International Progress Report

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Äspö Hard Rock Laboratory

Status Report

January – June 1999

August 1999

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Summary

Investigations and experiments

The barrier function of the host rock

A project has been initiated to update the geoscientific models of Äspö with the new data that has become available since the Construction ended in 1995. The name of the project is GeoMode. The main aims of the project are to update the model descriptions of the rock volume around the laboratory tunnel below 300 m and to further develop tools for constructing such models.

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. A review meeting with external reviewers was held in March focussing on results from TRUE-1 and plans for future work within the TRUE Project and the Long-Term Diffusion Experiment. A draft of the final report for TRUE-1 was presented and discussed at the meeting. The report is now being updated on the basis of the received comments.

A tentative planning document for the second TRUE Stage (TRUE-2) was presented at the review meeting. 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 a new experimental site has to be found with a low hydraulic gradient. The SELECT-2 project has been organised to identify new test sites within the Äspö HRL. Four pilot holes have been drilled between the 300 and 400 m levels. Characterisation of these holes and evaluation of results is in progress.

As a part of the collaborative work between US DOE and SKB, SANDIA National Laboratories, SANDIA have conducted preliminary scoping microtomographic experimentation on Äspö core material. The experiments have been conducted using the Advanced Photon Source available at the Argonne National Laboratory. High resolution ($\cong$20 μm) 3D images can be generated.

The TRUE Block Scale project aims at studying the tracer transport in a fracture network over distances up to 50 m. The multi-packer systems in boreholes KA2511A and KA2563A have been optimised to facilitate planned (tracer) Pre-tests. In this context POSIVA flow logging have been performed in the boreholes. In addition, a series of tests have been performed targeted on the existence and connectivity of the interpreted Structure #9 in KA2563A.

A number of new conservative tracers have been tested in situ in Feature B at the TRUE-1 site. The tested tracers include deuterium, helium gas, dyes, metal complexes and benzoates. The field tests have been preceded by literature studies and contacts with experts and experimental groups worldwide. A preliminary assessment of the results indicates that it is possible to use Helium in the Äspö environment.

Important issues/questions to be addressed by the planned tracer tests in the block scale have been identified. Possible answers to the questions are posed in the form of hypotheses. In addition, design tasks related to the various hypotheses have been identified. The result will form a part of a Tracer Test Programme, which will detail the

tracer tests planned for the Tracer Test Stage. Work has progressed with building of stochastic continuum, discrete feature network and channel network models

The main field activity during the 2nd quarter has been performance of the Pre-test programme.

A reconciliation of the March'99 structural model has been performed using available hydraulic information and the available tracer test data, including the Pre-test results. A pathways modelling study have been performed using a channel network model to study fracture intersection effects. The same model has also been used to predict the four tracer injections associated with the lst of the Pre-test pumpings (PT-4).

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. Following the review meeting the test plan has been updated with a focus on an experimental concept, which builds on the experimental setup used for the REX project. This approach allows study of diffusion from a natural fracture, through the rim zone of fracture mineralisation and alteration, into the unalterad rock matrix.

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. 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, 5 to 10 days, both for the field and replica experiments.

The CHEMLAB probe has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions. The last diffusion experiment (experiment with 99Tc and 131I) in bentonite has been completed. A new site has been selected for the CHEMLAB experiments in the J-tunnel. Two new boreholes will be used for simultaneous running of both CHEMLAB 1 and 2. The planning for redox sensitive nuclide and actinide experiments in CHEMLAB 2 is made in cooperation with reseachers from Instittut für Nuklear Endsorchung in Karlsruhe (within the BMWi cooperation).

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 final report on the laboratory work on core samples from Äspö and artificial fractures has been published.

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. The 12th International Task Force meeting was held at Gimo, Sweden. Modelling results were presented for Task 4E, 4F and 5. Task 4E concerns blind prediction of tests with sorbing tracers (STT-1 and STT-1b). Task 4F comprises predictive modelling of STT-2 which uses the same setup as STT-1 but uses a lower flow rate, Q=200 ml/min. The objective of Task 5 is to assess the consistency of groundwater flow models and hydrochemical mixing-reaction models based on Äspö data.

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. A workshop was held in Wettingen, Switzerland, on February 3rd and 4th, at which the possible basis for an EC application was discussed. In order for the project to better match the expected date for granting of EC funding, if this will be the case, the start of installation has been postponed by six months. All field activities for characterisation of the rock mass around the Prototype Repository tunnel have been completed, including sampling and analysing of ground water with respect to redox conditions, which was done in April. Reporting of the results from the final hydraulic tests is in progress.

Type of instruments, number of and location in the buffer, backfill and rock have been further analysed and a report with proposed selection of instruments and their locations drafted. The study recommends that all instruments be made in titanium due to the highly corrosive environment.

The TBM machine for deposition hole boring is now running properly, and boring of the first hole in the Prototype Repository tunnels, the inner one, started on June 21^{th}. Drilling on the third hole had started on June 30^{th}. Optical inspection of the first two holes indicates that the holes meet the requirements on straightness and smoothness of the borehole wall.

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. Backfilling and compaction of 6 sections of a mixture of 30% bentonite and 70% crushed rock have been completed. Each section contains 6 layers with the axial thickness 35 cm and the inclination 35 degrees. The vibrating plate and the vibrating “roof compactor”, both developed for backfilling tunnels, were used during the compaction of each layer. The technique has worked very well. Four sections have been backfilled with 100% crushed rock and compacted. In order to avoid the appearance of an open slot between the none-swelling backfill of 100% crushed rock and the roof a 10 cm gap at the roof was filled with two layers of bentonite blocks in these sections. The remaining openings, caused by the irregularities of the rock, were filled with bentonite pellets. The pellets were placed with a “pellets blowing machine”. ENRESA has installed 13 devices for measuring the local hydraulic conductivity in section 4. The data collection house has been built and the cables and tubes have been led on cable ladders into the data collection systems in the house.

The Demonstration of Repository Technology project aims to show in a perceptible way the different steps in encapsulation, transport, deposition, and retrieval of spent nuclear fuel for specialists and the public. The four deposition holes that will be used in the project have been bored with good result.

The Canister 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 two deposition holes have been bored to a depth of about 8.5 m below the concrete floor surface and about 8 m below the rock floor surface. The equipment for registration of acoustic emission and rock mechanical response during boring worked well as far as could be seen during the data sampling.

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 have started. Five 76 mm core holes have been drilled down to a depth of 8 m in order to make flow and pressure investigations. Core mapping, BIPS analyses and hydraulic tests of the holes have been made, which show that the rock volume contains only a few natural fractures and the water inflow seems to be very low. The five pilot holes have been widened to the test hole diameter 300 mm by use of percussion drilling technique.

International Cooperation

Nine organizations from eight countries are currently (June 1999) participat-ing in the Äspö Hard Rock Laboratory.

A trilateral agreement between SKB, JNC and CRIEPI for the period through 2002 has been signed.

Posiva has participated in the fieldwork of the Äspö HRL according to the joint project agreement mainly in one project: Evaluation of the flow measurement methods for characterising the groundwater flow. The work began with pressure measurements using the Posiva Flowmeter in borehole KLX02.

Facility Operation

The new rescue chamber at the –420 m level will be taken into operation in September. The chamber is sited in an existing niche and will be equipped with a CO_2 scrubber system for cleaning of the used breathing air. The system is designed for 60 people in six hours and will considerably increase the safety at this level.

At the bottom of the tunnel a new fire brigade station has been built. Equipment, including a vehicle, for fire fighting is always kept at the station. The fire brigade has had several exercises at the deeper levels of the tunnel.

Data Management

The most important SICADA applications are now available for Windows 95 and Windows NT.

Version 2.0 of the Rock Visualisation System (RVS) was delivered in April 1999. The new version of RVS is compatible with MicroStation/J.

Groundwater head and chemistry monitoring

The Hydro Monitoring System has been operating without problems and supplied data to the various projects undertaken in the Äspö HRL.

The sampling campaign for the groundwater chemistry monitoring program was undertaken in April 1999. Many project specific samples were taken in addition to the “monitoring samples”.

Information activities

The total number of visitors to the Äspö HRL facilities during the first half of 1999 is 6236. About 300 people attended the “Äspö Day” on May 9th.

The ”Urberg 500” tours started on the 14th of June. These are guided tours open to the general public. The tours are arranged in cooperation with the tourist office in Oskarshamn. During the summer months there will be two tours a day during weekdays and one tour a day during weekends.

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 will be printed in June 1999.

Planned work

A short course on geological modelling will be held in June. 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 autumn 1999.

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 variablility 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 nearfild and farfield. 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 radiolyses 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

Reporting

A Review Meeting with external reviewers was held March 8-9 focused on plans for future work within the TRUE Project, including the Long-Term Diffusion Experiment and the Second TRUE Stage (TRUE-2). For this meeting a draft of the final report of the First TRUE Stage was presented (Winberg et al., in prep) and during the meeting integrated results and preliminary conclusions were presented.

TRUE-1 Conceptual modelling

An updated version of the structural geological model of the TRUE-1 site was presented in the status report for the 4th quarter 1998 (IPR 99-03). During the period a conceptual representation of Feature A has been produced, cf. Figure 3-1. The figure shows Feature A positioned non-centric in relation to the brittle mylonite precursor. The feature is also assumed to be partially filled with gouge material. As a consequence, the flowing water is interchangeably in contact with either mylonite (low porosity/diffusivity), altered Äspö diorite (high porosity/diffusivity), and gouge material. It should be pointed out that only traces of gouge material has been collected from Feature A, but collection of gouge will be attempted when drilling an additional exploration hole at the TRUE-1 site using triple-tube technique. It should be mentioned that the gouge material in Feature A is assumed to be made up of an assortment of size fractions, from the very fine clayish fraction 0.125-0.25 mm to the fraction to 0.25-0.5 mm. Future work will include a more comprehensive address of gouge material, its mineralogy and geochemistry and its transport characteristics (Kd and effective diffusivity De) on material from a wide range of structures, from the site scale NE-1 down to the detailed scale Feature A.

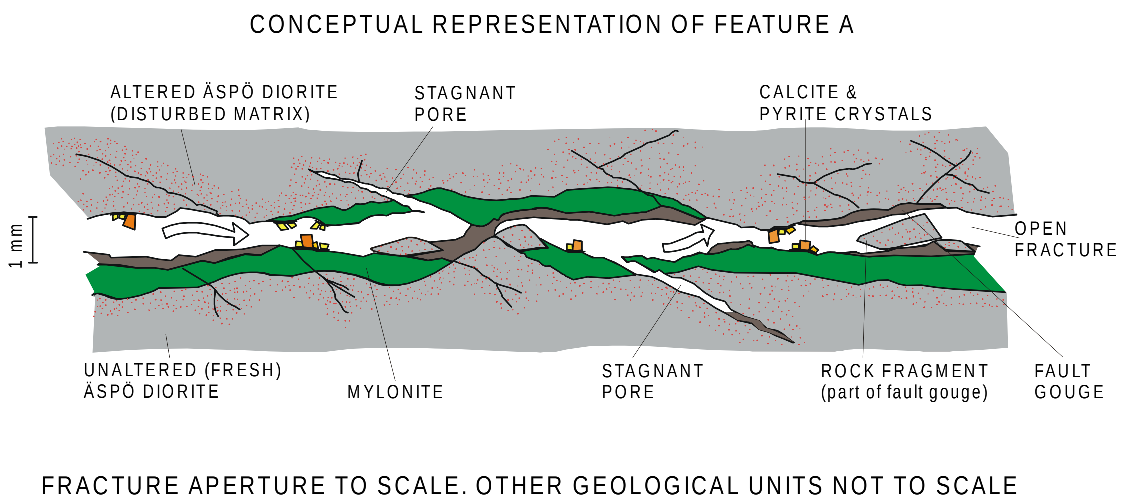

***Figure 3-1** Conceptual representation of Feature A seen in a vertical section (Winberg et al., in prep.)*

Experimental

The experimental results of the STT-2 tracer experiment run between KXTT4:R3 and KXTT3:R2 at Q=0.2 l/min feature some interesting results compared to STT-1 and previous tests in the same flow path with conservative tracers. Preliminary evaluation of the RC-1, PDT-2 and STT-1 experiments have all shown anomalous dispersivities, ranging from 1.1 to 2.0. This has been attributed to the fact that two fractures are present in KXTT4:R3, both fractures probably involved in the transport, cf. Figure 3-2, but both having the same properties, resulting in one single breakthrough.

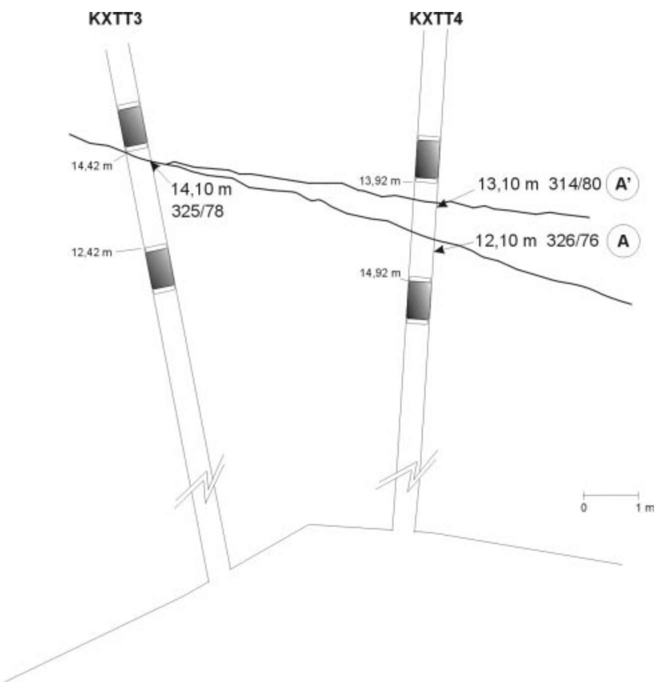

Figure 3-2 *Detailed conceptual model of geometry of flow path between sections. KXTT4:R3 and KXTT3:R2.*

The results of STT-2, however, show two distinct peaks, cf. Figure 3-3. The separation between the two peaks is about 17 hrs. During the two previous experiments run at Q=0.2 l/min in the same flow path, RC-1 and PDT-2, no signs of duality in breakthrough were observed. The noted change during STT-2 is attributed to imposed changes in hydraulic gradient or a physical change in the flow paths, or a combination of the two. We should acknowledge that the flow path has been pumped continuously from June 1997 till October 1998.

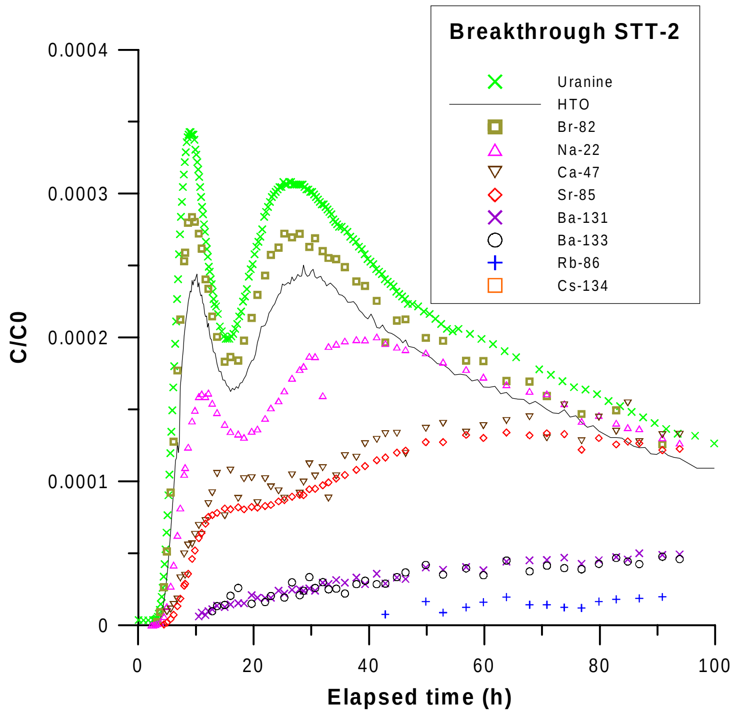

Figure 3-3 *Tracer breakthrough after 100 hours in the pumping section KXTT3:R2 during STT-2. Tracer concentrations are normalised to concentration in the injection section.*

3.2.2 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 a situation with a low hydraulic gradient such that pumping at low flow rates can be employed without loosing tracer mass.

At the March 8-9 review meeting the need and relevance of establishing TRUE-2 at a new site was questioned. The main argument for moving to another site is the address of repeatability in a different structure which ideally would offer a different mineralogy, and hence different sorption characteristics. The main argument for performing TRUE-2 in the TRUE-1 site is that the basic characterisation work is already completed. However, in answering up to the stated demands above one may be forced to search for a new structure deeper into the studied rock volume.

As a consequence of the ensuing discussions after the review meeting it has been decided to perform the planned programme for pilot drilling and characterisation, SELECT-2, with the added component that an additional borehole (KXTT5) will be drilled at the TRUE-1 site. The total number of boreholes drilled thus amounts to four, cf. Figure 3-4.

The time plan for SELCET-2 involves drilling of the boreholes during the Spring. A second TRUE-2 Review Meeting is scheduled for early 1999, with a scheduled detailed characterisation of the selected site starting in February 2000.

