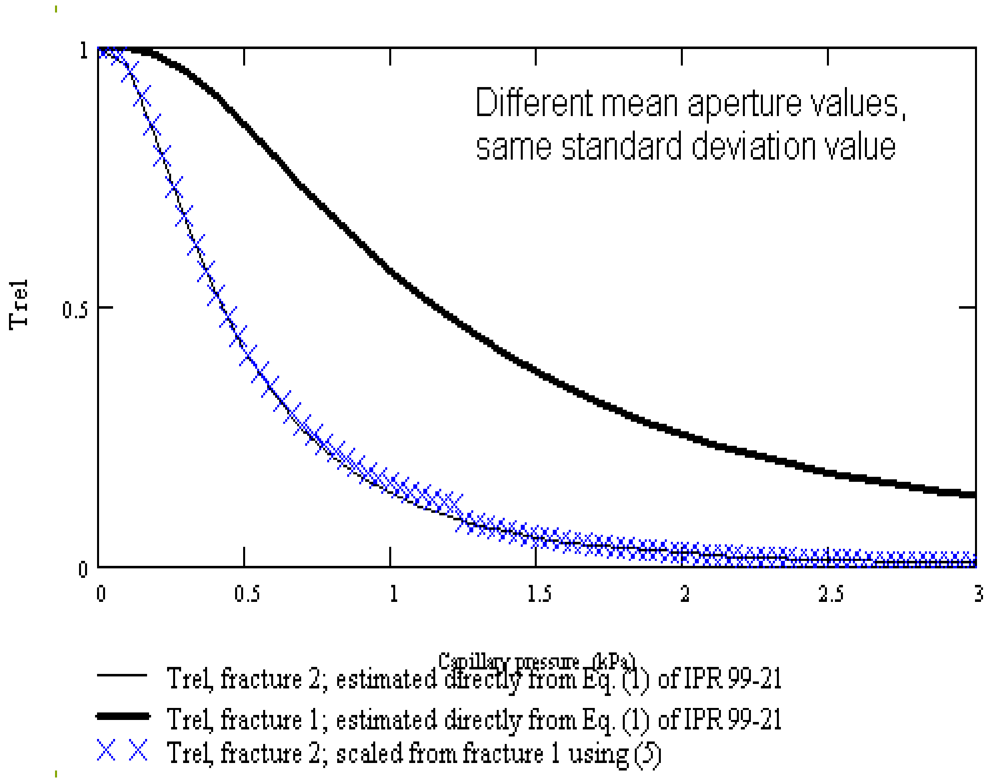

Figure 3-3. *Scaled characteristic curve for fracture 2 (crosses), based on the characteristic curve for fracture 1 (thick, solid line), compared with the directly estimated characteristic curve for fracture 2 (thin, solid line), for the case of different mean aperture values* $\mu_{\ln a}$, *but the same standard deviation value* $\sigma_{\ln a}$.

Then, we conducted steps (a) to (d) for two fractures 3 and 4, differing by their standard deviation values $\sigma_{\ln a}$, but having the same mean aperture value $\mu_{\ln a}$. Fracture 3 was characterised by $f_{\ln}(a_3;\ \mu_{\ln a3}=-3,\ \sigma_{\ln a3}=0.2)$ and fracture 4 was characterised by $f_{\ln}(a_4;\ \mu_{\ln a4}=\mu_{\ln a3}=-3,\ \sigma_{\ln a4}=0.5)$. Figure 3-3 shows that in this case, the scaled curve for fracture 4 (crosses), based on the curve for fracture 3 (thick, solid line) differs from the curve for fracture 4 estimated directly from aperture statistics (thin, solid line).

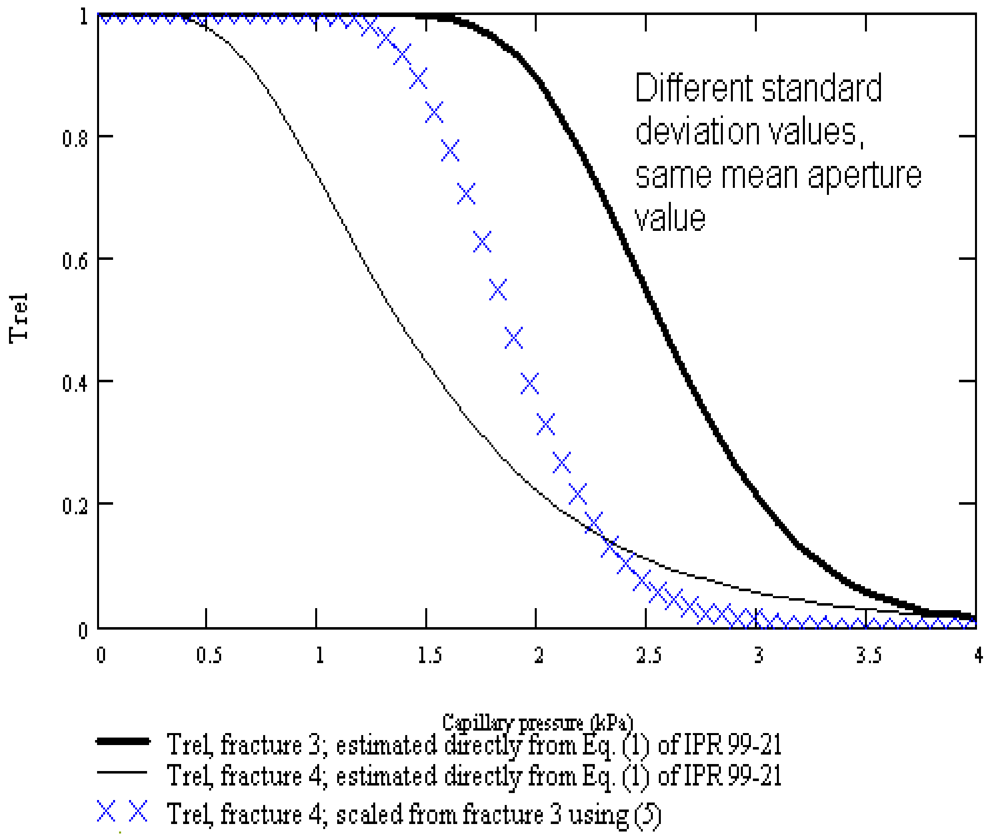

Figure 3-4. *Scaled characteristic curve for fracture 4 (crosses), based on the characteristic curve for fracture 3 (thick, solid line), compared with the directly estimated characteristic curve for fracture 4 (thin, solid line), for the case of different standard deviation values* σ_{lna}, *but the same mean aperture value* μ_{lna}.

Figure 3-3 and Figure 3-4 hence show that the scaling using equation (5) seem to be relevant for fractures of different mean apertures, as long as the aperture standard deviation between the fractures do not differ too much. One can also note that the modified Leverett scaling (5) seem to be relevant as long as the shape of the different aperture pdfs are similar; if the pdfs just differ by the mean aperture values μ_{lna}, the shape is the same between the different curves, whereas differences in the standard deviation value also imply differently shaped pdfs. Looking at the actual form of the scaling relation (5), the shape explanation makes sense since the scaled curve is obtained through a simple multiplication procedure, using the constant $\sqrt[3]{T_1/T_2}$.

Planned work

Continue to work on the final degassing report and the integrated analysis of existing data (to be included in the final degassing report).

3.8 Hydrochemistry modelling/Hydrochemical stability

Background

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

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

Objectives

The objectives of this project are:

- To clarify the general hydrochemical stability (= groundwater chemistry of importance for canister and bentonite durability and radionuclide solubility and migration)
- To describe the possible scenarios for hydrochemical evolution at Äspö over the next 100.000 years, separated into time intervals of 0-100, 100-1000, 1000-10000 and 10.000-100.000 years.
- To develop a methodology to describe the hydrochemical evolution at candidate repository sites, e.g. Olkiluoto.

Model concepts

Geochemical interpretation of groundwater-rock interaction along flow paths makes use of the results from groundwater chemical investigations, i.e. chemical constituents, isotopes and master variables pH and Eh in combination with the existing mineralogy, petrology and thermodynamic data. Useful tools for these calculations are reaction path codes like NETPATH and equilibrium-mass balance codes like EQ 3/6. These codes are frequently used in hydrochemical studies. A newly developed code M3 assumes a complete and complex mixing of the water in the investigated system. The principal assumptions behind this concept is that the varying hydraulic conditions of the past have caused the complex mixing pattern presently observed at Äspö. Mass balance calculations are then made to explain the difference between the ideal mixing and the observations.

The modelling strategy is based on:

– Process identification for Finnish and Swedish sites.

– Geochemical mixing for Äspö and Olkiluoto.

- Site intercomparison with PCA. Comparison between the M3 and NETPATH techniques for Olkiluoto.
- Hydrologic modelling for Äspö and Olkiluoto. Inclusion of the results from Task #5.

New Results

Task #5: All modelling groups should now have made their predictions and a description of the chemical reactions to be included in their individual modelling procedures. This was a direct request by the 12th Task Force Meeting at Gimo

EQUIP: The data from Äspö have been evaluated in order to produce a generalised description of the groundwater chemical inprint.

Modelling: At the 8th Project meeting the results of the different modelling tasks were examined:

- Site intercomparison using Principal Component Analysis. M3 plots illustrating the similarities and differences between the different sites give a good qualitative picture of the different types of groundwater origins. Data included from one year ago. Hästholmen data to be included.
- Process identification for all sites. Compilation of properties in tables. Topography plays the most important role for the groundwater chemistry
- Geochemical mixing for Äspö and Olkiluoto. The mixing modelling made for Olkiluoto is based on minimising the effects of reactions needed to describe the groundwater composition. This will be compared to the M3 mixing modelling done for Olikiluoto.
- Comparison between the M3 and NETPATH will be done for Äspö, perhaps also for Olikiluoto.

Planned work

- Prediction of the hydrochemical conditions of the future based on the climate scenario of the SR 97 safety assessment.
- Report the predictions of tunnel section 2900-3600.
- Sample groundwater from four sections in KLX02 using the Posiva PAVE sampling device.
- Assess the flow dynamics response to variation in groundwater and sea level fluctuations and effects on the boundary between groundwater of extremely saline brine at a postulated depth of 1000 m.

3.9 Matrix Fluid Chemistry

Background

Groundwater sampled from the Äspö site has been collected from water-conducting fracture zones with hydraulic conductivities greater than K= 10^{-9} ms^{-1}. The chemistry of these groundwaters probably results from mixing along fairly rapid conductive flow paths, being mainly determined by the hydraulic gradient, rather than by chemical water/rock interaction. In contrast, little is known about groundwater compositions from low conductive parts (K< 10^{-10} ms^{-1}) of the bedrock (i.e. matrix fluids), which are determined mainly by the mineralogical composition of the rock and the result of water/rock reactions. As rock of low hydraulic activity constitutes the major volume of the bedrock mass in any granite body, matrix fluids are suspected to contribute significantly to the salinity of deep formation groundwaters. It is considered expedient therefore to sample and quantify such fluids and to understand their chemistry and origin.

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

Objectives

The main objectives of the task are:

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

Experimental concept

The experiment has been designed to sample matrix fluids from predetermined, isolated borehole sections. The borehole was selected on the basis of: a) rock type, b) mineral and geochemical homogeneity, c) major rock foliation, d) depth in the tunnel, e) presence and absence of fractures, and f) existing groundwater data from other completed and 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 drilling water 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

A 'Matrix Fluid Experiment Workshop' was held recently at Äspö (September 6/7) when initial results (i.e. Feasibility Study) were presented and discussed, and future plans were laid. The main status aspects of the experiment are*:*

- Pressure increases in one of the packed-off sampling sections suggests that matrix fluids are slowly accumulating; this section will remain closed for a further six months to follow the pressure trend.

- Groundwater sampling from fracture zones representing a range of low to moderate transmissivities (10^{-9}-10^{-6} m^2/s) has been carried out in collaboration with the Prototype Repository Experiment, located at approximately the same level some 100-150 m from the Matrix Fluid site. This will extend knowledge of the general hydrogeological/hydrochemical character of the low to intermediate groundwater flow environment of the host rockmass close to the Matrix Fluid site. In addition to the normal SKB Class 4 and 5 analytical protocols, provision has also been made to carry out more isotopic analysis (e.g. $^{35/37}Cl$, $^{86/87}Sr$ and ^{11}B) in line with projected analysis of the matrix fluids. Initial hydrochemical data indicate that many of these low transmissive fractures may have been contaminated by shallow, young meteoric waters caused by the drawdown due to tunnel construction.

- This hydrogeological/hydrochemical database has been further extended by integrating similar data from the TRUE Block-scale Experiment and from future sampling activities within the TRUE Experiment programme.

- Two drillcore sections from the matrix fluid borehole were selected for the Feasibility Study:

- One representing one of the packed-off borehole sections presently demarcated for future sampling of matrix fluids. This section was used for the mineralogical and geochemical scooping studies, and

- One from a less important part of the borehole (nearest the tunnel face) which was used to quickly establish the general chemistry of the matrix fluids by crushing, grinding and leaching ("Quick and Dirty" approach). This procedure was duplicated at two laboratories.

- Scoping studies on the solid drillcore material are now available. The first stage comprised the basic mineralogy and major and trace element geochemistry to generally characterise the rockmass. These data will now be used to better focus future, more detailed studies, such as the selection of samples for fluid inclusion characterisation and which elements and isotopes to be determined. This will be carried out during October/November this year.

Planned work

- The borehole section furthest from the tunnel face, presently only demarcated for pressure monitoring, will be opened (November/December) to try and collect matrix fluids for initial characterisation.

- The Feasibility Study data are now being processed. The next stage is to: a) allocate rock samples to those groups who will participate in the mineralogy and fluid inclusion studies, b) allocate rock samples to those groups participating in petrophysical studies, c) continue the crushing/leaching experiments with drillcore material showing macroscopic variations in composition; some more extreme rock-types may be selcted from other locations at Äspö where groundwater chemistry is available, d) commence sampling of accumulated matrix fluids from one of the borehole sections, and e) establish suitable borehole locations adjacent to the matrix experiment for sampling low transmissive fractures (< $10^{-9} m^2/s$) and also for potentional in- and out-diffusion studies between more highly transmissive fractures and the rock matrix.

- Minutes of the Matrix Fluid Experiment Workshop will be available at the end of October, 1999. The next Working Group Meeting is scheduled for September, 2000.

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

Background

The Task Force shall be a forum for the organisations supporting the Äspö Hard Rock Laboratory Project to interact in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock. In particular, the Task Force shall propose, review, evaluate and contribute to such work in the project. The work within the Task Force is being performed on well defined and focused Modelling Tasks.

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

New results

Task No 4C and 4D

An overall evaluation of these Task's, 4C and 4D, has been undertaken and reported in the technical report series as SKB TR-99-04. The task was to predict groundwater drawdown and solute transport in a fracture feature.

Some of the conclusions pertinent to the overall evaluation reported are summarised below.

Predicted drawdown in the radially converging test was generally far from the experimental results. Except for a couple of the modelling teams, there were problems with overpredicting the drawdown in the radially converging experiment using transmissivities from the pressure build-up tests.

The predictions of the radially converging tracer test showed a high accuracy in the prediction of tracer breakthrough from the two closest injection, see figure below, while the models did not predict the lack of recovery from the two injection points further away.

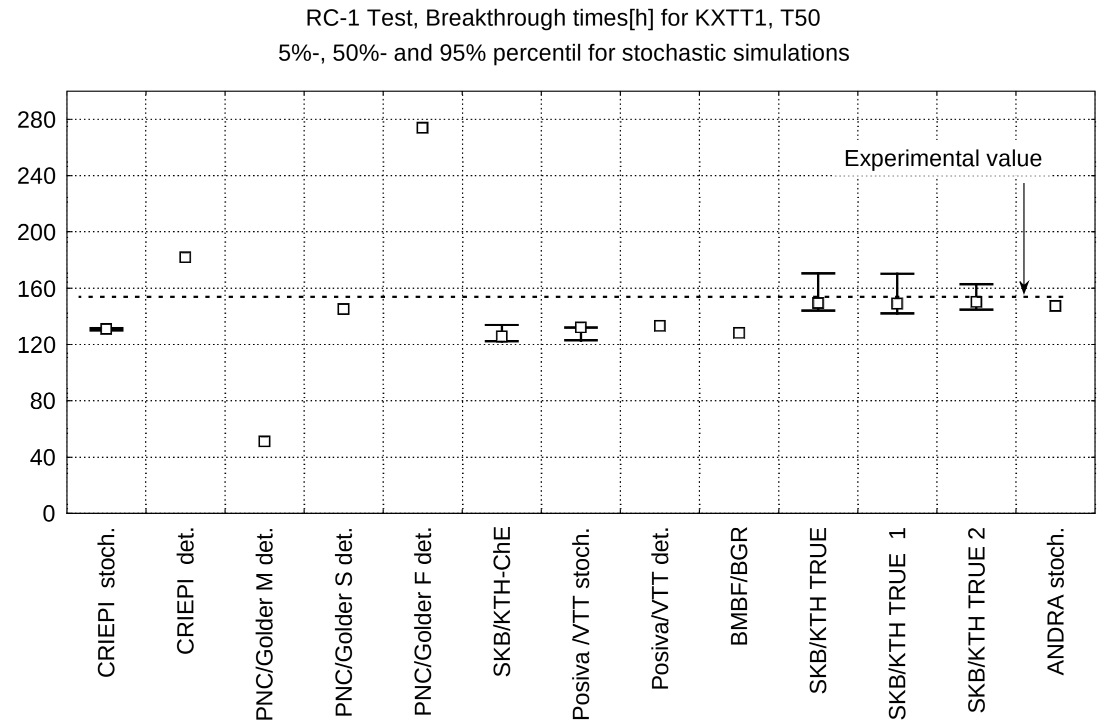

Figure 3-5. *Predictions of median breakthrough time (in hours) for injection in KXTT1 (5, 50 and 95-percentiles for stochastic models).*

There is a need for understanding the heterogeneity of the modelled fracture and the boundary conditions when making predictions of tracer tests.