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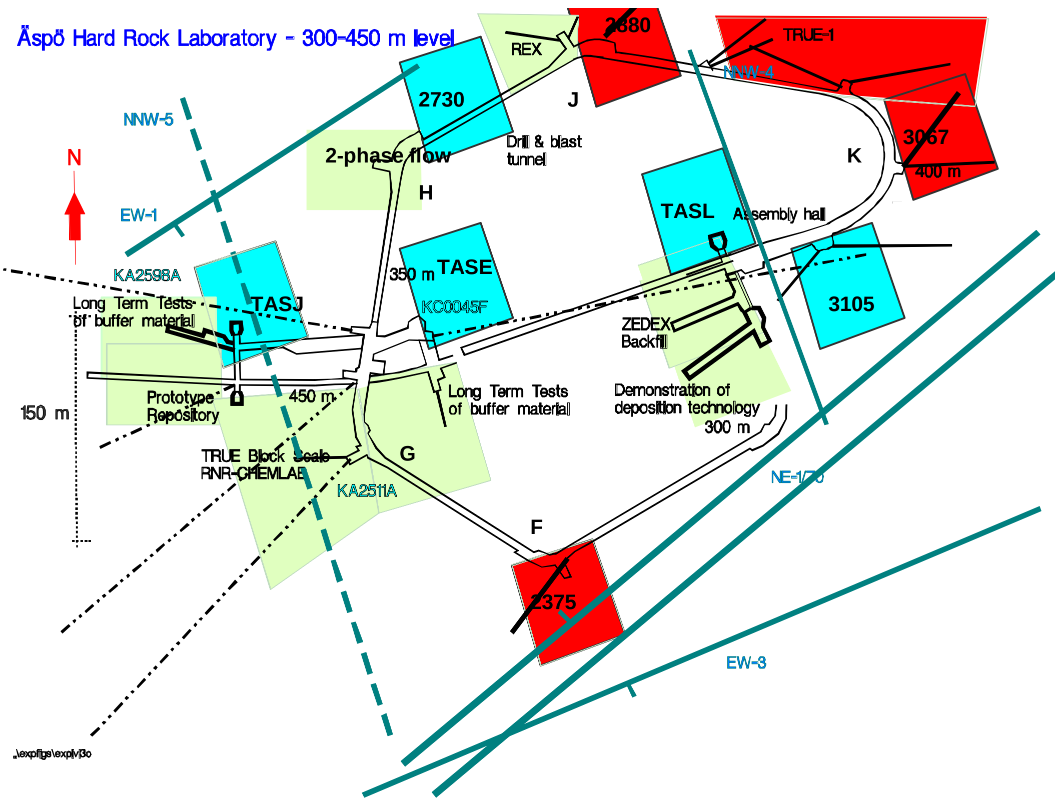


Figure 3-4 *Overview of planned pilot boreholes within the SELECT-2 programme. The blocks being targeted with pilot boreholes are indicated in red (dark shade).*

3.2.3 SELECT-2

During the period four pilot borholes have been drilled using triple tube technique; KA2377A, KA2865A01, KXTT5 and KA3065A01, the labels reflececting the collaring of the respective borehole. KXTT5 has been drilled at the TRUE-1 site, cf. Table 3-1.

The basic characterisation of the boreholes performed to date include borehole TV imaging (BIPS), POSIVA flow logging and borehole radar. BOREMAP core logging will be performed during the summer. The BIPS and POSIVA flow log in combination have identified a series of suitable candidates for LTDE and for TRUE-2.

Table 3-1. Collar cooordinates, bearings and inclinations of the boreholes drilled within the SELECT-2 project

Borehole ID	Easting (m) Y	Northing (m) X	Elevation (masl)	Azimuth (deg.)	Inclina-tion (deg.)	Length (m)
KA2377A01	2133.56	7123.74	-317.34	229.61	-5.05	41.17
KA3065A01	2389.61	7349.23	-408.25	59.91	-4.98	69.95
KA2865A01	2230.14	7462.75	-379.34	49.26	-4.09	27.73
KXTT5	2313.63	7429.34	-389.82	48.0	-15	25.85

Characterisation of gouge material

One secondary objective with drilling a new triple tube borehole at the TRUE-1 site was to verify existence of gouge material in Feature A. No firm evidence of gouge exists to date, but SEM/EDS has indicated a thin layer of clay material on the fracture surfaces of Feature A. Unfortunately, the drill bit suffered unexpected enhanced rotation at the intercept with feature A so no gouge material was collected.

The supposed material from Feature A was planned to be integrated in to a characterisation and experimentation effort with the aim of providing data on gouge material from a suite of structures of various size. The programme void of Feature A material 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.

Visualisation of diffusion processes

As a part of the collaborative work between US DOE and SKB, SANDIA National Laboratories, SANDIA have conducted preliminary scoping microtomographic experimentation on Äspö core material, cf. Figure 3-5. The experiments have been conducted using the Advanced Photon Source available at the Argonne National Laboratory. The APS source has a well-collimated, monochromatic beam such that high resolution images with less scattering can be generated. In addition, APS allows three-dimensional imaging. In the case of 2D averaging, pore space will be difficult to detect, as the porosity becomes smaller.

So far measurements have been performed on non-traced rock samples (cylinders, 9mm in diameter). In the next series of runs, the samples will be saturated with K or CsCl. Measurement will be performed at two different energies, one immediately below the absorption edge of the tracer, and one near the absorption edge. By differentiating the two resulting images, the tracer can be separated , and enhance the visualisation of the pore space.

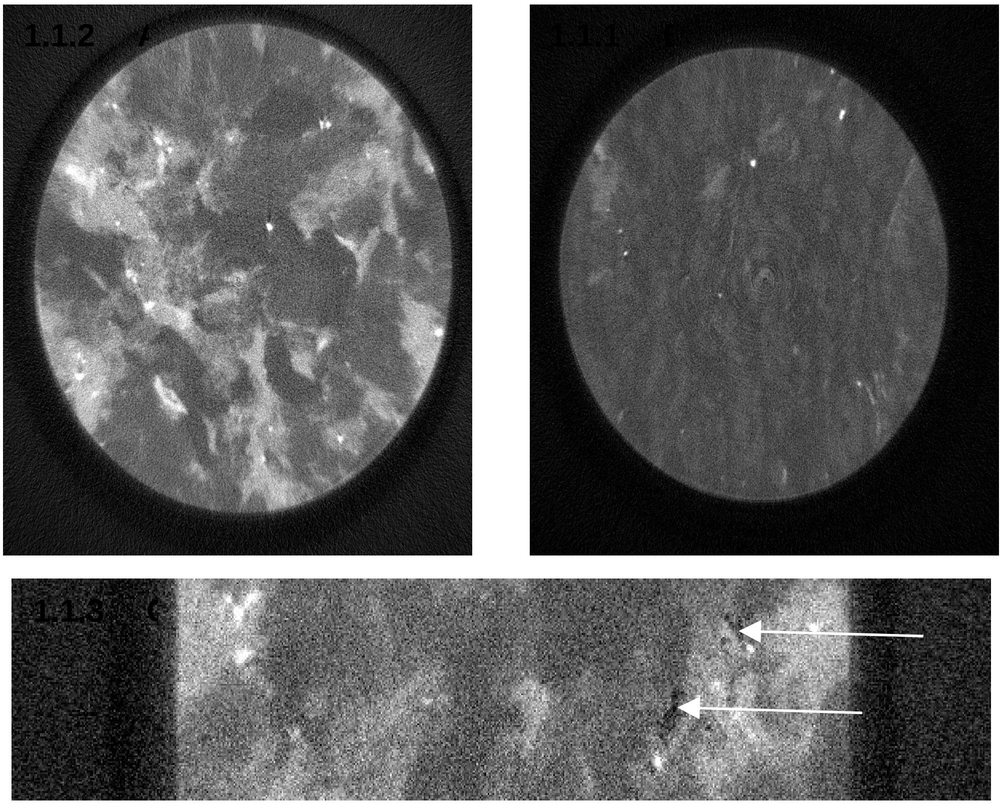


Figure 3-5*:* *Two-dimensional slices from tomographic reconstructions of images taken from Äspö diorite (A and C) and Äspö fine-grained granite (B). Voxel size of images is approximate 19 μm, however resolution has been lost in converting file to a jpeg file. .Variations in gray scale is due to different minerals in the sample. Note that some pore space can be seen in the Äspö diorite (arrows in C).*

3.2.4 TRUE Block Scale

Background

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

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

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

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

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

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

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

During 1997, 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 characterized using different geological, geophysical and hydrogeological methods. Based on the collected data the structural model of the block has been updated sequentially.

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

Overview of activities during the period

The multi-packer systems in boreholes KA2511A and KA2563A have been optimised to facilitate planned (tracer) Pre-tests. In this context POSIVA flow logging have been performed in the boreholes. In addition, a series of tests have been performed targeted on the existence and connectivity of the interpreted Structure #9 in KA2563A.

A reconciliation of the March'99 structural model has been performed using available hydraulic information and the available tracer test data, including the Pre-test results. A pathways modelling study have been performed using a channel network model to study fracture intersection effects. The same model has also been used to predict the four tracer injections associated with the lst of the Pre-test pumpings (PT-4). The studies listed above are all part of the planning process for the Tracer Test Stage. The results of the studies have been integrated into a Tracer test Programme.

A number of new conservative tracers have been tested in situ in Feature B at the TRUE-1 site. The tested tracers include deuterium, helium gas, dyes, metal complexes and benzoates. The field tests have been preceded by literature studies and contacts with experts and experimental groups worldwide.

Important issues/questions to be addressed by the planned tracer tests in the block scale have been identified. Possible answers to the questions are posed in the form of hypotheses. In addition, design tasks related to the various hypotheses have been identified. The result will form a part of a Tracer Test Programme which will detail the tracer tests planned for the Tracer Test Stage.

Work has progressed with building of stochastic continuum, discrete feature network and channel network models

The main field activity during the 2^{nd} quarter has been performance of the Pre-test programme.

Site characterisation

A series of flow measurements have been performed in borehole KA2563A using a double packer system with simultaneous observation of pressure responses in the adjacent borehole sections. Subsequently POSIVA flow logging in a continuous mode has been carried out in KA2563A and KA2511A. The results complement the corresponding results from KI0025F02 and KA3510A. Further POSIVA logging during open and closed borehole conditions has been carried in KA2563A, when flowing and not flowing Structure #9 in section KI0023B:P6. The latter with the intention to identify the existence or not of Structure #9 in KA2563A. The tests clearly identified Structure #20 and #13, but the results regarding Structure #9 remained inconclusive/uncertain. As a result a so called flow inhibitation test was conducted where a double packer straddle without a permeable screen was lowered to seal off selected depth intervals in KA2563A in an otherwise free-flowing KA2563A. The reduction in inflow before and beyond the straddle, and pressure responses in adjacent holes were monitored. The tests confirmed Structure #13, but no further evidence was provided regarding Structure #9 in KA2563A. A final confirmation test with a four packer system in KA2563A was devised to confirm the observed pressure responses associated with Structure#9 in KA2563A when a hydraulic disturbance is applied in sections containing Structure #20. The conclusion of the test is that the structure (candidate for Structure #9) at 265 m in KA2563A is not associated with structure #20 and the pressure responses monitored in previous crosshole tests were artefacts induced by the instrumentation. The structure (candidate for Structure #9) at 230 m in KA2563A is not in good hydraulic contact with structure #20 and is therefore not considered to be of interest for future tracer experiments.

As a result borehole KA2563A was instrumented such that the previous focus on Structure #9 was shifted to Structure #19 at L=245 m.. This allows a possibility to inject tracer in Structure #19 during experiments run in Structure #13 and #20 and to run experiments in the individual Structure #19 itself.

The pre-tests have had two principle goals, first to complement the existing series of tracer dilution data, and in particular for the new sections resulting from the reinstrumentation of the borehole array performed in March 1999. In addition to provide firm demonstration of feasibility of tracer tests in the block scale. In total three pumpings (PT-1, PT-2 and PT-3) were performed in sections containing Structures #13, #21 and #20, respectively. Between 6 to 12 sections were tested with tracer dilution techniques, before and during pumping. Out of a total of 28 separate tracer dilution tests, using 14 different sections and three sink sections, 16 (57%) show a significant increase in flow under pumped conditions compared to ambient conditions.

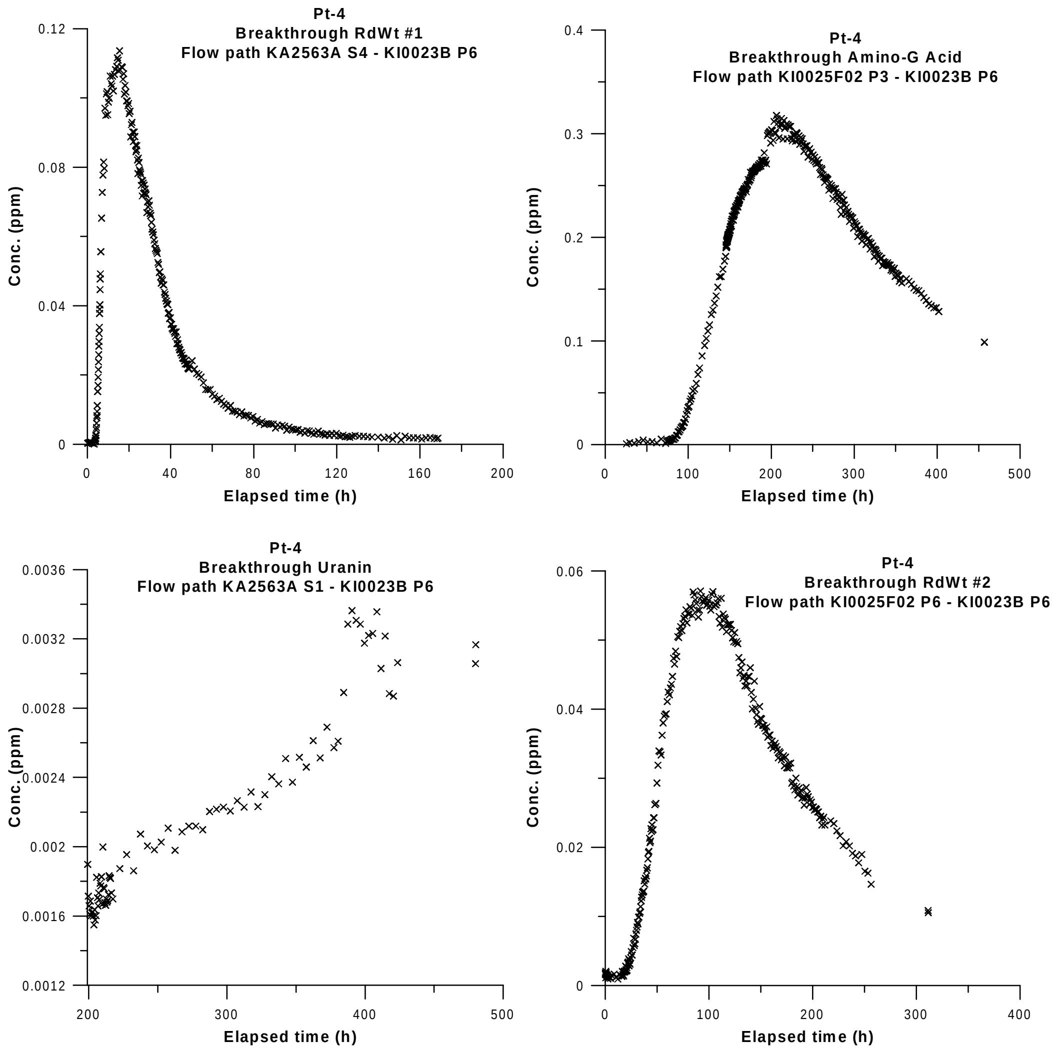


Figure 3-6. *Tracer breakthrough in KI0023B:P6 during PT-4. Note that .the scales of the axes differ between the plots.*

During a subsequent PT4, the PT-2 situation with pumping in Structure #21 in KI0023B was revisited with actual tracer injections in neighbouring sections containing Structures #22, #13/#21 and #20. The results of these tests show recovery from all sections, representing multiple structure pathways over distances ranging between XX-YY m, and very high recovery for the tracers injected in KI0025F02:P3 (#13/#21) and KI0025F02:P6 (#22), ranging between 76-80%, assumed to have shown full recovery had the experiment been prolonged, cf. Figure 3-6.

The prospects for block scale tracer test are consequently promising.

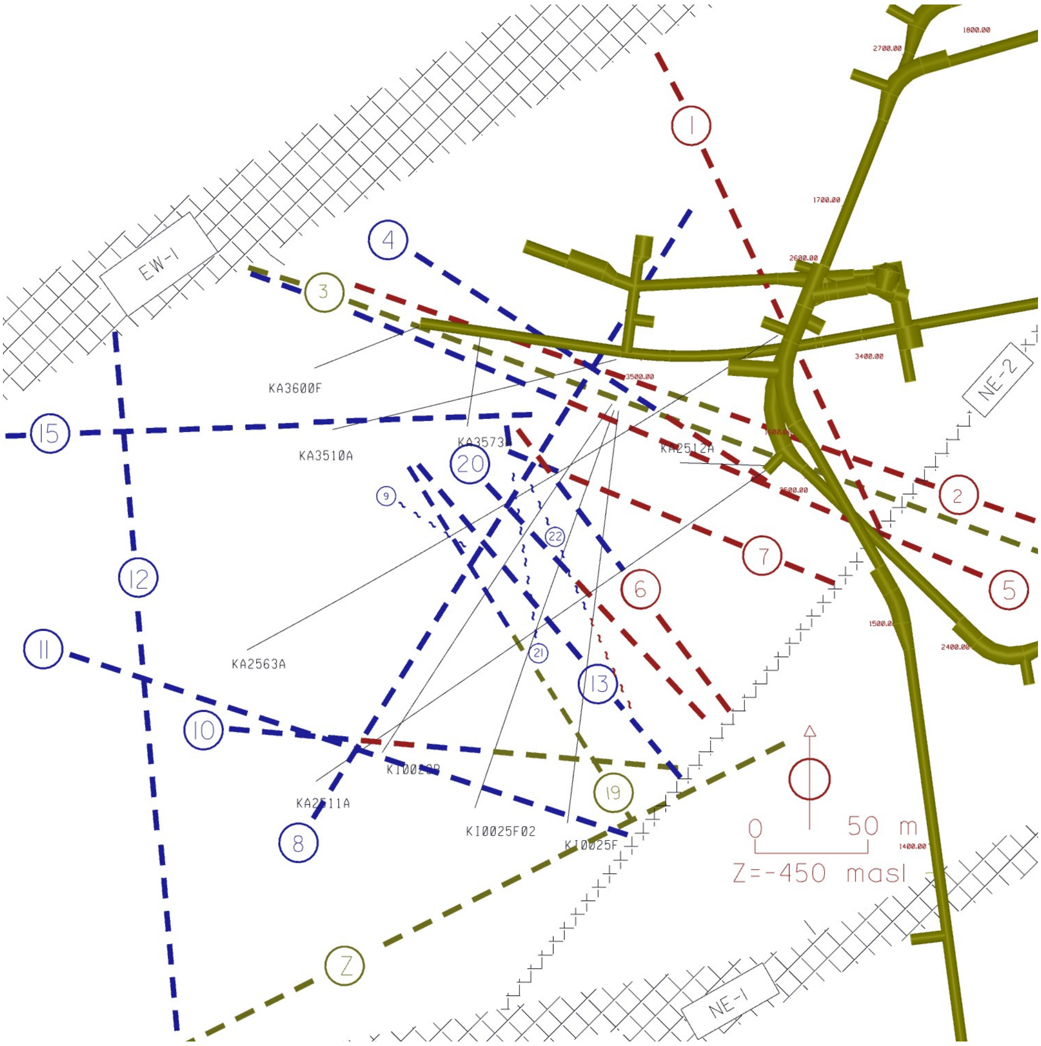


__Figure 3-7__ Structural model of the TRUE Block Scale rock volume (March 1999). Plan view at Z=450 masl.

March 1999 structural model

During the 1st quarter the structural model has been updated using new data from KI0025F02, KA2563A and KA2511A, including the results of the flow logging described above. The basic result is that the majority of structures are retained with minor or no changes. The major change is the downplaying of the role attributed to Structure #9 in connecting Structures#13 and #20. The latter seen as the primary network to be tested by future tracer tests. However, the detail added by the new POSIVA flow logs in combination with the BIPS, has allowed identification of two alternative structures which may provide the observed connection between Structures #13 and #20. These are denoted Structures #21 and #22, cf. Figure 3-7. It should be emphasised that these structures should be regarded as being associated with uncertainty. The results of the planned Pre-tests, which include complementary tracer dilution tests and actual tracer tests, will be used as a basis to strengthen the interpretation made and to investigate the need for additional optimisation of the multi-packer arrays, or even the need for an additional borehole.