Several factors that have contributed to the difficulties in performing the predictive calculations:

- the long source term used in the preliminary tracer test and the radially converging test reduced the potential for analysing relevant transport processes when interpreting the breakthrough curves.
- the lack of data concerning the head at the boundaries
- the slowly changing background head field during the series of experiments.
- the difficulty to simulate drawdown due to its sensitivity to local transmissivity.

More elaborate models with calibration or conditioning of transmissivities and transport apertures are required for more accurate predictions.

It is necessary to find suitable relationships between the fracture aperture derived from the hydrological tests (hydraulic aperture) and that derived from the tracer experiments (transport aperture or mass balance aperture). This is needed in order to correctly model both drawdown and tracer breakthrough.

The methodology to derive the necessary parameters for predictions needs development so does the methods to make use of all data produced from the site characterisation in the modelling.

Task No 4E

The final report for Task 4E will be published together with 4F. This work is presently ongoing. A deconvolution of breakthrough curves has been undertaken the report is presently on review.

Task No 4F

The final reporting for this task is presently ongoing and will be reported jointly with Task 4E.

Task No 5

Modelling and reporting for prediction between 2900-3600m tunnel length is ongoing.

Published reports

The following reports were published,

TR-99-04: Evaluation of modelling of the TRUE-1 radially converging and dipole tests with conservative tracers. Mark Elert, Kemakta Konsult AB, SKB Technical Report 99-04, Stockholm, Sweden.

Planned work

- In the pipeline for the next quarter are the following tasks:

- Publish the evaluation report for Task 4C and 4D
- Publish the results of the deconvolution studies on breakthrough curves of Task 4E.
- Compile a new action list resulting from the 12th International Task Force meeting
- Publish the proceeding from the 12th Task Force meeting
- Modelling groups should produce a draft final report for Task 4E&F
- Propose a new modelling Task, Task 6

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

4.1 General

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

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

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

- To furnish methods, equipment and procedures required for excavation of tunnels and deposition holes, near-field characterisation, canister handling and deposition, backfilling, sealing, plugging, monitoring and also canister retrieval.

- To integrate these methods and procedures into a disposal sequence, that can be demonstrated to meet requirements of quality in relation to relevant standards, as well as practicality.

With respect to *repository function*, objectives are:

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

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

4.2 Prototype Repository

Background

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

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

The aims of the Prototype Repository are:

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

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

New results

The EC-application under the 5th Framework Programme was completed and submitted to meet the deadline of October 4th. Eventually 8 other organisations joined the application bringing in new investigations and broadening the modelling exercises. Besides SKB, who will act as co-ordinator the participants are:

- POSIVA, Finland
- ENRESA, Spain
- AITEMIN, Spain (associated with ENRESA)
- CIMNE, Spain (associated with ENRESA)
- GRS, Germany
- BGR, Germany
- UWC (University of Wales)
- JNC, Japan

The boring machine, continued to performed well and could complete the two last holes in September. All six holes fulfil very well the stringent requirements on verticality, straightness and wall smoothness. The deviation of the center point is for instance only between 1 and 7 millimeters, when the requirement accepted up to 25 millimeters for the approximately 8,5 meter deep holes.

Prior to boring of those two last holes packers in investigation holes in the inner section, around the four inner holes, were reclaimed and mounted in investigation holes around the two outer deposition holes. After calibrating tests the system was ready for the hydraulic response during the boring. Also sensors for registration of acoustic emissions and ultrasonic transducers for monitoring of changes in wave velocities and amplitudes (in the zone closest to the bore hole walls) were installed as well as rock mechanics sensors for monitoring the mechanical response to boring in the rock around the holes. All these instruments performed to satisfaction, and evaluation and interpretation of received data have started.

Planned work

Detail planning of different parts of the Prototype Repository project will continue during the period. Main decisions on design and type of components to Section I have to be made so that the purchase processes may start. These decisions concern

- instrumentation plan including chemical samplers in the buffer, instruments in the canisters, thermocouples in rock, possible mechanical sensors in rock and needed number of cables out from the test tunnel
- heaters to canisters and design of cable handling
- consequent need for lead-through holes and their locations
- method for lead-through of cables
- location of permanent packers in investigation holes
- plug and slot designs
- supplementary investigation holes in the tunnel

Predictive modelling of the temperature distribution will be completed.

Characterisation of the deposition holes will be made concerning, geometric measurements, mapping of lithology and structures, and water inflow. Special efforts will be taken to evaluate the EDZ regarding depth and mechanical and hydraulic properties.

Testing of the deposition sequences in the assembly for the Prototype Repository and the Canister Retrieval Test as well as testing of the equipment that is planned to be used, will be made.

Reporting is due on mechanical modelling and DFN modelling as well as on temperature distribution and on water saturation of the buffer and backfill.

4.3 Backfill and Plug Test

Background

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

In 1998 the preparations and all the required work in the rock in the vicinity of the test tunnel have been finished e.g. excavation of the slot for the plug, casting of the first part of the plug, drilling of holes for the through connections, installation of the through connection tubes, installation of all packers for measurement of water pressure in the rock, and installation of the bore hole plugs. The backfilling started at the end of 1998 and the entire test set-up with casting of the final part of the plug has just been finished (end of September).

New results

At the end of the second quarter of 1999 the backfilling was almost finished. Only the blocks of 20/80 and the final beams of the retaining wall remained to be installed. The following main work has been carried out during the third quarter of 1999:

- About 4 m^3 blocks of brick-size with 20% bentonite and 80% sand have been installed in the triangular space left between the roof and the retaining wall, where compaction of backfill material could not be made. The final space of about 1.7 m^3 was filled with bentonite pellets, with the purpose to “buffer” the swelling pressure of the blocks.

- Tests of placing bentonite blocks in the slot for the O-ring of the Plug were made in July. The tests yielded a plan for the installation.

- About 1300 bentonite blocks (25x25x8 cm^3) have been installed in the inner 0.5x0.5 m^2 space between the first part of the plug and the rock wall to form an O-ring around the plug. In order to prevent concrete to penetrate between the blocks the tangential slots were caulked. The radial slots were filled with bentonite paste.

- The mould for the plug was built and required reinforcement installed (see Fig 4-1). Tubes for grouting between the concrete and the rock were also installed as well as cooling tubes. Finally the plug was cast on September 23 by pumping about 70 m^3 concrete into the mould.

- The panels and the tube system for measuring water pressure in the rock and for the flow testing have been installed in the data collection house. Registration of data from the 200 gauges has successively started.

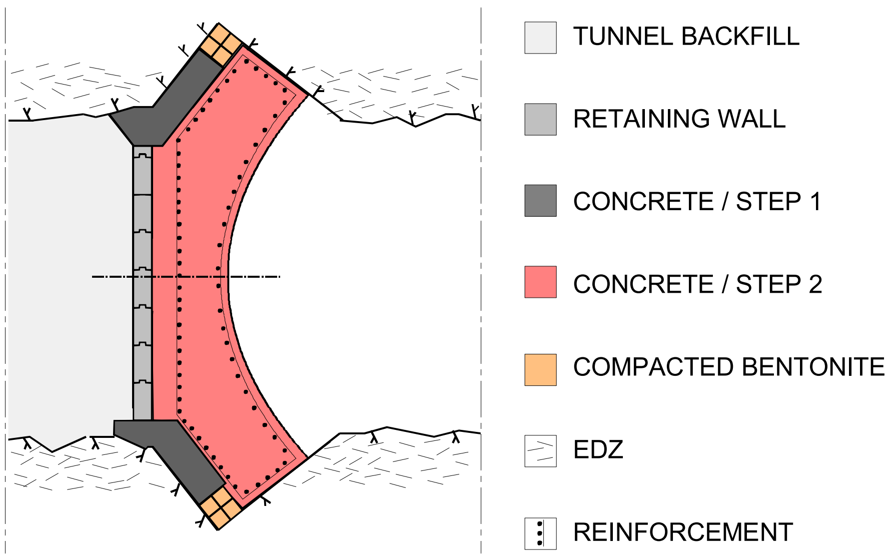

Figure 4-1. *Layout of the Plug*

Planned work

In the last quarter of 1999 the following main work is planned:

- The arrangements for pressurisation of the permeable mats will be completed and the water saturation of the backfill will start by filling the permeable mats with water. The strategy is to start with a low water pressure in every second mat section and follow the saturation process. If the saturation is too slow the pressure may be increased.
- Registration and following up of the water pressure in the rock and the saturation process and swelling pressure in the backfill will be made.
- Supplementary modelling and laboratory tests will be made and reporting of the installation will start.

4.4 Demonstration of repository technology

Background

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

Demonstration of Repository Technology is organised as a project under the Facilities Department. Development of equipment for handling and deposition of canisters will be the responsibility of the Deep Repository Department while the Äspö HRL will be responsible for the field activities. The description below focuses on the work that will be performed at the Äspö HRL.

The objectives of the demonstration of repository technology are:

- to develop and test methodology and equipment for encapsulation and deposition of spent nuclear fuel,
- to show in a perceptible way for specialists and the public the different steps in transport, deposition, and retrieval of spent nuclear fuel, and
- to develop and test appropriate criteria and quality systems for the deposition process.

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

New results

Nothing to report

Planned work

The four deposition holes will be characterised with respect to geometry and geology, and a model report compiled.

4.5 Canister Retrieval Test

Background

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

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

New results

Calculations on temperature distribution have indicated that a thermal load of about 2400 W per canister is needed in order to reach a temperature of 90 degrees on the canister´s surface.

The artificial watering can be made from porous mats attached to the rock wall. Calculations on saturation of the buffer indicate that the spacing of the mats can be made in such a fashion that saturation in the vertical parts around the canisters is reached after about two years.

The work on design of plugs on top of the holes shows that concrete blocks which are anchored by cables to the tunnel floor provides a more appealing structure than lids which are held by pillars taking support in the tunnel ceiling.

Planned work

Design of plugs in the top part of the two holes will be completed and reported as well as the design of the artificial watering during saturation.

Bentonite is purchased and blocks for both holes are fabricated including bentonite pellets.

Main decisions are made and purchases started during the next 3 months. These decisions concern

- type and number of heaters to the canisters
- design of cable ways out from the hole
- design of artificial watering and location of mats
- design of plugs and lead-throughs of cables
- instrumentation of the buffer and adjacent rock

4.6 Long term test of buffer material (LOT)

Background

Bentonite clay has been proposed as buffer material in several concepts for HLW repositories. In the Swedish KBS3 concept the demands on the bentonite buffer are to serve as a mechanical support for the canister, reduce the effects on the canister of a possible rock displacement, and minimise water flow over the deposition holes.

The decaying power from the spent fuel in the HLW canisters will give rise to a thermal gradient over the bentonite buffer by which original water will be redistributed parallel to an uptake of water from the surrounding rock. A number of laboratory test series, made by different research groups, have resulted in various buffer alteration models. According to these models no significant alteration of the buffer is expected to take place at the prevailing physico-chemical conditions in a KBS3 repository neither during nor after water saturation. The models may to a certain degree be validated in long term field tests. Former large scale field tests in Sweden, Canada, Switzerland and Japan have in some respects deviated from possible KBS3 repository conditions and the testing periods have generally been dominated by initial processes, i.e. water uptake and temperature increase.

The present test series aims at validating models and hypotheses concerning physical properties in a bentonite buffer material and of related processes regarding microbiology, 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, caution transport and gas penetration.

- Check of existing models concerning buffer-degrading processes, e.g. illitization 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 planned tests in the series (Table 4-2) is to emplace prefabricated units of clay blocks surrounding heated copper tubes in vertical boreholes. The test series will be performed under realistic repository conditions except for the scale and the controlled adverse conditions in three tests.

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

Table 4-1. Lay out of the planned 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 will be equipped with heaters in order to simulate the effect of the decay power from spent nuclear fuel. The heater effect will be 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 will be placed in boreholes with a diameter of 300 mm and a depth of around 4 m

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

New Results

The planning and construction of the four long-term test parcels and the extra one-year parcel are completed. The five pilot holes have been widened to the test hole diameter 300 mm by use of percussion drilling technique. The rock volume contains only a few natural fractures and the water inflow is very low also after the widening to the test hole dimension. A percussion-drilled hole for water supply has been drilled in the northern wall between the test holes A3 and A2. All parcels are/will be equipped with titanium filters in order to admit artificial water supply. The one year test parcel (A0) will be connected by tubes to the water supply hole. Possible connection to the four long term test parcels will be decided after discussion with all partners.

A total amount of 220 bentonite blocks have been produced which is sufficient for all five parcels. All instrument, data acquisition equipment and other important equipment have been delivered. All five test holes and the site around them are prepared for the assembly and submerge of the parcels.

The S3-parcels was assembled and submerged during week 35 and the S2-parcel three weeks later. Both were equipped with instruments , bacteria and the latter with the radioactive tracer Co-60 according to plans.

All instruments and heat controlling equipment for the two parcels have been installed and are found to work properly with the exception of one optical sensor. The fibre has been damaged in the tunnel part and is thereby possible to repair. Laboratory characterisation of the test material has started and will continue during the rest of the year.

Planned work

The remaining three parcels will be installed, starting in week 41 and completed in week 45. The official test start, i.e. heating start, for all test will thereafter take place in mid November. Pressure and water-flow from the water supply hole will be determined together with chemical analyses of the groundwater. Supporting laboratory tests concerning “critical” gas penetration pressure will be made parallel to the running field and laboratory characterising work.

5 Äspö facility operation

5.1 Facility operation

Two new office rooms were constructed above the new chemical laboratory.

The ”five year inspection” of the underground facility started this summer. The work will be completed during the autumn. The result so far has pointed out a few areas were intense reinforcement is necessary. Systematic bolting and mesh/spray concrete will probably be used.

The electrical supply to the facility comes today from two different sources. The underground part is supplied direct from the nuclear power station, while the Äspö village gets its electricity from an airborne net on the mainland. The latter is a relatively weak net and especially during the autumn and winter, there are several cuts in the delivery. A new cable from the nuclear station to Äspö has now been projected and will be in operation late this year.

The net surrounding the hoist shaft on the different landings is going to be changed to material in stainless steel due to corrosion. On the landing at –340 m this has already been done.

The fire protection system underground is going to be updated due to new activities. The only way to get an alarm through today is by the telephone. This is not sufficient and other solutions are looked upon.

A project for hands free registration when going down or up from the tunnel system has started. According to the plan, it will be in operation before next summer.

The project for installing a system for supervision of the facility is on schedule. The first screen pictures for display are ready and the data net is installed. In the beginning of next year, it is ready for use.

5.2 Data management and data systems

Background

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

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

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

A high quality baseline for the safety assessment will be established if the aspects specified above are met.

The data needed in a typical safety assessment have been reported in Andersson et al /1998/.

5.3 Program for monitoring of groundwater head and flow

Background

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

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

New results

The HMS program has been running real time data acquisition in support of the various projects undertaken in the Äspö Hard Rock Laboratory.

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

Planned work

For the next quarter it is planned to

- continued support to various projects
- formulate the goal for an overall assessment of the HMS system

5.4 Program for monitoring groundwater chemistry

Background

During the construction phase of the Äspö Hard Rock Laboratory, different types of water samples were collected and analysed with the purpose of monitoring the groundwater chemistry and its evolution as the construction proceeded. The samples were obtained from the cored boreholes drilled from the ground surface and from percussion and cored boreholes drilled from the tunnel.

Objectives

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

New results

The results from the sampling in October 1998 have been presented in TD-99-22. The results from the Monitoring program undertaken since 1995 have been presented in IPR-99-13. Sampling have been performed during w939 and 940. Sampled boreholes are listed in Table 5-1:

Planned work

The results from the sampling in April will be presented in a Technical Document in October. Next sampling occasion is scheduled to take place w014 and 015.

Table 5-1.

Idcode	Secup/seclow	Section	Class no.	Comment
HD0025A	0-200	1	4	
KA1061A	14.5-208.5	1	4	
KA1131B	8.0-203.1	1	4	
KA1755A	88-160	3	4	
KA2050A	155-212	1	4	
KA2162B	201.5-288.1	1	4	
KA2511A	92-109	4	4	
KA2511A	52-54	5	4	
KA2563A	206-208	3	5	TRUE BS
KA2563A	187-190	4	5	TRUE BS
KA2563A	242-246	1	4	
KA2862A	7.37-15.98	1	4	
KA3110A	20-29	1	4	
KA3385A	32-34	1	4	
KA3573A	4.5-17	2	4	
KA3573A	18-40	1	4	
KA3600F	4.5-21	2	4	
KA3600F	22-50	1	4	
KAS03	107-252	5	4	
KAS03	553-626	2	4	
KAS09	116-150	4	4	
KI0023B:P4	84.75-86.20	4	4	TRUE BS
KI0023B:P6	70.95-71.95	6	4	TRUE BS
KI0023B:P7	43.45-69.95	8	4	TRUE BS
KI0025F:R2	164-168	2	4	
KI0025F:R4	86-88	4	4	
KI0025F02:P3	93.35-99.25	3	5	TRUE BS
KI0025F02:P5	73.30-77.25	5	5	TRUE BS
KI0025F02:P6	64-72.30	6	5	TRUE BS
KI0025F02:P7	56.1-63	7	4	TRUE BS
KR0012B	5.0-10.57	1	5	
KR0013B	7.05-16.94	1	5	
KR0015B	19.82-30.31	1	5	
KXTT3 P2	12.42-14.42	1	4	
SA0813B	5.6-19.7	1	4	
SA1009B	6-19.5	1	4	
SA1229A	6-20.5	1	4	
SA1420A	6-50	1	4	
SA1730A	5.6-20	1	4	
SA2074A	6-38.7	1	4	
SA2273A	5.8-20	1	4	
SA2600A	5.8-19.4	1	4	
SA2783A	5.8-19.9	1	4	
SA2880A	11.92-13.92	1	4	
SA3045A	0-21	1	4	

5.5 Technical systems

Background

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

New results

The installation of the presentation system started in August. The system consist of two parts an PLC (Programable logic controller) and the Process system.

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

The prototype tunnel has been re-instrumented to adapt to the new experimental configuration with the full-scale drilled boreholes in place. The boreholes KG0021 and KG0048 have been connected to HMS:

REX experiment has been finished.

Planned work

During Autumn we planned to replace the old pressure transducers with new ultra sonic transducers in the last 6 weirs.

KI0025F03 will be connected to HMS during October.