Hydraulic reconciliation of the March 1999 structural model

The hydraulic reconciliation of the March'99 structural has involved analysis of drilling record of the most recent borehole, KI0025F02, and associated pressure responses. In addition available flow logging and flow and pressure build-up tests have been used.

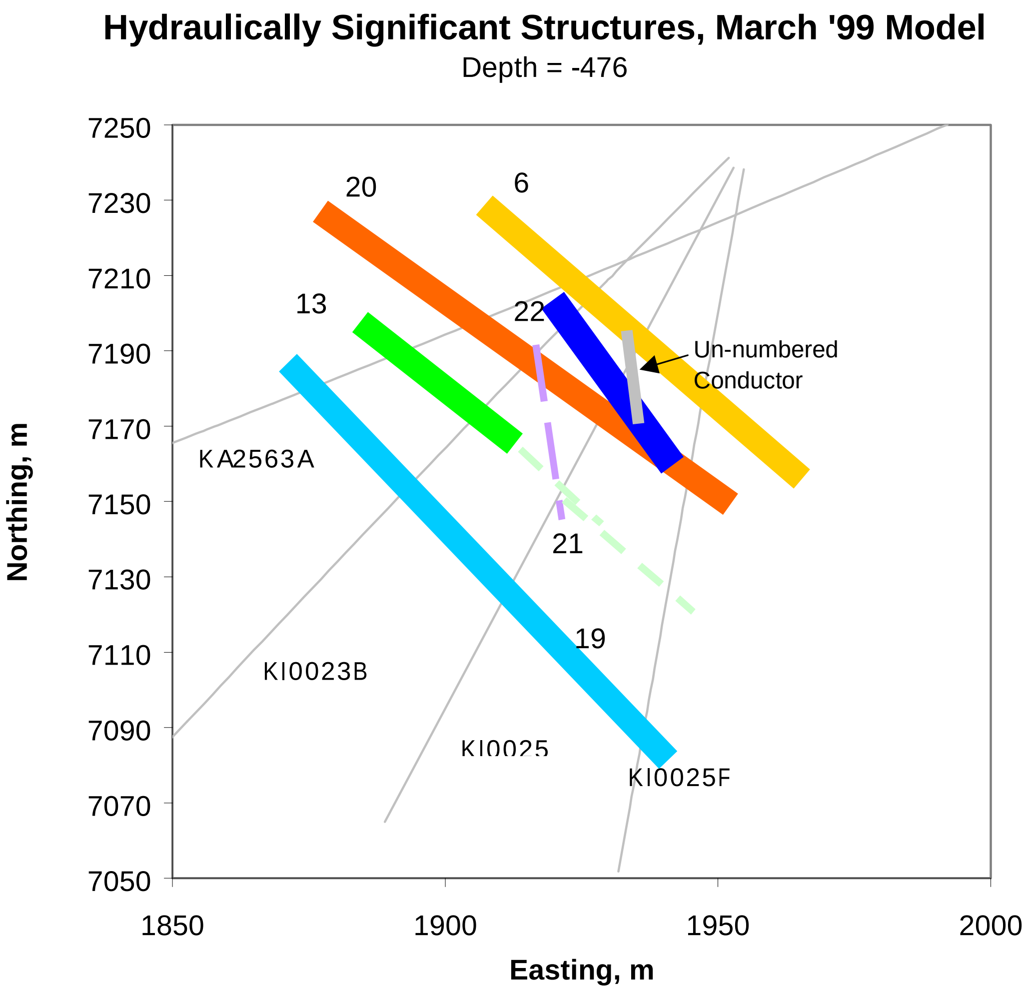


__Figure 3-8__ Reconciled March'99 structural model of the TRUE Block Scale rock volume. Plan view at Z=-450 masl

Finally the results of the tracer dilution tests have been utilised.

The hydraulic reconciliation overall confirm the principal structures contained in the March'99 structural model. Structures #10, #19, #20 and #6 appear hydraulically in a consistent manner with the structural model, cf. Figure 3-8. Structure #13 appear in KA2563A and KI0023B, but may not continue southeastward to KI0025F. Feature #22 is interpreted to appear in KI0023B and KI0025F02, but does not extend to KA2563A. Structure #21 is still difficult to interpret over larger distances based on the hydraulic information. The tracer dilution data, however, indicate connection between KI0025F02:P3 and KI0023B:P6. Additional connecting fractures between Structures #13 and #20 are likely to exist, and evidence for additional conductors have been presented.

Identification of issues to be addressed by tracer experiments

Three basic issues/questions have been identified as part of the ongoing development of a Tracer test Programme;

1) What is the conductive geometry of the block being investigated by the performed tracer tests? Does the most recent update of the structural model reflect the structure with sufficient accuracy to allow design and performance tracer tests?

The above question is a basic one and provides the geometrical constraints for establishment of connectivity in the studied network of structures.

2) What are the properties of the fractures/structures that control transport in the studied network of features?

Taking the step from study of a single fracture equivalent to the one studied within TRUE-1involves the inclusion of an additional potential source of heterogeneity. This added source of heterogeneity is the intersections between fractures, which can be expected to act as zones of enhanced conductivity, zones of reduced conductivity (barriers), or a combination of both. The challenge in TRUE Block Scale, with all due consideration to constraints imposed by the geometry of existing boreholes in relation to existing structures, available intersections etc., is to attempt to distinguish the effects of the heterogeneity exerted by fracture intersections from the heterogeneity within an individual fracture plane. Generic and site-specific scooping calculations to this effect are presently under way.

3) What are the retention processes that control transport in fracture networks, and which can be measured in field tracer experiments?

It is acknowledged that the type of potential retention processes in the block scale, diffusion into stagnant pores of into the matrix and sorption on outer or inner (matrix) surfaces should not change with scale, moving from a single fracture to a network of fractures. The step to block scale should involve address of a variety of different structures, both in terms of size, properties and scale of heterogeneity. Potentially the larger structures may include a higher amount of gouge infilling material, and potentially the fracture intersections may carry significant amounts of gouge, which may affect the retention capability.

In the Tracer Test Programme, which is under development, a full account of the hypotheses posed, results of design tasks including visualisations, tabulations of source and sink intervals, results of pre-tests, and scooping calculations will be presented.

Test of new conservative tracers

The *in-situ* tests of new non-reactive tracers have been finished. Four tests have been performed at the TRUE-1 site in Feature B. The first test was focused on a number of metal complexes earlier used in Stripa and also at Äspö, cf. Table 3-2. The second test focused on the feasibility of using Helium (performed in co-operation with ANDRA and Solexperts, Switzerland). The third test also included Helium, a number of fluorescent dyes and Deuterium. The final test focused on five different fluoro-benzoates.

Table 3-2. Tracers tested in Feature B at the TRUE-1 site

Tracer	Name	Analysis	Dynamic Range	Comment
Gases	He-3	Mass spectrometry	Large	Two tests performed by Solexperts
Stable isotopes	Deuterium	Mass spectrometry	? ?	Expensive analysis
Dyes	Eosin B, Y Phloxine Rose Bengal MTMBA UV-1 Sulphorhodamine G Pyranine	Fluorometry HPLC	Large	Phloxine and Rose Bengal not good, possible precipitation. HPLC-analyses from tests by Solexperts pending
Metal-Complexes	Yb-EDTA In-EDTA Lu-EDTA Ni-EDTA Gd-DTPA Ho-DTPA	ICP-MS	Large	Used in Finnsjön, Stripa, TRUE-1
Benzoates	PFBA 2,3-DFBA 2,6-DFBA 3,5-DFBA 2,3,4,5-TFBA	HPLC	Large?	Used by SANDIA in USA Analyses pending
Others	ReO_4	ICP-MS	Large	Used in Finnsjön

The results of the first test with metal complexes, cf. Figure 3-4, show that most of the complexes behave similar to the reference conservative tracer Uranine. However, two of the injected tracers, Phloxine B and Ni-EDTA, show significant losses (>50%). The high peak for ReO4- , has currently no explanation.

The tracer mass recovery was calculated to 100% for Uranine while the others are somewhat more uncertain due to the few analyses made in the injection loop. Assuming that the same relative mass for the metal complexes is injected as for Uranine, mass recoveries are somewhat lower for the metal complexes (81-93%), the analysis is still ongoing. The high values for ReO4 are also reflected by a 110% recovery which indicate analysis errors.

A closer inspection of the peak of the breakthrough curves shows that the rising part is almost identical for all tracers (except Ni-EDTA and Phloxine) while the peak and the falling part is slightly lower for all metal complexes in particular In-EDTA and Lu-EDTA. The significance of this difference is still being investigated.

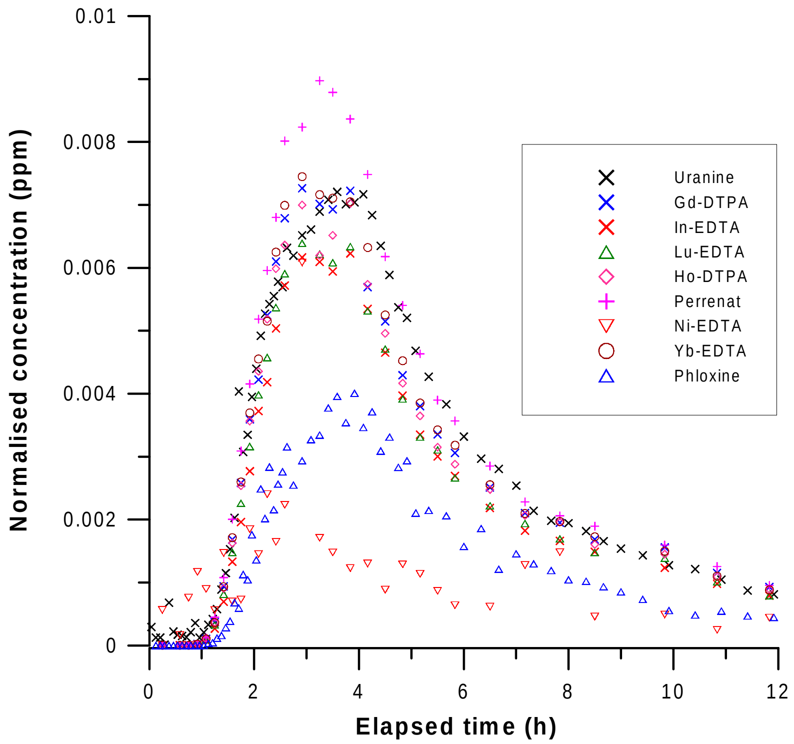


Figure 3-9 *Tracer breakthrough curves for the first 12 hours of the first tracer test. The tracer concentrations are normalised to the injection concentrations at t=1.99 hours.*

The results of the other tests are still being analysed. A preliminary assessment of the feasibility test of Helium indicates that it is possible to use Helium in the Äspö environment.

Design calculations of fracture intersection effects

As part of the panning for the Tracer test Stage, design calculations have been performed with the purpose to investigate the possibility to detect and distinguish effects of fracture intersection zones (FIZ) from the other types of heterogeneity present in a fracture network. Two types of modelling have been performed, one generic model focused on a fracture intersection, and one site-specific focused on the Structure #20/#21 intersection in the TRUIE Block Scale rock volume.

In both simulation cases tracer tests have been simulated along, across, and diagonally across the FIZ. In addition the sensitivity to transmissivity contrast between the FIZ and the structures forming it, heterogeneity and degree of heterogeneity in the structures, distance from borehole intercept to FIZ, have been analysed.

The results of the simulation show that it will be difficult, if not impossible to distinguish the effects of the FIZ from the overall, heterogeneity. One aspect which eg. has not been studied is the heterogeneity and spatial continuity within the FIZ itself.

Planned work

3rd Quarter, 1999

TRUE-1 reporting

- Finalisation of reporting

TRUE-2

- Allocation of experimental sites for LTDE and TRUE-2 based on SELECT-2 results.

TRUE Block Scale

Preliminary Characterisation Stage

- Finalisation of reporting of Preliminary Characterisation Stage

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

Background

The Long-Term Diffusion Experiment is intended as a complement to the *in-situ* dynamic experiments and the laboratory experiments performed within the TRUE Programme. The initial idea was to locate a static tracer experiment to an unfractured rock mass with the intention to characterise diffusion of radionuclides in the rock matrix. A test plan with this direction was presented at a Review Meeting held March 8-9, 1999.

Experimental concept and review

The experimental objectives include investigation of matrix diffusion in situ under natural mechanical, chemical and hydraulic conditions. The derived diffusivities will be compared with the corresponding parameters derived from performed laboratory experiments. Two experimental approaches were put forward to meet the stated project objectives. The first of the two approaches include injection of tracers with subsequent sampling over a period of about 4 years with continuous monitoring for breakthrough by diffusion in a monitoring hole some 0.2 m away. After termination of the injection, the injection borehole will be overcored and the core sampled and analysed for tracer content and distribution. The second approach include an initial tracer injection similar to the one described above. The difference being that following injection/circulation for about 0.5-1 years, the tracer solution will be exchanged with a non-spiked formation water. The successive back-diffusion of tracer from the matrix rock will be studied for about 3-4 years. In addition the natural back-diffusion of selected naturally occurring natural tracers (gases), assumed to saturate the rock, will be studied.

Two external reviewers, Professor Ivars Neretnieks (KTH-KAT) and Dr. Scott Altmann (ANDRA), have commented on the experimental plans and participated in discussions of the presented approaches. One major concern expressed during the review was the possibility of stress redistribution around the two boreholes in the case of the first approach which may cause changes of microfractures which in turn would entail an increase in porosity, and consequently also in diffusivity.

In addition, it was proposed to widen the scope to not only study the diffusion in the rock matrix alone, but also add study diffusion of solutes through the rim zone along a fracture into the rock matrix. One possible way to address this expanded scope would be to employ a variant of the instrumentation used for the in-situ part of the REX experiment.

During the period, the testplan has been updated with a focus on an experimental concept, which builds on the experimental setup used for the REX project. This approach allows study of diffusion from a natural fracture, through the rim zone of fracture mineralisation and alteration, into the unalterad rock matrix.

The search for an experimental site will be addressed within the SELECT-2 project, which primary objective is to find an experimental site for the Second TRUE Stage.

Planned work

- Updating of Test Plan
- Design of equipment
- Manufacturing of equipment

3.4 The REX-experiment

Background

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 oxidized 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 is on a field experiment involving motionless groundwater in contact with a fracture surface. To this aim a ≈20 cm borehole has been drilled in the Äspö tunnel at 2861 m. Field data (hydrochemical and bacteriological) are used to establish the boundary conditions for the experiments.

The field study is being supported by laboratory experiments to determine O_2 reaction rates and mechanisms with Äspö samples (both for inorganic and microbially mediated processes). A replica experiment has been 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 are 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, 5 to 10 days, both for the field and replica experiments.

Planned work

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 will be examined for mineralogical changes and biofilm formation.

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. The CHEMLAB probe, see Figure 3-10 has been constructed and manufactured for validation experiments in situ at undisturbed natural conditions.

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

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

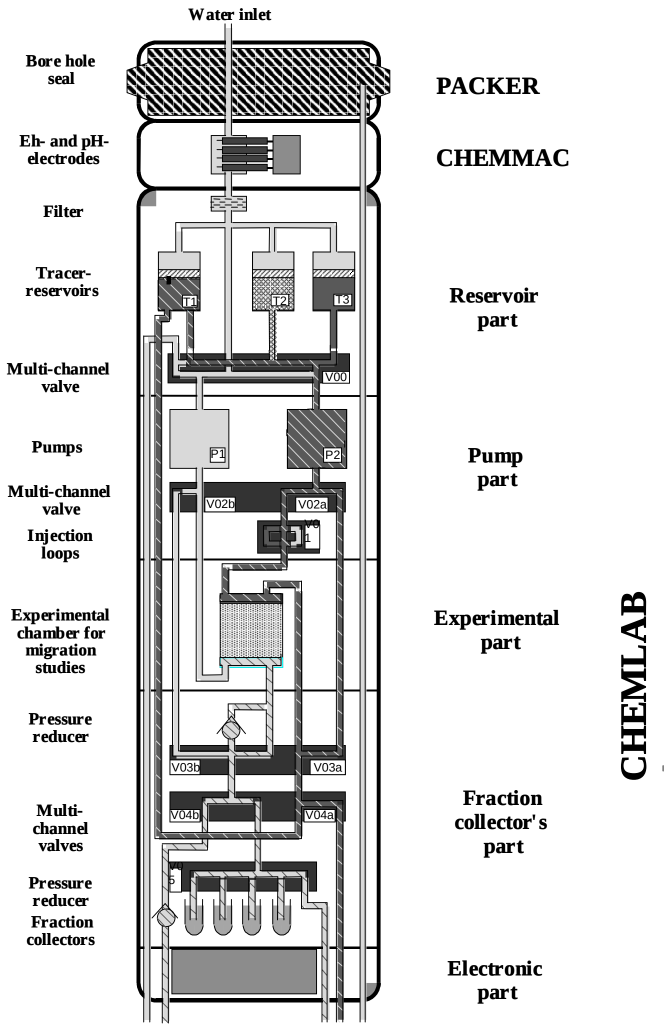


Figure 3-10 *Schematic illustration of CHEMLAB.*

New Results

- The last diffusion experiment (experiment with ^{99}Tc and ^{131}I) in bentonite has been completed.
- A new site has been selected for the CHEMLAB experiments. Two boreholes have been drilled in the J-tunnel. These will be used for simultaneous running of both CHEMLAB 1 and 2.
- The planning for redox sensitive nuclide and actinide experiments in CHEMLAB 2 is made in cooperation with reseachers from Instittut für Nuklear Endsorchung in Karlsruhe (within the BMBF cooperation).

Planned work

- Establish the new CHEMLAB site in the J-tunnel
- Prepare for the radiolysis experiments

- Continue preparation for actinide and redox sensitive nuclide 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

The characterisation and classification work has been completed. The developed procedure has been incorporated into the conceptual modelling of the TRUE-1 site. The final report is in preparation.

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

The degassing model predictions of Jarsjö and Destouni (1998) were obtained with a statistical description of the fracture aperture. The description was based on previous laboratory observations in rock fracture replicas; Jarsjö and Geller (1996) observed that water completely occupied the tighter aperture regions, whereas both water and gas co-existed in the wider aperture regions. Accordingly, Jarsjö and Destouni (1998) defined a critical cut-off aperture a_c in their model, and occupied all apertures smaller than a_c with water. For apertures greater than a_c, they assumed that water occupied a certain fraction α of the fracture, leaving the fraction (1-α) for the gas phase. This resulted in the following fractured rock relation for the unsaturated transmissivity T as a function of the capillary pressure p_c:

$$T(p_c;\mu_{\ln a},\sigma_{\ln a},\alpha) = T_S \frac{\int_0^{2\sigma_w/p_c} a^3 f_{\ln}(a;\mu_{\ln a},\sigma_{\ln a})da + \alpha \int_{2\sigma_w/p_c}^{\infty} a^3 f_{\ln}(a;\mu_{\ln a},\sigma_{\ln a})da}{\int_0^{\infty} a^3 f_{\ln}(a;\mu_{\ln a},\sigma_{\ln a})da} \tag{1}$$

where T_s is the transmissivity at water saturated conditions, a is the (local) fracture aperture value, σ_w is the water-gas interfacial tension, $f_{\ln}(a)$ is the log-normal fracture aperture probability density function, fully determined by the mean value of ln*a*, $\mu_{\ln a}$, and standard deviation (of ln*a*), $\sigma_{\ln a}$.

The model predictions obtained by use of relation (1) were found to be consistent with laboratory observations of groundwater degassing (Jarsjö and Destouni, 1998). The applicability under other conditions was however not investigated, because of the limited number of experimental observations. In order investigate the characteristics of relation (1) more thoroughly, we will in the following apply it to a wide range of hypothetical fracture aperture distributions, and compare the results with the widely used van Genuchten (vG) porous medium relation (van Genuchten, 1980):

$$K(h) = K_s \frac{\left(1-\left(\delta|h|\right)^{n-1}\left(1+\left(\delta|h|\right)^{n}\right)^{-(1-1/n)}\right)^2}{\left(1+\left(\delta|h|\right)^{n}\right)^{m(1-1/n)}} \qquad (2)$$

where K_s is the conductivity at water saturated conditions, h is the capillary pressure head, equalling $-p_c/\rho g$, δ and n are soil parameters which are inversely related to the bubble pressure head value and the with of the soil pore size distribution, respectively. Usually the parameters δ and n are determined by matching the above functional relation (2) with drainage curves, which are obtained from laboratory experiments on soil samples. The parameter m is an additional fitting parameter. Mualem (1976) and van Genuchten (1980) found that the value of m=0.5 provided the best match with a set of experimental data from 45 soils; this value will be used in the following comparison.

By comparing Equations (1) and (2), we can now identify similarities and/or differences between these two alternative relations. In this following comparison, we regard the mean aperture value $\mu_{\ln a}$, the standard deviation value $\sigma_{\ln a}$ and the parameter α as unknowns, like the parameters δ and n in the vG-relation. However, the measured range of $\mu_{\ln a}$ and $\sigma_{\ln a}$ in actual rock fractures constrain the range of plausible values for corresponding parameters in Equation (1). Hakami (1995) compiled results from different studies on a total of 19 different rock fractures, including for instance a well mated joint (relatively tight) and a minor fault (relatively wide). The results showed that the mean aperture values $\mu_{\ln a}$ ranged between –2.3 and 0.2, which corresponds to geometric mean apertures $a^G=\exp(\mu_{\ln a})$ between 0.1 and 1.2 mm. Furthermore, the standard deviation values $\sigma_{\ln a}$, ranged between approximately 0.2 and 1.0.

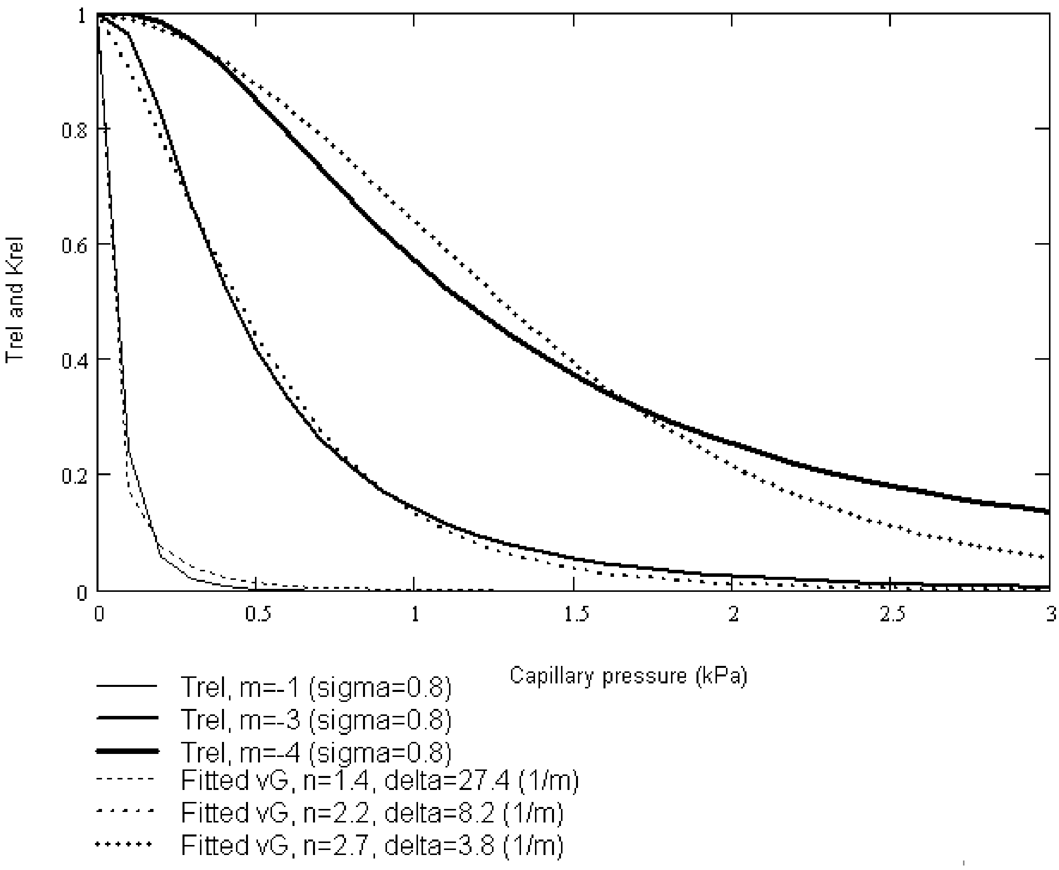


Figure 3-21. *Comparison between the fractured rock characteristic relation (Equation 1 with different mean aperture values $\mu_{\ln a}$) and the fitted vG-relation (Equation 2).*

In the following, we will for comparative purposes use relative transmissivities T_{rel} and, for the porous medium vG-relation, relative conductivities K_{rel}. They are defined as the ratio between the unsaturated transmissivity T, or conductivity K, and the saturated transmissivity T_s, or conductivity K_s. This implies that $0<T_{rel}<1$ and $0<K_{rel}<1$. The solid curves of Figure 3-21 show the relative transmissivity T_{rel} as a function of p_c (obtained through Equation (1)). The thinnest, solid curve was obtained for a mean aperture value $\mu_{\ln a}$ of –1 (corresponding to a geometric mean aperture a^G of 0.37mm) and the thickest solid curve was obtained for a considerably smaller mean aperture value of –4 (corresponding to a geometric mean aperture of 0.018mm). For all three solid curves, the standard deviation $\sigma_{\ln a}$ and the water occupancy fraction α were kept at constant values of 0.8 and 0, respectively. As expected, the relation (1) predicts that the widest fracture is drained at considerably lower capillary pressures than the other two fractures, such that the relative water transmissvity T_{rel} becomes equal to zero already for comparatively low values of p_c (see the thinnest, solid line of Figure 3-21).

Furthermore, Figure 3-21 shows that the vG-relation (Equation 2) yields similar curves (dotted in Figure 3-21) as the fractured rock relation (Equation 1; solid curves). The fitted vG-parameter δ ranged between 3.1 and 27 m^{-1}, and the parameter n ranged between 1.4 and 2.7 (Figure 3-21). For soils, δ usually ranges between 0.05 and 50 m^{-1} and n usually ranges between 1 and 8. Hence, the range of parameter values for the fitted vG-curves (Figure 3-21) is within the wider range of vG-parameters that previously have been reported for various soils in the literature. Furthermore, equally good matches between Equation (1) and (2) as those shown in Figure 3-21 are obtained for standard deviation values, $\sigma_{\ln a}$, within the range that has been measured in natural rock fractures (0.2 to 1.0; see paragraph above).

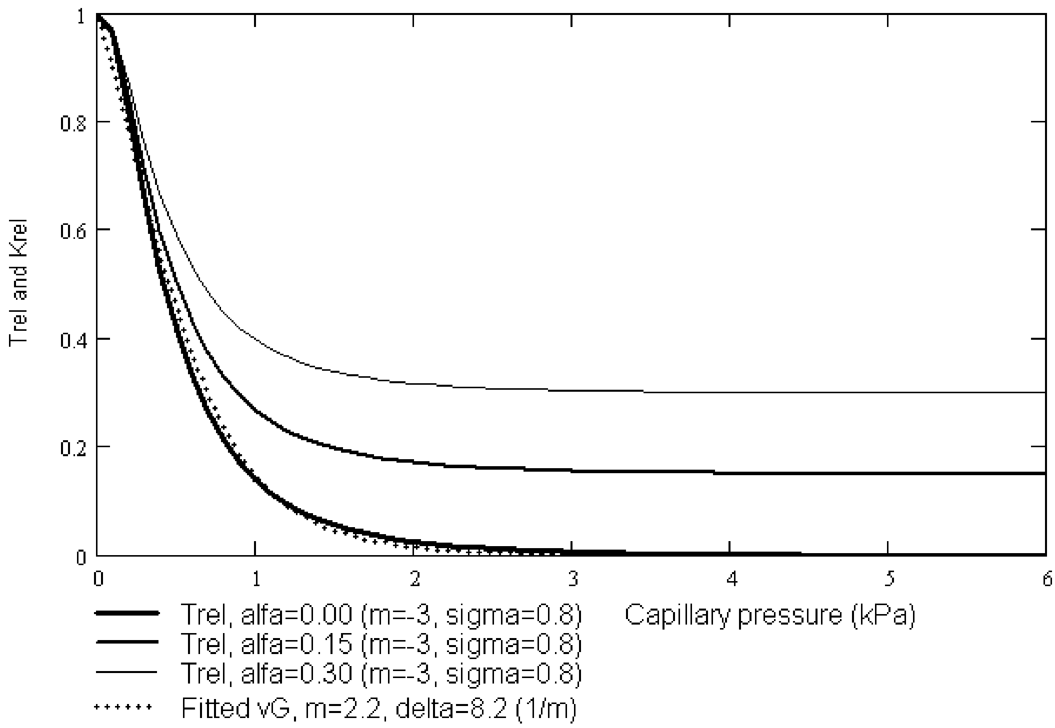


Figure 3-13. *Comparison between the fractured rock characteristic relation (Equation 1 with different water occupancy fractions α) and the fitted vG-relation (Equation 2; fitted only to the curve for α=0).*

In Figure 3-13, both the mean aperture value and the standard deviation value are fixed, and the three solid curves show the fractured rock characteristic relation (1) for different water occupancy fractions α, ranging from 0 (thickest, solid curve) to 0.3 (thinnest, solid curve). The figure shows that the fit between the fractured rock relation with α=0 and the vG-relation (dotted line) is good. However, for α>0, the shape of the vG-curve differs considerably from the fractured rock curves. In the latter curves, the relative transmissivity approaches the value of α as the capillary pressure approaches infinity, whereas the relative conductivity for the vG-curves approaches 0 as the capillary pressure approaches infinity. Hence, the vG-relation could not be fitted to the curves for α=0.15 and α=0.30 in Figure 3-13.

In the study of Jarsjö and Destouni (1998), the fractured rock relation (Equation 1) was used in the modelling of laboratory experiments of groundwater degassing. The model predictions were compared with the experimental results, assuming different values of the parameter α. The comparison showed that the agreement between model predictions and experimental observations was good for a relatively wide range of α-values between 0.2 and 0.4, whereas the agreement was poor for α=0. Based on that comparison and Figure 3-13, we may conclude that for cases where the fractured rock relation showed good agreement with experimental degassing data (i.e., for α>0), the traditional porous medium vG-relation could not be well matched with the fractured rock relation. For the particular case of α=0, the vG-relation could be well matched with the fractured rock relation (see Figure 3-13), but the agreement with the experimental degassing observations of Jarsjö and Geller (1996) was poor.

A final report on the laboratory work on core samples from Äspö and artificial fractures performed by Fracflow has been published (IPR 99-08).

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: Predictions of the hydrochemistry ahead of 2900 m section of the tunnel were presented at the 12th Task Force Meeting at Gimo.

EQUIP (Evidences from Quaternary Infillings for Palaeohydrology) is an EC project including several of the organisations participating in the Äspö project, (ANDRA, ENRESA, NIREX, POSIVA, SKB). The project started in 1997 and is planned to continue for three years. The second year Annual report has been prepared.

Planned work

- Investigations in the deep borehole KLX 02 include the testing of Posivas Difference flow measurements and PAVE groundwater sampling equipment to depths of 1400 m.
- The results of the measurements are used for the understanding of the hydrogeological, hydrogeochemical properties of the borehole and its surrounding.
- 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 .

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.

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

Objectives

The main objectives of the task are:

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

Experimental concept

The experiment has been designed to sample matrix fluids from predetermined, isolated borehole sections. The borehole was selected and drilled on the basis of: a) rock type, b) mineral and geochemical homogeneity, c) major rock foliation, d) depth, e) presence and absence of fractures, and f) existing groundwater data from other completed and on-going experiments at Äspö. Special equipment has been designed to sample the matrix fluids ensuring: a) an anaerobic environment, b) minimal contamination from the installation, c) minimal dead space in the sample section, d) the possibility to control the hydraulic head differential between the sampling section and the surrounding bedrock, e) in-line monitoring of electrical conductivity and uranine content, f) the collection of fluids (and gases) under pressure, and g) convenient sample holder to facilitate rapid transport to the laboratory for analysis.

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

New Results

After review of the testplan for the experiment a final version was decided in January 1999. The partners of the project are ANDRA, NAGRA, Posiva and SKB.

Planned work

Drillcores will be examined and analysed at laboratories in France, Switzerland, Finland, Sweden and Canada.

Groundwater analyses will be prioritized according to the sampled volume.

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	Cooperating 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

The 12th International Task Force meeting was held at Gimo, Sweden. Modelling results were presented for Task 4E, 4F and 5

Task No 4C and 4D

The evaluation report for this task was completed and submitted to the printer for reproduction. It will be published in the technical report series as TR 99-04.

Task No 4E

Modelling groups completed their evaluation of the Task 4E modelling and reported it in interim reports. The final report for Task 4E will be published together with 4F.

Task No 4F

Predictive modelling was completed and reported as interim reports. The final reporting for this task will be done jointly with Task 4E.

Task No 5

Two additional modelling groups joined the Task Force for to perform work in Task 5. They are both affiliated to ANDRA; ITASCA will adopt the discrete feature network approach and ANTEA the double porosity approach.

Predictive modelling has been performed for the tunnel lengths between 2900 – 3600m which was presented in interim reports.

Published reports

The following reports were published,

- ICR 98-04: Dynamic changes in groundwater conditions caused by tunnel construction at the Äspö Hard Rock Laboratory, Sweden. Task 5. By Y. Mahara et al (CRIEPI). This report was actually published during the first quarter of 1999.
- ICR 98-05: Issue Evaluation Table 1997/1998, by Anders Ström (SKB)
- ICR 98-06: Modelling TRUE-1 (RC-1) tracer tests using a heterogenous variable aperture approach. Task 4C. By W. Worraker, D. Holton, K. A. Cliffe (AEA Technology)
- ICR 98-07: Prediction of TRUE-1 radially converging and dipole tracer tests. Task 4C and 4D. By J-O. Selroos (SKB) and V. Cvetkovic (KTH)

WEB site

The Task Force web site is now operational. It contains information about the purpose of the Task Force, organisation, modelling tasks, data deliveries and an incomplete list of reports.

There are two areas on the site. A publicly accesible area (http://www.skb.se/omskb/forskning/aspo/tf/index.htm) with general information

and a member area with the following content

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 12^{th} International Task Force meeting
- Publish the proceeding from the 12^{th} 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 focuses on different aspects of engineering technology and performance testing, and will together form a major experimental program.

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

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

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

With respect to *repository function,* objectives are:

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

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

4.2 Prototype Repository

Background

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

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

The aims of the Prototype Repository are:

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

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

New results

A workshop was held in Wettingen, Switzerland, on February 3rd and 4th, at which the discussions on a possible basis for an EC application at the workshops in Brussels in November and at Äspö in December continued. The content of an application was outlined and a plan made for the compilation of the text. When the ECs call for proposal was released it became known that he application will be due on October 4th this year. In order for the project to better match the expected date for granting of EC funding, if this will be the case, the start of installation has been postponed by six months. Presently ongoing work with geoscientific characterisation of the tunnel and surrounding rock as well as the boring of the large simulated deposition holes are, however, not affected. And detailed planning has basically continued in accordance with the earlier time schedule during the period.