The presentation system will be in full operation during Spring 2000.

5.6 Information

Background

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

New results

During the third quarter of 1999 3719 visitors visited the Äspö HRL. The groups have represented the general public, communities where SKB performs feasibility studies, teachers, students, politicians, journalists and visitors from foreign countries

	Number of visitors second quarter 1999	Number of visitors totally 1999
General public	1 548	3 719
Students	37	2 547
Teachers	161	500
Politicians	179	553
Journalists	0	13
Foreign visitors	208	484
Oskarshamn Community	1 265	2 674
Nyköping Community	40	309
Tierp Community	32	239
Hultsfred Community	398	592
Östhammar Community	19	19
Älvkarleby Kommun	40	40
Total number of visitors	3 595	9 341

An information video concerning the safety for the visitors in the Äspö HRL has been made.

Urberg 500

During the summer we have had two ”Urberg 500” tours per day, in the weekends one tour per day. There has been a lot of people interested in the tour and 1771 persons visited ”Urberg 500”. The visitors filled in a questionnaire, the result showed that 98% of the visitors found the tour good or very good.

Because of the large interest from the public, ”Urberg 500” will continue every weekend until Christmas.

Before the entrance building for ”Urberg 500” is completed, the visitors will receive information in SKB´s trailer.

Special events

2nd WSM Euroconference

From the 22nd to the 25th of September, SKB and the Äspö HRL were hosts to the 2nd World Stress Map Euroconference. The main subject for the conference was rock stress and deformation in the earths crust. Around 65 scientists from all over the world met to discuss the latest results. The programme included a visit to the tunnel.

Planned work

To have ”Urberg 500” up and running during the third quarter of 1999.

To install, test and validate OKG´s visitors booking system.

A safety/instruction video for consultants concerning work and safety under ground will be produced.

6 International cooperation

6.1 Current international participation in the Äspö Hard Rock Laboratory

Nine organisations from eight countries are currently (June 1999) participating in the Äspö Hard Rock Laboratory.

In each case the cooperation is based on a separate agreement between SKB and the organisation in question. Table 6-1 shows the scope of each organisations 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 cooperation in the area of conceptual and numerical modelling of groundwater flow and solute transport in fractured rock.

A trilateral agreement between SKB, JNC and Criepi has been signed. JNC is the IJC representative for both JNC and Criepi.

Table 6-1. Scope of international cooperation

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
Bundesministerium für Wirtschaft und Technologie, **BMWi**, Germany	Two-phase flow investigations including numerical modelling and model calibration Participation in the Task Force on modelling of groundwater flow and transport of solutes by using "German" computer codes Participation in the geochemical modelling efforts in the Äspö HRL Work related to transport and retention of radionuclides and colloids in granitic rock In-situ geoelectrical measurements with respect to water saturation of rock masses in the near field of underground tunnels

Organisation	Scope of participation
	Work on design and performance of in-site tests using methods and equipment similar to those used in the Grimsel investigations
Empresa Nacional de Residuos Radiactivos, **ENRESA**, Spain	Test of models describing the barrier function of the bedrock (TRUE Block Scale) Demonstration of technology for and function of important parts of the repository system, (Backfill and Plug Test)
Japan Nuclear Cycle Development Institute, **JNC**, Japan. The Central Research Institute of the Electronic Power Industry**, CRIEPI,** Japan	The Tracer retention understanding experiments (TRUE) The detailed scale redox (REX) experiment Radionuclide retention experiments Task Force on modelling of groundwater flow and transport of solutes. Prototype repository project. Long-term test of buffer materials
Nationale Genossenschaft für die Lagerung Radioaktiver Abfälle, **NAGRA**, Switzerland	Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system
United Kingdom Nirex Limited, **NIREX**, Great Britain	TRUE Block Scale
POSIVA , Finland.	Detailed investigation methods and their application for modelling the repository sites Test of models describing the barrier function of the bedrock Demonstration of technology for and function of important parts of the repository system *Prototype repository*
USDOE/**Sandia National Laboratories**, USA	Test of models describing the barrier function of the bedrock

6.2 Summary of work by participating organisations

6.2.1 Work performed by Posiva Oy

Present status of Posiva Oy

Posiva Oy is waiting for the decision in principle from the Council of State for the Olkiluoto site in the municipality of Eurajoki, Southwestern Finland. The decision is expected to take place after the hearing process during the first half of the year 2000. Meanwhile complementary investigations are going on in the Olkiluoto and Hästholmen sites. One new borehole, 1000 m respective 800 m depth, was drilled in both sites during the summer 1999. The basic investigations, geophysical measurements and flow logging, are going on presently. The water sampling to study the hydrochemistry of the deep saline groundwater during the autumn 1999 will follow them.

Fieldwork at Äspö HRL

During the third quarter of 1999 Posiva has participated in the fieldwork of the Äspö HRL according to the joint project agreement mainly in two projects:

- Testing the Posiva groundwater sampling method in the borehole KLX02 for characterising the hydrochemistry of the deep saline groundwater in the Hydrochemical Stability project.
- Measuring the flow in the borehole for TRUE Block Scale experiment with the detailed flow logging method.

Groundwater sampling with PAVE equipment

Groundwater sampling is carried out in Laxemar area in the deep borehole KLX02 as a part of the on-going SKB-Posiva Hydrochemical stability project. The aim is to test the functioning and field operation of PAVE, Posivas pressurised groundwater sampling equipment, in deep borehole conditions. The aim is also to obtain additional information on the groundwater conditions at depth and especially on saline groundwater in the bedrock. The expected results of the PAVE sampling at borehole KLX02 are

- Representative water samples from well-defined isolated sections and laboratory analyses for the characterisation of local hydrogeochemical conditions at different depth levels and salinity.
- Samples, which represent the in-situ pressure conditions, for gas and microbiology analysis.
- Representative gas samples for isotope analyses.

Four sections have been selected to be sampled with the PAVE sampler.

So far sampling with the PAVE equipment has been successfully accomplished from the depths 1345-1355 m (July-August) and 1155-1165 m in KLX02 (August-September). Pumping is underway in section 1090-1097 m. Flow rates for the sections have varied from 450 ml/h to 6 l/h.

Difference flow measurements

The flow measurements were carried out in borehole KI0025F03 at the True Block Scale site on September 21-22. Posiva's detailed flow logging method was used with 1 m section length and 0,1 m depth increments. Flow and single point resistance were logged with high depth resolution. The objective of the measurements was to locate the leaky fractures and to determine the flow rate from these fractures.

An example of the results of the detailed flow logging is presented in Figure 6-1. The fieldwork. was conducted by PRG-Tec Oy.

Other investigations

Posiva has participated in the Technical Committee and modellers' meeting in the TRUE Block Scale –project. The premises of the tracer tests to be performed in the TTS phase of the project were discussed and some scoping modelling performed and presented in the meeting to address the possible effect of Fracture Intersect Zones (FIZ) on the flow and transport. Also the concept of transport calculations for TILA-99 were presented.

Related to the Task #5 project, the mixing calculations using the boundary conditions from the M3 modelling done by Gurban et al. (1998) have been completed to a large extent by VTT Energy (Eero Kattilakoski). The research at VTT Communities & Infrastructure (Ari Luukkonen) has been concentrated on the modelling of the given geochemical data set. Studies are based on the inverse mass-balance modelling and the aim is, in the first place, identification of geochemical processes and mixing end-members active at the Äspö site. Secondly, inverse calculations produce the end-member mixing-ratios for each studied sample. Studied samples include at the moment a representative set of undisturbed samples (before tunnel construction) and all time-sequenced control point samples of disturbed conditions (during tunnel construction) with exception of the point KA1061A (deficient geochemical data). As requested in the last Hydrochemical Stability Meeting the results of the mixing-ratios for disturbed samples together with estimations of the salinity distribution and the end-member ratios at the model boundaries have been passed to VTT Energy (Eero Kattilakoski) for hydrological simulations similar to those done for the boundary conditions from the M3 modelling**.** These calculations have been underway from early September.

Predictions of the last sorbing tracer test of the TRUE-1 (Task #4F) were presented at the 12th Task Force Meeting.

Planned fieldwork

The pressurised groundwater sampling at the borehole KLX02 continues. The final section to be sampled is suggested to be the section 1385-1395 m. The detailed flow logging with the Posiva flowmeter at the borehole KLX02 will continue after the groundwater sampling. The measuring programme will be revised according to the experience gained from the measurements during the spring 1999.