The work with the EC-application has continued with discussions with the potential participants, planning of the tasks that are going to be included in the EC-application and specification of subtasks with more precise designation of activities to participants in accordance to their announcements. The package was sent out to each organisation for their approval and their input in matters requested by EC for a complete application. Answers are due at the end of August.

The roadbed in the tunnel has been installed successfully and manufacturing of the deposition machine for the canister/heater unit has progressed as planned.

All field activities for characterisation of the rock mass around the Prototype Repository tunnel have been completed, including sampling and analysing of ground water with respect to redox conditions, which was done in April. Reporting of the results from the final hydraulic tests is in progress.

Type of instruments, number of and location in the buffer, backfill and rock have been further analysed and a report with proposed selection of instruments and their locations drafted. The study recommends that all instruments be made in titanium due to the highly corrosive environment. Contacts with instrument manufacturers suggests that the selection of titanium does not create any fabrication problem and only marginally higher costs. Final selection and decision on number of each type of instrument has been postponed six months, to August this year. Orders should not be placed earlier than January 2000. Instruments for hydraulic measurements in the rock as well as ground water sampling for chemical and biological analyses, resistivity measurements for monitoring changes in the water contents of the rock, buffer and backfill and stress/strain monitoring of the concrete plugs have as well been discussed.

The full-scale test of temperature distribution in a canister has continued in Kockum´s plant in Malmö. The results verify the first indications that the temperature gradient from the heater to the copper mantle will be sufficiently low – a couple of tens of degrees and not a couple of hundreds of degrees- for providing a safe margin to the highest temperature (about $400^{o}C$) that is recommended for the heater elements.

The form for compaction of the bentonite blocks has been somewhat modified and is planned to be tested in a series of some nine blocks in April this year. After that the manufacturing of blocks to the tests is planned to start.

The TBM machine for deposition hole boring is now running properly, and could move to the first hole, the inner one. The boring started on June 21th and the third hole was being bored on June 30th. By the human eye the first two holes look to be in good shape.

The field tests on measurement of forces from the cutters acting on the rock wall was made in the boring for the Canister Retrieval Test instead of in the holes for the Prototype Repository. The two instrumented cutters were mounted in their positions and the boring machine was run in the ordinary way. The transmitters and receivers worked well and a wealth of data was collected. They are quite enough for the evaluation of the relationship between the boring parameters and the boring induced disturbance, and the tests in the Prototype Repository will not be made. The evaluation may also benefit from the result of the acoustic emissions that were measured in parallel with the boring with the instrumented cutters.

A project on testing of the deposition sequences in the Prototype Repository and in the Canister Retrieval Test has been organised and has engaged Håkan Sandstedt, SCC, as project manager. The compilation of the test plan has started.

The test with percussion boring of lead-through holes from the adjacent tunnel, the G-tunnel, was made with very good result. This method is therefore the prime method for also the other holes.

A project meeting was held on June 17-18.

Planned work

Detail planning of different parts of the Prototype Repository project will continue during the period. Main technical matters are

- instrumentation plan including chemical samplers in the buffer, instruments in the canisters and needed number of cables out from the test tunnel
- electrical supply to heaters
- consequent need for lead-through holes and their locations
- sequence for emplacement of bentonite blocks, bentonite pellets, possible artificial addition of water, backfill in upper part of holes and backfilling of tunnel as well as plan for testing of key handling steps and deposition machine
- plug design

The hydraulic characterisation work will be reported and predictions of water inflow to the large holes will be based on all information obtained prior to boring of the large holes.

Instruments are installed in boreholes around the two outer large holes for acoustic emission and rock stress/strain changes during boring.

The packers installed in the inner part of the tunnel (for registration of hydraulic response to the boring) are relocated to investigation holes around the two outer holes. Once they have been installed in their new positions they will be connected to the HMS system, and hydraulic tests will be made for calibration purposes.

Predictive modelling of the temperature is made based on the results obtained in the in-situ measurements.

Planning for characterisation of the deposition holes will be completed and a program published. The characterisation includes, geometric measurements (laser scanning is no longer an alternative due to too high costs), mapping of lithology and structures, hydrogeology etc. Special efforts will be taken to evaluate the EDZ regarding depth and mechanical and hydraulic properties.

The assembly hall will be prepared for the start of testing of the deposition sequences in the Prototype Repository and in the Canister Retrieval Test as well as testing of the equipment that is planned to be used. (The Test Plan has been released.) The starting issues will be the levelling of the bottom of the holes and the methods for draining the holes.

Heater design will be completed and orders on manufacturing of these will be placed.

Design of the plugs meeting the experiment objectives and suitable for the TBM drift will be reported.

Boring of the six deposition holes in the Prototype Repository will be completed.

A draft application for EC funding will be compiled.

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 will be finished in 1999.

New results

Figure 4-1 shows the test site and the how far the backfilling had proceeded on June 18.

The following main work were carried out through June 1999:

- The inner part of the test drift has been filled with drainage material. This part will not be used for the tests.
- 2 pumps have been installed in order to keep the inner part free from water during the construction phase. Each pump was placed in a concrete tube with lid. The capacity of each pump is 5 l/min or equal to the measured inflow into this part of the drift.
- An inclined concrete wall has been built outside the inner part in order to separate this part from the test sections. The concrete was cast in contact with the roof except for at the inner part where rubber foam was placed between the roof and the concrete with the purpose to act like an O-ring and prevent backfill from penetrating into the drainage material.
- Backfilling and compaction of 6 sections of a mixture of 30% bentonite and 70% crushed rock have been completed. Each section contains 6 layers with the axial thickness 35 cm and the inclination 35 degrees. The vibrating plate and the vibrating “roof compactor”, both developed for backfilling tunnels, were used during the compaction of each layer. The technique has worked very well.
- Sections B2 – B5 have been backfilled with 100% crushed rock and compacted.
- In order to avoid the appearance of an open slot between the none-swelling backfill of 100% crushed rock and the roof a 10 cm gap at the roof was filled with two layers of bentonite blocks in Sections B2 - B5. The remaining openings, caused by the irregularities of the rock, were filled with bentonite pellets. The pellets were placed with a “pellets blowing machine”.
- 3 permeable mats (one large mat in the centre and two smaller mats at the roof and floor respectively) have been installed on top of the inclined concrete wall and between the backfill sections. They will be used for the flow testing of the backfill sections.
- Total pressure cells, pore pressure transducers, and moisture sensors have been installed in the backfill layers. The sensors have been placed from the surface of each layer. The cables from the sensors were led in Tecalan tubes and placed in notches on the surface of the backfill layers.
- ENRESA has installed 13 devices for measuring the local hydraulic conductivity in section 4.
- 12 packages with cables and tubes from instruments and mats have been installed in the through connection tubes and led from the test drift to the Demonstration drift. After installation the through connections were leakage tested. The installation has gone very well.

- The data collection house has been built and the cables and tubes have been led on cable ladders into the data collection systems in the house.

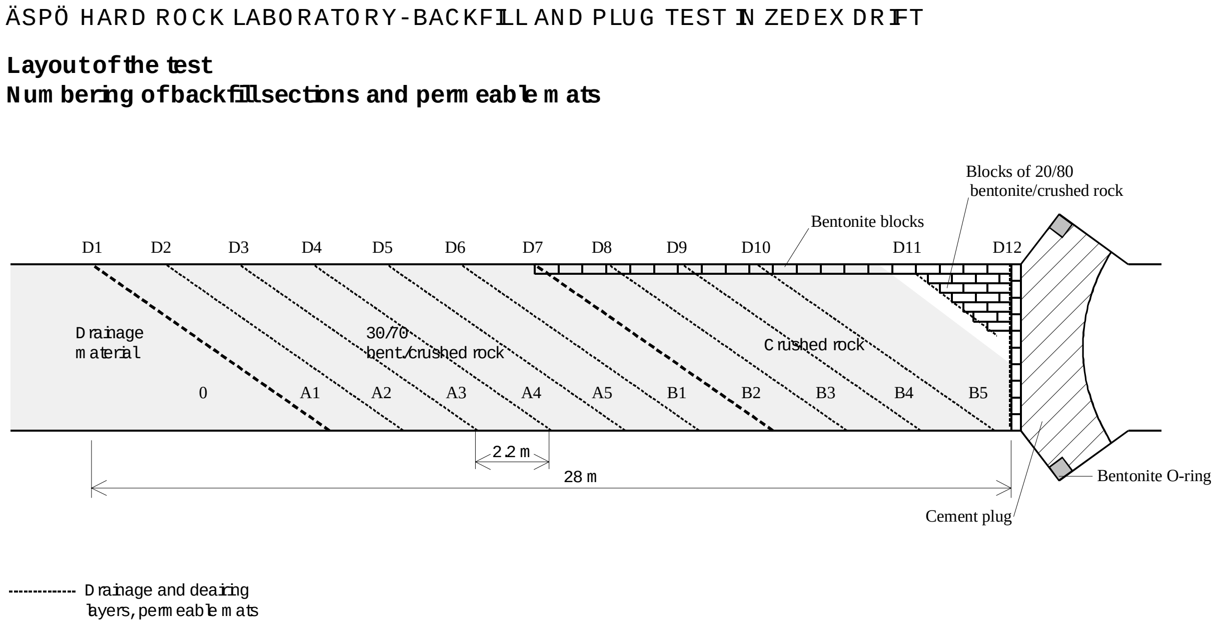


Figure 4-1. Test layout and the progress of the backfilling on June 18, 1999 (hatched sections).

Planned work

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

- The bentonite O-ring will be installed and the concrete plug cast.
- The panels and tube systems for measuring water pressure in the rock and for the flow testing will be installed in the data collection house.
- The water saturation of the backfill will start by filling the permeable mats with water

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

The four deposition holes have been bored with good result.

Planned work

The four deposition holes will be characterised with respect to geometry and geology.

The “visitors center” furnishing of the tunnel will start therafter as well as finalising of the assembling of the deposition machine.

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

The time plan for the installation has been changed due to the change in the time plane of the Prototype Repository. The new starting date for lowering the first block in the first hole is March 2000.

The two deposition holes have been bored to a depth of about 8.5 m below the concrete floor surface and about 8 m below the rock floor surface. The equipment for registration of acoustic emission and rock mechanical response during boring worked well as far as could be seen during the data sampling.

Planned work

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

Scoping calculation is made for temperature distributions using the model that was developed for the Prototype Repository.

A heater test with four simulated fuel assemblies, which have been manufactured by ABB ATOM, will be tested at Kockums before the final decision is made on the heater type to the canisters.

Planning and design of the instrumentation program for monitoring in buffer during operation is carried out in parallel with the work for the Prototype Repository. Decisions on instrumentation and ordering will continue to be carried out in parallel but with due consideration to the differences in the time plans between the Canister Retrieval Test and the Prototype Repository.

The purchase of bentonite and compaction of blocks are also planned and ordered for the combined needs of the Canister Retrieval Test and the Prototype Repository.

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 minimize 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 summarized in the following items:

- Data for validation of models concerning buffer performance under quasi-steady state conditions after water saturation, e.g. swelling pressure, cation transport and gas penetration.
- Check of existing models concerning buffer-degrading processes, e.g. 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 realization 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 4-1) 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. Layout 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
T = temperature
pH = high pH from cement
S = standard conditions
$[K^+]$ = potassium concentration
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 have started. Five 76 mm core holes have been drilled down to a depth of 8 m in order to make flow and pressure investigations. Core mapping, BIPS analyses and hydraulic tests of the holes have been made, which show that the rock volume contains only a few natural fractures and the water inflow seems to be very low. An artificial water supply is therefore taken into consideration.

The five pilot holes have been widened to the test hole diameter 300 mm by use of percussion drilling technique. Anchor hooks for the lift device have been mounted and security checked.

A new form for block production has been manufactured. The form gives the blocks the intended shape at the compaction, including the central hole, without successive treatment. Two test blocks have been produced and the equipment works fine after a few small initial adjustments. The intended compaction pressure of 100 MPa gave the expected block density of 2080 kg per cubic meter, and no annoying fractures were noticed. Approximately120 blocks out of the total need of 200 have been produced. Preparation for instrument installation have been started. The copper-tube manufacturing and leakage control have been carried out.

Fruitful discussions have been held with a number of instrument suppliers concerning new constructions of pressure and moisture gauges. A combination of optical and vibrating wire sensors will be used for pressure measurements. The sensors and cable protection will be made solely of titanium and completely sealed by welding up to the open tunnel. The moisture gauges will be standard capacitive gauges encapsulated in titanium housings. All instrument and other important equipment have been ordered and are expected to be delivered in due time fore the final assembly.

A quality assurance laboratory program for bentonite deliveries have been developed and tested as a co-operation with the Prototype project.

Planned work

A test installation will be made in July with a copper tube and dummy benonite rings. The real installation of the five remaining parcels will start in August and go on until October.

Supporting laboratory tests concerning “critical” gas penetration pressure and characterisation of the initial clay material will be made parallel to the running field tests during the rest of the year.

5 Äspö facility operation

5.1 Facility operation

The new rescue chamber at the –420 m level will be taken into operation in September. The chamber is sited in an existing niche and will be equipped with a CO_2 scrubber system for cleaning of the used breathing air. The system is designed for 60 people in six hours and will considerably increase the safety at this level.

A system to supervise the operation of the facility will be installed during the year. Design work has been going on since the end of last year and during the period a contract has been signed. The system will be put in operation early next year.

At the bottom of the tunnel a new fire brigade station has been built. Equipment, including a vehicle, for fire fighting is always kept at the station. The fire brigade has had several exercises at the deeper levels of the tunnel.

The water supply system has been extended and now includes outlets at all the experimental tunnels at levels –420m and –450m. The system includes both freshwater and groundwater.

New pipes for groundwater drainage have been installed at the –420 m level and some areas have got new asphalt.

In order to increase the redundancy of the pumping system several components have been purchased. We have also initiated work to look on the power supply for the whole facility.

A new inlet fan for the underground ventilation has been mounted. That means one of the fans can be taken out of operation for maintenance without any restrictions in the tunnel operations.

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/. In this context, management of investigation data, one of the most interesting illustration in that report is shown in Figure 5-1.

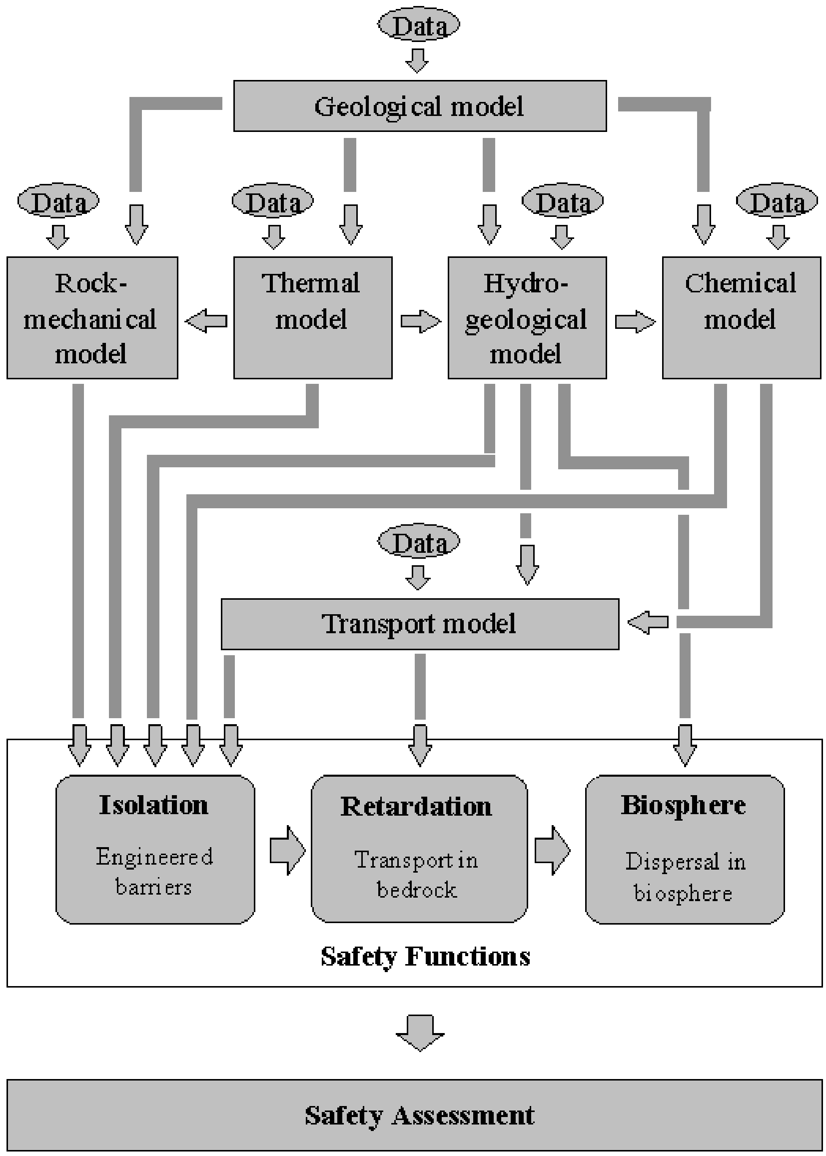


Figure 5-1 *Schematic illustration of how information is transferred between different geoscientific models and how these are utilised for safety suitability assessment.*

Behind the balloons in Figure 5-1, indicating data entry, SKB's Site Characterisation Database and SKB's Rock Visualisation System plays important roles as illustrated in Figure 5-2.

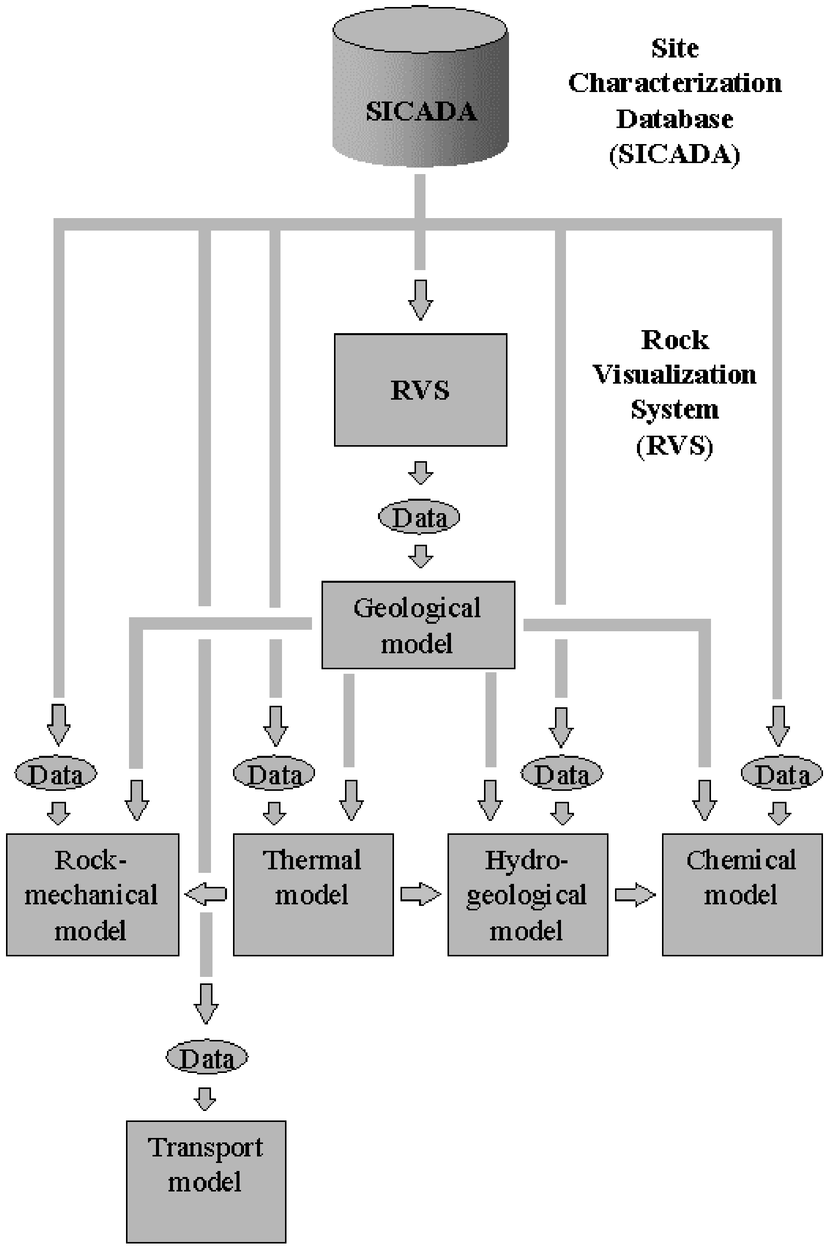


Figure 5-2 *Schematic flow chart describing where from data are taken to the different geoscientific models used as a baseline fore the safety assessment to be done. The balloons in Figure 5-1 have been complemented with the origin of data. As indicated SICADA and RVS are highly important tools on the way to convince the authorities that the safety requirements are met.*

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

New Results

SICADA

The major part of the development stage 99:1 has been completed and the most important SICADA applications are now available for Windows 95 and Windows NT as well. This stage included the following activities:

- Pre-study/Upgrade of OpenIngres (2.0)
- Pre-study/Replication technique
- Performance optimisation of OpenIngres and SICADA (based on OpenIngres)
- Development of a Excel macro supporting conversion to MIO-format
- Import templates for Excel
- Improved search capabilities in SICADA/Diary
- Y2K certification of SICADA (date formats in tables and applications)
- Development of an utility server process to superintend changes in the database
- Object search based on spatial conditions
- Co-ordinate calculations for deposition bore holes
- Transfer of information from the instrument database to SICADA. The instrument database will be phased out

Furthermore a new set of improvements in the SICADA system has been defined. This stage is called 99:2 and includes the following main activities:

- Implementation of a tool for import of data from Excel templates

- Implementation of an utility server process to superintend changes in the database

- Registration and handling of Field Notes in SICADA. (The Field Notes are handled outside the database at present.)

- Improve the stability of the interface between SICADA and RVS. (Currently the database administrators are free to change the tables in the database. The system should automatically give the administrator a warning if the table to be changed is used by RVS.)

RVS

Version 2.0 was delivered in April 1999. A final delivery test was then performed, according to established routines, and the new version was approved 1999-06-07. The previous self-instruction package has been updated to RVS 2.0. The new version of RVS is compatible with MicroStation/J.

Planned work

SICADA

The development stage 99:1 and 99:2 will be completed during 1999.

RVS

In Oktober 1999 the new version (2.1) of the system will be delivered and we plan to release it in the beginning of December 1999. RVS 2.1 will also include the first version of an interface between FracMan and RVS.

The programming of version 2.2 will probably start in December 1999. Currently we have a long list of suggested new features and modifications, but all of them will not fit into RVS 2.2. The priority of each function will finally be set in November 1999.

5.3 Programme 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.

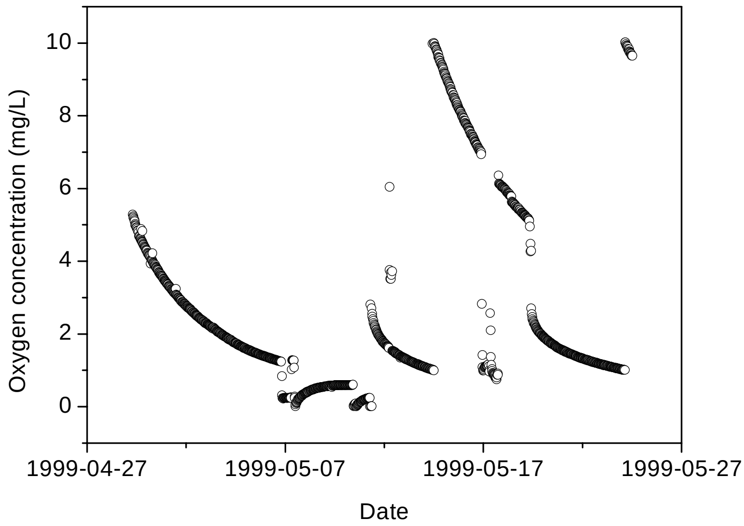
Data is transferred by means of radio link, cable and manually to a dedicated computerised database. The HMS computer system runs on Pentium computers with the Windows NT operating system where a real time engine is accessing the HMS database. This engine provides integrated data acquisition, monitoring,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

New results

The HMS program has been running real time data aquisition 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 REX, TRUE and the Prototype Respository projects.

An example of experiment-specific data collected through the HMS is in the figure below. This is showing the oxygen consumption in the reaction chamber to some of the injections from the REX project



Planned work

For the next quarter it is planned to

- disconnect the REX from the system since the that project will be finalized.
- 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

Sampling was undertaken in April 1999. Many project specific samples were taken in addition to the "monitoring samples". Sampled boreholes and sections are listed in Table 5-1. Class 2 samples were collected from all weirs including the pond.

Table 5-1. Boreholes and sections sampled within the Program for Monitoring Groundwater Chemistry.

ID-kod	Klass	Section	Comment
HD0025A	4	0-200	
KA1061A	4	0-208.5	
KA1131B	4	0-203.1	
KA1755A	4	88-160	
KA2050A	**4**	**155-211.6**	
KA2162B	4	201.5-288.1	
KA2511A	4	52-54	
KA2511A	4	92-109	
KA2563	5	4	
KA2563	5	3	
KA2862A	4	1	
KA3110A	4	20-29	
KA3385A	4	32-34	
KA3566G01	5	2	Prototype
KA3566G01	5	1	Prototype
KA3566G02	5	2	Prototype
KA3566G02	5	1	Prototype
KA3566G02	5	3	Prototype
KA3566G02	4	4	Prototype
KA3572G01	4	2	Prototype
KA3573A	4	18-40	
KA3573A	4	4.5-17	
KA3590G02	4	3	Prototype
KA3590G02	5	2	Prototype
KA3593G	4	2	Prototype
KA3600F	4	4.5-21	
KA3600F	4	22-50.1	
KAS03	4	107-252	
KAS03	4	553-626	
KAS09	4	116-150	
KI0023B	4	8	TRUE BS
KI0023B	4	4	TRUE BS
KI0023B	4	6	TRUE BS
KI0023B	4	9	TRUE BS
KI0025F	4	2	TRUE BS
KI0025F	4	4	TRUE BS
KI0025F02	4	7	TRUE BS
KI0025F02	5	5	TRUE BS
KI0025F02	4	3	TRUE BS
KI0025F02	4	6	TRUE BS
KR0012	5	5-10.57	
KR0012	5	5-10.57	
KR0013	5	7.05-16.94	
KR0013	5	7.05-16.95	
KR0015	5	19.82-30.31	
KR0015	5	19.82-30.32	
KXTT3	4	12-42-14-42	
SA0813B	4	1	
SA1009B	4	6-19.5	
SA1229A	4	6-20.5	
SA1420A	4	6-50	
SA1730A	4	5.6-20	
SA2074A	4	6-38.7	
SA2273A	4	5.8-20	

ID-kod	Klass	Section	Comment
SA2600A	4	5.8-19.4	
SA2783A	4	5.8-19.9	
SA2880A	4	11.9-13.9	
SA3045A	4	0-20.7	

Planned work

The results from the Monitoring program undertaken since 1995 will be presented in a report. The results from the monitoring in October 1998 will be presented in a Technical Note in June 1999. The results from the monitoring in April will be presented in a Technical Document in August. Next sampling occasion is scheduled to take place in September 1999.

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 weirs in the tunnel have been calibrated.

The section limits of the boreholes KA2511 and KA2563 has been changed.

Planned work

Evaluation of presentation system for the HMS-system will be made during spring 1999 and the evaluation will be done together with the facility operation.

The boreholes HAS03 and HAS11 are planned to be disconnected from the HMS-system. There will be only manual control in these boreholes in the future.

A new measurement server will be installed during spring 1999 to take care of data from the Backfill and Plug Test.

The boreholes KG0021 and KG0048 are planned to be connected to HMS.

5.6 Information

Background

The information group´s task is to give visitors to the Äspö HRL information about SKB, the Swedish Waste Management System, the Äspö Hard Rock Laboratory and SKB:s siting programme. An average visit takes around two hours and contains introduction and information in a conferenceroom and thereafter a guided tour underground.

Visitor statistics

During the first quarter of 1999 92 groups and 2 142 visitors visited the Äspö HRL. The Swedish groups have represented the general public, the technical community, communities where SKB performs feasibility studies, politicians, teachers and students. Groups from foreign counties, such as: Great Britain, Japan and Spain have mainly represented newspapers and companies in cooperation with SKB.

During the second quarter of 1999 4094 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	1572	2379
Students	1593	2706
Teachers	497	567
Politicians	191	384
Journalists	13	13
Foreign visitors	199	280
Oskarshamn Community	1291	1798
Nyköping Community	87	269
Tierp Community	155	205
Hultsfred Community	87	196
Östhammar Community	0	0

Special events

The 18th of January one of the spokes persons and a member of the Green Party of Sweden, Miljöpartiet, spent a day visiting CLAB and Äspö HRL. After the tours in the facilities a discussion was held about the feasibility studies and SKB:s future plans and the support from the swedish government.

At the end of March started the so called OKG education. The tours have a specially made programme for the employees of OKG. After a tour in the tunnel the guests are informed about the feasibility study in Oskarshamn. The OKG education will be held twice a week uptil summer.

The 17th of February a massmedia seminar was held at Äspö HRL. The purpose of the seminar was to learn about press contacts, how massmedia works and to be trained in giving interviews for newspapers, television and radio.

A project to create a photo archive has been started in cooperation with head office.

”Äspödagen”

”Äspödagen” of 1999 was taken place the 9th of May. Around 300 people came to visit ”Äspödagen”. The guests were offered information from SKB and:

- guided tours in the tunnel
- guided geologi tours on the Äspö nature path
- birdwatching
- information from Äspö Environmental Research Foundation
- Boat tours with the Swedish Searescue Institution´s resque boat ”Rolf Nilsson”
- information from Natural Board of Fishery Coastal Laboratory
- a ”quiz promenad” along the Äspö nature path

Grilled sausages were served to all the guests

”Urberg 500”

The 14th of June ”Urberg 500” had its opening day. On that day 77 specially invited guests came for a tour of ”Urberg 500”. From The 15th of June and onwards Urberg 500 is open for the general public. There will be two tours a day during weekdays and one tour a day during weekends. Urberg 500 is the marketing name for the VISA project.

Two guides have been employed over the summer for the ”Urberg 500” tours. So far 151 people have visited ”Urberg 500”

6 International cooperation

6.1 Current international participation in the Äspö Hard Rock Laboratory

Nine organizations 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 organization in question. Table 6-1 shows the scope of each organizations participation under the agreements.

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

A trilateral agreement between SKB, JNC and CRIEPI for the period through 2002 has been signed.

Table 6-1. Scope of international cooperation

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

Organization	**Scope of participation**
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 Posiva Oy

Present status of Posiva Oy

Posiva Oy submitted the application for the Council of States decision in principle on May 26th 1999. Posiva applied the decision in principle for the Olkiluoto site in the municipality of Eurajoki, Southwestern Finland. The decision is expected to take place after the hearingprocess early in 2000. Investigations are now mainly concentrated at Olkiluoto and Hästholmen sites. In both areas one new borehole will be drilled to 1000 respective 800 m depth during the summer 1999. The main objective for the new boreholes is to study the hydrochemistry of the deep saline groundwater. Due to the reducing site characterisation activity Posiva is able to contribute more in the Äspö HRL work and needs to learn more about underground laboratories.

Fieldwork at Äspö HRL

During the second quarter of 1999 Posiva has participated in the fieldwork of the Äspö HRL according to the joint project agreement mainly in one project: Evaluation of the flow measurement methods for characterising the groundwater flow. The work began with pressure measurements using the Posiva Flowmeter in borehole KLX02. Pressure measurement was carried out in natural condition with fresh water filled tube, which was open at both ends. The water level in the tube will settle at the groundwater level if the borehole is fresh water filled or higher level if the saline water occurs in the borehole. The result is that borehole is fresh water filled down to the depth of 1200 m and there are two relatively homogenous saline water layers below 1200 m. The work continued with the difference flow measurement using 2 m section and 2 m depth increments. The depth range 600 - 800 m represents intact bedrock while 800 - 1000 m represents fractured bedrock. All the measured flows in the depth range of 200 - 1100 m were negative, i.e. from the borehole into the fractures. Most of the flows were below the detection limit (6 ml/h). As a result of development of the Posiva Flowmeter the single point resistance was measured simultaneously with the flow. The aim was to continue with flow measurements in pumped conditions with the same method and with detailed flow logging combined with TDS measurement. Unfortunately the work had to be interrupted due to numerous technical problems. The work is planned to be continued in the autumn 1999.

Measurements in boreholes KA3065A02, KA2865A01 and KXTT5 at the TRUE Block Scale site were carried out in the Äspö HRL during the June 1999. The detailed flow logging method was used with 1 m section length and 0.1 m depth increments. This was followed with TDS (salinity) measurement using 0.5 m section length on fractures chosen on the basis of the detailed flow logging. The noise level is high on some fractures indicating gas flow. The gas flow was clearly visible in boreholes KA3065A02 and KA2865A01 but not in KXTT5. There was also “noise” in the TDS result in boreholes KA3065A02 and KA2865A01 but not in KXTT5.

Other investigations

The work aiming to clarify the hydrogeochemical evolution at Äspö for the future has developed one step further. The data from the Olkiluoto site, also partly included in this work, has been published on May 1999 as a report: Pitkänen et al. 1999. Geochemical modelling of groundwater evolution and residence time at the Olkiluoto site. Helsinki, Posiva Oy. 184 p. Report POSIVA 98-19.

In Task #5 of Task Force the Finnish way of approaching the problem how to combine hydrological model and geochemical data has been proposed. The work to transform the data to the right format for modelling has been done and some preliminary analyses of feature NE–2 are in process right now. The plan is to concentrate on a single feature at the time to be able to better verify the results. The process will be repeated with other features, one at the time, later on.

In situ failure test is a part of the investigations for demonstration of technology for and function of important parts of the repository system. This test is planned to be performed in the Research Tunnel of the Olkiluoto site. The modeling of the failure test by using FLAC3D–code has continued by analyzing different design alternatives. Study of microfracturing under loading of laboratory samples by using the ^{14}C–PMMA method is in progress. The first results are conformed with modelling data and show that most of the fracture propagation in samples takes place in a larger zone at a stress level close to the compressive strength of the rock. The sample fails when some fractures in the school of fractures propagate to form a continuous failure plane. The final part of the design of the failure test, the writing of the summary design report is being prepared. The preliminary test in the Research Tunnel has been replaced by a full scale test of expansive pressure development, which is being carried out in co-operation with the Helsinki University of Technology. More detailed modelling of the test is started. It is carried out by using PFC-code in co-operation with Itasca. The in situ failure test shall be carried out according to present plans in late October or November in the Olkiluoto Research Tunnel. The monitoring of the test by using acoustic emission and resin impregnation of the test area after failures have occurred are being prepared.

Planned fieldwork

Preparations and development of pressurised groundwater sampling equipment (PAVE) has been going on in Finland for the next fieldwork, which is the deep groundwater sampling at KLX02. This sampling is part of the on-going Hydrochemical stability project. The aim is to obtain more information on the groundwater conditions at depth and also to test the functioning of the sampling equipment in deep borehole conditions. The PAVE equipment allows to sample gases in groundwater in the prevailing pressure. Fieldwork is scheduled to start at the 5th of July. The four sections to be sampled are located below 1000 m depth since relatively little data with high quality is available from the depth. Also conditions in this borehole are more suitable for the groundwater sampling at the greater depth.

7 Other matters

7.1 Documentation

During the period January-June, 1999, the following reports have been published and distributed.

Äspö International Cooperation Reports

Ström A (editor)
The Äspö Task Force on Modelling of Groundwater Flow and Transport of Solutes. Issue Evaluation Table 1997/1998.
ICR 98-05

Worraker W, Holton D and Cliffe KA, 1998
Modelling TRUE-1 (RC-1) tracer tests using a heterogeneous variable aperture approach. Äspö Task Force, Task 4C
ICR 98-06

Selroos J-O, Cvetkovic V, 1998
Prediction of the TRUE-1 radially converging and dipole tracer tests. Äspö Task Force, Tasks 4C and 4D
ICR 98-07

Äspö International Progress Reports

Karnland O, 1998
Test plan. Long term test of buffer material.
IPR-99-01

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5 Technical Notes

17 Technical Document

7 International Technical Document

7.2 Quality Assurance

Quality assurance means to ensure that activities are undertaken with due quality of high effiency. In order to achieve this goal it is required that a smoothly running system are 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-HLK (SKB:s Handbook for Management and Quality Assurance). A review of the SKB quality assurance handbook is undertaken every year.