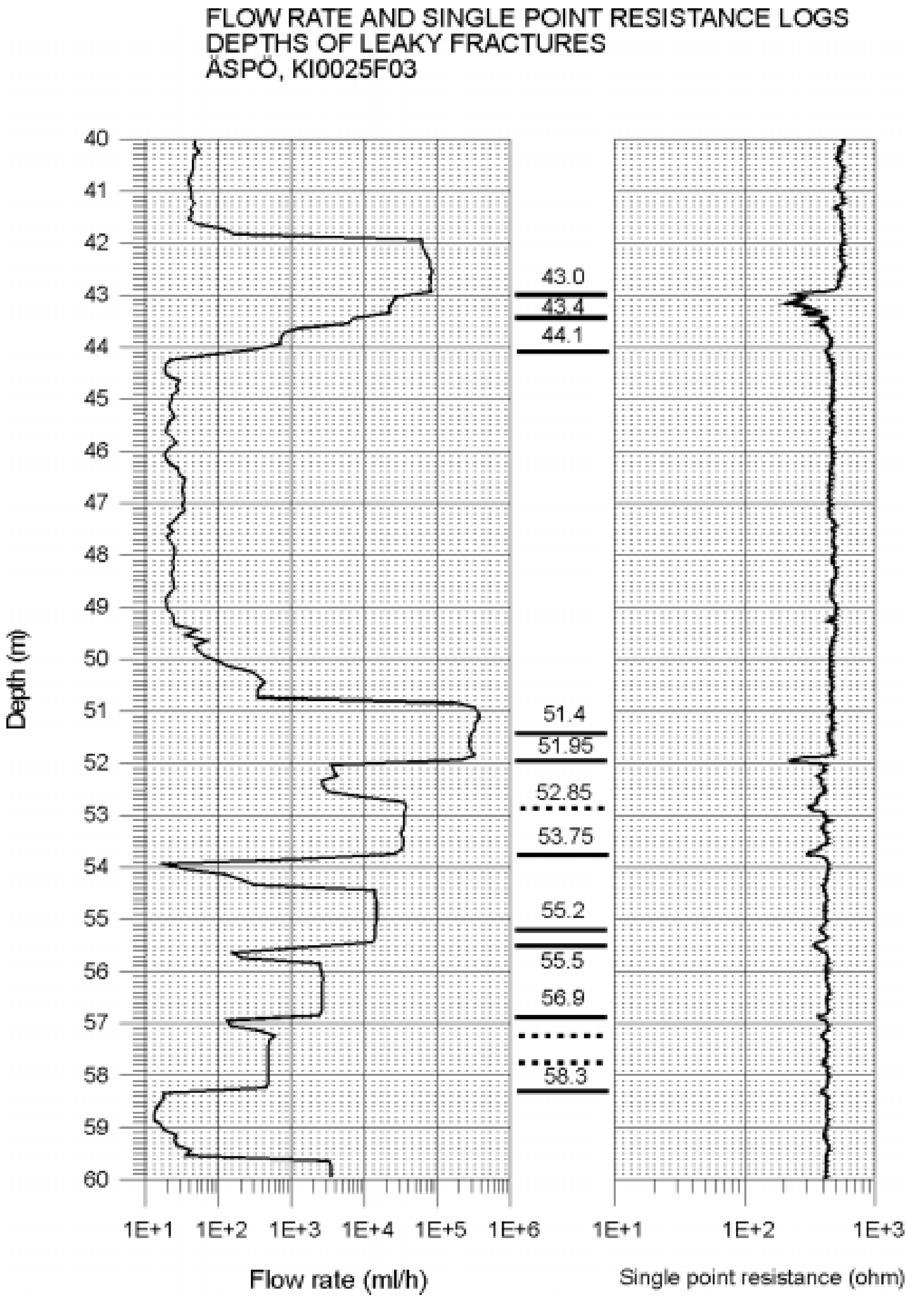

Figure 6-1. *An example of the results of the detailed flow logging measurements.*

7 Other matters

7.1 Documentation

During the period July-September, 1999, the following reports have been published and distributed:

7.1.1 Äspö International Cooperation Reports

Puigdomenech I, Banwart S A, Bateman K, Milodowski A E, West J M, Griffault L, Gustafsson E, Hama K, Yoshida H, Kotelnikova S, Pedersen K, Lartigue J-E, Michaud V, Trotignon L, Morosini M, Rivas Perez J, Tullborg E-L, 1999
Redox experiment in detailed scale (REX)
First project status report
ICR-99-01

7.1.2 Äspö International Progress Reports

Nilsson A-C, Säfvestad A, 1999
Compilation of groundwater chemistry data
IPR-99-13

Hakami E, Gale J, 1999
First TRUE Stage. Pilot Resin Experiment. Pore space analysis.
IPR-99-14

Andersson P, Wass E, Byegård J, Johansson H, Skarnemark G, 1999
TRUE 1st Stage Tracer Test Programme. Tracer tests with sorbing tracers, STT-2. Experimental description and preliminary evaluation.
IPR-99-15

Sundberg J, Gabrielsson A, 1999
Laboratory and field measurements of thermal properties of the rocks in the prototype repository at Äspö HRL
IPR-99-17

Autio J, Kirkkomäki T, Siitari-Kauppi M, Timonen J, Laajalahti M, Aaltonen T, Maaranen J, 1999
Use of the 14c-pmma and he-gas methods to characterise excavation disturbance in crystalline rock
IPR-99-18

10 Technical Document

1 International Technical Document

7.2 Quality Assurance

Background

Quality Assurance means to ensure that activities are undertaken with due quality of high efficiency. In order to achieve this goal it is required that a smoothly running system is in place to manage projects, personnel, economy, quality, safety and environment.

The structure of a quality assurance system is based on procedures, handbooks, instructions, identification and traceability, quality audits etc.

The overall guiding document for issues relating to management, quality and environment is SKB Handbook for Management and Quality Assurance. A review of the SKB quality handbook is undertaken every year.

Employees and contractors related to the SKB organisation are responsible that works will be performed in order to achieve SKB quality goals and guidelines.

Results

A project is in progress to implement a common management system for SKB to break down all requirements from legislator, authorities and from other interested parties and also internal requirements of our own organisation. The aim of the project is to certify SKB according to the Environmental Management System ISO 14001 and also to the new quality management standard ISO 9001 by October 1st year 2000.

In a prestudy within the company will compare the SKBs Management System with the requirements from the ISO-standards. Realised GAP-analysis will result in suggestions to actions.

The Repository Technology unit identifies the demands of additional steering documents and describing of routines. Steering documents will be more integrated in the department of Safety and Technology. This means that the number of steering documents for the activities in the Äspö organisation will be reduced.

Goals have been identified and important environmental aspects which influence the environment negatively have been specified in order to get through an Environmental Management System in the unit Repository Technology. This also includes to improve the working environment accordance to safety and health requirements.

SKB Project Handbook and Emergency Handbook have during this period been approved and distributed.

Processes have been surveyed in the Repository Technology unit. Other activities are carried out in projects.

A draft to a Purchasing Handbook is presently on review.

Planned work

To develop a better structure for managing time and resources, by means of a software application called Äspö Plan Right which is running under MS Project.

Great efforts are required to produce documents for the description processes, to documentate routines and instructions with the purpose to reach the first goal in being ISO-certified.

A draft to a new Purchasing Handbook has been distributed. It will be reviewed during October.

Revision of the Äspö Handbook is undertaken during the fourth quarter 1999. Co-ordination is done with the department of Safety och Technology.

Environment steering in the Repository Technology unit shall adjust to the demands of SKBs Environmental Management System (is a part of SKBs Management System to handle environment matters in the company). Action plan to attend to important issues with negative influences into the environment shall be established.

Projects in Repository Technology shall follow the guidelines given by SKBs Project Handbook. Requirements (from the legalisator, authorities and internal demands) to quality, safety and environment shall be implemented in the research projects, the plant layout for a deep repository in the future and also to realise site investigations.

SKB shall make an inventory of prerequisites for a common identification- and archival system. Important documents from activities shall be recorded and archived in a integrated and traceable manner.

References

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Parameters of importance to determine during geoscientific site investigation.
SKB TR 98-02

Bear, J., 1972.
Dynamics of Fluids in Porous Media, Dover Publications Inc., New York.

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Influences of the Tunnel Construction on the Groundwater Chemistry at Äspö.
Hydrochemical Initial and Boundary Conditions: WP D1, WP D2. Part 2.
Äspö Hard Rock Laboratory, Technical Note TN-98-17g.

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Groundwater degassing in fractured rock: Modelling and data comparison.
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The structure of conceptual models with application to the Äspö HRL Project.
SKB TR 94-08.