For each major project separate handbook (QA-program) will be issued similar to SKB Quality- and Environmental Management Handbook. The intent in applying a quality program is to have the work accomplished in a planned and systematic manner in order to decrease the probability of errors and malfunctions.

A draft project handbook has been worked out for the Prototype Repository project.

With the aim to enhance the competence of staff involved with purchasing and requisition new check lists have been developed and officers given the opportunity to attend courses in the subject. There has furthermore been an adjustment of conditions of delivery for purchases from contractors to comply with the activities at Äspö HRL.

SKB is investigating the prerequisite to become certified according to the ISO 9001 and ISO 14001 standards. Working groups have been established with the goal of certifying SKB by October 2000.

A new handbook for purchasing and requisition has been on review during 1998, with the ambition to publish it during 1999. Thereby complying with the conditions for an ISO-certification.

The work of developing a project handbook was initiated during the year. This handbook will specify the requirement for handling projects at SKB, i e how to initiate, administer, report and evaluate projects.

The Äspö Handbook cover issues of decision-making, instructions with regard to procedure, manuals etc to guide the work as pertaining to quality assurance and environmental issues at the Äspö HRL and to ensure that operations are covered by the criteria specified in SKB-HLK. During the year the handbook has been updated with a number of important documents guiding the Äspö HRL operations.

A software application called Äspö Plan Right for managing time and resources, running under MS Project, has been further developed with adaptations to the Äspö HRL operation.

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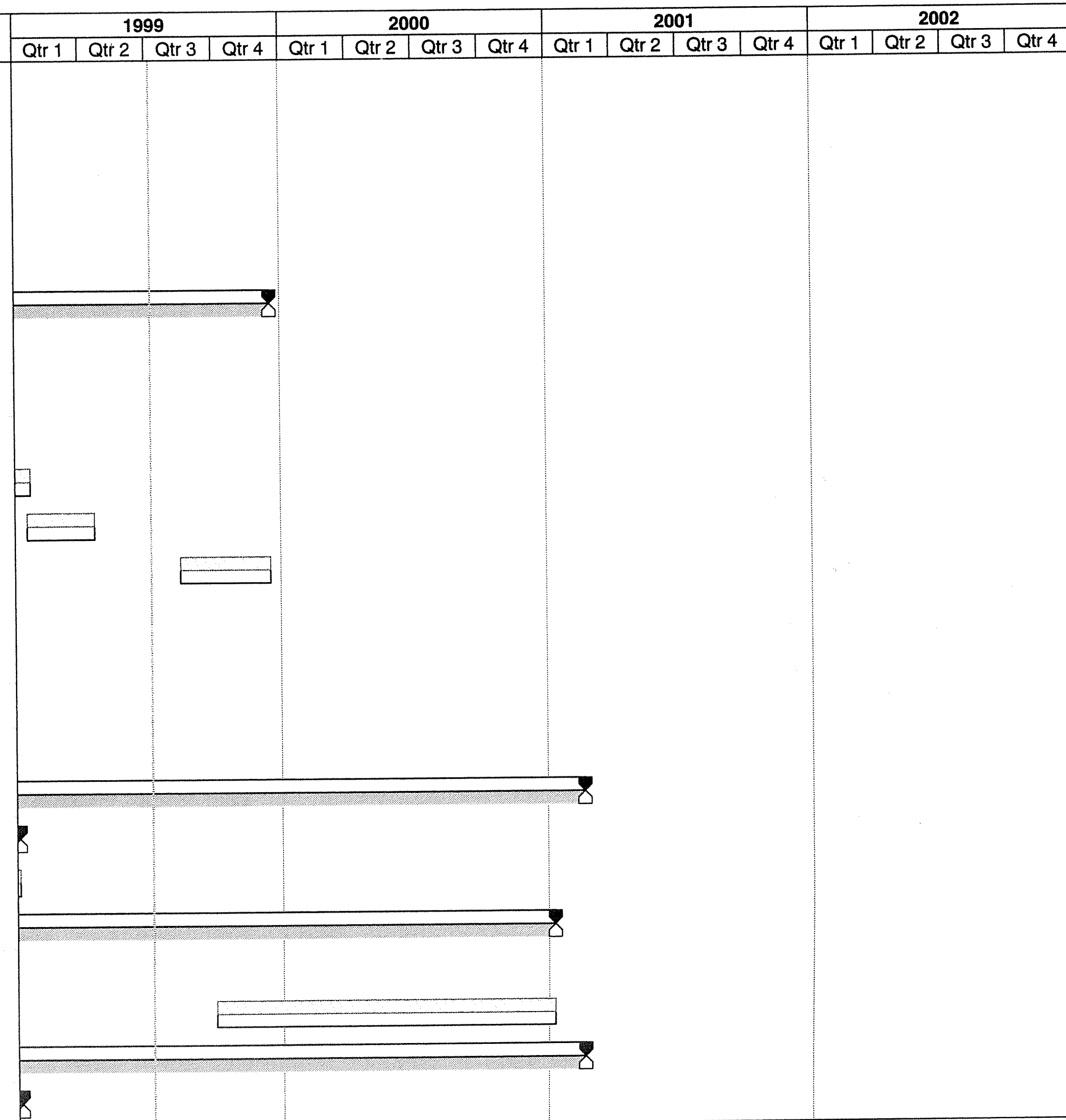
Appendix A

Äspölaboratoriet projektplan, 18 mån

Äspö Plan Right
Version 3.0

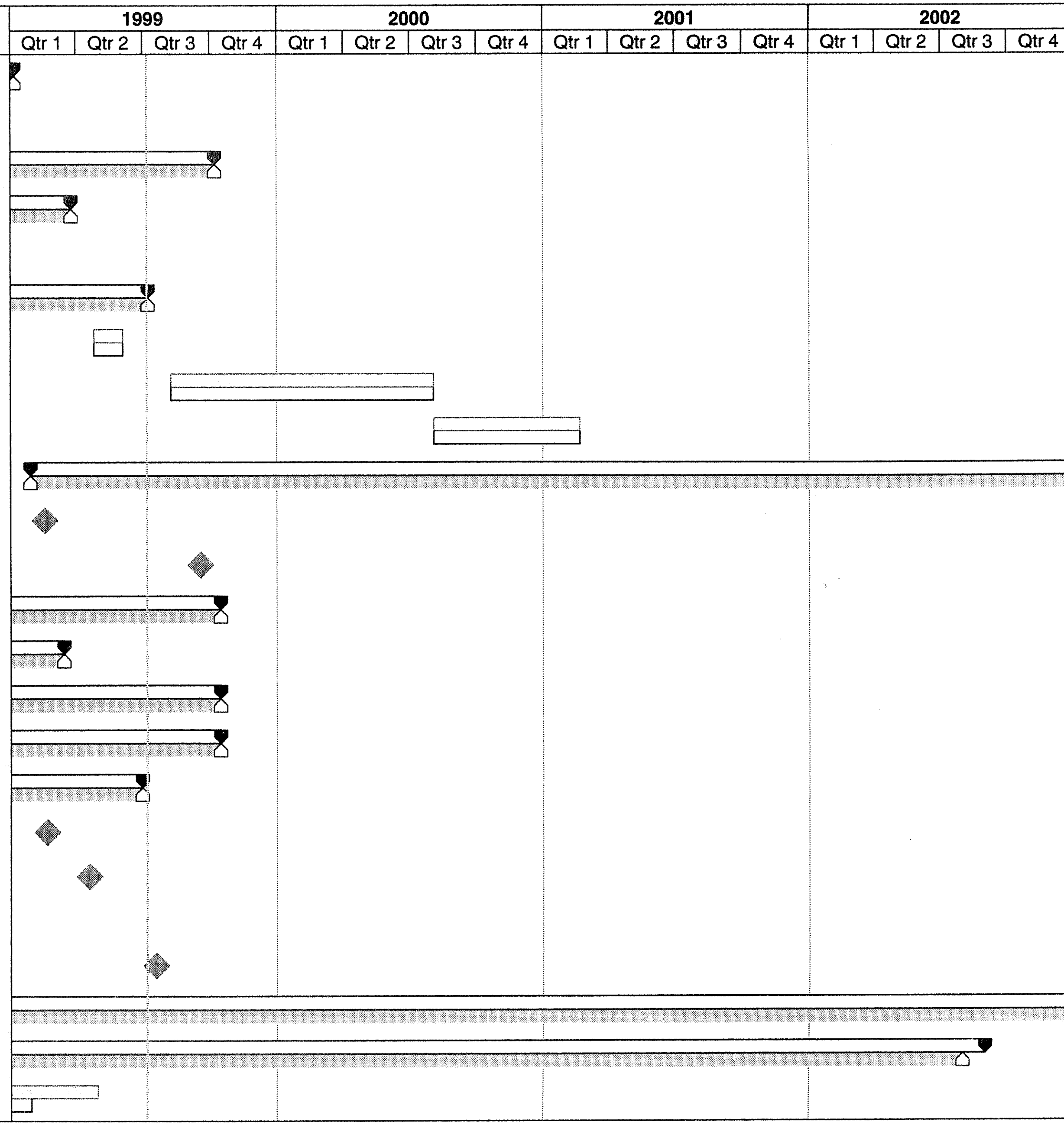
WBS		Activity
3		VERIFICATION OF PRE-INVESTIGATION METHODS
4		**CODE DEVELOPMENT/MODELLING**
4.1		PUBLISHING OF RESULTS
5		
6		METHOD. FOR DETAILED CHARACT. OF ROCK UNDERGROUND
7		**ROCK VISULATIZATION SYSTEM**
7.1		**Program and reports etc**
7.1.1		Update of system manuals Ver 1.1
7.1.2		Update of system manuals Ver 1.2
7.1.3		Update of system manuals Ver 1.3
7.1.4		Update of system manuals Ver 1.4
7.1.5		Update of system manuals Ver 2.0
8		
9		TEST OF MODELS FOR GROUNDWATER FLOW AND
10		RADIONUCLIDE MIGRATION
11		FRACTURE CHARACTERIZATION AND CLASSIFICATION
12		**TRACER RETENTION UNDERSTANDING EXPERIMENTS**
12.1		**TRUE-1**
12.1.1		Analysis of results and reporting of TRUE-1
12.2		**TRUE-2**
12.2.1		STT-2 tracer experiment
12.2.9		Tracer experiment
12.3		**TRUE BLOCK SCALE EXPERIMENT**
12.3.2		**PRELIMINARY CHARACTERIZATION STAGE**



Äspölaboratoriet projektplan, 18 mån

Äspö Plan Right
Version 3.0

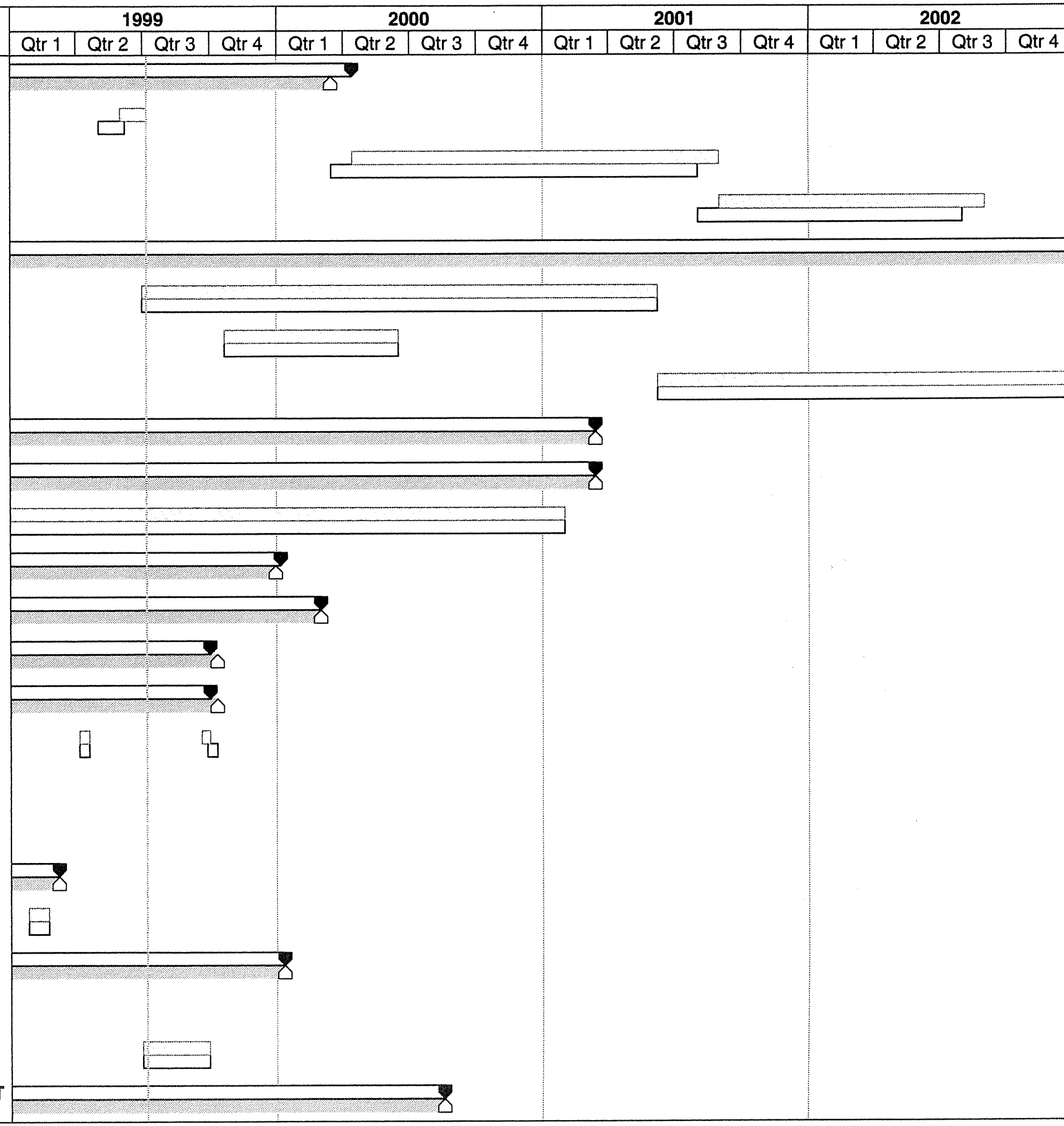
WBS		Activity
12.3.2.1		**PRELIMINARY CHARACTERIZATION STAGE - Phase III**
12.3.2.1		Reporting of Preliminary Characterization Stage
12.3.4		**Detailed Characetrization Stage**
12.3.4.2		**Detailed Characetrization Stage, Phase I**
12.3.4.2		Drill Bh#4 KI0025F02
12.3.4.3		**Detailed Characterization Stage, Phase II**
12.3.4.3		Drill and characterization of BH#5
12.3.5		Experimental Stage
12.3.6		Evaluation Stage
13		**LONG TERM DIFFUSION EXPERIMENT**
13.1		Testplan
13.5		Start experiment
14		**THE REX -EXPERIMENT**
14.1		**Laboratory Investigations**
14.2		**Field Investigations**
14.2.4		**Field Experiment in KA2861A**
14.3		**Program and reports etc**
14.3.5		CEA Lab. experiments 2st report
14.3.6		Univ. Bradford. Final report
14.3.8		MicrobeRex. Final report
14.3.10		REX Final Report report
15		**RADIONUCLIDE RETENTION**
15.1		**CHEMLAB I**
15.1.1		Diffusion experiments



Äspölaboratoriet projektplan, 18 mån

Äspö Plan Right
Version 3.0

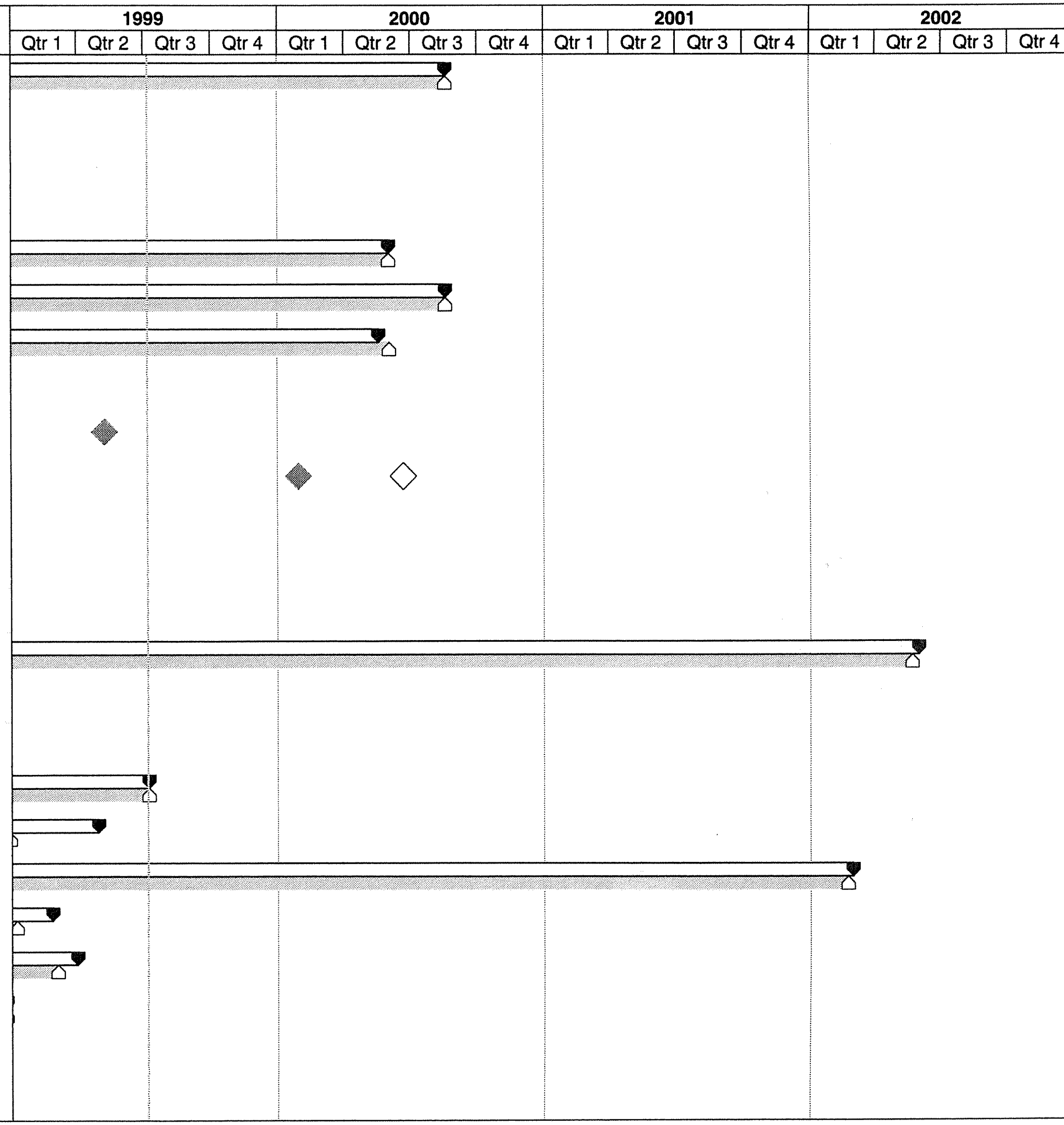
WBS	Activity
15.1.2	**Radiolysis experiment**
15.1.2.5	Radiolysis 1
15.1.3	Migration from the buffer to the rock
15.1.4	Radionuclide solubility, batch sorption
15.2	**CHEMLAB II, New Chemlab probe**
15.2.8	Redox sensitive nuclides
15.2.9	Desorpion from rock
15.2.10	Spent fuel experiment
16	**HYDROCHEMICAL STABILITY**
16.1	**Matrix fluid chemistry**
16.1.6	Water sampling and analyses
16.2	**KLX 02 resampling**
16.3	**Modelling**
17	**PROGRAM FOR MONITORING OF GROUNDWATER CHEMISTRY**
17.1	**GROUNDWATER CHEMISTRY MONITORING**
17.1.1	**Water sampling**
17.2	**FLOWMETER TESTS**
17.2.1	Posiva in KA3510 and KA2598A
17.3	**FORMATIONWATER**
17.3.1	Drill new hole
19	**DEGASSING AND TWO-PHASE FLOW**
19.14	Gas injection tests
19.17	Two-phase tests
20	**THE TASK FORCE ON MOD. OF GROUND. FLOW AND TRANSP. OF SOLUT**