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

Appendix A

MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

Activity

VERIFICATION OF PRE-INVESTIGATION METHODS

CODE DEVELOPMENT/MODELLING

- **PUBLISHING OF RESULTS**

METHOD. FOR DETAILED CHARACT. OF ROCK UNDERGROUND

ROCK VISULATIZATION SYSTEM

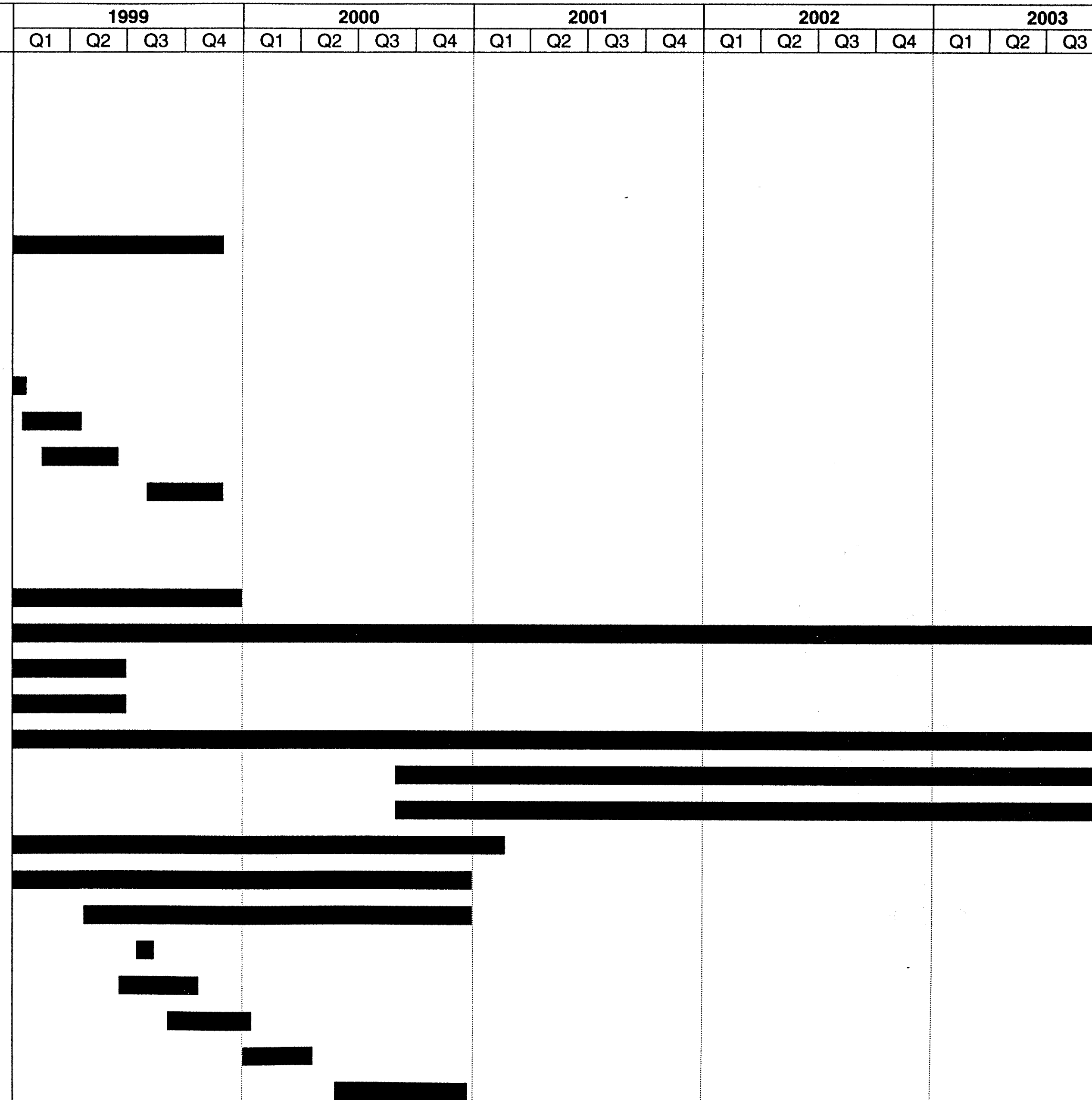
- **Program and reports etc**
  - Update of system manuals Ver 1.1
  - Update of system manuals Ver 1.2
  - Update of system manuals Ver 1.3
  - Update of system manuals Ver 1.4
  - Update of system manuals Ver 2.0
  - Update of system manuals Ver 2.1

TEST OF MODELS FOR DESCRIPTION OF THE BARRIER FUNCTION

FRACTURE CHARACTERIZATION AND CLASSIFICATION

TRACER RETENTION UNDERSTANDING EXPERIMENTS

- **TRUE-1**
  - Analysis of results and reporting of TRUE-1
- **TRUE-2**
  - STT-2 tracer experiment
  - Reporting
- **TRUE BLOCK SCALE EXPERIMENT**
  - Detailed Characetrization Stage
    - Tracer Test Stage
      - Optimisation of borehole array
      - Drilling of additional borehole
      - Tracer tests phase A
      - Tracer tests phase B
      - Tracer tests phase C



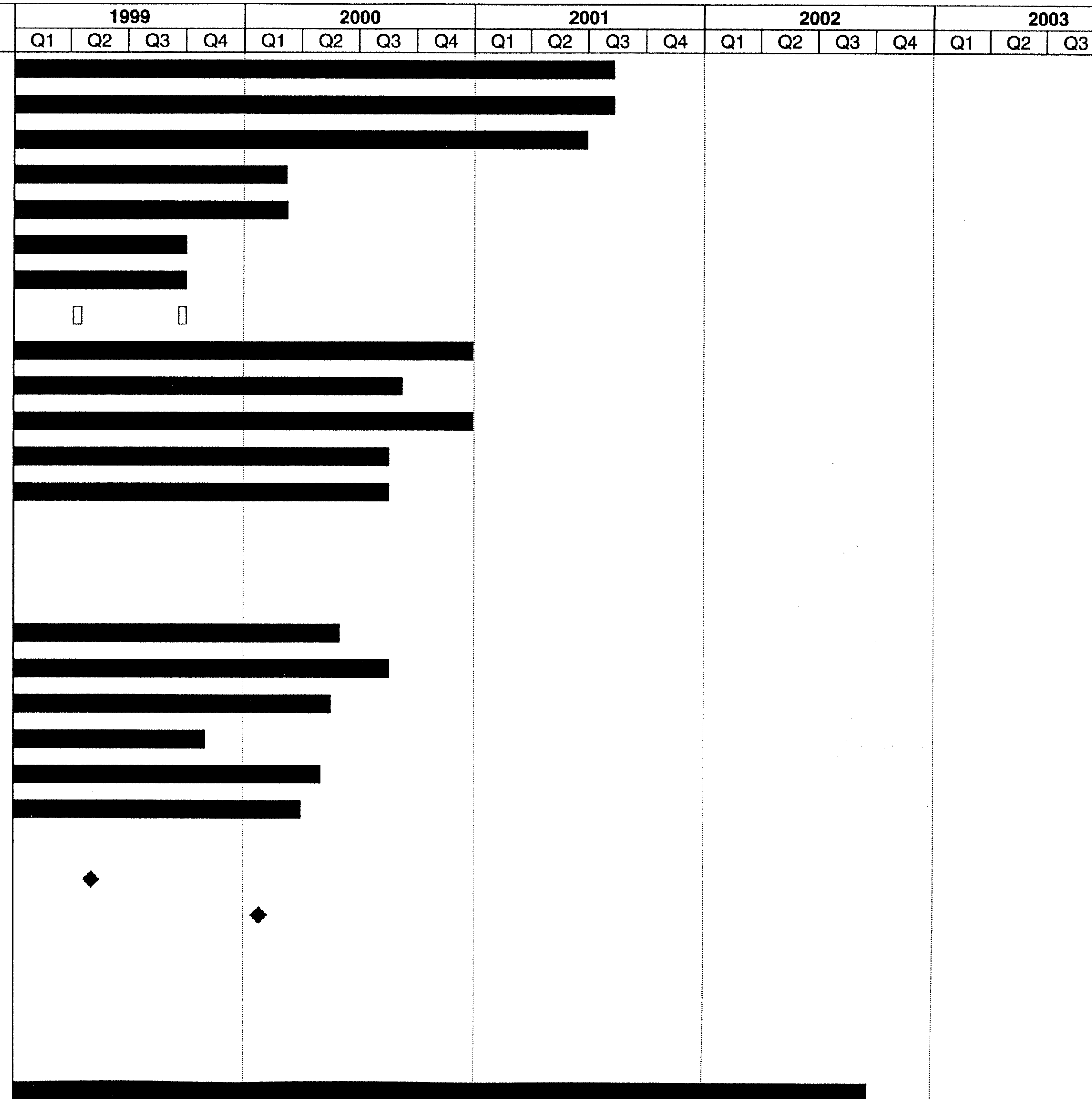
MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

Activity



HYDROCHEMICAL STABILITY
- Matrix fluid chemistry
  - Water sampling and analyses
- KLX 02 resampling
- Modelling

PROGRAM FOR MONITORING OF GROUNDWATER CHEMISTRY
- GROUNDWATER CHEMISTRY MONITORING
  - Water sampling

DEGASSING AND TWO-PHASE FLOW
- Gas injection tests
- Two-phase tests

THE TASK FORCE ON MOD. OF GROUND. FLOW AND TRANSP. OF SOLUTES
- TASKFORCE
  - Issue Evaluation Table
  - WWW Task Force
  - Task No 4C+4D: Non-sorbing tracer tests
  - Task No 4E: Sorbing tracer tests
  - Task No 4F: Sorbing tracer tests STT-2
  - Task No 5: integration Hydro-chemistry
    - Task A - Data compilation
    - Task C - Hydrogeological modelling
    - Task D - Hydrochemical modelling
  - Task Force meeting 11
  - Task Force meeting 12
  - Task Force meeting 13

DEMONSTRATION OF TECHNOLOGY FOR AND FUNCTION OF IMPORTANT PARTS OF THE REPOSITORY SYSTEM

BACKFILL AND PLUG TEST

MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

Activity

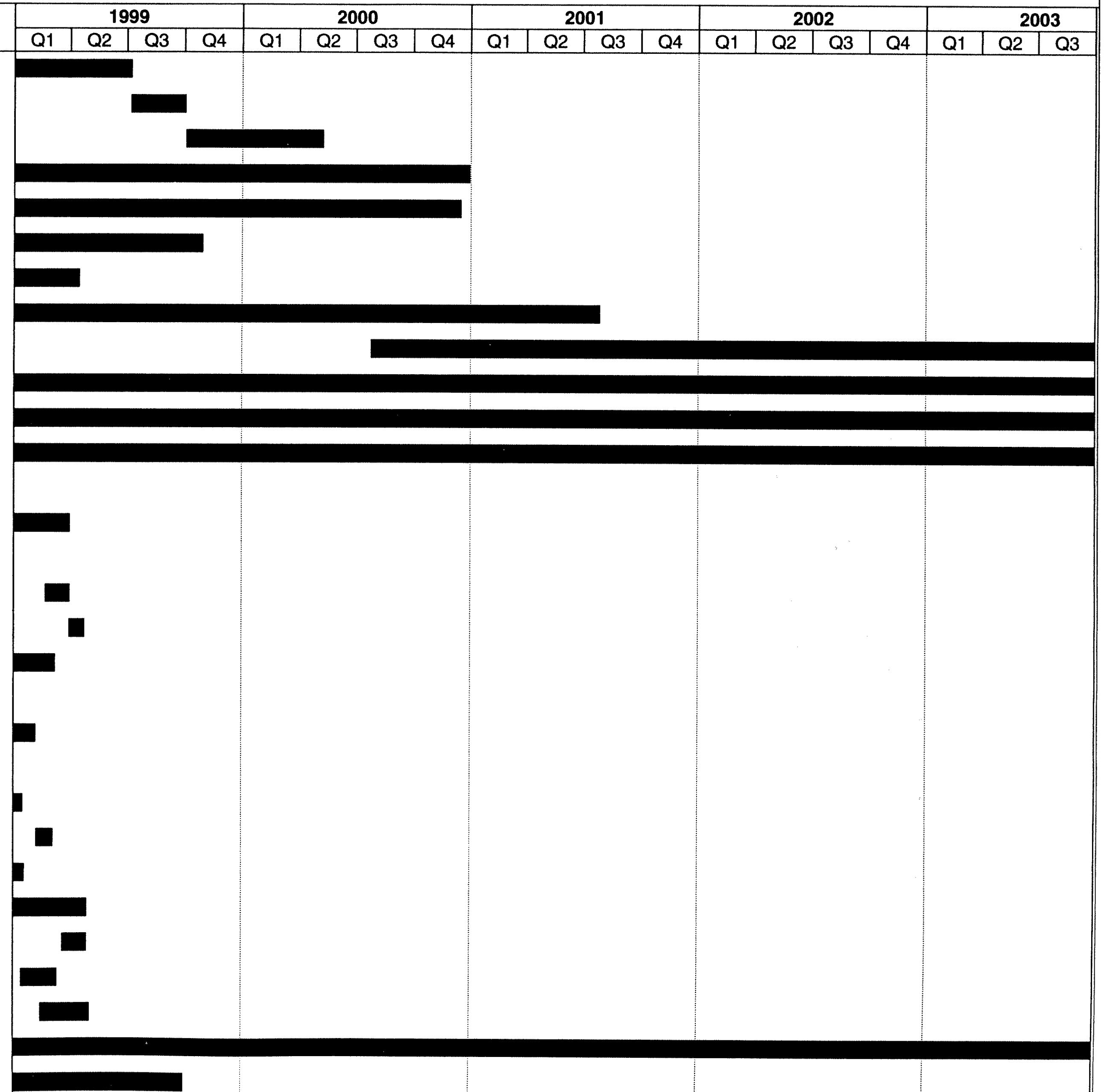
- Preparation
- Deposition hole drilling
- Characterization dep holes
- Canister manufacturing
- Bentonite block production
- Emplacement machine
- Roadbed
- Backfilling and Plug construction
- Monitoring and testing

TECHNOLOGY DEMONSTRATION

- Demotunnel
  - Detailed geomapping
  - Pilot hole characterization
  - Deposition hole drilling
    - Preparations Demo
    - Deposition hole drilling
  - Characterization dep. hole
- TBM-hall
  - Pilot hole characterization
  - Deposition hole drilling
    - Preparations TBM
    - Drill dep.hole 1
  - Characterization dep. hole
  - Testing of equipment prototyp/retrieval
- Deposit-machine
  - Transport down tunnel and assembly
  - Install rail in Demo-tunnel
- Install arrengement for "VISA-projektet"

Long Term Test of Buffer Material

- Pilot tests, S1, A1



MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

Activity

- Long Term Tests
  - Characterization
  - Heating tests
- Reporting
  - emplacement S2:A3

CRACKS CAUSED BY MECHANICAL EXCAVATION

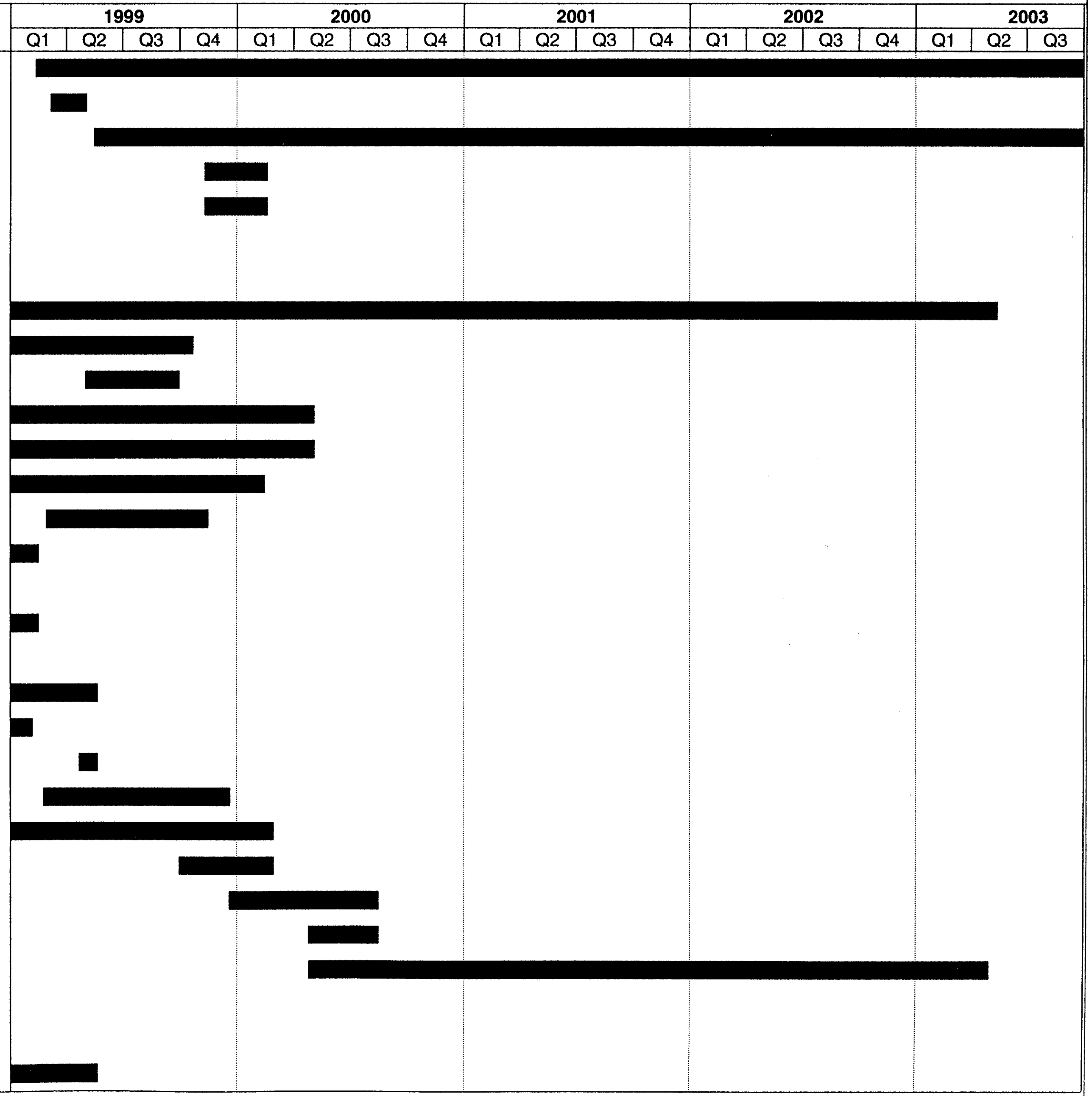
- Fieldtest inÄspö HRL

CANISTER RETRIEVAL TEST

- Design and planning
- Modelling
- Instrument developing and testing
  - Rock instrumentation
  - Buffer instrumentation
- Testing of deposition technique
- Characterisation
  - Tunnel investigation
  - Pilot borehole investigation
- Instrumentation holes
- Deposition hole drilling
  - Preparations
  - Deposition hole drilling
- Characterisation of dep holes
- Canister manufacturing
- Bentonite block production
- Test installation
  - Reporting of test set-up
- Saturation

ÄSPÖ FACILITY OPERATION

- New rescue chamber



MASTER SCHEDULE ÄSPÖ

Äspö Plan Right
Version 3.0

Activity

Alarm- and telesystem

Operations monitoring (proj alfa)

New redundant drainage system

Redundant pumpsystem