Äspölaboratoriet projektplan, 18 mån

Äspö Plan Right
Version 3.0

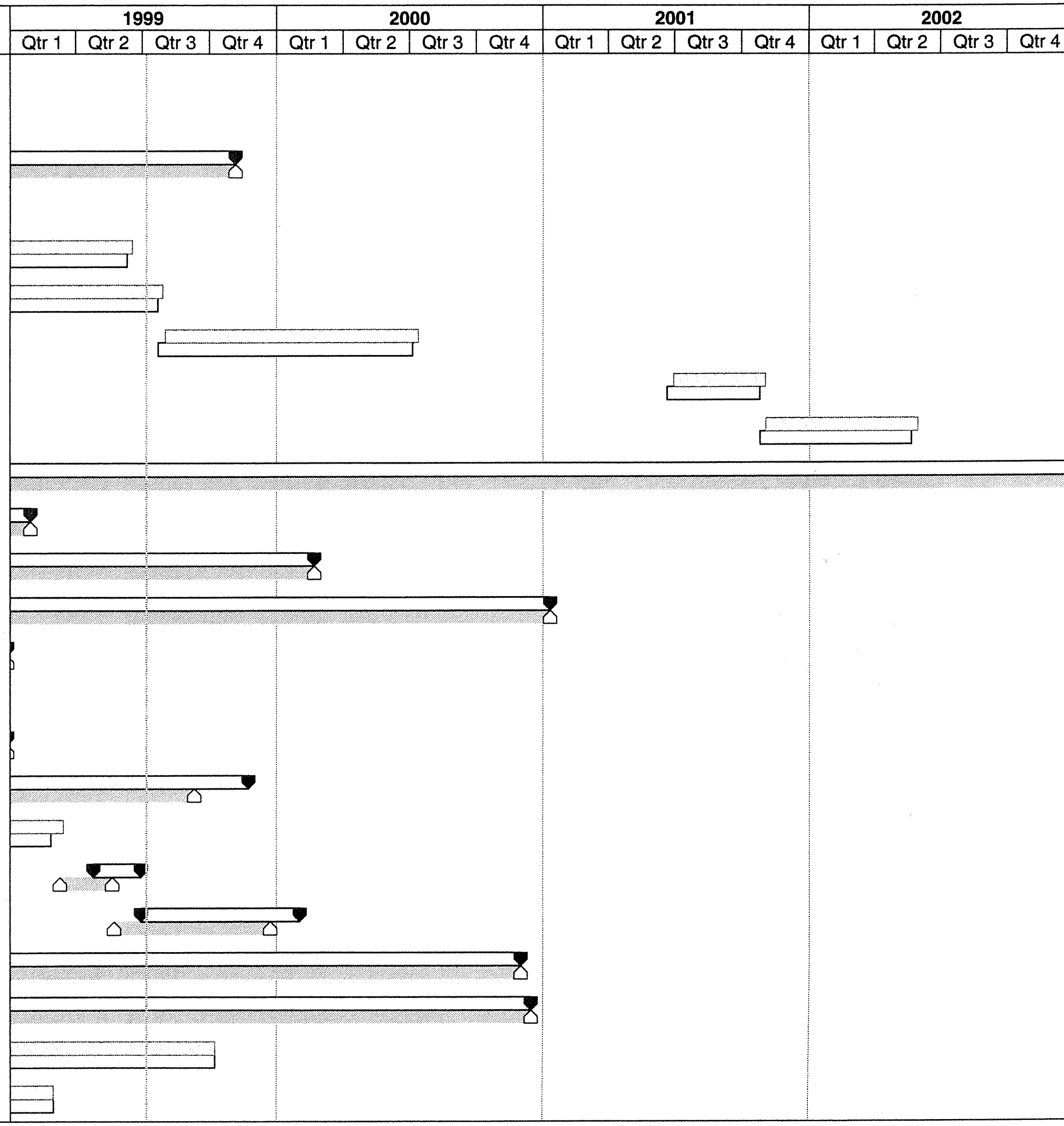
WBS	Activity
20.1	**TASKFORCE**
20.1.1	**Issue Evaluation Table**
20.1.2	**WWW Task Force**
20.1.3	**Task No 4C+4D: Non-sorbing tracer tests**
20.1.4	**Task No 4E: Sorbing tracer tests**
20.1.5	**Task No 4F: Sorbing tracer tests STT-2**
20.1.6	**Task No 5: integration Hydro-chemistry**
20.1.8	Task Force meeting 11
20.1.9	Task Force meeting 12
20.1.10	Task Force meeting 13
21	
22	DEMONSTRATION OF TECHNOLOGY FOR AND FUNCTION OF
23	IMPORTANT PARTS OF THE REPOSITORY SYSTEM
24	**BACKFILL AND PLUG TEST**
24.1	Design and planning
24.2	**Instrument development and testing**
24.3	**Laboratory testing**
24.4	**System for flow testing**
24.5	**Modelling**
24.6	**Backfilling technique**
24.7	**Plug design & preparations**
24.8	**Characterization**
24.8.14	Hole drilling
24.8.16	**Through connections**



Äspölaboratoriet projektplan, 18 mån

Äspö Plan Right
Version 3.0

WBS	Activity
24.8.17	Slot drilling and excavation
24.8.19	Hydraulic testing
24.10	**Set-up of experiment in drift**
24.10.2	Install rock instrumentation
24.10.5	Backfilling&instrument, drift
24.10.7	Plug construction
24.11	Water saturation
24.13	Backfill excavation
24.14	Evaluation & reporting
25	**PROTOTYPE REPOSITORY**
25.1	**Design and planning**
25.2	**Modelling**
25.3	**Instrument developing and testing**
25.4	**Characterization**
25.4.1	**Tunnel investigations**
25.4.2	**Borehole investigations**
25.5	**Deposition hole drilling**
25.5.1	Preparation
25.5.4	**Deposition hole drilling**
25.6	**Characterization dep holes**
25.7	**Canister manufacturing**
25.8	**Bentonite block production**
25.9	Emplacement machine
25.10	Roadbed



Äspölaboratoriet projektplan, 18 mån

Äspö Plan Right
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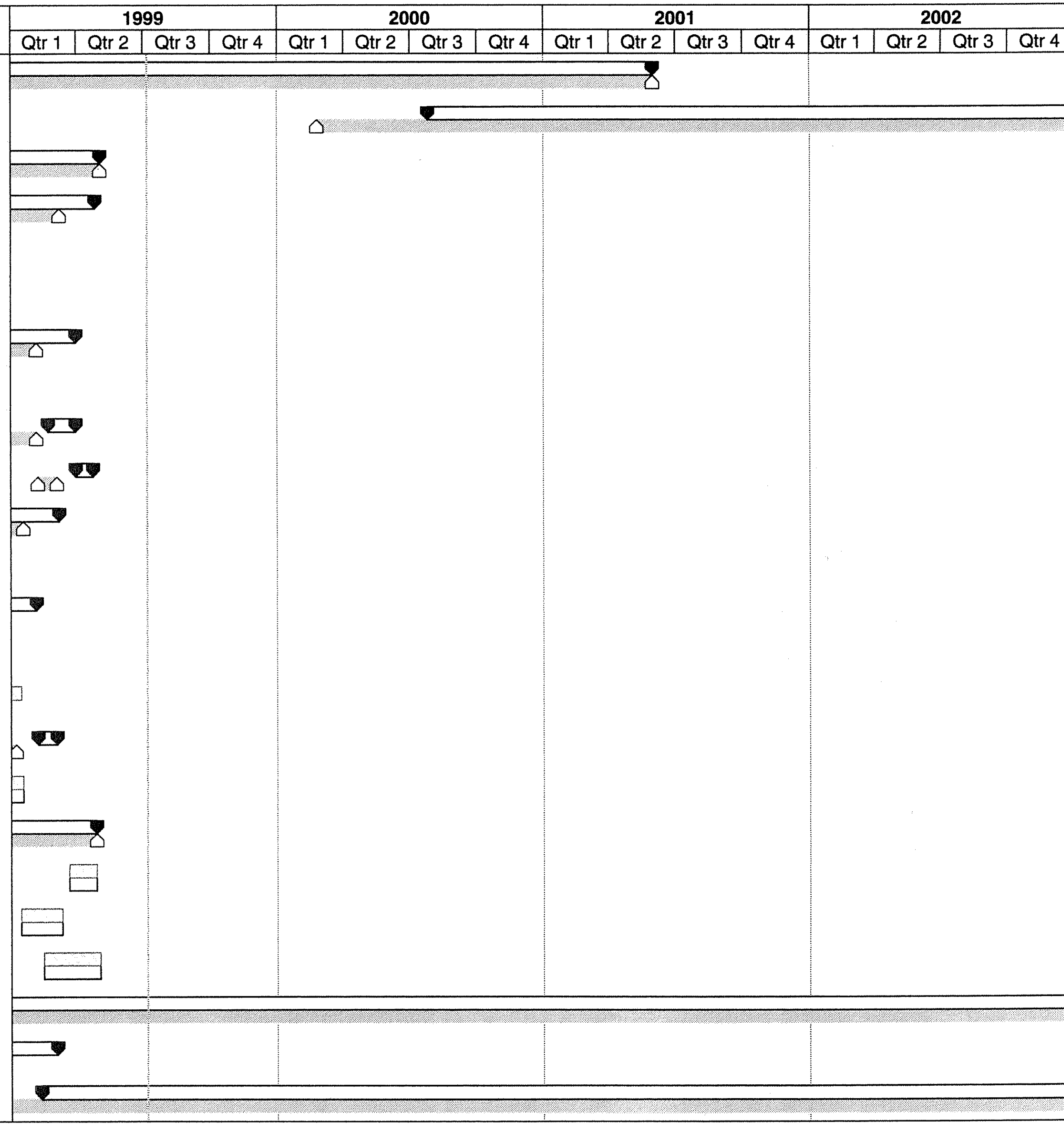
WBS		Activity
25.11		**Backfilling and Plug construction**
25.12		**Monitoring and testing**
27		**TECHNOLOGY DEMONSTRATION**
27.1		**Demotunnel**
27.1.1		**Detailed geomapping**
27.1.2		**Pilot hole characterization**
27.1.3		**Deposition hole drilling**
27.1.3.1		**Preparations Demo**
27.1.3.2		**Deposition hole drilling**
27.1.4		**Characterization dep. hole**
27.2		**TBM-hall**
27.2.1		**Pilot hole characterization**
27.2.2		**Deposition hole drilling**
27.2.2.1		**Preparations TBM**
27.2.2.2		Drill dep.hole 1
27.2.3		**Characterization dep. hole**
27.2.5		Testing of equipment prototyp/retrieval
27.3		**Deposit-machine**
27.3.2		Transport down tunnel and assembly
27.3.3		Install rail in Demo-tunnel
27.4		Install arrengement for "VISA-projektet"
28		**Long Term Test of Buffer Material**
28.1		**Pilot tests, S1, A1**
28.2		**Long Term Tests**



Äspölaboratoriet projektplan, 18 mån

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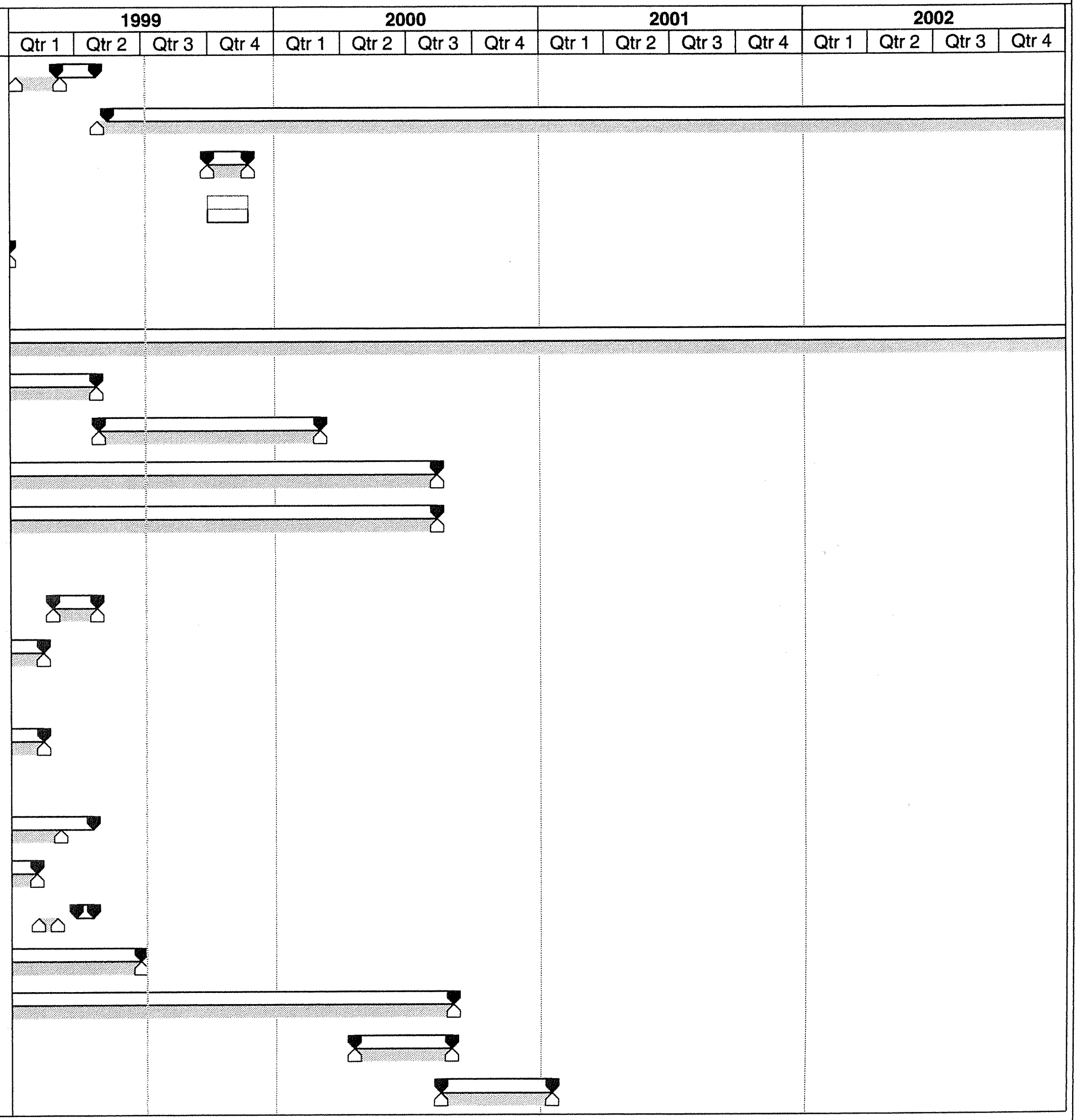
Version 3.0

WBS		Activity
28.2.1		Characterization
28.2.6		Heating tests
28.4		Reporting
28.4.1		emplacement S2:A3
29		CRACKS CAUSED BY MECHANICAL EXCAVATION
29.1		Fieldtest inÄspö HRL
30		CANISTER RETRIEVAL TEST
30.1		Design and planning
30.2		Modelling
30.3		Instrument developing and testing
30.3.4		Rock instrumentation
30.3.4.3		Installation for dep hole boring
30.4		Testing of deposition technique
30.5		Characterisation
30.5.1		Tunnel investigation
30.5.2		Pilot borehole investigation
30.6		Instrumentation holes
30.7		Deposition hole drilling
30.7.1		Preparations
30.7.2		Deposition hole drilling
30.8		Characterisation of dep holes
30.9		Canister manufacturing
30.10		Bentonite block production
30.11		Test commissioning



Äspölaboratoriet projektplan, 18 mån

Äspö Plan Right
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WBS	Activity
30.11.7	Reporting of test set-up
30.12	Saturation
32	
33	**ÄSPÖ FACILITY OPERATION**
33.1	**New rescue chamber**
33.2	**Alarm- and telesystem**
33.2.7	**Operations monitoring (proj alfa)**
33.4	**New redundant drainage system**